NAFO SCS Doc. 20/21, Serial No. N7143

NAFO/ICES *Pandalus* Assessment Group Meeting, 26 to 30 October 2020

By WebEx

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NAFO/ICES *Pandalus* Assessment Group Meeting (NIPAG)
26 to 30 October 2020

Contents

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NIPAG Participants 2020

NIPAG participants from left to right:

First row Dayna Bell MacCallum, Tom Blasdale, Carsten Hvingel, AnnDorte Burmeister, Ole Ritzau Eigaard.

Second row: CarmenFernández**,** Fabian Zimmermann, Frank Rigét, Guldborg Søvik, José Miguel Casas Sanchez

Third row: Kalvi Hubel, Katherine Skanes, Katherine Sosebee, Mark Simpson, Susan Thompson

Fourth row: Tanja Buch, Valeriy Paramonov, Wojciech Walkusz

Missing from photo: Brittany Beauchamp, Aleksei Stesko, Rui Catarino

Report of the NIPAG Meeting

26 to 30 October 2020

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

I. OPENING

The NAFO/ICES *Pandalus* Assessment Group (NIPAG) met by correspondence from 26 to 30 October 2020 to consider 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, Russian Federation, Ukraine and the United States of America. The NAFO Scientific Council Coordinator and Scientific Information Administrator were also in attendance.

II. GENERAL REVIEW

1. Review of Research Recommendations in 2019

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 14 September 2020 meeting of the Scientific Council in conjunction with NIPAG (NAFO SCS Doc. 20/22). NIPAG reviewed the assessment during the present meeting. There were no further recommendations.

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

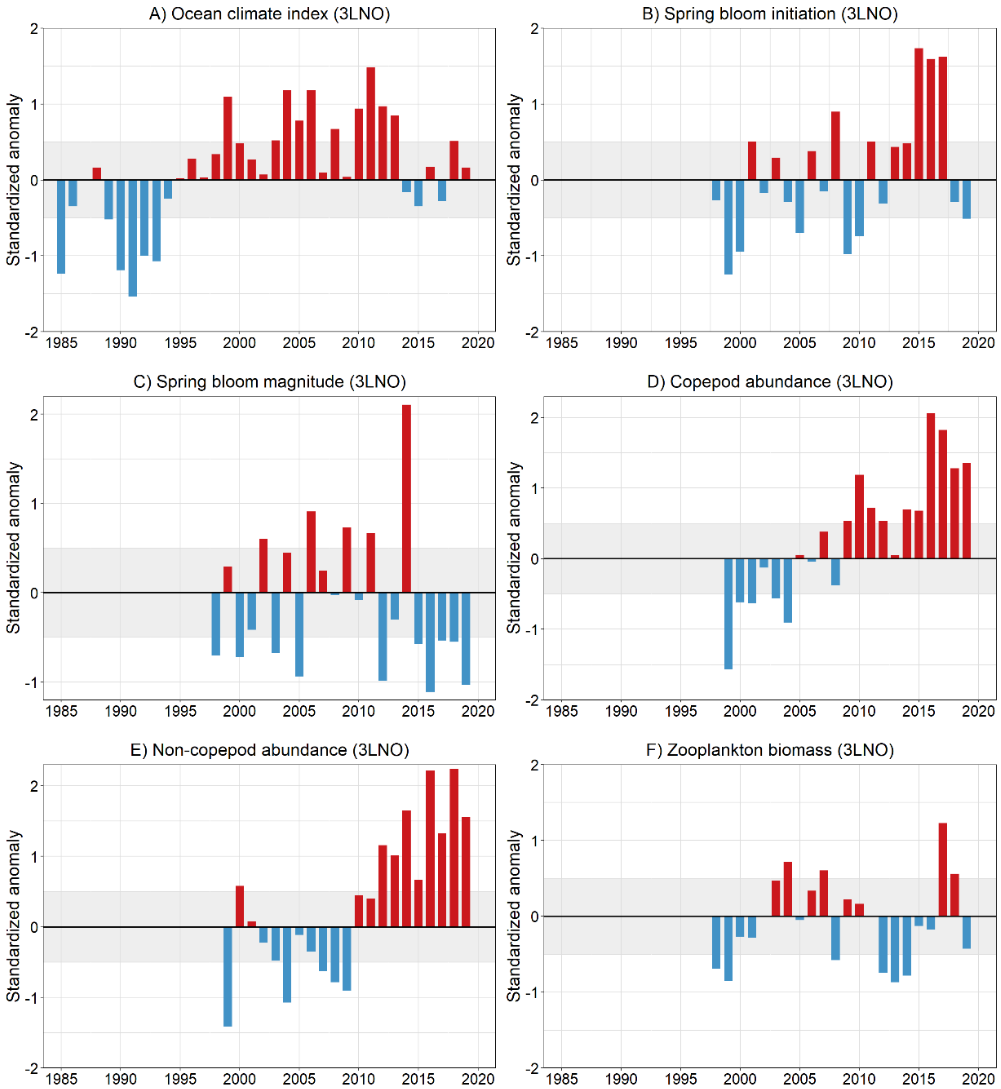
Interim monitoring report

(SCR Docs. 04/012, 20/059, 20/060, 20/061)

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) Ocean climate index (3LNO)
B) Spring bloom initiation (3LNO)
C) Spring bloom magnitude (3LNO)
D) Copepod abundance (3LNO)
E) Non-copepod abundance (3LNO)
F) Zooplankton biomass (3LNO)
Standardized anomaly
1985
1990
1995
2000
2005
2010
2015
2020

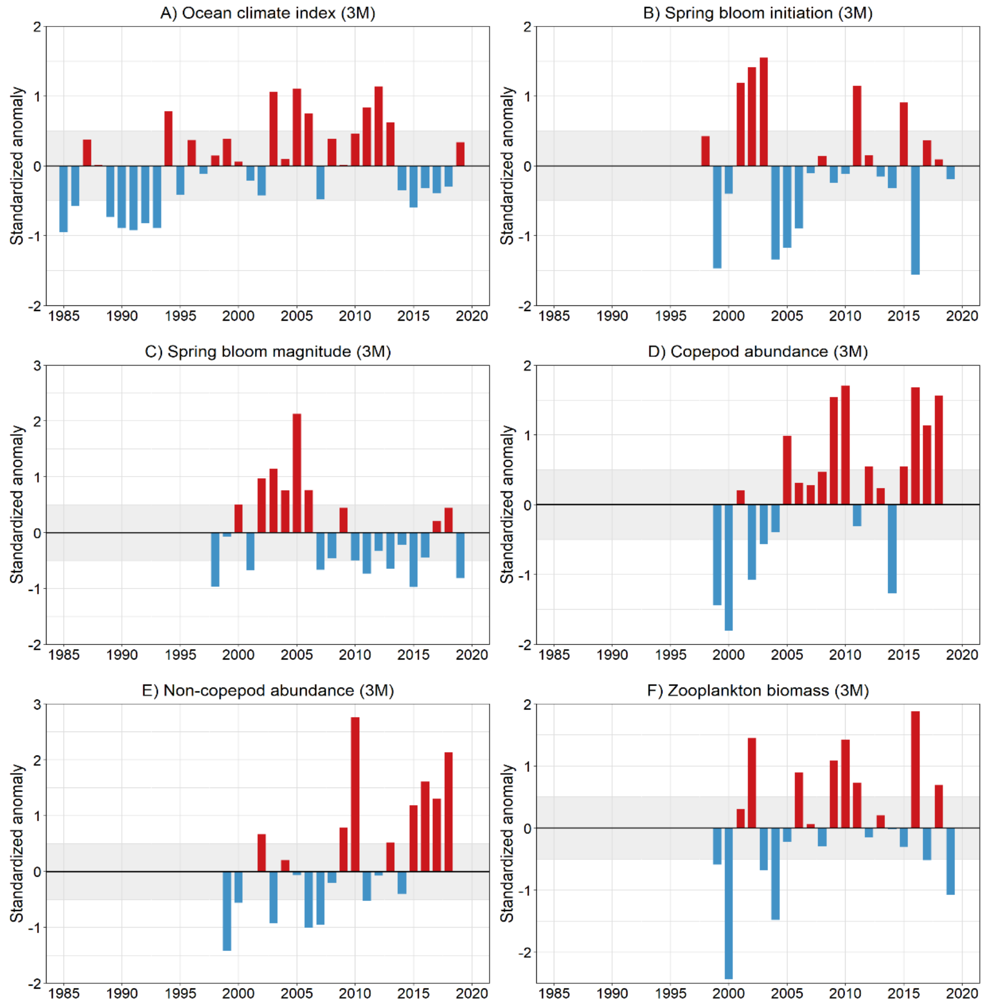


Figure 2.1. Environmental indices for NAFO Divisions 3LNO during 1990-2019. The ocean climate index (A) is the average of 12 individual time series of standardized ocean temperature anomalies: sea surface temperatures (SSTs) for Divs. 3L, 3N and 3O, vertically average ocean temperature (0-176 m) at Station 27, mean temperature and CIL volumes over standard hydrographic sections Seal Island, Bonavista and inshore Flemish Cap (FC-01 to FC-20), and mean bottom temperature in 3LNO for spring and fall. All these variables are presented in Cyr et al. (2020). Phytoplankton spring bloom magnitude (B) and duration (C) indices for the 1998-2019 period are derived from three satellite Ocean Colour boxes (Avalon Channel, Hibernia, and Southeast Shoal; see SCR Doc. 20/035 for box location). Zooplankton abundance copepod and non-copepod) and biomass (D & E) indices for the 1999-2019 period are derived from two cross-shelf oceanographic sections (Flemish Cap [3LN portion only] and Southeastern Grand Banks) and one coastal high-frequency sampling station (Station 27). Positive/negative anomalies indicate conditions above/below (or late/early initiation) the long-term average for the reference period. All anomalies are mean standardized anomaly calculated with the following reference periods: ocean climate index, 1981-2010; phytoplankton indices (magnitude and peak timing):1998-2015; zooplankton indices (abundance and biomass): 1999-2015. Anomalies within ±0.5 SD (shaded area) are considered normal conditions.

The water masses characteristic of the Grand Bank are typical cold intermediate layer (CIL) sub-polar waters which extend to the bottom in northern areas with average bottom temperatures generally <0°C. These are formed during winter and last throughout the year until the late fall. The CIL water mass is a reliable index of ocean climate conditions in this area. Bottom temperatures are higher in southern regions of 3NO reaching 1 - 4°C, mainly due to atmospheric forcing and along the slopes of the banks below 200 m depth due to the presence of Labrador Slope Water. On the southern slopes of the Grand Bank in Div. 3O bottom temperatures may reach 4 - 8°C due to the influence of warm slope water from the south. The general circulation in this region consists of the relatively strong offshore Labrador Current at the shelf break and a considerably weaker branch near the coast in the Avalon Channel. Currents over the banks are very weak and the variability often exceeds the mean flow.

Ocean Climate and Ecosystem Indicators

The ocean climate index in Divs. 3LNO (Figure 2.1.A) has remained mostly above normal between the late 1990s and 2013, reaching a peak in 2011. The index has returned to normal conditions between 2014 and 2019, with 2018 being the warmest of this 6th-year time series. A general trend towards later spring blooms (Figure 2.1.B) has been observed since 1998. However, spring bloom timing was back to near normal for a second consecutive year in 2019 after 3 years of late blooms. Spring bloom magnitude (Figure 2.1.C) oscillated between positive and negative anomalies with observable trends between 1998 and 2014. Bloom magnitude has remained below normal since 2015 with the second-lowest spring production of the time series observed in 2019. The abundance of copepod (Figure 2.1.D) and non-copepod (Figure 2.1.E) zooplankton showed strong increasing trends since the beginning of the time series. The abundance of copepods was above normal for a 6th consecutive year in 2019 with third highest anomaly of the time series. The abundance of non-copepods was also above normal for the 8th consecutive year in 2019. Zooplankton biomass (Figure 2.1.F) has been oscillating between periods of negative and positive anomalies throughout the time series with no strong departure from normal conditions except in 2017 when biomass reached a time series record high. Zooplankton biomass returned to near normal values in 2019 after two years of above normal levels

a) Introduction

This shrimp stock is distributed around the edge of the Grand Bank, mainly in Div. 3L. The fishery began in 1993 and came under TAC control in 2000 with a 6 000 t TAC. Annual TACs were raised several times between 2000 and 2009 reaching a level of 30 000 t for 2009 and 2010. The TAC was then reduced annually until no directed fishing (ndf) was implemented in 2015 to 2020 (Fig. 2.2). The TAC entries in the table below include autonomous TACs from Denmark (in respect of the Faroe Islands and Greenland) and STATLANT 21 entries.

Recent catches and TACs (t) for shrimp in Div. 3LNO (total) are as follows:

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
TAC[1]	20971	13108	9393	4697	ndf	ndf	ndf	ndf	ndf	ndf
STATLANT 21	13013	10099	7919	2282	0	0	0	0	0	
NIPAG[2]	12900	10108	8647	2289	0	0	0	0	0	

[1] Includes autonomous TAC as set by Denmark (in respect of the Faroe Islands and Greenland).
[2] NIPAG catch estimates have been updated using various data sources (see p. 13, SCR. 14/048).

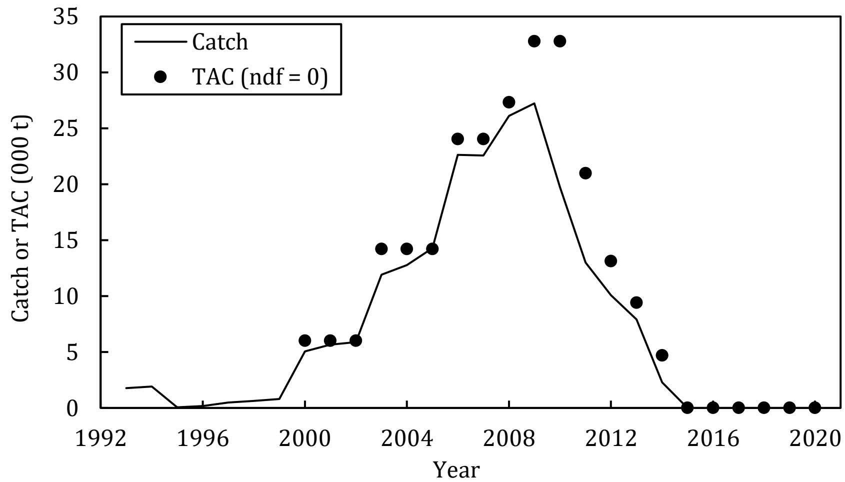


Figure 2.2. Shrimp in Div. 3LNO: Catches and TAC. The TAC illustrated includes the autonomous quotas set by Denmark (in respect of the Faroe Islands and Greenland). No directed fishing is plotted as zero TAC.

b) Input data

i) Commercial fishery data

Effort and CPUE. Catch and effort data have been available from Canadian vessel logbooks and observer records since 2000; however there was no fishery from 2015 to present.

ii) Research survey data

Canadian multi-species trawl survey. Canada has conducted stratified-random surveys in Div. 3LNO, using a Campelen 1800 shrimp trawl for spring (1999–2019) and autumn (1996–2019). The autumn survey in 2004, and the spring surveys in 2015, 2017-2018 and 2020 were incomplete and therefore could not be used to produce biomass indices for Div. 3LNO. The autumn 2014 survey only surveyed Div. 3L, however since about 95% of the biomass in Div. 3LNO comes from Div. 3L annually, it was considered useful as a proxy for Div. 3LNO for 2014.

Spanish multi-species trawl survey. EU-Spain has been conducting a stratified-random survey in the NAFO Regulatory Area (NRA) part of Div. 3L since 2003 and in the NRA part of Div. 3NO since 1995. Data are collected with a Campelen 1800 trawl. There was no EU-Spain Div. 3L survey in 2005 or Div. 3LNO survey in 2020.

c) Assessment results

No analytical assessment is available. Evaluation of stock status is currently based upon interpretation of research survey data.

Biomass indices. In Canadian surveys, about 95% of the biomass was found in Div. 3L, distributed mainly along the northeast slope in depths from 185 to 550 m. Total, fishable (shrimp with carapace length > 17mm) and female (SSB) biomass and abundance indices follow the same trend throughout the survey time series. There was an overall increase in both the autumn and spring indices to 2007 after which they decreased by over 95% to amongst the lowest levels in the autumn time-series in 2019 and the second lowest level in the spring time-series in 2019 (Figure 2.3).

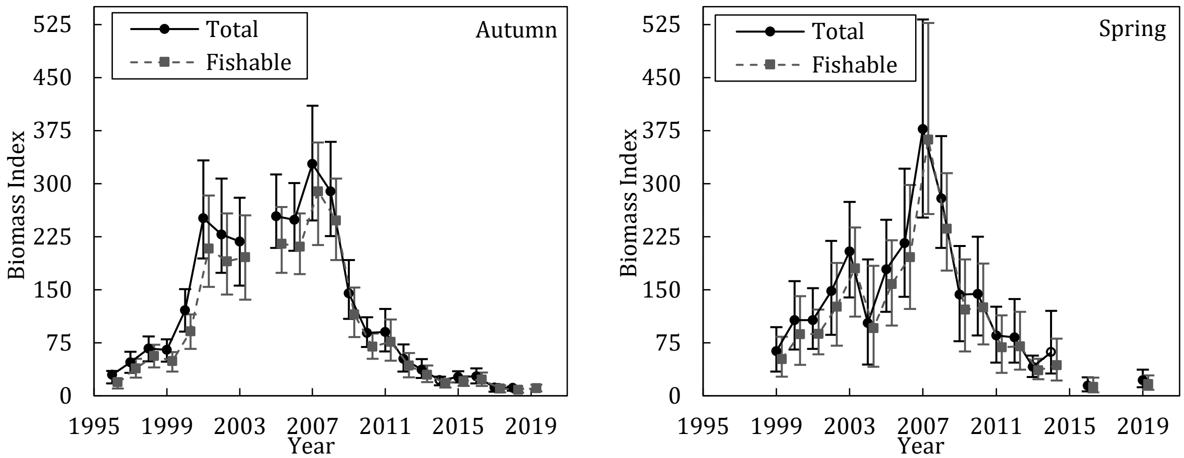


Figure 2.3. Shrimp in Div. 3LNO: Total and fishable biomass index estimates from Canadian autumn and spring multi-species surveys (with 95% confidence intervals). The 2014 autumn index is for Div. 3L only. There are no available biomass index estimates for spring 2015, 2017-2018 or 2020.

EU-Spain survey biomass indices for Div. 3L and Divs. 3NO, within the NRA only, increased from 2003 to 2008 followed by a 93% decrease by 2012 remaining near that level through 2019 (Figure 2.4).

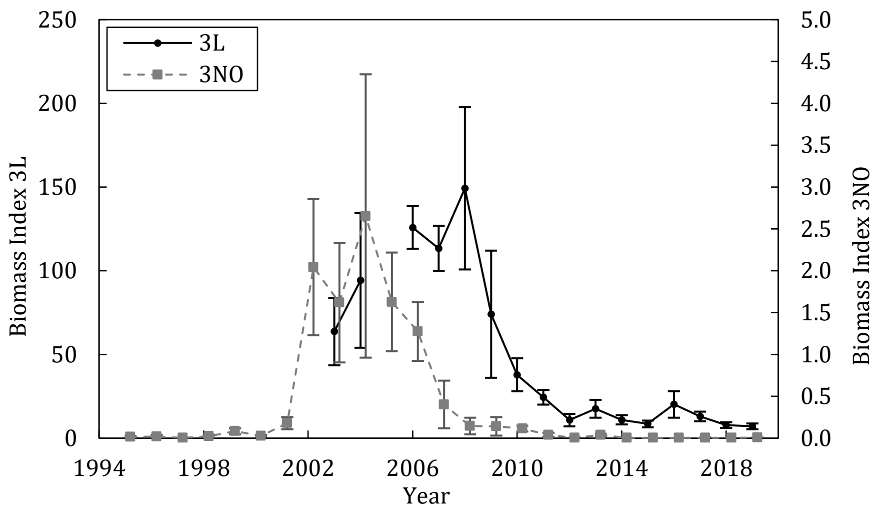


Figure 2.4. Shrimp in Div. 3LNO: Total biomass index estimates from EU - Spain multi-species surveys (± 1 SE) in the NAFO Regulatory Area (NRA) of Div. 3LNO. There are no available biomass index estimates for 2020.

Stock Composition. Both males and females showed a broad distribution of lengths in recent surveys indicating the presence of more than one year class (Figure 2.5).

