Stock Annex: Beaked redfish (*Sebastes mentella*) in Subareas I and II (Northeast Arctic)

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Beaked redfish (*Sebastes mentella*) in Subareas I and II (Northeast Arctic) ACOM considers it not necessary to assess this stock every year since the status of the stock can clearly be deducted from the surveys. No analytical assessment has been made since 2003. New analytical assessment since 2012.
Working Group	Arctic Fisheries Working Group (AFWG)
Created:	01.03.12
Authors:	
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A. General

A.1. Stock definition

The stock of *Sebastes mentella* (beaked redfish) in ICES Subareas I and II, also called the Norwegian-Barents Sea stock, is found in the northeast Arctic from 62ºN in the south to the Arctic ice north and east of Spitsbergen (Figure 1). The south-western Barents Sea and the Spitsbergen areas are first of all nursery areas. Although some adult fish may be found in smaller subareas, the main behaviour of *S. mentella* is to migrate westwards and south-westwards towards the continental slope and out in the pelagic Norwegian Sea as it grows and becomes adult. In the Norwegian Sea and along the slope south of 70°N only few specimens less than 28 cm are observed, and on the shelf south of this latitude *S. mentella* are only found along the slope from about 450 m down to about 650 m depth. The southern limit of its distribution is not well defined but is believed to be somewhere on the slope northwest of Shetland. The stock boundary 62º N is therefore more for management purposes than a biological basis for stock separation, although the abundance of this species south of this latitude becomes less. The main areas of larval extrusion are along the slope from north of Shetland to west of Bear Island. The peak of larval extrusion takes place during the first half of April. Genetic studies have not revealed any hybridisation with *S. norvegicus* or *S. viviparus* in the area. Recent genetic studies revealed no differentiation between *S. mentella* in the Norwegian Sea and the Barents Sea.

