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FISHERIES ORGANIZATION

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2021

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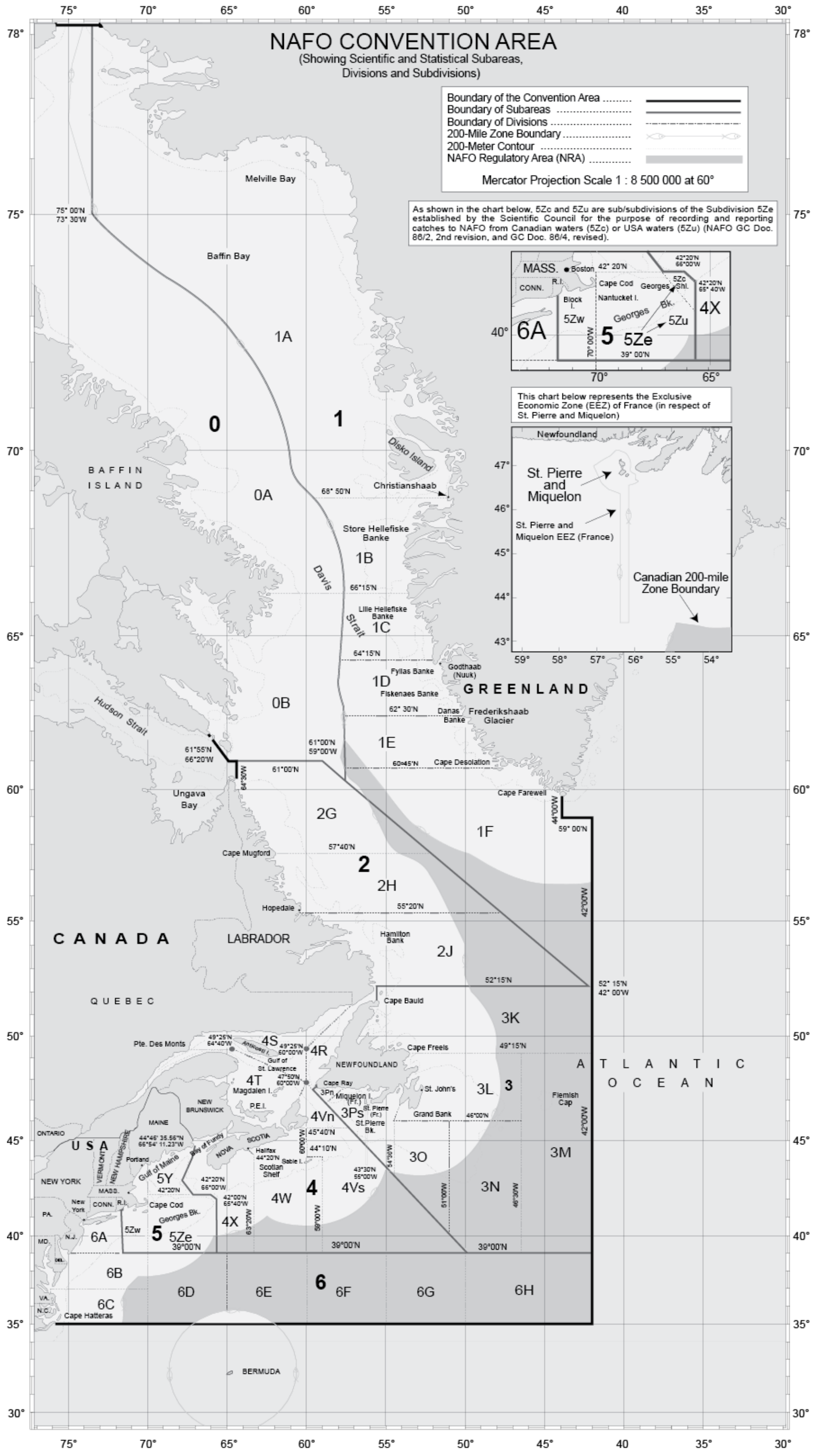
May 2022

PREFACE

This forty-third issue of *NAFO Scientific Council Reports* containing reports of Scientific Council Meetings held in 2021, is compiled in six sections: **Part A** – NAFO Scientific Council Meeting, 27 May –11 June 2021; **Part B** – NAFO Scientific Council (In conjunction with NIPAG) Meeting, 08 September 2021; **Part C** – NAFO Scientific Council Meeting, 20-24 September 2021; **Part D -** NAFO/ICES *Pandalus* Assessment Group (NIPAG) Meeting, 01 – 04 November 2021; **E** – NAFO Scientific Council (in conjunction with NIPAG) Meeting, 01 – 04 November 2021; **Part F** –the Agendas; Requests; Lists of Research and Summary Documents; List of Representatives, Advisers, Experts and Observers; Merit Awards; and List of Recommendations relevant to Parts A-E.

For the meeting report of the NAFO Scientific Council Working Group on Ecosystem Science and Assessment (WG-ESA), visit the NAFO website.


NAFO CONVENTION AREA
(Showing Scientific and Statistical Subareas, Divisions and Subdivisions)
Boundary of the Convention Area
Boundary of Subareas
Boundary of Divisions
200-Mile Zone Boundary
200-Meter Contour
NAFO Regulatory Area (NRA)
Mercator Projection Scale 1 : 8 500 000 at 60°
As shown in the chart below, 5Zc and 5Zu are sub/subdivisions of the Subdivision 5Ze established by the Scientific Council for the purpose of recording and reporting catches to NAFO from Canadian waters (5Zc) or USA waters (5Zu) (NAFO GC Doc. 86/2, 2nd revision, and GC Doc. 86/4, revised).
This chart below represents the Exclusive Economic Zone (EEZ) of France (in respect of St. Pierre and Miquelon)
St. Pierre and Miquelon
St. Pierre and Miquelon EEZ (France)
Canadian 200-mile Zone Boundary
Newfoundland
Melville Bay
Baffin Bay
BAFFIN ISLAND
Davis Strait
Disko Island
Christianshaab
Store Hellefiske Banke
Lille Hellefiske Banke
Fyllas Banke
Godthaab (Nuuk)
Fiskenaes Banke
Danas Banke
Frederikshaab Glacier
Cape Desolation
Cape Farewell
GREENLAND
Hudson Strait
Ungava Bay
Cape Mugford
Hopedale
Hamilton Bank
CANADA
LABRADOR
QUEBEC
Cape Bauld
Cape Freels
NEWFOUNDLAND
St. John's
Grand Bank
Flemish Cap
Gulf of St. Lawrence
Pte. Des Monts
Magdalen I.
Cape Ray
P.E.I.
NEW BRUNSWICK
NOVA SCOTIA
Halifax
Sable I.
Scotian Shelf
St. Pierre Bk.
Miquelon I. (Fr.)
Bay of Fundy
Gulf of Maine
MAINE
USA
Portland
Boston
Cape Cod
Georges Bk.
NEW YORK
Cape Hatteras
BERMUDA
ATLANTIC OCEAN
0 0A 0B 1 1A 1B 1C 1D 1E 1F 2 2G 2H 2J 3 3K 3L 3M 3N 3O 3Ps 3Pn 4 4R 4S 4T 4Vn 4Vs 4W 4X 5 5Y 5Ze 5Zw 5Zu 5Zc 6 6A 6B 6C 6D 6E 6F 6G 6H
June 2015

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PART A: REPORT OF THE SCIENTIFIC COUNCIL MEETING

27 May -11 June 2021
By correspondence

Recommended Citation:

NAFO. 2021. Report of the Scientific Council, 27 May -11 June 2021. NAFO SCS Doc. 21/14REV

REPORT OF SCIENTIFIC COUNCIL MEETING
27 May -11 June 2021J

Chair: Carmen Fernández Rapporteur: Tom Blasdale

I. PLENARY SESSIONS

The Scientific Council (SC) met by correspondence from 27 May to 11 June 2021 to consider the various matters in its agenda. Representatives attended from Canada, Denmark (in respect of Faroe Islands and Greenland), the European Union, Japan, the Russian Federation, Ukraine, the United Kingdom and the United States of America. Observers from the Ecology Action Centre, Sustainable Fisheries Greenland, and Oceans North were also present. The Executive Secretary, Scientific Council Coordinator and other members of the Secretariat were in attendance.

The Executive Committee met prior to the opening session of the Council to discuss the provisional agenda and plan of work.

The Council was called to order at 08:00 Halifax time (11:00 UTC) on 27 May 2021. The provisional agenda was **adopted** and the Scientific Council Coordinator was appointed the rapporteur. The opening session was adjourned at 12:30 on 27 May 2021.

Several sessions were held throughout the course of the meeting to deal with specific items on the agenda.

Because of having to meet by correspondence, with participants located in many different time zones, it was only possible to meet (by WebEx) from 08:00 to 13:00 (Halifax time), and this limited the amount of work that could be achieved in the meeting.

The concluding session was called to order at 08:00 on 11 June 2021.

The Council considered and **adopted** the Scientific Council Report of this meeting of 27 May -11 June 2021. The Chair received approval to leave the report in draft form for about two weeks to allow for minor editing and proof-reading on the usual strict understanding there would be no substantive changes.

The meeting was adjourned at 13:00 h on 11 June 2021.

The limitations of meeting by correspondence also implied that the reports of the Standing Committee on Fisheries Science (STACFIS) could only be formally **adopted** by correspondence, at a later date in 2021. This report is included as Appendix IV.

For the same reason, the reports of the Standing Committee on Fisheries Environment (STACFEN), the Standing Committee on Research Coordination (STACREC) and the Standing Committee on Publications (STACPUB), Appendices I-III, were deferred until September.

The Agenda, List of Research (SCR) and Summary (SCS) Documents, and List of Representatives, Advisers and Experts, are given in Appendices V-IX.

The Council's considerations on the Standing Committee Reports, and other matters addressed by the Council follow in Sections II-XV.

II. REVIEW OF SCIENTIFIC COUNCIL RECOMMENDATIONS IN 2020

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

III. FISHERIES ENVIRONMENT

The Report of the Standing Committee on Fisheries Environment (STACFEN) is deferred until the September meeting of SC.

IV. PUBLICATIONS

The Report of the Standing Committee on Publications (STACPUB) is deferred until the September meeting of SC.

V. RESEARCH COORDINATION

The Report of the Standing Committee on Research Coordination (STACREC) is deferred until the September meeting of SC.

VI. FISHERIES SCIENCE

Due to time limitations, it was not possible to adopt the report of the Standing Committee on Fisheries Science (STACFIS; Chair Katherine Sosebee) The Council **adopted** the report by correspondence on 15 September 2021 and this was then appended as Appendix IV.

VII. MANAGEMENT ADVICE AND RESPONSES TO SPECIAL REQUESTS

1. The NAFO Commission

The Commission requests are given in Annex 1.

For Northern shrimp in Division 3M, northern shrimp in Divisions 3LNO and northern shrimp in Subarea 1 and Div. 0A, advice for 2022 will be drafted during a WebEx scheduled for 8-14 September 2021 (however, it is noted that some change in these dates may occur). There will be an additional NIPAG meeting by WebEx in November 2021 to assess northern shrimp in Denmark Strait and off East Greenland.

a) Request for Advice on TACs and Other Management Measures

The Fisheries Commission at its meeting of September 2010 reviewed the assessment schedule of the Scientific Council and, with the concurrence of the Coastal States, agreed to request advice for certain stocks on either a two-year or three-year rotational basis. In recent years, thorough assessments of certain stocks have been undertaken outside of the assessment cycle either at the request of the Commission or by the Scientific Council given recent stock developments.

The Scientific Council advice for stocks fully assessed during this meeting follows below.

Cod in Division 3M Advice June 2021 for 2022

Recommendation for 2022

Scientific Council notes that the strong year-classes of 2009 to 2011 are dominant in the current SSB. Subsequent recruitments are much lower; therefore, substantial declines in stock size are occurring and expected to continue in the very near future under any fishing scenario.

Yield of less than or equal to 5 000 tonnes in 2022 results in a very low probability (≤10%) of SSB being below B_{lim} in 2023 and a very low probability of exceeding F_{lim}. However, given the present low level of the SSB and projected decline of total biomass under any fishing scenario, in order to promote growth in SSB, SC advises catches of no more than 3 000 tonnes in 2022.

Management objectives

No explicit management plan or management objectives have been defined by the Commission. Convention General Principles are applied.

Convention objectives	***Status***	***Comment/consideration***
Restore to or maintain at B_{msy}	Intermediate (yellow)	Stock above B_{lim} in 2021. B_{msy} is unknown
Eliminate overfishing	OK (green)	$F<F_{lim}$ in 2020
Apply Precautionary Approach	OK (green)	F_{lim} and B_{lim} defined
Minimise harmful impacts on living marine resources and ecosystems	Intermediate (yellow)	VME closures in effect, no specific measures
Preserve marine biodiversity	Unknown (white)	Cannot be evaluated

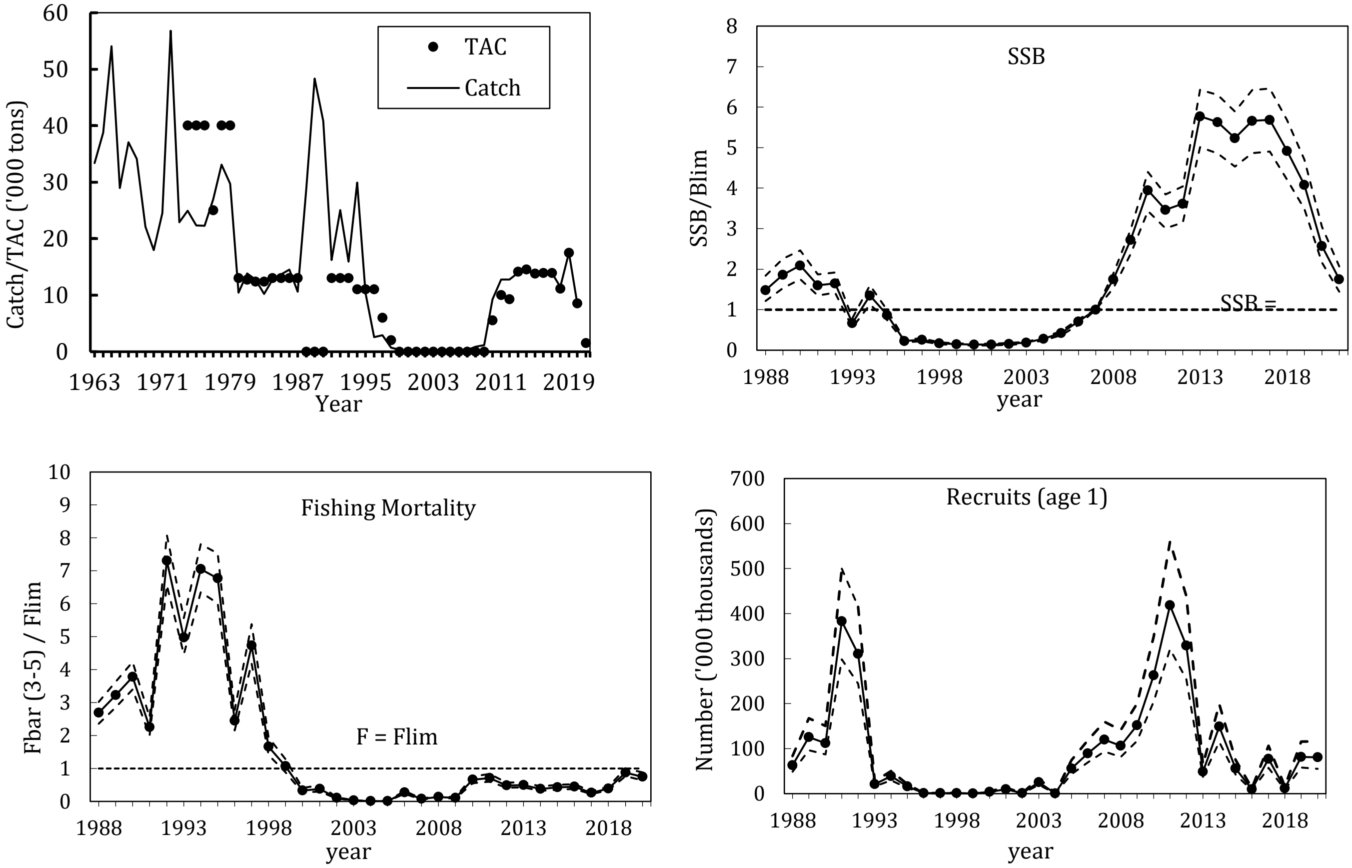
Legend: green = OK; yellow = Intermediate; red = Not accomplished; white = Unknown

Management unit

The cod stock in Flemish Cap (NAFO Div. 3M) is considered to be a separate population.

Stock status

SSB has been declining rapidly since 2017 but is still estimated to be above B_{lim} (median 15 408 t). This decline is expected to continue in the next couple of years due to poor recruitment between 2015 and 2018. Fishing mortality has remained below F_{lim} (median 0.196) since the fishery reopened in 2010. However, in 2019 and 2020 it increased substantially and is now close to F_{lim}.



Reference points

$B_{lim} = SSB_{2007}$:	Median = 15 408 tonnes of spawning biomass (Scientific Council, 2021).
$F_{lim} = F_{30\%SPR}$:	Median = 0.196 (Scientific Council, 2021).

Projections

Although advice is given only for 2022, projection results are shown to 2024 to illustrate the medium-term implications. F_{bar} is the mean of the F at ages 3-5 and used as the indicator of overall fishing mortality; F_{sq} is the status quo F, calculated as the mean of the last three years F_{bar} (2018-2020).

Table 1.

	B		SSB		Yield
	Median and 80% CI				
F_{bar} = Fsq (median = 0.131)					
2021	45787	(40635 - 51559)	27058	(23458 - 31446)	1500
2022	42969	(37884 - 48389)	24420	(21335 - 27970)	6525
2023	34733	(29703 - 40345)	18598	(15605 - 21773)	5291
2024	29999	(24718 - 36318)	19822	(16344 - 23723)	
F_{bar} = 0					
2021	45787	(40635 - 51559)	27058	(23458 - 31446)	1500
2022	42969	(37884 - 48389)	24420	(21335 - 27970)	0
2023	41143	(36076 - 46765)	24071	(21037 - 27322)	0
2024	42102	(36620 - 48376)	30514	(27027 - 34628)	
F_{bar} = 3/4F_{lim} (median = 0.147)					
2021	45787	(40635 - 51559)	27058	(23458 - 31446)	1500
2022	42969	(37884 - 48389)	24420	(21335 - 27970)	7160
2023	34111	(29091 - 39726)	18092	(15086 - 21246)	5694
2024	28966	(23642 - 35277)	18923	(15516 - 22770)	
F_{bar} = 1/2F_{lim} (median = 0.098)					
2021	45787	(40635 - 51559)	27058	(23458 - 31446)	1500
2022	42969	(37884 - 48389)	24420	(21335 - 27970)	5000
2023	36238	(31192 - 41834)	19854	(16887 - 23067)	4254
2024	32578	(27213 - 38900)	22092	(18612 - 25996)	
Catch = 1500 tons					
2021	45787	(40635 - 51559)	27058	(23458 - 31446)	1500
2022	42969	(37884 - 48389)	24420	(21335 - 27970)	1500
2023	39661	(34603 - 45288)	22807	(19826 - 26087)	1500
2024	38994	(33591 - 45246)	27691	(24211 - 31752)	
Catch = 1875 tons					
2021	45787	(40635 - 51559)	27058	(23458 - 31446)	1500
2022	42969	(37884 - 48389)	24420	(21335 - 27970)	1875
2023	39291	(34238 - 44913)	22482	(19454 - 25735)	1875
2024	38216	(32795 - 44488)	27028	(23511 - 31085)	
Catch = 2250 tons					
2021	45787	(40635 - 51559)	27058	(23458 - 31446)	1500
2022	42969	(37884 - 48389)	24420	(21335 - 27970)	2250
2023	38923	(33871 - 44544)	22151	(19150 - 25412)	2250
2024	37438	(32028 - 43736)	26354	(22862 - 30373)	
Catch = 3000 tons					
2021	45787	(40635 - 51559)	27058	(23458 - 31446)	1500
2022	42969	(37884 - 48389)	24420	(21335 - 27970)	3000
2023	38196	(33139 - 43808)	21520	(18528 - 24739)	3000
2024	35865	(30453 - 42155)	24986	(21477 - 28888)	

Table 2.

	Yield			P(SSB < B_{lim})				P(F_{bar} > F_{lim})			
	2021	2022	2023	2021	2022	2023	2024	2021	2022	2023	P(SSB_{24} > SSB_{21})
F_{bar} = F_{sq} = 0.131	1500	6525	5291	<1%	<1%	13%	8%	<1%	<1%	<1%	1%
F_{bar} = 0	1500	0	0	<1%	<1%	<1%	<1%	<1%	<1%	<1%	90%
F_{bar} = 3/4F_{lim} = 0.147	1500	7160	5694	<1%	<1%	17%	13%	<1%	1%	2%	<1%
F_{bar} = 1/2F_{lim} = 0.098	1500	5000	4254	<1%	<1%	5%	1%	<1%	<1%	<1%	4%
Catch = 1500 tons	1500	1500	1500	<1%	<1%	1%	<1%	<1%	<1%	<1%	58%
Catch = 1875 tons	1500	1875	1875	<1%	<1%	1%	<1%	<1%	<1%	<1%	48%
Catch = 2250 tons	1500	2250	2250	<1%	<1%	1%	<1%	<1%	<1%	<1%	36%
Catch = 3000 tons	1500	3000	3000	<1%	<1%	2%	<1%	<1%	<1%	<1%	20%

The results indicate that under all scenarios with F_{bar}>0, total biomass during the projected years will decrease, whereas the SSB is projected to increase slightly in 2024 (Table 1). The probability of SSB being below B_{lim} in 2023 is high (≥13%) in the scenarios with F_{bar}=F_{sq} and F_{bar}=3/4F_{lim}, while being very low (≤10%) in the rest of the cases (Table 2). The probability of SSB in 2024 being above that in 2021 ranges between <1% and 90%, depending on the scenario.

Under all scenarios, the probability of F_{bar} exceeding F_{lim} is less than or equal to 2% in 2022 and 2023.

SC notes that projected values of risk, in particular more than one year ahead (Table 2), will be inherently more uncertain than the projected median stock sizes (Table 1). The risks are typically derived from the tails of a probability distribution which are less precisely estimated compared to the median (centre) of the same distribution.

Assessment

A Bayesian SCAA model, introduced at the 2018 benchmark, was used as the basis for the assessment of this stock with data from 1988 to 2020.

The next full assessment for this stock will be in 2022.

Human impact

Mainly fishery related mortality. Other sources (e.g., pollution, shipping, oil-industry) are undocumented.

Biological and environmental interactions

Redfish, shrimp and smaller cod are important prey items for cod. Recent studies indicate strong trophic interactions between these species in the Flemish Cap.

Fishery

Cod is caught in directed trawl and longline fisheries and as bycatch in the directed redfish fishery by trawlers. The fishery is regulated by quota. New technical regulations were introduced in 2021, in particular a closure of the directed fishery in the first quarter as well as sorting grids to protect juveniles.

Recent catch estimates and TACs ('000 tonnes) are as follows:

,000 tons	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TAC	5.5	10.0	9.3	14.1	14.5	13.8	13.9	13.9	11.1	17.5	8.5	1.5
STATLANT 21	5.2	10.0	9.1	13.5	14.4	12.8	13.8	13.9	10.5	13.0	8.5	
STACFIS	9.3	12.8	12.8	14.0	14.3	13.8	14.0	13.9	11.5	17.5	8.5	

Effects of the fishery on the ecosystem

General impacts of fishing gear on the ecosystem should be considered. A large area of Div. 3M has been closed to protect sponge, sea pens and coral.

Special comment

The stock continues to decline and is expected to be at very low levels during the next few years.

Sources of information

SCS Doc. 21/05, 21/10, 21/13 and SCR Doc. 21/05, 21/17.

Redfish (*Sebastes mentella* and *Sebastes fasciatus*) in Division 3M Advice June 2021 for 2022 – 2023

Recommendation for 2022 and 2023

SC advises that catches do not exceed $F_{0.1}$ level, given the life history of the stock. This corresponds to a TAC of 10 933 t in 2022 and 11 171 t in 2023.

Management objectives

No explicit management plan or management objectives defined by Fisheries Commission. Convention General Principles are applied.

Convention objectives	*Status*	*Comment/consideration*
Restore to or maintain at B_{msy}	Unknown	B_{msy} unknown. Stock above historical average level
Eliminate overfishing	Not accomplished	F_{msy} unknown. Catch at a low level over past 25 years.
Apply Precautionary Approach	Not accomplished	Candidate yield per recruit reference points available and used, but need to be confirmed.
Minimise harmful impacts on living marine resources and ecosystems	Intermediate	VME closures in effect, no specific measures, low bycatch reported.
Preserve marine biodiversity	Unknown	Cannot be evaluated

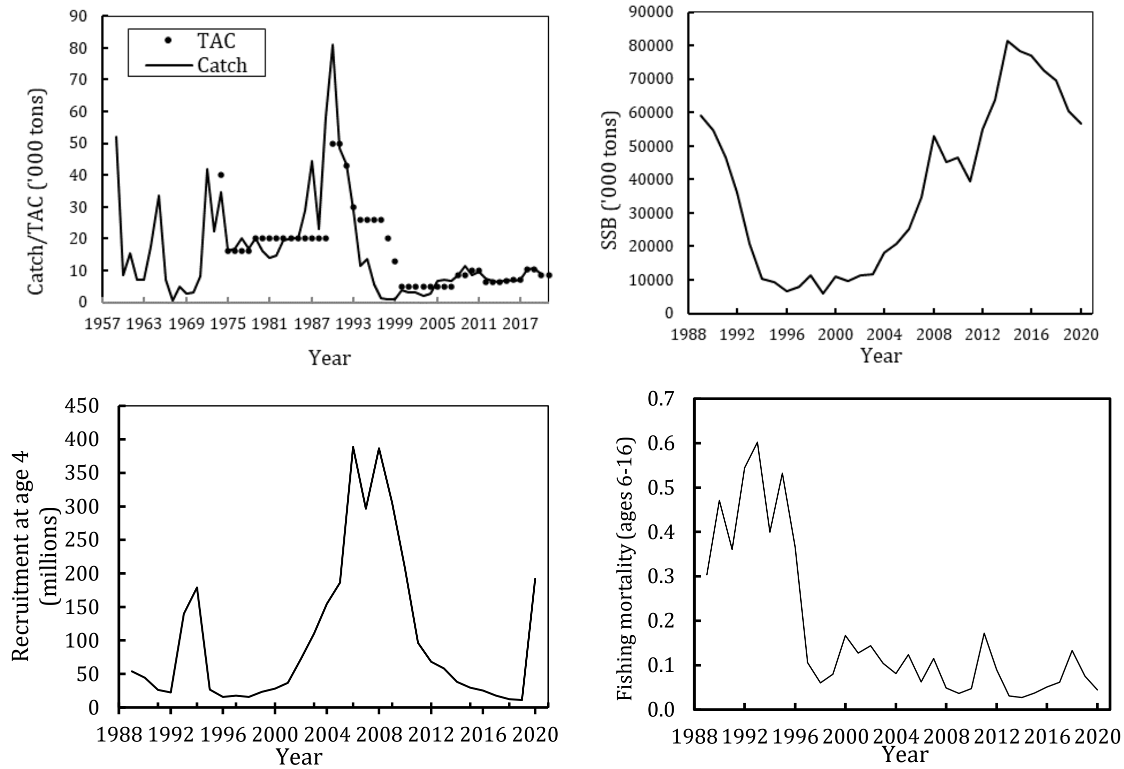
Green	OK
Yellow	Intermediate
Red	Not accomplished
White	Unknown

Management unit

Catches of redfish in Div. 3M include three species of the genus *Sebastes; S. mentella, S. norvegicus* (=*S. marinus*) and *S. fasciatus*. For management purposes, they are considered as one stock. The assessment and advice are based on data for only two species (*S. mentella* & *S. fasciatus*), labeled as beaked redfish. The TAC advice is adjusted to reflect all three species on the Flemish Cap, based upon the relative species distribution in recent surveys.

Stock status

SSB has declined continuously from its highest level in 2014. After an extended period of declining recruitment, the recruitment estimate for 2020 is high but associated with high uncertainty, and its magnitude needs to be confirmed in future assessments. Fishing mortality remains relatively low compared to the 1980s and 1990s.



Reference points

No reference points have been adopted.

Assessment

Input data comes from the EU Flemish Cap bottom trawl survey and the fishery. A quantitative model (XSA) introduced in 2003 was used. Increased natural mortality was assumed from 2006 to 2010, but natural mortality was low (more typical of redfish) in other years. There is no evidence that natural mortality has increased recently from the level of 0.1 adopted in the 2017 assessment, and therefore, the 2021 XSA assessment was run with average M from 2015 onwards kept at 0.1.

The next full assessment of this stock will be in 2023.

Projections

Short term (2022-2024) stochastic projections were carried out for female spawning stock biomass (SSB) and catch, under most recent level of natural mortality and considering five options for fishing mortality ($F_{0.1}$, F=M, $F_{statusquo}$, 1.25 TAC and 0.75 TAC). Projections assume that redfish catches (all species) in 2021 are equal to the redfish TAC ($F_{statusquo}$ is defined as the corresponding F). Recruitment entering in 2021 to 2023 is given by the geometric mean of the most recent recruitments (age 4 XSA, 2017-2019).

In all projection scenarios, the SSB is projected to decline, and to be at around the average for the assessment time-series (since the late 1980s) by 2024.

***F0.1* =0.0669**

	SSB Median and 80% CI	Yield	TAC
2021 deterministic	54264	8271	8448
2022	49021 (45226 - 54929)	10704	10933
2023	43311 (39721 - 48611)	10937	11171
2024	38147 (34488 - 43820)		

***F* =*M* =0.1**

	SSB Median and 80% CI	Yield	TAC
2021 deterministic	54264	8271	8448
2022	49021 (45226 - 54929)	15506	15837
2023	40898 (37522 - 45931)	14898	15217
2024	34029 (30695 - 39319)		

***FsqTAC* = 0.0558**

	SSB Median and 80% CI	Yield	TAC
2021 deterministic	54264	8271	8448
2022	49021 (45226 - 54929)	9027	9220
2023	44164 (40476 - 49546)	9415	9616
2024	39674 (35891 - 45447)		

1.25 TAC (*F* = 0.0644)

	SSB Median and 80% CI	Yield	TAC
2021 deterministic	54264	8271	8448
2022	49021 (45226 - 54929)	10339	10560
2023	43497 (39888 - 48815)	10610	10837
2024	38481 (34787 - 44163)		

0.75 TAC (*F* =0.0376)

	SSB Median and 80% CI	Yield	TAC
2021 deterministic	54264	8271	8448
2022	49021 (45226 - 54929)	6204	6337
2023	45578 (41810 - 51106)	6697	6840
2024	42303 (38374 - 48389)		

average beaked redfish proportion in the 2019-2020 3M redfish catch 0.979

	F0.1	F=M	Fsq	1.25 TAC	0.75 TAC
P(SSB_{2022}>SSB_{2021})	<10%	<10%	<10%	<10%	<10%
P(SSB_{2023}>SSB_{2021})	<10%	<10%	<10%	<10%	<10%
P(SSB_{2024}>SSB_{2021})	<10%	<10%	<10%	<10%	<10%

Human impact

Mainly fishery related mortality. Other sources (e.g., pollution, shipping, oil-industry) are undocumented.

Biology and Environmental Interactions

Since 2004 a rapid increase was observed on survey biomass both of golden (*Sebastes norvegicus*) and Acadian (*Sebastes fasciatus*) redfish stocks. Due to their shallower depth distributions, these two redfish species overlap with cod to an extent greater than deep sea redfish (*Sebastes mentella*). Since 2006, the cod stock started to recover, while those two redfish stocks declined sharply. Redfish is an important component in the diet of cod, especially in those years when successful recruitment events were observed in redfish stocks.

Fishery

Redfish is caught in directed bottom trawl fisheries at intermediate depths (300-700m), but also as bycatch in fisheries directed for cod and Greenland halibut. The fishery in NAFO Div. 3M is regulated by minimum mesh size and quota.

Recent catch estimates and TACs (‘000 t) are as follows:

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TAC	6.5	6.5	6.5	6.7	7.0	7.0	10.5	10.5	8.6	8.4
STATLANT 21	5.4	6.8	6.4	6.9	6.6	7.1	10.5	10.4	8.6	
STACFIS Total catch [1]	6.2	7.8	7.4	6.9	6.6	7.1	10.5	10.6	8.8	
STACFIS Catch [2]	6.3	5.2	4.6	5.2	6.2	6.9	10.3	10.2	8.7	

[1] STACFIS total catch on 2011-2014 based on the average 2006-2010 bias.
[2] STACFIS beaked redfish catch estimate, based on beaked redfish proportions on observed catch.

Effects of the fishery on the ecosystem

General impacts of fishing gears on the ecosystem should be considered. A large area of Div. 3M has been closed to protect sponge, sea pens and coral.

Sources of information: SCR Doc. 21/034 SCS Doc. 21/05, 06, 09,13

Cod in Divisions 3NO Advice June 2021 for 2022 - 2024

Recommendation for 2022 – 2024

No directed fishing in 2022 to 2024 to allow for stock rebuilding. Bycatch of cod in fisheries targeting other species should be kept at the lowest possible level. Projections of the stock were not performed but given the poor strength of all year-classes subsequent to 2006, the stock will not reach B_{lim} in the next three years.

Management objectives

General Convention Principles are applied in conjunction with an Interim Conservation Plan and Rebuilding Strategy adopted in 2011 (NAFO/FC Doc. 11/22). The long-term objective of this plan is to achieve and to maintain the spawning stock biomass in the "safe zone" of the NAFO PA framework (FC Doc. 04/18), and at or near B_{msy}.

Convention objectives	*Status*	*Comment/consideration*
Restore to or maintain at B_{msy}	Red (Not accomplished)	$B < B_{lim}$
Eliminate overfishing	Green (OK)	F is very low, $F < F_{lim}$
Apply Precautionary Approach	Green (OK)	B_{lim} and F_{lim} established, no directed fishery.
Minimise harmful impacts on living marine resources and ecosystems	Green (OK)	No directed fishery
Preserve marine biodiversity	White (Unknown)	Cannot be evaluated

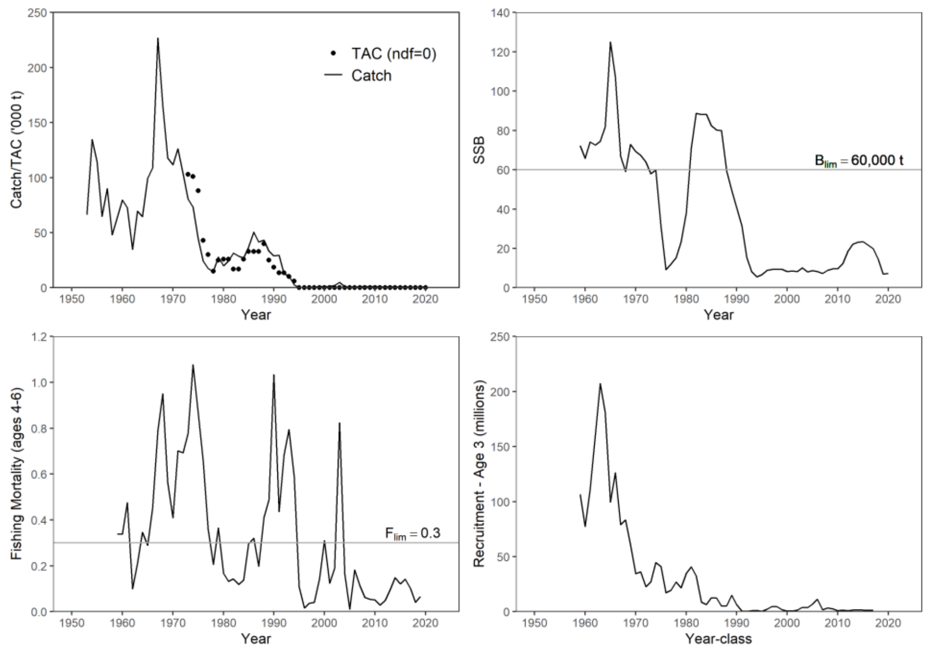
Legend: Green – OK; Yellow – Intermediate; Red – Not accomplished; White – Unknown

Management unit

The stock occurs in Divs. 3NO, with fish occupying shallow parts of the bank, particularly the southeast shoal area (Div. 3N) in summer and on the slopes of the bank in winter.

Stock status

The spawning biomass increased noticeably between 2010 and 2015 but has subsequently declined sharply and the 2020 estimate of 7279 t represents only 12% of B_{lim} (60,000 t). The relatively strong 2006 year-class left the population after 2018, which had some influence on the most recent SSB estimates but did not influence overall stock status. Subsequent year-classes are much weaker, suggesting that the medium-term prospects for the stock are not good. Fishing mortality values over the past decade have been low and well below F_{lim} (0.3). Lack of catch-at-age data in 2020 prevented the estimation of stock size for 2021, however it should not be markedly different than the 2020 estimate.



Reference points

B_{lim}:	60 000 t of spawning biomass (SC, 1999).
F_{lim} (=F_{msy}):	0.3 (SC, 2011).

Projections

Although projections of the stock were not performed because of various limitations identified with the assessment model, the poor strength of year-classes subsequent to 2006 suggests that the medium-term prospects for the stock are not good.

Assessment

A virtual population analysis model was used, and the results were consistent with the previous assessment. Input data comes from research surveys and commercial removals.

The next assessment is planned for 2024.

Human impact

Mainly bycatch related fishery mortality has been documented. Other sources (e.g., pollution, shipping, oil-industry) are undocumented.

Biology and Environmental interactions

Productivity of this stock was above average during the warm 1960s. During the cold 1990s, productivity was very low and surplus production was near zero. The Grand Bank (3LNO) Ecosystem Production Unit is currently experiencing low productivity conditions and biomass has declined across multiple trophic levels and stocks since 2014.

Fishery

A moratorium was implemented in 1994. Catches since that time are bycatch in other fisheries.

Recent catch estimates and TACs ('000 t) are as follows:

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TAC	ndf	ndf	ndf	ndf	ndf	ndf	ndf	ndf	ndf	ndf
STATLANT 21	0.7	1.1	0.7	0.5	0.6	0.6	0.3	0.5	0.3*	
STACFIS	0.7	1.1	0.7	0.6	0.7	0.6	0.4	0.5	0.6	

ndf: No directed fishery
*provisional

Effects of the fishery on the ecosystem
No specific information is available. There is no directed fishery for this stock. General impacts of fishing gears on the ecosystem should be considered. Areas of Divs. 3LNO have been closed to protect sponges and corals.

Special comments
The assessment model was accepted for stock status purposes, but a decision was made to not project the stock forward because of the limited age range (ages 2-12) considered in the model, as well as potential diagnostic issues (including directional retrospective patterns, trends in residuals in recent years). Limitations of the current assessment model suggest a need to explore more flexible models capable of dealing with uncertainty in model inputs (e.g., catch-at-age) and that do not impose assumptions about stationary natural mortality.

Sources of information
SCR Docs. 21/04; SCS Docs. 21/05, 06, 08, 09, 10, 13.

American plaice in Divisions 3LNO Advice June 2021 for 2022 – 2024

Recommendation for 2022-2024

Scientific Council recommends that, in accordance with the rebuilding plan, there should be no directed fishing on American plaice in Div. 3LNO in 2022, 2023 and 2024. Bycatch of American plaice should be kept to the lowest possible level and restricted to unavoidable bycatch in fisheries directing for other species.

Management objectives

In 2011 FC adopted an "Interim 3LNO American Plaice Conservation Plan and Rebuilding Strategy" (FC Doc. 11/21). There is a Harvest Control Rule (HCR) in place for this stock.

Convention objectives	*Status*	*Comment/consideration*
Restore to or maintain at B_{msy}	🔴	B<B_{lim}
Eliminate overfishing	🟡	No directed fishery, current bycatch are delaying recovery
Apply Precautionary Approach	🟢	Reference points defined
Minimise harmful impacts on living marine resources and ecosystems	🟡	VME closures in effect, no specific measures.
Preserve marine biodiversity	⚪	Cannot be evaluated

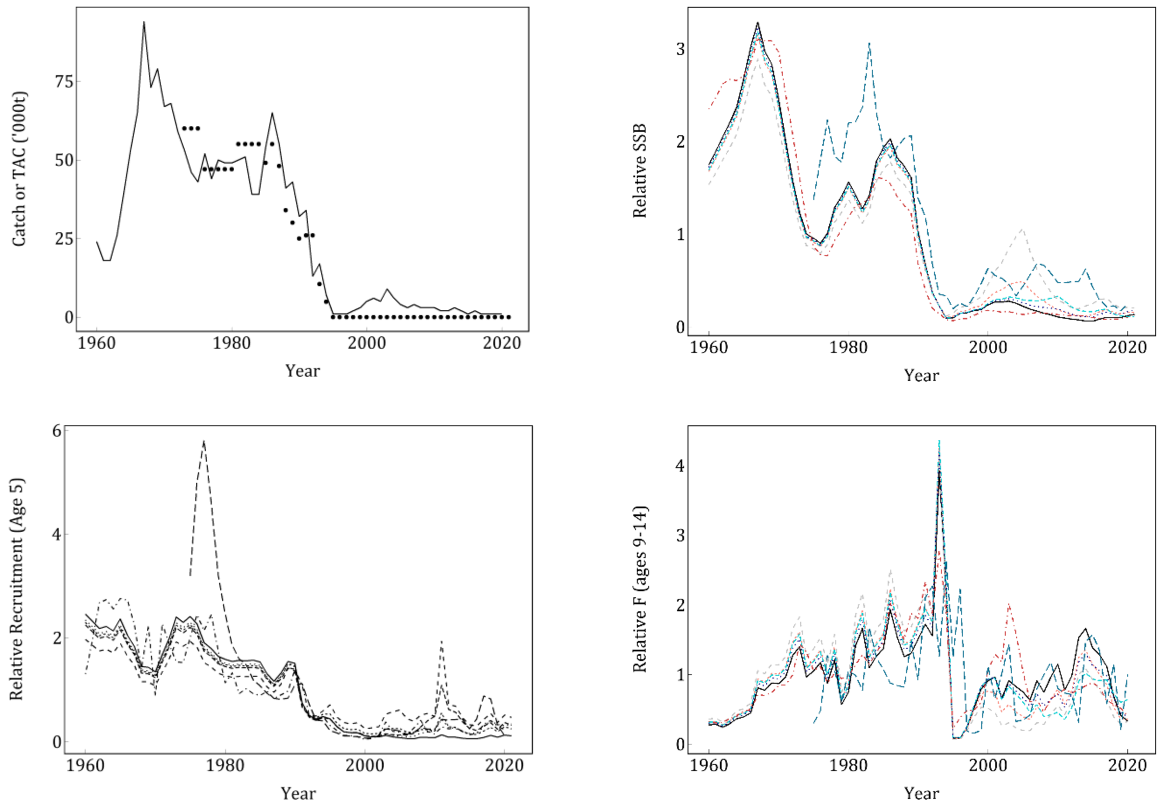
🟢 OK
🟡 Intermediate
🔴 Not accomplished
⚪ Unknown

Management unit

The management unit is NAFO Divisions 3LNO. The stock is distributed throughout Div. 3LNO but historically most of the biomass was found in Div. 3L.

Stock status

Fishing mortality increased from the late 1990s to 2015 and has subsequently declined. Recruitment has been very low in the last two decades. The stock remains low compared to historic levels and is presently considered to be below B_{lim}.



The multiple lines shown in the graphs correspond to alternate models and model formulations considered by SC. The black line indicates the base run of the ADAPT VPA.

Reference points

B_{lim}: 50 000 t of spawning biomass (Scientific Council Report, 2003).
B_{msy}: 242 000 t of spawning biomass (Scientific Council Report 2011).
F_{lim}: 0.31 (Scientific Council Report, 2011).

Projections

Due to model instability, projections were not completed for this stock. There is considered to be low potential for stock growth.

Assessment

An analytical assessment using the ADAPTive framework tuned to the Canadian 3LNO spring, Canadian 3LNO autumn and the EU-Spain Div. 3NO survey is used for this stock. While results are considered by SC to indicative of stock trends, the absolute magnitude of population estimates from this model was not accepted by SC given a large retrospective pattern that consistently and significantly overestimates SSB and underestimates F. Several formulations of the ADAPT VPA with increases in the natural mortality assumption since at least 2005 were also considered. In addition, results of two independent populations models – a State-Space Model and a Spatial SURBA – were presented. Overall stock trends were consistent across models and support the conclusions of stock status from the base ADAPT.

The next full assessment is scheduled for 2024.

Human impact
Mainly fishery related mortality. Other sources (e.g., pollution, shipping, oil-industry) are undocumented.

Biological and environmental interactions
Capelin and sandlance as well as other fish and invertebrates are important prey items for American plaice. There has been a decrease in age at 50% maturity over time, possibly brought about by some interaction between fishing pressure and environmental/ecosystem changes. The Grand Bank (3LNO) Ecosystem Production Unit is currently experiencing low productivity conditions and biomass has declined across multiple trophic levels and stocks since 2014.

Fishery

The stock has been under moratorium since 1995. American plaice in recent years is caught as bycatch mainly in otter trawl fisheries of yellowtail flounder, skate and redfish.

Recent catch estimates and TACs are:

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TAC	ndf	ndf	ndf	ndf	ndf	ndf	ndf	ndf	ndf	ndf
STATLANT 21	1.3	2.2	1.4	1.1	1.7	1.2	0.8	1.2	1.1	
STACFIS	2.1[1]	3.0[1]	2.3[1]	1.1[2]	1.7[2]	1.2[3]	1.0[3]	1.2[3]	1.2[3]	

ndf No directed fishing.

[1] Catch was estimated using fishing effort ratio applied to 2010 STACFIS catch.

[2] Catch was estimated using STATLANT 21 data for Canadian fisheries and Daily Catch Records for fisheries in the NRA.

[3] STACFIS Catches since 2017 are obtained from CESAG

Effects of the fishery on the ecosystem

No specific information is available. There is no directed fishery for this stock. General impacts of fishing gears on the ecosystem should be considered. Areas within Divs. 3LNO have been closed to protect sponges and coral.

Special Comments

SC has identified a need to undertake a benchmark process to develop a new modelling framework for this stock.

From the early 2000s to around 2015, there was an increase in fishing mortality, and there is evidence of a concurrent increase in natural mortality. The combined impact of these factors is impeding recovery of this stock.

Sources of information

SCS Doc. 21/05, 06, 08; SCR Doc. 20/08, 13, 21/04, 10, 25; FC Doc. 11/21

Yellowtail flounder in Divisions 3LNO Advice June 2021 for 2022 - 2024

Recommendation for 2022 to 2024
Scientific Council advises that fishing mortality up to 85% F_{msy}, corresponding to catches of 22 100 t, 20 800 t, and 19 900 t in 2022 to 2024 respectively, have risk of no more than 30% of exceeding F_{lim}, and are projected to maintain the stock above B_{msy}.