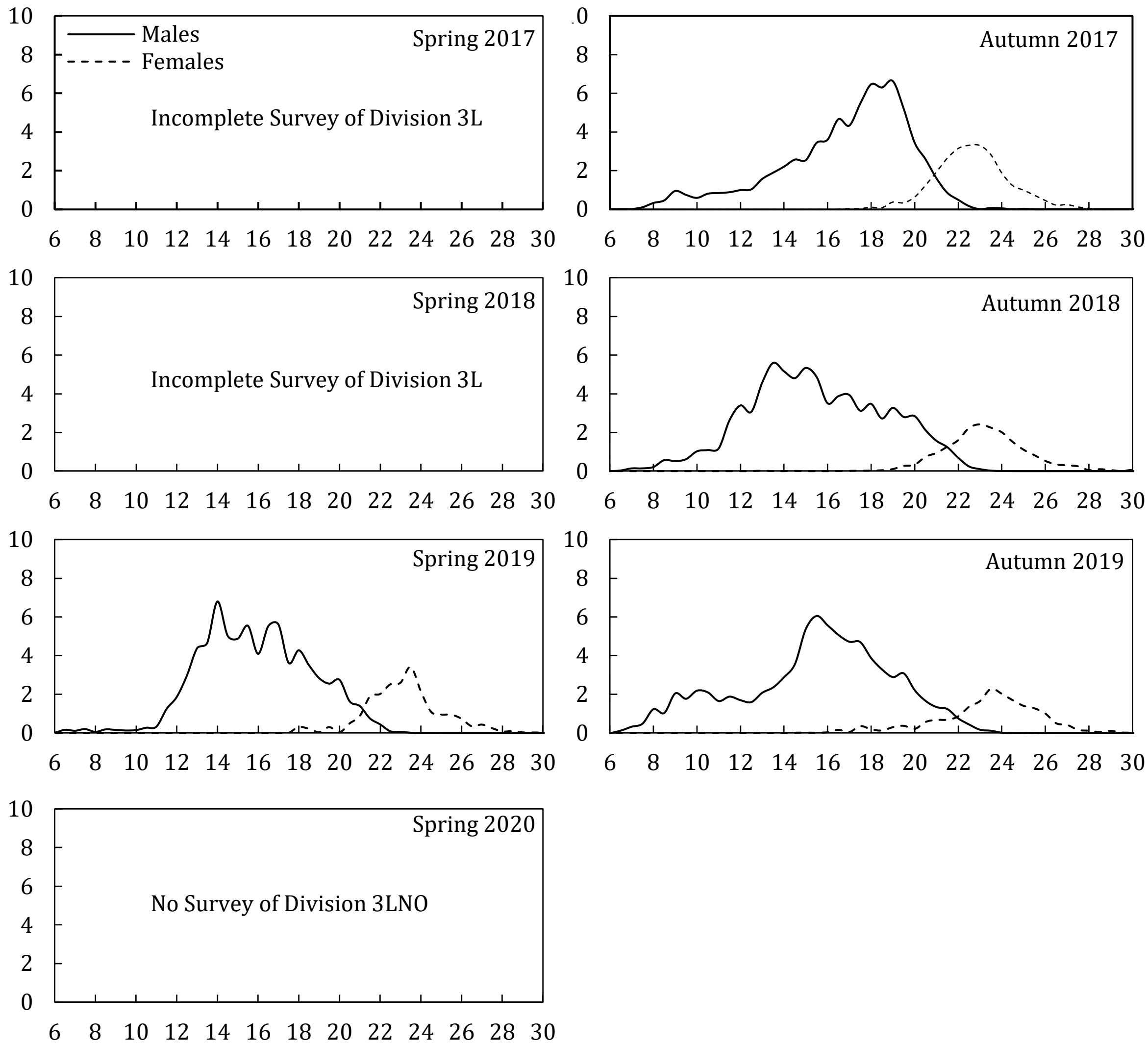


Figure 2.5. Shrimp in Div. 3LNO: Composition of survey catches (percentage at length) from Canadian spring and autumn multi-species survey data. No data for spring 2017-2018 or 2020.

Recruitment indices. Recruitment indices were based upon abundance indices of shrimp with carapace lengths of 11.5 – 17 mm from Canadian multi-species survey data. The 2006 – 2008 indices were among the highest in both spring and autumn time-series but have since declined to the lowest levels in the survey time series (Figure 2.6).

Research on transport of larval shrimp (Le Corre et al.) indicates that most larvae that originate in Div. 3L are transported out of that division. Additionally, it was found that most recruitment in Div. 3L originates further north of the area. The results of this research have not yet been quantified in order to develop a more comprehensive recruitment index for Div. 3LNO.

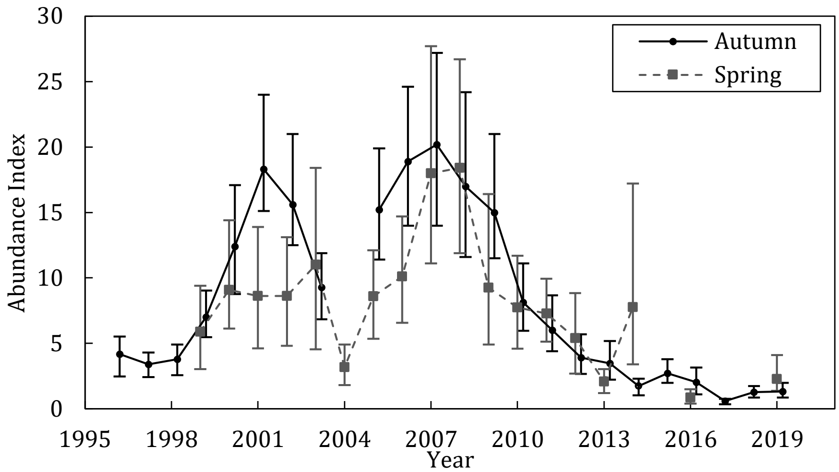


Figure 2.6. Shrimp in Div. 3LNO: Indices of recruitment-sized shrimp based on abundance of shrimp with 11.5 – 17 mm carapace lengths from Canadian spring and autumn multi-species surveys. Error bars represent 95% confidence intervals. The autumn index for 2014 is for Div. 3L only.

Exploitation index. An index of exploitation was derived by dividing the catch in a given year by the fishable biomass index from the previous autumn survey. The exploitation index generally increased throughout the course of the fishery until dropping sharply in 2014 (Figure 2.7). Since there was no directed fishing in 2015-2020, the exploitation index is zero for that period of time. Mortality due to bycatch during other fisheries is unknown.

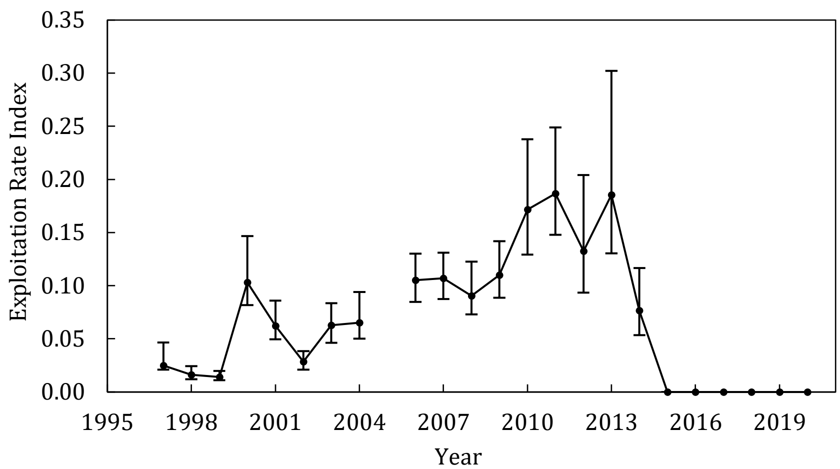


Figure 2.7. Shrimp in Div. 3LNO: Exploitation indices calculated as a year's catch divided by the previous year's autumn fishable biomass index. Error bars (calculated based on estimates of fishable biomass index) indicate 95% confidence intervals.

d) Reference points.

The point at which a valid index of female spawning stock size has declined to 15% of its highest observed value is considered to be B_{lim} (SCS Doc. 04/12). In 2020 the risk of being below B_{lim} was greater than 95% (Figure 2.8). A limit reference point for fishing mortality has not been defined.

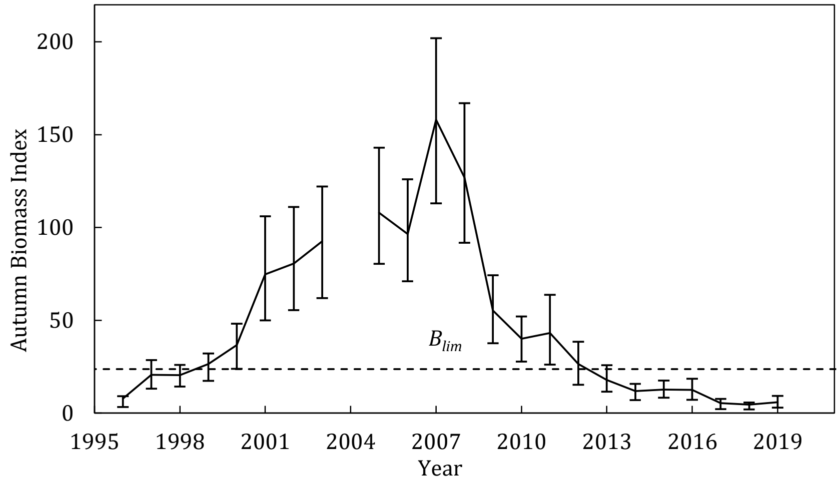


Figure 2.8. Shrimp in Div. 3LNO: Autumn female spawning stock biomass index (SSB) and B_{lim}. B_{lim} is defined as 15% of the maximum autumn female biomass over the time-series. Error bars indicate 95% confidence intervals. The autumn index for 2014 is for Div. 3L only.

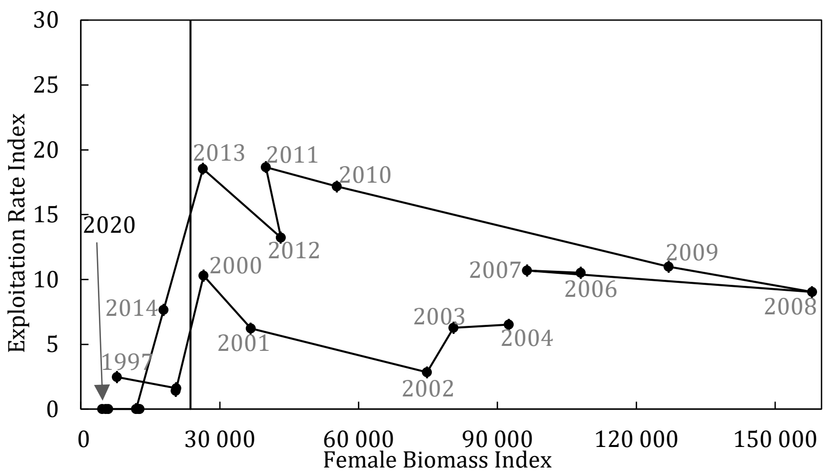


Figure 2.9. Shrimp in Div. 3LNO: Exploitation rate vs female SSB index from Canadian autumn survey. Vertical line denotes B_{lim}.

e) State of the stock

Biomass. Spring and autumn biomass indices have decreased considerably since 2007 and are among the lowest levels in the time series.

Recruitment. Recruitment indices have decreased since 2008 to the lowest levels in the time series.

Exploitation. The index of exploitation has been zero since 2015.

State of the Stock. Currently the risk of the stock being below B_{lim} is greater than 95%. There is no indication of improved recruitment.

f) Ecosystem considerations

The Grand Bank (3LNO) EPU is currently experiencing low productivity conditions and biomass has declined across multiple trophic levels and stocks since 2014.

g) Research recommendations

NIPAG **recommended in 2015** that *ecosystem information related to the role of shrimp as prey in the Grand Bank (i.e. 3LNO) Ecosystem be presented to NIPAG.*

Status: No new information was available to the current meeting and this recommendation is reiterated.

NIPAG **recommends in 2018** that *further work on the development of a recruitment index for Div. 3LNO be completed.*

Status: While it was anticipated that a length based model would improve knowledge of a recruitment index for Div. 3LNO, that work has not been successfully completed. Hence this recommendation is reiterated.

References

Le Corre N, Pepin P, Han G, Ma Z, Snelgrove PVR. Assessing connectivity patterns among management units of the Newfoundland and Labrador shrimp population. *Fish Oceanogr*. 2018;00:1–20. https://doi.org/10.1111/fog.12401 (in press).

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, 20/053, 20/054, 20/055, 20/056, 20/057, 20/058)

Environmental overview

Recent Conditions in Ocean Climate and Lower Trophic Levels

- The ocean climate index in Subareas 0-1 was at its highest value since the record-high of 2010, and the third highest since the beginning of the time series in 1985.
- The initiation of the spring bloom was delayed for a second consecutive year in 2019 compared to the 1998-2015 climatology.
- Total spring bloom production (magnitude) was below normal in 2019

Hydrographic conditions in this region, which influences the stocks off Greenland and in the Davis Strait, depend on a balance of ice melt, advection of polar and sub-polar waters and atmospheric forcing, including the major winter heat loss to the atmosphere that occurs in the central Labrador Sea. The cold and fresh polar waters carried south by the east Baffin Island Current are counter balanced by warmer waters are carried northward by the offshore branch of the West Greenland Current (WGC). The water masses constituting the WGC originate from the western Irminger Basin where the East Greenland Currents (EGC) meets the Irminger Current (IC). While the EGC transports ice and cold low-salinity Surface Polar Water to the south along the eastern coast of Greenland, the IC is a branch of the North Atlantic current and transports warm and salty Atlantic Waters northwards along the Reykjanes Ridge. After the currents converge, they turn around the southern tip of Greenland, forming a single jet (the WGC) that propagates northward along the western coast of Greenland. The WGC is important for Labrador Sea Water formation, which is an essential element of the Atlantic Meridional Overturning Circulation. At the northern edge of the Labrador Sea, after receiving freshwater input from Greenland and Davis Strait, part of the WGC bifurcates southward along the Canadian shelf edge as the Labrador Current.

Ocean Climate and Ecosystem Indicators

The ocean climate index in Subareas 0-1 has been predominantly above normal or near-normal since the early 2000s, except for 2015 and 2018 that were below and slightly below normal, respectively (Figure 3.1.A). In 2019, the index was at its highest value since the record high of 2010, and at its thirds highest value since the beginning of the time series in 1985. Before the warm period of the last decade, cold conditions persisted in the early to mid-1990s. The timing of the spring bloom transitioned from later to earlier than normal between 1998 and 2007. Spring bloom timing has shown a general trend of increasingly later initiation since the late 2000s with few exceptions of early timing observed in 2011, 2015, and 2017. The initiation of the spring bloom (Figure 3.1.B) occurred later than normal for a second consecutive year in 2019. Spring bloom magnitude (Figure 3.1.C) was mostly near normal between 1998 and 2007. Both below and above normal spring production occurred during that period but no clear pattern was observed. There was a general trend of increasing spring production since the record low in 2007. However, spring bloom magnitude in 2019 was back to below normal with the second-lowest anomaly of the time series. In general, early blooms are associated with high spring production and vice versa (Figure 3.1.B, 3.1.C).

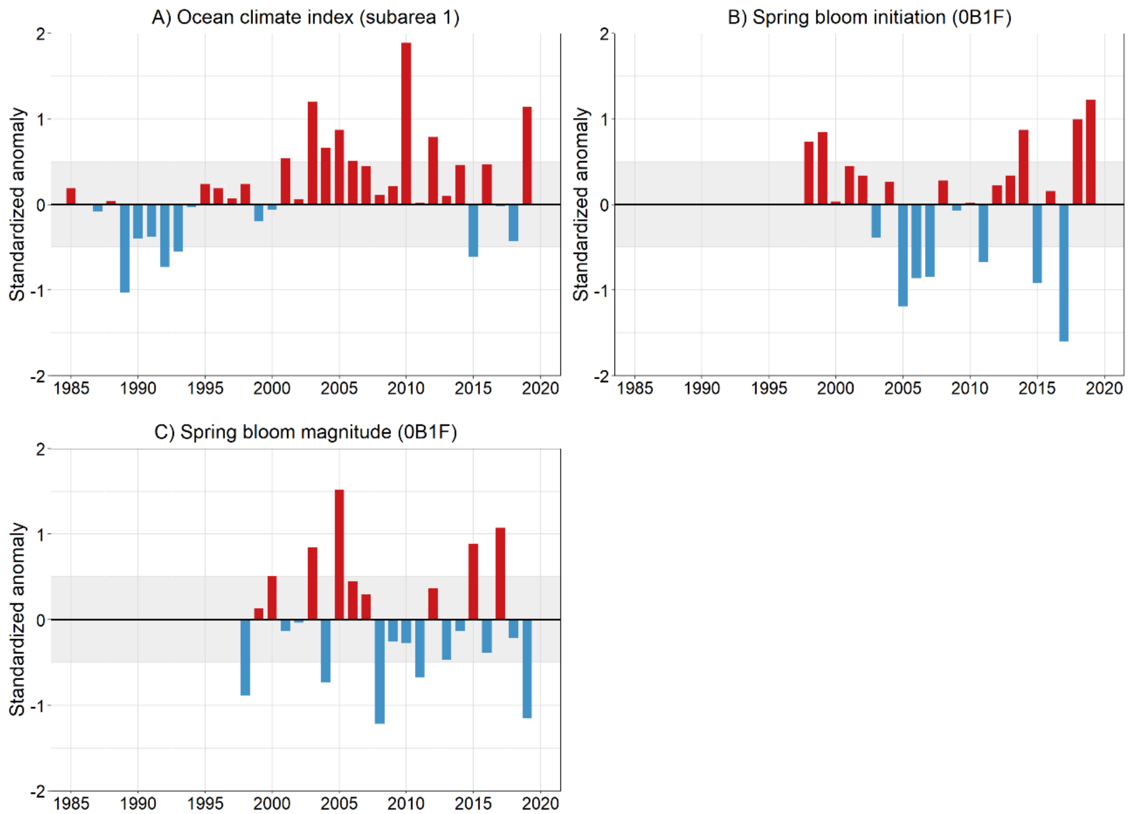


Figure 3.1. Environmental indices for NAFO Subareas 0 and 1 during 1990-2019. The climate index (A) for Subareas 0 and 1 is the average of 7 individual time series of standardized ocean temperature anomalies: sea surface temperatures (SSTs) for West Greenland Shelf, North and Central Labrador Sea and Hudson Strait, vertically average ocean temperature at Fyllas Bank Station 4 (FB-4; 0-50 m) and Cape Desolation Station 3 (CD-3; 75-200 m), as well temperature at 2000 m at CD-3, and air temperatures in Nuuk (Greenland) and Iqaluit (Baffin Island). Geographical boxes used for SSTs are presented in Cyr *et al.* (2019) and air temperature time series are presented in Cyr *et al.* (2020). FB-4 and CD-3 time series are obtained from the ICES Report on Ocean Climate (IROC; https://ocean.ices.dk/iroc/). Phytoplankton spring bloom initiation (B) and magnitude (C) indices for the 1998-2019 period are derived from three satellite boxes located in NAFO Div. 0B (Hudson Strait) and 2H1F (Labrador Sea) and 1F (Greenland Shelf) (see SCR Doc. 20/035 for box location). Positive/negative anomalies indicate above/below (or late/early timing) normal conditions, Anomalies were calculated using the following reference periods: ocean climate index: 1981-2010; spring bloom indices (magnitude and peak timing): 1998-2015. Anomalies within ± 0.5 SD (shaded area) are considered near-normal conditions.

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. Most trawlers in Greenland use mesh size at 44 mm. 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 2020 was set at 110 000 t and for Canadian Waters, 15 229 t.

Greenland requires that logbooks catch is recorded as 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. 20/054). 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. 20/054, 20/055). Total catch increased from about 10 000 t in the early 1970s to more than 105 000 t in 1992 (Figure 3.2). 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 2019, 104 440 t. The projected catch for 2020 is 117 000 t. The projected catch for Canada from Div. 0A in 2020 is expected to be in the region of 2 000 t.

Recent catches, projected catch for 2020 and recommended and enacted TACs (t) for northern shrimp in Sub-area 1 and Div. 0A (east of 60°30'W) are as follows:

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
TAC										
Advised	120 000	90 000	80 000	80 000	60 000	90 000	90 000	105 000	105 000	110 000
Enacted[1]	139 583	114 425	100 596	97 649	82 561	96 426	101 706	114 873	119 875	125 229
Catches (NIPAG)										
SA 1	122 659	115 965	95 379	88 765	72 254	84 356	89 369	93 189	101 997	115 000[2]
Div. 0A	1 330	12	2	0	2	1 171	3 215	1 689	2 463	2 000[2]
TOTAL	123 989	115 977	95 381	88 765	72 256	85 527	92 584	94 878	104 440	117 000[2]
STATLANT 21										
SA 1	122 061	114 958	91 800	88 834	71 777	82 922	88 947	90 457	100 990	
Div. 0A	1134	12	2	0	2	1 381	2 778	1 412	1716	

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. 20/054). 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. 20/054). In 2016 fishing increased in the Canadian EEZ and from 2016 to 2020, Canadian catches averaged about 2000 t.

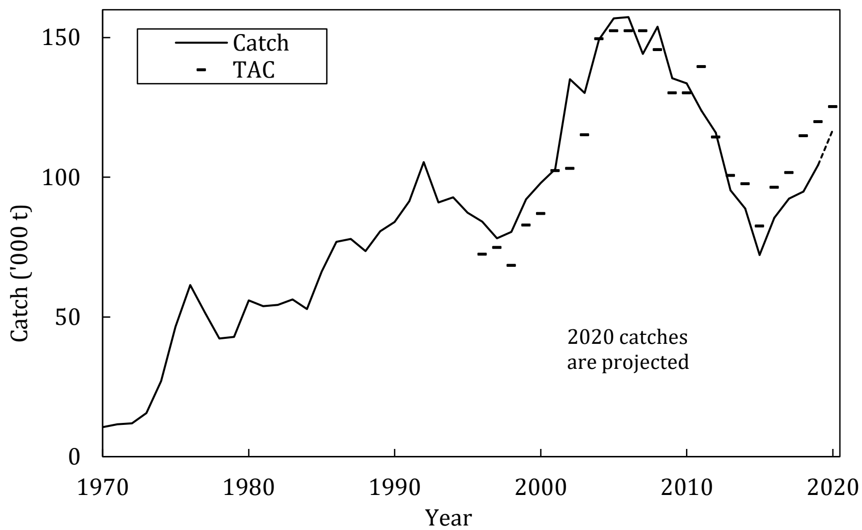


Figure 3.2. Northern shrimp in Subarea 1 and Div. 0A: Enacted TACs and total catches (2020 expected for the year).

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. 20/054). In recent years both the distribution of the Greenland fishery and fishing power have changed significantly: for example, larger vessels have been allowed in a limited part of 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, gear type, year, and statistical area. Standardized CPUE series were done separately for three different fleets (Figure 3.3); the early offshore fleet fishing in Div. 1A and part of 1B (KGH-index, 1976-1990), the present offshore fleet fishing in Subarea 1 (1987-2020) and the coastal fleet fishing in coastal and inshore areas (1989-2020). 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 dropped little in 2018 and remained stable in 2019.

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.

