Northwest Atlantic Fisheries Organization

Report of the Scientific Council and STACFIS Shrimp Assessment Meeting

12 to 16 September 2022
Vigo, Spain

NAFO
Halifax, Nova Scotia, Canada
2022

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REPORT OF THE SCIENTIFIC COUNCIL AND STACFIS SHRIMP ASSESSMENT MEETING
12-16 September 2022, Vigo, Spain

Chair: Diana Gonzalez Troncoso (EU) Rapporteur: Tom Blasdale

I. PLENARY SESSIONS

Scientific Council met from 12 to 16 September 2022 at the Hotel Ciudad de Vigo, Vigo, Spain to formulate management advice for northern shrimp stocks. Representatives attended from Canada, Denmark (in respect of the Faroe Islands and Greenland), the European Union, Norway, the Russian Federation and Ukraine. A full list of participants is included in Appendix VII.

The Chair, Diana Gonzalez Troncoso (EU) opened the meeting at 09:00 on 12 September and welcomed participants. The provisional agenda was adopted as circulated. The Scientific Council Coordinator was appointed as rapporteur.

II. REVIEW OF SCIENTIFIC COUNCIL RECOMMENDATIONS IN 2020 AND 2021

Recommendations from 2020 and 2021 are considered in the relevant sections of this report.

III. STANDING COMMITTEE ON FISHERIES SCIENCE (STACFIS)

Due to conflicts arising from ICES policy in relation to the war in Ukraine, it was not possible to hold the planned September meeting of NIPAG in 2022. Shrimp stocks in the NAFO Regulatory Area (NRA) and Greenland were therefore assessed by Scientific Council and STACFIS.

The September 2022 STACFIS report is presented as Appendix I in this report.

IV. MANAGEMENT ADVICE

1. Request for Advice on TACs and Other Management Measures

Scientific Council responded:

a) Northern Shrimp in Division 3M

Advice September 2022 for 2023

Recommendation

The indications of improved recruitment in 2020 did not result in an increase in stock biomass and the stock remains below B_{lim} in 2022. To be consistent with the NAFO precautionary approach, Scientific Council advises that no directed fishery should occur in 2023.

Management objectives

No explicit management plan or management objectives defined by the Commission. Convention general principles are applied. Advice is based on qualitative evaluation of biomass indices in relation to historic levels, and provided in the context of the precautionary approach framework (FC Doc. 04/18).

Convention objectives	*Status*	*Comment/consideration*
Restore to or maintain at B_{msy}	🔴	Stock below B_{lim}. B_{msy} is unknown.
Eliminate overfishing	🟢	No directed fishery
Apply Precautionary Approach	🟡	B_{lim} defined. No fishing mortality reference point defined
Minimize harmful impacts on living marine resources and ecosystems	🟢	VME closures in effect, sorting grids mandatory
Preserve marine biodiversity	⚪	Cannot be evaluated

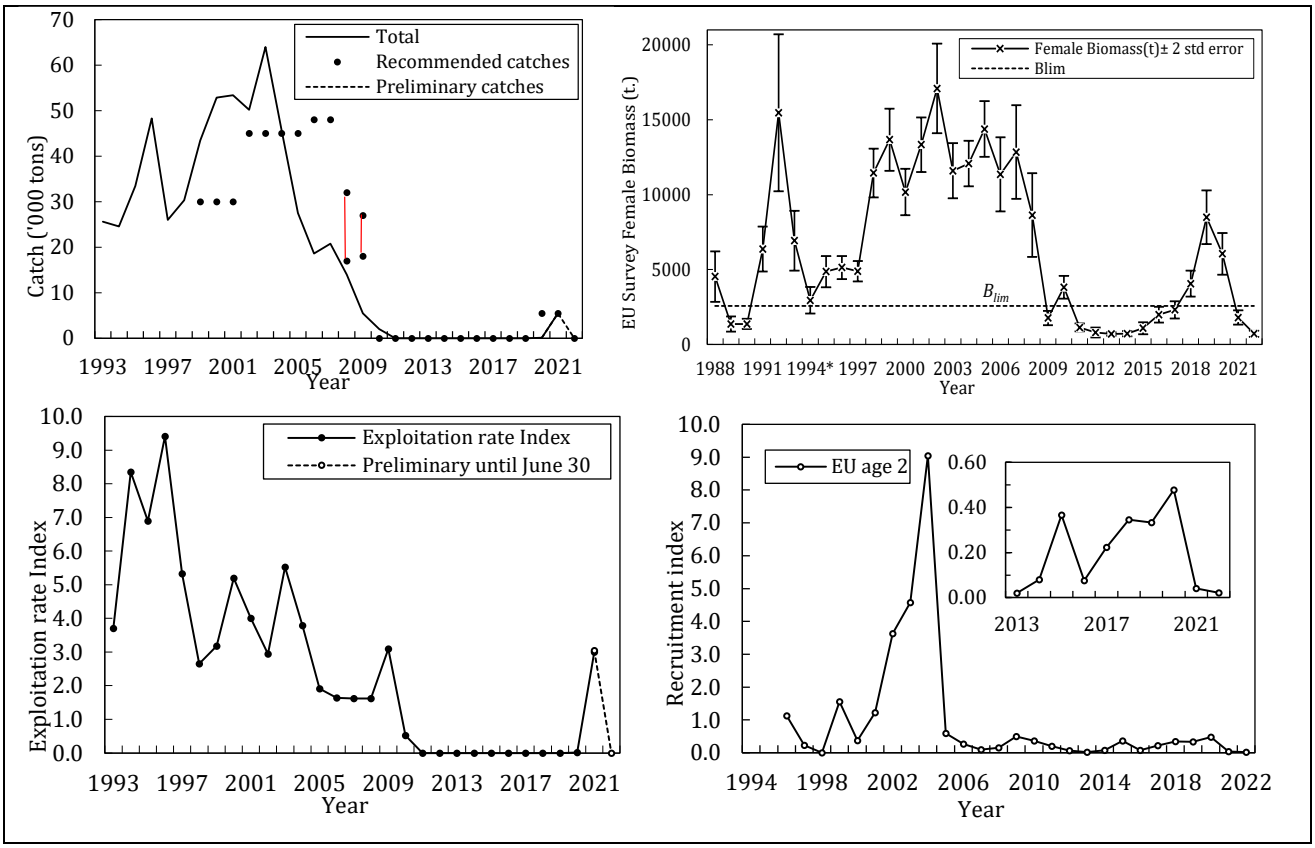
🟢 OK
🟡 Intermediate
🔴 Not accomplished
⚪ Unknown

Management unit

The northern shrimp stock on Flemish Cap is considered to be a separate population.

Stock status

Since 2021 the biomass has been below B_{lim}. The abundance at age 2 in 2021 and 2022 were the lowest of the historical series. Due to the low female survey biomass levels and weak recruitments, there are concerns that the stock will remain at low levels in the short term.



Reference points

Scientific Council considers that a female survey biomass index of 15% of its maximum observed level provides a proxy for B_{lim} (SCS Doc. 04/12). This corresponds to an index value of 2 564 t. A limit reference point for fishing mortality has not been defined.

Projections

Quantitative assessment of risk at various catch options is not possible for this stock at this time.

Assessment

No analytical assessment is available. Evaluation of stock status is based upon fishery and research survey data.

The next assessment will take place prior the NAFO Annual Meeting in September 2023.

Human impact

Mainly fishery related mortality and low bycatch in other fisheries. Other sources (e.g. pollution, shipping, oil-industry) are un-documented.

Biological and Environmental Interactions

Multispecies models (SCR Docs. 16-35, and 18-24), suggest that predation by cod and redfish, together with fishing, were the main factors driving the shrimp stock to the collapse after 2007.

Results of modelling suggest that, in unexploited conditions, cod and redfish would be expected to be a highly dominant component of the system, and high shrimp stock sizes like the ones observed in the 1998 – 2007 period would not be a stable feature in the Flemish Cap. It is uncertain whether this represents a causal relationship and/or covariance as a result of some environmental factor.

A 2018 summary of the state of the fish community in the Flemish Cap (3M) EPU indicated that this ecosystem has not experienced sustained reductions in overall productivity observed in other EPUs. With the exception of

a short-lived increase in 2005-2009, total biomass has remained fairly stable over time despite the changes in individual stocks.

Fishery

This fishery is effort-regulated. A moratorium was imposed in 2011. The fishery was reopened in 2020. Fishing effort and catches were very low in 2020 but increased in 2021. Due to the moratorium in 2022, catch and effort data is expected to be zero. Recent catches and agreed effort by the NAFO Commission were as follows:

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
NIPAG	0	0	0	0	0	0	0	79	6 042[3]	0[1]
STATLANT 21	0	0	0	0	0	0	0	0	5 905	N/A
Effort [2] (Agreed Days)	0	0	0	0	0	0	0	2 640	2 640	ndf
Effort days used								21	440	0[1]
SC Recommended Catches (tonnes)	ndf	ndf	ndf	ndf	ndf	ndf	ndf	5 448	5 448	0

[1] preliminary until 30 June

[2] effort regulated

[3] CESAG method

Effects of the fishery on the ecosystem

The fishery was closed to directed fishing from 2011 to 2019, and in 2022.

Special comments

In September 2019, the Commission asked the SC to advise on the possible sustainable management measures for northern shrimp in Div. 3M, including quota, fishing effort, periods or other technical measures. In its response, SC recommended that the management of 3M shrimp be converted from the existing "effort regulation" to "catch regulation" in line with all other stocks in the NAFO Regulatory Area. Full detail of the response is available in SCS Doc. 19-023

SC notes that only about 17% of the allocated effort was used in 2021, but the advised catch for 2021 was slightly exceeded. If all fishing days were used, the catches advised by SC would be expected to be greatly exceeded.

Source of Information

SCR Doc. 22/052

b) Northern shrimp in Denmark Strait and off East Greenland

Advice September 2022 for 2023

Recommendation

Catches of 2 500 t in 2023 will result in a low risk (6%) of biomass falling below B_{lim}. However, fishing at this level will result in a risk of more than 50% of fishing mortality exceeding F_{msy} and likely impede growth of the stock towards B_{msy}. SC recommends that catches should not exceed 2 000 t in 2023.

Management objectives

No explicit management plan or management objectives have been defined by the Government of Greenland. Advice was drafted to be consistent with the NAFO precautionary approach (FC Doc 04-12).

Objective	*Status*	*Comment/consideration*
Apply Precautionary Approach		B_{lim} is defined as 30% of B_{msy}

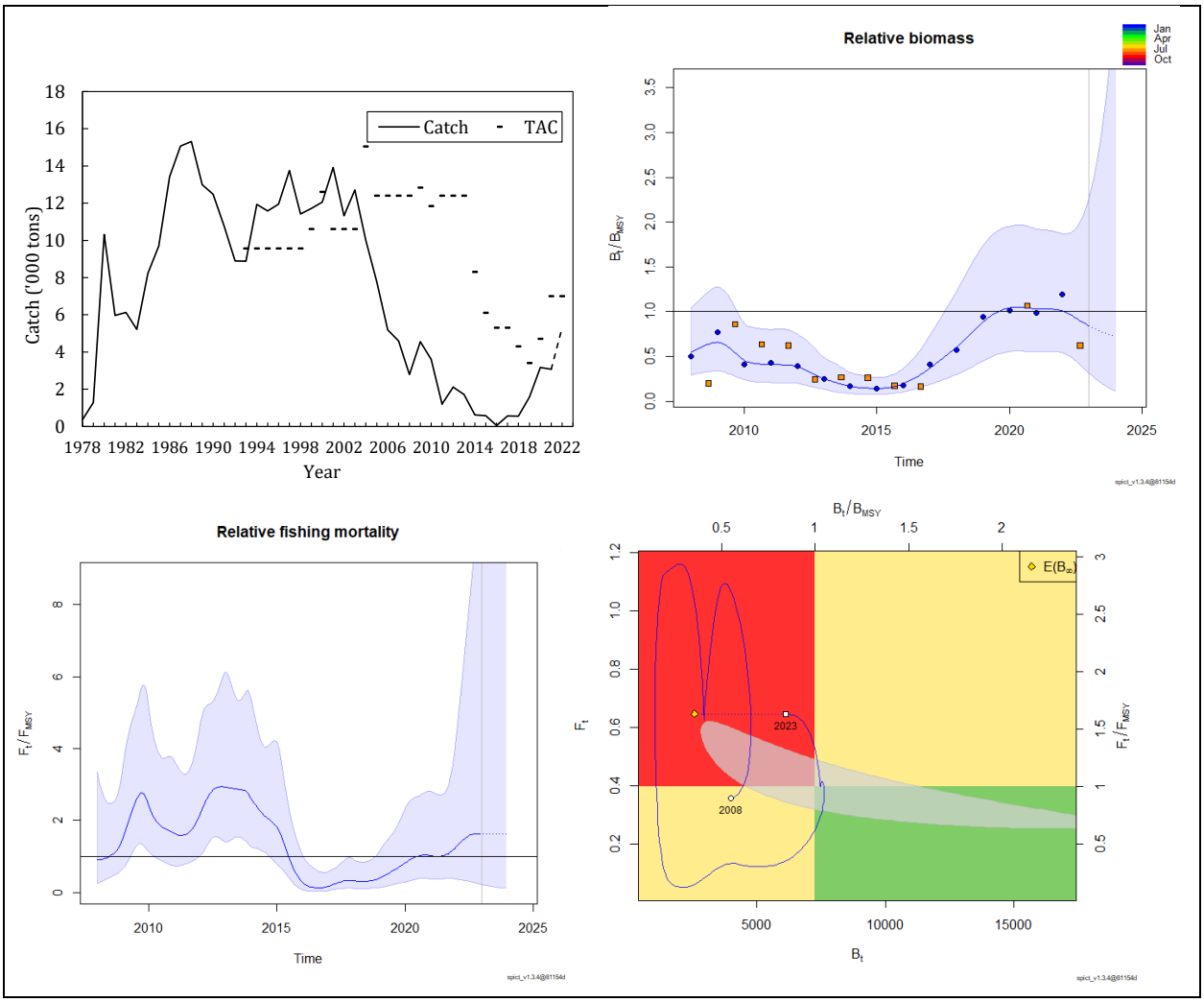
 OK

Management unit

The shrimp stock is distributed off East Greenland in ICES Div. 14b and 5a and is assessed as a single stock.

Stock status

Biomass is currently below B_{msy} (B/B_{msy} = 0.85). The probability of being below B_{lim} is currently 0.015. Fishing mortality is currently above F_{msy} (F/F_{msy} = 1.63). No estimates of recruitment are available.



Reference points

B_{lim} is 2 180 t which corresponds to 30% of B_{msy}. The SPiCT model uses relative reference points B/B_{msy} and F/F_{msy}. The current relative B/B_{msy} is 0.85 and the relative F/F_{msy} is 1.63. The probability of being below B_{lim} is currently 0.015.

Projections

Relative reference points are estimated for six catch options for 2023.

Catch (t)	B/B_{msy}	F/F_{msy}	Prob B > B_{msy}	Prob B < B_{lim}
1 500	1.03	0.56	0.52	0.01
2 000	0.96	0.77	0.47	0.03
2 500	0.89	1.01	0.43	0.06
3 000	0.81	1.26	0.40	0.10
3 500	0.74	1.54	0.37	0.16
4 000	0.66	1.86	0.34	0.22

Assessment

A comprehensive sensitivity analyses of the surplus production model in continuous time (SPiCT) was performed as recommended by NIPAG 2021 (SCR Doc 21/044). During the 2022 SC shrimp meeting an updated SPiCT model was presented and accepted as a valid assessment tool for this stock (SCR Doc. 22/051) based on a review of the model diagnostics.

The next assessment is scheduled for 2023.

Human impact
Mainly fishery related mortality has been documented. Other sources (e.g. pollution, shipping, oil-industry) are considered un-documented.

Biological and Environmental Interactions
Cod is an important predator on shrimp. The cod stock has fluctuated in East Greenland waters since 2014. The impact on the shrimp biomass is unknown.

Fishery

Shrimp is caught in a directed trawl fishery. The fishery is regulated by TAC and bycatch reduction measures include move-on rules and sorting grids.

Recent catches and TAC (t) were as follows:

	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Enacted TAC	12 400	8 300	6 100	5 300	5 300	4 300	3 384	4 750	7 000	6 850
SC Recommended TAC	12 400	2 000	2 000	2 000	2 000	2 000	2 000	3 000	3 000	3 000
NIPAG catch	1 717	622	576	49	561	547	1 580	3 172	3 067	5 295[1]

[1] To June 30

Effects of the fishery on the ecosystem

Measures to reduce effects of the fishery on the ecosystem include move-on rules to protect sponges and corals.

Source of Information

SCR Docs. 22/049, 22/050, 22/051, 21/044, FC Doc. 04-18

c) Northern shrimp in Subarea 1 and Div. 0A

Advice September 2022 for 2023

Recommendation

In line with Greenland's stated management objective of maintaining a mortality risk of no more than 35% (subject to a risk of biomass being below B_{lim} of less than 1%), Scientific Council advises that catches in 2023 should not exceed 110 000 t.

With regard to the Canadian harvest strategy, Scientific Council notes that catches of 110 000 t in 2023 would result in less than 35% risk of exceeding Z_{msy} in 2023 and 2024, and a 35% risk of exceeding Z_{msy} in 2025, assuming catches at the same level as in 2023.

Management Objectives

A management plan and management objectives have been defined by the Government of Greenland in 2018. The objective is to maintain a mortality risk of no more than 35% (subject to a risk of biomass being below B_{lim} of less than 1%). Canada has a harvest strategy with the objective to maintain the stock in the Healthy Zone (>80% of B_{msy}); when the biomass is above 80% of B_{msy}, the risk of being above Z_{msy} should be no more than 35%, based on the 3-year projections. Advice was also drafted to be consistent with the NAFO precautionary approach (FC Doc. 04-12).