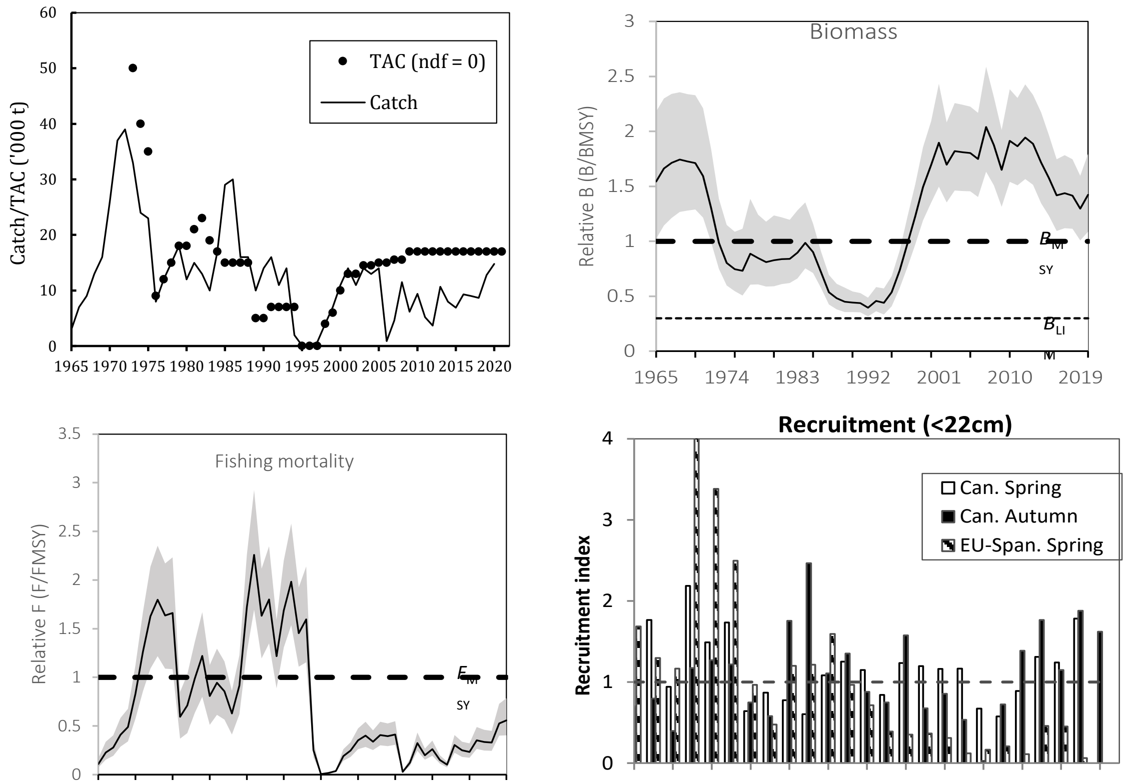
Management objectives
No explicit management plan or management objectives are defined by the Commission. Convention General Principles are applied.

Convention objectives	***Status***	***Comment/consideration***
Restore to or maintain at B_{msy}	OK (green)	B> B_{msy}
Eliminate overfishing	OK (green)	$F < F_{lim}$
Apply Precautionary Approach	OK (green)	Stock in safe zone of PA framework
Minimise harmful impacts on living marine resources and ecosystems	Intermediate (yellow)	Bycatch regulations in place for moratorium stocks, general VME closures in effect
Preserve marine biodiversity	Unknown (white)	Cannot be evaluated

Legend: green = OK; yellow = Intermediate; red = Not accomplished; white = Unknown

Management unit
The management unit is NAFO Divisions 3LNO. The stock is mainly concentrated on the southern Grand Bank and is recruited from the Southeast Shoal area nursery ground.

Stock status
The stock biomass increased from 1994 to 2001, after which it remained stable until 2014. Biomass subsequently declined from ~2 times B_{msy} and is currently 1.4 times B_{msy} (B_{msy} = 89 790 tons). There is very low risk of the stock being below B_{msy} or F being above F_{msy}. Recent recruitment appears to be higher than average.



Reference points

B_{lim} is 30% B_{msy} and F_{lim} is F_{msy} (STACFIS 2004 p 133).

Projections

Medium-term projections were carried forward to the year 2025 with catch in 2021 assumed to be the TAC=17 000 t. Constant fishing mortality was applied from 2022-2025 at several levels of *F* (*F*=0, $F_{status\ quo}$, 2/3 F_{msy}, 85% F_{msy} and F_{msy}).

F_{msy} was estimated to be 0.21. Fishing at F_{msy} would first lead to a considerable yield in 2022, but yields are then projected to decline in the medium term with catch at 2/3 F_{msy}, 85% F_{msy} and F_{msy}. At the end of the projection period, the risk of biomass being below B_{lim} is less than 1% in all cases.

For the $F_{status\ quo}$ projections, probability that $F > F_{lim}=F_{msy}$ in 2022-2025 was less than 0.04 in the medium term. At 2/3 F_{msy}, the probability that F > F_{lim} was between 0.08 and 0.11 in the medium term. Projected at the level of 85% F_{lim}, the probability that F > F_{lim} ranges between 0.27 and 0.30 and for F_{msy} projections, this probability increased to 0.50. For biomass projections, in all scenarios for 2022-2025, the probability of biomass being below B_{lim} was less than 0.01. The probability that biomass in 2025 is greater than B_{2021} is 0.48, 0.41, 0.32 and 0.26 for projections of $F_{status\ quo}$, 2/3 F_{msy}, 85% F_{msy}, and F_{msy} respectively.

Projections with $Catch_{2021}$= TAC=17 000 t		
Year	Yield ('000t) median	Projected Relative Biomass(B/B_{msy}) median (90% CL)
F =0		
2022	0.00	1.39 (0.92, 1.97)
2023	0.00	1.56 (1.03, 2.18)
2024	0.00	1.69 (1.13, 2.32)
2025		1.78 (1.22, 2.41)
$F_{status\ quo}$ = 0.112		
2022	13.99	1.39 (0.92, 1.97)
2023	14.06	1.4 (0.91, 2)
2024	14.12	1.41 (0.89, 2.01)
2025		1.42 (0.88, 2.02)
2/3 F_{MSY} = 0.139		
2022	17.36	1.39 (0.92, 1.97)
2023	16.98	1.37 (0.87, 1.96)
2024	16.73	1.35 (0.83, 1.94)
2025		1.33 (0.8, 1.94)
85% F_{MSY} =0.177		
2022	22.11	1.39 (0.92, 1.97)
2023	20.77	1.31 (0.83, 1.9)
2024	19.92	1.26 (0.75, 1.85)
2025		1.22 (0.69, 1.83)
F_{MSY} =0.21		
2022	26.05	1.39 (0.92, 1.97)
2023	23.70	1.27 (0.79, 1.85)
2024	22.20	1.19 (0.68, 1.78)
2025		1.13 (0.59, 1.75)

	Yield ('000t)			P(F>F_{lim})				P(B<B_{lim})				P(B<B_{MSY})				
$Catch_{2021}$=17 000t	2022	2023	2024	2022	2023	2024	2025	2022	2023	2024	2025	2022	2023	2024	2025	P(B_{2025}>B_{2021})
F =0	0.00	0.00	0.00	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	9%	4%	2%	1%	82%
$F_{status\ quo}$ = 0.112	13.99	14.06	14.12	2%	3%	3%	4%	<1%	<1%	<1%	<1%	9%	9%	10%	10%	48%
2/3 F_{MSY} = 0.139	17.36	16.98	16.73	8%	9%	10%	11%	<1%	<1%	<1%	<1%	9%	11%	13%	15%	41%
85% F_{MSY} =0.177	22.11	20.77	19.92	27%	28%	29%	30%	<1%	<1%	<1%	<1%	9%	14%	20%	24%	32%
F_{MSY} =0.209	26.05	23.70	22.20	50%	50%	50%	50%	<1%	<1%	<1%	<1%	9%	18%	27%	34%	26%

Assessment

A Schaefer surplus production model in a Bayesian framework was used for the assessment of this stock. The results were comparable to the previous assessment. Input data comes from research surveys and the fishery. Next assessment: 2024.

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

Biology and Environmental interactions
As stock size increased from the low level in the mid-90s, the stock expanded northward and continues to occupy this wider distribution. This expansion of the stock coincided with warmer temperatures.

Despite the increase in stock size observed since the mid-90s, the average length at which 50% of fish are mature has been lower for both males and females in the recent period. There also seems to have been a slight downward trend in weight at length since 1996. The cause of these changes is unknown.

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

Fishery
Yellowtail flounder is caught in a directed trawl fishery and as bycatch in other trawl fisheries. The fishery is regulated by quota and minimum size restrictions. Catches in several years were low due to industry-related factors, but in recent years catches have increased and in 2019 and 2020 were 75% and 87% of the TAC respectively. American plaice and cod are taken as bycatch in the yellowtail fishery. There is a 15% bycatch restriction on American plaice and a 4% limit on cod.

Recent catch estimates and TACs ('000 t) are as follows:

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TAC	17	17	17	17	17	17	17	17	17	17
STATLANT 21	3.1	10.7	8.0	6.7	8.3	9.2	8.6	12.3	14.0	
STACFIS	3.1	10.7	8.0	6.9	9.3	9.2	8.7	12.8	14.8	

Effects of the fishery on the ecosystem
Fishing intensity on yellowtail flounder has impacts on Div. 3NO cod and Div. 3LNO American plaice through bycatch. General impacts of fishing gears on the ecosystem should also be considered. Areas within Divs. 3LNO have been closed to protect sponge and coral.

Special comments
Management of yellowtail flounder should take into consideration impacts on other stocks. Bycatch in the yellowtail flounder fishery may be impeding recovery of Div. 3NO cod and American plaice in Div. 3LNO, which have both been below B_{lim} for many years and are currently experiencing reduced productivity conditions. Measures to reduce bycatch of American plaice in the yellowtail flounder fishery in particular, which currently has a 15% limit, could reduce the impact of fishing on the recovery of that stock. Such measures could include maintaining or reducing the yellowtail flounder TAC, reducing the bycatch limit, or seasonal closures in areas of high bycatch, in order to protect stocks in the collapsed zone.

Sources of information
SCR 20/09, 04, 21/18, 19; SCS 21/05, 06, 09, 13; NAFO/GC Doc 08/3 NAFO/FC 04/18

Capelin in Divisions 3NO Advice June 2021 for 2022 - 2024

Recommendation for 2022-2024
No directed fishery.

Management objectives

No explicit management plan or management objectives defined by the Commission. General Convention Principles (GC Doc. 08-03) are applied. Advice is based on qualitative evaluation of biomass indices in relation to historic levels.

Convention objectives	***Status***	***Comment/consideration***
Restore to or maintain at B_{msy}	🔴	B_{msy} unknown, stock at low level
Eliminate overfishing	🟢	No directed fishery
Apply Precautionary Approach	⚪	Reference points not defined
Minimise harmful impacts on living marine resources and ecosystems	🟢	VME closures in effect, no directed fishing
Preserve marine biodiversity	⚪	Cannot be evaluated

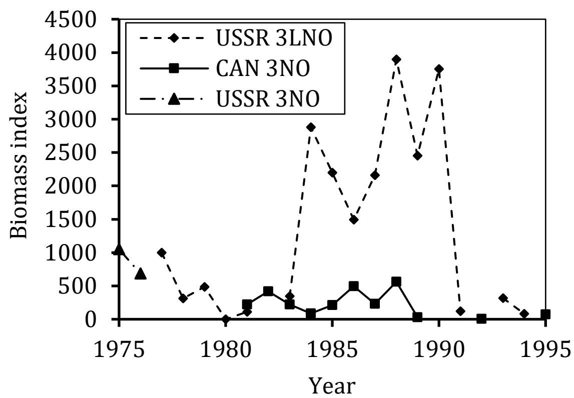
🟢	OK
🟡	Intermediate
🔴	Not accomplished
⚪	Unknown

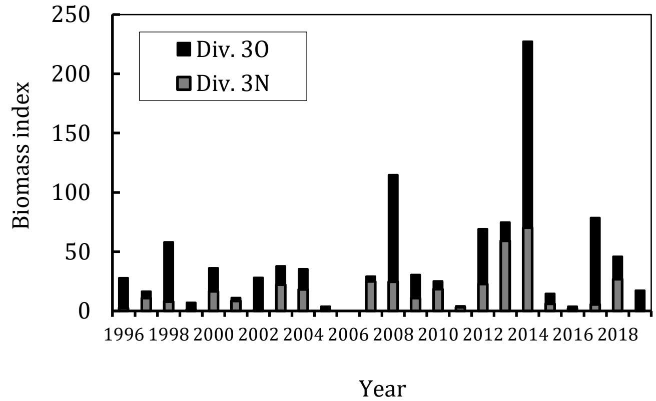
Management unit

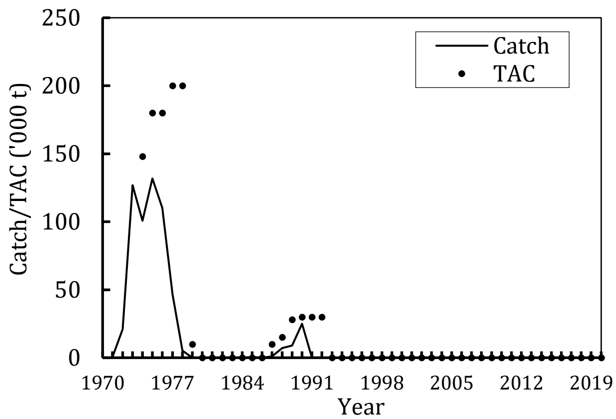
The capelin stock is distributed in Div. 3NO, mainly on the Grand Bank.

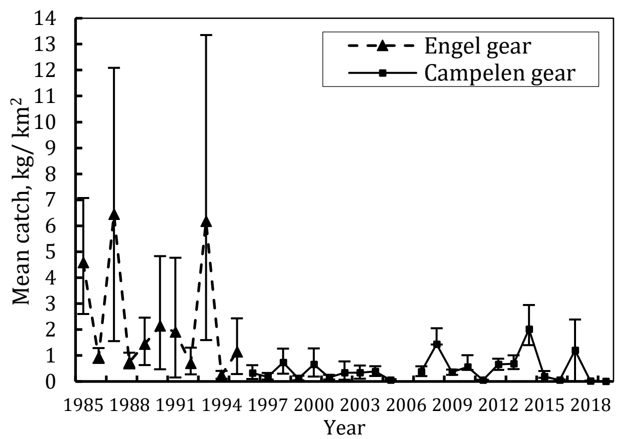
Stock status

Acoustic surveys series terminated in 1994 indicated a stock at a low level. Although biomass indices have increased in recent years, bottom trawl surveys are not considered a satisfactory basis for a stock assessment of a pelagic species.









Reference points
Not defined.
Projections
Quantitative assessment of risk at various catch options is not possible for this stock at this time.

Assessment
Assessment was based on evaluation of trends in acoustic survey data (1975 – 1994) and bottom trawl surveys (1996 – 2019: upper right figure – Canadian spring surveys biomass index; 1985 – 2019: lower right figure – Canadian spring surveys mean catch). Bottom-trawling is not a satisfactory basis for a stock assessment of a pelagic species. The assessment is only sensitive to large-scale fluctuations in biomass and abundance. Therefore, although the next full assessment is in principle scheduled for 2024, SC recommends that this stock be monitored in future by interim monitoring reports only, until such time conditions change to warrant a full assessment.

Human impact
Low fishery related mortality due to moratorium and low bycatch in other fisheries. Other sources (e.g., pollution, shipping, oil industry) are considered minor.

Biological and environmental interactions
Changes in growth, maturity and recruitment are linked to temperature on the Grand Banks. The Grand Bank (3LNO) ecosystem production unit is currently experiencing low productivity conditions and biomass has declined across multiple trophic levels and stocks since 2014.

Fishery

Capelin has been fished in a directed trawl fishery. There is low bycatch in other trawl fisheries. The directed fishery was closed in 1992 and the closure has continued through 2020. No catches have been reported for this stock from 1993 except one tonne of Spanish catch in 2014 and five tonnes Estonian catch in 2016.

Recent catch estimates and TACs (t) are as follows:

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
TAC	ndf*	ndf*	ndf*	ndf*	ndf*	ndf*	ndf*	ndf*	ndf*	ndf*
STATLANT 21	0	0	0	1	0	5	0	0	0	0
STACFIS	-	-	-	-	0[1]	4[1]	11[2]	2[2]	2[2]	1[2]

*ndf - no directed fishing

[1] Catch was estimated using STATLANT 21 data for Canadian fisheries and Daily Catch Records for fisheries in the NRA.
[2] STACFIS Catches since 2017 are obtained from CESAG

Effects of the fishery on the ecosystem

No fishery.

Special comments

Bottom-trawling is not a satisfactory basis for a stock assessment of a pelagic species. Investigations to evaluate the status of capelin stock should utilize trawl acoustic surveys to allow comparison with historical time series.

Source of Information

SCR Doc. 21/029, SCS Doc. 21/06

White Hake in Divisions 3NO and Subdiv. 3Ps Advice June 2021 for 2022-2023

Recommendation for 2022-2023
Given the absence of strong recruitment, catches of white hake in 3NO should not increase.
Average annual total catches of the most recent five years were around 400 tonnes.

Management objectives
No explicit management plan or management objectives defined by Fisheries Commission. General Convention Principles (NAFO/GC Doc 08/3) are applied. Advice is based on survey indices and catch trends in relation to estimates of recruitment.

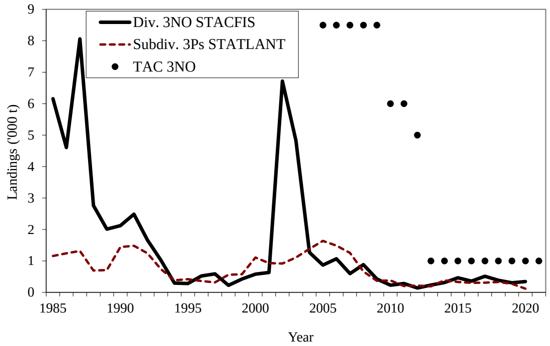
Convention objectives	*Status*	*Comment/consideration*
Restore to or maintain at B_{msy}	Unknown (white)	B_{msy} unknown, stock at low level
Eliminate overfishing	Unknown (white)	F_{msy} unknown, fishing mortality is low
Apply Precautionary Approach	Not accomplished (red)	Reference points not defined
Minimise harmful impacts on living marine resources and ecosystems	Intermediate (yellow)	No specific measures, general VME closures in effect
Preserve marine biodiversity	Unknown (white)	Cannot be evaluated

Legend: green – OK; yellow – Intermediate; red – Not accomplished; white – Unknown

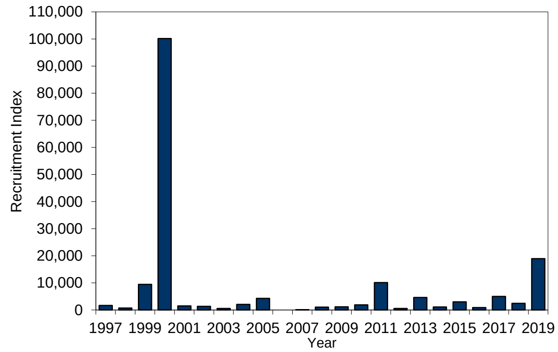
Management unit
The management unit is confined to NAFO Div. 3NO, which is a portion of the stock that is distributed in NAFO Div. 3NO and Subdivision 3Ps.

Stock status
The assessment is considered data limited and is associated with a relatively high uncertainty. Biomass of this stock increased in 1999 and 2000, generated by the large recruitment observed in those years. Subsequently, the biomass index decreased and has since remained variable but lower. No large recruitments have been observed since 2000, however the 2019 index is the highest in two decades. Fishing mortality is low.

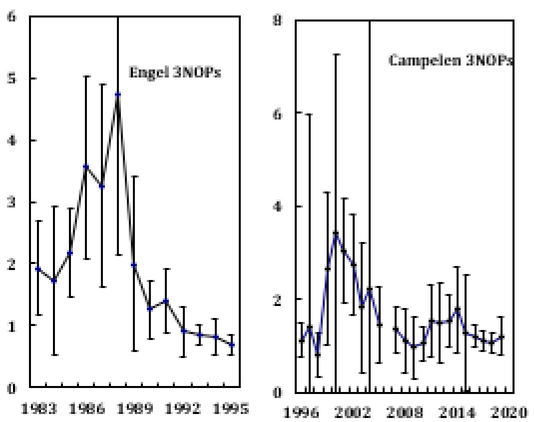
Catch History/TAC



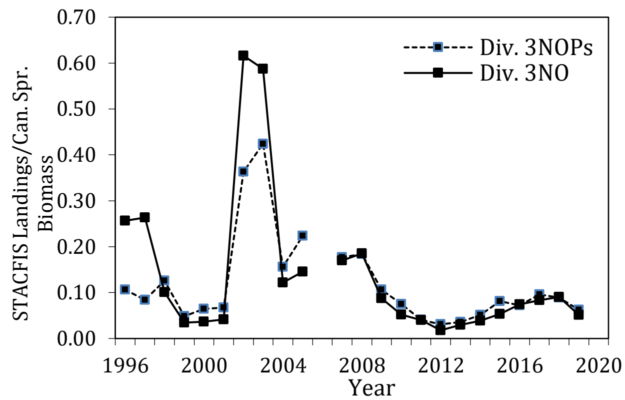
Recruitment Index



Spring Biomass Index



Fishing Mortality Index



Reference Points

Not defined

Assessment

Based upon a qualitative evaluation of stock biomass trends and recruitment indices. The assessment is considered data limited and as such associated with a relatively high uncertainty. Input data are research survey indices and fishery data (STACFIS 2021).

The next full assessment of this stock will be in 2023.

Human impact
Mainly fishery related mortality has been documented. Mortality from other human sources (e.g. pollution, shipping, oil-industry) are undocumented.

Biology and Environmental interactions
On the Grand Bank, white hake are near the northern limit of their range, concentrating along the southwest slope of the Grand Bank at temperatures above 5°C. The major spawning area is located on the shelf-edge on the Grand Bank. Weaker ocean currents on the continental slope during the spawning period are hypothesized to reduce potential losses of eggs and larvae due to entrainment in the Labrador Current and increase recruitment potential.

White hake feed mostly on crustaceans and fish. Larger individuals are reported to be cannibalistic and to feed upon eggs and juveniles. In nearshore areas, white hake are also thought to predate on smaller juvenile cod. Predators of white hake include Atlantic cod, other fish species, Atlantic puffins, Arctic terns, other seabirds and seals.

This stock straddles the 3Ps and 3LNO Ecosystem Production Units (EPU), which have been experiencing low productivity conditions in recent years, including biomass declines across multiple trophic levels and stocks in 3LNO since 2014.

Fishery
White hake is caught in directed gillnet, trawl and long-line fisheries. In directed white hake fisheries, Atlantic cod, black dogfish, monkfish and other species are landed as bycatch. In turn, white hake are also caught as bycatch in gillnet, trawl and long-line fisheries directing for other species. The fishery in NAFO division 3NO, and subdivision 3Ps, are regulated by quotas.

Recent catch estimates and TACs ('000 t) are:

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Div. 3NO:										
TAC	5	1	1	1	1	1	1	1	1	1[1]
STATLANT 21	0.1	0.2	0.3	0.4	0.4	0.5	0.3	0.3	0.3	
STACFIS	0.1	0.2	0.3	0.5	0.4	0.5	0.4	0.3	0.3	
Subdiv. 3Ps:										
TAC							0.5	0.5	0.5	0.5
STATLANT 21	0.2	0.2	0.4	0.3	0.4	0.3	0.3	0.3	0.1	

[1]May change in-season. See NAFO FC Doc. 19/01.

Effects of the fishery on the ecosystem
No specific information is available. General impacts of fishing gears on the ecosystem should be considered.

Special comments
No special comments.

Sources of Information
SCR Doc.20/010; 21/004, 022; SCS Doc. 21/05, 06, 08, 09

b) Monitoring of Stocks for which Multi-year Advice was Provided in 2019 and 2020

Interim monitoring for northern shortfin squid (*Illex illecebrosus*) in Subareas 3+4 will be carried out in September 2021. Interim monitoring updates of other stocks assessed in prior years were conducted and Scientific Council reiterates its previous advice as follows:

Recommendation for American Plaice in Division 3M for 2021 – 2023: The stock has recovered to the levels of the mid 1990s, when the fishery was closed. SC considers that there is not sufficient evidence that the stock would be able to sustain a fishery at this time and recommends that there be no directed fishing in 2021, 2022 and 2023. Bycatch should be kept at the lowest possible level.

Recommendation for redfish in Division 3O for 2020 – 2022: There is insufficient information on which to base predictions of annual yield potential for this resource. Stock dynamics and recruitment patterns are also poorly understood. Catches have averaged about 12 000 tonnes since the 1960s and over the long term, catches at this level appear to have been sustainable. Scientific Council is unable to advise on an appropriate TAC for 2020, 2021 and 2022.

Recommendation for witch flounder in Divisions 3NO for 2021 and 2022: There is more than a 10% probability of the stock being below B_{lim} in 2021 (11%). For 2022 and 2023 this probability ranges from 7% to 11% for scenarios with fishing mortality greater than zero. Advice is provided in the context of the NAFO Precautionary Approach framework which specifies that there should be a very low probability of being below B_{lim}.

SC considers that there is not sufficient evidence that the stock would be able to sustain a fishery at this time and recommends that there be no directed fishing in 2021 and 2022.

Recommendation for Thorny skate in Divisions 3LNO and Subdiv. 3Ps 2021 and 2022: The stock has been stable at recent catch levels (approximately 3511 tonnes, 2015 - 2019). However, given the low resilience of this species and higher historic stock levels, Scientific Council advises no increase in catches.

Recommendation for roughhead grenadier in Subareas 2 and 3: There will be no new assessment until monitoring shows that conditions have changed.

Recommendation for alfonsino in Division 6G for 2019 and beyond: The substantial decline in CPUE and catches on the Kükenthal Peak in the past year indicates that the stock may be depleted. SC advises to close the fishery until biomass increases to exploitable levels.

c) Special Requests for Management Advice

i) Request #2: Greenland halibut in SA2 + Divs. 3KLMNO: monitor, compute the TAC using the agreed HCR and determine whether exceptional circumstances are occurring

The Commission requests the Scientific Council to monitor the status of Greenland halibut in Subarea 2+Div. 3KLMNO annually to compute the TAC using the agreed HCR and determine whether exceptional circumstances are occurring. If exceptional circumstances are occurring, the exceptional circumstances protocol will provide guidance on what steps should be taken.

Scientific Council responded:

The TAC for 2022 derived from the HCR is 15 864 t. This is 4% lower than the 2021 TAC (16 498 t).

SC advises that Exceptional Circumstances are not occurring.

SC notes that the disruption of the 2021 Canadian Spring 3LNO survey, in addition to the years 2020 and 2017, will trigger Exceptional Circumstances next year.

An HCR for Greenland halibut in Subarea 2+Div. 3KLMNO was adopted by the Commission in 2017. The HCR has two components: target based and slope based. The full set of control parameters for the adopted HCR are shown in **Table i.1** with a starting TAC of 16 500 t in 2018. All data inputs used to calculate the TAC for 2022 are shown in **Table i.2**.

*Target based (**t**)*
The target harvest control rule (HCR) is:

$$\mathrm{TAC}_{y+1}^{target} = \mathrm{TAC}_y(1 + \gamma(J_y - 1)) \qquad (1)$$

where TAC_y is the TAC recommended for year y, γ is the “response strength” tuning parameter, J_y is a composite measure of the immediate past level in the mean weight per tow from surveys (I_y^i) that are available to use for calculations for year y; five survey series are used, with i = 1, 2, 3, 4 and 5 corresponding respectively to Canada Fall 2J3K, EU 3M 0-1400m, Canada Spring 3LNO, EU-Spain 3NO and Canada Fall 3LNO:

$$J_y = \sum_{i=1}^{5} \frac{1}{\sigma^{i^2}} \frac{J_{current,y}^i}{J_{target}^i} \Big/ \sum_{i=1}^{5} \frac{1}{\sigma^{i^2}} \qquad (2)$$

with $(\sigma^i)^2$ being the estimated variance for index i (estimated in the SCAA model fitting procedure),

$$J_{current,y}^i = \frac{1}{q} \sum_{y'=y-q}^{y-1} I_{y'}^i \qquad (3)$$

$$J_{target}^i = \alpha \frac{1}{5} \sum_{y'=2011}^{2015} I_{y'}^i \quad \text{(where } \alpha \text{ is a control/tuning parameter for the MP)} \qquad (4)$$

and q indicating the period of years used to determine current status. Note the assumption that when a TAC is set in year y for year $y + 1$, indices will not at that time yet be available for the current year y. Missing survey values are treated as missing in the calculation using the rule, as was done in the MSE. In such cases, q in equation (3) is reduced accordingly.

*Slope based (**s**)*
The slope harvest control rule (HCR) is:

$$\mathrm{TAC}_{y+1}^{slope} = \mathrm{TAC}_y[1 + \lambda_{up/down}(s_y - X)] \qquad (5)$$

where $\lambda_{up/down}$ and X are tuning parameters, s_y^i is a measure of the immediate past trend in the survey-based mean weight per tow indices, computed by linearly regressing lnI_y^i, vs year y' for $y' = y - 5$ to $y' = y - 1$, for each of the five surveys considered, with

$$s_y = \sum_{i=1}^{5} \frac{1}{(\sigma^i)^2} s_y^i / \sum_{i=1}^{5} \frac{1}{(\sigma^i)^2} \qquad (6)$$

with the standard error of the residuals of the observed compared to model-predicted logarithm of survey index i (σ^i) estimated in the SCAA base case operating model. Missing survey values are treated as missing in the calculation using the rule, as was done in the MSE. In such cases, the slope in equation (6) is calculated from the available values within the last five years.

*Combination Target and Slope based **(s+t)***
For the target and slope based combination:

1) $\mathrm{TAC}_{y+1}^{target}$ is computed from equation (1),
2) $\mathrm{TAC}_{y+1}^{slope}$ is computed from equation (5), and
3) $\mathrm{TAC}_{y+1} = (\mathrm{TAC}_{y+1}^{target} + \mathrm{TAC}_{y+1}^{slope})/2$

Finally, constraints on the maximum allowable annual change in TAC are applied, viz.:

$$\text{if} \quad \mathrm{TAC}_{y+1} > \mathrm{TAC}_y(1 + \Delta_{up}) \quad \text{then} \quad \mathrm{TAC}_{y+1} = \mathrm{TAC}_y(1 + \Delta_{up}) \qquad (7)$$

and

$$\text{if} \quad \mathrm{TAC}_{y+1} < \mathrm{TAC}_y(1 - \Delta_{\mathrm{down}}) \quad \text{then} \quad \mathrm{TAC}_{y+1} = \mathrm{TAC}_y(1 - \Delta_{\mathrm{down}}) \qquad (8)$$

During the MSE process, this inter-annual constraint was set at 10%, for both TAC increases and decreases, and these constraints were adopted as part of the adopted HCR.

Table i.1. Control parameter values for the adopted HCR. The parameters α and X were adjusted to achieve a median biomass equal to B_{msy} for the exploitable component of the resource biomass in 2037 for the Base Case SCAA Operating Model.

TAC_{2018}	16 500 t
γ	0.15
q	3
α	0.972
λ_{up}	1
λ_{down}	2
X	-0.0056
Δ_{up}	0.1
Δ_{down}	0.1

Table i.2 Data used in the calculation of the TAC for 2022. The weights given to each survey in obtaining composite indices of abundance (target rule) and composite trends (slope rule) are proportional to the inverses of the squared values of the survey error standard deviations σ^i listed below.

	Canada Fall 2J3K	**Canada Fall 3LNO**	**Canada Spring 3LNO**	**EU-Spain 3NO**	**EU 3M 0-1400m**
2011	26.736	2.206	1.046	7.093	26.152
2012	23.504	1.712	1.941	7.373	19.198
2013	29.645	2.589	0.730	5.463	19.110
2014	33.336		0.664	6.239	23.921
2015	22.290	0.869		9.486	47.517
2016	18.541	1.314	0.658	8.796	28.298
2017	15.104	1.246		16.627	42.665
2018	17.054	1.887	1.884	7.875	29.803
2019	16.285	1.872	1.446	8.824	16.887
2020	15.840	2.714			13.230
s^i_{2021}	-0.0240	0.1859	0.2998	-0.0738	-0.2447
$J^i_{\text{current, 2021}}$	16.393	2.158	1.665	8.350	19.973
J^i_{target}	26.343	1.792	1.065	6.931	26.418
σ^i	0.220	0.260	0.490	0.380	0.210
		TAC_{2021}	16 498 t	TAC^t_{2022}	16 264 t
		s_{2021}	-0.0369	TAC^s_{2022}	15 464 t
		J_{2021}	0.905	TAC_{2022}	15 864 t

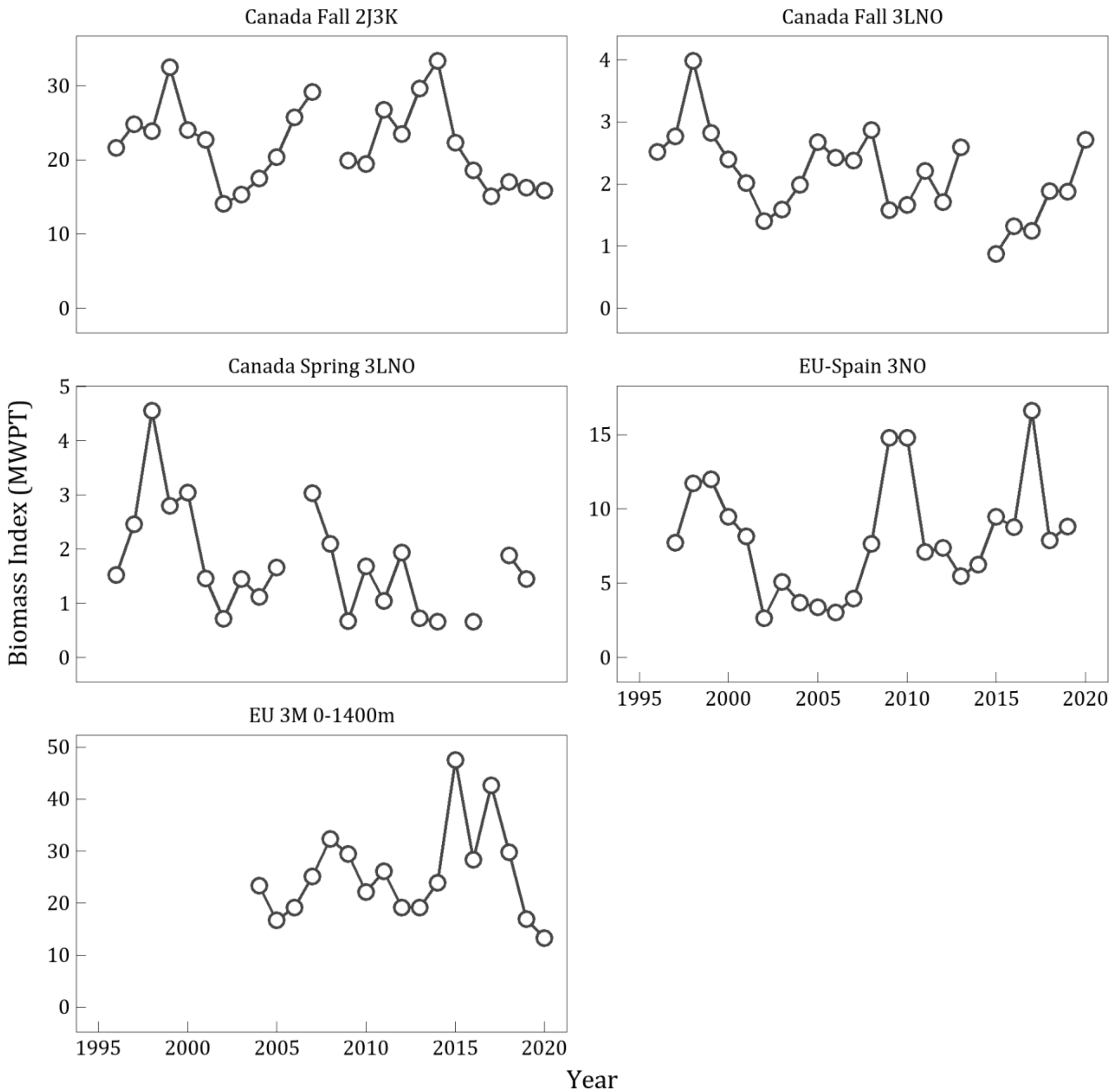


Figure. i.1. Input for the Greenland Halibut in Subarea 2 + Divs. 3KLMNO Harvest Control Rule. Survey data come from Canadian fall surveys in Divs. 2J3K, Canadian spring surveys in Divs. 3LNO, Canadian fall surveys in Divs. 3LNO, EU Flemish Cap surveys (to 1400m depth) in Div. 3M and EU-Spain surveys in 3NO. Missing values within the last five years are not used in the calculation of the TAC using the HCR.

Exceptional Circumstances

In 2021, the SC evaluated each of the criteria indicated in the Exceptional Circumstances Protocol, as described below.

The following criteria constitute Exceptional Circumstances:

1. *Missing survey data:*

- *More than one value missing, in a five-year period, from a survey with relatively high weighting in the HCR (Canadian Fall 2J3K, Canadian Fall 3LNO, and EU 3M surveys);*
- *More than two values missing, in a five-year period, from a survey with relatively low weighting in the HCR (Canadian Spring 3LNO and EU-Spain 3NO surveys);*

The Canadian Spring 3LNO and the EU-Spain 3NO surveys were not conducted in 2020 due to the COVID-19 pandemic. Despite the pandemic and past survey issues, each survey series contains sufficient values, as defined under the Exceptional Circumstances Protocol, to compute the TAC for 2022 using the HCR. Therefore, this does not constitute Exceptional Circumstances this year.

SC notes that the disruption of the 2021 Canadian Spring 3LNO survey, in addition to the years 2020 and 2017, will trigger Exceptional Circumstances next year.

2. *The composite survey index used in the HCR, in a given year, is above or below the 90 percent probability envelopes projected by the base case operating models from SSM and SCAA under the MS;*

The composite survey index has remained within the 90% probability envelopes from the base case SCAA operating model (**Figure i.2**). Probability envelopes from the base case SSM indicate that the most recent composite survey index is within the 90% probability envelopes (**Figure i.3**). Prior values were above the 90% probability envelopes, though exceeding these values is not a conservation concern. Given the composite index remains within the 90% probability envelope from the SCAA and has been above or within the 90% probability envelope from the SSM projections, SC concludes that this does not constitute Exceptional Circumstances.

3. *TACs established that are not generated from the MP*.

The TAC established for 2021 was generated from the MP. This does not constitute Exceptional Circumstances.

The following elements will require application of expert judgment to determine whether Exceptional Circumstances are occurring:

1. the five survey indices relative to the 80, 90, and 95 percent probability envelopes projected by the base case operating models (SSM and SCAA) for each survey;

Survey indices from the past four years are primarily within the 80% probability envelopes from the base case SCAA operating model (14 out of 17 observations). In 2017, both the EU 3M and EU-Spain 3NO surveys were above the 90% but within the 95% probability envelope, and in 2020 the EU 3M survey index was just below the 95% envelope (**Figure i.2**). Likewise, survey indices were primarily within the 80% probability envelopes from the SSM projections (10 out of 17 observations); however, one observation was below the 90% but within the 95% envelope (EU 3M in 2020), two were above the 90% but within the 95% envelope (Canada Fall 3LNO in 2018 and 2020), and three were above the 95% envelopes (EU 3M 0-1400m in 2017, Canada Spring 3LNO in 2018, and EU-Spain 3NO in 2017; **Figure i.3**). Though the declining trajectory of the EU 3M survey index in isolation is a possible concern, SC does not consider this Exceptional Circumstances as most indices are within or above the probability envelopes from both models.

2. *survey data at age four (age before recruitment to the fishery) compared to its series mean to monitor the status of recruitment;*

Recruitment at age four has returned to average levels following six years of below average recruitment (**Figure i.4**). SC concludes that this does not constitute Exceptional Circumstances at this time; however, this remains a possible concern given the long preceding period of below average recruitment.

3. discrepancies between catches and the TAC calculated using the MP

The TAC for 2020 was 16 926 t. The catch in 2020 was 16 307 t (<4% difference). SC concludes that this does not constitute Exceptional Circumstances.

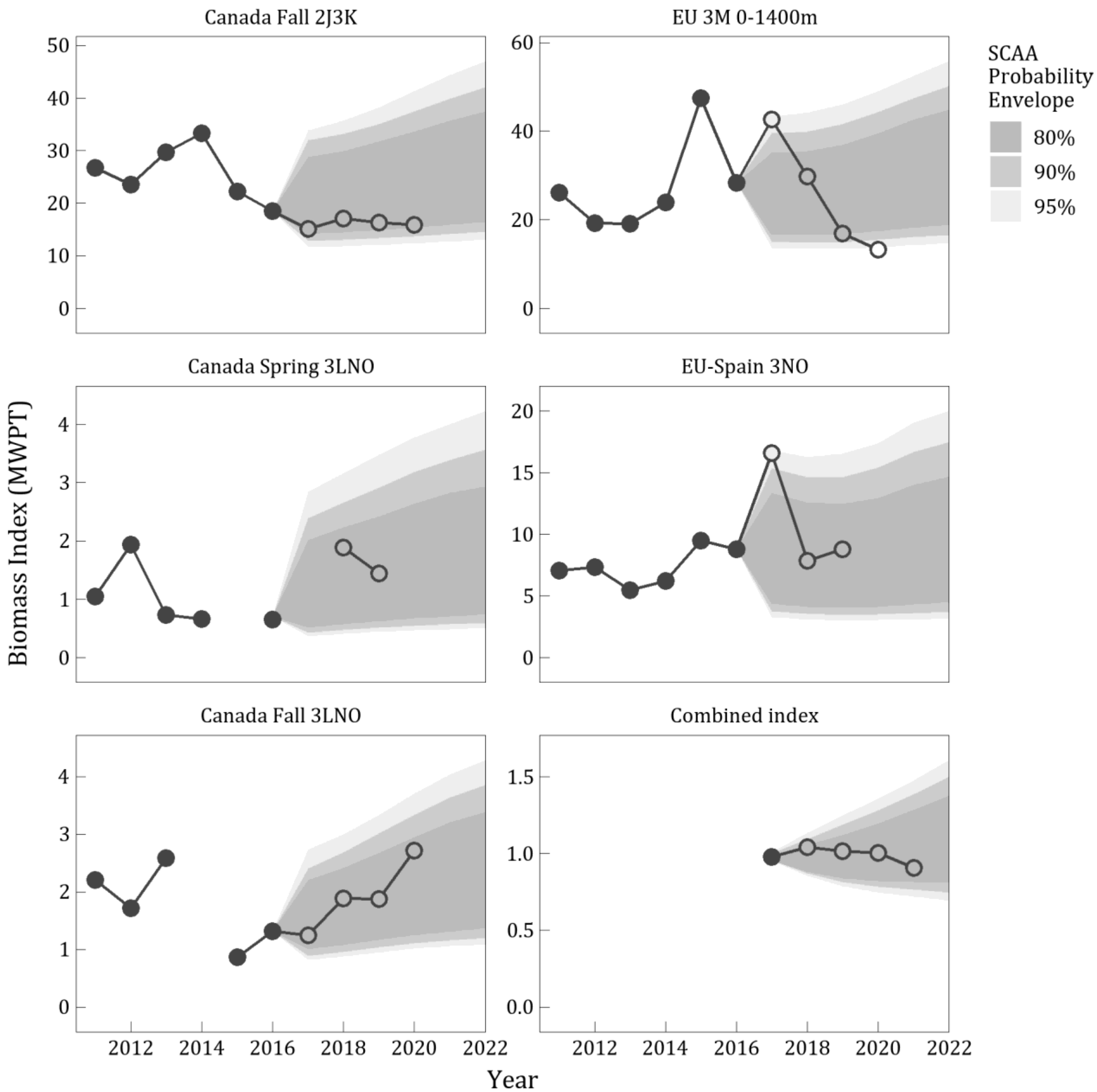


Figure. i.2. Greenland Halibut in Subarea 2 + Divs. 3KLMNO. Mean weight per tow from Canadian fall surveys in Divs. 2J3K, Canadian spring surveys in Divs. 3LNO, Canadian fall surveys in Divs. 3LNO, EU Flemish Cap surveys (to 1400m depth) in Div. 3M and EU-Spain surveys in 3NO. The figure also shows the combined index used in the target based component of the HCR. For the survey and combined indices, 80%, 90% and 95% probability envelopes from the SCAA base case simulation are shown. Index values observed from 2017 onward are shown using open circles.

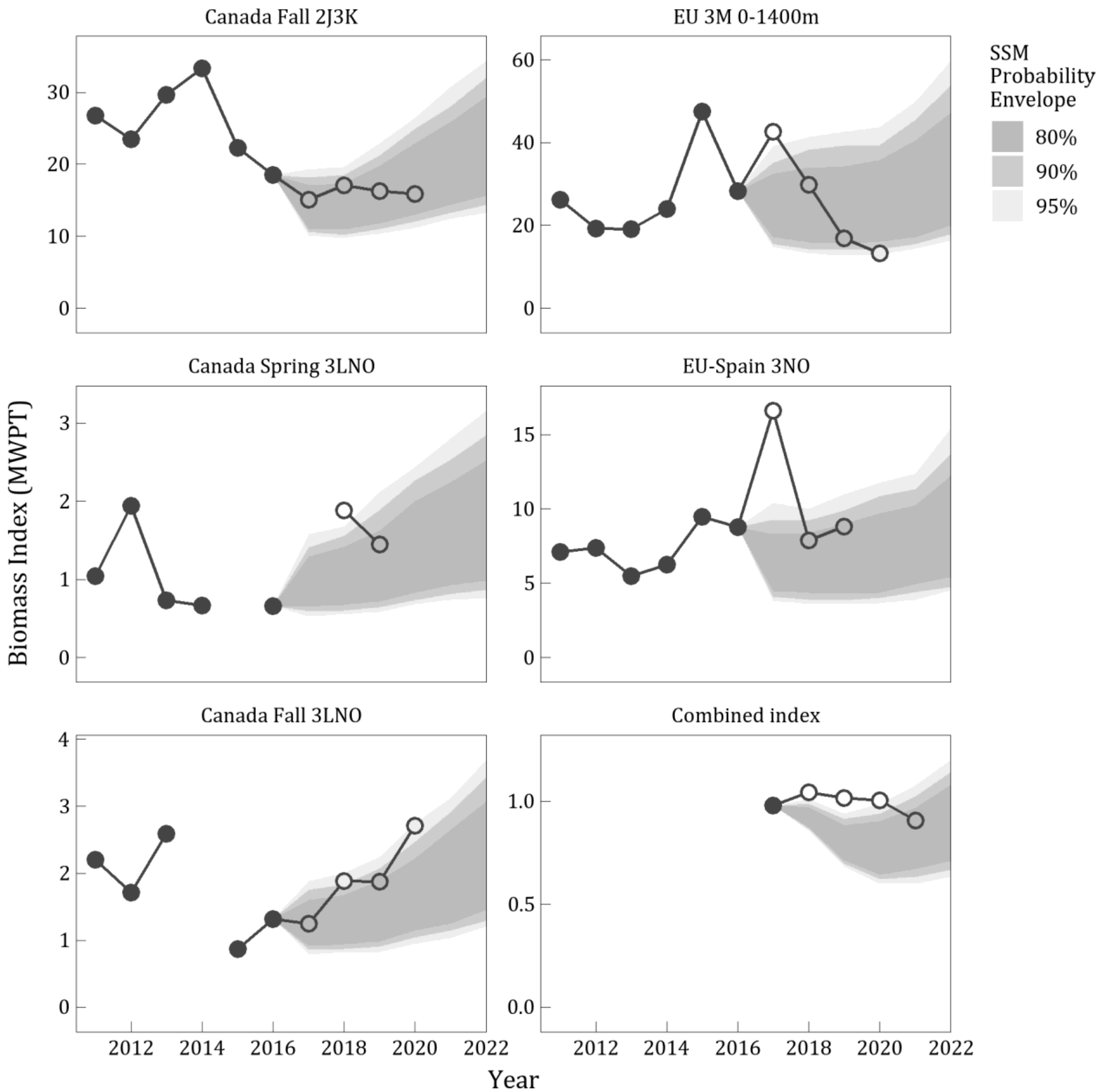


Figure. i.3. Greenland Halibut in Subarea 2 + Divs. 3KLMNO. Mean weight per tow from Canadian fall surveys in Divs. 2J3K, Canadian spring surveys in Divs. 3LNO, Canadian fall surveys in Divs. 3LNO, EU Flemish Cap surveys (to 1400m depth) in Div. 3M and EU-Spain surveys in 3NO. The figure also shows the combined index used in the target based component of the HCR. For the survey and combined indices, 80%, 90% and 95% probability envelopes from the SSM base case simulation are shown. Index values observed from 2017 onward are shown using open circles.

