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Stock Annex: Capelin (*Mallotus villosus*) in subareas 5 and 14 and Division 2.a west of 5°W (Iceland and Faroes grounds, East Greenland, Jan Mayen area)

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Capelin
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A. General

A.1. Stock definition

The capelin is a small pelagic schooling fish. It is a cold-water species that inhabits arctic and subarctic waters in the North Atlantic and North Pacific. Capelin in the Iceland-East Greenland-Jan Mayen area is considered to be a separate stock.

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 pre-spawning fish on or close to the spawning grounds south and west of Iceland. In January 1973 a successful capelin fishery began in deep waters near the shelf break east of Iceland. In 1976 a summer capelin fishery began in the Iceland Sea. This fishery became multinational with vessels from Iceland, Norway, Faroes, and Denmark. In mid 1990s the pelagic trawl was introduced to the capelin fishery. Fishery during winter (January–March) has taken place in all years, with the exception of 1982/1983 and 2008/2009 fishing seasons, when a moratorium was in effect. Until late 1980s the fishery in October–December was much more pronounced than the fishery in June–September, whereas it was the opposite in the 1990s. During the 1990s the fishery in autumn was at low levels and practically no autumn fishery has taken place since 2000. Since the mid-2000s, the summer fishery has only taken place twice and then at a low level.

The fishing season has extended from end of June to March the following year since the mid-1990s. However, when stock size has been estimated to be low the fishing season has started later, or after a survey in October/November, or in January/February after a winter survey.

A regulation calling for immediate, temporary area closures when a high abundance of juveniles is measured in the catch (more than 20% of the catch composed of fish less than 13 cm) is enforced, using on-board observers. In Icelandic waters, fishing with pelagic trawl is only allowed in a limited area off the NE-coast (fishing in January). The area where pelagic trawling is allowed is regulated due to the risk of juvenile bycatch in addition to concerns about mortality and behaviour disturbance associated with capelin passing through the trawl. The use of pelagic trawls in the fishery varies depending on a combination of factors, among them the timing of TAC issuance.

Areas with high abundances of juvenile age 1 and 2 capelin (on the shelf region off NW-, N- and NE-Iceland) have usually been closed to the summer and autumn fishery.

It is permissible to transfer catches from the purse-seine of one vessel to another vessel, in order to avoid slippage. However, if the catches are beyond the carrying capacity of the vessel and no other vessel is nearby, slippage is allowed. In recent years, reporting of such slippage has not been frequent in the logbooks. Industrial trawlers do not have permission to slip capelin, in order to align catch rates to the processing capacity.

In recent years, the fishery has changed from being mostly an industrial fishery to having increased emphasis on fishing for human consumption, especially when abundance and TACs have been low.

The timing and selection of the fishery that leads to the maximum yield (MSY) has not been estimated for IGJM capelin. In the Barents Sea, it has been suggested that MSY from the capelin fishery would be obtained by fishing in autumn; however, a later opening of the fisheries (January 1st) would preserve more capelin for the predators (Hamre and Tjelmeland, 1982; Gjösæter *et al*., 2002).

Research on the ecosystem role and growth of IGJM capelin is much more limited than in the Barents Sea but the ecosystem role of capelin is likely to be similar in both areas.

A.3. Ecosystem aspects

A.3.1. Spatio-temporal distribution (spawning, nursery, feeding)

IGJM capelin are demersal spawners that deposit their eggs on fine gravel at 10–150 m depth (Vilhjálmsson, 1994). The main spawning areas are off the southeast, south and west coast of Iceland (Figure A.3.1). Other spawning areas, such as off the north coast, are of less importance. Spawning peaks in March in the main spawning areas but somewhat later (April) elsewhere. The larvae hatch after approximately three weeks and drift toward the nursery areas.

Most juveniles are found on or close to the continental shelf. Until early 2000s, the nursery areas were located northwest, north and northeast of Iceland, and on the East Greenland plateau, west of the Denmark Strait. Since the early 2000s, the nursery areas have expanded to colder waters near east Greenland, however, juveniles are still found in the western part of their old nursery area in Icelandic waters.

Maturing capelin usually undertakes extensive migrations in spring and summer to the feeding areas north of the nursery areas. The summer–autumn distribution of the maturing stock has, like that of the juveniles, shifted west since the early 2000s. Southern return migration in September–October leads the adults to the shelf edge off the northwest Iceland where they are found in November. They are also found north and northeast of Iceland in some years.

The southward spawning migration starts in December/January. The migration routes follow 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, while late arrivals spawn further east at the southeast and south coast. Only a small proportion survives spawning (Carscadden and Vilhjálmsson, 2002).