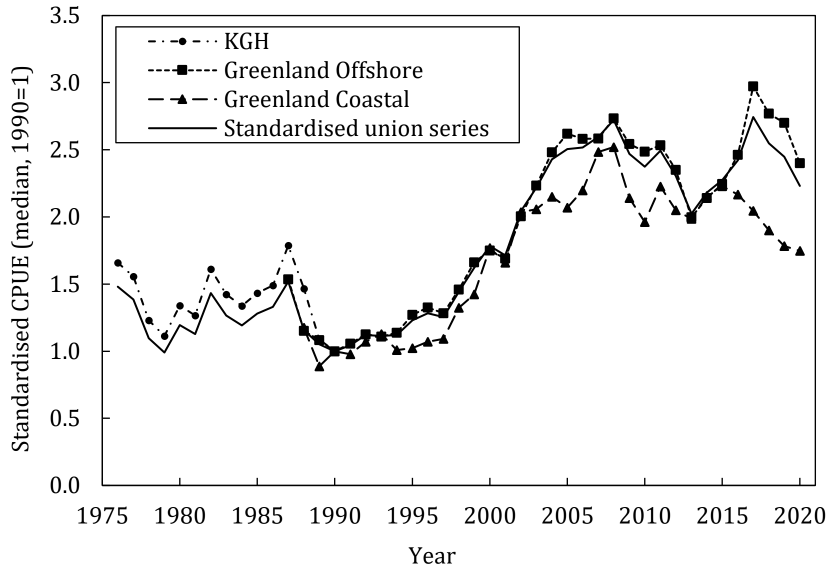


Figure 3.3. Northern shrimp in Subarea 1 and Div 0A: Standardized CPUE index series 1976–2020.

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 3.4). 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.

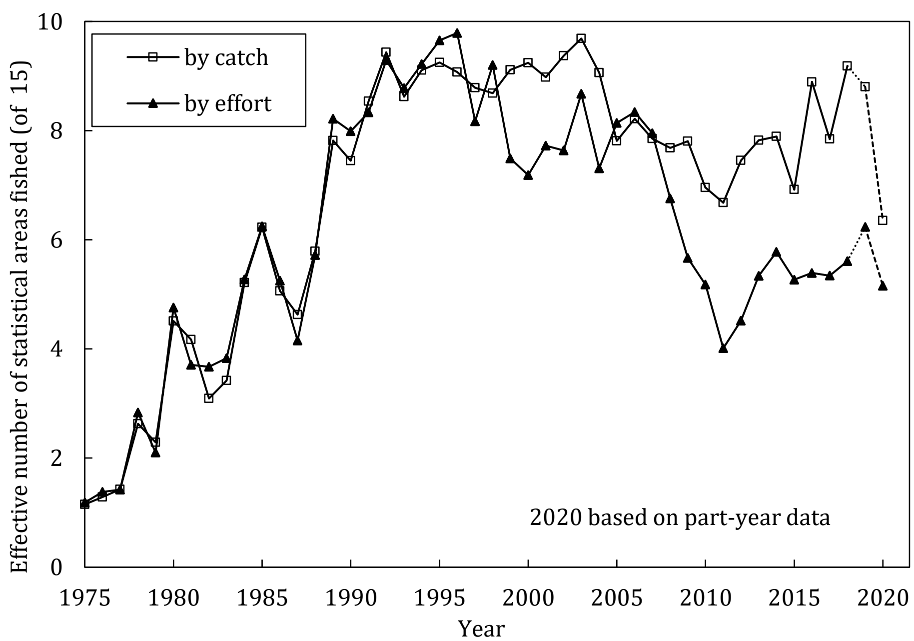


Figure 3.4. Northern shrimp in Subarea 1 and Div. 0A: Indices for the distribution of the Greenland fishery between statistical areas in 1975–2020.

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. 20/053). 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 2019-2020, 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 members from Paamiut participated in each of the surveys. NIPAG therefore assumed that the 2018 and 2019-2020 results were directly comparable with the previous surveys. A more detailed description is available in SCR Docs. 20/053.

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 and remained stable in 2020 (SCR Doc. 20/053). 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. 20/053). 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 3.5) (SCR Doc. 20/053). Over the past 5 years biomass has increased and was in 2020 210% of the low 2014 level. Offshore regions comprise 82% of the total survey biomass, and 18% is inshore in Disko Bay and Vaigat. The inshore regions have far higher densities and is almost three times as high as offshore (Figure 3.5) (SCR Doc. 20/053).

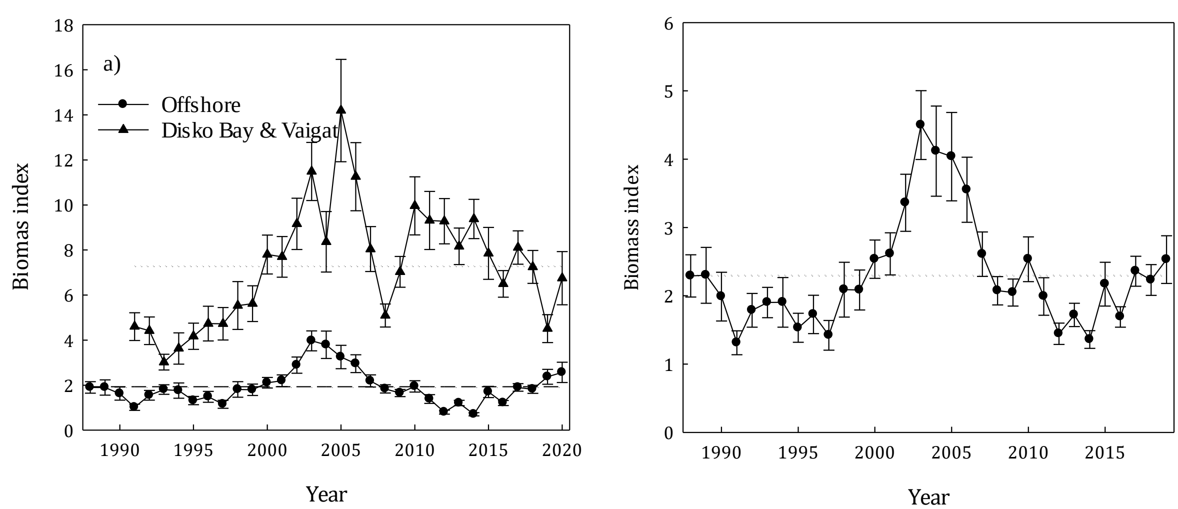


Figure 3.5. Northern shrimp in Subarea 1 and Div. 0A: Biomass index (survey mean catch rates) inshore and offshore (left panel) and overall (right panel) 1988–2020 (error bars 1 SE). Horizontal lines are the series average.

Length and sex composition (SCR 20/053). In 2020, in Disko Bay regions the proportion of fishable males of survey increased, to a level close to its 15-year median. In offshore regions the proportion declined little to a value above its 15-year lower quartile. Like in most recent years, females compose a high proportion of survey and fishable biomass index in both regions, however close to their 15-year lower quartile offshore, but above and at their 15-year upper quartile in Disko Bay (SCR Doc. 20/056).

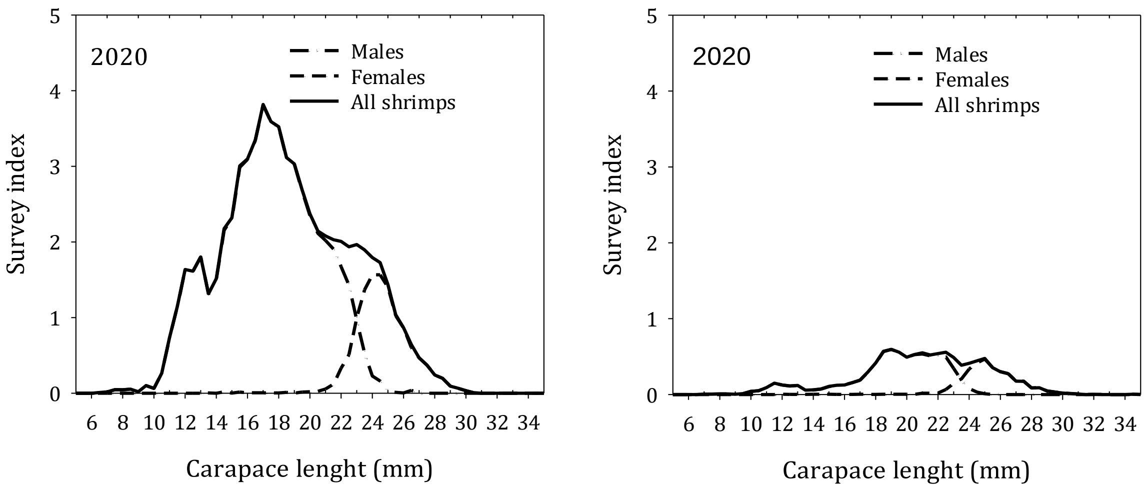


Figure 3.6. Northern Shrimp in Subarea 1 and Div. 0A: Survey mean catch rates at length in offshore regions (left) and Disko Bay & Vaigat (right) at the West Greenland trawl survey in 2020.

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 three high values in 2015, 2019 and 2020. 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, 2017 and 2020 (SCR Doc. 20/053, 20/056) (Figure 3.7). Numbers of age-2 and pre-recruits in 2020 are above the 1993 to 2020 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 20/053), whereas the correlation was strongest (R^2 = 0.68) between pre-recruits and fishable biomass 1 year later (SCR doc 20/057). Furthermore, there was also a significant relationship between number of age-2 shrimp and the number of pre-recruits 2-years later (R^2 = 0.52) (SCR doc 20/057).

The stock composition in Disko Bay has historically been characterized by a higher proportion of young shrimps than that offshore, exceptions were in 2017, 2019 and 2020, where younger shrimps offshore were much higher in numbers and relative to survey biomass. Both in 2019 and 2020, 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. 20/053, 20/056). Numbers of pre-recruits relative to survey biomass were considerably lower inshore than offshore regions (SCR Doc. 20/053, 20/056).

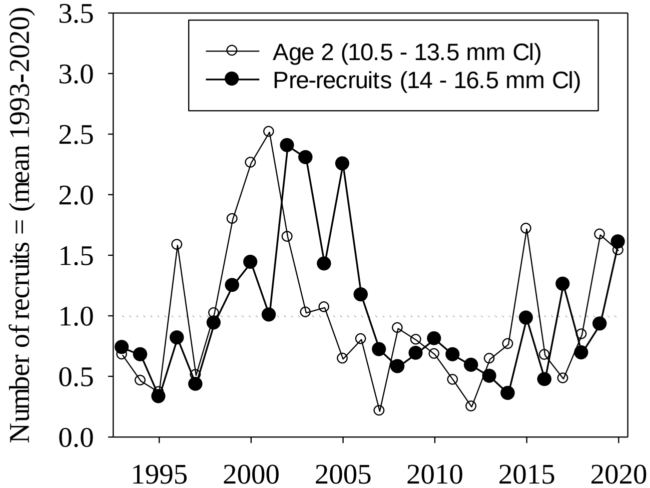


Figure 3.7. Northern shrimp in Subarea 1 and Div. 0A: Survey index of numbers at age 2 (10.5 - 13.5 mm) and index of number of pre-recruits (14-16.5 mm), 1993-2020. Indices are standardized to the series mean.

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.

The overall cod-stock biomass index, used within the shrimp assessment model, was from 2020 modelled in a state-space assessment model (SAM) (SCR-Doc. 20/058) and based on catch at age in the commercial fishery and the Greenland trawl survey (Skjærvøj and Cosmos trawl).

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). Currently the cod stock at West Greenland is at a low level compared to the period before the collapse in the beginning of 1990s, but has since 2010 shown a slow, but progressive increases and has remained almost stable since 2015. The index of its overlap with the shrimp stock decline to an average below the serial value. This resulted in a 2020 'effective cod biomass' index of 7 kt, compared with 7.5 kt in 2019 (recalculated from 21 kt in 2019 due to exclusion of the German survey series from the SAM model) (Figure 3.8) (SCR Doc. 16/042, 16/047, SCR Doc. 20/056, SCR Doc. 20/058).

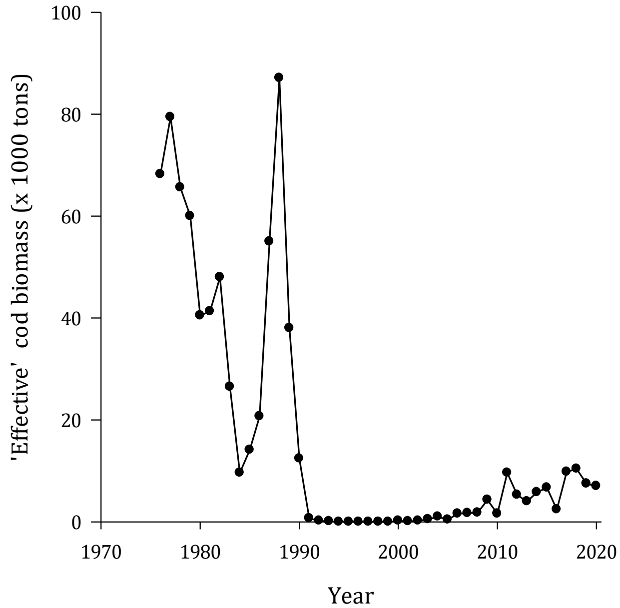


Figure 3.8. Indices of the 'effective' cod biomass in Subarea 1 and Div. 0A 1976 - 2020 (measure of the potential predation pressure by cod on shrimps).

c) Assessment

A Schaefer surplus-production model of population dynamics was fitted to series of CPUE, catch, and survey biomass indices (SCR Doc. 20/056). The model includes a term for predation by Atlantic cod. Total shrimp catches for 2020 are expected to be 117 000 t.

In 2017 NIPAG noted concern about the degree of instability in MSY estimates in successive assessments. To solve this problem, two changes were made. Firstly, 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 3.10).

Estimates of stock-dynamic parameters from fitting a Schaefer stock-production model to 45 years' data are given in Table 3.1. Median values from the 2019 assessment are provided for comparison. The modelled biomass (Figure 3.9a) was relatively 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 3.9b). Estimates of total mortality have increased in the most recent years. Assuming catches of 117 000 t, total mortality in 2020 is estimated to be below Z_{msy} with probability of $Z_{2020} > Z_{msy}$ = 40%. Biomass at the end of 2020 is projected to be close to the 2019 value and above B_{msy}. The probability of the biomass at the end of 2020 being below B_{msy} is 24% and the probability of being below B_{lim} is very low (<1%).

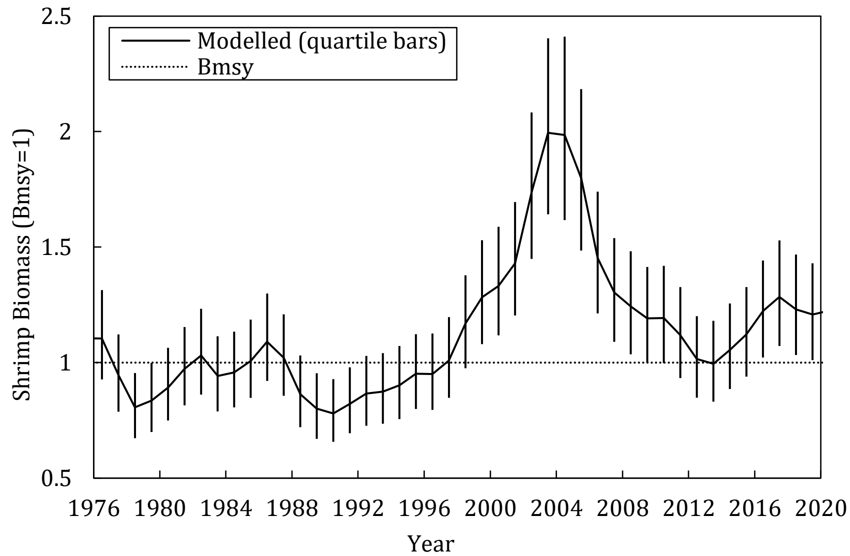


Figure 3.9a. Northern shrimp in SA 1 and Div. 0A: Relative stock biomass with quartile error bars 1976–2020. Dotted line corresponds to $B = B_{msy}$.

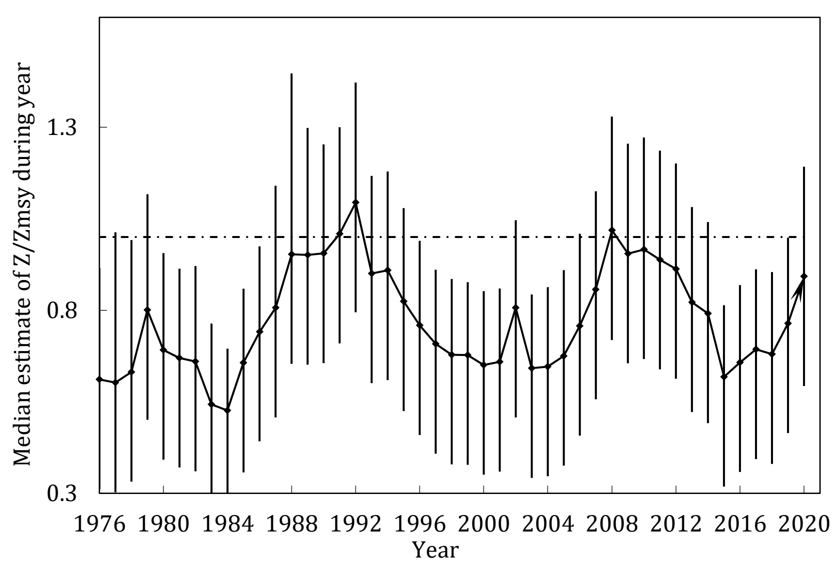


Figure3.9b. Northern shrimp in SA 1 and Div. 0A: Trajectory of the median modelled estimate of mortality relative to Z_{msy} during the year, 1976–2020 with quartile error bars.

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 2020. The median (2019) column shows results from last year's assessment.

	Mean	S.D.	25%	Median	75%	Est. mode	Median (2019)
Max.sustainable yield	135.3	56.6	103.1	123.0	153.3	98.4	121.6
B/Bmsy, end current year (proj.)(%)	126.3	34.2	101.4	122.5	148.2	114.9	126.3
Biomass risk, end current year(%)	23.6	42.5	–	–	–	–	–
Z/Zmsy, current year (proj.)(%)	–	–	61.7	89.3	119.2	–	80.1
Carrying capacity	3444	1981	1931	2896	4522	1800	2999
Max. sustainable yield ratio (%)	10.0	5.4	6.1	9.0	12.9	7.1	8.6
Survey catchability (%)	18.9	13.2	9.5	15.4	24.5	8.2	14.8
CPUE(1) catchability	1.1	0.8	0.6	0.9	1.4	0.5	0.9
CPUE(2) catchability	1.7	1.2	0.9	1.4	2.3	0.7	1.4
Effective cod biomass 2020 (Kt)	9.1	18.1	5.2	7.0	8.9	2.8	20.9
$P_{50\%}$ (prey biomass index with consumption 50% of max.)	4.1	7.2	0.2	1.3	4.6	-4.3	1.2
V_{max} (maximum consumption per cod)	2.0	2.3	0.4	0.9	2.6	-1.1	0.8
CV of process (%)	13.1	2.9	11.2	13.0	14.9	12.7	13.8
CV of survey fit (%)	17.6	3.2	15.3	17.2	19.5	16.6	16.2
CV of CPUE (1) fit (%)	7.0	1.5	5.9	6.7	7.7	6.2	6.7
CV of CPUE (2) fit (%)	7.6	2.4	5.8	7.0	8.6	5.7	6.8

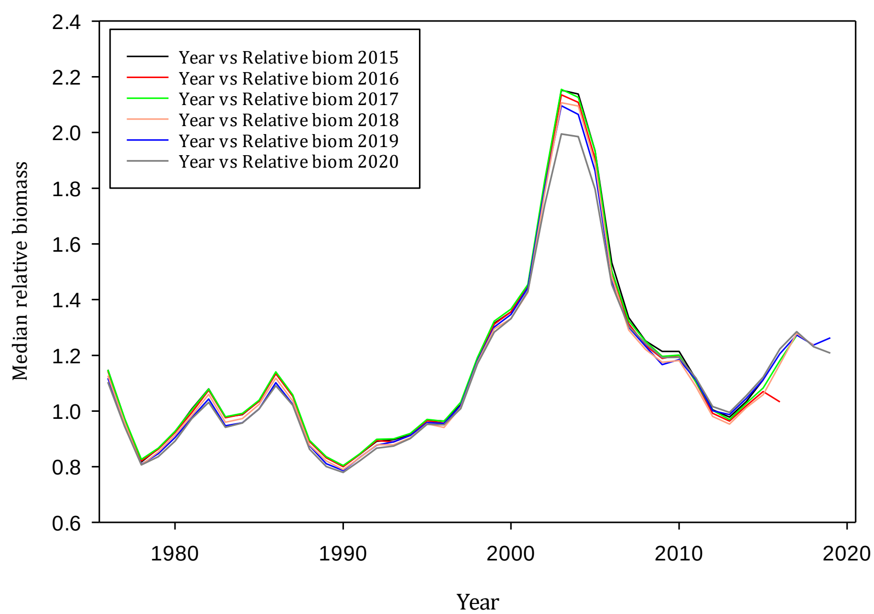


Figure 3.10. Retrospective plots of the relative biomass B/B_{msy} 2015 to 2020. Mohn's rho is estimated to – 0.024.

A six-year retrospective analysis was performed (Figure 3.10) 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.