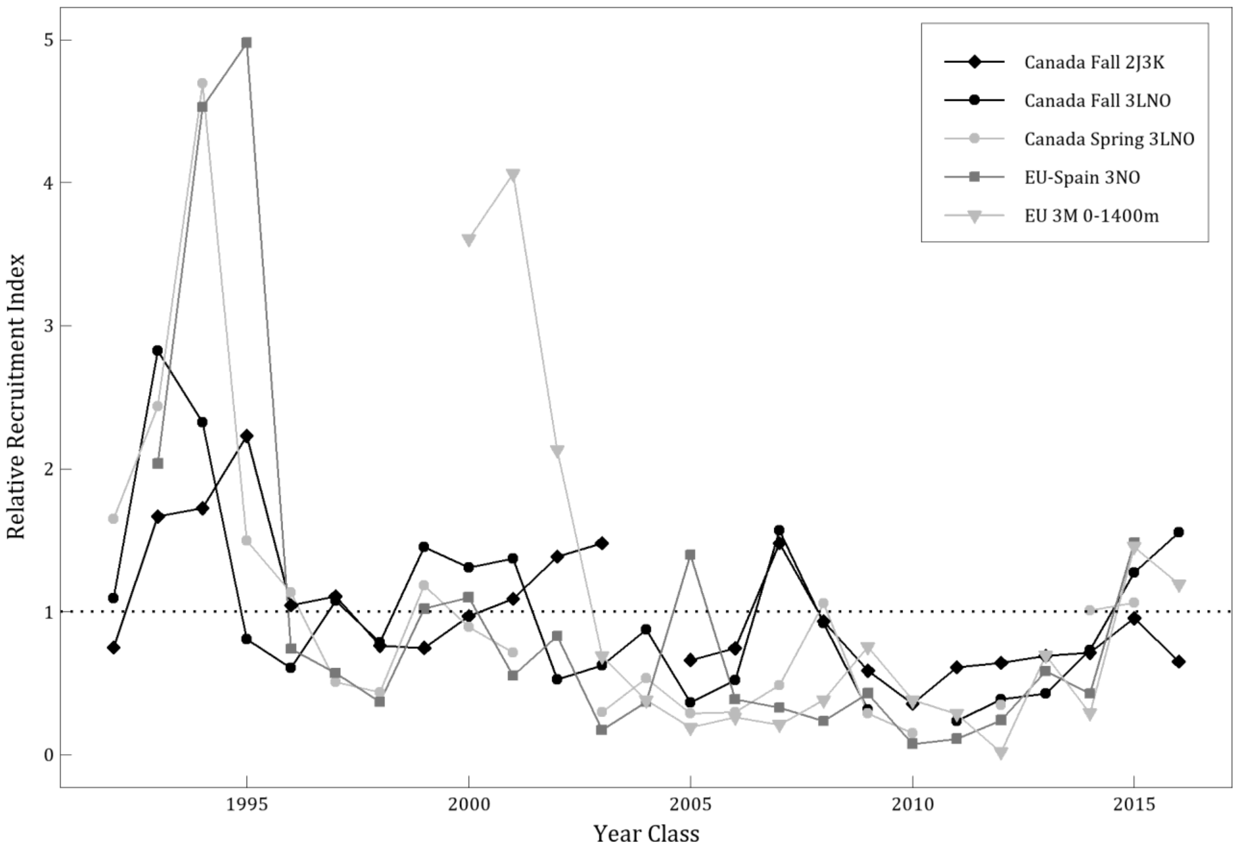


Figure. i.4. Greenland Halibut in Subarea 2 + Divs. 3KLMNO. Relative recruitment (age 4) indices from Canadian fall surveys in Div. 2J3K, Canadian spring surveys in Div. 3LNO, Canadian fall surveys in Div. 3LNO, EU-Spain survey in 3NO and EU survey of Flemish Cap. Each series is scaled to its average, which then corresponds to the horizontal dotted line at 1.

Initial evaluation of Exceptional Circumstances for 2022 due to missing survey data

The cancellation of the 2021 Canadian spring 3LNO survey, in addition to missing survey indices required for the Greenland halibut HCR for the years 2020 and 2017, will trigger Exceptional Circumstances in 2022, potentially disrupting the calculation of the TAC for 2023. Following guidance under the Exceptional Circumstances Protocol (Annex I.G of NAFO/COM Doc. 21-01), SC conducted an initial evaluation of the severity of this issue, assuming no other reason for Exceptional Circumstances arises in 2022. To conduct this evaluation, past TACs were calculated using the HCR with and without the Canadian spring 3LNO survey series; this showed that this survey had a minimal impact on the calculation of past TACs (<3% difference; **Table i.3**). Although missing survey data is a serious concern, the impact of the issue in this case is relatively small because the Canadian spring 3LNO survey has the lowest weighting in the TAC calculation from the HCR and, therefore, is the least influential series used in the resulting TAC values. Conditional on the absence of other reasons for Exceptional Circumstances arising next year, SC advises that adjusting the TAC advised for 2022 using the HCR informed by four survey indices only (Canadian fall 2J3K, Canadian fall 3LNO, EU 3M 0-1400m, and EU-Spain 3NO surveys) may serve as a reasonable option for providing TAC advice for 2023 with minimal deviation from the agreed Management Procedure.

Table i.3. Effect of excluding the Canadian spring survey of NAFO Divs. 3LNO on the calculation of the TAC using the Greenland halibut HCR. Percent differences are indicated in parentheses.

TAC Year	Baseline	Excluding Canadian Spring 3LNO
2019	16 434*	16 486 (0.3%)
2020	16 867*	16 733 (-0.8%)
2021	16 498	16 094 (-2.5%)
2022	15 864	15 456 (-2.6%)

* These TAC values are slightly different from those used because of a minor misspecification of J_{target} (SCR Doc. 20/042).

Provisional workplan for a revised Management Strategy Evaluation for Greenland halibut

Article 10 of NAFO/COM Doc. 21-01 states that "The current Management Strategy (MS) for Greenland halibut stock in Subarea 2 + Divs. 3KLMNO adopted by NAFO in 2017 shall be in force from 2018 to 2023 inclusive." Following this Rebuilding Program, a TAC for 2024 will need to be recommended using a revised MS developed before September 2023. In anticipation of this required review of the MS for Greenland halibut, SC has developed a coarse workplan outlining the time required to conduct this review:

1. *SC June, Year 1 - Proposal and review of the data to be used; consensus required at this time for Operating Model (OM) development to commence.*
2. *SC January, Year 2 (intersessional) - Proposal and review of OMs to be used; consensus required at this time for Candidate Management Procedure (CMP) testing to commence.*
3. *WG-RBMS April, Year 2 - Refinement of performance statistics including risk tolerances and constraints; identify initial CMPs.*
4. *SC June, Year 2 - Review and test CMPs; finalise the suite of CMPs to be used in the Management Strategy Evaluation (MSE).*
5. *WG-RBMS August, Year 2 - Evaluate performance statistics and make a final decision on the MS to propose to the Commission.*
6. *COM September, Year 2 - The Commission considers adoption of proposed new MS for Greenland halibut.*

SC notes that this process is expected to take two years and its timing is conditional on decisions on the overall SC five-year workplan (response to Commission request #10)

When considering workplans, the issue of reference points was also raised. Reference points are not explicitly defined for this stock and this precludes the qualification of stock status under the PA framework. While such concerns are implicitly addressed within the MSE process, it is also possible to develop an MS that responds to a specified reference point (e.g., B_{lim} expressed in terms of an observable composite index). SC will seek the views of WG-RBMS on pursuing the addition of such a feature to the MS.

ii) Request #3: Continue the evaluation of scientific trawl surveys in VME closed areas and the effect on stock assessments of excluding the surveys from these areas

The Commission requests that the Scientific Council continue its evaluation of the impact of scientific trawl surveys on VME in closed areas, and the effect of excluding surveys from these areas on stock assessments.

This request was not addressed in June 2021 and is deferred to September 2021 (if possible) or June 2022 (otherwise).

iii) Request #4: Implement the steps of the bycatch and discards action plan relevant to SC

The Commission requests the Scientific Council to implement the steps of the Action plan relevant to the Scientific Council and in particular the tasks identified under section 2.2 of the Action Plan, for progression in the management and minimization of Bycatch and discards (COM Doc. 17-26).

- *Tasks outlined in Tasks 3.1 and 3.2 of the NAFO Action Plan in the Management and Minimization of Bycatch and Discards (COM Doc. 17-26).*

SC already provided a response to Section 2.2 of the Action Plan ("Identification of species under NAFO catch or effort limits with high survivability rates") in the September 2020 SC report. Responses to Tasks 3.1 and 3.2 are presented here.

Task. 3.1. Moratoria species. Identify moratoria stocks where the level of bycatch/discards may be impeding recovery.

Scientific Council responded:

Evidence suggests that current stock dynamics in most moratoria stocks are being driven primarily by natural causes (high natural mortality, low ecosystem productivity). Under these conditions, SC noted that even the low levels of bycatch observed in recent years may be contributing to the lack of recovery of these stocks, particularly for American plaice in Div. 3LNO and cod in 3NO.

The fish communities in the Newfoundland and Labrador (which includes the Grand Bank Ecosystem Production Unit), and Flemish Cap bioregions have experienced major structural changes over the last 40 years. Synergies between historical overfishing and/or extreme environmental conditions, have resulted in a regime shift and collapse of the fish community in Newfoundland and Labrador (NL) in the late 1980s and early 1990s, as well as significant changes in the Flemish Cap fish community.

While total fish biomass has remained generally stable over time in the Flemish Cap, the situation is different in the NL ecosystems, where total fish biomass remains well below pre-collapse levels, and ecosystem conditions remain indicative of reduced productivity. Considering these changes in ecosystem structure and productivity is key to evaluate the factors that may impede recovery of specific stocks because they can drive and/or influence natural mortality, growth, reproductive potential, and/or recruitment.

In this context of changing ecosystem conditions, stock recovery depends on environmental factors as well as fishing impact. For stocks under moratoria, bycatch in fisheries directed for other species, whether retained or discarded, constitute such fishing impact. Under any given set of environmental conditions, bycatch will impede recovery, the extent depending on the mortality it induces, and how it relates to natural mortality.

In this analysis of bycatch impact on stocks under moratoria, CESAG total catch estimates were used, in conjunction with fishing mortality and stock biomass estimates from the assessments done by SC (Table iii.1).

Shrimp in Div. 3LNO, Capelin in Div. 3NO, and Alfonsino in Div. 6G all have a very low or almost zero level of catches, and also low fishing mortality (F), in the years in which they have been in moratorium (Table iii.1). Without further analyses, the impact of these levels of catches on these stocks recovery may be seen as negligible.

For the other stocks of the Table iii.1, the situation is the following:

American plaice in Divs. 3LNO (SCR Doc. 21/20): The stock has been under moratorium since 1995. Biomass and abundance have been relatively stable at a low level, well below B_{lim}, since around 2000. Significant retrospective patterns in the ADAPT VPA put into question the estimates of the absolute levels of fishing mortality (F). However, all sources of information considered by SC point towards a recent relative increase in both natural mortality (M) and F, although separating the impacts of M and F in this stock remains difficult. While recruitment continues to be poor, current levels of bycatch may also be contributing to a lack of recovery in this stock.

Northern cod in Divs. 2J3KL (DFO 2019a, DFO 2021): This stock has been under moratorium since 1992. The stock was at very low levels until it began to increase in 2007. The stock is now at 52% of B_{lim} but has plateaued since 2017. Fishing mortality on ages 5-14 is low, at 0.02, and has been for more than a decade. Levels of natural mortality are thought to be delaying the recovery of this stock.

Witch flounder in Divs. 2J3KL (DFO 2019b): This stock has been under moratorium in Canadian waters since 1995, and in the NAFO regulatory area since 1998. The stock remains below B_{lim}; however biomass indices have been steadily increasing since the early 2000s. Bycatch remains low, averaging 106 t annually from 2015-2019. Current levels of fishing mortality do not appear to be limiting recovery of this stock.

Atlantic cod in Divs. 3NO (SCR Doc. 21/031): This stock has been under moratorium since 1994. Overall, the Grand Bank Ecosystem Production Unit is experiencing low productivity conditions and, despite fishing mortality estimates for 3NO cod being very low for well over a decade, the stock has shown no sign of sustained recovery and remains well below B_{lim} (SSB estimated at 12% of B_{lim} in 2020). It is likely that stock dynamics are currently being driven primarily by natural causes (high natural mortality, low ecosystem productivity). However, under these conditions even the low levels of by catch observed in recent years may be contributing to the lack of recovery for this stock.

American plaice in Div. 3M: The most recent assessment of this stock can be found in NAFO (2020). The stock has been under moratorium since 1996. Stock biomass and SSB recorded a minimum in 2007, due to consistent year-to-year recruitment failure from the 1991 to 2005 year-classes. Since 2006 the recruitment improved, particularly the 2006, 2012, 2013 and 2015 year-classes. Stock biomass and SSB increased from 2007 to 2012 and have remained stable at a relatively low level. From 2016 to 2019 both biomasses recovered, to the levels of mid 90´s, when the fishery was closed. Both catches and F remain low, although slightly higher catches are observed since 2013. American plaice Div. 3M bycatch may be delaying the recovery but the main factor is inconsistency of the recruitment.

References

DFO. 2019a. Stock assessment of Northern cod (NAFO Divisions 2J3KL) in 2019. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2019/050.

DFO. 2019b. Stock Assessment of Witch Flounder (Glyptocephalus cynoglossus) in NAFO Divisions 2J3KL. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2018/053

DFO. 2021. 2020 Stock Status Update for Northern Cod. DFO Can. Sci. Advis. Sec. Sci. Resp. 2021/004.

NAFO, 2020. "Report of the June Scientific Council Meeting, 28 May - 12 June 2020". NAFO SCS Doc. 20/14, Serial nº N7099, 261pp.

Table iii.1. NAFO Stocks in moratoria: catches, fishing mortality (F) and biomass based on the SC most recent assessments.

	Catches (tons)						F						Biomass					
Stock	2015	2016	2017	2018	2019	2020	2015	2016	2017	2018	2019	2020	2015	2016	2017	2018	2019	2020
Cod 2J3KL	4436	10110	13152	9518	10556	10224	0.014	0.02	0.022	0.021	0.022	0.018	510166	585509	634098	569033	622740	678140
Shrimp 3LNO	0	0	0	0	0	0							34600	38700	16500	13200	20300	
Witch flounder 2J3KL	217	117	136	178	56													
Cod 3NO	586	666	637	401	526	588	0.121	0.142	0.102	0.04	0.066	23439	21727	19789	14563	7020	7279	
Capelin 3NO 0	0	4	11	2	2	1												
Amercan Plaice 3LNO	1149	1664	1172	1002	1248	1175												
American Plaice 3M	268	161	157	215	302	187												
Alfonsino 6G	122	127	51	2	1	0												

(yellow)	open fishery
(grey)	Unknown

Task 3.2. Areas where there is a risk of causing serious harm to bycatch species: Identify areas, times and fisheries where bycatch and discards, notably of moratoria species, that have a higher rate of occurrence.

Scientific Council responded:

In the NRA, the moratoria stocks with the highest levels of bycatch are American plaice 3LNO, cod 3NO and American plaice 3M. The highest frequencies of hauls with bycatch occur in the fisheries that are being carried out at less than 200 meters: yellowtail flounder 3LNO, thorny skate 3LNO and cod 3M. Differences in the distribution of bycatch were observed among quarters. However, there were no differences in the distribution of sets with and without bycatch within fisheries within quarters.

As recommended in the NAFO Action Plan, the best information to analyze spatio-temporal patterns of catches and bycatch is the haul by haul (HbH) data. In NAFO, the HbH data is compiled by the NAFO Secretariat and is only available for the NAFO Regulatory Area (NRA). Therefore, the analyses presented for stocks in Divisions 3LNO based on the HbH data are not complete and the results are partial.

Two different analyses of bycatch of moratorium species, both based on the HbH data, have been carried out and reviewed by the SC. One is based on the bycatch composition of the moratoria species in the different fisheries; so, the starting point is the fishery and the catch composition of the fishery is examined, paying particular attention to the bycatch of moratoria stocks. The other analysis is based on the contribution of the different fisheries to the bycatch of the moratoria stocks; so, the starting point is the bycatch of the moratoria stock and the contribution of different fisheries to this bycatch is examined. These two analyses are, therefore, complementary of each other.

The first of the analyses examined eleven interactions (Table iii.2) between fishery stocks (i.e. stocks to which a fishery is directed) and moratoria stocks taken in the fishery as bycatch. The objective of this temporal and spatial analysis was to identify "hotspots" of bycatch occurrence in fisheries. In general, the results show that there is no obvious spatial or interannual variability within each fishery, i.e., their respective behaviors have not changed. Cod and American plaice are the major bycatch species of the ground fish fisheries in the NRA, corresponding to the following moratoria stocks: Div. 2J3KL cod, Div. 3NO cod, Div. 3M American plaice and Div. 3LNO American plaice.

Table iii.2. Interactions between the directed fishery species/stock and the main bycatch moratoria stocks (analyzed by the NAFO Secretariat, NAFO/COM Doc. 20-04).

Directed Fishery	By catch moratoria species/stocks
Cod Div. 3M	American plaice Div. 3M
Redfish Div. 3M	American plaice Div. 3M
Redfish Div. 3LN	Cod Div. 2J3KL Cod Div. 3NO American Plaice Div. 3LNO
Redfish Div. 3O	Cod Div. 3NO American Plaice Div. 3LNO
Yellowtail flounder Div. 3LNO	Cod Div. 3NO American Plaice Div. 3LNO
Skates Div. 3LNO	Cod Div. 3NO American Plaice Div. 3LNO

The results by fishery show that:

- *No interannual spatial and temporal variation was observed in the 11 fisheries-bycatch interactions.*
- *Cod and American plaice are the major bycatch species of the groundfish fisheries in the NRA. They comprise the moratorium stocks of cod in Div. 2J3KL, cod in Div. 3NO, American plaice in Div. 3M and American plaice in Div. 3LNO.*
- *Redfish fisheries hotspots in the Nose and Tail of the Grand Bank (Divisions 3LN and 3O) are located near the slopes of the Bank.*
- *Similar Directed stock - Bycatch stock interactions were observed in the yellowtail flounder and skate fisheries in Divisions 3LNO despite the different minimum mesh size requirements for the fisheries, i.e. 130 mm and 280 mm, respectively.*
- *In redfish in Div. 3LN fishery, two stocks of cod were observed to be bycatch, namely the cod in Div. 3NO and cod in Div. 2J3KL stocks.*

A monthly analysis of the yellowtail flounder Div. 3LNO fishery and the skate Div. 3LNO fishery illustrate that:

- *In the yellowtail fishery, American plaice bycatch, in terms of weight and percentage relative to the weight in the fishery, is generally bigger than cod bycatch.*
- *In the yellowtail flounder fishery, American plaice bycatch is prevalent in non-winter months.*
- *In the skates fishery, no monthly trend can be discerned regarding the American plaice or the cod bycatch.*
- *American plaice bycatch occurs in both yellowtail flounder and skates fisheries.*

The second study presented to the SC (SCR Doc 21/024) focuses on the different stocks under moratoria and examines, for each of them, which are the main fisheries that contribute to the catch (actually, bycatch) of the stock. For some of the moratoria stocks, the level of catch is low and/or the NRA only represents a very small proportion of their distribution area. For this reason, the seasonal/spatial catch analysis based on the HbH data in this study was restricted to the following moratoria stocks: Div. 3M American plaice, Div. 3LNO American plaice and Div. 3NO cod. The conclusions on the last two stocks are partial since the data analyzed only cover part of their distribution (the NRA). The general conclusions of this second analysis (based on stocks) are consistent with those of the previous one (based on fisheries) and indicate there are no remarkable spatial differences between the hauls with and without bycatch of the moratoria stocks of the different directed fisheries. It can be observed that the directed fisheries that have a higher frequency of bycatch of these species / stocks in moratorium are those that are carried out at less than 200 meters of depth: yellowtail flounder Div. 3LNO, skates Div. 3LNO and cod Div. 3M in the shallowest part of the Flemish Cap (Table iii.3). In some fisheries, it is possible to observe variations in the frequencies of sets with moratoria species bycatch by quarter; this is the case for cod Div. 3M fishery-American plaice Div. 3M bycatch, yellowtail flounder Div. 3LNO fishery-American plaice Div. 3LNO bycatch, skates Div. 3LNO fishery-American plaice Div. 3LNO bycatch. In some cases this temporal pattern is related to the displacement of the directed fishery to different areas, as is the case of the cod fishery in Div. 3M, which in the second semester moves to shallower areas of Flemish Cap, increasing the bycatch frequency of America plaice.

The more detailed space-time results found in this second study for the analyzed moratoria stocks were as follows:

American plaice Div. 3M stock: the main fisheries that catch American plaice in Div. 3M as bycatch are the cod trawl fishery and the redfish trawl fishery, which represent 54% and 44% of the HbH stock total catches, respectively. In Div. 3M, 53% of the sets targeting cod and 38% of the sets targeting redfish caught America plaice as bycatch. The frequency with which American plaice bycatch occurs in the sets targeting cod presents a clear increasing trend throughout the year, while it remains much more constant for the sets targeting redfish.

American plaice Div. 3LNO stock: The main fisheries catching American plaice as bycatch in the NRA Div. 3LNO are the yellowtail flounder fishery, with 43% of the total HbH American plaice catches in the NRA Div. 3LNO, the redfish fishery (36%) and the skate fishery (15%). In the NRA Division 3LNO, 75% of sets targeting yellowtail flounder, 57% of sets targeting redfish and 87% of sets targeting skates caught America plaice as bycatch. The frequency with which American plaice bycatch appears in the sets targeting yellowtail flounder and skates presents a growing trend throughout the year, whereas in the redfish fishery the frequency is quite stable in all quarters, except for the third quarter, in which the frequency is much lower. Yellowtail flounder and skates fisheries in the NRA Div. 3LNO are mainly conducted at depths shallower than 200 meters, and it seems that at these depths American plaice is caught much more frequently than at the greater depths where the redfish fishery is carried out.

Cod 3NO stock: The main fisheries that have cod as bycatch in the NRA Div. 3NO are the redfish trawl fishery, with 54% of the HbH NRA Div. 3NO cod total catches, the skate fishery (22%) and the yellowtail flounder fishery (16%). Although the percentage of total catch of cod as bycatch is higher in the redfish fishery, the highest frequency of sets where cod appears as bycatch is in the skate fishery (73% of the sets), followed by the redfish fishery (62% of the sets) and yellowtail flounder fishery (43% of the sets). There is no clear pattern to these frequencies throughout the year. The yellowtail flounder fishery and the skate fishery in the NRA Division 3NO are mainly conducted in similar areas, in depths shallower than 200 meters. It should be noted that although the fisheries are carried out in similar areas, the frequency with which cod appears as bycatch is higher in the fishery directed to skates than in the fishery directed to yellowtail flounder.

Table iii.3. Bycatch of moratoria stocks in Divs. 3LMNO in different fisheries (SCR Doc 21/024). For Divs. 3LNO, only the NRA part could be analyzed.

Moratoria stock	Main fisheries with bycatch of moratoria stock	% of the moratoria stock bycatch in different fisheries	% of hauls in fisheries with occurrence of the moratoria stock
American plaice Div. 3M	Cod in 3M; Redfish in 3M	Cod in 3M (54%); Redfish in 3M (44%)	Cod in 3M (53%); Redfish in 3M (38%)
American plaice Div. 3LNO	Yellowtail flounder in 3LNO; Redfish fisheries in 3LN and 3O; Skates in 3LNO	Yellowtail flounder (43%); Redfish fisheries (36%); Skates (15%)	Yellowtail flounder (75%); Redfish fisheries (57%); Skates (87%)
Cod Div. 3NO	Redfish fisheries in 3LN and 3O; Skates in 3LNO; Yellowtail flounder in 3LNO	Redfish fisheries (54%); Skates (22%); Yellowtail flounder (16%)	Redfish fisheries (62%); Skates (73%); Yellowtail flounder (43%)

iv) Request #5: Continue to refine work on the Ecosystem Roadmap

The Commission requests that Scientific Council continue to refine work on the Ecosystem Road Map:

- *Continue to test the reliability of the ecosystem production potential model and other related models*
- *Report on these results to WG-EAFFM and WG-RBMS to further develop how it may apply to management decisions*
- *Develop options of how ecosystem advice could inform management decisions, an issue which is directly linked to the results of the foreseen EAFM roadmap workshop.*
- *Continue its work to develop models that support implementation of Tier 2 of the EAFM Roadmap.*

Scientific Council responded:

While there has been no further scientific development of Tier 1-related work (e.g. Fisheries Production Potential models, TCI) the SC reiterates the advice provided on this topic in 2020 (SCS Doc 20/14):

“SC **recommends** that*, as an interim measure in the implementation of the NAFO Roadmap, the particular circumstances in the state of stocks and the potential consequences to fishery sustainability be considered and addressed in management decisions when the combined TACs can result in overall catches about two-fold greater than the TCI guidance. Total catches above TCIs would require more frequent ecosystem monitoring/reporting*.

SC also **recommends** *the development of simulation-based analyses (Management Strategy Evaluation, or analogous processes), to evaluate the reliability of specific decision rules for species-aggregated catch levels based on the TCI, though recognizing that this will be a complex exercise requiring considerable time, resources and stakeholder involvement, and hence the need for interim measures as indicated above.*

Furthermore, SC **recommends** that *priority be given for the development of multispecies dynamic models to a) complement the recommended simulation-based exercises and investigate the consequences of time-dependent dynamics on the operational reliability of the TCIs as guidance for ecosystem-level advice, and b) contribute to the development of tools toward implementation of the Tier-2 level of the Roadmap*.”

The NAFO Roadmap toward an Ecosystem Approach to Fisheries is organized around two general components dealing with a) sustainability of the fisheries exploitation (i.e., impacts on fished stocks), from an ecosystem (Tier 1), multispecies (Tier 2) and single species (Tier 3) perspective, and b) the effects of fishing on other ecosystem elements (i.e., impacts of fishing on habitats). The effects of fishing on other ecosystem elements is being addressed through the SAI-VME work, and other NAFO processes (e.g. COM WG-BDS). The work on the sustainability of fisheries exploitation has been focused, among other things, on making Tier 1 operational through the use of the Total Catch Index (TCI) to be considered and addressed in management decisions.

The 2020 advice provides for an interim implementation of Tier 1 while a more fulsome discussion on the Roadmap implementation can take place. SC has continued its collaboration with managers in the context of COM-SC WG-EAFFM to further the implementation of the Roadmap. The Covid-19 pandemic prevented a workshop planned to inform this process from taking place. Despite the delays, SC remains fully committed to the process, and is contributing (via COM-SC WG-EAFFM) to the organization of an internal NAFO dialogue session on the Roadmap in late 2021 to further clarify concepts and ideas in preparation for the full EAFM Roadmap Workshop currently scheduled as a face-to-face meeting in 2022.

v) Request #6: Re-assessment of NAFO bottom fisheries in 2021

The Commission requests that Scientific Council, in preparation for the re-assessment of NAFO bottom fisheries in 2021 and discussion on VME fishery closures:

- *Assess the overlap of NAFO fisheries with VME to evaluate fishery specific impacts in addition to the cumulative impacts for NRA fisheries;*
- *Consider clearer objective ranking processes and options for weighting criteria for the overall assessment of significant adverse impacts and the risk of future adverse impacts;*
- *Maintain efforts to assess all six FAO criteria including the three FAO functional SAI criteria which could not be evaluated in the current assessment.*
- *Provide input and analysis of potential management options, with the goal of supporting meaningful and effective discussions between scientists and managers at the 2021 WG-EAFFM meeting.*
- *Continue to work on the VME indicator species as listed in Annex IE, Section VI to prepare for the next assessment.*

The SC response to this request is structured into three main parts:

Part (i) presents the assessment of the risk of Significant Adverse Impacts (SAIs) from bottom fishing activities on VMEs in the NRA, conducted by SC in the last year.

Part (ii) presents potential management options in relation to the latest review of VME closures.

Part (iii) reviews the adequacy of seamount closure boundaries and results in recommendations for some changes to them.

Details are provided below.

Part (i) Assessment of the risk of SAI from bottom fishing activities on VMEs in the NRA.

Scientific council responded:

SC completed the assessment of the risk of Significant Adverse Impacts (SAIs) from bottom fishing activities on VMEs in the NRA. The assessment was based on estimates of the biomass distribution of VMEs, the distribution of fishing effort (VMS data), and a set of assessment metrics that considers ecosystem function and fragmentation. Structurally, the assessment is similar to that conducted in 2016 but with greater spatial resolution of updated survey trawl biomass and commercial fishing effort. The greater spatial resolution applied in the present assessment (from 5km to 1km) results in more precise and generally larger estimates of the area and biomass protected by the current VME closures, relative to the 2020 review of VME closures.

Results indicated that small gorgonian, black coral, erect bryozoan and sea squirt VMEs have a high overall risk of SAI[1], whereas the large-sized sponges and large gorgonian coral VMEs have a low overall risk of SAI. The sea pen VME was assessed as having an intermediate risk of SAI.

	Large-sized Sponges		Sea pens		Large gorgonians		Small gorgonians		Black coral		Erect bryozoans		Sea Squirts	
SAI metric	**Area**	**Biomass**	**Area**	**Biomass**	**Area**	**Biomass**	**Area**	**Biomass**	**Area**	**Biomass**	**Area**	**Biomass**	**Area**	**Biomass**
VME Protected	64%	93%	16%	33%	60%	89%	2%	2%	17%	23%	<1%	<1%	<1%	1%
VME At Risk	19%	6%	74%	65%	23%	10%	72%	86%	63%	67%	96%	99%	79%	85%
VME Impacted	18%	1%	9%	2%	16%	1%	26%	12%	20%	10%	4%	1%	21%	14%
SAI Risk (biomass)	**Low**		**Intermediate**		**Low**		**High**		**High**		**High**		**High**	
VME Fragmentation/Proximity	1112		394		255		125		109		717		802	
Fishing effort stability (over 10 yrs.)	82%		39%		44%		80%		54%		0%		39%	
VME Sensitivity	3.3		0.2		1.7		0.5		1.4		0.1		0.5	
Proportion of VME area/biomass overlapping in closures (km^2 and kg)	62%	99%	19%	42%	65%	82%	9%	9%	21%	23%	4%	3%	0%	0%
Number of important functions in unprotected portions of the VME.	2		4		2		1		3		4		4	
Overall SAI Risk[2]	**Low (1, 6)**		**Intermediate (3, 1)**		**Low (2, 4)**		**High (5, 2)**		**High (6, 0)**		**High (6, 1)**		**High (5, 1)**	
Ranking for Management Action	**7**		**5**		**6**		**4**		**1**		**2**		**3**	

[1] Significant Adverse Impact is a term defined by FAO (2009). It does not imply statistical significance, but rather to identify and quantify impacts which are important.

[2] The overall SAI Risk score was calculated by simply counting the number of high-risk category scores (in red) and the low-risk category scores (in green) for both the area and biomass metrics. These numbers are respectively shown in parenthesis. A combination of the high and low SAI risk scores provides the basis for ranking the management priority from high to low.

The 2021 reassessment of bottom fisheries including the assessment of SAI was completed by SC based on results generated through SC WG-ESA work (NAFO SCS 20/23). To avoid repetition, references to the 2020 WG-ESA Report are used in this advice. The SAI methodology followed the same general approach as presented by SC in 2016 (NAFO SCS Doc. 16/14), but with improved spatial modelling of survey trawl biomass and commercial fishing effort at higher spatial resolution, and the addition of an evaluation of the ecological functions associated with VMEs and VME fragmentation.

The requirement for the assessment followed the specification described in the NAFO Conservation and Enforcement Measures (NCEM; NAFO/FC Doc 13/1), according to the following set of tasks:

Task No.	NCEM Fisheries Reassessment Task	WG-ESA Report (SCS Doc. 20/23)
1	Type(s) of fishing conducted or contemplated, including vessels and gear types, fishing areas, target and potential bycatch species, fishing effort levels and duration of fishing (harvest plan).	Section 7.c (fisheries - page 61)
2.	Existing baseline information on the ecosystems, habitats and communities in the fishing area, against which future changes can be compared.	Section 7.a, (introduction – page 11); Section 7.b, (VMEs – page 26); Section 7.c (fisheries – page 61).
3.	Identification, description and mapping of VMEs known or likely to occur in the fishing area.	Section 7.b (VMEs – page 26)
4.	Identification, description and evaluation of occurrence, scale and duration of likely impacts, including the cumulative impacts of activities covered by the assessment of VMEs.	Section 7.d (SAI – page 100) Section 7.c (fisheries – page 61)
5.	Consideration of the VME elements known to occur in the fishing area.	See SCS 15/19 (WG-ESA report 2015)
6.	Data and methods used to identify, describe and assess the impacts of the activity, the identification of the gaps in knowledge and an evaluation of uncertainties in the information presented in the assessment.	Section 7.d (SAI – page 100) Section 7.c (fisheries – page 61)
7.	Risk assessment of likely impacts by fishing operations to determine which impacts on VMEs are likely to be significant adverse impacts.	Section 7.d (SAI – page 100)
8.	The proposed mitigation and management measures to be used to prevent significant adverse impacts on VMEs, and the measure to be sued to monitor effects of the fishing operations.	Section 7.e (VME management options – page 192)

The assessment of Significant Adverse Impacts (SAI)

The assessment of SAI from bottom fishing activities on VMEs in the NRA was conducted on 7 VME types (large and small gorgonians, large sponges, black corals, sea pens, bryozoans and sea squirts). The analyses were based on the recent 2020 review of existing closures (NAFO SCS Doc. 20/14). The same general methodological approach that was applied in 2016 (NAFO SCS Doc. 16/14) was used, but with improved analyses and datasets, including higher spatial precision data for VME, survey biomass and commercial fishing.

The greater spatial resolution applied in the present assessment (from 5km to 1km) results in more precise and generally larger estimates of the area and biomass protected by the current VME closures, relative to the estimates from the 2020 review of VME closures. This is because the biomass associated with 5km^2 cells whose area mostly intersects with areas outside of the VME protected polygon boundaries were not considered as protected and therefore excluded from the biomass calculations performed as part of the review of VMEs. In the present SAI analysis, the higher spatial resolution allows more of the biomass data (some of which constitute very high values) to be accurately associated with the VME protected areas. However, the differences in the overall VME biomass values in each of the assessment categories (protected, impacted and at risk) between the spatial grids does not alter the overall earlier conclusions of either the review of the VME closures or the assessment of SAI.

Fishing effort was calculated as kilometres (*km*) of trawl track travelled by a fishing vessel per *km*^{2}, per year (NAFO SCS doc. 19/25), which provides a more accurate estimate of fishing effort. The resulting refined area of high fishing effort and corresponding potential impact is reduced compared to the analysis conducted in 2015 (NAFO SCS Doc. 15/19), as can be seen in Figure v.1.

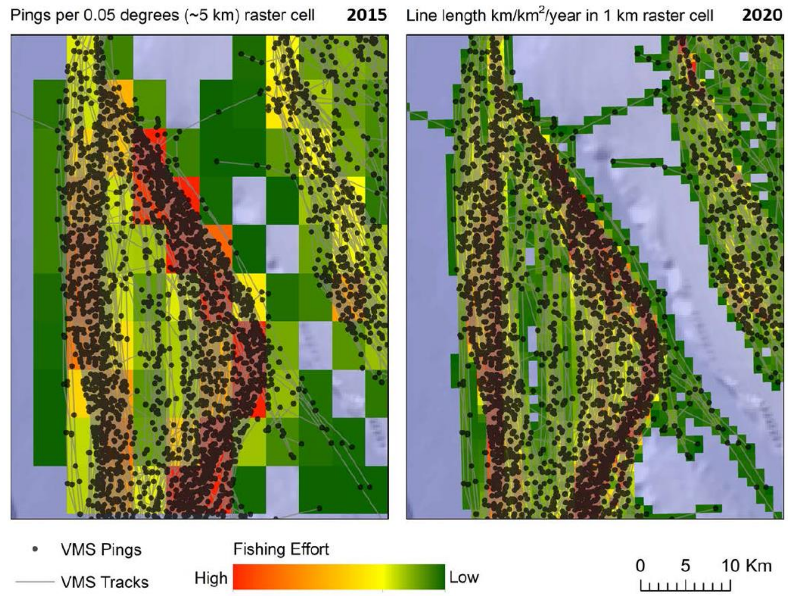


Figure v.1. Comparison of spatial resolution of fishing effort layers derived from VMS pings and trawl tracks showing the grid resolution of 5 km used in the first assessment (left panel) and the higher grid resolution of 1 km applied in the present assessment (right panel).

The final and updated map of the distribution of fishing effort as calculated from the high-resolution VMS tracks for the trawl fisheries is shown in Figure v.2.

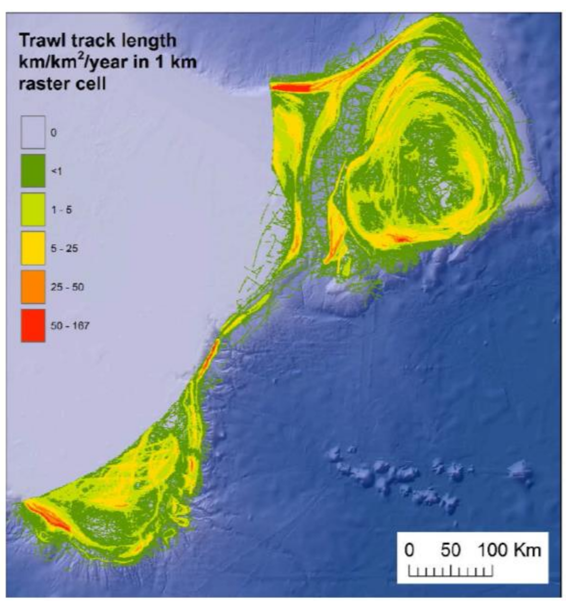


Figure v.2. Distribution of effort from trawl fisheries in the NRA between 2010 - 2019 at the 1 km resolution as used in the present assessment of SAI, based on VMS data.

To achieve better spatial correspondence between the scientific survey VME species biomass data and the commercial fishing effort, the current analysis applied a defined buffer area around each scientific trawl (500 m in all directions around the survey trawl line) and intersected the trawl survey buffer polygon with the mean annual fishing effort calculated by summing the line length of VMS tracks from 2010 - 2019 falling within each survey trawl buffer area and dividing the total length of the VMS track lines (*km*) by the area of the buffer (km^2). Finally, the total length by area was divided by the effort 10 years of the track dataset to derive the cumulative metric $km/km^2/year$ for each survey trawl biomass record. The new methodology gives a more accurate estimate of the fishing effort associated with each sample biomass from scientific trawl surveys and allows for a more accurate estimation of the fishing impact. The level of fishing effort at which high VME biomass no longer occurs in any scientific trawl was considered to indicate a sustained impacted state. The cut-off value for the level of fishing effort corresponding to an 'impacted' *vs* 'at risk' state was determined by plotting cumulative biomass curves for each VME type. The point at which 95% of the biomass is accumulated was taken as the point distinguishing between an 'impacted' *vs* 'at risk' state. A separate analysis was conducted for each VME type (Table v.1) to determine the cut-off values used to produce maps of each VME area impacted, at risk and protected (Figures v.3 to v.9).

Table v.1. Cut-off values for fishing effort signifying an impacted state based on the VME cumulative biomass curves against ranked fishing effort (km/ km^2/year). The cut-off value equals the fishing effort at which 95% of the total biomass has been accumulated. Values are also shown converted into h/km^2/year using an estimated average fishing speed of 4 knots for comparison with values resulting from the previous analysis in 2015.

	2020		2015
	km/km²/year	**h/km²/year**	**h/km²/year**
Black corals	0.7	0.1	
Sea squirts	2.0	0.3	-
Erect bryozoans	6.8	0.9	-
Large gorgonians	0.6	0.1	0.1
Sea pens	4.3	0.6	0.5
Small gorgonians	2.2	0.3	-
Large-sized sponges	0.3	0.04	0.3

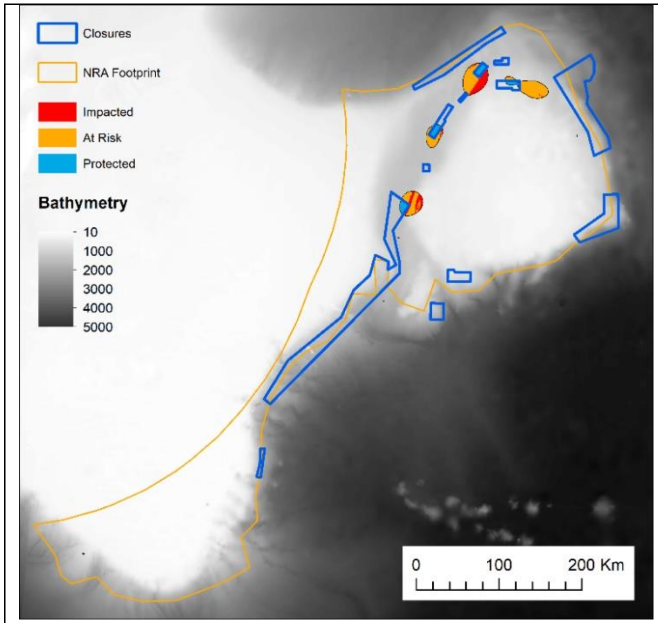
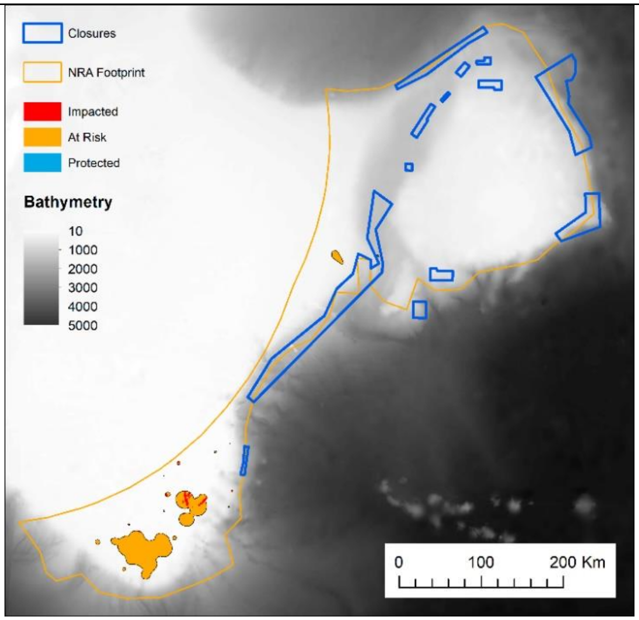
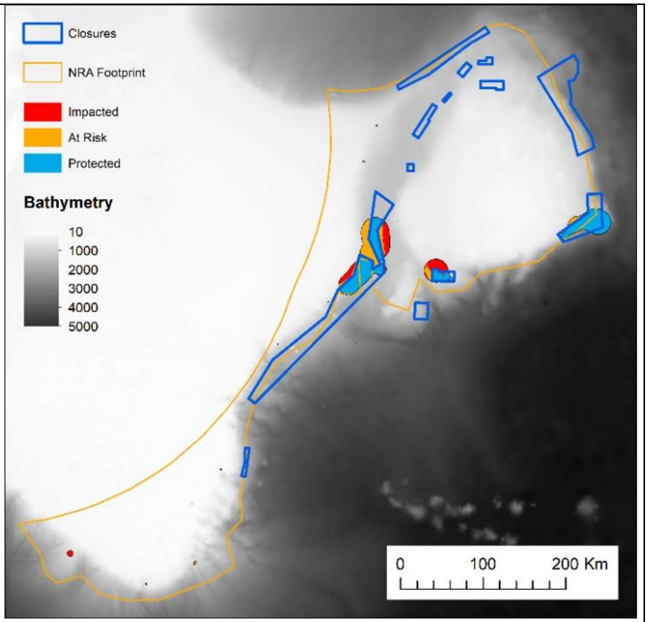
		

Figure v.3. Black coral VME classified impacted, at risk and protected, with the boundaries of the NRA fishing footprint and fisheries closures.	**Figure v.4.** Erect bryozoans VME classified impacted, at risk and protected, with the boundaries of the NRA fishing footprint and fisheries closures.	**Figure v.5.** Large gorgonian VME classified impacted, at risk and protected, with the boundaries of the NRA fishing footprint and fisheries closures.

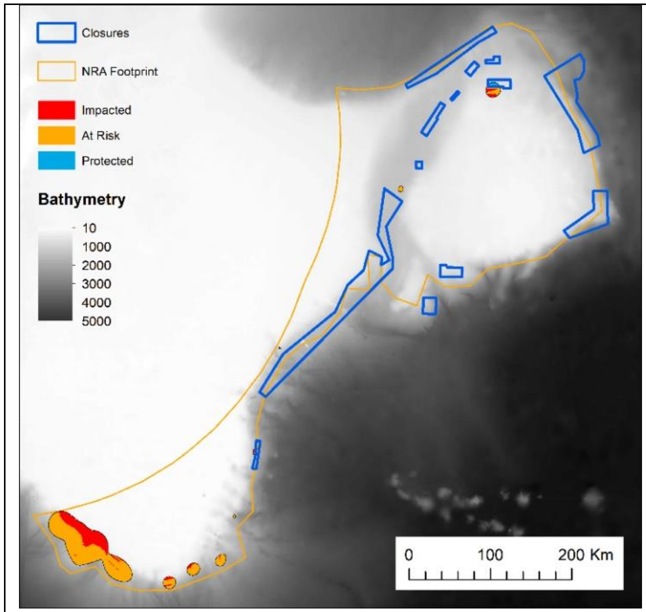


Figure v.6. Small gorgonian VME classified impacted, at risk and protected, with the boundaries of the NRA fishing footprint and fisheries closures.