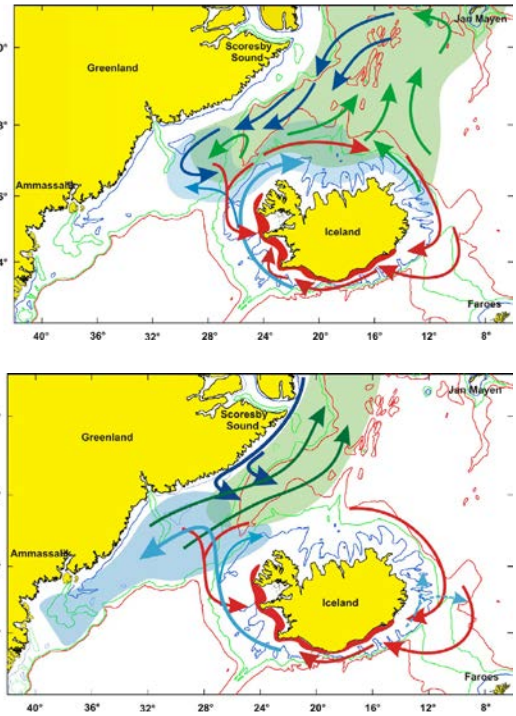

Figure A.3.1. Distribution and migration of IGJM capelin. Historical until early 2000s (top) and since early 2000s (below). Red areas: spawning grounds. Blue areas: Nursery areas. Green area: Feeding area for the maturing capelin. Green arrows indicate the adult feeding migrations, blue arrows indicate return migration from feeding areas to overwintering areas, and red arrows indicate the spawning migrations (From Carscadden et al., 2013).

The observed shift in distribution and migration patterns in the early 2000s took place during a period of environmental changes observed since the mid-1990s. Temperature and salinity have increased during that period southwest of Iceland, with a temperature increase of one degree or more (Figure A.3.2). Temperature and salinity have been about or above the mean during the last two decades, except for the most recent years that were slightly colder (Hafro, 2014).

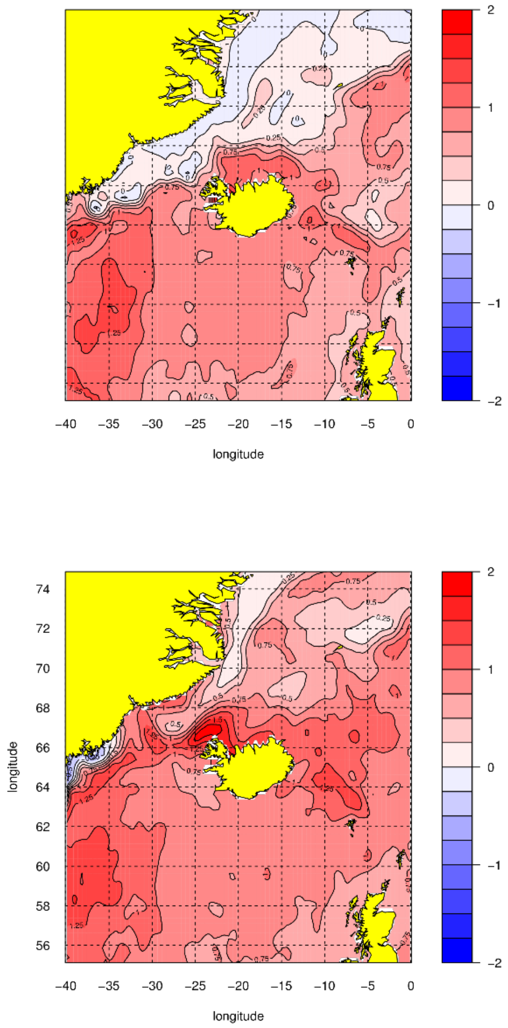

Figure A.3.2. Difference between Reynolds Optimum Interpolation Sea Surface Temperature in 1982–1999 and 2000–2014, in January (top) and October (bottom) in the IGJM habitat. (Reynolds, 2007, data from ftp://eclipse.ncdc.noaa.gov/pub/OI-daily-v2/ **in December 2014 and January 2015).**

A.3.2. Fecundity

Capelin reaches maturity-at-age 2–4. The main part of each year class matures and spawns at age 3 (Figure A.3.1). The remainder of the year class spawns at age 4. On occasion a small contribution to the SSB from age group 2 has been observed but only negligible from age group 5. Spawning mortality is believed to be very high.

