JOINT NAFO/ICES *PANDALUS* ASSESSMENT WORKING GROUP (NIPAG)

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i Executive summary

PandSKND, a subgroup of the NAFO/ICES *Pandalus* Assessment Group (NIPAG), met 20–21 February 2020 at ICES HQ in Copenhagen to assess the *Pandalus* stock in divisions 3a and 4a east. Experts attended from Norway, Sweden and Denmark (Chair: Ole Ritzau Eigaard, Denmark) and the objective was to assess stock status and to draft advice according to the current EU and Norway Long-term Management Strategy (LTMS). The LTMS requires ICES to provide both an update in-year TAC advice for 2020 and an initial TAC advice for the first two quarters of 2021.

The length-based Stock Synthesis (SS3) statistical framework was used to assess status of the stock based on updated input data (commercial catches for 2019 and survey catches from January 2020). The assessment demonstrated that the spawning–stock biomass (SSB) declined after 2008 and has fluctuated at a lower level since then. SSB in 2020 is between MSY-$B_{trigger}$ and B_{lim}. Fishing mortality (F) has been above F_{MSY} in all years since 2011, except in 2015, 2018 and 2019. Recruitment has been below average since 2008, except for the 2013 year class.

In accordance with the LTMS reference points and Harvest Control Rules, the subgroup suggests that catches in 2020 should be no more than 8736 tonnes and that catches for the first two quarters of 2021 should be no more than 4552 tonnes. This corresponds to a 31% reduction of the initial catch advice for 2020 and a 0.2% increase for the 2021 catch advice. The main reason for this change is that the realized 2019 catches were 29% higher than advised catches (7944 t compared to 6163 t) due to banking from 2018 (768 t), discarding (368 t), lack of correction for the loss in weight due to on-board boiling (approximately 463 t) and catching more than the TAC (approximately 180 t).

SS3 model diagnostics of the assessment did not indicate any issues with the model fit. There is a positive retrospective bias in SSB and recruitment, and a negative retrospective bias in F, but these are all within the acceptable range (Mohns Rho threshold values) of requiring no action.

ii Expert group information

Expert group name	Joint NAFO/ICES *Pandalus* Assessment Working Group (NIPAG)
Expert group cycle	Annual
Year cycle started	2020
Reporting year in cycle	1/1
Chair	Ole Ritzau Eigaard, Denmark
Meeting venue and dates	20–21 February 2020 (six participants)

1 Northern shrimp (*Pandalus borealis*) in the Skagerrak and Norwegian Deep (ICES Subdivision 27.3a.20 and the eastern part of Division 27.4a)

Background documentation is found in SCR Docs. 08/75; 13/68, 74; 14/66; 20/01 and in the ICES Stock Annex.

1.1 Introduction

The shrimp in ICES Division 27.3.a (Skagerrak and Kattegat) and the eastern part of Division 27.4.a (Norwegian Deep) are assessed as one stock and are exploited by Norway, Denmark and Sweden. Shrimp fisheries expanded significantly in the early 1960s. By 1970, the landings had reached 5000 t and in 1981 they exceeded 10 000 t.

Since 1992, the shrimp fishery has been regulated by a TAC (Figure 5.1, Table 5.1). The overall TAC is shared according to historical landings, giving Norway 59%, Denmark 27%, and Sweden 14% between 2011 and 2019. The advised TACs were until 2002 based on catch predictions. In 2003, the cohort-based assessment was abandoned and no catch predictions were available. The advised TACs were therefore based on perceived stock development in relation to recent landings until 2013, when an assessment based on a stock production model was introduced for this stock. Thereafter, a new length-based assessment model was agreed on in a benchmark in January 2016 (ICES, 2016a).

The shrimp fishery is also regulated by a minimum mesh size (35 mm stretched), and by restrictions in the amount of landed bycatch. Sorting grids are mandatory in the whole area (see below). In 2009, an EU ban on high-grading was implemented and since 2016, the EU landing obligation applies for *Pandalus* in 27.3.a and 27.4.a. Norway has had a discard ban for many years.

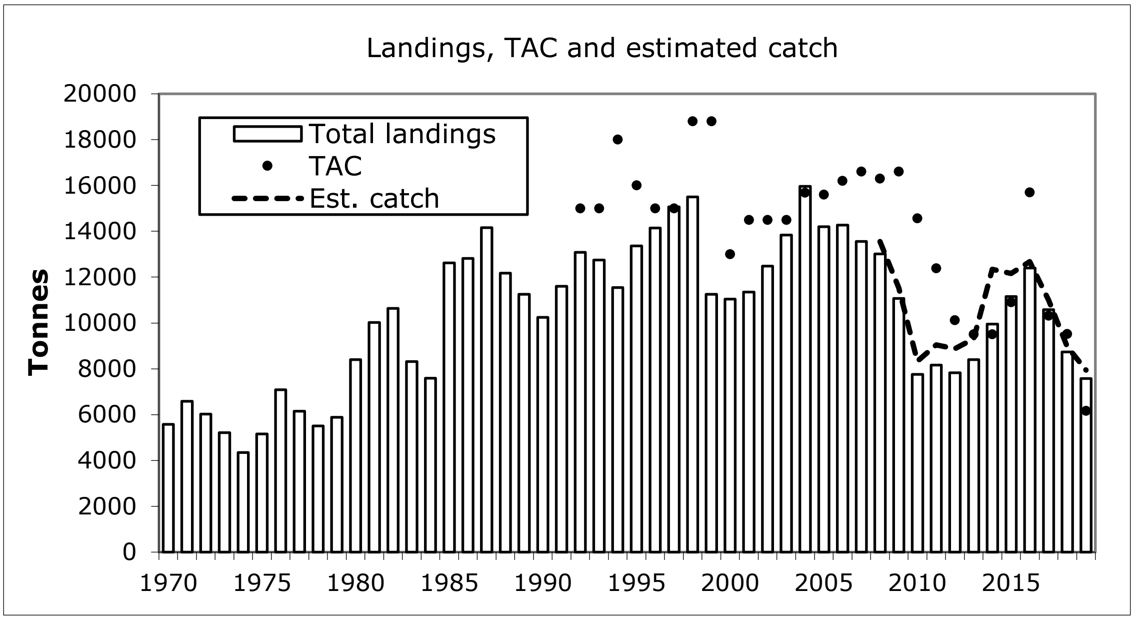

Figure 5.1. Northern shrimp in Skagerrak and Norwegian Deep: TAC, total landings by all fleets, and total estimated catch including estimated Swedish discards for 2008–2019, and Norwegian and Danish discards for 2009–2019.

Table 5.1. Northern shrimp in Skagerrak and Norwegian deep: TACs, landings, and estimated discards and catches (t).

Year	2009	2010	2011	2012	2013	2014	2015	2016[1]	2017	2018	2019
Advised TAC[2]	15000	13000	8800	*	5800	6000	10900	13721	10316	8571	6163
Agreed TAC	16600	14558	12380	10115	9500	9500	10900	15696	10316	8900	6163
Denmark landings	2224	1301	1601	1454	2026	2432	2709	1997	2173	1863	2058
Norway landings	6362	4673	4800	4852	5179	6123	6808	8305	6778	5493	4414
Sweden landings	2483	1781	1768	1521	1191	1397	1644	2095	1634	1374	1105
Total landings	11069	7755	8169	7827	8396	9952	11161	12397	10585	8730	7577
Est. Swedish discards	337	386	504	671	265	572	325	87	99	114	106
Est. Norw. Discards	94	133	247	292	459	1289	476	162	114	115	178
Est. Danish discards	36	53	123	88	185	526	204	35	206	12	83
Total catch	11536	8327	9043	8878	9305	12339	12166	12681	11004	8971	7944

[1] **Advised and agreed TACs from October 2015 were changed in March 2016 following the benchmark assessment.**

[2] **From 2014, TAC advice has been given for catches.**

The Danish and Norwegian fleets have undergone major restructuring during the last 25 years. In Denmark, the number of vessels targeting shrimp has decreased from 138 in 1987 to only eight in 2019. The efficiency of the fleet has increased due to the introduction of twin trawls and increased trawl size.

