Northwest Atlantic
Fisheries Organization

International Council for
the Exploration of the Sea

Conseil International pour
l'Exploration de la Mer

NAFO SCS Doc. 19/24 Serial No. N7026 **ICES CM 2019/FRSG1:84**

NAFO/ICES *Pandalus* Assessment Group Meeting, 08 to 13 November 2019

Havforskningsinstituttet (IMR), Tromsø, Norway

THIS REPORT IS NOT TO BE CITED WITHOUT PRIOR REFERENCE

TO THE NAFO OR ICES SECRETARIATS

NAFO/ICES *Pandalus* Assessment Group Meeting
NIPAG 08-13 November 2019

Contents

NIPAG Participants 2019

From left to right: Carsten Hvingel, Katherine Sosebee, AnnDorte Burmeister, Susan Thompson, José Miguel Casas Sanchez, Katherine Skanes, Frank Rigét, Tom Blasdale, Guldborg Søvik, Ole Ritzau Eigaard, Trude Thangstad, Kalvi Hubel, Fabian Zimmermann

Report of the NIPAG Meeting

08 –13 November 2019

Co-Chairs: Katherine Sosebee, Ole Ritzau Eigaard. Rapporteur: Tom Blasdale

I. OPENING

The NAFO/ICES *Pandalus* Assessment Group (NIPAG) met at the Havforskningsinstituttet (IMR), Tromsø, Norway from 08 to 13 November 2019 to review stock assessments referred to it by the Scientific Council of NAFO and by the ICES Advisory Committee. Representatives attended from Canada, Denmark (in respect of Greenland), European Union, Norway and the USA. The NAFO Scientific Council Coordinator and Scientific Information Administrator were also in attendance.

II. GENERAL REVIEW

1. Review of Research Recommendations in 2018

Recommendations applicable to individual stocks are given under each stock in the "stock assessments" section of this report.

2. Review of Catches

Catches and catch histories were reviewed on a stock-by-stock basis in connection with each stock.

III. STOCK ASSESSMENTS

1. Northern shrimp (*Pandalus borealis*) on the Flemish Cap (NAFO Div. 3M)

This stock was assessed during the September 2019 meeting of Scientific Council in conjunctions with NIPAG (NAFO SCS Doc. 19/21). NIPAG reviewed the assessment during the present meeting and made the following recommendations:

- NIPAG **recommends** that *in future years NIPAG should investigate the options to implement an analytical assessment for this stock. Models to explore could include SPiCT, Stock Synthesis (as applied for Northern shrimp in Skagerrak and Norwegian Deep), or other length based models.*

- NIPAG **recommends** that *this stock be considered for a benchmark workshop in conjunction with the benchmark of the Skagerrak and Barents Sea stocks anticipated for 2020/21. The NIPAG 2020 meeting will be utilized for a workshop to clarify the data situation and potential assessment models.*

2. Northern shrimp (*Pandalus borealis*) on the Grand Bank (NAFO Divs. 3LNO)

This stock was assessed during the September 2019 meeting of Scientific Council in conjunctions with NIPAG (NAFO SCS Doc. 19/21). NIPAG reviewed the assessment during the present meeting. There were no further recommendations.

3. Northern shrimp (*Pandalus borealis*) off West Greenland (NAFO SA 0 and SA 1)

(SCR Docs. 04/075, 04/076, 08/006, 11/053, 11/058, 12/044, 13/054, 19/043, 19/044, 19/045, 19/046, 19/048)

Environmental overview

Recent Conditions in Ocean Climate and Lower Trophic Levels

- The ocean climate index, (a composite temperature index) in Subarea 0-1 has remained mostly above normal since the early 2000s. It reached a peak in 2010 but has been in decline since then, reaching normal conditions in 2015, 2017 and 2018.
- Total production of the spring bloom (magnitude) was normal in 2018 and similar to conditions observed in 2017.
- Spring bloom initiation was delayed in 2018 compared to 1998-2015 climatology.

a) Introduction

The shrimp stock off West Greenland is distributed mainly in NAFO Subarea 1 (Greenland EEZ), but a small part of the habitat, and of the stock, intrudes into the eastern edge of Div. 0A (Canadian EEZ). Canada has defined 'Shrimp Fishing Area 1' (Canadian SFA1), to be the part of Div. 0A lying east of 60°30'W, i.e. east of the deepest water in this part of Davis Strait.

The stock is assessed as a single population. The Greenland fishery exploits the stock in Subarea 1 (Div. 1A– 1F). The Canadian fishery has been limited to Div. 0A.

Four fleets, one from Canada and three from Greenland (Kongelige Grønlandske Handel (KGH) fleet fishing from 1976 to 1990, the offshore fleet and coastal fleet) have participated in the fishery since the late 1970s. The Canadian fleet and the Greenland offshore fleets have been restricted by areas and quotas since 1977. The Greenland coastal fleet has privileged access to inshore areas (primarily Disko Bay and Vaigat in the north, and Julianehåb Bay in the south). Coastal licenses were originally given only to vessels under 80 tons, but in recent years larger vessels have entered the coastal fishery. Greenland allocates a quota to EU vessels in Subarea 1; this quota is usually fished by a single vessel which, for analyses, is treated as part of the Greenland offshore fleet. Mesh size is at least 40 mm in both Greenland, and Canada. Sorting grids to reduce bycatch of fish are required in both of the Greenland fleets and in the Canadian fleet. Discarding of shrimps is prohibited.

The enacted TAC for Greenland Waters in 2019 was set at 105 000 t and for Canadian Waters, 14 875 t.

Greenland requires that logbooks should record catch live weight. For shrimps sold to on-shore processing plants, a former allowance for crushed and broken shrimps in reckoning quota draw-downs was abolished in 2011 to bring the total catch live weight into closer agreement with the enacted TAC. Since 2012, *Pandalus montagui* has been included among the species protected by a 'moving rule' to limit bycatch and there are no licenses issued for directed fishing on it (SCR Doc. 19/044). Instructions for reporting *P. montagui* in logbooks were changed in 2011, to improve the reporting of these catches.

The table of recent catches was updated (SCR Doc. 19/044, 19/045). Total catch increased from about 10 000 t in the early 1970s to more than 105 000 t in 1992 (Figure 3.1). Actions by the Greenlandic authorities to reduce effort, as well as fishing opportunities elsewhere for the Canadian fleet, caused catches to decrease to about 80 000 t by 1998. Total catches increased to an average over 150 000 t in 2005 to 2008, but have since decreased to 72 256 t in 2015. Since 2016, the catches have been increasing in conjunction with increasing TACs and was in 2018, 93 189 t. The projected catch for 2019 is 100 000 t. The projected catch for Canada from Div. 0A in 2019 is expected to be in the region of 2 000t.

Recent catches, projected catch for 2019 and recommended and enacted TACs (t) for northern shrimp in Subarea 1 and Div. 0A (east of 60°30'W) are as follows:

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
TAC										
Advised	110 000	120 000	90 000	80 000	80 000	60 000	90 000	90 000	105 000	105 000
Enacted[1]	130 153	139 583	114 425	100 596	97 649	82 561	96 426	101 706	114 873	119 875
Catches (NIPAG)										
SA 1	128 109	122 659	115 965	95 379	88 765	72 254	84 356	89 369	93 189	100 000[2]
Div. 0A	5 882	1 330	12	2	0	2	1 171	3 215	1 689	2 000[2]
TOTAL	133 991	123 989	115 977	95 381	88 765	72 256	85 527	92 584	94 878	102 000[2]
STATLANT 21										
SA 1	123 973	122 061	114 958	91 800	88 834	71 777	82 922	88 947	90 457	
Div. 0A	5206	1134	12	2	0	2	1 381	2 778	1 412	

1Canada and Greenland set independent and autonomous TACs

2 Projected total catches for the year.

Until 1988 the fishing grounds in Div. 1B were the most important. The offshore fishery subsequently expanded southward, and after 1990 catches in Div. 1C–D, taken together, began to exceed those in Div. 1B. However, since 1998 catch and effort in southern West Greenland have continually decreased, and since 2008 effort in Div. 1F has been virtually nil (SCR Doc. 19/044). The fishery has moved north and, since 2009, at least 35% of the total catch was taken in Div. 1A.

In 2002–2005 the Canadian catch was stable at 6000 to 7000 t - about 4–5% of the total - but since 2007 fishing effort has been sporadic and catches variable, averaging about 1750 t in 2007–11 and from 2012 to 2015 catches in Div. 0A did not exceed 5 t (SCR Doc. 19/044). In 2016 fishing increased in the Canadian EEZ and from 2016 to 2019, Canadian catches averaged about 2000 t.

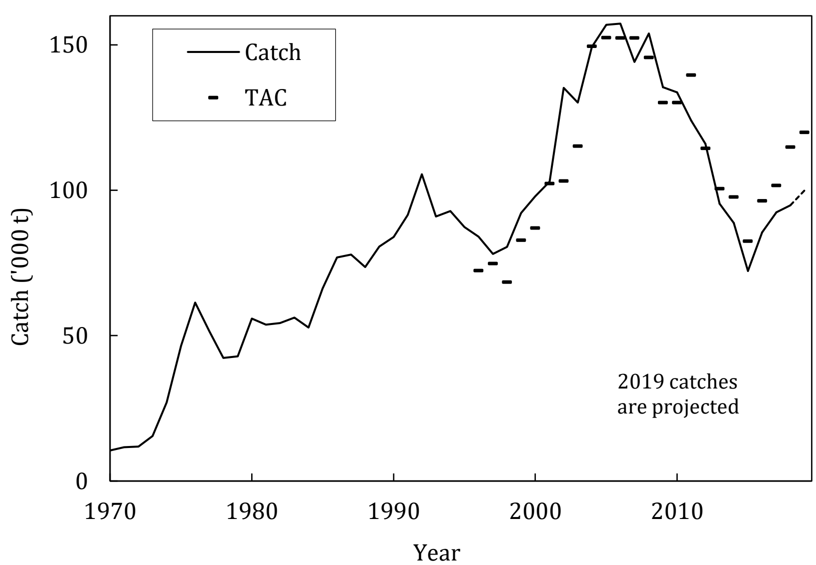

Figure 3.1. Northern shrimp in Subarea 1 and Div. 0A: Enacted TACs and total catches (2019 expected for the year).

b) Input data

i) Fisheries Data

Fishing effort and CPUE. Catch and effort data from the fishery were available from Greenland logbooks for Subarea 1 (SCR Doc. 19/044). In recent years both the distribution of the Greenland fishery and fishing power have changed significantly: for example, larger vessels have been allowed in coastal areas; the coastal fleet has fished outside Disko Bay; the offshore fleet now commonly uses double trawls. Furthermore, quota transfers between the two fleets are now allowed. Catch data before 2004 were under-reported, which was corrected in 2008.

CPUEs were standardized by linearized multiplicative models including terms for vessel, month, year, and statistical area. Standardized CPUE series were done separately for three different fleets (Figure 3.2); the early offshore fleet fishing in Div. 1A and part of 1B (KGH-index, 1976-1990), the present offshore fleet fishing in Subarea 1 (1987-2019) and the coastal fleet fishing in coastal and inshore areas (1989-2019). CPUE for the Canadian fleet fishing in Div. 0A has not been updated because it is not possible to receive new logbook information from Canada. In the recent three years the CPUE of the coastal fleet has slightly decreased while the CPUE of the offshore fleet increased from 2016 to 2017 and remained high in 2018.

The three CPUE series are combined by assuming they all reflect the overall biomass series scaled by a constant fleet factor, and that the errors had mean zero and variances inversely proportional to the fishing ground of the fleet. The estimation was done in a Bayesian framework.

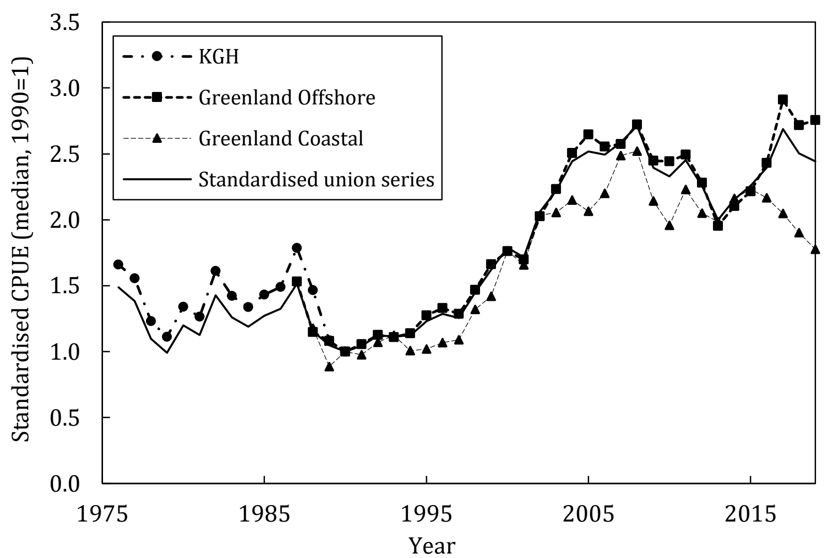

Figure 3.2. Northern shrimp in Subarea 1 and Div 0A: Standardized CPUE index series 1976–2019.

The distribution of catch and effort among statistical areas was summarized using Simpson's diversity index to calculate an 'effective' number of statistical areas being fished as an index of how widely the fishery is distributed (Figure 3.3). The 'effective' number of statistical areas being fished in Subarea 1 reached a plateau in 1992–2003. The range of the fishery has since contracted northwards and the 'effective' number of statistical areas being fished has decreased.

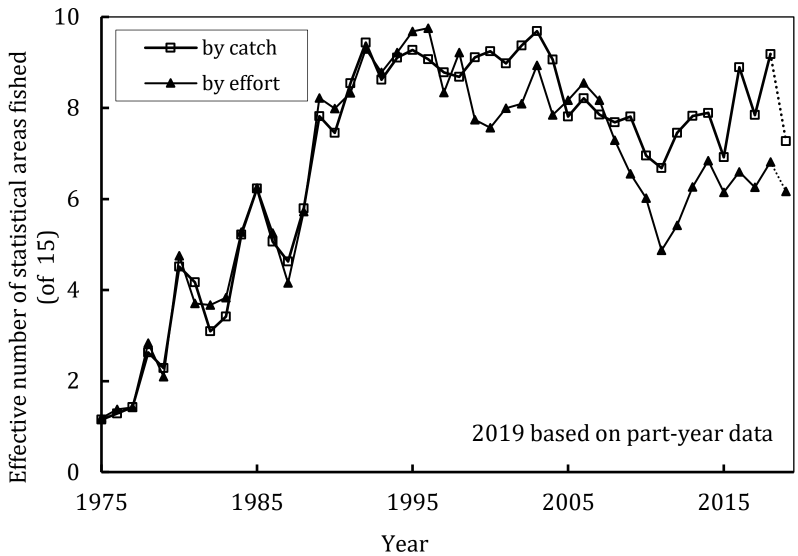

Figure 3.3. Northern shrimp in Subarea 1 and Div. 0A: Indices for the distribution of the Greenland fishery between statistical areas in 1975–2019.

Catch composition. There is no biological sampling program from the fishery that is adequate to provide catch composition data to the assessment.

ii) Research survey data

Greenland trawl survey. Stratified semi-systematic trawl surveys designed primarily to estimate shrimp stock biomass have been conducted since 1988 in offshore areas and since 1991 also inshore in Subarea 1 (SCR Doc. 19/043). From 1993, the survey was extended southwards into Div. 1E and 1F. A cod-end liner of 22 mm stretched mesh has been used since 1993. From its inception until 1998 the survey used 60-min. tows, but since 2005 all tows have lasted 15 min. In 1988 to 2005 the *Skjervøy 3000* survey trawl used was replaced by a *Cosmos 2000* with rock-hopper ground gear, calibration trials were conducted, and the earlier data were adjusted.

In 2018 and 2019, the annual trawl survey was conducted with two different chartered vessels during the same time period as the usual survey. All the standard gear from the research vessel Paamiut (such as cosmos trawl, doors, all equipment such as bridles etc., Marport sensors on doors and headlines) were used and all the standard research protocols were followed in an attempt to make the surveys as comparable as possible to earlier surveys. At least two crew member from Paamiut participated in each of the surveys. It was therefore assumed that the 2018 and 2019 results were directly comparable with the previous surveys. A more detailed description is available in SCR Docs. 19/43.

The survey average bottom temperature increased from about 1.7°C in 1990–93 to about 3.1°C in 1997–2014, but has since declined to 2.5° in 2019 (SCR Doc. 19/043). About 80% of the survey biomass estimate is in water 200–400 m deep throughout the time series. Since 2001 most of the biomass has been in water 200–300 m deep (SCR Doc. 19/043). The proportion of survey biomass in Div. 1E–F has been low in recent years and the distribution of survey biomass, like that of the fishery, has become more northerly.

Biomass. The survey index of total biomass remained fairly stable from 1988 to 1997. It then increased by, on average, 19%/yr until 2003, when it reached 316% of the 1997 value. Subsequent values were consecutively lower, with the second lowest level in the last 20 years occurring in 2014 (Figure 3.4) (SCR Doc. 19/043). Over the past 5 years biomass has increased and was in 2019 186% of the low 2014 level. Offshore regions comprise 87% of the total survey biomass, and 13% is inshore in Disko Bay and Vaigat. The inshore regions have far higher densities than other areas, almost three times as high as offshore (Figure 3.4) (SCR Doc. 19/043).

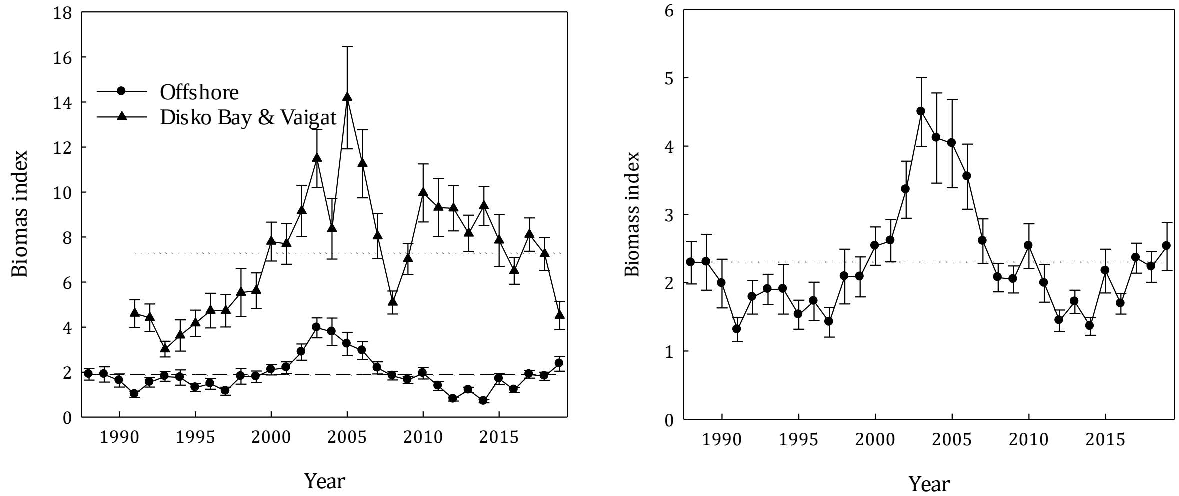

Figure 3.4. Northern shrimp in Subarea 1 and Div. 0A: Biomass index (survey mean catch rates) inshore and offshore (left panel) and overall (right panel) 1988–2019 (error bars 1 SE).

Length and sex composition (SCR 19/043). In 2019, in Disko Bay regions fishable biomass of males declined to a record low level far below its 14-year lower quartile, but increased offshore to a value well above its 14-year upper quartile. Like in most recent years, females compose a high proportion of survey and fishable biomass index in both regions, however at their 14-year lower quartile offshore, but well above their 14-year upper quartile in Disko Bay (SCR Doc. 19/046).

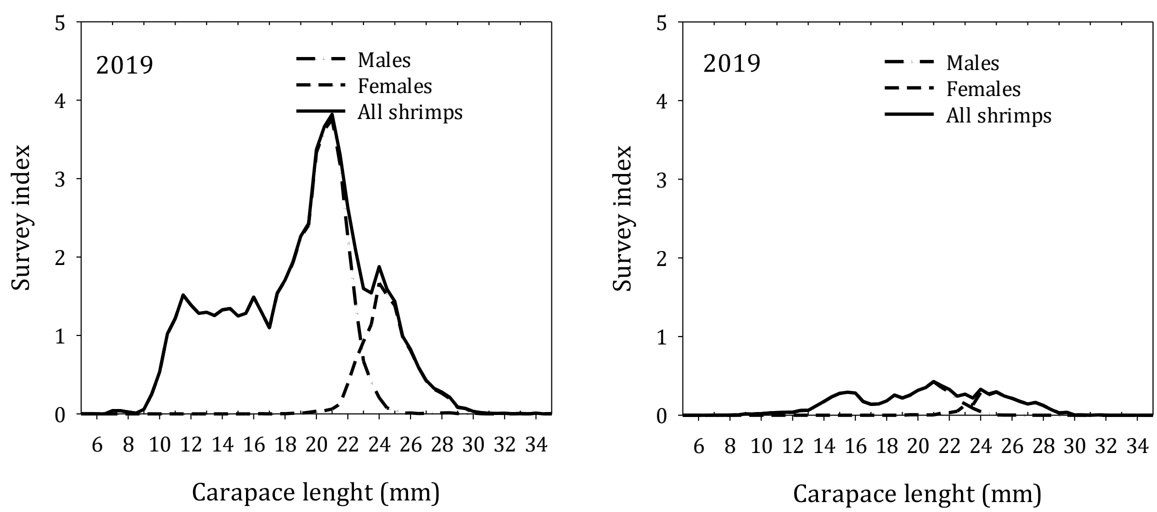

Figure 3.5. Northern Shrimp in Subarea 1 and Div. 0A: Survey mean catch rates at length in offshore regions (left) and Disko Bay & Vaigat (right) at the West Greenland trawl survey in 2019.