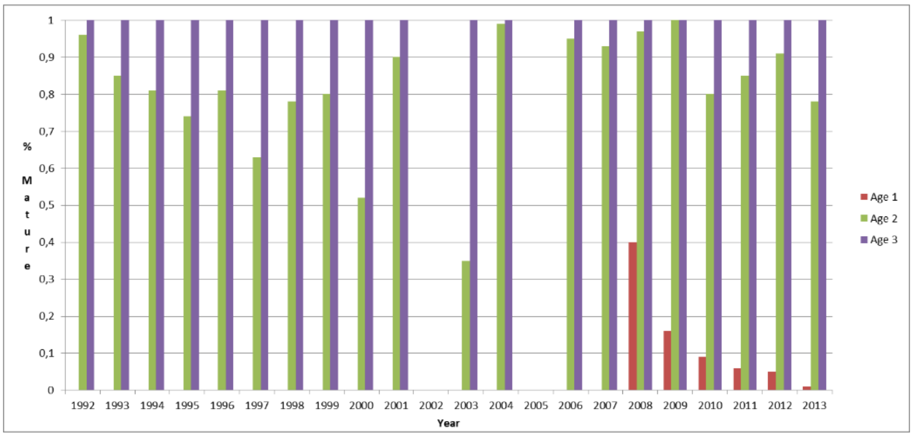

Figure A.3.1. Time-series of maturity ogives for capelin age classes 1, 2 and 3 (on autumn surveys).

A.3.3. Diet

Capelin is a planktivore that mainly eat copepods, euphausiids and amphipods (see overview in Vilhjálmsson, 1994; Gjøsæter, 1998; Carscadden *et al*., 2001). Generally, the importance of copepods decreases with capelin size and that of euphausiids and amphipods increases. On the feeding grounds north of Iceland, euphausiids were estimated to constitute between 74% and 90% of the capelin diet (in weight) (Vilhjálmsson, 1994; Trenkel *et al*., 2014). The main copepod species eaten by small larval and juvenile capelin is *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

Capelin is a very important forage species in the ecosystems of Greenland and Iceland. 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 (Vilhjálmsson, 2002).

B. Data

B.1. Commercial catch

The stock is shared between Iceland, Norway and Greenland according to a management plan agreed by the parties in 2003. The Faroe Islands participates in the fishery through an annual bilateral agreement with Iceland and the EU participates in the fishery through an annual bilateral agreement with Greenland. The vast majority of catches are landed at Icelandic harbours; however in some year capelin might also be landed in Norwegian or EU harbours.

B.1.1. Landings

Information about landings in the fishery is collected by the Icelandic Directorate of Fisheries which has access to both landing figures in the Icelandic ports (the official landing) and the recorded catch in the digital logbook kept by all Icelandic vessels. The logbooks contain 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.

B.1.2. Discards

The Icelandic legislation allows for slipping in those cases where the catches are beyond the carrying capacity of the vessel and none nearby vessels are able to take the surplus quantity on board. The practice of transferring catches from the purse-seine of one vessel to another vessel is a long-standing tradition, and since skippers of purse-seine vessels generally operate in groups due to the behaviour of the fish, discards are practically zero. In the pelagic trawl fishery, such large catches of capelin rarely occur.

B.2. Biological information

Biological samples from the catch are taken at sea by the fishermen, in the ports by the Marine Research Institute in Iceland (MRI) or inspectors from the Icelandic Directorate of Fisheries. The samples are analysed at MRI (fish length, weight, age (from otoliths), sex, maturation, and gonad weight). 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. Similar programmes are conducted by other participants in the fishery to a varying extent, sometimes providing catches in numbers; e.g. IMR Norway.

For biological data on survey, see B3.2.

B.3. Surveys

Acoustic surveys have been conducted in late autumn (October–December) in 1978–2009, in early autumn (September–October) since 2010 and in winter (January–February) since 1979.

The surveys in autumn have a dual purpose, aimed at covering both the immature and the mature part of the stock. Until 2010 the survey covered the shelf west, north and northeast of Iceland. Since 2010, it has been expanded to cover the shift in capelin distribution on the continental shelf of East Greenland (to 73°N in 2013), the Denmark Strait and the continental slope north off Iceland. The survey area varies and has often been influenced by drift ice conditions in the Denmark Strait-East Greenland-NW Iceland area. The surveys were therefore shifted forward since 2010 (starting soon after the middle of September; an exception occurred in autumn 2011 when the survey was postponed because of a strike). The shift in timing and spatial coverage from 2010 therefore, to some extent, initiated a new time-series. The indices of immature capelin are used to predict an expected catch for the fishing season starting in the year after the surveys are conducted. The estimate of the maturing stock is used to set an intermediate TAC, sometimes revising an already set initial TAC.

The winter surveys in January–March target the spawning migration. 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. The purpose of these surveys is to assess the size of the spawning stock and on its basis to set a final TAC for the rest of the season. The stock, or parts of it, has often been covered repeatedly (up to four times e.g. in 2008 and 2009) in the area along the shelf break N and E of Iceland. Sometimes the surveys are continued onto the shelf in shallow areas, however data from those areas are not used for assessment purposes due to lack of knowledge of target strength

(TS) in shallow waters, and the acoustic dead-zones near the bottom and surface as well as uncovered shallow areas where the vessel cannot navigate safely.

The acoustic surveys have often been complemented with scouting surveys by commercial vessels. In 2009 calibrated commercial vessels measured the stock in the area off NE-Iceland. Furthermore, the 2011 winter estimate of SSB was based in part on data from a commercial vessel (but in the nearshore area and therefore not covered here, see above).

