ICES WKSHORT REPORT 2009

ICES ADVISORY COMMITTEE

ICES CM 2009/ACOM:34

Report of the Benchmark Workshop on Short-lived Species (WKSHORT)

31 August–4 September 2009

Bergen, Norway

ICES International Council for the Exploration of the Sea
CIEM Conseil International pour l'Exploration de la Mer

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H. C. Andersens Boulevard 44–46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

Recommended format for purposes of citation:

ICES. 2009. Report of the Benchmark Workshop on Short-lived Species (WKSHORT), 31 August–4 September 2009, Bergen, Norway. ICES CM 2009/ACOM:34. 166 pp.

Contents

1 Executive summary

The WKSHORT 2009 Benchmark Workshop was held at the Institute of Marine Research in Bergen, Norway from 31 August–4 September 2009. The Workshop was chaired by Jim Berkson (USA), with support from ICES Coordinator Harald Gjøsaeter (Norway), and involved 29 participants from 12 nations. The primary objectives of the Workshop were to evaluate the appropriateness of the data and methods used in the assessments of four stocks – Barents Sea capelin, Icelandic capelin, Bay of Biscay anchovy, and North Sea sprat – and also to discuss possible improvements to these assessments. The Stock Annexes are the most important product of this process, with each annex containing all relevant information that the Benchmark Workshop participants have identified as current best practice assessment inputs and models, providing sufficient detail to ensure that future assessment scientists can readily replicate assessments without the need to have been previously involved in such assessments.

The WKSHORT came to following conclusions:

The data and methodology used for the Barents Sea capelin was endorsed. The way that predator-prey interactions and uncertainty were incorporated in this assessment, were deemed particularly praiseworthy. Unfortunately, the WKSHORT could not formally endorse the written description of this assessment because it was incomplete at the conclusion of the WKSHORT.

The WKSHORT was unable to approve the assessment of Icelandic capelin. This was primarily because there are reasons to believe that that the value of natural mortality used in the assessment (0.035 per month) is too low. Also, the description of the first stage of quota setting was inadequate, in the sense that it would not be sufficient to allow someone else to conduct the assessment given the data.

For Bay of Biscay anchovy, the WKSHORT endorsed both the assessment methods and stock annex.

For North Sea Sprat, the WKSHORT felt that current analyses of the available data do not provide adequate information for an acceptable stock assessment.

Some suggestions are offered at the end of the Report regarding the Benchmark Workshop process, see Section 7.1.

2 Introduction

The requirements for benchmark workshops were detailed by ACOM in 2008 (ACOM December 2008 22/12/2008 FINAL document). Terms of reference of the Benchmark Workshop on Short Lived Species (WKSHORT 2009) are available in Annex 1. The key aspects of the Terms of reference are:

- to compile and evaluate data sources for stock assessments;
- to solicit relevant data from industry and other stakeholders, and to update the relevant Stock Annexes to include what benchmark participants identify as current best practice assessment inputs and methods, providing sufficient detail to ensure that assessment scientists can readily replicate assessments without the need to have been previously involved in such assessments.

The first day of this benchmark was devoted to background presentations of each stock focusing on biology, life history, ecology, history of the fishery, history of past assessments methodologies and data used. The following days were then focused on resolving the assessment issues to the extent possible, with a view to revising the Stock Annexes for adoption for the following years and to set recommendations for future work. The detailed Agenda is available at Annex 2.

The Workshop was chaired by Jim Berkson (USA). Chris Francis (New Zealand), Robert Furness (UK), and Yimin Ye (FAO) were invited experts. Harald Gjøsæter was the ICES Coordinator. Other participants included members of the AFWG, NWWG, HAWG and WGANSA ICES assessment groups, industry representatives, and member of the ICES Secretariat. A full list of participants is provided in Annex 3. A numbered list of Working Documents considered by the WK, and subsequently archived by ICES, is given in Annex 4.

3 Capelin in Subareas I and II, excluding Division IIa west of 5°W (Barents Sea capelin)

3.1 Current status and assessment issues

The data and methodology used for the Barents Sea capelin assessment is endorsed by the WKSHORT, based on the combination of available background materials, presentations, discussions, and the draft Report and Stock Annex. Unfortunately, the WKSHORT cannot formally endorse the written version of the approach which appears in the WKSHORT Report and the Stock Annex as of the completion of the WKSHORT on September 4, 2009, as it is incomplete. The WKSHORT is confident that if the Report and Stock Annex can fully convey in writing the information provided throughout the WKSHORT, the Report and Stock Annex will be acceptable. Given that the WKSHORT will be over before the completion of this writing, it will be up to ICES to decide how they will evaluate when/if the write-ups are sufficient.

The WKSHORT endorses the way in which the Barents Sea capelin assessment has incorporated predator-prey interactions (specifically having identified the crucial role of cod predation on capelin mortality rate), and we would suggest that this is world-leading in development of an ecosystem approach. Similarly, the incorporation of uncertainty (through bootstrapping simulations) is to be applauded and has clearly been very effective.

Prior to the WKSHORT meeting, we had background papers on the biology of Barents Sea capelin, the history of the fishery and stock assessment and on tools used in the assessment up to 2002. The documents available provided a useful context, but did not include a description of the current assessment process, data or model structure. No draft Stock Annex was provided for review until the evening of the 4th day of the Workshop. However, the unfinished draft Stock Annex read on Friday morning has come a long way towards what is required. Further editing of this was underway on Friday as the meeting came towards an end.

After a stable period at high stock abundance in 1972–1984 the Barents Sea capelin has undergone three collapse periods connected to inflow of large year classes of Norwegian spring-spawning herring (Gjøsæter *et al.*, 2009). It is now increasing and a commercial fishery was reopened in 2009.

The assessment is based on a yearly Russian-Norwegian survey in September and the capelin is managed following a precautionary approach where the probability of the projected spawning stock by April 1 the following year being below 200 000 tonnes shall not exceed 5%. The projection takes into account consumption by cod but neglects the influence of other predators such as harp seals. An important management issue that is not addressed in present management is how to take account of the capelin's influence on other species.

The capelin dies after spawning and it is not possible to measure the spawning stock, so the assessment depends on the projection of the mature stock from October to spawning April 1 the following spring, which involves modelling both maturation and consumption by cod.

Relevant working documents: The WD by Johannesen and Lindstrøm discusses the overlap between capelin and cod.

3.2 Compilation of available data

3.2.1 Commercial catch

The fishery is conducted by purse-seiners and to a lesser degree by trawlers on the prespawning capelin January–March, with a minimum landing size of 11 cm and a northern border of 74°N to protect juvenile fish. Numbers-at-age are calculated using samples from catches.

3.2.1.1 Evaluation of the quality of the catch data

Discards are considered to be insignificant, as vessels having taken an excess catch can transfer to other vessels. The catch data are considered representative. Catch reporting is considered to be accurate.

3.2.2 Biological data

Biological data used in the assessment are samples taken from survey and from commercial vessels, and acoustic information from the survey. Age reading is considered precise and accurate. Routine cross reading exchanges and workshops take place regularly every two years.

3.2.3 Survey data

3.2.3.1 Evaluation of the quality of the survey data

At low capelin densities the allocation of acoustic integrator values on species can be difficult. At high densities this is a minor problem, except when the capelin mixes with high densities of polar cod in the northeast Barents Sea.

3.2.4 Industry/stakeholder inputs

There is at present no information from industry or stakeholders.

3.3 Stock identity and migration issues

The Barents Sea capelin stock is confined to the Barents Sea, i.e. the ICES Divisions I, the eastern parts of IIa, and IIb. There is no exchange between this capelin stock and the capelin stock in Subareas V, XIV and Division IIa west of 5°W (Iceland-East Greenland-Jan Mayen area). Capelin undertakes extensive migrations within the Barents Sea (see Stock Annex). Spawning takes place near the Norwegian and Russian Barents Sea coasts, while the feeding area stretches to the northern and northeastern parts of the Barents Sea.

3.4 Spatial changes in fishery or stock distribution

Changes in the distribution and migration routes of capelin have been documented (Gjøsæter, 1998) and have, at least partly, been associated with changes in water temperature in the Barents Sea (Fauchald *et al.*, 2006). Ingvaldsen and Gjøsæter (submitted) argue that changes in spatial distribution are partly governed by changes in stock size, partly by changes in temperature conditions. Based on such studies, it could be suggested that a further rise in temperature, for instance as a result of global warming, in combination with increased stock sizes, could displace the capelin distribution areas east and northeastward. No dramatic changes in distribution have been seen in the recent period, characterized by record high water temperatures in the Barents Sea.

3.5 Environmental drivers of stock dynamics

Growth of the youngest capelin is correlated with abundance of the smallest zooplankton, whereas growth of older capelin is more closely correlated with abundance of the larger zooplankton (ICES 2009). The developed regression equations have low determination coefficient, and are therefore not used currently in prediction. However, they may prove useful in future when further developed.

In recent years there has been a northwards extension of the geographical distribution of the cod stock, leading to a higher degree of overlap between cod and capelin in autumn. This expansion of the cod stock may partly be as a consequence of the increase in abundance of the cod, partly as a consequence of changing environmental conditions (warming of the sea).

3.6 The role of multispecies interactions

Capelin is an important part of the diet for many predators, including cod, harp seals, minke whales, humpback whales, and haddock. It is the main prey item for cod. The estimated annual consumption of capelin by cod has varied between 0.2 and 3.0 million t over the period 1984–2007 (ICES 2009).

The marine mammals in the Barents Sea may eat 1.5 times the amount of fish caught by the fisheries (e.g. Bogstad *et al.*, 2000; Folkow *et al.*, 2000; Nilssen *et al.*, 2000). Minke whales and harp seals may consume 1.8 million and 3–5 million tonnes of prey per year, respectively. Capelin is a substantial part of their diet.

Young herring consume capelin larvae (Gjøsæter and Bogstad, 1998), and this predation pressure is thought to be one of the reasons for poor year classes of capelin in the periods 1984–1986, in 1992–1994, and in 2001–2005. In future, the negative influence of herring on capelin recruitment should be included in the B_{lim} based rule, if such a relationship can be described quantitatively.

Haddock may feed intensively on capelin eggs when they are available (Tseeb, 1960, cited by Langton and Bowman, 1980; Antipova *et al.*, 1980). Predation on capelin eggs by the red king crab was studied by Anisimova *et al*, (2005, unpublished) in the period from 1994 to 2003 in the west Murmansk waters. The most frequent occurrence of capelin eggs in crab stomachs in the period of study was 19.4% in 2001, but fish eggs accounted for only 1.2 % of the crab diet. The average frequency of occurrence in the period of study was considerably lower than in 2001. These indications reveal that the overall effect of egg predation by the red king crab may not be significant when the capelin stock is high. However, when the capelin stock is low and the density of red king crab at spawning sites is high, the effect could most certainly be significant.

Predation on capelin eggs from haddock and red king crab and the possible effect of such predation is under study. The red king crab is an introduced species in the Barents Sea ecosystem and it is important to investigate its potential effect of the Barents Sea capelin in years when capelin spawn in areas where the red king crab is abundant. If the egg predation from haddock and red king crab is significant, a stock recruitment relationship taking into account this environmental effect should be constructed.

The capelin feed in the central and northern Barents Sea in autumn. During January–February the maturing capelin migrates to the shore along the southern Barents Sea to spawn. During this migration it invariably will overlap with immature cod, being subjected to heavy predation (Figure 3.1). As it has not been possible to measure the mature stock, modelling of the consumption of prespawning capelin by cod is essential to the assessment procedure. The mature cod will have only a small impact on the mature capelin stock in this period, as it is migrating westwards to spawn.

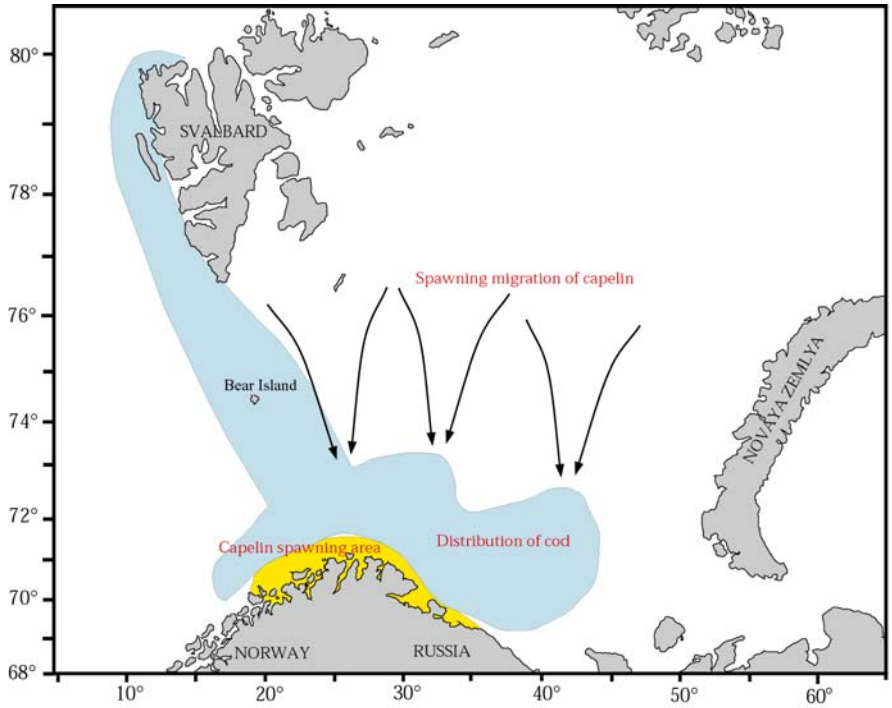


Figure 3.1. Spawning migration of Barents Sea capelin and overlap with cod.

The immature capelin will also migrate southwards, being subjected to geographical overlap with cod that will vary from year to year. When the cod stock is large the overlap area will be larger. The latest years' geographical overlap between cod and capelin in the feeding area has been observed quite far north.

The consumption of immature capelin will be captured by the assessment model as decrease of the modelled number of immature capelin of age *a* from the survey in September in year *y* to the observed number of capelin of age *a+1* in year *y+1*.

The consumption of capelin by cod is a significant portion of the cod's diet. When the capelin disappears the cod to a large extent turns to feeding on crustaceans (Figure 3.2).

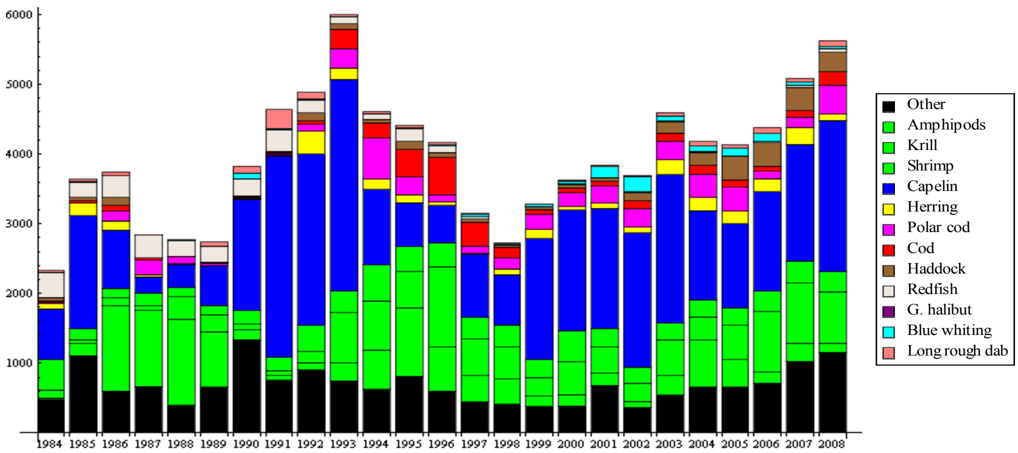


Figure 3.2. Consumption by cod.

The importance of capelin for cod is not captured in the assessment model from 2003 that is reviewed at the present benchmark meeting. In periods of little capelin in the system the cannibalism will increase, which will be important for models used for long-term simulations to test harvest rules of in the cod-capelin system.

During the spawning migration the capelin will also be subjected to predation from female harp seals on a regular basis. During the period October–January both immature and maturing capelin may also be subjected to consumption by harp seals along the northern ice border. Stomach samples from harp seals demonstrate that the dominant food item is large plankton organisms, but on occasions capelin may dominate. This is probably connected to the relative positions of the ice border and the northernmost part of the capelin feeding distribution. The consumption of capelin by harp seals is not a part of the 2003 version of the assessment model.

Other predators of capelin that may be important are minke whales, humpback whales and dolphins. For minke whales diet data exist that could be used to model the consumption of capelin, possibly along the lines of Tjelmeland and Lindstrøm, 2005.

3.7 Impacts of fisheries on the ecosystem

The capelin fishery is a single-species pelagic fishery where bycatches of other species are negligible.

The pelagic fisheries are less mixed, and are weakly linked to the demersal fisheries (however, bycatches of young pelagic stages of demersal species have been reported in some pelagic fisheries).

Fishing on capelin has the potential to disrupt the food chain between zooplankton and predators like cod, haddock, harp seals, minke whales and some birds. Dead post-spawning capelin serves as a fertilizer of the coastal ecosystem and may be important for red king crab and other bottom organisms which in turn are eaten by cod and haddock. Much basic research is lacking in order to convert this insight into practical management of the fishery. The predation by the red king crab on dead capelin is under investigation.

Studies of seabirds in the Barents Sea demonstrated that common guillemots *Uria aalge* are highly dependent on the presence of an adequate abundance of capelin. During the period of low capelin abundance in the late 1980s about 90% of all the common guillemots at major colonies in the Barents Sea disappeared, and are believed to have died overwinter (Barrett and Krasnov, 1996). However, numbers have recovered since (Krasnov *et al.*, 2007), and other seabirds were not so drastically affected as they were apparently better able to switch to alternative diets (Barrett and Krasnov, 1996).

3.8 Stock assessment methods

The capelin is managed by regulating the influence of the fishery on the spawning stock. The fishery is conducted in January–March and the input data for the stock size is the number-at-age and length and the weight-at-length from the acoustic survey in September. The stock assessment builds on a projection of the mature stock from October 1 (at the end of the acoustic survey) to the assumed spawning time of April 1. It is not possible to infer the mature component directly from the September data, so the procedure involves modelling of the mature component as well as projecting it until spawning time. No alternative approaches have been tried.

3.8.1 Models

The assessment method is implemented in two models. The model Bifrost estimates the parameters p_2 (length-at-maturity), M (natural mortality for immature capelin, 1972–1980), C_{max} (maximum consumption) and $C_{½}$ (half value in type II predation function) repeatedly by resampling from the input data. The replicates are transferred to CapTool along with the calculated natural mortalities of immature capelin by year, one line for each set of replicates. At present 1000 replicates are used.

The relation between the two models is shown in Figure 3.3.

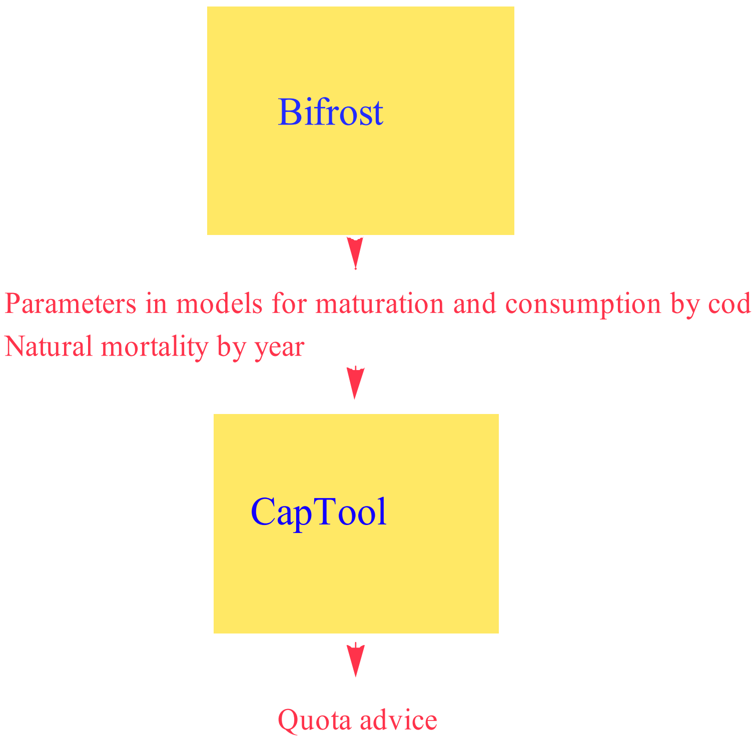


Figure 3.3. The connection between the models Bifrost and CapTool.

3.8.1.1 Bifrost

The model formulations and the approach to estimating parameters described here pertain to the version of Bifrost used for estimating parameters in 2003. Bifrost is written in Mathematica.

Bifrost has evolved considerably since 2003, at present describing consumption by cod on both capelin and cod (cannibalism) the year around and with harp seals as an endogenous entity. Thus, Bifrost can be used to estimate MSY-based harvest rules as well as being an operating model to test harvest rule in a multispecies context. This version of the model was not considered at the benchmark meeting, however.

The version used for estimating parameters to CapTool in 2003 is described below:

3.8.1.1.1 Data for Bifrost

Table 3.1 displays an overview of Bifrost input data. “Symbol” is the notation used in the present document, “Name” is a descriptive name of the data source, “Structure” describes how the data are partitioned for use in Bifrost and "Origin" describes the origin of the raw data. Bifrost works on stochastic replicates of the data, and "Resampling depth of original data" describes at which level of data aggregation the data are resampled.

Table 3.1. Overview of Bifrost input data.

Symbol	Name	Structure	Origin	Resampling depth of original data
N_{ca}	Capelin September data	Yearly files of replicates of number and age at length and weight at length	Russian - Norwegian trawl samples and Sa values	Individual Sa values in each square Trawl samples connected to each square Individual fish in each trawl sample
C_{ca}	Capelin catch	Number by age by maturation component	Catc reports in tonnes Biological samples	Not resampled
SV	Proportion at age of cod in the Spitsbergen area	Proportion by age by year	Norwegian and Russian bottom trawl indices	Not resampled
N_{co}	Number at age from the Arctic Fisheries WG assessment	Number at age by year	XSA tuned with survey indices	Not resampled
W_{co}	Weight at age from the Arctic Fisheries WG assessment	Weight at age by year	Russian and Norwegian biological samples	Not resampled
O_{co}	Proportion mature at age from the Arctic Fisheries WG assessment	Proportion mature at age by year	Russian and Norwegian biological samples	Not resampled
CM	Consumption per cod	Files of replicates of consumption of mature capelin during January - March by immature cod where mature capelin is defined as capelin longer than 13.5, 14.0 or 14.5 cm For each file the structure of each replicate is : year consumption of mature capelin by cod age	Individual stomach content data Station temperature data Replicates of evacuation rate parameters	Station temperature uncertainty Prey length uncertainty

3.8.1.1.2 Bifrost model formulations

Maturation model

The maturation of capelin is modelled as a logistic function:

$$m(l) = \frac{1}{1 + e^{4p_1(p_2 - l)}}$$

Where l is the length in cm, p_2 is the length at 50% maturity and p_1 describes the increase in maturity by length at p_2. It is further assumed that the maturation is nearly a cut-off maturation and p_1 has been fixed to 3.5, which gives the maturation function shown in Figure 3.3:

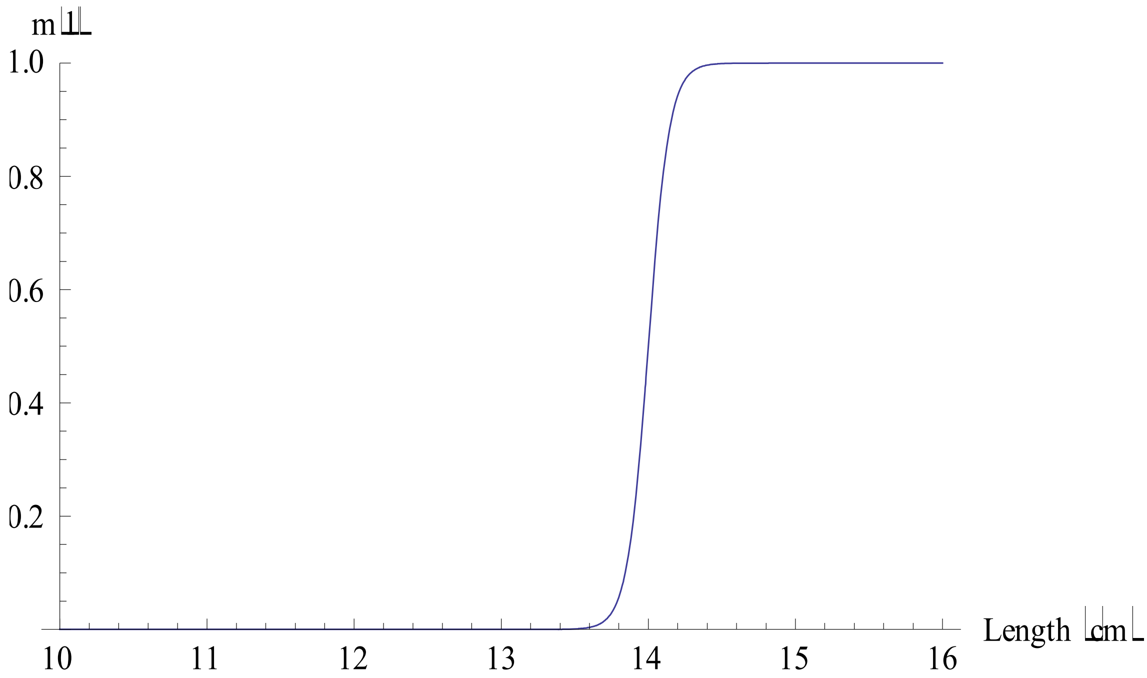


Figure 3.3. Maturation function used in the 2003 version of Bifrost, for a typical value of p_2 (length-at-maturity).

It is assumed that p_2 and p_1 are the same for males and females and for all age groups.

For a given value of p_2, the maturation function is applied to the length distribution (0.5 cm wide length groups) of each age group from the September survey. The resulting length distribution of maturing fish is then integrated over length to give the age distribution of mature fish. The proportion immature-at-length is given as 1–m(l) which also is integrated over length groups to give the age distribution of immature fish.

The estimation of p_2 is based on building a likelihood function by comparing the immature capelin projected one year ahead with the total stock measured in that year. The projection involves the natural mortality of immature capelin, the estimation of which thus becoming confounded with the estimation of p_2. Two age groups are included in the estimation: age 2 to age 3 and age 3 to age 4. Age group 1–2 is excluded because the survey data for age 1 are unreliable in the 1970s and age group 4–5 is excluded because of fear of the assumption of constant p_2 being violated for older ages. This age group is also of lesser significance.

The projection assumes a constant natural mortality within each period 1 October–1 October. Pope's approximation is used for the catch during 12 months:

$$N_{ca,i} = N_{ca,\,i-1}e^{-M} - C_{ca,imm,i-1}e^{-0.5M}$$

Where $N_{ca,i}$ is the number of fish in the cohort, M is the monthly natural mortality and $C_{ca,imm,i}$ the catch of immature fish in the cohort in month i. The catch data are split on mature and immature fish.

The likelihood function is given by:

$$objective = \prod_{y,a} \frac{1}{\sqrt{2\pi\sigma_{y,a}}} e^{-\frac{(Nca,_{y,a} - \hat{N}ca,_{y,a}(p2,M))^2}{2\sigma_{y,a}^2}}$$

where:

$Nca,_{y,a}$ is the observed abundance of capelin of age *a* in year *y*

$\hat{N}ca,_{y,a}$ is the modelled abundance of capelin of age *a* in year *y*

$$\sigma^2_{y,a} = \sigma^2_{y-1,a-1,obs} \left(\frac{N_{y,a}}{N_{y-1,a-1}}\right)^2 + \sigma^2_{y,a,obs}$$

$\sigma^2_{y,a,obs}$ is the variance of the survey estimate calculated by resampling (see below).

p_2 and M are estimated by finding those values that maximize *objective*.

$\sigma^2_{y,a,obs}$ is based on resampling the September estimates (both total acoustic abundance and biological samples), as described by Tjelmeland, 2002. Figure 3.4 shows the estimated parameters for 500 replicates.

The estimations were made using data from 1972–1980, and an M-value for this period was also estimated. The reason for using the chosen time range is that the population dynamics was stable, with relatively constant M-values. Later there were large variations in M, possibly connected to large fluctuations in the harp seal stock and in changes in geographical distributions of other predators. For years after 1980, annual mortality parameters are calculated using the estimated maturation parameters for the period 1972–1980.

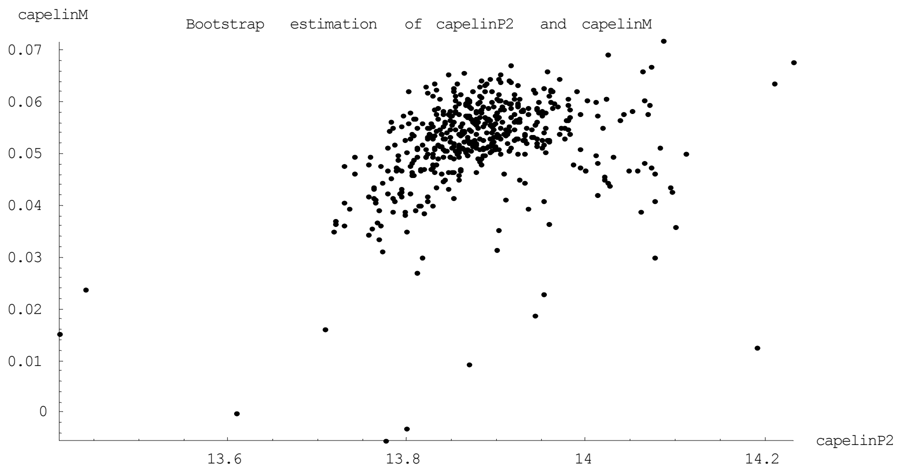


Figure 3.4. Bootstrap estimates of length-at-maturity (x-axis) and monthly natural mortality (y-axis) of immature capelin in the period 1972–1980.

Predation model

Predation by cod is modelled by modelling the consumption by cod of mature capelin only, and comparing this to estimates of consumption by cod on mature capelin based on stomach content data and an evacuation rate function. The effect of other food is accounted for in the parameter $C_{½}$ that denotes the amount of mature capelin present that gives consumption equal to half the maximum consumption C_{max}. It should be noted that the predation model is based on data from 1984 while Bifrost runs from 1972. It is noteworthy that the prevailing feeding conditions may have been different in the 1970s than from 1984 onwards.

The consumption of capelin by cod in year *y* and month *t* is modelled by a type II functional relationship):

$$Cons(y,t) = \frac{C_{\max} \bullet predationAbility(y,t) \bullet MatBio(y,t)}{C_{1/2} + MatBio(y,t)}$$

where *MatBio(y,t)* is the biomass of mature capelin in year *y* and month *t* and *predationAbility(y,t)* is given as:

$$predationAbility(y,t) = \sum_{A} Nco(y,t,A)CodSuit(a)(1-Oco(y,a))(1-SV(y,a))Wco(y,a)^{0.801}$$

The natural mortality on mature capelin in the months January–March is then calculated from the equation:

$$M_{mature}(y,t) = -\ln(1-\frac{Cons(y,t)}{MatBio(y,t)})$$

t denotes the time, and each month is divided into six steps, where the catch is applied after the third step using a formulation similar to that for the consumption by cod. The catch over the whole period January–March is allocated with 20% in January, 30% in February and 50% in March, based on experience.

The parameters C_{max} and $C_{½}$ in the above model are estimated by minimizing sum of squares (SSQ) of the difference between the modeled consumption during January–March and consumption calculated directly from the individual stomach content data over the same period.

$$SSQ = \sum_y(\sum_t Cons(y,t) - \sum_{a,t} NCod(y,t,a)(1 - O_{co}(y,a)) (1 - SV(y,a))CM(y,a))^2$$

$O_{co}(y,a)$ the proportion mature from the Arctic Fisheries WG assessment in year *y*, SV(y,a) is the proportion of immature cod of age *a* residing in the Svalbard area in year *y* and CM(*y,a*) is the consumption per cod of age *a* calculated from cod stomach content samples for January–March in year *y*.

The total abundance of cod in year *y* and month *t*, *NCod(y,t,A)*, is given by

$$NCOD(y,t,a) = Nco(y,a)e^{-(t-0.5)*Z(y,a)/12}$$

where *Nco(y,a)* is the number of cod of age *a* at the beginning of year *y* given by the VPA-based assessment of cod made by the Arctic Fisheries Working Group (AFWG). *O(y,a)* is the proportion mature-at-age for cod, and it is assumed that only immature cod preys on prespawning capelin. The component of immature cod that reside in the Spitsbergen area is assumed not to prey on prespawning capelin. *Z(y,a*) is the total mortality of cod.

Geographical overlap between cod and capelin

The calculation of the Spitsbergen (*SV(y,a))* component is based on the following data sources:

Norwegian bottom-trawl abundance indices by age in the Barents Sea in February and the Spitsbergen area in August–September, from 1981 onwards.

Jakobsen *et al*., 1997 describe the methodology of the February survey, and the survey indices are given in ICES 2009.

Results of the coverage in the Spitsbergen and Barents Sea areas in August–September from 1995 onwards are given in Anon. 2007. In the years 1995, 1996, 1999, 2004, 2005 and 2006 there was fairly complete area coverage of the cod stock in August–September.

Russian bottom-trawl indices on ICES areas (I, IIa, IIb) from the Russian survey in October–December from 1982 onwards (Lepesevich and Shevelev, 1997). The results are given in ICES (2009).

It was found that the most appropriate way to calculate the Spitsbergen component based on the available data, was to combine the Barents Sea survey with the Spitsbergen survey in the same year, i. e. calculate the proportion of age *a* fish found in the Spitsbergen area in year *y*, *SV(y,a)* as

$$SV(y,a) = \frac{IS(y,a)}{IS(y,a) + IB(y,a)}$$

where *IS(y,a)* and *IB(y,a)* are the survey indices in the Spitsbergen area and the Barents Sea, respectively. This will tend to underestimate the proportion of cod found in the Spitsbergen area, because the survey in the Spitsbergen area takes place half a year later than the Barents Sea survey. On the other hand, the Spitsbergen area stretches so far east that some of the cod in that area probably will overlap with capelin, causing an overestimate of the proportion of cod found in the area where it does not overlap with capelin. If these two factors approximately cancel out, our approach is reasonable. The Spitsbergen component (a vector with proportion-by-age) in 2005 and later years is drawn randomly from the values in the period 1983–2004, calculated in the way outlined above.

As a consequence of changes in the strata system used in the Spitsbergen survey, values from 2005 and later years are not available at present.

CodSuit(a) is the suitability of mature capelin for cod of age *a*. It is set to 0.0 for age 1 cod, 0.1 for age 2 cod and 1.0 for age 3 and older cod, in all years. The suitability for age 2 cod is based on the results by Dalpadado and Bogstad (2004) who found very little capelin >14 cm in stomachs of age 2 cod during the period January–March. Also, the proportion of capelin in the diet of cod <25 cm (corresponding to age 2) in January–April is much lower than the proportion of capelin in the diet of larger cod (Bogstad and Gjøsæter, 2001).

Cod stomach content data and consumption calculations

Stomach content data for cod are collected jointly by IMR and PINRO, averaging about 5000 stomachs annually for the period January–March. For the calculation of consumption it is assumed that over the period January–March the amount of capelin consumed equals the amount of stomach content evacuated. For each stomach collected in this period the amount of capelin evacuated instantaneously is calculated using an evacuation rate model. The measurement value *CM(y,a)* used in the sum of squares is the average of the instantaneous evacuation rate multiplied by the length of the period.

The evacuation rate model of capelin for an individual stomach is given by the formula:

$$R = \ln(2) e^{\gamma T} W^{\delta} S^{\xi} / \alpha$$

where:

- α: evacuation rate halftime for capelin
- γ: dependence on ambient temperature
- δ: dependence on predator body weight
- ξ: shape parameter
- S: stomach content in grams
- T: ambient temperature. This is taken as the nearest measured temperature in space and time at the depth of the trawl station
- W: body weight in grams
- R: Consumption

This is essentially the same model as used by Bogstad and Mehl (1997), but in the evacuation rate model the initial meal size is not used (Temming and Andersen, 1994), rather the model parameters are estimated using a non-linear dependence on stomach content.

The empirical consumption of capelin per cod of age *a* is thus given as:

$$CM(y,a) = \sum_{area}(\sum_{a,i}R_{y,a,i})N^{imm}_{y,a,area}) / \sum_{a,area} N^{imm}_{y,a,area}$$

Where the outer summation extends over cod ages *a*. The innermost summation extends over individual fish *i* which are weighted with the number of observed immature cod in each area shown in Figure 3.5 for the calculation to be somewhat robust against the possibility that the stomach sampling is geographically biased with regard to the distribution of the cod. The cod stock is here distributed on the Multspec areas (Bogstad *et al.*, 1997). This distribution is based on data from the joint IMR-PINRO demersal fish survey in February (Jakobsen *et al.*, 1997).

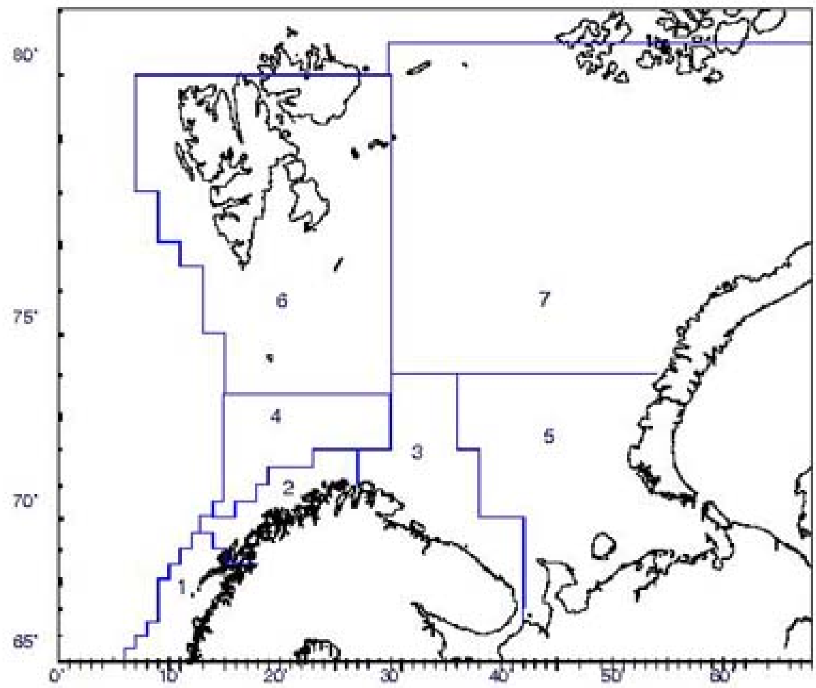


Figure 3.5. Areas used for scaling consumption per cod with observed number of immature fish from biological samples.

The temperature used in the evacuation rate model is taken as the nearest measured temperature in space and time at the depth of the trawl station (www.assessment.imr.no/Bifrost/temperatureData.html). For Norwegian stomach content data there as a rule is a temperature station quite close, for Russian stomach content data the nearest temperature (only Norwegian temperature data are used) can be further away in space and time. The uncertainty in using temperature stations that are not in the vicinity of the trawl station has been quantified.

Studies by Bogstad and Gjøsæter (2001) indicate that a significant part of the predation by cod on capelin in January–March (1993–1999 average: ca. 25%) is on immature capelin. This conclusion is drawn from analyses of stomach content data. The stomach content data contain information about the prey length. In calculations of the consumption made in Bifrost and CapTool (for the latter, see below) it has been assumed that all consumption of capelin by cod in January–March is on mature capelin. The empirical consumption CM used to estimate parameters in the consumption model should thus be consumption of mature capelin only. The length information in the stomach content database is used to base the calculation of CM on only mature capelin as closely as practically possible. Maturation is determined by length, but the length-at-maturity is a modelled entity, and not known a priori. Therefore, CM has been calculated using capelin in cod stomachs with either 13.5, 14.0 or 14.5 cm as lower limit. During stochastic model simulations the length-at-maturity will vary and the consumption per cod replicates corresponding to a length-at-maturity closest to the model maturation length are selected. The uncertainty in the proportion of the consumption of capelin by cod during January–March, which consists of immature capelin, is also accounted for. The parameters are estimated by using the historically calculated total consumption as observations and the total consumption calculated from the above model as model results. As the estimation depends on quantities that in nature are stochastic a new regression is made for each historical run.

3.8.1.2 CapTool

CapTool is a tool for making short-term (1 October–1 April) probabilistic projections of the maturing capelin stock in order to give quota advice. CapTool is implemented in Excel using the @RISK add-on package. Usually 15 000 simulations are made for each catch option.

The timing of the processes can be summed up in the following way:

TIME	PROCESS
1 October	Calculate number of maturing fish
October-December	Apply M(based on Bifrost estimates of M on immature capelin)
January–March	Apply M from cod predation, apply fishing
1 April	Calculate SSB

The following data sources enter into the CapTool short-term (October–April) projection.

Table 3.8.1. Input to CapTool 6-month projection.

MODEL INPUT	DATA SOURCE	UNCERTAINTY
Number and weight by age and length October 1	September survey	Assumed CV (0.2, log scale) on number-at-age
Proportion mature October 1	Bifrost estimates of maturation parameters	1000 replicates of maturation parameters
Mortality in October–December	Bifrost estimates of M on immature capelin	Draw year randomly from period 1972–2001, then draw randomly from 1000 replicates of mortality for this year
Mortality in January–March	Bifrost estimates of predation parameters, cod abundance from AFWG cod assessment geographical distribution of cod from surveys	Random draw from 1000 replicates of predation parameters assumed CV (0.3, log scale) of cod abundance cod geographical distribution drawn randomly from historical data (1983–2004), see under Bifrost
Catch in January–March	Capelin catch in biomass, catch distribution by month (January–March)	None

The equations used (Gjøsæter *et al*., 2002) are described at the end of this section.

The quota is determined by running CapTool for various catch options and calculating P(SSB <200 000 t) for each of the options. The results of such runs are shown in Figure 3.6, and the uncertainty in stock development during October–April is illustrated in Figure 3.7.

CapTool can also be used for medium-term (1.5 year) prognosis. This prognosis is done in two steps. First, the immature stock 1 October in year *y* is used to predict the total stock 1 October in year *y+1*. Then, the stock 1 October in year *y+1* is carried forward to 1 April in year *y*+2 using the methodology described above. These predictions are not used for giving quota advice, but can be used as an indication of the likelihood of a fishery in year *y*+2 and are also useful for prognosis of e.g. cod growth.

The prediction from 1 October year *y* to 1 October year *y+1* is done by drawing randomly from historical data on growth and mortality, as explained in Table 3.8.2. Also, a regression between 0-group and 1-group abundance for the year classes 1980–present is used to predict the 1-group abundance in year *y+1* (ICES 2009).

Table 3.8.2. Input to CapTool 1.5 year projection.

MODEL INPUT	DATA SOURCE	UNCERTAINTY
Number and weight-by-age and length October 1 year y	September survey	Assumed CV (0.2, log scale) on number-at-age
Proportion immature October 1 year *y*	Bifrost estimates of maturation parameters	Replicates of maturation parameters
Mortality from year y to year y+1	Bifrost estimates of M on immature capelin	Draw year randomly from period 1972–2001, then draw randomly from replicates of mortality for this year
Length growth from year y to year *y+1*	Calculate mean growth in cm. Shift length distribution upwards accordingly	Calculate mean growth in cm of immature capelin based on mean length-at-age for each age group and year from survey data (1973–present) as well maturation parameters. Draw randomly from these years for each age group.
Weight-at-length in year *y+1*		Draw weight-at-length vector randomly from historical survey data (1973–present)
Number-of-age 1 in year *y+1*	0-group abundance in year y Regression between 0-group survey and age 1 survey abundance (1980–present)	Residuals from regression

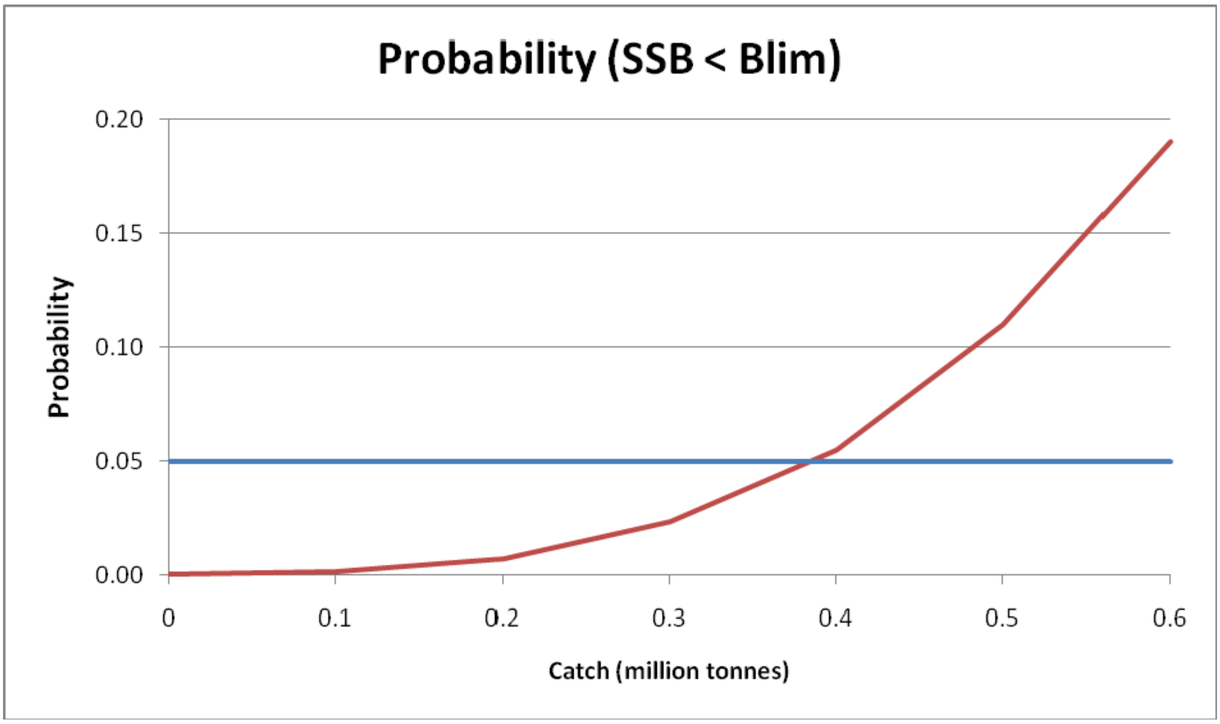


Figure 3.6. Probability of SSB < B_{lim} as a function of catch (from assessment autumn 2008).

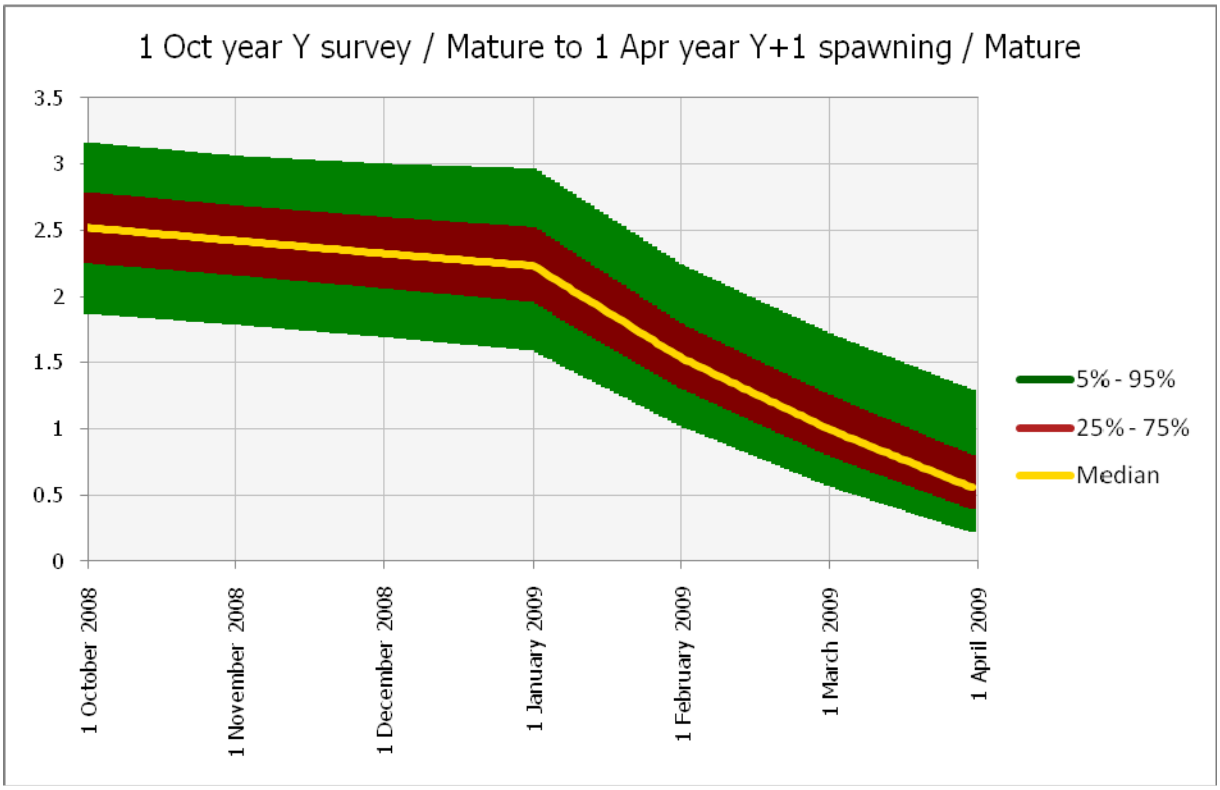


Figure 3.7. Stock development, with uncertainty, 1 October 2008–1 April 2009. From autumn 2008 assessment.

CapTool model formulation

$N_{mc,y,a,i,t}$ is the abundance (10^9) of mature capelin (mc), of age *a* and length group *i* in year *y* and month *t*.

$N_{mc,y,a,t}$ is the abundance (10^9) of mature capelin, of age *a* in year *y* and month *t*.

$W_{mc,y,a,t}$ is the average weight (kg) of mature capelin, of age *a* in year *y* and month *t*.

$Nca,_{y,a,i}$ is the acoustic abundance estimate (10^9) of capelin of age *a* and length-class *i* in year *y*.

$Wca_{y,i}$ is the average weight (kg) of capelin of length-class *i* in the acoustic survey in year *y*.

The population number at the beginning of October (t = 10) of mature capelin is given by:

$$N_{mc,y,a,i,10} = Nca_{y,a,i} Oca_i \quad ,$$

where the proportion of mature capelin of length-class *i*, Oca_i, is given by

$$Oca_i = \frac{1}{1 + e^{4p_1(p_2 - L_i)}} \quad .$$

L_i is the mean length of capelin in length-class *i*, and p_1 and p_2 are estimated from Bifrost.