Objective	*Status*	*Comment/consideration*
Maintain risk of being above Z_{msy} at no more than 35%		The TAC set for 2022 equates to a risk of being above Z_{msy} by the end of 2022 of 43%
Maintain the stock in the Healthy Zone (>80% of B_{msy})		The stock is above B_{msy} in 2022
Maintain risk of biomass being below B_{lim} of less than 1%		The risk of biomass in 2022 being below B_{lim} is less than 1%

 OK

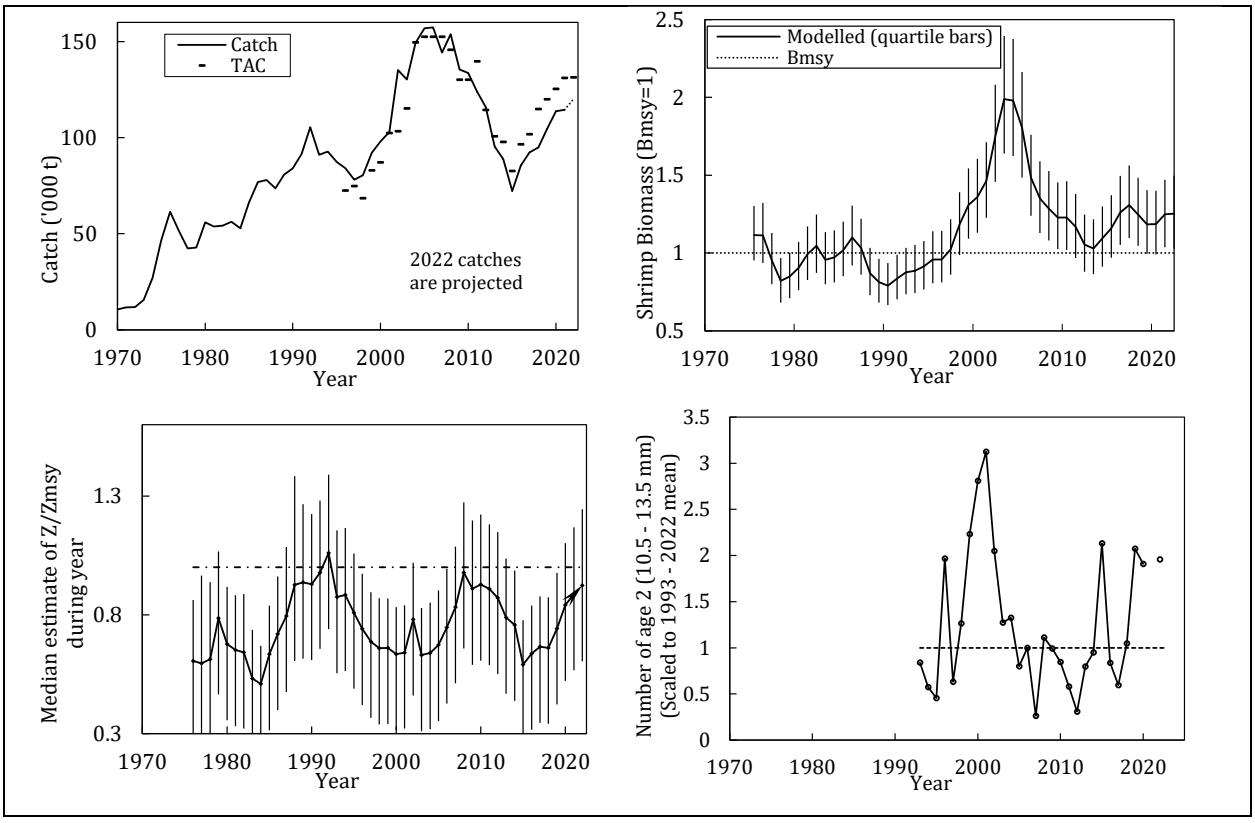
 Intermediate

Management unit

The stock, considered distinct from all others, is distributed throughout Subarea 1, extends into Div. 0A east of 60°30'W, and is assessed as a single stock. In 2021, more than 99% of the landings were from Greenland.

Stock status

Biomass in 2022 is above B_{msy} and the probability of being below B_{lim} is very low (<1%). The probability of mortality in 2022 being above Z_{msy} is 43%. Recruitment (number of age-2 shrimp) in 2022 was above average.



Reference points

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

Projections

Predicted probabilities of transgressing precautionary reference points in 2023 – 2025 under eight catch options and subject to predation by a cod stock with an effective biomass of 19 Kt.

19 Kt cod	**Catch option ('000 tons)**							
Risk of:	**95**	**100**	**105**	**110**	**115**	**120**	**125**	**130**
falling below Bmsy end 2023 (%)	24	24	23	25	25	25	26	26
falling below Bmsy end 2024 (%)	25	25	26	27	28	29	30	29
falling below Bmsy end 2025 (%)	25	27	27	29	30	32	33	33
falling below Blim end 2023 (%)	0	0	0	0	0	0	0	0
falling below Blim end 2024 (%)	0	0	0	0	0	0	0	0
falling below Blim end 2025 (%)	0	0	0	0	0	0	0	0
exceeding Zmsy in 2023 (%)	22	25	29	32	36	39	43	46
exceeding Zmsy in 2024 (%)	22	26	30	33	38	40	44	47
exceeding Zmsy in 2025 (%)	23	27	30	34	38	42	45	49
falling below Bmsy 80% end 2023 (%)	8	8	8	8	9	9	9	9
falling below Bmsy 80% end 2024 (%)	9	9	10	11	11	11	13	12
falling below Bmsy 80% end 2025 (%)	10	11	12	13	14	13	16	16

Assessment

Advice is based on risk analysis from a quantitative model. The analytical assessment was run in 2022 with updated input data series.

The next assessment is scheduled for 2023.

Human impact

Mortality related to the fishery has been documented. Other human sources (e.g. pollution, shipping, oil-industry) are un-documented.

Biological and Environmental Interactions

Cod is an important predator on shrimp. This assessment incorporates this interaction. Other predation is likely but not explicitly considered. Shrimps might be important predators on, for example, fish eggs and larvae.

Fishery

Shrimps are caught in a directed trawl fishery. Bycatch of fish in the shrimp fishery is around 1% by weight. The fishery is regulated by TAC.

Recent catches and TACs (t) have been as follows:

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Enacted TAC[1]	100 596	97 649	82 561	96 426	101 706	114 876	119 875	125 229	130 937	131 292
STATLANT 21	91 802	88 834	71 779	84 303	91 725	91 869	102 706	110 250	107 571	
NIPAG	95 381	88 765	72 256	85 527	92 584	94 878	104 314	113 758	114 569	120 000[2]

[1] Sum of TACs autonomously set by Canada and Greenland.
[2] Projected to year end.

Effects of the fishery on the ecosystem

Measures to reduce effects of the fishery on the ecosystem include area closures, moving rules and gear modifications to reduce damage to benthic communities and reduce bycatch.

Special comment

From 1993 to 2010 the Greenlandic survey in the Canadian area (SFA1) was conducted annually. In that period, average biomass in that area was 2% of the total biomass estimated in Subarea 1 and Div. 0A. Since 2011, due to ice cover, there has only been sporadic information from the Greenlandic survey in the Canadian area (SFA1). The area was surveyed only in 2013 and 2017. In 2013, the biomass in that area (SFA1) was less than 1% of the total estimated biomass in Subarea 1 and Div. 0A, whereas it was about 2% in 2017.

SC recommends that the projection table should be given in projected catch increments of no less than 5 Kt due to uncertainty in calculating risk levels.

Source of Information

SCS Doc 13/04, FC Docs 04-18, SCR Docs. 20/053, 20/057, 22/045, 22/046, 22/047, 22/048.

V. OTHER MATTERS

1. Scheduling of Future Meetings

a) Scientific Council meetings

i) Scientific Council, September 2022

The Annual Meeting will be held at the Palácio da Bolsa, Porto, Portugal from 19 to 23 September 2022.

ii) Scientific Council inter-sessional meeting, January 2023

SC will meet by Webex in January 2023 to finalize data series for MSEs. The meeting dates will be determined closer to the time.

iii) STACREC survey presentation virtual meeting, May 2023

STACREC will meet by Webex for one day during 1-10 May 2023 (day to be confirmed).

iv) Scientific Council, June 2023

The Scientific Council June 2023 meeting will be held at Saint Mary's University, Halifax from 2 to15 June 2023.

v) Scientific Council (in conjunction with NIPAG), 2023

Dates and location to be determined.

vi) Scientific Council Annual Meeting, September 2023

The Annual meeting will be held in Santiago de Compostela, from 18 to 22 September 2023.

b) NAFO/ICES Joint Groups

i) ICES/NAFO Working Group on Deep-water Ecosystem (WG-DEC), 2022

Dates and location to be determined.

ii) Joint ICES/NAFO/NAMMCO Working Group on Harp and Hooded Seals (WGHARP)

Dates and location to be determined.

iii) NIPAG, 2023

Dates and location to be determined.

c) Commission- Scientific Council Joint Working Groups

i) Joint Commission–Scientific Council Working Group on Ecosystems Approach Framework to Fisheries Management (WG-EAFFM), 2023

WG-EAFFM will meet in Halifax, Nova Scotia (unless an invitation to host the meeting is extended by a Contracting Party), likely during 17 - 28 July (to be confirmed).

ii) Joint Commission–Scientific Council Working Group on Risk-based Management Strategies (WG-RBMS), 2023

There will be two WG-RBMS meetings in 2023, both in Halifax, Nova Scotia (unless an invitation to host the meeting is extended by a Contracting Party), likely during 24 April - 5 May and 17 - 28 July (to be confirmed).

iii) Joint Commission–Scientific Council Catch Estimation Strategy Group (CESAG), 2023

Dates and location to be determined.

2. Topics for Future Special Sessions

No special session was proposed.

3. Other Business

No other business was discussed.

VI. ADOPTION OF REPORTS

The STACFIS report was adopted on 15 September 2022 subject to editorial revision following this meeting.

VII. ADJOURNMENT

NIPAG meeting was adjourned at 17:00 on 15 September 2022. The Chairs thanked all participants, especially the designated experts, for their hard work. The Chairs thanked the NAFO Secretariat for all of their logistical support and Spain for hosting the meeting. The report was adopted at the close of the meeting, subject to a period for editorial revision following this meeting.

APPENDIX I. REPORT OF STANDING COMMITTEE ON FISHERIES SCIENCE (STACFIS)

Chair: Mark Simpson Rapporteur: Tom Blasdale

I. OPENING

Due to conflicts arising from ICES policy in relation to the war in Ukraine, it was not possible to hold the planned September meeting of NIPAG in 2022. Shrimp stocks in the NAFO Regulatory Area (NRA) and Greenland were therefore assessed by Scientific Council and STACFIS.

STACFIS met from 12 to 16 September 2022 at the Hotel Ciudad de Vigo, Vigo, Spain to review stock assessments northern shrimp stocks. Representatives attended from Canada, Denmark (in respect of the Faroe Islands and Greenland), the European Union, Norway, the Russian Federation and Ukraine. A full list of participants is included in Appendix VII.

The Chair, Mark Simpson (Canada) opened the meeting at 09:00 on 12 September and welcomed participants. The provisional agenda was adopted as circulated. The Scientific Council Coordinator was appointed as rapporteur.

II. GENERAL REVIEW

1. Review of Research Recommendations in 2020 and 2021

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 on Flemish Cap (NAFO Div. 3M)

(SCR Doc. 04/77, 16/35, 18/24, 22/021,052)

Environmental Overview

Recent Highlights in Ocean Climate and Lower Trophic Levels for 3M

- After being mostly below normal between 2015 and 2019 (except for 2018), the ocean climate index in 3M has been normal in 2020 and 2021.
- The initiation of the spring phytoplankton bloom was earlier than normal in 2021 after 2 consecutive years of near-normal timing.
- Spring bloom magnitude returned to near normal in 2021 after the low production spring of 2020.
- The abundance of copepods and non-copepods as well as total zooplankton biomass increased to above normal in 2021 after two consecutive years of near or below-normal levels.

The water masses characteristic of the Flemish Cap area are a mixture of Labrador Current Slope Water and North Atlantic Current water, generally warmer and saltier than the sub-polar Newfoundland Shelf waters with a temperature range of 3-4°C and salinities in the range of 34-34.75. The general circulation in the vicinity of the Flemish Cap consists of the offshore branch of the Labrador Current which flows through the Flemish Pass on the Grand Bank side and a jet that flows eastward north of the Cap and then southward east of the Cap. To the south, the Gulf Stream flows to the northeast to form the North Atlantic Current and influences waters around the southern areas of the Cap. In the absence of strong wind forcing the circulation over the central Flemish Cap is dominated by a topographically induced anti-cyclonic (clockwise) gyre. Variation in the abiotic environment

influences the distribution and biological production of Newfoundland and Labrador Shelf and Slope waters where arctic, boreal, and temperate species coexist. The elevated temperatures on the Flemish Cap result in relatively ice-free conditions that may allow longer phytoplankton growing seasons compared to the Grand Banks where cooler conditions prevail. The entrainment of nutrient-rich North Atlantic Current water around the Flemish Cap generally supports higher primary and secondary production compared with the adjacent shelf waters. The stability of this circulation pattern may also influence the retention of ichthyoplankton on the Grand Bank which may influence year-class strength of various fish and invertebrate species.

Ocean Climate and Ecosystem Indicators

The ocean climate index in Div. 3M (Figure. 1.1A) has remained mostly above normal between the late 1990s and 2013. After the record high of 2011, the index gradually decreased reaching in 2016 its lowest value since 1993. After being below normal between 2015-2019 (with the exception of 2018 that was normal), the index was normal in 2020 and 2021.

Mean spring bloom initiation timing has been oscillating between earlier and later than normal between 2003 and 2020 with no clear variation pattern except for three consecutive early blooms from 2004 to 2006 (Figure 1.1B). Spring bloom magnitude (total production) has also been oscillating between above and below normal throughout the time series with a change in the sign of the anomalies (positive to negative) every 2-3 years (Figure 1.1C). Bloom magnitude returned to near normal in 2021 after the below-normal levels of the previous year and the three consecutive years of above-normal production from 2017-2019 (Figure 1.1C). In general, early bloom onsets (i.e., negative initiation anomalies) are associated with higher primary production (i.e. positive magnitude anomalies) and vice versa, but there are exceptions (Figure. 1.1B-C). Total copepod abundance rapidly increased between 1999 and 2010 and varied more during the 2010s although it mostly remained near or above normal except for the low abundances recorded in 2014 and 2019 (Figure 1.1D). The abundance of non-copepods showed a general increase from 1999 to 2018 but followed by a decline in the late 2010s similar to that of copepod. In 2021 the abundance of both copepods and non-copepods was back to above normal (Figure. 1.1D-E). Total zooplankton biomass generally increased during the 2010s despite interannual variability, and remained mostly near normal afterwards besides the high value of 2016. In 2021, mean zooplankton biomass in the region was slightly above normal (Figure. 1.1F).

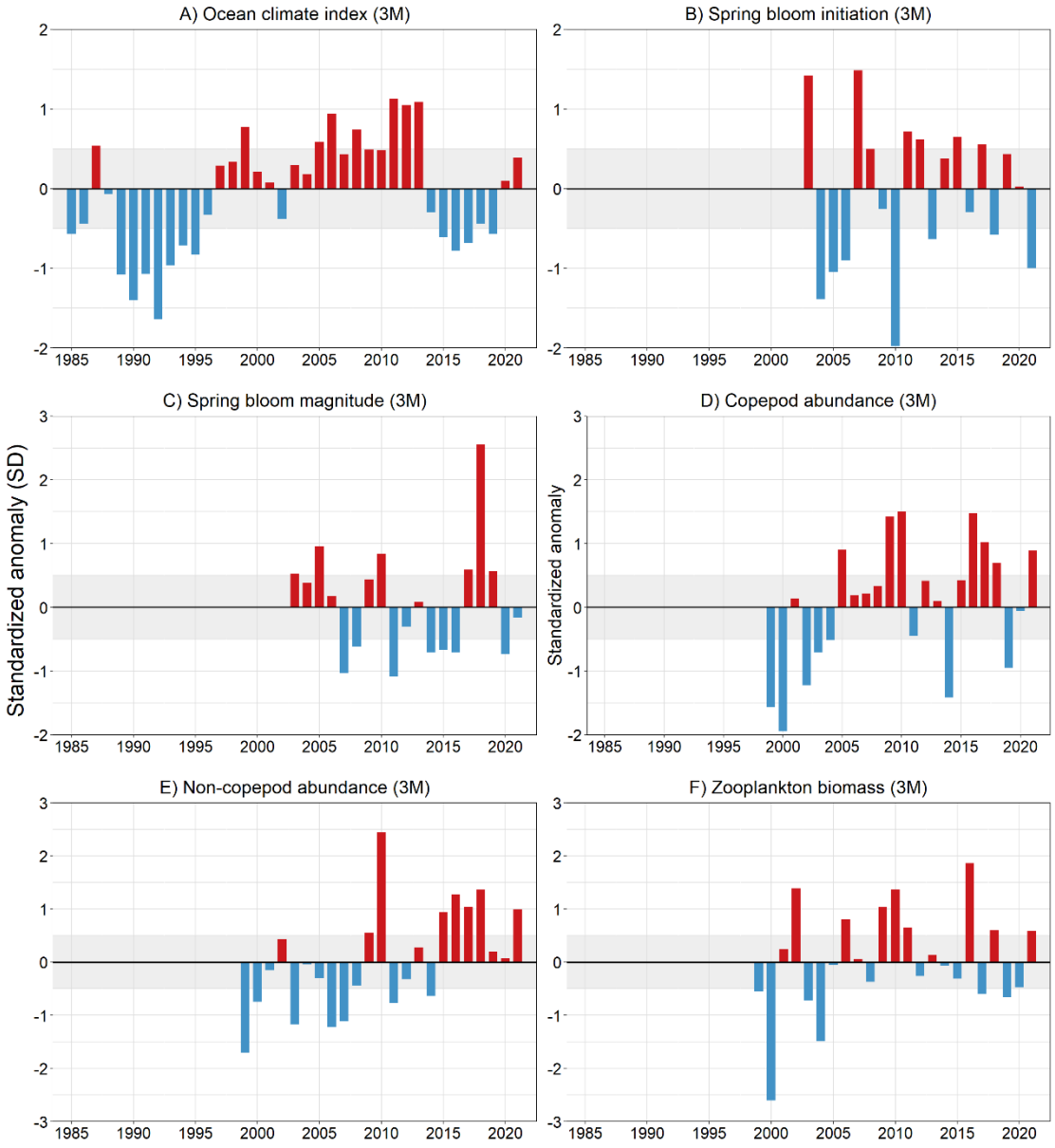


Figure 1.1. Annual anomalies of environmental indices for Flemish Cap (in NAFO Div. 3M). The ocean climate index (A) for the period 1990-2020 is the average of three time series of standardized ocean temperature anomalies of sea surface temperatures (SSTs), hydrographic section observations and summer mean bottom temperature over the cap (see SCR Doc.18-024 for details). Spring bloom anomalies (B, C) for the 2003-2021 period were averaged over two satellite boxes (FP, FC – see SCR Doc. 22-021 for details). Zooplankton anomalies (D-F) for the period 1999-2021 were calculated using data from the portion of the FC section located within NAFO Div. 3M (see SCR Doc.18-024 for details). Positive (negative) anomalies indicate late (early) bloom timing or conditions above (below) the mean for the reference period. Anomalies were calculated using the following reference periods: ocean climate index: 1981-2010, spring bloom indices: 2003-2020, zooplankton indices: 1999-2020. Anomalies within ± 0.5 SD (shaded area) are considered near-normal conditions.

a) Introduction

The shrimp fishery in Div. 3M began in 1993. Catches peaked at over 60 000 t in 2003 and declined thereafter. A moratorium was imposed from 2011 to 2019. In 2020 the fishery was resumed with very low catches that increased to 5 457 t in 2021. Due to a new moratorium for 2022, there is no shrimp fishing in Div. 3M.