B.3.1. Acoustic data

The two-dimensional distribution of backscattering energy is measured in Nautical Area Scattering Coefficient (NASC) or sA (Maclennan, Fernandes and Dalen, 2002). Along track registrations are generally averaged over the so called elementary distance sampling unit (EDSU). The EDSU size was 1 nmi in the years up to 2010 where the BI500 post-processing software was used. Since 2011 LSSS has been used with an EDSU of 0.1 nmi, except for a few cases where the EchoView has been applied on 0.2 nmi EDSUs.

The average NASC in each 'rectangle' in a grid covering the surveyed area are calculated. The rectangles used for the winter surveys measure 15′ latitude by 30′ longitude (quarter of an ICES statistical rectangle). In autumn they measure 30′ latitude by 1° longitude due to the wider distribution of the stock in autumn, and to avoid autocorrelation in NASC averages for the smaller rectangles. The Echo Abundance (EA) of a rectangle equals the product of mean NASC and the area of the rectangle. The EA of partly covered rectangles are reduced (from sailed distance or judgment of survey experts, depending on the situation).

During the survey, biological samples are collected from trawl catches on stations targeted on IGJM capelin generally numbering 100 individuals. All fish are aged and maturity staged, and in the estimation process described below, empirical values are used throughout. Maturity staging has been uncertain on a few occasions and knife edge maturity at a given length has been assumed.

B.3.2. Bootstrap treatment of survey data

The HCR bootstrap replicates use the survey estimates of SSB and the number of immature capelin. A stratified bootstrap of echo abundance by rectangle, trawl station and fish in samples has been performed, which might be simplified by omitting the resampling the fish samples. A short description of the method is given below:

Simple bootstrap: By simple we mean unstratified, which may or may not be an adequate approach. Rectangle EA values and trawl stations are bootstrapped in parallel and are assumed independent of each other. Further, for each bootstrap realization of a trawl station the individual fish on the station are bootstrapped as well, an approach similar to that taken in studies of sampling levels from landings and surveys and their effects on assessment results. For each bootstrap sample of EA values, trawl stations and fish in sample, an SSB and other stock parameters of interest are estimated.

Stratified bootstrap: In order to capture structure that may be present in the capelin population/distribution, stratification is introduced. We implement a post-stratification based mainly on the proportion mature. This choice is made because the split between SSB and the immature part of the stock is of primary interest, generally in autumn and can also be important in parts of the distribution area in winter. For each area we generate bootstrap replicates in the same way as for the whole as described above. Necessary components from the defined strata are then combined in order to produce overall parameters of interest, primarily SSB and number of immature capelin in autumn.

B.4. Commercial cpue

Data on a haul by haul basis are available from logbooks. However cpue is not used in the assessment as it is not considered a reliable indicator of stock size due to among other things the schooling behaviour of the species.

B.5. Other relevant data

Projected predator (cod, haddock and saithe) stock sizes from (Hafró/NWWG) assessments, predator distributions from Icelandic Groundfish Survey (IGFS) data.

Surveying outside the main survey periods has been undertaken through the years:

B.5.1. Surveys in summer

Surveys on 0-group and 1-group in August discontinued in 2003 (ICES 2009a). The survey was aimed at 0-group fish in general and had been conducted since the early 1970s. The indices for young capelin were used in a model to predict quota for the next fishing season. The results from the model were too optimistic and in the early 1990s the model was dismissed.

B.5.2. Oceanography/ecology surveys

In July 2006 a multidisciplinary project began (oceanography/ecology) covering the area from Ammassalik in the west to about 10°W east of Iceland as well as the Iceland Sea north to 71–72°N. One of the main purposes of this project is to study the distribution, behaviour and feeding habits of all age groups of capelin in spring and summer.

C. Assessment: data and method

WKICE endorsed using 150 kt as B_{lim} (never before set for this stock). B_{lim} was set at B_{loss} as the recruitments that were generated by SSB around B_{loss} (yc 90,81 and 82) were of average strength and the S–R diagram showed that recruitment did not decline at the lowest observed stock sizes.

WKICE adopted the stochastic HCR described below. This HCR was adapted from the one for Barents Sea capelin. A new method for setting an initial/preliminary quota was also developed during the benchmark meeting.

The application of the new HCRs following acoustic assessment surveys are given below:

Following acoustic survey in winter (January–February)

Bootstrap replications of survey estimates of SSB are used in combination with predicted predator stocks from NWWG assessments in the previous year (cod, haddock, saithe). Predator distributions are sampled from observed distributions in the March survey and fed into a predation model run with varying catches until spawning in late March. The **Final TAC** is set at catch giving p(SSB $<B_{lim}$ = 150 kt) <0.05.