In Norway, the number of vessels participating in the shrimp fishery has decreased from 423 in 1995 to 184 in 2019. Twin trawls were introduced around 2002, and in 2011–2019 were used by more than half of the Norwegian trawlers longer than 15 meters.

The Swedish specialized shrimp fleet (landings of shrimp larger than 10 t per year) has decreased from more than 60 vessels in 1995–1997 to below 30 in 2018–2019. There has not been any major change in single trawl size or design, but during the last ten years, the landings of the twin trawlers have increased from 7 to over 60% (recent four years) of the total Swedish *Pandalus* landings.

Landings and discards. Total landings have varied between 7500 and 16 000 t during the last 30 years. In the Swedish and Norwegian fisheries, approximately 50% of catches (large shrimp) are boiled at sea, and almost all catches are landed in homeports. The Danish vessels are boiling approximately 35% of the shrimp on board and landing the product in Sweden to obtain a better price. The rest is landed fresh in homeports. In the total catch estimates, the boiled fraction of the landings has been raised by a factor of 1.13 to correct for weight loss caused by boiling. Total catches, estimated as the sum of landings and discards, decreased from 2008 to 2012, to 8800 t, and then increased to around 12 600 t in 2016. In the recent three years, catches have again decreased, to around 7900 t in 2019 (Table 5.1 and Figure 5.1).

Shrimps may be discarded to replace small and medium-sized, lower-value shrimps with larger and more profitable ones (“high-grading”). Since 2016, shrimp <15 mm CL are marketable, but fetch a lower price than medium-sized shrimp. The Swedish fishery has often been constrained by the national quota, which may have resulted in high-grading. Based on on-board sampling by observers, discards in the Swedish fisheries were estimated to be between 12 and 31% of total catch for 2008–2015, and Danish discards were estimated to be between 2 and 18% for 2009–2015. In 2016, due to the landing obligation, discarding decreased to 4 and 2% in Sweden and Denmark respectively. In 2019, the discard percentages were 9 and 4%, respectively. In 2017 to 2019, approximately 80% of the Swedish landings were caught with mesh sizes of at least 45 mm. From 2009 to 2016, Norwegian discards in Skagerrak were estimated by applying the Danish discards-to-landings ratio to the Norwegian landings. In 2017, Norwegian discards were estimated by comparing length–frequency distributions of on-board samples of unsorted catches with samples from landings. In 2018, an error in a script was discovered, and upon correcting this, the method was no longer considered appropriate (rendering negative discards). Thus, the working group estimated the 2018 discards based on data from the Norwegian Reference fleet, and updated the 2017 discards using the same type of data. Discards in the Norwegian fisheries have been estimated to be between 2 and 4% of total catch for 2017–2019.

Bycatch and ecosystem effects. Shrimp fisheries in the Norwegian Deep and Skagerrak have bycatches of 10–23% (by weight) of commercially valuable species, which are legal to land if quotas allow (Table 5.2). Since 1997, trawls used in Swedish national waters must be equipped with a Nordmøre grid, with a bar spacing of 19 mm, which excludes fish >approximately 20 cm length from the catch. Landings delivered by vessels using grids comprise 95–99% of shrimp (Table 5.2). Following an agreement between EU and Norway, the Nordmøre grid has been mandatory since 1st February 2013 in all shrimp fisheries in Skagerrak (except Norwegian national waters within the 4 nm limit where the grid became mandatory in 2019). From 1st of January 2015, the grid has also been mandatory in shrimp fisheries in the North Sea south of 62°N. If the fish quotas allow, it is legal to use a fish retention device of 120 mm square mesh tunnel at the grid’s fish outlet.

Table 5.2. Northern shrimp in Skagerrak and Norwegian Deep: Bycatch landings by the *Pandalus* fishery in 2019. Combined data from Danish and Swedish logbooks and Norwegian sale slips (t).

Species	SD IIIa, grid		SD IIIa, grid+fish tunnel		SD IVa East, grid+fish tunnel	
	Landings (t)	% of total landings	Landings (t)	% of total landings	Landings (t)	% of total landings
Pandalus	295.5	97.1	4942.5	77.4	1256.0	74.6
Norway lobster	4.0	1.3	28.9	0.5	4.6	0.3
Anglerfish	0.1	0.0	104.9	1.6	48.5	2.9
Whiting	0.1	0.0	3.8	0.1	2.3	0.1
Haddock	0.1	0.0	33.0	0.5	12.1	0.7
Hake	0.0	0.0	21.2	0.3	20.3	1.2
Ling	0.0	0.0	46.9	0.7	27.4	1.6
Saithe	0.8	0.3	682.0	1.7	141.4	8.4
Witch flounder	0.2	0.1	47.2	0.7	1.9	0.1
Norway pout	2.5	0.8	19.3	0.3	4.5	0.3
Cod	0.4	0.1	294.3	4.6	59.1	3.5
Other marketable fish	0.8	0.3	158.1	2.5	105.9	6.3

The use of a fish retention device also prevents the escape of larger individuals of non-commercial species. Deep-sea species such as roundnose grenadier, rabbitfish, and sharks are frequently caught in shrimp trawls in the deeper parts of Skagerrak and the Norwegian Deep. No quantitative data on this mainly discarded catch are available and the impact on stocks is difficult to assess.

Catches of demersal fish species in the Campelen-trawl of the Norwegian annual shrimp survey covering Skagerrak and the Norwegian Deep (see below) give an indication of the level of potential bycatch of non-commercial species in shrimp trawls (Table 5.3 and Figure 5.2).

The catches of demersal fish in the Campelen-trawl are also used to calculate an index of potential shrimp predators. The large interannual variation in this predator biomass index is mainly due to variations in the indices of saithe, blue whiting and roundnose grenadier, which in some years are important components. The catch of these species depends to some extent on which survey stations are trawled, as the largest densities of saithe are found in shallow water and roundnose grenadier is found in deep water. The peak in 2013 was due to a high abundance of both saithe and blue whiting. An index of potential shrimp predators without these three species fluctuated without trend from 2007 to 2015, was at a higher level in 2017-2019, but decreased again in 2020 (Figure 5.2; the 2016 survey data were omitted, see below).

Table 5.3. Northern shrimp in Skagerrak and Norwegian Deep: Estimated indices of predator biomass (catch in t per square nautical mile) from the Norwegian shrimp survey in 2007–2020. The 2016 survey data have been omitted (see text for details).