Recruitment. The number at age-2 (10.5 to 13.5 mm) reached a peak in 2000 and 2001 and has since declined to a much lower level, with two high values only in 2015 and 2019. The pre-recruit index (14–16.5 mm, expected to recruit to next year's fishable biomass) had high values in 2002 -2005 (except in 2004) and has since fluctuated at a lower level, with relatively high values in 1999-2000 and again in 2015 and 2017 (SCR Doc. 19/043, 19/046) (Figure 3.6). Numbers of age-2 and pre-recruits in 2019 are above and close to the 1993 to 2019 average, respectively.

Linear regression has shown a significant relationship between the number of age-2 shrimp, pre-recruits and the fishable biomass with a lag of 2, 3 or 4 years. The correlation was strongest (R^2 = 0.64) between number of age-2 shrimp and the fishable biomass 4 years later (SCR doc 19/0043), whereas the correlation was strongest (R^2 = 0.69) between pre-recruits and fishable biomass 1 year later (SCR doc 19/049). Furthermore there was also a significant relationship between number of age-2 shrimp and the number of pre-recruits 2-years later (R^2 = 0.56) (SCR doc 19/049).

The stock composition in Disko Bay has historically been characterized by a higher proportion of young shrimps than that offshore, exceptions were in 2017 and 2019, where younger shrimps offshore were much higher in numbers and relative to survey biomass. In 2019, numbers of age 2-shrimps relative to survey biomass are much higher among offshore regions than inshore, where numbers of age-2 shrimps were record low (SCR Doc. 19/043, 19/046). Numbers of pre-recruits relative to survey biomass were comparable between inshore and offshore regions (SCR Doc. 19/043, 19/046).

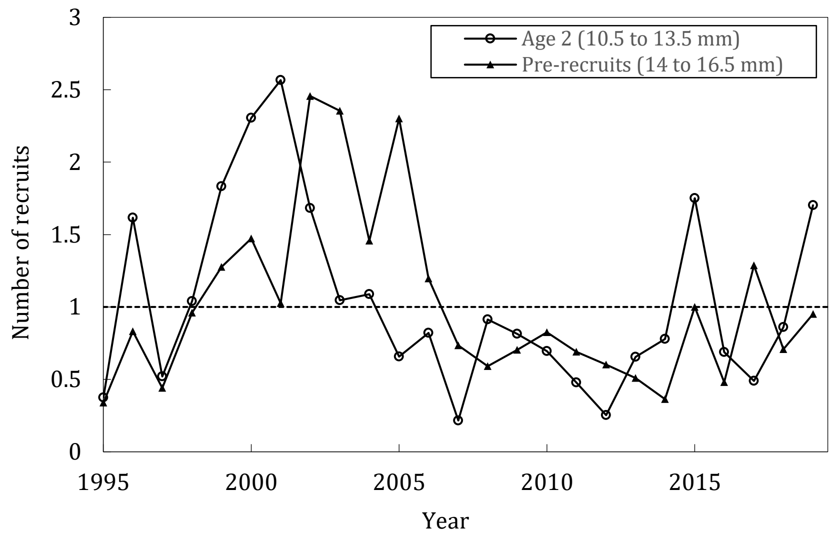

Figure 3.6. Northern shrimp in Subarea 1 and Div. 0A: Survey index of numbers at age 2 (10.5 - 13.5 mm) and index of number of pre-recruits (14-16.5 mm), 1993-2019.

Predation index. Four distinct stocks of Atlantic cod, spawning variously in inshore and offshore West Greenland, East Greenland, and Iceland, mix at different life stages on the West Greenland banks. They are subject to different influences, oceanographic and others, including drift of pelagic larval stages from east to west. The resulting dynamics are unpredictable both for the individual stocks and for their combination.

Series of estimates of cod biomass in West Greenland waters are available for different periods from VPA, from the German groundfish survey at West Greenland and from the Greenland trawl survey for shrimps. The results from the German survey for the current year are not available in time for the assessment. The overall cod-stock biomass index, used within the shrimp assessment model, was from 2019 modelled in a state-space assessment model (SAM) (SCR-Doc. 19/048) and based on catch at age in the commercial fishery, Greenland trawl survey (Skjærvøj and Cosmos trawl) and the German survey.

Indices of cod biomass are adjusted by a measure of the overlap between the stocks of cod and shrimps in order to obtain an index of 'effective' cod biomass, which is entered in the assessment model (SCR-Doc. 14/062). In 2019 the cod biomass density estimated by research trawl survey in West Greenland increased by a factor of 14 over 2018 but the index of its overlap with the shrimp stock decline to an average below the serial value. This resulted in an 'effective cod biomass' index of 20.9 kt, compared with 29 kt in 2018 (Figure 3.7) (SCR Doc. 16/042, 16/047, SCR Doc. 19/046, SCR Doc. 19/048).

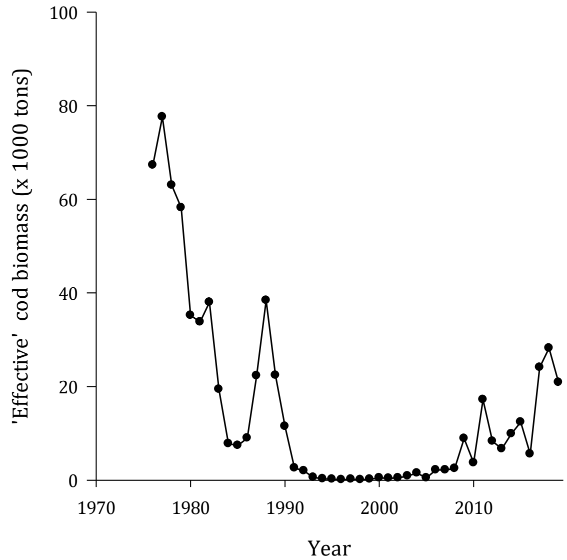

Figure 3.7. Indices of the 'effective' cod biomass in Subarea 1 and Div. 0A 1976 - 2019 (measure of the potential predation pressure by cod on shrimps).

c) Assessment

A Schaefer surplus-production model of population dynamics was fitted to series of CPUE, catch, and survey biomass indices (SCR Doc. 19/046). The model includes a term for predation by Atlantic cod. Total shrimp catches for 2019 are expected to be 100 000 t.

- In 2017 NIPAG noted concern about the degree of instability in MSY estimates in successive assessments. In an attempt to solve this problem, two changes were. First the time window was changed from 30- year to the entire time series from 1976 to 2018. Secondly the time invariant catchability in the CPUE time series was changed to a time variant by including two periods with different catchability.

A more comprehensive description of the evaluation and changes of the model are available in SCR Doc. 18/060. These changes have been included in the assessment since 2018 and have resulted in increased stability of the model parameters and a much improved retrospective pattern (Figure 3.9).

Estimates of stock-dynamic parameters from fitting a Schaefer stock-production model to 44 years' data are given in Table 3.1. Median values from the 2018 assessment are provided for comparison. The modelled biomass (Figure 3.8a) was low and stable until the late 1990s, when it started a rapid increase, doubling by 2004. Modelled biomass steadily declined from 2004 to 2013 but has since slightly increased. The median biomass has been above B_{msy} since the late 1990s except from 2013 to 2014. Mortality has generally been close to or below Z_{msy} during the modelled period (Figure 3.8b). Estimates of total mortality have increased in the most recent years. Assuming catches of 102 000 t, total mortality in 2019 is estimated to be below Z_{msy} with probability of $Z_{2019} > Z_{msy}$ = 32%. Biomass at the end of 2019 is projected to be close to the 2018 value and above B_{msy}. The probability of the biomass at the end of 2019 being below B_{msy} is 21% and the probability of being below B_{lim} is very low (<1%).

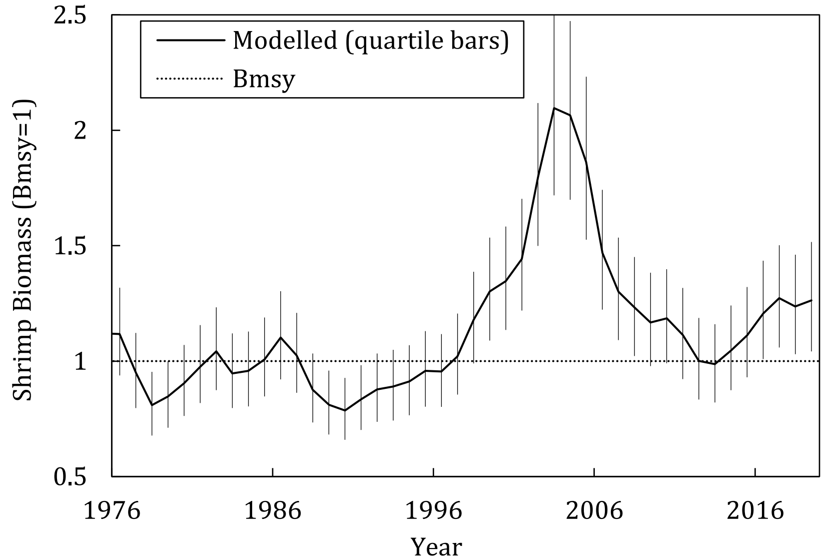

Figure 3.8a. Northern shrimp in SA 1 and Div. 0A: Relative stock biomass with quartile error bars 1976–2019. Dotted line corresponds to $B = B_{msy}$.

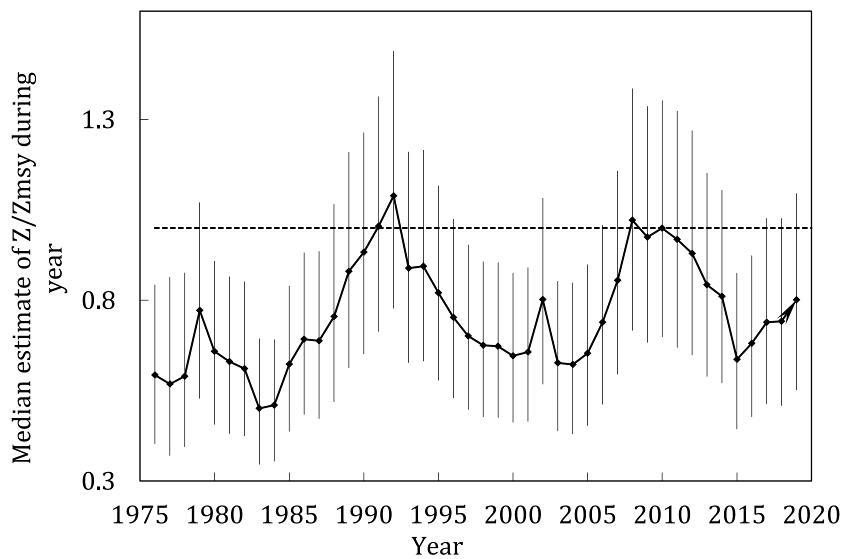

Figure3.8b. Northern shrimp in SA 1 and Div. 0A: Trajectory of the median modelled estimate of mortality relative to Z_{msy} during the year, 1976–2019 with quartile error bars.

Table 3.1. Estimates of stock-dynamic and parameters from fitting a Schaefer stock-production model to 44 years' data on the West Greenland stock of the northern shrimp in 2019. The median (2018) column shows results from last year's assessment

	Mean	S.D.	0.25	Median	0.75	Est. mode	Median (2018)
Max.sustainable yield	133.3	58.66	98.5	121.6	153.9	98.2	126.1
B/Bmsy, end current year (proj.)(%)	129.5	34.29	104.2	126.3	151.6	119.9	114.2
Biomass risk, end current year(%)	20.68	40.5	–	–	–	–	–
Z/Zmsy, current year (proj.)(%)	–	–	55.18	80.12	109.6	–	88.42
Carrying capacity	3561	1953	2094	2999	4558	1875	2237
Max. sustainable yield ratio (%)	9.142	4.681	5.809	8.557	11.79	7.387	11.74
Survey catchability (%)	17.07	10.41	9.316	14.78	22.27	10.2	21.71
CPUE(1) catchability	0.9956	0.6069	0.5439	0.8639	1.294	0.6005	1.234
CPUE(2) catchability	1.596	0.983	0.8686	1.378	2.099	0.942	1.983
Effective cod biomass 2019 (Kt)	26.07	30.01	16.38	20.91	26.4	10.59	33.89
P50% (prey biomass index with consumption 50% of ma	4.171	7.644	0.1904	1.159	4.585	-4.865	1.931
Vmax (maximum consumption per cod)	1.778	2.189	0.3358	0.7638	2.329	-1.2646	1.291
CV of process (%)	14.01	2.908	11.98	13.77	15.77	13.29	13.15
CV of survey fit (%)	16.56	2.99	14.44	16.15	18.32	15.33	15.86
CV of CPUE (1) fit (%)	7.052	1.511	5.895	6.748	7.861	6.14	6.485
CV of CPUE (2) fit (%)	7.463	2.329	5.813	6.837	8.386	5.585	6.888

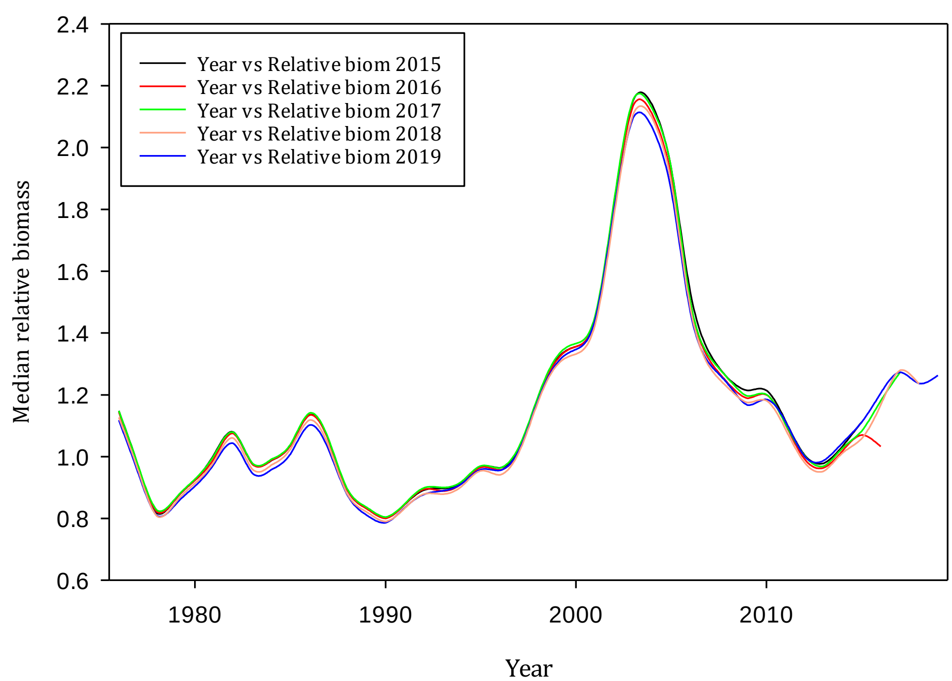

Figure 3.9. Retrospective plots of the relative biomass B/B_{msy} 2015 to 2019.

A five year retrospective analysis was performed (Figure 3.9) and results were found to be quite stable.

d) Reference points

B_{lim} has been established as 30% B_{msy}, and Z_{msy} (fishery and cod predation) has been set as the mortality reference point. B_{msy} and Z_{msy} are estimated directly from the assessment model.

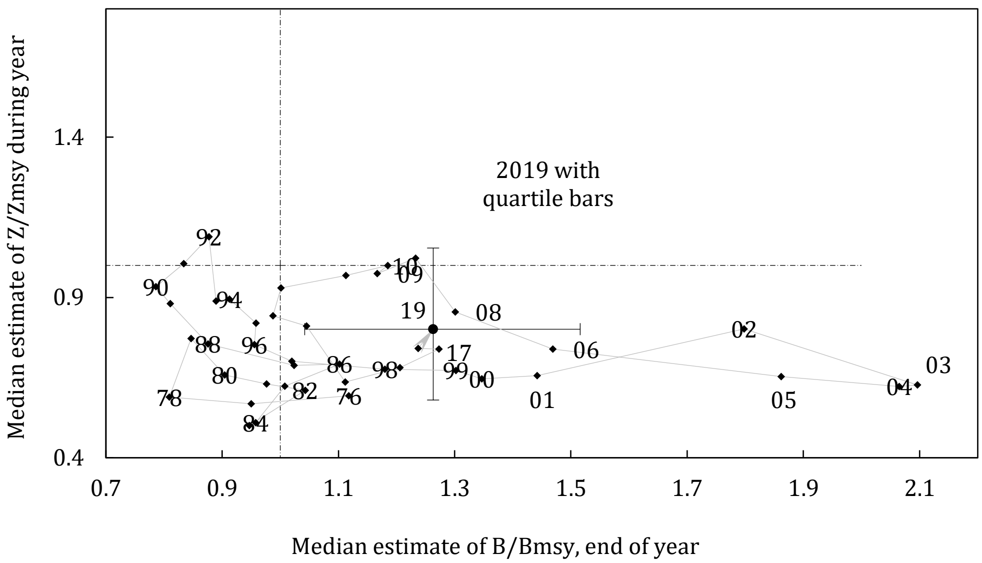

Figure 3.10. Northern shrimp in Subarea 1 and Div. 0A: Trajectory of relative biomass and relative mortality, 1976–2019.

e) State of the stock

Biomass. Biomass at the end of 2019 is above B_{msy} and the probability of being below B_{lim} is very low (<1%).

Mortality. Assuming catches of 102 000 t, the probability of being above Z_{msy} is 32%.

Recruitment. Numbers of age-2 in 2019 are above average and numbers of pre-recruits are close to the 1993 to 2019 average.

State of the Stock. Biomass at the end of 2019 is above B_{msy} and the probability of being below B_{lim} is very low (<1%). The probability of mortality in 2019 being above Z_{msy} is 32%. Recruitment (number of age-2 shrimp) in 2019 is above average.

f) Projections

Three years projections for years 2020–2022 under eight catch options and subject to predation by the cod stock with an 'effective' biomass of 21 kt (the estimated value for 2019 was 20.9 Kt) were evaluated. Additional projections assuming 'effective' cod biomasses of 15 kt, and 25 kt were conducted but results indicated small differences in risk probabilities (SCR Doc 19/046).

21 000 t cod	Catch option ('000 tons)							
Risk of:	85	90	95	100	105	110	115	120
falling below B_{MSY} end 2020 (%)	23	23	23	24	24	24	24	25
falling below B_{MSY} end 2021 (%)	24	24	25	25	26	27	27	27
falling below B_{MSY} end 2022 (%)	24	25	26	27	29	29	30	31
falling below B_{lim} end 2020 (%)	0	0	0	0	0	0	0	0
falling below B_{lim} end 2021 (%)	0	0	0	0	0	0	0	0
falling below B_{lim} end 2022 (%)	0	0	0	0	0	0	0	0
exceeding Z_{MSY} in 2020 (%)	17	20	24	27	30	34	37	40
exceeding Z_{MSY} in 2021 (%)	18	21	25	28	32	35	38	41
exceeding Z_{MSY} in 2022 (%)	19	22	26	29	33	36	39	43

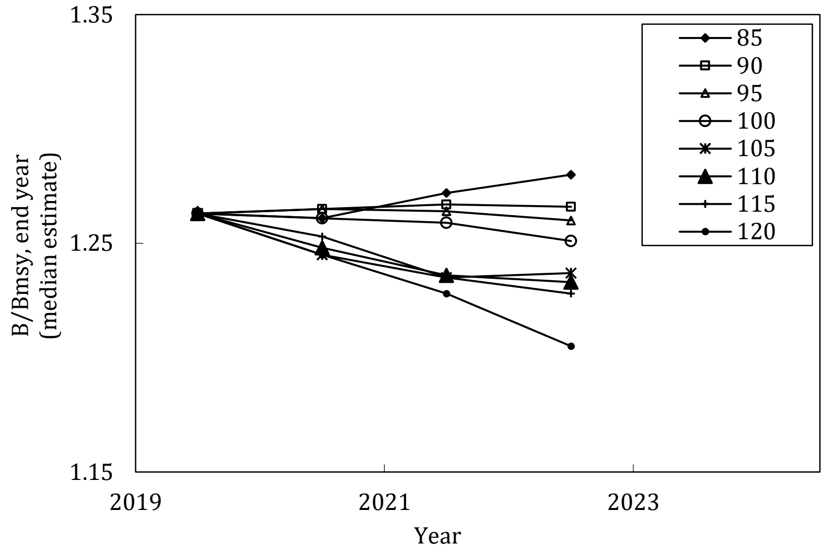

Figure 3.11. Northern shrimp in Subarea 1 and Div. 0A: Median estimates of year-end biomass trajectory for 2020–2022 with annual catches at 85 –120 kt and an 'effective' cod stock assumed at 21 kt.

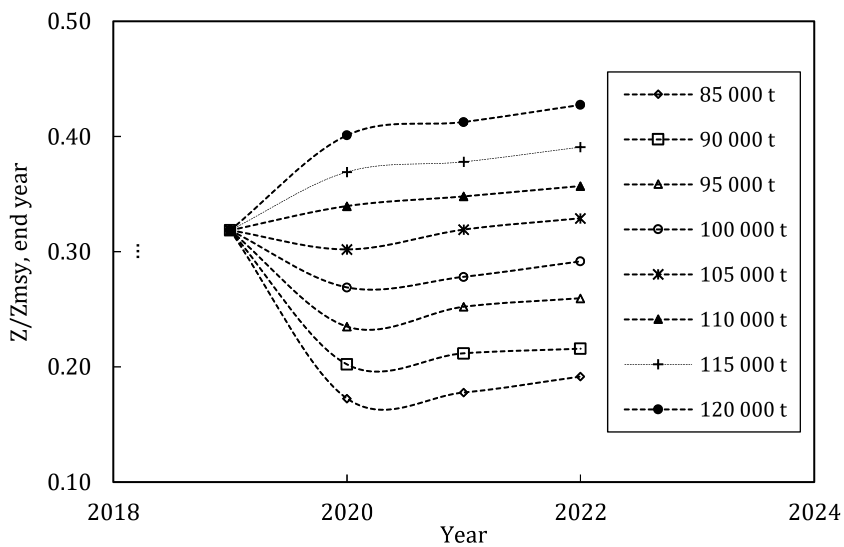

Figure 3.12. Northern shrimp in Subarea 1 and Div. 0A: Risks of transgressing mortality and biomass precautionary limits with annual catches at 85–120 kt projected for 2020–22 with an 'effective' cod stock assumed at 21 kt.

g) Research recommendations

- NIPAG **recommends** that *the SAM model should be used to produce short term forecasts of cod biomass for use in NIPAG shrimp projections in future years.*

- NIPAG **recommended** in 2016 that *genetic stock structure in West and East Greenland should be further explored.*

Status: In progress; this recommendation is reiterated.