Following acoustic survey in autumn (September–October)

a) For the mature/maturing part of the stock (for the current season)

Bootstrap replicates of survey estimates of SSB are updated based on revised assumptions about growth, mortality, etc. Additional uncertainty is included due to variable mortality and fed into the predation model with same supporting data as when applied to winter survey results. The **Intermediate TAC** is set at catch giving p(SSB <B_{lim} = 150 kt) <0.05.

b) Based on estimates for the immature part of the stock (for the next fishing season)

Numbers of immature capelin in autumn ($U_{trigger}$) are input to a simple model estimating catch based on point estimates and assumed mortality, growth and CV in estimated numbers. The trigger is set at 50 billion and cap on a preliminary TAC at 400 kt.

New survey results can overwrite previous TACs. The final TAC will take account of both the autumn and winter surveys, down-weighting autumn results. Discrepancies (such as later surveys indicating lower stock) will be addressed on an as needed basis in the application of the new HCR suite.

The model

The assessment method is similar to the one used in the Barents Sea; i.e. stochastic projection of the stock starting from acoustic measurements, and finding the TAC that leads to SSB <B_{lim} = 5%. The uncertainty in the acoustic measurements is estimated by bootstrapping (see B.3). The bootstrap returns 10 000 stochastic replicates, each of which is run through the stochastic predation model (see A.3.4).

Predation model

Processes being addressed by the model

Capelin spend most of their life in the cold water north and east of the Iceland and between Greenland and Iceland but the main spawning areas are south and west of Iceland where the capelin spawn in March. The traditional migration route to the spawning grounds is deep east of Iceland and west along the south coast. During their migration to the spawning areas capelin often stop for some time near the boundary between the warm and cold water southeast of Iceland, until the roes/gonads have matured enough to enter the warm sea and start the final trip to the spawning areas. This final trip seems to take relatively short time (three weeks) and the distance covered is 120–350 nautical miles depending on where the capelin spawn. Cod, which is the most important predator of capelin also spawns south of Iceland, migrating both the western and eastern route to the spawning areas. Immature cod is more stationary. Other predators included in the model are haddock and saithe.

As can be seen above things are changing rapidly in the period January–March with large proportion of the fishes migrating towards the spawning areas south and west of Iceland.

Data used in the model

Available data on interactions between capelin and its main predators in the period January–March are:

- Acoustic measurements of capelin in January–February.
- Landings of capelin by day 1982–2014.
- Location of catches in 1993–2014 and by statistical squares in 1982–1993.

- Spatial distribution of demersal fishes from the groundfish survey in March 1985–2014.
- Stomach samples of cod from the groundfish survey in March 1985–2014 and from haddock 1992 and 2005–2014 and from number of other demersal fishes in 1992.
- Stomach samples collected from demersal trawl contemporary with the acoustic surveys in January 1993 and 1994.
- Stomach samples from fishing vessels since 2002.

Assumptions on spatial and temporal overlap between capelin and its predators

The proportion of fish predators inhabiting the different areas along the capelin migration route is obtained from the groundfish survey in March. There may be some change in distribution from January to March as some of the mature fish may migrate to the spawning areas so the distribution in March may be underestimating the proportion of cod and other predators east of Iceland. The area crossed and time spent in it by the eastern capelin migration is divided into three parts (Figure C.1).

- Eastern Area: six weeks (January 15th–March 1st).
- Southern Area: six weeks (February 1st–March 15th)
- Western Area: four weeks (February 15th–March 15th).

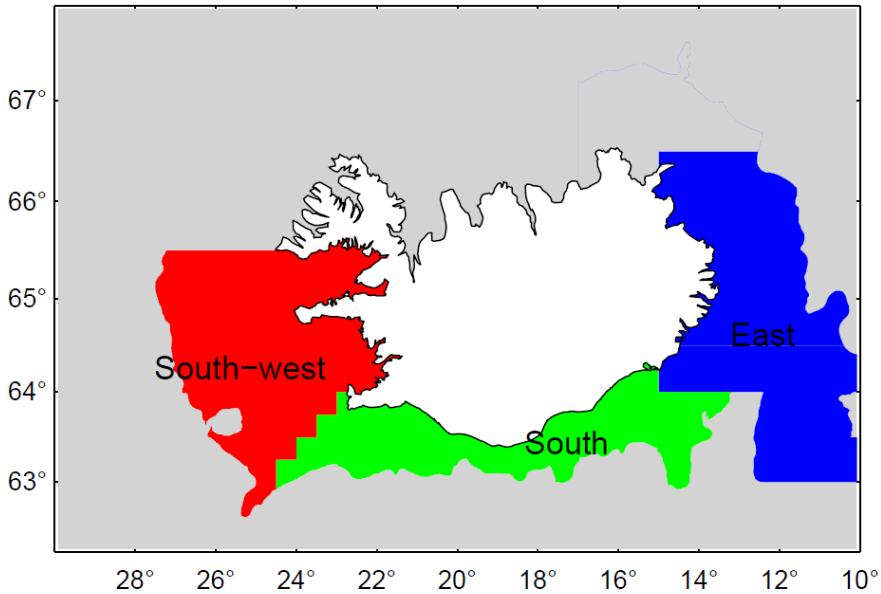

Figure C.1. The three regions used in the simulations of predation on capelin migrating through the eastern part of the Icelandic shelf.