The average weight of mature capelin of age *a* at time *t* = 10 in year *y* is given by:

$$W_{mc,y,a,10} = \frac{\sum_{i=1}^{i_{max}} N_{mc,y,a,i,10} Wca_{y,i}}{\sum_{i=1}^{i_{max}} N_{mc,y,a,i,10}} \quad .$$

After these initial length-based calculations, the population model is structured by age but not by length.

The abundance of age class *a* of mature capelin in year *y* and month *t* = 10 is given by

$$N_{mc,y,a,10} = \sum_{i=1}^{i_{max}} N_{mc,y,a,i,10}$$

In the period October–December (t = 10, 11, 12) it is assumed that the individual growth in weight is zero and the only processes affecting the stock are natural mortality, and increase of age at 1 January 1, i.e.

$$N_{mc,y,a,t+1} = N_{mc,y,a,t} e^{-M_{mc,y,t}}$$

for *t* = 10, 11, and

$$N_{mc,y+1,a+1,1} = N_{mc,y,a,12} e^{-M_{mc,y,12}} \quad ,$$

where

$$M_{mc,y,10} = M_{mc,y,11} = M_{mc,y,12} = M_{ic,y}$$

In the period January–March, the stock is also affected by fishing, and Pope's approximation is used to calculate the population:

$$N_{mc,y+1,a+1,t+1} = N_{mc,y+1,a+1,t} e^{-M_{y+1,t}} - \frac{C_{y,t} N_{mc,y+1,a+1,t}}{\sum_{a=1}^{5} N_{mc,y+1,a+1,t} W_{mc,y+1,a+1,t}}$$

for t = 1, 2, 3

The natural mortality $M_{y+1,t}$ is calculated from a predation model, based on calculation of the consumption of capelin by cod:

$$M_{y+1,t} = -\ln\left(1 - \frac{K_{m,y+1,t}}{\sum_{a=1}^{5} N_{mc,y+1,a+1,t} W_{mc,y+1,a+1,t}}\right),$$

where

$$K_{m,y+1,t} = C_{max} Cod_{y+1,t} \frac{\sum_{a=1}^{5} N_{mc,y+1,a+1,t} W_{mc,y+1,a+1,t}}{C_{1/2} + \sum_{a=1}^{5} N_{mc,y+1,a+1,t} W_{mc,y+1,a+1,t}}$$

(maximum consumption C_{max} and half-value $C_{1/2}$ are parameters estimated by Bifrost), and

$$Cod_{y+1,t} = \sum_{A=3}^{13} N_{co,y+1,A,1}(1 - O_{y+1,A})(1 - S_{y+1,A}) e^{-(t-0.5)Z_{y+1,A}/12} W_{y+1,A,1}^{0.801},$$

where

$N_{co,y+1,a,1}$ is the abundance of age *a* cod (billion) at the beginning of year *y+1*,

$W_{co,y+1,a,1}$ is the average weight of age *a* cod (kg) at the beginning of year *y+1*,

$Z_{co,y+1,a}$ is the total annual mortality of age *a* cod in year *y+1*, assumed to be the same as in year *y*, when no decision on the TAC for cod in year *y+1* has yet been made, and

$O_{co,y+1,a}$ is the maturity ogive for age *a* cod in year *y+1*.

These numbers are calculated on the basis of the latest stock prognosis made by the ICES Arctic Fisheries Working Group. $S_{co,y+1,a}$ is the proportion of cod of age *a* found in the Svalbard area during the Norwegian bottom-trawl survey for demersal fish in year *y* (based on data from survey reports).

3.9 Stock assessment

The stock assessment in 2008 was carried out using the same approach as in 2003, but the CapTool spreadsheet has been slightly modified to make it more user-friendly.

The parameter replicates from Bifrost have not been updated since 2003. The input data to the 1.5 year prediction are updated with data from more years.

3.10 Recruitment estimation

Numbers of recruits to enter into the management model is measured as number of one-year-olds in the acoustic survey in September each year. However, time-series of stock indices at younger stages exits. First, a survey conducted in June, resulted in a larval index. This survey was conducted annually from 1981 to 2006. Second, a survey in August–September, carried out annually from 1965 till present, resulted in a 0-group index. Gundersen and Gjøsæter (1998) compared the larval index and 0-group index with the 1-group acoustic measurement, and concluded that for the number of years studied (1981–1994) the larval index revealed no correlation with either the 0-group index or the 1-group estimate. The 0-group index, on the other hand, displayed a significant correlation with the acoustic estimate of the one-year-olds ($r^2 = 0.75$, $p < 0.0001$), allowing for predictions of year-class strength-at-age 1 at 1 October year *Y+1* to be made in September Year *Y*. This regression has been updated annually, and is used when making a 1.5 years prognosis with the CapTool model (see Section 3.11). Note that the 0-group indices recently have been recalculated (Eriksen *et al*., 2009).

3.11 Short-term forecasts

The methodology is described under 3.8.

3.12 Biological reference points

The reference point used for Barents Sea capelin is a B_{lim} of 200 000 tonnes that shall not be exceeded with a probability of 95%. ICES has advised according to this rule since 1999, and the Joint Norwegian-Russian Fishery Commission has adhered strictly to the ICES advice during this period.

Although the assessment methodology incorporates cod-capelin interactions, the harvest rule is a single species rule. Because of the importance of capelin as source of food for the cod a harvest rule taking this into account is frequently being suggested in public debate. This could be realized, for instance, by defining an upper bound for the catch.

A MSY approach for capelin could also be feasible, where a rule that maximizes long-term yield or long-term economic benefit, conditional on complying with the precautionary approach, could be envisaged. Such a rule must be estimated with long-term simulations, however, which goes beyond the 2003 version of the Bifrost model considered at the present benchmark meeting.

3.13 Modifications from previous stock annex

Not applicable, as no stock annex existed previous to WKSHORT.

3.14 Recommendations for future work

WKSHORT recommends work on the impact from harp seals and interactions with herring.

3.15 Industry-supplied data

For vessels fishing capelin VMS data exist that could be supportive of a study of the dynamics of the spawning migration. A cooperation with the industry is probably necessary in order to interpret such data, defining operational rules for whether the vessel is fishing or just having low speed because of bad weather, for instance.

An initiative has been taken to collect cod stomachs from commercial vessels, which could be helpful in studying geographical overlap between cod and capelin, and the dynamics of the spawning migration.

3.16 References

Anon. 2007. Survey report from the joint Norwegian/Russian ecosystem survey in the Barents Sea August–October 2007, Vol. 1. IMR-PINRO joint report series.

Anisimova, N., Berenboim, B., Gerasimova, O., Manushin, I. and M. Pinchukov. On the effect of red king crab on some components of the Barents Sea ecosystem. http://www.assessment.imr.no/Request/HTMLLinks/Symposium2005/Anisimova.pdf.

Antipova, T. V., Ponomarenko, I. Y., Yaragina, N. A. 1980. Seasonal and year-to-year dynamics of occurrence frequency of the main food objects for haddock and their stomach fullness degree in the Barents Sea. ICES CM 1980/H: 21.

Barrett, R.T. and Krasnov, Y.V. 1996. Recent responses to changes in stocks of prey species by seabirds breeding in the southern Barents Sea. ICES Journal of Marine Science 53: 713–722.

Bogstad, B. and Gjøsæter, H. 2001. Predation by cod (*Gadus morhua*) on capelin (*Mallotus villosus*) in the Barents Sea: implications for capelin stock assessment. Fisheries Research 53:197–209.

Bogstad, B., Haug, T. and Mehl, S. 2000. Who eats whom in the Barents Sea? NAMMCO Sci. Publ. 2: 98–119.

Bogstad, B., Hiis Hauge, K., and Ulltang, Ø. 1997. MULTSPEC – A Multi-Species Model for Fish and Marine Mammals in the Barents Sea. J. Northw. Atl. Fish. Sci. 22: 317–341.

Bogstad, B., and Mehl, S. 1997. Interactions Between Atlantic Cod (*Gadus morhua*) and Its Prey Species in the Barents Sea. Pp. 591–615 in Proceedings of the International Symposium on the Role of Forage Fishes in Marine Ecosystems. Alaska Sea Grant College Program Report No. 97–01. University of Alaska Fairbanks.

Dalpadado, P. and Bogstad, B. 2004. Diet of juvenile cod (age 0–2) in the Barents Sea in relation to food availability and cod growth. Polar biology 27:140–154.

Eriksen, E., Prozorkevich, D., and Dingsør, G. E. 2009. An Evaluation of 0-Group Abundance Indices of Barents Sea Fish Stocks. The Open Fish Science Journal 2: 6–14.

Fauchald, P., Mauritzen, M. and Gjøsæter, H. 2006. Density-dependent migratory waves in the marine pelagic ecosystem. Ecology, 87: 2915–2924.

Folkow, L.P., Haug, T., Nilssen, K.T. and Nordøy, E.S. 2000. Estimated food consumption of minke whales *Balaenoptera acutorostrata* in Northeast Atlantic waters in 1992–1995. NAMMCO Scientific Publications 2: 65–80.

Gjøsæter, H. 1998. The population biology and exploitation of capelin (*Mallotus villosus*) in the Barents Sea. Sarsia, 83: 453–496.

Gjøsæter, H. and Bogstad, B. 1998. Effects of the presence of herring (*Clupea harengus*) on the stock–recruitment relationship of Barents Sea capelin (*Mallotus villosus*). Fisheries Research 38, (1): 57–71.

Gjøsæter, H, Bogstad, B., and Tjelmeland, S. 2002. Assessment methodology for Barents Sea capelin (*Mallotus villosus*, Muller). ICES Journal of Marine Science, 59: 1086–1095.

Gjøsæter, H., Bogstad, B., and Tjelmeland, S. 2009. Ecosystem effects of the three capelin stock collapses in the Barents Sea. Marine Biology Research, 5 (1), 40–53.

Gundersen, A. C. and Gjøsæter, H. 1998. A comparison between abundance estimates of the Barents Sea capelin (*Mallotus villosus* Müller) at the larval, 0-group and 1-group stage, for the year classes 1981–1994. ICES Journal of Marine Science, 55: 95–101. ICES. 2009. Report of the Arctic Fisheries Working Group, 21–27 April 2009. ICES CM 2009/ACOM:02.

Ingvaldsen, R. and Gjøsæter, H. (submitted). Impact of climate variability, stock size and age composition on the spatial distribution of Barents Sea capelin.

ICES 2009. Report of the Arctic Fisheries Working Group, San Sebastian, Spain, 21–27 April 2009. ICES C.M. 2009/ACOM:01, 580 pp.

Jakobsen, T., Korsbrekke, K., Mehl, S., and Nakken, O. 1997. Norwegian combined acoustic and bottom-trawl surveys for demersal fish in the Barents Sea during winter. ICES C.M. 1997/Y:17, 26 pp.

Krasnov, YV, Barrett, RT, Nikolaeva, NG. 2007. Status of black-legged kittiwakes (*Rissa tridactyla*), common guillemots (*Uria aalge*) and Brunnich's guillemots (*U. lomvia*) in Murmansk, northwest Russia, and Varanger, northeast Norway. Polar Research 26: 113–117.

Langton, R. W., and Bowman, R. E. 1980. Food of fifteen Northwest Atlantic gadiform fishes. NOAA Technical Report NMFS SSRF-740. Department of Commerce, USA.

Lepesevich, Yu. M., and Shevelev, M. S. 1997. Evolution of the Russian survey for demersal fish: From ideal to reality. ICES C. M. 1997/Y:09.

Nilssen, K.T., Pedersen, O-P., Folkow, L. and Haug, T. 2000. Food consumption estimates of Barents Sea harp seals. NAMMCO Scientific Publications 2: 9–27.

Temming, A. and Andersen, N.G. 1994. Modelling gastric evacuation without meal size as a variable. A model applicable for the estimation of daily ration of cod (*Gadus morhua* L.) in the field. ICES Journal of Marine Science 51:429–438.

Tjelmeland, S. 2002. A model for the uncertainty around the yearly trawl-acoustic estimate of biomass of Barents Sea capelin, *Mallotus villosus* (Müller). ICES Journal of Marine Science 59: 1072–1080.

Tjelmeland, S., and Lindstrøm, U. 2005. An ecosystem element added to the assessment of Norwegian spring-spawning herring: implementing predation by minke whales. ICES Journal of Marine Science, 62: 285–294.

Capelin in Subareas I and II, excluding Division IIa west of 5°W (Barents Sea capelin)–Stock Annex

Quality Handbook Stock Annex: Barents Sea Capelin

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Barents Sea capelin
Working Group	AFWG
Date	02.09.2009

Revised by (in alphabetical order): Bjarte Bogstad, Harald Gjøsæter, Yuri Kovalev, Nina Mikkelsen and Sigurd Tjelmeland.

A. General

A.1. Stock definition

Capelin in the Barents Sea spawn in March–April in shallow water off the north coasts of Norway and Russia (Gjøsæter, 1998). The juveniles are transported to central and eastern parts of the Barents Sea where they grow. A large proportion of each year class matures and spawns at age 4. The remainder of the year class spawns at either age 3 or age 5. In recent years, the numbers spawning at age 5 has been negligible, but during the 1970s the total number of year classes in the total stock and in the spawning stock was larger and five-year-olds and even six-year-old spawners were not uncommon. The capelin dies after spawning (Christiansen *et al.*, 2008). Maturing capelin usually undertakes extensive feeding migrations in spring and summer north- and northeastwards into the northern and eastern parts of the Barents Sea. They return to central areas near the polar front (an oceanographic frontal area with water of Atlantic origin to the south and Arctic waters to the north) in November or December (Gjøsæter, 1998). The area north of this front is ice covered during winter. By February the mature part of the stock has assembled south of the polar front and starts a spawning migration towards the coast. The main spawning migration usually reaches the coast and spawns there during March, but earlier or later arrival and spawning may occur. "Summer spawning" occurring from July to August may take place some years, normally further east than the main spawning during spring (Gjøsæter, 1998).

A.2. Fishery

Some fishing for Barents Sea capelin have taken place for centuries, but fishery was intensified during the early 1960s, when a Norwegian purse-seine fishery began on capelin (Gjøsæter, 1998). It soon became a large-scale fishery, and was followed by a Russian fishery conducted mainly with pelagic trawl. Fishery took place from January to March on schools of prespawning fish on or close to the spawning grounds, but in the early 1970s fishery also took place on the feeding grounds in the central and northern Barents Sea during August to October. In recent years, this summer and autumn fishery has been banned (ICES, 2009). The winter fishery has also been banned during periods when the capelin stock was at a low level. This has happened three times, in the mid 1980s, in the mid 1990s and in the early 2000s. During each of these periods the fishery was stopped for 5 years.

In recent years, the fishery has changed from being mostly an industrial fishery to being mostly for human consumption. This is partly because of low TACs, but also because new markets for frozen capelin for human consumption have developed.

A.3. Ecosystem aspects

A.3.1. Geographic location and timing of spawning

The spawning takes place in March–April. The main spawning grounds are shallow waters on the seabed off the north coasts of Norway and Russia. Some minor spawning may take place during summer, normally further east than the main spring-spawning.

A.3.2. Fecundity

The individual fecundity has been found to be on average 11 500 eggs per female (Huse and Gjøsæter, 1997). The maturity is quite dependent on growth and the fecundity varies with individual weight. Capelin of this stock is considered semelparous (Christiansen *et al*., 2008), and in any case the number of capelin surviving spawning is probably very low, since the predation pressure during the spawning season is heavy (Gjøsæter, 1998).

A.3.3. Diet

The main food of larval capelin is small copepodits and small coastal invertebrates (Fossheim *et al*., 2006), and as they grow, they gradually feed more on copepod species such as *Calanus finmarchicus*, *C. glacialis* and *C. hyperboreus*, *Oithona similis*, *Metridia longa*, and *Pseudocalanus elongates* (Panasenko, 1984; Orlova *et al*., 2002). The importance of each species differs according to areas and size of the capelin. Larger capelin eat larger prey, mainly euphausids.

A.3.4. Predators

The capelin plays a key role in the marine ecosystem in this area and is by far the most important pelagic fish stock in the Barents Sea. They are the main item in the diet of northeast arctic cod (Mehl and Yaragina, 1992; Gjøsæter *et al*., 2009). Juvenile herring may feed intensively on capelin larvae (Hallfredsson and Pedersen, 2009 in press). They are prey to several species of marine mammals, e.g. harp seals, humpback and minke whales, and seabirds, e.g. kittiwakes and guillemots. They are also important as food for several other commercial fish species (Dolgov, 2002).

B. Data

B.1. Commercial catch

The fishing is mainly shared between Norway and Russia by a special agreement, and TACs are set by the Joint Norwegian-Russian Fishery Commission. Smaller quanta are in some years allocated to third countries.

B.1.1. Landings

Information about landings in the fishery are collected by the Norwegian Directorate of Fisheries which has access to both landing figures in the ports (the official landing) and the recorded catch in the logbook kept by all the vessels.

Biological samples from the catch are taken at sea by the fishermen or in the ports by people from IMR and/or inspectors from the Directorate of Fisheries then analysed by IMR (record at least the fish length, weight, age (from otoliths), sex, and maturation).

The information from the samples are then used along with the total landing data and the logbook data to estimate the age and length composition and numbers of fish by age of the total landings.

Information on landings is provided by Norway and Russia as catches-in-numbers-by-age, numbers-by-length and mean weight-by-length. Other countries that have taken part in the capelin fishery have typically only provided landings in tonnes. In such cases the Norwegian or Russian (depending on where the catches were taken) age–length and length–weight keys have been used to calculate the numbers-at-age. IUU landings are not considered to be a problem in the capelin fishery.

B.1.2. Discards

No discards are allowed in the Barents Sea capelin fishery, and discarding has not been considered a problem. However, there are indications that in cases where the catches are sorted on board the vessels into females, that are valuable in the Japanese capelin-with-roe consumption market, and males, which are landed for meal and oil purposes, some discarding may take place.

B.2. Biological

Natural mortality rates of immature Barents Sea capelin are estimated, together with length-at-maturity, based on consecutive acoustic number-by-age and number-by-length estimates. Natural mortality of immature capelin and maturation is confounded. Therefore, for this estimation the historical period is restricted to the 1970s, when the fluctuations in natural mortality were small. The length-at-maturity is assumed constant, and based on the estimated value the natural mortality for the rest of the year is calculated.

The natural mortality of maturing capelin during October–December is assumed to be equal to the natural mortality of immature capelin. For the period January–March it is assumed that there is no other source of natural mortality than consumption by cod, which is estimated using the assessment of the cod stock from the Arctic Fisheries WG.

B.3. Surveys

Beginning in 1972, and for a number of years, several surveys aimed at different age groups of capelin have been conducted annually. After some years the annual surveys were reduced to four, i.e. a winter survey (on prespawning fish) a larval survey in June, a 0-group survey in August, and an acoustic survey aimed to cover the total stock in September. During the early 1980s the winter survey was stopped, and in 2007 the larval survey was discontinued.

The main survey for capelin has always been the September acoustic survey. In recent years, the coverage of the capelin stock has been included in an "ecosystem survey" but the acoustic survey for capelin is still carried out in the same manner as in previous years. The coverage of all parts of the stock has, though, been more complete in the period after 1980. Before that year, the southeastern part of the Barents Sea, where large parts of the youngest age group is normally found, was poorly covered. Trawl samples are taken to get the species- and length composition. Age, length, sex, maturity stage and stomach data are recorded. The results from this survey (a number per length group and age group matrix) are used to predict the quota for the fishing season starting in January the year after the survey is conducted.

B.4. Commercial cpue

Not relevant to this stock.

B.5. Other relevant data

The consumption of capelin by cod is taken into account in the assessment model. The consumption per cod is modelled based on cod stomach content data and temperature data from the demersal fish survey in the Barents Sea in January–March. The number of cod is taken from the assessment of cod made by the ICES Arctic Fisheries Working Group, while the geographical distribution of cod is based on cod survey data.

C. Assessment methodology

Models used: Age based

Software used: (Gjøsæter *et al.*, 2002) Bifrost (Mathematica) and CapTool (Excel including @RISK)

Model Options chosen: Cut-off maturation-at-length, same for males and females

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Catch-at-age in numbers	CapCatch.xls	1972–last data year	1–5	Yes
Number-at-age and length* and weight-at-length in the stock	CapTab.xls	1972–last data year	1–5	Yes
Proportion mature-at-age	Not relevant			
Natural mortality	In capTool.xls	1972–last data year	1–5	Yes

Tuning data:

Type	Name	Year range	Age range
Not relevant			

*** Considered an absolute estimate of the stock.**

C.1. The Bifrost model

The model formulations and the approach to estimating parameters described here pertain to the version of Bifrost used for estimating parameters in 2003. Bifrost is written in Mathematica.

Bifrost has evolved considerably since 2003, at present describing consumption by cod on both capelin and cod (cannibalism) the year around and with harp seals as an endogenous entity. Thus, Bifrost can be used to estimate MSY-based harvest rules as well as being an operating model to test harvest rule in a multispecies context. This version of the model was not considered at the benchmark meeting, however.

The version used for estimating parameters to CapTool in 2003 is described below:

C.1.1. Data to Bifrost

Table C.1 displays an overview of Bifrost input data. "Symbol" is the notation used in the present document, "Name" is a descriptive name of the data source, "Structure" describes how the data are partitioned for use in Bifrost and "Origin" describes the origin of the raw data. Bifrost works on stochastic replicates of the data, and "Resampling depth of original data" describes at which level of data aggregation the data are resampled.

Table C.1. Overview of Bifrost input data.

Symbol	Name	Structure	Origin	Resampling depth of original data
N_{ca}	Capelin September data	Yearly files of replicates of number and age at length and weight at length	Russian - Norwegian trawl samples and Sa values	Individual Sa values in each square Trawl samples connected to each square Individual fish in each trawl sample
C_{ca}	Capelin catch	Number by age by maturation component	Catc reports in tonnes Biological samples	Not resampled
SV	Proportion at age of cod in the Spitsbergen area	Proportion by age by year	Norwegian and Russian bottom trawl indices	Not resampled
N_{co}	Number at age from the Arctic Fisheries WG assessment	Number at age by year	XSA tuned with survey indices	Not resampled
W_{co}	Weight at age from the Arctic Fisheries WG assessment	Weight at age by year	Russian and Norwegian biological samples	Not resampled
O_{co}	Proportion mature at age from the Arctic Fisheries WG assessment	Proportion mature at age by year	Russian and Norwegian biological samples	Not resampled
CM	Consumption per cod	Files of replicates of consumption of mature capelin during January - March by immature cod where mature capelin is defined as capelin longer than 13.5, 14.0 or 14.5 cm For each file the structure of each replicate is : year consumption of mature capelin by cod age	Individual stomach content data Station temperature data Replicates of evacuation rate parameters	Station temperature uncertainty Prey length uncertainty

C.1.2. Bifrost model formulations

Maturation model

The maturation of capelin is modelled as a logistic function:

$$m(l) = \frac{1}{1 + e^{4p_1(p_2 - l)}}$$

Where l is the length in cm, p_2 is the length at 50% maturity and p_1 describes the increase in maturity-by-length at p_2. It is further assumed that the maturation is nearly a cut-off maturation and p_1 has been fixed to 3.5, which gives the maturation function shown in Figure C.1:

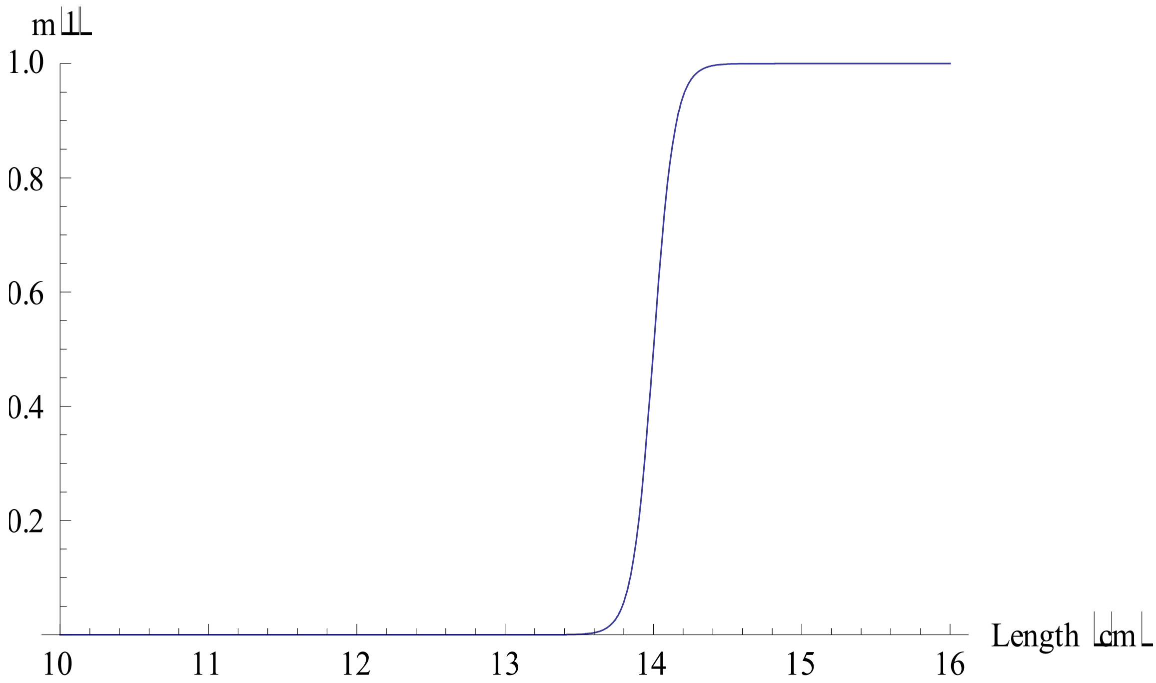


Figure C.1. Maturation function used in the 2003 version of Bifrost, for a typical value of p_2 (length-at-maturity).

It is assumed that p_2 and p_1 are the same for males and females and for all age groups.

For a given value of p_2, the maturation function is applied to the length distribution (0.5 cm wide length groups) of each age group from the September survey. The resulting length distribution of maturing fish is then integrated over length to give the age distribution of mature fish. The proportion immature at length is given as 1 – m(l) which also is integrated over length groups to give the age distribution of immature fish.

The estimation of p_2 is based on building a likelihood function by comparing the immature capelin projected one year ahead with the total stock measured in that year. The projection involves the natural mortality of immature capelin, the estimation of which thus becoming confounded with the estimation of p_2. Two age groups are included in the estimation: age 2 to age 3 and age 3 to age 4. Age group 1–2 is excluded because the survey data for age 1 are unreliable in the 1970s and age group 4–5 is excluded because of fear of the assumption of constant p_2 being violated for older ages. This age group is also of lesser significance.

The projection assumes a constant natural mortality within each period 1 October–1 October. Pope's approximation is used for the catch during 12 months:

$$N_{ca,i} = N_{ca,\, i-1}e^{-M} - C_{ca,imm,i-1}e^{-0.5M}$$

Where $N_{ca,i}$ is the number of fish in the cohort, M is the monthly natural mortality and $C_{ca,imm,i}$ the catch of immature fish in the cohort in month *i*. The catch data are split on mature and immature fish.

The likelihood function is given by:

$$objective = \prod_{y,a} \frac{1}{\sqrt{2\pi\sigma_{y,a}}} e^{-\frac{(Nca,_{y,a} - \hat{N}ca,_{y,a}(p2,M))^2}{2\sigma_{y,a}{}^2}}$$

where:

$Nca,_{y,a}$ is the observed abundance of capelin of age *a* in year *y*

$\hat{N}ca,_{y,a}$ is the modelled abundance of capelin of age *a* in year *y*

$$\sigma^2_{y,a} = \sigma^2_{y-1,a-1,obs} \left(\frac{N_{y,a}}{N_{y-1,a-1}}\right)^2 + \sigma^2_{y,a,obs}$$

$\sigma^2_{y,a,obs}$ is the variance of the survey estimate calculated by resampling (see below).

p_2 and M are estimated by finding those values that maximize *objective*.

$\sigma^2_{y,a,obs}$ is based on resampling the September estimates (both total acoustic abundance and biological samples), as described by Tjelmeland, 2002. Figure C.2 shows the estimated parameters for 500 replicates.

The estimations were made using data from 1972–1980, and an M-value for this period was also estimated. The reason for using the chosen time range is that the population dynamics was stable, with relatively constant M-values. Later there were large variations in M, possibly connected to large fluctuations in the harp seal stock and in changes in geographical distributions of other predators. For years after 1980, annual mortality parameters are calculated using the estimated maturation parameters for the period 1972–1980.

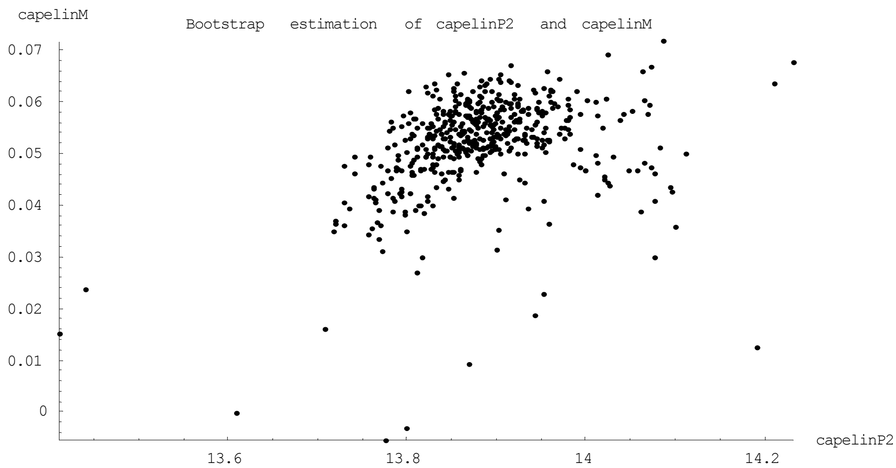


Figure C.2. Bootstrap estimates of length-at-maturity (x-axis) and monthly natural mortality (y-axis) of immature capelin in the period 1972–1980.

Predation model

Predation by cod is modelled by modelling the consumption by cod of mature capelin only, and comparing this with estimates of consumption by cod on mature capelin based on stomach content data and an evacuation rate function. The effect of other food is accounted for in the parameter $C_{½}$ that denotes the amount of mature capelin present that gives consumption equal to half the maximum consumption C_{max}. It should be noted that the predation model is based on data from 1984 while

Bifrost runs from 1972. It is noteworthy that the prevailing feeding conditions may have been different in the 1970s than from 1984 onwards.

The consumption of capelin by cod in year *y* and month *t* is modelled by a type II functional relationship):

$$Cons(y,t) = \frac{C_{\max} \bullet predationAbility(y,t) \bullet MatBio(y,t)}{C_{1/2} + MatBio(y,t)}$$

where *MatBio(y,t)* is the biomass of mature capelin in year y and month t and *predationAbility(y,t)* is given as:

$$predationAbility(y,t) = \sum_{A} Nco(y,t,A)CodSuit(a)(1-Oco(y,a))(1-SV(y,a))Wco(y,a)^{0.801}$$

The natural mortality on mature capelin in the months January–March is then calculated from the equation:

$$M_{mature}(y,t) = -\ln(1 - \frac{Cons(y,t)}{MatBio(y,t)})$$

t denotes the time, and each month is divided into six steps, where the catch is applied after the third step using a formulation similar to that for the consumption by cod. The catch over the whole period January–March is allocated with 20% in January, 30% in February and 50% in March, based on experience.

The parameters C_{max} and $C_{½}$ in the above model are estimated by minimizing sum of squares (SSQ) of the difference between the modeled consumption during January–March and consumption calculated directly from the individual stomach content data over the same period.

$$SSQ = \sum_y (\sum_t Cons(y,t) - \sum_{a,t} NCod(y,t,a)(1 - O_{co}(y,a))\ (1 - SV(y,a))CM(y,a))^2$$

$O_{co}(y,a)$ the proportion mature from the Arctic Fisheries WG assessment in year *y*, *SV(y,a)* is the proportion of immature cod of age *a* residing in the Svalbard area in year *y* and *CM(y,a)* is the consumption per cod of age *a* calculated from cod stomach content samples for January–March in year *y*.

The total abundance of cod in year *y* and month *t*, *NCod(y,t,A)*, is given by

$$NCOD(y,t,a) = Nco(y,a)e^{-(t-0.5)*Z(y,a)/12}$$

where *Nco(y,a)* is the number of cod of age *a* at the beginning of year *y* given by the VPA-based assessment of cod made by the Arctic Fisheries Working Group (AFWG). *O(y,a)* is the proportion mature-at-age for cod, and it is assumed that only immature cod preys on prespawning capelin. The component of immature cod that reside in the Spitsbergen area is assumed not to prey on prespawning capelin. *Z(y,a)* is the total mortality of cod.

Geographical overlap between cod and capelin

The calculation of the Spitsbergen (*SV(y,a)*) component is based on the following data sources:

Norwegian bottom-trawl abundance indices by age in the Barents Sea in February and the Spitsbergen area in August–September, from 1981 onwards.

Jakobsen *et al*., 1997 describe the methodology of the February survey, and the survey indices are given in ICES 2009.

Results of the coverage in the Spitsbergen and Barents Sea areas in August–September from 1995 onwards are given in Anon., 2007. In the years 1995, 1996, 1999, 2004, 2005 and 2006 there was fairly complete area coverage of the cod stock in August–September.

Russian bottom-trawl indices on ICES areas (I, IIa, IIb) from the Russian survey in October–December from 1982 onwards (Lepesevich and Shevelev, 1997). The results are given in ICES 2009.

It was found that the most appropriate way to calculate the Spitsbergen component based on the available data, was to combine the Barents Sea survey with the Spitsbergen survey in the same year, i. e. calculate the proportion of age *a* fish found in the Spitsbergen area in year *y*, *SV(y,a)* as

$$SV(y,a) = \frac{IS(y,a)}{IS(y,a) + IB(y,a)}$$

where *IS(y,a)* and *IB(y,a)* are the survey indices in the Spitsbergen area and the Barents Sea, respectively. This will tend to underestimate the proportion of cod found in the Spitsbergen area, because the survey in the Spitsbergen area takes place half a year later than the Barents Sea survey. On the other hand, the Spitsbergen area stretches so far east that some of the cod in that area probably will overlap with capelin, causing an overestimate of the proportion of cod found in the area where it does not overlap with capelin. If these two factors approximately cancel out, our approach is reasonable. The Spitsbergen component (a vector with proportion-by-age) in 2005 and later years is drawn randomly from the values in the period 1983–2004, calculated in the way outlined above.

As a consequence of changes in the strata system used in the Spitsbergen survey, values from 2005 and later years are not available at present.

CodSuit(a) is the suitability of mature capelin for cod of age *a*. It is set to 0.0 for age 1 cod, 0.1 for age 2 cod and 1.0 for age 3 and older cod, in all years. The suitability for age 2 cod is based on the results by Dalpadado and Bogstad (2004) who found very little capelin > 14 cm in stomachs of age 2 cod during the period January–March. Also, the proportion of capelin in the diet of cod < 25 cm (corresponding to age 2) in January–April is much lower than the proportion of capelin in the diet of larger cod (Bogstad and Gjøsæter, 2001).

Cod stomach content data and consumption calculations

Stomach content data for cod are collected jointly by IMR and PINRO, averaging about 5000 stomachs annually for the period January–March. For the calculation of consumption it is assumed that over the period January–March the amount of capelin consumed equals the amount of stomach content evacuated. For each stomach collected in this period the amount of capelin evacuated instantaneously is calculated using an evacuation rate model. The measurement value *CM(y,a)* used in the sum of squares is the average of the instantaneous evacuation rate multiplied by the length of the period.

The evacuation rate model of capelin for an individual stomach is given by the formula

$$R = \ln(2) e^{\gamma T} W^{\delta} S^{\xi} / \alpha$$

where:

α: evacuation rate halftime for capelin
γ: dependence on ambient temperature
δ: dependence on predator body weight
ξ: shape parameter
S: stomach content in grams
T: ambient temperature. This is taken as the nearest measured temperature in space and time at the depth of the trawl station
W: body weight in grams
R: Consumption

This is essentially the same model as used by Bogstad and Mehl (1997), but in the evacuation rate model the initial meal size is not used (Temming and Andersen, 1994), rather the model parameters are estimated using a non-linear dependence on stomach content.

The empirical consumption of capelin per cod of age a is thus given as:

$$CM(y,a) = \sum_{area}(\sum_{a,i}R_{y,a,i})N^{imm}_{y,a,area}) \,/\, \sum_{a,area} N^{imm}_{y,a,area}$$

Where the outer summation extends over cod ages *a*. The innermost summation extends over individual fish *i* which are weighted with the number of observed immature cod in each area shown in Figure C.3 for the calculation to be somewhat robust against the possibility that the stomach sampling is geographically biased with regard to the distribution of the cod. The cod stock is here distributed on the Multspec areas (Bogstad *et al.*, 1997) .This distribution is based on data from the joint IMR-PINRO demersal fish survey in February (Jakobsen *et al.*, 1997).

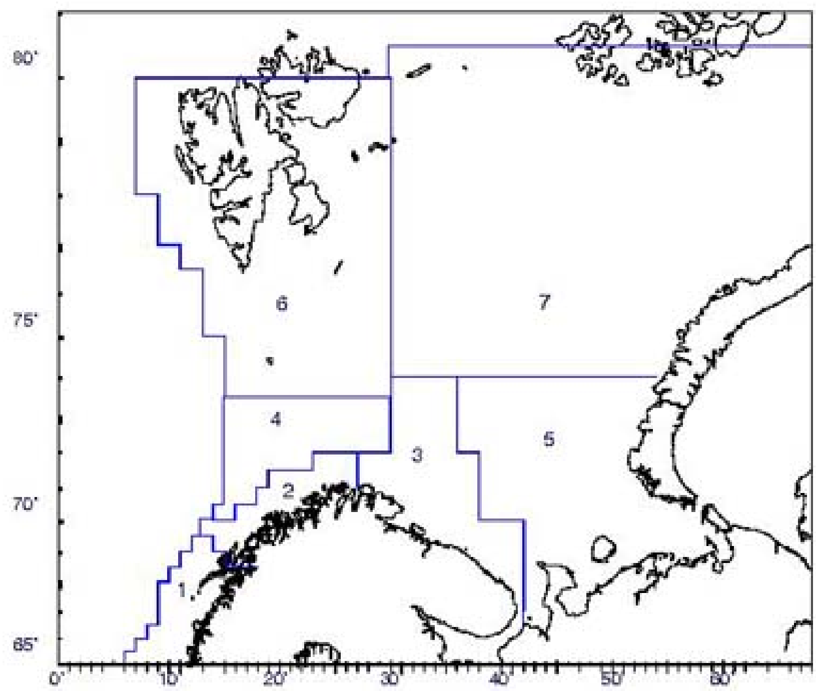


Figure C.3. Areas used for scaling consumption per cod with observed number of immature fish from biological samples.

The temperature used in the evacuation rate model is taken as the nearest measured temperature in space and time at the depth of the trawl station (www.assessment.imr.no/Bifrost/temperatureData.html). For Norwegian stomach content data there as a rule is a temperature station quite close, for Russian stomach content data the nearest temperature (only Norwegian temperature data are used) can be further away in space and time. The uncertainty in using temperature stations that are not in the vicinity of the trawl station has been quantified.

Studies by Bogstad and Gjøsæter (2001) indicate that a significant part of the predation by cod on capelin in January–March (1993–1999 average: ca. 25%) is on immature capelin. This conclusion is drawn from analyses of stomach content data. The stomach content data contain information about the prey length. In calculations of the consumption made in Bifrost and CapTool (for the latter, see below) it has been assumed that all consumption of capelin by cod in January–March is on mature capelin. The empirical consumption *CM* used to estimate parameters in the consumption model should thus be consumption of mature capelin only. The length information in the stomach content database is used to base the calculation of *CM* on only mature capelin as closely as practically possible. Maturation is determined by length, but the length-at-maturity is a modelled entity, and not known *a priori*. Therefore, CM has been calculated using capelin in cod stomachs with either 13.5, 14.0 or 14.5 cm as lower limit. During stochastic model simulations the length-at-maturity will vary and the consumption per cod replicates corresponding to a length-at-maturity closest to the model maturation length are selected. The uncertainty in the proportion of the consumption of capelin by cod during January–March, which consists of immature capelin, is also accounted for. The parameters are estimated by using the historically calculated total consumption as observations and the total consumption calculated from the above model as model results. As the estimation depends on quantities that in nature are stochastic a new regression is made for each historical run.

C.2. The CapTool model

CapTool is a tool for making short-term (1 October–1 April) probabilistic projections of the maturing capelin stock in order to give quota advice. CapTool is implemented in Excel using the @RISK add-on package. Usually 15 000 simulations are made for each catch option.

The timing of the processes can be summed up in the following way:

TIME	PROCESS
1 October	Calculate number of maturing fish
October–December	Apply M(based on Bifrost estimates of M on immature capelin)
January–March	Apply M from cod predation, apply fishing
1 April	Calculate SSB

The following data sources enter into the CapTool short-term (October–April) projection:

Table C.2. Input to CapTool 6-month projection.

MODEL INPUT	DATA SOURCE	UNCERTAINTY
Number and weight-by-age and length October 1	September survey	Assumed CV (0.2, log scale) on number-at-age
Proportion mature October 1	Bifrost estimates of maturation parameters	1000 replicates of maturation parameters
Mortality in October–December	Bifrost estimates of M on immature capelin	Draw year randomly from period 1972–2001, then draw randomly from 1000 replicates of mortality for this year
Mortality in January–March	Bifrost estimates of: predation parameters, cod abundance from AFWG cod assessment geographical distribution of cod from surveys	Random draw from 1000 replicates of predation parameters assumed CV (0.3, log scale) of cod abundance cod geographical distribution drawn randomly from historical data (1983–2004), see under Bifrost
Catch in January–March	Capelin catch in biomass, catch distribution by month (January–March)	None

The equations used (Gjøsæter *et al*., 2002) are described at the end of this section.

The quota is determined by running CapTool for various catch options and calculating P(SSB <200 000 t) for each of the options. The results of such runs are shown in Figure C.4, and the uncertainty in stock development during October–April is illustrated in Figure C.5.

CapTool can also be used for medium-term (1.5 years) prognosis. This prognosis is done in two steps. First, the immature stock 1 October in year *y* is used to predict the total stock 1 October in year *y+1*. Then, the stock 1 October in year *y+1* is carried forward to 1 April in year *y+2* using the methodology described above. These predictions are not used for giving quota advice, but can be used as an indication of the likelihood of a fishery in year *y+2* and are also useful for prognosis of e.g. cod growth.

The prediction from 1 October year *y* to 1 October year *y+1* is done by drawing randomly from historical data on growth and mortality, as explained in Table C.3. Also, a regression between 0-group and 1-group abundance for the year classes 1980–present is used to predict the 1-group abundance in year *y+1* (ICES 2009).

Table C.3. Input to CapTool 1.5 year projection.

MODEL INPUT	DATA SOURCE	UNCERTAINTY
Number and weight-by-age and length October 1 year y	September survey	Assumed CV (0.2, log scale) on number-at-age
Proportion immature October 1 year *y*	Bifrost estimates of maturation parameters	Replicates of maturation parameters
Mortality from year y to year *y+1*	Bifrost estimates of M on immature capelin	Draw year randomly from period 1972–2001, then draw randomly from replicates of mortality for this year
Length growth from year y to year *y+1*	Calculate mean growth in cm. Shift length distribution upwards accordingly	Calculate mean growth in cm of immature capelin based on mean length-at-age for each age group and year from survey data (1973–present) as well maturation parameters. Draw randomly from these years for each age group.
Weight-at-length in year *y+1*		Draw weight-at-length vector randomly from historical survey data (1973–present)
Number of age 1 in year *y+1*	0-group abundance in year y Regression between 0-group survey and age 1 survey abundance (1980–present)	Residuals from regression

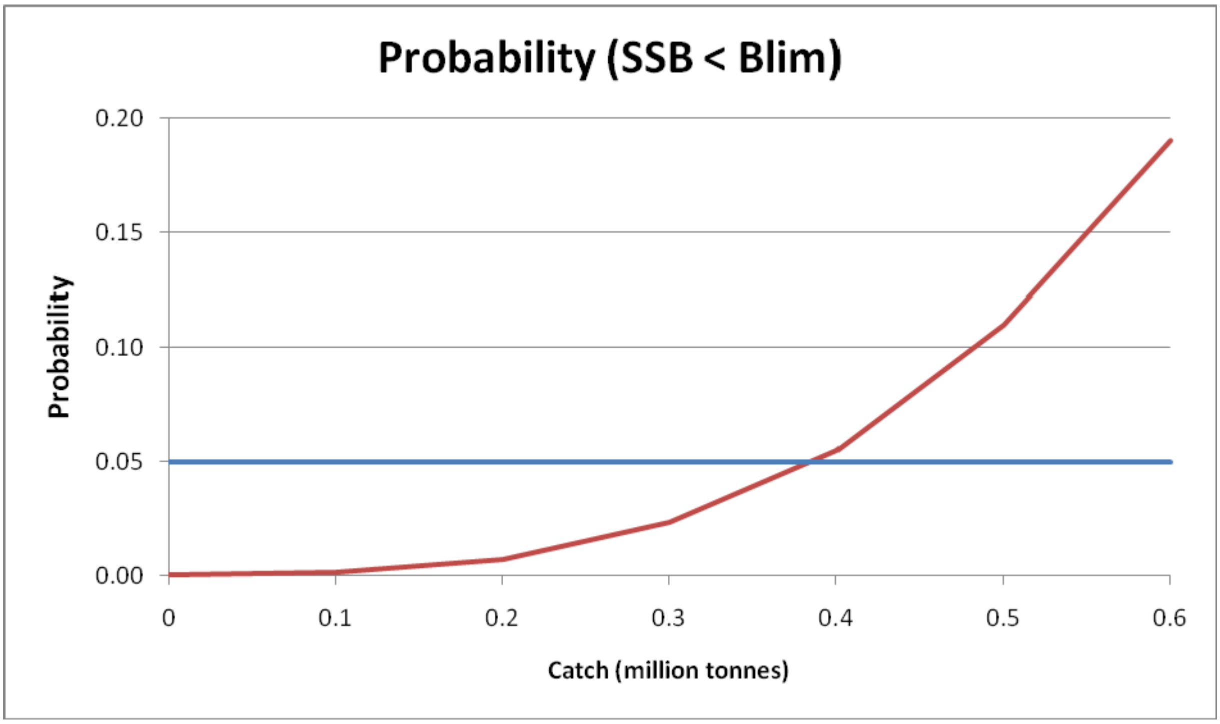


Figure C.4. Probability of SSB < B_{lim} as a function of catch (from assessment autumn 2008).

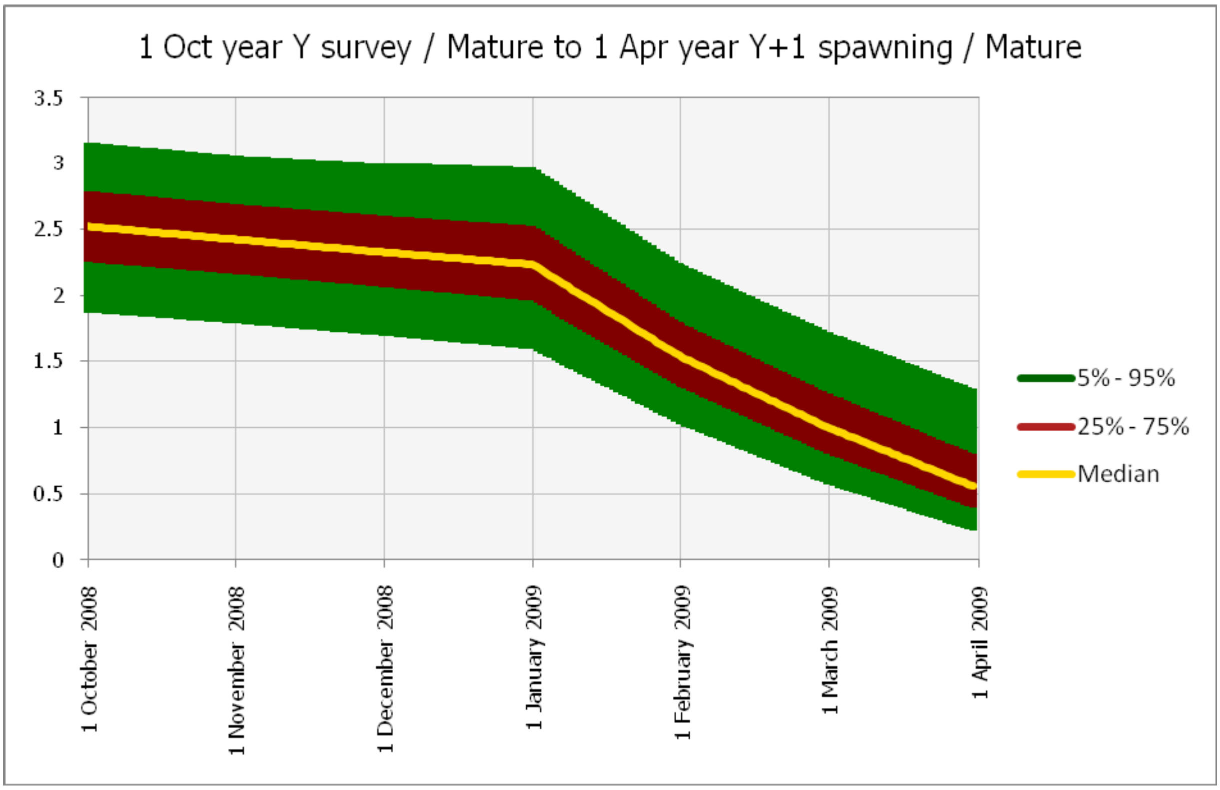


Figure C.5. Stock development, with uncertainty, 1 October 2008–1 April 2009. From autumn 2008 assessment.

CapTool model formulation

$N_{mc,y,a,i,t}$ is the abundance (10^9) of mature capelin (mc), of age *a* and length group *i* in year *y* and month *t*.

$N_{mc,y,a,t}$ is the abundance (10^9) of mature capelin, of age *a* in year *y* and month *t*.

$W_{mc,y,a,t}$ is the average weight (kg) of mature capelin, of age *a* in year *y* and month *t*.

$Nca,_{y,a,i}$ is the acoustic abundance estimate (10^9) of capelin of age *a* and length-class *i* in year *y*.

$Wca_{y,i}$ is the average weight (kg) of capelin of length-class *i* in the acoustic survey in year *y*.

The population number at the beginning of October (t = 10) of mature capelin is given by:

$$N_{mc,y,a,i,10} = AN_{y,a,i}Oca_i,$$

where the proportion of mature capelin of length-class *i*, Oca_i, is given by

$$Oca_i = \frac{1}{1+e^{4p_1(p_2-L_i)}} .$$

L_i is the mean length of capelin in length-class *i*, and p_1 and p_2 are estimated from Bifrost.

The average weight of mature capelin of age *a* at time *t* = 10 in year *y* is given by:

$$W_{mc,y,a,10} = \frac{\sum_{i=1}^{i_{max}} N_{mc,y,a,i,10} Wca_{y,i}}{\sum_{i=1}^{i_{max}} N_{mc,y,a,i,10}} \;.$$

After these initial length-based calculations, the population model is structured by age but not by length.