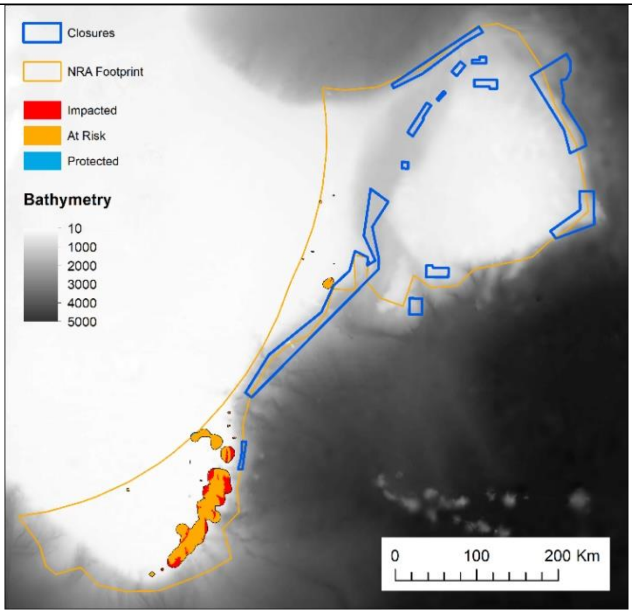


Figure v.7. Sea squirt VME classified impacted, at risk and protected, with the boundaries of the NRA fishing footprint and fisheries closures.

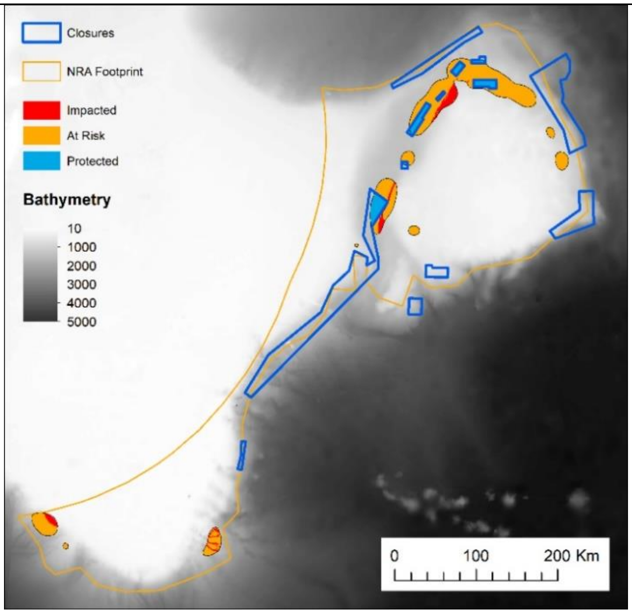


Figure v.8. Sea pen VME classified impacted, at risk and protected, with the boundaries of the NRA fishing footprint and fisheries closures.

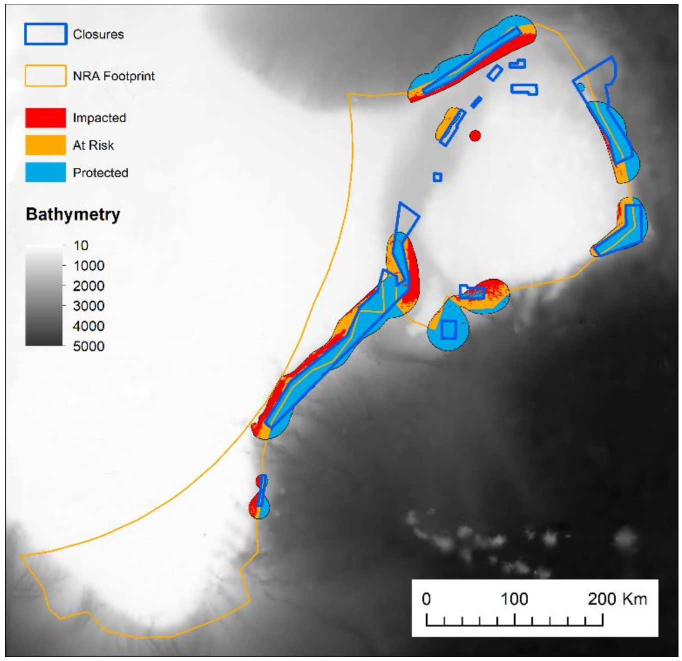


Figure v.9. Large-sized sponge VME classified impacted, at risk and protected, with the boundaries of the NRA fishing footprint and fisheries closures.

To conduct an overall assessment of SAI, a full set of assessment metrics was developed and compiled as described in Table v.2.

Table v.2. Assessment metrics applied in the 2nd reassessment of bottom fisheries SAI. The references to sections correspond to the 2020 WG-ESA Report (NAFO SCS 20/23).

SAI Assessment Metrics	Definition
Area/Biomass protected (low risk)	This refers to the proportion of the area or biomass of VME which is currently at low risk either because it falls within a fishery closure area and/or is in an area outside of the fishing footprint. (see Section 7.d.iii).
Area/Biomass impacted	Proportion of the area or biomass of VME which has been exposed to a level of fishing effort above the defined cut-off point within any one year. (See Section 7.d.iii).
Area/Biomass at high risk	Proportion of the area or biomass of VME which falls below the defined cut-off point of fishing effort within any one year which is not protected. (See Section 7.d.iii).
Proportion of overlapping VME in closures	Proportion of VME area and biomass overlapping with two or more VME types inside VME closures. The greater the proportion of overlapping VME area/biomass protected by closures the lower the risk of SAI occurring (See Section 7.d.x).
Index of VME sensitivity	The inverse of the VME impact cut-off value is used as a proxy of sensitivity as it indicates the point at which trawl duration/length exceeds the VME indicator patch size within the habitat. The higher the sensitivity the greater the risk of SAI occurring (See Section 7.d.v).

Index of fishing stability	The proportion of the total fishing effort for each VME associated with cells repeatedly fished above the impact cut-off value over a 10 period. The greater the proportion of effort associated with areas fished repeatedly above the cut-off value in 10 out of 10 years, the more spatially stable the fishery, and therefore the lower the risk of new SAI occurring (See Section 7.d.x)
Index of VME fragmentation/proximity	The spatial extent (size) and location (distance) of VME polygons in relation to their neighbours of the same VME type. The more fragmentation (a low index value) the greater the risk for SAI. (See section 7.d.x).
Number of important functions in unprotected portions of the VME.	The number of functional types that have important associations with VME and are present in unprotected portions of the VME. Functional types that have >50% area overlap with a VME are considered to show important associations with that VME. Because each VME can be associated with multiple functions, the more associated functions present in the unprotected portions of a VME, the greater the risk of SAI occurring at the functional level (See Section 7.d.ix).

The FAO guidelines (FAO, 2009) define SAI as: "*those that compromise ecosystem integrity (i.e., ecosystem structure or function) in a manner that: (i) impairs the ability of affected populations to replace themselves, (ii) degrades the long-term natural productivity of habitats, and (iii) causes, on more than a temporary basis, significant loss of species richness, habitat or community types*". These guidelines also indicate that "*When determining the scale and significance of an impact, the following six criteria should be considered:*

i. The intensity or severity of the impact at the specific site being affected.

ii. The spatial extent of the impact relative to the availability of the habitat type affected.

iii. The sensitivity/vulnerability of the ecosystem to the impact.

iv. The ability of an ecosystem to recover from harm, and the rate of such recovery.

v. The extent to which ecosystem functions may be altered by the impact.

vi. *The timing and duration of the impact relative to the period in which a species needs the habitat during one or more of its life-history stages*."

While these criteria help evaluating the different factors involved in assessing SAIs, they do not imply that these factors are necessarily independent nor mutually exclusive of one another. For example, the way in which criteria *i* (intensity) and/or *ii* (extent) interact with criterion *iii* (sensitivity) would be expected to impact criterion *iv* (recovery). This also means that any metric aimed at capturing any one specific criterion, would likely contribute to inform the others. Under this premise, the metrics utilized in this SAI were conceptually mapped onto the FAO criteria, focusing on the most obvious/direct connections. This does not preclude metrics from informing the other criteria in more subtle ways and/or through indirect pathways. The basic mapping of the metrics onto the FAO criteria is shown in Table v.3.

Table v.3. Conceptual mapping between SAI metrics and FAO SAI criteria

	FAO SAI Criteria					
SAI Assessment Metrics	**i**	**ii**	**iii**	**iv**	**v**	**vi**
Area/Biomass protected (low risk)	X	X		X	X	
Area/Biomass impacted	X	X			X	X
Area/Biomass at high risk	X	X			X	
Proportion of overlapping VME in closures			X		X	

Index of VME sensitivity			X	X		
Index of fishing stability	X	X				
Index of VME fragmentation/proximity	X	X				
Number of important functions in unprotected VME areas			X	X	X	

The rationale involved in this mapping exercise is summarized in Table v.4.

Table v.4. Rationale for mapping SAI metrics onto FAO SAI criteria.

SAI Assessment Metrics	**Rationale for mapping onto FAO SAI criteria**
Area/Biomass protected (low risk)	Main FAO criteria informed by this metric: i. (intensity), ii. (extent), iv. (recovery), v.(functionality) This metric informs the interpretation and quantification of both the intensity and extent of an impact by estimating the fraction of a VME not currently exposed to an impact. It also informs an assessment of recovery because protected VMEs are sources of recruitment for recolonization, and contributes to functionality because VME functions are generally expected to scale with the area/biomass of the VME and the status (i.e. protected, at risk, impacted) of that area/biomass.
Area/Biomass impacted	Main FAO criteria informed by this metric: i. (intensity), ii. (extent), v.(functionality), vi. (time/duration in relation to habitat use) This metric informs the interpretation and quantification of both the intensity and extent of an impact by estimating the fraction of a VME impacted. It also relates to functionality because VME functions are generally expected to scale with the area/biomass of the VME and the status (i.e. protected, at risk, impacted) of that area/biomass, and informs the time/duration of an impact in relation to habitat use because impacted areas are considered to be impaired in the provision of habitat.
Area/Biomass at high risk	Main FAO criteria informed by this metric: i.(intensity), ii.(extent), v.(functionality) This metric informs the interpretation and quantification of both the intensity and extent of an impact by estimating the fraction of VME at risk of impact. It also relates to functionality because VME functions are generally expected to scale with the area/biomass of the VME and the status (i.e. protected, at risk, impacted) of that area/biomass.
Proportion of overlapping VME in closures	Main FAO criteria informed by this metric: iii.(sensitivity), v.(functionality) This metric informs the sensitivity to an impact because each individual VME type has its own sensitivity to physical perturbation, so areas with overlapping VMEs are expected to have a different overall sensitivity compared to those with only a single VME type. It also informs risks to functionality because areas with overlapping VME types are more likely to contribute to more (or more complex) ecosystem functions.

Index of VME sensitivity	Main FAO criteria informed by this metric: iii.(sensitivity), iv.(recovery) This metric informs the sensitivity to an impact because each individual VME type has its own sensitivity to physical perturbation. It also informs recovery because the capacity of a VME to tolerate a physical perturbation has direct implications for its persistence, and consequently recovery (i.e. taking this concept to its extreme, only habitats that still exist are able to generate recruitment).
Index of fishing stability	Main FAO criteria informed by this metric: i.(intensity), ii.(extent) This metric informs the interpretation and quantification of both the intensity and extent of an impact by estimating the spatial consistency of impacted areas over time. The first pass of a bottom trawl through a VME potentially causes the greatest impact to the benthic organisms in the path of the trawl, so a fishery that is stable in space has a lower risk of creating additional 'new' impacts beyond the its core stable area of operation.
Index of VME fragmentation/proximity	Main FAO criteria informed by this metric: i.(intensity), ii.(extent) This metric informs the interpretation and quantification of both the intensity and extent of an impact by estimating the level of spatial fragmentation of the VME habitat. Current VME habitats are considered remnants of former more extensive distributions, so more fragmented VMEs (e.g., smaller patches and/or more distant patches) are expected to be less capable of tolerating physical perturbation and will therefore be at higher risk of SAI.
Number of important functions in unprotected VME areas	Main FAO criteria informed by this metric: iii.(sensitivity), iv.(recovery), v.(functionality) This metric informs the interpretation and quantification of the sensitivity, recovery and functionality of VMEs in response to bottom trawling by estimating the number of ecological functions potentially impacted in those portions of the VME habitat that remain without protection. The VME types involved inform on sensitivity and recovery (see Index of VME sensitivity above), but here in a context of the associated functions, while the associated functions themselves inform the potential impacts on ecological functionality. Since not all VMEs have important associations with all ecological functions, this metric is restricted to important associations (i.e., functional types that have >50% area overlap with a VME).

It was noted previously by SC that one of the principal limitations of the assessment is that all metrics applied to each VME have equal weight, when it is likely that some of the metrics will have greater importance for the assessment of SAI than others. In addition, greater consistency and objectivity in assigning the categories of 'high, moderate and low' to VME specific metrics has been sought in the present assessment.

For example, SC first considered the full list of SAI criteria (FAO, 2009) with respect to the expanded list of assessment metrics to be applied to the reassessment of bottom fisheries in 2021 (the 2nd SAI assessment). It was noted then that the first two SAI criteria are essentially directly related to the management of the fishing activity and therefore their status and trend will largely drive the responses in the remaining four FAO SAI criteria. Accordingly, the metrics which correspond to the assessment of the first two SAI criteria were considered to be of greater importance (and hence influence), e.g., VME biomass impacted, at risk and protected, and VME fragmentation and fishing stability. Of these the area/biomass protected was considered to be the most important assessment metric as the VME 'protected', 'at risk' and 'impacted' metrics are not mutually exclusive of one another, *e.g.*, an increase in the biomass protected will (by definition) result in a decrease in the combined biomass 'at risk' and 'impacted' categories, and therefore the potential risk of SAI would decrease accordingly. Therefore, by focusing the result of the assessment on the 'protected' VME biomass status, the assessment is essentially one which determines the ***risk of SAI occurring*** rather than an assessment of whether or not ***SAI has occurred***.

In the 1st assessment of SAI, three categories (or scores) of assessment were applied to each metric value, namely, 'high, moderate and low'. The limits used to define the scores were selected to highlight the relative differences between the VME specific metrics. Although in most cases the differences were sufficiently clear to assign either a high or low assessment score to each metric, the actual importance of the values in relation to ecosystem function and impact was not known. For the present assessment, it was considered important to agree and define a set of objective criteria for the SAI assessment scores, especially as applied to the first assessment metric (i.e., area/biomass protected). Also, to ensure consistency between the assessment score categories used in the review of VMEs in 2020 (NAFO SCS Doc. 20/14) and the present assessment of SAI, the same general VME 'protected' score categories (break points) were applied (Table v.5).

Table v.5. Definition of categories used to assess the protection status of VMEs. Status definitions (recommendations) are based on definitions from the online Oxford English Dictionary: Good – To be desired or approved of; Adequate – Satisfactory or acceptable in quantity or quality; Incomplete – Not having the necessary or appropriate parts; Limited – Restricted in size, amount, or extent; Poor – Of low or inferior standard or quality; Inadequate – Lacking in quality or quantity required.

SAI Score[3] Categories	VME Status	Proportion of biomass protected	Projected Connectivity Among Closures	Management Action
Good (Low SAI risk) >60%	Good	> 60% VME Biomass	Good connectivity	Beneficial
	Adequate	> 60% VME Biomass	Limited connectivity or redundancy	Beneficial
Limited (Intermediate SAI risk) 30% - 60%	Incomplete	60% - 30% VME Biomass	Good connectivity	Desirable
	Limited	60% - 30% VME Biomass	Limited connectivity or redundancy	Desirable
Poor (High SAI risk) <30%	Poor	30% - 15% VME Biomass	Limited connectivity or redundancy	Essential
	Inadequate	< 15% of Biomass	Limited connectivity or redundancy	Essential

As some limited fishing activity is known to occur within the area defined as "at risk" SC acknowledges that there is likely to be some impact associated with this effort which is currently not taken into account in the 'impacted' category. As the present assessment has not been able to determine what proportion of the 'at risk' biomass has actually been impacted, the overall weighting of the SAI assessment was therefore based primarily on the 'protected' SAI metric score. The score criteria applied for all the assessment metrics used in the overall assessment of SAI is shown in Table v.6 and the overall assessment of SAI is presented in Table v.7. Results indicated that small gorgonian, black coral, bryozoan and sea squirt VMEs have a high overall risk of SAI, whereas the sponge and large gorgonian VMEs have a low overall risk of SAI. The sea pen VME was assessed as having an intermediate risk of SAI.

[3] For the review of VMEs (NAFO SCS Doc. 19/25) six assessment categories were used. In the present assessment these have been grouped into three assessment categories as shown.

Table v.6. Overall SAI score category criteria as applied to each of the SAI assessment metrics. The first SAI metric uses the same categories as applied during the 2nd review of VMEs. For each of the remaining SAI metrics the breakpoints were generally set by dividing the range in values by 3 and rounding to the nearest whole number.

SAI metric	**SAI Score Categories**		
	Good (Low SAI risk)	**Limited (Intermediate SAI risk)**	**Poor (High SAI risk)**
VME Protected	> 60%	30% - 60%	< 30%
VME At Risk	-	-	-
VME Impacted	-	-	-
VME Fragmentation/Proximity	>740	340 - 740	< 340
Fishing effort stability Index (over 10 yrs.)	> 60%	30% - 60%	< 30%
VME Sensitivity Index	< 0.5	0.5 - 1	>1
Proportion of VME area/biomass overlapping in closures	> 60%	30% - 60%	< 30%
Number of important functions in unprotected VME	<2	2 - 3	>3

Table v.7. Overall SAI[4] assessment scores for each VME and SAI metric categorised as either good (low risk), limited (intermediate risk), or poor (high risk), following the SAI score categories as defined in Table v.4. The overall SAI Risk is based upon the count of 'poor' and 'good' ratings for each VME using biomass data where appropriate.

	Sponge		Sea pen		Large gorgonian		Small gorgonian		Black Coral		Bryozoan		Sea Squirt	
SAI metric	**Area**	**Biomass**	**Area**	**Biomass**	**Area**	**Biomass**	**Area**	**Biomass**	**Area**	**Biomass**	**Area**	**Biomass**	**Area**	**Biomass**
VME Protected	64%	93%	16%	33%	60%	89%	2%	2%	17%	23%	<1%	<1%	<1%	1%
VME At Risk	19%	6%	74%	65%	23%	10%	72%	86%	63%	67%	96%	99%	79%	85%
VME Impacted	18%	1%	9%	2%	16%	1%	26%	12%	20%	10%	4%	1%	21%	14%
SAI Risk (biomass)	**Low**		**Intermediate**		**Low**		**High**		**High**		**High**		**High**	
VME Fragmentation/Proximity	1112		394		255		125		109		717		802	
Fishing effort stability (over 10 yrs.)	82%		39%		44%		80%		54%		0%		39%	
VME Sensitivity	3.3		0.2		1.7		0.5		1.4		0.1		0.5	
Proportion of VME area/biomass overlapping in closures (km² and kg)	62%	99%	19%	42%	65%	82%	9%	9%	21%	23%	4%	3%	0%	0%
Number of important functions in unprotected portions of the VME.	2		4		2		1		3		4		4	
Overall SAI Risk[5]	**Low (1, 6)**		**Intermediate (3, 1)**		**Low (2, 4)**		**High (5, 2)**		**High (6, 0)**		**High (6, 1)**		**High (5, 1)**	
Ranking for Management Action	**7**		**5**		**6**		**4**		**1**		**2**		**3**	

[4] Significant Adverse Impact is a term defined by FAO (2009). It does not imply statistical significance, but rather to identify and quantify impacts which are important.

[5] The overall SAI Risk score was calculated by simply counting the number of high-risk category scores (in red) and the low-risk category scores (in green) for both the area and biomass metrics. These numbers are respectively shown in parenthesis. A combination of the high and low SAI risk scores provides the basis for ranking the management priority from high to low.

Part (ii) Potential management options in relation to VME closures

Scientific Council responded:

In evaluating potential management options for the protection of VMEs in the NRA, SC gave careful consideration to the review of existing closures and to the outcome of the SAI assessment in evaluating possible tradeoffs required to achieve appropriate conservation measures, whilst minimizing the possible consequences to ongoing bottom-contact fisheries.

SC **recommends** *improving the protection of VMEs and, as requested, proposes potential management options that appreciably enhance the current protection to VMEs.* Collectively, the proposed management options result in NAFO achieving 'good' VME protection status for six VMEs and 'limited' protection status for one VME. At the same time, the recommended measures result in a less than 1% overall impact on current fishing activities. The **recommended** measures take a system perspective, and include ten extensions to existing closures, the creation of three new closures and modifications to Area 14. Specifically, **SC recommends** the following changes to the existing VME closures:

- *Extension of Area Closure 1 (Area 1a), to protect large-sized sponges;*
- *Establishment of two new closures (Areas 17 & 18) on the tail of the Grand Bank, to protect sea squirts;*
- *Establishment of a new closure (Area 16) on the tail of the Grand Bank, to protect erect bryozoans;*
- *Creation of a new closure (Area 15a) to the northeast of the 3O Closure in the NRA, to protect important concentrations of small gorgonian coral, sea pens and large gorgonian coral;*
- *Westward extension of the Area 2 closure, in the form of the closure of the "notch" on the northwestern side of the Area 2, to better protect large gorgonian coral (Area 2a);*
- *Northward extension of Area 2, to protect significant concentrations of sea pens and black coral (Area 2b);*
- *Extension of closures between Area Closures 4 & 5 (Area 4a), to increase protection of large gorgonian coral and large-sized sponges;*
- *Eastward extension of Area Closure 7, to provide greater protection for sea pens and black coral (Area 7a);*
- *Extension to Area Closures 8 & 9 (linking with Area Closures 8, 9 & 12), to provide a more continuous closure to protect sea pens and black coral (Areas 8a & 9a) and improve connectivity;*
- *Westward extension to Area Closure 10, to provide combined protection for sea pens and large-sized sponges (Area 10a);*
- *Northeastward extension of Area Closure 11, to provide enhanced protection for sea pens (Area 11a);*
- *Re-establishment of a modified Area Closure 14 (Areas 14a & 14b), over areas of high sea pen concentrations in the eastern portion of the Flemish Cap.*

No changes to Area Closure 3 and Area Closure 13 are necessary.

The 1995 UN Fish Stocks Agreement (UNFSA) – an implementing agreement to UNCLOS – in giving effect to the duty to cooperate under UNCLOS and in order to conserve and manage straddling and highly migratory fish stocks, obliges coastal State Parties and Parties fishing on the high seas to "assess the impacts of fishing, other human activities and environmental factors on target stocks and species belonging to the same ecosystem or associated with or dependent upon the target stocks"[6]. Further to these, UNGA Resolution 61/105 calls upon RFMOs to exclude bottom contact fishing from those areas where VMEs are known or likely to occur until management measures to prevent SAIs have been established[7]. The NAFO Convention recalls the relevant provisions of UNCLOS and UNFSA and takes relevant FAO instruments[8] into account. More specifically, the

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[6] UNFSA, Art 5 (d).

[7] UNGA Resolution 61/105. Art. 83(c).

[8] NAFO Convention. See 2nd and 3rd preamble paragraphs.

NAFO Convention is to be interpreted and applied consistently with UNCLOS and UNFSA[9]. Furthermore, the Convention commits its Parties to apply an ecosystem approach to fisheries management[10] in the Northwest Atlantic that includes safeguarding the marine environment, conserving its marine biodiversity, minimizing the risk of long term or irreversible adverse effects of fishing activities and taking account of the relationship between all components of the ecosystem[11]. Article III of the Convention obliges its Contracting Parties to take due account of the fishing impacts on other species and marine ecosystems by adopting measures to minimise harmful impacts on living marine resources and ecosystems[12].

Review of existing closures by SC in 2020 (SCS Doc. 20/14) revealed that increased protection was essential for five of seven VMEs in the NRA (small gorgonian coral, sea squirts (*Boltenia ovifera*), erect bryozoans, black coral and sea pens) and desirable to beneficial for large gorgonian coral and large-sized sponge VMEs. As a result, expert groups with diverse scientific and fisheries management expertise evaluated the benefits and consequences of extensions to existing closures, as well as the addition of areas in instances where no protection existed (SCS Doc. 20/23).

In evaluating potential management options for the protection of VMEs in the NRA, the subject matter experts gave careful consideration to the review of existing closures and the outcome of the SAI in evaluating the possible tradeoffs required to achieve appropriate conservation measures and their possible consequences to ongoing bottom-contact fisheries. There are no established rules to quantify such tradeoffs, but the basic principles applied in expert deliberations were to reduce the risk of SAI and to the protection of VMEs, while limiting potential losses to harvesters relative to the overall activities for all fisheries monitored in the NRA. SC's empirical approach relied on expertise from fishery and ecosystem scientists, which could have been augmented using algorithmic methods (e.g., MARXAN). However, application of algorithmic methods would have required development of cost-benefit weighting criteria for conservation potential and the risk of adverse impact for each VME and fishery; this would have required considerable investment in effort and time by SC with no certainty of improvement in the overall outcome. Prior experiences by expert participants using algorithmic approaches have led to the conclusion that, while such methods can be very useful, especially in cases with multiple competing objectives, the final delineation of options always require expert input. In the case here, given the rather straightforward nature of the tradeoff involved, the diversity of expertise and knowledge brought together for this exercise, and the expediency that the issue requires, SC is confident that these results are reasonably close to an optimal solution. The careful balancing of improvement in the protection of VMEs while limiting potential losses to harvesters by SC experts is demonstrated in the overall results of the analyses described below.

Estimates of biomass and areas of high concentration of large-sized sponges, sea pens, sea squirts, erect bryozoans, black coral, large gorgonian coral and small gorgonian coral generated from the output kernel density raster surfaces, with an increased resolution of 1 km^2, served as the foundation in the development of management options. Two elements were overlaid for each VME to identify areas of high concentrations that could be considered at lower risk because of limited fishing activity: [1] an estimate of fishing stability (2010-2019) with VME catches above the effort cut-off threshold (i.e., level of fishing effort corresponding to an 'impacted' compared to an 'at risk' state based on the point at which 95% of the biomass is accumulated) (NAFO 2020b) for each VME taxon (years fished$\cdot$$km^{-2}$); [2] VME polygons and closures along with VME catches above the biomass threshold (i.e., significant research vessel catch concentration based on Kernel Density estimation as defined in SCS 13/024) (NAFO 2020b). Boundaries were chosen to ensure the incorporation of known observations of high VME biomass to avoid potential impact by exposure to fishing activity.

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9 NAFO Convention, Art. XXI (2).

10 Technical guidance on the implementation of the ecosystem approach to fisheries is elaborated under the FAO, *The* ecosystem *approach to fisheries. FAO Technical Guidelines for Responsible Fisheries*. No. 4, Suppl. 2. Rome, FAO. 2003. 112 p.; See also FAO, *The ecosystem approach to fisheries. FAO Technical Guidelines for Responsible Fisheries*. No. 4, Suppl. 2, Add. 2. Rome, FAO. 2009. 88p.

11 NAFO Convention, 8th preamble para. See also Article II, which states the Convention's objective to ensure the long-term conservation and sustainable use of the fishing resources in the Convention Area by safeguarding the marine ecosystems in which these resources are found.

12 NAFO Convention, Art. III (d).

Potential changes to existing closures were evaluated relative to the distribution of overall fishing effort (km·km^{-2}·year^{-1}) from trawl fisheries in the NRA between 2010–2019 based on VMS data, as presented in Figure v.2. The consequences to fisheries of any potential changes to existing closures were estimated based on the average haul-by-haul total and species specific catch biomass per distance of trawling (kg·km^{-1}) provided by the Secretariat (2016-2019) and matched to VMS data (NAFO 2020b), and cumulative fishing effort (fishing effort × years fished [2010-2019]) averaged over the number of years each fishery (cod, redfish, Greenland halibut, skate, and total across all species) was active.

Expert assessment of potential management options was based on the outcome of the re-assessment of VME closures (SCS Doc. 20/14) and evaluation of risk of significant adverse impact. This yielded proposals for ten extensions to existing closures, the creation of three new closures and modifications to Area 14 (Figure v.10).

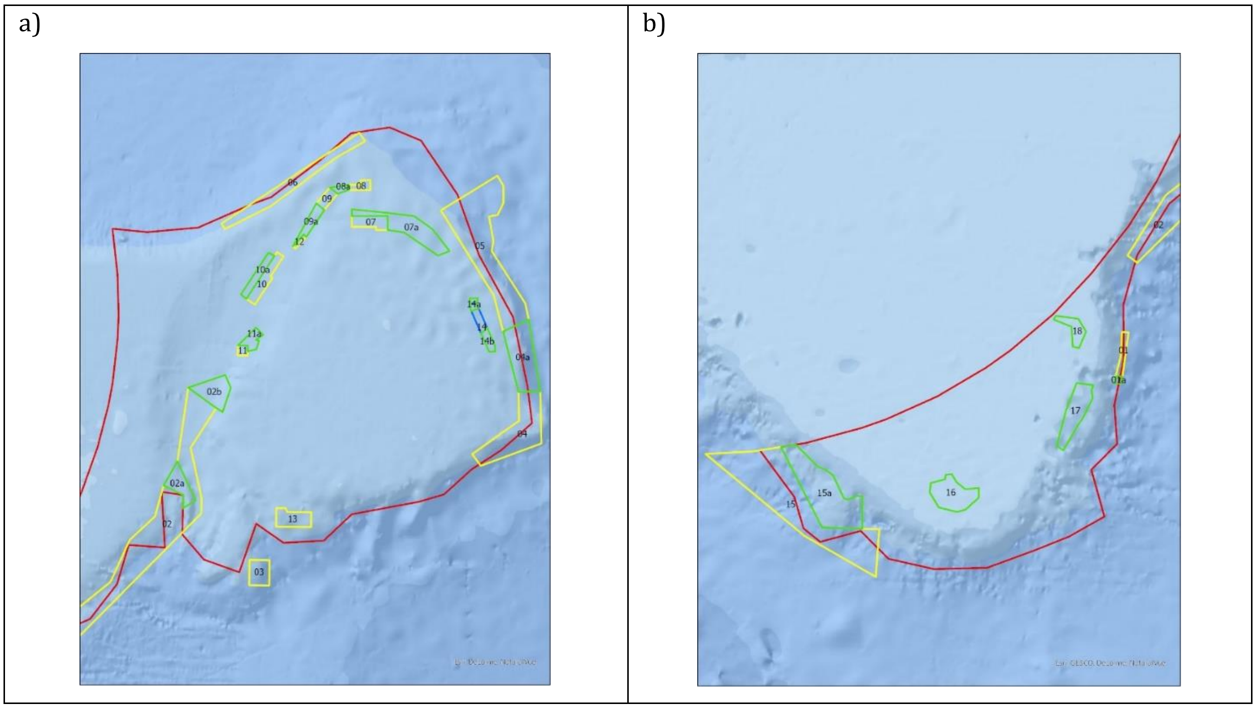


Figure v.10. Location of existing closures (in yellow) proposed extensions and new closures (in green), and removals (in blue) in a) the northern, and b) the southern portions of the NRA. The fishing footprint is indicated in red. Numerals represent existing or proposed new closures; number-letter combinations represent extensions or modifications to existing closures.

In general, high concentrations of VMEs occurred in areas with low fishing effort over a 10-year period (Figure v.2) which provides further evidence that the current distribution of high concentrations of VMEs very likely represents remnants of populations that were present before the onset of extensive and intensive trawl fisheries. Separation between the occurrence of VMEs from fishing effort together with stability reflected the vulnerability of each VME taxon to encounters with trawls based on the biomass threshold (high – large gorgonian coral, large-sized sponges, black coral; intermediate – sea squirts, small gorgonian coral; low – sea pens, erect bryozoans). Because of the sensitivity and long periods required for VMEs to recover from the impacts of bottom contact gear, the overall negative mirror-image in the distribution of high concentrations of VMEs and fishing effort likely reflects the outcome of long-term patterns in fishing activity in the NRA.

Area 1 – Tail of the Grand Bank large-sized sponge Closure

The tail of the Grand Bank has important concentrations of large-sized sponges, sea squirts, erect bryozoans, sea pens, and small and large gorgonian coral. There is strong stability in fishing activity to the west of the Area

1 large-sized sponge Closure, but limited fishing activity at the southern end of the closure where large-sized sponge concentrations above the biomass threshold occur. **SC recommends an extension of the Area Closure 1 (Area 1a).**

Sea squirts are broadly distributed along the eastern edge of the tail of the Grand Bank. There are notable occurrences of catches above the biomass threshold in areas with limited fishing activity in the northern-most polygon located east of the Southeast Shoal and in the northern portion of the VME polygon along the eastern portion of the tail of the Grand Bank. Given the very limited protection for sea squirts (<1% area; 1% biomass), **SC recommends the establishment of two new closures (Areas 17 & 18)**.

Erect bryozoans are also broadly distributed over the tail of the Grand Bank, but mostly in shallow areas. Two large areas with a high occurrence of catches above the biomass threshold were found west of the large sea squirt polygon, and fishing stability above the effort cut-off threshold is very limited over the large southwestern polygon. **SC recommends the establishment of a new closure (Area 16)**.

<u>Southwestern Tail of Grand Bank</u>

SCS Doc. 19/25 identified important concentrations of small gorgonian coral, sea pens and large gorgonian coral on the southwestern edge of the tail of the Grand Bank, in close proximity to the 3O coral Closure. Evaluation of fishing activities relative to the distribution of small gorgonian coral and sea pens revealed similar bathymetrically constrained areas of high fishing stability, below which catches above the biomass threshold of small gorgonian coral, sea pens and large gorgonian coral occur. **SC recommends the creation of a new closure (Area 15a) to the northeast of the 3O closure in the NRA, to protect important concentrations of small gorgonian coral, sea pens and large gorgonian coral**.

<u>Area 2 large-sized sponge Closure</u>

Large aggregations of large-sized sponges, large gorgonian coral, sea pens and black coral occur in the vicinity of the Area 2 large-sized sponge Closure. There is considerable overlap of large-sized sponges and large gorgonian coral, while sea pens and black coral co-occur in the northern part of Area 2 Closure. The improved delineation of sea pen and black coral polygons has identified several locations outside the Area 2 Closure where concentrations above the biomass threshold occur, and there is limited stability in fishing pressure above the effort cut-off threshold for both taxa. There is very limited fishing activity in the Area 2 "notch" on the northwestern side of the Area 2 closure, where there is a high occurrence of catches above the biomass threshold for large gorgonian coral. Given the occurrence of catches above the biomass threshold for sea pens, black coral and large gorgonian coral in parts of the VME polygons with very limited fishing stability, **SC recommends that two extensions to the Area 2 closure be put in place in the form of the closure of the "notch" on the northwestern side of the Area 2 to better protect large gorgonian coral (Area 2a), and a northward extension of Area 2 to protect significant concentrations of sea pens and black coral (Area 2b)**.

<u>Area 3 and 13 Large-sized sponge and large gorgonian coral Closures</u>

Although there have been changes to the VME polygons associated with Area 3 and 13 Closures based on the further data now available (SCS Doc. 19/25), the occurrence of VME concentrations above the biomass thresholds for both large-sized sponges and large gorgonian corals generally coincide with these two closures. There is no occurrence of fishing activity above the appropriate effort cut-off thresholds for these two VMEs. As a result, **SC concludes that no changes to Area 3 and Area 13 Closures are necessary**.

<u>Eastern Flemish Cap Area 4 & 5 Large-sized sponge and large gorgonian coral Closures</u>

There is one major area with high concentrations of large gorgonian coral and two areas with high concentrations of large-sized sponges along the eastern portion of the Flemish Cap. However, there are very few observations from scientific surveys between the two closures because the area is difficult to trawl. There is limited overall fishing activity by vessels using bottom-contact gear between Area 4 & 5 Closures, likely because of the steep topography and unsuitable nature of the bottom for trawling. **SC recommends that an**

extension of closures between Areas Closures 4 & 5 (Area 4a) be implemented to increase protection of large gorgonian coral and large-sized sponges.

Northwestern Flemish Cap Area 6 to 12 Closures

Extensive VME polygons for large-sized sponges, sea pens, small gorgonian coral and black coral have been identified on the northwestern portion of the Flemish Cap, where there is an important Area Closure for large-sized sponge (Area 6) and several small Area Closures for sea pens (Areas 7-12). There is also extensive overlap among VME polygons for these four VMEs. Existing Area Closures provide protection for a high proportion of VME catches above the biomass threshold for each taxon, but the review of closures has also identified many sites with high VME concentrations where there is currently little or no protection.

Fishing stability above the effort cut-off threshold overlaps with the black coral VME polygon to the east of Area Closure 9. A polygon for small gorgonian coral is associated with Area Closure 7, and overlaps with moderate fishing stability. Sea pens are broadly distributed in this part of Flemish Cap and have a relatively high fishing effort cut-off threshold (4.3 $km \cdot km^{-2} \cdot y^{-1}$), but the overlap of areas of high fishing stability with sea pens polygons is limited to areas east of Area Closures 9, 10 and 11. Catches of large-sized sponges above the biomass threshold have been identified to the east and west of Area Closure 10 and coincide with low levels of fishing stability. As a result of the limited overlap of high VME concentrations with fishing activity, **SC recommends;**

- *An eastward extension of Area Closure 7 to provide greater protection for sea pens and black coral (Area 7a);*
- *The extension to Area Closures 8 and 9 (linking with Area Closures 8, 9 and 12) to provide a more continuous Closure to protect sea pens and black coral (Areas 8a and 9a) and improve connectivity;*
- *A westward extension to Area Closure 10 to provide combined protection for sea pens and large-sized sponges (Area 10a);*
- *A northeastward extension of Area Closure 11 to provide enhanced protection for sea pens (Area 11a).*

Area 14 Sea Pen Closure

Area Closure 14 (sea pens) was established in January 2017 and re-opened to fishing in December 2018 (SCS Doc. 19/25). There are strong indications of important concentrations of sea pen VMEs in the eastern portion of the Flemish Cap, and to the west of Area Closure 5 although the re-assessment of the closures (NAFO 2020) resulted in a substantial reduction in the area of the VME polygon associated with Area Closure 14 relative to the previous assessment. There are low levels of fishing stability associated with these sea pen polygons. Owing to the importance of Area 14 to the connectivity among areas of high sea pen concentration, **SC recommends the re-establishment of a modified Area 14 (Areas 14a & 14b) over areas of high sea pen concentrations in the eastern portion of the Flemish Cap**.

Management Options – VME Protection, Fishery Activity and Catches

Re-assessment of the effectiveness of NAFO Area Closures by SC in 2020 (SCS Doc. 20/14) concluded that protection was inadequate for three VME taxa (small gorgonian coral, sea squirts and erect bryozoans), poor for two VME taxa (black coral and sea pens), which implied that management action was considered essential. While two VME taxa (large gorgonian coral and large-sized sponges) had incomplete to good protection, management action was considered desirable to beneficial, though not essential (SCS Doc. 20/14). Proposed extensions of and modifications to existing closures, and the implementation of three new closures, would result in an overall areal protection ranging from 21 to 68% of VMEs, with increases in protection ranging from 4 to 55%, and overall biomass protection ranging from 32 to 96%, constituting increases in protection ranging from 3 to 78% relative to the reassessment of existing Area Closures (Tables v.8 and v.9).

Based on the haul-by-haul data for the period 2016-2019, a total of 47 492 km^2 over the entire NRA was fished with an associated catch. Total catch per effort ranged from 0.5 to 51 536 $kg \cdot km^{-1}$ (median: 3563). Of the area fished, 9468 km^2 overlapped with VME polygons (excluding closures), with total catch per effort ranging from 37 to 33 872 $kg \cdot km^{-1}$ (median: 3780). Of the area overlapping VMEs, only 366 km^2 overlapped with the proposed changes to existing closures (0.77% of the total area fished), with total catch per effort ranging from 319 to 17 146 $kg \cdot km^{-1}$ (median: 3511).

The direct impact of the new closures to the total catches and to catches of five important fishery species are detailed in Table v.10. Overall, approximately 28.5% of effort occurs in VME polygons, while approximately 20% of the total catches occur in VME polygons. The proposed closures would result in a 0.61% loss of total average effort and a 0.75% loss of total average catch. The losses from the proposed changes to VME Closures could be compensated by a very minor adjustment in the spatial distribution of fishing effort, and such changes are very small relative to inter-annual changes in TACs associated with changes in population abundance.

Potential future changes in the distribution of fishing activity as a result of changes in population status (i.e., abundance and biomass) and environmental conditions over periods longer than the data available for the current assessments of current Area Closures, together with the risk of significant adverse impacts, are very likely reflected in the negative mirror distributions in areas of high concentrations of VMEs and the distribution of fishing effort. Currently, ~88% of the average cumulated effort ($km \cdot km^{-2}$) occurs in less than 58% [about 42%] of the area (km^2) over which effort occurred for 6-10 years during 2010-2019, providing opportunity for potential compensatory expansion of fishing activities in areas where VMEs are unlikely to occur in high concentrations.

Table v.8. Total area and percent of total area for VMEs within the polygons estimated from Kernel Density estimates, Closed Areas, Conditionally Protected (outside closures and outside fishing footprint), Protected Overall (sum of protected biomass inside and outside fishing footprint) and Unprotected, for Existing Closures (including Area 14 but excluding 3O Closure) together with Existing + Proposed Closures.

Existing Closures (excluding Area 14, excluding 3O)										
	VME Polygons	Closed Area		Conditionally Protected		Protected Overall		Unprotected		
VME	Area (km²)	Area (km²)	Percent	Area (km²)	Percent	Area (km²)	Percent	Area (km²)	Percent	
Black coral	2,799	521	19%	0	0%	521	19%	2,278	81%	
Erect bryozoans	3,498	5	0%	0	0%	5	0%	3,493	100%	
Large gorgonian coral	5,415	2,918	54%	316	6%	3,234	60%	2,181	40%	
Sea pens	9,085	1,459	16%	1	0%	1,460	16%	7,625	84%	
Sea squirts	4,081	0	0%	17	0%	17	0%	4,064	100%	
Small gorgonian coral	4,756	84	2%	0	0%	84	2%	4,672	98%	
Large-sized sponges	26,011	10,163	39%	6,409	25%	16,572	64%	9,439	36%	

Existing + Newly Proposed Closures									
	VME Polygons	Closed Area		Conditionally Protected		Protected Overall		Unprotected	
VME	Area (km²)	Area (km²)	Percent	Area (km²)	Percent	Area (km²)	Percent	Area (km²)	Percent
Black coral	2,799	1,543	55%	0	0%	1,543	55%	1,256	45%
Erect bryozoans	3,498	690	20%	0	0%	690	20%	2,808	80%
Large gorgonian coral	5,415	3,346	62%	316	6%	3,662	68%	1,753	32%
Sea pens	9,085	4,093	45%	1	0%	4,094	45%	4,991	55%
Sea squirts	4,081	856	21%	17	0%	873	21%	3,208	79%
Small gorgonian coral	4,756	1,752	37%	0	0%	1,752	37%	3,004	63%
Large-sized sponges	26,011	11,483	44%	6,032	23%	17,516	67%	8,495	33%

Table v.9. Total biomass and percent of total biomass for VMEs within the polygons estimated from Kernel Density estimates, Closed Areas, Conditionally Protected (outside closures and outside fishing footprint), closed areas within the fishing footprint, conditionally protected outside fishing footprint, protected overall (sum of protected biomass inside and outside fishing footprint) and unprotected for existing closures (including Area 14 but excluding 3O closure), together with existing + proposed closures.

Existing Closures (excluding area 14, excluding 3O)										
	VME Polygons	Closed Area		Conditionally Protected		Protected Overall		Unprotected	
VME	Biomass (kg)	Biomass (kg)	Percent	Biomass (kg)	Percent	Biomass (kg)	Percent	Biomass (kg)	Percent
Black coral	10,441	2,615	25%	0	0%	2,615	25%	7,826	75%
Erect bryozoans	65,567	4	0%	0	0%	4	0%	65,563	100%
Large gorgonian coral	133,448	97,157	73%	19,808	15%	116,965	88%	16,483	12%
Sea pens	100,244	32,900	33%	24	0%	32,924	33%	67,320	67%
Sea squirts	41,572	0	0%	215	1%	215	1%	41,357	99%
Small gorgonian coral	3,351	61	2%	0	0%	61	2%	3,290	98%
Large-sized sponges	276,985,425	212,834,753	77%	44,191,066	16%	257,025,819	93%	19,959,606	7%

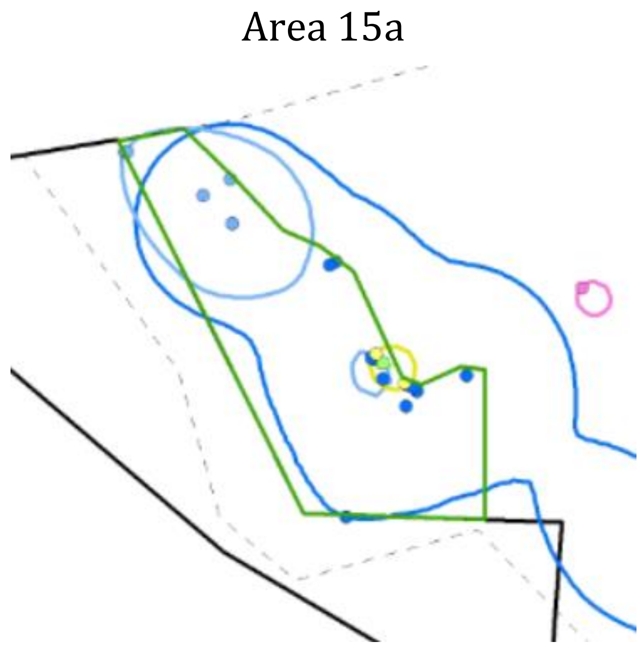
Existing + Newly Proposed Closures									
	VME Polygons	Closed Area		Conditionally Protected		Protected Overall		Unprotected	
VME	Biomass (kg)	Biomass (kg)	Percent	Biomass (kg)	Percent	Biomass (kg)	Percent	Biomass (kg)	Percent
Black coral	10,441	8,002	77%	0	0%	8,002	77%	2,439	23%
Erect bryozoans	65,567	50,856	78%	0	0%	50,856	78%	14,711	22%
Large gorgonian coral	133,448	99,651	75%	19,808	15%	119,460	90%	13,988	10%
Sea pens	100,244	64,272	64%	24	0%	64,296	64%	35,948	36%
Sea squirts	41,572	24,635	59%	215	1%	24,850	60%	16,722	40%
Small gorgonian coral	3,351	1,067	32%	0	0%	1,067	32%	2,285	68%
Large-sized sponges	276,985,425	244,258,553	88%	20,875,096	8%	265,133,649	96%	11,851,776	4%

Table v.10. Percent of total effort (2010-2019, no discrimination among fisheries) and percent of total average catch (2016-2019, discriminating key fishery species) overlapping with VME polygons. Percentages represent values relative to total effort and total catch over the entire NRA. Current refers to Existing Closures (excluding Area 14 and 3O Coral Closures); Current + Proposed refers to Existing and Proposed Closures. Note that estimates of percent effort and percent catch for individual VME taxa do not take overlap with other VME taxa into account. "All VMEs combined" allows for calculations of the percent of total effort and of total average catch without double counting overlapping VMEs.