Species													
English	Latin	2008	2009	2010	2011	2012	2013	2014	2015	2017	2018	2019	2020
Blue whiting	*Micromesistius poutassou*	0.12	1.21	0.27	0.62	3.30	29.03	1.88	5.25	31.18	6.38	19.68	13.04
Saithe	*Pollachius virens*	208.32	53.89	18.53	7.52	5.66	112.80	14.13	8.56	9.71	12.87	5.77	1.88
Cod	*Gadus morhua*	0.78	2.01	1.79	1.66	1.26	1.69	2.92	2.37	2.00	2.05	2.58	0.58
Roundnose grenadier	*Coryphaenoides rupestris*	19.02	19.03	10.05	4.99	4.43	1.97	2.90	1.46	1.41	2.17	2.10	3.53
Rabbit fish	*Chimaera monstrosa*	3.41	3.26	3.51	2.73	2.22	3.05	3.90	2.19	5.99	5.03	5.40	4.35
Haddock	*Melanogrammus aeglefinus*	1.85	3.18	3.46	5.82	5.75	5.18	2.15	2.60	1.86	1.51	0.97	1.15
Redfish	*Scorpaenidae*	0.26	0.43	0.80	1.02	0.37	0.47	0.48	0.20	0.53	0.97	0.82	0.31
Velvet belly	*Etmopterus spinax*	1.95	2.42	2.52	1.47	1.59	2.67	1.91	2.51	4.19	3.85	4.34	2.92
Skates, rays	*Rajidae*	0.64	0.17	0.60	0.88	0.98	1.00	2.25	1.69	1.64	1.20	1.76	0.65
Long rough dab	*Hippoglossoides platessoides*	0.42	0.28	0.47	0.51	0.56	0.56	1.17	1.45	0.94	0.81	1.02	0.34
Hake	*Merluccius merluccius*	0.64	2.56	1.60	0.56	0.52	1.06	0.69	0.59	1.24	1.66	0.91	1.00
Angler	*Lophius piscatorius*	0.87	1.25	1.70	0.92	0.17	0.65	0.75	0.58	1.13	0.57	1.12	0.71
Witch	*Glyptocephalus cynoglossus*	0.54	0.16	0.13	0.24	0.29	0.27	0.35	1.38	0.47	0.17	0.16	0.19
Dogfish	*Squalus acanthias*	0.28	0.14	0.11	0.21	0.60	1.02	1.00	0.36	0.42	0.45	0.43	0.26
Black-mouthed dogfish	*Galeus melastomus*	0.05	0.15	0.09	0.09	0.09	0.12	0.11	0.35	0.26	0.24	0.24	0.35
Whiting	*Merlangius merlangus*	1.35	3.02	2.42	3.07	1.64	2.02	3.38	1.59	2.60	4.56	5.20	2.62

Species													
English	Latin	2008	2009	2010	2011	2012	2013	2014	2015	2017	2018	2019	2020
Blue Ling	*Molva dypterygia*	0	0	0	0	0	0.01	0.01	0.03	0.01	0.03	0.02	0.25
Ling	*Molva molva*	0.34	0.79	0.64	0.24	0.17	0.22	0.32	0.63	0.90	0.99	1.09	0.41
Four-bearded rockling	*Rhinonemus cimbrius*	0.04	0.03	0.05	0.03	0.09	0.04	0.06	0.12	0.04	0.05	0.09	0.05
Cusk	*Brosme brosme*	0.02	0.05	0.13	0.29	0.04	0.10	0.05	0.19	0	0.14	0.38	0.02
Halibut	*Hippoglossus hippoglossus*	3.88	0.09	0.20	0.05	0.19	0	0	0.10	0.16	0.09	0.24	0.29
Pollack	*Pollachius pollachius*	0.03	0.13	0.12	0.15	0.07	0.24	0.65	0.23	0.10	0.15	0.22	0.19
Greater forkbeard	*Phycis blennoides*	0	0.01	0.04	0.02	0.05	0.06	0.12	0.05	0.18	0.22	0.2	0.07
Total		244.81	94.26	49.23	33.09	30.04	164.23	41.18	34.48	66.96	46.16	54.74	35.16
Total (except saithe and roundnose grenadier)		17.47	21.34	20.65	20.58	19.95	49.46	24.15	24.46	55.84	31.12	46.87	29.75

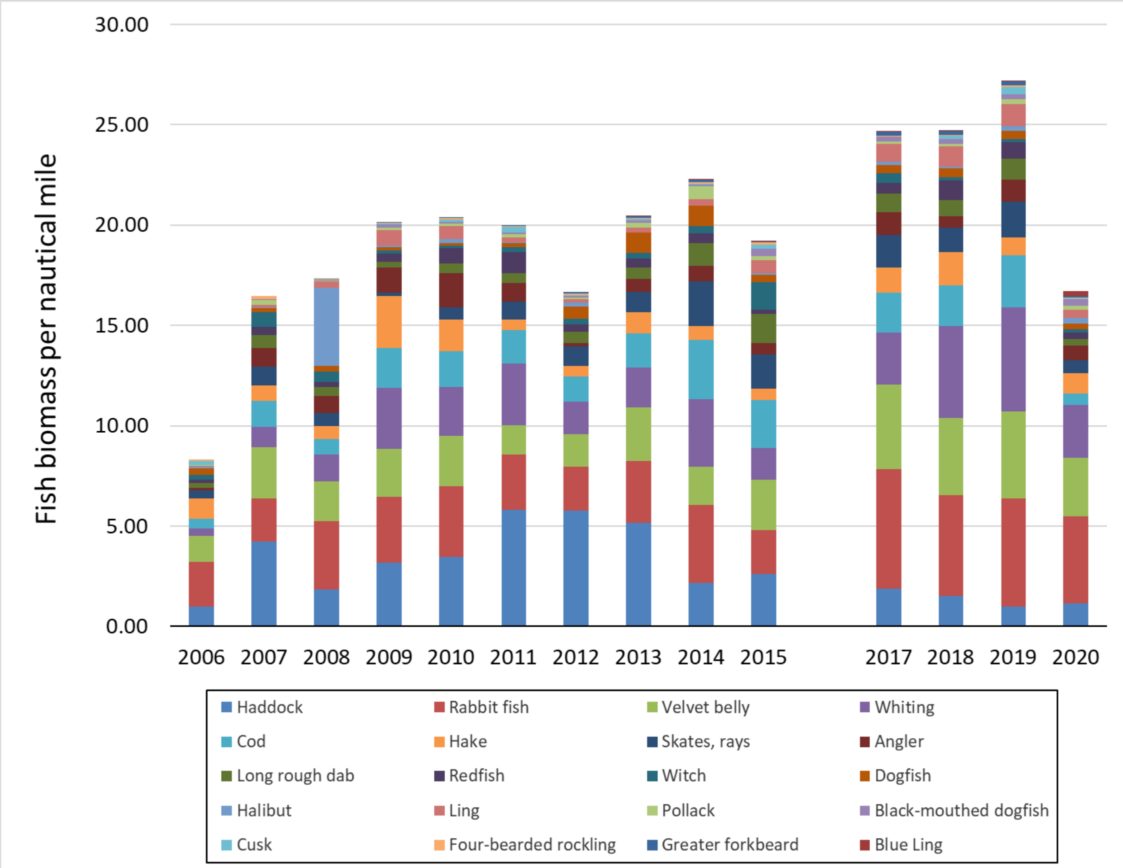

Figure 5.2. Northern shrimp in Skagerrak and Norwegian Deep: Estimated indices of predator biomass (catch in t per square nautical mile) from the Norwegian shrimp survey in 2006–2020 excluding saithe, roundnose grenadier and blue whiting. The 2016 survey data have been omitted (see text for details).

1.2 Input data

1.2.1 Fishery data

Danish, Swedish and Norwegian catch and effort data from logbooks have been analysed and standardised (SCR Doc. 08/75). All three series increased from 2012 until 2015, but have decreased since (Figure 5.3).

Time-series of standardised effort indices from Norway and Denmark have been fluctuating without any clear trend since the late 1990s while the Swedish standardised effort has decreased (Figure 5.4).

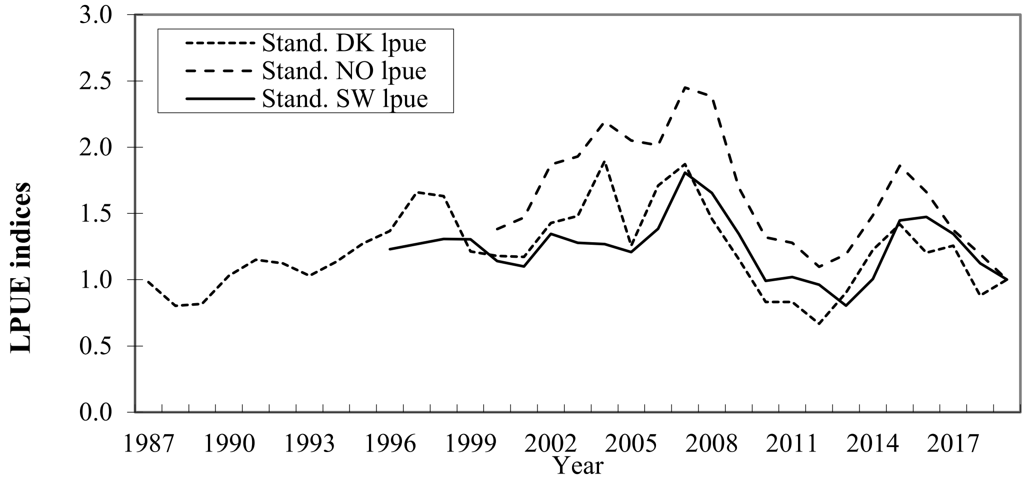

Figure 5.3. Northern shrimp in Skagerrak and Norwegian Deep: Danish, Norwegian and Swedish standardised landings per unit of effort (LPUE) until 2019. Each series is standardised to its final year.

