Stock Annex: Northern shrimp (*Pandalus borealis*) in Division 4.a East and Subdivision 20 (northern North Sea in the Norwegian Deep and Skagerrak)

Stock-specific documentation of standard assessment procedures used by ICES.

Stock:	Northern shrimp
Working Group:	Joint NAFO/ICES *Pandalus* Assessment Working Group (NIPAG)
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Last updated:	January 2016
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A. General

A.1. Stock definition

At present the populations of northern shrimp (*Pandalus borealis*) in the North Sea area including Skagerrak and the northernmost part of Kattegat are assumed to be distributed into three main stocks (ICES, 1990):

1) The Skagerrak and Norwegian Deep stock;

2) The Fladen Ground stock;

3) The Farn Deeps stock.

The *Pandalus* on the Fladen Ground and in Farn Deeps are recognised as separate stocks and management units on the basis of geographical separation and hydrographical considerations. Up to 1990 the *Pandalus* in the Norwegian Deep and Skagerrak were considered as two separate stocks for assessment purposes.

There is a continuous distribution of *Pandalus* from the Norwegian Deep (4.a East) into the Skagerrak and Kattegat, but often differences in size distribution between the shrimp from the Norwegian Deep and those from the Skagerrak are recorded. Multivariate analyses of length distributions from the Fladen Ground, Norwegian Deep and Skagerrak indicated that the length–frequency distributions for these three areas were different, but the difference between the Norwegian Deep and Skagerrak distributions was less pronounced than between either of these two and those from the Fladen Ground (ICES, 1989). Since 1990 *Pandalus* in the Norwegian Deep and Skagerrak are considered as one single stock. A recent genetic study on *Pandalus* showed that the stock in the Skagerrak and Norwegian Deep area comprises one biological unit (Knutsen *et al*., 2015). Smaller, genetically different stocks were identified in some fjords along the Norwegian and Swedish Skagerrak coasts, but as the fishery on these shrimp units is comparatively small, these stocks are not treated separately in the assessment. The exception is *Pandalus* in the Gullmarfjord (Swedish west coast)

which is managed as a stock separated from the Skagerrak and Norwegian Deep stock.

A.2. Fishery

The Skagerrak and Norwegian Deep shrimp stock is exploited by Denmark, Norway and Sweden. The Norwegian and Swedish fisheries began already around 1900, while the Danish fishery started in the early 1930s. The gears used in the fishery for northern shrimp are bottom trawls. In the early days of the fisheries, all shrimp were landed boiled (on-board processing), but today most of the Danish shrimp are landed fresh. Because of local demand, Swedish fishers have always maintained a high proportion of shrimp landings as boiled (high quality) shrimp.

A.2.1. General description

Countries involved:

Denmark

Historically, the Danish *Pandalus* fishery has targeted both the shrimp stock in Skagerrak and Norwegian Deep as well as the stock on the Fladen Ground. In the period 1994 to 1999 the fisheries in these two areas were of about the same size, but since 2000 the Fladen fishery declined and came to a stop in 2004. Virtually no shrimp landings have been recorded from Fladen since 2004 and at present, all Danish shrimp landings come from Skagerrak and Norwegian Deep. Since 'at sea' boiled shrimp fetch better prices, an increasing number of Danish vessels now land boiled shrimp. In 2012, around 38% of the landings were boiled, whereas in 2005 it was only around 12%. Most of the boiled shrimp are landed in Sweden. The majority of the Danish catches are, however, still landed in Danish fishing ports unprocessed. Most of these shrimp are landed directly to a few large factories processing almost all sizes of shrimp. The number of vessels participating in the *Pandalus* fishery has decreased from 191 vessels in 1987 to only ten vessels in 2014. The vessels that have left the *Pandalus* fishery are the smaller ones, and the average vessel size has increased from 20 to 26 m in the period, while the average horse power has increased from 415 to around 700.

Estimates of total shrimp discards from the Danish fishery based on on-board sampling of catches have been available since 2009. Discards constitute around 5% of the catches (Munch-Petersen *et al*., 2013). A higher discard rate was observed in 2014, which is likely linked to the high abundance of age 1 shrimp in that year.