Percent of Effort from VMEs	All VMEs	Black coral	Sea squirts	Erect bryozoans	Small gorgonian coral	Sea pens	Large gorgonian coral	Sponges
All fisheries								
Percent Effort Current	28.494	0.676	2.670	1.445	2.594	4.079	10.283	9.842
Percent Effort Current + Proposed	27.884	0.515	2.572	1.409	2.573	3.777	10.071	9.828
Percent Difference	-0.610	-0.161	-0.098	-0.036	-0.021	-0.302	-0.212	-0.014

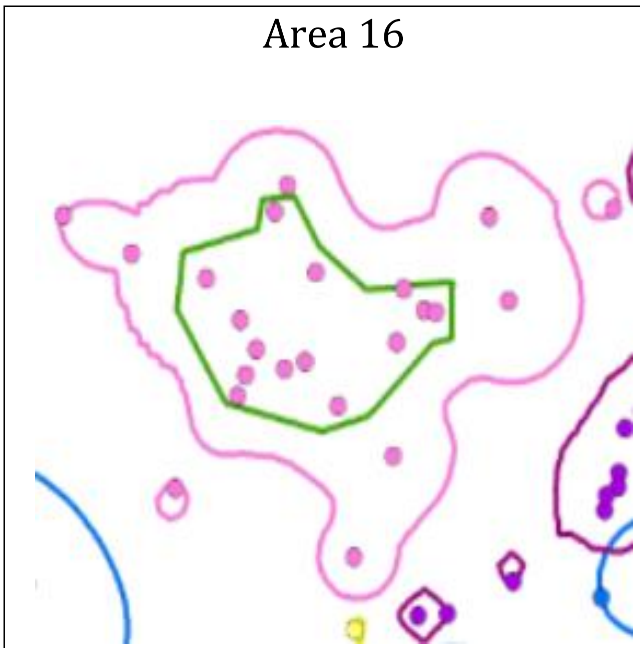
Percent of Catch from VMEs	All VMEs	Black coral	Sea squirts	Erect bryozoans	Small gorgonian coral	Sea pens	Large gorgonian coral	Sponges
All Fisheries								
Percent Catch Current	20.106	1.422	2.632	2.552	2.674	4.158	3.375	5.876
Percent Catch Current + Proposed	19.354	1.255	2.588	2.548	2.549	3.792	3.135	5.814
Percent Difference	-0.752	-0.166	-0.044	-0.005	-0.125	-0.366	-0.239	-0.062
Cod								
Percent Catch Current	5.752	0.053	0.535	0.331	3.975	0.089	0.314	0.562
Percent Catch Current + Proposed	5.729	0.053	0.530	0.325	3.972	0.087	0.305	0.561
Percent Difference	-0.023	0.000	-0.005	-0.006	-0.003	-0.002	-0.009	-0.002
Greenland Halibut								
Percent Catch Current	39.132	3.157	0.383	0.004	2.344	13.098	1.767	23.404
Percent Catch Current + Proposed	37.822	2.592	0.383	0.004	2.342	11.939	1.589	23.347
Percent Difference	-1.310	-0.566	0.000	0.000	-0.001	-1.159	-0.178	-0.057
Redfish								
Percent Catch Current	21.213	1.054	9.429	0.313	2.441	2.087	6.281	1.566
Percent Catch Current + Proposed	20.561	1.054	9.379	0.313	2.256	1.907	5.942	1.459
Percent Difference	-0.652	-0.001	-0.050	0.000	-0.185	-0.180	-0.339	-0.107

Skate								
Percent Catch Current	15.942	0.068	3.359	11.105	0.090	0.190	1.553	0.330
Percent Catch Current + Proposed	15.706	0.064	3.216	11.061	0.080	0.176	1.511	0.327
Percent Difference	-0.236	-0.004	-0.143	-0.043	-0.010	-0.014	-0.042	-0.003
Yellowtail flounder								
Percent Catch Current	28.692	0.000	4.936	24.018	0.003	0.010	0.148	0.007
Percent Catch Current + Proposed	28.154	0.000	4.869	23.552	0.000	0.009	0.142	0.007
Percent Difference	-0.539	0.000	-0.067	-0.465	-0.003	-0.002	-0.007	0.000



Latitude	Longitude
43.08257 N	51.34857 W
43.07500 N	51.30799 W
43.10609 N	51.22945 W
43.10403 N	51.17983 W
42.87897 N	51.15700 W
42.86778 N	51.52889 W
43.18927 N	51.79235 W
43.40361 N	51.97000 W
43.42934 N	51.83784 W
43.36821 N	51.73464 W
43.29003 N	51.61594 W
43.27069 N	51.53741 W
43.23694 N	51.46538 W
43.08257 N	51.34857 W

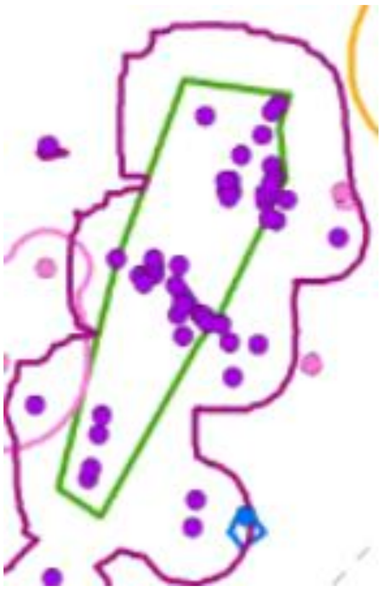
Figure v.11. Decimal coordinates for proposed Area Closure 15a. Area labels as in Figure v.10.



Latitude	Longitude
43.16494 N	50.55787 W
43.23062 N	50.55408 W
43.26304 N	50.42504 W
43.29544 N	50.41978 W
43.30229 N	50.36430 W
43.24879 N	50.31657 W
43.20279 N	50.22954 W
43.21674 N	50.10497 W
43.14914 N	50.10001 W
43.06057 N	50.21448 W
43.04049 N	50.29363 W
43.06389 N	50.46425 W
43.16494 N	50.55787 W

Figure v.12. Decimal coordinates for proposed Area Closure 16. Area labels as in Figure v.10.

Area 17



Latitude	Longitude
43.54086 N	49.40267 W
43.79167 N	49.33333 W
43.98800 N	49.24760 W
43.97838 N	49.08808 W
43.94285 N	49.10246 W
43.88806 N	49.08831 W
43.73380 N	49.17938 W
43.70567 N	49.20598 W
43.51276 N	49.33884 W
43.54086 N	49.40267 W

Figure v.13. Decimal coordinates for proposed Area Closure 17. Area labels as in Figure v.10.

Area 18

Latitude	Longitude
44.24110 N	49.30176 W
44.37984 N	49.32388 W
44.42318 N	49.49658 W
44.45008 N	49.47870 W
44.43734 N	49.26429 W
44.35077 N	49.18364 W
44.23285 N	49.24218 W
44.24110 N	49.30176 W

Figure v.14. Decimal coordinates for proposed Area Closure 18. Area labels as in Figure v.10.

Area 1a

Latitude	Longitude
44.04850 N	48.88119 W
44.04828 N	48.81930 W
43.99931 N	48.82402 W
44.00031 N	48.89132 W
44.04850 N	48.88119 W

Figure v.15. Decimal coordinates for proposed extension for Area Closure 1 (Area 1a). Area labels as in Figure v.10.

Area 2a

Latitude	Longitude
46.50617 N	47.18415 W
46.67800 N	47.05130 W
46.40669 N	46.85639 W
46.35133 N	46.98139 W
46.44222 N	46.98139 W
46.50617 N	47.18415 W

Figure v.16. Decimal coordinates for proposed extension for Area Closure 2 (Area 2a). Area labels as in Figure v.10.

Area 2b

Latitude	Longitude
47.19639 N	46.96058 W
47.29139 N	46.58349 W
47.20159 N	46.52367 W
47.03052 N	46.60236 W
47.05808 N	46.66790 W
47.19639 N	46.96058 W

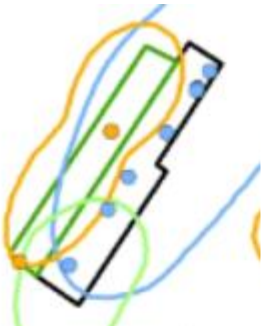
Figure v.17. Decimal coordinates for proposed extension for Area Closure 2 (Area 2b). Area labels as in Figure v.10.

Area 11a

Latitude	Longitude
47.50040 N	46.45919 W
47.62746 N	46.27531 W
47.57767 N	46.20109 W
47.54136 N	46.27405 W
47.53611 N	46.24163 W
47.47439 N	46.26826 W
47.46008 N	46.35658 W
47.50040 N	46.35658 W
47.50040 N	46.45919 W

Figure v.18. Decimal coordinates for proposed extension for Area Closure 11 (Area 11a). Area labels as in Figure v.10.

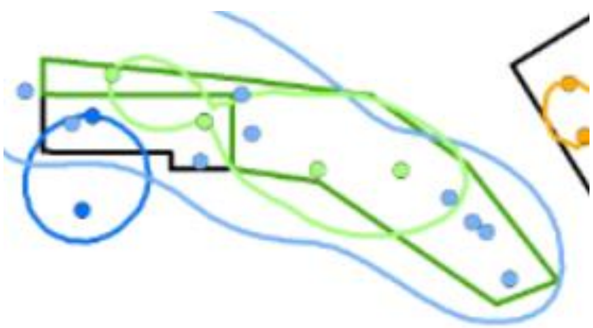
Area 10a



Latitude	Longitude
47.82819 N	46.38003 W
47.85837 N	46.43767 W
48.15374 N	46.15862 W
48.13325 N	46.09395 W
47.82819 N	46.38003 W

Figure v.19. Decimal coordinates for proposed extension for Area Closure 10 (Area 10a). Area labels as in Figure v.10.

Area 7a



Latitude	Longitude
48.16916 N	44.26527 W
48.13845 N	44.38627 W
48.30190 N	44.73967 W
48.31908 N	44.91058 W
48.41728 N	44.91058 W
48.41728 N	45.28789 W
48.46450 N	45.28868 W
48.43927 N	44.90961 W
48.41587 N	44.63289 W
48.32513 N	44.44400 W
48.16916 N	44.26527 W

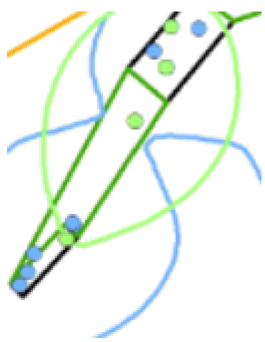
Figure v.20. Decimal coordinates for proposed extension for Area Closure 7 (Area 7a). Area labels as in Figure v.10.

Area 8a

Latitude	Longitude
48.61528 N	45.52108 W
48.63553 N	45.32553 W
48.59900 N	45.32553 W
48.57319 N	45.43858 W
48.61528 N	45.52108 W

Figure v.21. Decimal coordinates for proposed extension for Area Closure 8 (Area 8a). Area labels as in Figure v.10.

Area 9a



Latitude	Longitude
48.45850 N	45.57789 W
48.26863 N	45.76336 W
48.28661 N	45.79036 W
48.20183 N	45.90358 W
48.50508 N	45.66178 W
48.45850 N	45.57789 W

Figure v.22. Decimal coordinates for proposed extension for Area Closure 9 (Area 9a). Area labels as in Figure v.10.

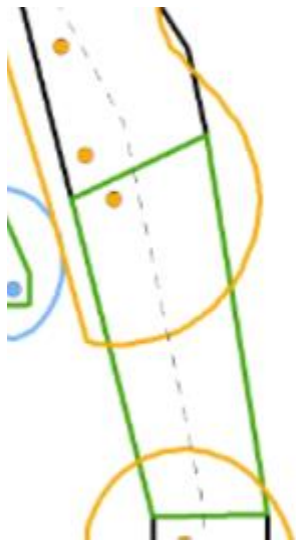
Area 14a	Latitude	Longitude
	47.75679 N	44.05179 W
	47.79843 N	44.05179 W
	47.83648 N	44.05958 W
	47.83635 N	43.97472 W
	47.79843 N	43.98983 W
	47.76533 N	43.96915 W
	47.74572 N	44.04486 W
	47.75679 N	44.05179 W

Figure v.23. Decimal coordinates for proposed modification of Area Closure 14 (Area 14a). Area labels as in Figure v.10.

Area 14b	Latitude	Longitude
	47.58938 N	43.94725 W
	47.62598 N	43.88236 W
	47.50133 N	43.80515 W
	47.45969 N	43.80515 W
	47.45969 N	43.86676 W
	47.58938 N	43.94725 W

Figure v.24. Decimal coordinates for proposed modification of Area Closure 14 (Area 14b). Area labels as in Figure v.10.

Area 4a



Latitude	Longitude
47.17500 N	43.57120 W
47.59928 N	43.71920 W
47.68178 N	43.45186 W
47.17500 N	43.34770 W
47.17500 N	43.57120 W

Figure v.25. Decimal coordinates for proposed extension for Area Closures 4 & 5 (Area 4a). Area labels as in Figure v.10.

Part (iii) Review of seamount closure boundaries

Scientific Council responded:

SC **recommends** *changes to the existing boundaries for the Fogo, Newfoundland and Corner Rise Seamount closures, as well as the implementation of seven new individual seamount closures in the NRA north of Orphan Knoll.* The proposed revisions for all seamounts in the NRA supersede the 2020 SC advice on this topic. SC notes that current and proposed seamount closures have no impact on ongoing fishing activities. All seamounts and current seamount closures fall outside the NAFO fishing footprint. There are no bottom-contacting fishing activities outside the NAFO fishing footprint, and any exploratory bottom fishing activity in this area is subject to the provisions of Chapter 2 of the NCEM, including the prohibition of bottom-contact fishing within seamount closures.

The UN General Assembly (UNGA) resolution 59/25 calling for urgent action to protect VMEs from destructive fishing practices in areas beyond national jurisdiction (ABNJ) was adopted in 2004 (A/RES/59/25 https://undocs.org/en/A/RES/59/25). RFMOs responded promptly, and on January 1 of 2005, NEAFC closed the Hecate and Faraday Seamounts, the Altair Seamounts and the Antialtair Seamounts to bottom trawling and fishing with static gear (NEAFC 2004). In 2006, UNGA resolution 61/105 was adopted (https://undocs.org/A/RES/61/105), elaborating on a series of actions to be taken by States and RFMOs for the protection of VMEs. Effective January 1, 2007, both SEAFO and NAFO introduced closures to protect seamounts in accordance with those UNGA resolutions. SEAFO, an area with a large number of seamounts, closed seven areas with seamounts, including one area in which ten seamounts were known to be present (http://www.fao.org/fishery/vme/24238/170275/en). NAFO closed the Newfoundland Seamounts, the New England Seamounts, the Corner Rise Seamounts and the Orphan Knoll following a review of seamounts in the NAFO Convention Area (Kulka et al., 2007). The Fogo Seamounts were later identified and closed effective January 1, 2009. Both the Corner and the New England Seamount chains extend into the Western Central

Atlantic Fishery Commission (WECAFC) mandate area. In 2016, WECAFC assigned the status of Vulnerable Marine Ecosystem (VME) to Corner Seamounts, New England Seamounts, Wyoming Seamounts and Congress and Lynch Seamounts, all of which border on the NAFO Convention Area. No further changes to the NAFO Seamount closures were made until 2017 when the boundaries of the New England Seamount Chain were extended, effective January 1, 2018, to connect across to the EEZ of the United States of America (COM Doc. 18-01).

In 2020, as part of the review of the VME closures, SC concluded that the available information supported the continued designation of these areas as VMEs (SCS Doc. 20/14). At that time SC proposed new boundaries for the Corner Rise Seamounts and Newfoundland Seamounts, to maintain connectivity across the seamount chains and to improve the protection of vulnerable seamounts in the NRA. The SC seamount recommendations in 2020 were, however, not adopted; given the availability of new bathymetric data towards the end of 2020, SC has taken the opportunity to undertake a more extensive review of the seamounts in the NAFO Areas Beyond National Jurisdiction (ABNJ).

The history of development of NAFO seamount closures since the mid-2000s, and the evolving analyses that supported this process over time, has resulted in an inconsistent approach to seamount protection, giving rise to some seamounts in a local area being protected whilst others at a similar depth were left outside the seamount closures. Therefore, since 2019 SC has undertaken a systematic review of all seamount closed areas to ensure a consistency of approach that should reduce the need for any further revision unless new information emerges.

SC also notes that current and proposed seamount closures have no impact on ongoing fishing activities. All seamounts and current seamount closures fall outside the NAFO fishing footprint. There is no bottom-contact fishing activity outside the NAFO fishing footprint, and any exploratory bottom fishing activity in this area is subject to the provisions of Chapter 2 of the NCEM, including the prohibition of bottom-contact fishing within seamount closures.

Since the last seamount assessment in 2019 (SCS Doc. 19/25), new information on VMEs in the seamounts from the NRA has been published, which supports the designation of these areas. A new species of sponge, *Tedania* (*Tedaniopsis*) *rappi*, of 25 cm (width) x 15 cm (height), collected during the Canadian mission HUD2010-029 and the British RRS Discovery Cruise DY081, has been described in the Orphan Seamount within the Orphan Knoll closed area between 3000 and 3450 m depth (Ríos et al. 2021). Additionally, Lapointe et al. (2020) have described the megabenthic assemblages in the lower bathyal (700 – 3000 m) on the New England and Corner Rise Seamounts, based on 34 dives which took place from 2003 to 2014 on 17 seamounts/peaks and over 400 hours of bottom time video.

SC's primary source for the identification of seamounts is the publication by Kim and Wessel (2011). They used altimetry-derived gravity data available at that time to identify morphological features extracted from the geometry of the contours (base dimensions, height etc.). A similar database by Yesson and colleagues (2011) was cross-referenced but was not used as the primary source of information as its scope was different from SC's purposes and some of their seamount locations off the tail of the Grand Bank have been shown to be invalid from the NEREIDA multibeam surveys (SCS Doc. 11/022). There are few data of the occurrence of VME on seamounts with peaks deeper than 4000 m. Furthermore, given that most seamount fisheries operate up to 2000 m, and considering current technological limitations, a precautionary depth limit for bottom-contacting fishing for this assessment was set at 4000 m. As a result seamounts with peaks below 4000 m were not considered in the current SC review.

Fogo Seamount Chain: The current closures in the Fogo Seamounts protect only three seamounts between 3000 and 3500 m depth. Several seamounts between 2500 and 4000 m depth are found south of the Tail of the Grand Bank. SC **recommends** *boundary changes to the current closures to protect the seamounts shallower than 4000 m depth to complete the protection of all vulnerable seamounts in the area.*

Newfoundland Seamount Chain: The current closure includes seamounts with peaks ranging from 2446-3756 m. There are three other seamounts in this depth range that are not within the boundaries of the current closure (depth range of 3192-3617 m). SC **recommends** *boundary revisions to ensure inclusion of the 15 seamounts in the Newfoundland Seamount Chain with peak depths ranging between 2446 and 3756 m*.

Corner Rise Seamount Chain: In 2020 SC proposed boundaries included 18 seamounts ranging in depth from 913-3319 m. To ensure consistency in approach in seamount closures, SC **recommends** that *the boundary proposed in 2020 for the Corner Rise Seamount area (SCS Doc. 20/14) be extended to the east to include the seven seamounts ranging in peak depth from 2747-3881 m.*

Seamounts north of Orphan Knoll: In order to apply a consistent approach across the remaining areas of the NAFO Convention Area in ABNJ, Scientific Council examined any seamounts with peak depth < 4000 m. All of the seamounts that met this criterion were north of Orphan Knoll. Seven seamounts shallower than 4000 m depth were identified by Kim and Wessel (2011) and/or by using the 2019 GEBCO bathymetry in the NAFO Divisions 1F, 2HJ, and 3K. SC **recommends** *the implementation of seven seamount closures in the NAFO Convention Area in ABNJ north of Orphan Knoll.*

The proposed revisions for all seamounts in the NRA supersede the 2020 SC advice on this topic and are summarized in Figure v.26. Further details can be found in Figures v.27-v.35.

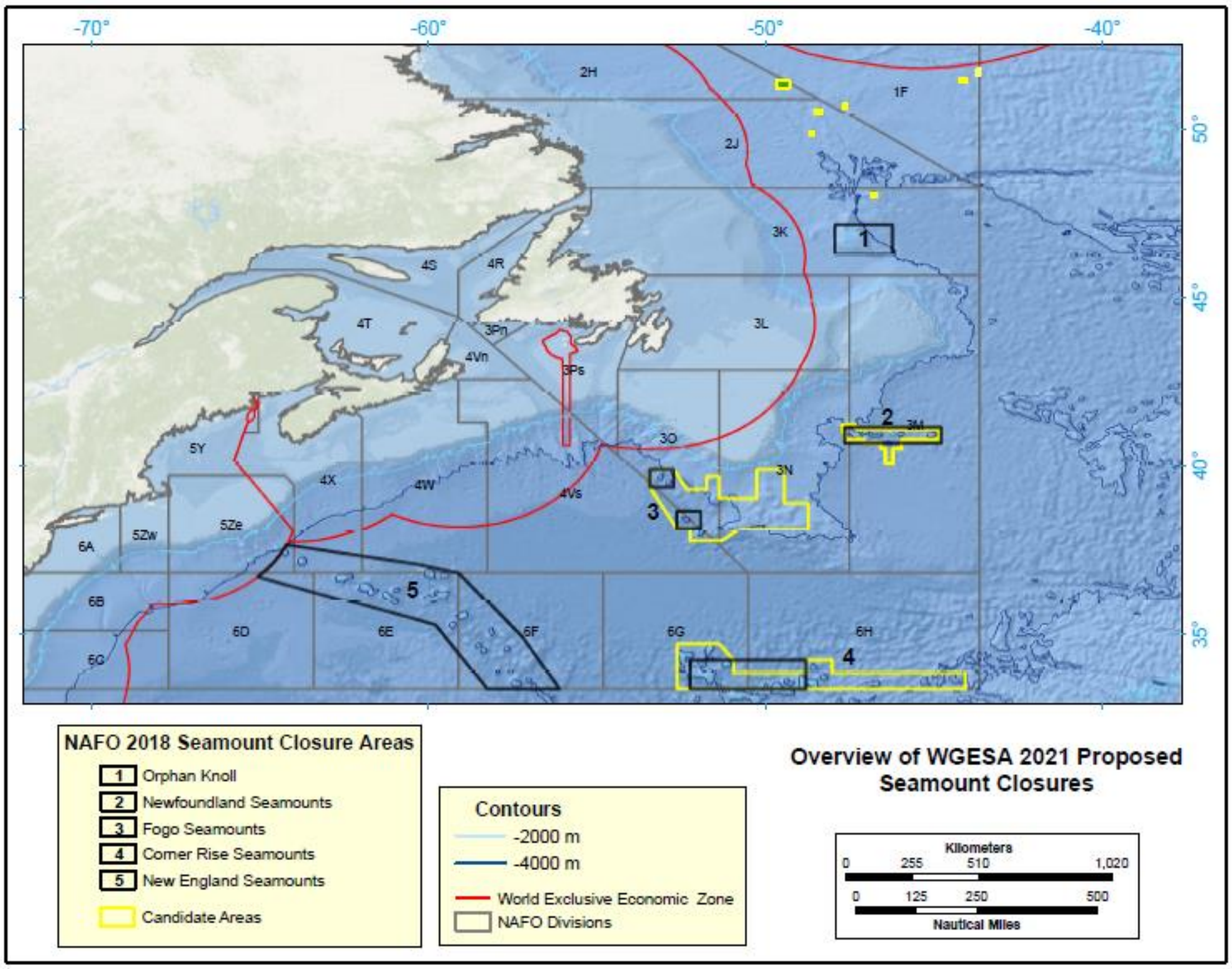


Figure v.26. Location of the seamount areas in the NRA with current closures indicated in black outline (SCS Doc. 20/14). Proposed changes and new closures are indicated by yellow lines.

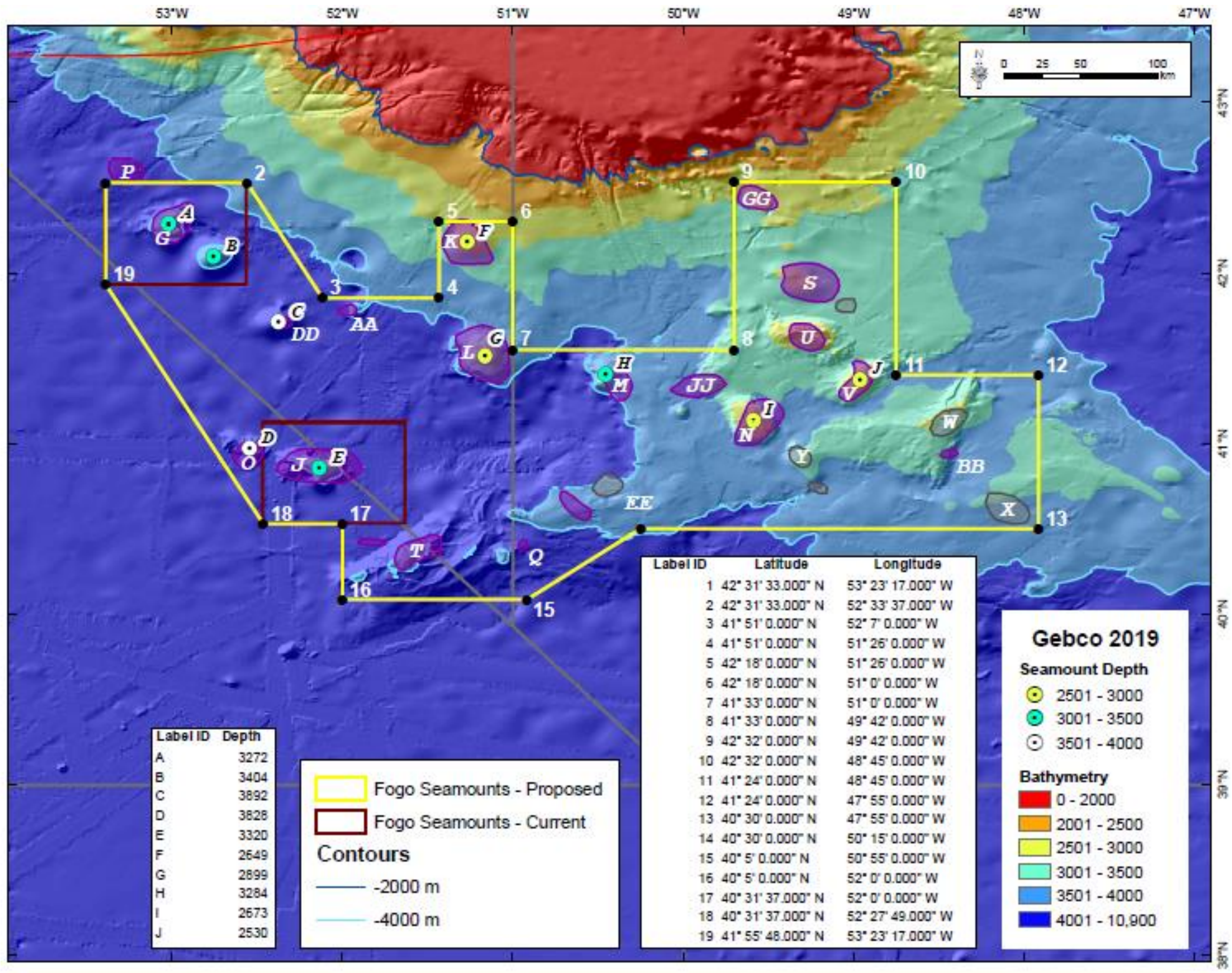


Figure v.27. Close up of the current closed area to protect VMEs on the Fogo Seamounts (red outline; Fogo Seamounts I and 2 - SCS Doc. 20/14), with proposed boundary changes to capture the unprotected seamounts in the chain (yellow outline). Circles (A – J indicate seamounts identified by Kim and Wessel (2011) and colour-coded by peak depth. Purple and grey polygons, and associated lettering, indicates seamounts and possible seamounts identified by Pe-Piper et al., (2007). Light blue lines represent the 4000 m depth contour, while the dark blue line indicates the 2000 m depth contour. Coordinates for the new boundary and feature depths are listed in the legends.

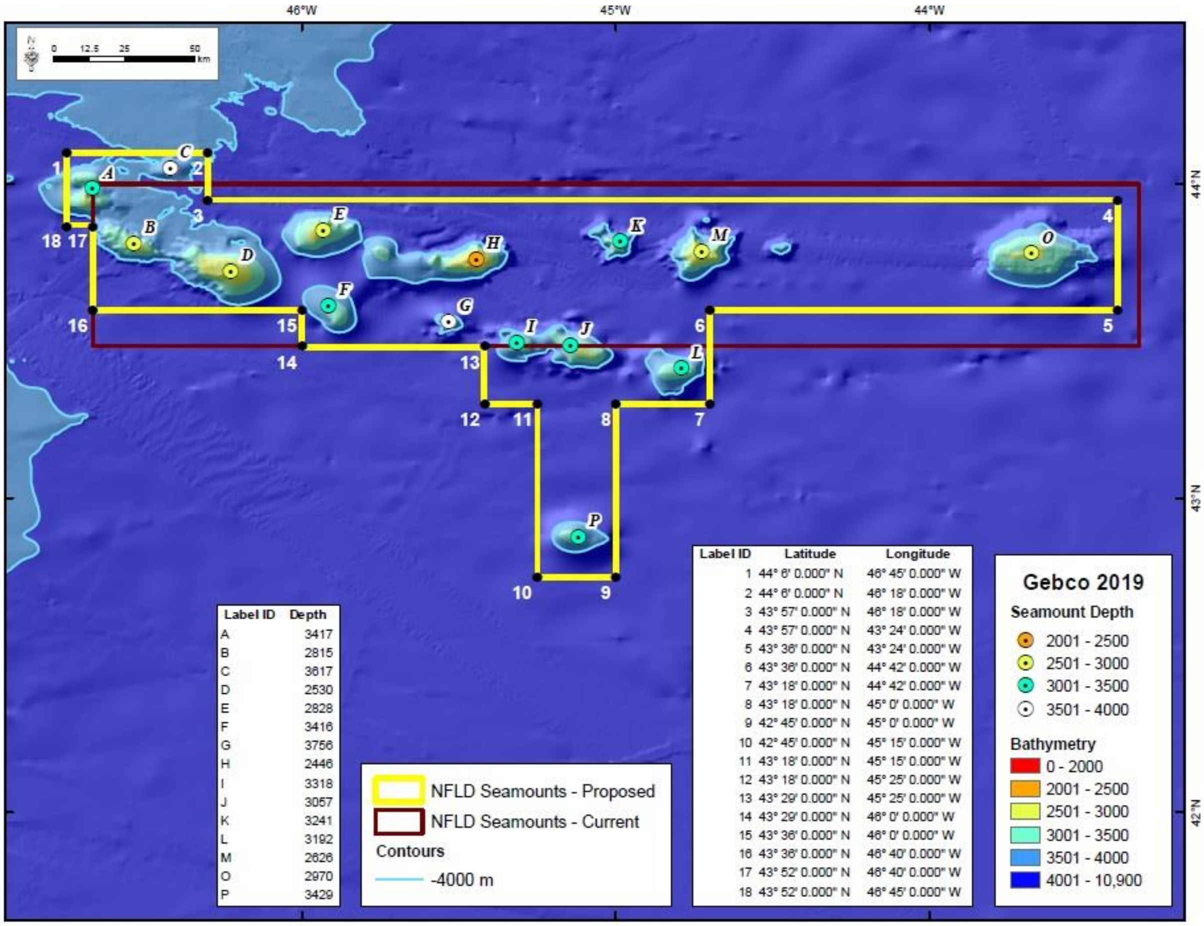


Figure v.28. Close up of the current closed area to protect VMEs on the Newfoundland Seamounts (red outline), with proposed boundary changes to capture the unprotected seamounts of similar peak depths in the seamount chain (yellow outline). Circles (A – P) indicate seamounts colour-coded by depth (source Kim and Wessel 2011). The light blue line represents the 4000 m depth contour. Coordinates for the new boundary and feature depths are listed in the legends.

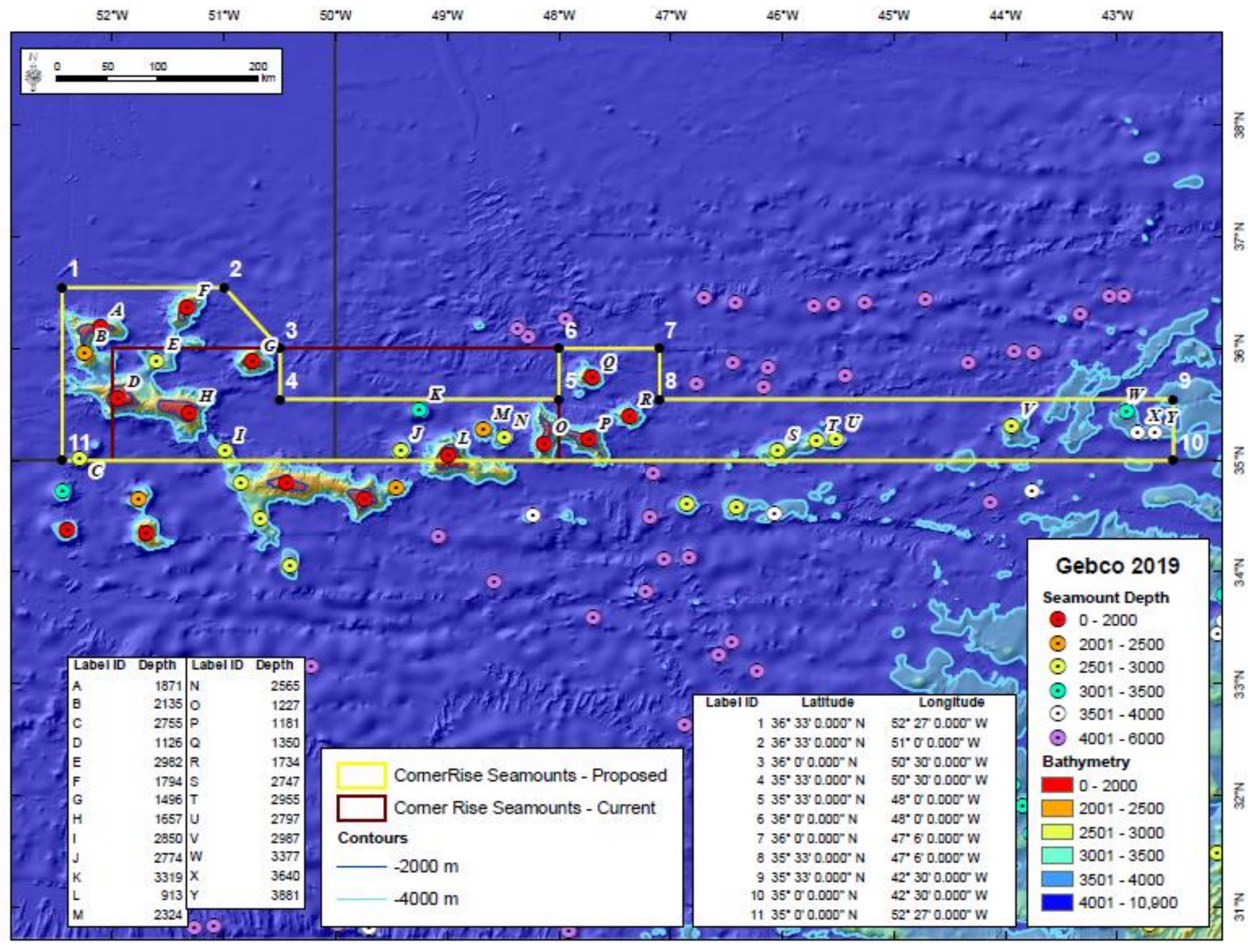


Figure v.29. Close up of the current closed area to protect VMEs on the Corner Rise Seamounts (red outline), with proposed boundary changes to capture the unprotected seamounts nearby shallower than 4000 m depth (yellow outline). The area outlined in yellow to the west of a vertical line extending south from point 8 was previously accepted by Scientific Council (SCS Doc. 20/14). Circles (A – Y) indicate seamounts (Kim and Wessel 2011) shallower than 4000 m depth. The light blue line represents the 4000 m depth contour. Coordinates for the new boundary and peak depths are listed in the legends. Note that the area south of 35N falls within the WECAFC area; those seamounts have been separately protected by that RFMO/A.

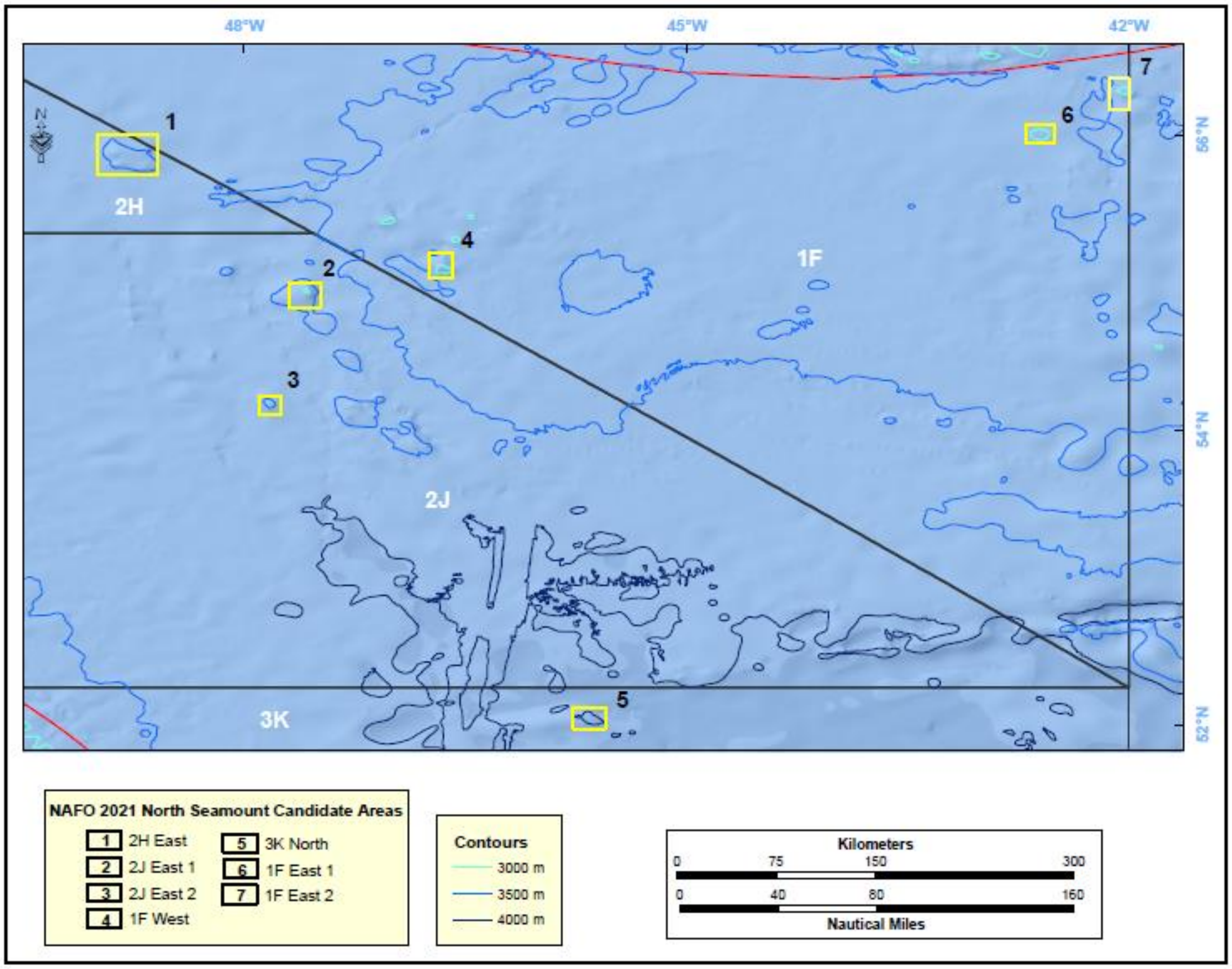


Figure v.30. Location of the proposed closures (yellow boxes) to protect the seven individual and tentative seamounts in NAFO Divisions 1F, 2HJ, and 3K. The EEZ of Greenland (north) and Canada (southwest) are outlined in red. Detailed maps are provided in Figures v.31 to v.35.

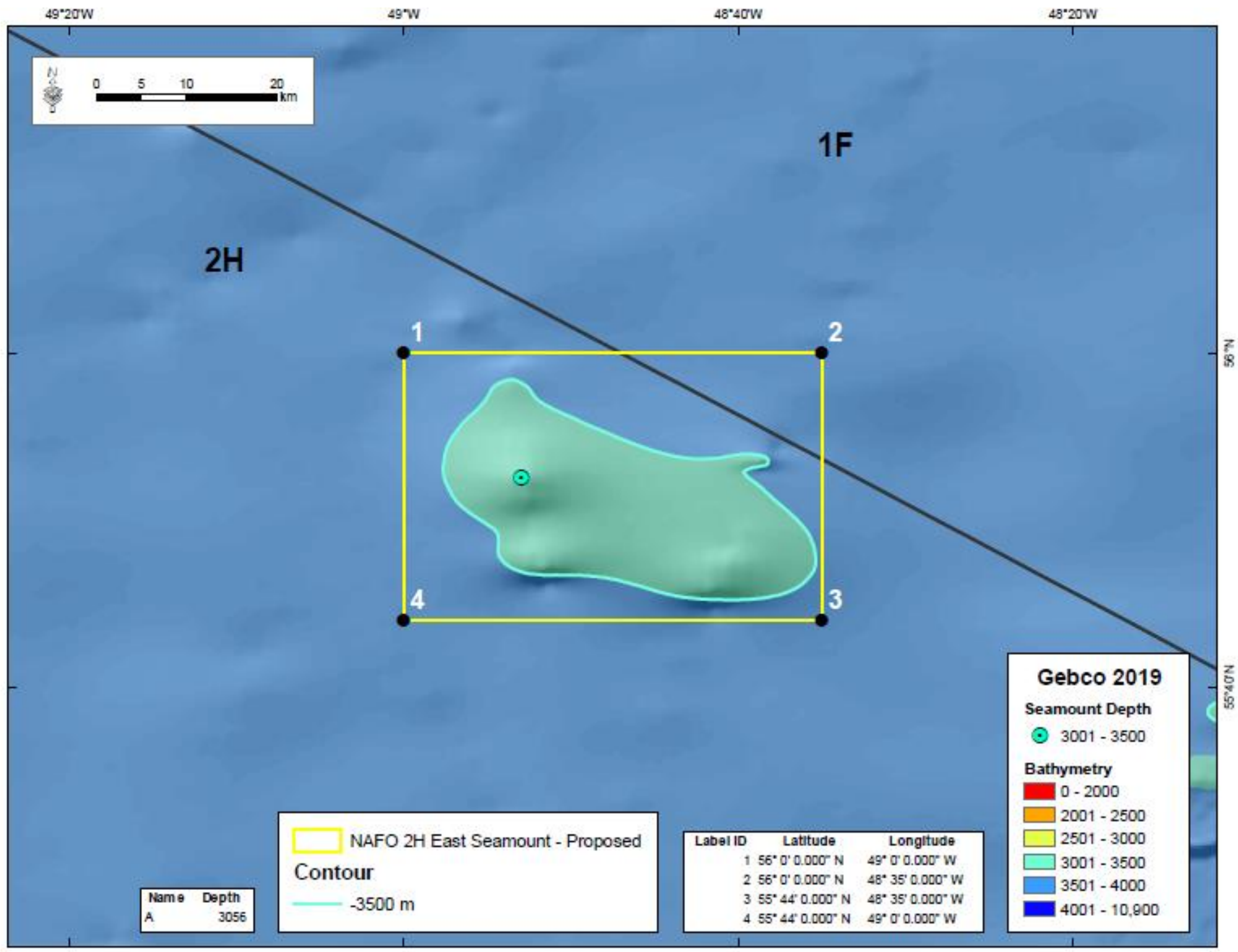


Figure v.31. Close up of Area 1 (2H East) from Figure X5. Proposed individual seamount closures to capture the unprotected seamounts shallower than 4000 m depth in NAFO Division 2H (source Kim and Wessel 2011) are shown. Coordinates for the new boundary and feature depth are listed in the legends.

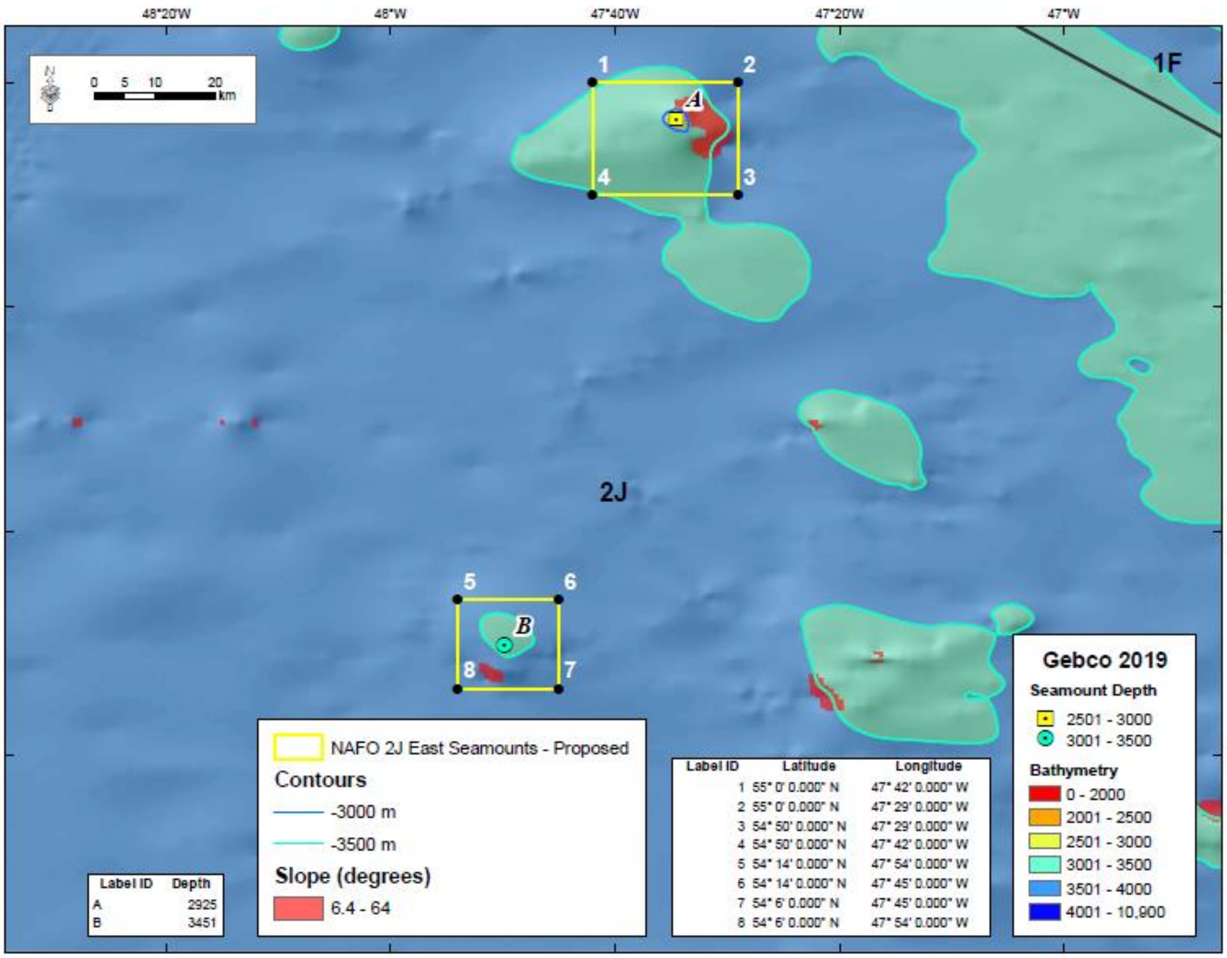


Figure v.32. Close up of Areas 2 (2J East 1) and 3 (2J East 2) from Figure X5. Proposed seamount closures to capture the unprotected seamounts shallower than 4000 m depth in the NAFO Division 2J. The Seamount A (yellow square) represents a tentative seamount based on the 2019 GEBCO. Seamount B (blue circle) was identified by Kim and Wessel (2011). Red areas highlight slopes greater than 6.4°. Depth contours for 3000 m and 3500 m are highlighted. Coordinates for the new boundary and feature depth are listed in the legends.