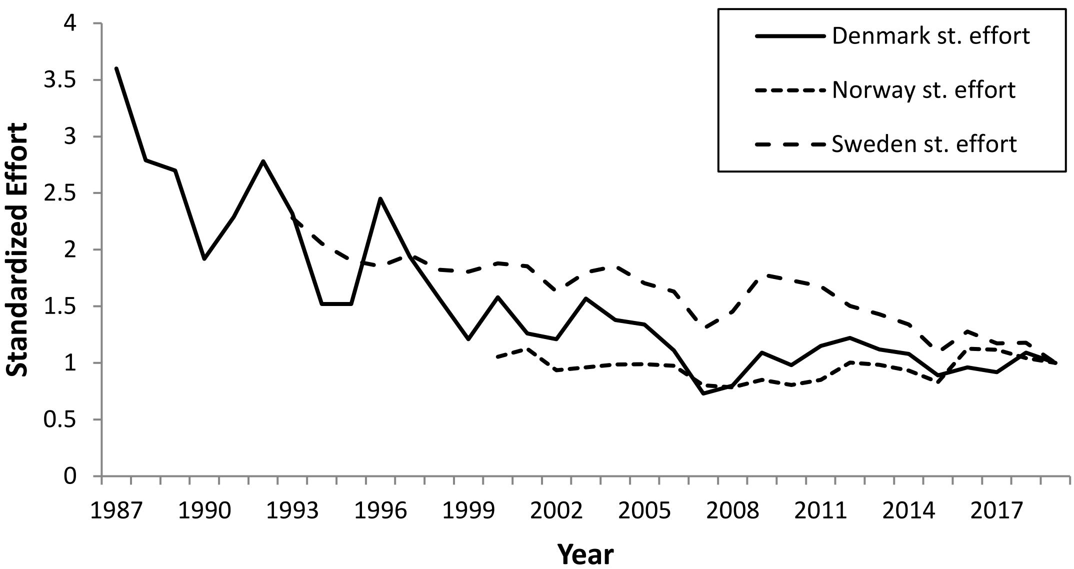

Figure 5.4. Northern shrimp in Skagerrak and Norwegian Deep: Estimated standardised effort until 2019. Each series is standardised to its final year.

1.2.2 Sampling of catches

Length frequencies of the commercial catches from 1985 to 2019 have been obtained by sampling. The samples also provide information on sex distribution and maturity. Numbers-at-length are input data to the length-based assessment model for this stock (see below).

1.2.3 Survey data

The Norwegian shrimp survey went through large changes in vessel, gear and timing in 2002–2006, resulting in four indices: Survey 1: October/November 1984–2002 with Campelen trawl; Survey 2: October/November 2003 with shrimp trawl 1420; Survey 3: May/June 2004–2005 with Campelen trawl; and Survey 4: January/February 2006–present with Campelen trawl.

Due to time and weather restrictions, not all survey strata have been covered in all years. The following years have missing strata: 1984, 1986, 2002, 2006, 2012, 2014, and 2015 (Figure 5.5). The index of total biomass for these years has been standardised by applying the missing strata's mean portion of the total biomass (averaged over all years within a time-series with complete coverage) to the total biomass of the year. The corrected indices increased by 3–12%, except for the corrected 2002 biomass value which increased by 48%. However, total numbers-at-length have not yet been standardised, which means that the length-based model (see below) uses un-standardized survey data. This implies that the total numbers-at-length from years with incomplete survey coverage are underestimated.

In 2016, there were technical problems with the survey trawl (unequal wire lengths of the trawl gear) and this year's data have therefore been omitted from the time-series.

The biomass peaked in 2007, then declined until 2012. The index thereafter increased until 2015, then decreased to the fourth time-series' lowest observed level in 2019, and then increased slightly in 2020 (Figure 5.5). The survey time-series has not been standardised for variability of factors such as swept volume, spatial coverage and trawling speed, which might add uncertainty to the stock estimates. A recruitment index has been calculated for the fourth survey time-series as the abundance of age 1 shrimp. The recruitment index declined from 2007 to 2010, and has since fluctuated at a lower level except for a peak in 2014 (Figure 5.6). The 2019 year class is estimated to be below the median of the fourth time-series.

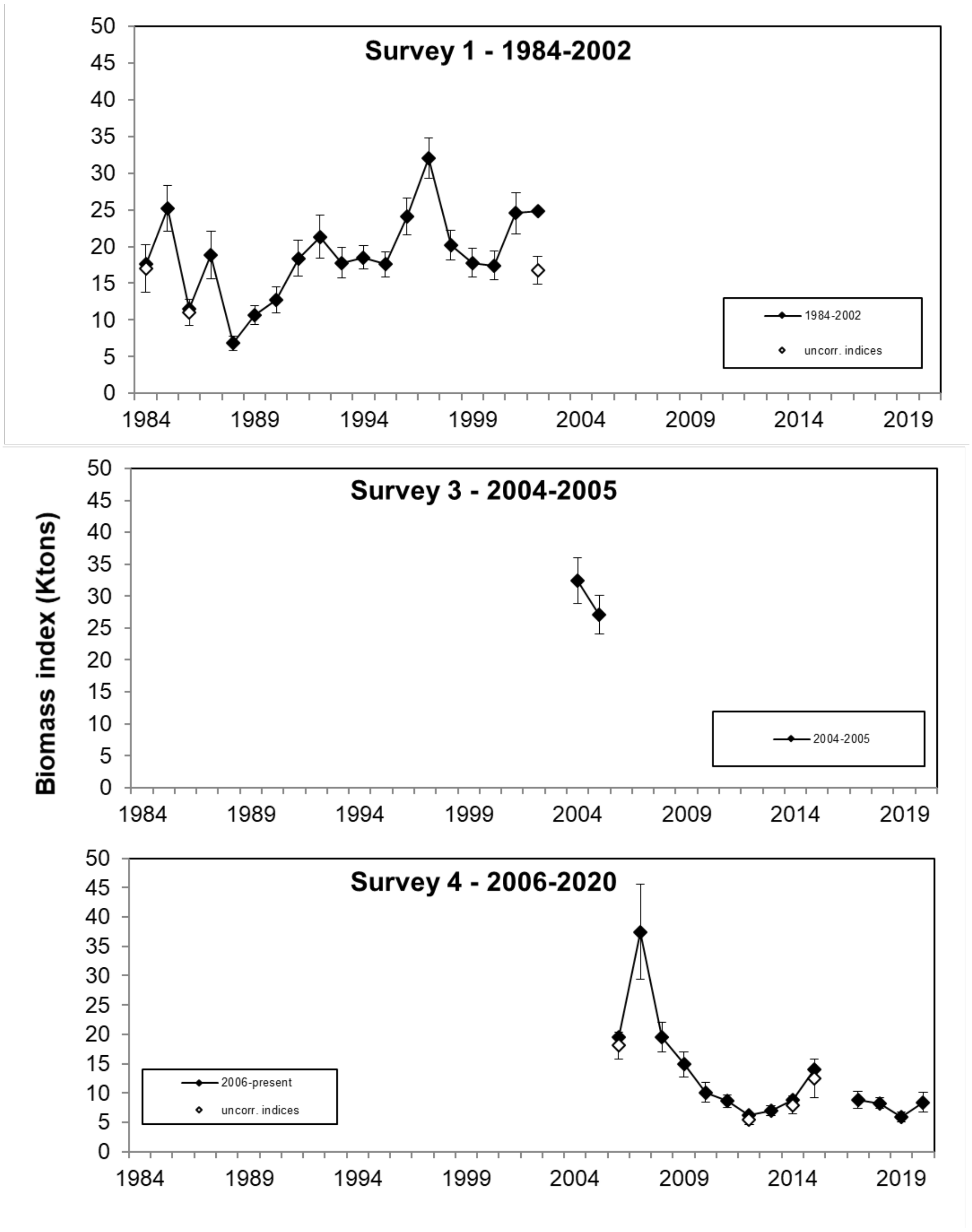

Figure 5.5. Northern shrimp in Skagerrak and Norwegian Deep: Estimated survey biomass index in 1984–2020. The point estimate of 2003 is not shown. The 2016 survey data have been omitted (see text for details).