Norway

The Norwegian shrimp fishery is conducted by multi-purpose fishing vessels mainly trawling south of 59ºN. The total number of vessels in the fishery has decreased from more than 400 in 1995 to 203 in 2014. In 2014, as in the recent preceding years, vessels in the length group 10–10.99 m dominated in numbers, with the length group 11–14.99 m as the second largest. However, the fleet has changed considerably when compared to the vessel size composition in the mid-1990s. The number of trawlers <10 m has decreased, as has the number of vessels 11–20.99 m, while there has been an increase in vessels 10–10.99 m. A high number of small vessels <15 m characterises the Skagerrak, while the fleet in the west is more varied. Almost all catches are landed in ports along the Norwegian coast, with a minor portion landed in Denmark (Søvik and Thangstad, 2014). In 2012–2014, boiled shrimp constituted about 50% of

the landings from the Skagerrak, and about 60% of the landings from the Norwegian Deep.

Despite the Norwegian discard ban (see below), shrimp are discarded also by Norwegian fishers. As there up until recently has been no Norwegian on-board sampling of catches, estimates of Norwegian shrimp discards have been based on Danish discard rates and weight of catches <15 mm CL (details later in the Stock Annex).

Sweden

At present, there are around 35 Swedish trawlers, which can be considered specialised in shrimp fishery in the Skagerrak. The size of the vessels ranges between 12 and 35 m with an average of 22 m. GRT varies from 18 to 343, with an average of 118 GRT. The average engine effect is around 409 kW (92–738 kW). The larger trawlers are normally fishing in the eastern and central part of Skagerrak. The smaller trawlers are mostly fishing in the Swedish coastal zone inside a 'trawling border' where special regulations apply for the use of trawls: Trawling in these areas is restricted to waters deeper than 60 m and there are special limits to the length of ground rope and the size of the trawl and trawl doors.

In Sweden there are two different markets for *Pandalus*, resulting in two different kinds of landings: a) higher value, larger sized shrimp sorted by a 10.5 mm sieve and boiled onboard before landed, and b) lower value, smaller sized shrimp, sorted by 8.5 mm sieve, landed fresh and sold to the industry for further processing. In recent years, approximately 50% of the landings have consisted of boiled shrimp.

In some years the Swedish shrimp fishery has been constrained by the Swedish share of the TAC. This has had the effect of discarding, due to high grading of the catches in order to increase the amount of higher-value boiled shrimp. On-board sampling of Swedish catches has taken place since 2008, and estimated total discards have ranged from 12% to 30% of the catch (Munch-Petersen *et al*., 2013). In 2012, 2% of the Swedish shrimp trawls had a mesh size ≥45 mm; this increased to 41% in 2014 in order to increase the size selectivity.

A.2.2. Fishery management regulations

The shrimp fishery is regulated by minimum mesh size in the codend (35 mm stretched), and by restrictions in the amount of landed bycatch. Since February 1st 2013, all shrimp trawls in the Skagerrak must be equipped with a species sorting Nordmøre grid with 19 mm bar spacing, and since January 1st 2015, the same regulation applies to the North Sea south of 62°N. Since 1st of January 2016, a landing obligation applies for *Pandalus* in EU waters, and work is ongoing in order to improve size selection in shrimp trawls, both by increasing mesh sizes and by developing size selective grids. Norway has had a discard ban for many years.

Norway is the only country that has a minimum catch size, which previously was 6 cm total length (15 mm carapace length (CL)), but was increased to 7 cm total length (17.5 mm CL) from January 1st 2016. Shrimp landings can nonetheless contain up to 10% undersized shrimp (in weight in the Skagerrak and in numbers in the Norwegian Deep). A Real-Time Closure system to restrict the fishing of undersized shrimp was implemented in Norwegian waters south of 62°N as of January 1st 2016.

A.3. Ecosystem aspects

Pandalus is an important prey species for many fish species, including cod and saithe.

The traditional trawls used in the shrimp fisheries have small-meshed codends (35–40 mm), which means that a considerable amount of bycatch of fish is caught in shrimp trawls. According to the current EU regulations, the total amount of landed human consumption (h.c.) bycatch species should not exceed 50% (by weight) of the total landings from a fishing trip. According to the available data on bycatch of h.c. species in the shrimp fishery, they constitute around 25% of the catches. Among the common h.c. bycatch species in this fishery are cod, haddock, anglerfish, saithe and witch flounder. Also deep-sea species such as lantern sharks, roundnose grenadier and greater silver smelt are frequently caught as bycatch. Bycatch of commercial species is recorded in the logbooks (Sweden and Denmark) or landings statistics (Norway), but bycatch of non-commercial, mainly discarded, species is not recorded.