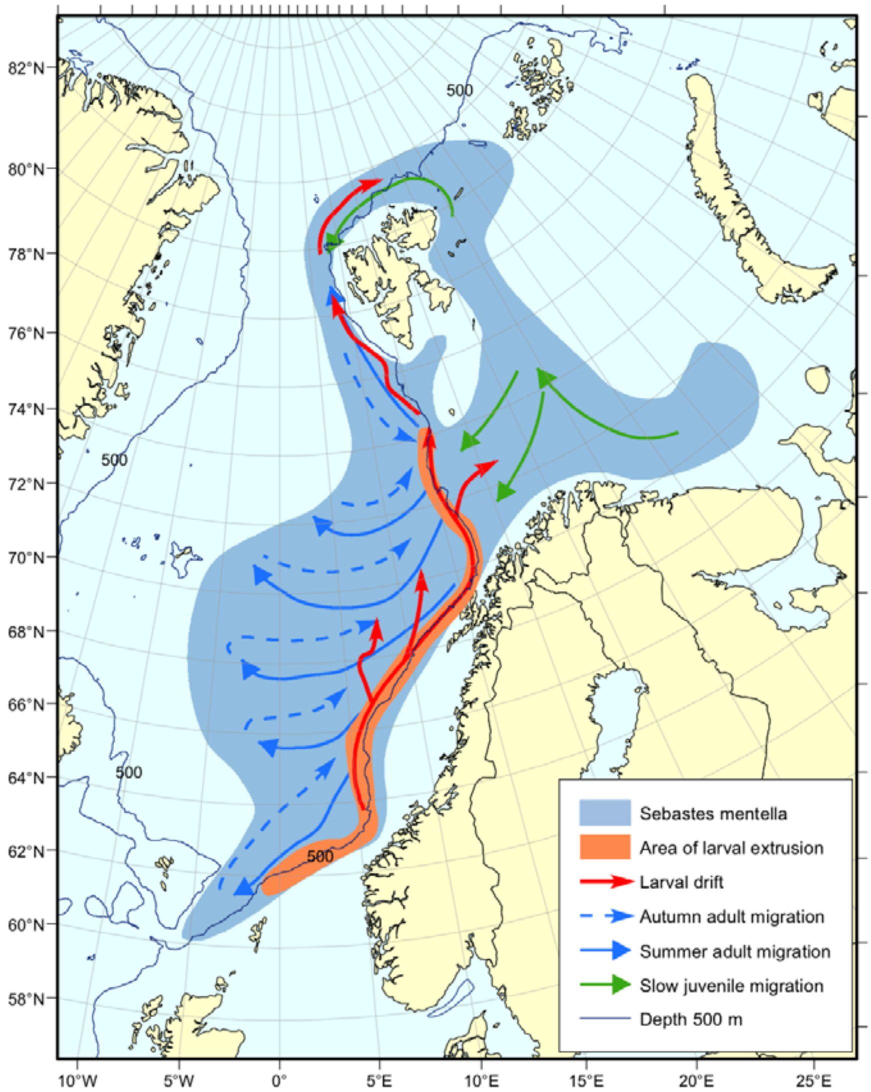

Figure 1. Beaked redfish distribution, area of larval extrusion larval drift and migration routes. Reproduced from Drevetnyak et al. (2011).

A.2. Fishery

The only directed fisheries for *Sebastes mentella* (deep sea redfish) are trawl fisheries. Bycatches are taken in the cod fishery, occasionally also by longline, and as juveniles in the shrimp trawl fisheries. Traditionally, the fishery for *S. mentella* was conducted by Russia and other East European countries on grounds located south of Bear Island towards Spitsbergen. The highest landings of *S. mentella* were 293,000 t in 1976. This was followed by a rapid decline to about 80,000 t in 1979–1981, and a second peak of 114,000 t in 1982. The fishery in the Barents Sea decreased in the mid-1980s to the low level of 10,500 t in 1987. At this time Norwegian trawlers showed interest in fishing *S. mentella* and started fishing further south, along the continental slope at approximately 500 m depth. These grounds had never been harvested before and were inhabited primarily by mature redfish. After an increase to 49,000 t in 1991 due to this new fishery, landings have been at a level of 10,000–15,000 t, except in 1996-1997 when they dropped to 8,000 t. Since 1991 the fishery has been dominated by Norway and Russia. Since 1997 ACFM has advised that there should be no directed fishery and that the bycatch should be reduced to the lowest possible level.

Strong regulations were enforced in the fishery in 1997. Since then it has been forbidden to fish redfish (both *S. norvegicus* and *S. mentella*) in the Norwegian EEZ north and west of straight lines through the positions:

1. N 7000′ E 0521′
2. N 7000′ E 1730′
3. N 7330′ E 1800′
4. N 7330′ E 3556′

and in the Svalbard area (Division IIb). When fishing for other species in these areas, a maximum 25% bycatch (in weight) of redfish in each trawl haul is allowed.

To provide additional protection of the adult *S. mentella* stock, two areas south of Lofoten have been closed for all trawl fishing since 1 March 2000. The two areas (A and B) are delineated by straight lines between the following positions:

A	B
1. N 6630′ E 0659′	1. N 6236′ E 0300′
2. N 6621′ E 0644′	2. N 6210′ E 0115′
3. N 6543′ E 0600′	3. N 6240′ E 0052′
4. N 6520′ E 0600′	4. N 6300′ E 0300′
5. N 6520′ E 0530′	
6. N 6600′ E 0530′	
7. N 6630′ E 0634.27′	

Area A has recently been enlarged to include the continental slope north to N 67º10′.

Since 1 January 2003 all directed trawl fishery for redfish (both *S. norvegicus* and *S. mentella*) is forbidden in the Norwegian Economic Zone north of 62°N. When fishing for other species it is legal to have up to 20% redfish (both species together) in round weight as bycatch per haul and on board at any time. Since 1 January 2005 the bycatch percentage has been reduced to 15% (both species together).

From 1 January 2000 until 31 December 2005 a maximum legal bycatch criterion of 10 juvenile redfish (both *S. norvegicus*, *S. mentella* and *S. viviparus*) per 10 kg shrimp has been enforced in the shrimp fishery. Since 1 January 2006 this bycatch criterion has been reduced to 3 juvenile redfish (both *S. norvegicus*, *S. mentella* and *S. viviparus*) per 10 kg shrimp.