Fishery and catches: This stock is under effort regulation. The fishery was reopened in 2020 after nine years under moratorium with 2 640 fishing days. The effort directed to the shrimp fishery and catches in 2020 were very low (19 days and 79 t) but increased in 2021 (440 days and 5 457 t) (Figure 1.2).

Recent catches (tonnes) and effort agreed by the NAFO Commission were as follows (ndf=no directed fishery):

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
NIPAG	0	0	0	0	0	0	0	79	6 042[3]	0[1]
STATLANT 21	0	0	0	0	0	0	0	0	5 905	0
SC Recommended Catches	ndf	ndf	ndf	ndf	ndf	ndf	Ndf	5 448	5 448	ndf
Effort[2] (Agreed Days)	0	0	0	0	0	0	0	2 640	2 640	0

[1] preliminary until 30 June

[2] effort regulated

[3] CESAG method

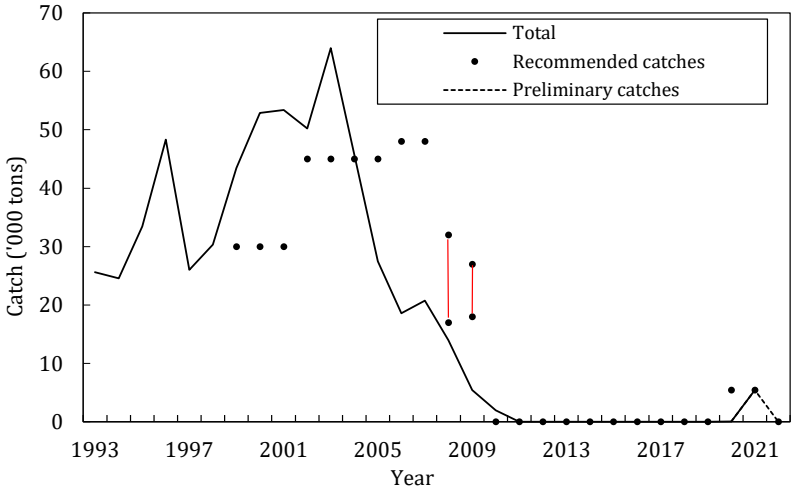


Figure 1.2. Shrimp in Div. 3M: Catches ('000 t) of shrimp on Flemish Cap and catches recommended in the period 1993-2022 (red lines in 2008 and 2009 indicate the catches range recommended by SC and dashed line preliminary catches of 2022).

b) Input Data

i) Commercial fishery data

Because of the moratorium, catch and effort data were not available from 2011 to 2019. For the fishery in 2020 and 2021, the standardized CPUE series were not analyzed for this assessment.

ii) Research Survey Data

EU Bottom Trawl Research Survey. Stratified-random trawl surveys have been conducted on Flemish Cap by the EU in July from 1988 to 2022. A new vessel was introduced in 2003 which continued to use the same trawl employed since 1988. The series prior to 2003 was converted into comparable units with the new vessel using the methods accepted by STACFIS in 2004 (SCR Doc. 04-77).

c) Assessment

No analytical assessment is available. Evaluation of stock status is based upon interpretation of commercial fishery information and research survey data.

Biomass: The survey female biomass index was stable at a high level from 1998 to 2007, and subsequently declined until 2014. Since 2015 the female biomass index increased successively and in 2019 the estimated female biomass was well above B_{lim}. In 2020 the female biomass experienced some decrease but remained above $B_{lim.}$ Since 2021 the biomass has been below B_{lim} (Figure 1.3).

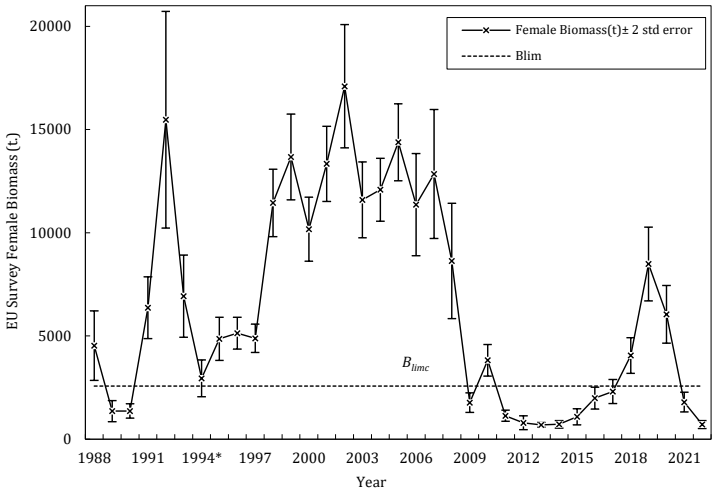


Figure. 1.3. Shrimp in Div. 3M: Female biomass index from EU trawl surveys, 1988-2022. Error bars are 2 std. err.

Recruitment: Considering the abundance at age 2 as indicator of recruitment, recruitment has been low since 2005, with the exception of 2020 (juvenile bag). The abundance at age 2 in the main gear in 2021 and 2022 were the lowest of the historical series (Figure 1.4).

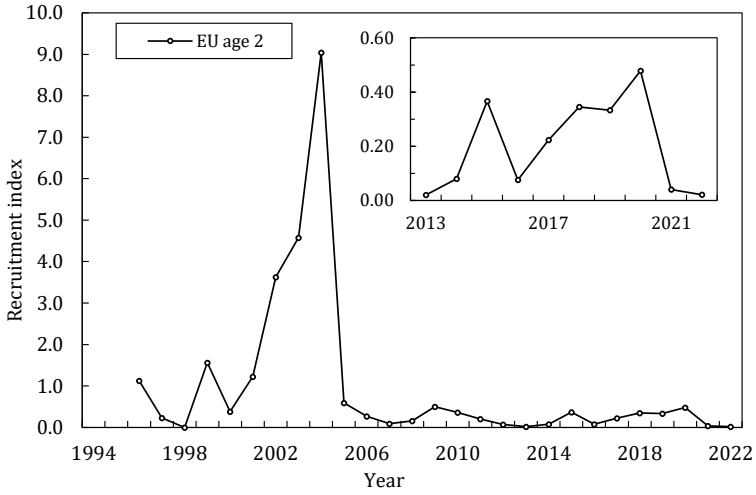


Figure. 1.4. Shrimp in Div. 3M: Abundance indices at age 2 from the EU survey. Each series was standardized to its mean. Inset shows EU main gear on a different vertical scale for the most recent period.

Exploitation rate: Due to the moratorium, the exploitation rate index was zero from 2011 to 2019. In 2020, the fishery resumed but the effort directed to shrimp fisheries and catches were low resulting in a very low exploitation rate (0.01). In 2021 the exploitation rate increased notably (3.0) due to the increase in the catches (5 457 t) and the decrease in the EU survey female biomass index (Figure 1.5). With the new moratorium established for 2022 the exploitation rate is expected to be zero.

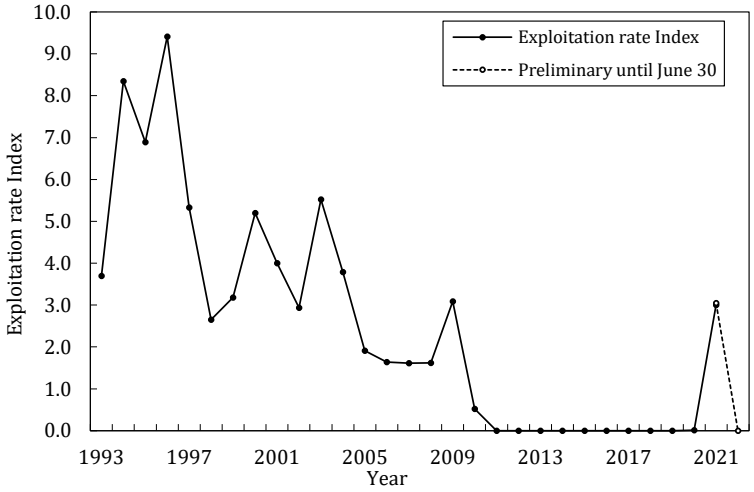


Figure. 1.5. Shrimp in Div. 3M: Exploitation rate index as derived by catch divided by the EU survey biomass index of the same year.

d) State of the stock

Since 2021 the biomass has been below B_{lim}. The abundance at age 2 in the main gear in 2021 and 2022 were the lowest of the historical series. Due to the low female survey biomass levels and weak recruitments, there are concerns that the stock will remain at low levels in the short term.

e) Reference Points

Scientific Council considers that a female survey biomass index of 15% of its maximum observed level provides a proxy for B_{lim}. This corresponds to an index value of 2 564 t (Figure 1.6). A limit reference point for fishing mortality has not been defined.

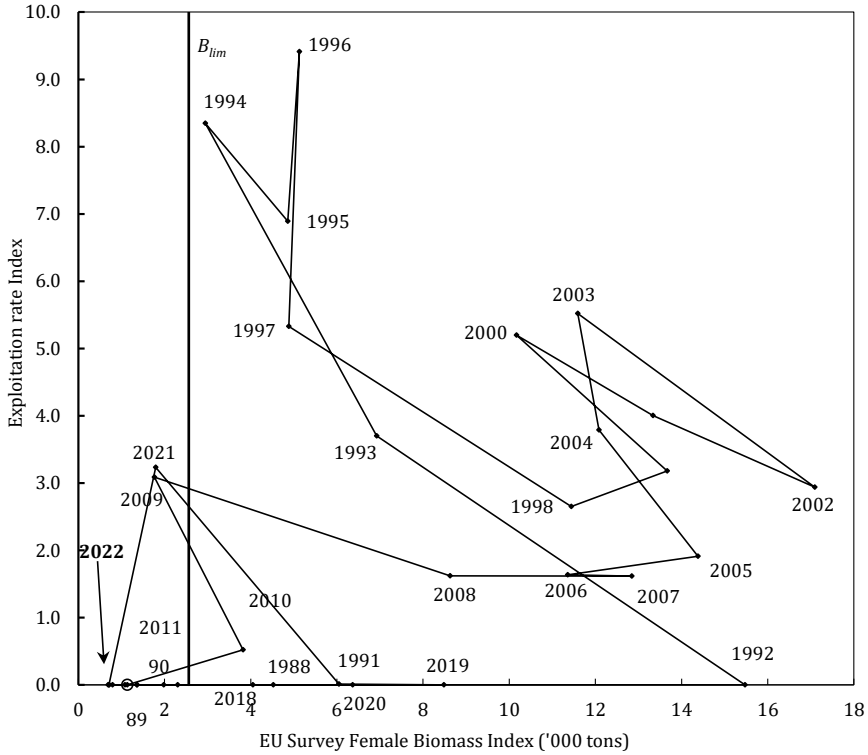


Figure. 1.6. Shrimp in Div. 3M: Exploitation rate index plotted against female biomass index from EU survey. Line denoting B_{lim} is drawn where biomass is 15% of the maximum point in 2002.

f) Ecosystem considerations

Multispecies models (SCR 16/35, SCR 18/24), suggest that predation by cod and redfish, together with fishing, have been the main factors driving the shrimp stock to the collapse after 2007. Results of modelling suggest that, in unexploited conditions, cod and redfish would be expected to be a highly dominant component of the system, and high shrimp stock sizes like the ones observed in the 1998 – 2007 period would not be a stable feature in the Flemish Cap (Figure 1.7). It is uncertain whether this represents a causal relationship and/or covariance as a result of some environmental factor.

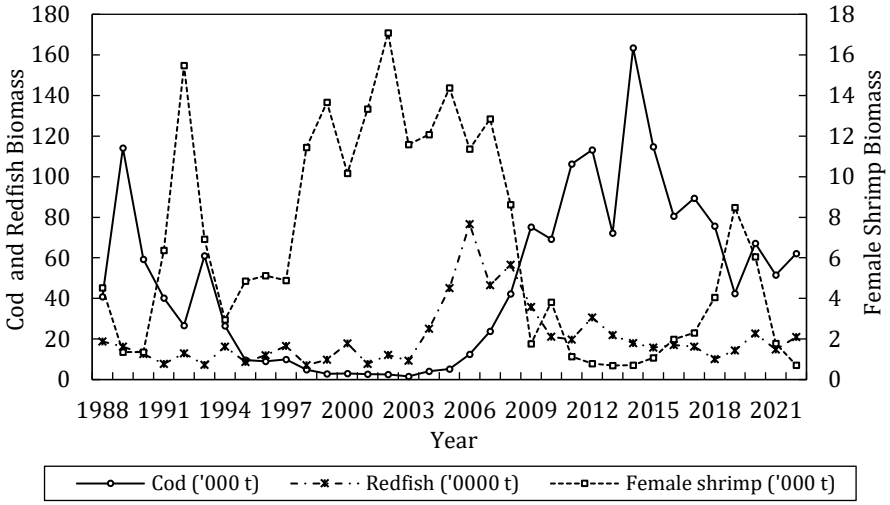


Figure. 1.7. Shrimp in Div. 3M: Cod, redfish and female shrimp biomass from EU trawl surveys, 1988-2022. Data from 2022 for cod and redfish are preliminary.

g) Research Recommendations

For Northern shrimp in Div. 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.*

STATUS: No progress from last year.

In 2019, NIPAG **recommended** 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.*

STATUS: addressed under the next recommendation below.

In 2019, NIPAG **recommended** 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.

STATUS: Advances were made during the benchmark workshop in January 2022. Modelling with SS3 and SPiCT yielded limited progress due to lack of adequate information to implement the models. Work will continue.

The next assessment will take place prior the NAFO Annual Meeting in September 2023.

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

(SCR Docs. 04/01, 22/021)

Environmental Overview

Recent Highlights in Ocean Climate and Lower Trophic Levels for 3LNO

- In 2021, the ocean climate in NAFO Divs. 3LNO - Grand Bank, was at its second warmest value of the entire time series started in 1975 (after the record high of 2011).
- Spring bloom initiation was near normal in 2021 for a 3rd consecutive year.
- Spring bloom magnitude decreased to below normal in 2021 and was among the lowest of the time series.
- The abundance of copepods and non-copepods remained above normal in 2021 for a 6th consecutive year with a time series record high for copepods.
- Zooplankton biomass was above normal in 2021 for the third time over the past five years.

The water mass characteristic of the Grand Bank are typical of sub-polar waters, with the presence of a cold intermediate layer (CIL) formed during winter, and which last throughout the year until the late fall. The CIL (defined as water <0°C) extends to the ocean bottom in the northern areas of 3LNO, covering the bottom with sub-zero temperatures. The CIL is thus 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 Gulf Stream. 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 2.1A) 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 (except for 2015 and 2017 that was below normal). In 2020 and 2021, the ocean climate index was back to above normal value, reaching in 2021 the second highest value of the entire time series started in 1985 (only 2011 was warmest).

There was a general shift toward earlier spring bloom timing on the Grand Bank from 2003 to 2013 despite interannual variability (Figure 2.1B). Spring bloom timing remained either near or later than normal afterward except for the early blooms of 2018. Spring bloom magnitude (total production) was quite variable in 3LNO throughout the time series with no clear temporal pattern. Total spring production in 2021 was third lowest of the time series after three years of a steady decline that followed the 2018 record high (Figure 2.1C). The abundance of copepods and non-copepods generally increased throughout the time series with a clear transition from negative to positive anomalies around 2010. Abundance has remained above normal since 2016 for both groups with a record high for copepods and one of the three highest values on record for non-copepods in 2021 (Figure 2.1D-E). Total zooplankton biomass generally declined from the early 2000s through 2014 but has increased to near or above normal afterward. In 2021, biomass was above normal for the third time over the past five years (Figure 2.1F).