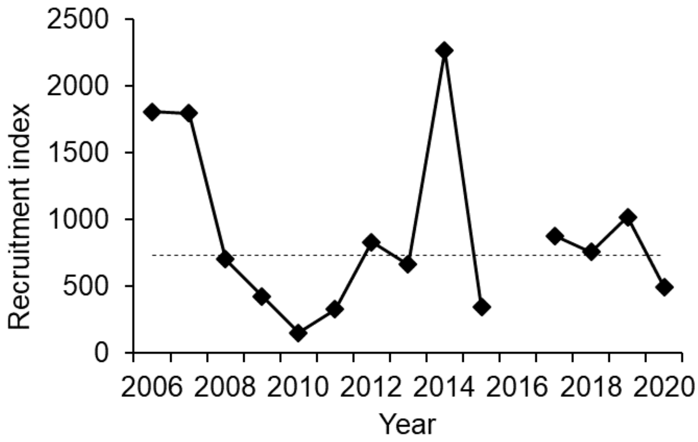

Figure 5.6. Northern shrimp in Skagerrak and Norwegian Deep: Estimated recruitment index, 2006–2020. The horizontal line is the median of the time-series. The 2016 survey data have been omitted (see text for details).

In 2020 it was discovered that the SS3-model has been run with a partly incorrect survey data time-series (numbers-at-lengths for the years 1988, 1995, 1998–2001, and 2006–2009). When corrected the total numbers-at-lengths increased by 0.4 to 6.4%, except for the year 1988 when the corrected number was 31.1% higher. This correction only brought about very marginal changes in the assessment model outputs of F and SSB (Figure 5.7), which do not affect the assessment results or the reference points.

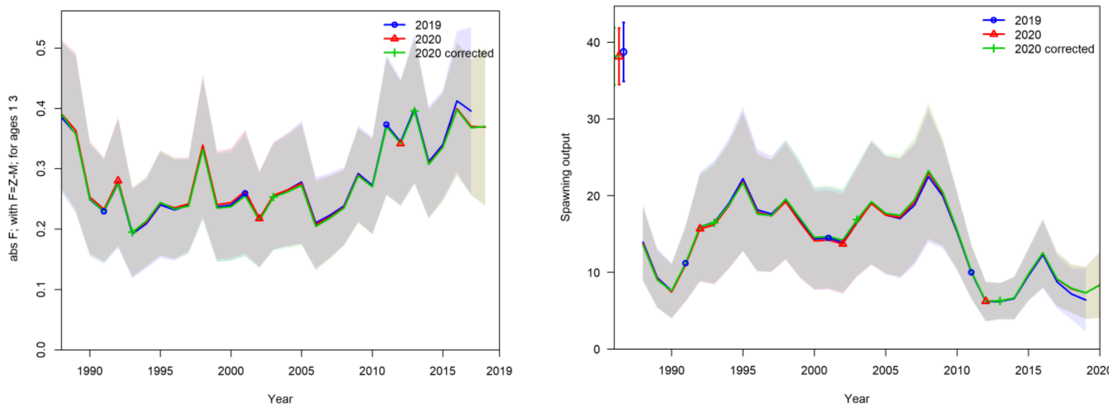

Figure 5.7. Northern shrimp in Skagerrak and Norwegian Deep: F and SSB assessment results for model runs with corrected survey data (2020 corrected) and un-corrected data (2019, 2020). It should be noted that values of F shown in this figure are not directly comparable to the F in the standard graphs of the assessment output in Figure 5.9 (as the figures here are from the standard output of r4SS). Here, F is presented as an average weighted by the number of shrimp in the age classes of F_{bar} ages 1 to 3.

1.2.4 Model

The stock assessment was benchmarked in January 2016 (ICES, 2016). At the benchmark it was decided that a length-based Stock Synthesis (SS3) statistical framework (ICES, 2016, and references therein) should replace the surplus production model (SCR Doc. 15/059) used since 2013, to assess status of the stock and form a basis for advice. New reference points were also defined at the 2016 benchmark (ICES, 2016).

As part of a Management Strategy Evaluation (MSE) in 2017, ICES reviewed the MSY reference points for this stock (ICES, 2017a). The analysis resulted in an update of the F_{MSY} value to F_{MSY} = 0.60 (previously 0.62), whereas MSY $B_{trigger}$ = 9900 t remained unchanged (see below).

1.2.5 Assessment results

SS3 model diagnostics of this year's run do not indicate any issues with the model fit. There is a small positive retrospective pattern in SSB and a negative retrospective pattern in F, but the patterns are within the acceptable range of requiring no action. (See section below on model retrospective).

1.2.6 Sensitivity analysis

The benchmark in 2016 (ICES, 2016) recognized the uncertainty in the current assumption of M = 0.75 to the assessment, which is based on estimates from the Barents Sea in the 1990s (Barenboim *et al.*, 1991), and recommended that the sensitivity of model outputs and catch advice to the specifications of M should be explored. Preliminary sensitivity analyses of the assessment model regarding different levels of M carried out at the 2016 NIPAG meeting, showed that M = 0.90 did not change the perception of the current level of F and SSB relative to the reference points of F_{MSY} and MSY $B_{trigger}$ compared with M = 0.75 (base model) (Figure 5.8). However, shrimp in the Norwegian Deep/Skagerrak are considered to have a lifespan of only about half of that of shrimp in the Barents Sea and it is therefore likely that M could be substantially higher and outside the 0.75–0.90 range explored. Previous analyses of different M assumptions for this stock (SCR 14/66) provide support for this hypothesis. NIPAG was not in a position at the meeting to fully explore the sensitivity to the M assumption used and stresses the importance of further investigations to be conducted well in advance of the next proposed benchmark in 2020–2021.

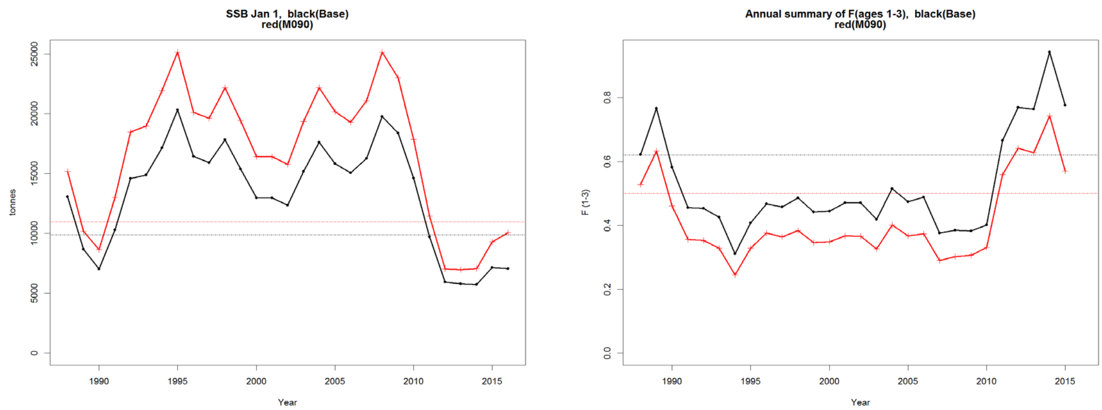

Figure 5.8. Northern shrimp in Skagerrak and Norwegian Deep: F and SSB assessment results for natural mortality M = 0.75 (base model, black) and M = 0.90 (red). The horizontal lines indicate MSY $B_{trigger}$ (left panel) and F_{MSY} (right panel) values for each of the two M-levels.