The abundance of age class *a* of mature capelin in year *y* and month $t = 10$ is given by

$$N_{mc,y,a,10} = \sum_{i=1}^{i_{max}} N_{mc,y,a,i,10} \;.$$

In the period October–December (t = 10, 11, 12) it is assumed that the individual growth in weight is zero and the only processes affecting the stock are natural mortality, and increase of age at 1 January 1, i.e.

$$N_{mc,y,a,t+1} = N_{mc,y,a,t} e^{-M_{mc,y,t}}$$

for t = 10, 11, and

$$N_{mc,y+1,a+1,1} = N_{mc,y,a,12} e^{-M_{mc,y,12}} \;,$$

where

$$M_{mc,y,10} = M_{mc,y,11} = M_{mc,y,12} = M_{ic,y}$$

In the period January–March, the stock is also affected by fishing, and Pope's approximation is used to calculate the population:

$$N_{mc,y+1,a+1,t+1} = N_{mc,y+1,a+1,t} e^{-M_{y+1,t}} - \frac{C_{y,t} N_{mc,y+1,a+1,t}}{\sum_{a=1}^{5} N_{mc,y+1,a+1,t} W_{mc,y+1,a+1,t}}$$

for t = 1, 2, 3

The natural mortality $M_{y+1,t}$ is calculated from a predation model, based on calculation of the consumption of capelin by cod:

$$M_{y+1,t} = -\ln\left(1 - \frac{K_{m,y+1,t}}{\sum_{a=1}^{5} N_{mc,y+1,a+1,t} W_{mc,y+1,a+1,t}}\right) \;,$$

where

$$K_{m,y+1,t} = C_{max} Cod_{y+1,t} \frac{\sum_{a=1}^{5} N_{mc,y+1,a+1,t} W_{mc,y+1,a+1,t}}{C_{½} + \sum_{a=1}^{5} N_{mc,y+1,a+1,t} W_{mc,y+1,a+1,t}}$$

(maximum consumption C_{max} and half-value $C_{1/2}$ are parameters estimated by Bifrost), and

$$Cod_{y+1,t} = \sum_{A=3}^{13} N_{co,y+1,A,1}(1-O_{y+1,A})(1-S_{y+1,A})e^{-(t-0.5)Z_{y+1,A}/12}W_{y+1,A,1}{}^{0.801},$$

where

$N_{co,y+1,a,1}$ is the abundance of age *a* cod (billion) at the beginning of year *y+1*,

$W_{co,y+1,a,1}$ is the average weight of age *a* cod (kg) at the beginning of year *y+1*,

$Z_{co,y+1,a}$ is the total annual mortality of age *a* cod in year *y+1*, assumed to be the same as in year *y*, when no decision on the TAC for cod in year *y+1* has yet been made, and

$O_{co,y+1,a}$ is the maturity ogive for age *a* cod in year *y+1*.

These numbers are calculated on the basis of the latest stock prognosis made by the ICES Arctic Fisheries Working Group. $S_{co,y+1,a}$ is the proportion of cod of age *a* found in the Svalbard area during the Norwegian bottom-trawl survey for demersal fish in year *y* (based on data from survey reports).

D. Short-term projection

Model used: Age and length structured. Maturing stock is calculated using the length-at-maturity is projected from 1 October (acoustic survey) to 1 April (spawning) as number and weight-by-age.

Software used*:* CapTool (Excel including @RISK) (Gjøsæter *et al*., 2002).

Initial stock size: Acoustic measurements in numbers-at-length at age 1–4 from autumn surveys.

Maturity:

F and M before spawning: F is calculated from the proposed catch in biomass units. M is calculated from the model for consumption by cod.

Weight-at-age in the stock: Calculated as the weight-at-age of the maturing stock by October 1.

Weight-at-age in the catch: Not relevant.

Exploitation pattern: F is assumed equal for all mature age groups in January–March.

Intermediate year assumptions: Not relevant.

Stock recruitment model used: Not relevant.

Procedures used for splitting projected catches: Not relevant.

E. Medium-term projections

As the capelin is a short-lived species this is not considered relevant. (Most capelin die at age 5). However, the CapTool model presents projections 1.5 years ahead of time.

F. Long-term projections

Not relevant.

G. Biological reference points

B_{lim} = 200 000 tonnes. A stochastic B_{lim} equal to the modelled SSB in 1989 has been suggested, but not used in management.

H. Other issues

None.

References

Anon. 2007. Survey report from the joint Norwegian/Russian ecosystem survey in the Barents Sea August–October 2007, Vol. 1. IMR-PINRO joint report series.

Bogstad, B., Hiis Hauge, K., and Ulltang, Ø. 1997. MULTSPEC – A Multi-Species Model for Fish and Marine Mammals in the Barents Sea. J. Northw. Atl. Fish. Sci. 22: 317–341.

Bogstad, B., and Mehl, S. 1997. Interactions Between Atlantic Cod (*Gadus morhua*) and Its Prey Species in the Barents Sea. Pp. 591–615 in Proceedings of the International Symposium on the Role of Forage Fishes in Marine Ecosystems. Alaska Sea Grant College Program Report No. 97–01. University of Alaska Fairbanks.

Bogstad, B. and Gjøsæter, H. 2001. Predation by cod (*Gadus morhua*) on capelin (*Mallotus villosus*) in the Barents Sea: implications for capelin stock assessment. Fisheries Research 53:197–209.

Christiansen, J. S., Præbel, K., Siikavuopio, S. I. and Carscadden, J. E. 2008. Facultative semelparity in capelin *Mallotus villosus* (Osmeridae)-an experimental test of a life history phenomenon in a sub-arctic fish. Journal of Experimental Marine Biology and Ecology, 360: 47–55.

Dalpadado, P. and Bogstad, B. 2004. Diet of juvenile cod (age 0–2) in the Barents Sea in relation to food availability and cod growth. Polar biology 27:140–154.

Dolgov, A. V. 2002. The role of capelin (*Mallotus villosus*) in the foodweb of the Barents Sea. ICES Journal of Marine Science, 59: 1034–1045.

Fossheim, M., Tande, K. S., Semenova, T. and Timonin, A. 2006. Capelin larvae (*Mallotus villosus*) and community structure of zooplankton off the coast of northern Norway. Journal of Plankton Research, 28: 585–595.

Gjøsæter, H. 1998. The population biology and exploitation of capelin (*Mallotus villosus*) in the Barents Sea. Sarsia, 83: 453–496.

Gjøsæter, H, Bogstad, B., and Tjelmeland, S. 2002. Assessment methodology for Barents Sea capelin (*Mallotus villosus*, Muller). ICES Journal of Marine Science, 59: 1086–1095.

Gjøsæter, H., Bogstad, B. and Tjelmeland, S. 2009. Ecosystem effects of the three capelin stock collapses in the Barents Sea. Marine Biology Research, 5: 40–53.

Hallfredsson, E.H., and Pedersen, T. 2009. Effects of predation from juvenile herring (*Clupea harengus*) on mortality rates of capelin (*Mallotus villosus*) larvae. Can. J. Fish. Aquat. Sci. (In press).

Huse, G. and Gjøsæter, H. 1997. Fecundity of the Barents Sea capelin (*Mallotus villosus*). Marine Biology, 130: 309–313.

ICES 2009. ICES AFWG Report 2009. ICES CM 2009\ACOM:01: 1–590.

ICES 2009. Report of the Arctic Fisheries Working Group, San Sebastian, Spain, 21–27 April 2009. ICES C.M. 2009/ACOM:01, 580 pp.

Jakobsen, T., Korsbrekke, K., Mehl, S., and Nakken, O. 1997. Norwegian combined acoustic and bottom-trawl surveys for demersal fish in the Barents Sea during winter. ICES C.M. 1997/Y:17, 26 pp.

Lepesevich, Yu. M. and Shevelev, M. S. 1997. Evolution of the Russian survey for demersal fish: From ideal to reality. ICES C. M. 1997/Y:09.

Mehl, S. and Yaragina, N. A. 1992. Methods and results in the joint PINRO-IMR stomach sampling program. In Interrelations between fish populations in the Barents Sea. Proceedings of the fifth PINRO-IMR Symposium Murmansk, pp. 5–16. Ed. by B. Bogstad and S. Tjelmeland. Institute of Marine Research, Bergen, Norway, Bergen, Norway.

Orlova, E. L., Ushakov, N. G., Nesterova, V. N. and Boitsov, V. D. 2002. Food supply and feeding of capelin (*Mallotus villosus*) of different size in the central latitudinal zone of the Barents Sea during intermediate and warm years. ICES Journal of Marine Science, 59: 968–975.

Panasenko, L. D. 1984. Feeding of the Barents Sea capelin. ICES C.M. 1984, H:6: 1–16.

Temming, A. and Andersen, N.G. 1994. Modelling gastric evacuation without meal size as a variable. A model applicable for the estimation of daily ration of cod (*Gadus morhua* L.) in the field. ICES Journal of Marine Science 51:429–438.

4 Capelin in Subareas V, XIV and Division IIa west of 5°W (Iceland-East Greenland-Jan Mayen area)

4.1 Current stock status

WKSHORT is unable to approve the stock annex for two reasons. The first, and main, reason is a concern that the value of *M* (natural mortality) used in the assessment calculations (0.035 per month) is too low. Material presented by the assessment team during the Workshop suggested that the mortality as a consequence of cod alone could be substantially greater than 0.035. In considering the effect on the assessment of using a value of *M* that is too low we need to distinguish between the two stages of quota setting: first, the setting of a preliminary quota, based on the October/November survey; and second, the quota adjustment based on a January/February survey. The effect on the second stage is clear: use of a value of *M* that is too low will result in an increased probability that the spawning biomass will fall below B_{target}. The effect on the first stage is unclear, because *M* is used in two places in the calculations (in the back-calculations [equations (1) and (2) of Gudmundsdottir and Vilhjámsson, 2002] and the forward projections from 1 August [equations (8)–(13) of Gudmundsdottir and Vilhjámsson, 2002]).

The second, and more minor, concern about the assessment is that the description of the first stage of quota setting [in Gudmundsdottir and Vilhjámsson, 2002] is inadequate, in the sense that it would not be sufficient to allow someone else to conduct the assessment given the data.

The fisheries for Icelandic capelin have been at very low level from 2005/2006 till 2008/2009 when they were the lowest since in 1982 when the fishery was closed. In 2008/2009 the measured biomass in January was close to 300 thousand tonnes, not enough to open the fisheries. Acoustic measurements of immature capelin in autumn indicate that the mature stock in 2009/2010 will be small and most likely not large enough to allow fisheries. Results from a research project (Capelin in the Iceland Sea) from August 2008 do indicate that year class 2008 might be larger than many recent year classes that have been small. A more reliable measurement of this year class will be conducted in November 2009.

The relatively low abundance of capelin in recent years has also been confirmed by low mean weight-at-age of cod that are now similar to what they were in period around 1982 when the capelin stock collapsed. Mean weight-at-age of cod is closely correlated with capelin abundance (Vilhjálmsson, 2002) and the difference between period of low and high capelin abundance is close to 30%.

Assessment of the stock aims at estimating the amount of capelin that spawns and the HCR is based on keeping the spawning stock above 400 000 tonnes. The final assessment is usually based on acoustic surveys in January-February 4–6 weeks before spawning of the capelin.

4.2 Compilation of available data

The fishing is shared between Iceland, Norway, Faroe Islands and Greenland by a special agreement, but by far the largest quantities are fished by Iceland.

4.2.1 Landings

Information about landings in the fishery are collected by the Icelandic Directorate of Fisheries which has access to both landing figures in the ports (the official landing) and the recorded catch in the digital logbook kept by all the vessels. The logbooks keep information about timing (day and time), location (latitude and longitude), fishing gear, duration (minutes), catch size, and species composition in the catch of each fishing operation for each vessel.

Biological samples from the catch are taken at sea by the fishermen or in the ports by people from MRI and/or inspectors from the Directorate of Fisheries then analysed by MRI (record at least the fish length, weight, age (from otoliths), sex, maturation, and weight of sexual organs). The information from the samples are then used along with the total landing data and the logbook data to estimate the age and length composition and numbers of fish by age of the total landings.

Landings are provided by Norway, Faroe Island and Greenland as catches-in-numbers-at-age. They are added to the Icelandic catches-in-numbers-at-age to get the annual landings-at-age.

4.2.2 Discards

Discards are allowed when catches are beyond the carrying capacity of the vessel. Methods of transferring catches from the purse-seine of one vessel to another vessel were developed long ago, and because skippers of purse-seine vessels generally operate in groups as a consequence of the behaviour of the fish, discards are practically zero. In the pelagic trawl fishery, such large catches of capelin rarely occur.

4.2.3 Surveys

Several acoustic surveys aimed at different age groups of capelin have been conducted through the years. (Vilhjálmsson, 1994) The purpose of the surveys on young capelin is to locate and estimate the abundance of young capelin. These surveys have been conducted in November since 1978 and the survey area is the nursery area on the shelf west, north and northeast of Iceland. Trawl samples are taken to get the species- and length composition. All ages, sex and maturity stage are recorded. The results from these surveys are used to predict an initial quota for the fishing season starting in the year after the surveys are conducted.

The surveys aimed at the fishable part of the stock are conducted in the fishing season, either in autumn, in conjunction with the survey of the juveniles, and/or in January–March on the spawning migration. The purpose of these surveys is to assess the size of the fishable stock and on its basis to set a final TAC for the season. These acoustic surveys on the adult component of the stock have been ongoing since 1979. The survey area varies spatially and is often influenced by drift ice conditions in the Denmark Strait-East-Greenland-NW-Iceland area in autumn. In January–March the main survey area is along the spawning migration route off NE-, E- and S-Iceland as well as off W- and NW Iceland in late February–early March. Trawl samples are taken to get the age and length structure as well as sex and maturity stage of the fishable stock. The results from these surveys are used to set a final quota for the ongoing fishing season.

4.2.4 Evaluation of data quality

4.3 Stock identity and migration issues

Capelin in the Iceland-East Greenland-Jan Mayen area is considered to be a separate stock. They spawn in March in shallow water off the southeast, south and west coast of Iceland. Most juveniles grow on or close to the continental shelf off northwest, north and northeast Iceland, and on the East Greenland plateau, west of the Denmark

Strait. A large proportion of each year class matures and spawns at age 3 and dies thereafter. The remainder of the year class spawns at age 4 and dies. Maturing capelin usually undertakes extensive feeding migrations in spring and summer northwards into the Iceland Sea and the Denmark Strait. They return in September and October. By November the adults have assembled near the shelf edge, usually off northwest Iceland, but also off north and northeast Iceland. The spawning migration starts in December/January southward along the shelf break off the east coast and on entering the mixed waters off the Southeast coast they move into shallow waters and follow the coast westwards on their spawning migration. The main spawning migration usually reaches the west coast and spawns there but late arrivals spawn further east at the southeast and south coast.

4.4 Spatial changes in fishery or stock distribution

For last 10 years adult capelin has returned later from the feeding area and measured abundance in autumn has been much lower than catches from the same year classes in January–February. Earlier the acoustic surveys in autumn had been moved from October to November as a consequence of later return of the feeding migration. In recent years the same has happened to the immature capelin as very small proportion of it has been within the Icelandic continental shelf so acoustic measurements of immature capelin in autumn have indicated too few capelin to give starting quota for the next fishing season. Most of these year classes have turned out to be small, although they have been considerably larger than indicated by the acoustic measurements when they were immature. This lack of immature capelin within the Icelandic continental shelf is also confirmed by very few age 1 capelin found in cod stomachs in the groundfish survey in March from 1999 to 2008.

To summarize findings from recent year indicates smaller proportion of both immature and mature capelin have been close to or within the Icelandic continental shelf. The fishery has changed so from 2005/2006–2008/2009 it is only winter fishery, the reason being that the abundance of capelin measured in autumn has been too low to allow opening of the fisheries.

The changes in spatial distribution of capelin in recent years can also been demonstrated by mean weight of cod being lower that would be predicted from the size of the adult stock of capelin (Vilhjálmsson, 2002). Cod is more or less limited to the Icelandic continental shelf so increased absence of capelin from the shelf makes it not available for cod.

4.5 Environmental driver of stock dynamics

No information.

4.6 Role of multispecies interactions

4.6.1 Predation on capelin

Data such as stomach samples and cod growth have demonstrated the importance of capelin for the Icelandic ecosystem. (Magnússon and Pálsson, 1989: Vilhjálmsson 2002; Anon., 1996.). Estimated number for cod are 600–1000 thousand tonnes per year and total amount for the whole ecosystem is 2 million tonnes or more (Vilhjálmsson, 2002). The values for cod are reasonably well founded and are both supported by stomach samples as well as reduced growth in periods of low capelin abundance. Predation on capelin by some other species is based on much less data. Marine mammals are the most important of those. They are potentially very important predators of capelin but knowledge of their diet is limited. Most of the predation on capelin by cod is considered to occur in the winter months October–March (Magnússon and Pálsson, 1989). Sampling of cod stomachs done by the crewmember of a number of fishing vessels since 2001 confirms their findings that capelin is primarily winter food for cod. Stomach samples indicate that the role of immature capelin in the diet of cod is relatively small. The data may though be biased as immature disappears faster from stomachs than mature capelin.

4.6.2 Diet

The main food of larval and juvenile and small capelin are copepod species such as *Calanus finmarchicus*, *Oithona* spp, *Temora* spp, *Acartia* spp, *Oncaea borealis* and *Pseudocalanus elongatus*. The importance of each species differs according to areas and size of the capelin. Later in the season there is a shift from smaller to larger food items. *C. finmarchicus*, *C. hyperboreus* and euphausids (mainly *Thysanoessa inermis*) become increasingly important in the stomachs of larger capelin.

4.7 Impact of fisheries on the ecosystem

No information.

4.8 Stock assessment methods

Previously to WKSHORT, Icelandic capelin assessment was based on backcalculations with fixed *M* and several regressions. The regressions are between different measurements of the same cohort, weight-at-age *vs.* stock size and weight-at-age *vs.* earlier measurements of weight-at-age of the same cohort (Gudmundsdóttir and Vilhjálmsson, 2002). Indications of strong underestimation of the natural mortality value are the main cause for rejecting the previous methodology.

4.9 Stock assessment

4.9.1 Assessment methodology before WKSHORT

The stock assessment methods used for Icelandic capelin are described in Gudmundsson and Vilhjálmsson, 2002.

Historical estimate of stock abundance is based on backcalculations of cohorts, using a natural mortality of 0.035 per month and adding the catches in number each month. The back calculations start from the last "successful" survey on the year class (usually in January–February). The result presented from the back calculations is the stock abundance August 1st and January 1st.

Growth of capelin continues until spawning commences in March and is taken into account when estimating the spawning stock from surveys in January–February or in October.

The value of 0.035 that has been used for the natural mortality of capelin was obtained by comparing eight pairs of autumn and winter surveys in the period 1978–1988. (Vilhjálmsson and Carscadden, 2002; Vilhjálmsson, 1994). Strictly it does therefore only apply to adult capelin in early winter. Magnússon and Pálsson, 1989 demonstrated that this estimate was most likely too low to include just predation by cod and later analyses have confirmed their findings. The reason for the discrepancy is not clear as the correlation between autumn and winter surveys was very good in the period 1978–1988. Lower target strength in autumn than winter, or that in October only part of the stock has returned from the feeding migration are possible explanations. Those explanations open the question which (if either) of the acoustic measurement (autumn or winter) is an absolute measure.

4.9.2 Assessment methodology agreed at WKSHORT

No assessment is currently available for this stock (see justification in Section 4.1).

4.10 Recruitment estimation

Recruitment is estimated from acoustic measurements in October–November that covers both the immature and mature part of the stock.

The calculations are described in Gudmundsdóttir and Vilhjálmsson, 1999 and are basically regressions of earlier measurements of immature capelin at age 1 and age 2 and back calculated number of mature-at-age 2 and 3 August 1st the following year.

To get the predicted biomass of the adult stock the following year, the mean weight-at-age also have to be predicted. The equation used is based on observed relationship between weight-at-age and total number of capelin in the stock. The result is that mean weight-at-age is inversely proportional to weight-at-age in the stock.

4.11 Short-term forecast

4.11.1 Forecast methodology before WKSHORT

The most important goal of the assessment is to predict the spawning stock.

The spawning stock in numbers based on measurements of the mature part of the stock is estimated by calculating the last measurement forward using the same value of M as used in back calculations (0.035), subtracting the catches in numbers each month.

The spawning stock in weight is then the spawning stock in numbers multiplied by the estimated mean weight in the spawning stock and the landings in tonnes are landings in numbers multiplied by estimated weight-at-age in landings (estimated from the surveys). The allocated TAC is the catches that lead an SSB of 400 thousand tonnes.

The chapter on recruitment estimation described how the size of the mature part of the stock on the following season is estimated from the measured number of immature capelin in October–November. The TAC is then estimated as described before and a preliminary TAC of 2/3 of the estimated TAC is given. No preliminary TAC is given if predicted spawning stock with no catches is below 500 thousand tonnes.

4.11.2 Forecast methodology at WKSHORT

WKSHORT do not endorse the value of M assumed on forecast calculations.

4.12 Biological reference points

B_{lim} has not been defined for this stock but stochastic predictions of the spawning stock require B_{lim} to be defined.

4.13 Modifications to previous stock annex

Major modifications to the content of the "Assessment Methodology" and "Short-term Projection" (see justification under Section 4.1).

WKSHORT is unable to approve the stock assessment for two reasons. The first, and main, reason is a concern that the value of M (natural mortality) used in the assessment calculations (0.035 per month) is too low. Material presented by the assessment team during the Workshop suggested that the mortality as a consequence of cod alone could be substantially greater than 0.035. In considering the effect on the assessment of using a value of M that is too low, we need to distinguish between the two stages of quota setting: first, the setting of a preliminary quota, based on the October/November survey; and second, the quota adjustment based on a January/February survey. The effect on the second stage is clear: use of a value of M that is too low will result in an increased probability that the spawning biomass will fall below B_{target}. The effect on the first stage is unclear, because M is used in two places in the calculations (in the back-calculations [equations (1) and (2) of Gudmundsdottir and Vilhjámsson, 2002] and the forward projections from 1 August [equations (8)–(13) of Gudmundsdottir and Vilhjámsson, 2002]).

The second, and more minor, concern about the assessment is that the description of the first stage of quota setting [in Gudmundsdottir and Vilhjámsson, 2002] is inadequate, in the sense that it would not be sufficient to allow someone else to conduct the assessment given the data.

WKSHORT 2009 concluded that they could not support the use of stock projections to set a starting quota without testing the impact on them using higher M, as there are indications that the M used so far is too low.

4.14 Recommendation for future work

Calculate the confidence intervals for the acoustic surveys by bootstrapping. The data required should be available for the last 10–15 years if not longer;

Redo the regressions between acoustic survey indices and "back calculated" numbers in the stock using higher values of natural mortality;

Try to understand the nonzero intercept in regressions between measured numbers of immature capelin and back calculated number of mature capelin of the same year class the following year;

Compare measured and back calculated immature capelin at age 2;

Estimate predation on capelin by cod, other demersal fish and marine mammals from the January–February survey until spawning in March. Look at any trends in spatial distribution of cod, i.e. changes in proportion of the cod stock SE of Iceland where the capelin spawning migrations passes. Do similar things for autumn–early winter period north of Iceland;

Set up an age and maturity stage disaggregated population model to replace the series of regression models. The model should also be useable for stochastic prognosis of the spawning stock, using estimated confidence interval of the surveys and mortality estimated from predation analysis;

Look at candidate measures of how much capelin spawned (stomach samples from the groundfish survey, 0 group indices or something else). Having some measure can be important to see if the management of the fisheries is successful;

Repeating some of the steps described earlier in a multispecies model.

4.15 Industry supplied data

Industry did for a long time supply data on the average fat content of capelin (Vilhjálmsson, 1994). Those numbers could be used to analyse TS value in the acoustic measurements.

In the last years a number of fishing vessels have been equipped with equipment for acoustic measurements. If properly conducted they could contribute to increased reliability of acoustic measurement.

4.16 References

Anon. 1997. Fjölstofna rannsóknir 1992–1995. (Multispecies research 1992–1995). Reports of the Marine Research Institute. 57.

Gudmundsdottir, A. and Vilhjálmsson, H. 2002. Predicting total allowable catches for Icelandic capelin, 1978–2001. ICES Journal of Marine Science, 59: 1105–1115. M.

Magnússon, K. G. and Pálsson, Ó K. 1989. Trophic ecological relationships of Icelandic cod. Rapp P.-v. Réun. Con. Int. Explor. Mer. 188: 206–224.

Vilhjálmsson, H. 1994. The Icelandic capelin stock. Journal of the Marine Research Institute of Reykjavík 13.

Vilhjálmsson, H. 2002. Capelin (*Mallotus villosus)* in the Iceland-East Greenland-Jan Mayen ecosystem. ICES Journal of Marine Science, 59: 870–883.

Vilhjálmsson, H. and Carscadden, J.E. 2002. Assessment surveys for capelin in the Iceland-East Greenland-Jan Mayen area, 1978–2001. ICES Journal of marine Science, 59: 1069–1104.

Vilhjálmsson, H. 2002. Capelin (*Mallotus villosus)* in the Iceland-East Greenland-Jan Mayen ecosystem. ICES Journal of Marine Science, 59: 870–883.

Capelin in Subareas V, XIV and Division IIa west of 5°W (Iceland-East Greenland-Jan Mayen area)–Stock Annex

Quality Handbook Stock Annex: Capelin in the Iceland-East Greenland-Jan Mayen ecosystem

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Capelin in the Iceland-East Greenland- Jan Mayen ecosystem
Working Group	NWWG
Date	3. 9. 2009 [WKSHORT]
Revised by	Asta Gudmundsdottir, Sveinn Sveinbjörnsson and Höskuldur Björnsson

A. General

A.1. Stock definition

Capelin in the Iceland-East Greenland-Jan Mayen area is considered to be a separate stock. They spawn in March in shallow water off the southeast, south and west coast of Iceland. Most juveniles grow on or close to the continental shelf off northwest, north and northeast Iceland, and on the East Greenland plateau, west of the Denmark Strait. A large proportion of each year class matures and spawns at age 3 and dies thereafter. The remainder of the year class spawns at age 4 and dies. Maturing capelin usually undertakes extensive feeding migrations in spring and summer northwards into the Iceland Sea and the Denmark Strait. They return in September and October. By November the adults have assembled near the shelf edge, usually off northwest Iceland, but also off north and northeast Iceland. The spawning migration starts in December/January southward along the shelf break off the east coast and on entering the mixed waters off the Southeast coast they move into shallow waters and follow the coast westwards on their spawning migration. The main spawning migration usually reaches the west coast and spawns there but late arrivals spawn further east at the southeast and south coast.

A.2. Fishery

In the mid 1960s purse-seine fishery began on capelin. It soon became a large-scale fishery. During its first eight years, the fishery was conducted in February and March on schools of prespawning fish on or close to the spawning grounds south and west of Iceland. In January 1973 a successful capelin fishery began in deep water near the shelf break east of Iceland. In July 1976 a summer capelin fishery began in the Iceland Sea. This fishery became multinational with vessels from Iceland, Norway, Faroes and Denmark. The fishery is conducted all years in July–March except in periods of low stock size. Over the years the fishery has been closed during April–late June and the season has started in late June/August or later, depending on the state of the stock.

A regulation calling for immediate, temporary area closures when high abundance of juveniles are measured in the catch (more than 20% of the catch composed of fish less than 13 cm) is enforced, using on-board observers.

In recent years, the fishery has changed from being mostly an industrial fishery to being mostly for human consumption. This is largely because of the low abundance and low TACs.

A.3. Ecosystem aspects

A.3.1. Geographic location and timing of spawning

The spawning takes place in March–April. The main spawning grounds are shallow waters on the seabed off the south and west coasts. Some minor spawning may take place elsewhere.

A.3.2. Fecundity

The main part of each year class matures and spawns at age 3. The remainder of the year class spawns at age 4. Only few spawns at age 2 and very few at age 5. Spawning mortality is considered very high.

A.3.3. Diet

The main food of larval and juvenile and small capelin are copepod species such as *Calanus finmarchicus*, *Oithona* spp, *Temora* spp, *Acartia* spp, *Oncaea borealis* and *Pseudocalanus elongatus*. The importance of each species differs according to areas and size of the capelin. Later in the season there is a shift from smaller to larger food items. *C. finmarchicus*, *C. hyperboreus* and euphausids (mainly *Thysanoessa inermis*) become increasingly important in the stomachs of larger capelin.

A.3.4. Predators

The capelin plays a key role in the marine ecosystem in this area and is by far the most important pelagic fish stock in Icelandic waters. They are the main single item in the diet of Icelandic cod. They are prey to several species of marine mammals and seabirds and are also important as food for several other commercial fish species.

B. Data

B.1. Commercial catch

The fishing is shared between Iceland, Norway, Faroe Islands and Greenland by a special agreement, but by far the largest quantities are fished by Iceland.

B.1.1. Landings

Information about landings in the fishery are collected by the Icelandic Directorate of Fisheries which has access to both landing figures in the ports (the official landing) and the recorded catch in the digital logbook kept by all the vessels. The logbooks keep information about timing (day and time), location (latitude and longitude), fishing gear, duration (minutes), catch size, and species composition in the catch of each fishing operation for each vessel.

Biological samples from the catch are taken at sea by the fishermen or in the ports by people from MRI and/or inspectors from the Directorate of Fisheries then analysed by MRI (record at least the fish length, weight, age (from otoliths), sex, maturation, and weight of sexual organs). The information from the samples are then used along with the total landing data and the logbook data to estimate the age and length composition and numbers of fish by age of the total landings.

Landings are provided by Norway, Faroe Island and Greenland as catches-in-numbers-at-age. They are added to the Icelandic catches-in-numbers-at-age to get the annual landings-at-age.

B.1.2. Discards

Discards are allowed when catches are beyond the carrying capacity of the vessel. Methods of transferring catches from the purse-seine of one vessel to another vessel were developed long ago, and because skippers of purse-seine vessels generally operate in groups as a consequence of the behaviour of the fish, discards are practically zero. In the pelagic trawl fishery, such large catches of capelin rarely occur.

B.2. Biological

Natural mortality rates of Icelandic capelin were derived from eight successive acoustic estimates of spawning stock abundance and catch in November 1978 to January 1989. It is estimated as 0.035/Month with SD=0.011.

B.3. Surveys

Several acoustic surveys aimed at different age groups of capelin have been conducted through the years. The purpose of the surveys on young capelin is to locate and estimate the abundance of young capelin. These surveys have been conducted in November since 1978 and the survey area is the nursery area on the shelf west, north and northeast of Iceland. Trawl samples are taken to get the species- and length composition. All ages, sex and maturity stage are recorded. The results from these surveys are used to predict an initial quota for the fishing season starting in the year after the surveys are conducted.

The surveys aimed at the fishable part of the stock are conducted in the fishing season, either in autumn, in conjunction with the survey of the juveniles, and/or in January–March on the spawning migration. The purpose of these surveys is to assess the size of the fishable stock and on its basis to set a final TAC for the season. These acoustic surveys on the adult component of the stock have been ongoing since 1979. The survey area varies spatially and is often influenced by drift ice conditions in the Denmark Strait-East-Greenland-NW-Iceland area in autumn. In January–March the main survey area is along the spawning migration route off NE-, E- and S-Iceland as well as off W- and NW Iceland in late February–early March. Trawl samples are taken to get the age and length structure as well as sex and maturity stage of the fishable stock. The results from these surveys are used to set a final quota for the ongoing fishing season.

B.4. Commercial cpue

Is not relevant to this stock.

B.5. Other relevant data

None.

C. Assessment methodology

The main objectivity of the management rule for the capelin is to leave 400 000 t for spawning in March each year. This goal has not been reached all years. In the fishing seasons 1979/1980–1982/1983, 1989/1990–1990/1991 and 2008/2009 the spawning-stock biomass was below the target biomass. The stock has been at a low level the last four years.

No assessment is currently available for this stock.

WKSHORT is unable to approve the stock assessment for two reasons. The first, and main, reason is a concern that the value of *M* (natural mortality) used in the assessment calculations (0.035 per month) is too low. Material presented by the assessment team during the Workshop suggested that the mortality as a consequence of cod alone could be substantially greater than 0.035. In considering the effect on the assessment of using a value of *M* that is too low, we need to distinguish between the two stages of quota setting: first, the setting of a preliminary quota, based on the October/November survey; and second, the quota adjustment based on a January/February survey. The effect on the second stage is clear: use of a value of *M* that is too low will result in an increased probability that the spawning biomass will fall below B_{target}. The effect on the first stage is unclear, because *M* is used in two places in the calculations (in the back-calculations [equations (1) and (2) of Gudmundsdottir and Vilhjámsson, 2002] and the forward projections from 1 August [equations (8)–(13) of Gudmundsdottir and Vilhjámsson, 2002]).

The second, and more minor, concern about the assessment is that the description of the first stage of quota setting [in Gudmundsdottir and Vilhjámsson, 2002] is inadequate, in the sense that it would not be sufficient to allow someone else to conduct the assessment given the data.

D. Short-term projection

WKSHORT 2009 concluded that they could not support the use of this stock projection to set a starting quota without testing the impact on them using higher M, as there are indications that the M used so far is too low.

E. Medium-term projections

As the capelin is a short-lived species this is not considered relevant. (Most capelin die at age 3).

F. Long-term projections

G. Biological reference points

Reference points have not been defined for this stock. Since 1979 the targeted remaining spawning stock has been 400 000 t.

H. Other issues

None.

I. References

Gudmundsdottir, A., and Vilhjálmsson, H. 2002. Predicting total allowable catches for Icelandic capelin, 1978–2001. ICES Journal of Marine Science, 59: 1105–1115.

Vilhjálmsson, H. and Carscadden, J.E. 2002. Assessment surveys for capelin in the Iceland-East Greenland-Jan Mayen area, 1978–2001. ICES Journal of Marine Science, 59: 1069–1104.

Vilhjálmsson, H. 2002. Capelin (*Mallotus villosus)* in the Iceland-East Greenland-Jan Mayen ecosystem. ICES Journal of Marine Science, 59: 870–883.

5 Anchovy in Subarea VIII (Bay of Biscay)

5.1 Current stock status and assessment issues: summary of presentations

The Workshop endorsed the Stock Annex, as it provides sufficient description about the Bay of Biscay anchovy fishery, the data (fishery dependent and independent) and methodologies used for stock assessment and major outputs. We endorse the continuing use of the Bayesian biomass dynamic model BBM for the assessment of the anchovy fishery.

The fishery of anchovy in the Bay of Biscay is currently closed since July 2005. This fishery is composed of pelagic trawlers and purse-seiners from France and Spain. Low recruitment-at-age 1 since 2002 and the almost complete recruitment failure of the 2004 year class are the primary causes of the current low stock size which led to the closure of the fishery. The last assessment pointed out that median SSB in 2009 was just above B_{lim}, with a 47% probability of being below B_{lim}. The recruitment-at-age 1 in 2009 is at the same level as last year but lower than in 2006 and 2007. The SSB in 2009 is among the lowest in the time-series starting in 1987.

This stock is assessed using the two-stage Bayesian biomass dynamic model (BBM) (Ibaibarriaga *et al.*, 2008). This assessment takes as inputs the Daily Egg Production Method (DEPM) and the acoustic surveys' estimates of biomass and percentages at age 1 in the population. In addition, total catches in tones from both the French and Spanish fisheries are just accounted as removals from the population.

The assessment has been considered reliable by ICES and consistent with previous years evaluations. However there were several issues that deserved further attention:

The current assessment is mainly driven by inputs provided by the surveys (SSB and proportion of 1-group). For the DEPM survey, uncertainties include the assumed spawning frequency (which is under revision) and the daily mortality rate of egg. For the acoustic estimate, although commercial vessels were used during the survey to explore the coastal area, there may still be problems with the coverage of coastal areas where age 1 dominates.

The revision of the Spawning Frequency parameter being carried out for the application of the DEPM will affect the past Spawning Biomass estimates of anchovy by this method leading to a reduction of previous estimates by about 39% on average. The compatibility of this revision with the current assumption of the assessment that DEPM survey data measures the spawning biomass in absolute terms may require revision. As a result of all the output for SSB produced by the assessment might be rescaled up/down and the current precautionary reference biomass levels might require revision as well. So the choice of a relative or absolute catchability model to be used for the surveys remains to be discussed.

Potential use of Relative Biological Reference Points and implications for management advice.

Some retrospective patterns were noticed in recent years: penultimate SSB estimates tends to be higher (average 15%) than a year before (when they were the last SSB estimates).

Recent SSB estimates were below surveys estimates in both 2008 and 2009 assessment. This can be connected with incorrect natural mortality or with some differential catchabilities at age by surveys.

Some assumptions need to be revisited: Are the assumptions about natural mortality and intrinsic growth (in mass) correct? What can we learn about natural mortality after four years fishery closure? Is the intrinsic assumption of a constant catchability valid?

Methods for short-term outlook. The current Proposal of a Long-term Management Plan for anchovy does not need of any projection but achieving a way of forecasting recruitment should allow open new possibilities for the fishery. In this context, the use of JUVENA and PELACUS, development of sentinel surveys and using environmental indices into probabilistic projection requires consideration.

The following table summarizes the working documents that have been presented during the Benchmark Workshop:

WD	Title
#5.1	Environmental monitoring using biophysical models and statistical detection procedures: application to the Bay of Biscay Mathieu Woillez, Pierre Petitgas, Martin Huret
#5.2	Anchovy recruitment mixed long series prediction using supervised classification Jose A. Fernandes, Xabier Irigoien, Uriarte Andres, Ibaibarriaga Leire, Jose A. Lozano, Iñaki Inza
#5.3	Anchovy assessment in the Bay of Biscay using a two-stage biomass random effects model (BREM) Verena Trenkel
#5.4	Preliminary evaluation of the potential implications of the DEPM revision in the assessment of the Bay of Biscay anchovy under different assumptions on g Leire Ibaibarriaga, Andrès Uriarte, Maria Santos
#5.5	Inclusion of the 1989 acoustics data into the assessment of the Bay of Biscay anchovy Leire Ibaibarriaga, Andrès Uriarte
#5.6	Overview of a pilot-study of anchovy and sardine "sentinel" surveys in the Bay of Biscay: a partnership between science and industry Damien Delaunay, Jacques Massé, Lionel Pawlowski
#5.7	Overview of the ISIS-Fish fishery simulator applied to the management of the Bay of Biscay anchovy Sigrid Lehuta, Lionel Pawlowski
#5.8	Juvena 2003–2008: Anchovy juvenile biomass estimates and recruitment prediction capacity G. Boyra, U. Martinez, U. Cotano, A. Uriarte
#5.9	Assessing natural mortality of anchovy from the surveys population and biomass estimates: evaluation through a seasonal ICA assessment Andrès Uriarte, Leire Ibaibarriaga
#5.10	Bay of Biscay anchovy fishery Updated approximate figures for the fleet and fishing effort displacement SouthWestern Waters Regional Advisory Council

5.2 Compilation of available data

The assessment is currently only based on two surveys providing abundances indices from acoustic and DEPM (Daily Egg Production Method) in spring every year and commercial data. An additional survey takes place in autumn and a pilot study using commercial vessels has started in April 2009. Those data are not included in the assessment for now.

5.2.1 Commercial catch

5.2.1.1 Overview

The fishery has been closed since July 2005 as a consequence of poor condition of the stock. Annual Landings are available since 1940. The fisheries for anchovy are targeted by purse-seiners and pelagic trawlers. The Spanish and French fleets fishing for anchovy in Subarea VIII are spatially and temporally quite well separated. The Spanish fleet (purse-seine fleet) operates mainly in Divisions VIIIc and VIIIb in spring, while the French fleet (mainly pelagic trawlers fishing since 1989) operates in Division VIIIa in summer and autumn and in Division VIIIb in winter and summer. A small fleet of French purse-seiners operates in the South of the Bay of Biscay (Division VIIIb) in spring and in the North (Division VIIIa) during autumn.

5.2.1.2 Evaluation of the quality of the catch data

The fishing statistics are considered accurate. The sampling protocols dictated by the European Commission Programme on Fisheries Data Collection Regulation are applied and followed in the anchovy fishery. Discards are not measured and hence not included in the assessment, but nowadays they are considered not relevant to the two fleets. In the past (late eighties and early nineties for the French pelagic trawlers and sixties and seventies for the Spanish purse-seine fleet) they seemed to be more relevant (according to disputes among fishermen), but were never quantified.

5.2.2 Biological data

5.2.2.1 Overview

The biological sampling made during surveys and for monitoring catches allows having good knowledge of the basic biological parameters of the population particularly at spawning time (when the surveys take place and the assessment output of biomass is produced). Mean lengths and weights-at-age at the stock at spawning time and in the catches all across the year are well known.

Growth

Growth in mass rate of the population is taken as a constant across ages: G=0.52 for the assessment model. This value is a weighted mean of G by ages according to average abundance-of-age classes in the population:

	Age 1	Age 2	Age 3
Growth_weighted/	0,62	0,15	0,18

Certainly assuming G as a single parameter constant across age was a simplification and the suggestion was made towards a parametization of G by age was made.

Maturity

Maturity is well known (all age classes are fully mature at spawning time).

The parameters defining the Daily Fecundity are also well known: sex ratio, R, Female mean weight, batch fecundity and spawning frequency.

However the Spawning fraction is subject to a thorough revision: The procedures for the estimation of the Spawning frequency (S) for the Bay of Biscay anchovy have been revised as a consequence of a better understanding of the POF degeneration cycle (Alday *et al.*, 2008). Those results were already presented in WGACEGG 2007 and 2008 and will affect the past Spawning Biomass estimates of anchovy by the DEPM leading to a reduction of those estimates by about 39%. WGACEGG 2008 acknowledged the suitability of those changes and recommended a complete revision of the historical SSB series (1987–2007) for the WGANSA–not yet submitted. In the Workshop the completion of such a revision was demanded as soon as possible.

Natural mortality

Natural mortality is fixed at 1.2 according to previous studies (see stock annex) may require revision given the new information gathered since 2005 with the fishery being closed. The recent period of survey estimates will give valuable information for essaying estimation of the Natural mortality and several essays of estimating this parameter are presented in Section 5.8.2 (sensitivity analysis).

5.2.2.2 Evaluation of data quality

Overall, biological data are of high quality: mean weight and mean length-at-age are well known both in the surveys (for the population) and in the catches. And the Daily Fecundity, once corrected the Spawning Frequency with revision mentioned above, will be considered correct as well. So the quality of the biological data is sufficient and satisfies the required level for the assessment performed currently with anchovy. Age reading is considered precise and accurate. Routine cross reading exchanges and workshop take place regularly every four years (approximately) (see stock annex).

5.2.3 Survey data

5.2.3.1 Overview

PELGAS (Spring acoustic survey)

Yearly acoustic surveys (PELGAS) are carried out in the Bay of Biscay in spring from the Spanish coast to south Brittany. They are standardized and coordinated through the ICES Working Group WGACEGG since 2003 with similar Spanish and Portuguese acoustic surveys. The objectives are both to evaluate small pelagic populations (mainly anchovy and sardine) and to collect environmental data according to physical parameters, primary and secondary production, fish behaviour and top predators. In terms of fish abundance, echoes are stored at a standard format (HAC) to be processed in real time and/or at the end of the survey in a short delay. Fishing operations are aimed to identify echoes and collect biological samples.

Acoustic data are stored from Simrad echosounder, the sampling rate is dependent on the bottom depth (one ping each 0.3s to 1.2s) at a vessel speed of 10 knots and the vertical samples are 30 cm high. Acoustic energies (sA) are gathered every nautical mile and classified according to school shapes and level in the column water. Combined to identification hauls these backscattered energies provide abundance indices inside strata where combination of species is coherent. Then abundance is distributed along each mile and for each species in numbers and biomass according to length distributions provided by closed hauls. Finally, a global age–length key allows the estimate of each year-class-abundance.

A database (BARACOUDA) stores all together biological data, backscattered energies and interpretation scenarios such as anybody is allowed to check the data processing. These data (numbers and biomass/species/length class/age/nautical miles are available for the whole area (Bay of Biscay) since 2000. They are then combined to other surveys results during WGACEGG to have a global view of small pelagics from Gibraltar to Brittany.

BIOMAN (Spring DEPM survey)

Using egg production survey data to estimate spawning-stock biomass of the anchovy stock in the Bay of Biscay through the Daily Egg Production Model (DEPM) is a well established approach for pelagic species. These surveys are well designed and have been carried out consistently over time. The series started in 1987 is annually available up to 2009 (with a single gap in 1993). The methods and results are reviewed annually in ICES Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VIII and IX (WGACEGG). The survey covers successfully all the potential spawning areas for anchovy. It usually covers the area with an Egg cruise and adult sampling either through an additional vessel or in collaboration with the Acoustic survey, or with the support from the commercial fishery with direct samples. The icthyoplankton sampling with Pairovet net every 3 nm along radials spaced every 15 nm. + CUFES for adaptive sampling + Fishing hauls.

The survey produces Spawning Biomass and Population at age estimates. The resulting data are suitable for the estimation of stock abundance of the anchovy stock through various models. This is very relevant information as it is tuning the assessment as an absolute index of abundance, and it is the longest input series.

The procedures for the estimation of the Spawning frequency (S) for the Bay of Biscay anchovy have been revised as a consequence of a better understanding of the POF degeneration cycle (Alday *et al.*, 2008). This will affect the past Spawning Biomass estimates of anchovy by the DEPM leading to a reduction of those estimates by about 39% (Figure 5.2.3.1.1). A partial revision of the series of SSB for anchovy was presented to WGACEGG 2008 based on the new estimates of S and a revision of P0 and Ptot using GLM estimates.

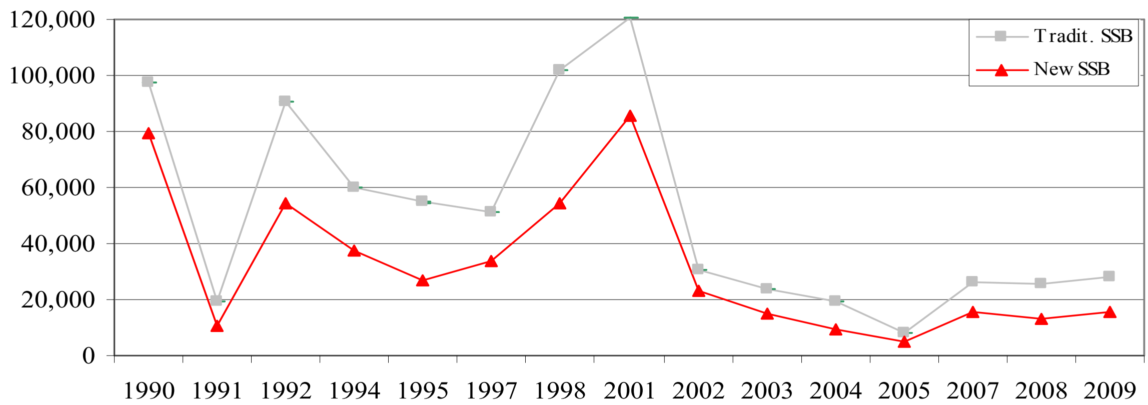


Figure 5.2.3.1.1. Comparison of official series of DEPM estimates of Spawning Biomass (SSB) and the provisional revision of this series according to new spawning fraction estimates (Definitive series since 1987 should be available during 2009). Definitive values are to be adopted by WGACEGG 2009.

WGACEGG acknowledged the suitability of those changes and recommended a complete revision of the historical SSB series (1987–2007) for WGANSA. The revision has not yet been completed and the WK recommends its completion for next WGACEGG 2009.

The compatibility of this revision with the current assumption of the assessment that DEPM survey data measures the spawning biomass in absolute terms may require revision. As a result of all the output for SSB produced by the assessment might be rescaled up/down and the current precautionary reference might require revision as well.

JUVENA acoustic survey index of Juvenile abundance

JUVENA started in 2003 and has been applied since then in September every year. It aims at predicting the anchovy recruitment which will enter the fishery the next year as 1 year old fish, in addition to other ecological studies.

The JUVENA series, up to the last survey which took place in autumn 2008, has been discussed and reported in WGACEGGs (ICES, 2008) and to WGANSA (ICES, 2009). A new survey is taking take place in September 2009. A summary of the series was presented in a WD to this Workshop (Boyra *et al.*, WD #5.8).

In all years, the sampling area has covered the waters of the Bay of Biscay to the East of 5º W and to the South of 46º N. where most of the distributions of juvenile anchovy is usually found. Since 2005 the survey was expanded more to the North (up to 47º30′ N aprox.), following recommendations from WGACEGG. Despite the modifications in coverage and in part of the sampling methodology, both the WGMHSA and WGACEGGs concluded that the result of the juvenile's survey can be used as an index of the evolution of juvenile abundance (ICES, 2007a and 2007b).

The Workshop revisited the issue of the performance of JUVENA survey as predictor of next coming recruitment-at-age 1. Figure 5.2.3.1.2 shows the past performance of this index (from WGANSA report, ICES 2009). A simple regression demonstrates a positive correlation between the variables with a coefficient of determination of 64% and a p-value = 0.053, that is, almost statistically significant relationship at the 95% confidence interval.

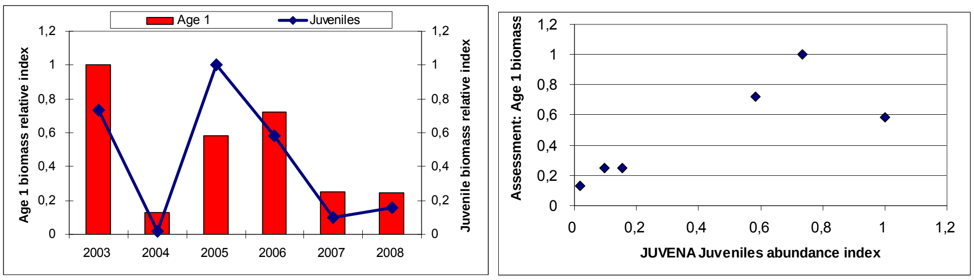


Figure 5.2.3.1.2. Left panel: comparison of the time-series of the JUVENA anchovy juveniles abundance index with the assessment-at-age 1 in the following year (median values) produced by Bayesian assessment in WGANSA. Right panel: scatterplot of the series. The comparisons are made in relative terms, scaling the series to their maximum estimate. R=0.801, R2=0.642 P(R=0)=0.06.

The size of anchovy juveniles captured in JUVENA ranged from 3 to 14 cm. Boyra *et al.*, WD #5.8 points out that the probability of survival of the juveniles along winter may be larger for big juveniles than smaller ones, for that reason an analysis was performed on the regression of age 0 (for varying ranges of juvenile sizes) vs. age 1 abundance. The analysis is done subtracting the contribution of smaller sizes to the estimates of age 0 abundances in steps of 0.5 cm. As a result, the recruitment prediction capacity of the JUVENA index increased becoming significant at the 95% confidence interval for minimum sizes ranging 4 to 9 cm and highly significant between 6 and 8.5 (Figure 5.2.3.1.3).