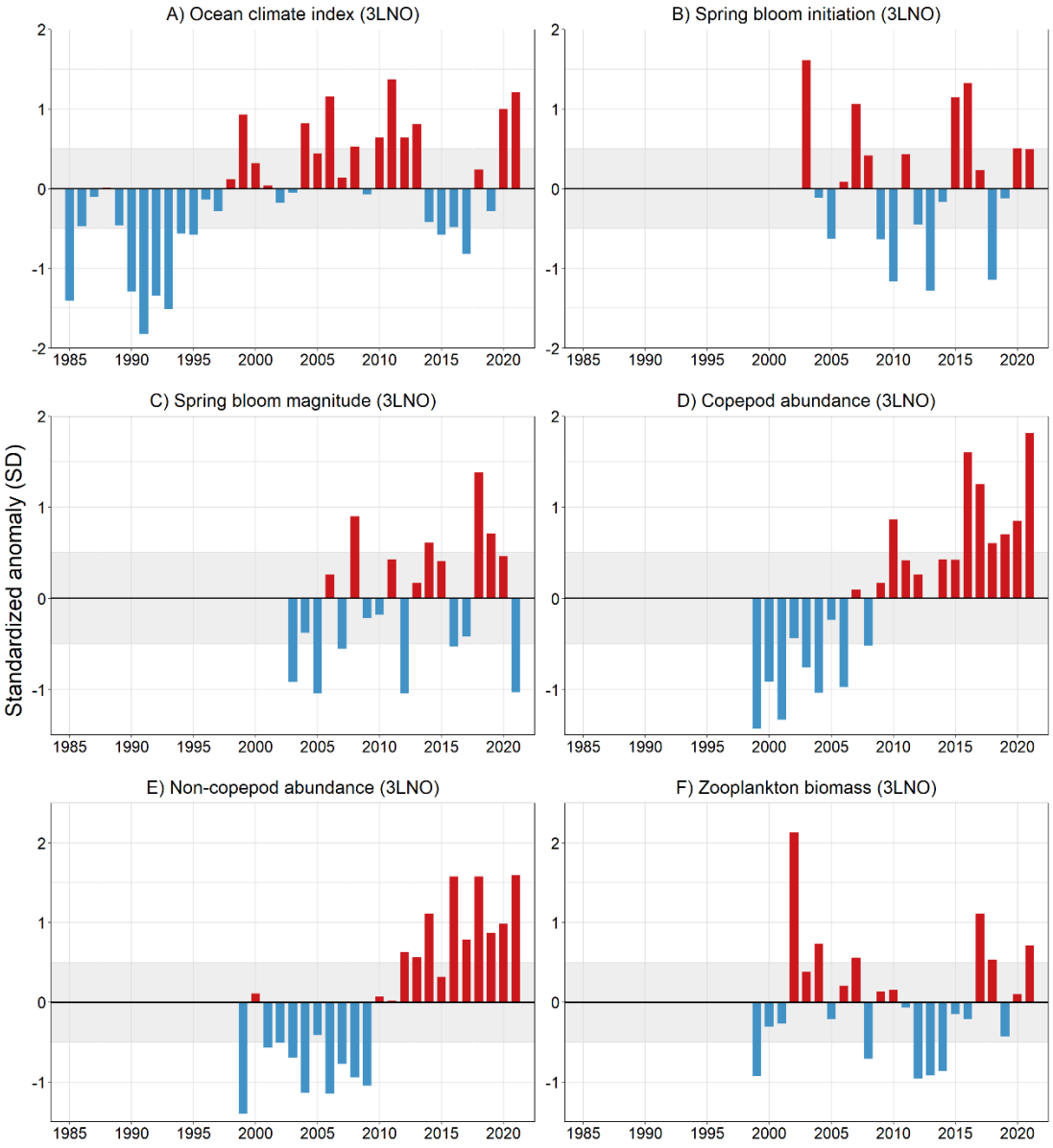

A) Ocean climate index (3LNO)
B) Spring bloom initiation (3LNO)
C) Spring bloom magnitude (3LNO)
D) Copepod abundance (3LNO)
E) Non-copepod abundance (3LNO)
F) Zooplankton biomass (3LNO)
Standardized anomaly (SD)
2
1
0
-1
-2
1985
1990
1995
2000
2005
2010
2015
2020

Figure 2.1. Annual anomalies of environmental indices for NAFO Divs. 3LNO. The ocean climate index (A) during 1985-2012 is the average of twelve individual time series of standardized ocean temperature anomalies: 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 (see SCR Doc. 22-021 for details). Spring bloom anomalies (B, C) for the 2003-2020 period were averaged over two satellite boxes (NGB, SE – see SCR Doc. 22-021 for details). Zooplankton anomalies (D-F) for the 1999-2021 period are derived from two oceanographic sections (3LN portion of FC, SEGB – see SCR Doc. 22-021 for details) and one coastal high-frequency sampling site (S27). Positive (negative) anomalies indicate late (early) bloom timing or conditions above (below) the mean for the reference period. Anomalies were calculated using the following reference periods: ocean climate index: 1981-2010, phytoplankton indices: 2003-2020, zooplankton indices: 1999-2020. Anomalies within ±0.5 SD (shaded area) are considered normal conditions.

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 2022 (Figure 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 Divs. 3LNO (total) are as follows:

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
TAC	9 393	4 697	ndf	ndf	ndf	ndf	ndf	ndf	ndf	ndf
STATLANT 21	7 919	2 282	0	0	0	0	0	0	0	
NIPAG	8 647	2 289	0	0	0	0	0	0	0	

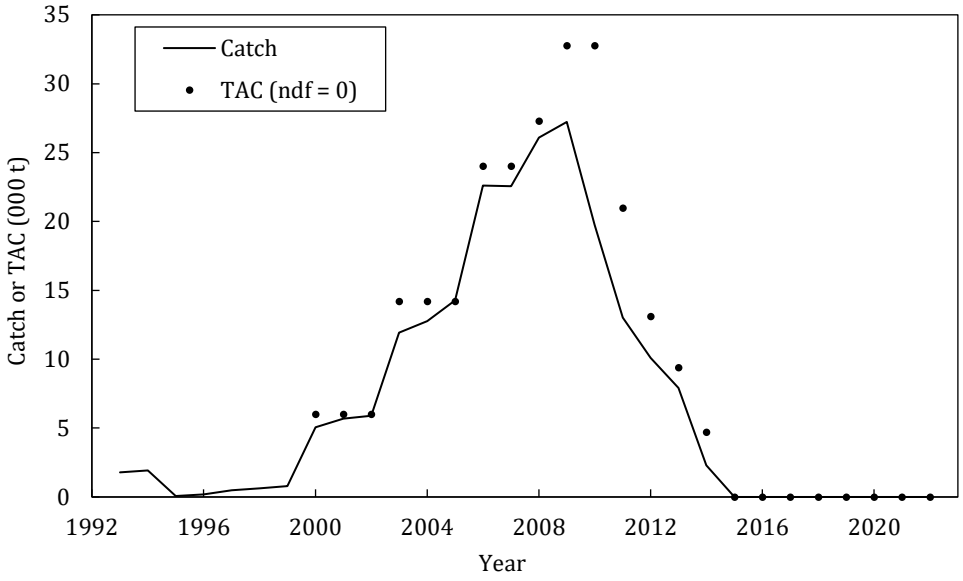


Figure 2.2. Shrimp in Divs. 3LNO: Catches and TAC. The TAC illustrated includes the autonomous quotas set by Denmark (in respect of the Faroe Islands and Greenland). No directed fishing is plotted as zero TAC.

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 has been no fishery from 2015 to present.

ii) Research survey data

Canadian multi-species trawl survey. Canada has conducted stratified-random surveys in Divs. 3LNO, using a Campelen 1800 shrimp trawl for spring (1999–2019) and autumn (1996–2020). The autumn survey in 2004 and 2021, and the spring surveys in 2015, 2017-2018 and 2020-2022 were incomplete and therefore could not be used to produce biomass indices for Divs. 3LNO. The autumn 2014 survey only surveyed Div. 3L, however since about 95% of the biomass in Divs. 3LNO comes from Div. 3L annually, it was considered useful as a proxy for Divs. 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 Divs. 3NO since 1995. Data are collected

with a Campelen 1800 trawl. There were no EU-Spain Div. 3L surveys in 2005 or 2020-2022 and no Divs. 3NO 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 the lowest levels in the autumn time-series in 2018 and the second lowest level in the spring time-series in 2019 (Figure 2.3). While autumn indices increased slightly from 2018 to 2020, they remained amongst the lowest levels in the autumn time-series. There have been no updated Canadian surveys since autumn 2020.

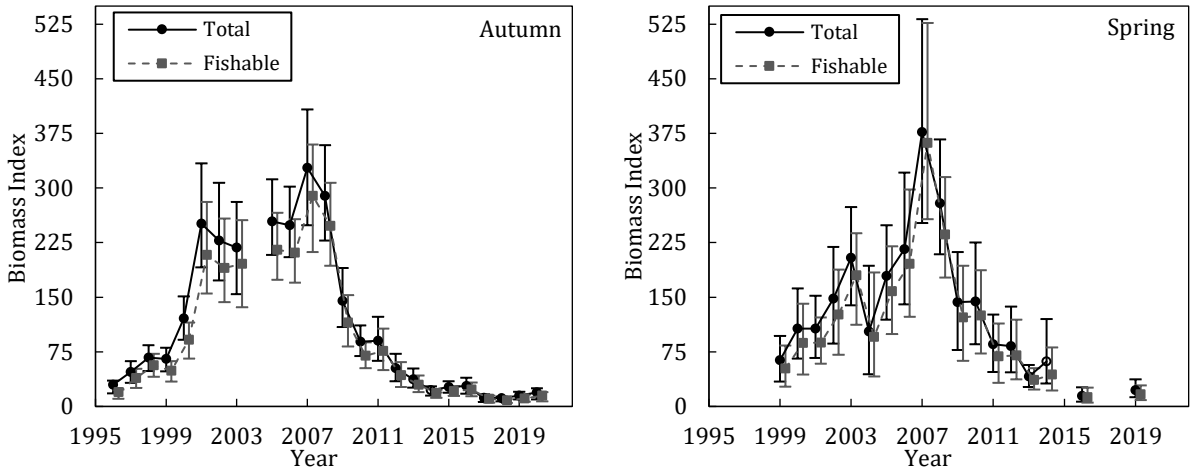


Figure 2.3. Shrimp in Divs. 3LNO: Total and fishable biomass index estimates from Canadian autumn and spring multi-species surveys (with 95% confidence intervals). The 2014 autumn index is for Div. 3L only. There are no available biomass index estimates for autumn 2021 or for spring 2015, 2017-2018 or 2020-2022.

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). Over 95% of the biomass is caught in the Div. 3L area of this survey. The 2022 survey of Divs. 3NO indicated that the biomass index has increased since 2021, however it is still far below the biomass levels of 2003-2007.

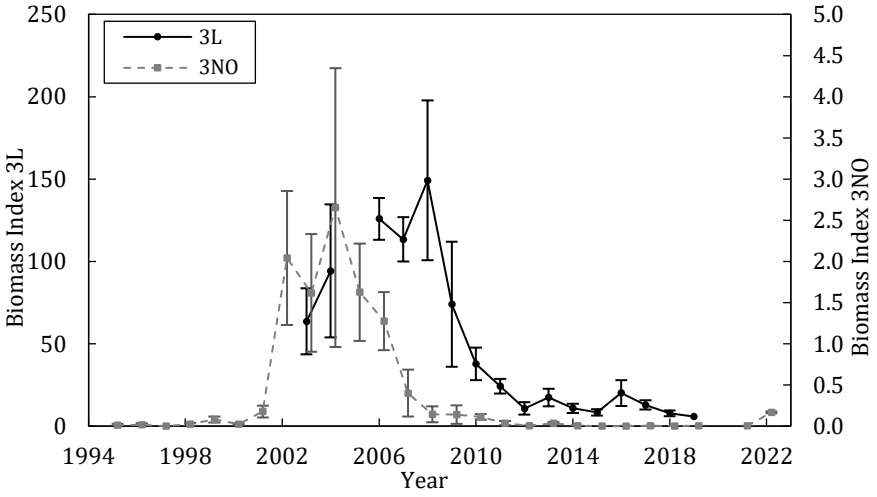


Figure 2.4. Shrimp in Divs. 3LNO: Total biomass index estimates from EU - Spain multi-species surveys (± 1 SE) in the NAFO Regulatory Area (NRA) of Divs. 3LNO. There are no available biomass index estimates for 2020 and only Divs. 3NO were surveyed in 2005 and 2021-2022.

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).

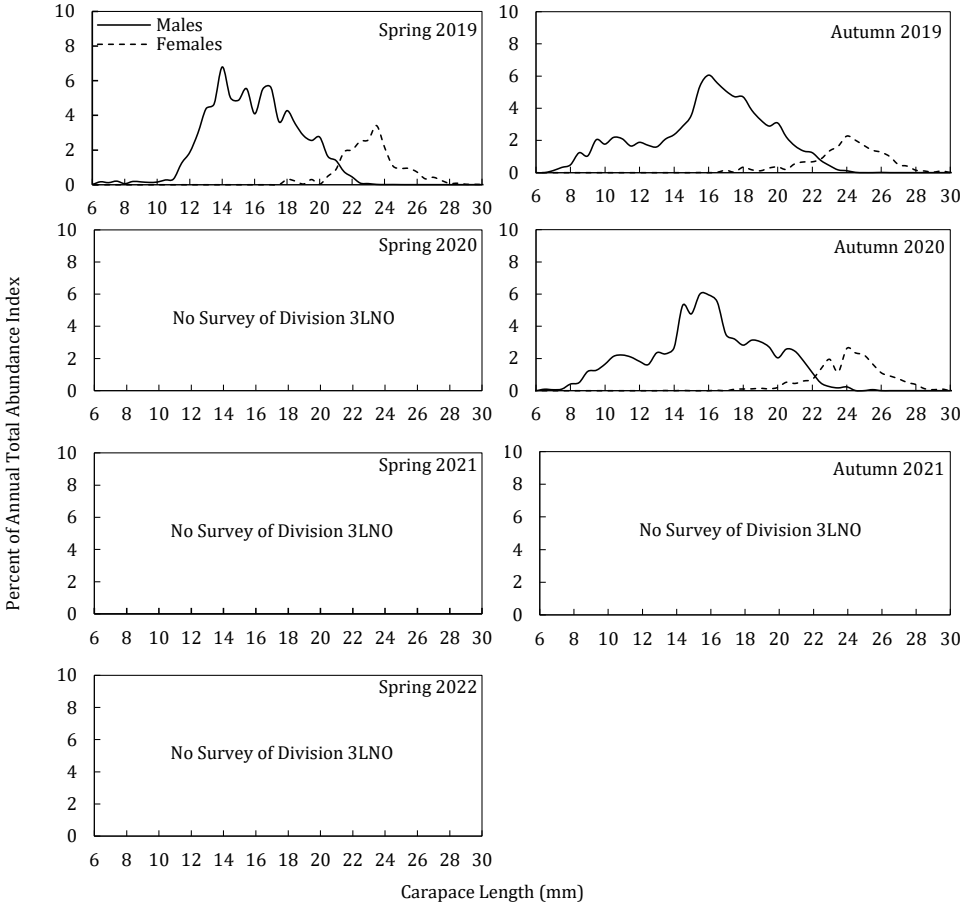


Figure 2.5. Shrimp in Divs. 3LNO: Composition of survey catches (percentage at length) from Canadian spring and autumn multi-species survey data. No data for autumn 2021 or spring 2020-2022.

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., 2018) 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 Divs. 3LNO.

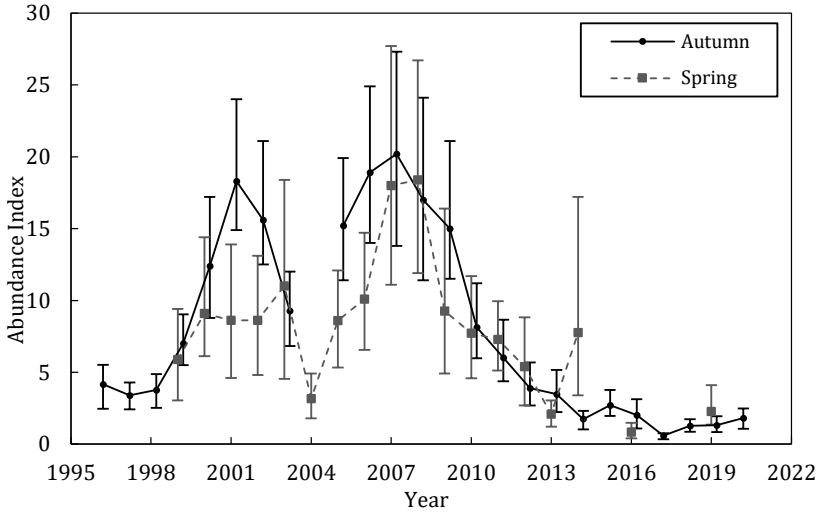


Figure 2.6. Shrimp in Divs. 3LNO: Indices of recruitment-sized shrimp based on abundance of shrimp with 11.5 – 17 mm carapace lengths from Canadian spring and autumn multi-species surveys. Error bars represent 95% confidence intervals. The autumn index for 2014 is for Div. 3L only.

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 2015-2022, the exploitation index is zero for that period of time. Mortality due to bycatch during other fisheries is unknown.

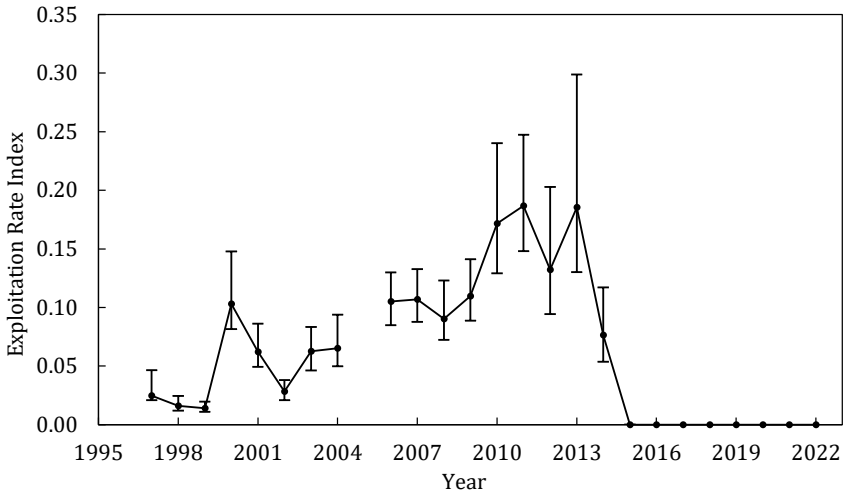


Figure 2.7. Shrimp in Divs. 3LNO: Exploitation indices calculated as a year's catch divided by the previous year's autumn fishable biomass index. Error bars (calculated based on estimates of fishable biomass index) indicate 95% confidence intervals.

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 2021 the risk of being below B_{lim} was greater than 95% (Figure 2.8 and Figure 2.9), there has been no Canadian survey to update the stock related to B_{lim} since. A limit reference point for fishing mortality has not been defined.

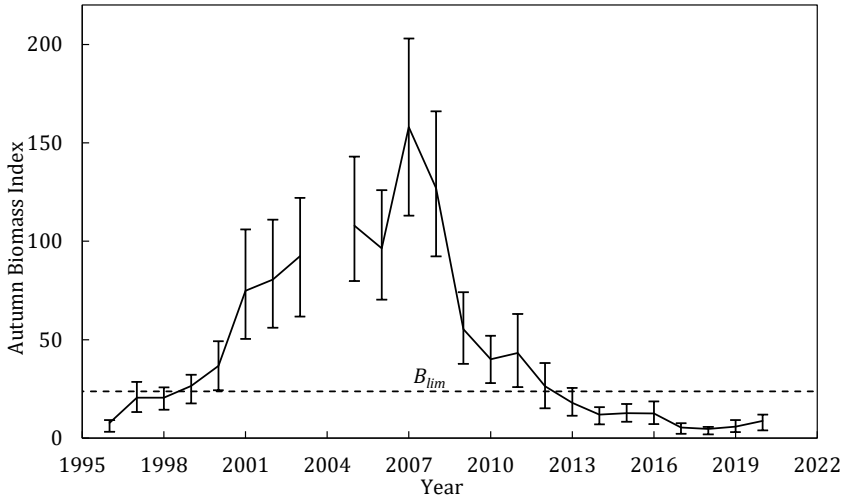


Figure 2.8. Shrimp in Divs. 3LNO: Autumn female spawning stock biomass index (SSB) and B_{lim}. B_{lim} is defined as 15% of the maximum autumn female biomass over the time-series. Error bars indicate 95% confidence intervals. The autumn index for 2014 is for Div. 3L only.