1.2.7 Historical stock trends and recruitment

Historical stock trends are shown in Figure 5.9.

Since 2008, when SSB was 23 270 t, which is the highest SSB estimate of the time-series, the SSB decreased to the time-series low of 6211 t in 2012. The SSB then increased up to 2016, but decreased again to 7331 t in 2019, which is between B_{pa} and B_{lim} of 6300 t. The SSB in 2020 is 8319 t.

SS3 models recruitment as the abundance of the 0-group. A series of lower recruitment years since 2008, with the exception of year 2013 and 2018, should be noted. During this period of lower recruitment, the estimates of SSB were also for some years historically low and close to or below B_{lim}. The uncertainty around the estimate of recruitment in the terminal year of the assessment is generally relatively large. The reason for this is that the model has not yet fully seen the recruits in the commercial catch data (catch data are until and including the terminal year) but only in the survey data (collected with a smaller meshed survey trawl in January the terminal year +1).

Fishing mortality (F) for ages 1 to 3 remained relatively stable from the beginning of the 1990s to about 2010. After 2010, F increased steeply to 0.74 in 2014, which is the highest observed value of the time-series. F has been above F_{MSY} in all years since 2011, except in 2015, 2018 and 2019. F in 2019 is 0.53.

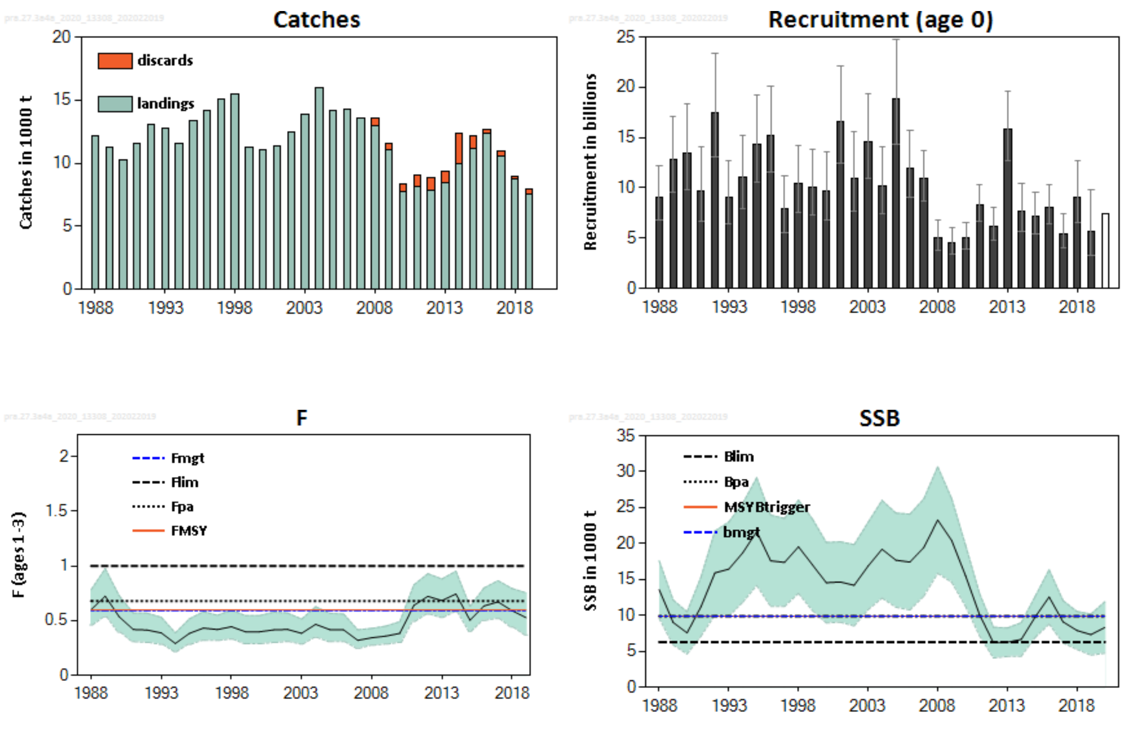

Figure 5.9. Northern shrimp in Skagerrak and Norwegian Deep: Summary assessment output. Total catch, including estimated discards since 2008 (tonnes) and F, SSB and R assessment results. SSB and R are depicted with 90% confidence intervals. The assumed recruitment value (geometric mean of the last ten years) for 2019 is unshaded.

1.2.8 Model retrospective

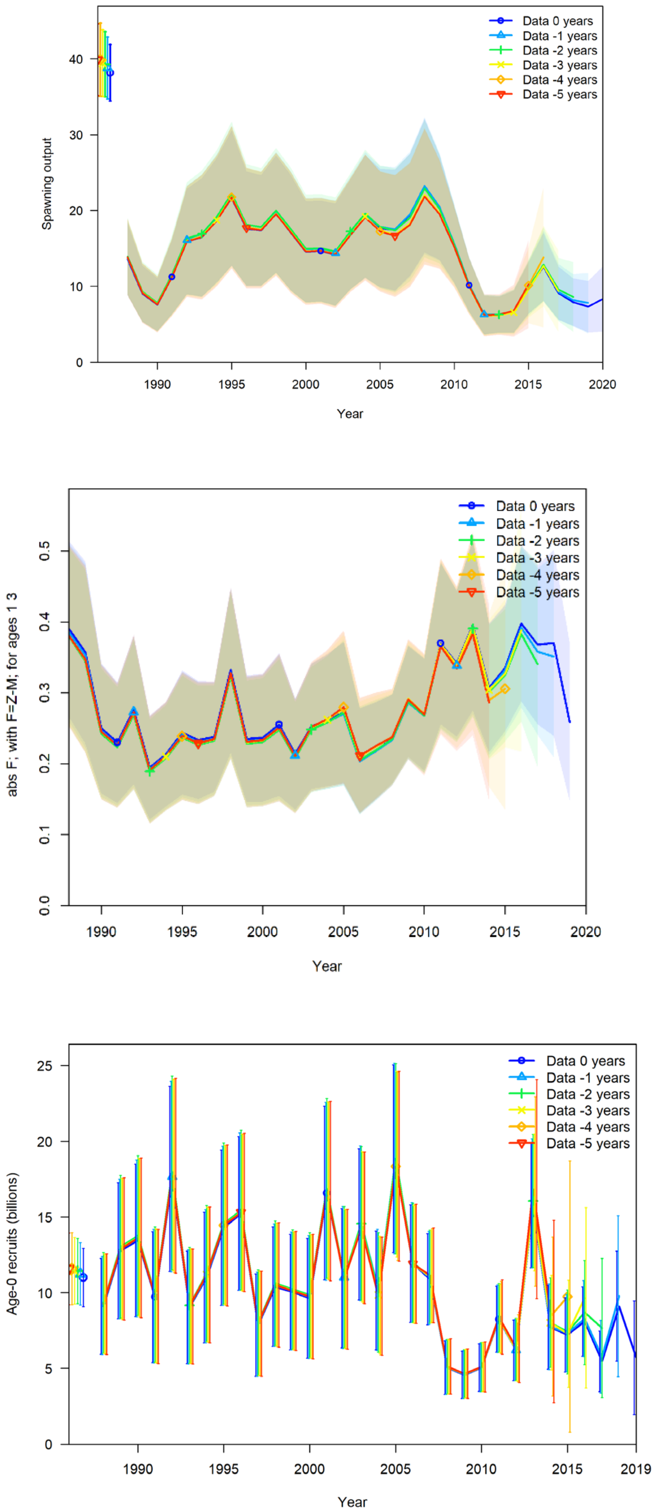

Figure 5.10. Northern shrimp in Skagerrak and Norwegian Deep: Model retrospective of SSB, F (ages 1–3) and R. It should be noted that values of F shown in these figures are not directly comparable to the F in Figure 5.9 (as the figures here are from the standard output of r4SS). Here, F is presented as an average weighted by the number of shrimp in the age classes of F_{bar} ages 1 to 3.