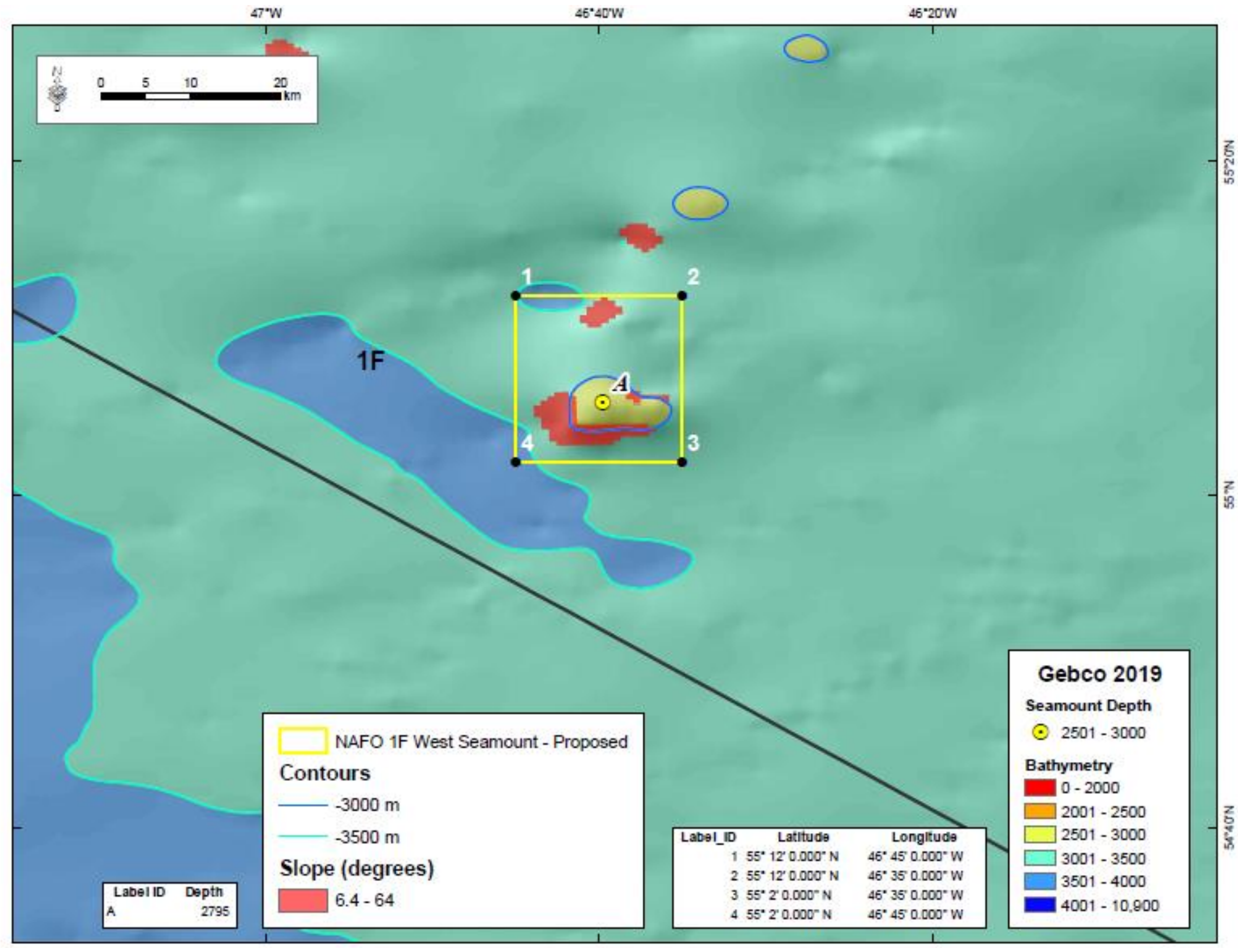


Figure v.33. Close up of Area 4 (1F West) from Figure X5. Proposed seamount closures to capture the unprotected seamount shallower than 4000 m depth in the NAFO Division 1F. Seamount A (yellow circle) represents a tentative seamount based on the 2019 GEBCO. Red areas highlight slope greater than 6.4°. Depth contours for 3000 and 3500 m are highlighted. Coordinates for the new boundary and feature depth are listed in the legends.

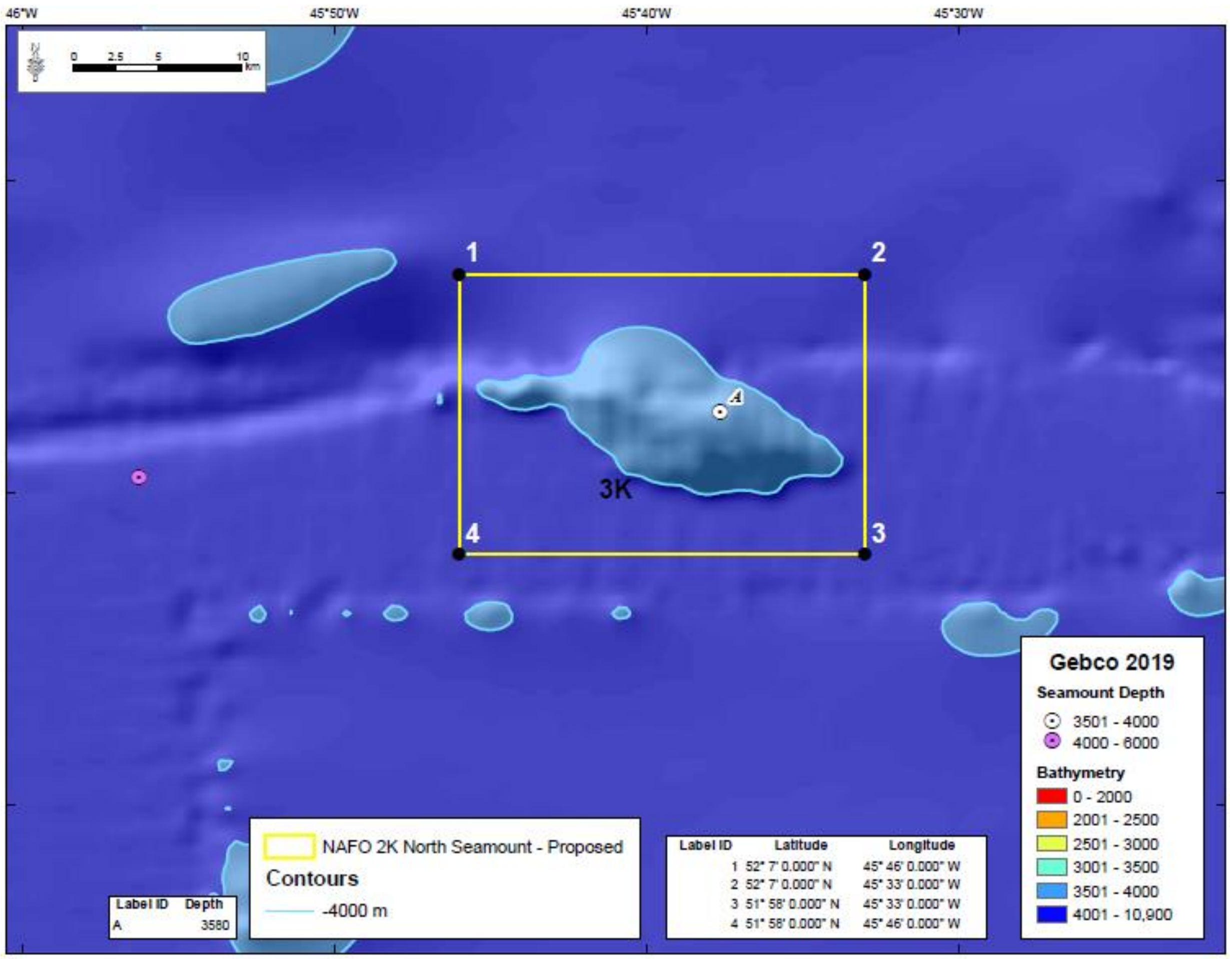


Figure v.34. Close up of Area 5 (3K North) from Figure X5. Proposed individual seamount closures to capture the unprotected seamounts shallower than 4000 m depth in the NAFO Division 3K (source Kim and Wessel 2011) are shown. Depth contours for 4000 m are highlighted. Coordinates for the new boundary and feature depth are listed in the legends.

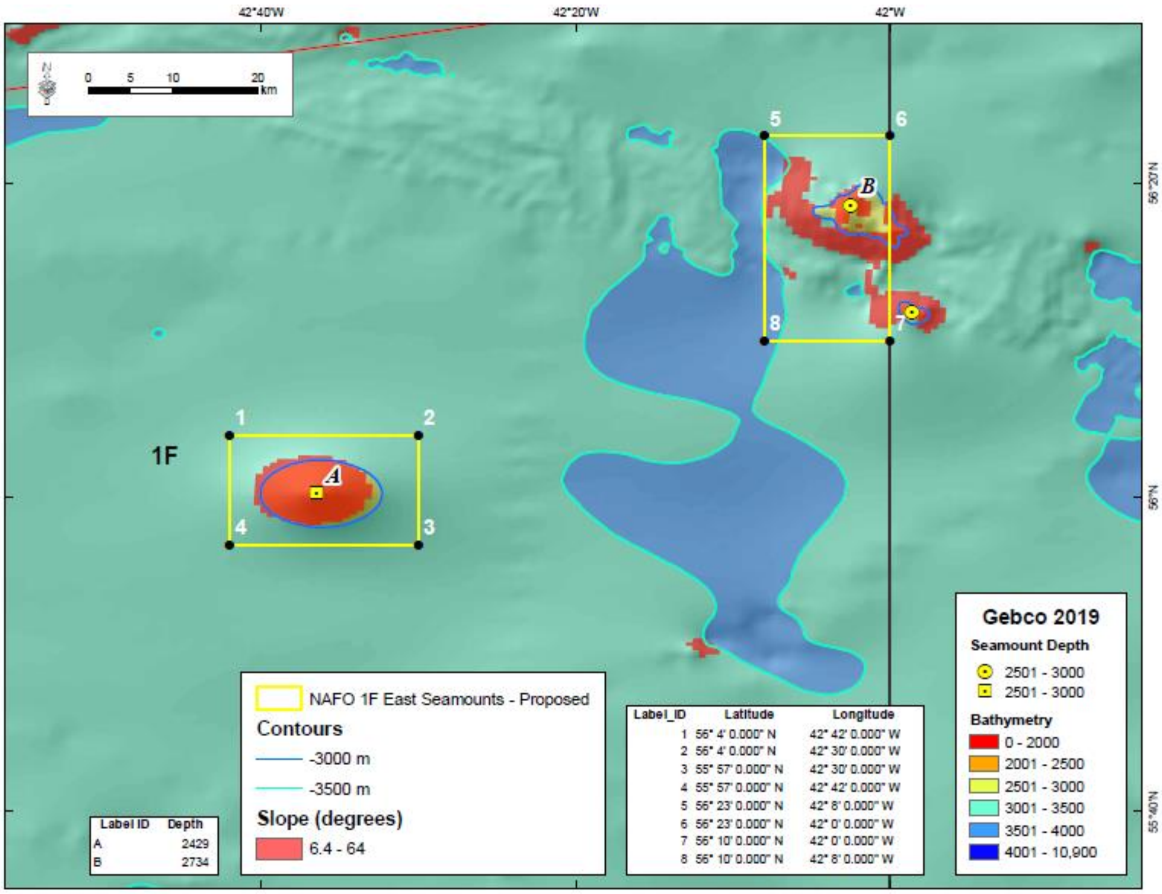


Figure v.35. Close up of Areas 6 (1F East 1) and 7 (1F East 2) from Figure X5. Proposed seamount closures to capture the unprotected seamount shallower than 4000 m depth in NAFO Division 1F. Seamount A (yellow square) represents a tentative seamount based on the slope estimated from the 2019 GEBCO dataset. Seamount B (yellow circle) was identified by Kim and Wessel (2011). Red areas highlight slope greater than 6.4°. Depth contours for 3000 and 3500 m are highlighted. Coordinates for the new boundary and feature depths are listed in the legends.

References

Kim, S.-S., and Wessel, P. 2011. New global seamount census from the altimetry-derived gravity data, Geophys. J. Int. 186: 615-631.

Kulka, D., Templeman, N., Janes, J., Power, A., and Brodie, W. 2007. Information on seamounts in the NAFO Convention Area. NAFO SCR Doc. 07/61, Serial No. N5414.

Lapointe, A.E., Watling, L., France, S.C., and Auster, P. 2020. Megabenthic assemblages in the lower bathyal (700-3000 m) on the new England and Corner Rise Seamounts, Northwest Atlantic. Deep-Sea Res. I, 165:

Pe-Piper, G., Piper, D.J.W., Jansa, L.F., and De Jonge, A. 2007. Early Cretaceous opening of the North Atlantic Ocean: Implications of the petrology and tectonic setting of the Fogo Seamounts off the SW Grand Banks, Newfoundland. Geological Society of America Bulletin, 119: 712-724.

Ríos, P., Cristobo, J., Baker, E., Beazley, L., Culwick, T., and Kenchington, E. 2021. Increasing knowledge of biodiversity on the Orphan Seamount: a new species of *Tedania* (*Tedaniopsis*) Dendy, 1924. Front. Mar. Sci., 16. https://doi.org/10.3389/fmars.2021.612857

Yesson, C., Clark, M.R., Taylor, M.L., and Rogers, A.D. 2011. The global distribution of seamounts based on 30 arc seconds bathymetry data. Deep. Res. Part I. 58: 442–453.

vi) Request #7: Review the proposed revisions to Annex I.E, Part VI

The Commission requests that Scientific Council review the proposed revisions to Annex I.E, Part VI as reflected in COM/SC WG–EAFFM WP 18-01, for consistency with the taxa list annexed to the VME guide and recommend updates as necessary.

Scientific Council responded:

SC **recommends** the *following changes to Annex I.E, Part VI to reflect current correct taxonomic nomenclature, to correct spelling errors in previous versions and add three letter ASFIS codes where they are available.*

Revisions are highlighted in grey and footnotes provide a description of the revisions.

VI. List of VME Indicator Species

Common Name and FAO ASFIS 3-ALPHA CODE	Taxon	Family	FAO ASFIS 3-ALPHA CODE
Large-Sized Sponges (PFR - Porifera)	*Asconema foliatum*	Rossellidae	ZBA
	Aphrocallistes beatrix	Aphrocallistidae	
	Asbestopluma (Asbestopluma) ruetzleri	Cladorhizidae	ZAB (Asbestopluma)
	Axinella sp.	Axinellidae	
	Chondrocladia grandis	Cladorhizidae	ZHD (Chondrocladia)
	Cladorhiza abyssicola	Cladorhizidae	ZCH (Cladorhiza)
	Cladorhiza kenchingtonae	Cladorhizidae	ZCH (Cladorhiza)
	Craniella spp.	Tetillidae	ZCS (Craniella spp.)
	Dictyaulus romani	Euplectellidae	ZDY (Dictyaulus)
	Esperiopsis villosa	Esperiopsidae	ZEW
	Forcepia spp.	Coelosphaeridae	ZFR
	Geodia barretti[13]	Geodiidae	
	Geodia macandrewii	Geodiidae	
	Geodia parva	Geodiidae	
	Geodia phlegraei	Geodiidae	
	Haliclona sp.	Chalinidae	ZHL
	Iophon piceum	Acarnidae	WJP
	Isodictya palmata	Isodictyidae	
	Lissodendoryx (Lissodendoryx) complicata	Coelosphaeridae	ZDD

[13] Spelling correction

Common Name and FAO ASFIS 3-ALPHA CODE	Taxon	Family	FAO ASFIS 3-ALPHA CODE
	Mycale (Mycale) lingua	Mycalidae	YHL (Mycale lingua)[14]
	Mycale (Mycale) loveni	Mycalidae	
	Phakellia sp.	Axinellidae	
	Polymastia spp.	Polymastiidae	ZPY
	Stelletta normani	Ancorinidae	WSX (Stelletta)
	Stelletta tuberosa	Ancorinidae	WSX (Stelletta)
	Stryphnus fortis	Ancorinidae	WPH
	Thenea muricata	Pachastrellidae	ZTH (Thenea)
	Thenea valdiviae	Pachastrellidae	ZTH (Thenea)
	Weberella bursa	Polymastiidae	ZWB (Weberella spp.)[15]
Stony Corals (CSS - Scleractinia)	*Enallopsammia rostrata**	Dendrophylliidae	FEY
	*Lophelia pertusa**	Caryophylliidae	LWS
	*Madrepora oculata**	Oculinidae	MVI
	*Solenosmilia variabilis**	Caryophylliidae	RZT
Black corals (AQZ-Antipatharia)	*Stichopathes* sp.	Antipathidae	QYX
	Leiopathes cf. *expansa*	Leiopathidae	
	Leiopathes sp.	Leiopathidae	
	Plumapathes sp.	Myriopathidae	
	Bathypathes cf. *patula*	Schizopathidae	
	Parantipathes sp.	Schizopathidae	
	Stauropathes arctica	Schizopathidae	SQW
	Stauropathes cf. *punctata*	Schizopathidae	
	Telopathes magnus	Schizopathidae	
Small Gorgonians (GGW)	*Acanella arbuscula*	Isididae	KQL (Acanella)
	Anthothela grandiflora	Anthothelidae	WAG
	Chrysogorgia sp.	Chrysogorgiidae	FHX

[14] Code in 2020 ASFIS list. The ASFIS list of species is compiled by FAO Fishery and Aquaculture Statistics and Information Branch.

[15] Code in 2020 ASFIS list.

Common Name and FAO ASFIS 3-ALPHA CODE	Taxon	Family	FAO ASFIS 3-ALPHA CODE
	*Metallogorgia melanotrichos**	Chrysogorgiidae	QFY (Chrysogorgiidae)[16]
	Narella laxa	Primnoidae	QON (Primnoidae)[17]
	Radicipes gracilis	Chrysogorgiidae	CZN
	Swiftia sp.	Plexauridae	
	Acanthogorgia armata	Acanthogorgiidae	AZC
	Calyptrophora sp.*	Primnoidae	QON (Primnoidae)[18]
	Hemicorallium bathyrubrum[19]	Coralliidae	COR (Corallium)
	Hemicorallium bayeri[20]	Coralliidae	COR (Corallium)
	Iridogorgia sp.*	Chrysogorgiidae	QFY (Chrysogorgiidae) [21]
	Keratoisis cf. *siemensii*	Isididae	IQO (Isididae)[22]
	Keratoisis grayi	Isididae	IQO (Isididae) [23]
Large Gorgonians (GGW)	*Lepidisis* sp.*	Isididae	QFX (Lepidisis)
	Paragorgia arborea	Paragorgiidae	BFU
	Paragorgia johnsoni	Paragorgiidae	BFV
	Paramuricea grandis	Plexauridae	PZL (Paramuricea)
	Paramuricea placomus	Plexauridae	PZL (Paramuricea)
	Paramuricea spp.	Plexauridae	PZL (Paramuricea)
	Parastenella atlantica	Primnoidae	QON (Primnoidae)[24]
	Placogorgia sp.	Plexauridae	
	Placogorgia terceira	Plexauridae	

[16] Code in 2020 ASFIS list.

[17] Code in 2020 ASFIS list.

[18] Code in 2020 ASFIS list.

[19] Name changed in taxonomic revision

[20] Name changed in taxonomic revision

[21] Code in the 2020 ASFIS list.

[22] Code in the 2020 ASFIS list.

[23] Code in the 2020 ASFIS list.

[24] Code in the 2020 ASFIS list.

Common Name and FAO ASFIS 3-ALPHA CODE	Taxon	Family	FAO ASFIS 3-ALPHA CODE
	Primnoa resedaeformis	Primnoidae	QOE
	*Thouarella (Euthouarella) grasshoffi**	Primnoidae	QON (Primnoidae)[25]
Sea Pens (NTW – Pennatulacea)	*Anthoptilum grandiflorum*	Anthoptilidae	AJG (Anthoptilum)
	Distichoptilum gracile	Protoptilidae	WDG
	Funiculina quadrangularis	Funiculinidae	FQJ
	Halipteris cf. *christii*	Halipteridae	ZHX (Halipteris)
	Halipteris finmarchica	Halipteridae	HFM
	Halipteris sp.	Halipteridae	ZHX (Halipteris)
	Kophobelemnon stelliferum	Kophobelemnidae	KVF
	Pennatula aculeata	Pennatulidae	QAC
	Ptilella spp.[26]	Pennatulidae	
	Pennatula sp.	Pennatulidae	
	Protoptilum carpenteri	Protoptilidae	
	Umbellula lindahli	Umbellulidae	OJZ (Ombellula spp)[27]
	Virgularia mirabilis	Virgulariidae	
Tube-Dwelling Anemones	*Pachycerianthus borealis*	Cerianthidae	WQB
Erect Bryozoans (BZN – Bryozoa)	*Eucratea loricata*	Eucrateidae	WEL
Sea Lilies (CWD – Crinoidea)	*Conocrinus lofotensis*	Bourgueticrinidae	WCF
	Gephyrocrinus grimaldii	Hyocrinidae	
	Trichometra cubensis	Antedonidae	
	Boltenia ovifera	Pyuridae	WBO

[25] Code in the 2020 ASFIS list.

[26] Name change in taxonomic revision

[27] Listed in the 2020 ASFIS code list as Ombellula which is a spelling variant. Umbellula is correct but they are the same genus (synonyms)

Common Name and FAO ASFIS 3-ALPHA CODE	Taxon	Family	FAO ASFIS 3-ALPHA CODE
Sea Squirts (SSX – Ascidiacea)	*Halocynthia aurantium*	Pyuridae	
Unlikely to be observed in trawls; *in situ* observations only:			
Large xenophyophores	*Syringammina* sp.	Syringamminidae	

vii) Request #8: Continue progress on the NAFO PA Framework review

The Commission requests the Scientific Council to continue progression on the review of the NAFO PA Framework in accordance to the PAF review work plan approved in 2020 (NAFO COM-SC Doc. 20-04)

Scientific Council responded:

SC reported on progress made on addressing the mapping of objectives deliverable (ToR 1a, c, and g of the PA-WG), to consider how the objectives and general principles of the NAFO Convention can be represented in the Precautionary Approach Framework. Many of the objectives and general principles of the NAFO convention can be represented in the Precautionary Approach Framework. The PA-WG recommends that the PA framework should: 1) promote rebuilding of stocks toward the stock biomass associated with maximum sustainable yield (B_{msy}), 2) account for uncertainty through buffer reference points or other risk-based approaches, 3) develop limit reference points for stock biomass (B_{lim}) and fishing mortality (F_{lim}) that are consistent with each other, 4) base B_{lim} on sustainability and reduced productive capacity where possible. To the extent possible, all options considered for a revised PA framework should be performance tested by simulation with respect to whether management measures set in accordance with the framework could achieve the following objectives: a very low risk of stock reduction below B_{lim}, rebuild stocks to around B_{msy}, maintain stocks above B_{msy} more often than not, and maintain average catches of approximately MSY in the long-term.

Depending on further progress of the PA-WG, it is possible that SC may have a one-day meeting on August 17, 2021 to further expand on this response.

The Precautionary Approach Working Group (PA-WG) continued progress in the steps needed to review the NAFO PA Framework. The group started work on the Mapping Objectives deliverable laid out by SC/RBMS in 2020, starting with the addition of three external experts to work with the PA-WG. This objective focused on Terms of Reference (SCS 16/15) 1 a, c, and g, where conceptual questions are presented and address how the framework will represent many of the basic NAFO Convention objectives (NAFO 2017). This deliverable will be provided to WG-RBMS for feedback from managers in August at their meeting.

SC reviewed the Working Paper presented by the PA-WG, and progress was made on the following points, which were provided to external experts to guide their review:

a. *Compile information on the use of MSY in the PA frameworks reviewed by SC WG-PAF, as well as other relevant sources (e.g., FAO, other jurisdictions) and summarize these findings identifying the pros and cons of the two conceptual roles (i.e., as a limit or a target) of MSY. The possibility of applying a "weight of evidence" approach (Tao et al. 2018), to tabulate the arguments for and against alternative options, should be considered.*
b. *Examine how different PA frameworks address (or not) changes in stock and/or ecosystem productivity over time, focused on long term changes and different productivity regimes, and summarize these findings identifying the pros and cons of the various approaches.*

c. *Based on the results from the examination above, consider the definitions used in the existing NAFO PAF, highlight potential contradictions or inconsistencies, and propose alternative definitions that could address them.*
d. *Other relevant matters that may be identified in the process of conducting this work.*

NAFO Secretariat hired three external experts to contribute to the revision of the PA-WG: Dr. Steve Cadrin (University of Massachusetts, Dartmouth, USA), Dr Jan Horbowy (National Marine Fisheries Resources Institute, Gdynia, Poland) and Dr. Daniel Howell (Institute Marine Resources, Bergen, Norway). These scientists were selected based on discussions between the PA-WG and the co-chairs of WG-RBMS and approved by SC. The PA-WG met by WebEx meetings (26 February 2021, 8 April 2021, and 14 May 2021) to review the terms of reference and workplan, consider external review of the 'Discussion Paper on the NAFO Precautionary Approach Framework' (NAFO SC Working Paper 20/010), and a subgroup drafted a report on how the objectives and general principles of the NAFO Convention can be represented in the Precautionary Approach Framework. The PA-WG reached consensus on most aspects of the mapping deliverable, which are reported as preliminary findings. Many of the objectives and general principles of the NAFO convention can be represented in the Precautionary Approach Framework, together with other NAFO processes to minimize bycatch, catch by lost/abandoned gear, pollution and waste from fishing, safeguard the marine environment, conserve its marine biodiversity, minimize the risk of long term or irreversible adverse effects of fishing activities, and take account of the relationship between all components of the ecosystem. The PA-WG recommends that the PA framework should: 1) promote rebuilding of stocks toward the stock biomass associated with maximum sustainable yield (B_{msy}), 2) account for uncertainty through buffer reference points or other risk-based approaches, 3) develop limit reference points for stock biomass (B_{lim}) and fishing mortality (F_{lim}) that are consistent with each other, 4) base B_{lim} on sustainability and reduced productive capacity where possible. To the extent possible, all options considered for a revised PA framework should be performance tested by simulation with respect to whether management measures set in accordance with the framework could achieve the following objectives: a very low risk of stock reduction below B_{lim}, rebuild stocks to around B_{msy}, maintain stocks above B_{msy} more often than not, and maintain average catches of approximately MSY in the long-term.

It was noted that work should continue on ToR 1g (Examine how different PA frameworks address (or not) changes in stock/ecosystem productivity over time, focused on long term changes/productivity regimes, and summarize these findings, including identifying the pros and cons of the different approaches) and the current plan is to finalize this ToR before the WG-RBMS meeting in August 2021.

viii) Request #9: bycatch and discards of Greenland sharks

The Commission requests that the Scientific Council work with WG-BDS to identify areas and times where bycatch and discards of Greenland sharks have a higher rate of occurrence in time for consideration by the Commission in 2021 to inform the development of measures to reduce bycatch in the NRA.

Scientific Council responded:

Greenland shark (*Somniosus microcephalus*) are caught as bycatch in fisheries throughout the Northwest Atlantic Fisheries Organization Convention Area (NCA). The highest levels are outside the NAFO Regulatory Area (NRA) in the Canadian and Greenland EEZs. Within the NRA, the slopes of the Flemish Cap and the shelf edge of Divs. 3LNO are areas of predicted Greenland shark bycatch. A higher occurrence of Greenland shark bycatch relative to the fishing effort was found during December to March, and August to September, for the Canadian fishery within the NRA.

Greenland shark bycatch within the NCA were analyzed using a variety of models. Given that not all fisheries have At-Sea Observers (ASOs) and that logbooks provide less precise data that are prone to bias, it is difficult to make definitive conclusions on the times/location of areas with higher rates of bycatch, which consequently affects inferences about the suitability of spatial or temporal fishing closures. SC reiterates that alternative management methods should also be considered (SCS Doc. 18/19). SC notes that management measures applied should be consistent across the NCA owing to the broad distribution of Greenland sharks.

SC reiterates its recommendation for reporting of all shark bycatch by species from all fisheries within the NCA as outlined in the current NCEM, and recommends including the collection of shark numbers, sex, measurements (when feasible without causing undue harm), and bycatch discard disposition (i.e., dead or alive) in all fisheries.

Background:

In 2018 NAFO SC responded to a request by the NAFO Commission to review available information on Greenland shark life history, distribution and bycatch in surveys and fisheries. Greenland shark were found to be present as bycatch in fisheries throughout the NAFO Convention Area, with higher levels of occurrence in deeper waters of 2GHJ3KL and in northern Subareas 0 and 1, compared to the NRA (Figure viii.1). NAFO commission subsequently requested the SC to identify areas and times where bycatch and discards of Greenland sharks have a higher rate of occurrence in NRA.

Greenland shark is a widely distributed species across the Arctic and cold temperature waters of the North Atlantic, it occurs not only within the NRA but also extends into both the Canadian and Greenlandic EEZs. Therefore, SC has recommended that all relevant information on this stock be reviewed when considering management decisions within the NRA. Below are summaries of three presentations provided to NAFO SC during the June 2021 meeting.

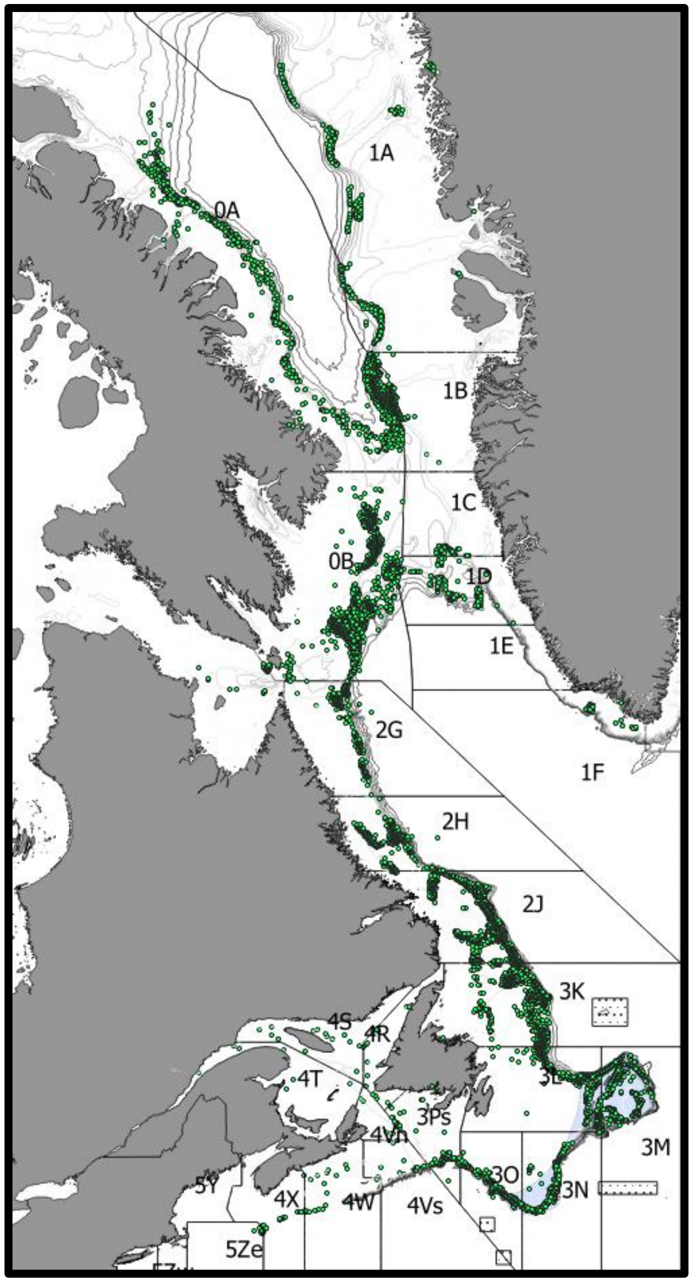


Figure viii.1. Overall distribution map of Greenland shark bycatch (Simpson et al. NAFO SCR 21/028).

Spatial-temporal variation in Greenland shark (*Somniosus microcephalus*) bycatch in the NAFO Regulatory Area (Simpson et al. NAFO SCR 21/28).

A MaxEnt model was applied to investigate the spatial distribution of Greenland shark bycatch in NAFO Divisions 2GHJ3KLMNO and Subarea 3Ps, to gain insight into areas where bycatch occurs, and expand upon the point pattern distributions previously provided to SC (e.g., Simpson et al 2018). Data were from Newfoundland and Labrador (NL) (1983–2019), Spain (1999–2017), and the NAFO Secretariat (2014–2019). Three environmental variables were included in the final model: bathymetry and monthly mean bottom temperature for March and November.

Overall, Greenland shark bycatch is greatest in the deeper waters of NAFO Subareas 2 and 3 (Figure viii.2). There are areas of modelled Greenland shark bycatch distribution in the NRA, along the slopes of the Flemish Cap, and the shelf edge in Divs. 3LNO.

The frequency of occurrence of observed Greenland shark bycatch compared to frequency of occurrence of all fishing effort for the Canadian fishery within the NRA suggests there is higher occurrence of Greenland shark bycatch relative to the fishing effort during December to March, and August to September.

While the results of this analysis suggest spatial or temporal fishing closures might be considered by managers, it is important to keep in mind that the model indicates where and when the bycatch of Greenland shark was highest for only those fisheries that had an at-sea observer collect data. Management measures that are not linked to space or time considerations that could be considered to provide increased protection to Greenland sharks include: a) live release and care in handling; b) gear modifications; c) shark bycatch limits; or d) reductions in fishing effort.

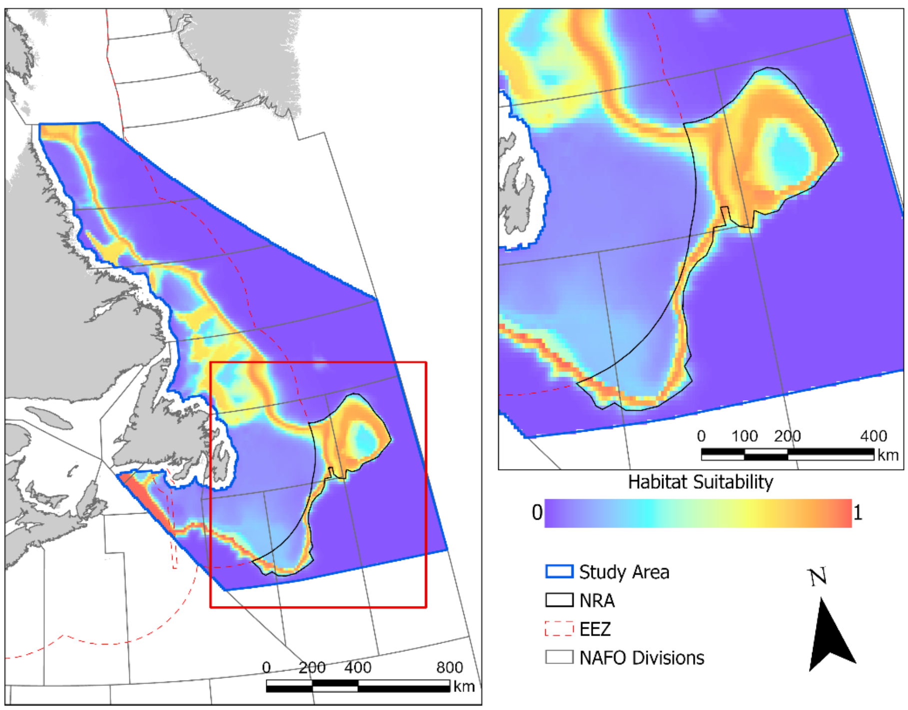


Figure viii.2. Bycatch model for Greenland shark.

Spatiotemporal Modelling of Bycatch Data: Methods and a Practical Guide through a Case Study in a Canadian Arctic Fishery (Yan et al. 2021, CJFAS in press).

A two-part spatial model was used to examine bycatch occurrence probability and positive bycatch weight of Greenland shark in Subarea 0 (Yan et al., 2021). Areas of higher bycatch occurrence were identified along the Baffin Island coast, consistent with observations in inshore areas (Cosandey-Godin et al., 2015) and Devine et al., 2018). While encounter probability was higher in the coastal area (Div. 0A), the weight of bycatch or biomass was higher in Northern Davis Strait (Div. 0B), suggesting sharks caught in the Davis Strait fishing grounds are larger than those caught on the grounds along the Baffin coast. This observation concurs with reports of juvenile Greenland sharks in Northern Baffin Bay fjords (Hussey et al., 2014). Month, gear and data source (ASO vs non-ASO) had a significant effect on the model. They indicate that management measures such as limiting the use of twin trawls and ensuring robust data is collected by continuing to deploy ASOs on fishing vessels may be important. Results indicate that bycatch is higher in winter months compared to summer months, suggesting a seasonal closure could be considered.

Greenland shark bycatch in NAFO Subareas 0+1 (Hedges et al. SCR 21/033)

Analysis of the number and total weight of Greenland shark caught as bycatch and mean fishing depth, ordinal date, year and NAFO Division based on records of bycatch were compiled from Canadian at-sea observers (ASO) assigned to offshore fleets in Subarea 0 (1980-2020), German ASO data in Subarea 1 (2000-2020) and Greenland logbooks in Subarea 1 offshore as well as Div. 1A inshore fisheries (2000-2020) was conducted using generalized linear models. The number and total weight of Greenland shark caught per fishing set was higher at depths of 950 to 1200 m, and 950 to 1400m, respectively. This suggest that higher weights reported at depths of 1200-1400 m are due to catches of larger bodied sharks. Higher numbers were caught during July to September, and higher total weights were reported during November and December, however this was not corrected for fishing effort. The number and total weight of Greenland shark caught per fishing set was higher in Subarea 0, but this pattern was likely affected by limitations in the data from Subarea 1. It is important to note that several countries are fishing in the Greenland EEZ but only Greenland and Germany have reported Greenland shark bycatch.

Results suggest that concentrated areas with high bycatch exist in northern Baffin Bay while areas with high bycatch are more dispersed in southern Baffin Bay and Davis Strait. The locations in Baffin Bay with higher and more concentrated bycatch amounts are near the northern extent of the data that could be an artefact of sampling bias.

Future analyses will benefit from improvements in the consistency of data collection regarding Greenland shark bycatch.

References

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Yan, Y., Cantoni, E., Field, C., Treble, M. and Mills Flemming, J. (2021). Spatiotemporal Modelling of Bycatch Data: Methods and a Practical Guide through a Case Study in a Canadian Arctic Fishery, Can J Fish Aquat Sci. (in press).

ix) Request #10: Continue to develop a 3-5 year work plan

The Commission requests the Scientific Council to continue to develop a 3-5 year work plan, which reflects requests arising from the 2020 Annual Meeting, other multi-year stock assessments and other scientific inquiries already planned for the near future. The work plan should identify what resources are necessary to successfully address these issues, gaps in current resources to meet those needs and proposed prioritization by the Scientific Council of upcoming work based on those gaps.

Scientific Council responded:

SC updated the 5-year work plan including identification of priorities and required resources, noting this is an iterative discussion between the Commission and SC .

The 5-year plan allows for a high-level view of activities planned for the next five years, with more detailed annual plans for each year in which resource gaps and priorities are addressed.

The plan includes requests from the Commission, including stock assessments, other scientific inquiries (e.g. from specific contracting parties for straddling stocks) and SC work and advice of its own accord.

SC updates and reviews the plan each June and September to include all requests with prioritization and rationale where appropriate as well as the resources required to respond to the requests.

The SC notes that in the next two to three years the revision of two Management Strategies (redfish Div. 3LN and Greenland halibut Sub 2 Div. 3KLMNO) and the PAF revision coincide in time and, given the complexity and the high level of SC resources/capacity required to complete these tasks, SC strongly recommends against attempting to perform all three concurrently. Given the review of the PAF is well underway with dedicated external experts participating, SC recommends that the Commission prioritize one of the MSEs to commence first. SC expects the Greenland halibut MSE process to take at least two years to complete and the redfish MSE process to take at least three years. Consequently, the commencement of one of these MSE processes will need to be postponed and SC expects options will be discussed with RBMS in the August 2021 meeting. In that context, SC and WG-RBMS can also discuss how to proceed to produce management advice for the affected stock in the interim.

The special requests from Commission, as well as the work required by SC to support ongoing requests more generally (e.g. stock-assessment, SAI-VME assessments, EAF Roadmap implementation), exceeds current SC capacity (i.e. time, allocated resources and expertise). While SC has managed to address most requests so far, this has been achieved at the expense of substantially overburdening SC members. Present workloads are not sustainable. Meeting current demands would require an appreciable reduction in the number of upcoming special requests, as well as increasing SC capacity in different areas. The most critical gaps are in quantitative modelling for stock assessment, as well as more specialized ecosystem analyses and modelling.

The work plan will be posted after updating each June and September on the Commission SharePoint site in the Scientific Council Summary (SCS) document series (this year NAFO COM-SC Doc. 21-15).

The work plan was requested first in 2018 by the Commission in response to Scientific Council concerns over increased workload in recent years. It was recognized at that time that increased demands on Scientific Council (with more numerous and more complex requests, some of which are outside Council members areas of expertise) combined with a decrease in numbers of scientists participating, were making it difficult to address all requests over the year and to have thorough and transparent documentation.

The plan includes requests from the Commission from the annual meeting, including stock assessments and other scientific inquiries (e.g. requests from coastal states). The plan includes requests SC has made of its own accord.

The plan is structured first by using both the NAFO Road Map components and second by Commission request number.

The 5-year plan allows for a high-level view of activities planned for the next five years, with annual plans in which resource gaps and priorities will be addressed. More detailed plans are found in working group specific work plans.

In documenting resources needed as well as resource/capacity gaps, SC noted there is no dedicated NAFO funding source for scientific research, and therefore the activities are subject to Contracting Party allocations that may not be stable/guaranteed. SC updates and reviews the plan each June and September for the next year to include all requests with prioritization where appropriate as well as the resources required to respond to the requests. As such, the plan is a living document and September and June reviews will include prioritization of current versus strategic work/requests. Updated work plans will be posted on the NAFO Commission site in the Scientific Council Summary (SCS) series (this year NAFO SCS Doc. 21-15). The Excel version of the work plan will be made available each September to the Commission on the SharePoint.

At the June 2021 meeting, Scientific Council updated the work plan including identifying priorities and required resources.

Specific work plan highlights:

The SC notes that in the next two to three years the revision of two Management Strategies (redfish Div. 3LN and Greenland halibut Sub 2 Div. 3KLMNO) and the PAF revision coincide in time and, given the complexity and the high level of SC resources/capacity required to complete these tasks, SC strongly recommends against attempting to perform all three concurrently. Given the review of the PAF is well underway with dedicated external experts participating, SC recommends that the Commission prioritize one of the MSEs to commence first. SC expects the Greenland halibut MSE process to take at least two years to complete and the redfish MSE process to take at least three years. Consequently, the commencement of one of these MSE processes will need to be postponed and SC expects options will be discussed with WG-RBMS in the August 2021 meeting. In that context, SC and WG-RBMS can also discuss how to proceed to produce management advice for the affected stock in the interim.

Stock Assessments for June and September 2022 include:

- *3M cod*
- *3NO witch flounder*
- *3LNO thorny skate*
- *3LN redfish (MSE will not complete in time for 2023 TAC)*
- *3O redfish*
- *SA 3+4 Northern shortfin squid*

Sub area 0+1:

- *SA 0 + 1 Greenland halibut*
- *Greenland halibut SA1 inshore*

NIPAG (targeting September 2021 pre-Commission):

- *3M N. shrimp*
- *N. shrimp in Denmark Strait*
- *N. shrimp SA 0 and 1*

Requests relating to Ecosystem productivity will be addressed in part through two planned WG-EAFFM meetings (dialogue session and workshop), to further progress the application of an ecosystem approach to fisheries management, including progress on how ecosystem advice can inform management decisions.

While work on the 2021 re-assessment of NAFO bottom fisheries and VME fishery closures is largely complete, this task is ongoing, both to prepare for the next re-assessment as well as develop methods to assess changes in VME biomass inside closures to consider potential recoveries.

Despite the virtual environment for all Scientific Council meetings from March 2020 to June 2021 (and ongoing), the majority of requests and work planned was completed, and for those that were deferred, progress is planned for 2021-2022.

Special requests from the Commission, as well as the work required by SC to support ongoing requests more generally (e.g. stock-assessment, SAI-VME assessments, EAF Roadmap implementation), exceeds current SC capacity (i.e. time, allocated resources and expertise). While SC has managed to address most requests so far, this has been achieved at the expense of substantially overburdening SC members. Present workloads are not sustainable. Meeting current demands would require an appreciable reduction in the number of upcoming special requests, as well as increasing SC capacity in different areas. The most critical gaps are in quantitative modelling for stock assessment, as well as more specialized ecosystem analyses and modelling.

x) *Request #11: Scoping exercise for 3LN redfish MSE*

The Commission requests that the Scientific Council, carry out a scoping exercise to provide guidance to the WG-RBMS on the process of conducting of a full review/evaluation of the management strategy of Div. 3LN redfish.

Scientific Council responded:

Scientific Council conducted a scoping exercise for the review/evaluation of the management strategy of Div. 3LN redfish and proposed a provisional workplan. SC concluded that a full review/evaluation of the MSE for Div. 3LN redfish should include review of data and model inputs, followed by the identification of a suite of models to test the robustness of management procedures to alternative scenarios. This process is expected to take three years and its timing is conditional on decisions on the overall SC 5-year workplan (response to Commission request #10)

Background:

In 2014 SC, upon a request from the Fisheries Commission (now NAFO Commission-COM), conducted a review and evaluation of a management strategy of Div. 3LN redfish stock (NAFO, 2014).

At that time SC considered a range of operating models (OMs) based on the Schaeffer surplus production model. The following set of OMs were chosen for the Management Strategy Evaluation (MSE):

i. *old stock assessment model updated to 2012 (ASPIC 2012)*
ii. *new stock assessment model (ASPIC 2014)*
iii. *"ASPIC2012-like" surplus production model in a Bayesian framework (same constraints on parameters)*
iv. *"ASPIC-like" new stock assessment in a Bayesian framework (ASPIC 2014 fixed MSY)*
v. *Surplus production model in a Bayesian framework with all data sets, minimum constraints*
vi. *A spatially disaggregated surplus production model in a Bayesian framework (treating carrying capacity in Div. 3L and 3N separately)*

In addition, the MSE considered 4 harvest control rules (HCR):

i. *HCR1 stepwise: (from WG-RBMS)*
ii. *HCR2 stepwise slow: this HCR is designed to reach 18 100 t of annual catch by 2019-2020 through a stepwise biennial catch increase, with the same amount of increase every two years between 2015 and 2020. 18 100 t is the equilibrium yield in 2014 assessment under the assumption of an MSY of 21 000 t.*
iii. *HCR3: Constant catch (20 000 t)*
iv. *HCR4: Constant F (2/3 of F_{MSY})*

In September 2014, the NAFO General Council / Fishery Commission (now COM) adopted HCR#2 for the period 2015-2020 (NAFO/FC Doc 14/29). This measure was to be in effect only until December 2020, but in September 2020 COM, based on SC advice (request #11, NAFO, 2020), extended the HCR for another two years (18 100 t – 2021 and 2022, NAFO/COM Doc. 20-19).

For a full review/evaluation of the management strategy of Div. 3LN redfish several steps should be taken, as in other MSEs:

1. *A data review – to ensure that the best data available are being used.*

   Review of the available biological, commercial and survey data and its possible use in the MSE process.