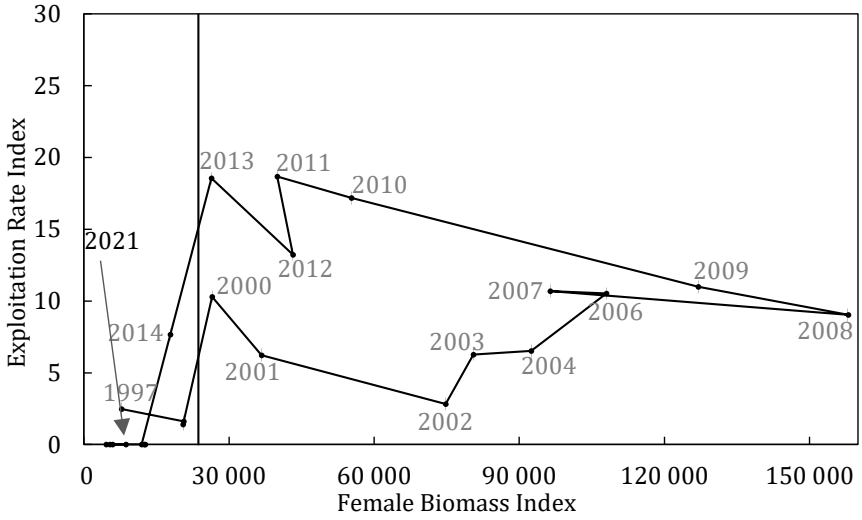


Figure 2.9. Shrimp in Divs. 3LNO: Exploitation rate vs female SSB index from Canadian autumn survey. Vertical line denotes B_{lim}.

e) State of the stock

Biomass. Spring and autumn biomass indices have decreased considerably since 2007 and were among the lowest levels in the time series as of the last available surveys.

Recruitment. Recruitment indices had 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. Based on the autumn 2020 survey, the risk of the stock being below B_{lim} is greater than 95%. At that time there was 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 Divs. 3LNO be completed.*

Status: While it was anticipated that a length based model would improve knowledge of a recruitment index for Divs. 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.

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

(SCR Docs. 04/075, 076, 08/006, 11/053, 058, 12/044, 13/054, 20/053, 054, 058, 22/021, 045, 046, 047, 048)

Environmental overview

Recent Conditions in Ocean Climate and Lower Trophic Levels

- The ocean climate index in Subarea 0-1 above normal in 2021.
- Mean initiation timing of the spring phytoplankton bloom in 2021 was the earliest of the time series.
- Spring bloom magnitude (total production) was slightly below normal in 2021

Hydrographic conditions in this region 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 Subarea 0-1 has been predominantly above or near normal since the early 2000s, except for 2015 and 2018 that were below normal (Figure 3.1A). After being in 2019 at its highest value since the record high of 2010, the index was normal in 2020 and again above normal in 2021. Before the warm period of the last decade, cold conditions persisted in the early to mid-1990s.

Spring bloom initiation has been oscillating between early (negative anomalies) and late (positive anomalies) timing between 2003 and 2020. In 2021, the average timing of the spring bloom in Subarea 0B1EFT was the earliest of the time series and followed the two latest bloom onset on record for the region (Figure 3.1B). Spring bloom magnitude (total production) remained mostly below or near-normal between 2003 and 2020 with the exception of a few highly productive bloom in 2006, 2015 and 2018. In 2021, mean bloom magnitude in the region was slightly higher than normal (Figure 3.1C).

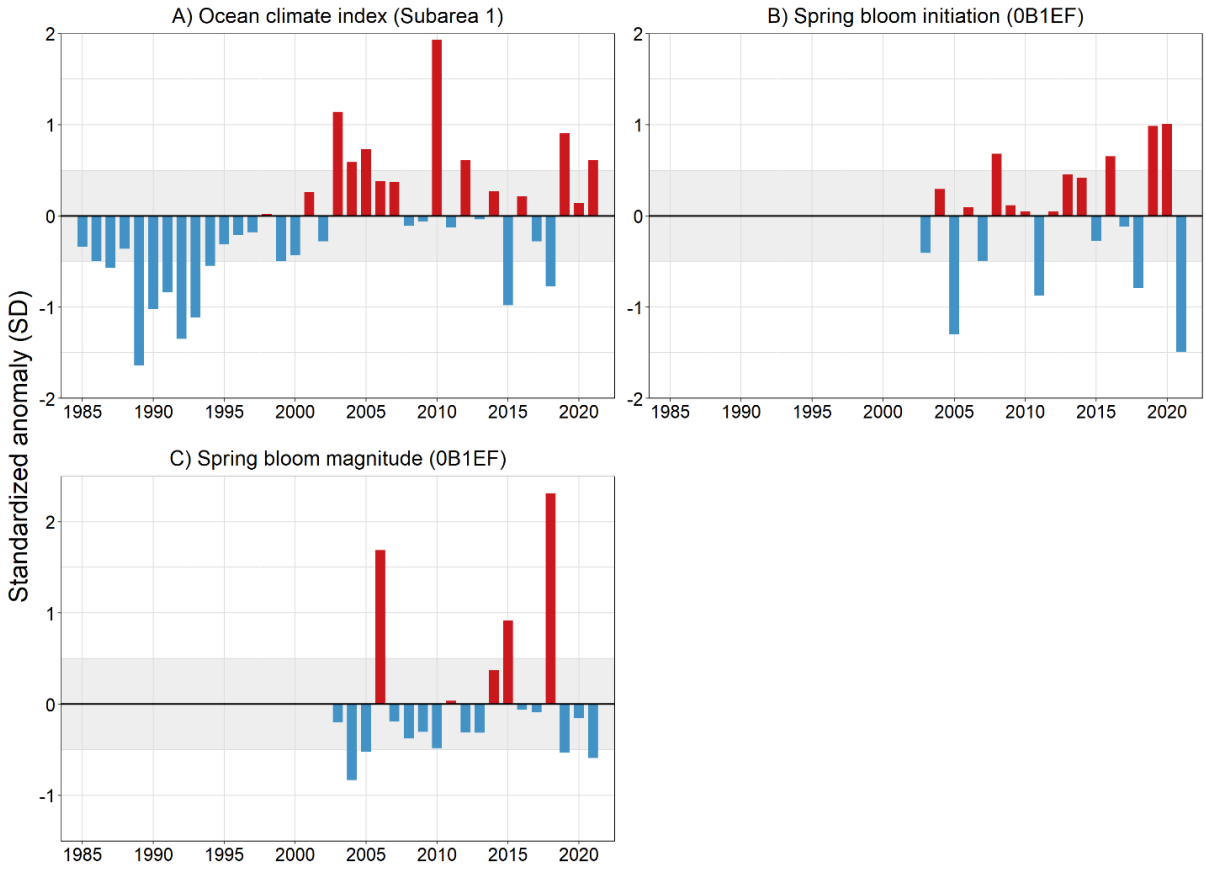


Figure 3.1. Annual anomalies of environmental indices for NAFO Subareas 0 and 1. The ocean climate index (A) for the period 1990-2020 is the average of 10 individual time series. These includes standardized anomalies of 4 SSTs time series, 4 temperature time series at 3 hydrographic stations and 2 air temperatures time series (see SCR Doc. 22-021 for details). Spring bloom anomalies (B, C) for the 2003-2021 period are derived from four satellite boxes (HS, NLAB, CLAB, GS – see SCR Doc. 22-021 for details). Positive (negative) anomalies indicate late (early) bloom timing or magnitude above (below) the mean for the reference period. Anomalies were calculated using the following reference periods: ocean climate index: 1981-2010, spring bloom indices: 2003-2020. 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.

i) Fishery

The Greenland fishery exploits the stock in Subarea 1 (Div. 1A– 1F). The Canadian fishery has been limited to Div. 0A.

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). Sorting grids are required in both the Greenland and the Canadian fleets to reduce bycatch of fish. Discarding of shrimps is prohibited.

The enacted TAC for Greenland waters in 2022 was set at 115 000 t and for Canadian waters, 16 291 t.

Total catches increased to an average over 150 000 t in 2005 to 2008 but have since decreased to 72 256 t in 2015 (Figure 3.2). Since 2016, the catches have been increasing in conjunction with increasing TACs and was 114 569 t in 2021. The projected catch for 2022 is 120 000 t in Greenlandic EEZ (DIV 1). The projected catch for Canada from Div. 0A in 2022 is expected to be low.

Recent catches, projected catch for 2022 and recommended and enacted TACs (t) for northern shrimp in Sub-area 1 and Div. 0A (east of 60°30'W) are as follows:

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
TAC										
Advised	80 000	80 000	60 000	90 000	90 000	105 000	105 000	110 000	115 000	115 000
Enacted[1]	100 596	97 649	82 561	96 426	101 706	114 873	119 875	125 229	130 937	131 292
Catches(NIPAG)										
SA 1	95 379	88 765	72 254	84 356	89 369	93 189	101 997	113 117	114 348	120 000[2]
Div. 0A	2	0	2	1 171	3 215	1 689	2 463	641	221	0[2]
TOTAL	95 381	88 765	72 256	85 527	92 584	94 878	104 440	113 758	114 569	120 000[2]
STATLANT 21										
SA 1	91 800	88 834	71 777	82 922	88 947	90 457	98 219	110 095	107 367	
Div. 0A	2	0	2	1 381	2 778	1 412	1328	155	204	

1Canada and Greenland set independent and autonomous TACs

2 Projected total catches for the year.

Since the early 2000s the Greenlandic fishery has moved north and currently about 80% of the total catch is taken in Div. 1A and 1B.

Canadian fishing effort has been sporadic and catches variable. In 2016 fishing increased in the Canadian EEZ and from 2016 to 2021, Canadian catches averaged about 1 100 t.

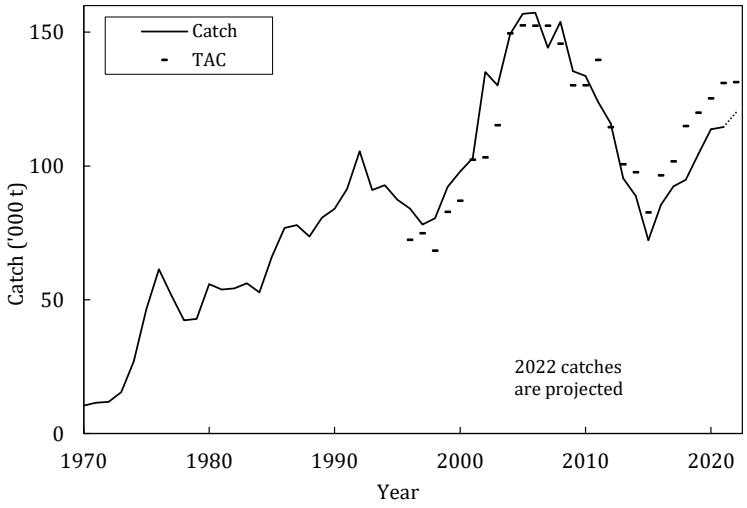


Figure 3.2. Northern shrimp in Subarea 1 and Div. 0A: Enacted TACs and total catches.

b) Data overview

i) Fisheries Data

Fishing effort and CPUE. Catch and effort data from the fishery were available from Greenland logbooks for Subarea 1 (SCR Doc. 22/046, 22/047). 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.

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 (1987-2022) and the coastal fleet fishing in coastal and inshore areas (1989-2022). 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 years the CPUE of the coastal fleet has slightly decreased while the CPUE of the offshore fleet increased to 2017 and declined until 2020. The decline has stopped and CPUE increased in 2021. Partial data from 2022 indicate CPUE for both fleet components will remain stable.

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.

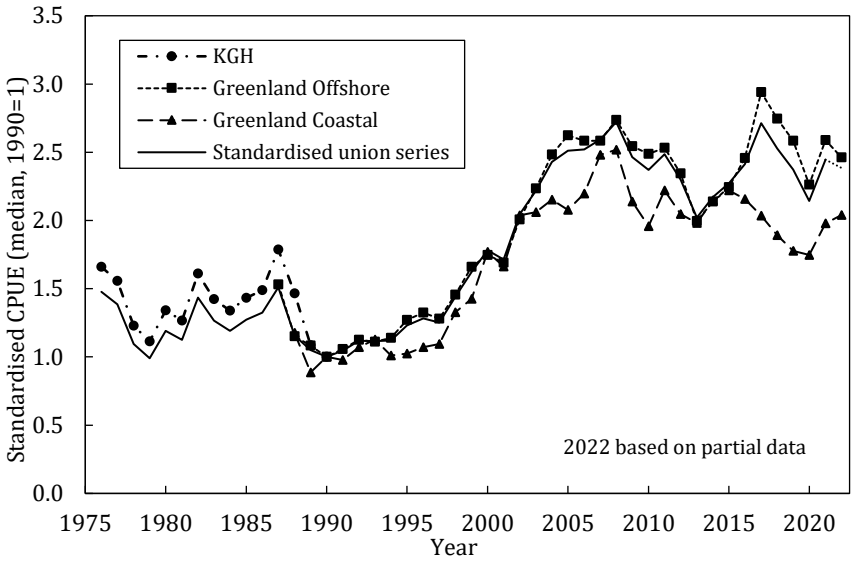


Figure 3.3. Northern shrimp in Subarea 1 and Div. 0A: Standardized CPUE index series 1976–2022.

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.

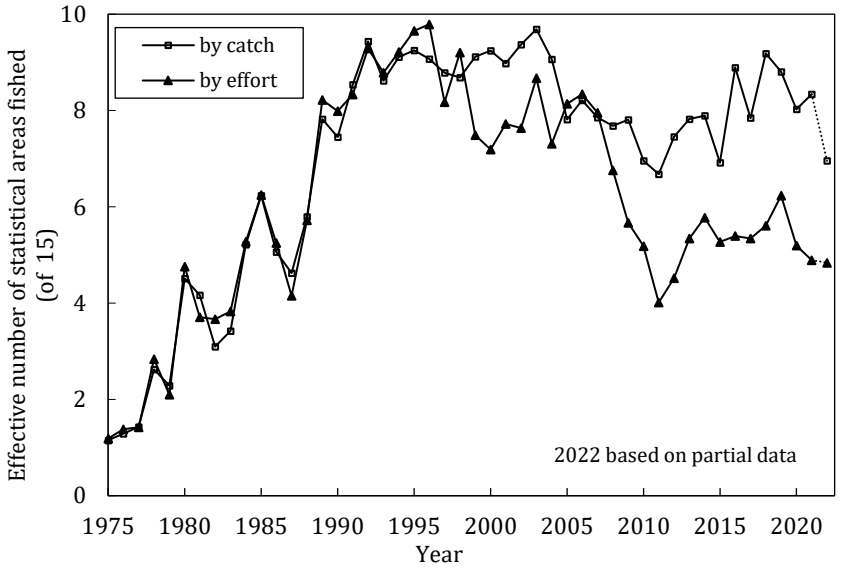


Figure 3.4. Northern shrimp in Subarea 1 and Div. 0A: Indices for the distribution of the Greenland fishery between statistical areas in 1975–2022.

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. 22/045). 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 of year as the usual survey, and in 2022 the survey was conducted with the new Greenlandic research vessel *Tarajoq*. All the standard gears were identical to those used at the research vessel *Paamiut* (such as *Cosmos* trawl, doors, all equipment such as bridles etc., *Marport* sensors on doors and headlines), and all the standard research protocols were followed in attempt to make the surveys as identical as possible with the previous years' survey with the research vessel *Paamiut* (SCR Doc. 20/53 and 22/45). NIPAG therefore assumed that the 2018, 2019-2020 and 2022 results were directly comparable with the previous surveys, however without comparative fishing there remains some uncertainty.

The survey average bottom temperature increased from about 1.7°C in 1990–1993 to about 3.1°C in 1997–2014 but declined to 2.1°C in 2018. In the recent years bottom temperature has increased and was 3 °C in 2022 (SCR Doc. 22/045). About 80% of the survey biomass is in water 200–400 m deep throughout the time series. Since 2001 most of the survey biomass has been in water 200–300 m deep (SCR Doc. 22/045). 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 until 2003. Subsequent values were consecutively lower, with the second lowest level in the last 21 years occurring in 2014 (Figure 3.5) (SCR Doc. 22/045). Over the past 5 years biomass has remained stable. In 2022, offshore regions comprise 83% of the total survey biomass, and the remainder is inshore in Disko Bay and Vaigat.

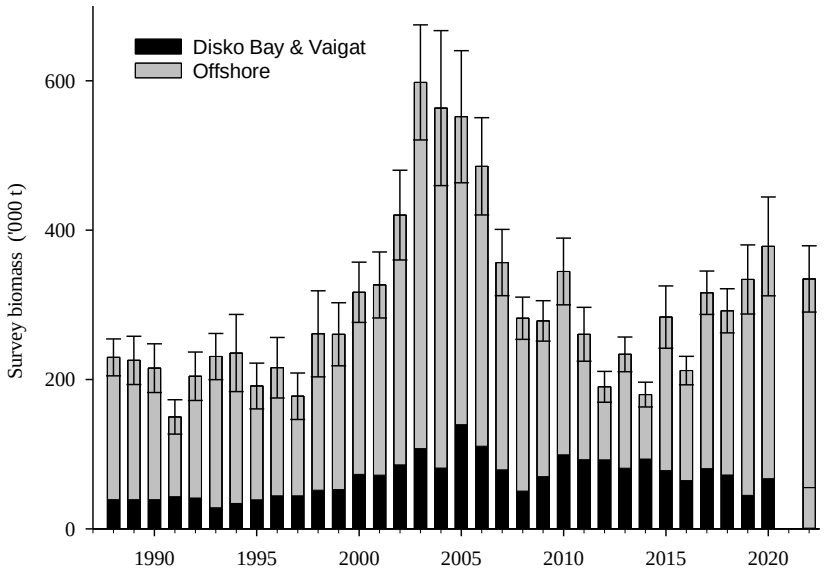


Figure 3.5. Northern shrimp in Subarea 1 and Div. 0A: Biomass index (survey mean catch rates) inshore and offshore 1988–2022 (error bars 1 SE).

Length and sex composition (SCR Doc. 22/045). In 2022, in Disko Bay regions the proportion of fishable males in the survey decreased slightly to a level below its 16-year median. In offshore regions this proportion increased

to a value above its 16-year mean. Females compose a high proportion of survey and fishable biomass indices in both regions. They were close to their 16-year median offshore, and at their 16-year upper quartile in Disko Bay (Figure 3.6).