- NIPAG **recommended** in 2017 that *the relationship between the pre-recruit index and the subsequent years' fishable biomass should be investigated further.*

Status: information is presented in SCR Doc. 19/049 **Completed.**

- NIPAG **recommended** in 2018 that *random sampling of the catches be conducted to provide catch composition data to the assessment.*

Status: In progress; this recommendation is reiterated.

4. Northern shrimp (*Pandalus borealis*) in the Denmark Strait and off East Greenland (ICES Div. XIVb and Va)

(SCR Docs. 04/012, 16/045, 19/047)

a) Introduction

Northern shrimp off East Greenland in ICES Div. XIVb and Va is assessed as a single population.

A multinational fleet exploits the stock. During the recent ten years, vessels from Greenland, EU, the Faroe Islands and Norway have fished in the Greenland EEZ. Only Icelandic vessels are allowed to fish in the Icelandic EEZ. At any time access to these fishing grounds depends strongly on ice conditions.

In the Greenland EEZ, the minimum permitted mesh size in the cod-end is 44 mm, and the fishery is managed by catch quotas allocated to national fleets. In the Icelandic EEZ, the mesh size is 40 mm and there are no catch limits, however there have been no catches by Iceland after 2005. In both EEZs, sorting grids with 22-mm bar spacing to reduce by-catch of fish are mandatory. Discarding of shrimp is prohibited in both areas.

The fishery started in 1978 and during the period 1985 to 2003 the total catches fluctuated between 9 000 t and 15 000 t. Since 2004 the total catch has decreased and in 2018 only 547 t were caught (Figure 4.1). Since 2012, no or very little fishery has taken place in the southern area.

Catches in the first half year of 2019 were 1579 t. Since 2015, this has mainly been an opportunistic fishery with vessels stopping off on route between other fishing grounds.

Recent catches and TACs (t) for shrimp in in the Denmark Strait and off East Greenland (ICES Div. XIVb and Va) are as follows:

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019[1]
Recommended TAC, total area	12 400	12 400	12 400	12 400	2 000	2 000	2 000	2 000	2 000	2 000
Actual TAC, Greenland	11 835	12 400	12 400	12 400	8 300	6 100	5 300	5 300	4 300	3 384
North of 65°N, Greenland EEZ	3 323	1 145	1 893	1 714	622	576	49	561	547	1 577
North of 65°N, Iceland EEZ	0	0	0	0	0	0	0	0	0	0
North of 65°N, total	3 323	1 145	1 893	1 714	622	576	49	561	547	1 577
South of 65°N, Greenland EEZ	280	53	215	3	0	0	0	0	0	2
TOTAL NIPAG	3 602	1 199	2 109	1 717	622	576	49	561	547	1 579

[1] Catches until July 2019

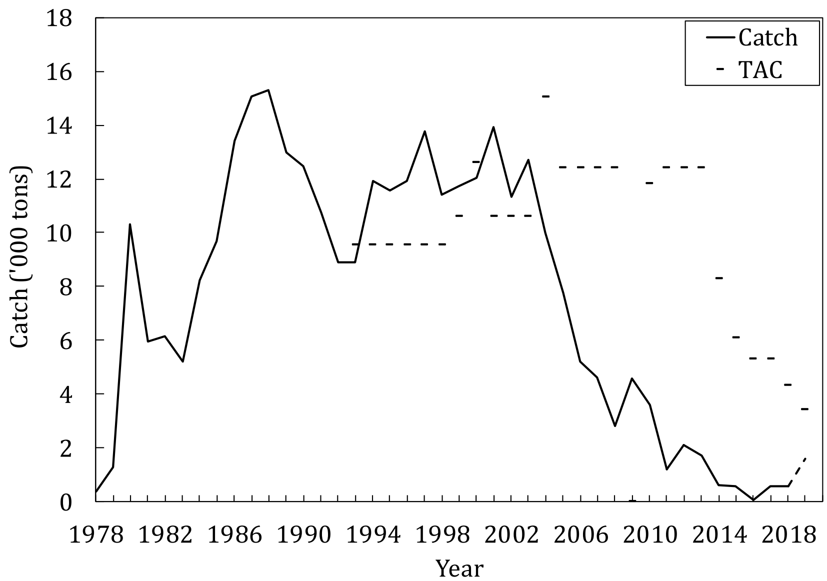

Figure 4.1. Shrimp in Denmark Strait and off East Greenland: Catch and TAC (2019 catches until July).

b) Input data

i) Commercial fishery data

Fishing effort and CPUE. Data on catch and effort (hours fished) on a haul by haul basis from logbooks from Greenland, Iceland, Faroe Islands and EU since 1980 and from Norway since 2000 are used. Since 2004, more than 60% of all hauls were performed with double trawl, and both single and double trawl are included in the standardized catch rate calculations.

Catches and corresponding effort are compiled by year for the two areas, north and south of 65˚N. Standardised Catch-Per-Unit-Effort (CPUE) was calculated and applied to the total catch of the year to estimate the total annual standardised effort.

The overall CPUE index increased from 1993 to 2009, followed by a continuous decline to a low value in 2014 and has been increasing since 2014 (Figure 4.2), reaching a record high level in the first half of 2019, which may indicate an improvement of the stock state. However, the estimates for these years are based on relative low number of hauls (from 50 to 396 in first half of 2019) and are therefore subject to large uncertainty. Furthermore, the fishing has taken place in a localized area. As most of the fishing has been conducted in the northern area the overall CPUE index is dominated by the CPUE index for this area (Figure 4.2 and Figure 4.3). In the southern area a standardized catch rate series increased until 1998, and then fluctuated without a trend until 2012 (Figure 4.4). No index for the southern area has been calculated since 2012 due to a low number of hauls.

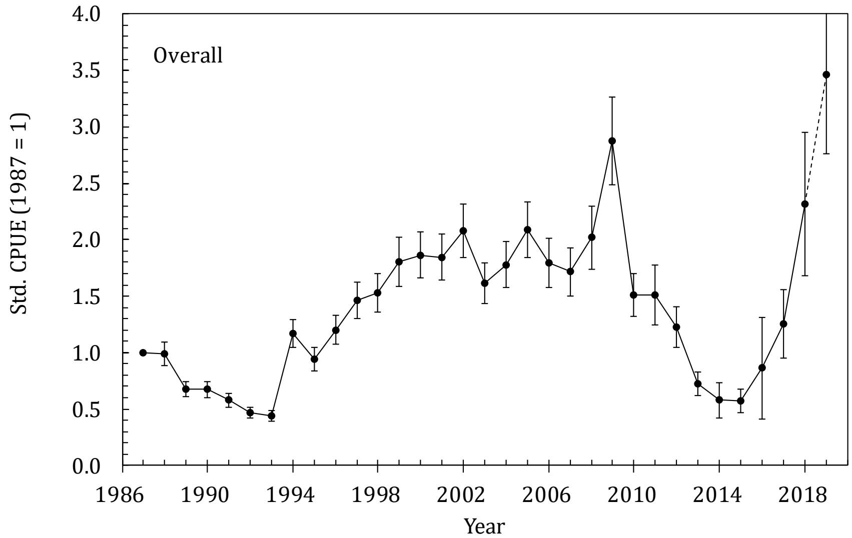

Figure 4.2. Shrimp in Denmark Strait and off East Greenland: Annual standardized CPUE index (1987 = 1) with ± 1 SE combined for the total area. 2019 data until July (grey dotted line).

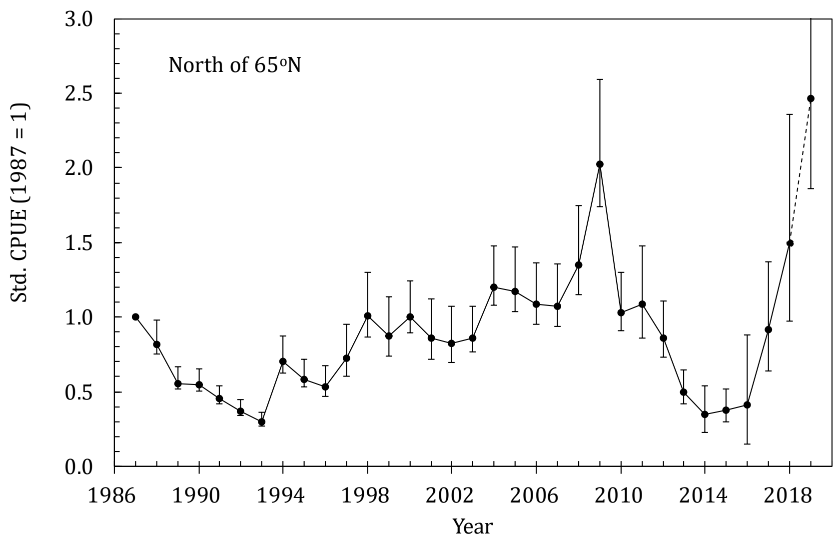

Figure 4.3. Shrimp in Denmark Strait and off East Greenland: Annual standardized CPUE (1987 = 1) with ±1 SE fishing north of 65°N. 2019 data until July (grey dotted line).

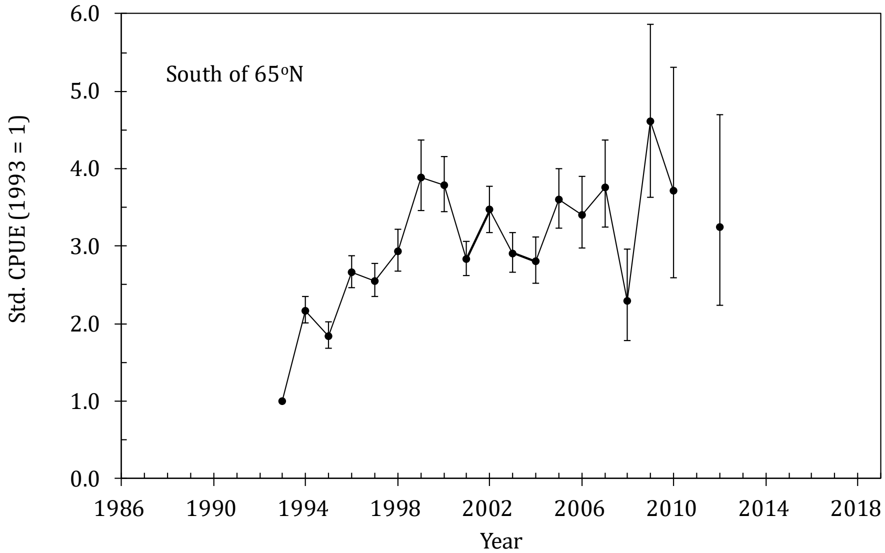

Figure 4.4. Shrimp in Denmark Strait and off East Greenland: Annual standardized CPUE (1993 = 1) with ±1 SE fishing south of 65°N (no data for the area since 2010/2012).

Standardized effort indices (catch divided by standardized CPUE) as a proxy for exploitation rate for the total area shows a decreasing trend since 1993. Recent levels are the lowest of the time series (Figure 4.5). The 2016 to 2019 levels of exploitation rate may be biased given the issues on CPUE described above.

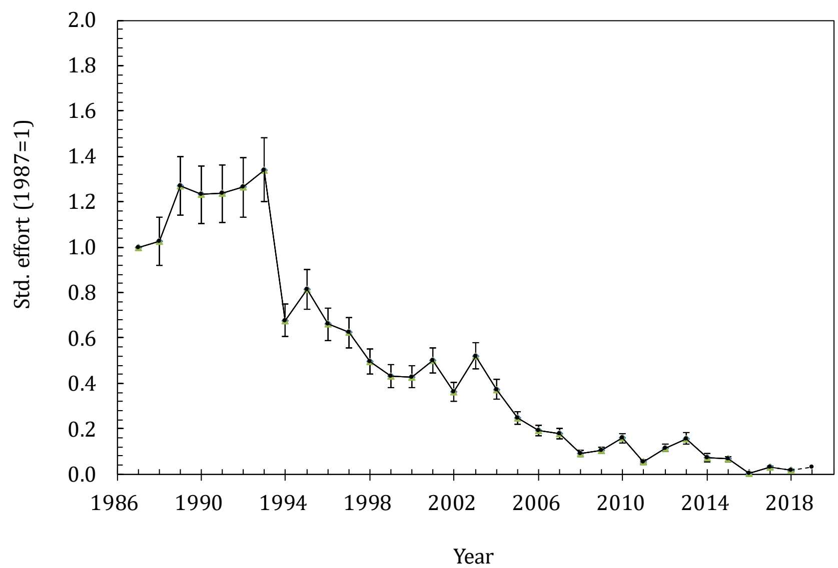

Figure 4.5. Shrimp in Denmark Strait and off East Greenland: Annual standardized effort indices, as a proxy for exploitation rate (± 1 SE; 1987 = 1), combined for the total area (2019 effort until July).

ii) Research survey data

Trawl surveys have been conducted to assess the stock status of northern shrimp in the East Greenland area since 2008. Due to lack of research vessel, no survey was conducted in the period 2017 to 2019. Smaller geographical areas were also surveyed in 1985-1988 (Norwegian survey) and in 1989-1996 (Greenlandic survey). The historical surveys are not directly comparable with the recent survey due to different areas covered, survey technique and trawling gear.

Biomass. The survey biomass index decreased from 2009 to 2012 and then remained at a low level until 2016, since when no surveys have been conducted (Figure 4.6).

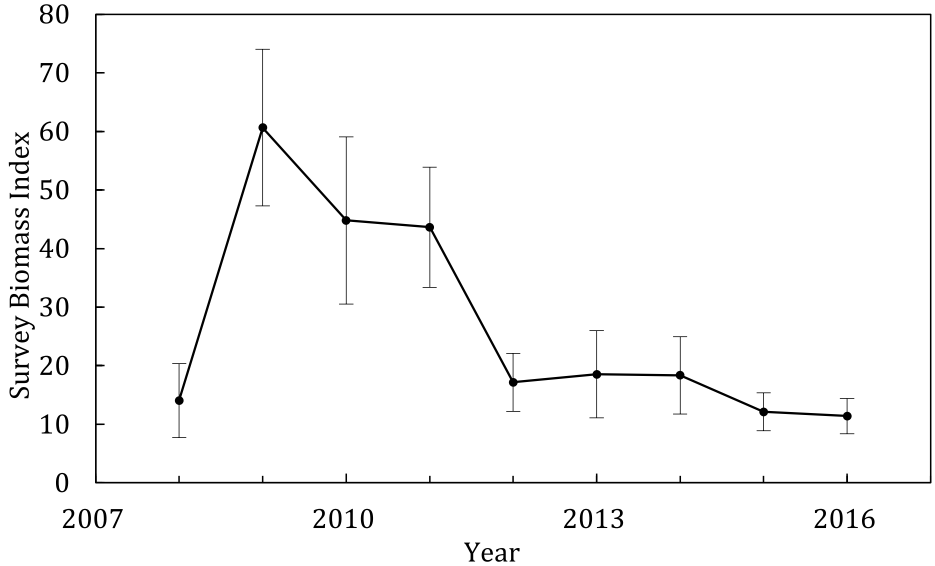

Figure 4.6. Shrimp in Denmark Strait and off East Greenland: Survey biomass index from 2008- 2016 (± 1 SE). No survey was carried out in the period 2017 to 2019.

The surveys conducted since 2008 indicate that the shrimp stock is concentrated in the area north of 65°N (Figure 4.7).

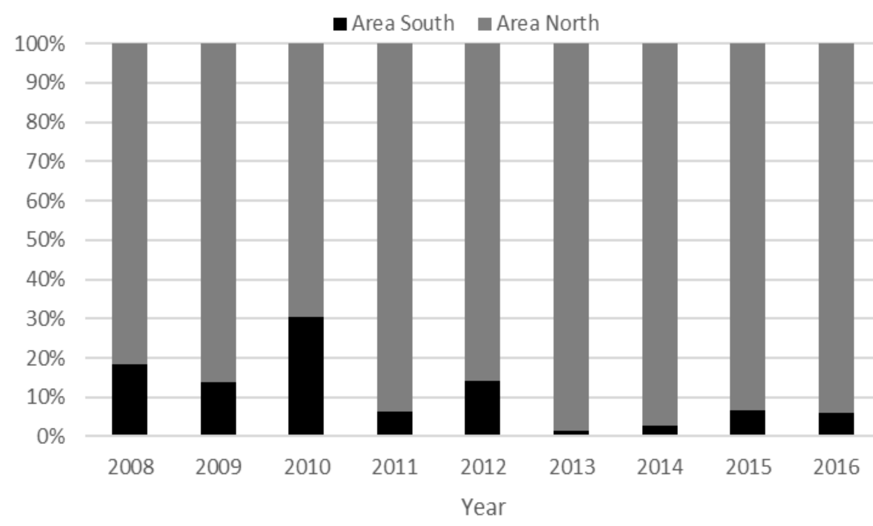

Figure 4.7. Shrimp in Denmark Strait and off East Greenland: Distribution of survey biomass north and south of 65°N (in %) from 2008-2016. No survey was carried out in the period 2017 to 2019.

Stock composition. The demography in East Greenland is dominated by a large proportion of females and shows a paucity of males smaller than 20 mm CL (Figure 4.8).

Scarcity of smaller shrimp in the survey area stresses that the total area of distribution and recruitment patterns of the stock are still unknown.

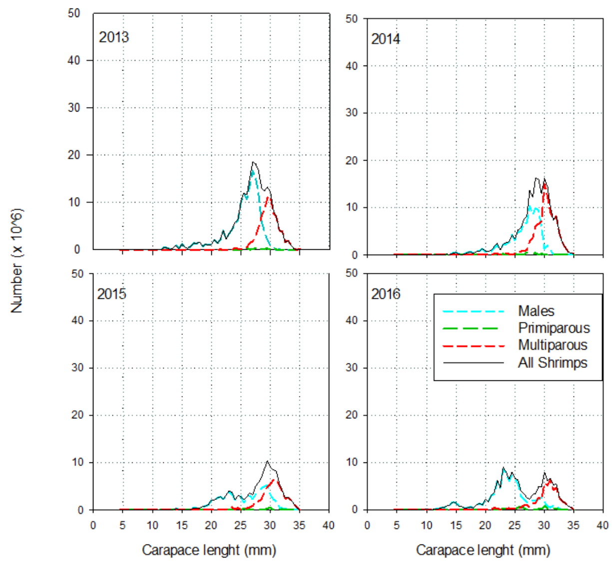

Figure 4.8. Shrimp in Denmark Strait and off East Greenland: Numbers of shrimp by length group (CL) in the total survey area in 2013–2016. No survey was carried out in the period 2017 to 2019.

c) Assessment results

Evaluation of stock status is based upon interpretation of commercial fishery and research survey data. The trends in the survey and the standardized CPUE have been similar since the start of the survey, however they diverged in 2016. Since 2015, this has mainly been an opportunistic fishery with vessels stopping off on route between other fishing grounds. Recent increasing CPUE values may indicate an improvement of the shrimp density in the northern area, however this may not reflect overall stock status as the fishery occurs in a localized area and includes only a small number of hauls. No research survey was carried out in the period 2017 to 2019.

d) Reference points

Scientific Council considers that a female survey biomass index of 15% of its maximum observed level provides a proxy for B_{lim} (SCS Doc. 04/12).

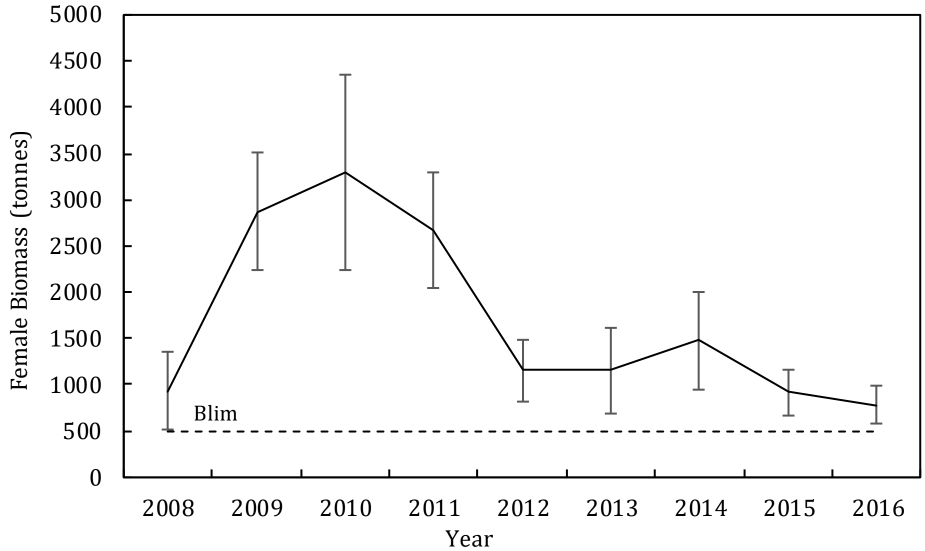

Figure 4.9. Shrimp in Denmark Strait and off East Greenland: Spawning stock biomass index (SSB) ±SE from 2008-2016 and precautionary approach B_{lim}. B_{lim} is defined as 15% of the maximum female biomass over the time series. No survey was carried out in the period 2017 to 2019.

e) State of the stock

CPUE: The CPUE index declined continuously from its highest point in 2009 to a low value in 2014 and has been increasing since then (Figure 4.2). Estimates for the period 2016 to 2019 are associated with higher uncertainty and, due to changes in the fishing pattern, may not reflect the state of the stock.

Recruitment. No recruitment estimates were available.

Biomass. The survey biomass index decreased by around 80% from 2010 to 2016. No survey was conducted in the period 2017 to 2019.

Exploitation rate. Since the mid-1990s the exploitation rate index has decreased, currently reaching the lowest levels seen in the time series. The 2016 to 2019 levels of exploitation rate may be biased given the issues on CPUE described above.

State of the stock. The stock size remained at a very low level in 2016 (relatively close to B_{lim}) despite several years of very low exploitation rates. There is no new fishery independent information to indicate a change in stock status.

f) Research recommendations

- NIPAG **recommended** in 2016 that: *genetic stock structure of Pandalus borealis in West and East Greenland should be further explored.*

Status: in progress. This recommendation is reiterated.