2. *Decision on the models to apply to the data.*

   Revision and discussion of the problems with the current OM's, as well as the development of new models that are required to cover any uncertainties that are identified (for example: sporadic recruitment events, stock mixing, modelling a mixed stock, etc.).

3. *Initiate discussion on the Operating Models (OM) to be used.*

   The original MSE had six different operating models. SC Canadian delegation have recently updated the OM's from the original MSE. The results of these updates may provide information for the development of a new MSE. It will also assist in the review of the different models and discussions regarding any new models. Final selection on operating models will likely be made later, after further developments as may be appropriate.

4. *Decisions on new objectives.*

   The current objective of the 3LN redfish HCR is "…to maintain the biomass in the 'safe zone', as defined by the NAFO Precautionary Approach framework". Any new MSE process will need to consider the validity of the current objectives, and any additional objectives with performance metrics.

   At the 2020 meeting of the WG-RBMS, new potential objectives for this MSE were discussed in a preliminary manner, as well as new possible HCRs. The decision of these new objectives and possible HCRs will require discussion at WG-RBMS and SC.

5. *Decisions on Harvest Control Rules.*

   It should be noted that the current HCR for 3LN redfish was a step-wise increasing TAC rule designed for an increasing stock, without feedback related to stock status. Given the declining trend of this stock, in both the current assessment model and survey indices, new HCRs must be developed which consider a declining stock and a potentially long period of low recruitment.

6. *Conduct an MSE process with the above information.*

   Development of models code, first runs of MSEs with proposed HCRs, evaluation of objectives and review of performance metrics.

   These actions will require substantial SC work depending on the decisions taken based on the experience in previous processes.

7. *Final decision on objectives, performance metrics for the objectives, first approach to HCRs to be considered.*

   These actions will require SC work and meetings between WG-RBMS and SC, with a final recommendation to the Commission.

Provisional work plan for a revised Management Strategy Evaluation for 3LN redfish

1. *SC June 2021 – Scoping discussion to provide possible direction for WG-RBMS on a full evaluation of the existing MSE.*
2. *WG-RBMS August 2021 – discussion on scoping exercise and a possible calendar of how to develop the 3LN redfish MSE which is a three-year process. Note that an assessment of 3LN redfish will be required in June 2022 to provide advice to COM for 2023/2024.*
3. *Year 1: SC must review the data to be used; consensus is required at this time for Operating Model (OM) development to commence.*
4. *Year 2: SC must review the proposed OMs to be used; obtain consensus on Candidate Management Procedures (CMPs), and with WG-RBMS refine the performance statistics, including risk tolerances and constraints.*
5. *Year 3: SC must review and test CMPs; finalise the suite of CMPs to be used in the Management Strategy Evaluation; and with WG-RBMS evaluate performance statistics and make a final decision on the Management Strategy to propose to the Commission.*

SC notes that this process is expected to take three years and its timing is conditional on decisions on the overall SC 5-year workplan (response to Commission request #10).

xi) Request #12: Review of submitted survey protocol for splendid alfonsino

The Commission requests the Scientific Council review submitted protocols for a survey methodology to inform the assessment of Splendid Alfonsino. The Scientific Council to report on the outcome of this work at next Commission annual meeting.

Scientific Council responded:

Scientific Council considers the acoustic survey plan presented is appropriate to collect fishery-independent information to establish a consistent time-series that can help the future evaluation of this stock.

The SC reviewed SCR Doc. 20/036 in which a possible sampling plan for an acoustic survey on Kükenthal Peak (NAFO Division 6G) to quantify alfonsino (*Beryx splendens*) biomass, abundance and size composition was presented. Acoustic surveys have previously been used in other parts of the world to assess alfonsino stock size, distribution and size composition (Niklitschek et al., 2011, Wiff et al., 2012).

The main objectives of this survey plan are to estimate the distribution, abundance, biomass and size composition of alfonsino on Kükenthal Peak (NAFO Div. 6G) by conducting a hydroacoustic survey. Specific objectives are:

- *Estimate the abundance (in number) and biomass (in weight) of alfonsino in Kükenthal Peak.*
- *Estimate the alfonsino size composition, length-weight relationship, sex ratio and sexual maturity characterization by sex.*
- *Collection of alfonsino gonad and otolith samples for future studies of maturity and age.*
- *Characterize the biological environment and the physical environment (Tº, S ‰) of the pelagic habitat of this species to produce a map of these variables within the survey area in association with alfonsino abundance estimates.*

The proposed plan is to use a commercial vessel for collecting acoustic data to obtain biomass, abundance and size composition estimates. The best option from a technical point of view could be to use the same vessel that has been fishing in the area since 2004. The "Esperanza Menduiña" fishing vessel was built in 1988 and sails under the flag of Spain. This vessel has the appropriate acoustic and fishing equipment to carry out the survey, and, perhaps more importantly, its crew has knowledge of the species and the area, and experience necessary for the proper execution of this survey.

Two strata with different levels of sampling effort are proposed due to the patchy distribution of alfonsino as revealed by the echograms provided by the skipper, and also the major occurrence of the species around the slope of the mountains, with little extension towards deeper water (i.e., no extension towards open waters). The survey design will consist of systematic parallel transects with random starting points, with two different levels of sampling intensity, allocating the maximum effort in the area that historically contained the bulk of the acoustic and trawl commercial records. Transects will be placed to ensure they are primarily perpendicular to the bathymetry of the survey area.

There is some evidence that relates vertical migrations of alfonsino concentrations to light levels related to diurnal and lunar cycles. The acoustic survey will collect acoustic data during the daylight hours for the calculation of biomass and abundance. Nevertheless, the area will be also surveyed at night during the first year in order to obtain insights on the alfonsino behaviour (i.e., diel aggregation and distribution patterns). Trawl hauls will be conducted only for fish identification and the collection of alfonsino length distribution and biological data. Therefore, trawl station locations will be selected according to the acoustic records.

During the presentation of this acoustic survey plan, several questions were raised in the SC related to the Target Strength (TS) that will be used in the absolute estimates of biomass (however, it is noted that an existing TS-length conversion exists for alfonsino), the possible distribution of the resource in greater depths of the acoustic coverage which may result in underestimates of stock size, as well as the close spacing of survey transects and whether this could overestimate biomass.

The SC noted that many of these problems are related to the scarcity of information available to better inform survey design at this point. Therefore, the design of this or other surveys may be adjusted after the first year as more information about alfonsino becomes available. The SC considers the acoustic survey plan presented is appropriate to collect fishery independent information to establish a consistent time-series that can help the future evaluation of this stock.

References

Niklitschek, E., C. Barra, E. Hernandez, C. Herranz, J. Lamilla, R. Roa and P. Toledo (2011). Evaluacion hidroacustica de alfonsino 2009. Universidad Austral de Chile, Coyhaique Informe final CT 2011-03.

Whiff, J. C. Quiroz, A. Flores and P. Galvez. 2012. An overview of the alfonsino (*Beryx splendens*) fishery in Chile. Workshop on Management of Alfonsino Fisheries. 25

xii) Request #13: Presentation of the stock assessment and the scientific advice of Cod 2J3KL (Canada), Witch 2J3KL (Canada) and Pelagic Sebastes mentella (ICES Divisions V, XII and XIV; NAFO 1)

The Commission requests that results from stock assessments and the scientific advice of Cod 2J3KL (Canada), Witch 2J3KL (Canada) and Pelagic Sebastes mentella (ICES Divisions V, XII and XIV; NAFO 1) to be presented to the Scientific Council (SC), and request the SC to prepare a summary of these assessments to be included in its annual report.

Stock assessment and scientific advice for Cod 2J3KL (Canada),

The results of the most recent stock assessments and scientific advice of Atlantic cod (*Gadus morhua*) ("Northern cod", Divs. 2J3KL) was presented to SC. The summary is as follows:

The Atlantic cod *Gadus morhua* stock on the Newfoundland and Labrador continental shelf in NAFO Divs. 2J3KL ("Northern cod") is typically assessed annually by Fisheries and Oceans Canada using an age-structured state-space model (Northern Cod Assessment Model; NCAM, Cadigan 2016a and 2016b). A conservation limit reference point (LRP) was established for Northern cod in 2010 (DFO 2010), re-evaluated in 2019 (DFO 2019a), and is defined as the average spawning stock biomass (SSB) during the 1980s. This reference point is the stock level below which serious harm is occurring and the ability to produce good recruitment is seriously impaired. This reference point also defines the boundary between the critical and cautious zones within Fishery and Oceans Canada's (DFO) Precautionary Approach (PA) framework (DFO 2009).

The 2021 stock assessment reported that the Northern cod spawning stock biomass (SSB) remained at 52% (95% CI = 39-69%) of the Limit Reference Point, in the Critical Zone of DFO's PA framework (DFO 2009; DFO 2021) (Figure xii.1). SSB was 411 Kt in 2021 (95% CI = 307-549 Kt).

A one year projection carried out with six catch scenarios ranging from zero to 1.3 times the model estimated catch for 2020 (11 815 t) indicated that the probability that SSB would reach the LRP by 2022 was less than 1%.

Ecosystem conditions in the Newfoundland Shelf and Northern Grand Bank (NAFO Divs. 2J3KL) are indicative of limited productivity of the fish community. Total RV biomass level remains much lower than prior to the ecosystem collapse in the early-1990s.

Recent declines in average cod stomach content weights as well as reductions in capelin and shrimp in the diet, coupled with an apparent relative increase in cannibalism, point to a limitation in food availability. With capelin forecasted to decline to 2022, cod productivity will likely be negatively impacted.

Annual average removals from the commercial (stewardship) fishery were 11,000 t over 2016-2019 (Figure xii.2) and removals from recreational catches were about 2000 t (estimated from tagging data) over the same time period.

The advice from this assessment stated: "Consistency with the DFO decision-making framework incorporating the precautionary approach requires that removals from all sources must be kept at the lowest possible level until the stock clears the critical zone".

SC comments:

In September 2020 SC asked for some clarification on the objectives and management measures from the stewardship fishery, given that catches are occurring. Colleagues from the Canadian delegation explained that this was with the intent to allow limited harvest for the benefit of local inshore fishers while allowing science to gain insights on cod abundance in inshore areas, and further inform fishers' participation in the annual science and management processes.

SC **endorsed** the conclusions of both the assessment results and advice.

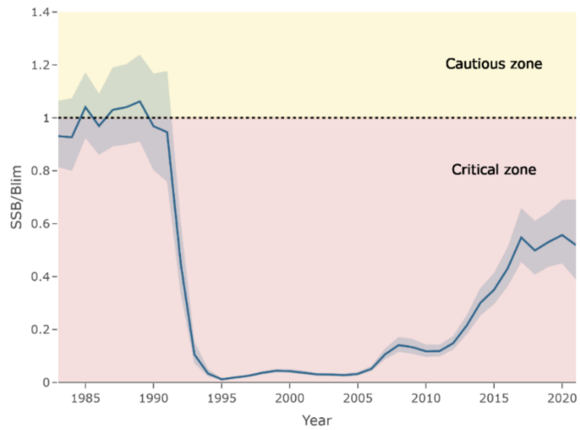

Figure xii.1. SSB/B_{lim} for Northern cod from NCAM (1983-2021) from the 2021 assessment.

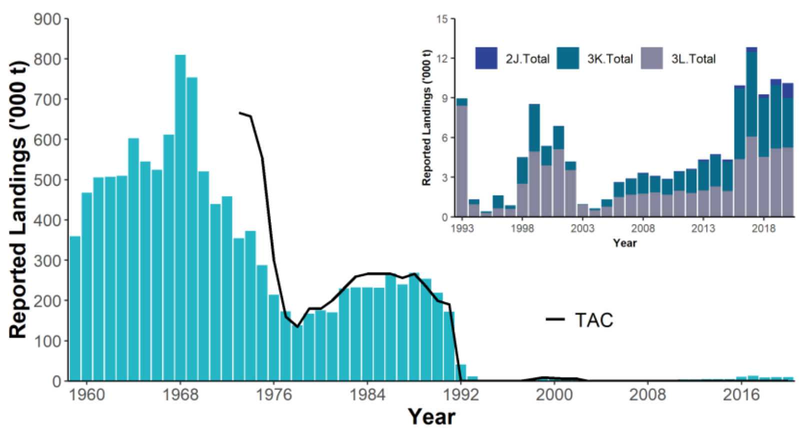

Figure xii.2. Landings (bars) and TAC (lines) for Atlantic Cod in Div. 2J3KL by Division from 1959 to 2020 (and inset plot show 1993-2020 by NAFO Division).

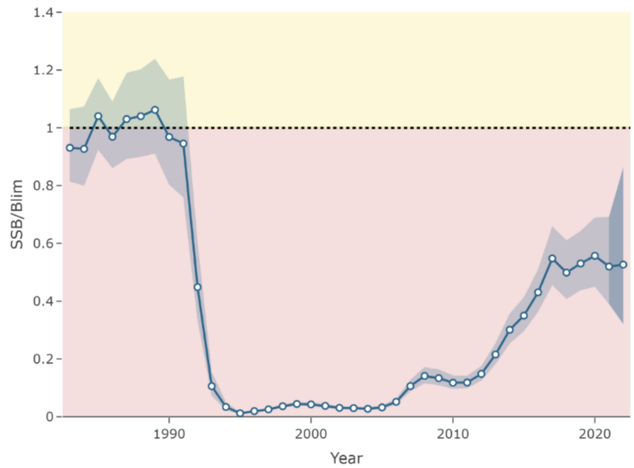

Figure xii.3. One year projection (to 2022) of Northern cod SSB under status quo NCAM-predicted catch levels (11 816 t) relative to the limit reference point B_{lim}, where B_{lim} (horizontal dashed line) is defined as the average SSB during the 1980s. Solid line with circles is the model median estimate and light grey envelope is 95% confidence intervals. Dark grey envelope are 95% confidence intervals for the projection period.

Update on witch founder in NAFO Divs. 2J3KL

There has been no update to the assessment and advice of witch flounder (*Glyptocephalus cynoglossus*) in Divs. 2J3KL since the last update was presented to SC in September 2020.

The last assessment of witch flounder in NAFO Divs. 2J3KL was completed by Fisheries and Oceans Canada (DFO) in May 2018 (DFO 2019b, Wheeland et al., 2019). B_{2017} was below the limit reference point (LRP), and the stock is in the Critical Zone of the Canadian Precautionary Approach framework. Consistency with the DFO decision-making framework incorporating the precautionary approach, requires that removals from all sources must be kept at the lowest possible level until the stock clears the critical zone. This stock has been under moratorium in Canadian waters since 1995, and in the NAFO regulatory area since 1998. Bycatch of witch flounder averaged 106 t annually from 2015-19, and provisional bycatch in 2020 was 114 t (Figure xii.4).

In years between full assessments survey biomass trajectory is monitored (see DFO 2019 for details on the agreed procedure) to determine if there is a need for an assessment. Survey indices from 2018 to 2020 have not been fully peer reviewed at this time, but an assessment has not been triggered.

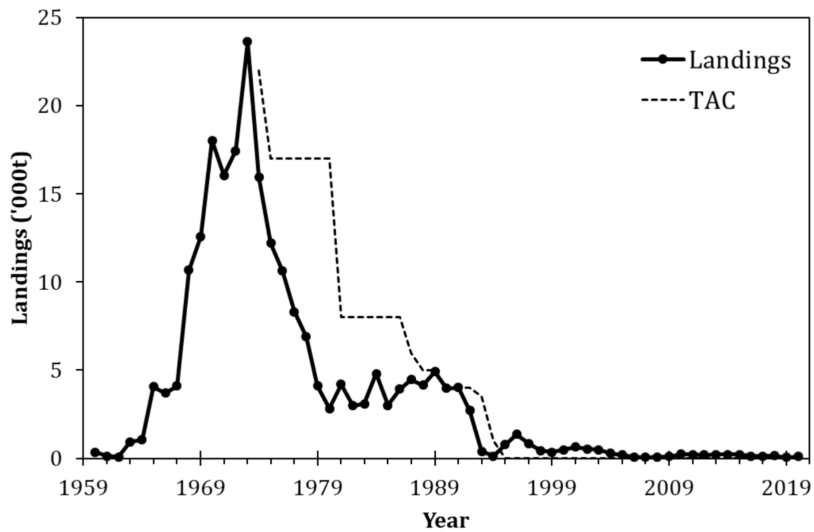

Figure xii.4. Landings (1960-2020, line) and TAC (points) for witch flounder in Div. 2J3KL.

References

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DFO. 2009. A fishery decision-making framework incorporating the Precautionary Approach.

DFO. 2010. Proceedings of the Newfoundland and Labrador Regional Atlantic Cod Framework Meeting: Reference Points and Projection Methods for Newfoundland cod stocks; November 22-26, 2010. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2010/053.

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Wheeland, L. 2018. Limit reference point for Witch Flounder in NAFO Divisions 2J+3KL. NAFO SCR Doc. 18/050.

Wheeland, L., Rogers, B., Rideout, R., and Maddock Parsons, D. 2019. Assessment of Witch Flounder (*Glyptocephalus cynoglossus*) NAFO Divisions 2J3KL. DFO Can. Sci. Advis. Sec. Res. Doc. 2019/066. iv + 57 p.

Update on Pelagic *Sebastes mentella* (ICES Divisions 5, 12 and 14; NAFO 1):

This stock is assessed by ICES and no new developments have occurred since SC last presented a review, in September 2020. It is understood that ICES will be conducting a new assessment in September 2021, which will be discussed in SC once ICES makes it publicly available. This may not occur in time for the September 2021 SC meeting, in which case SC will discuss it in its June 2022 meeting.

xiii) Request #14: Conduct ongoing analysis of the Flemish Cap cod fishery data

The Commission requests the Scientific Council, jointly with the Secretariat, to conduct ongoing analysis of the Flemish Cap cod fishery data by 2022 in order to:

(1) monitor the consequences of the management decisions (including the analysis of the redistribution of the fishing effort along the year and its potential effects on ecosystems, the variation of the cod catch composition in lengths/ages, and the bycatch levels of other fish species, benthos in general, and VME taxa in particular), and

(2) carry out any additional monitoring that would be required, including Div. 3M cod caught as bycatch in other fisheries during the closed period.

Scientific Council responded:

Given that only one year of data with the new measures will be available for this evaluation by June 2022, the analysis that SC will present next year will have to be completed in subsequent years as the relevant dataset increases.

The evaluation will compare the situation before and after the measures were in place, and will include analyses of, at least, the following aspects:

- *Fishing pattern (e.g. spatial and temporal distribution of catch and effort).*
- *Impact of the fishing activity on VMEs.*
- *Length / age composition of the cod catch.*
- *Bycatch levels of 3M cod and distribution in other fisheries.*
- *Bycatch levels of other species in the 3M cod fishery.*

The new management measures agreed by the Commission in 2020 include 1) a seasonal closure of the fishery for cod in Div. 3M during the first quarter of the year to preserve spawning activity, and 2) the use of sorting grids in the directed 3M cod fishery with the purpose of reducing catches of smaller individuals of cod. These measures came into force at the beginning of 2021 and a preliminary evaluation of their effectiveness and consequences will be conducted by SC in June 2022. Given that only one year of data with the new measures will be available for this evaluation and considering the sampling limitations due to the COVID-19 pandemic, and the low level of TAC, only initial results will be available in June 2022. The full analysis will be completed in subsequent years as the relevant dataset increases.

This preliminary evaluation will compare the situation before (the period for which the haul-by-haul data is available, 2016-2020) and after the measures were in place (since 2021), and include analyses of at least the following aspects:

- *Fishing pattern (e.g. spatial and temporal distribution of catch and effort).*
- *Impact of the fishing activity on VMEs.*
- *Length / age composition of the cod catch.*
- *Bycatch levels of 3M cod and distribution in other fisheries.*
- *Bycatch levels of other species in the 3M cod fishery.*

xiv) Request #15: measures to reduce the catch of juvenile and immature cod across all fisheries in 3M

The Commission requests the Scientific Council, in its future work, to consider whether other measures, such as depth restrictions, spatial and mesh changes, could reduce the catch of juvenile and immature cod across all fisheries in 3M.

Scientific Council responded:

SC considers that the effectiveness of the newly implemented measures in the 3M directed cod fishery should be evaluated before considering if additional and/or different measures may be required to further reduce juvenile cod catches.

The bycatch of 3M cod in other fisheries observed in 2016-2020 is considered low (both in weight and in number of individuals) when compared to the directed cod fishery. SC considers that, at this time, the implementation of measures to avoid juvenile cod bycatch in fisheries not directed to cod would be premature, given that the burden of implementing and enforcing these measures on multiple fisheries may outweigh its potential benefits.

An analysis of all 3M cod catches (from the directed fishery as well as bycatch in other fisheries) for years 2016-2020 was performed (SCR 21/021).

Results from the analysis of the directed fishery may not be fully applicable to the fishery after 2021 due to the technical measures implemented in January 2021, which are expected to impact selectivity.

Most cod catches in Div. 3M were taken in the directed cod fishery. Bycatch of cod in other fisheries represents less than 5% of cod total catches (Table xiv.1). Most of the cod bycatch is taken in the redfish fishery, which is mainly carried out in the first and third quarters of the year at depths of 300-600 meters (Figure xiv.1).

Table xiv.1. 3M cod catch in tons by year based on the Haul by Haul data, in the directed cod fishery and bycatch in other fisheries. The right-most column is the cod bycatch taken in the redfish fishery, expressed as a percentage with respect to the total cod bycatch across all fisheries in 3M.

Year	3M cod catch (tons)			% cod bycatch	Bycatch of 3M cod by fishery							RED (%)
	Directed	bycatch	Total		CAB (t)	GHL (t)	HAD (t)	HAL (t)	RED (t)	REG (t)	WIT (t)	
2016	10980.5	341.0	11321.5	3.0	0.0	0.0	12.3	0.4	302.5	0.0	6.2	94.5
2017	9775.1	192.8	9967.9	1.9	0.0	0.0	0.0	0.4	187.6	0.0	4.8	97.3
2018	10213.3	494.4	10707.6	4.6	1.9	0.0	0.0	0.0	484.0	0.0	8.5	97.9
2019	18723.1	379.7	19102.9	2.0	0.0	2.3	0.0	0.6	374.2	1.8	0.8	98.6
2020	6931.9	360.9	7292.8	4.9	0.0	4.9	0.0	0.0	320.1	0.0	35.9	88.7
Mean	**11324.8**	**353.8**	**11678.5**	**3.3**	**0.4**	**1.4**	**2.5**	**0.3**	**333.7**	**0.4**	**11.2**	**95.4**

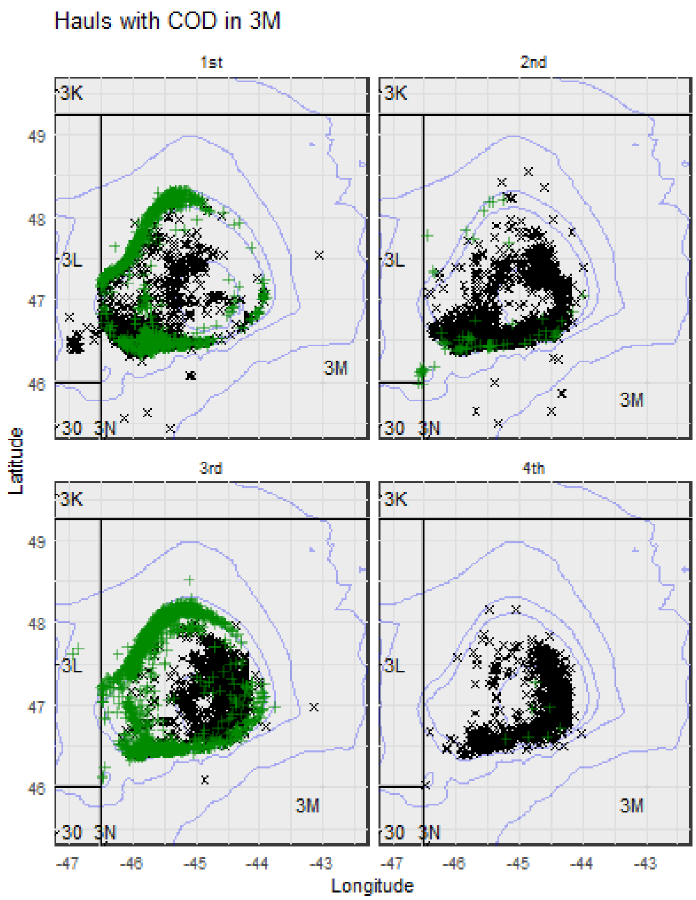

Figure xiv.1. Position of all hauls with cod by quarter. In black, hauls directed to cod. In green, hauls with bycatch of cod.

The number of length samples from cod bycatch in the Div. 3M redfish fishery is low. Still, most sampled hauls targeting redfish do not contain cod smaller than the Minimum Landing Size (MLS) (41 cm), and a large number of these hauls have more than 90% of mature individuals (greater than 52 cm). In terms of size distribution, the cod bycatch has a larger proportion of small fish than the directed fishery, especially during the first semester (Figure xiv.2), but this needs to be commensurate with the much lower amount of cod caught as bycatch (Table xiv.1).

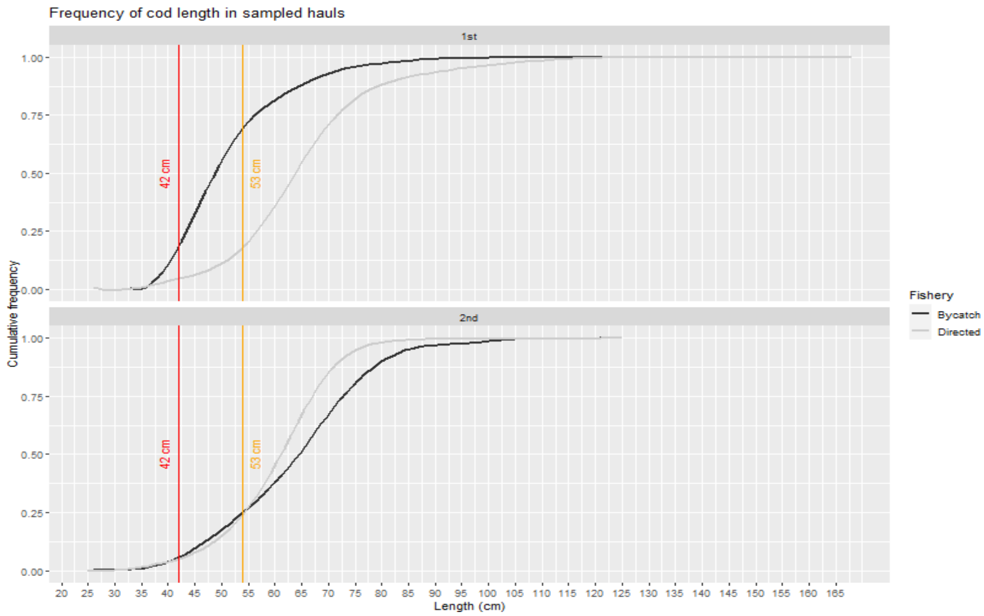

Figure xiv.2. Cumulative frequency of the lengths of 3M cod in the sampled hauls, for the directed and the bycatch fishery, by semester.

In conclusion, the bycatch of 3M cod in other fisheries observed in 2016-2020 is considered low (both in weight and in number of individuals) when compared to the directed cod fishery. While the actual impact of this bycatch is unknown, these levels of bycatch would not be expected to have had significant impacts on the trajectory of the stock during this period. A large proportion of the cod caught, both as bycatch and in the directed fishery, were above the MLS, with most of them being mature. Therefore, SC considers that, at this time, the implementation of measures to avoid juvenile cod bycatch in fisheries not directed to cod would be premature, given that the burden of implementing and enforcing these measures on multiple fisheries may outweigh its potential benefits. With respect to the directed 3M cod fishery, and considering that new measures have been just implemented, SC considers it prudent to first analyze the effectiveness of these measures (i.e. sorting grids) to protect juveniles before considering which additional and/or different measures may be required to further reduce juvenile cod catches if needed.

xv) Request #16: updates on relevant research related to activities other than fishing

The Commission requests the Scientific Council to continue to monitor and provide updates resulting from relevant research related to the potential impact of activities other than fishing in the Convention Area. Further, that the Secretariat and the Scientific Council work with other international organizations, such as the FAO and ICES, to bring in additional expertise to inform the Scientific Council's work.

Scientific Council responded:

SC reiterates its **recommendation** that *standardized protocols for marine litter data collection should be implemented by all Contracting Parties as part of their groundfish surveys.*

SC reiterates its prior advice that there are a number of activities occurring in the NRA (especially oil and gas activities) which have the potential to impact fisheries resources and the ecosystem, and that current expertise within SC WG-ESA in particular, and SC in general, is insufficient to fully assess the long term, cumulative impacts of these activities on the wider marine ecosystem and specifically VMEs.

SC notes that while there is an apparent significant spatial conflict between oil and gas exploration and production activities, fisheries and VME in the Flemish Pass area, activities other than fishing occurring in the NRA are not formally, nor regularly reported to SC.

Furthermore, SC notes that based on available information on exploration leases and development projections, it would be expected that oil and gas exploration and production activities will increase in the NRA until at least 2030. However, the oil and gas sector is currently experiencing significant and rapid changes globally, so it is difficult to gauge how these changes may impact projects in the NRA.

SC reiterates its advice that periodic up-dates of the Ecosystem Summary Sheets for these activities is dependent on Contracting Parties making effective their commitments and **recommends** *to a) establish regular reporting of activities other than fishing with sufficient detail to allow for adequate analysis and assessment, and b) increase SC capacity to address these issues.*

Standardized protocol for collection of seabed litter data in the EU groundfish surveys

Scientific Council recommended to the NAFO Commission that standardized protocols for seabed litter data collection should be implemented by all Contracting Parties as part of their groundfish surveys, to facilitate the on-going monitoring and assessment of seabed litter in the NAFO area.

In line with such recommendation, the Spanish Institute of Oceanography (IEO) developed a protocol to be used in all the EU groundfish surveys in the NRA. The objective of the protocol is to expand the seabed litter data collection started in year 2006 (García-Alegre *et. al*., 2020) in the Flemish Pass (Div. 3L) to the other areas sampled by the EU surveys: Flemish Cap (Div. 3M) and the Grand Banks (Divs. 3NO) using a common methodology and standardized forms. This protocol was implemented in Divs. 3LNO (2018) and Div. 3M (2019) as a pilot experiment. In 2020, a common standardized protocol was ready to use in all the EU groundfish surveys in the NRA, but this year, due to COVID-19 situation, only the EU-Spain & Portugal groundfish survey (Div. 3M) was conducted. For each haul, all items collected by the bottom trawl gear were examined, counted, weighed, categorized and recorded onboard. Moreover, the size of items was recorded and photos were taken, when possible. Table xv.1. summarizes the information on seabed litter available from EU groundfish surveys. Data from 2006-17 (Div. 3L) has previously been summarized (NAFO, 2019; García-Alegre et al., 2020)[28]. Results indicate a generally low occurrence and density of seabed litter, with only 8.3% of hauls having seabed litter present; however, 62% of the seabed litter sampled were identified as being associated with both NAFO managed and non-managed fishing activities.

[28] EU Funded projects ATLAS (A Transatlantic Assessment and Deep-water Ecosystem-based Spatial Management Plan for Europe) and CLEANATLANTIC (Tracking Marine Litter in the Atlantic Area)

Table xv.1. Information on seabed litter available from EU groundfish surveys.

NAFO Divs.	Data period	Source
3L	2006-2019	EU-Spain groundfish survey
3NO	2018-2019	EU-Spain groundfish survey
3M	2019-2020	EU-Spain & Portugal groundfish survey

Update on oil and gas activities

Information on geographical location of offshore oil and gas activities in the NAFO Convention Area (wells, licenses, proposed project areas, etc.) is publicly available from several sources, including websites and project reports (e.g. **https://oilandgas.nalcorenergy.com/ness/overview/**). In contrast, available information on the potential impacts of such activities (routine operations and accidental events) in the NAFO Regulatory Area (NRA) and the corresponding mitigation measures is scarce or difficult to obtain.

Based on the available information on exploration leases and development projections, oil and gas exploration and production activities would be expected to increase in the NRA until at least 2030. However, the oil and gas sector is currently experiencing significant and rapid changes globally, so it is difficult to gauge how these changes may impact projects in the NRA.

Offshore oil and gas activities can have detrimental environmental effects during each of the main phases of exploration, production, and decommissioning (Cordes et al., 2016), but these impacts have not been adequately assessed within the NRA. Environmental effects include impacts from routine operational activities such as drilling waste and produced water discharges (Neff et al., 2011; Neff et al., 2014), accidental discharges and spills (Cordes et al., 2016, https://www.cnlopb.ca/incidents/ibjul182019/), long-term impacts on deep-sea corals (e.g., Girard and Fisher, 2018) and impacts on deep-sea sponges and their associated habitats (Vad et al., 2016).

The map in Figure xv.1 shows the updated information on oil and gas activities in NAFO Divs. 3LMN, collected from publicly available sources. In comparison with the information assessed previously reported by WG-ESA (NAFO, 2019), the updated map reveals an increase of the exploration activities within Divs. 3LMN. The map shows four additional *Wells* located in Div. 3L (one of them inside NAFO Closed Area No2 (large sponges)), two additional *Significant Discovery Licenses* in Div. 3M and several additional *Exploration licenses* in Divs. 3LN. Figure xv.1 also shows an additional *Exploration Drilling Project* that can proceed in Divs. 3LM, involving exploration drilling within two *Exploration licenses* within the Flemish Pass Basin (EL1144 and EL1150: see location in Figure xv.2). Moreover, the updated map reveals the overlap, and potential conflicts, between different regulatory and jurisdictional frameworks (e.g., NAFO and C-NLOPB[29]). Vulnerable ecosystems inside NAFO VME closures (and/or outside NAFO footprint) are currently protected against Significant Adverse Impacts from commercial bottom fishing, but they are unprotected regarding potential threats from activities other than fishing (e.g., drilling activities inside VME closures in Divs. 3LM).

Some of the oil and gas exploration and proposed production activities in Divs. 3LMN, appear to have significant spatial overlap with NAFO fisheries and VMEs, which could result in potential conflicts between users of the marine space (e.g., reduction of fishing opportunities) and between users and the environment (e.g., VMEs). Particularly, this is the case of the Bay du Nord Development Project (Figures xv.1 and xv.2) located in the Flemish Pass. Figure xv.2 shows the details of the planned production installations (i.e., templates, flowlines, FPSO vessel, anchors, and moorings), the location of some templates within NAFO Closed Area 10 (sea pen) as

[29] Canada-Newfoundland and Labrador Offshore Petroleum Board

well as future potential tie-back opportunities inside a VME polygon and close to the NAFO fishing grounds. This could result in a future expansion of the Proposed Core Development Area of the project (outlined in red in Figures xv.1 and xv.2), which is a cause for concern.

Pollution incidents are often a source of conflicts between different users of the marine space and between users and the marine ecosystems (Durán Muñoz et al., 2020). Table xv.2 summarizes the updated information on recent incidents, including a transboundary oil spill, derived from offshore oil and gas activities in the Northwest Atlantic, based on available data. During the period 2015-2020, there have been twelve reported incidents of different nature, with a major oil spill in 2018 (250 000 L), and one in 2019 that occurred in the EEZ of the coastal state but extended outside the EEZ into the NAFO Regulatory Area. Other incidents included a near-miss collision between an iceberg and an oil platform in March 2017 and the occurrence of unauthorized discharges in recent years, revealing the potential risks of offshore oil and gas activities in the Northwest Atlantic. There is a need to assess the cumulative impacts of human activities (e.g., fisheries and oil and gas exploration/exploitation) on the NAFO ecosystems. Moreover, in order to better understand the contribution of each anthropogenic activity, impacts should be assessed both inside VME polygons and VME closure areas (e.g., NAFO Closed Areas 10 and 2).

Information presented here, based on the results from the EU ATLAS research project and public information, will be useful to update the current 3LNO Ecosystem Summary Sheet (ESS) and to develop the 3M ESS.

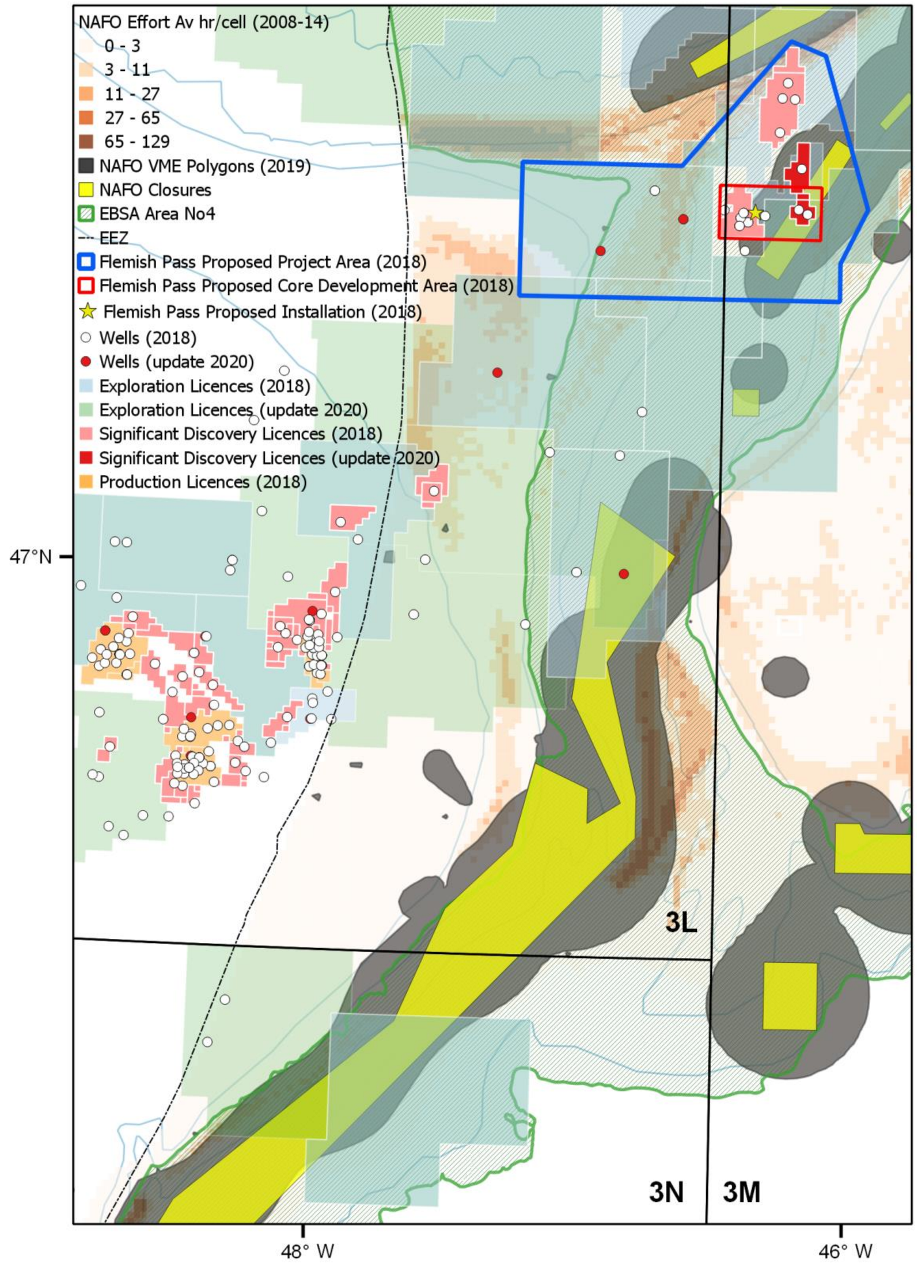

Figure xv.1. Geographical location of oil and gas activities in NAFO Divs. 3LMN. The map shows the potential conflicts between different users of the marine space (e.g. oil and gas vs. fisheries) and between users and marine environment (oil and gas vs. VMEs). The yellow star indicates the location of the proposed production installation within the Bay du Nord Development Project in the Flemish Pass (outlined in blue). Information previously reported by WG-ESA (NAFO, 2018) and new available information (2020) is noted in brackets. Sources: NAFO, C-NLOPB, NESS and CBD.

Table xv.2. Updated list of recent offshore oil spills and other relevant incidents in the NW Atlantic, based on available information. Period 2015-2020 (source C-NLOPB).

Date	Incident description	Observations
20/07/2020	Unauthorized Discharge (Hibernia Platform)	Produced water discharge (mixture of seawater from the reservoir/used in injection, drilling and production fluids). The volume of the discharge and its composition are being determined
18/06/2020	Unauthorized Discharge (SeaRose FPSO), White Rose Field	1,098 L of an anti-microbial agent (X-Cide 450) was released along with 1,916,000 litres of water that were intended for reservoir injection.
17/08/2019	Hibernia Oil Spill	Estimated volume of oil on the water was 2,184 L at that time
17/07/2019	Hibernia Oil Spill	Oil expressed on the water could be in the order of 12,000 L. It occurred inside Canadian EEZ, but the analysis indicated that the oil was extended outside the EEZ and into the NAFO NRA[30]
16/10/2018	White Rose Field Oil Spill	250,000 L of oil were released to the environment
27/04/2018	Unauthorized Discharge of Synthetic Based Mud (SBM) (Transocean Barents platform)	28,000 L of SBM was released to the environment
29/03/2017	Near Miss - Iceberg Approaches Close to the SeaRose Floating Production, Storage and Offloading (FPSO) Vessel	A medium size iceberg came within 180 meters of the FPSO (about 340,000 barrels of crude oil on board at that time)
15/07/2016	Unauthorized Discharge/Impairment of safety critical equipment (Henry Goodrich drilling)	Approximately 1,800 L of hydraulic fluid was released to the environment
15/02/2016	Unauthorized Discharge of glycol (West Aquarius)	1,317 L of glycol was released to the sea
30/09/2015	Unauthorized Discharge of methanol (Terra Nova field)	3,000 L of methanol was released to the sea
31/08/2015	Major hydrocarbon gas release (Southern drill center)	8,938 kg of natural gas was released to the sea
28/07/2015	Major hydrocarbon gas release (Terra Nova FPSO)	10,000 kg of gas was released

[30] Ref. NAFO/19-205. 23 July 2019.

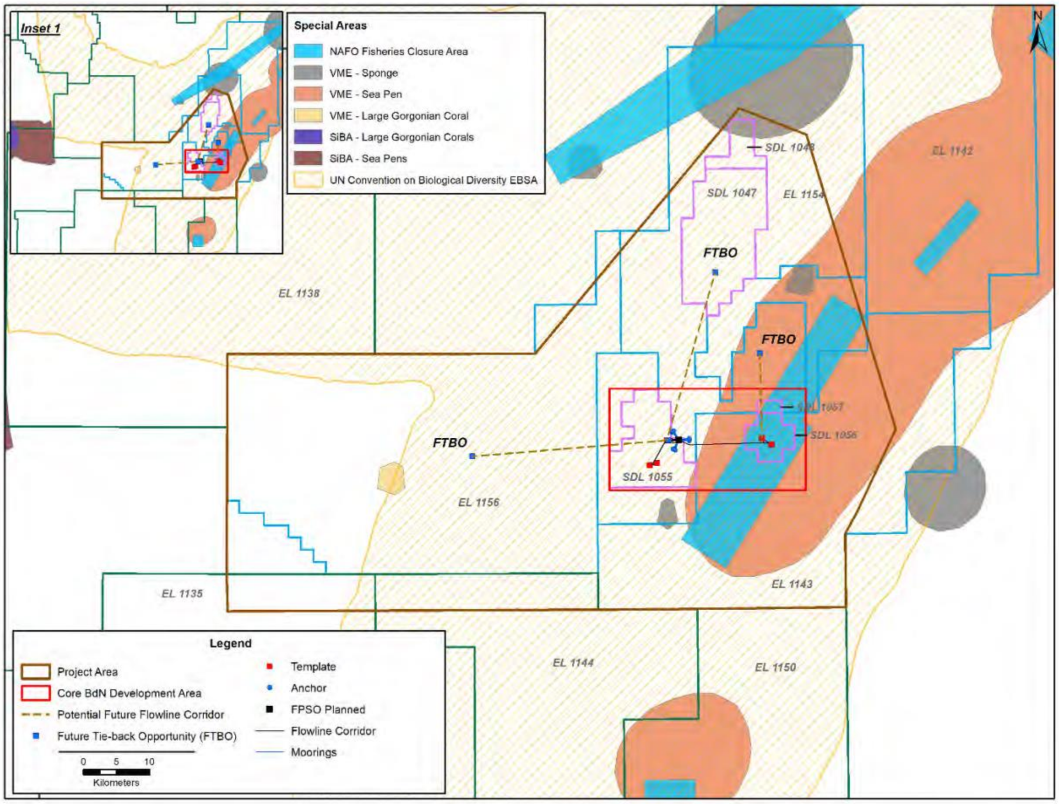

Figure xv.2 Details of the planned production installations (i.e., templates, flowlines, FPSO vessel, anchors, moorings) within the Bay du Nord Development Project in the Flemish Pass (outlined in brown). The map shows the location of templates within NAFO Closed Area No 10 (sea pen) as well as potential tie-back opportunities inside VME polygon and close to the fishing grounds. The figure also shows the geographical location of two *Exploration Licences* (EL1144 and EL1150). Source: Equinor Canada Ltd. (2020).

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xvi) Request #17: Information on sea turtles, sea birds, and marine mammals that are present in NAFO Regulatory Area

The Commission requests the Scientific Council to provide information to the Commission at its next annual meeting on sea turtles, sea birds, and marine mammals that are present in NAFO Regulatory Area based on available data.

Scientific Council responded:

SC noted that most marine mammals, turtles and seabirds are widespread through the northwest Atlantic and undertake extensive seasonal migrations, often moving across the North Atlantic or from the Caribbean to the Arctic. The Grand Bank is a transition zone with both Arctic and temperate species occurring. There is considerable uncertainty about the residence time of taxa in the NAFO Regulatory Area (NRA). Data for this assessment came from scientific surveys, opportunistic sightings, acoustic recorders, satellite telemetry studies and also from bycatch reporting and light-level geolocators.

There are approximately 25 cetacean and seven pinniped species present in the NAFO Convention Area (NCA), with most of them widely distributed across the part of the Convention Area which lies beyond the areas in which Costal States exercise fisheries jurisdiction, outside of the Exclusive Economic Zones (i.e., NRA). Of these, five pinnipeds (walrus, and ring, bearded, harbour, and grey seals) and two cetaceans (beluga and narwhal) are unlikely to occur in the NRA because they are mainly observed in nearshore waters.

Three species of sea turtles, loggerhead, green and leatherback, have been reported in the NRA. However, only leatherback turtles occur regularly.

An initial literature review indicates a total of 58 species of seabird have been found to use the NCA and, of those, 31 species have more specific geographic data that indicates they use the NRA. Families Laridae (terns and gulls), Procellariidae (petrels and shearwaters), Stercorariidae (skuas and jaegers) and Alcidae (puffins and murres) make up 27 of the 31 species observed in the NRA.

Data on the presence and abundance of marine mammals and turtles in the NAFO regulatory area are obtained from dedicated sighting surveys, opportunistic sightings, acoustic recorders, and satellite telemetry studies. However, the amount of survey data available from the NRA is limited as a result of difficulties reaching the area with survey aircraft, while opportunistic sightings reflect the distribution of observers rather than the distribution of animals. Marine mammal observers during the Spanish groundfish survey (Div. 3L) and on the fishing fleet (Div. 3LMNO) have provided some information on cetacean species presence in the NRA, based on sightings from an opportunistic sampling (Roman-Marcote et al., 2019; SCR Doc. 20/023). The deployment of acoustic recorders in offshore areas is recent and not fully analyzed. These instruments provide information on the presence or absence of individual species although preliminary analyses have indicated that identification of marine mammals present is difficult because of the high level of background noise from vessels and seismic activity.