Mandatory fish selective grids, such as the commonly used Nordmøre grid (see above), reduce the amount of bycatch significantly. Many shrimp fishers consider the h.c. fish bycatch a significant component of the catch and, when the TACs for fish species are not exhausted, it is legal to use a tunnel of 120 mm square mesh in front of the grid to allow for the fish bycatch to be retained.

B. Data

B.1. Commercial catch

B.1.1. Landings data

B.1.1.1. Commercial landings

Commercial landings data for *Pandalus* are available (to NIPAG) from 1970 as totals from Denmark, Norway and Sweden. Since a significant amount of the landings consist of boiled shrimp, the officially recorded landings of this component have been adjusted for weight loss due to boiling. The adjustment factor used is: fresh weight = 1.13 * boiled weight.

B.1.1.2. Data coverage and quality

Swedish landings for all years, and Danish and Norwegian landings from 2000–2014 have been corrected for loss in weight due to boiling. Danish vessels started landing boiled shrimp around 2000 (see above). Prior to 2000, the amount of boiled shrimp landings from Danish vessels was probably insignificant. Unfortunately, no information exists on the fraction of boiled landings before year 2000 for Norway.

B.1.2. Discards estimates

Estimates of total discards, based on on-board sampling, have been available from Sweden since 2008 and from Denmark since 2009. Until 2015 no Norwegian observer data exist. However, in 2016 Norway initiated a sampling programme in Skagerrak (data from the Reference fleet), which will generate Norwegian discard data. For 2009–2015, Norwegian discards of *Pandalus* in the Skagerrak have been estimated by applying the Danish discards-to-landings ratio to the Norwegian landings. As there are no Danish observer data from the Norwegian Deep, Norwegian discards from this area are estimated as the weight of catches of shrimp <15 mm CL (former minimum catch size), obtained from length distributions of catches and mean weight-at-length.

In the stock assessment, total combined landings from all three countries (numbers-at-length) are used since 1988. Total catches (landings + discards) (numbers-at-length) are available and used in the assessment since 2009.

B.1.2.1. Data coverage and quality

Annual sample numbers and sample sizes are presented by country and quarter in the NIPAG report. The numbers-at-length for 1988 and 1989 are based on the Danish length–frequency data only (Danish length–frequencies raised to total combined landings). No data were available from Sweden or Norway.

Estimated Norwegian discards from the Skagerrak are probably underestimated as the proportion of boiled large shrimp in the Norwegian landings is larger than in the Danish landings (whereas Danish discard ratios are applied to Norwegian landings to estimate discards). Estimated Norwegian discards from the Norwegian Deep are probably also underestimated.

B.1.3. Recreational catches

There is no recreational fishery for *Pandalus*.

B.2. Biological sampling

B.2.1. Maturity

Pandalus is a protandric hermaphrodite, i.e. the individuals are born as males and then become females. In the Skagerrak and Norwegian Deep, sex change takes place at-age 2 during the summer. Based on the on-board sampling of the commercial catches, maturity data on size distributions (in length of the carapace in mm) of the shrimp in the catches are available and used in the assessment. The proportion of females at length was fitted to a logistic maturity curve.

B.2.2. Natural mortality

Natural mortality is assumed to be 0.75 for all ages and years. This value was chosen by the ICES *Pandalus* Assessment Working Group in 1987 based on biological knowledge about the species (ICES, 1988). This value was partly confirmed by Berenboim *et al*. (1991); however, their estimates are for *Pandalus* in the Barents Sea. Simple catch curve analyses were made by the NAFO/ICES *Pandalus* Assessment Group in 2013. Some of these analyses confirm the value of 0.75, while others indicate a higher M.

B.2.3. Length and age composition of landed and discarded fish in commercial fisheries

Norwegian unsorted catches have been sampled onboard by fishermen and the Norwegian Coast Guard since 2006. Before 2006 Danish length data were applied to the Norwegian landings (see above). Norway initiated a sampling programme in Skagerrak through the Reference fleet in 2016, where all catch components including discards will be sampled separately.