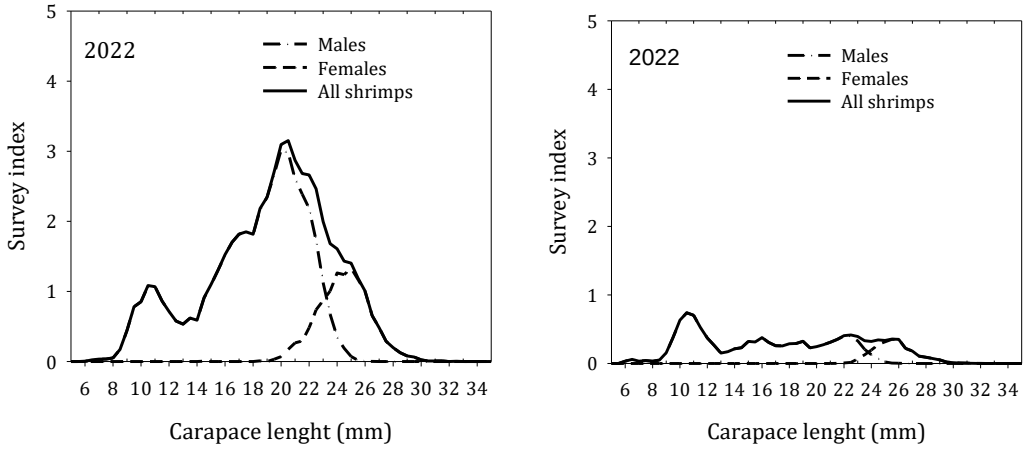


Figure 3.6. Northern Shrimp in Subarea 1 and Div. 0A: Survey mean catch composition at length in offshore regions (left) and Disko Bay & Vaigat (right) at the West Greenland trawl survey in 2022.

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 four high values in 2015, 2019, 2020 and 2022. The pre-recruit index (14–16.5 mm, expected to recruit to next year's fishable biomass) has fluctuated at a lower level, with relatively high values in 1999-2000 and again in 2015, 2017 and 2020 (SCR Doc. 22/045, 22/048) (Figure 3.7). Numbers of age-2 and pre-recruits in 2022 are above and below the time-series average, respectively.

Linear regression was performed 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 significant between number of age-2 shrimp and the fishable biomass 4 years later (R^2 = 0.63), and between pre-recruits and fishable biomass 1 year later (R^2 = 0.68). Furthermore, there was also a significant relationship between number of age-2 shrimp and the number of pre-recruits 2 years later (R^2 = 0.50, SCR Doc. 22/045).

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 at a record low (SCR Doc. 22/045, 22/048). In 2022, numbers of age-2 shrimps relative to survey biomass were at a record high level. Both number of pre-recruits and number of age-2 shrimp relative to survey biomass were higher inshore than in offshore regions (SCR Doc. 22/045, 22/048).

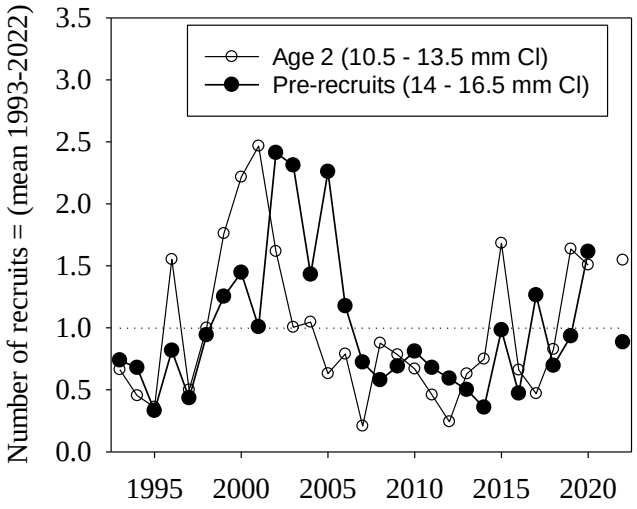


Figure 3.7. Northern shrimp in Subarea 1 and Div. 0A: Survey index of numbers at age 2 (10.5 - 13.5 mm) and index of number of pre-recruits (14-16.5 mm), 1993-2022. Indices are standardized to the series mean.

Predation index. Four distinct stocks of Atlantic cod, spawning in inshore and offshore West Greenland, East Greenland, and Iceland, mix at different life stages on the West Greenland banks.

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.

Indices of cod biomass are adjusted by a measure of the overlap between the stocks of cod and shrimp to obtain an index of 'effective' cod biomass, which is entered in the assessment model (SCR Doc. 14/062). Currently the cod stock in West Greenland is at a low level compared to the period before the cod collapse in the beginning of 1990s. The cod stock biomass has been slightly increasing since 2017 and was estimated to be 67 Kt in 2022 and is composed of several year-classes. The index of its overlap with the shrimp stock is still below an average of the series value. This resulted in a 2022 'effective' cod biomass index of 19 Kt (Figure 3.8, SCR Doc. 16/042, 16/047, SCR Doc. 20/058, SCR Doc. 22/048).

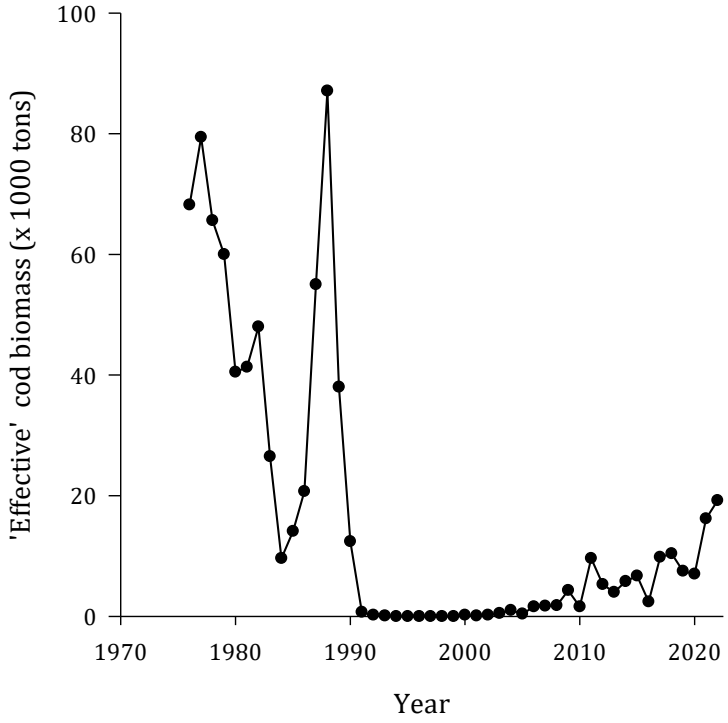


Figure 3.8. Northern shrimp in Subarea 1 and Div. 0A: Indices of the 'effective' cod biomass in Subarea 1 and Div. 0A, 1976 - 2022.

c) Assessment

A Schaefer surplus-production model of population dynamics was fitted to series of CPUE, catch, and survey biomass indices (SCR Doc. 22/048). The model includes a term for predation by Atlantic cod (Figure 3.8). Total shrimp catches for 2022 are expected to be 120 000 t.

Estimates of stock-dynamic parameters from fitting a Schaefer stock-production model to 47 years' data are given in Table 3.1. Median values from the 2021 assessment are provided for comparison. The modelled biomass (Figure 3.9a) steadily declined from 2004 to 2013 but has since slightly increased and has been stable over the most recent years. The median biomass has been above B_{msy} since the late 1990s. Mortality has generally been close to or below Z_{msy} during the modelled period (Figure 3.10). Estimates of total mortality have increased in the most recent years. Assuming catches of 120 000 t, total mortality in 2022 is estimated to be below Z_{msy} with probability of $Z_{2022} > Z_{msy}$ = 43%. Biomass at the end of 2022 is projected to be close to the 2021 value and above B_{msy}. The probability of the biomass at the end of 2022 being below B_{msy} is 22% and the probability of being below B_{lim} is very low (<1%).

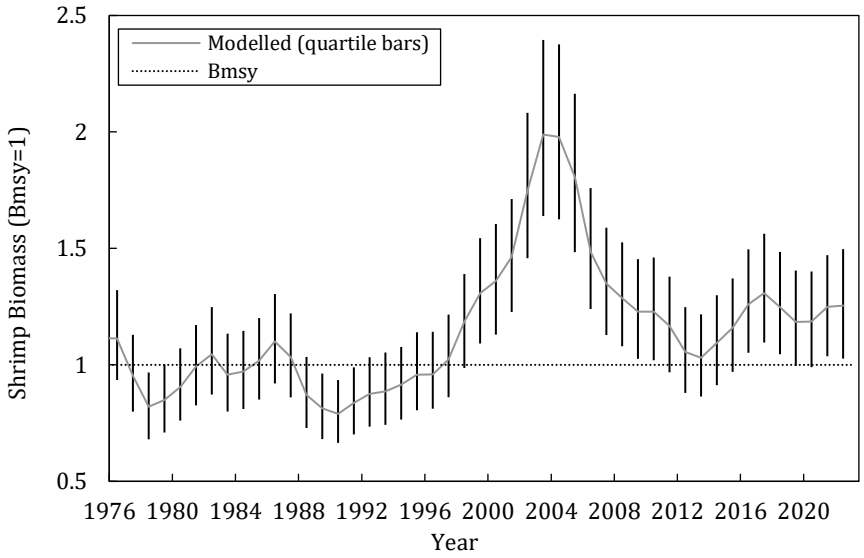


Figure 3.9. Northern shrimp in SA 1 and Div. 0A: Relative stock biomass with quartile error bars 1976–2022. Dotted line corresponds to $B = B_{msy.}$

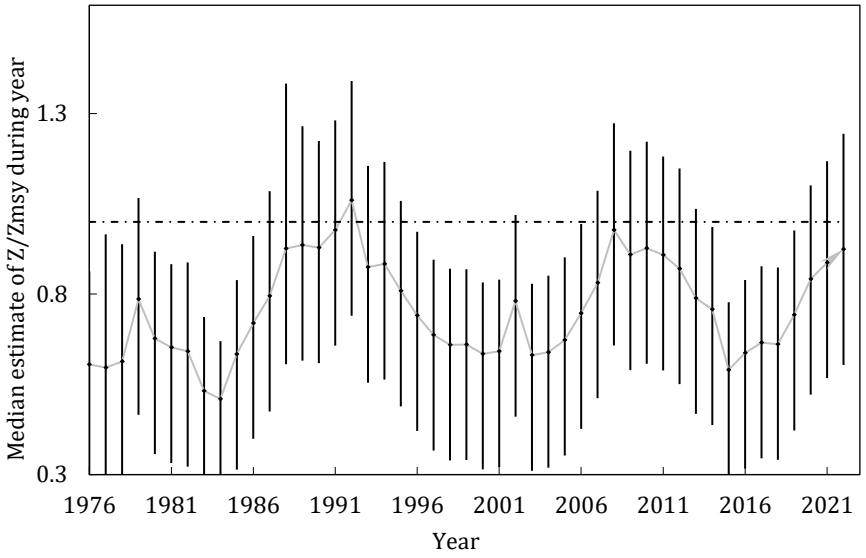


Figure3.10. Northern shrimp in SA 1 and Div. 0A: Trajectory of the median modelled estimate of mortality relative to Z_{msy} during the year, 1976–2022 with quartile error bars.

Table 3.1. Northern shrimp in Subarea 1 and Div. 0A: Estimates of stock-dynamic and parameters from fitting a Schaefer stock-production model to 47 years' data on the West Greenland stock of the northern shrimp in 2022. The median (2021) column shows results from last year's assessment.

	Mean	S.D.	25%	Median	75%	Est. mode	Median (2021)
Max.sustainable yield	137.7	60.0	103.9	124.5	155.6	98.1	123.4
B/Bmsy, end current year (proj.)(%)	128.1	34.6	102.7	125.4	149.7	120.0	123.2
Biomass risk, end current year(%)	21.8	41.3	–	–	–	–	–
Z/Zmsy, current year (proj.)(%)	–	–	64.2	92.4	124.4	–	81.8
Carrying capacity	3601	2030	2064	3047	4592	1939	3048
Max. sustainable yield ratio (%)	9.5	4.9	6.0	8.8	12.4	7.4	8.8
Survey catchability (%)	17.5	11.5	9.1	14.3	23.2	7.8	14.5
CPUE(1) catchability	1.0	0.7	0.5	0.8	1.3	0.5	0.8
CPUE(2) catchability	1.6	1.0	0.8	1.3	2.1	0.7	1.3
Effective cod biomass 2022 (Kt)	25.6	51.9	14.5	19.2	24.7	6.4	6.0
$P_{50\%}$ *(prey biomass index with consumption 50% of max.)*	4.3	7.4	0.2	1.3	4.9	-4.6	1.3
V_{max} *(maximum consumption per cod)*	2.0	2.3	0.4	0.9	2.7	-1.2	0.9
CV of process (%)	12.7	2.7	10.8	12.4	14.3	12.0	12.6
CV of survey fit (%)	18.2	3.1	16.1	17.8	20.0	17.1	17.7
CV of CPUE (1) fit (%)	7.0	1.4	5.9	6.7	7.8	6.2	6.7
CV of CPUE (2) fit (%)	7.2	2.1	5.7	6.6	8.1	5.5	6.9

A six-year retrospective analysis was performed (Figure 3.11) and results were found to be quite stable.

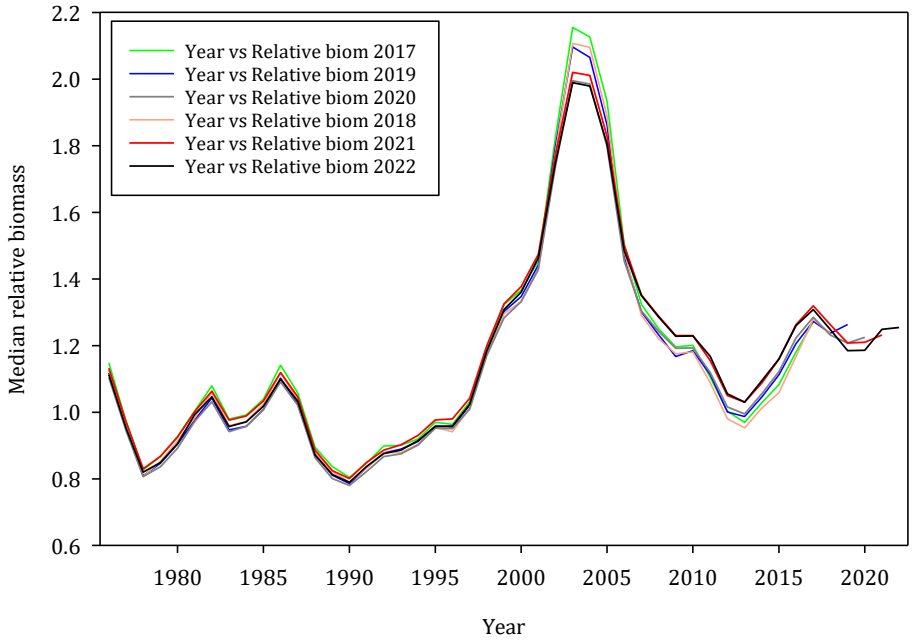


Figure 3.11. Northern shrimp in Subarea 1 and Div. 0A: Retrospective plots of the relative biomass B/B_{msy} 2016 to 2022. Mohn's rho is estimated to – 0.005.

d) Reference points

B_{lim} has been established as 30% B_{msy}, and Z_{msy} has been set as the mortality reference point. B_{msy} and Z_{msy} are estimated directly from the assessment model (SCR Doc. 022/048).

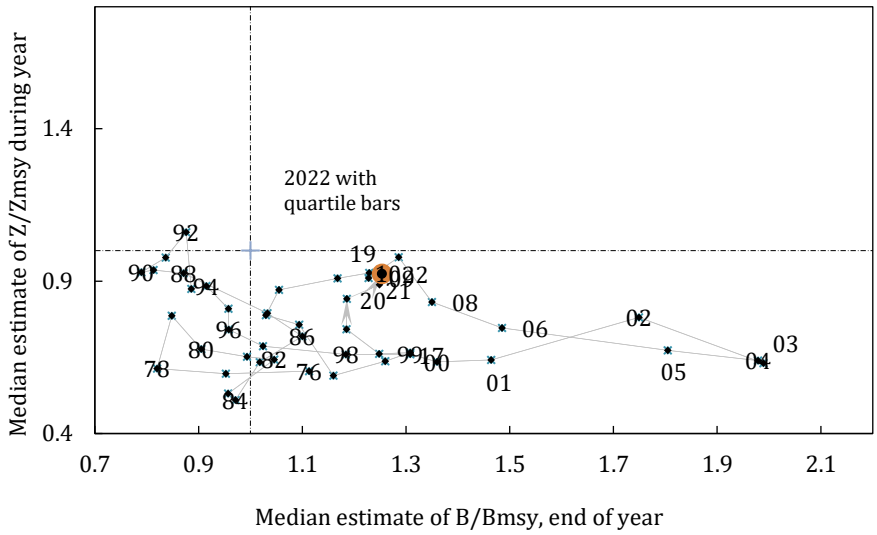


Figure 3.12. Northern shrimp in Subarea 1 and Div. 0A: Trajectory of relative biomass and relative mortality, 1976–2022.

e) State of the stock

Biomass. Biomass in 2022 is above B_{msy} and the probability of being below B_{lim} is very low (<1%).

Mortality. Assuming catches of 120 000 t and an effective cod biomass of 19 Kt, the probability of being above Z_{msy} is 43%.

Recruitment. In 2022 numbers of age-2 were above the time-series average.

State of the Stock. Biomass in 2022 is above B_{msy} and the probability of being below B_{lim} is very low (<1%). The probability of mortality in 2022 being above Z_{msy} is 43%. Recruitment (number of age-2 shrimp) in 2022 was above average.

f) Projections

Three years projections for years 2023–2025 under eight catch options and subject to predation by the cod stock with an 'effective' biomass of 19 kt (the estimated value for 2022 was 19.2 Kt) were evaluated. Additional projections assuming 'effective' cod biomasses of 18 Kt and 20 Kt were conducted but results indicated small differences in risk probabilities (SCR Doc 22/048).