The predators in each area are assumed to be able to prey on capelin in the time periods specified above. Proportion of the survey biomass index in each of the areas is calculated for each predator and is used as a measure of the proportion of the predator in that area. This proportion is then multiplied by total biomass of the predator from the assessment giving an estimate of the total predator biomass in the area. In the March survey the measurement error is highest for saithe which also has the largest variability of the survey distribution and therefore biomass. Cod is however by far the most important predator of capelin of the three species included in the model.

Predation mortality

Feeding is modelled using the type II feeding function below:

$$C_{pred,area} = B_{pred,area} \frac{C_{max,pred,T}\, B_{prey}}{B_{half} + B_{prey,area}}$$

The equation above is a special case for one prey, and is taken as a good approximation for predation on capelin in January–March when capelin is the dominating prey in the area.

Here B refers to biomass and C to consumption. $C_{max,pred,T}$ is called maximum consumption, theoretically the amount that the predator will eat if it is fed to satiation. Values for cod in fish farming are obtained from an equation from Jobling (1988) that indicates that capelin eat over 50% of their body weight at a temperature around three degrees, typical for the eastern area, increasing by approximately 10% for every degree. This value is unrealistic for wild populations as the prey will always be difficult to access compared to fish in captivity. B_{half} is called half feeding value and is the value where the predator eats half the maximum $C_{max,pred,T}$. B_{half} depends on the spatial overlap between predator and prey and is in each case also dependent on the spatial disaggregation used.

Setting appropriate values for the parameters $C_{max,pred,T}$ and B_{half} is not straightforward. Here the values are based on available stomach samples (see above) and consumption is based on the evacuation rate model by Magnusson and Palsson (1989). In the tables below the range of the parameters (maximum consumption and half feeding values) used in the simulations is presented:

Predator	Maximum consumption (Cmax,pred,T)
Cod	20–40% of body weight per month
Haddock	5–20% of body weight per month
Saithe	20–40% of body weight per month

Area	Half feeding values (Bhalf)
Eastern area	300–600 thous. Tonnes
Southern area	100–200 thous. Tonnes
Western area	100–200 thous. Tonnes

Half feeding values in the southern and western areas are lower than in the eastern area, due to smaller area inhabited by capelin in the south. The capelin are also more easily captured by demersal predators when it approaches spawning areas. The above range of values are supposed to cover interannual variability as well as uncertainty in the parameters but the overlap of capelin and cod varies from year to year, depending on the exact time of overlap and distribution of cod and capelin within the areas.

As discussed above the parameters in the feeding function are dependent on the spatial disaggregation used, the exact timing of the migrations and the spatial distribution of the predators within the areas. Variability of the parameters is obtained by randomly selecting the predation parameters in the feeding function from a uniform distribution.

Timing and location of catches

In many years relatively large proportion of the capelin stock is caught, reducing the amount of capelin available for predators. Normally the main bulk of the catches is taken from February 1st to March 15th. In the period 1993–2013 average landings per year were 68 kt in January, 240 kt in February and 162 kt in March. Additionally 75% of the landings are taken after February 10th (60% from February 10th to March 10th). Majority of the catch in the winter season after the January acoustic measurements is taken in the southern and south-western area (Figure 4) or 65% and 25% respectively.

Bootstrap model

Acoustic measurements in January are the main indicator of capelin stock size. Results from them are given as bootstrap replicates where each bootstrap replicate is treated as if it represents the true capelin stock (see B.3).

Each bootstrap replicate is then run through a predation model as outlined above. Some of the parameters in the predation model are stochastic and are selected randomly in each run.

- The final capelin advice is given in January so the spatial distribution of predator stocks in the advisory year is not available. Therefore the spatial distribution of the predator stocks (cod, haddock and saithe) is set by randomly selecting proportions for each of the three areas in the March survey since 1985.
- The stock size of the predator stocks is based on the prediction from last year´s advice. Bootstrap replicates are generated by assuming the uncertainty in stock size is lognormal with a CV of 0.15 for cod and haddock but 0.2 for saithe. The biomass in each area is the total stock size multiplied by the proportions from the survey.
- Maximum consumption ($C_{max,pred,T}$) and half feeding (B_{half}) values are from a uniform random distribution as described above.

Predation per area is calculated independently for the three areas: east, south and southwest. In the model 10% of the catches are assumed to be taken in the eastern area between 15 January and 1 February, 65% of the catches in the southern area between 1 February and 15 March, and the remaining 25% in the southwestern area between 15 February and15 March.