Length compositions of landed and discarded shrimp from the Swedish and Danish fisheries exist from, respectively, 2008 and 2009 (data from on-board sampling). In years previous to 2008, the Swedish length compositions are based on lengths from landings. The Danish length compositions up to 2008 are based on sampling of either the landings and/or landings component only (onboard) of the catch.

B.3. Surveys

A bottom-trawl survey for *Pandalus* in Skagerrak and the Norwegian Deep has since 1984 been conducted annually by the Norwegian Institute of Marine Research, with the objective of assessing the distribution, biomass, recruitment, and demographic composition of the shrimp stock, the size of the stocks of shrimp predators, as well as measuring hydrographical conditions in the distributional area of shrimp. The survey data consist of 1) one time-series from October/November 1984–2002 using R/V *Michael Sars* and the Campelen-trawl; 2) a point estimate for 2003 as R/V *Michael Sars* was taken out of service and substituted with R/V *Håkon Mosby*, whose winches at that time were not powerful enough for the Campelen trawl, resulting in the survey being conducted with a shrimp trawl; 3) a start of a potential new series as the survey in 2004 and 2005 was conducted in May/June with R/V *Håkon Mosby* using the standard Campelen trawl; and 4) one time-series from January/February 2006 until present, using R/V *Håkon Mosby* and the Campelen trawl. Conducting the survey in the 1st quarter gives good estimates of the 1-group abundance and SSB (berried females) and was recommended by the ICES *Pandalus* working group in 2004 (ICES, 2005).

B.3.1. Survey design and analysis

The survey is stratified by four depth zones (100–200 m, 200–300 m, 300–500 m, and >500 m) and has a fixed station design, assuming that the temporal variation in the shrimp stock generates the necessary randomness. A coverage of one haul per 142 nm^2 is obtained when all stations are trawled.

The trawl used is a Campelen 1800/35 bottom trawl with rockhopper gear. Mesh size in the codend is 20 mm with a 6 mm inner lining net. Tow duration was 1 hour until 1989 when it was reduced to 0.5 hour. Tow speed is roughly 3 knots. No compensation for diurnal vertical migration is made. Strapping is used to ensure fixed trawl geometry (10 m rope 200 m in front of the doors).

A sample of approximately 300 shrimps is taken from each trawl haul; the shrimp are length measured, and sex and maturity stage are determined.

Swept area is estimated by applying a wingspread of 11.7 m to tow length. Tow length is time towed multiplied by a fixed towing speed of 3 knots. The catch in each tow divided by the swept-area represents a sample of shrimp density in a stratum. Mean strata densities (numbers) are multiplied by strata area to give estimates of strata abundance, which are summed to give the overall value for the survey area.

B.3.2. Survey data used

Input data to the SS3 model from the survey are total numbers by year and proportions-at-length by year.

B.4. Commercial cpue

Commercial standardised lpue data are provided by Denmark from 1987, by Sweden from 1996, and by Norway from 2000. The standardised lpues are presented to NIPAG, but not used in the assessment at present.

B.5. Other relevant data

C. Assessment methods and settings

C.1. Choice of stock assessment model

The model used for this assessment is Stock Synthesis (Version3, SS3, Methot and Wetzel, 2013) as decided at the Benchmark on the Northern Shrimp (*Pandalus borealis*) in Skagerrak and Norwegian Deep Sea 2016 (WKPAND; ICES, 2016).

Stock Synthesis is designed to accommodate both age and size structures in the population (Methot and Wetzel, 2013). For northern shrimp, the numbers and proportions-at-length in the fisheries and survey data are related to ages using the von Bertalanffy growth function. The model is run in quarterly steps to account for the growth of individual shrimp throughout the year. The model assumes a length-based selection pattern for the fishery (logistic) and that this selection pattern remains the same throughout the year; thus, the shrimp become increasingly more selected as they grow throughout the year.

Stock Synthesis 3 is programmed in the ADMB C++ software and searches for the set of parameter values that maximise the goodness-of-fit, then calculates the variance of these parameters using inverse Hessian and MCMC methods.