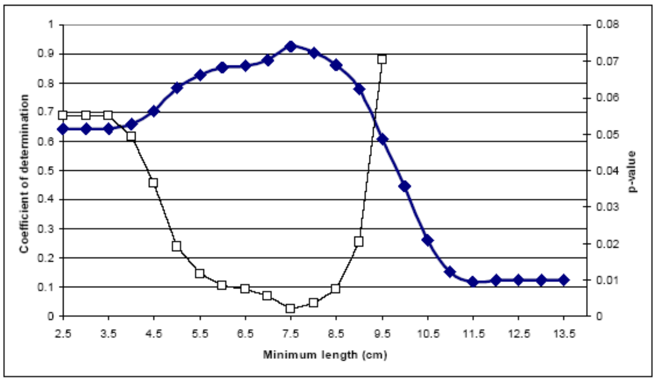


Figure 5.2.3.1.3. Shows the sensitivity of the coefficient of determination between the juvenile abundance index and the age 1 biomass estimates in next year (obtained from the ICES assessment) (left axes) and the probability of this being due to random (right axes) to the size of the juveniles retained for the production of the abundance index.

The Workshop endorsed the conclusions of WGANSA as follows: the results from the six years of the JUVENA abundance indices of anchovy juveniles are encouraging, but the short life of this series and the lack of contrast (all observations refer to the period of low recruitments) prevents yet a proper evaluation of its performance as a predictor of the age 1 entering the population and the fishery the next year. In particular the ability of the JUVENA index to predict a large recruitment has not been confirmed yet. A high juvenile abundance observation should be confirmed by the following spring surveys. If a high juvenile abundance would appear in the survey beyond former estimates making simple linear inference from it would be dangerous as far as it will be an extrapolation out of range.

When trying to calibrate JUVENA indices, caution should be taken with the procedure of removing some small length classes. If so done, this should be clearly based on *a priori* biological or ecological criteria adopted independently of the changes in the fit to the output of the assessment.

The possibility of a qualitative use of this series is open for discussion but no formal proposal was yet made.

5.2.3.2 Evaluation of data quality

The research surveys used for the assessment of the Bay of Biscay anchovy stock are planned, coordinated, reviewed and developed in the ICES Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VIII and IX (WGACEGG). Therefore, the quality of the data obtained from these surveys is discussed yearly within this working group.

PELGAS (Spring acoustic survey)

This survey provides anchovy SSB and age structure indices since 1989 (with some gaps before 2000) which are used for tuning the assessment model. The survey indices 2000–2007 were reviewed and updated recently in WGACEGG (ICES, 2007). The survey covers systematically all the French shelf in the Bay of Biscay including almost the entire potential spawning area for anchovy. However, there is uncertainty on the coverage of the coastal areas, where the population is composed mainly by age 1 individuals. This could lead to some underestimation of the age 1 individuals of the population. Otherwise, the methodology is well established, and it is coordinated with similar acoustic surveys. In addition, the survey aims at an ecosystem approach and also provides data on hydrology, primary and secondary production, species interaction and higher predator's abundance.

BIOMAN (Spring DEPM survey)

This survey provides anchovy SSB and age structure indices since 1987 (with some gaps) which are used for tuning the assessment model. Since the DEPM measures all the biological parameters leading to SSB it has been historically assumed that it provides absolute indices of the population. However, a recent work on degeneration of postovulatory follicles (Alday *et al*., 2008) has lead to a revision of the spawning frequency parameter pointing out to SSB estimates 39% lower. The DEPM assumptions on egg mortality are also under revision, and this could also affect the current DEPM SSB estimates. When the full revision of the DEPM parameters is completed and validated by WGACEGG, the new estimates should be incorporated into the Bay of Biscay anchovy assessment. In addition, the survey catchability assumptions and the biological reference points may require a revision.

JUVENA (Juvenile acoustic survey)

The JUVENA autumn juvenile acoustic survey has been conducted since 2003. It covers a minimum sampling area (5º W and 46º N) and combines two different fishing gears: a purse-seiner and a pelagic trawler. Despite the initial problems, the methodology nowadays seems to be well established with the coordination of other juvenile acoustic surveys (JUVAGA and PELACUS). The survey abundance indices are not yet used for the assessment or management advice of the stock. ICES 2009 considers that the potential use of this survey to predict recruitment and therefore help on the provision of TAC levels for subsequent years is still to be tested for a strong incoming year class.

5.2.4 Industry and stakeholder data inputs

Stake holders from SWWRAC have brought to the meeting a WD (WD # 5.10) about the recent evolution of the fleet and redirection of effort towards other species. This has been reflected in the Stock Annex.

Sentinel surveys

In addition a cooperative research with them has started in France: the Sentinel survey (WD #5.6) summarized here below:

A 2-years pilot study of "sentinel" surveys is in progress in France because April 2009 (WD #5.6). This study relies on a partnership with IFREMER, CNPMEM (National Committee of Marine Fisheries and Aquaculture), DPMA (Direction of Marine Fisheries and Aquaculture) and is funded by national and European funds. The first survey took place in August 2009.

This project aims at developing an early indicator of the evolution of small pelagic resources (anchovy and sardine) in the Bay of Biscay from observations performed by fishermen assisted by scientists. Surveys are carried out five times a year using purse-seiners and pelagic trawlers in 2 key areas, Gironde and Southern Brittany. Additional areas could be considered in future on the Cantabrian and Basque areas and in the Western part of the English Channel.

The surveys can follow a route visiting predefined stations on a grid or have an opportunistic pattern. In that case, preliminary exchanges between the fishermen in charge of the surveys and other local fishermen direct the vessels towards patches of anchovies or sardines where they move around to measure the spatial extents of the patches.

Those surveys provide acoustic measurements, record physical parameters of the environment along the boat tracks in addition to environmental data from the fishing gears. Trawls or seines are used to identify the acoustic echoes and the species which are sorted to get length distributions, stomach contents, otoliths. Some plankton fishing will also be done to spot the presence of eggs and/or larvae.

5.3 Stock identity and migration issues

Anchovy is considered to be isolated from a small population in the English Channel and from the population in the Division IXa. No subpopulations have been defined. ICES considers that the anchovy in this area should be dealt as a single stock for assessment and management (ICES, 2007a). No new information has been presented during this benchmark that would affect the stock identity.

Migrations occur during the life cycle of anchovy but it is not considered to have a potential impact on the assessment. No new information has been presented on migration.

5.4 Spatial changes in fishery and stock distribution

A common issue in anchovy fisheries around the world is that catch rates did not decline as abundance declined (as a consequence of schooling behaviour of the fish); so that fishing remained profitable until stock size is very low. Density has been also related with habitat selection. MacCall, 1990 developed a model suggesting that at low population densities, the fish occupy only the most suitable habitats. If population abundance increases, the population occupies a wider geographical range, as intrinsically poorer habitats are occupied. If this model is valid, the densities in the better habitats will remain high, even if fishing reduces overall abundance, which could have important implications for fisheries management. Reduction in spawning area and concentration of the population decrease the possibility of occupying suitable spawning grounds, and thus decrease the ability of sustaining a given population size.

No new evidence of some spatial changes in the stock distribution has been presented during the benchmark.

As the fishery has been closed since 2005, the fleets have experienced substantial changes in their fishing capacity including reduction of the number of boats. The remaining vessels that used to target anchovies have redeployed their effort to other species (e.g. small pelagics, tunas) (WD #5.10).

5.5 Environmental drivers and stock dynamics

Over the years, several attempts have been made to relate recruitment to hydrographic conditions. A more detailed description of the state-of-the-art in this field is given in the stock annex. At present no environmental factor has been identified that can explain the low recruitment in the last years, and none of the environmental indices have sufficient predictive power to be used as input to the stock prediction.

Two WD were submitted to this Workshop related to this issue:

The first one (WD #5.1) deals with environmental monitoring using biophysical models and statistical detection procedures and its application to the Bay of Biscay. The authors developed an environmental monitoring procedure that can be operationalized in order to deliver information on a regular basis to fish stock assessment working groups. The procedure relies on some model hindcasts (1971–2007) from a NPZD model of the Bay of Biscay to evaluate long-term changes in the spatial patterns from a list of 11 hydro-climate indices. The complete processing is described in the WD. The end results are a set of "traffic light" tables for the joint visualization of significant deviations in all indices, to achieve an integrated assessment.

From the analysis, the maps of local explained variance led to three major groups: off shelf, mid-shelf and coastal in the North. The Shewhart-CUSUM-detected shifts in all the 28 EOFs time-series were assembled and summarized visually (Figure. 5.5.1) in a traffic-light type of representation.

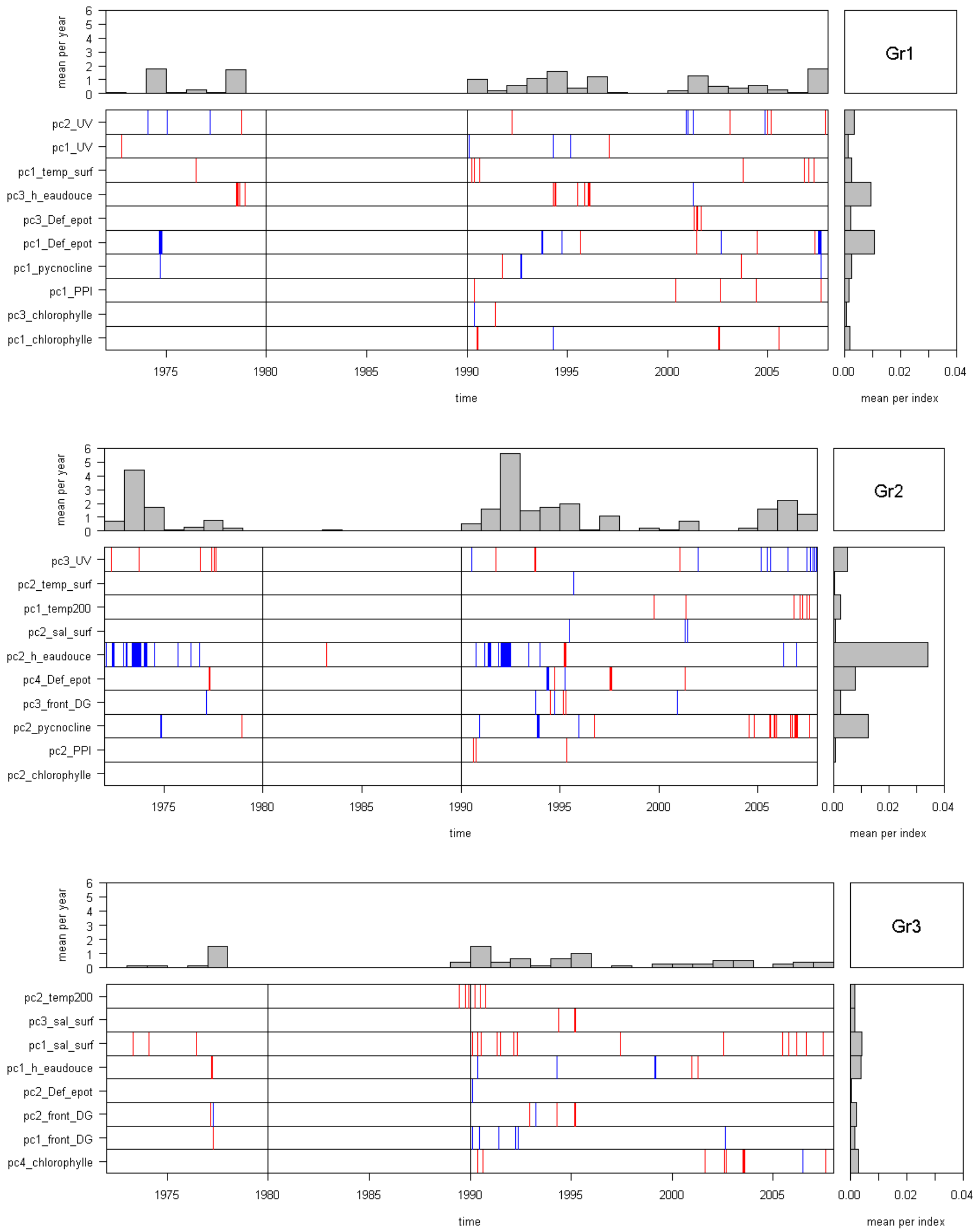


Figure 3. Combined Shewhart-CUSUM detected shifts from seasonal mean assembled in a traffic-light representation. Shifts above the mean are in red and below in blue. EOFs are grouped by the spatial pattern group of their explained variance (see Figure 1): Gr1: off-shelf, Gr2: shelf, Gr3: coast in the North. Bars indicate the mean nb of deviations by series (line) and year (column). The reference period is materialized by vertical lines.

There were three periods of increased deviation signals: early 1970s, early 1990s and since 2005. But the indices concerned were not the same ones. The shelf (group 2 of patterns) was by far the area where the major variability occurred as seen from the number of deviation signals detected by the combined Shewhart-CUSUM. In the early 1970s and 1990s, the deviations concerned the river plume index (lower than average). Since 2005, the flowfield, the bottom temperature and the depth of the pycnocline have been outside reference limits: PC3 of flowfield has been reversed, bottom temperature warmer and the pycnocline deeper. Also surface temperature has been warmer since 2005. The windforcing affects surface currents and vertical mixing and therefore the depth of the pycnocline and bottom temperature. These were the driving parameters of the environmental change observed since 2005. But in the hindcast run the switch between the forcing series was in 1996.

The procedures described here are ready to be implemented in operational mode to contribute on a regular basis to assessments of regional sea ecosystems as well as fish stocks. Small pelagic fish being in general responsive to hydro-climate changes, an operational procedure as the one presented here is thought helpful, which statistically detects changes in the hydro-climate space-time patterns. The environmental monitoring as performed here provides a context for potential changes in fish stocks' distribution and recruitment.

The second WD (Fernandez *et al.*, WD #5.2)) makes use of 'Machine-learning' techniques to produce robust predictions of recruitment based on environmental covariates. In the WD, they apply to anchovy the methodology to build a robust classifier of recruitments and to make early predictions using climatic indices. The proposed methodology (model-building) consists of performing supervised predictors discretization, carrying out supervised predictors selection (in a leaving one out cross-validation scheme) and learning a 'naive Bayes' classifier (Fernandes *et al.*, 2009).

The following model (Model 1 of the paper) gives an idea of the type of prediction achieved using robust supervised classification methods. The model will assign probabilities of occurrence for a set of model selected recruitment levels:

Model 1

Recruitment is measured in tons of age 1 biomass in January. Three levels of recruitment were considered: below between and above the following Boundaries 30 000 t and 80 000 t. The environmental Predictors selected were: CLI1 January–September, NS WindStress 45N2W March–July, Upwelling 4502 January–September CLI1 is the first component from PCA of NAO, TNH, UI, SCA, EA/WR, POL and EA (Bode *et al.*, 2006). Principal contributors EA/WR and POL.

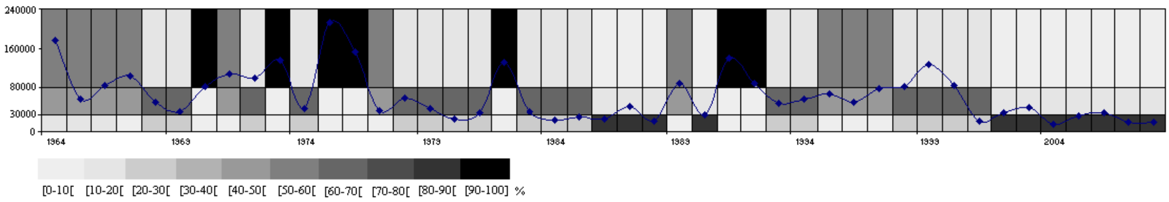


Figure 5.5.2. Mixed Long Series of Anchovy Recruitment in relation to the probabilities assigned to each recruitment level by model 1 for each year.

The model was demonstrated to be implementable for series of environmental covariates measured from January to September, so that prediction based on these types of models could be available on time to provide management advice for next.

Table 5.5.1. Comparing the Predictive Performance of the two models shown in Fernandez *et al.*, WD #5.2 for model using predictors' annual means or January to September means. The predictive performance is achieved by a fivefold cross-validation.

Metrics	Annual	January-September
Accuracy	41.6% ± 7.8	48.7% ± 7.2
Brier score	0.32 ± 0.05	0.27 ± 0.05
TP low	26.7%	38.4%
TP medium	46.6%	33.1%
TP high	40.2%	57.2%

The model fits demonstrates how the probabilistic predictions allow giving more informed advices and it behaves well for very low and high recruitments.

The recruitment index of Fernandez *et al.*, 2009 based on environmental indices was considered by the Workshop valuable and of interest in the context of the Bayesian forecast as it fits nicely with the concept projection according to weighted mixture of past recruitment (years or levels): However a more clear explanation of its performance in predicting next 1 y.o. recruiting anchovy was required in order to be able to support already its use. Evaluate the utility of these types of approaches in practical management: What is the gain of using it compared with for instance blind management to recruitment (as proposed in the harvest control rule of the Management Plan) or assuming same recruitment as past year or just average recruitment, etc. Incorporate considerations of the risks of being wrong in predicting high or low R when evaluating its performance, etc. This information can be valid in the frame of a two step management advice (to set a TAC for the first part of the year), by giving probabilities to different levels (or scenarios) of recruitment.

5.6 Role of multispecies interactions

Anchovy is a prey species for other pelagic and demersal species in the Bay of Biscay, and also for cetaceans and birds. An historical database on the stomach contents of the species involved in the foodweb in which anchovy plays a role is missing. The information available is on the description of the diet of several pelagic, demersal and benthic species. In the Cantabrian Sea (Division VIIIc, south of the Bay of Biscay) a series on the stomach contents of the demersal-benthic foodweb is also available. This is clearly insufficient to study the role of multispecies interactions in the dynamics of anchovy and there is a clear need to further investigate. Nowadays, several projects are dealing to cover this gap (e.g. UNCOVER, ECOANCHOA) and it is expected to increase the efforts in this direction in future.

5.7 Impacts of fishing on the ecosystem

There is no information on this regard in relation with anchovy fishery.

5.8 Stock assessment methods

5.8.1 Models

Three different assessment models were investigated during this benchmark workshop for this stock: Bayesian Biomass-based Model (BBM), Integrated Catch-at-age Analysis (ICA) and its seasonal counterpart (seasonal ICA) and two-stage Biomass Random Effects Model (BREM).

Bayesian Biomass Model

The Bayesian Biomass-based Model (BBM; Ibaibarriaga *et al.*, 2008) has been used for the assessment of this stock since 2005 (ICES WGMHSA, 2005). It consists on a state-space model where the population dynamics is modelled in terms of biomass distinguishing two age groups (age 1 or recruits and individuals of age 2 or older). Catches are just taken as removals of the population. The observation equations are for the spawning-stock biomass and age 1 proportion in mass from spring surveys (DEPM and acoustics). Bayesian inference is performed using Markov chain Monte Carlo (MCMC) methods and it is implemented in WinBUGS.

Integrated Catch-at-age Analysis

The Integrated Catch-at-age Analysis (ICA; Patterson and Melvin, 1996) was used for the assessment of this stock before 2005. This is an age-structured model that assumes a period in which the fishing mortality is separable into age and year effects. Model fitting is done on the total catches, on the catch-at-age and, if available, on additional information on the spawning-stock biomass or the numbers-at-age from research surveys. This model, which is set on an annual basis, was extended in Uriarte, 2005 to a seasonal fishery basis. This allows analysing and comparing the fishing mortality for each of the fisheries exploiting the stock. In addition, because the model is implemented in Excel, it is flexible to allow testing different assumptions regarding the survey catchability by age and the natural mortality by age.

Biomass Random Effects Model

The two-stage Biomass Random Effects Model (BREM; Trenkel, 2008, WD #5.3) has been considered for the first time for the assessment of this stock in an ICES working group. The model is expressed in terms of biomass and distinguishes two age groups (age 1 or recruits and individuals of age 2 or older). The recruitment and the biomass annual change (accounting for growth in mass, natural mortality and fishing mortality) are considered as random effects. The recruits and the total biomass from spring surveys (DEPM and acoustics) are used in the observation equations. So, catch data are not used in this model. Estimation of the model parameters is carried out by maximum likelihood and it is implemented in AD Model Builder.

5.8.2 Sensitivity analysis

Sensitivity analyses regarding model assumptions on natural mortality and survey catchability were conducted both for BBM and for seasonal ICA. In addition, the influence of using the new estimates of the spawning fraction to obtain the DEPM SSB estimates (Section 5.2.3.2) was studied. These SSB estimates are not fully revised and therefore, are not definitive, but they can serve to anticipate changes in the current perception of the stock.

BBM

The BBM was applied to the Bay of Biscay anchovy using the official DEPM SSB estimates (ICES, WGANSA 2009) and the new DEPM SSB estimates after the revision of the S estimates (Section 5.2.3.2). For each of the datasets two different catchability assumptions regarding the DEPM and Acoustic SSB estimates were explored:

DEPM as absolute and Acoustics as relative SSB indices (standard run).

DEPM and Acoustics as relative SSB indices.

In addition, different assumptions regarding the g parameter (g=M-G where M is annual natural mortality rate and G is annual growth rate in mass) were tested:

a) g fixed at 0.68 (standard run)

g fixed at 0.2, 0.4, 0.6, 0.8 and 1.0

g estimated.

When comparing different assumptions on the g-parameter, regardless the dataset used and the catchability assumption for the surveys, the larger the g parameter is the larger the recruitment estimates are (Figure 5.8.2.1). Similarly, when comparing the DEPM SSB catchability assumption (both for g fixed or estimated), larger recruitment estimates are obtained when both surveys catchabilities are estimated, i.e. when DEPM and Acoustics are considered as relative indices (Figure 5.8.2.2.). These two effects are as a consequence of the high correlation between some of the parameters, and were already detected in previous assessments (Ibaibarriaga *et al*., 2008).

The effect of the new DEPM SSB series into the current perception of the stock changes depending on the assumptions on g and on the DEPM SSB catchability. When at least one of the parameters (g or q_{depm}) is estimated, the new DEPM series is accommodated by increasing the variance of the observation equation of DEPM SSB (i.e. by decreasing the parameter ψ_{depm}). However, when both g and q_{depm} are estimated the catchability of the DEPM SSB surveys (q_{depm}) also decreases. The perception of the stock in the last years' with respect to the 1989 state, which is used to set the limit biomass reference point (B_{lim}) is only affected by the DEPM SSB series revision when the DEPM is an absolute SSB index and the g parameter is estimated (Figure 5.8.2.2).

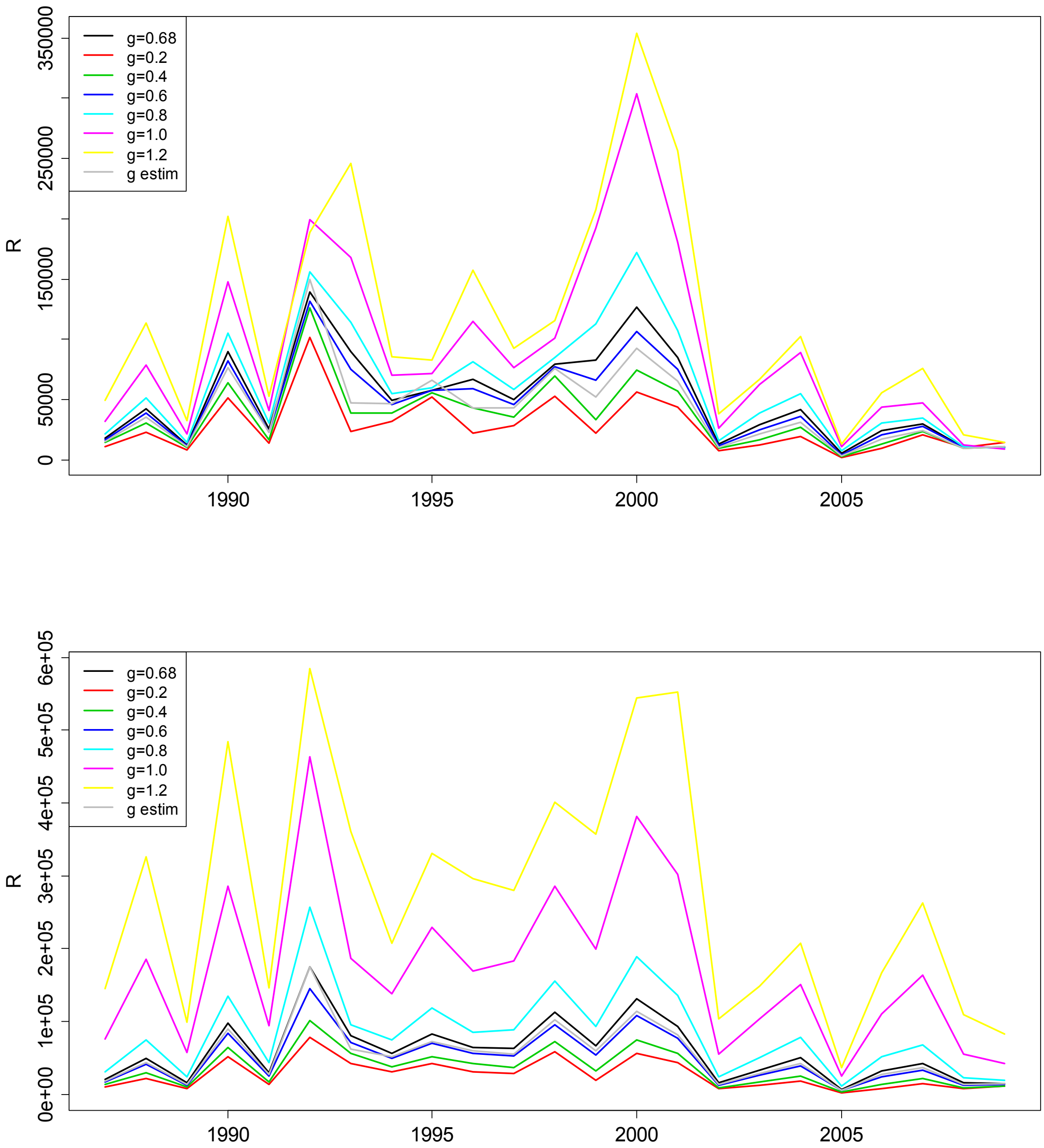


Figure 5.8.2.1. Comparison between recruitment medians under different assumptions on g when the DEPM is taken as absolute (top panel) and when DEPM is taken as relative (bottom panel) using the official DEPM SSB series.

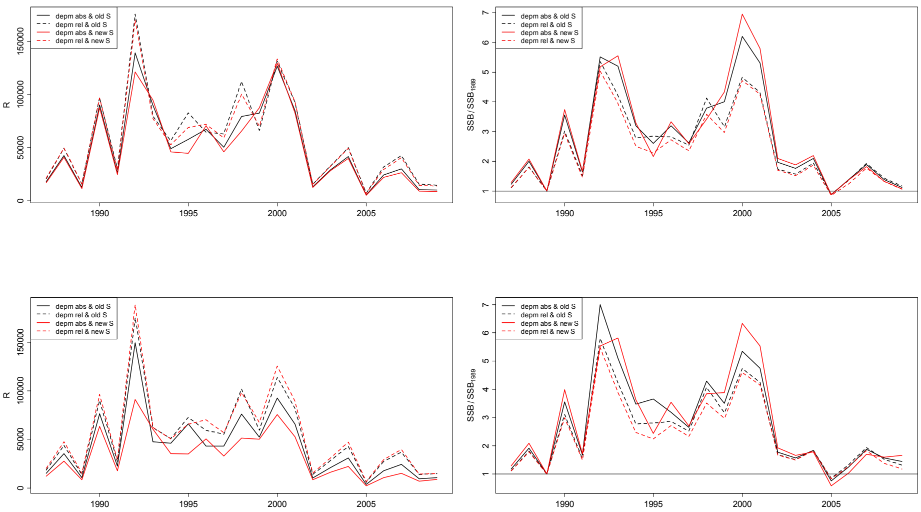


Figure 5.8.2.2. Comparison between the recruitment (on the left column) and relative SSB (on the right column) medians depending on the DEPM SSB series used (black and red lines for the old and new DEPM SSB respectively) and the DEPM SSB catchability assumption (solid and dashed line for the DEPM SSB absolute and relative respectively) when g is fixed (on the top row) and when g is estimated (on the bottom row).

Seasonal ICA

In the past ICA assessments demonstrated that catchabilities at age 2 in the two tuning surveys were far above those of age 1 (almost doubling that value) (ICES 2005). The addition of new years of surveys since then, while the fishery has been close, allowed to try to measure the natural mortality of this population which in the past was perceived to be around 1,2 (ICES 2005) by the application of this ICA model.

The seasonal ICA model was used to search for an optimum value natural mortality for this population, or alternatively a pattern of natural mortality-at-ages 1 and 2+. (Uriarte and Ibaibarriaga, WD #5.9). As catchability parameters and natural mortality cannot be estimated at the same time, the model has to assume that catchabilities of the surveys were equal for all ages and as such the information about natural mortality should in the assessment process. In order words the natural mortality of pattern of natural mortality-at-age which best accommodates the relative abundance-at-age of surveys and catches-at-age (given their selectivity pattern) should appear.

This is done for both the official and the expected new series of DEPM abundances. In this way the Catchability which may be required to assume for the new series of the DEPM would be in parallel be inferred by this exercise.

Figures 5.8.2.3 and 5.8.2.4 show that regardless the series of DEPM tuning the assessment the minimum weighted sum of squares are found around single natural mortalities (M) of about M=0.8, although the sensitivity is low for a range of M values between 1.1 and 0.5. In addition when natural mortality is allowed to change between ages, a low value for natural NM1 around 0.5 gives the minimum sum of squares corresponding to NM2+ of about 1.1.

For a single M at age equal to 0.8, Catchabilities for acoustic and DEPM surveys were 1.1 and 3.1 respectively, but the facto if estimated *a posteriori* over the final estimates the catchabilties for ages 1–2+ were 2.4–3.7 for acoustics and 1–1.5 for the DEPM. As such the single natural mortality reduced the discrepancy in catchabilities between ages compared with the old assessment at M=1.2, but did not entirely solved the problem. Here there is an indication for a smaller natural mortality than the one so far assumed for the assessment.

In Figure 5.8.2.5 it shows that a single catchability value do fit well all age indices observations when the pattern of NM at age is allowed (at M1=0.5 and M2=1.14). In this way the assumption of no differential catchability by ages can stand up when Natural mortality is allowed. This assumption is implicit to the BBM model when the percentages at age 1 in the surveys are taken as representative of the population at age.

There is a drop in the general level of SSB estimates when the natural Mortality is moved to 0.8 or pattern at age mentioned before. Regardless of the use of the official or new DEPM series. For these cases the value of catchability fitted to the new DEPM series is very close to 1 and therefore this analysis does not demonstrate incompatibility between the new series of DEPM and the classical assumption of it being an absolute estimator of biomass.

There may be some contradictions in the former results pointing out a drop in SSB with an assessment making use of the direct indices as relative ones (Qflat) when M is estimated, compared with the parallel Bayesian assessment when g is estimated which points out towards an increase in SSB when g is estimated. The reason should be around the different ways of fitting the information at age (LogNormal of indices by age and the Beta distribution of the proportion at age 1), in addition catches are dealt and modelled in the ICA type of assessments and finally in ICA no "*a priori*" information about the parameters is considered. This contradictory result deserve further analysis and revision than what was possible in the WG and should try to be clarify in future.

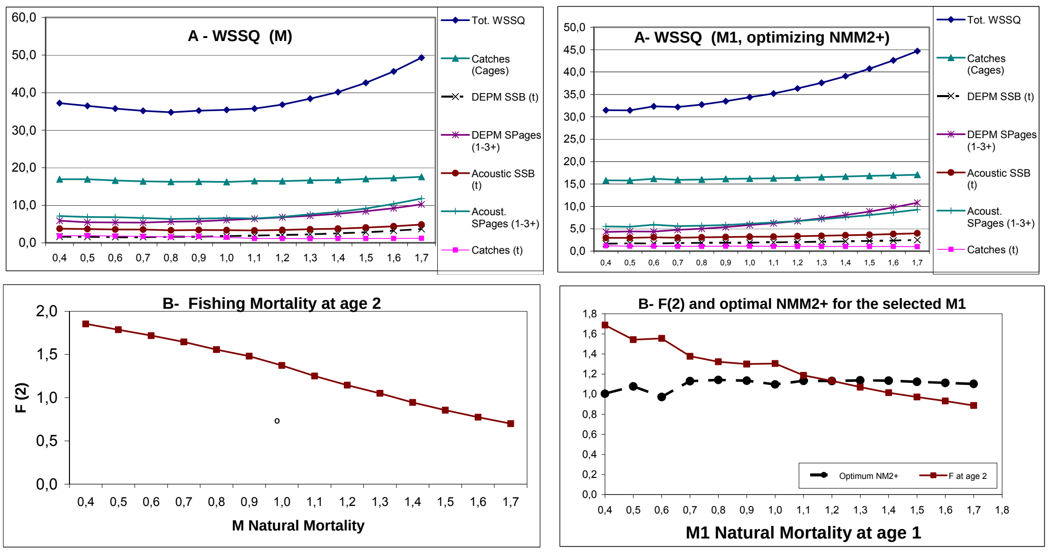


Figure 5.8.2.3. Weighted sum of squares (upper panels) for different choices of single Natural Mortality at age (left panels) or for a pattern of Natural Mortality at age 1 (X axes). Bottom panels show average F at age 1 to 3, in the right bottom panel the value of the natural mortality-at-age 2 also appears. Graphs resulting from the Seasonal ICA model when the official DEPM series are included in the assessment.

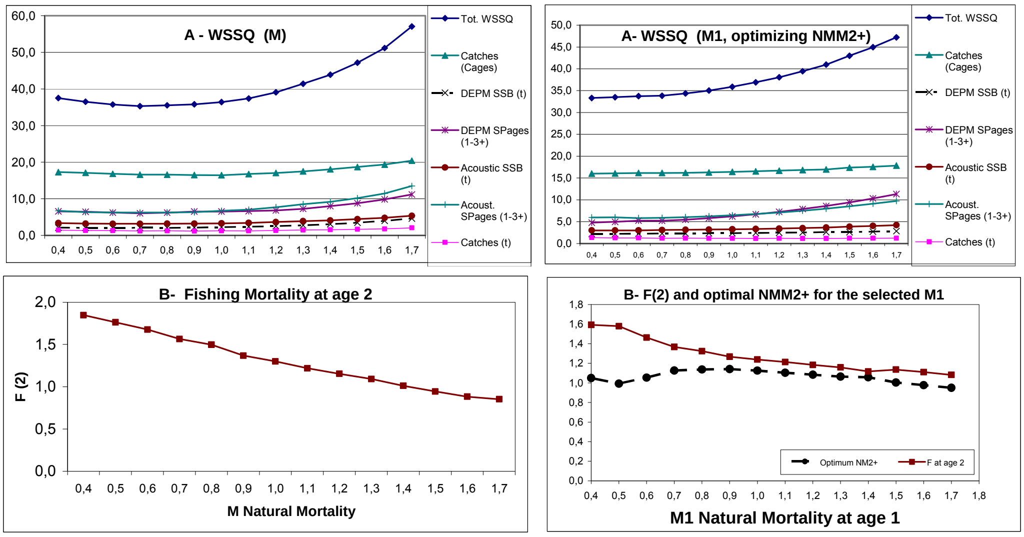
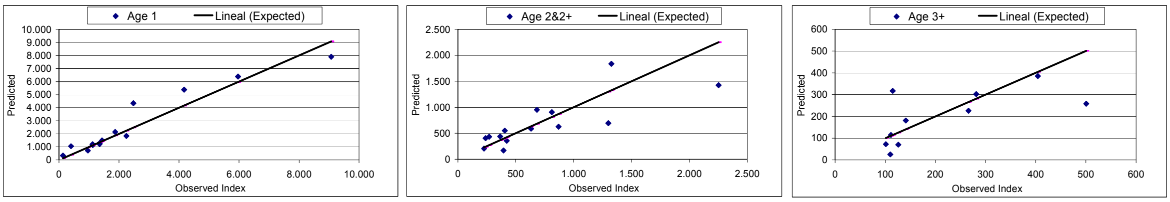


Figure 5.8.2.4. Weighted sum of squares (upper panels) for different choices of single Natural Mortality at age (left panels) or for a pattern of Natural Mortality at age 1 (X axes). Bottom panels show average F at age 1 to 3, in the right bottom panel the value of the natural mortality-at-age 2 also appears. Graphs resulting from the Seasonal ICA model when the DEPM new series are included in the assessment.

ACOUSTIC index at age fitting with a catchability of 3.2 (slopes).



DEPM index at age fitting with a catchability of 1.14 (slopes).

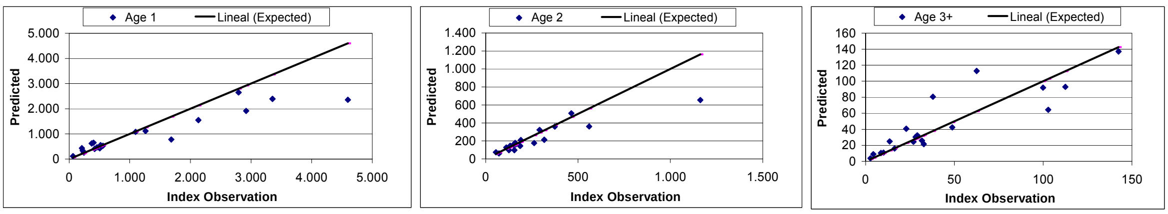


Figure 5.8.2.5. Model predicted index *vs.* the index observations and its fitting through the constant catchability at age model (Qflat) for a pattern at age of natural mortality (example for the new DEPM series, but the same could be shown for the official DEPM series).

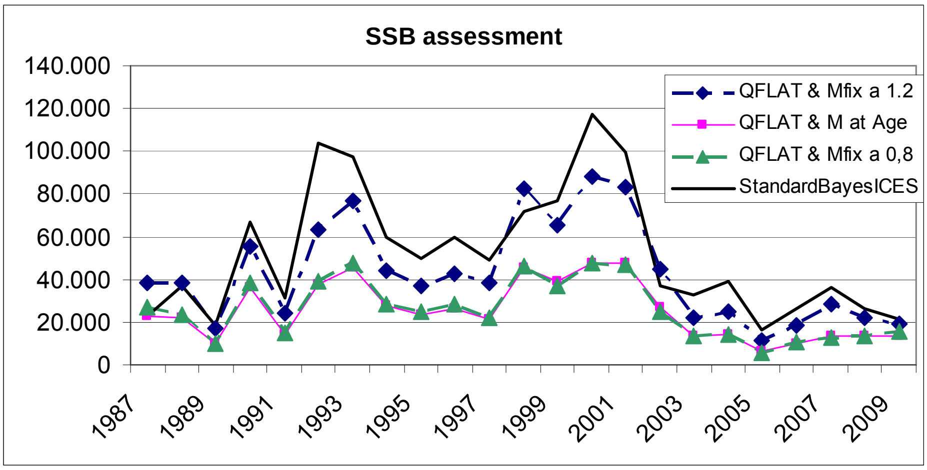


Figure 5.8.2.6. Series of the different seasonal ICA assessments for M=1.2, M=0.8 or Natmor at age compared with the BBM assessment of ICES in June 2009 (ICES 2009) (new series of DEPM).

Biomass Random Models (BREM)

Biomass Random Models (BREM) provides relative biomass estimates only. Fixing catchability for acoustic index to 1 leads to higher estimates compared with fixing catchability for the DEPM index, but time-trends are similar. The data for 2005 seems unreliable in terms of not tracking the 2005 cohort. Removing data for 2005 impacts biomass estimates for the period 2005–2009: it points towards a continuous gradual decrease of total biomass.

About the BREM model warnings were given about the double use of total B and age 1 biomass of which total B is strongly dependent. A better use can be made of these inputs as that of total biomass and proportion of age1/total. Nevertheless this was already mentioned in the Trenkel's WD #5.3 and her 2008 paper (V. Trenkel, 2008) not supposing a major drawback.

5.8.3 Retrospective patterns

An analysis of the retrospective pattern in the current assessment using BBM was conducted during the last assessment working group for this stock (ICES, WGANSA 2009). During this benchmark workshop no new analyses were conducted. However, the group reviewed and discussed the previous work. Even if the estimates obtained in the last assessment year are almost always within the 95% probability intervals of the next year's assessments, it was recognized that there might be a tendency to underestimate biomass in the last assessment year. This might be due either to wrong assumptions on the g parameter (this parameter accounts for growth in mass and natural mortality and it is assumed to be constant by ages and across years) or to different catchability by age in the surveys (which are assumed to be equal by ages). The Group suggested to further study the retrospective patterns through simulation.

5.8.4 Evaluation of models

Three models were available to assess the anchovy population, the Integrated Catch-at-age Analysis (ICA), the Biomass Random Models (BREM) and the Bayesian Biomass Model (BBM). The ICA is an age-based model which was used here as an exploratory tool in search of estimating natural mortality rate but its use was abandoned some years ago as a consequence of its larger complexity and of being designed primarily to be a catch based assessment tool demanding catches and abundance-at-age indices. In contrast, the other two models are 2 stage models designed to take into account just two age classes which are sufficient for this short-living species, they are relatively less data demanding and parsimonious. The BBM model has been put in a state-space framework and fitted using a Bayesian approach, providing a means of including different sources of uncertainty in the model and *a priori* knowledge, while BREM model provides MLE estimates and allows random walk in the g parameter. For these reasons the BBM is the preferred and adopted method at ICES, and the Workshop supported that election.

5.9 Stock assessment

No change has been made to the set of procedures used for the stock assessment.

5.10 Recruitment estimations

Two approaches have been developed during the last years to obtain forecasts of recruitment-at-age 1 to the population and the fishery:

the first one is based on the acoustic surveys of juvenile abundance during the September–October (as JUVENA survey series is 6 year of data, Boyra *et al.*, WD #5.8 and PELACUS10 survey). This series has demonstrated quite good relationship so far with the assessed recruitment-at-age 1 in the following year arising from the BBM assessment (R2= 0.64, P(R=0)=0.06) (Section 5.8.2.3), but the lack of contrast in recruitment levels hampers still its application.

And the second consists on using environmental indices as predictors, based on several environmental indices which may partly affect recruitment and which demonstrated significant relationship for several years (although for some of them significance vanished subsequently). These are mainly Borja *et al.*, 1996, 2008 and Allain *et al.*, 2001. Upwelling indices, stratification indices (Allain *et al.*, 2001; Huret and Petitgas, 2007), Rivers run-off (Planque and Buffaz, 2008), or East-West Eckman transport (Irigoien *et al.*, 2008). The coefficient of determination of the individual indices of the recruitment-at-age 1 is in any case is medium (around 50%) or lower. In the present workshop a method for combining different environmental indices to predict the recruitment of anchovy has been presented (Fernandez *et al.*, WD #5.2) using "machine-learning" methodologies (see Section 5.5). As the model allocates probabilities to different levels of next coming recruitment, it fits nicely with the concept of stochastic projection applied to this anchovy as weighted mixture of past recruitments (years or levels). The Workshop considered the convenience of further testing the performance of this method.

No methods are currently at the stage where they can be routinely applied as recruitment predictors. Common practice for ACOM has been to make assumptions about recruitment taking all available information into account.

5.11 Short-term forecast

No change on the short-term forecast procedures has been proposed during this benchmark. A long-term management plan based on harvest control rules is currently pending for approval at the European Commission. That plan does not require short-term forecast.

A spatial fishery simulator, ISIS-Fish, is being developed by IFREMER (WD #5.7). One of the case studies is the Bay of Biscay anchovy. This tool integrates several sub-models: a biological model, an exploitation model and some economical modelling. Various types of measures will be tested from exchanges with the industry: harvest control rules, temporal and spatial closures, change of efforts, mesh size. ISIS-Fish in the case of anchovy aims at providing guidance for implementing alternate or complementary management options to the usual fishing quotas options. At the time of the Workshop, the model was under calibration.

5.12 Biological reference points

The precautionary reference points were set accordingly to stock estimates with ICA and within the standard framework related to deterministic stock assessments. For the anchovy, a Bayesian assessment is now well established, and the reference points may need to be revisited within that conceptual framework.

Because the assessment provides the probability distributions for the SSB, the rationale to maintain a B_{pa} under the assumption that being at B_{pa} would imply a low risk to B_{lim} becomes irrelevant. Hence, in the WGANC, it was suggested that the B_{pa} be abandoned as a reference point. However, Bayesian assessment provides the posterior distribution of the current biomass. The present practice of using the 5 percentile as a precautionary guidance may become misleading. It is needed to clarify precisely how the posterior distribution should be used with some harvest control rules. This discussion was raised in Section 2.7 of the 2009 WGANSA report (ICES, 2009).

B_{lim} is defined by ICES as the SSB below which recruitment becomes impaired (ICES 2003). For stocks with a clear plateau in the S/R scatterplot (a wide dynamic range of SSB, but no evidence that recruitment is impaired) it was recommended to identify B_{loss} as a candidate value of B_{lim}, below which the dynamics of the stock is unknown.

For anchovy it was considered that "the dynamic range in SSB and R has been relatively large, but there is no clear signal in the S/R relationship. Furthermore, the assessment time-series is relatively short. B_{loss} should be maintained as B_{lim}." Hence B_{lim} was set equal to B_{loss} = 21 000 t, which was the lowest spawning biomass (SSB) in the ICA 2003 assessment (corresponding to year 1989).

Following the comments suggested during the Benchmark meeting, another approach may be considered in the definition of the biological reference points.

Because the B_{lim} is set with reference to a particular year, for which the assessment provides a probability distribution which is updated every year, an alternative would be to consider the current SSB relative to SSB1989 in probabilistic terms. This could be done by considering the distribution of the ratio SSBcurrent/SSB1989. On the other hand, the uncertainty in some of the key population parameters used in the assessment (e.g. M), or the possible revision of abundance estimates from DEPM surveys, points out that the stock size estimates must be seen as relative indices rather than absolute values (Rivard, 1989), and therefore the definition of the reference points should follow the same logic. This approach would require some substantial changes in the management procedure of the fishery as well as in the advice.

These issues were discussed during the Workshop but no recommendations were made.

5.13 Recommended modifications to the stock annex

During the Workshop, the external experts agreed that the stock annex was sufficiently documented. No significant modifications are recommended.

5.14 Recommendations on the procedure for assessment updates

The following recommendations were made during the benchmark:

To continue using the BBM as a baseline model for the assessment the anchovy fishery.

Biomass Bayesian Model (BBM) setup: the Group recommends using to investigate the use of more informative priors for some of the parameters (there is possibly information to set more restrictive priors of g and Qs). For instance; instead of just assuming one of the surveys as absolute (by fixing Q=1) a restrictive prior on survey's catchabilities could be introduced in the modelling, without subtracting that parameter from the Bayesian inference. Other possibility is to make use of the CVs given with surveys' estimates and reduce thus the uncertainty around their *a priori* distribution. In this way, survey results can be used in the Bayesian framework but incorporating more restrictive priors. The general idea is thus to play more with the priors by restricting the range of inference when a wide range is not required *a priori*.

Retrospective Pattern in most recent SSB estimate: the Group recommends trying to figure out their origins (e.q. value of Qs or other parameters) and to use simulated data to investigate further this pattern although some difficulties are expected to reproduce the assessment with simulated data. If confirmed, it can be taken into account to correct most recent assessment.

The SSB estimation from the DEPM should be revised accordingly to the new estimates of spawning frequency and a thorough investigation should be carried out to examine the impact of this revision on stock assessment output, particularly in the determination of SSB_{lim}.

In relation with the sensitivity analysis of different parameters (e.g. Qs and M) used with the BBM model, other model may be used (separable models or others) for exploratory analysis. This can be done using something different from win-bugs (e.g. ADMB) that can compute only the MLE to speed up the work. It would be worthwhile making the effort of putting the Seasonal ICA in a state-space framework and fit the model using a Bayesian approach. As the number of model parameters to be estimated changes from model to model, more testing should be conducted and a formal statistical procedure such as AIC may be applied for model selection in this sensitivity analysis.

The discrepancies between acoustic and DEPM indices should be explored further (especially in years with big discrepancies such as 2000 and 2002), by going to the source and trying to explain them. Perhaps understanding the discrepancies, different ways of taking into account surveys outputs may arise: for instance by modelling inherent subparameters defining those estimates (i.e. fecundity, target strength, etc.) or by including some catchability into the 1 year old class of one of the two surveys, etc.

The recruitment surveys on Juveniles should be continued and the use of recruitment survey index in the prediction of abundance of age 1 anchovies in the coming year should be tested.

Further effort should be made to investigate the relationship between anchovy recruitment and environmental variables.

The group recommended investigating for some potential changes in natural mortality which may explain why the stock has not recovered. The fact biomass has been remaining at low levels despite the closure of the fishery in 2005 has remained unexplained so far.

The Benchmark Workshop endorses the practice followed for anchovy of passing to managers the probability of the SSB falling below the B_{lim}.

In relation with other issues that can be useful in future but are not used in the present assessment:

The WK agreed the JUVENA is indicating very promising results. The Group advised that if a high juvenile abundance would appear in the survey beyond former estimates, making inference from it would be dangerous as far as it would be an extrapolation out of range. When trying to calibrate JUVENA indices, caution should be taken with the procedure of removing some small length classes. If so, this should be clearly based on *a priori* biological or ecological criteria adopted independently of the changes in the fit to the output of the assessment.

The recruitment index of Fernandes *et al*. based on environmental indices was considered valuable and of interest in the context of the Bayesian forecast: However a more clear explanation of its performance in predicting next 1 y.o. recruitment was required in order to be able to support already its use.

A potential forecast model may be developed to predict anchovy recruitment from both the survey juvenile index and the oceanographic conditions using a Bayesian approach. It is necessary to evaluate the benefits of these types of approaches in practical management compared with management options not directly demanding recruitment forecast (such as proposed in the harvest control rule of the Management Plan). It is necessary to incorporate considerations of the risks of being wrong in predicting high or low R when evaluating its performance, etc. These information can be valid in the frame of a 2-step management advice (to set a TAC for the first part of the year), by giving probabilities to different levels (or scenarios) of recruitment.

5.15 Industry-supplied data

5.15.1 Industry-supplied data

Extension of sentinelle surveys

A pilot-study of sentinel surveys on anchovy and sardine between science and industry is already in progress in France through national and EU funds. This project aims at providing biological and environmental indices five times a year for two areas in addition to the collaboration established for the various scientific surveys. The preliminary data obtained from the first survey in August 2009 appear to complement well those from spring and autumn surveys. Additional areas (Western channel, Cantabria, Basque Country) would bring additional knowledge of the life cycle of anchovies on questions like recruitment and migration out of the context of spring surveys. This implies the international participation of scientific institutes and fishing organizations outside.

Bycatch

As a consequence of the closure of the fishery, bycaught anchovies by pelagic or bottom trawls cannot be sold and are discarded. Both representatives of the fishermen and French scientists expressed their interests of having samples of those bycatches allowed to be sent to laboratories for various analyse without risks to the fishermen of being fined.

Stomach contents

The Group encourages research on potential changes on natural mortality. As a substantial component of natural mortality is predation, collecting stomach contents from landed predators of anchovy such as meagre, sea bass, tuna would bring new information on the intensity of trophic relationships in the Bay of Biscay at various locations and seasons.