19 Kt cod	Catch option ('000 tons)							
Risk of:	**95**	**100**	**105**	**110**	**115**	**120**	**125**	**130**
falling below Bmsy end 2023 (%)	24	24	23	25	25	25	26	26
falling below Bmsy end 2024 (%)	25	25	26	27	28	29	30	29
falling below Bmsy end 2025 (%)	25	27	27	29	30	32	33	33
falling below Blim end 2023 (%)	0	0	0	0	0	0	0	0
falling below Blim end 2024 (%)	0	0	0	0	0	0	0	0
falling below Blim end 2025 (%)	0	0	0	0	0	0	0	0
exceeding Zmsy in 2023 (%)	22	25	29	32	36	39	43	46
exceeding Zmsy in 2024 (%)	22	26	30	33	38	40	44	47
exceeding Zmsy in 2025 (%)	23	27	30	34	38	42	45	49
falling below Bmsy 80% end 2023 (%)	8	8	8	8	9	9	9	9
falling below Bmsy 80% end 2024 (%)	9	9	10	11	11	11	13	12
falling below Bmsy 80% end 2025 (%)	10	11	12	13	14	13	16	16

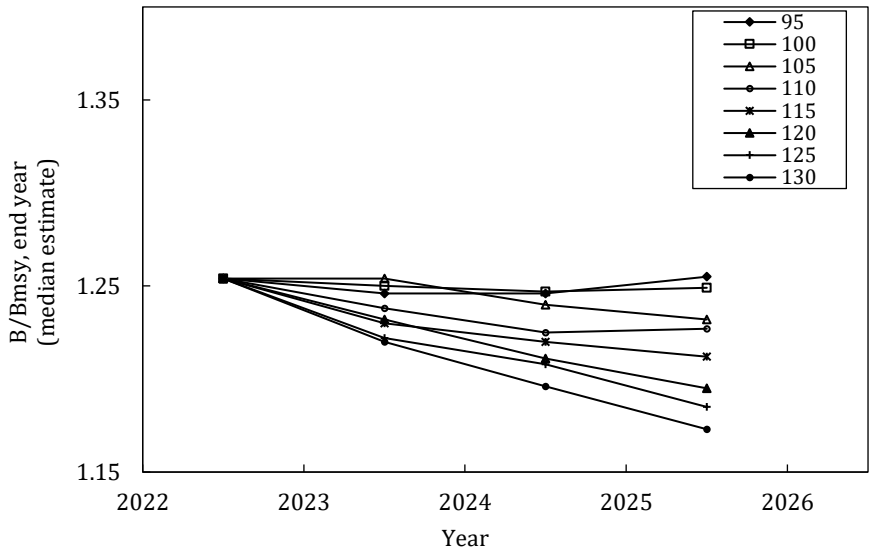


Figure 3.13. Northern shrimp in Subarea 1 and Div. 0A: Median estimates of year-end biomass trajectory for 2023–2025 with annual catches at 95 –130 Kt. and an 'effective' cod stock assumed at 19 Kt.

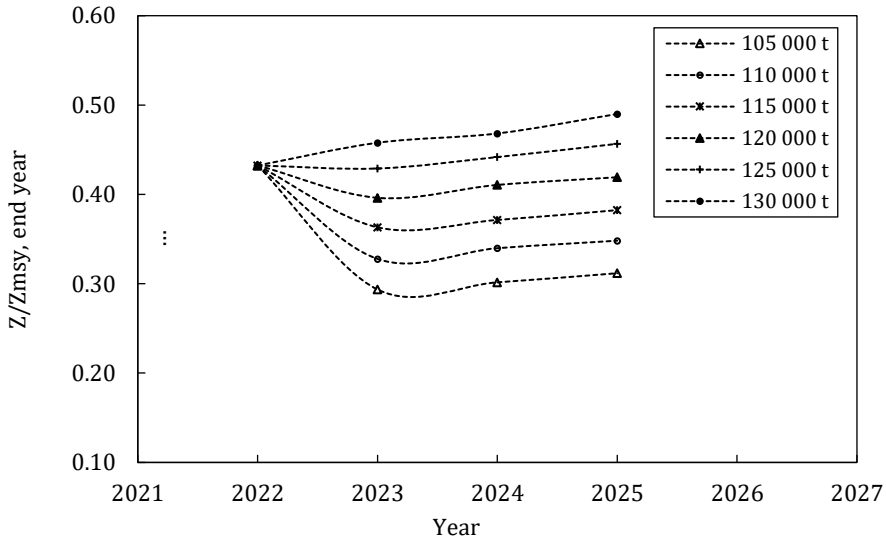


Figure 3.14. Northern shrimp in Subarea 1 and Div. 0A: Risks of transgressing mortality precautionary limits with annual catches at 105–130 Kt projected for 2023–25 with an 'effective' cod stock assumed at 19 Kt.

g) Research recommendations

SC **recommends** *increasing commercial sampling of catch composition to cover both Canadian and Greenlandic fleets.*

SC **recommends** *developing a joint Canadian and Greenlandic sampling program to determine predation pressure from various fish species.*

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

(SCR Docs. 04/012, 22/049, 22/050, 22/051)

Environmental Overview

Oceanography

In the region of East Greenland, South of Denmark Strait, the polar waters are constrained to a narrow coastal region on the shelf, which means that warmer and more saline Atlantic waters, originating from the Subtropical Gyre and transported by the Irminger Current, are more prevalent. The region is dominated by an inflow of multi-year ice from the Central Arctic Ocean, with maximum coverage in March and minimum in September. In the region drift ice is seasonal (early spring), transported from the region further north. Much of the waters in the region are stratified shelf waters, with cold and fresher polar waters overlaying warmer and more saline Atlantic waters (ICES, 2020).

Ecosystem changes

Sea ice coverage in the area north of the region has been diminishing in the several past decades, including a decrease in winter maximum sea ice extent since the start of satellite records in 1979, and a weak decline in summer minimum ice coverage since 2006 (ICES, 2020).

Surface waters on the narrow south-eastern Greenland shelf and in the area north of Denmark Strait are 1–2°C warmer than the mean conditions for 1981–2010 for much of the year. In contrast, surface waters in the south-eastern reaches of the region have cooled by up to 2°C. Surface salinity has increased in the open waters of the ecoregion but decreased in the East Greenland shelf waters and Irminger Sea surface waters (ICES, 2020).

a) Introduction

Northern shrimp off East Greenland in ICES Div. 14b and 5a is assessed as a single stock.

i) fishery and catches

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 since 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 5 295 t in 2022 (Figure 4.1). Since 2012, no or very little fishery has taken place in the southern area.

Catches in the first half year of 2022 were 3 868 t based on available logbooks, however logbooks for two foreign vessels were not available at the time of the assessment. Total catches have been provided by the Greenland Fishery and License Control and are 1 427 t in the first half of 2022. The total catches for the first half of 2022 are therefore 5 295 t. It has not been possible to include information on CPUE and effort for the two foreign vessels mentioned above, and all further analysis are based solely on available logbooks in 2022. Since 2014, the fishing effort has been historically low and concentrated in a relatively small area.

Recent catches and TACs (t) for shrimp in in the Denmark Strait and off East Greenland (ICES Div. 14b and 5a) are as follows:

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022[1]
Recommended TAC, total area	12 400	2 000	2 000	2 000	2 000	2 000	2 000	2 000	3 000	3 000
Actual TAC, Greenland	12 400	8 300	6 100	5 300	5 300	4 300	3 384	4 750	7 000	6 850
Catches North of 65°N, Greenland EEZ	1 714	622	576	49	561	547	1 574	3 172	3 067	5 295
Catches North of 65°N, Iceland EEZ	0	0	0	0	0	0	0	0	0	0
Catches North of 65°N, total	1 714	622	576	49	561	547	1 574	3 172	3 067	5 295
Catches South of 65°N, Greenland EEZ	3	0	0	0	0	0	2	0	0	0
Total NIPAG Catches	1 717	622	576	49	561	547	1 576	3 172	3 067	5 295

[1] Catches until June 30

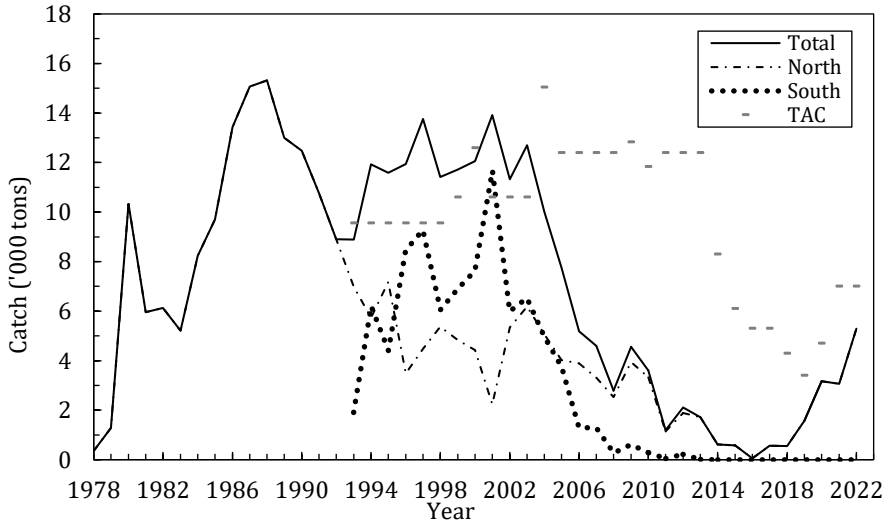


Figure 4.1. Shrimp in Denmark Strait and off East Greenland: Catch and TAC (2022 catches until June 30th).

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. 22/050).

The overall CPUE index increased from 1993 to 2009, followed by a continuous decline to a low value in 2015 and has been increasing since (Figure 4.2), reaching a record high level in 2020.

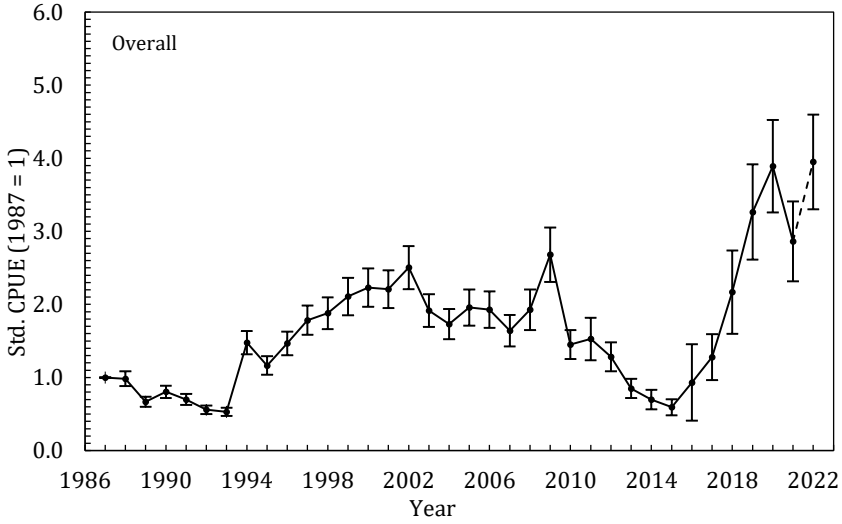


Figure 4.2. Shrimp in Denmark Strait and off East Greenland: Annual standardized CPUE index (1987 = 1) with ± 1 SE combined for the total area. 2022 data until June 30th (dotted line).

In 2022 the CPUE index value is the highest in the time series and at a similar level to 2020. It should be noted that the two foreign vessels for which logbooks were not available are not included in CPUE index value. The estimates for recent years are based on relatively low fishing effort (from 300 fishing hours in 2016 to 3 890 fishing hours in 2022) which is concentrated in a relatively small area north of 65°N and west of 30°W. 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).

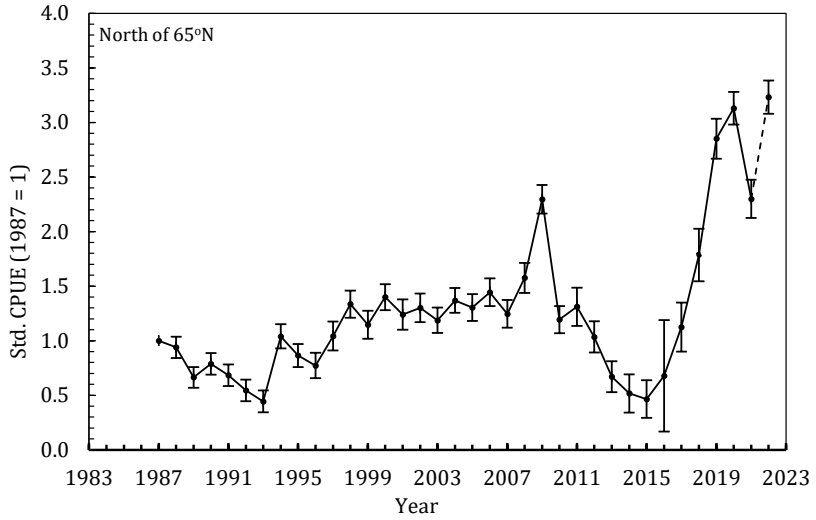


Figure 4.3. Shrimp in Denmark Strait and off East Greenland: Annual standardized CPUE (1987 = 1) with ±1 SE fishing north of 65°N. 2022 data until June 30th (dotted line).

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. In 2021 EU fleet in the northern area started fishing in April, which is later than previous year when the larger portion of the catch was taken in February/March; this is likely to have caused the drop in CPUE in 2021.

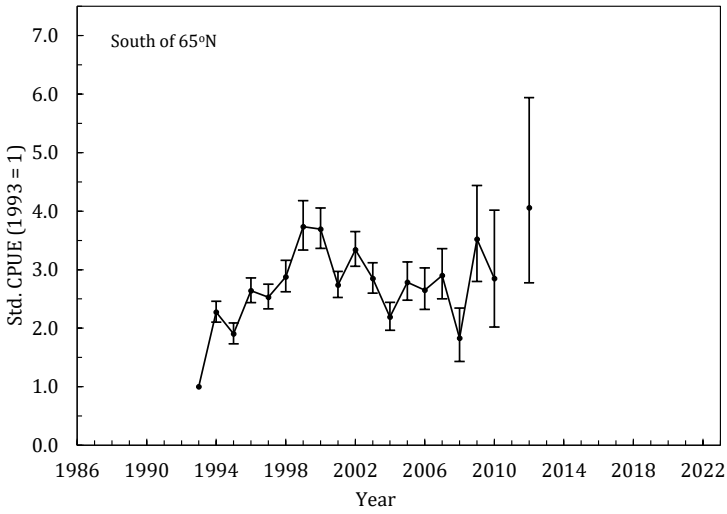


Figure 4.4. Shrimp in Denmark Strait and off East Greenland: Annual standardized CPUE (1993 = 1) with ±1 SE fishing south of 65°N (no data for the area since 2010/2012).

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). In 2022, levels of effort are expected to increase once all logbooks are included.

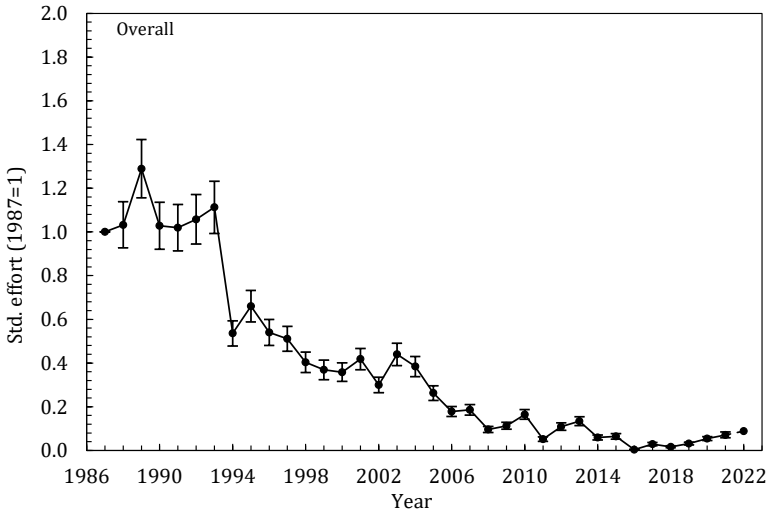


Figure 4.5. Shrimp in Denmark Strait and off East Greenland: Annual standardized effort indices, as a proxy for exploitation rate (± 1 SE; 1987 = 1), combined for the total area (2022 effort until June 30th).

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. 22/049). Due to lack of research vessel, no survey was conducted in the period 2017 to 2019 and in 2021. In 2020 the survey was conducted with the chartered fishing vessel *Helga Maria* and in 2022 with the new research vessel *Tarajoq* using the same gear configuration as in previous years (SCR Doc. 22-45, 20-060 and 22-049). NIPAG therefore assumed that the 2020 and 2022 results were directly comparable with the previous surveys, however without comparative fishing there remains some uncertainty.

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 and 2021. The 2020 estimate is the highest in the time series (Figure 4.6) but the 2022 biomass index has dropped to a level similar to 2010-2011.

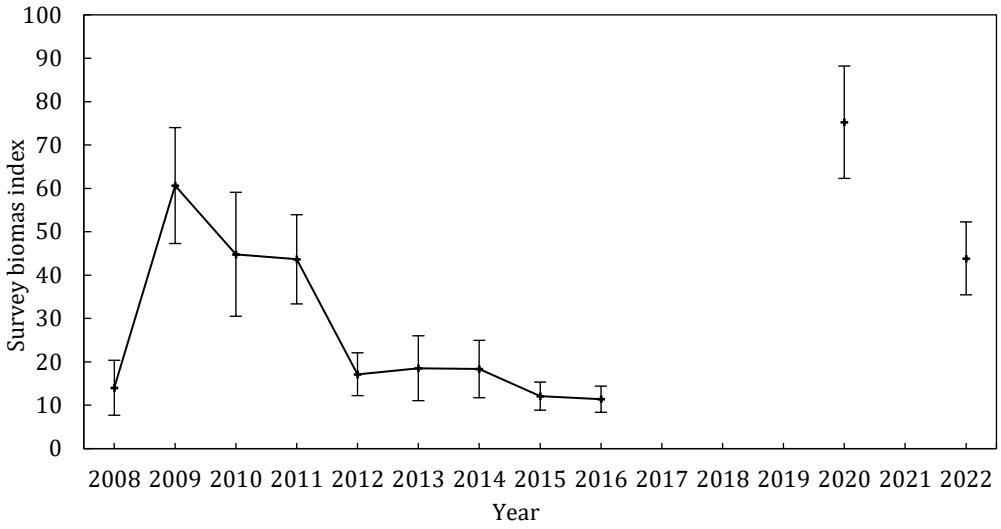


Figure 4.6. Shrimp in Denmark Strait and off East Greenland: Survey biomass index from 2008 - 2016, 2020 and 2022 (± 1 SE). No survey was carried out in the period 2017 - 2019 and in 2021.