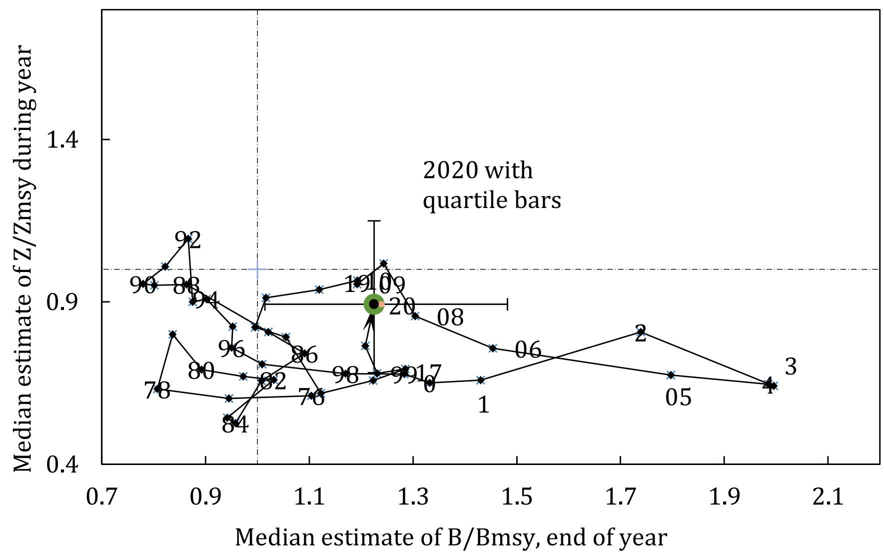


Figure 3.11. Northern shrimp in Subarea 1 and Div. 0A: Trajectory of relative biomass and relative mortality, 1976–2020.

e) State of the stock

Biomass. Biomass at the end of 2020 is above B_{msy} and the probability of being below B_{lim} is very low (<1%).

Mortality. Assuming catches of 117 000 t and an 'effective cod biomass' of 7 kt, the probability of being above Z_{msy} is 40%.

Recruitment. Both numbers of age-2 and numbers of pre-recruits in 2020 are above the 1993 to 2020 average.

State of the Stock. Biomass at the end of 2020 is above B_{msy} and the probability of being below B_{lim} is very low (<1%). The probability of mortality in 2020 being above Z_{msy} is 40%. Recruitment (number of age-2 shrimp) in 2020 is above average.

f) Projections

Three years projections for years 2021–2023 under eight catch options and subject to predation by the cod stock with an 'effective' biomass of 7 kt (the estimated value for 2020 was 7 Kt) were evaluated. Additional projections assuming 'effective' cod biomasses of 5 kt, and 9 kt were conducted but results indicated small differences in risk probabilities (SCR Doc 20/056).

7 000 t cod	**Catch option ('000 tons)**							
Risk of:	**95**	**100**	**105**	**110**	**115**	**120**	**125**	**130**
falling below Bmsy end 2021 (%)	24	24	25	27	26	27	27	28
falling below Bmsy end 2022 (%)	25	25	27	28	29	29	30	31
falling below Bmsy end 2023 (%)	25	26	28	30	31	32	33	33
falling below Blim end 2021 (%)	0	0	0	0	0	0	0	0
falling below Blim end 2022 (%)	0	0	0	0	0	0	0	0
falling below Blim end 2023 (%)	0	0	0	0	0	0	0	0
exceeding Zmsy in 2021 (%)	19	22	26	30	33	37	40	44
exceeding Zmsy in 2022 (%)	19	22	27	31	34	39	42	45
exceeding Zmsy in 2023 (%)	20	23	28	32	35	39	43	46
falling below Bmsy 80% end 2021 (%)	8	8	9	9	9	9	10	9
falling below Bmsy 80% end 2022 (%)	9	10	11	11	11	12	13	13
falling below Bmsy 80% end 2023 (%)	10	10	12	12	13	14	16	17

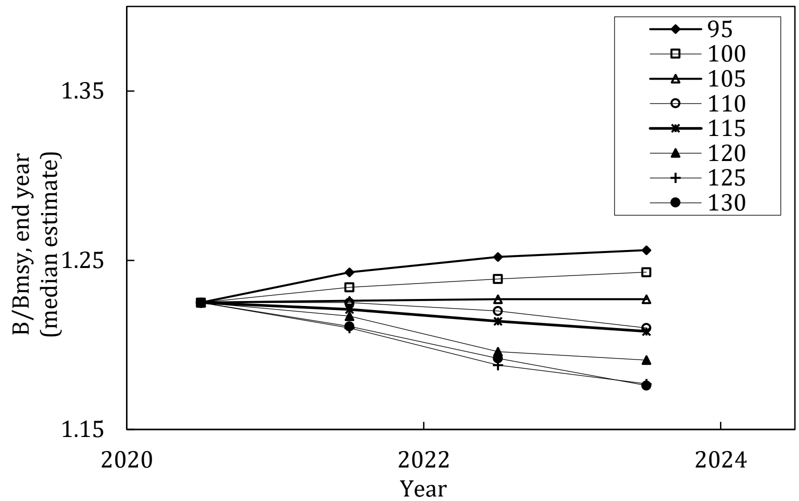


Figure 3.12. Northern shrimp in Subarea 1 and Div. 0A: Median estimates of year-end biomass trajectory for 2021–2023 with annual catches at 95 –130 kt. and an 'effective' cod stock assumed at 7 kt.

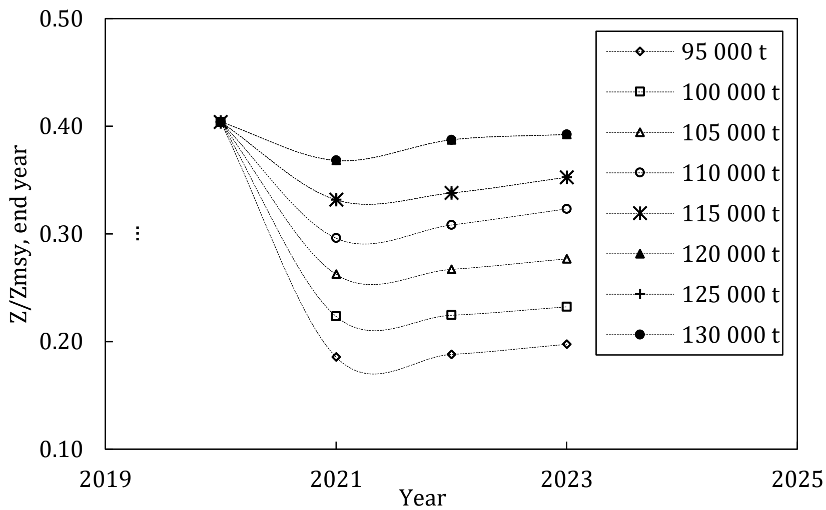


Figure 3.13. Northern shrimp in Subarea 1 and Div. 0A: Risks of transgressing mortality and biomass precautionary limits with annual catches at 95–130 kt projected for 2021–23 with an 'effective' cod stock assumed at 7 kt.

g) Research recommendations

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

Status: No progress; this recommendation will not be progressed further at present.

- 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.

- NIPAG **recommends** that *diagnostics of the model should be further explored.*

4. Northern shrimp (*Pandalus borealis*) in the Denmark Strait and off East Greenland (ICES Div. 14b and 5a)

(SCR Docs. 04/012, 20/059, 20/060, 20/061)

a) Introduction

Northern shrimp off East Greenland in ICES Div. 14b and 5a 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 of the year access to these fishing grounds depends strongly on ice conditions.

In the Greenland EEZ, the minimum permitted mesh size in the cod-end is 40 mm but most trawlers used 44 mm in the cod-end. 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. Between 2004 and 2016 the total catch decreased to 49 t in 2016. Catches have since then increased to 1576 t in 2019 (Figure 4.1). Since 2012, no or very little fishery has taken place in the southern area.

Catches in the first half year of 2020 were 2839 based on logbooks. Since 2014, the fishing effort have been concentrated in a relatively small area.

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

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020[1]
Recommended TAC, total area	12 400	12 400	12 400	2 000	2 000	2 000	2 000	2 000	2 000	2 000
Actual TAC, Greenland	12 400	12 400	12 400	8 300	6 100	5 300	5 300	4 300	3 384	4 750
North of 65°N, Greenland EEZ	1 145	1 893	1 714	622	576	49	561	547	1 578	2 836
North of 65°N, Iceland EEZ	0	0	0	0	0	0	0	0	0	0
North of 65°N, total	1 145	1 893	1 714	622	576	49	561	547	1 578	2 836
South of 65°N, Greenland EEZ	53	215	3	0	0	0	0	0	2	1
TOTAL NIPAG	1 199	2 109	1 717	622	576	49	561	547	1 580	2 839

[1] Catches until July 2020

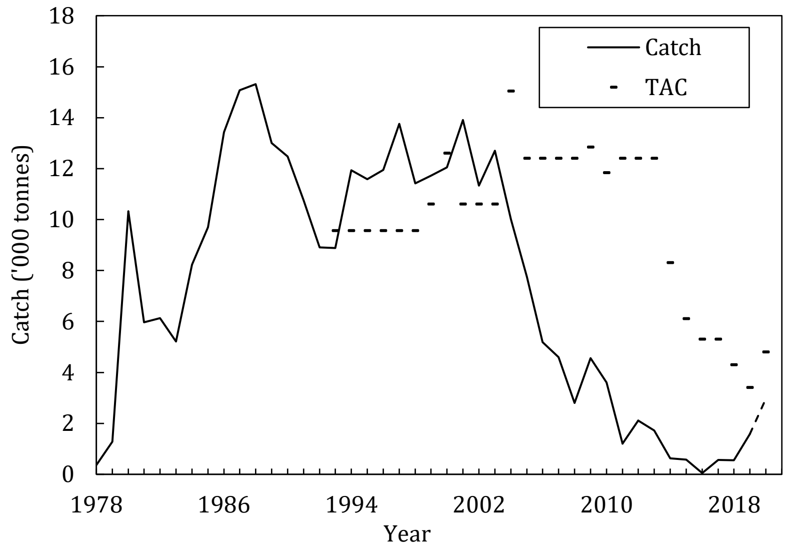


Figure 4.1. Shrimp in Denmark Strait and off East Greenland: Catch and TAC (2020 catches until July).

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 (SCR doc 020/059).

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 2020, which may indicate an improvement of the stock state. However, the estimates for these years are based on relatively low fishing effort (from 300 fishing hours in 2016 to 3000 fishing hours in first half of 2020) and concentrated in a relatively small area north of 65^0N and west of 30^0W. 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.

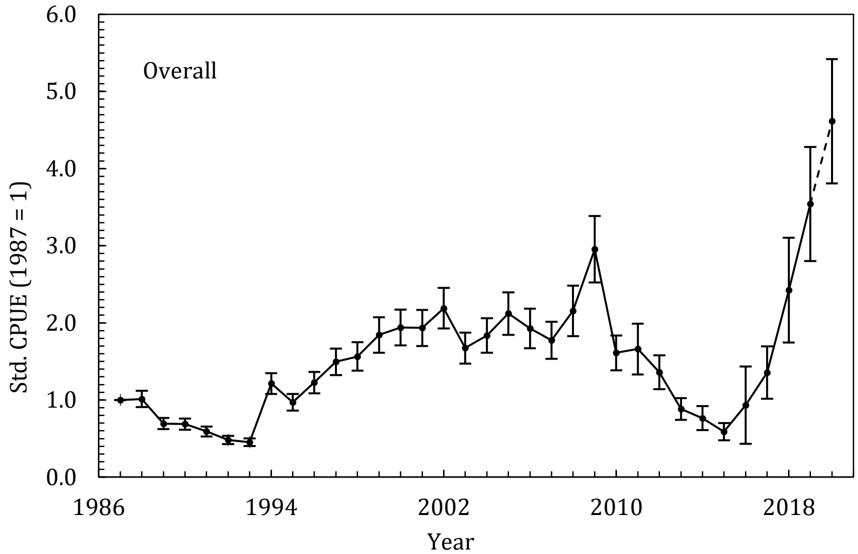


Figure 4.2. Shrimp in Denmark Strait and off East Greenland: Annual standardized CPUE index (1987 = 1) with ± 1 SE combined for the total area. 2020 data until July (grey dotted line).

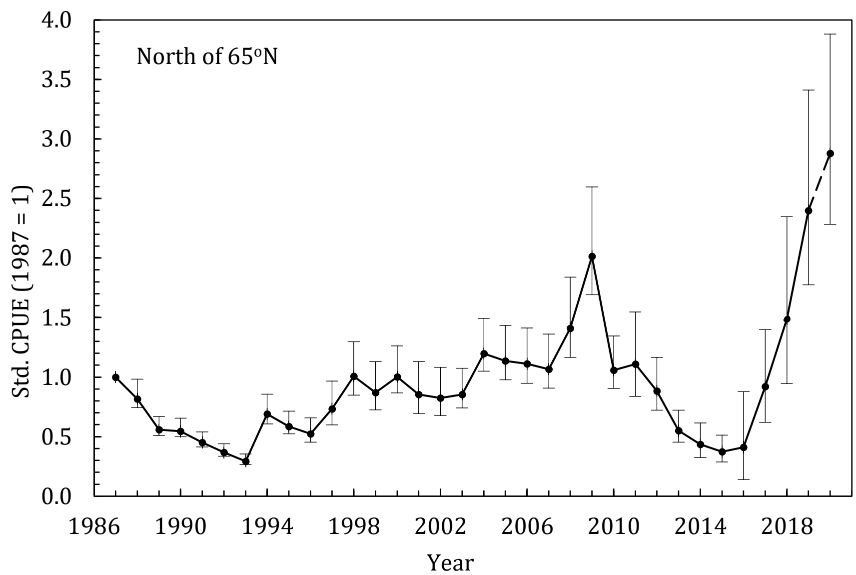


Figure 4.3. Shrimp in Denmark Strait and off East Greenland: Annual standardized CPUE (1987 = 1) with ±1 SE fishing north of 65°N. 2020 data until July (grey dotted line).

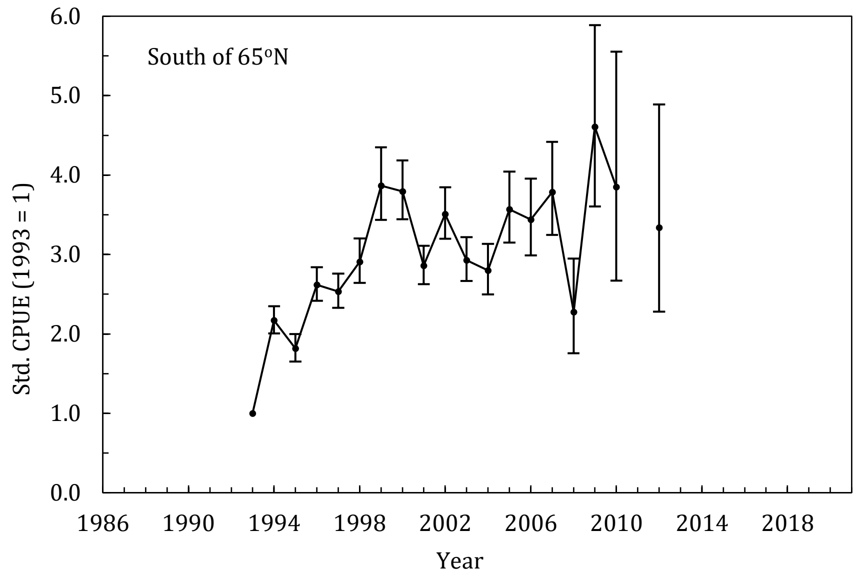


Figure 4.4. Shrimp in Denmark Strait and off East Greenland: Annual standardized CPUE (1993 = 1) with ±1 SE fishing south of 65°N (no data for the area since 2010/2012).

Standardized effort index time series (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 2020 levels of exploitation rate may be biased given the issues on CPUE described above.

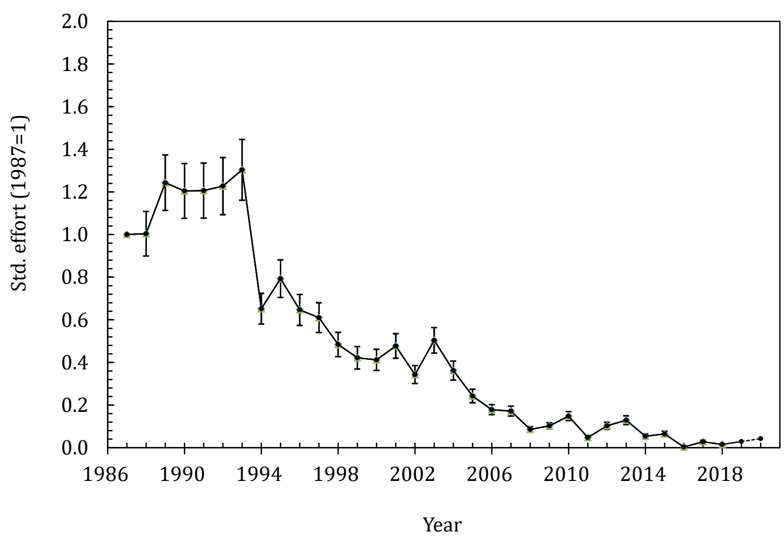


Figure 4.5. Shrimp in Denmark Strait and off East Greenland: Annual standardized effort indices, as a proxy for exploitation rate (± 1 SE; 1987 = 1), combined for the total area (2020 effort until July).

ii) Research survey data

Trawl surveys have been conducted to assess the stock status of northern shrimp in the East Greenland area since 2008 (SCR doc 20/060). Due to lack of research vessel, no survey was conducted in the period 2017 to 2019. In 2020 the survey was conducted with the chartered fishing vessel *Helga Maria* using the same gear configuration (SCR Doc. 20-53 and 20-060). 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, there are no estimates for the years 2017-2019. The 2020 estimate is the highest in the timeseries (Figure 4.6).

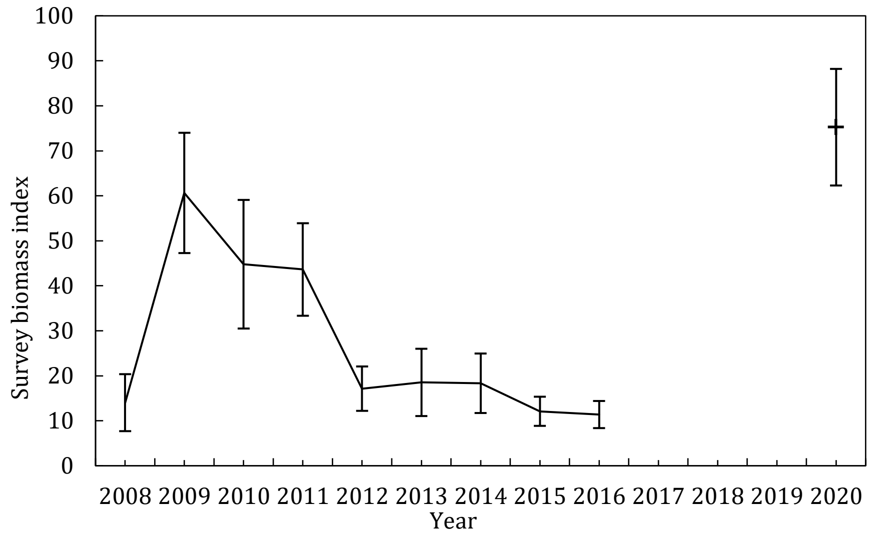


Figure 4.6. Shrimp in Denmark Strait and off East Greenland: Survey biomass index from 2008- 2016 and 2020 (± 1 SE). No survey was carried out in the period 2017 to 2019.

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

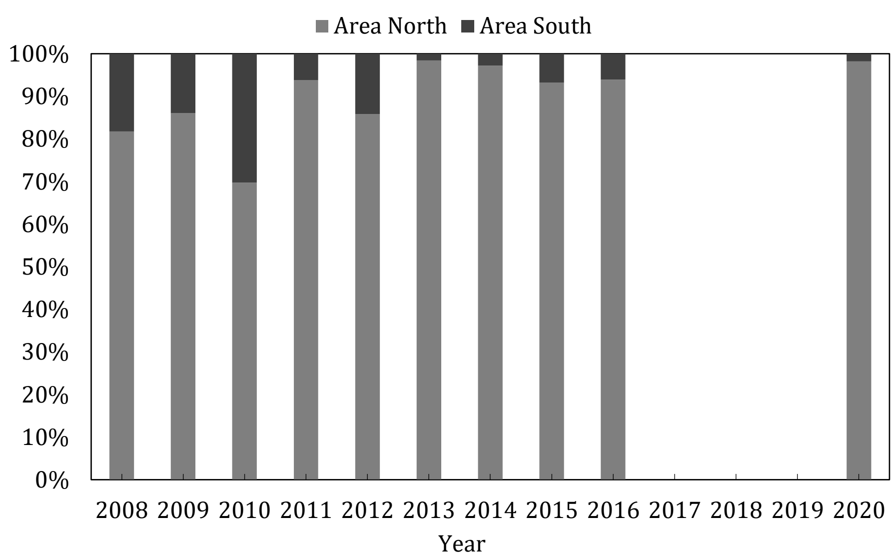


Figure 4.7. Shrimp in Denmark Strait and off East Greenland: Distribution of survey biomass north and south of 65°N (in %) from 2008-2016 and 2020. No survey was carried out in the period 2017 to 2019.

Stock composition. The demography in East Greenland consists of roughly equal proportions of males and females in most years. The proportion of females fluctuates between 40-60% all years except 2009 and 2020. In 2020 36.9 % of the biomass was female, the second lowest in the time series (SCR doc 20/060). In 2020 there may have been some issues regarding the classification of primiparous and multiparous females. The analysis was carried out on the combined female biomass.

Very few males smaller than 20 mm CL are caught in the survey (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.