Landings of *S. mentella* taken in the pelagic fishery for blue whiting and herring in the Norwegian Sea have for some countries for some years been reported to the working group. In 2004-2006 this fishery developed further to become a directed and free fishery in 2006. Faroes and Russian vessels were the first to report large catches in 2004. Since 2007 NEAFC has decided on a TAC to be fished in an olympic fishery starting in August each year. In 2008, seven countries and 31 trawlers were involved in this fishery. Although single specimens of *S. norvegicus* occasionally may be observed and caught, biological samples of the catches collected by observers and fishers show that the commercial catches are completely dominated by the deep-water redfish *S. mentella*.

Vinnichenko (WD 9, AFWG 2007) gives a good and comprehensive description of the previous abundance of pelagic *S. mentella* in the international waters of the Norwegian Sea, and how bycatches and exploratory fishing have developed during 1979-2006.

From the first years with a free pelagic fishery, i.e., 2005-2006, it is possible to observe the seasonality and migration pattern of this pelagic behavior of the *S. mentella*. During summer small quantities of redfish were present regularly in catches from the blue whiting and herring fisheries in the international waters of the Norwegian Sea and the Bear Island-Spitsbergen area. Targeted redfish fishery began south of the Mohn Ridge (i.e., the ridge separating the Norwegian Sea into two main basins) in August. The fishery was conducted with gigantic "Gloria" trawls. The fishery finished at the beginning of November after the redfish dispersed and migrated eastwards into the Norwegian EEZ and the Svalbard fishery protection zone.

Some countries have only reported catches taken in Subarea IIa, without information whether the fish were caught pelagic or demersal. For these countries, the WG has considered all catches not reported to Norwegian authorities as being caught in international waters outside the EEZ.

Bycatch of herring could be a problem during daytime trawling in these waters at the time of the olympic fishery (August-September). In some catches with the research survey trawl (40 mm mesh size in codend) up to 30% (in weight) herring was caught as bycatch when targetting the redfish. Even with a commercial trawl (100 mm mesh size in codend) reports from the fishery show that mixed catches of herring may occur. Even if some of the herring escape through the meshes, mortality through mesh selection may be high. During the 2007 olympic fishery bycatches of blue whiting were small. Best catch-rates of *S. mentella* were usually achieved during daytime. According to the skippers they observed and obtained the best catch-rates of redfish about 50 meters deeper than last year, i.e. at about 400 m. Two tons redfish per trawl hour was considered as a very good catch rate. With a common haul duration of 18 hours, catch rates of 30-40 tons/day were not uncommon. Even catch rates up to 70 tons/day were reported.

In the directed Norwegian fishery which started in 2014, reasonable catch rates and low by-catches of other species were reported. However, the TAC was not taken, as several vessels did not fish their vessel quota.

The redfish population in Subarea IV (North Sea) is believed to belong to the Northeast Arctic stock. Since this area is outside the traditional areas handled by this Working Group, the catches are tabulated but not included in the assessment. The landings from Subarea IV have been 1,000–3,000 t per year. Historically, these landings have been *S. norvegicus*, but since the mid-1980s trawlers have also caught *S. mentella* in Subarea IV along the northern slope of the North Sea. Approximately 80% of the Norwegian catches in Subarea IV are considered to be *S. mentella*.

A.3. Ecosystem aspect

As 0-group and juvenile fish, this stock is an important plankton eater in the Barents Sea, and when this stock was sound, 0-group fish have been observed in great abundance in the upper layers utilizing the plankton production. Especially during the first five-six years of life *S. mentella* is also preyed upon by other species, of which its contribution to the cod diet is well documented.

B. Data

B.1. Commercial catch

The landings statistics used by the Arctic Fisheries Working Group (AFWG) are those officially reported to ICES. In cases where such reports to ICES do not exist, reports made directly to Norwegian authorities during the fishery have been used as preliminary figures. Norwegian commercial catch in tonnes by quarter, area and gear are derived from the sales notes statistics of The Directorate of Fisheries. Data are aggregated on 17 areas for bottom trawl. Because of uncertainties in the geographical allocation of reported catches, the quarterly areal distributions of bottom trawl catches are area adjusted on the basis of logbook data available from The Directorate of Fisheries. No discards are reported or taken into account. Reliable estimates of species breakdown (*S. mentella* vs. *S. norvegicus*) by area are available back to 1989. The national landings of redfish for Norway and Russia are split into species by the respective national laboratories. For other countries (and areas) the AFWG has split the landings into *S. mentella* and *S. norvegicus* based on reports from different fleets to the Norwegian fisheries authorities.