The model configuration is as follows (see Table 1 for a summary of input and estimated parameter values):

- The fisheries data are included as total catch in weight (tonnes) by quarter and proportions-at-length in the catch (only available on an annual basis).
- The survey data are included as total numbers by year and proportions-at-length by year.
- Survey data are available from 1988 to the last data year (excluding 2003), including the year in which the assessment is conducted (even if the catch data are not yet available for that year when the assessment is conducted). Due to changes in timing, the Norwegian survey is split into three different parts (1988–2002, 2004–2005 and 2006–present) and the average timing of each period is assigned to each part (the fraction of year elapsed until survey time is assumed to be 0.807, 0.398, and 0.076, respectively).

<u>Population dynamics model and settings:</u>

- Quarterly time-step. The model does not differentiate between genders and is based on a single area and fishing fleet. Lengths 0 to 4 cm, in steps of 0.1 cm, are used to represent the population, and 0.7 to 3.5 cm, in steps of 0.1 cm, for the data.
- Lengths are related to ages (age classes 0 to 8+) assuming a von Bertalanffy growth function in the population model, with normally-distributed variability around the growth curve. Growth parameters (k, L_{inf}, t_0) and the CV of the normally-distributed variability are estimated by the model. There are two CV parameters: one for the youngest age and one for the oldest, with linear interpolation in between these ages.
- M is set at 0.75 (fixed) for all age classes in all years.
- Maturity was externally estimated during WKPAND (2016), assuming a logistic length-at-maturity relationship, based on data from the last two years of the time-series. The parameters of the estimated relationship ($L_{50\%}$ = 1.8 cm and $L_{95\%}$ = 1.9 cm) are fixed in the assessment model for all age

classes in all years. Additionally, all shrimp of ages 0 and 1 are considered immature.

- The weight-at-length (cm to kg) relationship is treated as a fixed input in the assessment, constant over time, with parameters a=0.0016 and b=2.7532.
- Catchability and logistic selectivity-at-length curves are estimated separately for each of the three survey periods, assuming no variation over time (i.e. time-invariant catchability and selectivity within each survey period).
- A logistic selectivity-at-length, assuming no variation over time, is estimated for the commercial trawl fleet. The fishing mortality-at-length is the product of selectivity-at-length (normalized to have a maximum of 1 over the lengths) and (year, quarter)-specific fishing mortality parameters.
- The stock–recruitment function is a Beverton–Holt parameterization, with unexploited recruitment (R_0) estimated in the assessment. The recruitment variability (standard deviation of normal distribution of ln(recruitment)) is fixed a 0.6, while the steepness and the autocorrelation between year classes are fixed at 0.99 and 0, respectively. Year-specific recruitment deviations are estimated from 1981–2014 (recruitment deviations start before the first assessment year to allow increased flexibility in the initial population at-age).
- Initial catches (i.e. catches before the start of the model, 1988) are assumed to be equal to the average catches observed between 1983 and 1987 with a standard error of 0.05; the initial catches are used as part of the process of setting the initial population at-age.

Likelihoods of observed data:

- The ln(commercial catch in tonnes, by quarter) is assumed to have a standard error of 0.05. The catch for the year in which the stock assessment is conducted (e.g. the 2015 catch for an assessment conducted in 2015) is typically not available at the time the assessment is conducted. In order to be able to include the survey index from that year in the assessment, it is necessary to assume quarterly catch values for that year: these assumed catches should be based on a "best guess" and a standard error of 1 assigned to them; if the actual catches are known, then the assigned standard error may be lower, e.g. 0.05.
- The observed ln(survey indices) are assumed to follow Normal distributions. As the information on the standard deviation (in log-scale, i.e. approximately the CV in original scale) of the survey indices is lacking, it is assumed that the ln(survey indices) are known with a standard deviation of 0.20. For the first and third survey periods, a parameter reflecting extra variability, to be added to the input standard deviation, is estimated for each period.
- SS3 assumes multinomial likelihoods for the proportions-at-length in catches and survey data. Yearly sample sizes for these data (i.e. number of hauls per year) are not available and, thus, a 100 yearly sample is initially assumed for the catches and surveys in all years. The sample size of the catches and the surveys length–frequency distributions are subsequently reweighted (i.e. multiplied by 0.52, 0.29, 0.39 and 0.42, for the catches and

three survey periods, respectively) using Francis' method (Francis, 2011). The procedure used to estimate the Francis' weights is the following: the model is first initialized and run with a sample size of 100 for both the catches and the surveys length–frequency distributions. Then, the sample size of the catches and of the surveys length–frequency distributions are reweighted using Francis' method (i.e. in this case using the lower bound of the weight estimated by the Francis method) and the model is run again. Then, the newly estimated lower bound of the sample weight, as estimated by the Francis method, is used as the "final" weighting.