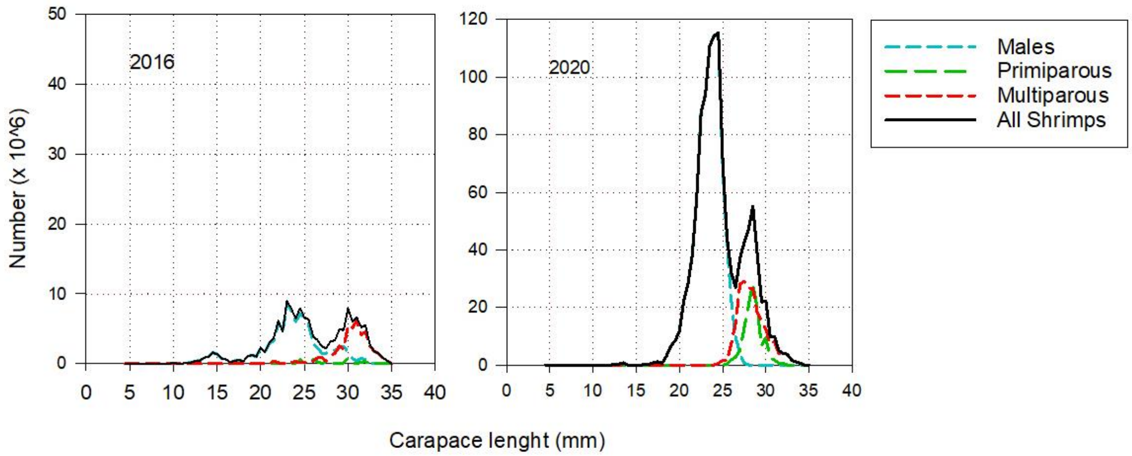


Figure 4.8. Shrimp in Denmark Strait and off East Greenland: Numbers of shrimp by length group (CL) in the total survey area in 2016 and 2020. No survey was carried out in the period 2017 to 2019.

c) Assessment results

In 2020 a surplus production model (SPiCT) was used for preliminary assessment of the stock. 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 rather similar since the start of the survey. In 2020 historical high survey biomass and standardised CPUE were seen and may indicate an improvement of the shrimp density, however, this may not reflect overall stock status as both the CPUE and the survey biomass were driven by a relative restricted area in Q1.

Applying the SPiCT surplus model as a preliminary analytical assessment tools showed that B/B_{MSY} is well above 1 and F/F_{MSY} is well below 1 indicating a healthy stock status (Figure 4.8, SCR Doc 20/061).

NIPAG consider this as being indicative results and the SPiCT model should be further explored for this stock, including adding risk levels for different catch projection scenarios.

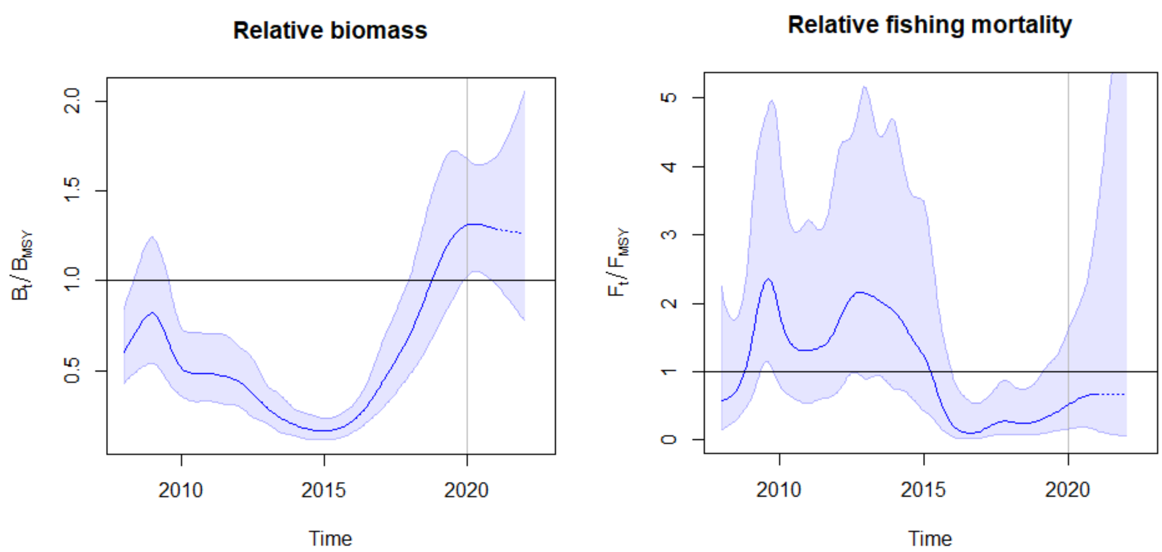


Figure 4.8. Plot of the estimated relative biomass (B_t/B_{MSY}) and relative fishing mortality (F_t/F_{MSY}) through time.

Projections.

Below is shown forecast for 2021 for seven scenarios.

Predictions:

	C	B	F	Bt/Bmsy	Ft/Fmsy	perc.dB	perc.dF
1. Keep current catch	2 966	7 371.3	0.403	1.235	0.756	-4.2	12.1
2. Keep current F	2 735.9	7 551.6	0.359	1.265	0.675	-1.8	0
3. Fish at Fmsy	3 821.3	6 774.8	0.533	1.135	1	-11.9	48.2
4. No fishing	3.1	9 039.1	0	1.514	0.001	17.5	-99.9
5. Reduce F 25%	2 113.4	7 944.7	0.27	1.331	0.506	3.3	-25
6. Increase F 25%	3 317.6	7 150.4	0.449	1.198	0.844	-7	25
7. MSY advice rule	3 821.3	6 774.8	0.533	1.135	1	-11.9	48.2

d) Reference points

Scientific Council considers that 15% of the maximum survey female biomass provides a proxy for B_{lim}. In 2020 B_{lim} was recalculated based on new high survey female biomass from 2020 survey (Figure 4.2).

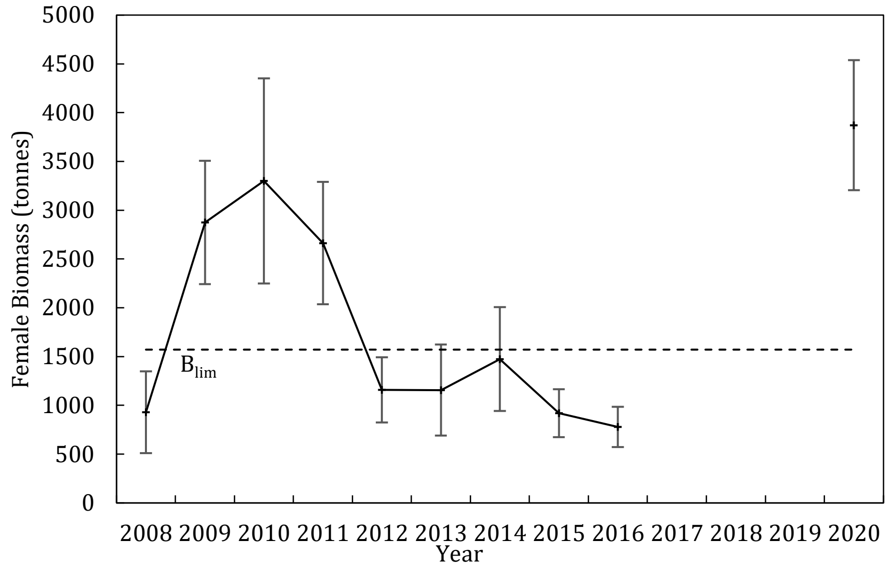


Figure 4.9. Shrimp in Denmark Strait and off East Greenland: Spawning stock biomass index (SSB) ±SE from 2008-2016 and 2020, and B_{lim} estimated as 15% of maximum survey female biomass. No survey was carried out in the period 2017 to 2019.

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 2020 are based on fishing in a relatively small area and may not reflect the state of the total 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. The survey biomass in 2020 is the highest observed.

Exploitation rate. Since the mid-1990s the exploitation rate index based on standardized commercial effort has decreased, currently reaching the lowest levels seen in the time series. The 2016 to 2020 levels of exploitation rate may be biased given the issues on CPUE described above.

State of the stock. The stock in 2020 is at a high level. The survey biomass in 2020 is the highest observed since the beginning of the survey, in 2008. The commercial CPUE in 2020 is also the highest since the beginning of the time series, in 1986. There is no recruitment index available for this stock, few juvenile shrimps are caught in the survey area.

f) Research recommendations

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

Status: No progress; this recommendation will not be progressed further at present.

- NIPAG **recommends** in 2020 that: *further model exploration should be carried out, including adding risk levels for different catch projection scenarios.*

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. 20/65, 66,67; 70; 08/56, 07/86, 7506/64.

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).

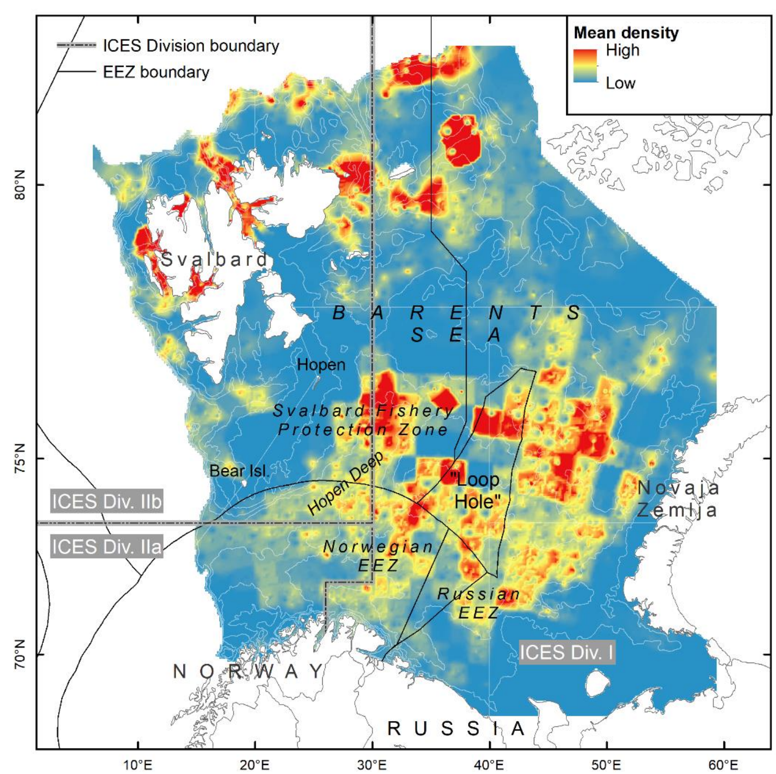


Figure 6.1. Shrimp in ICES SA 1 and 2: Stock distribution (Mean survey density index (kg/km2) from the joint Norwegian-Russian survey).

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 on a regular basis.

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 76 083 tons in 2019 and are predicted to reach 53000 tons by the end of 2020.

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

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020[1]
Recommended TAC	60 000	60 000	60 000	60 000	70 000	70 000	70 000	70 000	70 000	150000
Norway	19928	14158	8846	10234	16618	10896	7010	23100	23925	16500
Russia	0	0	1067	741	1151	2460	3849	12561	28078	21000
Others	10298	10598	9336	9989	16252	16223	19582	20025	24083	15500
Total	30226	24756	19249	20964	34022	29609	30441	55911	76 083	53000

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

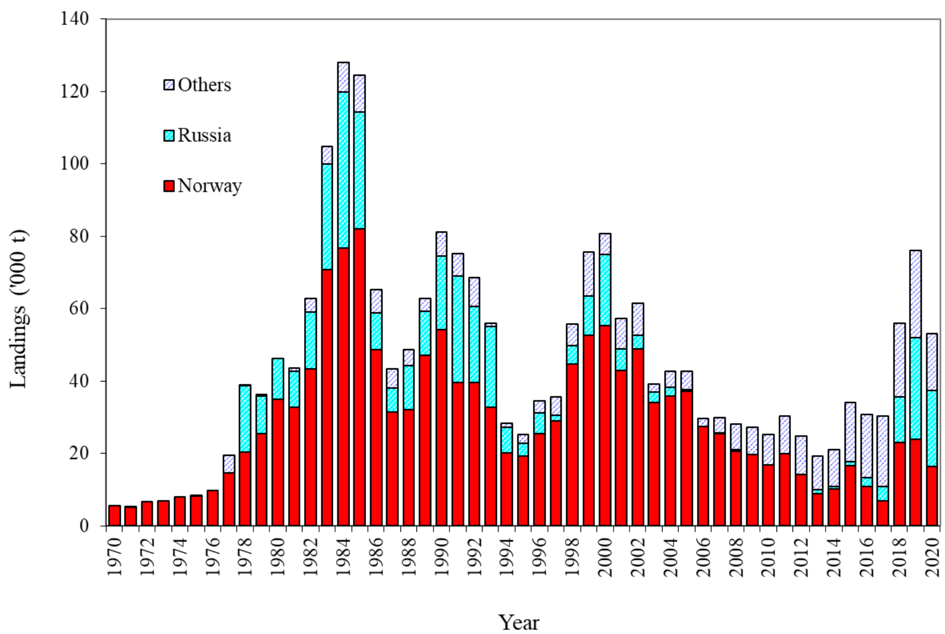


Figure 6.2. Shrimp in ICES SA 1 and 2: Total catches (2020 projected to the end of the year).

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.

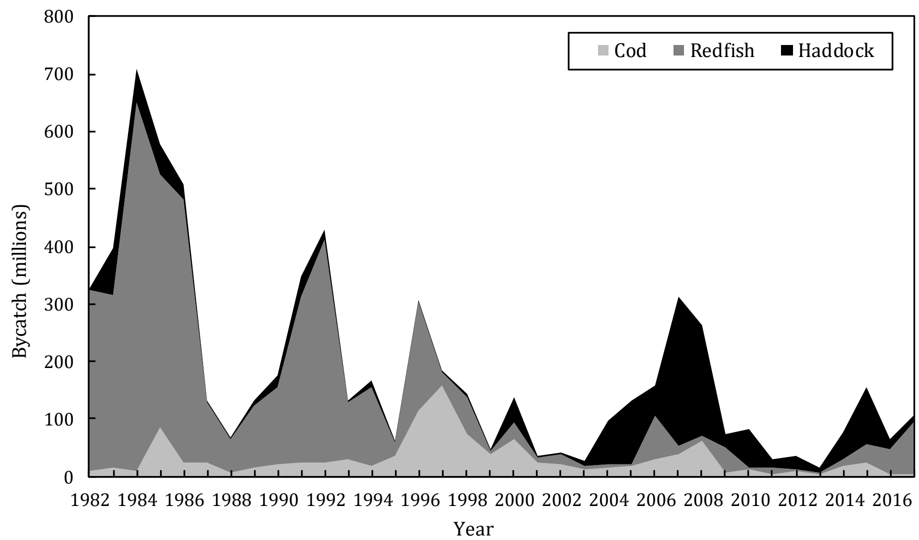


Figure 6.3. Shrimp in ICES SA 1 and 2: Estimated bycatch of cod, haddock and redfish in the Norwegian shrimp fishery (million individuals). The sorting grid was introduced in 1992 and has been mandatory since and following that, the vast majority of bycatch is assumed to have been juveniles.

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. In 2020 summary catch and effort data was received from Poland, Latvia and Estonia. In addition, information was provided by Russia in SCR Doc. 20-063, including information on catch distribution and standardized catch rates in 2020.

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.

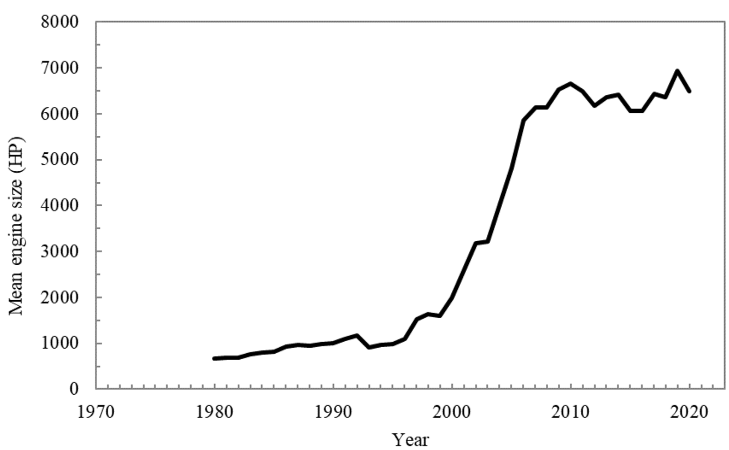


Figure 6.4. Shrimp in ICES SA 1 and 2: Mean engine power (HP) weighted by trawl-time (Norwegian vessels).

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.

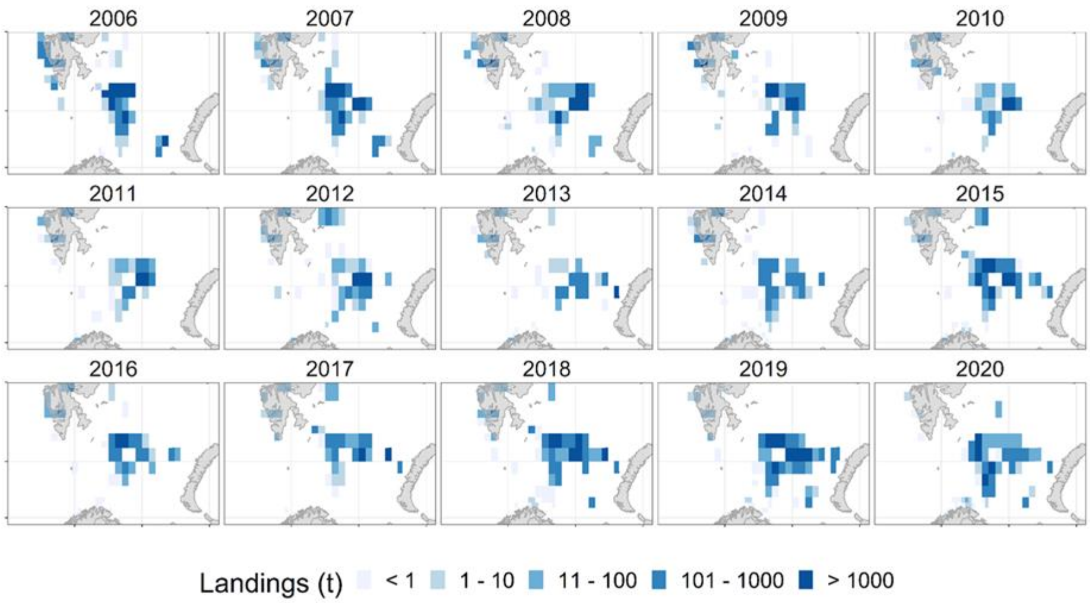


Figure 6.5. Shrimp in ICES SA 1 and 2: Distribution of catches by Norwegian vessels since 2000 based on logbook information. 2020 includes only data until September.

The Soviet/Russian fishery for the northern shrimp in the Barents Sea started in 1978. Catches peaked in 1983-1985 and varied in subsequent years (Fig. 6.2) In 2009-2012, the Russian fishery for shrimp came to a full stop. Following a restructuring of the fleet catches have again increased and are projected to reach 21000 tons by the end of 2020.

In the early 2000s, the Russian fishery was mainly conducted in the open part of the Barents Sea and the Svalbard area (Fig. 6.6). With the resumption of fishery in 2013, the main fishing grounds were shifted eastward. Currently fishing occurs in the Russian EEZ in the areas of the Novaya Zemlya Bank, the Perseus Upland, Cape Zhelaniya and Cape Sukhoi Nos. The main fishing period is March to September; however, some vessels fish all year round.

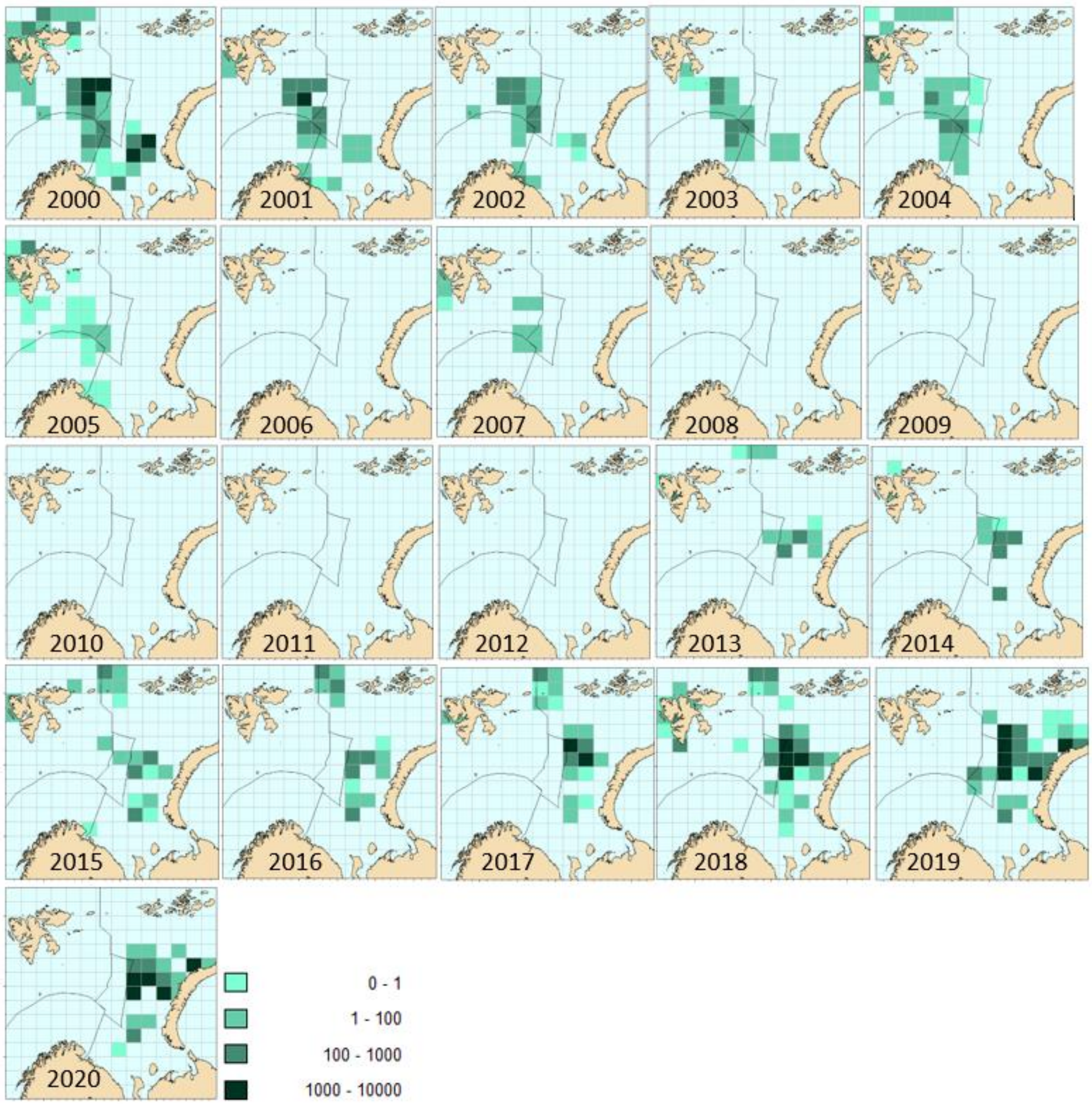


Figure 6.6. Distribution of catches by Russian vessels since 2000 based on logbook information. (2020 only data until September)

A standardized CPUE index based on a generalized linear model (GLM) that took area, depth, gear, and month into account, was stable from 2000 to 2015 and then increased (Fig. 6.7). From a maximum in 2019 it decreased by 23% in 2020. This standardized CPUE, being new and not fully evaluated by NIPAG was at this point not used as input to the assessment model. However, it was noted that in the period since 2016 when the Russian shrimp fishery was revived, the trajectory of this index series (Fig. 6.7) was in good agreement with that seen in the survey (Fig. 6.11). The inclusion of this index should be further considered at the up-coming benchmark.