Others

Several other potential contributions from the fleet could be considered.

As an example an idea commented with fishermen is the Collection of information on sea field observations of occurrence of juvenile anchovy at surface during summer and autumn period, as this could be of utility in qualifying next coming recruitment if the data are properly collected and analysed.

In any case the above initiatives and ideas could be as well directly be dealt with the frame of SWWRAC in a joint meeting with scientists.

5.15.2 Impact of the provision of such data

Such data would be useful to increase our understanding of the life cycle of anchovy and its relationships within the Bay of Biscay ecosystem. It would also provide answers on some hypotheses proposed (e.g. competition with species for food, predation) to explain why despite the closure of the fishery, the stock remains at low biomass level.

5.16 References

Alday, A., Uriarte, A., Santos, M., Martín, I., Martínez de Murguia, A. and Motos, L. 2008. Degeneration of postovulatory follicles of the Bay of Biscay anchovy (*Engraulis encrasicolus* L.) Scientia Marina 72: 565–575.

Allain, G., Petitgas, P. and Lazure, P. 2001. The influence of mesoscale ocean processes on anchovy (*Engraulis encrasicolus*) recruitment in the Bay of Biscay estimated with a three-dimensional hydrodynamic model. Fisheries Oceanography, 10: 151–163.

Borja, A., Uriarte, A., Valencia, V., Motos, L. and Uriarte, A. 1996. Relationships between anchovy (*Engraulis encrasicholus*) recruitment and the environment in the Bay of Biscay. Scientia Marina 60(Suppl. 2):179–192.

Borja, A. Fontán, A., Saez, J. and Valencia, V. 2008: Climate, oceanography, and recruitment: the case of the Bay of Biscay anchovy (Engraulis encrasicolus). Fisheries Oceanography. 17:6, 477–493, 2008.

Fernandes J. A., Irigoien X., Goikoetxea N., Lozano J. A., Inza I., Perez A., Bode A. 2009. Fish recruitment prediction, using robust supervised classification methods. Ecological Modelling. Submitted.

Huret, M., and Petitgas, P. 2007. Anchovy recruitment forecasting and environment. Working document to ICES WGMHMSA 2007.

Ibaibarriaga, L., Fernández, C., Uriarte, A., and Roel, B. A. 2008. A two-stage biomass dynamic model for Bay of Biscay anchovy: a Bayesian approach. – ICES Journal of Marine Science, 65: 191–205.

ICES, 2003. Report of the study group on precautionary reference points for advice on fishery management. ICES CM 2003/ACFM:15, 79 pp.

ICES. 2005. Report of the Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy (WGMHSA), 6–15 September 2005, Vigo, Spain. ICES CM 2005/ACFM:08. 615 pp.

ICES. 2007a. Report of the Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy (WGMHSA), 4–13 September 2007, ICES Headquarters. ICES CM 2007/ACFM:31. 712 pp.].

ICES. 2007b. Report of the Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VIII and IX (WGACEGG), 26–30 November 2007, Palma de Mallorca, Spain. ICES CM 2007/LRC:16. 167 pp.

ICES. 2008. Report of the Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VIII and IX (WGACEGG), 24–28 November 2008, Nantes, France. ICES CM 2008/LRC:17. 183 pp.

ICES. 2009. Report of the Working Group on Anchovy and Sardine (WGANSA), 15–20 June 2009, ICES Headquarters, Copenhagen. 354 pp.

Irigoien, X., Cotano, U., Boyra, G., Santos, M., Alvarez, P., Otheguy, P., Etxebeste, E., Uriarte, A., Ferrer, L. and Ibaibarriaga, L. 2008. From egg to juvenile in the Bay of Biscay: spatial patterns of anchovy (*Engraulis encrasicolus*) recruitment in a non-upwelling region. Fisheries Oceanography 17: 446–462.

MacCall, A.D. 1990. Dynamic Geography of Marine Fish Populations. University of Washington Press, Seattle.

Patterson, K.R., and Melvin, G.D. 1996. Integrated catch-at-age analysis, version 1.2. Scottish Fisheries Research Report, 58: 60 pp.

Planque, B. and Buffaz, L. 2008. Quantile regression models for fish recruitment-environment relationships - four case studies. Marine Ecology Progress Series 357:213–223.

Rivard, D. 1989. Overview of the systematic, structural, and sampling errors in cohort analysis. American Fisheries Society Symposium 6, 49–65.

Trenkel, V. 2008. A two-stage biomass random effects model for stock assessment without catches: What can be estimated using only biomass survey indices? Canadian Journal of Fisheries and Aquatic Sciences, 65: 1024–1035.

Anchovy in Subarea VIII (Bay of Biscay)–Stock Annex

Quality Handbook Stock specific documentation of standard assessment procedures used by ICES

Stock	Bay of Biscay Anchovy (Subarea VIII)
Working Group	WGANSA (Working Group on the Assessment of Anchovy and Sardine)
Date	15–20 June 2009
Revised at	WGANSA

Authors by alphabetic order E. Duhamel, L. Ibaibarriaga, J. Massé, L. Pawlowski, M. Santos and A. Uriarte.

A. General

A.1. Stock definition

Anchovy (*Engrulis encrasicolus, L*) stock in Subarea VIII (Bay of Biscay) is considered to be isolated from a small population in the English Channel and from the population in the Area IXa. No subpopulations have been defined, although morfometrics and meristic studies suggest some heterogeneity at least in morphotipes (Prouzet and Metuzals, 1994; Junquera and Perez-Gandaras, 1993). Some genetic heterogeneity based on proteins allocime loci have been found between the Garonne spawning regions and southern regions in the Bay of Biscay (Adour and Cantabrian shores) (Sanz *et al.*, 2008). Nevertheless, the evident inter connection of fisheries and rather homogenous recruitment pulses occurring in the Bay of Biscay lead ICES to consider that the anchovy in this area should be dealt as a single stock for assessment and management (ICES 2007).

A.2. Fishery

Presently the fishery is closed since June 2006 as a consequence of poor condition of the stock. The fisheries for anchovy are targeted by purse-seiners and pelagic trawlers. The Spanish and French fleets fishing for anchovy in Subarea VIII are spatially and temporally quite well separated. The Spanish fleet (purse-seine fleet) operates mainly in Divisions VIIIc and VIIIb in spring, while the French fleet (mainly pelagic trawlers) operates in Division VIIIa in summer and autumn and in Division VIIIb in winter and summer. A small fleet of French purse-seiners operates in the South of the Bay of Biscay (VIIIb) in spring and in the North (VIIIa) during autumn. An overview of the history of the fishery until the mid nineties and its spatial behaviour is found in Junquera, 1986 and Uriarte *et al.*, 1996 and for more recent perspective see ICES 2007 and 2008 or STECF 2008 for the international fishery and Uriarte *et al.*, 2008; Villamor *et al.*, 2008 for the Spanish fishery and Duhamel, 2004 and Vermard *et al.*, 2008 for the French pelagic trawlers. A recent updated information (2009) provided by the SWWRAC reveals an 18% decrease in the fleet size operating on anchovy since the closure of the fishery (2005). This decrease is much more important for the pelagic trawlers' fleet (-39%) than for the purse-seiners (-11%). Since the fishery closure, the fleets have redeployed their effort mainly towards other small pelagic species (57%) and tunas (29%) (Table A.2.2).

Table A.2.1. Evolution of the French and Spanish fleets on anchovy in Subarea VIII. Fishery closed in 2006, 2007 and 2008. Units: numbers of boats.

	FRANCE				SPAIN *	
Year	P. seiner	P. trawl		Total	P. seiner	Total
1960	-	-			571	571
1972	-	-			492	492
1976	-	-			354	354
1980	-	-			293	293
1984	-	-			306	306
1987	-	-			282	282
1988	-	-			278	278
1989	18	6	(1,2)	24	215	239
1990	25	48	(1,2)	73	266	339
1991	19	53	(1,2)	72	250	322
1992	21	85	(1,2)	106	244	350
1993	34	108	(1,2)	142	253	395
1994	34	77	(1,2)	111	257	368
1995	33	44	(1,2)	77	257	334
1996	30	60	(1,2)	90	251	341
1997	27	52	(1,2)	79	267	346
1998	29	44	(1,2,3)	73	266	339
1999	30	49	(1,2)	79	250	329
2000	32	57	(1,2)	89	238	327
2001	34	60	(1,2)	94	220	314
2002	32	47	(1,2)	79	215	294
2003	19	47	(1,2)	66	208	274
2004	31	54	(1,2)	85	201	286
2005	8	41	(1,2,4)	49	197	246
2006	1 **	6 **	(1,2,4)	7 **	0	7
2007	0	0		0	0	0
2008	0	0		0	0	0

*** Spanish purse-seiners are those with licences that landed anchovy.**

(1) Only purse-seiners having catch anchovy at least once a year but fishing sardine most of the time.

(2) only trawlers that targeted anchovy (annual catch > 50 t).

(3) doubtful in terms of separation between gears because of misreporting.

(4) Provisional estimate.

**** French number of boats involved in the experimental fishery; not the actual size of the fleet.**

Table A.2.2. Approximate figures for the anchovy fleet and fishing effort displacement for the period 2005–2009 (based on reports from stakeholders 28 August 2009, provided by the SWWRAC). Report vers = report to add; bolincheurs Sud Bretagne = purse-seiners in southern Brittany; chinchard = horse mackerel; maquerau = mackerel; thon rouge = bluefin tuna; thon blanc = albacore; Autres = others.

Fishing ports	Seiners		Pelagic trawlers		report vers												number of targeted species
					sardine		chinchard		maquereau		thon rouge		thon blanc		autres		
	2005	2009	2005	2009													
Galice	67	61			1	15,3	1	15,3	1	15,3					1	15,3	4
Asturies	10	6			1	3,0	1	3,0									2
Cantabrie	54	47			1	9,4	1	9,4	1	9,4	1	9,4	1	9,4			5
Vizcaya	25	25			1	5,0	1	5,0	1	5,0	1	5	1	5			5
Guipuzkoa	52	44			1	8,8	1	8,8			1	8,8	1	8,8	1	8,8	5
StJean de Luz	8	8	4	4			1	12,0									1
la Turballe			39	23									1	11,5	1	11,5	2
St Gilles			24	14	1	0,0					1	0					2
Bolincheurs sud bretagne	8	8			1	2,7	1	2,7							1	2,7	3

A.3. Ecosystem aspects

Anchovy is a prey species for other pelagic and demersal species in the Bay of Biscay, and also for cetaceans and birds.

The recruitment depends strongly on environmental factors. Two environmental recruitment indices have been considered during the last 10 years: i) Borja *et al.*, 1998 index, which is an upwelling index, and ii) Allain *et al.*, 2001 index, which is a combination of upwelling and stratification breakdown. Allain's model was reviewed by Huret and Petitgas (WD 2007 in ICES2008) including a) the previous "upwelling" index, plus a new "stratification" index according to a new hydrodynamic model and b) an adult spatial indicator. The role of the Eastern Atlantic pattern in relation to the Upwelling index and the recruitment of anchovy have also been recently pointed out (Borja *et al.*, 2008). Other approaches based on coupling spawning habitat with hydrodynamic and production models are being tried for this anchovy population with promising results (Allain *et al.*, 2007).

The significance and reliability of all these indices is considered still insufficient for their consideration in the provision of management advice and no update was provided on their performance for the meeting in 2008 of WGANC (ICES 2008).

B. Data

B.1. Commercial catches

Fishery closed since July 2006.

Annual Landings are available since 1940. The fishing statistics are considered accurate. Discards are not measured and hence not included in the assessment, but nowadays they are considered not relevant to the two fleets. In the past (late eighties and early nineties for the French Pelagic trawlers and sixties and seventies for the Spanish Purse seine fleet) they seemed to be more relevant (according to disputes among fishermen), but were never quantified.

B.2. Biological

Catches-at-length and catches-at-age are known since 1984 for Spain and since 1987 for France. They are obtained by applying to the monthly Length distributions half year or quarterly ALKs (and when possible monthly ALKs, as for the Spanish fishery in spring). Biological sampling of the catches has been generally sufficient, except for 2000 and 2001, when an increase of the sampling effort seemed useful to have a better knowledge of the age structure of the catches during the second semester in the North of the Bay of Biscay. Complete age composition and mean weight-at-age on half year basis, were reported in ICES (2008 WGANC report).

Age reading is considered accurate. The most recent cross reading exchanges and workshop between Spain and France took place in 2005 and 2006 respectively (Uriarte *et al.*, 2006 and 2007). The overall level of agreement and precision in anchovy age reading determinations seems to be satisfactory: Most of the anchovy otoliths were well classified by most of the readers during the 2006 workshop (with an average agreement of 92.7% and a CV of 9.2%). CVs were on average smaller than 15% for any age, although individual CVs for ages or readers might be 30–35%.

A new otolith exchange and age reading workshop will take place in November 2009.

Anchovies are mature at their first year of life.

Growth in weight and length are well known from surveys and from the monitoring of the fishery (Uriarte *et al.*, 1996).

Natural mortality is fixed at 1.2 as an average of varying values obtained under the assumption of past DEPM providing absolute estimates of the population in numbers-at-age (Uriarte *et al.*, 1996). This parameter is considered to vary between years, but it is assumed to be constant for the assessment of the stock.

In the Bayesian Biomass Model, the parameter *g* describes the annual change in mass of the population by encapsulating the growth in weight (G) and the natural Mortality (M) of the population as G-M (0.52-1.2=-0.68)

B.3. Surveys

Spring surveys: series of DEPM(Daily egg production method) and acoustic surveys in Spring every year.

The population is monitored by the two annual surveys carried out in spring on the spawning stock, namely, the Daily Egg Production Method (since 1987 with a gap in 1993) (Santiago and Sanz, 1992; Motos *et al.*, 2005) and the Acoustics surveys (regularly since 1989, although surveys were also conducted in 1983, 1984 and some in the seventies) (Massé 1988, 1994, 1996). Both surveys provide spawning biomass and population at age estimates. The surveys have demonstrated pronounced interannual variability of biomass according to the pulse of recruitments, because one year old anchovies can conform up to more than 75% of the spawning population. Spawning area and biomass are positive and closely related, revealing expansion of the area occupied by the population when SSB increases (Uriarte *et al.*, 1996, Somarakis *et al.*, 2004).

This survey based monitoring system provides population estimates by the middle of the year, when about half of the annual catches have been already taken; and provide very little information about the anchovy population in the next year, because the bulk of it will consist of 1-year old anchovies being born at the time the surveys take place. Spawning Biomass in spring equals total-stock biomass because all anchovies are mature (the youngest being 1-year old by then).

B.3.1. Anchovy Daily Egg Production Method

B.3.1.1. The DEPM model

The anchovy spawning-stock biomass estimates is derived according to Parker, 1980 and Stauffer and Picquelle, 1980 from the ratio between daily production of eggs in the sea and the daily specific fecundity of the adult population:

Equation 1
$$SSB = P_{tot} / DF = \frac{P_0 \cdot A+}{k \cdot R \cdot F \cdot S / W}$$

Where,

SSB = Spawning stock biomass in metric tons;

P_{tot} = Total daily egg production in the sampled area;

P_0 = daily egg production per surface unit in the sampled area;

A+ = Spawning area, in sampling units;

DF = Daily specific fecundity. $DF = \frac{k \cdot R \cdot F \cdot S}{W}$;

W = Average weight of mature females in grammes;

R = Sex ratio, fraction of population that are mature females, by weight;

F = Batch fecundity, numbers of eggs spawned per mature females per batch;

S = Fraction of mature females spawning per day;

k = Conversion factor from gramme to metric tons (10^6).

An estimate of an approximate variance and bias for the biomass estimator derived using the *delta* method (Seber, 1982, *in* Stauffer and Picquelle, *op. cit.*) was also developed by the latter authors.

Population estimates of numbers-at-age are derived as follows:

Equation 2
$$N_a = N \cdot E_a = \frac{SSB}{W_t} \cdot E_a$$

Where,

N_a = Population estimate of numbers-at-age *a*;

N = Total spawning stock estimate in numbers. $N = \frac{SSB}{W_t}$;

B = spawning-stock biomass estimate;

W_t = average weight of anchovies in the population;

E_a = Relative frequency (in numbers) of age *a* in the population.

Variance estimate of the anchovy stock in numbers-at-age and total is derived applying the delta method.

B.3.1.2. Collection of plankton samples

Every year the area covered to collect the plankton samples is the southeast of the Bay of Biscay which corresponds to the main spawning area and season of anchovy.

Predetermined distributions of the vertical hauls that will be performed with the PairoVET net are shown in **Figure B.3.1.2.1**. The strategy of egg sampling is as follow: a systematic central sampling scheme with random origin and sampling intensity depending on the egg abundance found. Stations are located every three miles, along 15-mile-apart transects perpendicular to the coast. The sampling strategy is adaptive. When the egg abundances found are relatively high, additional transects separated by 7.5 nm are completed.

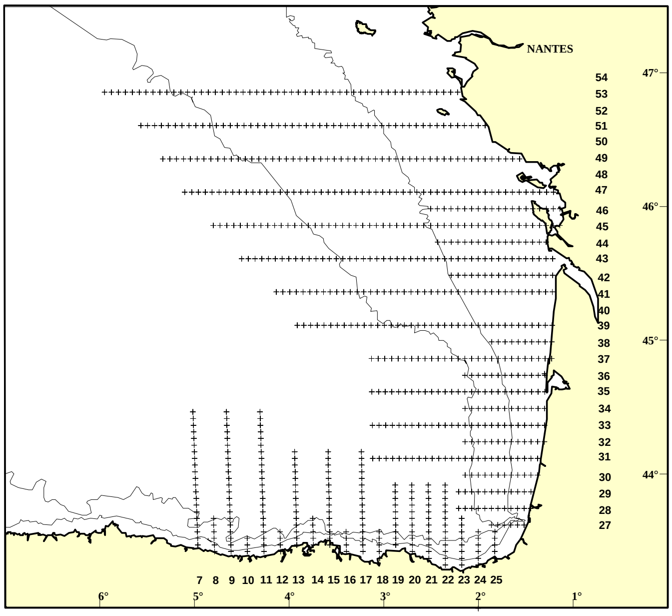


Figure B.3.1.2.1. Predetermined stations of the vertical hauls (PairoVET) that could be performed during the survey.

The Continuous Underway Fish Egg Sampler (CUFES) is also used to record the eggs found at 3 m depth. The samples obtained are immediately checked under the microscope so that presence/absence of anchovy eggs is detected in real time. This allowed knowing whether there were anchovy eggs in the area. When anchovy eggs are not found in 6 consecutive CUFES samples in the oceanic area, transect is left.

A vertical plankton haul is performed in each sampling station, using a PairoVET net (2-Calvet nets, Smith *et al.*, 1985 in Lasker, 1985) with a mouth aperture of 0.05 m^2 each CalVET. The frame was equipped with nets of 150 µm. The net is lowered to a maximum depth of 100 m or 5 m above the bottom in shallower waters. After allowing 10 seconds at the maximum depth for stabilization, the net is retrieved to the surface at a speed of 1 m s^{-1}. A 45 kg depressor was used to allow for correctly deploying the net. "G.O. 2030" flowmeters were used to know the amount of water filtered during the tow.

Immediately after the haul, the net is washed and the samples obtained are fixed in formaldehyde 4% buffered with sodium tetra borate in seawater. After 6 hours of fixing, anchovy, sardine and other species eggs are identified and sorted out on board. Afterwards, in the laboratory a percentage of the samples are checked to assess the quality of the sorting made at sea. According to that, when necessary, a portion of the samples are sorted again to assure no eggs are left. In the laboratory the anchovy eggs are staged (Moser and Alshtrom, 1985).

During the survey, the presence/absence of eggs was recorded per PairoVET station and the area where anchovy eggs occurred was quantified. The spawning area was delimited with the outer zero anchovy egg stations. It contains some inner zero egg stations embedded on it (Picquelle and Stauffer, 1985). Following the systematic central sampling scheme (Cochran, 1977) each station was located in the centre of a rectangle. Egg Abundance found at a particular station was assumed to represent the abundance in the whole rectangle. The area represented by each station was measured. A standard station has a surface of 45 squared nautical miles (154 km^2) = 3 (distance between two consecutive stations) x 15 (distance between two consecutive transects) nautical miles. Because sampling was adaptive, station area changed according to sampling intensity.

Real depth, temperature and salinity profiles are obtained in every station using a CTD RBR-XR420 coupled to the PairoVET. In addition, surface temperature and salinity is recorded in each station with a manual termosalinometer WTW LF197. Moreover current data are obtained all along the survey with an ADCP (Acoustic Doppler Current Profiles). In some point determinate previously to the survey, water is filtered from the surface to obtain chlorophyll samples.

B.3.1.3. Collection of adult samples

In 1987 and 1988 the samples were obtained from commercial purse-seines, the adult sampling was opportunistic. From years 1989 to 2005 the adult samples were obtained both from commercial purse-seines and a research vessel with pelagic trawl so the adult sampling was both opportunistic and directed. Since 2006 the samples are obtained from a research vessel with pelagic trawl but not from the purse-seines as a consequence of the closure of the fishery so the adult sampling is only directed not opportunistic.

The research vessel pelagic trawler covers the same area as the plankton vessel. When the plankton vessel encountered areas with anchovy eggs, the pelagic trawler is directed to those areas to fish. In each haul 100 individuals of each species are measured. Immediately after fishing, anchovy is sorted from the bulk of the catch and a sample of nearly 2 kg is selected at random. Sampling finished as soon as a minimum of 1 kg or 60 anchovies are sexed, and from those, 25 non-hydrated females (NHF) are preserved. Sampling is also stopped when more than 120 anchovies have to be sexed to achieve the target of 25 NHF. Moreover, otoliths are extracted to obtain the age composition per sample.

In the case the sample are obtained from the purse-seines a sample of nearly 2 kg is selected from the fishing and are directly kept in 4% formaldehyde. Afterwards, in the laboratory the samples are process in the same way as explained above.

B.3.1.4. Total daily egg production estimates

When all the anchovy eggs are sorted and staged, it is possible to estimate total daily egg production (P_{tot}). This is calculated as the product between the daily egg production (P_0) and the spawning area (SA).

$$P_{tot} = P_0 \, SA$$

A standard sampling station represents a surface of 45 nm^2 (i.e. 154 km^2). Because the sampling was adaptive, area per station changes according to the sampling intensity and the cut of the coast. The total area is calculated as the sum of the area represented by each station. The spawning area (SA) is delimited with the outer zero anchovy egg stations but it can contain some inner zero stations embedded. The spawning area is computed as the sum of the area represented by the stations within the spawning area.

The staged eggs are transformed into daily cohort abundances using the Bayesian ageing method (ICES 2004) Daily egg production (P_0) and daily mortality rates (Z) are estimated by fitting an exponential mortality model to the egg abundance by cohorts and corresponding mean age.

The model is fitted as a Generalised Linear Model (GLM) with Negative Binomial distribution and log link.

The ageing process and the model fitting are repeated until convergence. Eggs younger than 4 hours and older than 90% of the incubation time are removed from the model fitting to avoid any possible bias.

B.3.1.5. Adult parameters and Daily Fecundity estimates

The DF estimate for this WGANSA in June is obtained from a linear regression model between DF and sea surface temperature (SST). Two weeks after arriving from the survey the adult parameters are not processed yet, uniquely the anchovies were weighted, measured, sexed and the otoliths were extracted, consequently Daly Fecundity has to be derived from the past historical series. Afterwards in the ICES WGACEGG in November the complete DEPM with all the adult parameters estimates is presented and approval.

From the whole set of adult samples gathered during the survey, a subset is chosen for final processing with the criterion of collection within ±5 days of the egg sampling in the same particular area. In the last years the samples are collected within the same day as the egg sampling. These samples are used to obtain adult parameters estimates leading to the estimate of Daily Fecundity, i.e. batch fecundity, spawning fraction, average female weight and sex ratio. These adult parameters are estimates for November as follows:

Sex Ratio (R): Given the large variability among samples of the sex ratio and taking into account that for most of the years when the DEPM has been applied to this population the final estimate has come out to be not significantly different from 50% for each sex (in numbers), since 1994 the proportion of mature females per sample is being assumed to be equal to 1:1 in numbers. This leads to adopt as R the value of the average sample ratio between the average female weight and the sum of the average female and male weights of the anchovies in each of the samples.

Total weight of hydrated females is corrected for the increase of weight as a consequence of hydration. Data on gonad-free-weight (Wgf) and correspondent total weight (W) of non hydrated females is fitted by a linear regression model. Gonad-free-weight of hydrated anchovies is then transformed to total weight by applying the following equation:

$$W = -a + b * W_{gf}$$

For the **Batch fecundity (F)** estimates i.e. number of eggs laid per batch and female, the hydrated egg method was followed (Hunter *et al.*, 1985). The number of hydrated oocytes in gonads of a set of hydrated females is counted. This number is deduced from a subsampling of the hydrated ovary: Three pieces of approximately 50 mg are removed from different parts of each ovary, weighted with precision of 0.1 mg and the number of hydrated oocytes counted. Sanz and Uriarte, 1989 demonstrated that three tissue samples per ovary are adequate to get good precision in the final batch fecundity estimate and the location of subsamples within the ovary does not affect it. Finally the number of hydrated oocytes in the subsample is raised to the total gonad of the female according to the ratio between the weights of the gonad and the weight subsampled.

A linear regression between female weight and batch fecundity is established for the subset of hydrated females and used to calculate the batch fecundity of all mature females. The average of the batch fecundity estimates for the females of each sample as derived from the gonad free weight; eggs per batch relationship is then used as the sample estimate of batch fecundity.

Moreover, an analysis is conducted to verify if there are differences in the batch fecundity if strata are defined to estimate SSB.

To estimate **Spawning Frequency (S)**, i.e. the proportion of females spawning per day, until the new series of spawning frequency (S) is accepted a model based on the historical series was considered. This model relates S linearly with Sea Surface Temperature (SST).

Mean and variance of the adult parameters are estimated following equations for cluster sampling (as suggested by Picquelle and Stauffer, 1985):

Equation 3
$$Y = \frac{\sum_{i=1}^{n} M_i y_i}{\sum_{i=1}^{n} M_i}$$

Equation 4
$$Var(Y) = \frac{\sum_{i=1}^{n} M_i^2 (y_i - Y)^2}{\overline{M}^2 n(n-1)}$$

Where,

Y_i is an estimate of whatever adult parameter from sample *i* and M_i is the size of the cluster corresponding to sample *i*. Occasionally a station produced a very small catch, resulting in a small subsample size. To reflect the actual size of the station and its lower reliability, small samples were given less weight in the estimate. For the estimation of W, F and S, a weighting factor was used, which equalled to 1 when the number of mature females in station *i* (M_i) was 20 or greater and it equalled to $M_i/20$ otherwise. In the case of R when the total weight of the sample was less than 800 g then the weighting factor was equal to total weight of the sample divided by 800 g, otherwise it was set equal to 1. In summary for the estimation of the parameters of the Daily Fecundity we are using a threshold-weighting factor (TWF) under the assumption of homogeneous fecundity parameters within each stratum.

B.3.1.6. SSB estimates

In the WGANSA during June the Spawning Stock Biomass is preliminary estimates as the ratio between the total egg production (P_{tot}) and Daily Fecundity (DF) estimates and its variance is computed using the Delta method (Seber, 1982):

$$V\hat{a}r[SSB] = \frac{V\hat{a}r[Ptot]}{DF^2} + \frac{{P_{tot}}^2 V\hat{a}r[DF]}{DF^4}$$

The definitive SSB estimate with all the adult parameters is presented and approval at the WGACEGG during November.

B.3.1.7. Numbers at age

For the purposes of producing population-at-age estimates, the age readings based on otoliths from the adult samples collected were available. Estimates of anchovy mean weights and proportions-at-age in the adult population were computed as a weighted average of the mean weight and age composition per samples where the weights were proportional to the population (in numbers) in each stratum. These weighting factors are proportional to the egg abundance per stratum divided by the numbers of samples in the stratum and the mean weight of anchovy per sample. Weighting factors were allocated according to the relative egg abundance and to the amount of samples in the strata defined for the proposed of the estimation of the numbers-at-age. These strata are defined each year depending on the distribution of the adult samples i.e. size, weight, age and the distribution of the anchovy eggs.

Mean and variance of the adult parameters of the Population in numbers-at-age and the Population length distribution (total weight, proportion-by-ages and length distribution) are estimated following equations 4 and 5 for cluster sampling.

B.3.2. Anchovy acoustic indices

Acoustic surveys are carried out every year in the Bay of Biscay in spring on board the French research vessel Thalassa. The objective of PELGAS surveys is to study the abundance and distribution of pelagic fish in the Bay of Biscay. The main target species is anchovy but it will be considered in a multispecific context as species located in the centre of ecosystem.

These surveys are connected with IFREMER programmes on data collection for monitoring and management of fisheries and ecosystemic approach for fisheries. This task is formally included in the first priorities defined by the Commission regulation EU N° 199/2008 of 06 November 2008 establishing the minimum and extended Community programmes for the collection of data in the fisheries sector and laying down detailed rules for the application of Council Regulation (EC) No 1543/2000. These surveys must be considered in the frame of the Ifremer fisheries ecology action "resources variability" which is the French contribution to the international Globec programme. It is planned with Spain and Portugal in order to have most of the potential area to be covered from Gibraltar to Brest with the same protocol for sampling strategy. Data are available for the ICES Working Groups WGANSA, WGWIDE and WGACEGG.

B.3.2.1. Method and sampling strategy

In the frame of an ecosystemic approach, the pelagic ecosystem is characterized at each trophic level. In this objective, to assess an optimum horizontal and vertical description of the area, two types of actions are combined:

Continuous acquisition by storing acoustic data from five different frequencies and pumping seawater under the surface in order to evaluate the number of fish eggs using a CUFES system (Continuous Under-water Fish Eggs Sampler), and;

Discrete sampling at stations (by trawls, plankton nets, CTD). Satellite imagery (temperature and sea colour) and modelisation will be also used before and during the cruise to recognize the main physical and biological structures and to improve the sampling strategy. Concurrently, a visual counting and identification of cetaceans (from board) and of birds (by plane) will be carried out in order to characterize the higher level predators of the pelagic ecosystem.

Satellite imagery (temperature and sea colour) and modelisation are also used before and during the cruise to recognize the main physical and biological structures and to improve the sampling strategy.

Concurrently, a visual counting and identification of cetaceans and of birds (from board) is carried out in order to characterize the top predators of the pelagic ecosystem.

The strategy was identical to previous surveys (2000 to 2008):

Acoustic data were collected along systematic parallel transects perpendicular to the French coast (Figure 1.1.1). The length of the ESDU (Elementary Sampling Distance Unit) was 1 mile and the transects were uniformly spaced by 12 nautical miles covering the continental shelf from 20 m depth to the shelf break.

Acoustic data were collected only during the day because of pelagic fish behaviour in this area. These species are usually dispersed very close to the surface during the night and so "disappear" in the blind layer for the echosounder between the surface and 8 m depth.

Two echosounders are usually used during surveys (Simrad EK60 for vertical echosounding and OSSIAN 500 on the pelagic trawl). In 2009 the Simrad ME70 has been used for multibeam visualization. Energies and samples provided by split-beam transducers (five frequencies EK60, 18, 38, 70, 120 and 200 kHz), simple beam (OSSIAN 49 kHz) and multibeam echosounder were simultaneously visualized, stored using the MOVIES+ software and at the same standard HAC format.

The calibration method is the same that the one described for the previous years (see W.D. 2001) with a tungsten sphere hanged up 20 m below the transducer and is generally performed at anchorage in front of Machichaco cap or in the Douarnenez bay, in the west side of Brittany, in optimum meteorological conditions.

Acoustic data are collected by Thalassa along the totality of the daylight route from which about 2000 nautical miles on one way transect are usable for assessment. Fish are measured on board (for all species) and otoliths (for anchovy and sardine) are collected for age determinations.

B.3.2.2. Echoes scrutinizing

Most of the acoustic data along the transects are processed and scrutinised during the survey and are generally available one week after the end of the survey (Figure 2.2.1). Acoustic energies (Sa) are cleaned by sorting only fish energies (excluding bottom echoes, parasites, plankton, etc.) and classified into several categories of echotraces according to the year fish (species) structures.

Some categories are standard such as:

D1 – energies attributed to mackerel, horse mackerel, blue whiting, divers demersal fish, corresponding to cloudy schools or layers (sometimes small dispersed points) close to the bottom or of small drops in a 10 m height layer close to the bottom.

D2 – energies attributed to anchovy, sprat, sardine corresponding to the usual echotraces observed in this area since more than 15 years, constituted by schools well designed, mainly situated between the bottom and 50 meters above. These echoes are typical of clupeids in coastal areas and sometime more offshore.

D3 – energies attributed to blue whiting and myctophids offshore, just closed to the shelf break.

D4 – energies attributed to sardine, mackerel or anchovy corresponding to small and dense echoes, very close to the surface.

D6 – energies attributed to a mix, usually between 50 and 100 m depth when D1 and D2 were not separable.

Some particular categories are usually specifically designed according to several identifications during the survey (when Thalassa and/or commercial vessels hauls are available), such as:

D7 – energies attributed exclusively to sardine (big and very dense schools).

D5 – energies attributed to small horse mackerel only when they are gathered in very dense schools.

B.3.2.3. Data processing

The global area is split into several strata where coherent communities are observed (species associations) in order to minimize the variability as a consequence of the variable mixing of species. For each stratum, a mean energy is calculated for each type of echoes and the area measured. A mean haul for the strata is calculated to get the proportion of species into the strata. This is obtained by estimating the average of species proportions weighted by the energy surrounding haul positions. Energies are therefore converted into biomass by applying catch ratio, length distributions and TS relationships. The calculation procedure for biomass estimate and variance is described in Petitgas *et al*., 2003.

The TS relationships used since 2000 are still the same and as following:

Sardine, anchovy and sprat: TS = 20 Log L–71.2

Horse-mackerel: TS = 20 Log L–68.7

Blue whiting: TS = 20 Log L–67.0

Mackerel: TS = 20 Log L–86.0

The mean abundance per species in a stratum (tons m.n.$^{-2}$) is calculated as:

$$M_e(k) = \sum_D \bar{s}_A(D,k)\bar{X}_e(D,k)$$

and total biomass (tons) by: $B_e = \sum_k A(k)Me(k)$

where,

k : strata index;

D : echo type;

e : species;

S_A : Average S_A (NASC) in the strata (m^2/nautical mile ^{2});

X_e : species proportion coefficient (weighted by energy around each haul) (tons m^{-2});

A : area of the strata (m.n.^{2}).

Then variance estimate is:

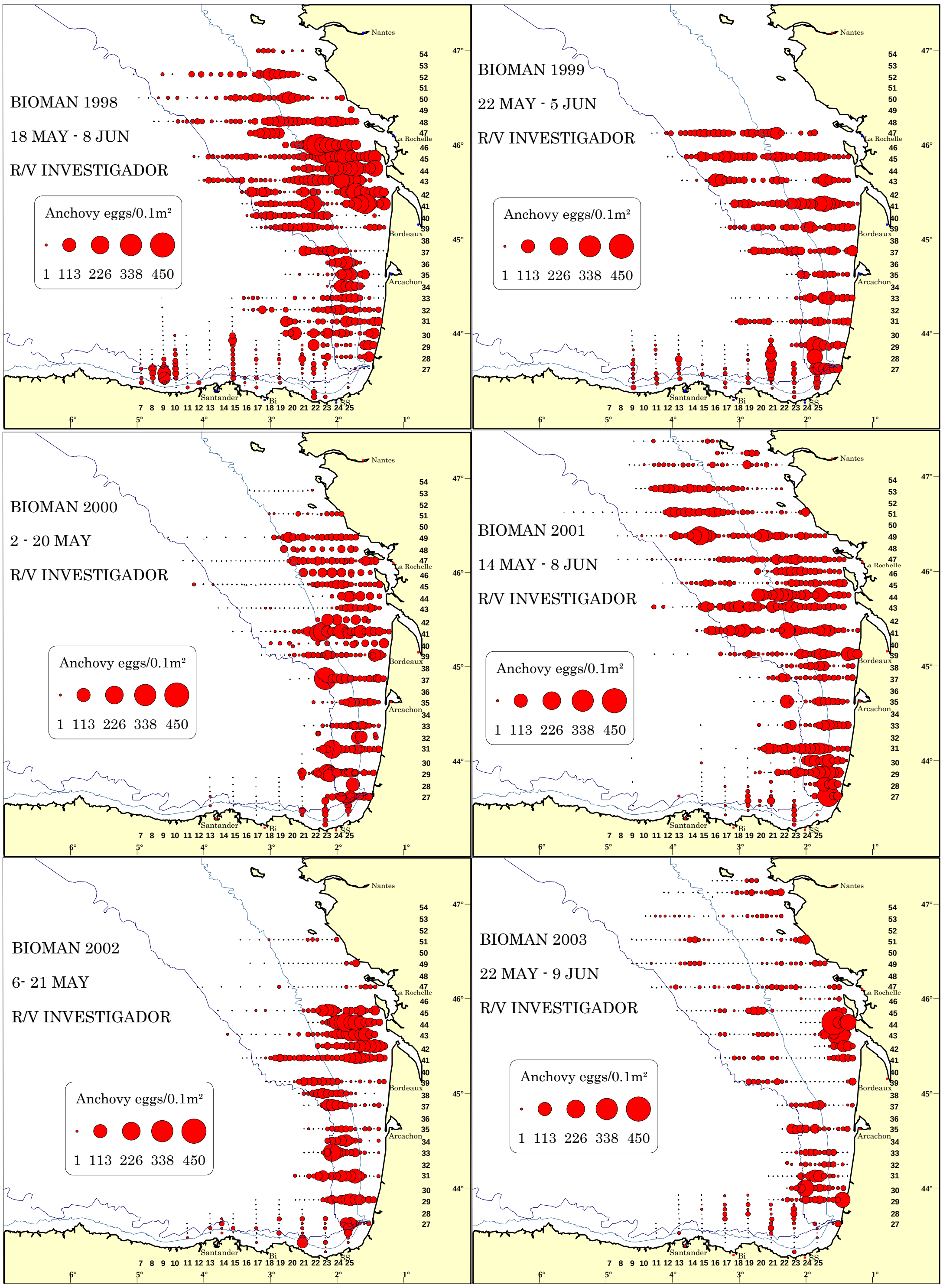
$$Var.M_e(k)=\sum_D \bar{s}_A^{\,2}(D,k)Var[X_e(D,k)]/n.cha(k)+\overline{X}_e^{\,2}\,\mathrm{var}[s_A(D,k)]/n.esu(D,k)$$

$$Var.B_e=\sum_k A^2(k)Var.Me(k)$$

$$cv=\sqrt{Var.Be}/Be$$

At the end, density-in-numbers and biomass-by-length and age are calculated for each species in each ESDU according to the nearest haul length composition. These numbers and biomass are weighted by the biomass in each stratum and data are used for spatial distributions by length and age.

B.3.3. Historical series DEPM and acoustic surveys



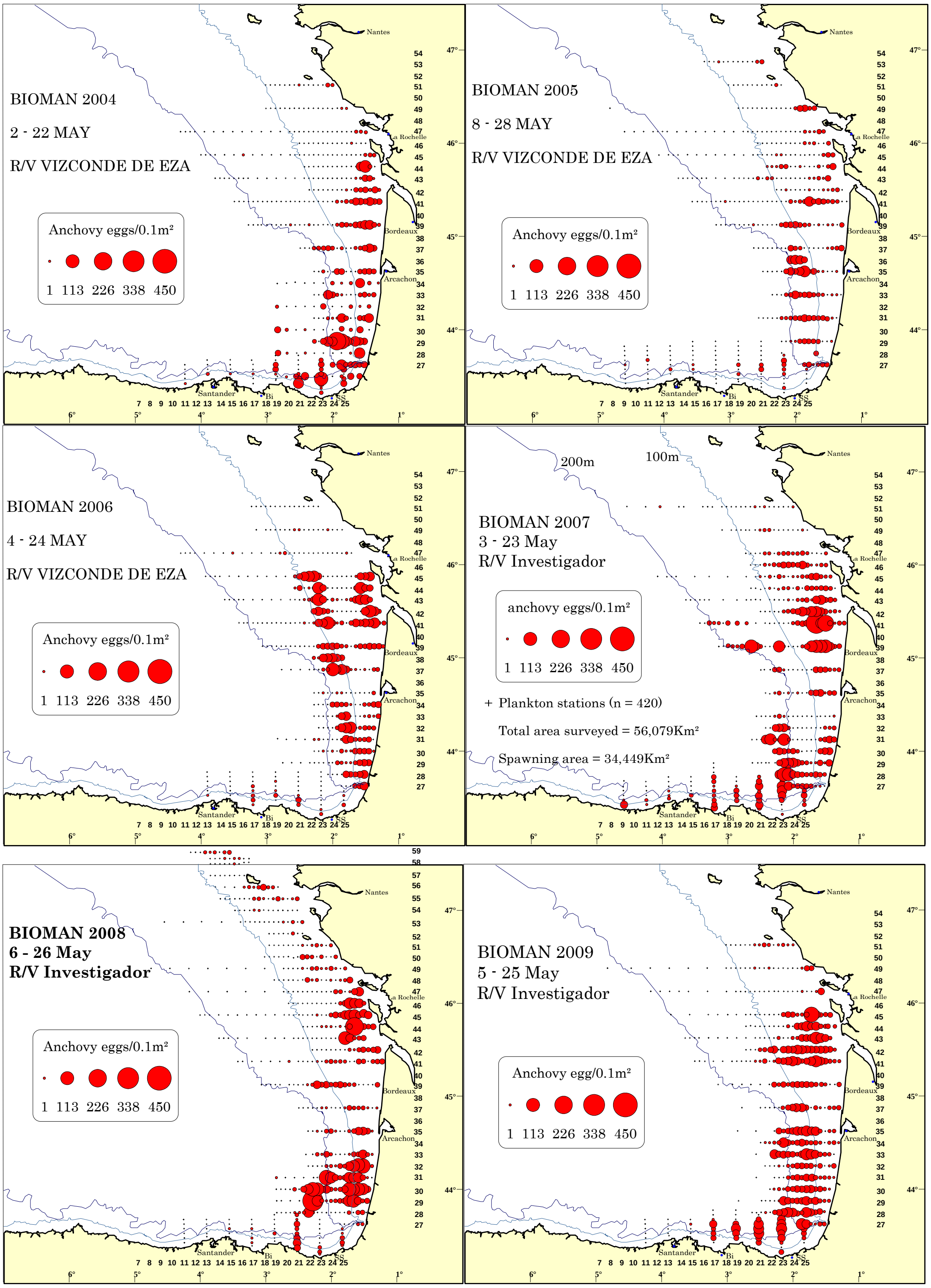
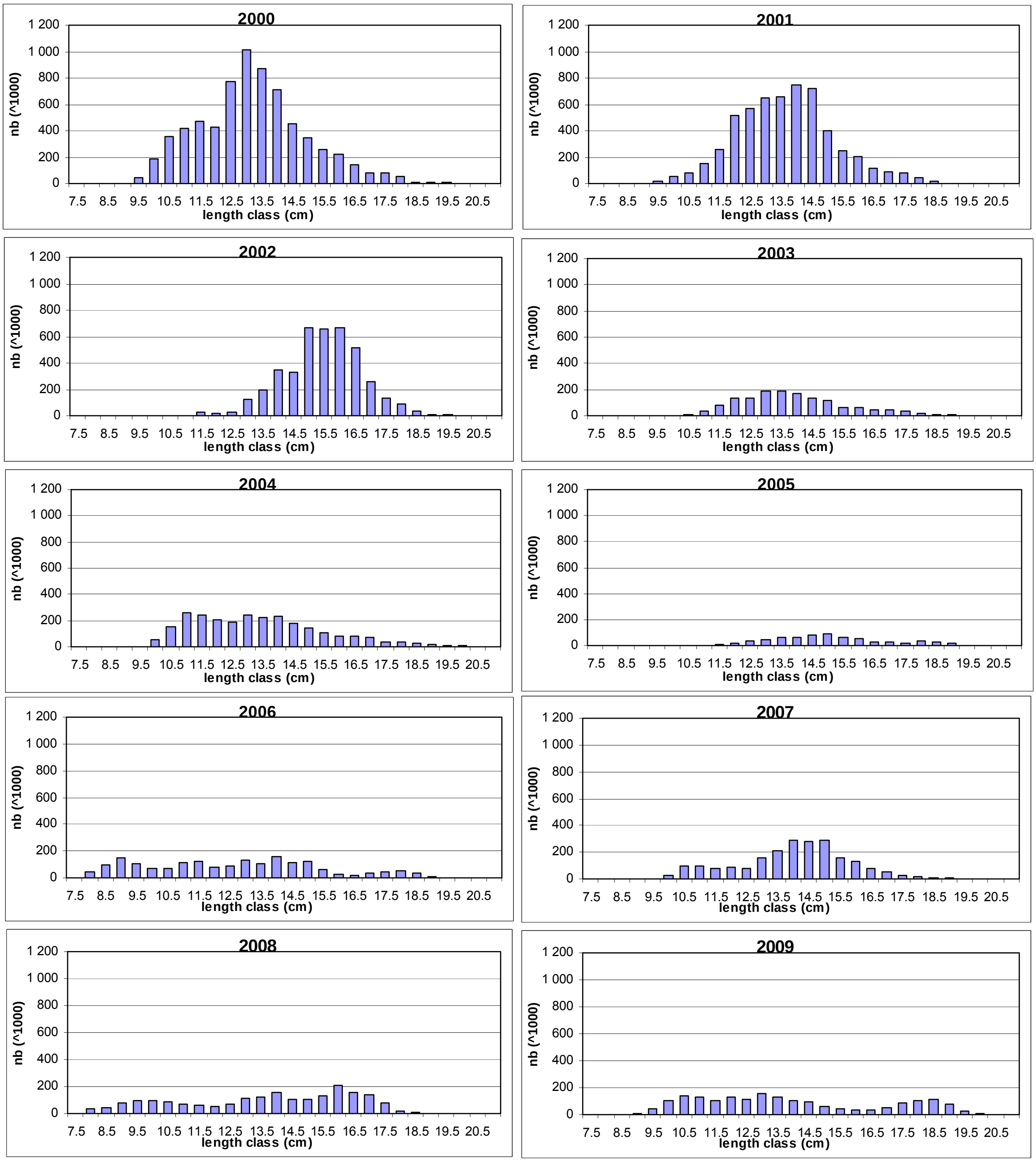
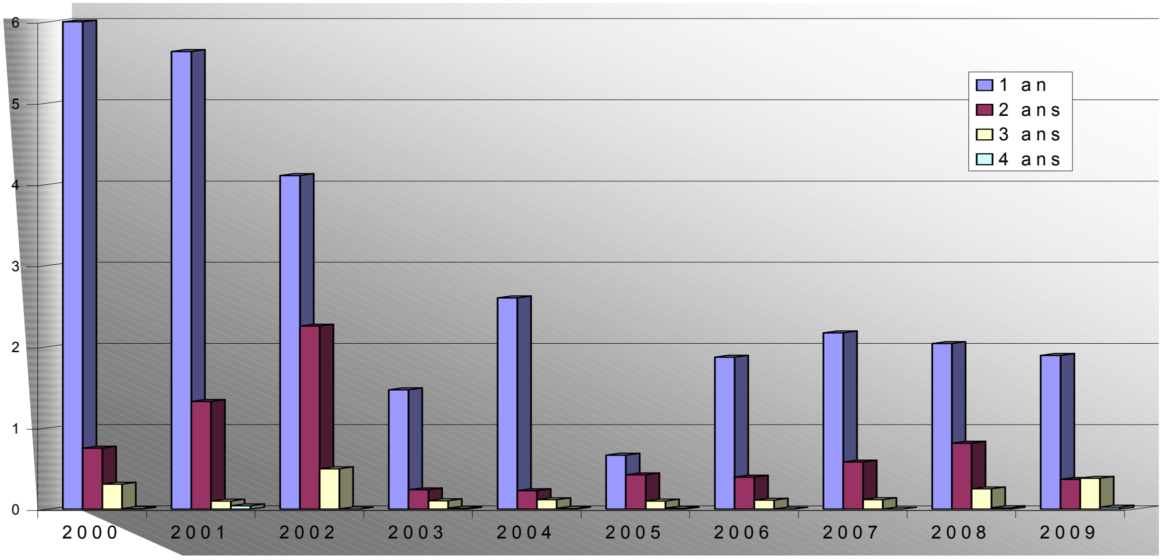


Figure B.3.3.1. Anchovy egg distribution from 1998 to 2009.The circles represent the anchovy egg abundance /0.1 m² encountered in each plankton station.

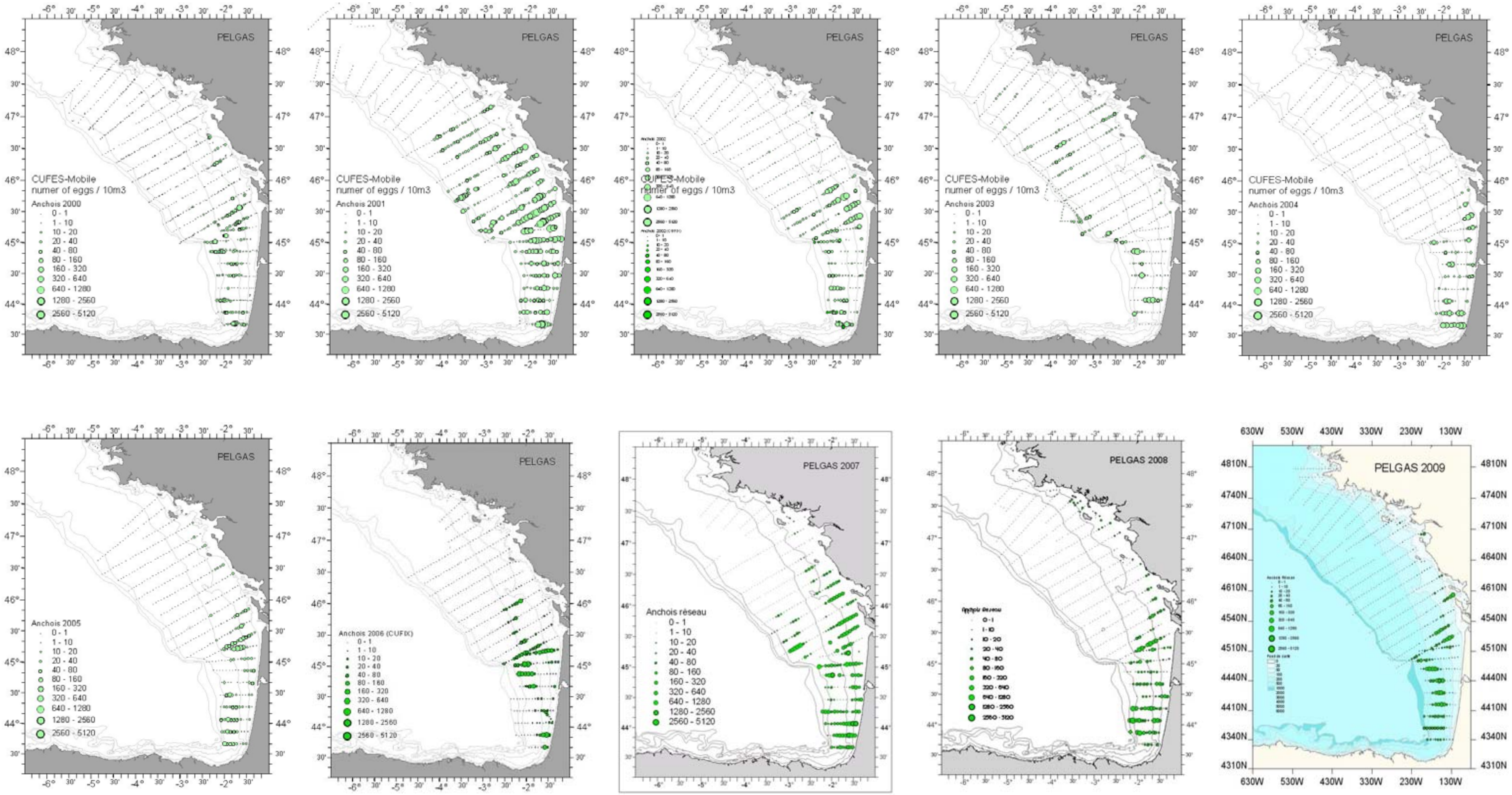


Length composition of adults of anchovy as estimated by acoustics since 2000 during PELGAS surveys.