Calculation of an annual F_{bar}:

- F_{bar} is computed as the average of F at-age for ages 1 to 3. An F-at-age is calculated for each (year, quarter) combination taking into account the selectivity-at-length and the growth model applied to the population ages in the corresponding quarter. An annual summary of F-at-age is calculated by averaging the quarterly F-at-age values. Internally, the model calculates total annual catches stepping through the four quarters and applying the relevant F in each quarter; the resulting catches by quarter and then summed to get the annual catch.

Recruitment estimated from the assessment:

- The assessment model starts at-age 0 and, hence, recruitment in the model refers to abundance of age 0 shrimp in the population. Age 0 shrimp are almost totally absent from the survey or the commercial catches, so the first data information about a particular year class comes from survey and catches of age 1 shrimp on the following year. Between age 0 and age 1 essentially only natural mortality occurs (F is almost identical to 0 at age 0). The benchmark has displayed recruitment estimates from the stock assessment as a time-series of shrimp abundance-at-age 0, but NIPAG may perhaps prefer to display recruitment estimates from the assessment as a time-series of abundance-at-age 1. Both options are essentially equivalent.

Table 1. Settings and results of the final SS3 assessment model (as of WKPAND, 2016) of northern shrimp (*Pandalus borealis*) in Skagerrak and Norwegian Deep (ICES Division 3.a and 4.a East). The table columns show: number of estimated parameters, the initial values (from which the numerical optimization is started), the intervals allowed for the parameters, and the value estimated by maximum likelihood (MLE) during WKPAND 2016. Parameters in bold are set and not estimated by the model.

Parameter	Number estimated	Initial value	Bounds (low,high)	Value (MLE) estimated in 2016 WKPAND benchmark
Natural mortality				
M		**0.75**	(0.1,1.5)	
Stock and recruitment				
Ln(R0)	1	6	(3,30)	16.26
Steepness (h)		**0.99**		
Recruitment variability (σR)		**0.60**	(0,2)	
Ln (Recruitment deviation): 1981–2014	34			
Recruitment autocorrelation		**0**		
Growth				
Linf (cm)	1	2.9	(2,4)	2.81
k (per year)	1	0.39	(0.20–0.45)	0.42
L at minimum age (0.001 years) t0	1	0	(0,4)	0.08
CV of young individuals	1	0.20	(0.005–0.40)	0.13
CV of old individuals	1	0.05	(0.005–0.40)	0.03
Weight (kg) at length (cm)				
A		**0.0016**		
B		**2.7532**		
Maturity				
Length (cm) at 50% mature		**1.8**		
Length (cm) at 95% mature		**1.9**		
Initial fishing mortality				
Commercial trawl fleet	1	0.1	(0,4)	1.88
Catchability and selectivity (logistic)				
Commercial trawl fleet				
Time-invariant length based logistic selectivity	2	1,1 the parameters are $L_{50\%sel}$ and $L_{95\%sel}$-$L_{50\%sel}$ (in cm)	(0,4.5)	(1.64,0.35)
Norway survey (1988–2002)				

Parameter	Number estimated	Initial value	Bounds (low,high)	Value (MLE) estimated in 2016 WKPAND benchmark
Ln(Q)-atchability	1	-	(0,1)	0.0026
Extra variability added to input standard deviation	1	0	(0,1)	0.13
Time-invariant length based logistic selectivity	2	1,1 the parameters are $L_{50\%sel}$ and $L_{95\%sel}$-$L_{50\%sel}$ (in cm)	(0,4.5) for both parameters	(1.97,0.80)
Norway survey (2004–2005)				
Ln(Q) – catchability	1	-	(0,1)	0.0022
Extra variability added to input standard deviation		**0**		
Time-invariant length-based logistic selectivity	2	1,1 the parameters are $L_{50\%sel}$ and $L_{95\%sel}$-$L_{50\%sel}$ (in cm)	(0,4.5) for both parameters	(1.45,0.35)
Norway survey (2006–2015)				
Ln(Q)-catchability	1	-	(0,1)	0.0011
Extra variability added to input standard deviation	1	0	(0,1)	0.06
Time-invariant length-based logistic selectivity	2	1,1 the parameters are $L_{50\%sel}$ and $L_{95\%sel}$-$L_{50\%sel}$ (in cm)	(0,4.5) for both parameters	(1.49,0.58)

C.2. Model used of basis for advice

The model used as a basis for advice is Stock Synthesis (Version 3).