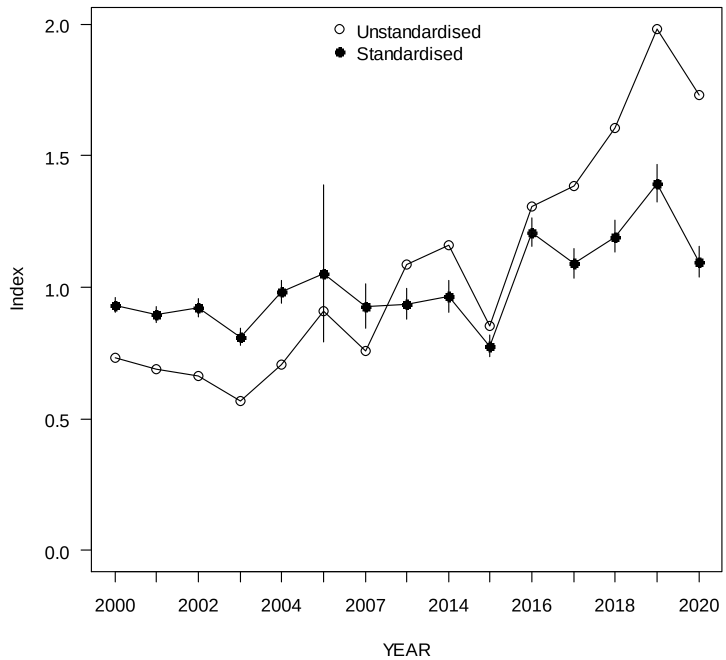


Figure 6.7. Unstandardized (geometric mean of annual observations) and standardized (year coefficients from GLM) CPUE indices for Russian shrimp fishery. Error bars indicate +2 s.e. Each series has been normalized to a geometric mean of 1.

Norwegian logbook data were used in a GLM to calculate standardized annual catch rate indices (SCR Doc. 19/56). The GLM 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 6.8). The minimum commercial size in this fishery is 15mm.

Figure 6.8. Shrimp in ICES SA 1 and 2: Standardized CPUE based on Norwegian data. Black line indicates the mean estimate, the shaded area the 95% confidence intervals.

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.

In last year's assessment (2019) the 2018 and 2019 index values were record high. Input data and model diagnostics were scrutinized but there was at that time not found anything to indicate errors or model deficiencies. For this year's calculation the code for vessel filtering and GLM fit was revised. The CPUE index used in last year's assessment was determined to be overestimated due to incomplete data and filtering issues (Fig. 6.9). The correction of the CPUE index reduced current CPUE to levels that correspond better with past trends, and subsequently resulted in stock estimates that align more closely with historic patterns.

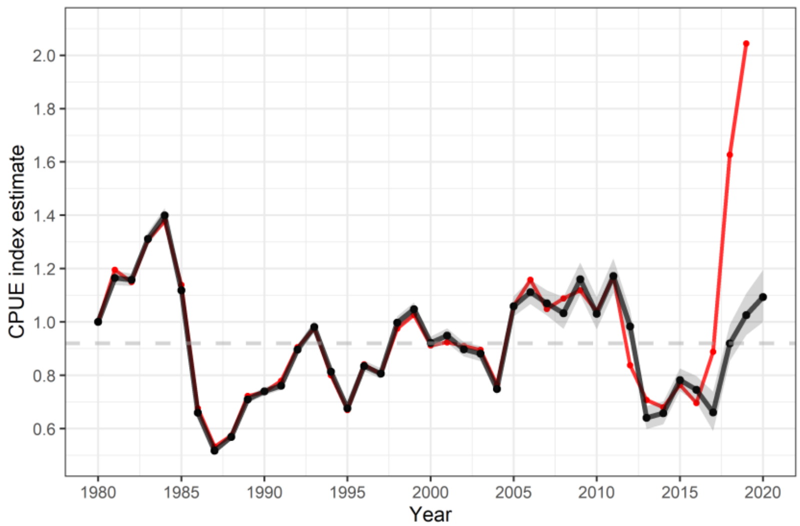


Figure 6.9. Shrimp in ICES SA 1 and 2: Comparison of standardized CPUE (Norwegian data) from the 2019 assessment (red line) and the revised version for this year's assessment (black line).

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 6.12). The most recent survey series (survey 3) has increased substantially since a low in 2016 to reach its highest value in 2019. However, the 2020 value is down again close to the 2016 value. In general, the entire survey area of the Ecosystem survey (survey 3 in Figure 6.12) 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.

In the 2020 the Russian part of the survey area (about 50%) was not finalized before the start of this assessment due to technical issues (Fig. 6.10). This part of the survey is expected to be finalized later in the year. NIPAG discussed whether to exclude this data point from the assessment or use the existing partial survey data to estimate a biomass index value for the entire area. As the partial data from the Norwegian survey area and information from the Russian fishery (figure 6.7) both indicated a significant decline in biomass as compared to 2019, NIPAG decided to reconstruct a total biomass estimate for 2020 for use as input in the assessment model. The biomass index value was constructed as follows: a time-series of biomass estimates for the area covered by the 2020 survey was produced for the entire survey time series. The proportion of total biomass situated in this partial survey area was then calculated (Fig. 6.11). The mean of these proportions (60.3%) was then applied to the partial 2020 estimate (220 kt*100/60.3) giving a total 2020 biomass index value of 365 kt. The variance was taken as the mean variance of the 2010-2019 series times two. The resulting survey series is shown in Fig. 6.12 and the spatial distribution in Fig. 6.13.

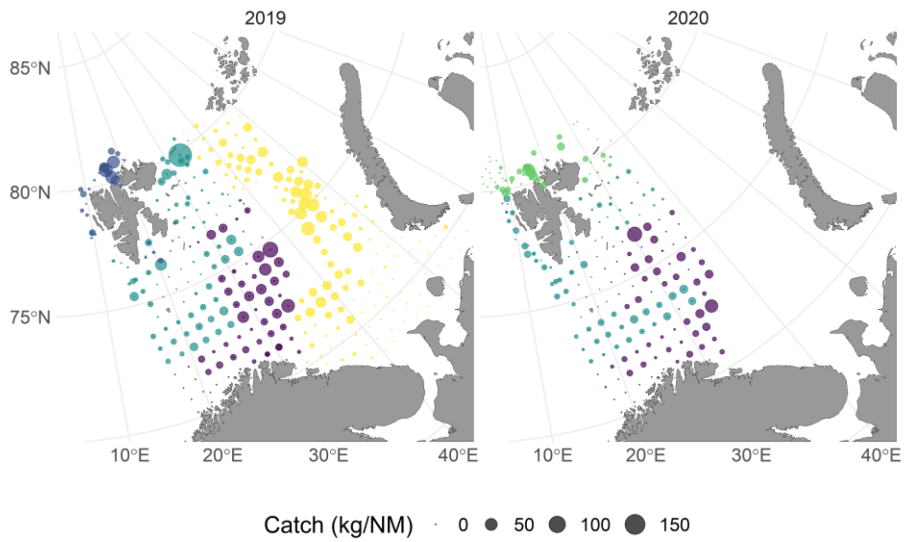


Figure 6.10. Survey coverage 2019 and 2020. Dots are scaled to the registered catches of shrimp, colors indicate different survey vessels.

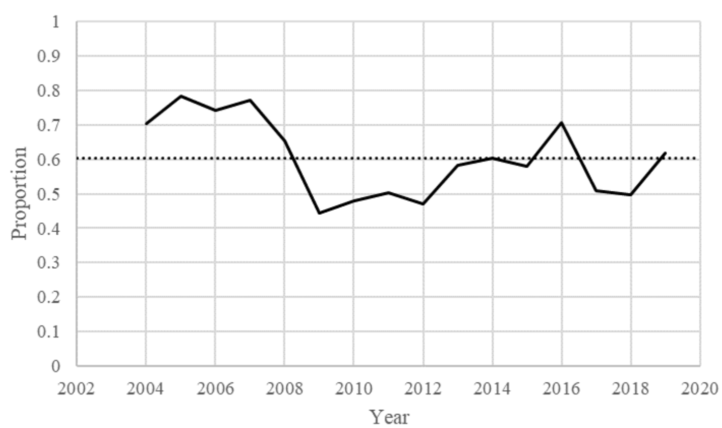


Figure 6.11. Proportion of total biomass found in the partial area covered by the 2020 survey. Dotted line is the mean of the series (60.3%).

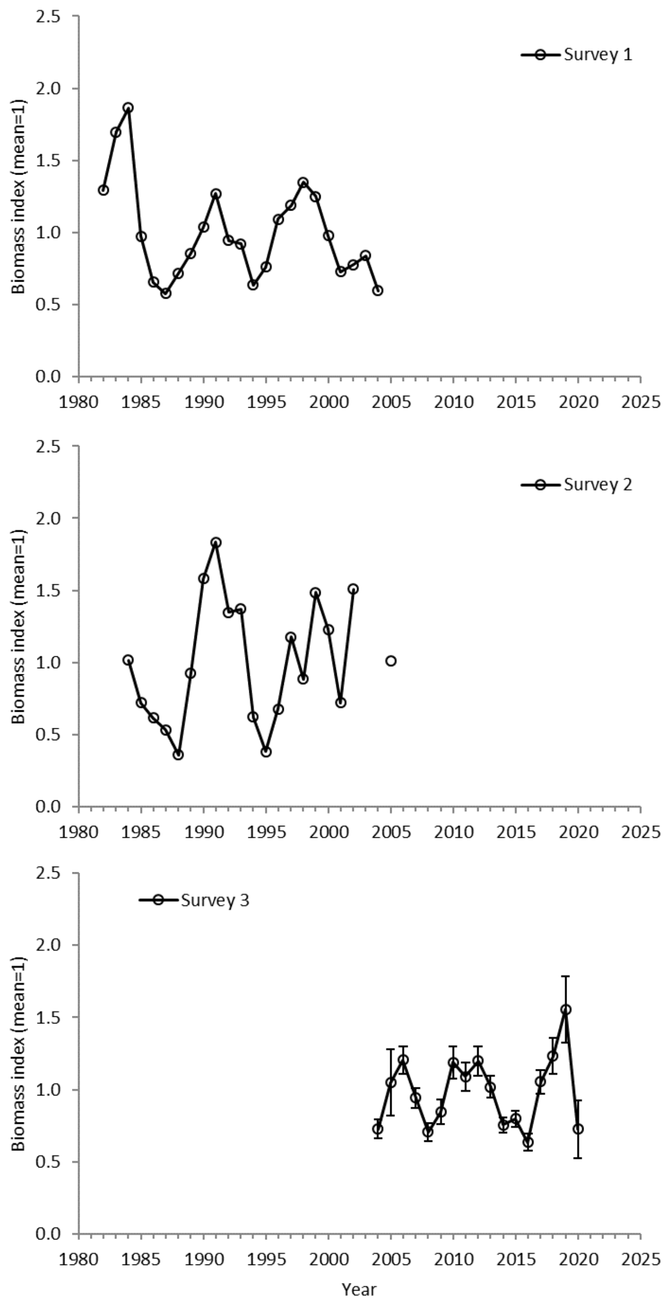


Figure 6.12. Shrimp in ICES SA 1 and 2: Indices of total stock biomass from the (1) 1982-2004 Norwegian shrimp survey, (2) the 1984-2005 Russian survey, and (3) the joint Russian-Norwegian ecosystem survey since 2004. Error bars represent 1 SE.

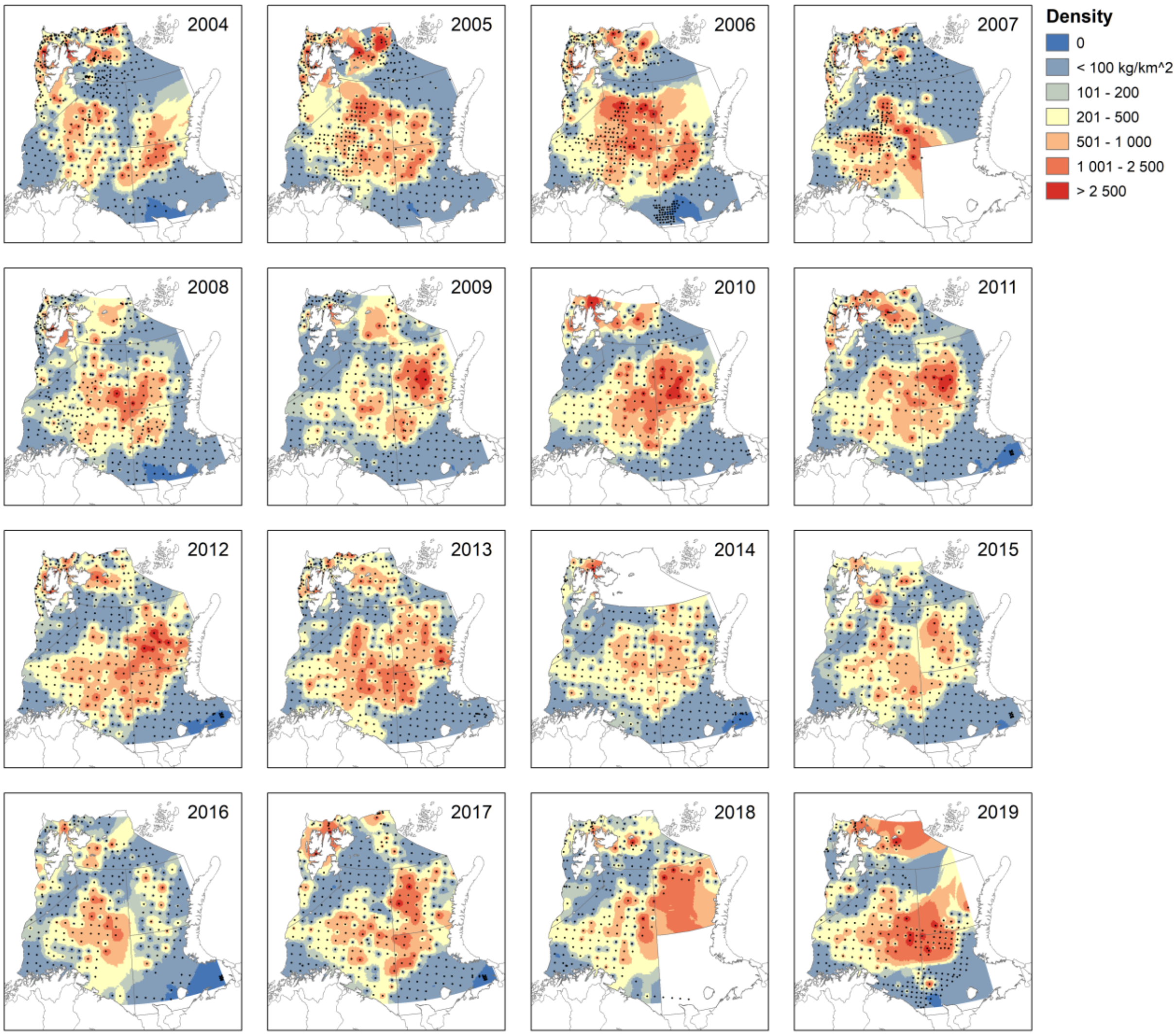


Figure 6.13. Shrimp in ICES SA 1 and 2: shrimp density (kg/km2) as calculated from the Ecosystem survey data since 2004 (no data for stratum 3 in 2014 due to ice conditions; no data for stratum 5 in 2018 and 4 in 2019 due to vessel malfunction; for survey 2020 see text and Fig. 6.10.

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. However, the observation error for the 2020 survey data point was assumed to be twice that of the remaining series, taking into account that the survey only covered about 50% of the distribution area.

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. 20/066).

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 1980–2020 (Figure 6.6, SCR Doc. 20/067); and trawl-survey biomass indices for 1982–2004, 1984–2005 and for 2004–2020 (Figure 6.7, SCR Doc. 20/065). 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. 20/067). 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_ε^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 2020 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 2019 assessment.

	Mean	sd	25 %	Median	75 %	Median (2019)
MSY (ktons), maximum sustainable yield	223	119	126	204	307	160
K (ktons), carying capacity	2978	1517	1870	2686	3757	2664
r, intrinsic growth rate	0.33	0.15	0.22	0.32	0.42	0.26
q_R, catchability of survey 2	0.13	0.08	0.07	0.11	0.16	0.12
q_{Ru}, catchability of survey 1	0.33	0.21	0.19	0.27	0.40	0.31
q_E, catchability of survey 3	0.20	0.13	0.12	0.17	0.25	0.18
q_C, catchability of CPUE index	4.7E-04	3.0E-04	2.7E-04	3.8E-04	5.8E-04	4.5E-04
P_0, initial relative biomass (1969)	1.50	0.26	1.33	1.51	1.68	1.50
P_{2020}, relative biomass in 2020	1.90	0.47	1.59	1.86	2.16	2.37
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	0.34	0.37	0.33
σ_E, coefficient of variation for survey 3	0.19	0.04	0.17	0.19	0.22	0.16
σ_C, coefficient of variation for CPUE index	0.13	0.02	0.12	0.13	0.15	0.14
σ_P, coefficient of variation for process	0.19	0.03	0.17	0.18	0.20	0.20

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). 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 6.14, 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 2020 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 6.14 lower). In 2020, there is a less than 5% risk of the *F* being above F_{msy} (Table 6.3).

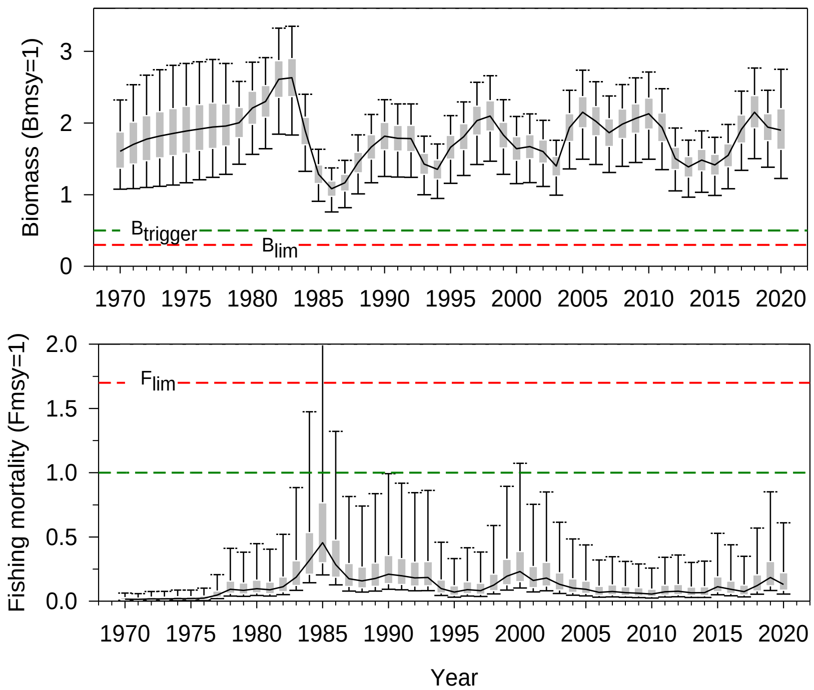


Figure 6.14. Shrimp in ICES SA 1 and 2: Estimated relative biomass (B/B_{msy}) and fishing mortality (F/F_{msy}) since 1970. Boxes represent inter-quartile ranges and the solid black line in the middle of each box is the median; the arms of each box cover the central 90% of the distribution. The broken lines indicate *MSY* and precautionary approach reference points.

Table 6.3. Shrimp in ICES SA 1 and 2: Stock status for 2019 and projected to the end of 2020.

Status	2019	2020*
Risk of falling below B_{lim}	0.0 %	0.0 %
Risk of falling below $B_{trigger}$	0.1 %	0.1 %
Risk of exceeding F_{MSY}	3.9 %	2.2 %
Risk of exceeding F_{lim}	1.6 %	1.0 %
Stock size (B/Bmsy), median	1.90	1.86
Fishing mortality (F/Fmsy),	0.19	0.14

*Predicted catch = 53ktons

Projections. Catch advice at the median of F_{msy} (ICES MSY approach) would imply no more than 266 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 140 kt. Assuming a catch of 53 kt for 2020, catch options up to 140 kt for 2021 have low risks of exceeding F_{msy} (<16%), F_{lim} (<7%), and of going below $B_{trigger}$ (<1%) by the end of 2021 (Table 6.4) and all these options are likely to maintain the stock above B_{msy}.

Table 6.4. Shrimp in ICES SA 1 and 2: Predictions of risk and stock status associated with optional catch levels for 2021.