Anchovy numbers-at-age as observed during PELGAS surveys since 2000. The 1-year old class still seems to be low since 2005 and 2 and 3 years old are increasing most likely because of the closure of the fishery.

Number of eggs observed during PELGAS surveys with CUFES from 2000 to 2009.



Distribution of anchovy eggs observed with CUFES during PELGAS surveys from 2000 to 2009 (number for 10 m^3).

B.3.4. Autumn surveys on Juveniles, still under testing period

In recent years two series of acoustic surveys on juvenile anchovy (JUVENA and PELACUS10) have been launched in September–October, expecting that in future the estimates can allow forecasting the strength of the anchovy recruitment which will enter the fishery the next year (ICES 2008, WGACEGG Report). Both surveys were coordinated with WGACEGG and are being merged nowadays. These surveys are expected to provide further insights on the recruitment process and additional knowledge of the biology and ecology of the juveniles Despite the encouraging results obtained with the series of six years of data available, the lack of sufficient contrast in the recent levels of recruitments prevents a proper evaluation of its performance as a predictor and the series are therefore not yet used for improving the management advice for the population (ICES 2008, WGANC Report).

B.3.4.1. Juvena survey

B.3.4.1.1. Data acquisition

JUVENA surveys take place annually since 2003, around September. In the period 2003 to 2005, the area was covered on board commercial purse-seiners. Since 2006 in addition to purse-seiners, an oceanographic vessel, the RV Emma Bardán, was incorporated to the survey. The abundance estimation is obtained by means of acoustic methodology (MacLennan and Simmonds, 1992). The acoustic equipment includes split-beam echosounders Simrad EK60 (Kongsberg Simrad AS, Kongsberg, Norway). The transducers of 38 kHz and 120 kHz (and 200 kHz since 2006) were installed looking vertically downwards, about 2.5 m deep, at the end of a tube attached to the side of the purse-seiners and at the hull in the case of the RV Emma Bardan. The transducers were calibrated using standard procedures (Foote *et al.*, 1987). Fishing was based on purse seining up to 2005 but since then onwards both pelagic trawling and purse-seines are being used for species identification and biological sampling, along with hydrological recordings. In addition, the spatial distribution of the juvenile population is studied along with their growth condition. Two boats have been used since 2005 and therefore some extension of the northern limits of the surveys thus facilitated.

The water column was sampled to depths of 200 m. A threshold of -100 dB was applied for data collection. Acoustic backscattered energy by surface unit (S_A, MacLennan *et al.*, 2002) was recorded for each geo-referenced ESDU (Echointegration Sampling Distance Unit) of 0.1 nautical mile (185.2 m). Fish identity and population size structure was obtained from fishing hauls and echotrace characteristics. The commercial vessels used a purse-seine of about 400 m of perimeter and 75 m height to fish the samples to depths of 50 m and the RV Emma Bardan used a pelagic trawl. Acoustic data, thresholded to -60 dB, was processed using Movies+ software (Ifremer) for biomass estimation and the processed data were represented in maps using Surfer (Golden Software Inc., CO, USA) and ArcView GIS. Hydrographic recording was made with CTD casts.

B.3.4.1.2. Sampling strategy

The sampling area covered the waters of the Bay of Biscay (being 5º W and 47º45′ N the limits). Sampling was started from the Southern part of the sampling area, the Cantabrian Sea, moving gradually to the North to cover the waters in front of the French Coast. The acoustic sampling was performed during the daytime, when the juveniles are supposed to aggregate in schools (Uriarte, 2002 FAIR CT 97–3374) and can be distinguished from plankton structures.

The vessels followed parallel transects, spaced 15 nm., perpendicular to the coast along the sampling area, taking into account the expected spatial distribution of anchovy juveniles for these dates, that is, crossing the continental shelf in their way to the coast from offshore waters (Uriarte *et al*., 2001).

B.3.4.1.3. Other sources of information

During summer, information from the commercial live bait tuna fishery was collected, in order to have knowledge of the spatial distribution and relative abundance of anchovy previous to the beginning of the survey. We continued collecting this information about the captures of the fleet during the survey itself. In addition we maintained a constant communication with the responsible of the survey Pelacus-10, conducted by the IEO and Ifremer, survey performed on board RV Thalassa with a double objective: juvenile abundance estimation and ecologic studies.

B.3.4.1.4. Biological processing

Each fishing haul was classified to species and a random sample of each species was measured to produce size frequencies of the communities under study. A complete biological sampling of the anchovy juveniles collected is performed in order to analyse biological parameters of the anchovy juvenile population, as the age, size or size–weight ratio. Using these and other environmental parameters we will try to obtain, in a long term, indices of the state of condition of the juvenile population, in order to be able to improve the prediction of the strength of the recruitment.

B.3.4.1.5. Acoustic data processing

Acoustic data processing was performed by layer echo-integration by 0.1 nautical mile (s_A) of the first 65 m of the water column with Movies+ software, after noise filtering and bottom correction, increasing or decreasing this range when the vertical distribution of juveniles made it necessary.

The hauls were grouped by strata of homogeneous species and size composition. Inside each of these homogeneous strata, the echo-integrated acoustic energy s_A was assigned to species according to the composition of the hauls. Afterwards, the energy corresponding to each species-size was converted to biomass using their corresponding conversion factor.

Each fish species has a different acoustic response, defined by its scattering cross section that measures the amount of the acoustic energy incident to the target that is scattered backwards. This scattering cross section depends upon species *i* and the size of the target *j*, according to:

$$\sigma_{ij} = 10^{TS_j/10} = 10^{\{(a_i + b_i \log L_j)/10\}}$$

Here, L_j represents the size class, and the constants a_i and b_i are determined empirically for each species. For anchovy, we have used the following TS to length relationship:

$$TS_j = -72.6 + 20 \log L_j$$

The composition by size and species of each homogeneous stratum is obtained by averaging the composition of the individual hauls contained in the stratum, being the contribution of each haul weighted to the acoustic energy found in its vicinity (2 nm of diameter). Thus, given a homogeneous stratum with M hauls, if E_k is the mean acoustic energy in the vicinity of the haul *k*, w_i, the proportion of species *i* in the total capture of the stratum, is calculated as follows:

$$w_i = \sum_j w_{ij} = \sum_j \left(\frac{\sum_{k=1}^{M} \left(q_{ijk} \cdot E_k \Big/ Q_k \right)}{\sum_{k=1}^{M} E_k} \right).$$

Being q_{ijk} the quantity (in mass) of species *i* and length *j* in the haul *k*; and Q_k, the total quantity of any species and size in the haul *k*.

In order to distinguish their own contribution, anchovy juveniles and adults were separated and treated as different species. Thus, the proportion of anchovy in the hauls of each stratum (w_{ij}) was multiplied by a age–length key to separate the proportion of adults and juveniles. Then, separated w_i were obtained for each.

Inside each homogeneous stratum, we calculated a mean scattering cross section for each species, by means of the size distribution of such species obtained in the hauls of the stratum:

$$\langle \sigma_i \rangle = \frac{\sum_j w_{ij} \sigma_{ij}}{w_i}.$$

Let s_A be the calibration-corrected, echo-integrated energy by ESDU (0.1 nautical mile). The mean energy in each homogeneous stratum, $E_m = < s_A >$, is divided in terms of the size-species composition of the haul of the stratum. Thus, the energy for each species, E_i, is calculated as:

$$E_i = \frac{w_i \langle \sigma_i \rangle E_m}{\left(\sum_i w_i \langle \sigma_i \rangle \right)}$$

Here, the term inside the parentheses sums over all the species in the stratum. Finally, the number of individuals F_i of each species is calculated as:

$$F_i = H \cdot l \frac{E_i}{\langle \sigma_i \rangle}$$

Where *l* is the length of the transect or semi-transect under the influence of the stratum and *H* is the distance between transect (about 15 nm.). To convert the number of juveniles to biomass, the size–length ratio obtained in each stratum is applied to obtain the average weight of the juveniles in the stratum:

$$< W_i > = a \cdot < L_i >^b$$

Thus, the biomass is obtained by multiplying F_i times $< W_i >$

B.3.4.1.6. Commercial cpue

According to literature, cpue indices have been considered, as not reliable indicators of abundance for small pelagic fish (Ulltang, 1982; Csirke 1988; Pitcher 1995; Mackinson *et al.*, 1997). Current series of cpue available for the Spanish purse-seine are not considered of utility for the monitoring of the fishery (Uriarte *et al.*, 2008).

C. Stock assessment method

Model used

The assessment for the Bay of Biscay anchovy population is a Bayesian two-stage biomass-based model (BBM) (Ibaibarriaga *et al*., 2008), where the population dynamics are described in terms of biomass with two distinct age groups, recruits or fish aged 1 year, and fish that are 2 or more years old. The biomass decreases exponentially on time by a factor g accounting for intrinsic rates of growth (G) and natural mortality (M) which are assumed year- and age-invariant.

Two periods are distinguished within each year. The first begins on 1 January, when it is assumed that age incrementing occurs and age 1 recruits enter the exploitable population, and runs to the date when the monitoring research surveys (acoustics and DEPM) take place. The second period covers the rest of the year (from 15th May to 31st December). Catch is assumed to be taken instantaneously within each of these periods.

The observation equations consist on lognormally distributed spawning-stock biomass from the acoustics and DEPM surveys, where the biomass observed is proportional to the true population biomass by the catchability coefficient of each of the surveys, and the beta distributed age 1 biomass proportion from the acoustics and DEPM surveys, with mean given by the true age 1 biomass proportion in the population.

The model unknowns are the initial population biomass (in 1987), the recruitment each year, the catchability of the surveys and the variance related parameters of the observation equations. The model can be cast into a Bayesian state-space model framework where inference on the unknowns is done using Markov Chain Monte Carlo (MCMC).

Software used

The model is implemented in BUGS (www.mrc-bsu.cam.ac.uk/bugs/) and it is run from R (www.r-project.org) using the package R2WinBUGS.

Model options chosen

Catchability for the DEPM SSB is set to 1 because it is assumed to be an absolute indicator of Biomass and for consistency with the past practice in the assessment of this stock. Catchability of the acoustic SSB is estimated. DEPM and acoustic surveys are assumed to provide unbiased proportion of age 1 biomass estimates in the stock. The first set of priors as defined in Ibaibarriaga *et al*., 2008 is used. Each MCMC run has 150 000 draws, with a burn-in period of 50 000 (i.e. remove the first 50 000 draws to avoid dependence on the initial values) and keeping only 1 out of 10 draws (thinning) to diminish autocorrelation. Thus, the final chains have 10 000 values representing the joint posterior distribution of the parameters.

Input data types and characteristics

Type	Name	Year range	Age range	Variable from year to year. Yes/No
Caton	Catch in tonnes by periods	1987–2009	1 to 2+	Yes
Canum	Catch at age in numbers by periods	1987–2009	1 and 2+	Yes
Weca	Weight at age in the commercial catch by periods	1987–2009	1 to 2+	Yes
Mprop	Proportion of natural mortality before spawning	Not applicable		
Fprop	Proportion of fishing mortality before spawning	Not applicable		
Matprop	Proportion mature at age	Not applicable		
Natmor	Natural mortality M=1.2	1987–2009	1 to 2+	No
G	Intrinsic growth rate G= 0.52	1987–2009	1 to 2+	No

Tuning data

Type	Name	Year range	Age range
Tuning fleet 1	DEPM SSB spring series	1987–2009 (with gap in 1993)	
Tuning fleet 2	Acoustic SSB spring series	1989–2009 (with gaps)	
Tuning fleet 3	DEPM P1 (B1/SSB) spring series	1987–2009 (with gaps)	
Tuning fleet 4	Acoustic P1 (B1/SSB) spring series	1989–2009 (with gaps)	

Prior distributions of the parameters:

The current prior distributions (see table below) are described and justified in Ibaibarriaga *et al*., 2008 and ICES WGANC 2008.

Parameter	Prior 1	
	Hyper-parameters	Median (95% CI)
q_{surv}	$\mu_{q_{surv}} = 0$	1 (0.1, 16.0)
	$\psi_{q_{surv}} = 0.5$	
ψ_{surv}	$a_{\psi_{surv}} = 0.8$	10 (0.2, 65.1)
	$b_{\psi_{surv}} = 0.05$	
ξ_{surv}	$\mu_{\xi_{surv}} = 5$	5 (0.6, 9.4)
	$\psi_{\xi_{surv}} = 0.2$	
B_0	$\mu_{B_0} = 10.5$	36 316 (5 116, 257 806)
	$\psi_{B_0} = 1.0$	
μ_R	$\mu_{\mu_R} = 9.8$	9.8 (7.0, 12.6)
	$\psi_{\mu_R} = 0.5$	
ψ_R	$a_{\psi_R} = 4$	1.8 (0.5, 4. 4)
	$b_{\psi_R} = 2$	
g	$\mu_g = \log (0.7)$	0.7 (0.1, 5.0)
	$\psi_g = 1$	

The Benchmark Workshop recommended conducting some sensitivity analysis on the prior distributions. In particular, testing the effect of having more informative priors on the surveys' catchability and precision and on the g parameter. If this is done, any changes in the prior distributions of the parameters should be documented and justified in the ICES Anchovy Assessment Working Group Report (WGANSA).

D. Short-term projection

Model used

The Bayesian two-stage biomass-based model (Ibaibarriaga *et al*., 2008) used for the assessment of the stock is used to project the population one year forward from the current state and to analyse the probability of the population in the next year of being below the biological reference point B_{lim} (21 000 tonnes) under a recruitment scenario based on the past recruitment series and under alternative catch options for the second half of the current year and the first half of next year.

The predictive distribution of recruitment-at-age 1 (in mass) in January next year is defined as a mixture of the past series of posterior distributions of recruitments as follows:

$$R_{2008} = \sum_{y=1987}^{2007} w_y \; p(R_y | \cdot \,)$$

where $p(R_y \mid \cdot)$ denotes the posterior distribution of recruitment in year y and w_y are the weights of the mixture distribution, such that $\sum w_y = 1$. These weights can be based on information about incoming recruitment or on assumptions regarding different scenarios.

Software used

The projections are implemented in R (www.r-project.org)

Projection period

One year ahead from the spawning period (15 May) in the last assessment year.

Initial stock size

Posterior distribution of SSB in the last assessment year.

Maturity

NA

F and M before spawning

NA

Weight-at-age in the stock

NA

Weight-at-age in the catch

NA

Intrinsic growth rate (G)

Assumed constant same as in the assessment (G=0.52).

Natural mortality rate (M)

Assumed constant same as in the assessment (M=1.2).

Exploitation pattern

Alternative options for splitting catches by periods are tested.

Intermediate year assumptions

NA

Stock recruitment model used

No implicit S/R model is used. Recruitment is sampled from the posterior distributions of past series recruitments. Different recruitment scenarios are constructed by giving different weights to the past series recruitments.

Procedures used for splitting projected catches

NA

E. Medium-term projections

No medium-term projections are applied to this fishery for the provision of advice by ICES. Long-term projections (10 years ahead) were run by STECF in 2008 to set the basis of a management plan on anchovy to the EC, based on a Ricker stock recruitment relationship.

F. Long-term projections

No long-term projections are applied to this fishery for the provision of advice by ICES. Long-term projections (10 years ahead) were run by STECF in 2008 to set the basis of a management plan on anchovy to the EC, based on a Ricker stock recruitment relationship.

G. Biological reference points

A stock recruitment relationship is not explicitly used.

Current biological reference points for the Bay of Biscay anchovy were defined by ICES ACFM in October 2003 as follows:

	ICES considers that:	ICES proposes that:
Limits reference points	**B_{lim}** is 21,000 t, the lowest observed biomass in 2003 assessment.	B_{pa}= 33,000 t.
	There is no biological basis for defining F_{lim}.	F_{pa} be established between 1.0-1.2.
Target reference points		

Technical basis:

$B_{lim} = B_{loss} = 21{,}000$ t.	$B_{pa} = B_{loss} * 1.645$.
	F_{pa}= F for 50% spawning potential ratio, i.e., the F at which the SSB/R is half of what it would have been in the absence of fishing

H. Other issues

None.

I. References

Allain, G., Petitgas, P. and Lazure, P. 2001. The influence of mesoscale ocean processes on anchovy (*Engraulis encrasicolus*) recruitment in the Bay of Biscay estimated with a three-dimensional hydrodynamic model. Fisheries Oceanography, 10: 151–163.

Allain, G., Petitgas, P., Lazure, P. and Grellier, P. 2007. Biophysical modelling of larval drift, growth and survival for the prediction of anchovy recruitment in the Bay of Biscay (NE Atlantic). Fisheries Oceanography, 16(6), 489–505.

Borja, A. Uriarte, A., Egana, J., Motos, L. and Valencia, V. 1998. Relationships between anchovy (*Engraulis encrasicolus*) recruitment and environment in the Bay of Biscay (1967–1996). Fisheries Oceanography, 7(3–4), 375–380.

Borja, A. Fontán, A., Saez, J. and Valencia, V. 2008: Climate, oceanography, and recruitment: the case of the Bay of Biscay anchovy (*Engraulis encrasicolus*). Fish. Oceanogr. 17:6, 477–493, 2008.

Cochran, W.G. 1977. Sampling techniques. John Wiley and Sons (ed.) 428 pp, N.Y.

Csirke J. 1988. Small shoaling pelagic fish stocks. In Fish Population Dynamics (Second Edition). Edited by J.A. Gulland. John Wiley and Sons Ltd.

Duhamel, E., Biseau, A., Massé, J. and Villalobos, H. 2004. The French fishery. Working document to the ICES Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy (WGMHSA), 7–16 September 2004, ICES Headquarters, ICES CM 2005/ACFM:08.

Hunter, J. R., *et al*. Batch fecundity in multiple spawning fishes, R. Lasker (ed.), p. 67–77. US Dep. Commer., NOAA Tech. Rep. NMFS 36.

Huret, M., and Petitgas, P. 2007. Anchovy recruitment forecasting and environment. Working document to ICES WGMHMSA 2007.

Ibaibarriaga, L., Fernández, C., Uriarte, A., and Roel, B. A. 2008. A two-stage biomass dynamic model for Bay of Biscay anchovy: a Bayesian approach. – ICES Journal of Marine Science, 65: 191–205.

ICES. 2007. Report of the Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy (WGMHSA), 4–13 September 2007, ICES Headquarters. ICES CM 2007/ACFM:31. 712 pp.

ICES. 2008a. Report of the Working Group on Anchovy (WGANC), 13–16 June 2008, ICES Headquarters, Copenhagen. ICES CM 2008 ACOM:04. 226 pp.

ICES. 2008b. Report of the ICES Advisory Committee, 2008. ICES Advice, 2008. Book 7, 122 pp.

Junquera, S. 1986. Pêche de l'anchois (*Engraulis encrasicholus*) dans le golfe de Gascogne et sur le littoral atlantique de Galice depuis 1920. Variations quantitatives. Rev. Trav. Inst. Pêches Marit., 483–4: 133–142.

Junquera, S. and Perez-Gandaras, G. 1993. Population diversity in Bay of Biscay anchovy (*Engraulis engrasicholus*, L. 1758) as revealed by multivariate analysis of morphometric and meristic characters. ICES J. mar. Sci., 50:383:396.

Lasker, R. 1985. An Egg Production Method for Estimating Spawning Biomass of pelagic fish: Application to the Northern Anchovy, *Engraulis Mordax*. NOAA Technical report NMFS 36:100p.

Mackinson, S., Sumaila, U. R. and T. J. Pitcher. 1997. Bioeconomics and catchability: fish and fishers behaviour during stock collapse. Fisheries Research 31: 11–17.

Massé, J. 1988. Utilisation de l'echo-integration en recherche halieutique (analyse des campagnes effectuées dans le Golfe de Gascogne de 1983 à 1987). Direction des Ressources Vivantes, IFREMER.

Massé J. 1994. Acoustic Surveys DAAG 90, DAAG 91, DAAG 92. Annex to: Orestes (editor): Improvement of stock assessment by direct methods, its application to the anchovy (*Engraulis encrasicholus*) in the Bay of Biscay. Report of the EC FAR Project (1991–1993) (Contract No. MA 2495 EF), 90 pp. + annexes.

Massé, J. 1996. "Acoustics observation in the Bay of Biscay: schooling, vertical distribution, species assemblages and behaviour." Scientia Marina 60 (Suppl. 2): 227–234.

Moser, H.G. and E. H. Ahlstrom, 1985. Staging anchovy eggs. In: "An egg production method for estimating spawning biomass of pelagic fish: Application to the northern anchovy, *Engraulis mordax*, R. Lasker (ed.), p. 7–16. US Dep. Commer., NOAA Tech. Rep. NMFS 36.

Motos L., A. Uriarte, P. Prouzet, M. Santos, P. Alvarez and Y. Sagarminaga. 2005. Assessing the Bay of Biscay anchovy population by DEPM: a review 1989–2001. In Castro, LR, P. Fréon , C.D.

Petitgas, P., Massé, J., Beillois, P., Lebarbier, E. and Le Cann, A. 2003. Sampling variance of species identification in fisheries acoustic surveys based on automated procedures associating acoustic images and trawl hauls ICES Journal of Marine Science 60: 437–445 (1).

Pitcher, T. J. 1995. The impact of pelagic fish behaviour on fisheries. Sci. Mar., 59 (3–4): 295–306.

Prouzet, P. and Metuzals, K. 1994. Phenotypic and genetic studies on the Bay of Biscay anchovy. In Cendrero (Eds) 1994. Final report of the EC FAR project (1991–1993).

Santiago, J. and A. Sanz, 1992. Egg production estimates of the Bay of Biscay anchovy, *Engraulis encrasicolus* (L.), spawning stock in 1987 and 1988 (Estimaciones de la producción de huevos de l stock reproductor de anchoa, *Engraulis encrasicolus* (L.), del Golfo de Vizcaya en 1987 y 1988). Bol. Inst. Esp. Oceanogr. 8 (1):225–230.

Sanz, N., García-Marín, J-L., Viñas, J., Roldán, M., and Pla, C. 2008. Spawning groups of European anchovy: population structure and management implications. – ICES Journal of Marine Science, 65.

Sanz, A. and A. Uriarte. 1989. Reproductive cycle and batch fecundity of the Bay of Biscay anchovy (*Engraulis encrasicholus* L.) in 1987. CalCOFI Rep., vol. 30: 127–135.

Stauffer, G. and S. J. Picquelle. 1980. Estimates of the 1980spawning biomass of the of the central subpopulation of northern anchovy. Natl. Mar. Fish. Serv., NOAA. Southw. Fish. Cent. Admin. Rep. LJ-80–09, 41 p.

Picquelle, S. J. and G. Stauffer. 1985. Parameter estimation for an egg production method of anchovy biomass assessment. In R. Lasker (editor), An egg production method for estimating spawning biomass of pelagic fish: Application to the northern anchovy, *Engraulis mordax*, p. 7-16. US Dep. Commer., NOAA Tech. Rep. NMFS36.

STECF-SGRST. 2008. Report of the Meeting to inform the Commission on a long-term management plan for the stock of anchovy in the Bay of Biscay (ICES Subarea VIII). Held in Hamburg, 14–18 April 2008.

STECF/SGBRE-08–01: Working Group Report on the long-term management of Bay of Biscay anchovy. San Sebastian, 2–6 June.

Seber, G.A.F. 1982. Estimation of animal abundance and related parameters. Macmillan, New York.

Somarakis, S., Palomera, I., Garcia, A., Quintanilla, L., Koutsikopoulos, C. Uriarte, A. and L. Motos. 2004. Daily egg production of anchovy in European waters. ICES Journal of Marine Science, 61: 944–958.

Ulltang, O. 1980. Factors affecting the reaction of pelagic fish stocks to exploitation and requiring a new approach to assessment and management, Rapp. Procès-Verb. Réun. Cons. Int. Explor. Mer 177. 489–504.

Uriarte, A. 2005: Assessment of the Bay of Biscay anchovy by means of a seasonal separable VPA. Working Document to the ICES Working Group on the assessment of mackerel, horse mackerel, sardine and anchovy, held in Vigo from 06 to 15 September 2005.

Uriarte, A., Prellezo, R., Punzón, A., Aranda, M. and Villamor, B. 2008. The Spanish fishery on anchovy in the Bay of Biscay: Analysis of the relationship between fishing Capacity, Effort and mortality. ICES CM 2008/I:18.

Uriarte A. Prouzet, P. and B. Villamor. 1996. Bay of Biscay and Ibero Atlantic anchovy populations and their fisheries. Sci. Mar. 60 (Supl.2): 237–255.

Uriarte A (Coordinator), M. Blanco, E. Duhamel, P. Grellier, I. Rico, B. Villamor. 2006: 2005. Anchovy otolith exchange programme from subarea VIII: Working Document to the 2006 ICES Planning Group on Commercial Catch, Discards and Biological Sampling (PGCCDBS) 24 February 2006.

Uriarte, A. C. Dueñas, E. Duhamel, P. Grellier, I. Rico, B. Villamor. 2007: 2006 Anchovy Otolith Workshop. Working Document to the 2007 ICES Planning Group on Commercial Catch, Discards and Biological Sampling (PGCCDBS) (5–9 March).

Vermard, Y., Marchal, P., Mahevas, S. and Thebaud, O. 2008. A dynamic model of the Bay of Biscay pelagic fleet simulating fishing trip choice: the response to the closure of the European anchovy (*Engraulis encrasicolus*) fishery in 2005. Can. J. Fish. Aquat. Sci. 65: 2444–2453.

Villamor B., Aranda M., Punzón A., Uriarte A., Báez J. C. 2008. The Anchovy fishery in the Bay of Biscay I: Description and Analysis of the Spanish Fleet (2000–2005). ICES CM 2008/ I:30 (Theme session I).

6 Sprat in Subarea IV (North Sea)

6.1 Current stock status and assessment issues

The WKSHORT believes that the creation of an acceptable stock assessment is not possible at the present time. Current analyses of the available data do not provide adequate information for an assessment.

The longest and best time-series of information, the International Bottom Trawl Surveys (IBTS) in the first and third quarter, are plagued by large, infrequent hauls that dominate the index values: in some years, the largest haul can comprise up to 85% of the index. As a result, the confidence intervals associated with these indices are extremely broad, rending them unusable as indicators of stock status. The herring acoustic survey (HERAS) provides acoustic estimates of the abundance of sprat in the North Sea. However, this time-series is very short (five years) and it is therefore not currently possible to assess its suitability as an indicator of stock status: more data points are required.

New approaches to the analysis of existing dataseries were suggested during the Benchmark Workshop which could provide interesting clues as to the status of North Sea sprat, and possibly future assessments of the stock. Most of the suggestions fall into the category of exploratory data analysis, where both the resources required and expected benefits are uncertain.

It is the opinion of the WKSHORT participants that previously used assessment methods are inappropriate. For example, from 2001–2008 a catch prediction approach was adopted that utilized a regression of historical trawl survey index vs. sprat catch to develop a quota for an upcoming year given a current trawl value. There are a minimum of two fatal flaws to this approach. First, confidence intervals around the trawl survey are tremendously wide as a consequence of the occasional occurrence of large catches of sprat, rendering point estimates calculated in their current form virtually useless. Second, the North Sea sprat fishery is an opportunistic fishery, determined more often by the abundance of other species than sprat abundance.

6.2 Compilation of available data

6.2.1 Commercial catch

Annual sprat landings are provided by each country and are available from 1967 to 2008 (ICES HAWG 1977: Table 6.1; ICES IFWG 1988: Table 7.1.1; ICES HAWG 1981: Table 8.1; ICES HAWG 1993: Table 8.1.3; ICES HAWG 2000: Table 8.1.1; ICES HAWG 2009: Table 8.1.1).

The majority of the sprat landings are taken in the Danish industrial small-meshed trawl fishery. The Norwegian sprat fishery is mainly carried out by purse-seiners. Both landings are used for reduction to fishmeal and fishoil. In the last decade, also the UK occasionally lands small amounts of sprat.

The commercial catches are sampled for biological parameters. In the most recent years Denmark, Norway and Scotland have sampled their sprat catches. The sampling intensity for biological samples, i.e. age and weight-at-age is mainly performed following the EU regulation 1639/2001, requiring 1 sample per 2000 tonnes. The country landing most of the catches (Denmark) requires 1 sample per 1000 tonnes landed (www.fvd.fm.dk).

There exists no information about discards and unallocated catches, but it is not expected to be a problem for this fishery.

6.2.1.1 Evaluation of the quality of the catch data

As a consequence of large but unknown bycatches of juvenile North Sea herring in the industrial sprat fisheries prior to 1996 (Figure 6.1.1), sprat landings are only considered reliable from 1996 onwards. The reduction in bycatches of juvenile herring in 1996 coincides with the introduction of a bycatch limit on herring in the industrial fisheries, and improvements in catch-sampling.

6.2.2 Biological Data

Sprat in the North Sea has a prolonged spawning season ranging from spring to the late autumn, and is triggered by the water temperature (Alheit *et al.*, 1987; Alshulth 1988a; Wahl and Alheit 1988). Sprat is a batch spawner, producing up to 10 batches in one spawning season and 100–400 eggs per gramme of body weight (Alheit, 1987; George, 1987). The majority of the spawning sprat are 2 year olds, although spawning at age 1 can also occur (Bailey, 1980).

Disagreements in the age reading in North Sea sprat have been reported (*e.g*. Torstensen *et al*., 2004). The problems arise as a consequence of interpretation of winter rings. False winter rings can be set in periods of bad feeding conditions/starvation and as a consequence of rapid changes in temperature (E. Torstensen, personal communication 2009). False winter rings also occur in other species and areas, e.g. Baltic sprat (Kornilovs (edi.) 2006), herring (ICES WKARGH 2008) and sandeel (Clausen *et al*., 2006). Furthermore, the reading of the first winter ring can be difficult, as sprat can spawn until late autumn and larvae from these late spawning will likely not set down a winter ring during their first winter (Torstensen *et al*., 2004). The absence of such rings can lead to errors in age determination, as these individuals cannot be distinguished from the individuals born the following year. Age readings in North Sea sprat were estimated to have a high coefficient of variance (CV) of 28% (Torstensen *et al*., 2004).

Mean weight-at-age in the North Sea sprat is variable over time (ICES HAWG 2009). This may be ascribed as a consequence of both the aging problems previously described, and also the prolonged spawning period, by which the individuals can have very different birthdates. The mean weight-at-age in the catches is for age 1 is approximately 4 g, at age 2 app. 10 g, at age 3 app. 11 g, and at age 4+ app. 14 g (ICES HAWG 2009).

6.2.3 Survey Data

Three surveys cover this stock. Two International Bottom Trawl Survey (IBTS) cover the stock in the first and third quarters of the year. Additionally, the herring acoustic survey covers the same area during July. Here we examine the appropriateness and suitability of these surveys for use in the assessment of the North Sea sprat stock.

6.2.3.1 International Bottom Trawl Surveys (IBTS)

Background

The North-Sea International Bottom Trawl Surveys started as a coordinated international survey in the mid-1960s as a survey directed towards juvenile herring. The gear used was standardized in 1977 to use the GOV trawl, but took time to be phased in. By 1983 all participating nations were using this gear, and the index can be considered consistent from this point onwards. A third-quarter North Sea IBTS survey using the same methodology was started in 1991 and can be considered consistent from its initiation. IBTS Surveys were also performed in the North Sea in the second and fourth quarters in the period 1991–1996, but are not considered further here (ICES 2006). More details on the survey are available from the manual (ICES 2004).

Suitability

The appropriateness of the IBTS survey for use as an estimate of the abundance of North Sea sprat was examined in a working document (Jansen *et al.*, 2009, WD #6.1). Acoustic data collected during trawls performed as part of the IBTS were analysed, with focus on the vertical distribution. The relationship between the amount of sprat available in the water column (from acoustics) and the amount of sprat captured by the gear was found to be weak and highly variable in nature. The proportion of sprat in the water column that were in the bottom five metres was found to range widely between 0 and 100%, and also found to be a function of the time of day. The work therefore suggests that the IBTS survey, as it exists, may not be appropriate to use with sprat in the North Sea. However, further investigation, including the addition of further data points and comparison with results from other species (*e.g.* herring) are required before firm conclusions can be drawn.

Internal consistency

Internal consistency analysis (Payne *et al.*, 2009 and references therein) was used to examine the ability of the IBTS survey to track the abundance of individual cohorts. This method involves plotting the log-abundance estimated by the survey at one age against the log-abundance of the same cohort in the following year: in cases where the total mortality is constant and the relative survey noise is low, this relationship should be linear. However, deviations from linearity may arise as a consequence of either high noise levels in the survey or variations in the total mortality experienced by the stock. The test is therefore asymmetric, in that a linear relationship is a strongly positive result, while the absence of a relationship does not automatically mean that the survey is of poor quality. Examination of the internal consistency can therefore be used as a measure (albeit biased) of the survey quality.

We find that the relationship between the abundance of successive ages in a cohort from the first quarter (Figure 6.3.3.1) and third quarter (Figure 6.3.3.2) surveys is extremely poor, and is dominated by noise. This noise may arise as a consequence of either the nature of the survey (e.g. survey design, variability of catchability) or variations in total mortality. In the absence of information regarding either fishing mortality (e.g. from a stock assessment) or natural mortality (e.g. from a multispecies model), it is not possible to separate these two sources of variability.

Confidence intervals

Distribution of the IBTS indices are available from the ICES DATRAS database, following a bootstrapping procedure agreed upon in 2006 (ICES 2006). These data were analysed to extract key values characterizing the distribution, including the confidence intervals for both IBTS Q1 (Figure 6.3.3.3) and Q3. Generally, the confidence intervals for the indices were found to be extremely broad. The median upper confidence limit is 250% greater than the value of the index estimated (although in some cases this can be as much as 4600% greater) and the median lower confidence limit is 40% less than the estimated index. The uncertainties are therefore much larger than the estimated dynamics of the stock and it is thus not possible to say, statistically, that the index value in one year is statistically different from another.

Composition of the index

Catches of North Sea sprat in hauls in the IBTS survey can occasionally be extremely large; this phenomenon has previously been suggested as being important to the dynamics and uncertainty of IBTS survey indices (ICES HAWG 2007, ICES HAWG 2009). In order to examine this phenomenon more closely, the importance of each haul to the index was assessed by calculating the individual contribution of each haul to the total. These hauls were then ranked according to size and aggregated to produce an estimate of the cumulative contribution ranked by sized: in this manner, it is therefore possible to assess, for example, the proportional contribution of the largest 20 hauls in a given year. For all years in the both the IBTS Q1 (Figure 6.3.3.4) and Q3 (Figure 6.3.3.5), the 10 largest hauls contribute at least 35% of the survey index, and in some cases up to 85% of the index. The IBTS Q3 index appears to have more severe problems with large hauls than the Q1 index: in every year, the five largest hauls make up more than 50% of the index.

Alternative analysis methods

The method used by the ICES DATRAS database to calculate the IBTS indices is relatively simplistic, essentially comprising a set of stratified means (i.e. the mean cpue per statistical rectangle is averaged over the entire North Sea). As an attempt to resolve problems caused by the presence of large hauls in the calculation of the index, a Log-Gaussian Cox Process (LGCP) was fitted to the individual haul data (Kristensen *et al*., 2006; Kristensen, 2009a; Kristensen and Lewy, 2009). The LGCP model is a statistical model that can be used to account for the statistical nature of the catch process, including correlations between size classes, spatial correlation and between years. The model was fitted in a simplified form, where only spatial correlations were included. Total cpue of sprat, cpue by age and cpue by length class were all used as classification schemes and each fitted individually using the model.

Unfortunately, the LGCP model failed to fit the IBTS survey data adequately. Goodness of fit tests on the fitted model demonstrated that a number of key assumptions in the model were frequently violated. Furthermore, the confidence intervals on the estimated abundances were extremely broad, in some cases spanning more than six orders of magnitude. It was therefore concluded that the model, as fitted, was in appropriate to the dataset.

It is currently unclear as to why the LGCP model fails to fit the IBTS sprat data. A number of candidate explanations have been considered, including the large number of zero hauls and the extreme "boom-bust" nature of the catches. It is currently unclear whether this modelling framework is capable of dealing with the nature of the sprat catches in the IBTS survey: the ultimate appropriateness of this method should be considered carefully before further work is performed.

Conclusions

The IBTS Q1 and Q3 surveys are the best time-series of data available for use in characterizing the abundance of sprat in the North Sea, covering the years from 1984 and 1991 onwards respectively: for comparison, the time-series of catches begins in 1996 and the acoustic survey (see below) in 2004. However, the survey is greatly impacted by the presence of extremely large individual hauls that can make up 85% or more of the index in some years. The problem is compounded by the manner in which the ICES DATRAS database calculates the indices; the use of simple arithmetic means here does not account for the extremely high variability of sprat catches in the IBTS survey and propagates these problems through to the index value. The extremely broad confidence intervals and the lack of internal consistency can also be understood as consequences of this problem. Variability of the catchability of sprat in the IBTS's GOV gear caused by the time of day and the pelagic nature of sprat may contribute to this problem to a degree but seem unlikely to explain the order-of-magnitude variability observed. Instead, the highly schooling nature of sprat is likely to be the most important underlying cause: if the gear encounters and captures a high-density school of sprat, an extremely large haul could be produced.

Given the potential importance of the IBTS indices for the assessment of this stock, further investigations are warranted. The current analysis method is extremely simplistic and appears to be the main source of the problem. Future investigations should focus on attempting to analyse this large and valuable source of information in a manner that can account for both the large number of zero hauls and also the extremely large individual hauls. Qualitative indicators, such as distribution area, presence/absence metrics, and the frequency of large hauls may also be of use in an advice context.

6.2.3.2 Herring Acoustic Survey (HERAS)

Background

The Herring Acoustic Survey is a summer acoustic survey that has been performed by an international consortium since the 1980s. Sprat has been reported as a separate species in this survey from 1996 onwards. However, as the survey is targeted towards herring, which are generally in the northern half of the North Sea during summer, coverage in the southern-half has received less attention. The area covered was expanded progressively over time, and by 2004 covered the majority of the stock, reaching 52°N (the eastern entrance to the English Channel) and all of the way into the German Bight (ICES PGHERS 2005). The coverage of this survey has remained relatively unchanged since 2004 (*e.g.* ICES PGIPS 2009) and we consider the survey from this point and onwards.

Suitability

In theory, the herring acoustic survey should be better suited for the estimation of sprat abundance than the bottom-trawl IBTS survey, given that it integrates over the entire water column and is thus less susceptible to changes in vertical distribution and the presence of large schools.

However, there are a number of difficulties with the acoustic estimation of sprat that must be considered. Each survey report since 2004 has noted that the survey does not appear to reach the southern boundary of the stock, with there being significant concentrations of sprat at or close to this limit. Failing to reach the southern boundary line would lead to an underestimation of the stock size and may increase the interannual variability of the estimate. Similar observations have also been obtained from the IBTS survey, suggesting that the population may continue into the English Channel and Subdivision VIId (ICES HAWG 2009; see also Section 6.3).

The acoustic signatures of herring and sprat are also very similar and make the separation of these two species challenging. In the 2005 survey, an area containing large amounts of sprat was covered by two of the vessels, allowing a direct comparison of the estimated abundances. Unfortunately, the results varied widely, suggesting that the precision of the total abundance estimate may be poor (ICES PGHERS 2006).

Finally, the time-series of acoustic estimates is short, and may not be of sufficient length for use in a stock assessment.

Internal consistency

The internal consistency analysis employed above was also employed for the HERAS estimates of sprat abundance (Figure 6.3.3.6). The coefficients of determination for the relationship between the abundance-at-age for each cohort were appreciably better than those seen for the IBTS surveys, and are comparable with those used in other assessments (*e.g.* western Baltic spring-spawning herring (Payne *et al.*, 2009)). However, the length of the time-series is also extremely short (four pairs of observations), and there is therefore insufficient information to draw meaningful conclusions. Further data points in the time-series would be beneficial to understanding the suitability of this survey.

Confidence intervals

There are currently no confidence intervals available for the estimated acoustic abundances. Future versions of the FISHFRAME database used to estimate the abundances from the raw acoustic data are intended to include the estimation of uncertainties (T. Jansen, personal communication 2009).

Conclusions

The herring acoustic survey demonstrates potential as an estimate of the abundance of sprat in the North Sea. However, the current time-series is too short for use, and further data points are required before its potential can be fully assessed. Furthermore, problems regarding the acoustic identification of sprat and herring, and the southern boundary of the stock may severely limit the applicability of this survey: resolving these issues should be considered a high priority.

6.2.4 Industry/stakeholder data input

No data were available from stakeholders.

6.3 Stock identity and migration issues

Sprat in the North Sea is treated as a single management unit. However, questions have recently been raised about the geographic distribution of this stock and its interaction with neighbouring stocks: in particular, large abundances have been observed close to the boundaries of the stock (ICES HAWG 2009; Figure 6.3.1). The apparent overlap between North Sea sprat and English Channel sprat is very strong, whereas the overlap between North Sea sprat and Kattegat sprat is not as strong and varies between years (see ICES HAWG 2009 for more details).

A detailed genetic study has been performed to analyse the population structure of sprat over large ranges, from scales of seas to regions (Limborg *et al.*, 2009). The study was performed with individuals from the Baltic Sea, Danish waters, Kattegat, North Sea, Celtic Sea and Adriatic Sea (Figure 6.3.2). The analysis partitioned the samples into groups based upon their genetic similarity (Figure 6.3.3). The Adriatic Sea population exhibited a large divergence from all other samples. The samples from the North Sea, Celtic Sea and Kattegat were separated from the Baltic Sea samples, with the Belt Sea sample in between. The authors concluded that there exists a barrier to gene flow from the North Sea to the Baltic Sea, with the Belt Sea being a transition zone. This analysis does not support the separation of sprat into three stocks that is currently employed by ICES (i.e. Subdivision VIId (English Channel), Subdivision IIIa (Skagerrak/Kattegat) and Division IV (North Sea)). However, it is also important to note that this work is based on neutral markers, which are relatively insensitive. Further research on this issue is required.

6.4 Spatial changes in the fishery or stock distribution

The 1986 Workshop on Sprat Biology (ICES 1990) examined the distribution of sprat in the North Sea, and reported significant changes between the 1960s and 1980s. Specifically, the relative abundance of sprat off the east-coast of Great Britain decreased dramatically, while that of sprat in the German bight increased. The changes were attributed to overfishing in this area. These changes appear to have persisted until modern times, where the stock is dominated by the population in the German bight, and the concentration off the coast of Great Britain is relatively minor.

No data are available with regards to spatial changes in the distribution of the fishery or the stock in more recent times.

6.5 Environmental drivers of stock dynamics

No new information is available regarding the role of the environment in the dynamics of the North Sea sprat stock.

6.6 Role of multispecies interactions

Sprat is a prey species for piscivorous species in the North Sea. Its role in the ecosystem has been evaluated in the 1981 and 1991 stomach sampling programmes (ICES 1989, ICES 1997). Predation was strongest from whiting and mackerel (ICES SGMSNS 2006, ICES 1997). Predation from cod on sprat have been suggested to increase after the last sampling campaign in 1991 as sandeel and Norway pout stocks have decreased (ICES 1997).

Attempts have previously been made to include sprat in the MSVPA in the North Sea (ICES SGMSNS 2005). Recently, as no single species assessment on North Sea sprat has been performed, sprat was not included explicitly in the MSVPA. Sprat was therefore treated in the resent model as 'other food', and is thus included in the model indirectly as a prey organism. Unfortunately this method does not allow for an estimate on the predation mortality on sprat (ICES WGSAM 2008). Historically, MSVPA runs have included sprat by which it was found that the predation mortality on the species exceeds the fishing mortality (ICES SGMSNS 2005).

6.7 Impacts of fishing on the ecosystem

Bycatches

The bycatches in the Danish industrial small-meshed trawl fishery for sprat (1998–2008) have been estimated from samples of the commercial catches (ICES HAWG 2009: Table 8.2.1). The major bycatches are herring (4.2–11.1% in weight), horse mackerel (0.0–1.6%), whiting (0.2–1.5%), haddock (0.0–0.1%), mackerel (0.2–2.2%), cod (<0.0%), sandeel (0.0–10.0%) and other (0.3–2.4%). Although these catches are relatively small by weight, they are often juveniles, and therefore can represent a significant number of individuals.

There exists no information about the bycatches of the other fleets.

Historically, the bycatch of juvenile herring in the industrial sprat fisheries has been problematically high (Figure 6.1.1). To reduce this bycatch, an area closed to the sprat fishery (the "sprat box") was established off the west coast of Denmark (from Vadehavet to Hanstholm) in October 1984 (Hoffman *et al.*, 2004). It was estimated that about 90% of the bycatches of juvenile herring in the industrial fisheries was taken within this box, and the intention of the sprat box was thus to reduce this juvenile herring bycatch.

Despite the establishment of this sprat box, the juvenile herring bycatches increased in the early 1990s, partly because of larger incoming year classes having a wider distribution (Hoffman *et al*., 2004). It was concluded that there was no clear connection between the sprat box and the decrease in herring bycatches in the period 1984–1996 (Hoffman *et al*., 2004). The sprat box is still in operation (Fiskeridirektoratet, 2007).

After 1996, the bycatch mortality of juvenile herring was reduced (Figure 6.1.1; ICES HAWG 2009). This coincided with the introduction of a bycatch limit on herring in the industrial fisheries and improvements in the catch sampling.

Top predators

Many predators in the North Sea feed extensively on sprat, including predatory fish, marine mammals and seabirds. Sprat can be very important for breeding seabirds in southern areas of the North Sea (Durinck *et al*., 1991; Wilson *et al*., 2004). Estimates from 1985 have demonstrated that the total seabird consumption in the North Sea could be on the same level as the fisheries (Hunt and Furness (edi.) 1996). In winter, when sandeel are not available to most seabirds (because they are buried in the sand) many of the seabirds that overwinter in the North Sea take sprat as part of their diet. However, it is uncertain whether sprat abundance in the North Sea will affect seabird breeding success or overwinter survival.

6.8 Stock assessment methods

Two different stock assessment methods have been used in an exploratory manner in the past. From 1996 to 2002, a Schaefer biomass-production model was used (*e.g.* ICES HAWG 2002). Given the large uncertainties in the quality of catch information prior to 1996 (see above), such a model is not thought to be appropriate.

The biomass model was replaced in 2003 with the Catch-Survey Analysis model (CSA; Mesnil, 2003) a two-stage delay difference model tuned using the IBTS indices. However, this model has consistently failed to produce satisfactory results, most probably as a consequence of the poor quality of the IBTS indices. This method was therefore abandoned for the 2009 assessment (ICES HAWG 2009).

Length based assessment has been attempted (Skagen 2009, WD #6.2), hoping to avoid the problem of age-reading and prolonged recruitment season. The model used was an age–length structured forward projection model, from which survey and catch data were derived. The model was parameterized to give the best fit (in terms of log likelihood) of derived data to the actual observations. Variability of length-at-age was obtained by considering a large number of 'super-individuals' that were given individual, random growth parameters. So far, the model has only been fitted to the 1st quarter IBTS survey indices at length.

It was not possible to obtain firm estimates of model parameters unless such strong assumptions were included that the results essentially were reflecting the assumptions only. One reason for the failure of this approach clearly is the lack of consistent information in the data. This problem is highlighted above, and persists when the data are disaggregated by length rather than weight. Furthermore, the amount of information in length distributions is smaller than in age distributions, because the length distributions of survey indices will be driven both by mortality, growth rate and catchability at length.

There is currently no assessment for this stock.

6.9 Stock assessment

No formal assessment of this stock was attempted. The main sources of data (i.e. the IBTS surveys) may not be appropriate and suffer from extremely wide confidence intervals. The acoustic survey time-series is currently not of sufficient length (five-years) to enable its application in an assessment context. The catches taken from the fishery are driven by the availability and price of other industrial species and therefore are not representative of the stock abundance. There is therefore no basis for performing a formal assessment of this stock.

6.10 Recruitment estimation

There is no basis for estimating or forecasting recruitment.

6.11 Short-term forecasts

Previously, short-term forecasts of the catch in the current year have been made based on a correlation between the value of the IBTS index in a year and the catches in that year (*e.g*. ICES HAWG 1998; ICES HAWG 2008). However, given the extremely broad uncertainty in the IBTS, and the opportunistic nature of the sprat fishery, such an approach is no longer considered valid and was abandoned in 2009 (ICES HAWG 2009).

There is therefore currently no basis for performing short-term or medium-term forecasts.

6.12 Biological reference points

There is no basis for defining biological reference points.

6.13 Modifications from previous stock annex

Major modifications to the content of the "General" and "Data" sections of the stock annex were made during the course of this Workshop, to reflect the improved understanding of this stock.

6.14 Recommendations for future work

The following recommendations were made during the WKSHORT meeting:

There are currently no data sources that can be considered as reliable indicators of stock status. WKSHORT therefore recommends that the North Sea sprat stock is managed as a low data stock until sufficiently reliable information is available.

WKSHORT recommends that the coverage of North Sea sprat by the HERAS survey is continued. The Working Group believes that this survey offers the best potential source of information regarding the status of the stock; continuation of this time-series is therefore highly desirable.

The current method used in the ICES DATRAS database to produce the IBTS indices of abundance is inappropriate to the North Sea stock. This survey, however, represents the best currently available data source. As a starting point for future work, the Working Group recommends analysis of the IBTS survey data in a qualitative manner, including the examination of presence and absence measures and area occupied. Further quantitative analyses should focus on accounting for the statistical nature of the IBTS catches, in particular for both the large number of zeros and also large individual hauls.

Recent work by this and other groups has identified a possible mismatch between the stock definition applied in the management of North Sea sprat and the realized distribution of sprat. Further investigation, including the application of genetic techniques, is required to understand the significance of this issue and the relationship between sprat in the North Sea, the English Channel, Skagerrak and Kattegat.