- NIPAG **recommended** in 2017 that: *error bars should be added to the SSB so that risk can be assessed in relation to* B_{lim}.

Status: Has been completed.

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

This stock was assessed by a subgroup of NIPAG during 25–27 February 2019 at ICES HQ in Copenhagen. The report is included as Appendix VII to this report. NIPAG reviewed the assessment during the present meeting. There were no further recommendations.

6. Northern shrimp (*Pandalus borealis*) in the Barents Sea (ICES Subareas 1 and 2)

Background documentation (equivalent to stock annex) is found in SCR Docs. 19/54, 55, 56; 06/64, 08/56, 07/86, 07/75, 06/70.

a) Introduction

Northern shrimp (*Pandalus borealis*) in the Barents Sea and in the Svalbard fishery protection zone (ICES Subareas 1 and 2) is considered as one stock (Figure 6.1). Norwegian and Russian vessels exploit the stock in the entire area, while vessels from other nations are restricted to the Svalbard fishery zone and the "Loop Hole" (Figure 6.1).

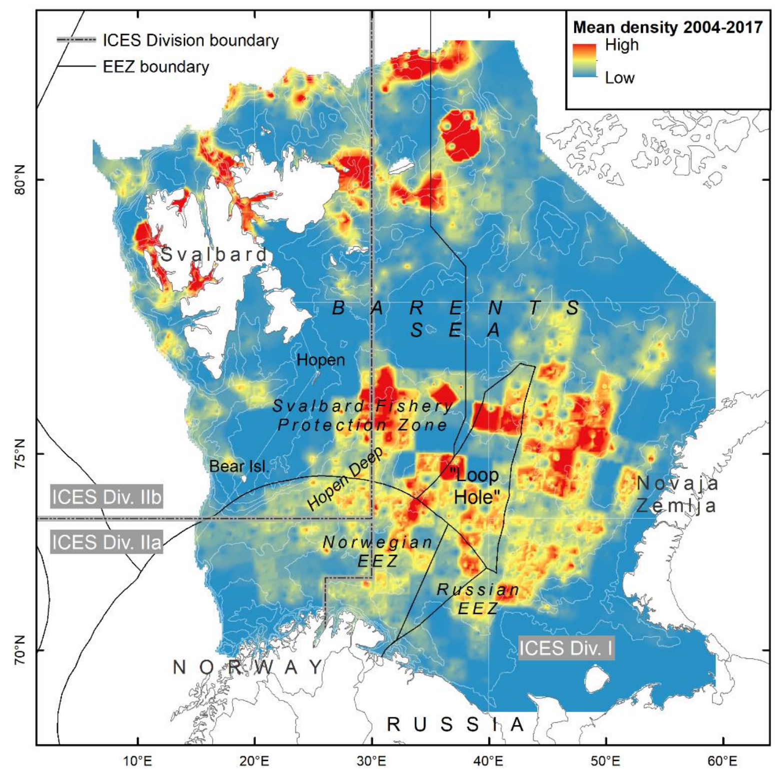

Figure 6.1. Shrimp in ICES SA 1 and 2: Stock distribution. Survey density index (kg/km2).

Norwegian vessels initiated the fishery in 1970. As the fishery developed, vessels from several nations joined and catches increased rapidly (Figure 6.2). Vessels from Norway, Russia, Iceland, Greenland, Faeroes and the EU participate in this fishery.

There is no overall TAC established for this stock. The fishery is partly regulated by effort control (Norwegian and Svalbard zone), and a TAC in the Russian zone only. Licenses are required for the Russian and Norwegian vessels. In the Norwegian and Svalbard zones, the fishing activity of these license holders is constrained only by bycatch regulations whereas the activity of third country fleets operating in the Svalbard zone is also restricted by the number of effective fishing days and the number of vessels by country. The minimum stretched mesh size is 35 mm. Bycatch is limited by mandatory sorting grids and by the temporary closing of areas where excessive bycatch of juvenile cod, haddock, Greenland halibut, redfish or shrimp <15 mm CL is registered.

Catch. Catches have increased from 20 000 t in 2013 to 78 000 tons predicted for 2019.

Table 6.1. Shrimp in ICES SA 1 and 2: Recent catches in metric tonnes, as used by NIPAG for the assessment.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019[1]
Recommended TAC	50 000	60 000	60 000	60 000	60 000	70 000	70 000	70 000	70 000	70 000
Norway	16779	19928	14158	8846	10234	16618	10896	7010	23100	23000
Russia	0	0	0	1067	741	1151	2460	3849	12561	33000
Others	8419	10298	10598	9336	9989	16252	16223	19582	20025	22000
Total	25198	30226	24756	19249	20964	34022	29609	30441	55911	78000

[1] Catches projected to the end of the year.

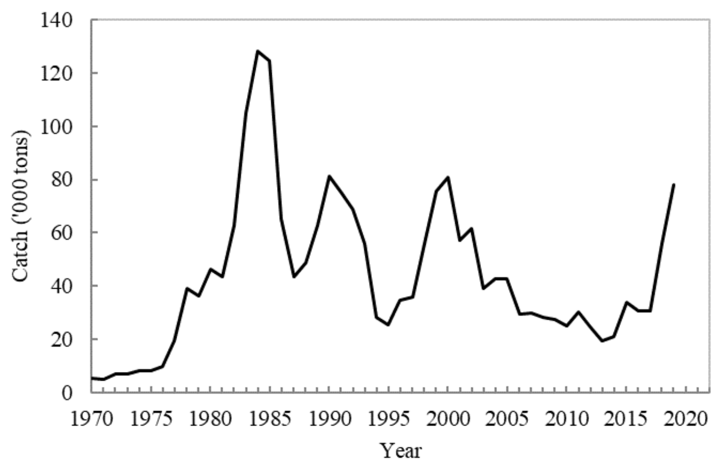

Figure 6.2. Shrimp in ICES SA 1 and 2: Total catches (2019 projected to the end of the year).

Discards and bycatch and ecosystem effects. Discard of shrimp cannot be quantified but is believed to be small as the fishery is not limited by quotas. Bycatch rates of other species are estimated from at-sea inspections and research surveys and are corrected for differences in gear selection pattern (ICES 2018a). Area-specific bycatch rates are then multiplied by the corresponding shrimp catches from logbooks to give an overall bycatch estimate. Revised and updated discards estimates (1983–2017) of cod, haddock and redfish juveniles in the Norwegian commercial shrimp fishery in the Barents Sea were available in 2018 (Figure 6.3). Since the introduction of the Nordmøre sorting grid in 1992, only small individuals of cod, haddock, Greenland halibut, and redfish, in the 5–25 cm size range, are caught as bycatch.

In 2017, specific information on bycatch from EU-Estonia based on onboard scientific observers was presented. They indicated 2.9% by weight of fish discards and 0.6% discards of shrimp. Work will continue to explore these data further. No new data were available in 2018 and 2019.

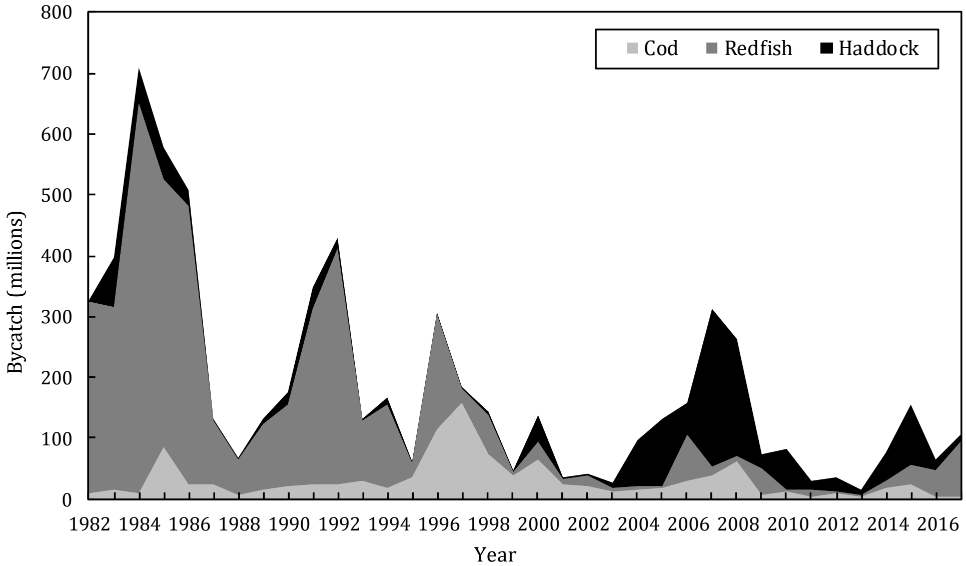

Figure 6.3. Shrimp in ICES SA 1 and 2: Estimated bycatch of cod, haddock and redfish in the Norwegian shrimp fishery (million individuals). The sorting grid was introduced in 1992 and has been mandatory since.

b) Input data

i) Commercial fishery data

Logbook data are normally available only from the Norwegian fleet, but 2017 data was also available from the EU-Estonia fleet. A major restructuring of the Norwegian shrimp fishing fleet towards fewer and larger vessels took place during the late-1990s through the early 2000s (Figure 6.4). Until 1996, the fishery was conducted using single trawls only. Double and triple trawls were then introduced. An individual vessel may alternate between single and multiple trawling depending on what is appropriate on given fishing grounds.

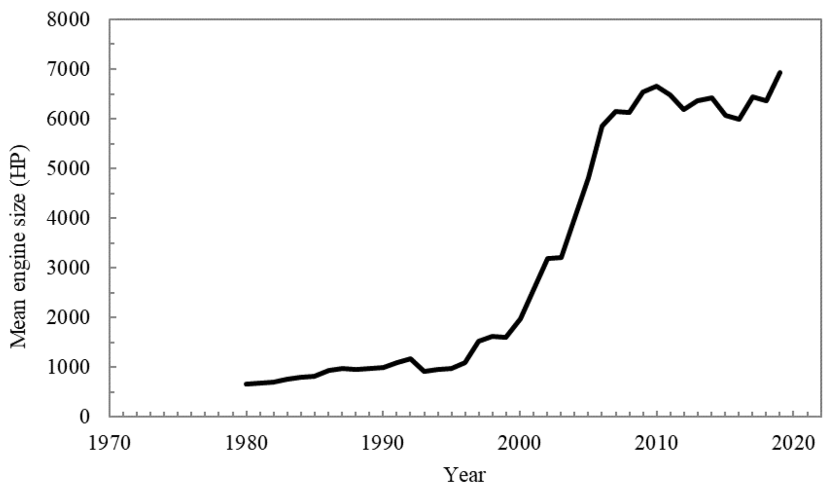

Figure 6.4. Shrimp in ICES SA 1 and 2: Mean engine power (HP) weighted by trawl-time (Norwegian vessels).

The fishery takes place throughout the year but may in some years be seasonally restricted by ice conditions. The lowest effort is generally in October through March, the highest in May to August.

The fishery was originally conducted mainly in the central Barents Sea and on the Svalbard Shelf along with the Goose Bank (southeast Barents Sea). Norwegian logbook data since 2009 show decreased activity in the Hopen

Deep and around Svalbard, coupled with increased effort further east in international waters (the "Loop Hole") (Figure 6.5). Information from the Norwegian industry points to decreasing catch rates and more frequent area closures due to bycatch of juvenile fish on the traditional shrimp fishing grounds as the main reasons for the observed change in fishing pattern.

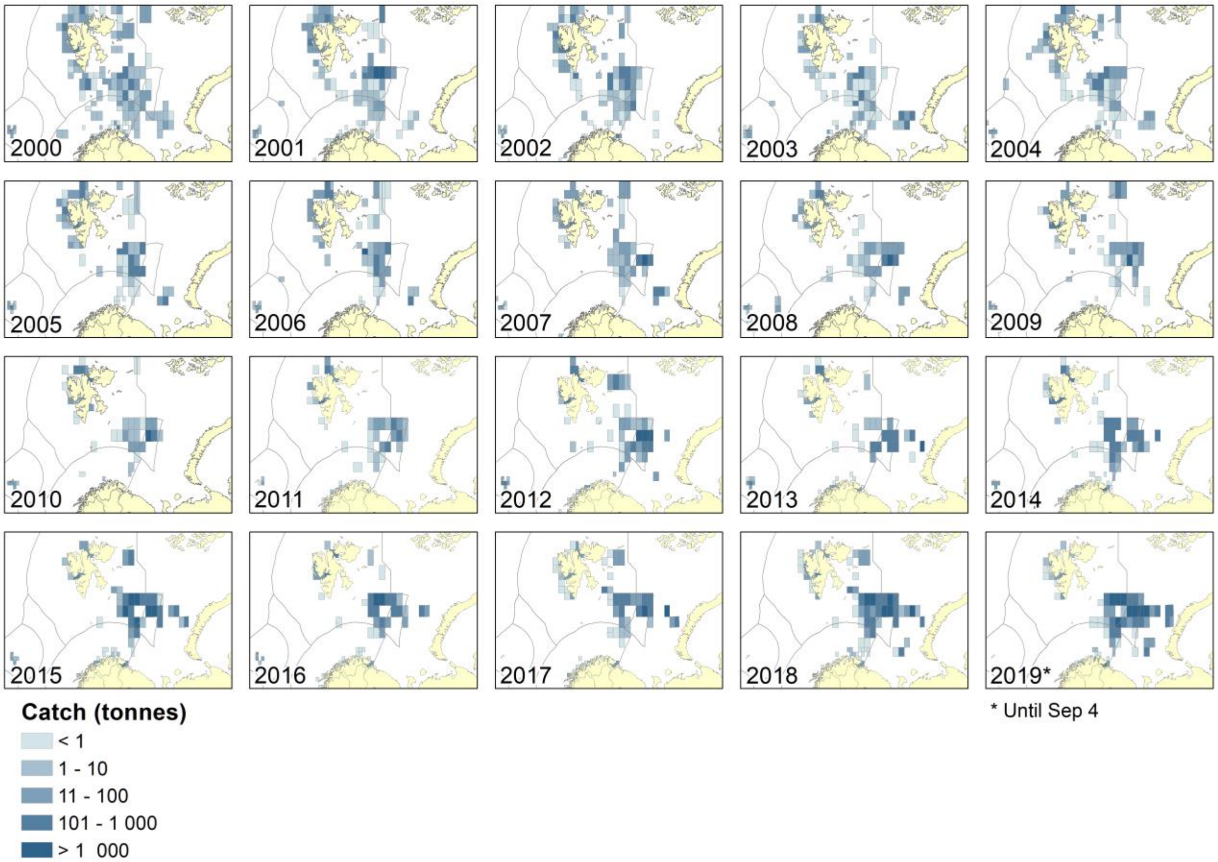

Figure 6.5. Shrimp in ICES SA 1 and 2: Distribution of catches by Norwegian vessels since 2000 based on logbook information.

Norwegian logbook data were used in a multiplicative model (GLM) to calculate standardized annual catch rate indices (SCR Doc. 19/56). The GLM model used to derive the CPUE indices included the following variables: (1) vessel, (2) season (month), (3) area (five survey strata), and (4) gear type (single, double or triple trawl). The resulting series provides an index of the fishable biomass of shrimp ≥17 mm CL, *i.e*. females and older males (Figure 6.6).

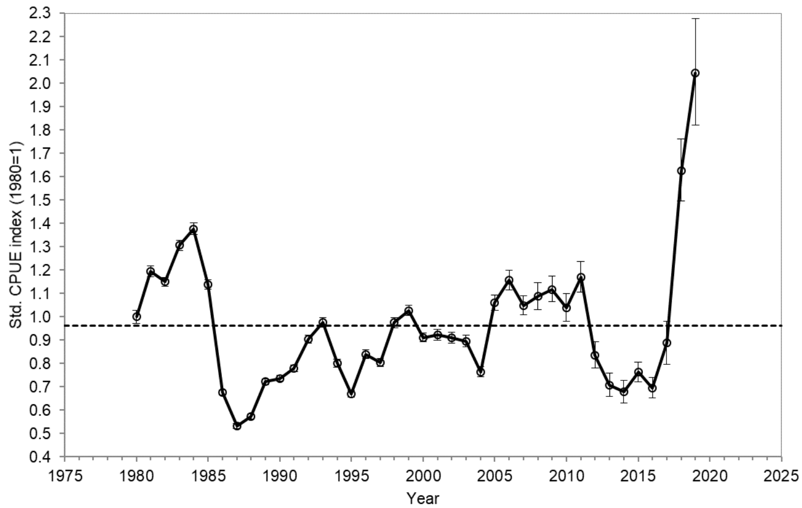

Figure 6.6. Shrimp in ICES SA 1 and 2: Standardized CPUE based on Norwegian data. Error bars represent 1 SE; dotted line is the mean of the series.

The Norwegian logbook data on which the CPUE index is based represents fishing activity from most of the stock distribution area. However, in recent years the portion of total catches taken by Norway has been halved and now only represents about one third of the total catches.

The 2018 and 2019 standardized CPUE values are record high. NIPAG discussed whether these values are good reflections of stock biomass: in the absence of any objective arguments why these values should be outliers and considering that the upward trend is corroborated by the results from the scientific survey, the 2018 and 19 data points were included in the input to the assessment model. However, NIPAG recommends that a full analysis of the appropriateness of the standardized CPUE index be included in the upcoming Benchmark process.

ii) Research survey data

Russian and Norwegian surveys were conducted in their respective EEZs of the Barents Sea from 1982 to 2005 to assess the status of the northern shrimp stock (SCR Docs. 06/70, 07/75, 14/51, 15/52). In 2004, these surveys were replaced by a joint Norwegian-Russian "Ecosystem survey" in August/September, which monitors shrimp along with a multitude of other ecosystem variables in the Barents Sea and around Svalbard (SCR Docs.14/55, 7/68).

Biomass. The biomass indices of survey 1 and 2 have fluctuated without trend over their respective time periods covered (Figure 6.7). The most recent survey series (survey 3) has increased substantially since a low in 2016 to reach its highest value in 2019. In general, the entire survey area of the Ecosystem survey (survey 3 in Figure 6.7) is covered in all years, however, due to heavy ice conditions in 2014 the northern part of the area (stratum 3, see SCR Doc. 17/68) was not covered. For the 2004-2013 survey period this area accounts for on average 13% of the biomass (range: 8-27%). The 2014 biomass for stratum 3 was estimated by calculating the average ratio of biomass density in stratum 3 to biomass density in the remaining survey area for the 2009-2013 period and applying this average to the density of the 2014 surveyed area. Estimates of variance for stratum 3 was taken as the variance of the 2009-2013 estimates for stratum 3. A similar method incorporating 2015 to 2017 data was used to compensate for missing coverage due to vessel malfunction of stratum 5 and stratum 4 in 2018 and 2019 respectively (Figure 6.8).

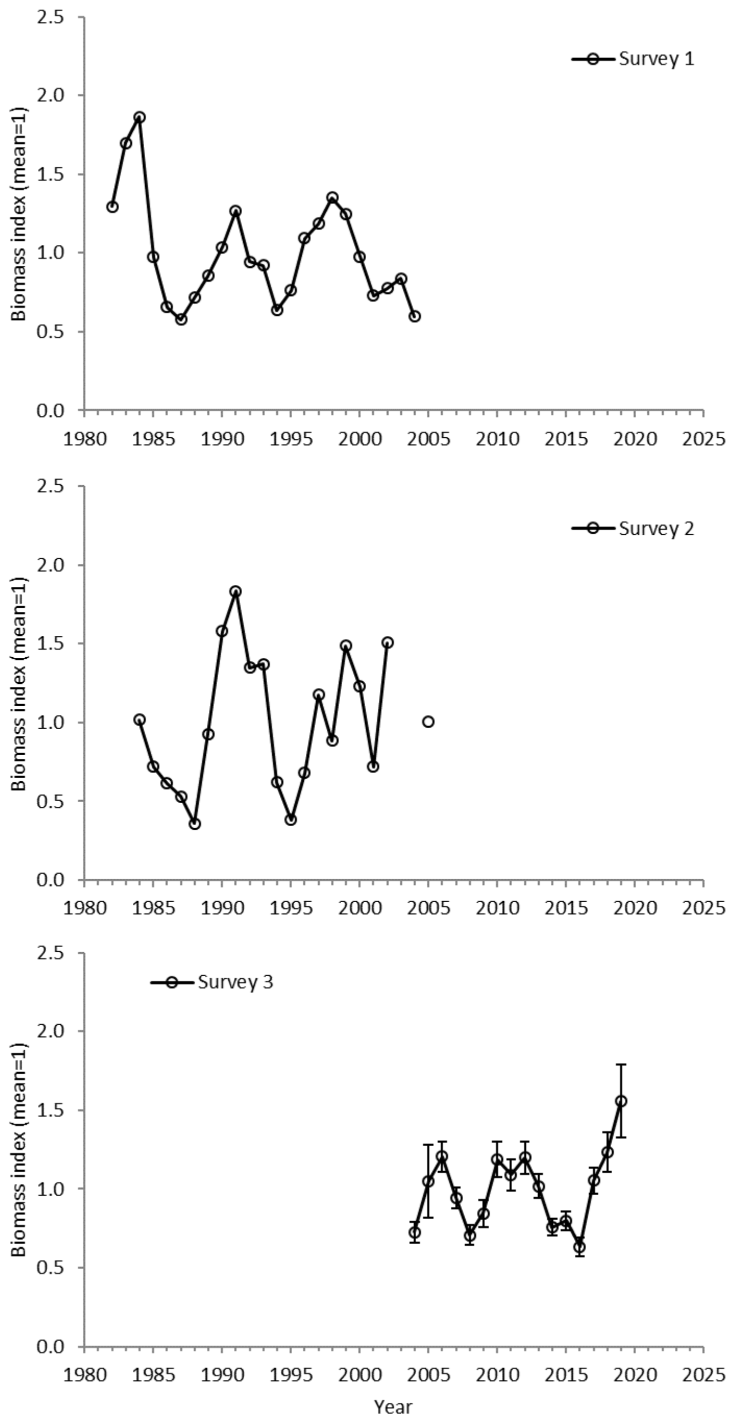

Figure 6.7. Shrimp in ICES SA 1 and 2: Indices of total stock biomass from the (1) 1982-2004 Norwegian shrimp survey, (2) the 1984-2005 Russian survey, and (3) the joint Russian-Norwegian ecosystem survey since 2004. Error bars represent 1 SE.