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

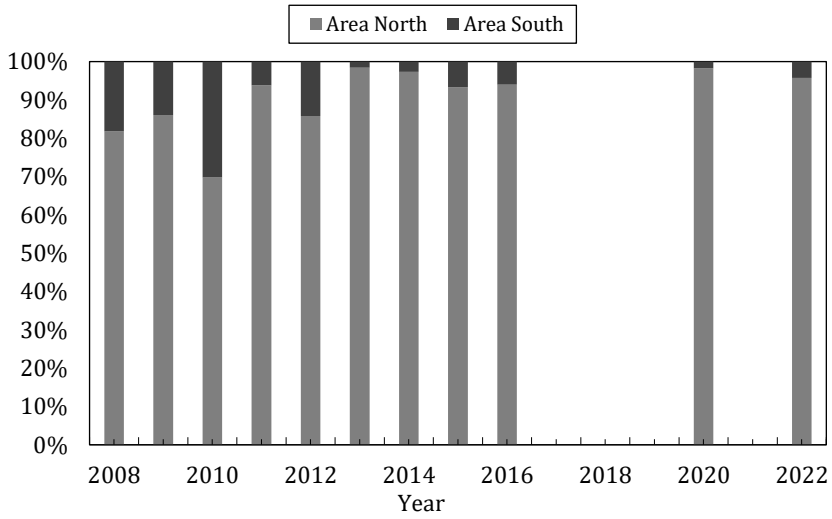


Figure 4.7. Shrimp in Denmark Strait and off East Greenland: Distribution of survey biomass north and south of 65°N (in %) from 2008 - 2016, 2020 and 2022. No survey was carried out in the period 2017 - 2019 and in 2021.

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% of the biomass in all years except 2009 and 2020. In 2009 and 2020, the biomass of females was 34% and 37 % respectively (SCR Doc. 22/049). In 2022, 52% of the biomass was composed of females.

Very few males smaller than 20 mm carapace length (CL) are caught in the survey, but in 2022 there is a small peak in male shrimps smaller than 20 mm CL (Figure 4.8). Scarcity of smaller shrimps in the survey area stresses that the total area of distribution and recruitment patterns of the stock are still unknown.

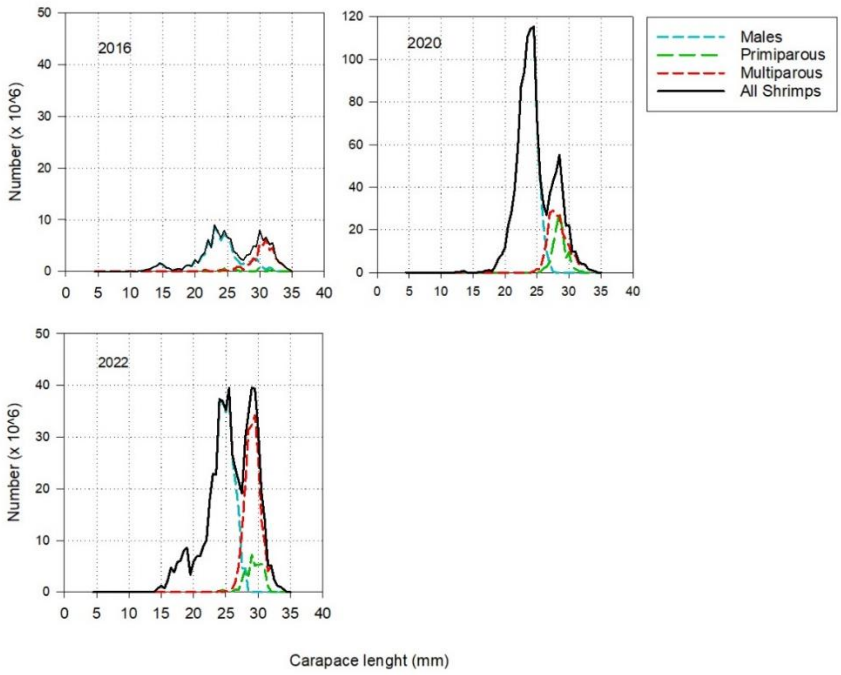


Figure 4.8. Shrimp in Denmark Strait and off East Greenland: Numbers of shrimp by length group (CL) in the total survey area in 2016, 2020 and 2022. No survey was carried out in the period 2017 - 2019 and in 2021.

c) Assessment results

During the 2021 NIPAG meeting a comprehensive sensitivity analysis of the surplus production model in continuous time (SPiCT) was presented (SCR Doc. 21/044). During the 2022 SC shrimp meeting an updated SPiCT model was presented and accepted as a valid assessment tool for this stock (SCR Doc. 22/051) based on a review of the model diagnostics.

The SPiCT model was fitted to series of CPUE, catch and survey biomass indices (SCR Doc 22/051). The relative B/B_{msy} is 0.85, and the relative F/F_{msy} is 1.63 (Figure 4.9).

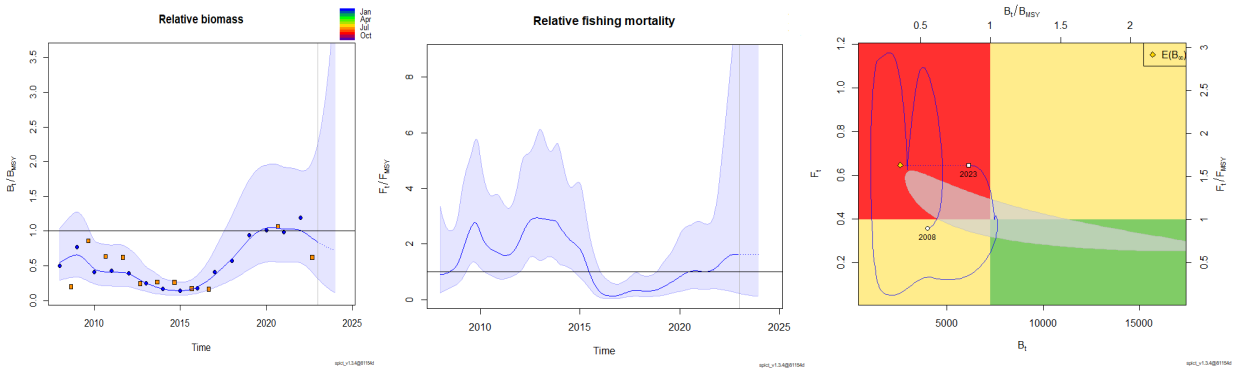


Figure 4.9. Shrimp in Denmark Strait and off East Greenland: Main results of the SPiCT model with n fixed to 2.

Estimates of stock-dynamic parameters from the SPiCT model are given in Table 4.1.

Table 4.1. Shrimp in Denmark Strait and off East Greenland: Results from the SPiCT model.

	Estimate	**CI lower**	**CI upper**	**log.est**
alpha1 (noise term for CPUE, $\alpha = SD_{Index}/SD_{Biomass}$)	1.53	0.24	9.55	0.42
alpha2 (noise term for survey, $\alpha = SD_{Index}/SD_{Biomass}$)	7.18	1.33	38.89	1.97
beta ($\beta = SD_{Catch}/SD_F$)	0.47	0.15	1.52	-0.75
r (intrinsic population growth rate)	0.79	0.55	1.13	-0.23
m (SPiCT parameter)	2894	1805	4641	7.97
K (Carrying capacity)	14608	6867	31077	9.59
q1 (Catchability for CPUE)	0.12	0.07	0.18	-2.16
q2 (Catchability for survey)	1.35	0.79	2.32	0.30
*n (*shape of the production curve, set to 2)	2.00	2.00	2.00	0.69
sdb (Standard deviation, biomass)	0.07	0.01	0.38	-2.62
sdf (Standard deviation, fishing mortality)	0.93	0.46	1.85	-0.08
sdi1 (Standard deviation, CPUE)	0.11	0.06	0.22	-2.20
sdi2 (Standard deviation, Survey)	0.52	0.34	0.80	-0.65
Sdc (Standard deviation, catch)	0.44	0.23	0.84	-0.83
B (Biomass end of 2022)	6199	2439	15754	8.73
F (Fishing mortality end of 2022)	0.65	0.09	4.41	-0.44
Relative reference points				
B/B_{msy}, end current year (proj.) (%)	0.85	0.33	2.20	-0.16
F/F_{msy}, end current year (proj.) (%)	1.63	0.23	11.37	0.49

A five-year retrospective analysis was performed (Figure 4.10) and results were found to be consistent for biomass and fishing mortality with respect to the removal of successive years.

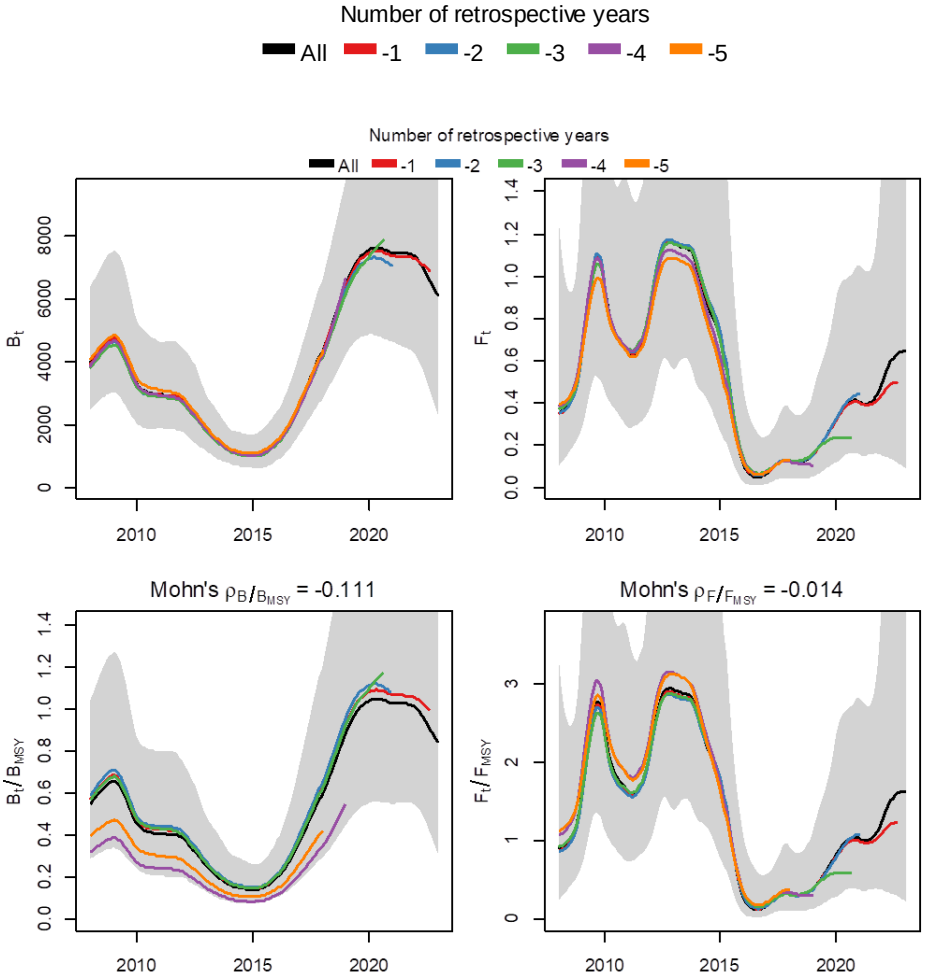


Figure 4.10. Shrimp in Denmark Strait and off East Greenland: Five years retrospective plots of fishing mortality and fishable biomass. Confidence intervals are 95%

d) Reference points

B_{lim} is 2 180 t which corresponds to 30% of B_{msy}. The SPiCT model uses relative reference points B/B_{msy} and F/F_{msy}. The current relative B/B_{msy} is 0.85 and the relative F/F_{msy} is 1.63. The probability of being below B_{lim} is currently 0.015.

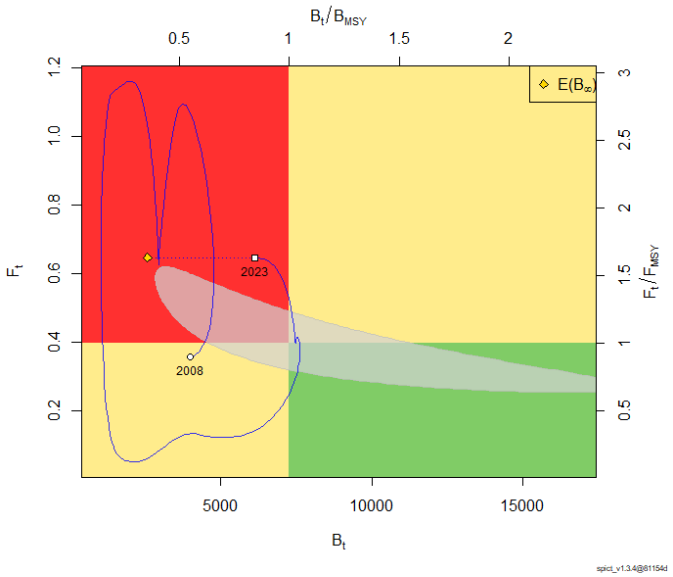


Figure 4.11. Shrimp in Denmark Strait and off East Greenland: Biomass vs fishing mortality 2008 – 2022.

State of the stock

Biomass. Biomass is currently below B_{msy} (B/B_{msy} = 0.85). The probability of being below B_{lim} is currently 0.015.

Fishing mortality. Fishing mortality is currently above F_{msy} (F/F_{msy} = 1.63).

Recruitment. No estimates of recruitment are available.

State of the stock. Biomass is currently below B_{msy} (B/B_{msy} = 0.85). The probability of being below B_{lim} is currently 0.015. Fishing mortality is currently above F_{msy} (F/F_{msy} = 1.63). No estimates of recruitment are available.

Projections

One year projection for 2023 under six catch options were evaluated.

Catch (t)	B/B_{msy}	F/F_{msy}	Prob B > B_{msy}	Prob B < B_{lim}
1 500	1.03	0.56	0.52	0.01
2 000	0.96	0.77	0.47	0.03
2 500	0.89	1.01	0.43	0.06
3 000	0.81	1.26	0.40	0.10
3 500	0.74	1.54	0.37	0.16
4 000	0.66	1.86	0.34	0.22

e) Research recommendations

SC **recommends** *commercial sampling of catch composition.*

SC **recommends** *exploration of the use of SPiCT for two and three year projections.*

SC **recommends** *exploration of available data from the east Greenland stock.*

SC **recommends** *development of possible harvest control rules for this fishery*

References

ICES, 2020, ICES Ecosystem Overviews Greenland Sea ecoregion. Published 10 December 2020 ICES Advice 2020 – https://doi.org/10.17895/ices.advice.763

APPENDIX II. PROVISIONAL AGENDA - SCIENTIFIC COUNCIL

Hotel Ciudad de Vigo, Vigo Spain
12-16 September 2022

I. Opening (Chair: Diana Gonzalez Troncoso)

1. Appointment of Rapporteur
2. Adoption of Agenda
3. Attendance of Observers
4. Plan of Work

II. Review of Recommendations in 2021

III. Fisheries Science (STACFIS Chair: Mark Simpson)

IV. Formulation of Advice (see Annexes 1–3)

1. Request for Advice on TACs and Other Management Measures (Item 1, Annex I)
   a) Northern shrimp in Div. 3M
   b) Monitoring of Stocks for which Multi-year Advice was provided in 2021

2. Requests from Coastal States (Items 5 and 6 of Annex II, item 2 of Annex III)
   a) Northern shrimp off West Greenland (Subareas 0 and 1)
   b) Northern shrimp in Denmark Strait and off East Greenland (ICES Div. XIVb and Va)

V. Other Matters

1. Scheduling of Future Meetings
2. Topics for Future Special Sessions
3. Other Business

VI. Adoption of Scientific Council and STACFIS Reports

VII. Adjournment

APPENDIX III. PROVISIONAL AGENDA – STACFIS

12-16 September 2022

I. Opening (Chair: Mark Simpson)

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 (*Pandalus borealis*) on the Flemish Cap (NAFO Div. 3M) (Full assessment)
- Northern shrimp (*Pandalus borealis*) on the Grand Bank (NAFO Div. 3LNO) (Interim monitoring)
- Northern shrimp (*Pandalus borealis*) off West Greenland (NAFO SA 0 and SA 1) (Full assessment)
- Northern shrimp (*Pandalus borealis*) in the Denmark Strait and off East Greenland (ICES Div. XIVb and Va) (Full assessment)

IV. Other Business

1. FIRMS Classification for NAFO Shrimp Stocks

V. Adjournment

APPENDIX IV. RELEVANT RECOMMENDATIONS FROM 2020 AND 2021

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 was **reiterated** in 2021.

In 2019, NIPAG **recommended** 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.*

In 2019, NIPAG **recommended** 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.*

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 was **reiterated** in 2021.

NIPAG **recommends** in 2018 that *further work on the development of a recruitment index for Divs. 3LNO be completed.* This recommendation was **reiterated** in 2021.

3. Northern shrimp in SA 0 and SA 1

NIPAG **recommends** *increasing sampling to cover the whole fleet.*

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

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

No new recommendations in 2020/2021.

APPENDIX V. DESIGNATED EXPERTS FOR PRELIMINARY ASSESSMENT OF CERTAIN NAFO STOCKS

The following is the list of Designated Experts for 2022 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

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Shrimp in Division 3M	Jose Miguel Casas Sanchez	Tel: +34 986 49 2111	mikel.casas@ieo.csic.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	Tanja B. Buch		TaBb@natur.gl

APPENDIX VI. LIST OF SCR AND SCS DOCUMENTS

RESEARCH DOCUMENTS (SCR)

SCR No.	Serial No.	Author(s)	Title
SCR Doc. 22-045	N7326	Burmeister et al	The West Greenland trawl survey for *Pandalus borealis* 2022 with reference to earlier results
SCR Doc. 22-046	N7327	Burmeister	The Fishery for Northern Shrimp (*Pandalus borealis*) off West Greenland, 1970–2022
SCR Doc. 22-047	N7328	Burmeister	Catch Table Update for the West Greenland Shrimp Fishery
SCR Doc. 22-048	N7329	Burmeister and Riget	A provisional Assessment of the shrimp stock off West Greenland in 2022
SCR Doc. 22-049	N7330	Buch et al	Results of the Greenland Bottom Trawl Survey for Northern shrimp (*Pandalus borealis*) Off East Greenland (ICES Subarea XIV b), 2008-2022
SCR Doc. 22-050	N7331	Buch, Burmeister and Riget	The Fishery for Northern Shrimp (*Pandalus borealis*) in Denmark Strait / off East Greenland 1978 – 2022
SCR Doc. 22-051	N7332	Riget, Burmeister and Buch	Applying a stochastic surplus production model (SPiCT) to the East Greenland Stock of Northern Shrimp
SCR Doc. 22-052	N7337	J.M. Casas Sánchez I. Chapela and M. Alvarez	Division 3M Northern shrimp (*Pandalus borealis*) – Interim Monitoring Update

SUMMARY DOCUMENTS (SCS)

SCS No.	Serial No.	Author(s)	Title
SCS Doc. 22/21	N7359	NAFO	Scientific Council and STACFIS Shrimp Meeting, 12- 16 September 2022

APPENDIX VII. LIST OF PARTICIPANTS, 12-16 SEPTEMBER 2022

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