	Catch option 2020 (ktons)						Yield at Fmsy (mode)	Yield at Fmsy (median)
	60	70	80	90	100	110	140	266
Risk of falling below B_{lim}	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.4 %	1.5 %
Risk of falling below $B_{trigger}$	0.2 %	0.2 %	0.2 %	0.2 %	0.2 %	0.2 %	0.9 %	3.9 %
Risk of exceeding F_{MSY}	3.0 %	4.1 %	5.0 %	6.3 %	7.5 %	9.3 %	15.2 %	50 %
Risk of exceeding F_{lim}	1.3 %	1.7 %	2.1 %	2.5 %	3.1 %	3.7 %	6.4 %	24 %
Stock size (B/Bmsy), median	1.83	1.83	1.83	1.81	1.80	1.79	1.74	1.57
Fishing mortality (F/Fmsy),	0.16	0.19	0.21	0.24	0.27	0.30	0.41	1.00

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 declined again after a recovery in 2017 and has likely fallen below B*lim*. Cod biomass has decreased in recent years following a peak around 2013 but is still at a relatively high level. With the recent decrease in capelin and cod abundance remaining on historically high levels, predation pressure on shrimp may be relatively high. 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 6.15). The differences between observed values of biomass indices and the corresponding values predicted by the model were checked numerically (SCR Doc 20/066). They were found generally not to include excessively large deviations.

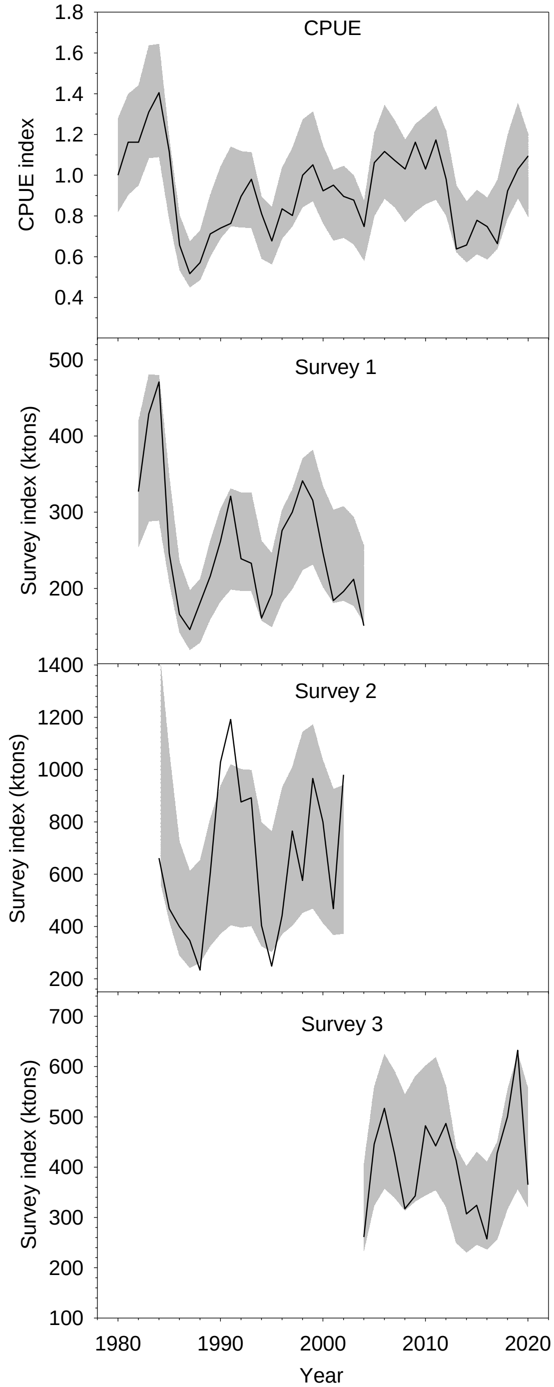


Figure 6.15. Shrimp in ICES SA 1 and 2: Observed (solid line) and estimated (shaded) series of the included biomass indices: the standardized catch-per-unit-effort (CPUE), the 1982–2004 Norwegian shrimp survey (survey 1), the 1984 to 2005 Russian survey (Survey 2) and the Joint Norwegian-Russian Ecosystem Survey (survey 3) since 2004. Grey shaded areas cover the 80% probability interval of their posteriors.

The model did have a tendency to be too pessimistic regarding the final years during the stock increase since 2015 to 2014 (Figure 6.16), but all of these were well inside the updated estimated probability distributions the following year. The model only slightly underestimated the decline from 2019 to 2020. A simple calculation of Mohn's rho based on the point estimates (medians) for five years is -0.15.

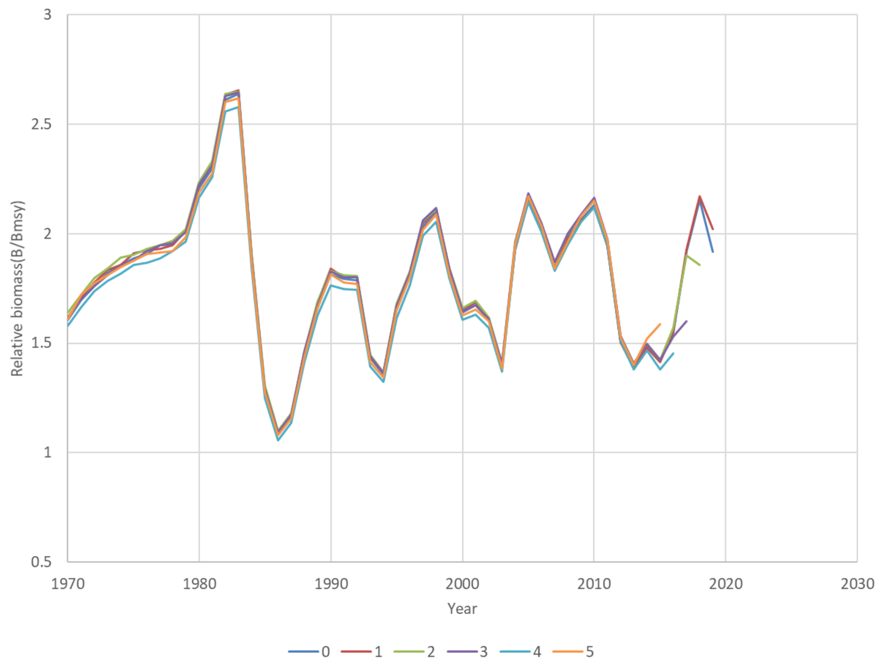


Figure 6.16. Shrimp in ICES SA 1 and 2: Retrospective plot of median relative biomass (B/B_{msy}). Relative biomass series are estimated by consecutively leaving out from 0 to 10 years of data.

A correction of the CPUE index in this year's assessment has resulted in a re-alignment with the stock trajectories estimated before 2019 as compared to the 2019 assessment. However, the incomplete survey coverage remains a source of uncertainty

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 2020 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 2020 there is 1% 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: Reiterated. NIPAG **recommends** the *benchmark to be as soon as possible*. 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. 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 (Fig. 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.

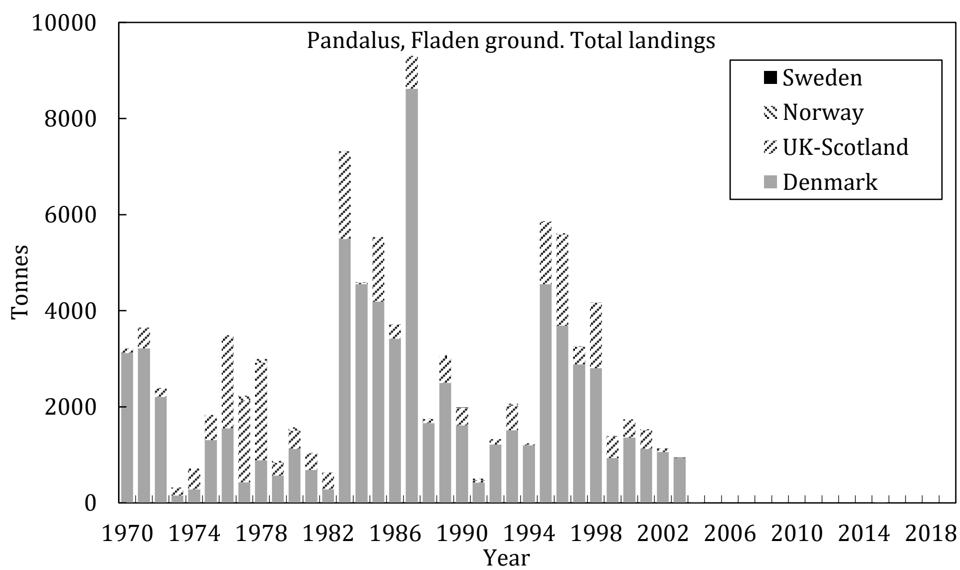


Figure 7.1. Northern shrimp in Fladen Ground: Landings by country and total.

IV. OTHER BUSINESS

1. 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 Northern shrimp[3] SA3+4 Northern shortfin squid	SA0+1 Northern shrimp[1] DS Northern shrimp[1] SA 0+1 (Offshore) Greenland halibut 3M Redfish[3] SA2+3KLMNO Greenland halibut	3M cod	Greenland halibut in Disko Bay[2] SA1 American Plaice SA1 Spotted Wolffish
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	1B-C Greenland halibut Inshore	1D Greenland halibut Inshore 1E-F Greenland halibut Inshore	6G Alfonsino

[1]Shrimp will be re-assessed at the SC shrimp meeting in November 2019
[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

2. Date and place for the next NIPAG meeting

As agreed at the 2018 meeting, NIPAG reassessed the timing of meetings in view of differing requirements for timing of advice and availability of survey data. The main considerations were as follows:

- In future years, advice for the Barents Sea stock will be required by late summer to accommodate the Norway/Russia Fisheries Commission meeting which takes place in October. It would be preferable to have the meeting in late November to allow inclusion of autumn survey data but, if the meeting is held earlier, it would be possible to do an update before Norway/Russia Commission meeting.
- There will be a survey of East Greenland with a new research vessel in mid-October 2021 so holding the meeting late November would be ideal for that stock. The timing of the East Greenland survey in

future years is uncertain but could be in the summer. The West Greenland survey will be August, as usual.

- The Skagerrak stock will continue to be assessed during February/March. This will be considered as a full NIPAG meeting, and meeting times will be arranged to allow full participation in North American time zones.
- As in the last two years, the NAFO Commission will require advice for the NAFO 3M stock to be available for their Annual Meeting starting 20 September. The EU Flemish Cap survey will be completed in late July but, due to the time taken for the vessel to return to Spain and the summer holiday season, it is not expected that the data would be available before the end of August.

In view of the experience gained in holding meetings by WebEx during the current pandemic, the group considered the possibility of conducting the majority of future meetings by WebEx, which would allow the possibility that multiple meetings could be held at different times of year. Under this option, full face to face would only occur every two or three years. Most NIPAG members considered it preferable to maintain the current arrangement of holding annual face to face meeting with additional meetings for stock that cannot be accommodated within the normal schedule. This allows for more thorough peer review than could be achieved through WebEx meetings.

It was agreed that the main 2021 NIPAG meeting will be held 8-14 September (including Saturday) in Copenhagen. It will be necessary to assess the 3M stock early in the meeting to allow the advice to be ready well in advance of the NAFO Annual Meeting.

There will be an additional NIPAG meeting by Webex in November to assess the east Greenland stock. Work on this stock during the September meeting will focus on developing the assessment model for this stock using available data.

3. Benchmark preparation

NIPAG reviewed the benchmark planning document drafted in 2019. This is attached to this report as appendix VIII.

NIPAG reviewed a draft timetable for the benchmark as follows:

2020: NIPAG meeting and formulation of work plan towards data workshop and benchmark meetings for 3M, Barents Sea and Skagerrak (present meeting).

2021: Data compilation workshop (3 days prior to the NIPAG meeting)

2022: Benchmark to be held in conjunction with the NIPAG (PANDSKND) meeting in February/March.

2022: there may be a meeting in summer or autumn to revise the management plan (MSE) for the NSSK stock

A data call will be drafted by ICES and NAFO secretariats and forwarded the relevant stock assessors for review prior to being issued, likely in January 2021. ICES secretariat will forward a link to the ICES benchmark issues list to NIPAG members with instruction on what needs to be done.

A decision will be taken by ICES in March 2021 on whether this benchmark will go ahead

V. ADJOURNMENT

The NIPAG meeting was adjourned at 1300 hours on 30 October 2020. 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. The report was adopted at the close of the meeting, subject to a period for editorial changes.

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

By WebEx
27 October – 02 November 2020

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 2019
2. Review of Catches

III. Stock Assessments

- Northern shrimp (NAFO Division 3M) (review of assessment September 2020 and new survey data analysis)
- Northern Shrimp (NAFO Divisions 3LNO) (interim monitoring)
- Northern shrimp (NAFO Subareas 0 and 1) (full assessment)
- Northern shrimp (in Denmark Strait and off East Greenland) (full assessment)
- Northern shrimp in the Skagerrak andNorwegian Deep (ICES Subdivision 27.3a.20 and the eastern part ofDivision 27.4a) (review of assessment February 2020)
- 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
2. Benchmark planning
3. Scheduling of future meetings

V. Adjournment

APPENDIX II. ICES TERMS OF REFERENCE FOR NIPAG

1. Generic ToRs for Regional and Species Working Groups

This resolution was approved 1 October 2019

2019/2/FRSG01

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 2020 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 2019.

   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.

h. Review and update information regarding operational issues and research priorities and the Fisheries Resources Steering Group SharePoint site.

i. Take 15 minutes, and fill a line in the audit spread sheet 'Monitor and alert for changes in ecosystem/fisheries productivity'; for stocks with less information that do not fit into this approach (e.g. higher categories >3) briefly note in the report where and how productivity, species interactions, habitat and distributional changes, including those related to climate-change, have been considered in the advice.

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

APPENDIX III. RELEVANT RECOMMENDATIONS FROM 2018 AND 2019

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 **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}.

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.*

NIPAG – 2019

1. Northern Shrimp in Division 3M

- NIPAG **recommended** in 2016 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. This recommendation is reiterated.*
- 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 in Divisions 3NLO

- NIPAG **recommended** in 2015 that *ecosystem information related to the role of shrimp as prey in the Grand Bank (i.e. 3LNO) Ecosystem be presented to NIPAG. This recommendation is reiterated.*
- NIPAG **recommended** in 2018 that *further work on the development of a recruitment index for Div. 3LNO be completed. This recommendation is reiterated.*

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

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

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

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

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

- NIPAG **recommended** in 2010-2014 that: *differences in recruitment and stock abundance between Skagerrak and the Norwegian Deep should be explored.* This recommendation is reiterated.
- 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.* This recommendation is reiterated.

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

- 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*. 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. This recommendation is reiterated.

- In 2017, NIPAG **recommended** that *a recruitment index should be developed for this stock.* This recommendation is reiterated.
- In 2017, NIPAG **recommended** that the informatio*n 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.* This recommendation is reiterated.

APPENDIX IV. DESIGNATED EXPERTS FOR ASSESSMENT OF CERTAIN NAFO STOCKS

The following is the list of Designated Experts for 2020 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 Divisions 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 Division 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 Subarea 0+1	AnnDorte Burmeister	Tel: +299 36 1200	anndorte@natur.gl
Northern shrimp in Denmark Strait	Frank Rigét		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. 20-051	N7102	J.M. Casas Sánchez and M. Álvarez	Division 3M Northern shrimp (Pandalus borealis) – Interim Monitoring Update
SCR Doc. 20-052	N7126	Heino Fock, Karl-Michael Werner and Christoph Stransky	Survey results of the German bottom trawl survey 1982-2019 with special reference to years 2016 - 2019
SCR Doc. 20-053	N7127	Burmeister and Rigét	The West Greenland trawl survey for Pandalus borealis, 2020, with reference to earlier results.
SCR Doc. 20-054	N7128	Burmeister and Rigét	The Fishery for Northern Shrimp (Pandalus borealis) off West Greenland, 1970–2020
SCR Doc. 20-055	N7129	Burmeister	Catch Table Update for the West Greenland Shrimp Fishery
SCR Doc. 20-056	N7130	Burmeister and Rigét	A provisional Assessment of the shrimp stock off West Greenland in 2020
SCR Doc. 20-057	N7131	Burmeister and Rigét	Relationship between abundance of age-2 shrimps, pre-recruits and fishable biomass two to four years later
SCR Doc. 20-058	N7132	Rigét 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. 20-059	N7133	Rigét	The Fishery for Northern Shrimp (Pandalus borealis) in Denmark Strait / off East Greenland 1978 – 2020.
SCR Doc. 20-060	N7134	Buch	Results of the Greenland Bottom Trawl Survey for Northern shrimp (Pandalus borealis) Off East Greenland (ICES Subarea XIV b), 2008-2020
SCR Doc. 20-061	N7135	Rigét, Burmeister and Buch	Applying a stochastic surplus production model (SPiCT) to the East Greenland Stock of Northern Shrimp
SCR Doc. 20-062	N7136	Burmeister	Reply to the Canadian request for advice of shrimps in Subarea 0 and 1.
SCR Doc. 20-063	N7137	Sergey Bakanev	Russian fishery for the northern shrimp (Pandalus borealis) in the Barents Sea in 2000-2020
SCR Doc. 20-064	N7138	J. M. Casas	Northern Shrimp (Pandalus borealis) on Flemish Cap Surveys 2020
SCR Doc. 20-065	N7139	Carsten Hvingel, Fabian Zimmermann and Trude H. Thangstad	Research survey results pertaining to northern shrimp (Pandalus borealis) in the Barents Sea and Svalbard area 2004-2020
SCR Doc. 20-066	N7140	Carsten Hvingel and Fabian Zimmermann	Shrimp (Pandalus borealis) in the Barents Sea – Stock assessment 2020
SCR Doc. 20-067	N7141	Carsten Hvingel, Trude H. Thangstad and Fabian Zimmermann	The Norwegian fishery for northern shrimp (Pandalus borealis) in the Barents Sea and round Svalbard 1970-2020

SUMMARY DOCUMENTS (SCS)

SCS No.	Serial No.	Author(s)	Title
SCS Doc. 20/20	N7142	NAFO	SC Shrimp Report 26-30 October 2020
SCS Doc. 20/21	N7143	NAFO/ICES	NAFO/ICES *Pandalus* Assessment Group Report, 26-30 October 2020
SCS Doc. 20/22	N7147	NAFO	SC Shrimp (in conjunction with NIPAG) Report, 14 September 2020

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

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

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

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

b) Expert group information

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

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; 20/01 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) are assessed as one stock and are exploited by Norway, Denmark and Sweden. Shrimp fisheries expanded significantly in the early 1960s. By 1970, the landings had reached 5000 t and in 1981 they exceeded 10 000 t.

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

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

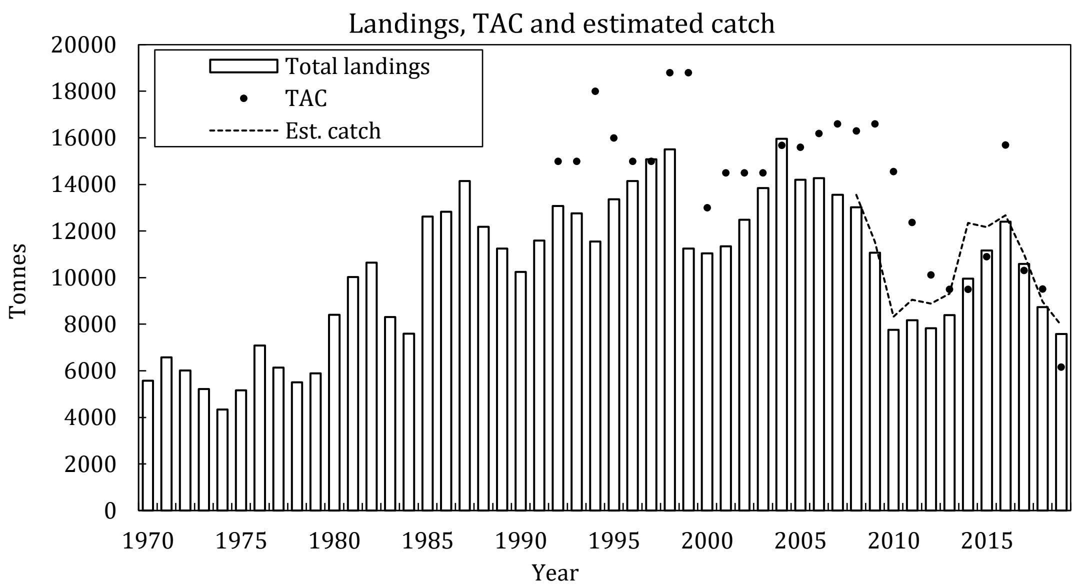

Figure 5.1. Northern shrimp in Skagerrak and Norwegian Deep: TAC, total landings by all fleets, and total estimated catch including estimated Swedish discards for 2008–2019, and Norwegian and Danish discards for 2009–2019.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