Model retrospectives for the assessment are shown in Figure 5.10. There is a negligible retrospective pattern for the more recent part of the time-series of SSB, with a small tendency to overestimate SSB. There is a moderate tendency to underestimate F. Recruitment is somewhat overestimated by the model (Figure 5.10), meaning that the previous year classes have been revised downwards. Figure 5.11 presenting the retrospective patterns in estimation of recruitment deviations shows that two years of observing a cohort is necessary to estimate it with low uncertainty.

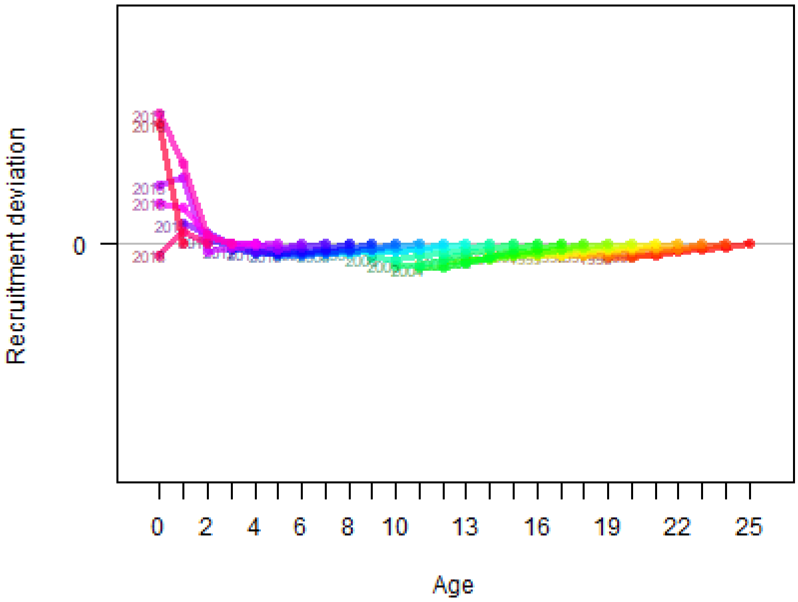

Figure 5.11. Northern shrimp in Skagerrak and Norwegian Deep: Model retrospective patterns in the estimation of recruitment deviations.

1.3 New long-term management strategy

In April 2018 following an ICES management strategy evaluation (ICES, 2017a), a long-term management strategy was agreed between EU and Norway (Anon., 2018):

Values for B_{MGT} ($B_{TRIGGER}$) and F_{TARGET} are fixed at levels of 9900 t and 0.59, respectively and the TAC will be established for each calendar year (from January 1st to December 31st).

- *By end of the year N-1, a preliminary TAC will be adopted by the Parties based on ICES catch forecast for the six first months of the year N, released in March of year N-1.*
- *The Parties will establish the final TAC for the entire year N in light of the ICES catch advice released in March of year N.*

When establishing the preliminary and the final TACs the following rules shall apply:

a) When the SSB at the start of the year is estimated at or above BMGT the Parties will fix a TAC consistent with a fishing mortality rate of F_{TARGET}.

b) When the SSB at the start of the year is estimated below B_{MGT}, the Parties will fix a TAC consistent with a fishing mortality rate of F_{TARGET} x (SSB/B_{MGT}).

The TAC will include all removals made from the stock.

When SSB is estimated to be at or above B_{MGT}, the TAC derived from paragraph (a) can be deviated with up to 10% according to the agreed "banking and borrowing" scheme described in Annex III of the agreed record (Anon., 2018).

The LTMS will be applicable from 1st of January 2019 onwards.

The management strategy shall be revised by the end of 2021 or following the next ICES benchmark of the stock.

The advised TAC for the first two quarters of year N is based on multiplying the full TAC from the short-term forecast for year N with the average proportion of quarterly catches ([Q1+Q2]/[Q1+Q2+Q3+Q4]) from the previous five years.

When the EU and Norway LTMS is fully implemented in 2019, it will rely on annual ICES advice issued in March. In the current transition phase the clients have requested ICES to issue an advice for the first two quarters of 2019, based on the LTMS, in October 2018.

1.4 Reference points

The reference points were computed at the benchmark in January 2016 based on the definition of the *Pandalus* stock as being a medium-lived species (ICES, 2016a; Table 5.4).

In 2009, ICES adopted a "Maximal Sustainable Yield (MSY) framework" (ACOM. ICES Advice, 2016. Book 1. Section 1.2) for deriving advice. It considers two reference points: F_{MSY} and MSY $B_{trigger}$. (Table 5.4). Under the ICES PA two reference points are also required; B_{lim} and B_{pa} (Table 5.4). B_{lim} was set to B_{loss}, which is the lowest observed value of the time-series estimated at the benchmark in 2016.

Two new reference points were computed as part of the MSE, F_{MGT} (F_{target}) and B_{MGT} ($B_{trigger}$) (ICES, 2017a). As part of the MSE, ICES also reviewed the MSY reference points for this stock, applying the stock-specific assessment/advice error settings developed for this *Pandalus* stock as part of the management strategy evaluation work. Applying the ICES guidelines (ICES, 2017b) for the calculation of reference points, the analysis resulted in an update of the F_{MSY} value to F_{MSY} = 0.60 (previously 0.62), whereas MSY $B_{trigger}$ = 9900 t remained unchanged. The lower Ftarget (F_{MGT}) for the HCR compared to the F_{MSY} is due primarily to the more stringent risk criterion of the HCR.

Table 5.4. Northern shrimp in Skagerrak and Norwegian Deep: Reference points, values, and their technical basis.

Framework	Reference point	Value	Technical basis
MSY approach	MSY $B_{trigger}$	9900 t	The 5th percentile of the equilibrium distribution of SSB when fishing at F_{MSY}, constrained to be no less than B_{pa}
	F_{MSY}	0.60	The F that maximizes median equilibrium yield (defining yield as the total catch)
Precautionary approach	B_{lim}	6300 t	B_{loss} (lowest observed SSB in the benchmark assessment 2016)
	B_{pa}	9900 t	$B_{lim} \times \exp(1.645 \times \sigma)$, where $\sigma = 0.27$
	F_{lim}	1.00	The F that leads to 50% probability of SSB < B_{lim}
	F_{pa}	0.68	$F_{lim} \times \exp(-1.645 \times \sigma)$, where $\sigma = 0.23$
Management plan	B_{MGT}	9900 t	The 5th percentile of the equilibrium distribution of SSB when fishing at F_{MGT}, constrained to be no less than B_{pa}
	F_{MGT}	0.59	The F that maximizes median equilibrium yield (defining yield as the total catch)

1.4.1 Catch scenarios

In accordance with the requirements of the LTMS, two sets of catch scenarios were provided; i) updated catch scenarios for the full year 2020 and ii) catch scenarios for the first semester of 2021.

Table 5.5. Northern shrimp in Skagerrak and Norwegian Deep: The basis for the updated catch scenarios for 2020.

Variable	Value	Notes
F2019	0.53	Corresponds to the estimated catches in 2019
SSB2020	8319	SSB beginning of 2020 (in tonnes)
R2020	7 442 212	GM 2010–2019 (in thousands)
Catches 2019	7944	Landings and estimated discards (in tonnes)

Given the new 2020 datapoint for the survey time-series and an estimated catch of 7944 t in 2019, updated catch scenarios were provided for 2020 (Table 5.6). The advised TAC for 2020 is 8736 tonnes.