C.3. Assessment model configuration

Type	Name	Year range	Age/length range	Variable from year to year Yes/No
Caton	Catch in tonnes, split into quarterly data according to WKPAND (2016)	1988–last data year	Not applicable	YES
Canum	Catch proportions (in number) per length class	1988–last data year	Length classes range 0.7–3.5 cm	YES
Weca	Weight-at-age in the commercial catch	1988-last data year	0–8+	NO (derived from weight and selectivity-at-length, and growth model, which are assumed constant over years)

Type	Name	Year range	Age/length range	Variable from year to year Yes/No
West	Weight-at-age of the spawning stock at spawning time.	1988–last data year	0–8+	NO (derived from weight at length and growth model, which are assumed constant over years)
Mprop	Proportion of natural mortality before spawning	1988–last data year	2–8+	NO (0 in all years)
Fprop	Proportion of fishing mortality before spawning	1988–last data year	0–8+	NO (0 in all years)
Matprop	Proportion mature-at-length	1988–last data year	2–8+	NO (logistic maturity-at-length relationship, with parameters set to $L_{50\%}$ = 1.8 cm and $L_{95\%}$ = 1.9 cm for all years; ages 0 and 1 are immature)
Natmor	Natural mortality	1988–last data year	0–8+	NO (set to 0.75 for all age classes and years)

Tuning data:

Type	Name	Year range	Age / length range
Norway survey, split into three periods	Norway survey	1988–2002 2004–2005 2006–present	Logistic selectivity-at-length (separate selectivity and catchability for each period)

D. Short-term prediction

Model used: Deterministic projection based on assessment model dynamics.

Software used*:* check SS3 capabilities; if not possible, then the already-existing R script (used for northern hake) could be considered.

Initial stock size: As estimated from the stock assessment; Recruitment at-age 0 is assumed to be the geometric mean of the most recent ten years.

Maturity: Maturity-at-length as in assessment.

F and M before spawning: SSB is computed in the forecast based on January 1st population, so 0 is used.

Weight-at-age in the stock: Weight-at-length as in assessment is used. Weight-at-age in the stock can be derived from weight-at-length and the growth model.

Weight-at-age in the catch: Weight-at-length as in assessment is used. Weight-at-age in the catch can be derived from weight-at-length, fishery selection-at-length and the growth model.

Exploitation pattern: Selection-at-length as in assessment.

Intermediate year assumptions: Based on assumptions about catch (TAC + potentially discards and any other appropriate considerations).

Stock–recruitment model used: Geometric mean of most recent ten years.

Procedures used for splitting projected catches: Discard ban starts in 2016 in the EU, while already ongoing for several years in Norway. There is a minimum catch size / conservation reference size, which could be used as the basis for the split, or recently observed practices could be used. NIPAG should consider the most appropriate basis for a split.

E. Medium-term prediction

Not conducted on a regular basis for this stock.

F. Long-term prediction

Not conducted on a regular basis for this stock.

G. Biological reference points

	Type	Value	Technical basis
MSY Approach	MSY Btrigger	9900 t	5th percentile of equilibrium distribution of SSB when fishing at FMSY, constrained to be no less than Bpa
	FMSY	0.62	F that maximises median equilibrium yield (defining yield as the total catch)
Precautionary Approach	Blim	6300 t	Bloss (lowest observed SSB)
	Bpa	9900 t	Blim * exp(1.645 * σ), where $\sigma = 0.27$
	Flim	1.00	F that leads to 50% probability of SSB <Blim
	Fpa	0.68	Flim * exp(- 1.645 * σ), where $\sigma = 0.23$

H. Other issues

H.1. Biology of species

H.2. Current fisheries

H.3. Management and advice

H.4. Others (e.g. age terminology)

I. References

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