The ability of acoustic surveys to separate herring and sprat is currently unclear. Inter-comparisons between vessels have previously raised questions regarding the consistent estimation of sprat abundance (e.g. ICES PGHERS 2006). WKSHORT asks that the Planning Group for International Pelagic Surveys (PGIPS) assess the quality of the HERAS sprat indices, including the calculation of confidence intervals around the estimated abundance.

WKSHORT asks WGSAM to attempt to generate an estimate of predation on sprat in the North Sea based on stomach content data and predator food requirements.

WKSHORT asks that the ICES Working Group on Seabird Ecology (WGSE) evaluate the contribution of sprat in the diet of seabirds and, if possible, present time-series that might indicate changes in North Sea sprat abundance.

WKSHORT is unclear as to whether the age-reading of sprat otoliths can be achieved with sufficient accuracy and precision for generation of age-structured data. Given that there has not been an age-reading comparison for this stock since 2004, the Working Group therefore recommends the formation of a workshop with the aims of reviewing past work, investigating new techniques for age reading and answering this important and unresolved question.

The Working Group finds that knowledge is weak regarding the vertical migration behaviour of the stock. This phenomenon has important consequences for the catchability of the IBTS survey and the resulting indices. More scientific investigations on this issue are therefore warranted.

6.15 Industry-supplied data

No data were supplied by stakeholders.

6.16 References

Alheit, J. 1987. Variation of batch fecundity of sprat, *Sprattus sprattus*, during spawning season. ICES CM 1987/H:44.

Alheit, J., Wahl, E., and Cibangir, B. 1987. Distribution, abundance, development rates, production and mortality of sprat eggs. ICES CM 1987/H:45.

Alshult, S. 1988. Seasonal variations in length–frequency and birthdate distribution of juvenile sprat (*Sprattus sprattus*). ICES CM 1988/H:44.

Bailey, R.S. 1980. Problems in the management of short-lived pelagic fish as exemplified by North Sea sprat. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer 177: 477–488.

Clausen L.W., Davis C.G. and Hansen S. 2006. Report of the sandeel otolith ageing workshop.

Durinck J., Skov H. and Danielsen F. 1991. The winter food of guillemots Uria-aalge in the Skagerrak. Dansk ornitologisk forenings tidsskrift 85: 145–150.

Fiskeridirektoratet 2007. Fiskeridirektoratet. Årsrapport 2006. ISBN: 87–89443–23–3.

George, M.R. 1987. Ovarian maturation cycle of sprat, *Sprattus sprattus*. ICES CM 1987/H:47.

Hoffman E, Dolmer P, Nordberg E, Blanner P. 2004. Beskyttede havområder i Norden. TemaNord 2004: 543.

Hunt G.L. and Furness R.W. 1996. Seabird/fish interactions, with particular reference to seabirds in the North Sea. ICES cooperative research report no. 216.

ICES. 1989. Database report of the stomach sampling project 1981. Cooperative research report no. 164.

ICES. 1990. Report of the Sprat Biology Workshop. Cooperative research report no. 169.

ICES. 1997. Database report of the stomach sampling project 1991. ICES cooperative research report no. 219.

ICES. 2004. Manual for the international bottom-trawl surveys. Revision VII.

ICES. 2006. Report of the Workshop on Implementation in DATRAS of Confidence Limits Estimation of, 10–12 May 2006, ICES Headquarters, Copenhagen. . 39 pp.

ICES HAWG. 1977. Report of the Herring Assessment Working Group for the Area South of 62º N. Charlottenlund, 9–18 March, 1977. ICES CM 1977/H:3.

ICES HAWG. 1981. Report of the Herring Assessment Working Group for the Area South of 62º N. ICES Headquarters, 27 April–5 May 1981. ICES CM 1981/H:8.

ICES HAWG. 1993. Report of the Herring Assessment Working Group for the Area South of 62º N. 22 March–2 April. ICES CM 1993/Assess:15.

ICES HAWG. 2000. Report of the Herring Assessment Working Group for the Area South of 62º N. 14–23 March. ICES CM 2000/ACFM:10.

ICES HAWG. 2002. Report of the Herring Assessment Working Group for the Area South of 62º N, ICES Headquarters, 12–21 March 2002. ICES CM 2002/ACFM:12.

ICES HAWG. 2007. Report of the Herring Assessment Working Group South of 62 N (HAWG), 13–22 March 2007, ICES Headquarters. ICES CM 2007/ACFM:11. 538pp.

ICES HAWG. 2008. Report of the Herring Assessment Working Group South of 62 N (HAWG), 11–19 March 2008, ICES Headquarters, Copenhagen. ICES CM 2008/ACOM:02. 601 pp.

ICES HAWG. 2009. Report of the Herring Assessment Working Group for the Area South of 62 N, 17–25 March 2009, ICES Headquarters, Copenhagen. 648 pp.

ICES IFWG. 1988. Report of the Industrial Fisheries Working Group. ICES CM 1988/Assess:15.

ICES PGHERS. 2005. Report of the Planning Group on Herring Surveys (PGHERS), ICES CM 2005/G:04.

ICES PGHERS. 2006. Report of the Planning Group on Herring Surveys (PGHERS), 24–27 January. 2006, Rostock, Germany. ICES CM 2006/LRC:04. 239 pp.

ICES PGIPS. 2009. Report of the Planning Group of International Pelagic Surveys (PGIPS), 20–23 January 2009, Aberdeen, Scotland, UK. ICES CM 2009/LRC:02. 217 pp.

ICES SGMSNS. 2005. Report of the study group on multi species assessment in the North Sea. ICES CM 2005/D:06.

ICES SGMSNS. 2006. Report of the study group on multispecies assessment in the North Sea. ICES CM 2006/RMC:02.

ICES WGSAM. 2008. Report of the working group on multispecies assessment methods. ICES CM 2008/RMC:06.

ICES WKARBH. 2008. Report of the workshop on age reading of Baltic herring. ICES CM 2008/ACOM:36.

Jansen, T., Verin, V., Payne, M. 2009. IBTS bottom-trawl survey cpue index for sprat (*Sprattus sprattus*) abundance estimation evaluated by simultaneous acoustic observations. Working document #6.1.

Kornilovs, G. (edi.). 2006. Sprat age reading workshop.

Kristensen, K. 2009. Statistical aspects of heterogeneous population statistics. PhD Thesis. University of Copenhagen.

Kristensen, K and Lewy, P. 2009. Incorporation of size, space and time correlation into a mode of single species fish stock dynamics. In preparation.

Kristensen, K. and Lewy, P. and Beyer, J.E. 2006. How to validate a length-based model of single-species fish stock dynamics. Canadian Journal of Fisheries and Aquatic Sciences, 63, 2531—2542.

Limborg, M.T., Pedersen, J.S., Hemmer-Hamsen, J., Tomkiewicz,J., Bekkevold, D. 2009. Genetic population structure of European sprat (*Sprattus sprattus*): differentiation across a steep environmental gradient in a small pelagic fish. Marine ecology progress series 379: 213–224.

Mesnil, B. 2003. The catch-survey analysis (CSA) method of fish stock assessment: An evaluation using simulated data. Fish. Res., 63: 193–212.

Payne, M. R., Clausen, L. W., and Mosegaard, H. 2009. Finding the signal in the noise: objective data-selection criteria improve the assessment of western Baltic spring-spawning herring. ICES Journal of Marine Science, 66: 1673–1680.

Skagen, D. 2009. The assessment of North Sea sprat: Is length structured models a way forward? Working Document #6.2.

Torstensen E., Eltink, A.T.G.W., Casini, M., McCurdy, W.J., Clausen, L.W. 2004. Report of the Work Shop on age estimation of sprat.

Wahl, E., and Alheit, J. 1988. Changes in the distribution and abundance of sprat eggs during spawning season. ICES CM 1988/H:45.

Wilson L.J., Daunt F. And Wanless S. 2004. Self-feeding and chick provisioning diet differ in the Common Guillemot Uria aalge. Ardea 92: 197–207.

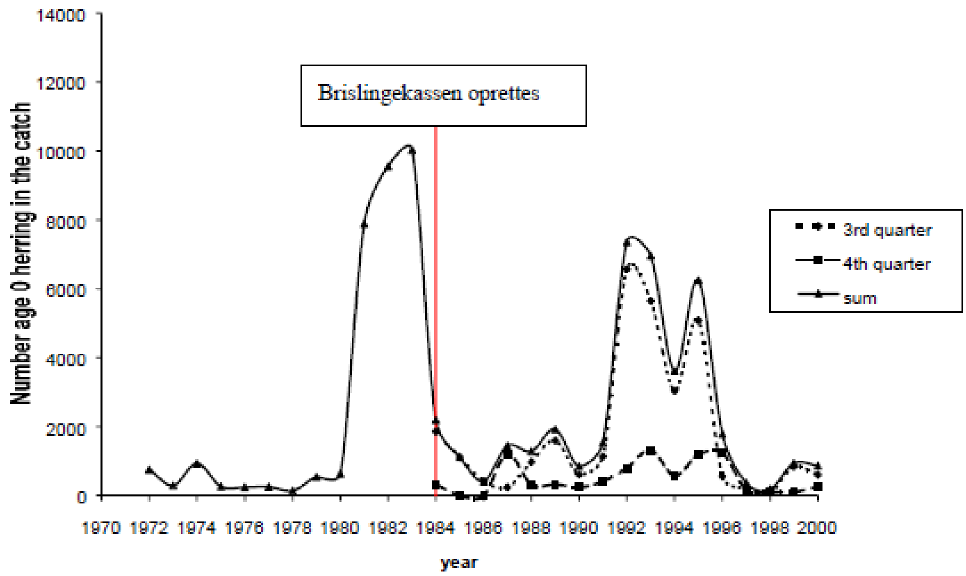


Figure 6.1.1. Catches of 0-group herring in the industrial fisheries in the central North Sea (IVb) in the 3rd and 4th quarter 1972–2000. The red line shows the time for establishing the sprat box. From Hoffman *et al.*, 2004.

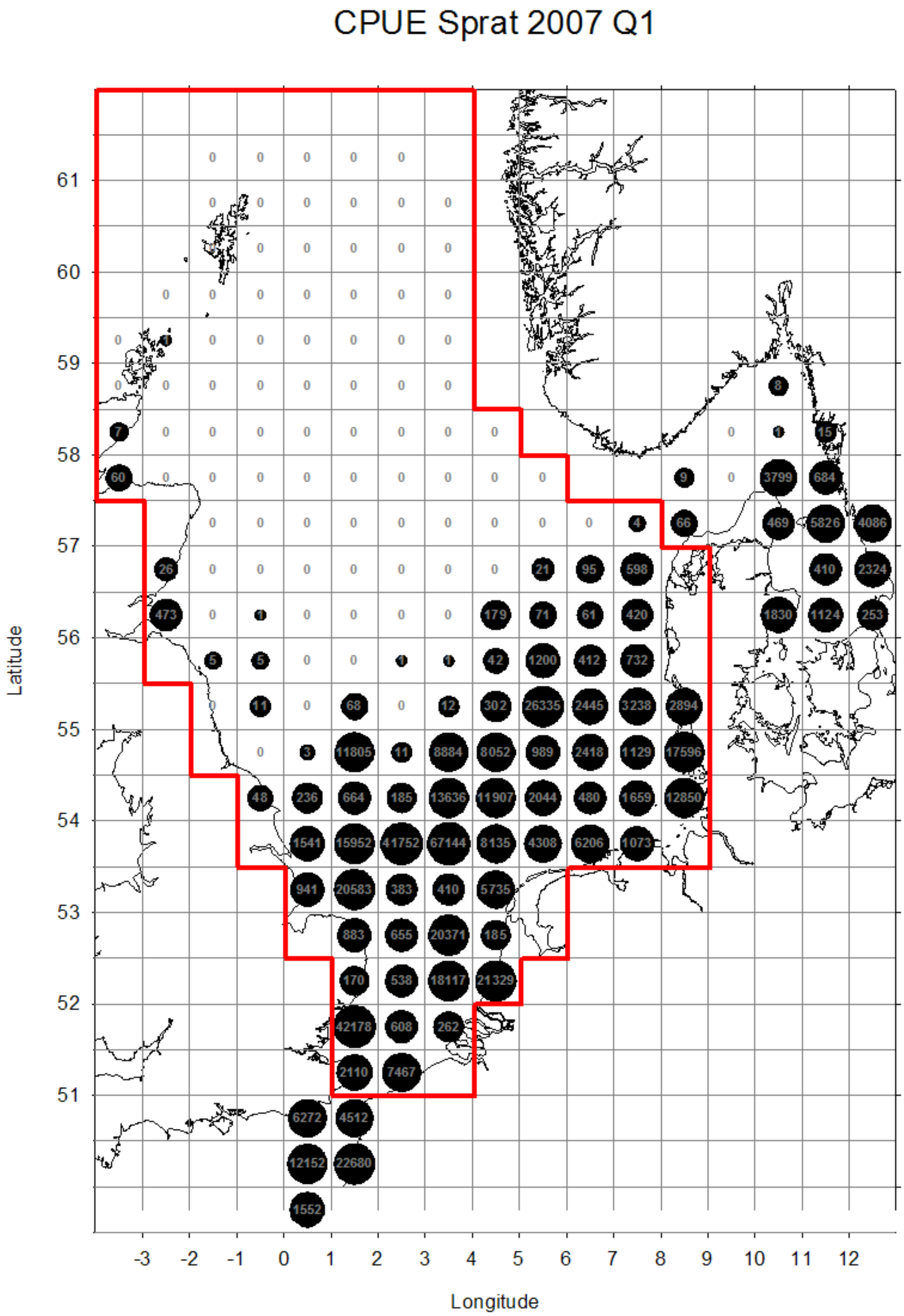


Figure 6.3.1. North Sea sprat. IBTS log cpue from Subareas; IV, IIIa, VII. The red area encircles the management area used for North Sea sprat.

Figure 6.3.2. North Sea sprat. Sampling stations (Limborg *et al.*, 2009).

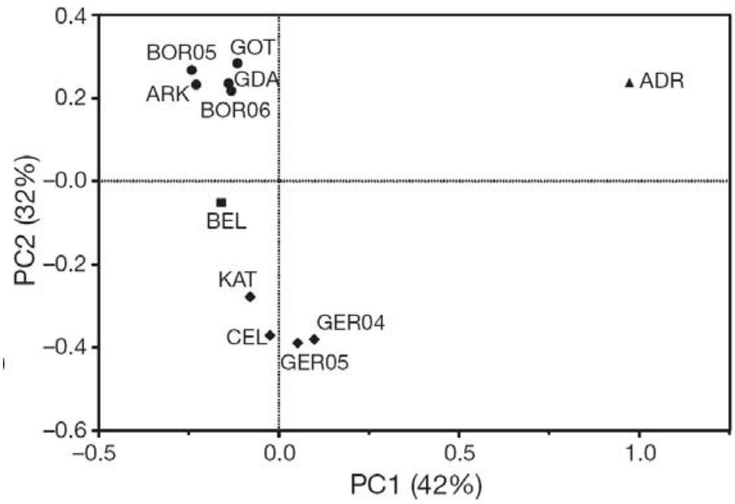


Figure 6.3.3. North Sea sprat. Plot of the generic variance in the samples. ADR = Adriatic Sea, ARK = Arkona Basin, BEL = Danish Belt, BOR = Bornholm Basin, CEL = Celtic Sea, GDA = Gdańsk Deep, GER = German Bight (North Sea), GOT = Gotland Basin (Limborg *et al.*, 2009).

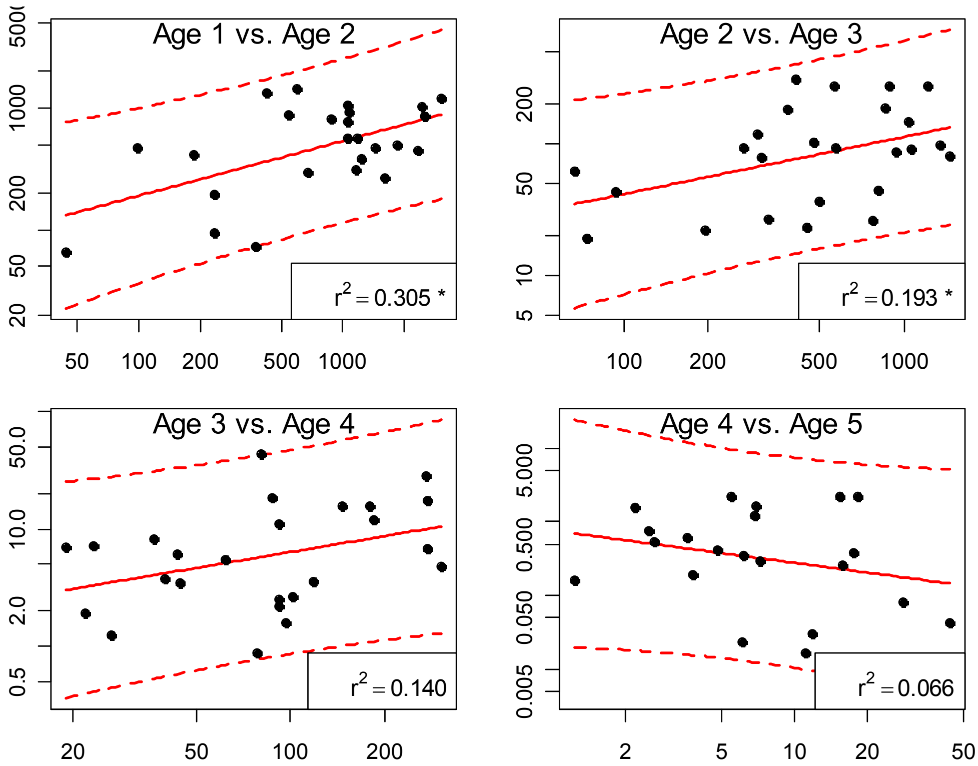


Figure 6.2.3.1. North Sea sprat. Internal consistency analysis from the IBTS Q1 survey. Each panel plots, on a log scale, the abundance of a cohort perceived at a given age (horizontal axis) against the abundance of the same cohort as perceived one year later (vertical axis). The coefficient of determination (r^2) is given in the lower-right corner and is based upon log-transformed values. The title of each panel gives the ages plotted, with the first age plotted on the horizontal axis and the second on the vertical. The top two relationships are statistically significant at the 95% level, while the bottom two are not.

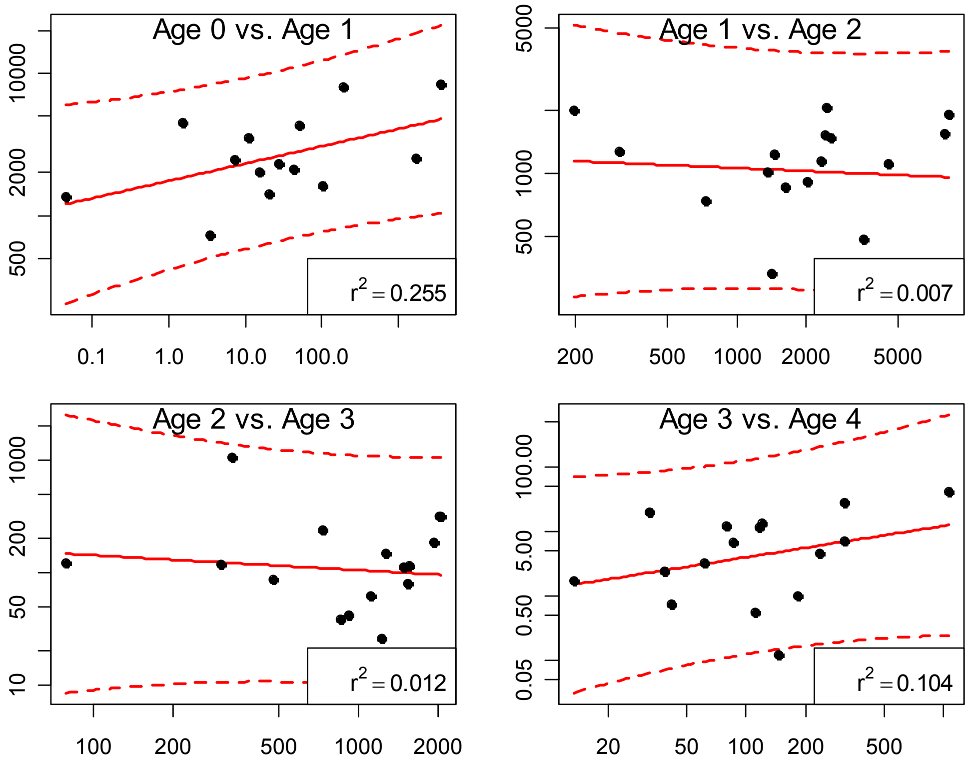


Figure 6.2.3.2. North Sea sprat. Internal consistency analysis from the IBTS Q3 survey. Each panel plots, on a log scale, the abundance of a cohort perceived at a given age (horizontal axis) against the abundance of the same cohort as perceived one year later (vertical axis). The coefficient of determination (r^2) is given in the lower-right corner and is based upon log-transformed values. The title of each panel gives the ages plotted, with the first age plotted on the horizontal axis and the second on the vertical. No correlations are statistically significant at the 95% level.

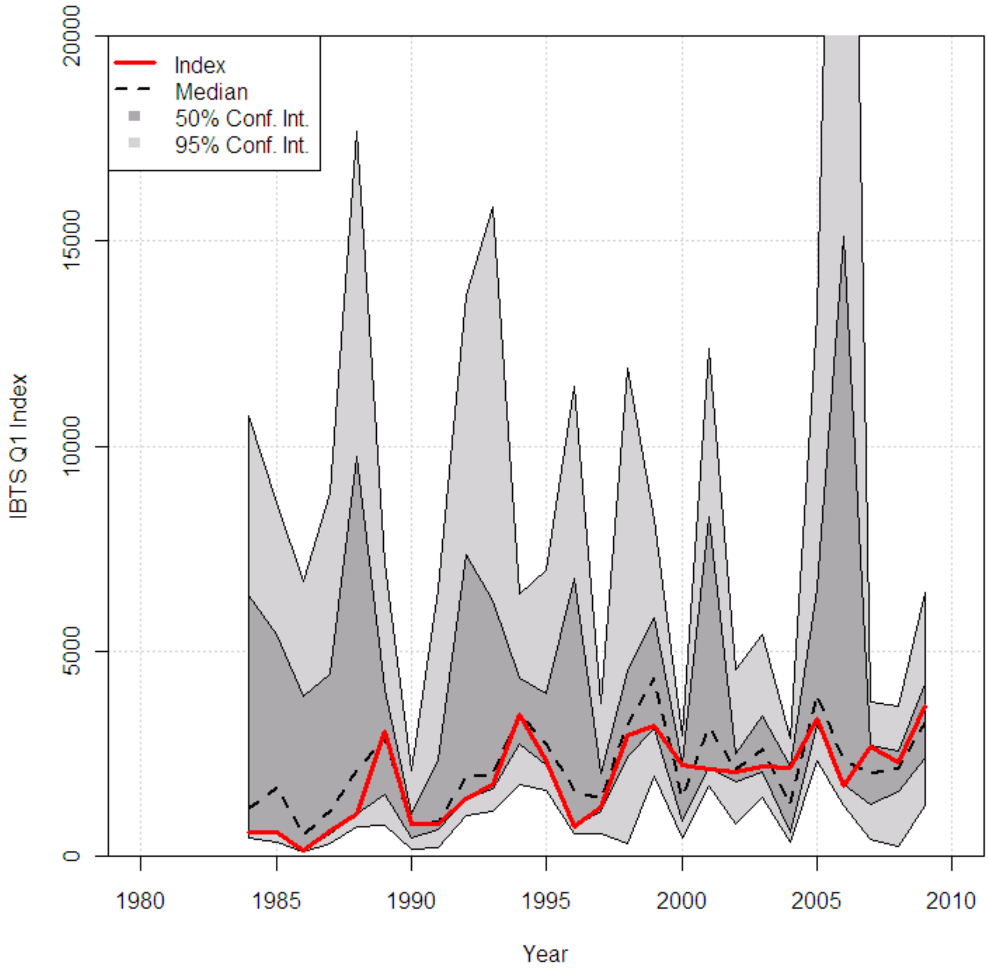


Figure 6.2.3.3. North Sea sprat. Distribution of index values for the IBTS Q1 index, as estimated by the DATRAS database. Values of both the mean index and median value are plotted, in addition to the 50% and 95% confidence bands.

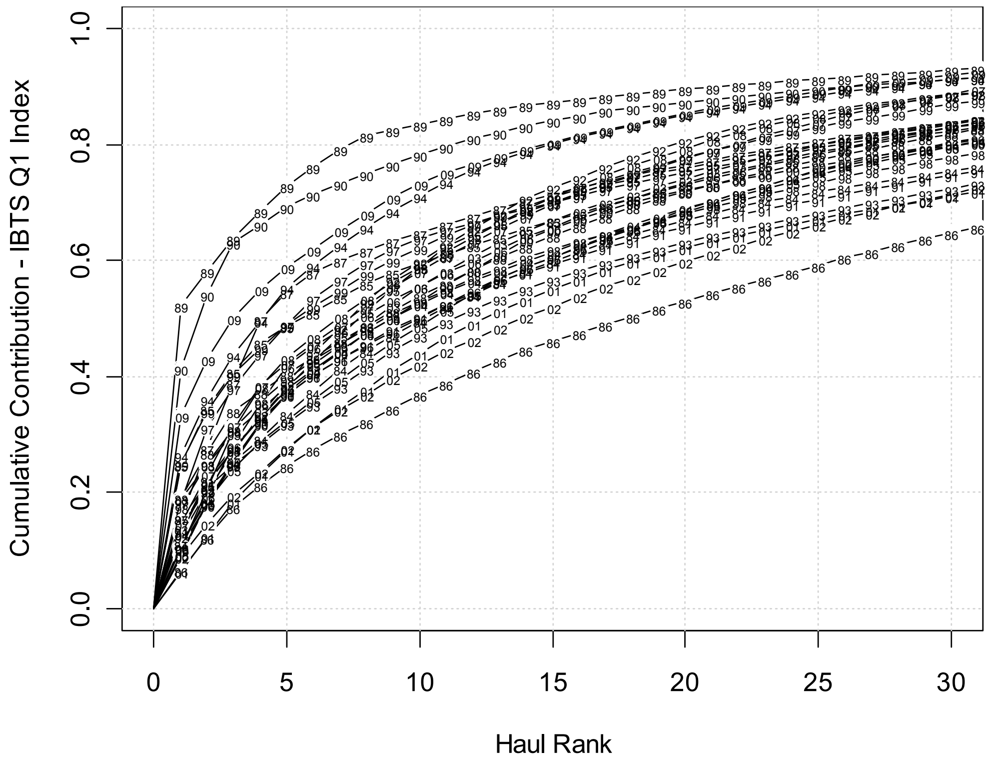


Figure 6.2.3.4. North Sea sprat. Cumulative distribution of the per-haul contribution to the total IBTS Q1 index. The 300–450 individual-haul contributions to the IBTS index in each year are sorted by size then aggregated to calculate a cumulative-distribution. The plot shows only the contributions for the 30 largest hauls. Numbers on each line indicate the year for the survey.

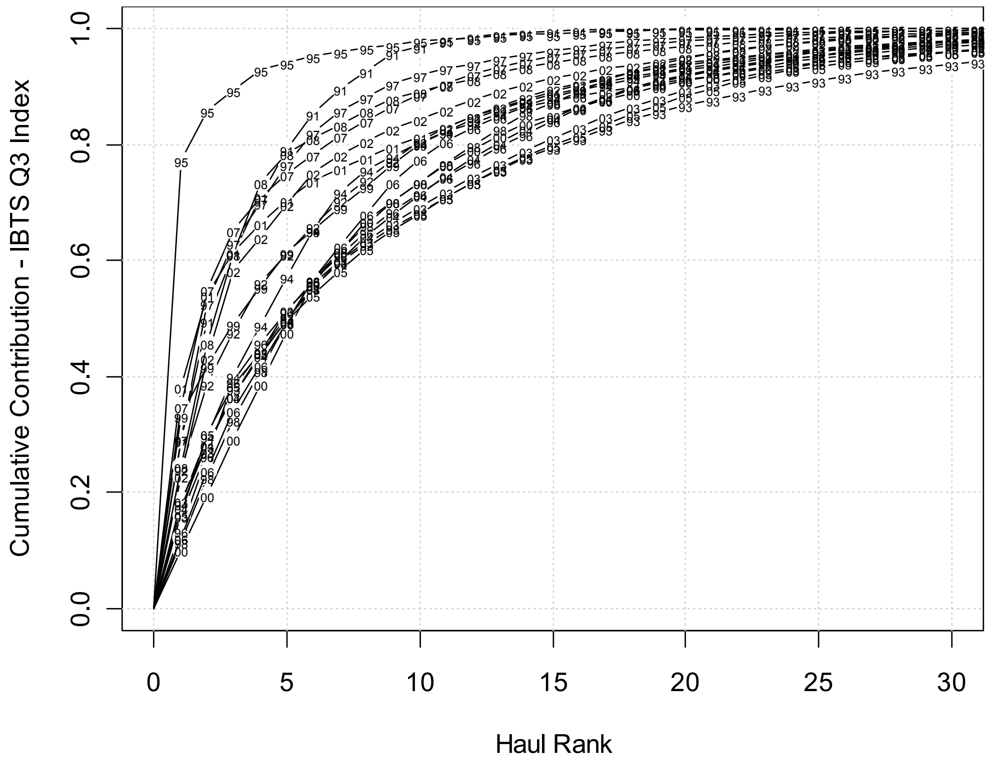


Figure 6.2.3.5. North Sea sprat. Cumulative distribution of the per-haul contribution to the total IBTS Q3 index. The 300–450 individual-haul contributions to the IBTS index in each year are sorted by size then aggregated to calculate a cumulative-distribution. The plot shows only the contributions for the 30 largest hauls. Numbers on each line indicate the year for the survey.

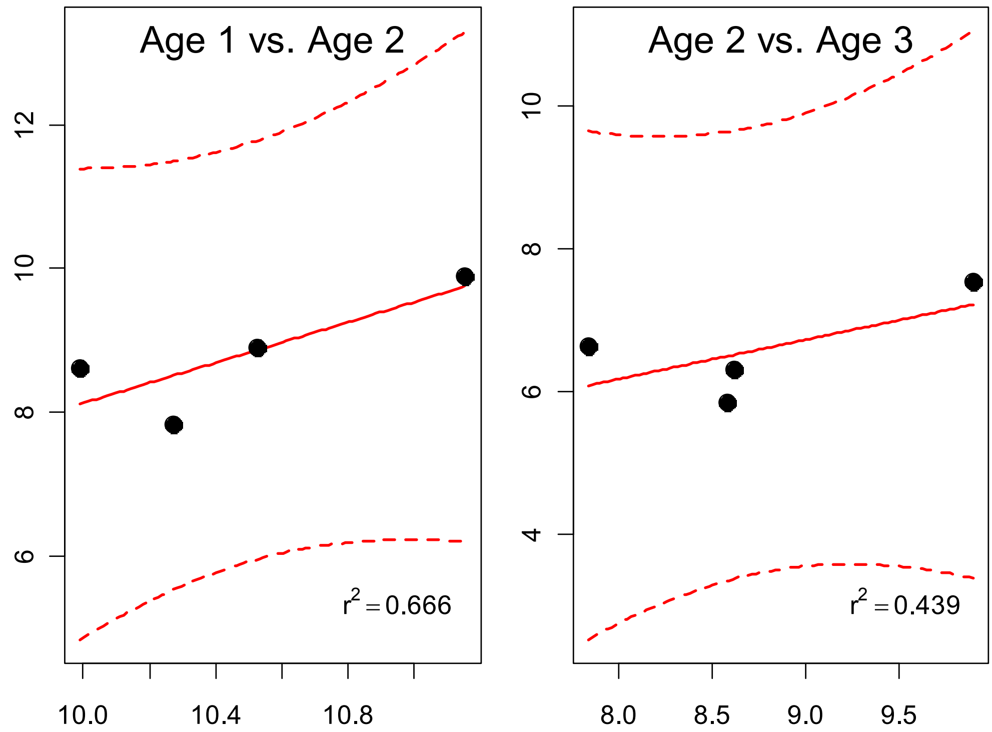


Figure 6.2.3.6. North Sea sprat. Internal consistency analysis from the herring acoustic survey, HERAS. Each panel plots, on a log scale, the abundance of a cohort perceived at a given age (horizontal axis) against the abundance of the same cohort as perceived one year later (vertical axis). The coefficient of determination (r_2) is given in the lower-right corner and is based upon log-transformed values. The title of each panel gives the ages plotted, with the first age plotted on the horizontal axis and the second on the vertical. Neither correlation is statistically significant at the 95% level.

Sprat in Subarea IV (North Sea)–Stock Annex

Quality Handbook Stock Annex: Sprat in the North Sea

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Sprat in the North Sea
Working Group	Herring Assessment Working Group (HAWG)
Date	4 September 2009
Authors	M. Payne, C. Frisk, C. Kvamme.

A. General

A.1. Stock definition

Sprat (*Sprattus sprattus* Linnaeus, 1758) in ICES Area IV (North Sea).

Sprat in the North Sea is treated as a single management unit. However, questions have recently been raised about the geographic distribution of this stock and its interaction with neighbouring stocks: in particular, large abundances have been observed close to the boundaries of the stock (ICES HAWG 2009; Figure 1). The apparent overlap between North Sea sprat and English Channel sprat is very strong, whereas the overlap between North Sea sprat and Kattegat sprat is not as strong and varies between years (see ICES HAWG 2009 for more details).

A detailed genetic study has been performed to analyse the population structure of sprat over large ranges, from scales of seas to regions (Limborg *et al.*, 2009). The study was performed with individuals from the Baltic Sea, Danish waters, Kattegat, North Sea, Celtic Sea and Adriatic Sea (Figure 2). The analysis partitioned the samples into groups based upon their genetic similarity (Figure 3). The Adriatic Sea population exhibited a large divergence from all other samples. The samples from the North Sea, Celtic Sea and Kattegat were separated from the Baltic Sea samples, with the Belt Sea sample in between. The authors concluded that there exists a barrier to gene flow from the North Sea to the Baltic Sea, with the Belt Sea being a transition zone. This analysis does not support the separation of sprat into three stocks that is currently employed by ICES (i.e. Subdivision VIId (English Channel), Subdivision IIIa (Skagerrak/Kattegat) and Division IV (North Sea)). However, it is also important to note that this work is based on neutral markers, which are relatively insensitive. Further research on this issue is required.

A.2. Fishery

The majority of the sprat landings are taken in the Danish industrial small-meshed trawl fishery. The Norwegian sprat fishery is mainly carried out by purse-seiners. Both landings are used for reduction to fishmeal and fishoil. In the last decade, also the UK occasionally lands small amounts of sprat.

The commercial catches are sampled for biological parameters. In the most recent years Denmark, Norway and Scotland have sampled their sprat catches. The sampling intensity for biological samples, i.e. age and weight-at-age is mainly performed following the EU regulation 1639/2001, requiring 1 sample per 2000 tonnes. The country landing most of the catches (Denmark) requires 1 sample per 1000 tonnes landed (www.fvd.fm.dk).

There exists no information about discards and unallocated catches, but it is not expected to be a problem for this fishery.

Historically, the bycatch of juvenile herring in the industrial sprat fisheries has been problematically high (Figure 4). To reduce this bycatch, an area closed to the sprat fishery (the "sprat box") was established off the west coast of Denmark (from Vadehavet to Hanstholm) in October 1984 (Hoffman *et al*., 2004). It was estimated that about 90% of the bycatches of juvenile herring in the industrial fisheries was taken within this box, and the intention of the sprat box was thus to reduce this juvenile herring bycatch.

Despite the establishment of this sprat box, the juvenile herring bycatches increased in the early 1990s, partly because of larger incoming year classes having a wider distribution (Hoffman *et al*., 2004). It was concluded that there was no clear connection between the sprat box and the decrease in herring bycatches in the period 1984–1996 (Hoffman *et al*., 2004). The sprat box is still in operation (Fiskeridirektoratet, 2007).

After 1996, the bycatch mortality of juvenile herring was reduced (Figure 4; ICES HAWG 2009). This coincided with the introduction of a bycatch limit on herring in the industrial fisheries and improvements in the catch sampling.

Evaluation of the quality of the catch data

As a consequence of large but unknown bycatches of juvenile North Sea herring in the industrial sprat fisheries prior to 1996 (Figure 4), sprat landings are only considered reliable from 1996 onwards. The reduction in bycatches of juvenile herring in 1996 coincides with the introduction of a bycatch limit on herring in the industrial fisheries, and improvements in catch-sampling.

The bycatches in the Danish industrial small-meshed trawl fishery for sprat (1998–2008) have been estimated from samples of the commercial catches (ICES HAWG 2009: Table 8.2.1). The major bycatches are herring (4.2–11.1% in weight), horse mackerel (0.0–1.6%), whiting (0.2–1.5%), haddock (0.0–0.1%), mackerel (0.2–2.2%), cod (<0.0%), sandeel (0.0–10.0%) and other (0.3–2.4%). Although these catches are relatively small by weight, they are often juveniles, and therefore can represent a significant number of individuals.

There exists no information about the bycatches of the other fleets.

A.3. Ecosystem aspects

Many predators in the North Sea feed extensively on sprat, including predatory fish, marine mammals and seabirds. Its role in the ecosystem has been evaluated in the 1981 and 1991 stomach sampling programmes (ICES 1989, ICES 1997). Predation was strongest from whiting and mackerel (ICES SGMSNS 2006, ICES 1997). Predation from cod on sprat have been suggested to increase after the last sampling campaign in 1991 as sandeel and Norway pout stocks have decreased (ICES 1997).

Sprat can be very important for breeding seabirds in southern areas of the North Sea (Durinck *et al*., 1991; Wilson *et al*., 2004). Estimates from 1985 have demonstrated that the total seabird consumption in the North Sea could be on the same level as the fisheries (Hunt and Furness (edi.) 1996). In winter, when sandeel are not available to most seabirds (because they are buried in the sand) many of the seabirds that overwinter in the North Sea take sprat as part of their diet. However, it is uncertain whether sprat abundance in the North Sea will affect seabird breeding success or overwinter survival.

Attempts have previously been made to include sprat in the MSVPA in the North Sea (ICES SGMSNS 2005). Recently, as no single species assessment on North Sea sprat has been performed, sprat was not included explicitly in the MSVPA. Sprat was therefore treated in the recent model as 'other food', and is thus included in the model indirectly as a prey organism. Unfortunately this method does not allow for an estimate on the predation mortality on sprat (ICES WGSAM 2008). Historically, MSVPA runs have included sprat by which it was found that the predation mortality on the species exceeds the fishing mortality (ICES SGMSNS 2005).

B. Data

B.1. Commercial catch

The majority of the sprat landings are taken in the Danish industrial small-meshed trawl fishery. The Norwegian sprat fishery is mainly carried out by purse-seiners. Both landings are used for reduction to fishmeal and fishoil. In the last decade, also the UK occasionally lands small amounts of sprat.

The commercial catches are sampled for biological parameters. In the most recent years Denmark, Norway and Scotland have sampled their sprat catches. The sampling intensity for biological samples, i.e. age and weight-at-age is mainly performed following the EU regulation 1639/2001, requiring 1 sample per 2000 tonnes. The country landing most of the catches (Denmark) requires 1 sample per 1000 tonnes landed (www.fvd.fm.dk).

There exists no information about discards and unallocated catches, but it is not expected to be a problem for this fishery.

As a consequence of large but unknown bycatches of juvenile North Sea herring in the industrial sprat fisheries prior to 1996 (Figure 4), sprat landings are only considered reliable from 1996 onwards. The reduction in bycatches of juvenile herring in 1996 coincides with the introduction of a bycatch limit on herring in the industrial fisheries, and improvements in catch-sampling.

B.2. Biological

Sprat in the North Sea has a prolonged spawning season ranging from spring to the late autumn, and is triggered by the water temperature (Alheit *et al*., 1987; Alshulth, 1988a; Wahl and Alheit, 1988). Sprat is a batch spawner, producing up to 10 batches in one spawning season and 100–400 eggs per gramme of body weight (Alheit, 1987; George, 1987). The majority of the spawning sprat are 2 year olds, although spawning at age 1 can also occur (Bailey, 1980).

Disagreements in the age reading in North Sea sprat have been reported (*e.g.* Torstensen *et al*., 2004). The problems arise as a consequence of interpretation of winter rings. False winter rings can be set in periods of bad feeding conditions/starvation and as a consequence of rapid changes in temperature (E. Torstensen, personal communication 2009). False winter rings also occur in other species and areas, e.g. Baltic sprat (Kornilovs (edi.) 2006), herring (ICES WKARGH 2008) and sandeel (Clausen *et al*., 2006). Furthermore, the reading of the first winter ring can be difficult, as sprat can spawn until late autumn and larvae from these late spawning will likely not set down a winter ring during their first winter (Torstensen *et al*., 2004). The absence of such rings can lead to errors in age determination, as these individuals cannot be distinguished from the individuals born the following year. Age readings in North Sea sprat were estimated to have a high coefficient of variance (CV) of 28% (Torstensen *et al*., 2004).

Mean weight-at-age in the North Sea sprat is variable over time (ICES HAWG 2009). This may be ascribed as a consequence of both the aging problems previously described, and also the prolonged spawning period, by which the individuals can have very different birthdates. The mean weight-at-age in the catches is for age 1 is approximately 4 g, at age 2 app. 10 g, at age 3 app. 11 g, and at age 4+ app. 14 g (ICES HAWG 2009).

B.3. Surveys

Three surveys cover this stock. Two International Bottom Trawl Survey (IBTS) cover the stock in the first and third quarters of the year. Additionally, the herring acoustic survey covers the same area during July. Here we examine the appropriateness and suitability of these surveys for use in the assessment of the North Sea sprat stock.

B.3.1. International Bottom Trawl Surveys (IBTS)

Background

The North Sea International Bottom Trawl Surveys started as a coordinated international survey in the mid-1960s as a survey directed towards juvenile herring. The gear used was standardized in 1977 to use the GOV trawl, but took time to be phased in. By 1983 all participating nations were using this gear, and the index can be considered consistent from this point onwards. A third-quarter North Sea IBTS survey using the same methodology was started in 1991 and can be considered consistent from its initiation. IBTS Surveys were also performed in the North Sea in the second and fourth quarters in the period 1991–1996, but are not considered further here (ICES 2006). More details on the survey are available from the manual (ICES 2004).

Suitability

The appropriateness of the IBTS survey for use as an estimate of the abundance of North Sea sprat was examined in a working document (Jansen *et al*., 2009). Acoustic data collected during trawls performed as part of the IBTS were analysed, with focus on the vertical distribution. The relationship between the amount of sprat available in the water column (from acoustics) and the amount of sprat captured by the gear was found to be weak and highly variable in nature. The proportion of sprat in the water column that were in the bottom five metres was found to range widely between 0 and 100%, and also found to be a function of the time of day. The work therefore suggests that the IBTS survey, as it exists, may not be appropriate to use with sprat in the North Sea. However, further investigation, including the addition of further data points and comparison with results from other species (*e.g.* herring) are required before firm conclusions can be drawn.

Internal consistency

Internal consistency analysis (Payne *et al*., 2009 and references therein) was used to examine the ability of the IBTS survey to track the abundance of individual cohorts. This method involves plotting the log-abundance estimated by the survey at one age against the log-abundance of the same cohort in the following year: in cases where the total mortality is constant and the relative survey noise is low, this relationship should be linear. However, deviations from linearity may arise as a consequence of either high noise levels in the survey or variations in the total mortality experienced by the stock. The test is therefore asymmetric, in that a linear relationship is a strongly positive result, while the absence of a relationship does not automatically mean that the survey is of poor quality. Examination of the internal consistency can therefore be used as a measure (albeit biased) of the survey quality.

We find that the relationship between the abundance of successive ages in a cohort from the first quarter (Figure 5) and third quarter (Figure 6) surveys is extremely poor, and is dominated by noise. This noise may arise as a consequence of either the nature of the survey (e.g. survey design, variability of catchability) or variations in total mortality. In the absence of information regarding either fishing mortality (e.g. from a stock assessment) or natural mortality (e.g. from a multispecies model), it is not possible to separate these two sources of variability.

Confidence intervals

Distribution of the IBTS indices are available from the ICES DATRAS database, following a bootstrapping procedure agreed upon in 2006 (ICES 2006). These data were analysed to extract key values characterizing the distribution, including the confidence intervals for both IBTS Q1 (Figure 7) and Q3. Generally, the confidence intervals for the indices were found to be extremely broad. The median upper confidence limit is 250% greater than the value of the index estimated (although in some cases this can be as much as 4600% greater) and the median lower confidence limit is 40% less than the estimated index. The uncertainties are therefore much larger than the estimated dynamics of the stock and it is thus not possible to say, statistically, that the index value in one year is statistically different from another.

Composition of the index

Catches of North Sea sprat in hauls in the IBTS survey can occasionally be extremely large; this phenomenon has previously been suggested as being important to the dynamics and uncertainty of IBTS survey indices (ICES HAWG 2007, ICES HAWG 2009). In order to examine this phenomenon more closely, the importance of each haul to the index was assessed by calculating the individual contribution of each haul to the total. These hauls were then ranked according to size and aggregated to produce an estimate of the cumulative contribution ranked by sized: in this manner, it is therefore possible to assess, for example, the proportional contribution of the largest 20 hauls in a given year. For all years in the both the IBTS Q1 (Figure 8) and Q3 (Figure 9), the 10 largest hauls contribute at least 35% of the survey index, and in some cases up to 85% of the index. The IBTS Q3 index appears to have more severe problems with large hauls than the Q1 index: in every year, the five largest hauls make up more than 50% of the index.

Alternative analysis methods

The method used by the ICES DATRAS database to calculate the IBTS indices is relatively simplistic, essentially comprising a set of stratified means (i.e. the mean cpue per statistical rectangle is averaged over the entire North Sea). As an attempt to resolve problems caused by the presence of large hauls in the calculation of the index, a Log-Gaussian Cox Process (LGCP) was fitted to the individual haul data (Kristensen *et al*., 2006; Kristensen, 2009a; Kristensen and Lewy, 2009). The LGCP model is a statistical model that can be used to account for the statistical nature of the catch process, including correlations between size classes, spatial correlation and between years. The model was fitted in a simplified form, where only spatial correlations were included. Total cpue of sprat, cpue by age and cpue by length class were all used as classification schemes and each fitted individually using the model.

Unfortunately, the LGCP model failed to fit the IBTS survey data adequately. Goodness of fit tests on the fitted model demonstrated that a number of key assumptions in the model were frequently violated. Furthermore, the confidence intervals on the estimated abundances were extremely broad, in some cases spanning more than six orders of magnitude. It was therefore concluded that the model, as fitted, was in appropriate to the dataset.

It is currently unclear as to why the LGCP model fails to fit the IBTS sprat data. A number of candidate explanations have been considered, including the large number of zero hauls and the extreme "boom-bust" nature of the catches. It is currently unclear whether this modelling framework is capable of dealing with the nature of the sprat catches in the IBTS survey: the ultimate appropriateness of this method should be considered carefully before further work is performed.

Conclusions

The IBTS Q1 and Q3 surveys are the best time-series of data available for use in characterizing the abundance of sprat in the North Sea, covering the years from 1984 and 1991 onwards respectively: for comparison, the time-series of catches begins in 1996 and the acoustic survey (see below) in 2004. However, the survey is greatly impacted by the presence of extremely large individual hauls that can make up 85% or more of the index in some years. The problem is compounded by the manner in which the ICES DATRAS database calculates the indices; the use of simple arithmetic means here does not account for the extremely high variability of sprat catches in the IBTS survey and propagates these problems through to the index value. The extremely broad confidence intervals and the lack of internal consistency can also be understood as consequences of this problem. Variability of the catchability of sprat in the IBTS's GOV gear caused by the time of day and the pelagic nature of sprat may contribute to this problem to a degree but seem unlikely to explain the order-of-magnitude variability observed. Instead, the highly schooling nature of sprat is likely to be the most important underlying cause: if the gear encounters and captures a high-density school of sprat, an extremely large haul could be produced.

Given the potential importance of the IBTS indices for the assessment of this stock, further investigations are warranted. The current analysis method is extremely simplistic and appears to be the main source of the problem. Future investigations should focus on attempting to analyse this large and valuable source of information in a manner that can account for both the large number of zero hauls and also the extremely large individual hauls. Qualitative indicators, such as distribution area, presence/absence metrics, and the frequency of large hauls may also be of use in an advice context.

B.3.2. Herring Acoustic Survey (HERAS)

Background

The Herring Acoustic Survey is a summer acoustic survey that has been performed by an international consortium since the 1980s. Sprat has been reported as a separate species in this survey from 1996 onwards. However, as the survey is targeted towards herring, which are generally in the northern half of the North Sea during summer, coverage in the southern-half has received less attention. The area covered was expanded progressively over time, and by 2004 covered the majority of the stock, reaching 52°N (the eastern entrance to the English Channel) and all of the way into the German Bight (ICES PGHERS 2005). The coverage of this survey has remained relatively unchanged since 2004 (*e.g.* ICES PGIPS 2009) and we consider the survey from this point and onwards.

Suitability

In theory, the herring acoustic survey should be better suited for the estimation of sprat abundance than the bottom-trawl IBTS survey, given that it integrates over the entire water column and is thus less susceptible to changes in vertical distribution and the presence of large schools.

However, there are a number of difficulties with the acoustic estimation of sprat that must be considered. Each survey report since 2004 has noted that the survey does not appear to reach the southern boundary of the stock, with there being significant concentrations of sprat at or close to this limit. Failing to reach the southern boundary line would lead to an underestimation of the stock size and may increase the interannual variability of the estimate. Similar observations have also been obtained from the IBTS survey, suggesting that the population may continue into the English Channel and Subdivision VIId (ICES HAWG 2009; see also Section 6.3).

The acoustic signatures of herring and sprat are also very similar and make the separation of these two species challenging. In the 2005 survey, an area containing large amounts of sprat was covered by two of the vessels, allowing a direct comparison of the estimated abundances. Unfortunately, the results varied widely, suggesting that the precision of the total abundance estimate may be poor (ICES PGHERS 2006).

Finally, the time-series of acoustic estimates is short, and may not be of sufficient length for use in a stock assessment.

Internal consistency

The internal consistency analysis employed above was also employed for the HERAS estimates of sprat abundance (Figure 10). The coefficients of determination for the relationship between the abundance-at-age for each cohort were appreciably better than those seen for the IBTS surveys, and are comparable with those used in other assessments (*e.g*. western Baltic spring-spawning herring (Payne *et al*., 2009)). However, the length of the time-series is also extremely short (four pairs of observations), and there is therefore insufficient information to draw meaningful conclusions. Further data points in the time-series would be beneficial to understanding the suitability of this survey.

Confidence intervals

There are currently no confidence intervals available for the estimated acoustic abundances. Future versions of the FISHFRAME database used to estimate the abundances from the raw acoustic data are intended to include the estimation of uncertainties (T. Jansen, personal communication 2009).

Conclusions

The herring acoustic survey demonstrates potential as an estimate of the abundance of sprat in the North Sea. However, the current time-series is too short for use, and further data points are required before its potential can be fully assessed. Furthermore, problems regarding the acoustic identification of sprat and herring, and the southern boundary of the stock may severely limit the applicability of this survey: resolving these issues should be considered a high priority.