Order of calculations in the predation model

The model starts with all capelin being in the eastern area on 15 January and ends with all capelin in the southern and south-western area on 15 March where they spawn. The length of each time-step is two weeks; i.e. four time-steps. An example of the output from the model is shown in Figure C.2.

Area	Period	Catches	Consumption	Migration
East	six Weeks	10%		
	15 January–1 February	Subtract 10% of the catches from the stock	Calculate consumption for two weeks and subtract it from the capelin stock.	45% of the stock migrates to the southern area.
	1 February–15 February		Calculate consumption for two weeks and subtract that consumption from the capelin stock.	60% of the stock migrates to the southern area.
	15 February–1 March		Calculate consumption for two weeks and subtract that consumption from the capelin stock.	The remaining stocks migrates to the southern area
South	six weeks	65%		
	1 February–15 February	Subtract 23.4% of the catches from the stock	Calculate consumption for two weeks and subtract that consumption from the capelin stock.	The remaining stock migrates to the southwestern area
	15 February–1 March	Subtract 33.3% of the catches from the stock	Calculate consumption for two weeks and subtract that consumption from the capelin stock.	The remaining stock migrates to the southwestern area
	1 March–15 March	Subtract 8.3% of the catches from the stock	Calculate consumption for two weeks and subtract that consumption from the capelin stock.	The remaining stock spawns in the area
Southwest	four weeks	25%		
	15 February–1 March	Subtract 12.5% of the catches from the stock	Calculate consumption for two weeks and subtract that consumption from the capelin stock.	
	1 March–15 March	Subtract 12.5% of the catches from the stock	Calculate consumption for two weeks and subtract that consumption from the capelin stock.	The remaining stock spawns in the area

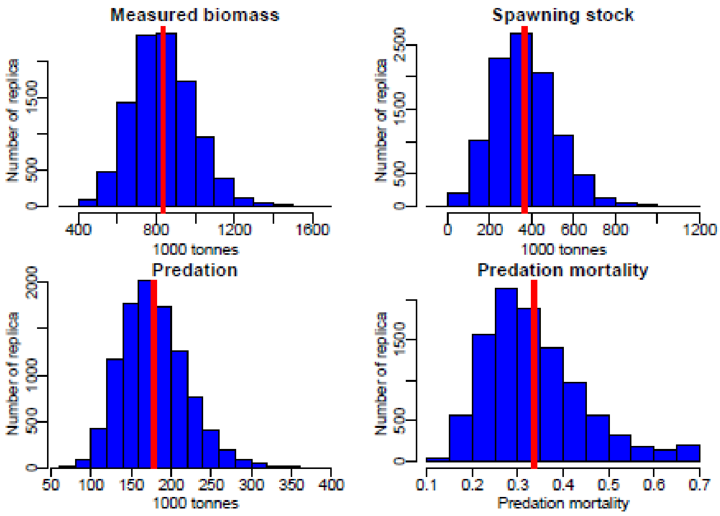

Figure C.2. Summary of results when advice is based on the autumn survey 2012 and the second January survey 2013 (taken from WD 13).

Setting an initial TAC

The proposed management scheme for IGJM-capelin is based on leaving more than 150 thous. tonnes for spawning with more than 95% probability. The basis of assessment is acoustic measurements in January with uncertainty added by bootstrapping. Stochastic predation in January–March is then added, based on the predicted abundance of predators in the assessment/advisory year. Average predation from January–March is estimated to be about 150 kt with a standard deviation of 50 kt. That standard deviation is much lower than standard deviation in the acoustic measurements (100–300 kt) and can therefore be ignored as those sources of uncertainty are assumed to be uncorrelated and the variances are therefore additive, leading to the larger standard deviation being dominant.

Acoustic estimates of the spawning stock with associated uncertainty are available since 1999 but for earlier years the average CV for the years 1999–2014 is used. In many of those years some catches are taken before the final acoustic measurement. Those catches are added to the acoustic estimate of mature stock and also to the lower fifth percentile of the acoustic estimate as the catches are assumed to be without error. All catches before January are scaled down by natural mortality in three months (0.315) i.e. like all that catch was taken in the autumn.

Adding the catches to the measured stock in January gives average and fifth percentiles of the fishable stock in January i.e. a proxy for what would have been measured if no fishery had taken place. Subtracting the average predation of capelin from 15 January to 15 March (150 kt) and B_{lim} (150) from the fifth percentile of the fishable stock will give the estimated advice each year.

The immature part of the capelin stock has been measured in the October survey since 1980. The measurements in 2002–2005 and 2007–2009 are not considered valid as the survey only located part of the immature portion of the stock.