The Norwegian sampling strategy is to have age–length samples from all major gears in each area and quarter. There are at present no defined criteria on how to allocate samples of catch numbers, mean length and mean weight at age to unsampled catches, but the following general process has been applied. First look for samples from a neighbouring area if the fishery extends to this area in the same quarter. If there are no samples available in neighbouring areas, search in neighbouring quarters, first from the same gear in the same area, and then from neighbouring areas and similar gears. The last option is to search for samples from other gears with the most similar selectivity in the same area or in neighbouring areas. For some gears, areas and quarters length samples taken by the coast guard are applied and combined with an ALK from a neighbouring area, gear or quarter. ALKs from research surveys (shrimp trawl) are also used to fill holes.

For Norway, weights at age in the catch are estimated from the length proportions-at-age in the catch combined with a length-weight equation of the for Weight = a*(Length)^b. The equation coefficients a and b are estimated annually from biological samples.

The text table below shows data types supplied by individual countries:

	Kind of data					
Country	Caton (catch in weight) of unidentified redfish	Caton (catch in weight) of S. mentella	Canum (catch at age in numbers)	Weca (weight at age in the catch)	Matprop (proportion mature by age)	Length composition in catch
Norway		x	x	x	x	x
Russia		x	x2)	x2)	X (86-01)	x
Germany	x	x3)				x3)
UK	x	1)				
France	x	1)				
Spain	x	1)				
Portugal	x	1)				x
Ireland	x	1)				
Greenland	x	1)				
Faroe Islands1)						
Iceland	x	1)				

1) As reported to Norwegian authorities during the fishery (only for the Norwegian Economic Zone and Svalbard)

2) For main fishing area until 2001

3) Irregularly

The Norwegian, Russian and German input files are Excel spreadsheet files. The data should be found in the national laboratories and also held by the stock co-ordinator. The data will soon be included in InterCatch.

The national data have been aggregated to international data on Excel spreadsheet files. The Russian and German length compositions have been assumed to apply to the Russian and German landings, respectively, using an annual age–length-key (ALK) and weight at age data from the Norwegian trawl landings. Catches from the other countries were assumed to have the same age composition and weight at age as the Norwegian trawl landings. The Excel spreadsheet files used for age distribution, adjustments and aggregations can be found with the stock co-ordinator and for the current and previous year in the ICES AFWG Sharepoint under 'Data'.

B.2. Biological

Since 1991, the catch in numbers at age of *S. mentella* from Russia is based on otolith readings. The Norwegian catch-at-age is based on otoliths back to 1990. Before 1990, when the Norwegian catches of *S. mentella* were smaller, Russian scale-based age–length keys were used to convert the Norwegian length distribution to age.

As input to analytical assessments, the weight at age in the stock is assumed to be the same as the weight at age in the catch.

A fixed natural mortality of $0.05y^{-1}$ is used both in the assessment and the forecast.

Age-based maturity ogives for *S. mentella* (sexes combined) are available for 1986–1993, 1995 and 1997–2001 from Russian research vessel observations in spring and from 1992-present from Norwegian samples (surveys and commercial samples combined).

In some years the maturity ogives are imprecise or unrealistic, mainly due to low sampling intensity. The approach taken is to model maturity at age with a double half Gompertz sigmoid[1], using mixed-effect models. In years of poor sampling intensity, the fixed ogive is used, while in years when more data are available, the random (i.e. annual) effects are incorporated.

B.3. Surveys

The results from the following research vessel survey series have annually been presented to the AFWG:

1) The international 0-group survey (since 2004 part of the Ecosystem survey) in the Svalbard and Barents Sea areas in August-September since 1980 (incl.).
2) The Russian bottom trawl survey in the Svalbard and Barents Sea areas in October-December since 1978 (incl.) in fishing depths of 100–900 m.
3) The Norwegian Svalbard (Division IIb) bottom trawl survey (August-September) since 1986 (incl.) in fishing depths of 100–500 m. Data disaggregated on age only since1992.
4) The Winter Norwegian Barents Sea bottom trawl survey (February) since 1986 (incl.) in fishing depths of 100–500 m. Data disaggregated on age only since 1992.
5) The Norwegian survey initially designed for redfish and Greenland halibut is now part of the ecosystem survey and covers the Norwegian Economic Zone (NEZ) and Svalbard including north and east of Spitsbergen during August 1996-2008 from less than 100 m to 800 m depth. This survey includes survey no. 3 above, and has been a joint survey with Russia since 2003, which since then has been called the Ecosystem survey.
6) The Russian acoustic survey in April-May since 1992 (except 1994, 1996 and 2002-2004) on spawning grounds in the western Barents Sea.