Table 5.6. Northern shrimp in Skagerrak and Norwegian Deep: Updated catch scenarios for 2019.

Basis	Total catch (2020)	Ftotal (2020)	SSB (2021)	% SSB change *	% TAC change **	% advice change ***
LTMS: $F = F_{MGT} \times (SSB_{2020}/\ MSY\ B_{trigger})$	8736	0.50	8867	6.6	41.7	41.7
Other scenarios						
MSY approach: $F = F_{MSY} \times (SSB_{2020}/\ MSY\ B_{trigger})$	8736	0.50	8867	6.6	41.7	41.7
F = 0	0	0	14940	79.6	-100.0	-100.0
F_{pa}	10932	0.68	7432	-10.7	77.4	77.4
F_{MSY}	9999	0.6	8035	-3.4	62.2	62.2
FMSY lower	7917	0.44	9414	13.2	28.5	28.5
FMSY upper	11362	0.72	7157	-14.0	84.4	84.4
Flim	13997	1	5524	-33.6	127.1	127.1
F2019	9127	0.53	8607	3.5	48.1	48.1
FMGT	9883	0.59	8111	-2.5	60.4	60.4
SSB2021 = BPA = Btrigger	7198	0.39	9898	19.0	16.8	16.8
SSB2021 = Blim	12728	0.86	6300	-24.3	106.5	106.5

*** * SSB_{2021} relative to SSB_{2020}.**

**** Advised catch in 2020 relative to TACs in 2019 (6163 t). Note that NO and DK banked 523 t and 245 t, respectively, from 2018. These catches are not included in the TAC change.**

***** Advised catch in 2020 relative to advice value 2019 (6163 t).**

The inclusion of the most recent survey data (2020) and catch data (2019) results in decline in SSB_{2020} and the reduction in catches advised.

Table 5.7. Northern shrimp in Skagerrak and Norwegian Deep: The basis for the 1st semester catch-scenarios for 2021.

Variable	Value	Notes
F_{2020}	0.49	Corresponds to the catch forecast for 2020
SSB_{2021}	9105	SSB beginning of 2021 (in tonnes) from assessment model, including 2020 catches
R_{2021}	7 464 504	GM 2010–2019 (in thousands) from assessment model, including 2020 catches
Catches 2020	8736	Catch forecast for 2020 (in tonnes)

Table 5.8. Northern shrimp in Skagerrak and Norwegian Deep: Catch scenarios for 1st semester in 2021.

Basis	Total catch (2021)	Q1 and Q2 catch (2021) ^	F_{total} (2021)	SSB (2022)	% SSB change *	% TAC change **	% advice change **
LTMS: F = F_{MGT} × (SSB_{2021}/ MSY $B_{trigger}$)	8753	4552	0.54	8206	-9.9	0.2	0.2
			Other scenarios				
MSY approach: F = F_{MSY} × (SSB_{2021}/ MSY $B_{trigger}$)	8875	4615	0.55	8130	-10.7	1.6	1.6
F = 0	0	0	0	13981	53.6	-100.0	-100.0
F_{pa}	10353	5384	0.68	7229	-20.6	18.5	18.5
F_{MSY}	9461	4920	0.60	7770	-14.7	8.3	8.3
$F_{MSY\ lower}$	7472	3885	0.44	9009	-1.1	-14.5	-14.5
$F_{MSY\ upper}$	10769	5600	0.72	6981	-23.3	23.3	23.3
F_{lim}	13311	6922	1	5521	-39.4	52.4	52.4
F_{2020}	8132	4229	0.49	8593	-5.6	-6.9	-6.9
F_{MGT}	9352	4863	0.59	7837	-13.9	7.1	7.1
SSB_{2022} = B_{pa} = $B_{trigger}$	6083	3163	0.34	9899	8.7	-30.4	-30.4
SSB_{2022} = B_{lim}	11933	6205	0.84	6300	-30.8	36.6	36.6

*** SSB_{2022} relative to SSB_{2021}.**

**** Advised catch in 2021 relative to advised catch in 2020 (8736 t).**

^ Total catch 2021 x average proportion of catch taken in the first two quarters of 2015–2019 (0.52).

The first semester (Q1 and Q2) catch scenarios for 2021 are based on multiplying the full TAC from the short-term forecast for 2021 with the average proportion of quarterly catches from the previous five years, which gives a factor of 0.52. When applied to the full 2021 advised TAC of 8753 t this results in an advised TAC for the first two quarters of 2021 of 4552 t.

The advice is in line with the previous year.

It should be noted that the predictive power of the model seems rather high. Last year's assessment predicted particularly well the levels of F and SSB given a certain level of catch. In 2019, at catches equal to the realized catches (i.e. 7944.4 t in 2019), the model predicted an SSB in 2020 only 7% larger than the assessed SSB in 2019 and an F only 2% lower than the assessed F in 2019.

1.5 State of the stock

Mortality. Fishing mortality (F) has been above F_{MSY} in all years since 2011, except in 2015, 2018 and 2019.

Biomass. The spawning–stock biomass (SSB) declined after 2008 and has fluctuated at a lower level since then.

Recruitment. Recruitment has been below average since 2008, except for the 2013 year class.

State of the Stock. At the beginning of 2020, the stock is estimated to be below MSY $B_{trigger}$ and between B_{pa} and B_{lim}. Recruitment is estimated to be below average in 2019. Fishing mortality was below F_{MGT}, F_{MSY} and F_{pa} in 2019.

Yield. According to the new long-term management strategy, catches in 2020 should be no more than 8736 tonnes and in the two first quarters of 2021 no more than 4552 tonnes.

1.6 Research recommendations

NIPAG **recommended** in 2010–2014 that differences in recruitment and stock abundance between Skagerrak and the Norwegian Deep should be explored.

Status: No progress has been made. NIPAG reiterates this recommendation.

NIPAG **recommended** in 2016 that seasonal patterns of spatial distribution resulting from the migration of different age and sex classes should be investigated, as well as seasonal patterns of LPUE in the three fisheries, particularly the reason why LPUE for a given year increases when we have the full year's data compared to the LPUE from only the first 5–6 months.

Status: Spatial patterns in *Pandalus* distribution of the different age and sex classes has not been addressed and with the current sampling regime it is unlikely this can be addressed in the near future. However, spatial distribution of LPUE will be addressed at the proposed benchmark for 2021.

NIPAG **recommended** in 2016 that age determination and validation using sections of eyestalks should continue and results used to refine the life-history knowledge of the stock including age–length relationship and natural mortality assumption.

Status: This work is ongoing.

NIPAG **recommended** in 2016 that a full benchmark for this stock, including a data compilation workshop, be conducted in the near future and no later than 2020.

Status: This recommendation is reiterated.

1.7 References

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ICES. 2017a. Report on the Long-term Management Strategy Evaluation for Northern Shrimp (*Pandalus borealis*) in Division 4.a East and Subdivision 20 (PandLTMS). October–November 2017, ICES CM 2017/ACOM:52. 182 pp.

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Annex 1: List of participants

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Annex 2: Stock Annex for Northern shrimp (*Pandalus borealis*) in Division 4.a East and Subdivision 20 (northern North Sea in the Norwegian Deep and Skagerrak)

The table below provides an overview of the NIPAG Stock Annex. Stock Annexes for other stocks are available on the ICES website Library under the Publication Type "Stock Annexes". Use the search facility to find a particular Stock Annex, refining your search in the left-hand column to include the *year*, *ecoregion*, *species*, and *acronym* of the relevant ICES expert group.

Stock ID	**Stock name**	**Last updated**	**Link**
Northern shrimp (*Pandalus borealis*) in Division 4.a East and Subdivision 20 (northern North Sea in the Norwegian Deep and Skagerrak)	*Pandalus borealis*	January 2016	Pand_SA