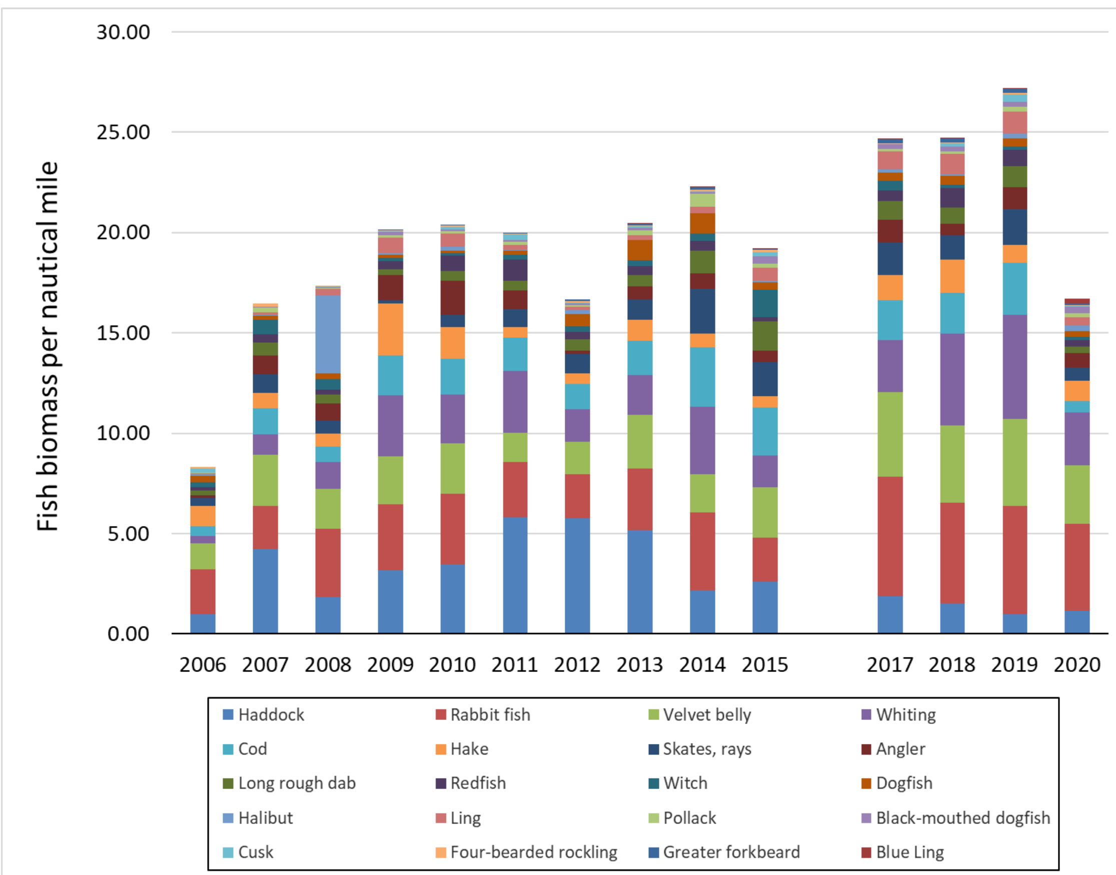

Figure 5.2. Northern shrimp in Skagerrak and Norwegian Deep: Estimated indices of predator biomass (catch in t per square nautical mile) from the Norwegian shrimp survey in 2006–2020 excluding saithe, roundnose grenadier and blue whiting. The 2016 survey data have been omitted (see text for details).

b) Input data

i) Fishery data

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

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

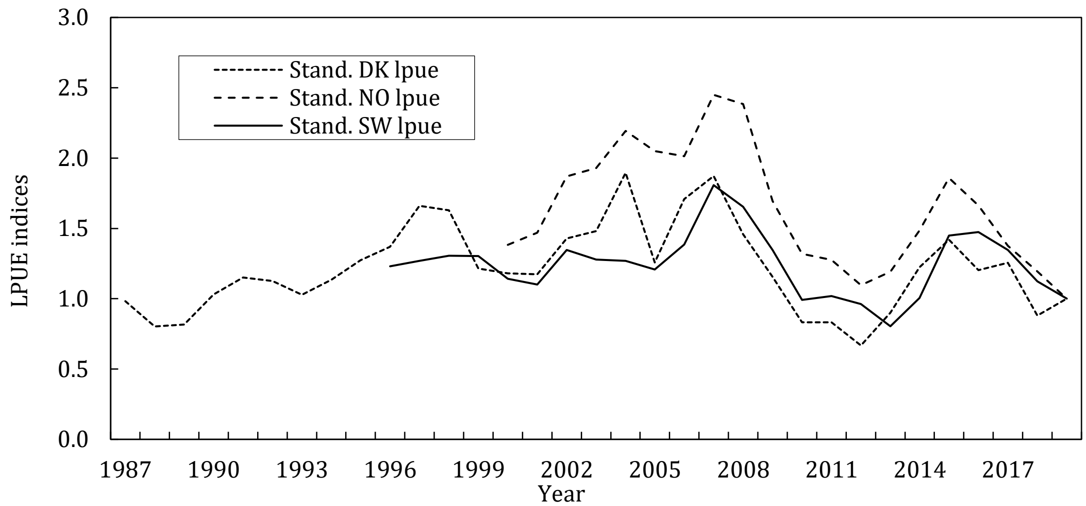

Figure 5.3. Northern shrimp in Skagerrak and Norwegian Deep: Danish, Norwegian and Swedish standardised landings per unit of effort (LPUE) until 2019. Each series is standardised to its final year.

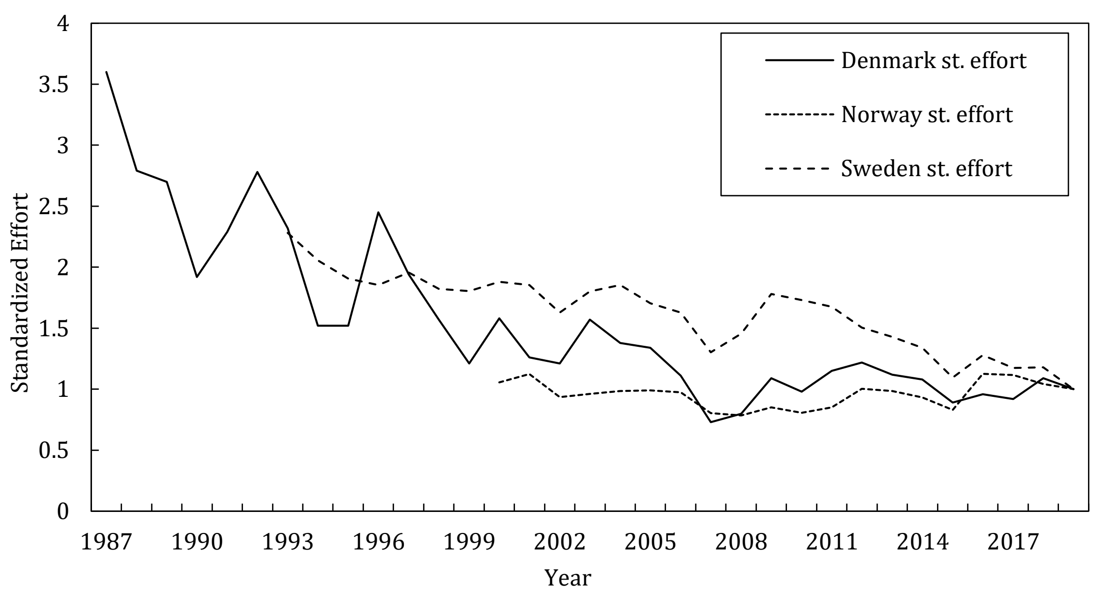

Figure 5.4. Northern shrimp in Skagerrak and Norwegian Deep: Estimated standardised effort until 2019. Each series is standardised to its final year.

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

ii) Survey data

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

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

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

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

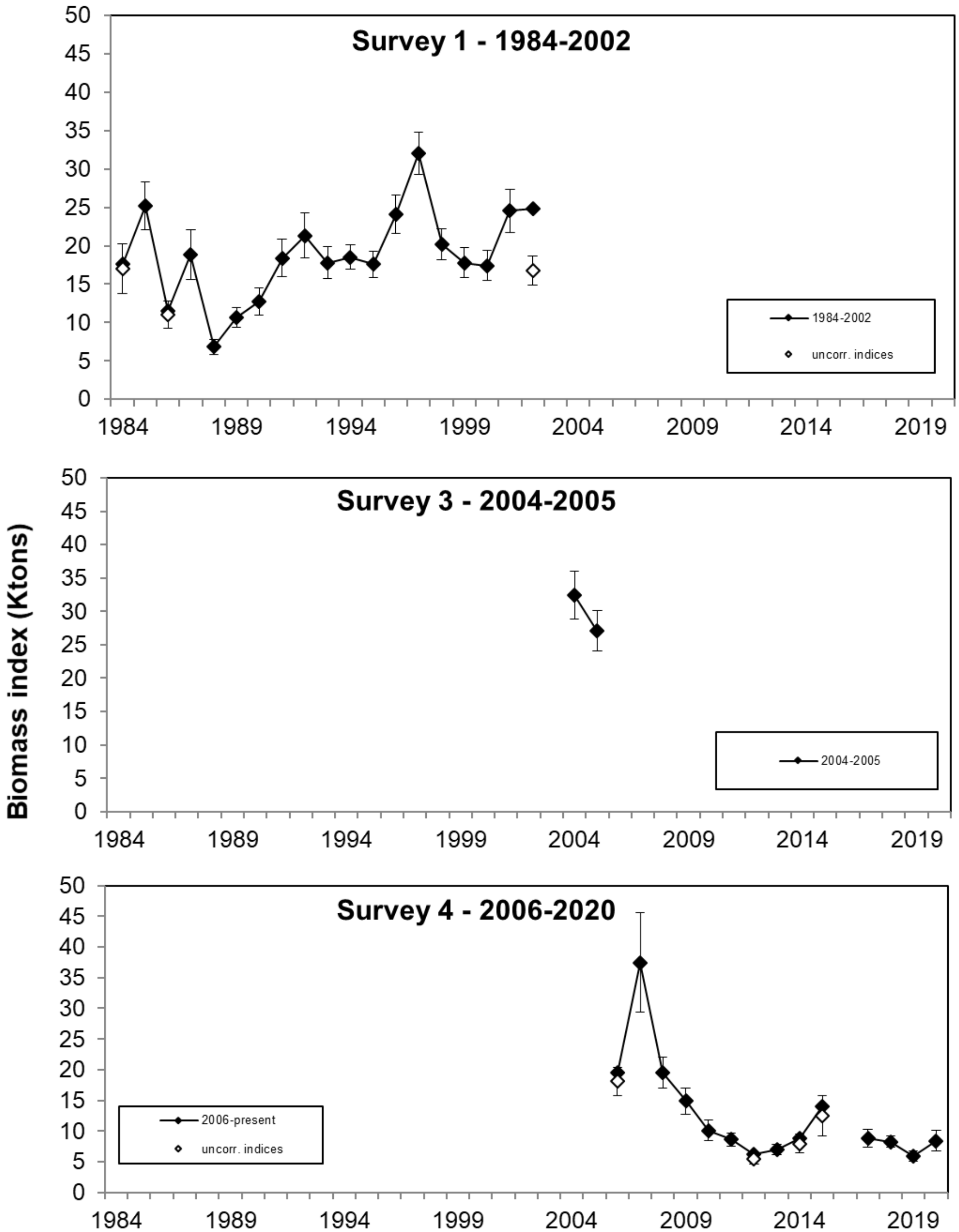

Figure 5.5. Northern shrimp in Skagerrak and Norwegian Deep: Estimated survey biomass index in 1984–2020. The point estimate of 2003 is not shown. The 2016 survey data have been omitted (see text for details).

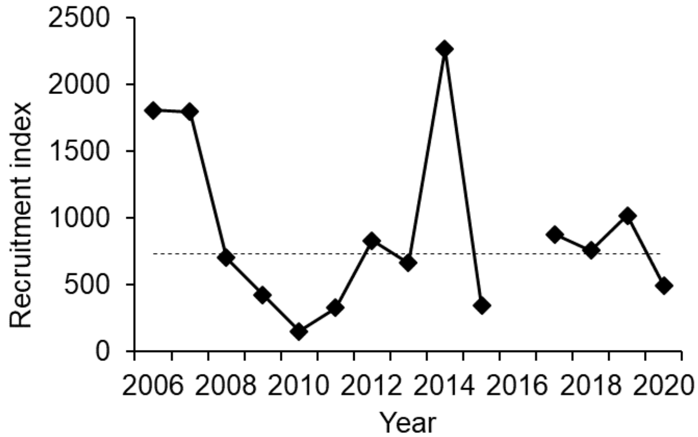

Figure 5.6. Northern shrimp in Skagerrak and Norwegian Deep: Estimated recruitment index, 2006–2020. The horizontal line is the median of the time-series. The 2016 survey data have been omitted (see text for details).

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

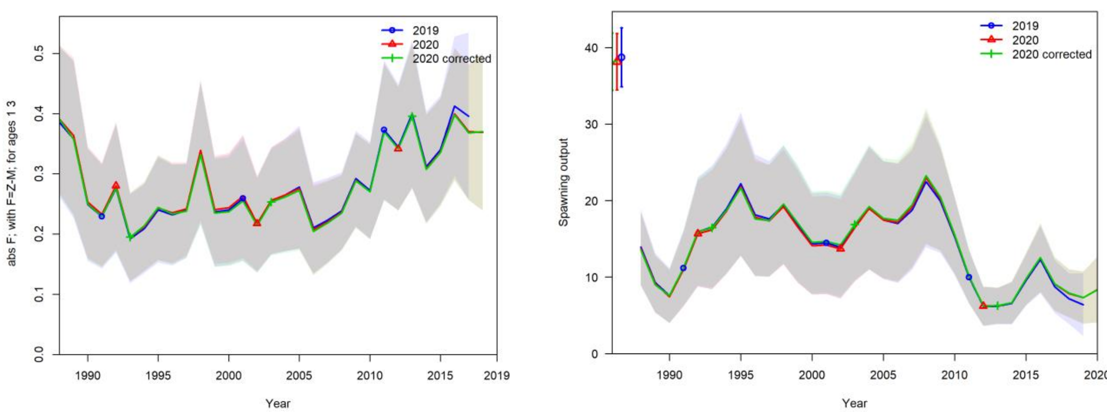

Figure 5.7. Northern shrimp in Skagerrak and Norwegian Deep: F and SSB assessment results for model runs with corrected survey data (2020 corrected) and un-corrected data (2019, 2020). It should be noted that values of F shown in this figure are not directly comparable to the F in the standard graphs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

c) Model

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

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

d) Assessment results

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

e) Sensitivity analysis

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

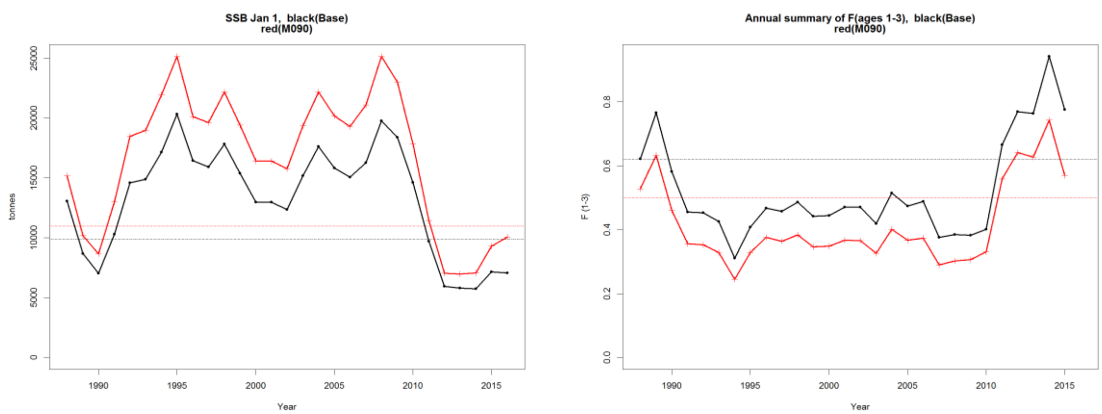

Figure 5.8. Northern shrimp in Skagerrak and Norwegian Deep: F and SSB assessment results for natural mortality M = 0.75 (base model, black) and M = 0.90 (red). The horizontal lines indicate MSY $B_{trigger}$ (left panel) and F_{MSY} (right panel) values for each of the two M-levels.

f) Historical stock trends and recruitment

Historical stock trends are shown in Figure 5.9.

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

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

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

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

g) Model retrospective

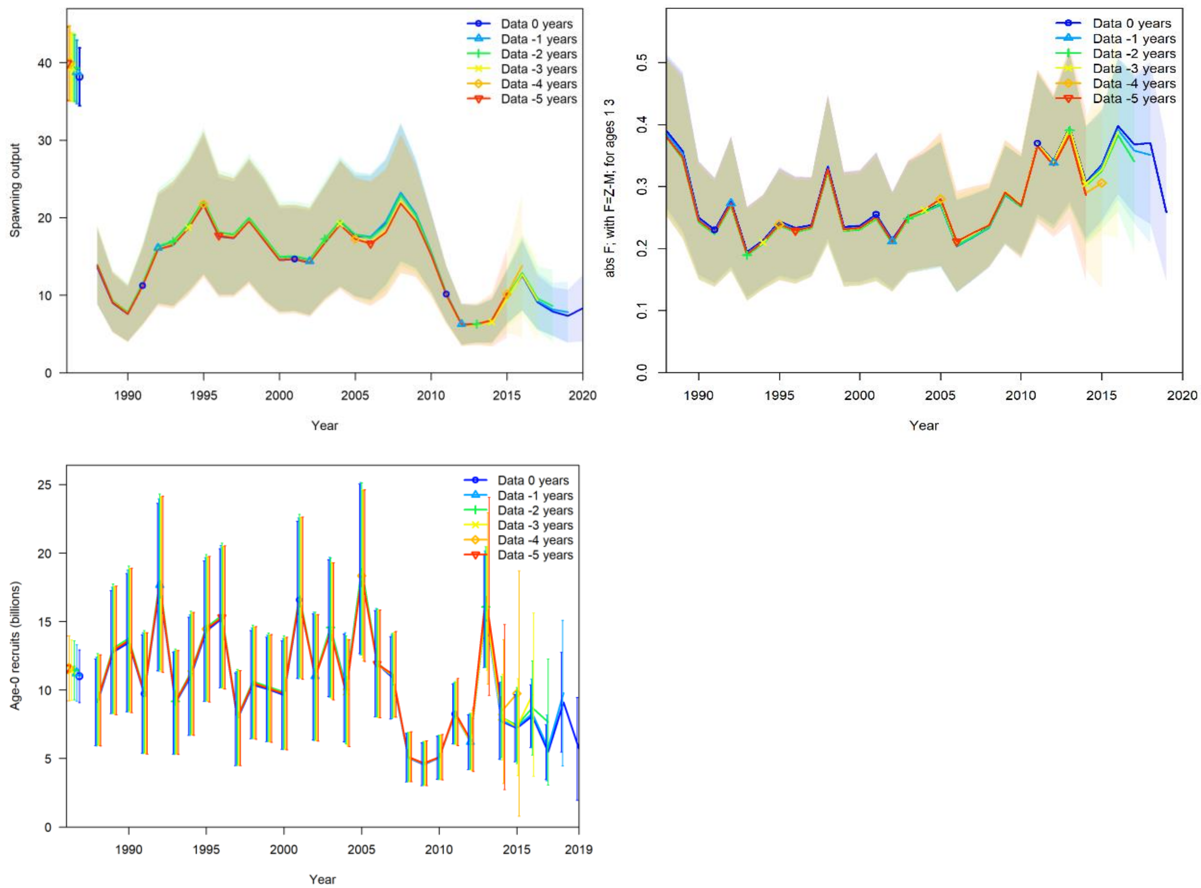

Figure 5.10. Northern shrimp in Skagerrak and Norwegian Deep: Model retrospective of SSB, F (ages 1–3) and R. It should be noted that values of F shown in these figures are not directly comparable to the F in Figure 5.9 (as the figures here are from the standard output of r4SS). Here, F is presented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

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

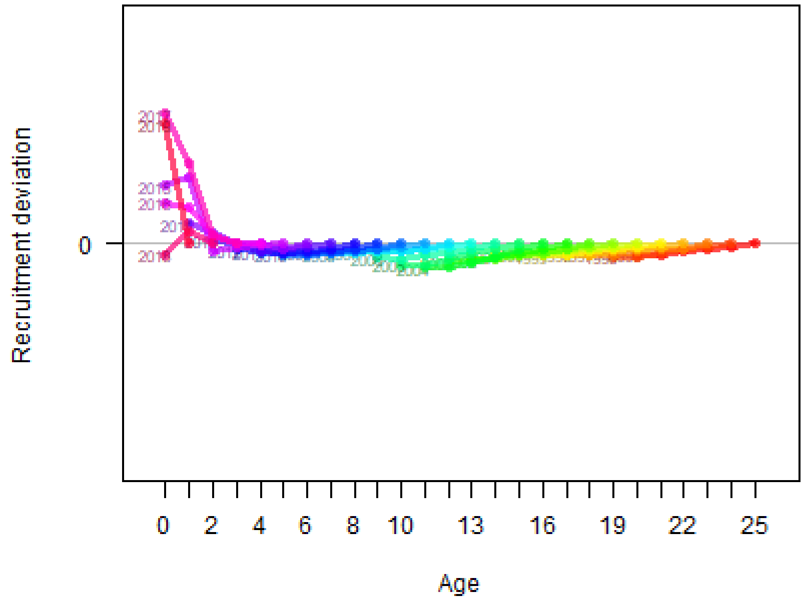

Figure 5.11. Northern shrimp in Skagerrak and Norwegian Deep: Model retrospective patterns in the estimation of recruitment deviations.

h) New long-term management strategy

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

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

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

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

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

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

The TAC will include all removals made from the stock.

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

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

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

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

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

i) Reference points

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

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

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

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

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

j) Catch scenarios

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

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

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

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

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

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

*** * SSB_{2021} relative to SSB_{2020}.**
**** Advised catch in 2020 relative to TACs in 2019 (6163 t). Note that NO and DK banked 523 t and 245 t, respectively, from 2018. These catches are not included in the TAC change.**
***** Advised catch in 2020 relative to advice value 2019 (6163 t).**

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

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

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

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

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

*** SSB_{2022} relative to SSB_{2021}.**
**** Advised catch in 2021 relative to advised catch in 2020 (8736 t).**
^ Total catch 2021 x average proportion of catch taken in the first two quarters of 2015–2019 (0.52).

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

The advice is in line with the previous year.

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

k) State of the stock

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

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

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

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

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

l) 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.

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APPENDIX VIII. ICES BENCHMARK PRIORITIZATION SCORING SHEET FOR NIPAG, NOVEMBER 2020

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 2020

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-analyze survey data for possible indices of recruitment need to develop a statistically coherent method to account for missing	4 If recruitment indices can be generated and CPUE data from all fleets are available, this is expected to reduce the retrospective problem. Explore the potential of age and/or size segregated models. Explore inclusion of explicit terms for natural mortality, eg. predation from cod etc. and the influence of other	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 2020	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.
	survey coverage Need to incorporate information on recruitment in the assessment model.	ecosystem parameters.			
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.	4 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. Correcting for missing survey data in some years using a statistical model. Alternative methods are currently	4 a,b,c	4 From the 2020 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.
		under development Work has been done to estimate M from unfished fjords.			
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	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.