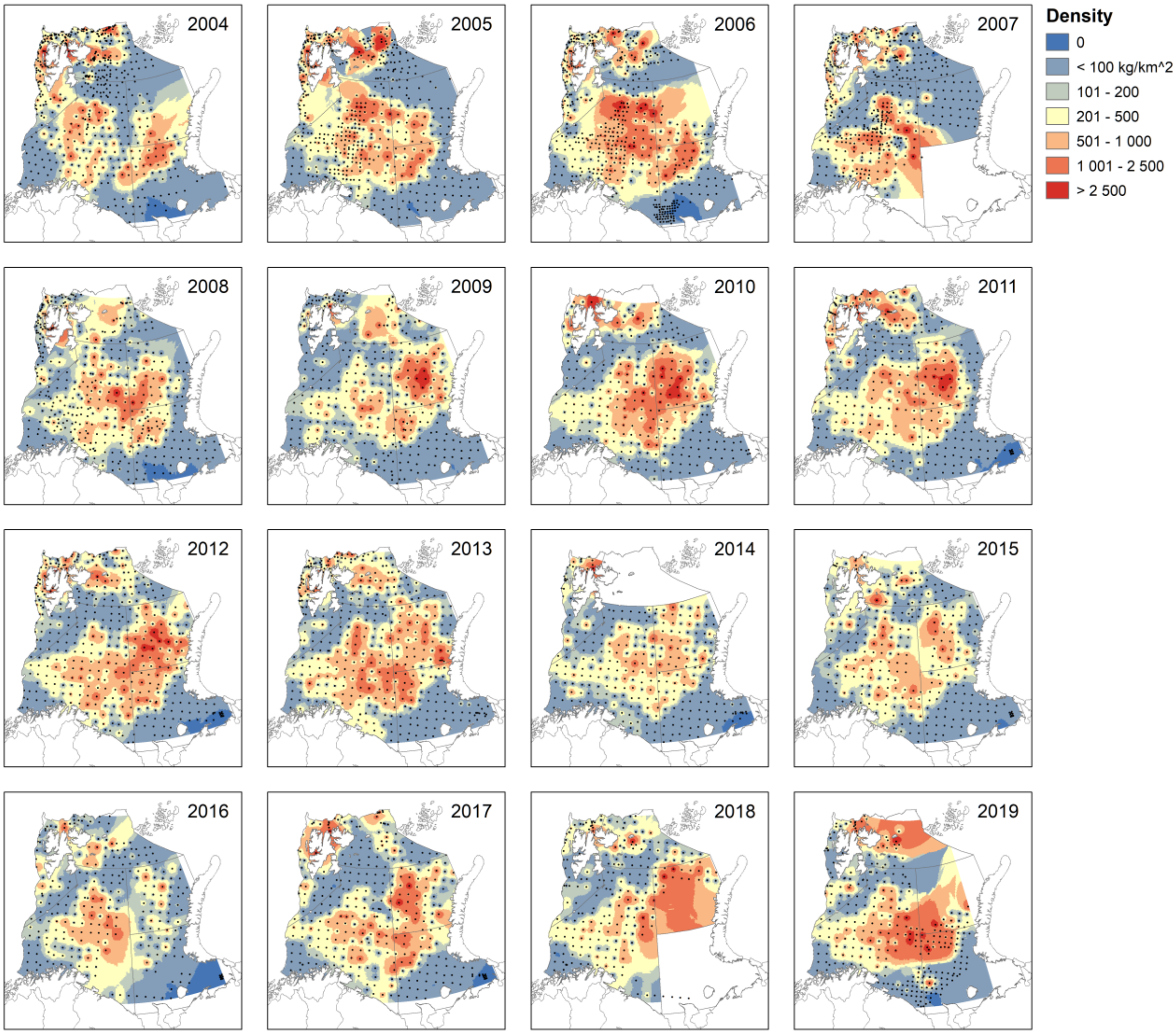

Figure 6.8. Shrimp in ICES SA 1 and 2: shrimp density (kg/km2) as calculated from the Ecosystem survey data since 2004 (no data for stratum 3 in 2014 due to ice conditions; no data for stratum 5 in 2018 and 4 in 2019 due to vessel malfunction).

Recruitment indices. No information is included as data are not available since 2013. Length distribution data from the Estonian fishery and survey data from the Norwegian EEZ were investigated during the meeting and these gave some indication of good recruitment in 2015 and 2019, however, NIPAG deferred further analysis to the upcoming benchmark.

c) Assessment

The modelling framework introduced in 2006 (SCR Doc. 06/64) was used for the assessment. Model settings were the same as those used in previous years.

Within this model, parameters relevant for the assessment and management of the stock are estimated, based on a stochastic version of a surplus-production model. The model is formulated in a state-space framework and Bayesian methods are used to derive "posterior" probability density distributions of the parameters (SCR Doc. 19/54).

The model synthesized information from input priors, four independent series of shrimp biomass indices and one series of shrimp catch. The biomass indices were: a standardized series of annual fishery catch rates for 1980–2019 (Figure 6.6, SCR Doc. 19/56); and trawl-survey biomass indices for 1982–2004, 1984–2005 and for 2004–2019 (Figure 6.7, SCR Doc. 19/55). These indices were scaled to true biomass by individual catchability parameters, q_j, and lognormal observation errors were applied. Total reported catch in ICES Div. 1 and 2 since 1970 was used as yield data (Figure 6.2, SCR Doc. 19/56). The fishery being without major discarding problems or variable misreporting, reported catches were entered into the model as error-free.

Biomass, *B,* was thus measured relative to the biomass that would yield Maximum Sustainable Yield, B_{msy}. The estimated fishing mortality, *F*, refers to the removal of biomass by fishing and is scaled to the fishing mortality at MSY, F_{msy}. The state equation describing stock dynamics took the form:

$$P_{t+1} = \left(P_t - \frac{C_t}{B_{MSY}} + \frac{2\,MSY\,P_t}{B_{MSY}}\left(1 - \frac{P_t}{2}\right)\right) \cdot \exp(\nu_t)$$

where P_t is the stock biomass relative to biomass at *MSY* ($P_t = B_t/B_{msy}$) in year *t*. This frames the range of stock biomass on a relative scale where B_{msy} = 1 and the carrying capacity (*K*) equals 2. The 'process errors', *v*, are normally, independently and identically distributed with mean 0 and variance σ_P^2.

The observation equations had lognormal errors, ω, κ, η and ε, for the series of standardised CPUE ($CPUE_t$), Norwegian shrimp survey ($survR_t$), The Russian shrimp survey ($survRu_t$) and joint ecosystem survey ($survE_t$) respectively giving:

$$CPUE_t = q_C B_{MSY} P_t \exp(\omega_t)\,,\ survR_t = q_R B_{MSY} P_t \exp(\kappa_t)\,,\ survRu_t = q_{Ru} B_{MSY} P_t \exp(\eta_t)\,,\ survE_t = q_E B_{MSY} P_t \exp(\varepsilon_t)$$

The observation error terms, ω, κ, η and ε are treated as normally, independently and identically distributed with mean 0 and variances σ_C^2, σ_R^2, σ_{Ru}^2 and σ_E^2 respectively.

Summaries of the estimated posterior probability distributions of selected parameters are shown in Table 6.2. Values are similar to the ones estimated in previous assessments. *K* could not be well estimated from the data alone and its posterior will depend somewhat on the chosen prior. For the estimates of relative stock size relaxing the *K*-prior did not have much effect (SCR Doc. 07/76) except for a slight increase in uncertainty. However, the posterior for *MSY* is sensitive as *K* is correlated with *MSY*: in particular, the right-hand side of the posterior distribution is widened while the left-hand side seems pretty well determined by the data. The mode of the distribution of *MSY* is around 150 kt and would likely be a best point estimate of this parameter.

Table 6.2. Shrimp in ICES SA 1 and 2: Summary of parameter estimates: mean, standard deviation (sd) and quartiles of the posterior distributions of selected parameters estimated in the 2019 assessment (symbols are as in the text; r = intrinsic growth rate, P_0 = the 'initial" stock biomass in 1969), and the median values from the 2018 assessment.

	Mean	sd	25 %	Median	75 %	Median (2018)
MSY (ktons), maximum sustainable yield	185	112	96	160	255	202
K (ktons), carying capacity	2973	1563	1816	2664	3803	2775
r, intrinsic growth rate	0.27	0.14	0.17	0.26	0.36	0.30
q_R, catchability of survey 2	0.15	0.10	0.08	0.12	0.19	0.10
q_{Ru}, catchability of survey 1	0.38	0.25	0.20	0.31	0.48	0.26
q_E, catchability of survey 3	0.22	0.15	0.12	0.18	0.28	0.16
q_C, catchability of CPUE index	5.5E-04	3.6E-04	3.0E-04	4.5E-04	6.9E-04	3.67E-04
P_0, initial relative biomass (1969)	1.50	0.26	1.33	1.50	1.67	1.51
P_{2019}, relative biomass in 2019	2.47	0.73	1.99	2.37	2.83	1.78
σ_R, coefficient of variation for survey 2	0.17	0.03	0.15	0.17	0.19	0.17
σ_{Ru}, coefficient of variation for survey 1	0.34	0.05	0.30	0.33	0.37	0.34
σ_E, coefficient of variation for survey 3	0.17	0.03	0.14	0.16	0.18	0.17
σ_C, coefficient of variation for CPUE index	0.14	0.02	0.12	0.14	0.15	0.13
σ_P, coefficient of variation for process	0.21	0.03	0.19	0.20	0.22	0.18

Reference points. Four reference points are considered (buffer reference points are obsolete as probability of transgressing the PA limit reference points can be calculated directly):

	Type	Value	Technical basis
MSY approach	$B_{trigger}$	$0.5B_{MSY}$	Approximately corresponding to 10th percentile of the B_{msy} estimate (NIPAG 2010)
	F_{MSY}		Resulting from the assessment model.
Precautionary approach	B_{lim}	$0.3B_{MSY}$	The *B* where production is reduced to 50% *MSY* (NIPAG 2006)
	F_{lim}	$1.7F_{MSY}$	The *F* that drives the stock to B_{lim}

The results of this year's assessment are at large consistent with those of previous years (model introduced in 2006). However, the relatively large increase in stock biomass in 2019 was not captured in the 2018 projections. The conclusions on stock status drawn from the model have been found on investigation to largely be insensitive to the setting of the priors for initial stock biomass and carrying capacity (SCR Docs. 06/64 and 07/76).

Stock size and fishing mortality. A steep decline in stock biomass in the mid-1980s was noted following some years with high catches and the median relative biomass almost dropped to the *Bmsy*-level (Figure 6.9, upper). Since the late 1980s, however, the stock has varied with a slightly increasing trend including a noticeable increase in the most recent years. The estimated risk of stock biomass being below $B_{trigger}$ by the end of 2019 is less than 1% (Table 6.3). The median estimate of fishing mortality has remained below F_{msy} throughout the history of the fishery (Figure 6.9 lower). In 2019, there is a less than 5% risk of the *F* being above F_{msy} (Table 6.3).

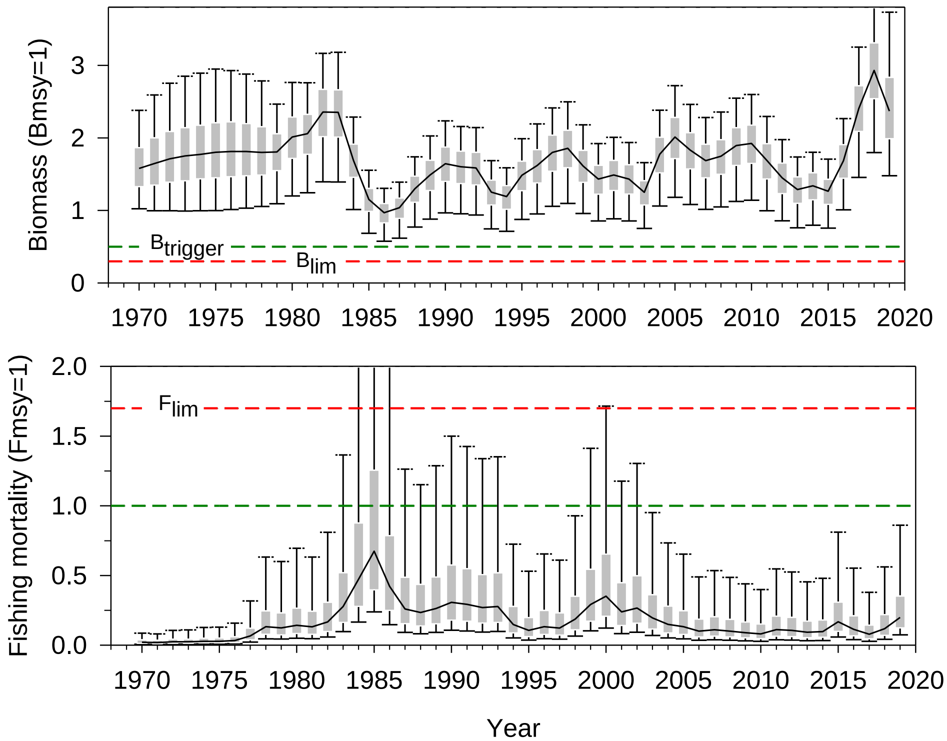

Figure 6.9. Shrimp in ICES SA 1 and 2: Estimated relative biomass (B/B_{msy}) and fishing mortality (F/F_{msy}) since 1970. Boxes represent inter-quartile ranges and the solid black line in the middle of each box is the median; the arms of each box cover the central 90% of the distribution. The broken lines indicate *MSY* and precautionary approach reference points.

Table 6.3. Shrimp in ICES SA 1 and 2: Stock status for 2018 and projected to the end of 2019.

Status	2018	2019*
Risk of falling below B_{lim}	0.0 %	0.0 %
Risk of falling below $B_{trigger}$	0.0 %	0.0 %
Risk of exceeding F_{MSY}	1.9 %	3.8 %
Risk of exceeding F_{lim}	0.8 %	1.6 %
Stock size (B/Bmsy), median	2.93	2.37
Fishing mortality (F/Fmsy),	0.12	0.20

*Projected catch = 78 ktons

Projections. Catch advice at the median of F_{msy} (ICES MSY approach) would imply no more than 306 kt – way outside the catch history of the fishery. Given that the right-hand side of the probability distributions of the yield at the F_{msy} is less well estimated, NIPAG considers it more appropriate to apply the mode as a point estimate of yield at F_{msy}. This mode is at 150 kt. Assuming a catch of 78 kt for 2019, catch options up to 150 kt for 2020 have low risks of exceeding F_{msy} (16%), F_{lim} (5%), and of going below $B_{trigger}$ (1%) by the end of 2020 (Table 6.4) and all these options are likely to maintain the stock at its current high level.

Table 6.4. Shrimp in ICES SA 1 and 2: Predictions of risk and stock status associated with optional catch levels for 2020.

	Catch option 2020 (ktons)						Yield at Fmsy (mode)	Yield at Fmsy (median)
	60	70	80	90	100	110	150	306
Risk of falling below B_{lim}	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.3 %	0.6 %
Risk of falling below $B_{trigger}$	0.0 %	0.0 %	0.1 %	0.1 %	0.1 %	0.0 %	0.9 %	1.7 %
Risk of exceeding F_{MSY}	2.8 %	3.7 %	4.8 %	5.8 %	7.2 %	9.1 %	16.2 %	50 %
Risk of exceeding F_{lim}	1.2 %	1.5 %	1.8 %	2.3 %	2.7 %	3.4 %	4.8 %	25 %
Stock size (B/Bmsy), median	2.17	2.17	2.16	2.15	2.14	2.13	1.95	1.67
Fishing mortality (F/Fmsy),	0.17	0.20	0.23	0.26	0.29	0.32	0.31	1.00
Productivity (% of MSY)	-36 %	-36 %	-35 %	-31 %	-29 %	-28 %	10 %	55 %

d) Environmental conditions

Since the 1980s, the Barents Sea has gone from a situation with high fishing pressure, cold conditions and low demersal fish stock levels, to the current situation with high levels of demersal fish stocks, reduced fishing pressure and warm conditions.

The capelin stock has recovered after a mini-collapse in 2015–2016. Cod biomass have decreased in recent years following a peak around 2013 but is still at a relatively high level. With the increase in capelin and a reduction in cod abundance, predation pressure on shrimp may be less intense. The levels of environmental and organic pollution in the Barents Sea are generally low and do not exceed threshold limits or global background levels. More detailed information can be found in ICES (2018b).

Temperature. In the ecosystem survey, shrimps were only caught in areas where bottom temperatures were above 0°C. Highest shrimp densities were observed between zero and 4°C, while the limit of their upper temperature preference appears to lie at about 6-8°C. The warming of the western Barents Sea coincides with the shift in shrimp distribution eastwards (Figure 6.8), thus temperature is probably a factor in explaining the observed changes in spatial distribution.

Predation. Both stock development and the rate at which changes might take place can be affected by changes in predation, in particular by cod, which has been documented as capable of consuming large amounts of shrimp. Continuing investigations to include cod predation as an explicit effect in the assessment model have so far not been successful; it has not been possible to establish a relationship between the density of cod and the stock dynamics of shrimp. The cod stock in the Barents Sea has decreased but remained at a relatively high level during the recent ten years. If predation on shrimp was to increase rapidly beyond the range previously experienced, the shrimp stock might decrease in size more than the model results have indicated as likely.

Recruitment, and reaction time of the assessment model. The model used is best at projecting trends in stock development but estimates and uses long-term averages of stock dynamic parameters. Large and/or sudden changes in recruitment or mortality may therefore be underestimated in model predictions which seems to be exemplified by the 2018-19 abrupt increase in stock biomass.

Model performance. The model was able to produce good simulations of the observed data (Figure 6.10). The differences between observed values of biomass indices and the corresponding values predicted by the model were checked numerically (SCR Doc 19/54). They were found generally not to include excessively large deviations.

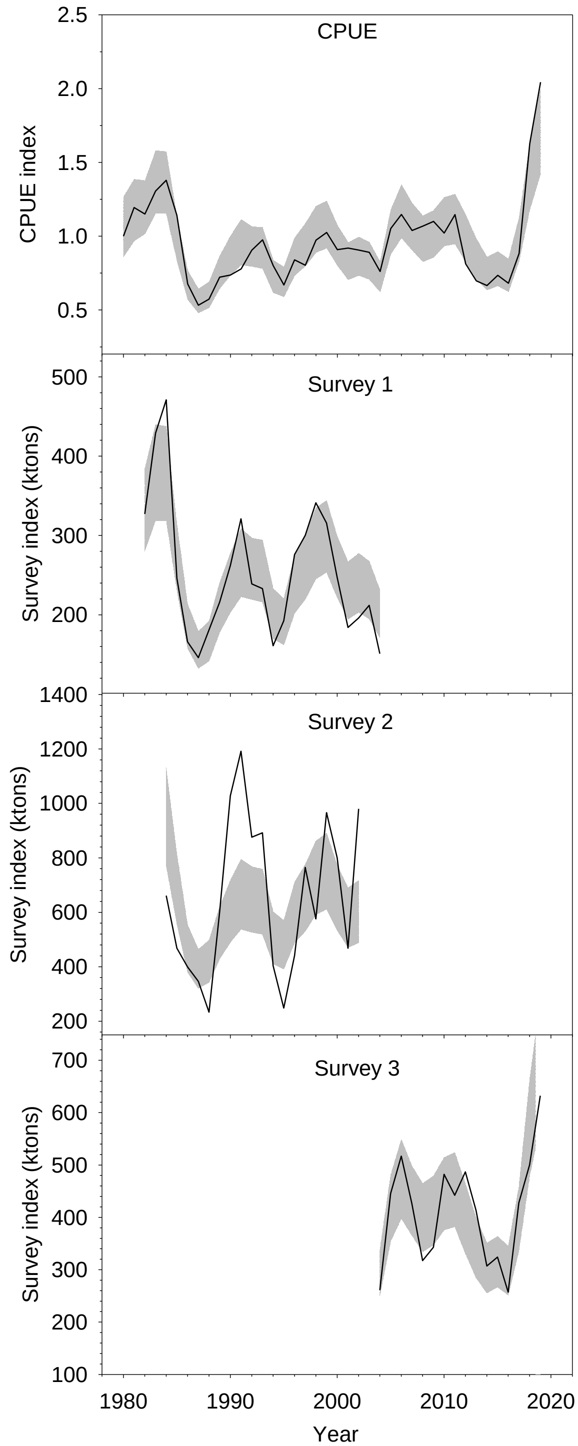

Figure 6.10. Shrimp in ICES SA 1 and 2: Observed (solid line) and estimated (shaded) series of the included biomass indices: the standardized catch-per-unit-effort (CPUE), the 1982–2004 Norwegian shrimp survey (survey 1), the 1984 to 2005 Russian survey (Survey 2) and the Joint Norwegian-Russian Ecosystem Survey (survey 3) since 2004. Grey shaded areas cover the 90% probability interval of their posteriors.

The model did have a tendency to be too optimistic regarding the final years during the stock decline 2010 to 2014 (Figure 6.11), but all of these were well inside the updated estimated probability distributions the following year. The model did however underestimate the 2018 and 2019 increases. NIPAG was not able to resolve this at this meeting and deferred this problem to the upcoming benchmark – currently this model behaviour does not constitute a conservation concern given that the stock is estimated to be well above B_{msy}.