B.4. Commercial cpue

None available.

B.5. Other relevant data

C. Assessment methodology

No assessment is currently available for this stock.

D. Short-term projection

No projections are performed.

E. Medium-term projections

No projections are performed.

F. Long-term projections

No projections are performed.

G. Biological reference points

No reference points are available.

H. Other issues

None.

I. References

Alheit, J. 1987. Variation of batch fecundity of sprat, *Sprattus sprattus*, during spawning season. ICES CM 1987/H:44.

Alheit, J., Wahl, E., and Cibangir, B. 1987. Distribution, abundance, development rates, production and mortality of sprat eggs. ICES CM 1987/H:45.

Alshult, S. 1988. Seasonal variations in length–frequency and birthdate distribution of juvenile sprat (Sprattus sprattus). ICES CM 1988/H:44.

Bailey, R.S. 1980. Problems in the management of short-lived pelagic fish as exemplified by North Sea sprat. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer 177: 477–488.

Clausen L.W., Davis C.G. and Hansen S. 2006. Report of the sandeel otolith ageing workshop.

Durinck J., Skov H. and Danielsen F. 1991. The winter food of guillemots Uria-aalge in the Skagerrak. Dansk ornitologisk forenings tidsskrift 85: 145–150.

Fiskeridirektoratet 2007. Fiskeridirektoratet. Årsrapport 2006. ISBN: 87–89443–23–3.

George, M.R. 1987. Ovarian maturation cycle of sprat, *Sprattus sprattus*. ICES CM 1987/H:47.

Hoffman E, Dolmer P, Nordberg E, Blanner P 2004. Beskyttede havområder i Norden. TemaNord 2004: 543.

Hunt G.L. and Furness R.W. 1996. Seabird/fish interactions, with particular reference to seabirds in the North Sea. ICES cooperative research report no. 216.

ICES. 1989. Database report of the stomach sampling project 1981. Cooperative research report no. 164.

ICES. 1997. Database report of the stomach sampling project 1991. ICES cooperative research report no. 219.

ICES. 2004. Manual for the international bottom-trawl surveys. Revision VII.

ICES. 2006. Report of the Workshop on Implementation in DATRAS of Confidence Limits Estimation of, 10–12 May 2006, ICES Headquarters, Copenhagen. 39 pp.

ICES. HAWG. 2007. Report of the Herring Assessment Working Group South of 62 N (HAWG), 13–22 March 2007, ICES Headquarters. ICES CM 2007/ACFM:11. 538pp.

ICES HAWG. 2009. Report of the Herring Assessment Working Group for the Area South of 62 N, 17–25 March 2009, ICES Headquarters, Copenhagen. 648 pp.

ICES PGHERS. 2005. Report of the Planning Group on Herring Surveys (PGHERS), ICES CM 2005/G:04.

ICES PGHERS. 2006. Report of the Planning Group on Herring Surveys (PGHERS), 24–27 January. 2006, Rostock, Germany. ICES CM 2006/LRC:04. 239 pp.

ICES PGIPS. 2009. Report of the Planning Group of International Pelagic Surveys (PGIPS), 20–23 January 2009, Aberdeen, Scotland, UK. ICES CM 2009/LRC:02. 217 pp.

ICES SGMSNS. 2005. Report of the study group on multi species assessment in the North Sea. ICES CM 2005/D:06.

ICES SGMSNS. 2006. Report of the study group on multispecies assessment in the North Sea. ICES CM 2006/RMC:02.

ICES WGSAM. 2008. Report of the working group on multispecies assessment methods. ICES CM 2008/RMC:06.

ICES WKARBH. 2008. Report of the workshop on age reading of Baltic herring. ICES CM 2008/ACOM:36.

Jansen, T., Verin, V., Payne, M. 2009. IBTS bottom-trawl survey cpue index for sprat (*Sprattus sprattus*) abundance estimation evaluated by simultaneous acoustic observations. Working document.

Kornilovs, G. (edi.). 2006. Sprat age reading workshop.

Kristensen, K. 2009. Statistical aspects of heterogeneous population statistics. PhD Thesis. University of Copenhagen.

Kristensen, K and Lewy, P. 2009. Incorporation of size, space and time correlation into a mode of single species fish stock dynamics. In preparation.

Kristensen, K. and Lewy, P. and Beyer, J.E. 2006. How to validate a length-based model of single-species fish stock dynamics. Canadian Journal of Fisheries and Aquatic Sciences, 63,2531–2542.

Limborg, M.T., Pedersen, J.S., Hemmer-Hamsen,J., Tomkiewicz,J., Bekkevold, D. 2009. Genetic population structure of European sprat (*Sprattus sprattus*): differentiation across a steep environmental gradient in a small pelagic fish. Marine ecology progress series 379: 213–224.

Payne, M. R., Clausen, L. W., and Mosegaard, H. 2009. Finding the signal in the noise: objective data-selection criteria improve the assessment of western Baltic spring-spawning herring. ICES Journal of Marine Science, 66: 1673–1680.

Torstensen E., Eltink, A.T.G.W., Casini, M., McCurdy, W.J., Clausen, L.W. 2004. Report of the Work Shop on age estimation of sprat.

Wahl, E., and Alheit, J. 1988. Changes in the distribution and abundance of sprat eggs during spawning season. ICES CM 1988/H:45.

Wilson L.J., Daunt F. And Wanless S. 2004. Self-feeding and chick provisioning diet differ in the Common Guillemot Uria aalge. Ardea 92: 197–207.

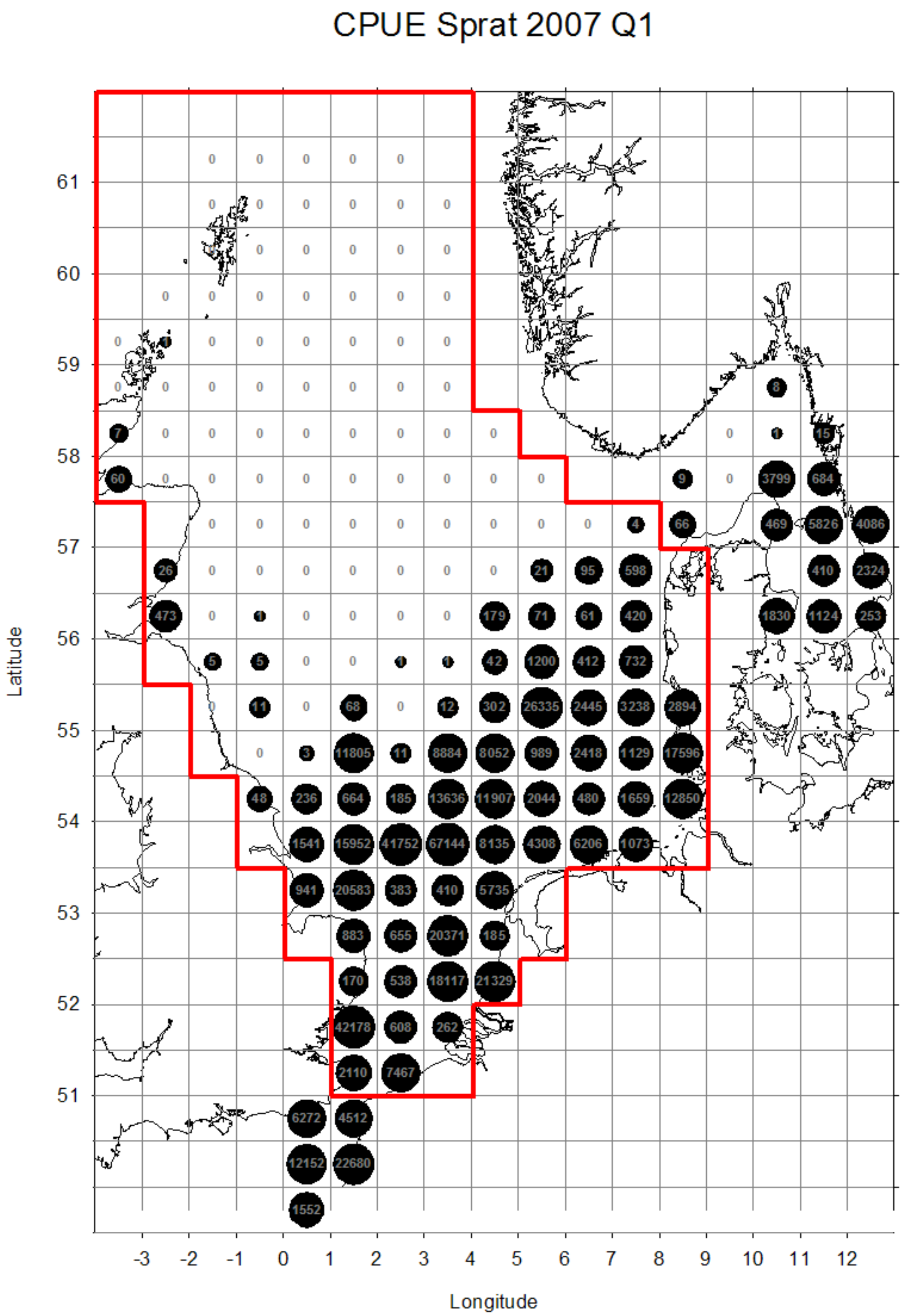


Figure 1. North Sea sprat. IBTS log cpue from Subareas; IV, IIIa, VII. The red area encircles the management area used for North Sea sprat. After ICES HAWG 2009.

Figure 2. North Sea sprat. Sampling stations (Limborg *et al.*, 2009).

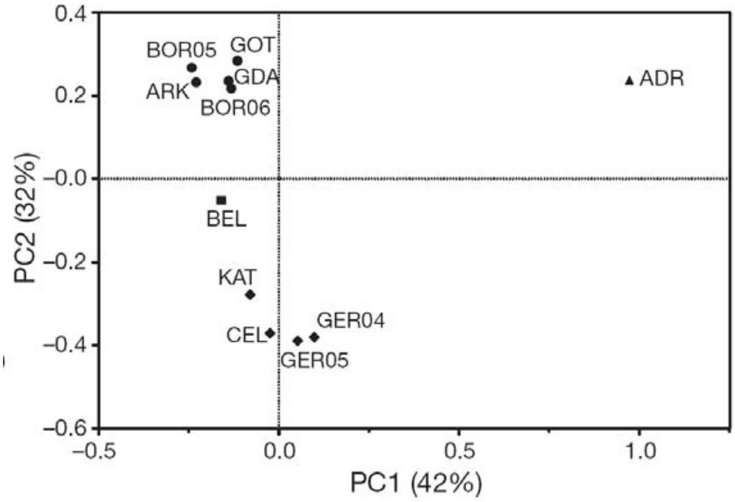


Figure 3. North Sea sprat. Plot of the generic variance in the samples. ADR = Adriatic Sea, ARK = Arkona Basin, BEL = Danish Belt, BOR = Bornholm Basin, CEL = Celtic Sea, GDA = Gdańsk Deep, GER = German Bight (North Sea), GOT = Gotland Basin (Limborg *et al.*, 2009).

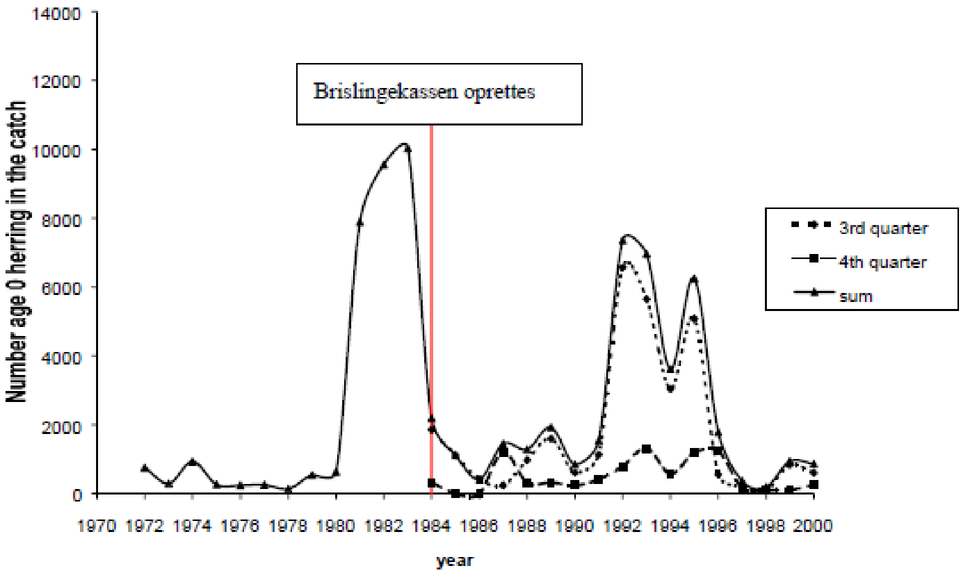


Figure 4. Catches of 0-group herring in the industrial fisheries in the central North Sea (IVb) in the 3rd and 4th quarter 1972–2000. The red line shows the time for establishing the sprat box. From Hoffman *et al.*, 2004.

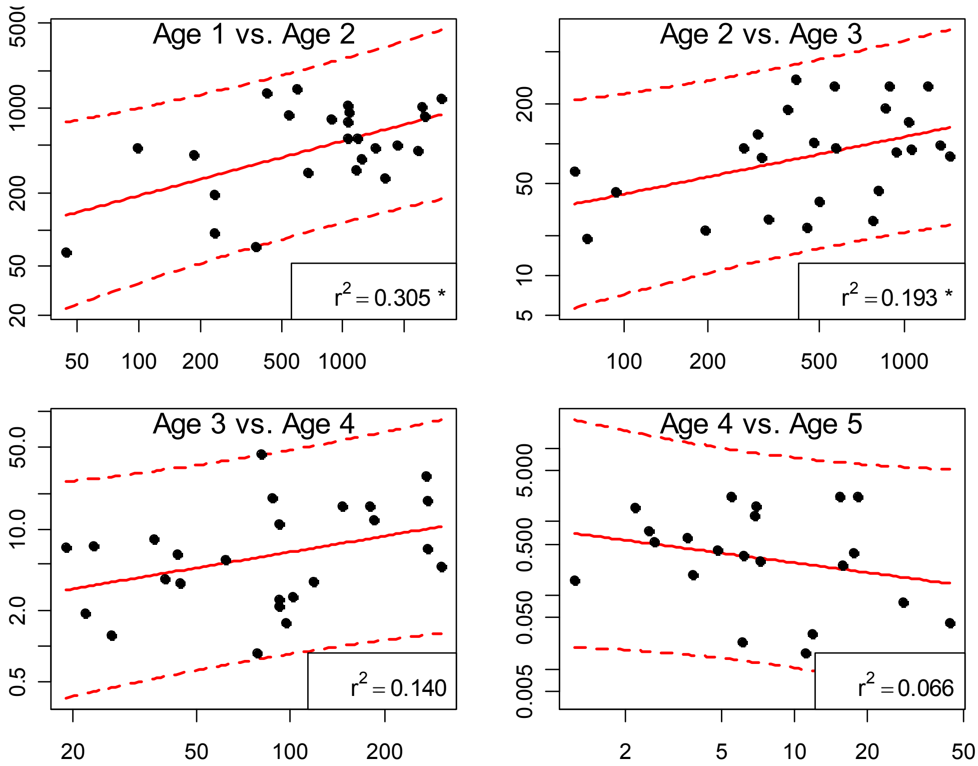


Figure 5. North Sea sprat. Internal consistency analysis from the IBTS Q1 survey. Each panel plots, on a log scale, the abundance of a cohort perceived at a given age (horizontal axis) against the abundance of the same cohort as perceived one year later (vertical axis). The coefficient of determination (r^2) is given in the lower-right corner and is based upon log-transformed values. The title of each panel gives the ages plotted, with the first age plotted on the horizontal axis and the second on the vertical. The top two relationships are statistically significant at the 95% level, while the bottom two are not.

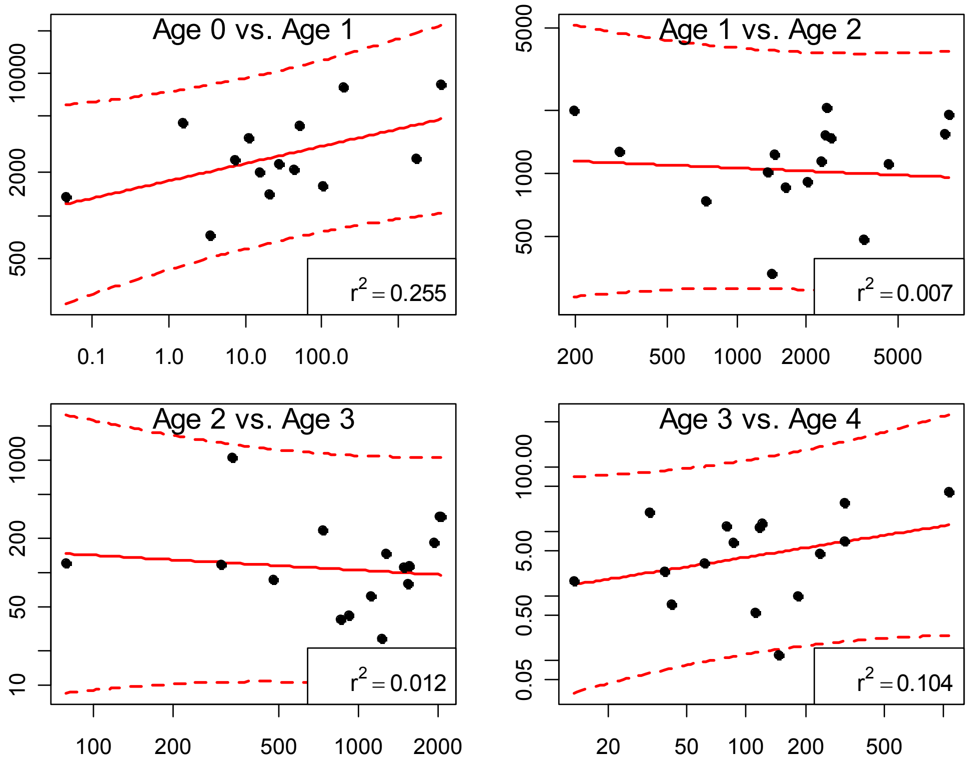


Figure 6. North Sea sprat. Internal consistency analysis from the IBTS Q3 survey. Each panel plots, on a log scale, the abundance of a cohort perceived at a given age (horizontal axis) against the abundance of the same cohort as perceived one year later (vertical axis). The coefficient of determination (r^2) is given in the lower-right corner and is based upon log-transformed values. The title of each panel gives the ages plotted, with the first age plotted on the horizontal axis and the second on the vertical. No correlations are statistically significant at the 95% level.

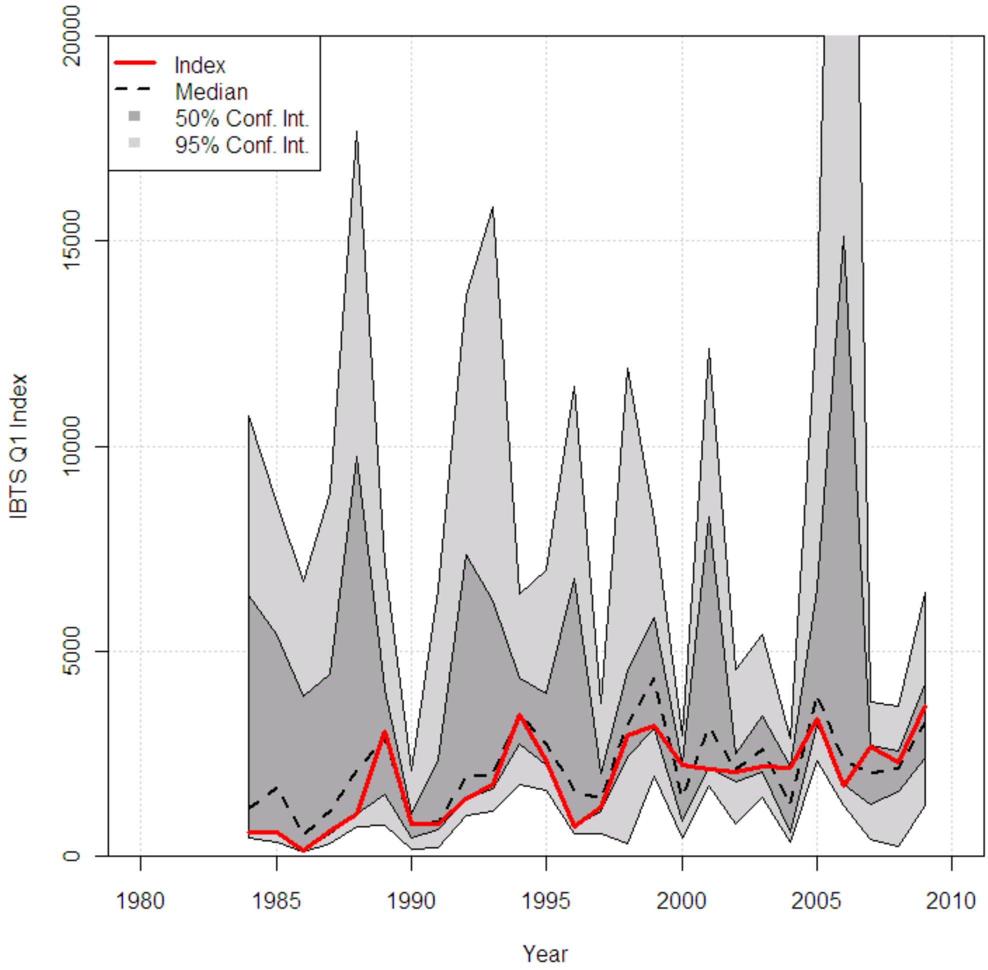


Figure 7. North Sea sprat. Distribution of index values for the IBTS Q1 index, as estimated by the DATRAS database. Values of both the mean index and median value are plotted, in addition to the 50% and 95% confidence bands.

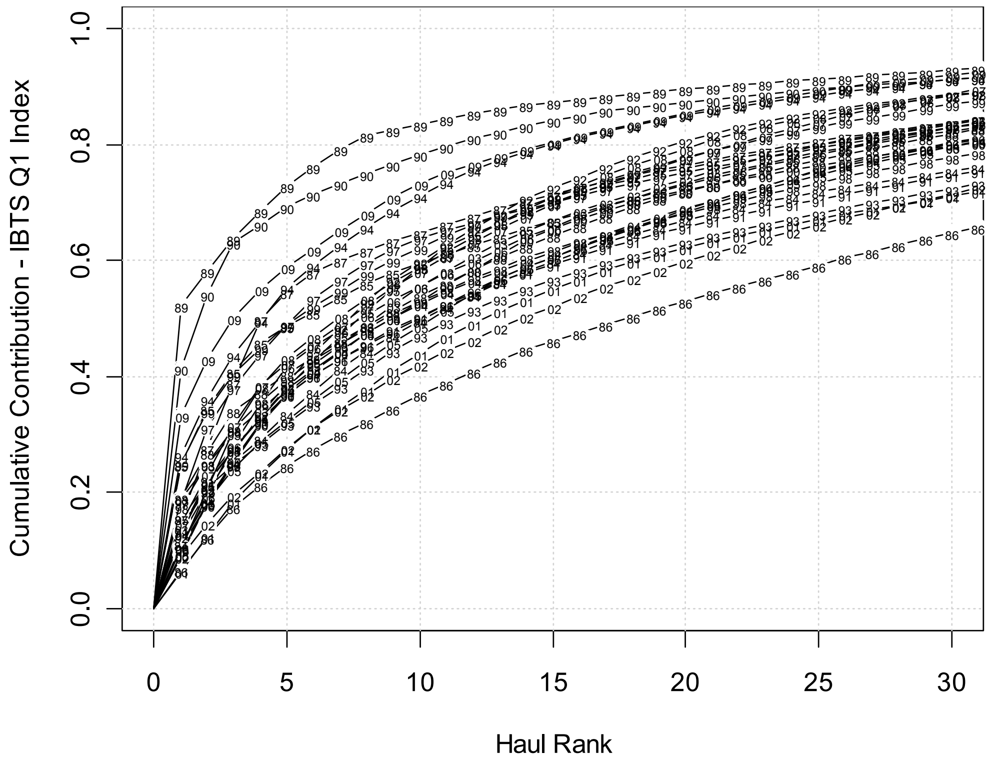


Figure 8. North Sea sprat. Cumulative distribution of the per-haul contribution to the total IBTS Q1 index. The 300–450 individual-haul contributions to the IBTS index in each year are sorted by size then aggregated to calculate a cumulative-distribution. The plot shows only the contributions for the 30 largest hauls. Numbers on each line indicate the year for the survey.

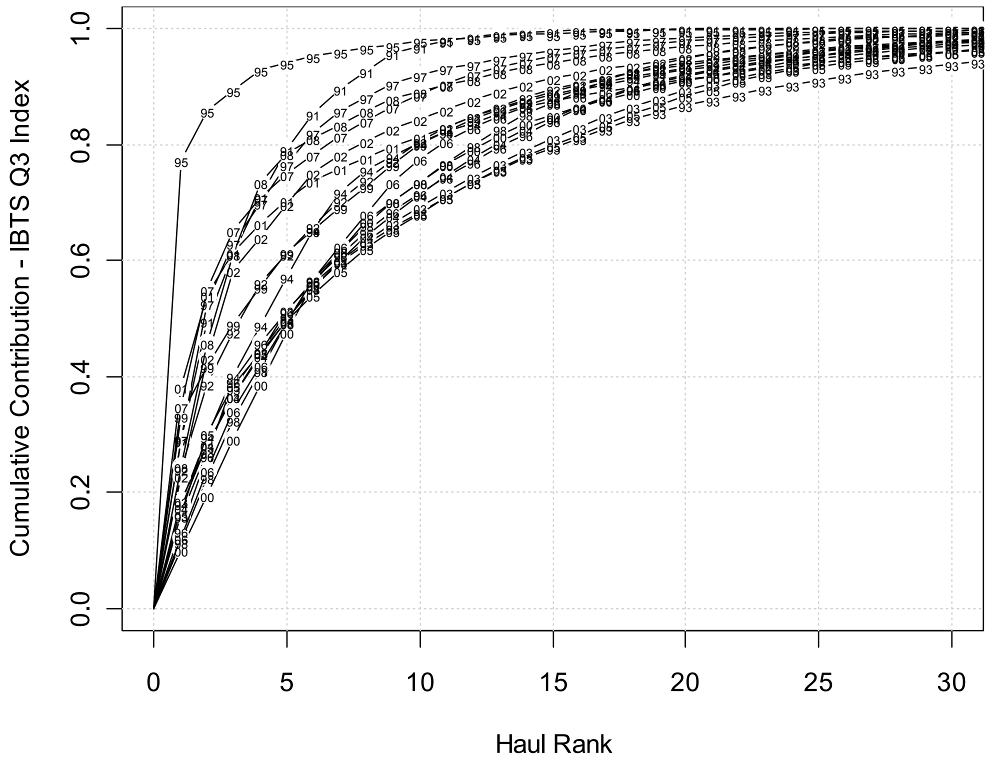


Figure 9. North Sea sprat. Cumulative distribution of the per-haul contribution to the total IBTS Q3 index. The 300–450 individual-haul contributions to the IBTS index in each year are sorted by size then aggregated to calculate a cumulative-distribution. The plot shows only the contributions for the 30 largest hauls. Numbers on each line indicate the year for the survey.

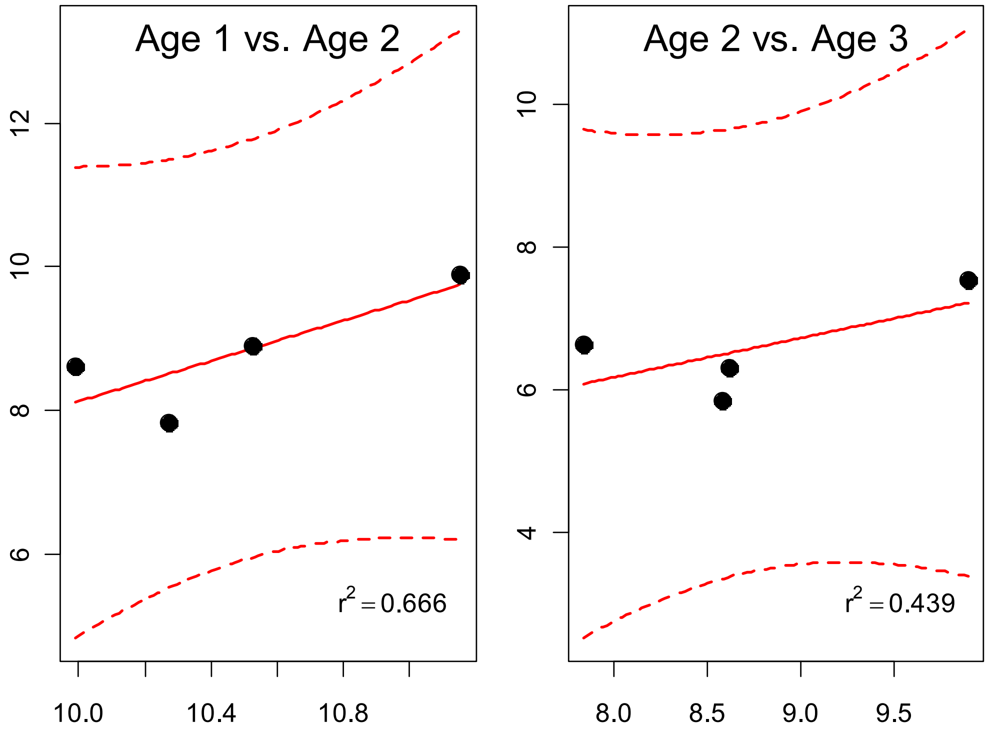


Figure 10. North Sea sprat. Internal consistency analysis from the herring acoustic survey, HERAS. Each panel plots, on a log scale, the abundance of a cohort perceived at a given age (horizontal axis) against the abundance of the same cohort as perceived one year later (vertical axis). The coefficient of determination (r_2) is given in the lower-right corner and is based upon log-transformed values. The title of each panel gives the ages plotted, with the first age plotted on the horizontal axis and the second on the vertical. Neither correlation is statistically significant at the 95% level.

7 Recommendations

STOCK	RECOMMENDATION	FOR FOLLOW UP BY:
Capelin in Subareas I and II, excluding Division IIa west of 5°W (Barents Sea capelin)	WKSHORT recommends work on the impact from harp seals and interactions with herring.	AFWG
Capelin in Subareas V, XIV and Division IIa west of 5˚W	WKSHORT recommends calculatING the confidence intervals for the acoustic surveys by bootstrapping. The data required should be available for the last 10–15 years if not longer.	NWWG
Capelin in Subareas V, XIV and Division IIa west of 5˚W	WKSHORT recommends redoing the regressions between acoustic survey indices and "back calculated" numbers in the stock using higher values of natural mortality.	NWWG
Capelin in Subareas V, XIV and Division IIa west of 5˚W	WKSHORT recommends further investigation on the nonzero intercept in regressions between measured numbers of immature capelin and back calculated number of mature capelin of the same year class the following year.	NWWG
Capelin in Subareas V, XIV and Division IIa west of 5˚W	WKSHORT recommends comparing measured and back calculated immature capelin at age 2.	NWWG
Capelin in Subareas V, XIV and Division IIa west of 5˚W	WKSHORT recommends estimating predation on capelin by cod, other demersal fish and marine mammals from the January–February survey until spawning in March (see Section 4.14).	NWWG
Capelin in Subareas V, XIV and Division IIa west of 5˚W	WKSHORT recommends further investigation on the use of an age and maturity stage disaggregated population model to replace the series of regression models (see Section 4.14).	NWWG
Capelin in Subareas V, XIV and Division IIa west of 5˚W	WKSHORT recommends further investigation on candidate measures of how much capelin spawned.	NWWG
Anchovy in the Bay of Biscay (Subarea VIII)	WKSHORT recommends investigating the use of more informative priors for some of the parameters in the BBM model (see Section 5.14).	WGANSA
Anchovy in the Bay of Biscay (Subarea VIII)	WKSHORT recommends investigating the origins of retrospective pattern in most recent SSB estimate and using simulated data to investigate further this pattern (see Section 5.14).	WGANSA
Anchovy in the Bay of Biscay (Subarea VIII)	WKSHORT recommends that SSB estimation from the DEPM should be revised accordingly to the new estimates of spawning frequency and a thorough investigation should be carried out to examine the impact of this revision on stock assessment output, particularly in the determination of SSB_{lim}.	WGANSA
Anchovy in the Bay of Biscay (Subarea VIII)	WKSHORT recommends using other models for exploratory analysis of the sensitivity analysis of different parameters (e.g. Qs and M) used with the BBM model (see 5.14).	WGANSA

STOCK	RECOMMENDATION	FOR FOLLOW UP BY:
Anchovy in the Bay of Biscay (Subarea VIII)	WKSHORT recommends exploring further the discrepancies between acoustic and DEPM indices (especially in years with big discrepancies such as 2000 and 2002), by going to the source and trying to explain them (see 5.14).	WGANSA
Anchovy in the Bay of Biscay (Subarea VIII)	WKSHORT recommends that recruitment surveys on Juveniles should be continued and the use of recruitment survey index in the prediction of abundance of age 1 anchovies in the coming year should be tested.	WGANSA, Spain, France
Anchovy in the Bay of Biscay (Subarea VIII)	WKSHORT recommends that effort should be made to investigate the relationship between anchovy recruitment and environmental variables.	WGANSA
Anchovy in the Bay of Biscay (Subarea VIII)	WKSHORT recommended investigating for some potential changes in natural mortality which may explain why the stock has not recovered. The fact biomass has been remaining at low levels despite the closure of the fishery in 2005 has remained unexplained so far.	WGANSA
Sprat in Subarea IV (North Sea)	WKSHORT therefore recommends that the North Sea sprat stock is managed as a low data stock until sufficiently reliable information is available	ACOM leadership
Sprat in Subarea IV (North Sea)	WKSHORT recommends that the coverage of North Sea sprat by the HERAS survey is continued. The Working Group believes that this survey offers the best potential source of information regarding the status of the stock; continuation of this time-series is therefore highly desirable.	PGIPS
Sprat in Subarea IV (North Sea)	The current method used in the ICES DATRAS database to produce the IBTS indices of abundance is inappropriate to the North Sea stock. This survey, however, represents the best currently available data source. As a starting point for future work, the Working Group recommends analysis of the IBTS survey data in a qualitative manner, including the examination of presence and absence measures and area occupied. Further quantitative analyses should focus on accounting for the statistical nature of the IBTS catches, in particular for both the large number of zeros and also large individual hauls.	HAWG
Sprat in Subarea IV (North Sea)	Recent work by WKSHORT and other groups has identified a possible mismatch between the stock definition applied in the management of North Sea sprat and the realized distribution of sprat. Further investigation, including the application of genetic techniques, is required to understand the significance of this issue and the relationship between sprat in the North Sea, the English Channel, Skagerrak and Kattegat.	Countries incolved in North Sea sprat research, HAWG

Stock	Recommendation	For follow up by:
Sprat in Subarea IV (North Sea)	The ability of acoustic surveys to separate herring and sprat is currently unclear. Inter-comparisons between vessels have previously raised questions regarding the consistent estimation of sprat abundance (e.g. ICES PGHERS 2006). WKSHORT asks that the Planning Group for International Pelagic Surveys (PGIPS) assess the quality of the HERAS sprat indices, including the calculation of confidence intervals around the estimated abundance.	PGIPS
Sprat in Subarea IV (North Sea)	WKSHORT asks WGSAM to attempt to generate an estimate of predation on sprat in the North Sea based on stomach content data and predator food requirements.	WGSAM
Sprat in Subarea IV (North Sea)	WKSHORT asks that the ICES Working Group on Seabird Ecology (WGSE) evaluate the contribution of sprat in the diet of seabirds and, if possible, present time-series that might indicate changes in North Sea sprat abundance.	WGSE
Sprat in Subarea IV (North Sea)	WKSHORT is unclear as to whether the age reading of sprat otoliths can be achieved with sufficient accuracy and precision for generation of age-structured data. Given that there has not been an age-reading comparison for this stock since 2004, the Working Group therefore recommends the formation of a workshop with the aims of reviewing past work, investigating new techniques for age reading and answering this important and unresolved question.	PGCCDBS
Sprat in Subarea IV (North Sea)	The Working Group finds that knowledge is weak regarding the vertical migration behaviour of the stock. This phenomenon has important consequences for the catchability of the IBTS survey and the resulting indices. More scientific investigations on this issue are therefore warranted.	Countries incolved in North Sea sprat research, HAWG

7.1 Improving the Benchmark Review Process

The WKSHORT participants recognize that this is only the fourth benchmark review to have taken place under the new ICES guidelines. As such, we would like to offer a number of observations and recommendations that may improve the process in the future.

For future benchmark workshops to be more effective there should be a clear understanding among all participants as to the goals of each Benchmark Workshop. This must be done well in advance of the workshop to allow adequate time for preparation. There was palpable confusion among the workshop participants as to the purpose of the Workshop. Several of the stock assessment teams focused their preparation and presentations on potential future improvements to assessment methodology, rather than presenting a full description of the current methodology. This made it difficult to achieve the main goal of the workshop: an evaluation of the appropriateness of the data and methods used in the current assessment.

It is recommended that consideration be given to making the benchmarking process an iterative process, involving more than one meeting, as is currently done in a number of other fisheries forums. At the WKSHORT, the stock assessment teams stated that they did not have time during their regularly scheduled assessment meetings to discuss and test new methodologies, as completing updates took up the allotted time. Ultimately, they wanted new, dedicated meeting time set aside specifically for brainstorming and incorporating new data sources and assessment approaches many possible improvements to assessment methods were suggested. In fact, that's what many of the stock assessment scientists in attendance thought was the purpose of this meeting. We suggest that an iterative process possibly be adopted, which would allow this to take place, before the peer review stage.

It is recommended that Benchmark Workshops are designed to allow sufficient time to allow for information transfer among participants. During the WKSHORT, four species were peer reviewed in five days. This proved to be an insufficient amount of time to complete the tasks at hand thoroughly. While benchmark workshops are designed to review stock annexes, they also provide tremendous opportunities for information transfer. Stock assessment teams can learn from each other and from the external reviewers.

It is recommended that all stock assessment teams be required to make critical background documents available to the workshop participants a minimum of two weeks prior to the Benchmark Workshop. It is most important that these documents contain sufficient detail. A critical component of a successful peer review process is the availability of suitable background materials with sufficient time for their review. In the case of the WKSHORT, many key documents were made available only days in advance of the meeting. Several documents became available the first day of the meeting. As a result, the external reviewers were not able to be fully prepared coming into the meeting.

Annex 1: Terms of Reference

WKSHORT

2008/2/ACOM34 A **Benchmark Workshop on Short-lived species** (Chair: Jim Berkson (USA) and ICES coordinator Harald Gjøsaeter (Norway)) will be established and will meet 31 August–4 September 2009 in Bergen, Norway to:

a) Evaluate the appropriateness of data and methods to determine stock status and investigate methods for short-term outlook taking agreed or proposed management plans into account for the stocks listed in the Text Table below. The evaluation shall include consideration of fishery-dependent, fishery-independent, and life-history data currently being collected for use in the current assessment work and the proposed assessment. Special attention shall be paid to methods for estimating spawning-stock biomass from survey results;

b) Agree and document preferred method for evaluating stock status and (where applicable) short-term outlook and update the assessment handbooks as appropriate;

c) Develop recommendations for future improving assessment methodology and data collection;

d) As part of the evaluation:

   i) consider the possible inclusion of environmental drivers for stock dynamics in the assessments and outlook;

   ii) evaluate the role of stock identity and migration;

   iii) evaluate the role of multispecies interactions on the assessments.

STOCK	ASSESSMENT LEAD
Barents Sea Capelin	Sigurd Tjelmeland
Icelandic Capelin	Asta Gudmundsdóttir
Bay of Biscay Anchovy	Andrés Uriarte
North Sea sprat	Mark Payne

The Benchmark Workshop will report for the attention of ACOM by 15 September 2009.

Annex 2: Agenda

		AUG 31–SEPT 4, 2009			WEEK 36
	Monday	Tuesday	Wednesday	Thursday	Friday
	31	Sept 01	02	03	04
	Day 1	Day 2	Day 3	Day4	Day 5
9 am		Barents Sea Capelin: data and methods presentation (Sigurd) + discussion	Plenary session: Sum up from yesterday (Jim)	Report writing (stock section and stock annex)	Plenary session: Report Barents Sea Capelin
10 am	Opening (Jim); Round Table;	Icelandic Capelin: data and methods presentation (Asta) + discussion	Working session: data and methods scrutiny		Plenary session: Report Icelandic Capelin
	Practicalities (Harald) Adoption of the agenda + timetable (Jim)	Icelandic Capelin: data and methods presentation (Asta) + discussion			
11am	Coffee break	Coffee break	Coffee break	Coffee break	Coffee break
	WKSHORT ToRs (Jim)	Icelandic Capelin: data and methods presentation (Asta) + discussion (cont.)	Working session: data and methods scrutiny	Report writing (stock section and stock annex)	Plenary: Report Bay of Biscay Anchovy
12 pm	Barents Sea Capelin: background presentation (Sigurd) + discussion	Lunch	Lunch	Lunch	Lunch
1 pm	Lunch				
2 pm		Bay of Biscay Anchovy: data and methods presentation (Andrés) + discussion	Plenary: Sum up (Jim)	Report writing (stock section and stock annex)	Plenary session: Report Bay of Biscay Anchovy
3 pm	Icelandic Capelin: background presentation (Asta) + discussion		Working session: data and methods scrutiny		Plenary session: Recommendations and other report sections
4 pm	Bay of Biscay Anchovy: background presentation (Andrés) + discussion	Coffee break	Coffee break	Coffee break	Coffee break

	Coffee break	North Sea Sprat: data and methods presentation (Mark) + discussion	Working session: data and methods scrutiny	Report writing (stock section and stock annex)	AOB and Close (at 17:00)
5 pm	North Sea Sprat: background presentation (Mark) + discussion			Plenary session: Report: overview section	
6 pm					

Annex 3: List of participants

NAME	ADDRESS	PHONE/FAX	EMAIL
Pablo Abaunza	Instituto Español de Oceanografía Centro Oceanográfico de Santander PO Box 240 E-39080 Santander Spain	Phone 0034 942 29 1060 Fax 0034 942 275072	pablo.abaunza@st.ieo.es
Jim Berkson Invited Expert and External Chair	National Marine Fisheries Services NMFS RTR Unit at Virginia Tech 114 Cheatham Hall Blacksburg VA 24061-0321 United States	Phone +1 540 231-5910 Fax +1 540 231-7580	jberkson@vt.edu
Höskuldur Bjornsson	Marine Research Institute Skúlagata 4 IS-121 Reykjavík Iceland	Phone +354 575 2000 Fax +354 575 2001	hoski@hafro.is
Bjarte Bogstad	Institute of Marine Research PO Box 1870 N-5817 Bergen Norway	Phone +47 55 23 86 81 Fax +47 55 23 86 87	bjarte.bogstad@imr.no
Aukje Coers	Secretariat Pelagic RAC PO Box 72 2280 AB Rijswijk Netherlands	Phone +31 70 336 9624 Fax +31 70 399 3004	a.coers@pelagic-rac.org
Chris Francis Invited Expert	National Institute of Water and Atmospheric Research Wellington PO Box 14901 Wellington New Zealand	Phone +64 4 386 0525 Fax +64 4 386 0574	c.francis@niwa.co.nz
Christina Frisk	National Institute of Aquatic Resources Jægersborg Allé 1 DK-2920 Charlottenlund Denmark	Phone +45 33963422	cfr@aqau.dtu.dk

Name	Address	Phone/Fax	Email
Bob Furness Invited Expert	Institute of Biomedical and Life Sciences University of Glasgow Graham Kerr Building G12 8QQ Glasgow UK	Phone + 44 141 330 3560 Fax + 44 141 330 5971	r.furness@bio.gla.ac.uk
Miren Garmendia	Federacion de Cofradias de Pescadores de Gipuzkoa Mirakontxa Pasealekua, 9 behean 20007 Donostia Spain	Phone +34 943 451782 Fax +34 943 455833	fecopegui@fecopegui.net
Harald Gjøsæter ICES Convener	Institute of Marine Research PO Box 1870 N-5817 Bergen Norway	Phone +47 55 238417 Cell +47 414 79 177 Fax +47 55 238687	Harald.Gjoesaeter@imr.no
Asta Gudmundsdóttir Stock Assessor, Icelandic capelin	Marine Research Institute Skúlagata 4 IS-121 Reykjavík Iceland	Phone +354-5752001 Fax +354-5752000	asta@hafro.is
Benoît Guerin	CCR-S 6, rue Alphonse Rio 56100 Lorient France	Phone +33 2 97 88 09 40 Fax +33 2 97 83 33 66	bguerin@ccr-s.eu
Leire Ibaibarriaga (by correspondance)	AZTI-Tecnalia Herrera Kaia, Portualde z/g E-20110 Pasaia (Gipuzkoa) Spain	Phone +34 943004800	libaibarriaga@pas.azti.es
Randi Ingvaldsen	Institute of Marine Research PO Box 1870 N-5817 Bergen Norway	Phone +47 55 23 85 96 Fax +47 55 23 85 31	randi.ingvaldsen@imr.no
Yuri A. Kovalev	Knipovich Polar Research Institute of Marine Fisheries and Oceanography 6 Knipovitch Street RU-183763 Murmansk Russian Federation	Phone +7 8152 472 469 Fax +7 8152 473 331	kovalev@pinro.ru

NAME	ADDRESS	PHONE/FAX	EMAIL
Cecilie Kvamme	Institute of Marine Research PO Box 1870 N-5817 Bergen Norway	Phone +47 55 23 69 31 Fax +47 55 23 68 30	cecilie.kvamme@imr.no
Sigrid Lehuta	IFREMER Nantes Centre PO Box 21105 F-44311 Nantes Cédex 03 France	Phone +33 2 40 37 41 65 Fax +33 2 40 37 40 75	sigrid.lehuta@ifremer.fr
Jacques Massé (by correspondance)	IFREMER Nantes Centre PO Box 21105 F-44311 Nantes Cédex 03 France	Phone +33 (0)240374075	jacques.masse@ifremer.fr
Nina Mikkelsen	University of Tromsø NFH C 120 Tromsø Norway	Phone +47 776 46593	nina.mikkelsen@uit.no
Cristina Morgado ICES Secretariat	International Council for the Exploration of the Sea H.C. Andersens Boulevard 44–46 DK-1553 Copenhagen V Denmark	Phone +45 33 38 67 21 Fax +45 33 93 42 15	cristina@ices.dk
Lionel Pawlowski	IFREMER Lorient Station 8 rue François Toullec F-56100 Lorient France	Phone +33 2 97 87 38 46 Fax +33 2 97 87 38 36	lionel.pawlowski@ifremer.fr
Mark Payne Stock Assessor, North Sea sprat	National Institute of Aquatic Resources Section for Fisheries Advice Charlottenlund Slot Jægersborg Alle 1 DK-2920 Charlottenlund Denmark	Phone +45 3396 3474 Fax +45 3396 3333	mpa@aqua.dtu.dk
Jean-Marie Robert	CLPMEM La Turballe Centre Marée BP 71038 44356 La Turballe France	Phone +33 2 40 11 83 55/+33 6 75 02 91 89 Fax +33 2 28 55 95 30	Clpmem.turballe@wanadoo.fr

Name	Address	Phone/Fax	Email
Alexandra Silva	INRB-IPIMAR Avenida de Brasilia PT-1449-006 Lisbon Portugal	Phone +351 21 302 7000 Fax + 351 21 301 59 48	asilva@ipimar.pt
Dankert Skagen	Institute of Marine Research PO Box 1870 N-5817 Bergen Norway	Phone +47 55 238419 Fax +47 55 238687	dankert.skagen@imr.no
Morten D. Skogen	Institute of Marine Research PO Box 1870 N-5817 Bergen Norway	Phone +47 55 23 84 61 Fax +47 55 23 85 31	morten.skogen@imr.no
Sigurd Tjelmeland Stock Assessor, Barents Sea capelin	Institute of Marine Research PO Box 1870 N-5817 Bergen Norway	Phone +47 55 238500 Fax +47 55 238531	sigurd.tjelmeland@imr.no
Andrés Uriarte Stock Assessor, Bay of Biscay anchovy	AZTI-Tecnalia Herrera Kaia, Portualde z/g E-20110 Pasaia (Gipuzkoa) Spain	Phone +34 943004816 / 800	auriarte@pas.azti.es
Yimin Ye Invited Expert	The Food and Agriculture Organization of the United Nations Fishery Management and Conservation Service Viale delle Terme di Caracalla IT-00153 Rome Italy	Phone +39 06 5705 4592 Fax +39 06 5705 3020	Yimin.Ye@fao.org

Annex 4: Working documents

Working Document #**3.1**: The capelin cod interaction in the Barents Sea: possible uses of the Joint IMR PINRO ecosystem survey data. Johannesen, E., Lindstrøm,U.

Working Document #**5.1**: Environmental monitoring using biophysical models and statistical detection procedures: application to the Bay of Biscay. Woillez, M., Petitgas, P., Huret, M.

Working Document #**5.2**: Anchovy Recruitment Mixed Long Series prediction using supervised classification. Fernandes, J.A., Irigoien, X., Uriarte, A., Ibaibarriaga, L., Lozano, J.A., Inza, I.

Working Document #**5.3**: Anchovy assessment in the Bay of Biscay using a two-stage biomass random effects model (BREM). Trenkel, V.

Working Document #**5.4**: Preliminary evaluation of the potential implications of the DEPM revision in the assessment of the Bay of Biscay anchovy under different assumptions on g. Ibaibarriaga, L., Uriarte, A., Santos, M.

Working Document #**5.5**: Inclusion of the 1989 Acoustics data into the assessment of the Bay of Biscay anchovy. Ibaibarriaga, L., Uriarte, A.

Working Document #**5.6**: Overview of a pilot-study of anchovy and sardine "sentinel" surveys in the Bay of Biscay: a partnership between science and industry. Delaunay, D., Massé, J., Pawlowski, L.

Working Document #**5.7**: Overview of the ISIS-Fish fishery simulator applied to the management of the Bay of Biscay anchovy. Lehuta, S., Pawlowski, L.

Working Document #**5.8**: JUVENA 2003-2008 Anchovy juvenile biomass estimates and recruitment prediction capacity. Boyra, G., Martínez, U., Cotano, U., Uriarte, A.

Working Document #**5.9**: Assessing natural mortality of anchovy from the surveys population and biomass estimates: evaluation through a seasonal ICA assessment. Uriarte, A., Ibaibarriaga, L.

Working Document #**5.10**: Bay of Biscay anchovy fishery Updated approximate figures for the fleet and fishing effort displacement. Southwestern Waters Regional Advisory Council.

Working Document #**6.1**: IBTS bottom-trawl survey cpue index for sprat (*Sprattus sprattus*) abundance estimation evaluated by simultaneous acoustic observations. Jansen, T., Verin, V., Payne, M.

Working Document #**6.2**: The assessment of North Sea sprat: Is length structured models a way forward? Analysis of data and runs with the program LCS. Skagen, D.