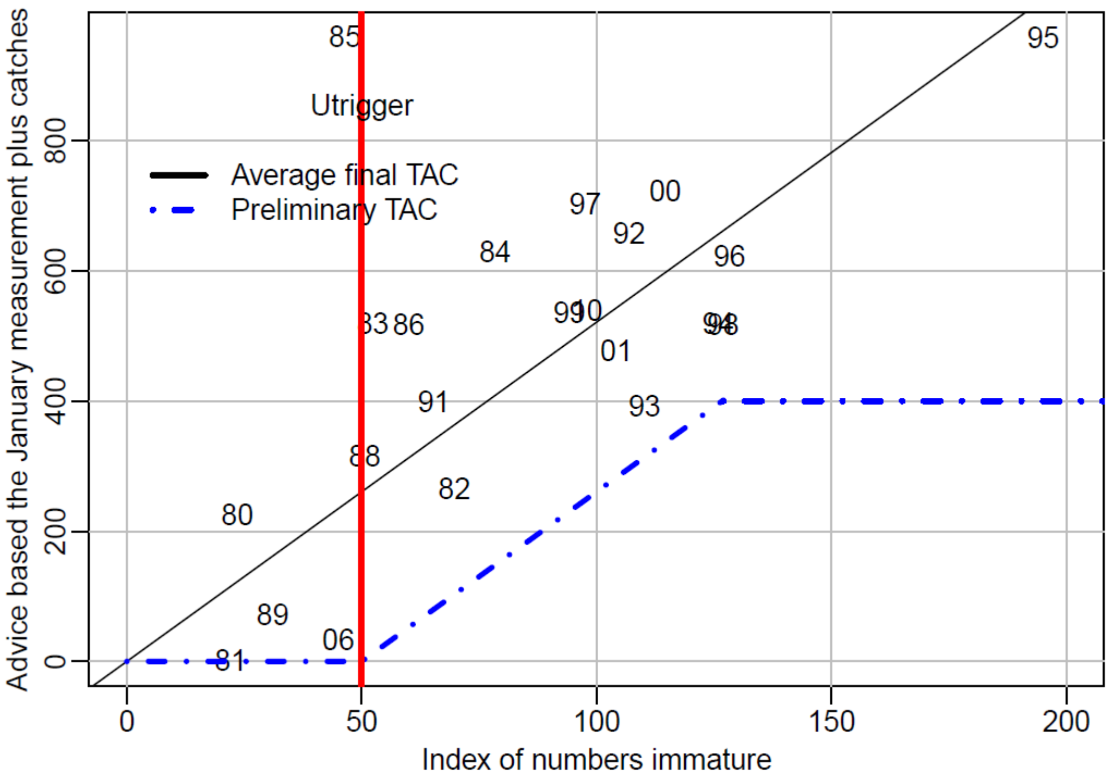

Figure C.3. Estimated final advice according to the proposed stochastic HCR against the measured number of immature capelin ~15 months earlier. The lines indicate the final TAC (unbroken) and the preliminary TAC (broken) when it is set using a $U_{trigger}$ (red vertical line) of 50 billion immature fish and a cap on the initial TAC of 400 kt.

The resulting advice is plotted in Figure C.3 against the measured number of immature capelin ~15 months earlier. The most apparent outlier is 1985. This is related to the part of the 1983 year class that spawned at age 4 but apparently did not show up in the acoustic measurement of immature capelin in 1985. Skipping this measurement leads to the regression line shown in the figure. The line is constrained to go through the origin (but if intercept was also fitted the line would intersect the y-axis at 50 kt). In one year (1981) the advice according to this equation would have been negative or -138 kt but was changed to zero here.

An index of immature numbers less than 50 billion will often mean very low final advice, so it is reasonable to set $U_{trigger}$ at 50 billion. The estimated slope of the regression line is 5.2. A preliminary TAC can be set using a line parallel with the fitted line crossing the x-axis at $U_{trigger}$ over most of the range of observations. A cap on the preliminary quota at 400 kt is prudent, since higher preliminary TACs would be the result of extrapolating beyond the main cluster of observations.

The proposal for the initial TAC is

- TAC = 5.2x(U_{imm}–$U_{trigger}$) kt for U_{imm} in the range 50–127 billion.
- TAC = 0 if U_{imm} <50 billion.
- TAC = 400 kt if Uimm >127 billion.

Capelin is a very important forage species in the ecosystems of Greenland and Iceland, playing a similar role as in the Barents Sea. For the Barents Sea ecosystem, it has been estimated that the maximum sustainable yield from its capelin fishery would be obtained by fishing in autumn, but that delaying opening of the fisheries until 1 January would be beneficial for the ecosystem (Hamre and Tjelmeland, 1982; Gjösæter *et al*., 2002).

Research on the ecosystem role and growth of IGJM-capelin is much more limited than in the Barents Sea but lack of data is generally not a sufficient reason to justify lack of action. A plausible null hypothesis is that the ecosystem role of capelin is similar in both areas. Therefore the initial TAC should not be of much importance as new measurement of the fishable stock would be available before the start of the fisheries. Initial TAC could still be beneficial for the industry to know how much to expect.

G. Biological reference points

H. Other issues

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