The international 0-group fish survey carried out in the Barents Sea in August-September since 1965 does not distinguish between the species of redfish but it is believed to be mostly *S. mentella*. The survey design has improved and the indices earlier than 1980 are not directly comparable with subsequent years.

Russian acoustic surveys which provide estimates of the commercially sized / mature part of the *S. mentella* stock have been conducted in April-May on the Malangen, Kopytov, and Bear Island Banks since 1986. In 1992 the area covered was extended, and data on age are available for 1992–1993, 1995 and 1997–2001.

In order to investigate the distribution and abundance of pelagic *Sebastes mentella* in the Norwegian Sea the following surveys are/have been conducted:

i. The Norwegian part of the international ecosystem survey in the Nordic Seas in spring 2007-2009 (PGNAPES).
ii. The Norwegian trawl and acoustic survey in September 2007,August 2009 and August 2013 and ICES coordinated international trawl and acoustic survey conducted by Norway, Russia and the Faroes in August 2008.

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[1] the double half sigmoid equation is of the form 0.5 * ((1+tanh(age- a50)/w1)) for age < a50 and 0.5 * ((1+tanh(age- a50)/w2)) for age > a50. a50 equals the age at 50% maturity.

A schematic illustration of these survey series is given below in Figure 2.

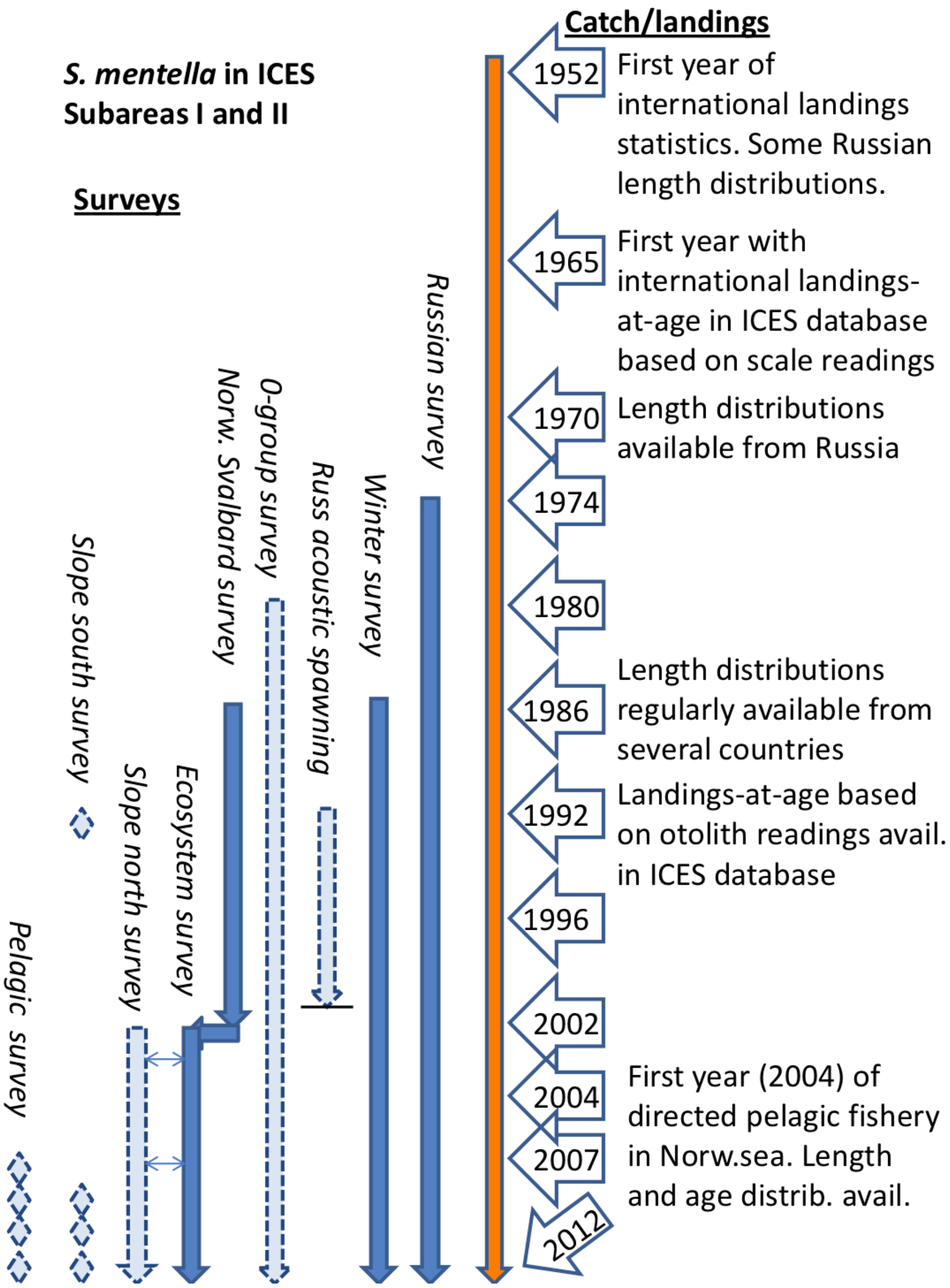

Figure 2. Illustration of the available time series of surveys and catch/landings data. Solid blue arrows show the scientific surveys currently used in both the SCAA and Gadget models, while the dotted light blue arrows show available surveys for which data are available, but are currently not used as inputs to the assessment models.

B.4. Commercial CPUE

No such data are used at present

B.5. Other relevant data

Estimates of predation by cod on redfish juveniles in the Barents Sea, derived from the ecosystem survey, are provided to the assessment working group. The series covers the period 1984 to present.