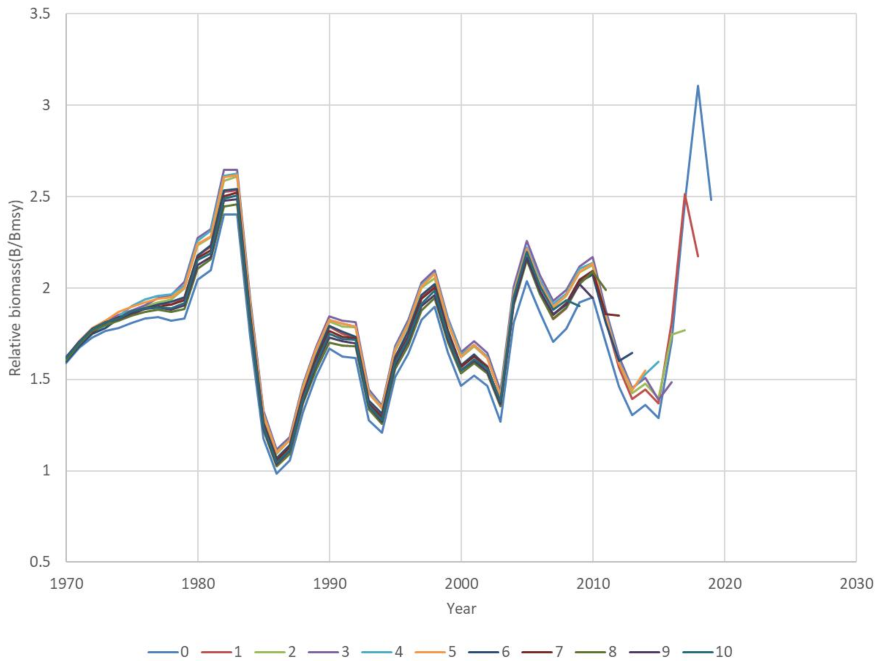

Figure 6.11. Shrimp in ICES SA 1 and 2: Retrospective plot of median relative biomass (B/B_{msy}). Relative biomass series are estimated by consecutively leaving out from 0 to 10 years of data.

e) State of the stock

Biomass. Stock biomass has been above $B_{trigger}$ throughout the history of the fishery. The probability that the biomass at the end of 2019 is below $B_{trigger}$ is less than 1%.

Mortality. Fishing mortality is likely to have remained below F_{msy} throughout the history of the fishery. In 2019 there is a less than 2% risk of fishing mortality exceeding F_{lim}.

Recruitment. No explicit information was available but there were some indications of good recent recruitment from preliminary investigation of observer and survey data.

State of the Stock. The Stock is estimated to be well above B_{msy} and exploited sustainably.

f) Research recommendations

- The assessment procedure used has been in place since 2006 and in 2016 NIPAG **recommended** that *it be considered for a benchmark workshop in near future, no later than 2019*.

Status: In progress. Planned to be conducted in conjunction with the benchmark of the Skagerrak stock. This recommendation is reiterated noting that the benchmark and associated data workshop are anticipated for 2020/21.

- The fishery has expanded since 2014 and catches by countries other than Norway have increased to account for about 65% of the total. In 2016, NIPAG therefore **recommended** that *available data (logbook data and catch samples) from the participating nations be made available to NIPAG.*

Status: In progress. Information from EU-Estonia was presented at the 2017 NIPAG. An official data call has been made. This recommendation is reiterated.

- In 2017, NIPAG **recommended** that *a recruitment index should be developed for this stock.*

Status: planned as part of upcoming benchmark. This recommendation is reiterated.

- In 2017, NIPAG **recommended** that *the information regarding catch effort and bycatch from the Estonian commercial fishery should be further analysed e.g. CPUE data explored as a potential index of biomass.*

Status: In progress. This recommendation is reiterated.

Reference list

ICES. 2018a. Report of the Arctic Fisheries Working Group (AFWG), 18–24 April 2018, Ispra, Italy. ICES CM 2018/ACOM:06. 859 pp

ICES. 2018b. Interim Report of the Working Group on the Integrated Assessments of theBarents Sea (WGIBAR). ICES WGIBAR REPORT 9-12 March 2018. Tromsø, Norway. ICES CM 2018/IEASG:04. 210 pp.

7. Northern shrimp (*Pandalus borealis*) in the Fladen Ground (ICES division IVa)

From the 1960s up to around 2000 a significant shrimp fishery exploited the shrimp stock on the Fladen Ground in the northern North Sea. A short description of the fishery is given, as a shrimp fishery could be resumed in this area in the future. The landings from the Fladen Ground have been recorded since 1970. Total reported landings have fluctuated between zero and 9 000 t (Figure 7.1). The Danish fleet has accounted for the majority of these landings, while the Scottish fleet has landed a smaller portion. The fishery took place mainly during the first half of the year, with the highest activity in the second quarter.

Since 1998 landings decreased steadily and since 2004 the Fladen Ground fishery has been virtually non-existent. Interview information from the fishing industry obtained in 2004 gave the explanation that this decline was caused by low shrimp abundance, low prices on the small shrimp which are characteristic of the Fladen Ground, and high fuel prices. The stock has not been surveyed for many years, and the decline in this fishery may reflect a decline in the stock.

There have been minor Danish, Scottish and Norwegian landings of Northern shrimp from the Fladen Ground stock since 2011, mainly taken as bycatch in the Norway pout fishery. Denmark landed 17 tons from shrimp trawls in 2015.

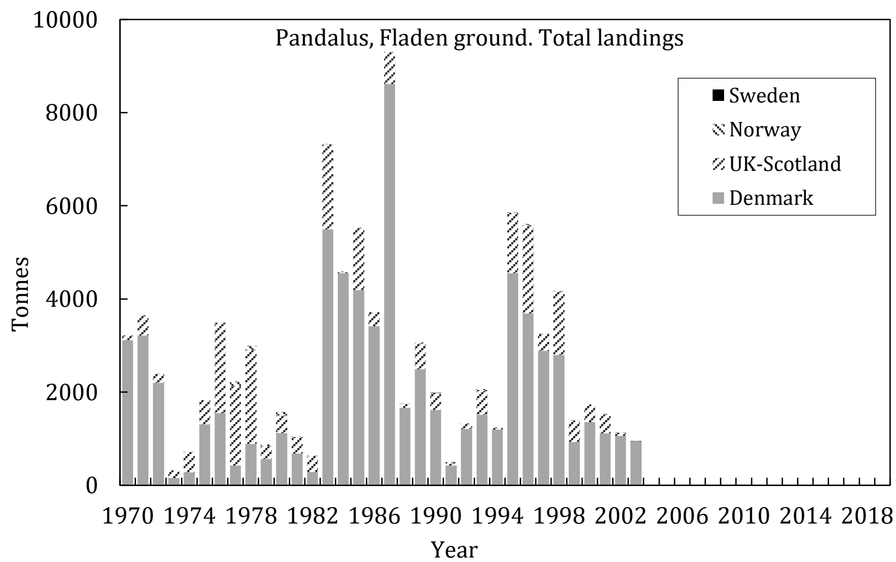

Figure 7.1. Northern shrimp in Fladen Ground: Landings by country and total.

IV. OTHER BUSINESS

a) FIRMS classification for NAFO shrimp stocks

The table as agreed during the September SC meeting was updated with the agreed classifications for the northern shrimp stocks assessed this year.

The Stock Classification system is not intended as a means to convey the scientific advice to the Commission, and should not be used as such. Its purpose is to respond to a request by FIRMS to provide such a classification for their purposes. The category choices do not fully describe the status of some stocks. Scientific advice to the Commission is to be found in the Scientific Council report in the summary sheet for each stock.

Stock Size (incl. structure)	Fishing Mortality			
	None–Low	Moderate	High	Unknown
Virgin–Large	3LNO Yellowtail Flounder 3LN Redfish			
Intermediate	3M cod 3M Northern shrimp[3] SA3+4 Northern shortfin squid	SA0+1 Northern shrimp 0&1A Offshore & 1B–1F Greenland halibut 3M Redfish[3]		Greenland halibut in Disko Bay[2] SA1 American Plaice SA1 Spotted Wolffish SA2+3KLMNO Greenland halibut
Small	3NOPs White hake 3NO Witch flounder 3LNOPs Thorny skate			Greenland halibut in Uummannaq[2] Greenland halibut in Upernavik[2]
Depleted	3M American plaice 3LNO American plaice 3NO Cod 3LNO Northern shrimp			SA1 Redfish SA1 Atlantic Wolffish
Unknown	SA2+3 Roughhead grenadier 3NO Capelin 3O Redfish			6G Alfonsino DS Northern shrimp

[2] Assessed as Greenland halibut in Div. 1A inshore
[3] Fishing mortality may not be the main driver of biomass for Div. 3M Shrimp and Redfish

b) Date and place for the next NIPAG meeting

The 2020 SC shrimp meeting will be held in Copenhagen, Denmark 27 October to 02 November 2020. For the shrimp stock in Division 3M, the next assessment will take place prior to the NAFO Annual Meeting in September 2020 and advice for 2021 will be provided prior to that meeting (as requested by the Commission).

V. ADJOURNMENT

The NIPAG meeting was adjourned at 1400 hours on 13 November 2014. The Co-Chairs thanked all participants, especially the designated experts and stock coordinators, for their hard work. The Co-Chairs thanked the NAFO and ICES Secretariats for all of their logistical support and Norway for hosting the meeting. The report was adopted at the close of the meeting, subject to a two week period for editorial changes.

APPENDIX I. AGENDA NAFO/ICES *PANDALUS* ASSESSMENT GROUP

Havforskningsinstituttet (IMR), Tromsø, Norway
08 – 13 November 2019

I. Opening (Co-chairs Katherine Sosebee and Ole Ritzau Eigaard)

1. Appointment of Rapporteur
2. Adoption of Agenda
3. Plan of Work

II. General Review

1. Review of Recommendations in 2017 and in 2018
2. Review of Catches
3. Review of advice given in September 2019

III. Stock Assessments

- Northern shrimp (Division 3M) (interim monitoring)
- Northern Shrimp (Divisions 3LNO) (interim monitoring)
- Northern shrimp (Subareas 0 and 1) (full assessment)
- Northern shrimp (in Denmark Strait and off East Greenland) (full assessment)
- Northern Shrimp in Barents Sea and Svalbard area (ICES Sub-areas I & II) (full assessment)
- Northern shrimp in Fladen Ground (ICES Division IVa) (full assessment)

IV. Other Business

1. FIRMS Classification for NAFO Shrimp Stocks

V. Adjournment

APPENDIX II. ICES TERMS OF REFERENCE FOR NIPAG

A. Generic ToRs for Regional and Species Working Groups 2018/2/ACOM05

The following ToRs apply to: AFWG, HAWG, NWWG, NIPAG, WGWIDE, WGBAST, WGBFAS, WGNSSK, WGCSE, WGDEEP, WGBIE, WGEEL, WGEF, WGHANSA and WGNAS.

The working group should focus on:

a. Consider and comment on Ecosystem and Fisheries overviews where available;

b. For the aim of providing input for the Fisheries Overviews, consider and comment for the fisheries relevant to the working group on:

  i. descriptions of ecosystem impacts of fisheries

  ii. descriptions of developments and recent changes to the fisheries

  iii. mixed fisheries considerations, and

  iv. emerging issues of relevance for the management of the fisheries;

c. Conduct an assessment on the stock(s) to be addressed in 2019 using the method (analytical, forecast or trends indicators) as described in the stock annex and produce a **brief** report of the work carried out regarding the stock, summarising where the item is relevant:

  i. Input data and examination of data quality;

  ii. Where misreporting of catches is significant, provide qualitative and where possible quantitative information and describe the methods used to obtain the information;

  iii. For relevant stocks (i.e., all stocks with catches in the NEAFC Regulatory Area) estimate the percentage of the total catch that has been taken in the NEAFC Regulatory Area in 2018.

  iv. Estimate MSY proxy reference points for the category 3 and 4 stocks

  v. The developments in spawning stock biomass, total stock biomass, fishing mortality, catches (wanted and unwanted landings and discards) using the method described in the stock annex;

  vi. The state of the stocks against relevant reference points;

  vii. Catch scenarios for next year(s) for the stocks for which ICES has been requested to provide advice on fishing opportunities;

  viii. Historical and analytical performance of the assessment and catch options with a succinct description of quality issues with these. For the analytical performance of category 1 and 2 age-structured assessment, report the mean Mohn's rho (assessment retrospective analysis) values for R, SSB and F. The WG report should include a plot of this retrospective analysis. The values should be calculated in accordance with the "Guidance for completing ToR viii) of the Generic ToRs for Regional and Species Working Groups - Retrospective bias in assessment" and reported using the ICES application for this purpose.

d. Produce a first draft of the advice on the stocks under considerations according to ACOM guidelines.

e. Review progress on benchmark processes of relevance to the Expert Group;

f. Prepare the data calls for the next year update assessment and for planned data evaluation workshops;

g. Identify research needs of relevance for the work of the Expert Group.

Information of the stocks to be considered by each Expert Group is available here.

1. NIPAG – Joint NAFO/ICES *Pandalus* Assessment Working Group 2019/2/ACOM08

A subgroup of The **Joint NAFO/ICES *Pandalus* Assessment Working Group** (NIPAG), chaired by Ole Ritzau Eigaard, Denmark (ICES) and Brian Healey, Canada (NAFO), will meet at ICES, in Copenhagen, Denmark, 25–27 February, 2019, to:

a. Address generic ToRs for Regional and Species Working Groups.

NIPAG will report by 11 March 2019 on the ICES Northern shrimp in divisions 3.a and 4.a East stock for the attention of ACOM

APPENDIX III. RELEVANT RECOMMENDATIONS FROM 2017 AND 2018

NIPAG – 2017

- **Northern Shrimp in Division 3M**

NIPAG **recommends** that *further exploration of the relationship between shrimp, cod and the environment be continued in WG-ESA and NIPAG encourages the shrimp experts to be involved in this work.*

- **Northern Shrimp in Divisions 3NLO**

NIPAG **recommends** that *ecosystem information related to the role of shrimp as prey in the Grand Bank (i.e. 3LNO) Ecosystem be presented to NIPAG.*

- Northern shrimp (*Pandalus borealis*) off West Greenland (NAFO Subarea 0 And Subarea 1)

NIPAG **recommends** that:

- *further refinements to the "partial MIXing" method of estimating numbers at age should be explored.*
- *Survey trends inshore and offshore are divergent and the nature and implications of this divergence should be explored.*
- *genetic stock structure in West and East Greenland should be further explored.*
- *as information from the fishery indicates that catch sensors have been used for some time, the use of new technology which may influence the CPUE should be investigated and documented.*
- *the relationship between the pre-recruit index and the subsequent years' fishable biomass should be investigated further.*
- *the instability of the model should be explored.*
- *the P. montagui fishery should be explored further.*

- **Northern shrimp (*Pandalus borealis*) In the Denmark Strait and off East Greenland (ICES Divisions XIVb and Va)**

NIPAG **recommends** that:

- *genetic stock structure of Pandalus borealis in West and East Greenland should be further explored.*
- *error bars should be added to the SSB so that risk can be assessed in relation to B_{lim}.*

- **Northern shrimp (*Pandalus borealis*) in the Skagerrak and Norwegian Deep (ICES Divisions IIIa and IVa East)**

NIPAG **recommends** 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.*

- *age determination and validation using sections of eye-stalks should continue and results used to refine the life-history knowledge of the stock including age–length relationship and natural mortality assumption.*
- *Differences in recruitment and stock abundance between Skagerrak and the Norwegian Deep should be explored.*
- *the results of the current assessment should be compared with those of an updated run including survey data collected early in the following year.*
- *a full benchmark for this stock including a data compilation workshop in the near future and no later than 2020 (Annex V).*

- **Northern shrimp (*Pandalus borealis*) in the Barents Sea (ICES Subareas I and II)**

NIPAG **recommends** that:

- *a recruitment index should be developed for this stock.*
- *the information regarding catch effort and bycatch from the Estonian commercial fishery should be further analysed eg. CPUE data explored as a potential index of biomass.*
- *information from all fleets fishing on this stock should be made available to NIPAG.*

NIPAG – 2018

1. Northern Shrimp in Division 3M

NIPAG **recommends** that *further exploration of the relationship between shrimp, cod and the environment be continued in WGESA and NIPAG encourages the shrimp experts to be involved in this work. [from 2016. some progress reported but not clear from the report whether this was intended to be reiterated]*

2. Northern Shrimp in Divisions 3NLO

NIPAG **recommends** that:

- *ecosystem information related to the role of shrimp as prey in the Grand Bank (i.e. 3LNO) Ecosystem be presented to NIPAG*
- *further work on the development of a recruitment index for Div. 3LNO be completed.*

3. Northern shrimp (*Pandalus borealis*) off West Greenland (NAFO Subarea 0 And Subarea 1)

NIPAG **recommends** that:

- *genetic stock structure in West and East Greenland should be further explored.*
- *the relationship between the pre-recruit index and the subsequent years' fishable biomass should be investigated further.*

4. Northern shrimp (*Pandalus borealis*) In the Denmark Strait and off East Greenland (ICES Divisions XIVb and Va)

NIPAG **recommended** that:

- *genetic stock structure of Pandalus borealis in West and East Greenland should be further explored.*
- *error bars should be added to the SSB so that risk can be assessed in relation to B_{lim}.*

5. Northern shrimp (*Pandalus borealis*) in the Skagerrak and Norwegian Deep (ICES Divisions IIIa and IVa East)

NIPAG **recommends** that

- *differences in recruitment and stock abundance between Skagerrak and the Norwegian Deep should be explored.*
- *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.*
- *age determination and validation using sections of eye-stalks should continue and results used to refine the life-history knowledge of the stock including age–length relationship and natural mortality assumption.*
- *a full benchmark for this stock, including a data compilation workshop, be conducted in the near future and no later than 2020.*

6. Northern shrimp (*Pandalus borealis*) in the Barents Sea (ICES Subareas I and II)

NIPAG **recommends** that:

- *this stock be considered for a benchmark workshop in near future no later than 2019.*
- *available data (logbook data and catch samples) from the participating nations be made available to NIPAG.*
- *a recruitment index should be developed for this stock.*
- *the information regarding catch effort and bycatch from the Estonian commercial fishery should be further analysed e.g. CPUE data explored as a potential index of biomass.*

APPENDIX IV. DESIGNATED EXPERTS FOR ASSESSMENT OF CERTAIN NAFO STOCKS

The following is the list of Designated Experts for 2018 assessments:

From the Science Branch, Northwest Atlantic Fisheries Centre, Department of Fisheries and Oceans, P. O. Box 5667, St. John's, NL, Canada A1C 5X1, Canada

Northern shrimp in Div. 3LNO	Katherine Skanes	Tel: +1 709-772-8437	Katherine.skanes@dfo-mpo.gc.ca

From the Instituto Español de Oceanografia, Aptdo 1552, E-36200 Vigo (Pontevedra), Spain

Shrimp in Div. 3M	Jose Miguel Casas Sanchez	Tel: +34 986 49 2111	mikel.casas@ieo.es

From the Greenland Institute of Natural Resources, P. O. Box 570, DK-3900 Nuuk, Greenland

Northern shrimp in SA 0+1	AnnDorte Burmeister	Tel: +299 36 1200	anndorte@natur.gl
Northern shrimp in Denmark Strait	Frank Rigét	Tel: +299 36 1200	frri@natur.gl

APPENDIX V. LIST OF RESEARCH (SCR) AND SUMMARY (SCS) DOCUMENTS

RESEARCH DOCUMENTS (SCR)

SCR No.	Serial No.	Author(s)	Title
SCR Doc. 19-043	N7007	Burmeister and Riget	The West Greenland trawl survey for *Pandalus borealis*, 2019, with reference to earlier results.
SCR Doc. 19-044	N7008	Burmeister and Riget	The Fishery for Northern Shrimp (*Pandalus borealis*) off West Greenland, 1970–2019
SCR Doc. 19-045	N7009	Burmeister	Catch Table Update for the West Greenland Shrimp Fishery
SCR Doc. 19-046	N7010	Burmeister and Riget	A provisional Assessment of the shrimp stock off West Greenland in 2019
SCR Doc. 19-047	N7011	Frank Rigét	The Fishery for Northern Shrimp (*Pandalus borealis*) in Denmark Strait / off East Greenland 1978 – 2019.
SCR Doc. 19-048	N7012	Riget and Burmeister	Estimation of the cod biomass by SAM and its implication for the assessment of Northern Shrimp (*Pandalus borealis*) in West Greenland.
SCR Doc. 19-049	N7013	Burmeister and Riget	Relationship between the survey abundance of Age – 2 shrimp, Pre-recruits and fishable biomass two to four years later
SCR Doc. 19-050	N7014	Burmeister	Reply to the Canadian request for advice of shrimps in Subarea 0 and 1.
SCR Doc. 19-051	N7015	J. M. Casas	Assessment of the International Fishery for Shrimp (*Pandalus borealis*) in Division 3M (Flemish Cap), 1993-2019
SCR Doc. 19-052	N7016	Casas, J.M., E. Román and M. Álvarez	Northern Shrimp (*Pandalus borealis, Krøyer*) from EU-Spain Bottom TrawlSurvey 2019 in NAFO Div. 3LNO
SCR Doc. 19-053	N7017	J. M. Casas	Northern Shrimp (*Pandalus borealis*) on Flemish Cap Surveys 2019
SCR Doc. 19-054	N7018	Carsten Hvingel	Shrimp (*Pandalus borealis*) in the Barents Sea – Stock assessment 2019
SCR Doc. 19-055	N7019	Carsten. Hvingel and Trude. H. Thangstad	Research survey results pertaining to northern shrimp (*Pandalus borealis*) in the Barents Sea and Svalbard area 2004-2019
SCR Doc. 19-056	N7020	Carsten. Hvingel and Trude. H. Thangstad	The Norwegian fishery for northern shrimp (*Pandalus borealis*) in the Barents Sea and round Svalbard 1970-2019

SUMMARY DOCUMENTS (SCS)

SCS No.	Serial No.	Author(s)	Title
SCS Doc. 19/21	N6970	NAFO/ICES	Report of the Scientific Council (in conjunction with NIPAG), 10 September 2019
SCS Doc. 19/23	N7025	NAFO	Report of the Scientific Council Shrimp Meeting, 8-13 November 2019
SCS Doc. 19/24 ICES CM 2019/ FRSG1:84	N7026	NAFO	Report of the NAFO/ICES *Pandalus* Assessment Group (NIPAG), 8-13 November 2019

APPENDIX VI. PARTICIPANTS LIST

CO-CHAIRS	
Katherine Sosebee	National Marine Fisheries Service, NEFSC, 166 Water St., Woods Hole, MA 02543 Tel: +508-495-2372 – E-mail: katherine.sosebee@noaa.gov
Ole Ritzau Eigaard	DTU-AQUA Technical University of Denmark, Charlottenlund Slot, DK-2920, Charlottenlund Email: ore@aqua.dtu.dk
CANADA	
Katherine Skanes	Fisheries and Oceans Canada, Northwest Atlantic Fisheries Centre, P.O. Box 5667, St John's, NL A1C 5X1 Tel:+709 772 8437 - Email:katherine.skanes@dfo-mpo.gc.ca
Susan Thompson	Science Advisor, Fish Population Science Fisheries and Oceans Canada / Government of Canada Tel:343-998-3982 - Email :Susan.Thompson@dfo-mpo.gc.ca
DENMARK (In respect of FAROE ISLANDS and GREENLAND)	
AnnDorte Burmeister	Greenland Institute of Natural Resources, P. O. Box 570. GL-3900, Nuuk Tel: +299 36 1200 -Email: anndorte@natur.gl
Frank Rigét	Greenland Institute of Natural Resources, P. O. Box 570. GL-3900, Nuuk Tel: +299 36 1200 -Email: frri@natur.gl
EUROPEAN UNION	
José Miguel Casas Sanchez	Instituto Espanol de Oceanografia, Centro Oceanografio, De Vigo, Subida a Radiofaro, 50 P.O. Box 1552, E-36200 Vigo (Pontevedra), Spain Email: mikel.casas@ieo.es
Kalvi Hubel	Estonian Marine Institute, University of Tartu, Estonia, Vanemuise 46a, Tartu, 51014 Tel: +372 5563 8283 – Email: kalvi.hubel@ut.ee
NORWAY	
Carsten Hvingel	Institute of Marine Research, Tromsø, Norway Tel: +47 95980565 – E-mail: carsten.hvingel@imr.no
Guldborg Søvik	Institute of Marine Research, Bergen, Norway Tel: +47 5523 5348 – Email: guldborg.soevik@imr.no
Trude Thangstad	Institute of Marine Research, Bergen, Norway Email: trude.thangstad@hi.no
Fabian Zimmermann	Institute of Marine Research, Bergen, Norway Email: Fabian.zimmermann@hi.no
NAFO SECRETARIAT	
Dayna Bell MacCallum	Scientific Information Administrator Tel: +1 902 468 5590 - Email: dbell@nafo.int
Tom Blasdale	Scientific Council Coordinator Tel: +1 902 468 5590 - Email: tblasdale@nafo.int

APPENDIX VII. ASSESSMENT OF NORTHERN SHRIMP (*PANDALUS BOREALIS*) IN THE SKAGERRAK AND NORWEGIAN DEEP

a) Executive summary

PandSKND, a subgroup of the NAFO/ICES Pandalus Assessment Group (NIPAG), met 25–27 February 2019 at ICES HQ in Copenhagen to assess the Pandalus stock in divisions 3.a and 4.a 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 2019 and a preliminary TAC advice for the first two quarters of 2020.

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

In accordance with the LTMS reference points and Harvest Control Rules, ICES advises that catches in 2019 should be no more than 6163 tonnes and that catches for the first two quarters of 2020 should be no more than 6329 tonnes. This corresponds to a 30.9% reduction for the 2019 TAC and a 102% increase of the 2020 TAC. The main reason for the reduction in the 2019 advice is that inclusion of the most recent survey and catch data results in a decline in SSB2019 close to Blim. The main reason for the increase in the 2020 advice is the strong reduction in F assumed for 2019 and the above average 2018 year class that provides catch opportunities while also bringing the SSB2020 above BMGT.

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.

b) Expert group information

Expert group name	Joint NAFO/ICES Pandalus Assessment Working Group (NIPAG)
Expert group cycle	Annual
Year cycle started	2019
Reporting year in cycle	1/1
Chair	Ole Ritzau Eigaard, Denmark
Meeting venue and dates	25–27 February 2019 (four participants)

5. 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 and in the ICES Stock Annex.

a) Introduction

The shrimp in ICES Division 27.3.a (Skagerrak and Kattegat) and the eastern part of Division 27.4.a (Norwegian Deep) is assessed as one stock and is 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 2018. The recommended TACs were until 2002 based on catch predictions. In 2003, the cohort-based assessment was abandoned and no catch predictions were available. The recommended 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 highgrading 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.

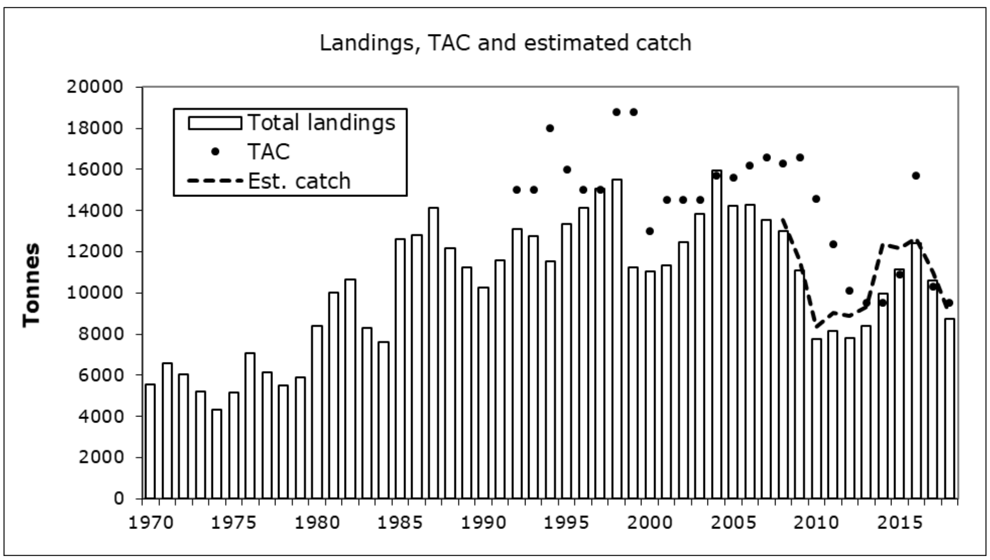

Figure 5.1. Northern shrimp in Skagerrak and Norwegian Deep: TAC, total landings by all fleets, and total estimated catch including estimated Swedish discards for 2008–2018, and Norwegian and Danish discards for 2009–2018.

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
Advised TAC[2]	15000	13000	8800	*	5800	6000	10900	13721	10316	8571
Agreed TAC	16600	14558	12380	10115	9500	9500	10900	15696	10316	8900
Denmark landings	2224	1301	1601	1454	2026	2432	2709	1997	2173	1863
Norway landings	6362	4673	4800	4852	5179	6123	6808	8305	6778	5493

Sweden landings	2483	1781	1768	1521	1191	1397	1644	2095	1634	1374
Total landings	11069	7755	8169	7827	8396	9952	11161	12397	10585	8730
Est. Swedish discards	337	386	504	671	265	572	325	87	99	114
Est. Norw. Discards	94	133	247	292	459	1289	476	162	114	115
Est. Danish discards	36	53	123	88	185	526	204	35	206	12
Total catch	11536	8327	9043	8878	9305	12339	12166	12681	10316	8971

[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 2018. 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 187 in 2018. Twin trawls were introduced around 2002, and in 2011–2018 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 40 in 2011–2018. 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 50% (recent eight 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 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 two years, catches have again decreased, to around 8900 t in 2018 (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 (“highgrading”). 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 highgrading. 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 2018, the discard percentages were 7 and 0.6%, respectively. In 2017 to 2018, 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.

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 (no fish retention device), 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). 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 2018. 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	481,5	96,3	5964,3	75,0	1244,0	76,1
Norway lobster	6,3	1,3	37,3	0,5	4,3	0,3
Anglerfish	0,3	0,1	113,8	1,4	54,5	3,3
Whiting	0,0	0,0	5,0	0,1	1,4	0,1
Haddock	0,1	0,0	37,7	0,5	11,8	0,7
Hake	0,0	0,0	28,8	0,4	25,7	1,6
Ling	0,0	0,0	71,8	0,9	36,0	2,2
Saithe	0,5	0,1	864,2	10,9	141,4	8,6
Witch flounder	0,1	0,0	79,1	1,0	1,7	0,1
Norway pout	9,2	1,8	36,4	0,5	4,8	0,3
Cod	1,1	0,2	511,8	6,4	58,3	3,6
Other marketable fish	0,9	0,2	200,4	2,5	51,1	3,1

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 blue whiting. An index of potential shrimp predators without these three species varied without a trend from 2007 to 2015, but has been at a higher level since 2017, indicating higher biomass of potential predators in the last three years (Figure 5.2; the 2016 survey data were omitted, see below). This is in agreement with increasing trends in stock size observed in recent stock assessments of demersal fish species in the North Sea and Skagerrak (ICES, 2018a; ICES, 2018b).

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 2007–2019. 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
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
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
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
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
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
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
Redfish	Scorpaenidae	0.26	0.43	0.80	1.02	0.37	0.47	0.48	0.20	0.53	0.97	0.82
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
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
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
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
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
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
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
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
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
Blue Ling	*Molva dypterygia*	0	0	0	0	0	0.01	0.01	0.03	0.01	0.03	0.02
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

Species												
English	Latin	2008	2009	2010	2011	2012	2013	2014	2015	2017	2018	2019
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
Cusk	*Brosme brosme*	0.02	0.05	0.13	0.29	0.04	0.10	0.05	0.19	0	0.14	0.38
Halibut	*Hippoglossus hippoglossus*	3.88	0.09	0.20	0.05	0.19	0	0	0.10	0.16	0.09	0.24
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
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
Total		244.81	94.26	49.23	33.09	30.04	164.23	41.18	34.48	66.96	46.16	54.74
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

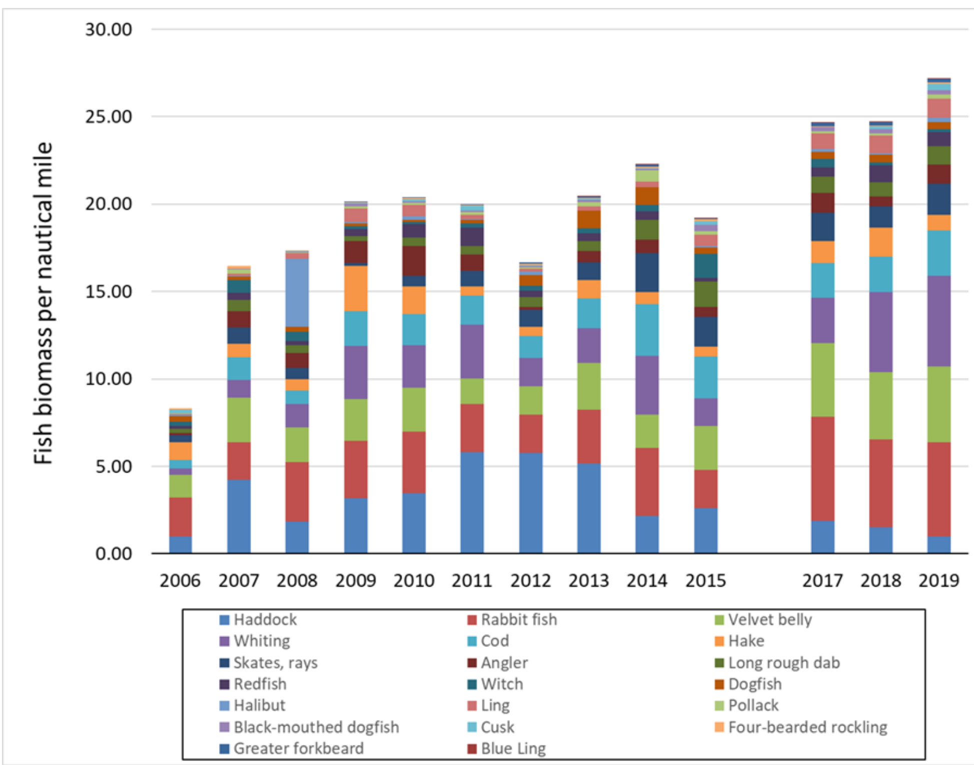

Figure 5.2. Northern shrimp in Skagerrak and Norwegian Deep: Estimated indices of predator biomass (catch in t per square nautical mile) from the Norwegian shrimp survey in 2006–2019 excluding saithe, roundnose grenadier and blue whiting. The 2016 survey data have been omitted (see text for details).

b) Input data

i) Fishery data

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

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

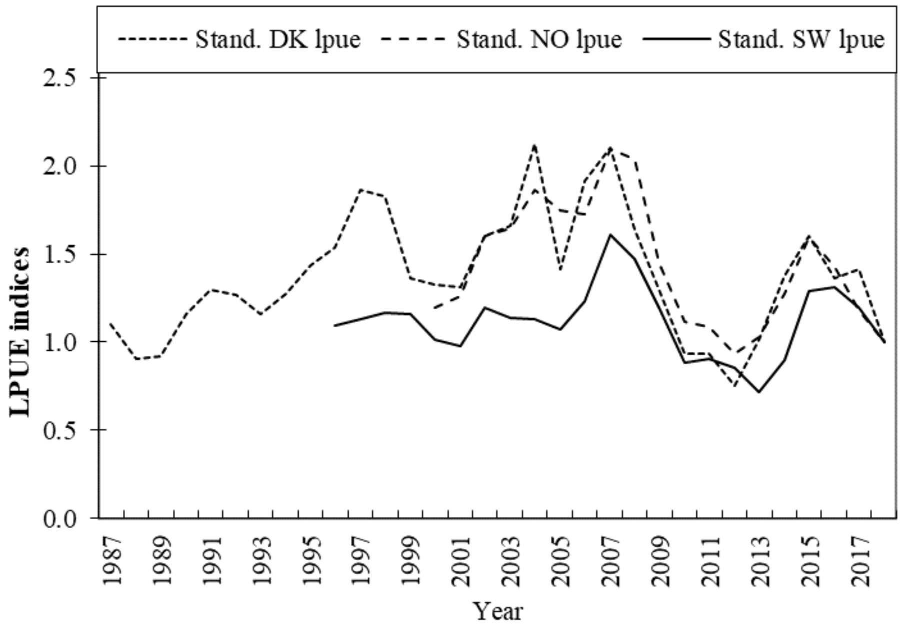

Figure 5.3. Northern shrimp in Skagerrak and Norwegian Deep: Danish, Norwegian and Swedish standardized landings per unit effort (LPUE) until 2018. Each series is standardized to its final year.

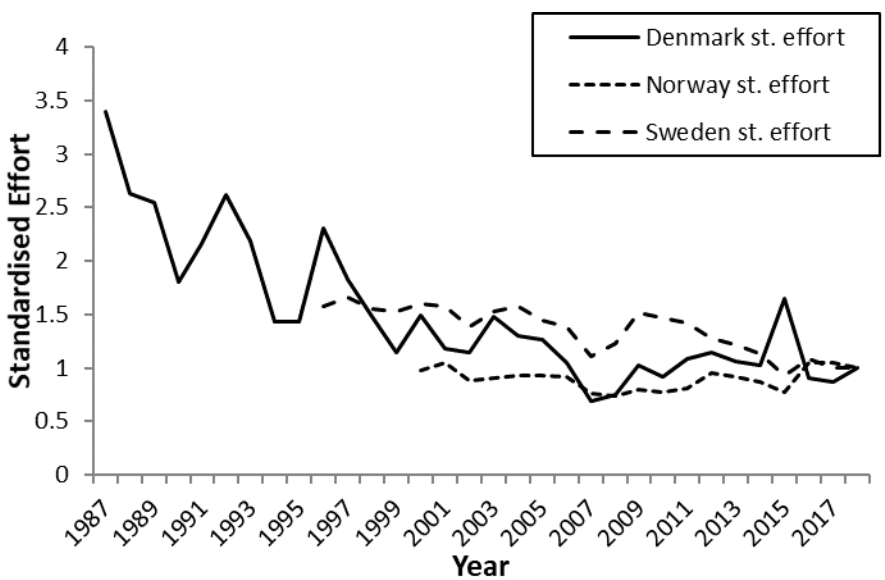

Figure 5.4. Northern shrimp in Skagerrak and Norwegian Deep: Estimated standardized effort. Each series is standardized to its final year.

Sampling of catches

Length frequencies of the commercial catches from 1985 to 2018 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).

ii) Survey data

The Norwegian shrimp survey went through large changes in vessel, gear and timing in 2003–2006, 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 were 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 with complete coverage) to the total biomass of the year. However, total numbers-at-length have not yet been standardised, which means that the length-based model (see below) uses unstandardised survey data.

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 but has decreased since, to the fourth time-series' lowest observed level in 2019 (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 2018 year class is estimated to be around the average of the fourth time-series.

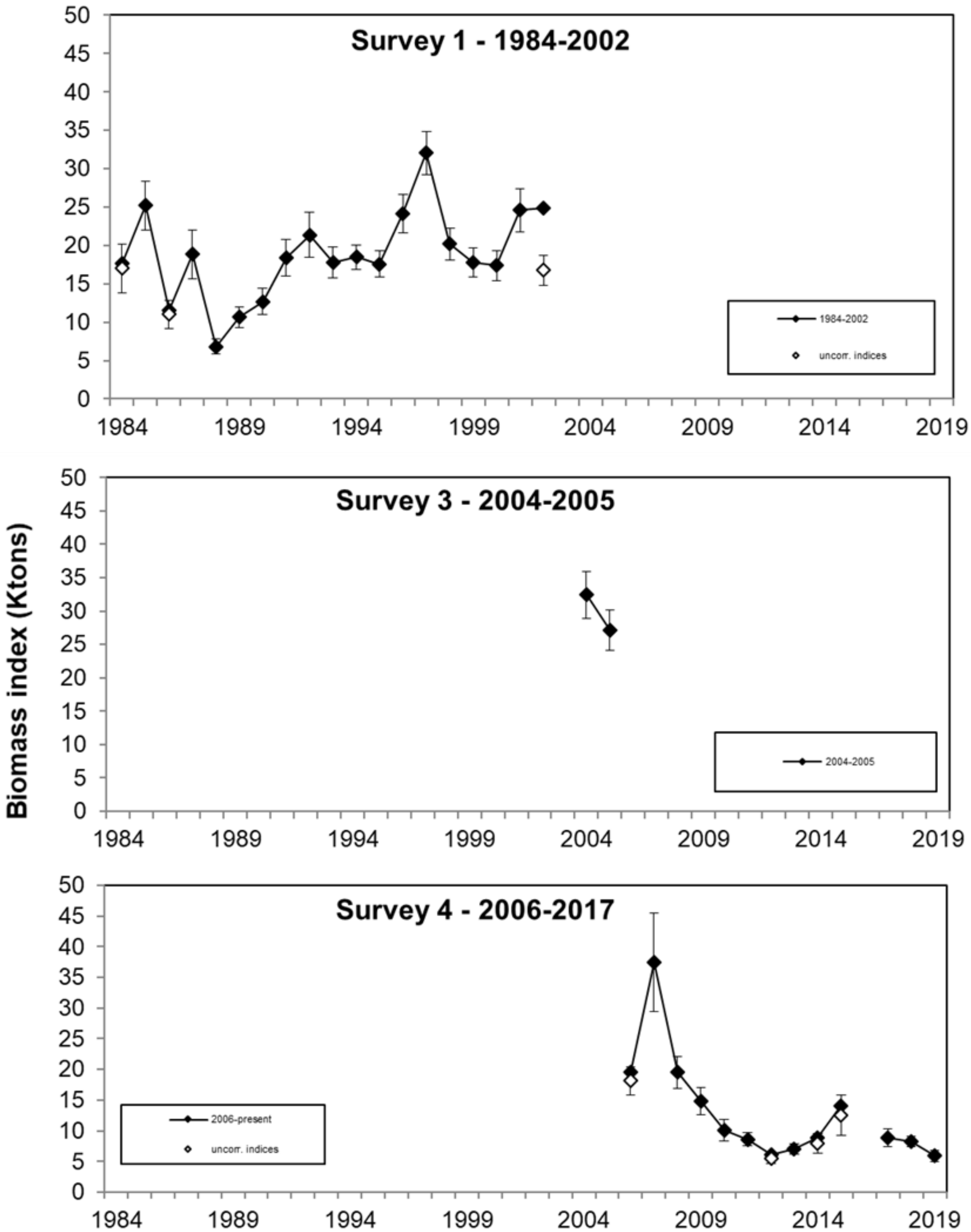

Figure 5.5. Northern shrimp in Skagerrak and Norwegian Deep: Estimated survey biomass index in 1984–2019. The point estimate of 2003 is not shown. The 2016 survey data have been omitted (see text for details).

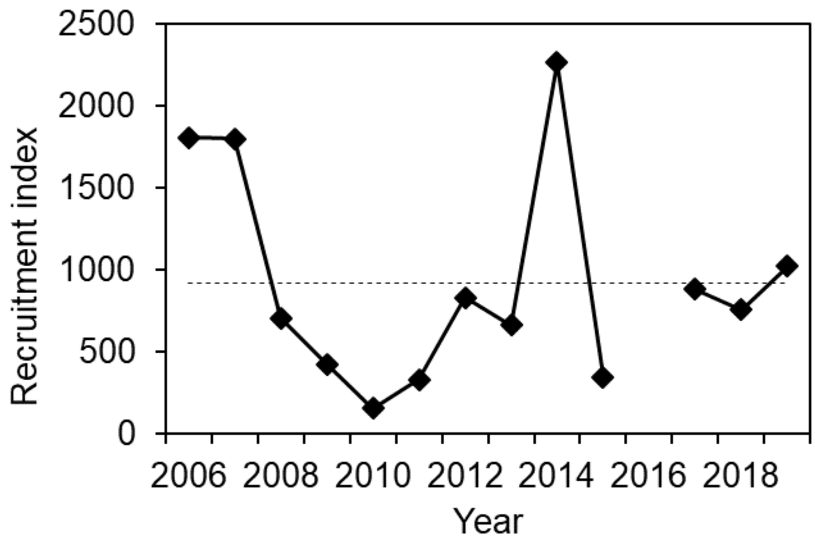

Figure 5.6. Northern shrimp in Skagerrak and Norwegian Deep: Estimated recruitment index, 2006–2019. The 2016 survey data have been omitted (see text for details).

c) Assessment

i) 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 FMSY value to FMSY = 0.60 (previously 0.62), whereas MSY Btrigger = 9900 t remained unchanged (see below).

ii) Assessment results

SS3 model diagnostics of this year's run do 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 (see section below on model retrospective). The bias is, however, within the acceptable range of requiring no action.

iii) 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 FMSY and MSY Btrigger compared with M = 0.75 (base model) (Figure 5.7). 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.