C. Analytical assessment model

Model used: Statistical Catch-at-Age (SCAA).

Additional models: Gadget and Schaefer models used for validation.

Software used: R ,ADMB and Gadget.

C.1. Statistical catch-at-age model structure

Statistical catch-at-age (SCAA) is used to estimate abundance, recruitment and fishing mortality for many exploited fish stocks. In contrast to virtual population analysis (VPA), in SCAA fishery catch-at-age data are assumed to be measured with error. Under many conditions, SCAA provides more accurate estimates of stock size and other important management quantities than other stock assessment techniques (Wilberg and Bence, 2006). An introduction to SCAA can be found for in Chapter 11.3 in Haddon (2001).

The basic equation SCAA relates numbers N in the population in year y and age a to numbers in the previous year ($y-1$) for the previous age ($a-1$):

$$N_{y,a} = N_{y-1,a-1}e^{-Z_{y-1,a-1}}$$

In the specific case of a +group, the contribution of the +group in the previous year should be added:

$$N_{y,a+} = N_{y-1,a-1}e^{-Z_{y-1,a-1}} + N_{y-1,a+}e^{-Z_{y-1,a+}}$$

where Z is the total mortality for year y and age a. $Z_{y,a}$ can be decomposed into 2 components: the natural mortality $M_{y,a}$ and the fishing mortality $F_{y,a}$. In SCA the fishing mortality is derived from two quantities: the fishing mortality in year y, F_y, and the fleet selectivity at age, σ_a. The resulting fishing mortality at age a in year y is given as $F_{y,a} = \sigma_a F_y$. The resulting equation becomes:

$$N_{y,a} = N_{y-1,a-1}e^{-(M_{y-1,a-1}+\sigma_{a-1}F_{y-1})}$$

Fitting the model requires estimating σ_a's, F_y's, the number of fish in year 1, for all ages ($N_{1,\cdot}$) and the number of fish of age 1 for all years ($N_{\cdot,1}$). The natural mortality cannot be estimated for each year and age, since such estimates would be confounded with the fishing mortalities. However, it is possible to estimate a fixed mortality term $M_{\cdot,\cdot}$ identical for all years and all ages.

The model is fitted to catch-at-age data, where predicted catch-at-age is given as:

$$\hat{C}_{y,a,f} = \frac{F_{y,a,f}}{M_{y,a} + F_{y,a,\cdot}} N_{y,a}\left(1 - e^{-(M_{y,a,\cdot}+F_{y,a,\cdot})}\right)$$

with f the fleet index. Two commercial fleets are considered. The bycatch fleet mostly operating in national waters are using bottom trawl, and the pelagic fleet operating in international waters and using very large pelagic trawls. The selectivity-at-age of the two fleets are different (due to differences in gear and in the geographical distribution of age groups of redfish). The fishing mortality for each year is also different, and the pelagic fleet only started to operate in 2006. Typically, the model is fitted on the log of the catch-at-age, $logC_{y,a,f}$, assuming normal error distribution.

In addition, the model can be fitted to auxiliary data such as survey indices, with:

$$\hat{I}_{y,a} = q\theta_a N_{y,a}$$

Where I is the survey index and q a survey scaling coefficient and θ_a is the survey selectivity at age. The above equation is valid if the survey is conducted at the beginning of the year, when this is not the case the equation must account for mortality prior to the survey:

$$\hat{I}_{y,a} = q\theta_a N_{y,a} e^{-\tau(M_{y,a}+F_{y,a})}$$

with τ the fraction of the year before the time of the survey.

Typically, the model is fitted on the log of the survey indices, $logI_{y,a}$, assuming normal error distribution.

Optimization is carried out by minimizing the negative log-likelihood on observations (log-catches and log-survey indices):

$$nll = \sum\left(\frac{1}{2}\log(2\pi\sigma_s) + \left(\frac{\widehat{\mathrm{LogO}_i} - \mathrm{LogO}_i}{\sigma_s}\right)^2\right)$$

Where $LogO_i$ are the log-observations (catches and survey indices), i is the observation index (from 1 to the total number of observations) and s is the index which relate to fleets or surveys from which an individual observation is originating. An additional log-likelihood component is calculated for the total catch in tonnes in each year (following the same equation as above, where C_y – catch in year y – are substituting O_i's).

The selectivity of fleets (σ_a) can be estimated for each individual age or can alternatively be approximated by a sigmoid function. The second option was chosen, and the sigmoid was modelled following the Gompertz sigmoid equation:

$$\sigma_a = \frac{1}{2} + tanh\left(\frac{(a - a50)}{w}\right)$$

The use of selectivity functions significantly reduces the number of parameters to estimate. Here there only two parameters need to be estimated: $a50$ (the age of 50% selectivity) and w (the slope of the sigmoid).

For the survey selectivity, several functions should be tested, including the sigmoid equation above, exponential declines or dome-shaped functions (e.g. exponential parabola). The shape selected for the assessment will depend on the results of these investigations.

C.2. Gadget and Schaefer models

These models are used for quality check and the detailed structured is not presented in the stock annex, although the model configurations are provided in the section below.

C.3. Model Options chosen:

	SCAA	Gadget	Schaefer
Year-span	1992-2010	(1986) 1990-2009	1965-2010
Population characteristics			
Maximum age	19+	30+	-
Genders	1	1	-
Number of maturity stages	2	2	-
Population lengths (cm)	N/A	1-60+	-
Summary biomass (mt)	Immature/SSB/Total	Immature/SSB/Total	Total
Data characteristics			
Data lengths	N/A	1-60+	-
Data ages	2-19+	2-19+	-
First mature age	From fitted annual ogives	Estimated age-based maturation	-
Starting year of estimated recruitment	1992	1986	-
Fishery characteristics			
Fishery timing	Annual	Quarterly	Annual
Fishery ages	6-19+	6-30+	-
Winter survey timing (year fraction or quarter)	0.12	Q1	Annual
Winter survey ages	2-15	3-15	-
Ecosystem survey timing	0.75	Q3	Annual
Ecosystem survey ages	2-15	3-15	-
Russian survey timing	0.90	Q4	Not included
Russian survey ages	2-11	3-11	-
Fishing mortality	Separable, age x year	Match reported catches (no selectivity)	Total catches
Fishery selectivity	Gompertz sigmoid	exponential	-
Winter & ecosystem survey selectivities	Exponential decline	exponential	-
Russian groundfish survey selectivity	Gompertz sigmoid	exponential	-

For the SCAA, the catchability coefficient for the Ecosystem survey needs to be fixed. After comparisons with the output from the Gadget model, it was agreed to set the value $q = 1/3.5$, so that the absolute biomass levels in SCAA are consistent with those in Gadget.