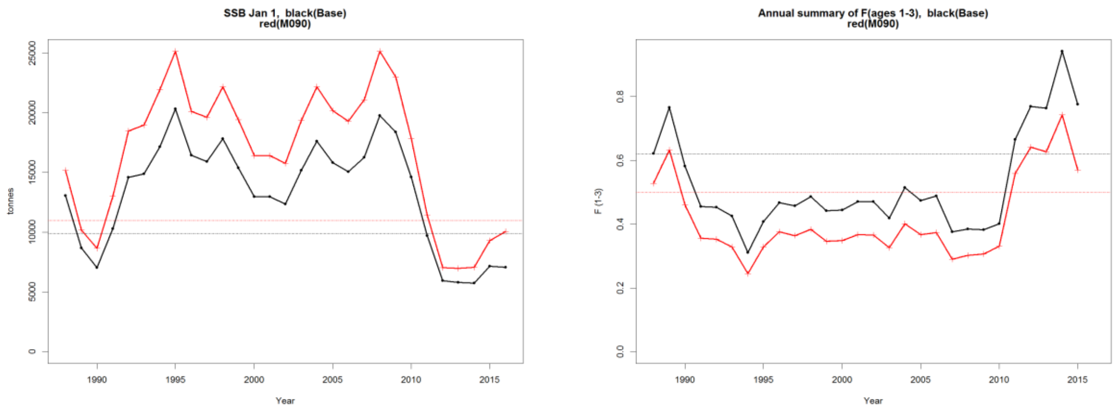

Figure 5.7. Northern shrimp in Skagerrak and Norwegian Deep: F and SSB assessment results for natural mortality M = 0.75 (base model, black) and M = 0.90 (red). The horizontal lines indicate MSY Btrigger (left panel) and FMSY (right panel) values for each of the two M-levels.

iv) Historical stock trends and recruitment

Historical stock trends are shown in Figure 5.8.

Since 2008, when SSB was 22 451 t, which is the highest SSB estimate of the time-series, the SSB decreased to the time-series low of 6119 t in 2012. The SSB then increased up to 2016, but decreased again to 6540 t in 2019, which is close to Blim of 6300 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 below Blim. The uncertainty around the estimate of recruitment in 2018 is 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 2018) but only in the survey data (collected with a smaller meshed survey trawl in January 2019).

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 0.76 in 2014, which is the highest observed value of the time-series. F then decreased to 0.51 in 2015, to increase again to 0.71 in 2017 and decrease to 0.65 in 2018. Since 2011, the stock has been exploited at a level greater than the FMSY of 0.60, except in 2015.

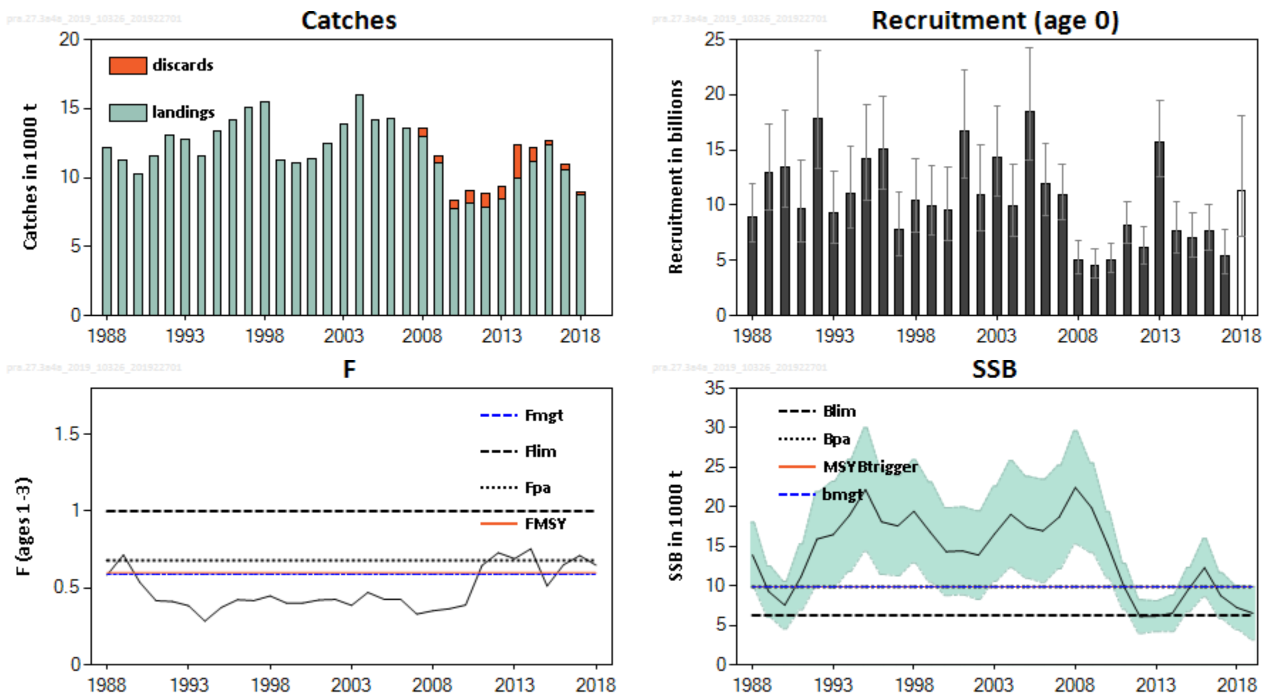

Figure 5.8. Northern shrimp in Skagerrak and Norwegian Deep: Summary assessment output. Total catch, including estimated discards since 2008 (tonnes) and *F*, SSB and *R* assessment results. SSB and *R* are depicted with 90% confidence intervals. The

v) Model retrospective

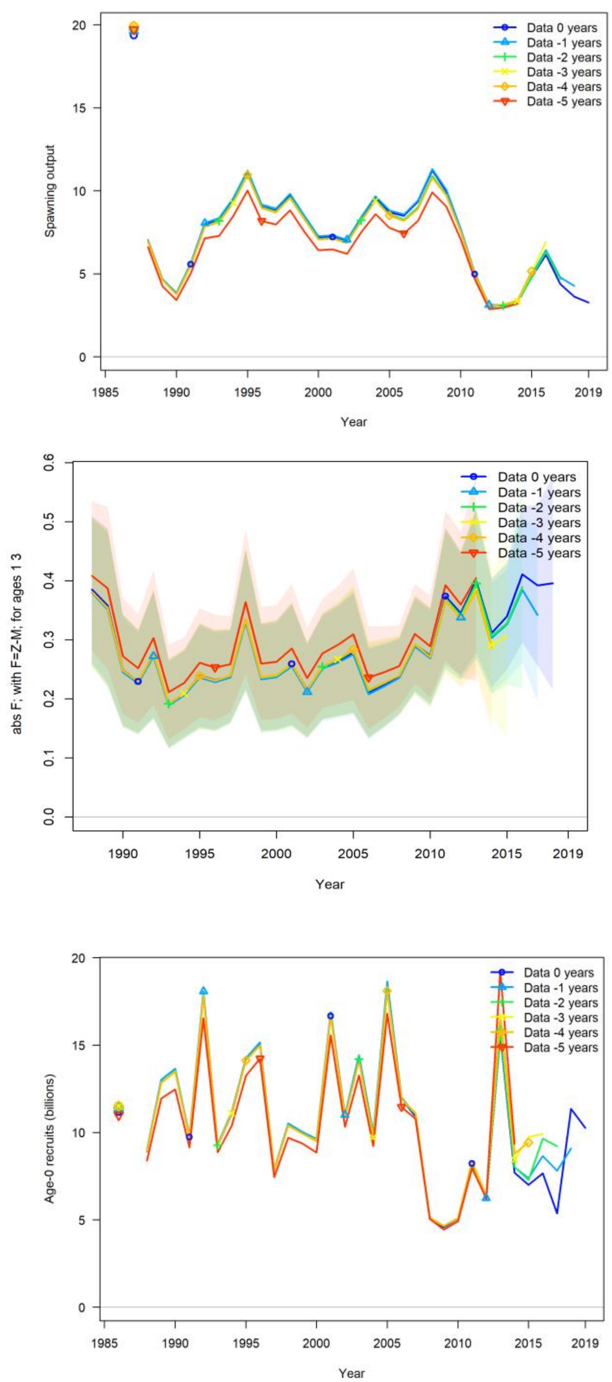

Figure 5.9. Northern shrimp in Skagerrak and Norwegian Deep: Model retrospective of SSB, F (ages 1–3) and R. It should be noted that values of SSB and F shown in these figures are not directly comparable to the SSB and F in Figure 5.8 (as the figures here are from the standard output of r4SS). Here, SSB is shown for females only (in this case 50% of the total SSB) and F is presented as an average weighted by the number of shrimp in the age classes of Fbar ages 1 to 3. For recruitment, the last year of each retrospective line is a predicted value from the

model (drawn from the stock recruitment relationship) and should not be included when interpreting the retrospective pattern.

Model retrospectives for the assessment are shown in Figure 5.9 and are similar to the assessment in October 2018. There is a moderate retrospective pattern for the historical part of the time-series of SSB, F and R. There is a small tendency to overestimate SSB and underestimate F. The retrospective pattern is however, negligible before 2018 for SSB and before 2016 for F. Recruitment is somewhat overestimated by the model (Figure 5.9), meaning that the previous year classes have been revised downwards. Figure 5.10 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.

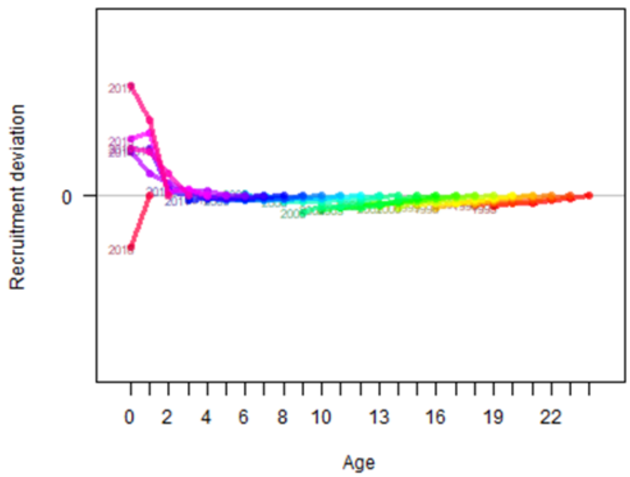

Figure 5.10. Northern shrimp in Skagerrak and Norwegian Deep: Model retrospective of SSB, F (ages 1–3) and R.

vi) 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 BMGT (BTRIGGER) and FTARGET are fixed at levels of 9 900 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 FTARGET.

b. When the SSB at the start of the year is estimated below BMGT, the Parties will fix a TAC consistent with a fishing mortality rate of FTARGET x (SSB/BMGT).

The TAC will include all removals made from the stock.

When SSB is estimated to be at or above BMGT, 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 5 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.

f) 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: FMSY and MSY Btrigger. (Table 5.4). Under the ICES PA two reference points are also required; Blim and Bpa (Table 5.4). Blim was set to Bloss, 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, FMGT (Ftarget) and BMGT (Btrigger) (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 FMSY value to FMSY = 0.60 (previously 0.62), whereas MSY Btrigger = 9900 t remained unchanged. The lower Ftarget (FMGT) for the HCR compared to the FMSY 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)

g) 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 2019 and ii) catch scenarios for the first semester of 2020.

Table 5.5. Northern shrimp in Skagerrak and Norwegian Deep: The basis for the updated catch scenarios for 2019.

Variable	Value	Notes
F_{2018}	0.65	Corresponds to the estimated catches in 2018
SSB_{2019}	6377	SSB beginning of 2019 (in tonnes)
R_{2019}	7 339 344	GM 2009–2018 (in thousands)
Catches 2018	8971	Landings and estimated discards (in tonnes)

Given the new 2019 datapoint for the survey time-series and an estimated catch of 8971 t in 2018, updated catch scenarios were provided for 2019 (Table 5.6). The advised TAC for 2019 is 6163 tonnes.

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

Basis	Total catch (2019)	F_{total} (2019)	SSB (2020)	% SSB change *	% TAC change **	% advice change ***
LTMS: $F = F_{MGT} \times (SSB_{2019}/ MSY\ B_{trigger})$	6163	0.38	9952	56.1	-30.8	-28.1
Other scenarios						
MSY approach: $F = F_{MSY} \times (SSB_{2019}/ MSY\ B_{trigger})$	6301	0.39	9872	54.8	-29.2	-26.5
F = 0	0	0	13678	114.5	-100	-100
F_{pa}	9780	0.68	7943	24.6	9.9	14.1
F_{MSY}	8901	0.6	8417	32.0	0.0	3.9
F_{lim}	12810	1	6392	0.2	43.9	49.5
F_{2018}	9562	0.66	8060	26.4	7.4	11.6
F_{MGT}	8785	0.59	8480	33.0	-1.3	2.5
$SSB_{2020} = B_{PA} = B_{trigger}$	6255	0.39	9900	55.2	-29.7	-27.0
$SSB_{2020} = B_{lim}$	12996	1.02	6300	-1.2	46.0	51.6

* SSB2020 relative to SSB2019.

** Advised catch in 2019 relative to TACs in 2018.

*** Advised catch in 2019 relative to advice value 2018.

The main reason for the reduction in the updated catch advice is that the inclusion of the 2019 survey data and the full 2018 catch data in the assessment model shows that SSB2019 is close to Blim.

Table 5.7. Northern shrimp in Skagerrak and Norwegian Deep: The basis for the 1st semester catch-scenarios for 2020.

Variable	Value	Notes
F_{2019}	0.38	Corresponds to the catch forecast for 2019
SSB_{2020}	10050	SSB beginning of 2020 (in tonnes)
R_{2020}	7 353 780	GM 2009-2018 (in thousands)
Catches 2019	6163	Catch forecast for 2019 (in tonnes)

Table 5.8. Northern shrimp in Skagerrak and Norwegian Deep: Catch scenarios for 1st semester in 2020.

Basis	Total catch (2020)	Q1 and Q2 catch (2020) ^	F_{total} (2020)	SSB (2021)	% SSB change *	% TAC change **	% advice change ***
LTMS	12439	6329	0.59	10282	2.3	101.8	101.8
Other scenarios							
MSY Approach	12593	6407	0.60	10182	1.3	104.3	104.3
F = 0	0	0	0	18878	87.8	-100.0	-100.0
F_{lim}	17640	8975	1.0	7012	-30.2	186.2	186.2
Fpa	13760	7001	0.68	9426	-6.2	123.3	123.3
F_{2019}	8852	4504	0.38	12672	26.1	43.6	43.6
$SSB_{2021} = B_{PA} = B_{trigger}$	13025	6627	0.63	9900	-1.5	111.3	111.3
$SSB_{2021} = B_{lim}$	18844		1.12	6300	-37.3	205.8	205.8

h) State of the stock

Mortality. Fishing mortality has been above FMSY since 2011 except in 2015.

Biomass. Stock biomass has been below Btrigger since 2012 except in 2016, and was below Blim in 2012 and 2013.

Recruitment. Recruitment has been below average since 2008, except for the 2013 and 2018 year class.

State of the Stock. At the beginning of 2019, the stock is estimated to be close to Blim. Recruitment is estimated to be above average in 2018. Fishing mortality was above FMGT and FMSY but below FPA in 2018.

Yield. According to the new long-term management strategy, catches in 2019 should be no more than 6163 tonnes and in the two first quarters of 2020 no more than 6329 tonnes.

i) 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.

j) References

Anon. 2018. Agreed Record of Fisheries Consultations between the European Union and Norway for 2018. 25. April 2018.

Berenboim, B.I., Korzhev, V.A., Tretjak, V.L. and Sheveleva, G.K. 1991. On methods of stock assessment and evaluation of TAC for shrimp Pandalus borealis in the Barents Sea. ICES C.M. 1991/K:15. 22 pp.

ICES. 2016. Report of the Benchmark Workshop on Pandalus borealis in Skagerrak and Norwegian Deep Sea (WKPAND), 20–22 January 2016, Bergen, Norway. ICES CM 2016/ACOM:39. 72 pp.

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.

ICES. 2017b. ICES fisheries management reference points for category 1 and 2 stocks. In Report of the ICES Advisory Committee, 2017. ICES Advice 2017 Technical Guidelines, Book 12, 12.4.3.1, DOI: 10.17895/ices.pub.3036.

ICES. 2018a. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK) 24 April–3 May 2018, Oostende, Belgium. ICES CM 2018/ACOM: 22. 1264 pp.

ICES. 2018b. Report of the Working Group for the Bay of Biscay and the Iberian waters Ecoregion (WGBIE) 3–10 May 2018, ICES HQ, Copenhagen, Denmark. ICES CM 2018/ACOM: 12. 585 pp.

k) List of participants

Name	Address	Country	E-mail
Mikaela Bergenius	SLU-Aqua	Sweden	mikaela.bergenius@slu.se
Ole Ritzau Eigaard Chair	DTU Aqua Section for Fisheries Advice	Denmark	ore@aqua.dtu.dk
Guldborg Søvik	Institute of Marine Research	Norway	guldborg.soevik@hi.no
Mats Ulmestrand	Institute of Marine Research	Sweden	mats.ulmestrand@slu.se

APPENDIX VIII. ICES BENCHMARK PRIORITIZATION SCORING SHEET FOR NIPAG, NOVEMBER 2019

SCORE	**Criteria 1 – Need to improve the quality of the previous assessment to provide advice** Weight: 0.4	**Criteria 2 – Opportunity to improve the assessment** Weight: 0.3	**Criteria 3 – Management importance** Attributes: a) Advice on fishing opportunities is requested for the stock. b) Stock is the object of an agreed management plan. c) Stock is the object of a directed fishery. d) Stock is included in a mixed fishery analysis, is a likely choke stock, or the object of a pelagic fishery (meets 1 of the 3) Weight: 0.1	**Criteria 4 – Perceived stock status** Weight: 0.1	**Criteria 5 - Time since previous benchmark** Weight: 0.1
5	Assessment judged to be inadequate to provide advice (e.g., bias, stock id, unreliable catches, major change in biological processes/productivity)	New approaches and new data sources will be available for the stock, and these are likely to address issues or change perception of stock dynamics	All attributes	Most likely below B_{lim}, or stock is in rapid decline, or state of the stock unknown	Stock has never been benchmarked
4	Assessment has high potential & priority to be upgraded to Cat. 1 from Cat. 3 or to Cat. 3 from Cat. 5 and 6	New data sources or corrections in data, or new methods will be available for the stock, and these are likely to address issues or change perception of stock dynamics	3 attributes	Between B_{lim} and $MSYB_{trigger}$	Stock has been benchmarked 10 years or more ago
3	Assessment judged to have substantial deficiencies (models and/or data) but considered acceptable	Some improvement in data /modelling approaches will be available, and unclear whether they will address issues or change perceptions	2 attributes	About $MSYB_{trigger}$	Stock has been benchmarked between 5 and <10 years ago

2	Assessment has no substantial or only minor issues	Minor improvement in data or methods will be available	1 attributes	Above $MSYB_{trigger}$	Stock has been benchmarked between 1 and < 5 years ago
1	Assessment has no obvious issues	No change in data or models will be available	No attributes	Near highest on record	Stock was benchmarked in the last year

SCORING SHEET for: **NIPAG**

Date: November 2019

Scored by: NIPAG

Stock Name	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5
Example stock xxx	3 Provide reason(s) for the rating, referring if possible to the issues list.	4 Provide reason(s), list the main data or approaches improvements (if applicable, include expected year that data will be available)	4 List attributes (e.g., a, c, d)	3 Indicate the basis for the determination (e.g. estimate from the advice issued in year x, survey index series, expert opinion, etc).	1 If a benchmark has been conducted indicate the year and reference to the benchmark report.
Pra.27.1-2	3 Big retrospective pattern in recent years. Current effort data come from a small portion of the total fishery and we need to incorporate data from other fisheries. Need to re-analyse survey data for possible indices of recruitment need to develop a statistically coherent method to account for missing survey coverage	4 If recruitment indices can be generated and CPUE data from all fleets are available, this is expected to reduce the retrospective problem.	3 a, c the importance of this fishery has increased greatly in recent years and a management plan is needed and is under development.	1 Assessment in 2019	5

Stock Name	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5
Example stock xxx	3 Provide reason(s) for the rating, referring if possible to the issues list.	4 Provide reason(s), list the main data or approaches improvements (if applicable, include expected year that data will be available)	4 List attributes (e.g., a, c, d)	3 Indicate the basis for the determination (e.g. estimate from the advice issued in year x, survey index series, expert opinion, etc).	1 If a benchmark has been conducted indicate the year and reference to the benchmark report.
	Need to incorporate information on recruitment in the assessment model.				
Pra.27.3a4a	3 The advice is very dependent on M, both for the estimations of the reference point and stock status. M assumptions are crude and very poorly substantiated. Model tends to over-estimate recruitment in the final year. B_{lim} is defined a B_{loss} and this may be inappropriate. Reference points need to be further explored	4 Analysis of empirical data is underway to improve estimates of M and expected to be finished in 2020. A new approach to calculating the survey index is available and this needs to be explored and approved at the benchmark. Catches will be split by fleet and area.	4 a,b,c	3 From the 2019 advice	2 2016, but there was not a data workshop

Stock Name	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5
Example stock xxx	3 Provide reason(s) for the rating, referring if possible to the issues list.	4 Provide reason(s), list the main data or approaches improvements (if applicable, include expected year that data will be available)	4 List attributes (e.g., a, c, d)	3 Indicate the basis for the determination (e.g. estimate from the advice issued in year x, survey index series, expert opinion, etc).	1 If a benchmark has been conducted indicate the year and reference to the benchmark report.
NAFO 3M shrimp	4 The fishery has been reopened after 9 years. The assessment is based on survey index only. There has never been an analytical assessment but the data may allow for some kind of model.	5 see answer to criterion 1. New assessment approaches using the survey data as well as new logbook and observer data will be available.	4 a,c,d	4 based on survey index only. B is considered to be above B_{lim} but $B_{trigger}$ is not defined for NAFO stocks.	5 While this is not an ICES stock, all the countries fishing the stock are ICES members and it would be beneficial to share experience in benchmarking the stock together with the ICES stocks.