C.4 Data sources

Fisheries data sources

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Total catch in tonnes	1992-2010	NA	yes
Canum1	Catch at age in numbers for the demersal fleet	1992-2010	6-19+	yes
Canum2	Catch at age in numbers for the pelagic fleet	2006-2010	6-19+	yes
Weca	Weight at age in the commercial catch	1992-2010	6-19+	yes
Matprop	Proportion mature at age	1992-2010	6-19+	yes
Natmor	Natural mortality	1965-2008	6-19+	Constant=0.05

numbers-at-age from surveys

Type	Name	Year range	Age range
Tuning fleet 1	Winter survey	1992-2010	2-15
Tuning fleet 2	Ecosystem survey	1996-2009	2-15
Tuning fleet 3	Russian survey	1992-2010	2-11

D. Short-Term Projection (<5y)

Model used: projection with SCAA model output

Software used: Excel / ADMB

Initial stock size: 1,150 thousand tonnes (SSB) in 2010

Natural mortality: 0.05

Maturity: as in 2010

F and M before spawning: $M = 0.05$, F varies with age

Weight at age in the stock: as in 2010

Weight at age in the catch: as in 2010

Exploitation pattern: as in 2010, i.e. sigmoid with 50% selectivity at 11y (demersal) and 14y (pelagic)

Intermediate year assumptions: constant recruitment, weight-at-age, maturity-at-age, exploitation patterns

Stock recruitment model used: N/A. Recruits do not contribute to the fishery before age 6.

Procedures used for splitting projected catches: Projected catches are allocated to fleets according to the proportions in the last year of assessment (2010).

E. Medium & Long-Term Projections(>5y)

Model used: projection with SCAA model output and different scenarios for recruitment.

Software used: Excel / ADMB

Initial stock size: as of last year of assessment

Natural mortality: 0.05

Maturity: as in 2010, sigmoid with 50% maturity at age 11

F and M before spawning: M = 0.05. F varies with age, as in last year of assessment (2010)

Weight at age in the stock: as in last year of assessment

Weight at age in the catch: as in last year of assessment

Exploitation pattern: as in 2010, i.e. sigmoid with 50% selectivity at 11y (demersal) and 14y (pelagic)

Intermediate year assumptions: constant recruitment, weight-at-age, maturity-at-age, exploitation patterns

Stock recruitment model used: Recruitment (age 2) scenarios with different levels: average of the last five years and average of the recruitment failure period (1998-2005).

Catch scenario: Future catches were set equal to zero (as a bound), half, the same and double the average catch for the last five years

Uncertainty models used:

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

G. Biological Reference Points

Biological reference points could be defined based upon SCAA and Gadget model results but this has yet to be done.

The Schaefer model (see WKRED report - Appendix ??) the estimates of MSY for r = 0.05 and 0.10 are respectively 27 (SE 9) and 30 (SE 12) thousand tonnes respectively.

The Schaefer model indicates the abundance of this resource to be appreciably above 50% (MSY level in terms of this model) over a wide range of r values (see WKRED report - Appendix ??). It should be noted that this model does not take explicit account of recent low recruitments.

H. Other Issues

The bulk of the population biomass of arctic *S. mentella* is constituted by individual of age 19 and older. The assessment of the status of Arctic *S. mentella* stock should therefore explicitly consider the demographic structure of the adult stock, beyond 19y, but this is not the case in the current assessment models used (SCAA and Gadget). It must be emphasized that even if these models can be configured to include more age groups, the survey series currently used in these models do not provide adequate data on the older age groups. The winter, ecosystem and Russian groundfish surveys are restricted to the Barents Sea where juveniles and young adults predominate, but a large fraction of older mature individuals migrate into the Norwegian Sea. Therefore, these surveys do not appropriately cover the demographic distribution of the adult population and are only considered for individuals up to age 11y (Russian survey) and 15 y (Winter and Ecosystem surveys). Priority should be given to data collection over the slope and open Norwegian Sea regions, were the adult population is most abundant, and to including these new surveys in the analytical assessment in the future.

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