Being highly mobile, marine mammals and turtles utilize large areas, often moving across the North Atlantic or from the Caribbean to the Arctic. Most species are seasonal migrants although some individuals may remain year-round, particularly in the warmer waters near the tail of the Grand Bank. Many of the cetaceans and turtles winter in southern waters, but summer on the Grand Bank and in the NRA, while others, such as harp and hooded seals, summer in the Arctic and winter on the Newfoundland Shelf and Grand Bank.

The Grand Bank is a transition zone with both Arctic and temperate species occurring. As a result, approximately 25 cetacean and seven pinniped species are present in the NAFO Convention Area (NCA). Of these, five pinnipeds (walrus, and ring, bearded, harbour, and grey seals) and two cetaceans (beluga and narwhal) are mainly observed in nearshore waters and so unlikely to occur in the NRA. Many of the remaining species, such as minke, humpback and killer whales, and most of the small cetaceans and harbour porpoise, are widely distributed across the continental shelf, including the NRA. They are also occasionally sighted in the deep water off the shelf edge. Sperm whales are commonly reported in NRA in both the opportunistic sightings database and by Spanish observers and groundfish surveys. Fin whales are also widely spread throughout the NCA, although a habitat suitability model identified the nose and tail of the Grand Bank, Flemish Pass and

Orphan Basin areas as important habitat during the spring and summer. The southern edge of the Grand Bank was also identified as important habitat for the endangered Northwest Atlantic blue whale population.

Some species are most commonly found along the continental slope. Long finned pilot whales were reported in the Flemish Pass (Div. 3L) by the Spanish groundfish surveys. Beaked whales (family Ziphiidae) are a poorly understood group that inhabit offshore slope habitats and appear to be particularly sensitive to sound. The best known member of this family is the Northern Bottlenose Whale, which occurs along the edge of the continental shelf from Davis Strait to the Scotian shelf. A habitat suitability model indicates that the area from the nose of the Banks, Orphan Basin to Flemish Pass and Flemish Cap are particularly important for this species. The species is commonly reported in Div. 3L (SCR Doc. 20/023).

There are considerable data available on the movements of harp and hooded seals based on satellite telemetry studies. Both species feed in the NRA prior to and after the pupping period in March. Harp seals utilize the continental shelf, particularly the nose of the Grand Bank, while hooded seals are common along the slope edges of the Flemish Pass and Flemish Cap. These are important feeding areas for both species.

Harp seals are the most abundant marine mammal in the North Atlantic. After two decades of being relatively stable, the Northwest Atlantic population is currently estimated to have increased over the past five years to 7.6 million. Hooded seals were last assessed in 2006 at 587 000. Less is known about abundance of cetaceans; only two large scale surveys have been carried out that covered the entirety of Canadian Atlantic waters, one in 2007 and the other in 2016. The estimates of abundance of the main species varied among surveys and could not be accounted for by population growth, suggesting a change in distribution from the earlier to the later survey. In 2016, abundance of minke whales, humpback whales and fin whales in Newfoundland and Labrador waters were estimated to be 12 000, 8400 and 2200, respectively. The most abundant cetacean was white-beaked dolphins (530 500). Because of the lack of long-term data, trends in abundance of almost all of the cetacean species are unknown.

Three species of sea turtles, loggerhead, green and leatherback, have been reported in the NRA. However, only leatherback turtles occur regularly. They migrate from South America to feed on jellyfish in the NCA each year and occur in the Northwest Atlantic primarily during the late summer and early fall when water temperatures reach a maximum. A habitat suitability model based on data from the 2016 megafauna survey did not extend to the NRA but indicated that suitable habitat for leatherback turtles extended across the Grand Bank to both the nose and tail.

Many of the species included in this summary have been reported caught in fishing gear in the NRA and the Convention Area but bycatch rates are unknown.

Data on the presence of seabirds in the NRA can also be obtained from scientific survey, opportunistic sightings, acoustic recorders and satellite telemetry studies and also from bycatch reporting and light-level geolocators. There are not many dedicated surveys conducted in the NRA specifically for seabirds and most visual surveying is done terrestrially on nesting sites or nearshore habitats. There are some opportunistic and citizen science reporting of seabirds in coastal waters, including the NRA, but these data are sparse and have limited use beyond determining presence/absence.

The summer seabird community and the distribution of seabirds in the Flemish Cap (Div. 3M) were described by Leyenda and Munilla (2002), based on data from EU groundfish surveys. Eight species were counted within census transects. Over 70% of seabirds were great shearwaters (*Ardenna gravis*), followed by northern fulmars (*Fulmarus glacialis*) with 17.1% of the seabirds recorded. Seabird abundance and seabird species richness were not evenly distributed across the Flemish Cap but seemed to concentrate at the edges of the southern half of the study area. Both species are also the most frequent seabirds reported in the Flemish Pass (Div. 3L) by the Spanish groundfish surveys (2012-2019), although abundance is not recorded on this survey platform (SCR Doc. 20/023). On the Flemish Pass survey, 13 seabird species were sighted.

A majority of the information available on the seabird species using the NRA comes from light-level geolocators or other small, lightweight tags allowing bird migrations to be recorded. There is an abundance of seabird tracking studies conducted in the Atlantic that indicate the NRA is being used by seabirds. These studies are helping to delineate seabird species' seasonal use patterns, migration routes and time spent at sea.

Seabirds can be highly migratory and travel great distances between foraging and nesting areas; for example, the Arctic Tern migrates between Arctic and Antarctic waters. As such, a majority of the species found in the NRA are only in the area seasonally; however, some species are found in the area year-round.

An initial literature review indicates a total of 58 species have been found to use the NCA and, of those, 31 species have more specific geographic data that indicates they use the NRA. Families Laridae (terns and gulls), Procellariidae (petrels and shearwaters), Stercorariidae (skuas and jaegers) and Alcidae (puffins and murres) make up 27 of the 31 species observed in the NRA (Table xvi.1).

Table xvi.1. Seabirds known to use the NAFO regulatory area (NRA) grouped by Family.

Common name	***Latin name***	**Family**
Atlantic puffin	*Fratercula arctica*	Alcidae
Common murre	*Uria aalge*	Alcidae
Dovekies (little auks)	*Alle alle*	Alcidae
Thick-billed murre	*Uria lomvia*	Alcidae
Arctic tern	*Sterna paradisaea*	Laridae
Black-legged kittiwake	*Rissa tridactyla*	Laridae
Common tern	*Sterna hirundo*	Laridae
Glaucous gull	*Larus hyperboreus*	Laridae
Great black-backed gull	*Larus marinus*	Laridae
Lesser black-backed gull	*Larus fuscus*	Laridae
Ivory gull	*Pagophila eburnea*	Laridae
Iceland gull	*Larus glaucoides*	Laridae
Sabine's gull	*Xema sabini*	Laridae
Red-necked phalarope	*Phalaropus lobatus*	Scolopacidae
Great skua	*Stercorarius skua*	Stercorariidae
Long-tailed jaeger (skua)	*Stercorarius longicaudus*	Stercorariidae
Parasitic jaeger	*Stercorarius parasiticus*	Stercorariidae
Pomarine jaeger	*Stercorarius pomarinus*	Stercorariidae
South polar skua	*Stercorarius maccormicki*	Stercorariidae
Leach's storm-petrel	*Oceanodroma leucorhoa*	Hydrobatidae
Bermuda petrel	*Pterodroma cahow*	Procellariidae
Black-capped petrel	*Pterodroma hasitata*	Procellariidae
Cory's shearwater	*Calonectriz diomedea*	Procellariidae
Desertas petrel	*Pterodroma deserta*	Procellariidae
Great shearwater	*Ardenna gravis*	Procellariidae
Manx shearwater	*Puffinus puffinus*	Procellariidae
Northern fulmar	*Fulmarus glacialis*	Procellariidae
Sooty shearwater	*Ardenna grisea*	Procellariidae
Trindade petrel	*Pterodroma arminjoniana*	Procellariidae
Wilson's storm petrel	*Oceanites oceanicus*	Oceanitidae
Northern gannet	*Morus bassanus*	Sulidae

References:

Leyenda, P. M., and I. M. Rumbao. (2005). The summer seabird community of the Flemish Cap in 2002. J. Northw. Atl. Fish. Sci., 37: 47-52. doi:10.2960/J.v37.m554

Román-Marcote, E., Durán Muñoz, P. and Sacau, M. (2019). Preliminary information from EU-Spain regarding Commision request #18. Oral presentation. 12th NAFO Working Group on Ecosystem Science Assessment. 18-28 November 2019. NAFO headquarters. Dartmouth. Canada.

xvii) Request #18: Ecosystem summary sheets for 3M and 3LNO & joint workshop with ICES

The Commission requests that the Scientific Council proceed with developing the ecosystem summary sheets for 3M and 3LNO move toward undertaking a joint Workshop with ICES (International Council for the Exploration of the Sea) as part of a peer review of North Atlantic ecosystems.

Scientific Council responded:

Owing to demands to complete Commission Request 6 (assessment of Significant Adverse Impacts of fishing activities on VMEs) via short virtual meetings, development of Ecosystem Summary Sheets for 3M could not yet be completed by SC. Development of the Ecosystem Summary Sheet for 3M will resume in 2021. The Ecosystem summary sheet for 3LNO was completed in 2019.

As a result of pandemic related limitations, undertaking a joint Workshop with ICES has been postponed until there is a greater likelihood of face-to-face meetings. Planning for a collaborative workshop will resume in 2021-2022. The process will benefit from NAFO's internal WG-EAFFM dialogue session on the Roadmap in late 2021 to further clarify concepts and ideas in preparation for the full WG-EAFFM Roadmap Workshop, currently scheduled as a face-to-face meeting in 2022.

2. Coastal States

a) Request by Denmark (on behalf of Greenland) for Advice on TACs and Other Management in 2022 of certain stocks in Subareas 0 and 1 (Annex 2)

i) Monitoring of Stocks for which Multi-year Advice was provided in 2019 or 2020

Interim monitoring updates of these stocks were conducted and Scientific Council reiterates its previous advice as follows:

Recommendation for Demersal redfish in Subarea 1 for 2021 – 2023: Deep-sea redfish and Golden redfish: The Scientific Council advises that there should be no directed fishery.

There will be no new assessment until monitoring shows that conditions have changed; until then, the advice given above will remain.

Recommendation for Wolffish in Subarea 1 for 2021 – 2023: Atlantic wolffish: The Scientific Council advises that there should be no directed fishery. **Spotted wolffish:** The Scientific Council advises that the TAC should not exceed 1158 tonnes.

Recommendation for Greenland halibut in Division 1A inshore - Upernavik for 2021 – 2022: Scientific Council recommends that catch should not exceed 5068 tonnes. This is a reduction over the previous advice accounting for the reduction in mean individual size in the recent catches

Recommendation for Greenland halibut in Division 1A inshore - Uummannaq for 2021 – 2022: Scientific Council recommends that catch should not exceed 5153 tonnes. This recommendation is a reduction over the previous advice accounting for the decrease in the mean size in the recent catches.

Recommendation for Greenland halibut in Division 1A inshore - Disko Bay for 2021 – 2022: The Scientific Council advises that the TAC should not exceed 4346 tonnes.

Recommendation for Greenland halibut in Subarea 1 Division 1BC inshore for 2021 – 2022: The Scientific Council recommends that catch in each of the years 2021 and 2022 should not exceed 300 tonnes, which corresponds to the Depletion Corrected Average Catch (DCAC).

Recommendation for Greenland halibut in Subarea 1 Division 1D inshore for 2021 – 2022: The Scientific council recommends a reduction of catches in this area to reach the 398 tonnes, corresponding to the Depletion Corrected Average Catch (DCAC), by 2023. The SC recommends to reduce catches to 647 tonnes in 2021 and 522 tonnes in 2022.

Recommendation for Greenland halibut in Subarea 1 Division 1EF inshore for 2021 – 2022: The Scientific Council recommends a reduction of catches in this area to reach 222 tonnes, corresponding to the Depletion Corrected Average Catch (DCAC), over a period of three years (2021-2023).

Recommendation for Greenland halibut in Subarea 0+1 (offshore) for 2021 – 2022: Scientific Council advises that there is a low risk of Greenland halibut in Subarea 0 + 1 being below B_{lim} if the TAC for 2021 and 2022 remains at 36 370 tonnes.

This year, for the first time, this catch advice is exclusive of catches taken in the inshore areas of Divisions 1B-F, for which separate advice is provided.

There is no scientific basis with which to provide separate advice for the offshore areas of Div. 0A+1AB and Div. 0B+1C-F. The SC advises that consideration be given to the distribution of effort in each area to avoid localized depletion.

3. Scientific Council Advice of its own accord

Scientific Council did not provide any advice of its own accord in 2021.

VIII. REVIEW OF FUTURE MEETINGS ARRANGEMENTS

1. Scientific Council meetings

a) Scientific Council (in conjunction with NIPAG) September 2021

Scientific Council (in conjunction with NIPAG) will meet by WebEx during 8-14 September 2021 (however, it is noted that some change in these dates may occur) to provide advice for northern shrimp in Division 3M, northern shrimp in Divisions 3LNO and northern shrimp in Subarea 1 and Div. 0A. There will be an additional NIPAG meeting by Webex in November 2021 to assess northern shrimp in Denmark Strait and off East Greenland.

b) Scientific Council, 17 August 2021

Scientific Council may hold an additional 1 day meeting on 17 August 2021 to update the advice on the review of the NAFO PA Framework (see response to Commission Request #8, earlier in this report). This will be contingent on further progress by PA-WG.

c) Scientific Council, September 2021

The Annual Meeting will be held by WebEx from 20 to 24 September 2021.

d) WG-ESA, 16- 25 November 2021

The Working Group on Ecosystem Science and Assessment (WG-ESA) will meet at the NAFO Secretariat, Nova Scotia, Canada, from 16 to 25 November 2021.

e) Scientific Council, June 2022

Scientific Council June 2022 meeting will be held in Halifax, Nova Scotia, Canada, from 3 to 16 June 2022.

f) Scientific Council (in conjunction with NIPAG), 2022

Dates and location to be determined.

g) Scientific Council, September 2022

The Annual meeting will be held in September in Halifax, Nova Scotia, unless an invitation to host the meeting is extended by a Contracting Party.

2. NAFO/ICES Joint Groups

a) NIPAG, 8-14 September 2021

The joint NAFO/ICES *Pandalus* Assessment Group will meet by WebEx during 8-14 September 2021 (however, it is noted that some change in these dates may occur).

b) ICES – NAFO Working Group on Deep-water Ecosystem, 2022

Dates and location to be determined.

c) Joint ICES/NAFO/NAMMCO Working Group on Harp and Hooded Seals (WG-HARP) 2021

Dates and location to be determined.

3. Commission- Scientific Council Joint Working Groups

a) WG-RBMS August 2021

The joint SC-Commission Working Group on Risk Based Management Systems (WG-RBMS) will be held via WebEx on 24-26 August 2021.

b) WG-EAFFM July 2021

The joint SC-Commission Working Group on the Ecosystem approach to Fisheries Management (WG-EAFFM) will be held via WebEx on 14-16 and 20-21 July 2021.

c) CESAG

The next meeting of the Catch Estimation Strategy Advisory Group (CESAG) will be in February 2022 via WebEx.

IX. ARRANGEMENTS FOR SPECIAL SESSIONS

1. Topics of Future Special Sessions

The Chair and participants of STACFEN reminded SC members of the upcoming "4th Symposium on Decadal Variability of the North Atlantic and its' Marine Ecosystem: 2010-2019", taking place 26-28 April 2022 in Bergen, Norway, hosted by the Institute of Marine Research (IMR). The symposium is jointly organized by ICES, NAFO and IMR, and its webpage can be found in

https://decadal2022.imr.no/registration-and-abstract-submission

X. MEETING REPORTS

1. Working Group on Ecosystem Science and Assessment (WG-ESA) - SCS Doc. 20/23

The report of the meeting of the Working Group on Ecosystem Science and Assessment (WG-ESA) held 17-26 November 2020 by WebEx was presented by its co-Chairs Pierre Pepin (Canada) and Andrew Kenny (UK).

2. ICES/NAFO/NAMMCO Working Group on Harp and Hooded Seals (WG-HARP)

SC will aim to get an update for September.

XI. REVIEW OF SCIENTIFIC COUNCIL WORKING PROCEDURES/PROTOCOL

a) General plan of work for September:

SC did not hold any discussion specifically on this during the June meeting, since it has managed to address all Commission requests (with the only exception of Request #3).

XII. OTHER MATTERS

1. Designated Experts

The list of current Designated Experts can be found below and will be reviewed by SC in September.

From the Science Branch, Northwest Atlantic Fisheries Centre, Department of Fisheries and Oceans, St. John's, Newfoundland & Labrador, Canada

Cod in Div. 3NO	Rick Rideout	rick.rideout@dfo-mpo.gc.ca
Redfish Div. 3O	Danny Ings	danny.ings@dfo-mpo.gc.ca
American Plaice in Div. 3LNO	Laura Wheeland	laura.wheeland@dfo-mpo.gc.ca
Witch flounder in Div. 3NO	Dawn Maddock Parsons	dawn.parsons@dfo-mpo.gc.ca
Yellowtail flounder in Div. 3LNO	Dawn Maddock Parsons	dawn.parsons@dfo-mpo.gc.ca
Greenland halibut in SA 2+3KLMNO	Paul Regular	paul.regular@dfo-mpo.gc.ca
Northern shrimp in Div. 3LNO	Katherine Skanes	katherine.skanes@dfo-mpo.gc.ca
Thorny skate in Div. 3LNO	Mark Simpson	mark.r.simpson@dfo-mpo.gc.ca
White hake in Div. 3NO	Mark Simpson	mark.r.simpson@dfo-mpo.gc.ca

From the Department of Fisheries and Oceans, Winnipeg, Manitoba, Canada

Greenland halibut in SA 0+1	Margaret Treble	margaret.treble@dfo-mpo.gc.ca

From the Instituto Español de Oceanografia, Vigo (Pontevedra), Spain

Roughhead grenadier in SA 2+3	Fernando Gonzalez-Costas	fernando.gonzalez@ieo.es
Splendid alfonsino in Subarea 6	Fernando Gonzalez-Costas	fernando.gonzalez@ieo.es
Cod in Div. 3M	Diana Gonzalez-Troncoso	diana.gonzalez@ieo.es
Shrimp in Div. 3M	Jose Miguel Casas Sanchez	mikel.casas@ieo.es

From the Instituto Nacional de Recursos Biológicos (INRB/IPMA), Lisbon, Portugal

American plaice in Div. 3M	Ricardo Alpoim	ralpoim@ipma.pt
Golden redfish in Div. 3M	Ricardo Alpoim	ralpoim@ipma.pt
Redfish in Div. 3M	Ricardo Alpoim (provisional)	ralpoim@ipma.pt
Redfish in Div. 3LN	Ricardo Alpoim (provisional)	ralpoim@ipma.pt

From the Greenland Institute of Natural Resources, Nuuk, Greenland

Redfish in SA1	Rasmus Nygaard	rany@natur.gl
Other Finfish in SA1	Rasmus Nygaard	rany@natur.gl
Greenland halibut in Div. 1A inshore	Rasmus Nygaard	rany@natur.gl
Greenland halibut in Div. 1BC inshore	Rasmus Nygaard	rany@natur.gl
Greenland halibut in Div. 1D inshore	Rasmus Nygaard	rany@natur.gl
Greenland halibut in Div. 1EF inshore	Rasmus Nygaard	rany@natur.gl
Northern shrimp in SA 0+1	AnnDorte Burmeister	anndorte@natur.gl
Northern shrimp in Denmark Strait	Frank Rigét	frri@natur.gl

From Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO), Russian Federation

Capelin in Div. 3NO	Konstantin Fomin	fomin@pinro.ru

From National Marine Fisheries Service, NEFSC, Woods Hole, Massachusetts, United States of America

Northern Shortfin Squid in SA 3 & 4	Lisa Hendrickson	lisa.hendrickson@noaa.gov

2. Election of Chairs

Scientific Council has elected the following chairs for the period October 2021 – September 2023:

Scientific Council Chair:	Karen Dwyer (Canada)
STACREC Chair (and SC vice-Chair):	Diana González-Troncoso (EU)
STACFIS Chair:	Mark Simpson (Canada)
STACPUB Chair:	Rick Rideout (Canada)
STACFEN Chair:	Miguel Caetano (EU)

3. Budget items

The proposed Scientific Council budget including requests for 2022 was submitted to the scientific council as SCWP 21/003. The SC chair requested that SC members read the Working Paper and provide comments during the course of the meeting. No comments were received, and the proposed budget was therefore considered to have been approved by SC.

4. Proposed MoU with the Sargasso Sea Commission

The NAFO Secretariat has been approached by the Secretariat of the Sargasso Sea Commission (SSSC) about the possibility of signing a Memorandum of Understanding (MOU) between the two Secretariats. A draft text of a proposed MOU was made available to Scientific Council as SCWP 21/001 and presented by the Executive Secretary. The NAFO Secretariat seeks the advice of Scientific Council as to whether NAFO should in principle respond positively to this initiative of the SSSC. If so, the Secretariat would appreciate the advice of SC as to suggestions to improve the draft text. The Secretariat notes that the current areas of collaboration proposed by the SSSC focus on marine scientific research and the collection of data, which would be of particular relevance for the NAFO Scientific Council.

SC agreed that the MoU would be a useful initiative. SC members made a number of comments as follows:

- *The text is rather non-committal and vague in relation to common measures and initiatives, particularly in relation to seamount closures close to the boundary of the NRA.*
- *The scope of the text needs to be broadened (particularly in clause 2b) to include reference to marine ecosystems as well as marine species.*
- *The text needs to be changed to include the UK as a NAFO Contracting Party.*

The NAFO Executive Secretary invited the SC participants to provide him with written comments to forward to the SSSC after it has been further considered by WG-EAFFM.

5. Other Business

No other business was considered.

XIII. ADOPTION OF COMMITTEE REPORTS

The limitations of meeting by correspondence implied that the reports of the Standing Committee on Fisheries Science (STACFIS) could only be formally adopted by correspondence later in the month of June. The adopted report is included as Appendix IV.

The reports of the Standing Committee on Fisheries Environment (STACFEN) and the Standing Committee on Research Coordination (STACREC) and the Standing Committee on Publications (STACPUB) were deferred until September.

XIV. SCIENTIFIC COUNCIL RECOMMENDATIONS TO THE COMMISSION

The Council Chair undertook to address the recommendations from this meeting and to submit relevant ones to the Commission.

XV. ADOPTION OF SCIENTIFIC COUNCIL REPORT

At its concluding session on 11 June 2021, the Council considered the draft report of this meeting, and adopted the report. The usual understanding that the report remains in draft form for about two weeks, and that during this period the Chair and the Secretariat may incorporate minor edits (after proof-reading) on the usual strict understanding there should be no substantive changes, is applied.

XVI. ADJOURNMENT

The Chair thanked the participants for their hard work and cooperation, noting the particularly difficult circumstances of this year's meeting. The Chair thanked the Secretariat for their valuable support. There being no other business the meeting was adjourned at 13:00 on 11 June 2021.

APPENDIX I. REPORT OF THE STANDING COMMITTEE ON FISHERIES ENVIRONMENT (STACFEN)

The report of STACFEN was deferred to September.

APPENDIX II. REPORT OF THE STANDING COMMITTEE ON PUBLICATIONS (STACPUB)

The report of STACPUB was deferred to September.

APPENDIX III. REPORT OF THE STANDING COMMITTEE ON RESEARCH COORDINATION (STACREC)

The report of STACREC was deferred to September.

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

Chair: Katherine Sosebee Rapporteurs: Various

I. OPENING

The Committee met by correspondence from 27 May to 11 June 2021 to consider and report on matters referred to it by the Scientific Council, particularly those pertaining to the provision of scientific advice on certain fish stocks. Representatives attended from Canada, Denmark (in respect of Faroe Islands and Greenland), the European Union, Japan, the Russian Federation, Ukraine, the United Kingdom and the United States of America. Observers from the Ecology Action Centre, Sustainable Fisheries Greenland, and Oceans North were also present. The Executive Secretary, Scientific Council Coordinator and other members of the Secretariat were in attendance.

The Chair, Katherine Sosebee (USA) opened the meeting by welcoming participants. The agenda was reviewed and a plan of work developed for the meeting in accordance with the Scientific Council plan of work. The provisional agenda was adopted with minor changes.

Owing to the limited time available during the meeting, it was not possible to consider drafts of report sections in plenary. Following presentation and discussion of the assessments, Designated Experts produced drafts of their respective report sections offline and uploaded them to the Scientific Council SharePoint. Committee members were given the opportunity to comment before the approval of these report sections. As in previous years, designated reviewers were assigned for each stock for which an interim monitoring update was scheduled (see SC Report).

II. GENERAL REVIEW

1. Review of Recommendations in 2019 and 2020

STACFIS agreed that relevant stock-by-stock recommendations from previous years would be considered during the review of a stock assessment or noted within interim monitoring report as the case may be and the status presented in the relevant sections of the STACFIS report

2. General Review of Catches and Fishing Activity

The NAFO Secretariat presented the catch estimates developed by CESAG in COM-SC CESAG-WP 21-05 and made the supplementary data that went into the analyses available for SC to review. The Secretariat noted that the catches were estimated based on the strategy outlined in Annex 1 of COM-SC Doc. 17-08, amended following a recommendation from STACFIS in 2018, to include catch estimates of broken down by quarter and gear type.

It was also noted that a number of contracting parties had not submitted catch submissions for 2019 at the time of the meeting, therefore many of the STATLANT 21A catches reported in the catch tables in this report should be considered provisional.

3. External Review

Due to the difficulties caused by the COVID-19 pandemic, the SC executive decided not to have an external reviewer in 2021.

III. STOCKS ASSESSMENTS

A. STOCKS OFF GREENLAND AND IN DAVIS STRAIT: SA 0 AND SA 1

Recent Conditions in Ocean Climate and Lower Trophic Levels

- *The ocean climate index in Subarea 0-1 was normal in 2020;*
- *The initiation of the spring bloom was delayed for a second consecutive year in 2020;*
- *Total spring bloom production (magnitude) was near normal in 2020.*

Environmental Overview

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. A1.A). After being in 2019 at its highest value since the record high of 2010, the index was normal in 2020. 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 but several notable late bloom onsets have been recorded during the late 2010s (Figure. A1.B). In 2020, the initiation of the spring bloom was later than normal for a second consecutive year. Spring bloom magnitude (total production) remained mostly below to near normal between 2003 and 2020 with the exception of a few highly productive bloom in 2006, 2015 and 2018 (Figure. A1.C). The late bloom onset observed in 2019 and 2020 are associated below or near normal total production for the corresponding years (Figure. A1.B-C).

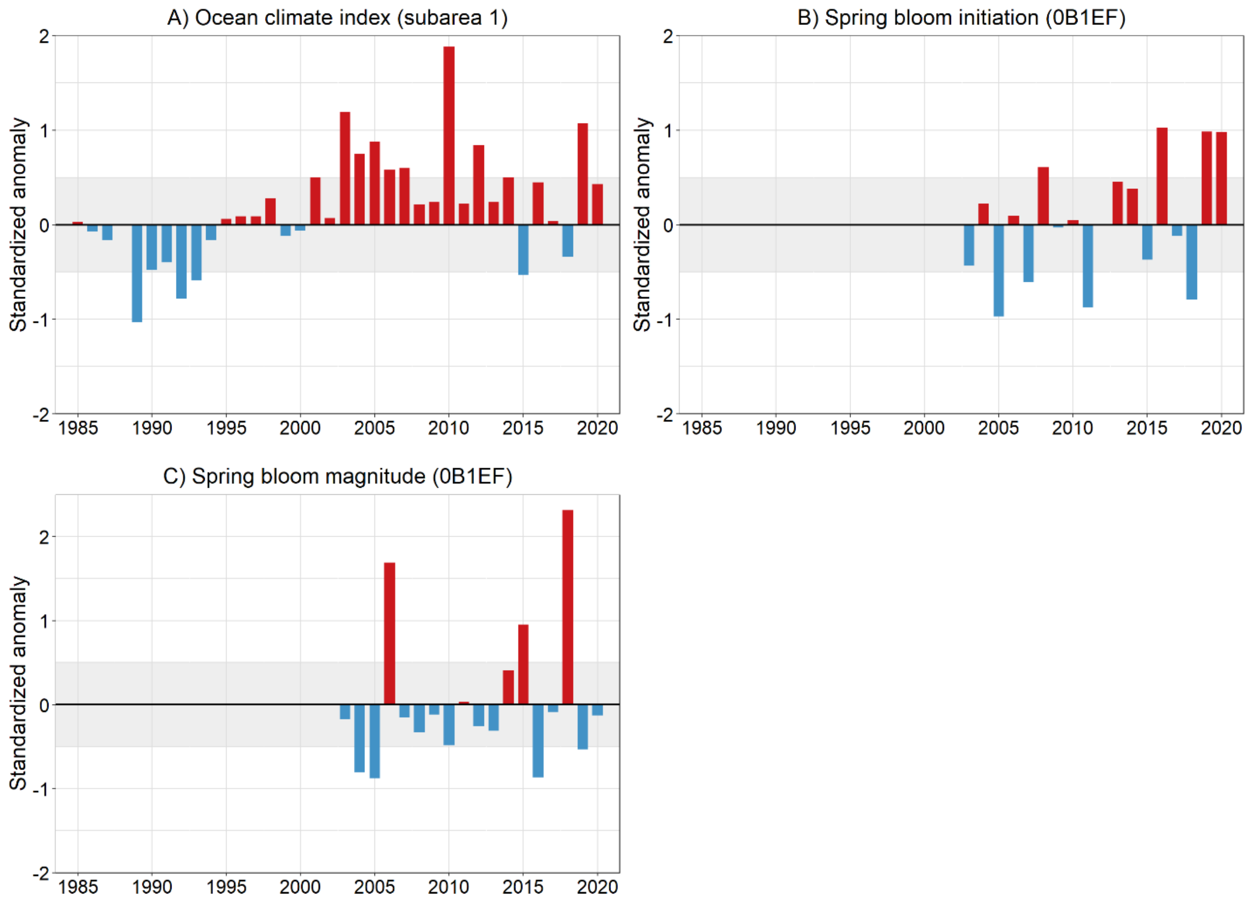


Figure A1. Environmental indices for NAFO Subarea 0 and 1. The climate index (A) for Subarea 0 and 1 is the average of 10 individual time series. These includes standardized anomalies of 4 SSTs time series, 4 temperature time series at 3 hydrographic stations and 2 air temperatures time series (see text for details). Phytoplankton spring bloom initiation (B) and magnitude (C) indices for the 2003-2020 period are derived from three satellite boxes covering NAFO Divs. 0B and 1EF (see text for details). Positive/negative anomalies indicate values above/below (or late/early timing) the long-term average for the reference period. Anomalies were calculated using the following reference periods: 1981-2010 for ocean climate index, 2003-2020 for spring bloom initiation and magnitude. Anomalies within ±0.5 SD (grey rectangle) are considered near-normal conditions.

1. Greenland Halibut (Reinhardtius hippoglossoides) in SA0+1 (offshore)

Interim Monitoring Report (SCR 21/008, 21/014; SCS 21/007, 21/009, 21/010, 21/011)

a) Introduction

A TAC for Greenland halibut in Subarea 0 + 1 (offshore) was established in 1994, following the separation of the Division 1A inshore stock area from the offshore. In 2020 the Divisions 1B-F inshore stock areas were also separated from the offshore management area. Catches prior to 1994 varied with peaks in 1975 and 1992 of 20,000 t. Since 1994 catches have increased in response to increases in TAC from approximately 9000 t to 36,400 t in 2019.

Table 1.1. Recent catches and TACs ('000 t)

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TAC	27	27	30	30	30	32.3	32.3	36.4	36.4	36.4
SA 0	13.3	13.4	14.9	15.4	14.1	15.9	16.0	18.3	17.9	
SA 1	13.5	13.5	14.7	14.9	15.2	16.2	16.2	18.0	18.1	
Total STACFIS[1]	26.8	26.9	29.6	30.3	29.3	32.1	32.2	36.3	36.0	

[1] Based on STATLANT, with information from Canada and Greenland authorities used to exclude Divs. 1A-F and Div. 0B inshore catch. The 2020 STATLANT data is provisional.

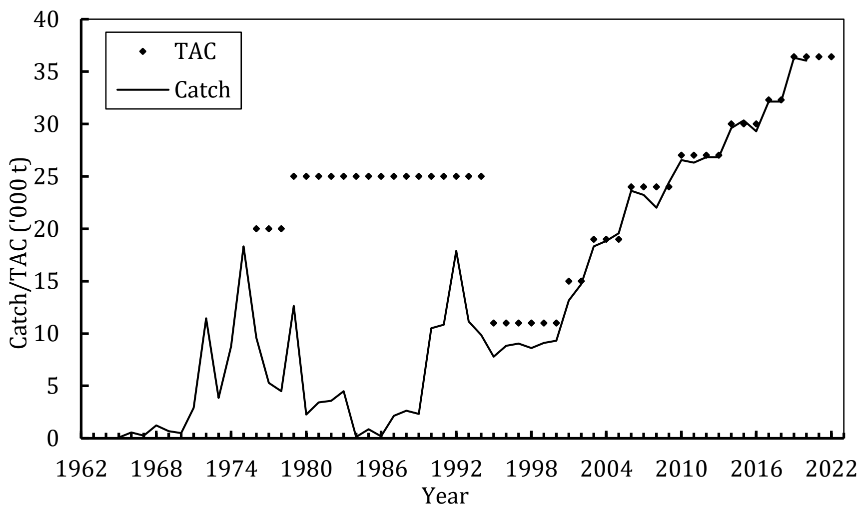


Figure 1.1. Greenland halibut in Subareas 0+1 (offshore): catch and TAC from 1964 to 2020.

b) Data Overview

In the past, surveys were conducted by Russia and the Federal Republic of Germany in 0B (1987-1992) and by Greenland and Japan in 1BCD (1987-1995). Greenland and Canada began conducting surveys in 1997 and 1999, respectively.

Surveys for both Greenland and Canada were completed with the RV Pâmiut until this vessel was decommissioned following the 2017 surveys. Commercial vessels were contracted to conduct surveys during 2018 to 2020 using all of the standard gear from the RV Pâmiut (cosmos and alfredo trawls, doors, bridles etc.) with trawl performance monitored using Marport sensors on doors and headlines, in an effort to make the surveys as similar as possible with the previous surveys. No comparative fishing was conducted between the vessels. Trawl performance was examined in 2019 using data on net height, wing spread and door spread (SCR 20/015). Results for the RV Pâmiut, C/V Sjudarberg and C/V Helga Maria used for the West Greenland shrimp and fish survey, from which the age-1 Greenland halibut abundance index is derived, indicated the gear performance was similar among the vessels and years and the results of the surveys were comparable. However, gear performance for the deepwater 1CD and 0A-South surveys in 2019 was substantially different from that of the RV Pâmiut, particularly at depths below 700 m and the results of the 2019 survey were not considered comparable to the previous time series.

Greenland Surveys. Since 1997 Greenland has conducted stratified random bottom trawl surveys during September-October in NAFO Div. 1CD, from 400 to 1500 m. Biomass in 1CD has fluctuated with a slight positive trend through most of the time series. In 2017, biomass was similar to levels seen in 2015 and 2016. There were no surveys in years 2018 and 2020, and the 2019 estimate is not comparable to previous values.

Canada Surveys. Since 1999 Canada has conducted surveys in Subarea 0 in the fall. Surveys in 0A-South (to 72°N) were completed in 1999, 2001, every second year between 2004 and 2014, and annually to 2017. The 2006 survey had poor coverage and was not considered valid. Biomass in Div. 0A-South varied with an increasing trend from 1999 to 2016 followed by a marked decline in 2017. Surveys in 0B have been less frequent with surveys in 2000, 2001, 2011 and 2013-2016. Biomass for Div. 0B in 2016 was similar to a previous high observed in 2011. There were no surveys in years 2018 and 2020, and the 2019 estimate is not comparable to previous values.

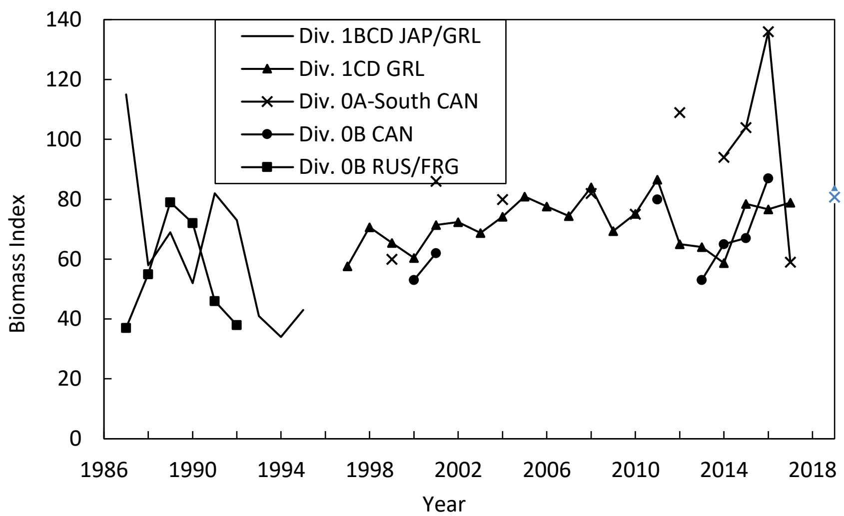


Figure 1.2. Greenland halibut in Subareas 0+1 (offshore): biomass indices from bottom trawl surveys. The survey in Div. 0A-South in 2006 is not included due to poor coverage.

Combined 0A-South and 1CD Survey Index. In 2014 STACFIS adopted a recommendation from the ICES Greenland halibut benchmark meeting (ICES 2013) to create a combined survey index with which to monitor the overall Subarea 0+1 (offshore) stock. The surveys are conducted with the same vessel and gear during the fall which allowed for simple addition of the survey estimates to create the index. The index had remained stable at a relatively high level during 1999-2012 and therefore, based on Precautionary Approach Framework guidance from NAFO SC for stocks assessed using an index (SCS 04/12), the average over this period was accepted as a proxy for B_{msy}, and B_{lim} was set as 30% of the proxy B_{msy}. The index increased between 2014 and 2016 and while it declined in 2017 it remained well above B_{lim}. The decline observed in 2017 was a result of a decline in 0A-South. The 2019 value is included for information purposes only, as it is not considered directly comparable to previous values due to the vessel change.

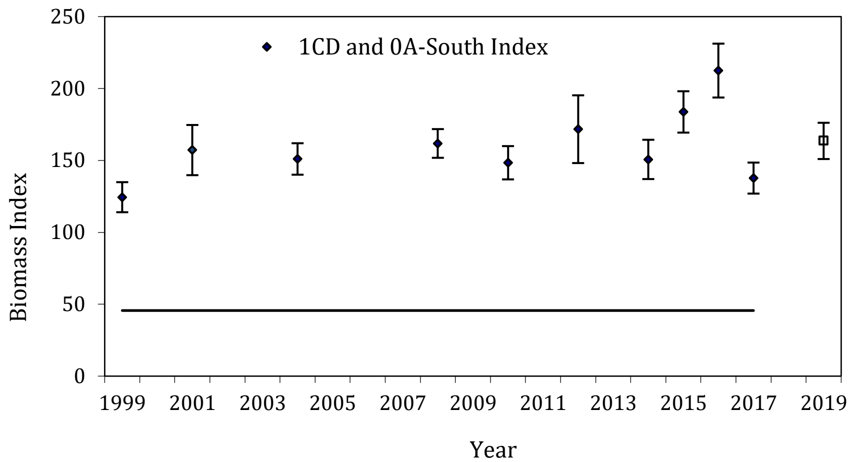


Figure 1.3 Greenland halibut in Subarea 0+1 (offshore): 0A-South and 1CD combined biomass index 1999-2017 (solid diamonds), B_{lim} (line), and the 2019 survey (open square).

Age-1 Abundance Index. The Petersen-method is used to assign Greenland halibut caught during the West Greenland shrimp survey to age 1, 2 and 3+ using length data. The number of 1 year old fish in the survey area, including Disko Bay (also area within Division 0A when available), is used as an age-1 index to help inform stock status. The index was generally increasing from 1988 to 2003, followed by a declining trend to 2010, and since then the index has been variable with series high values observed in 2011, 2013 and 2017. Abundance in 2020 is near the series average. A change in survey vessel occurred in 2018, but gear performance analyses concluded the surveys were comparable.

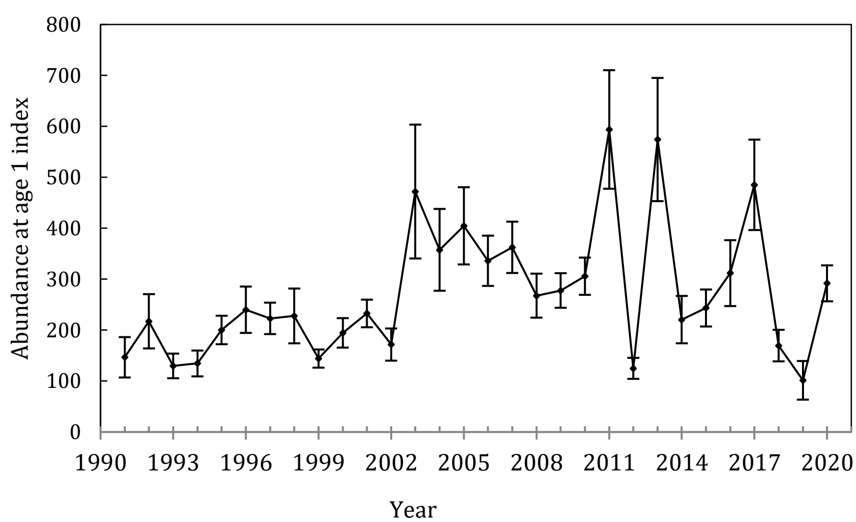


Figure 1.4. Greenland halibut in Subareas 0+1: age-1 abundance index for Subarea 1, derived from the Greenland shrimp and fish surveys (including sets in Division 0A where available).

c) Conclusion

The combined Divs. 1CD and Div. 0A-South biomass index was above B_{lim} throughout the time series, 1999 to 2017.

In 2020, the age-1 abundance index was near the series average and there have been high abundances in 2011, 2013 and 2017. It is unclear if age-1 abundance is representative of future recruitment, but it is considered to contribute to the perception of overall stock status.

In 2020 Scientific Council advised that there is a low risk of Greenland halibut in Subareas 0 + 1 being below B_{lim} if the TAC for 2021 and 2022 remained at 36 370 tonnes. This advice is still considered valid.

The next full assessment of this stock is planned for 2022.

2. Greenland halibut Subarea 1 inshore.

Interim monitoring report (SCR Doc. 21/011 012 013 014 015 SCS Doc. 21/11)

a) Introduction

The Greenland halibut fishery in Subarea 1 developed in the beginning of the twentieth century, with the introduction of the longline to Greenland in 1910. The inshore stock in Division 1A was separated from the offshore management area in the Davis strait and Baffin Bay in 1994. In 2020 divisions 1B to 1F inshore were separated from the offshore management area. The fishery is a small boat fishery using longlines and gillnets in the fjords. In division 1A gillnets are also allowed and the fishery also takes place from sea ice during the winter months. A shared TAC was introduced in divisions 1A inshore in 2008 and changed in 2012 to a shared TAC for small boats and ITQ for small vessels. The fishery in Divisions 1B to 1F is comparably smaller and has never been quota regulated. The fjord stocks are believed to depend on recruits from the offshore stocks in the Davis strait and East Greenland. Adults in the fjords are considered isolated from the stocks in Davis Strait and Baffin Bay. Besides the three main areas, a fishery is slowly developing in the Qaanaaq fjord (77 degrees North).

In the Disko Bay (1A inshore) catches increased in the 1980s, peaked from 2004 to 2006 at more than 12 000 t, but then decreased substantially. From 2009, catches been in most years been between 8000 and 9000 t annually. In 2020 catches decreased to 7602 t.

Catches in the Uummannaq fjord (1A inshore) gradually increased from the 1980s reaching 8 425 t in 1999, but then decreased and remained between 5000 and 6000 t from 2002 to 2009. After 2009 catches gradually increased reaching a record high 10 677 t in 2020.

In the fjords in the Upernavik area (1A inshore) catches increased from the mid-1980s and peaked in 1998 at a level of 7000 t. Landings then decreased sharply, but during the past 15 years, they have gradually returned to the higher level.

In the Sisimiut/Maniitsoq area (1BC inshore) catches increased in the area from the 1960s reaching more than 1500 t in 1980. After this intense fishing period, catches decreased and from 1987 catches were at a low level. From 2008, catches have gradually increased reaching 300 t in 2019 and decreasing to 190 t in 2020.

In the fjords near Nuuk (1D inshore) catches were around 500 t annually from 1966 to the end the 1980s and peaking in 1985 with 2136 t. After this intense fishing period, the fishery was at a low level for two decades. From 2003 catches gradually increased, reaching 1369 t in 2016. In 2020, catches were 855 t.

In the fjords in the Paamiut/Qaqortoq area (1EF) a fishery for Greenland halibut took place from 1910-1931 in Division 1F and from 1919 to 1939 in Division 1E. No data are available from 1940 to 1960. From 1960 catches gradually increased and were around 1000 t/year from 1982 to 1985. From 1990 and the following two decades the average catches were just around 60 t/year, but since 2014 annual catches have been at 400-800 t/year. In 2020, catches decreased to 391 t.

Recent catch and TACs ('000 tonnes) are as follows:

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1A Qaanaaq - Catch	0.02	0.05	0.01	0.13	0.14	0.14	0.21	0.25	0.22	0.18	
1A Qaanaaq - TAC	-	-	-	-	-	-	-	-	-	-	-
1A Upernavik - TAC	6.50	6.50	7.95	9.50	9.50	9.50	9.50	9.50	8.46	8.46	8.13
1A Upernavik - Catch	6.47	6.83	6.04	7.38	6.27	7.36	6.78	7.55	8.97	7.57	
1A Uummannaq - TAC	6.00	6.00	7.45	8.38	9.50	9.85	9.50	9.50	9.90	9.90	9.17
1A Uummannaq - catch	6.40	6.13	7.01	8.20	8.24	10.30	9.05	8.84	10.16	10.68	
1A Disko Bay – TAC	8.00	8.00	9.00	9.00	9.20	9.65	9.20	9.20	11.08	10.58	7.85
1A Disko Bay - Catch	8.00	7.76	9.07	9.18	8.67	10.76	6.41	8.40	8.76	7.60	
1BC Sis Man - TAC	-	-	-	-	-	-	-	-	-	-	-
1BC Sis Man - Catch	0.10	0.06	0.11	0.24	0.18	0.15	0.20	0.28	0.30	0.19	
1D Nuuk - TAC	-	-	-	-	-	-	-	-	-	-	-
1D Nuuk - Catch	0.10	0.28	1.02	1.21	0.86	1.37	1.10	1.18	0.83	0.86	
1 EF Paa – Qar -TAC	-	-	-	-	-	-	-	-	-	-	-
1EF Paa – Qar -Catch	0.05	0.07	0.14	0.37	0.48	0.51	0.79	0.66	0.45	0.39	
STACFIS Total	21.38	21.17	23.40	26.71	24.86	30.59	24.53	27.09	29.69	27.46	

Note: Upernavik catch for 2019 corrected.

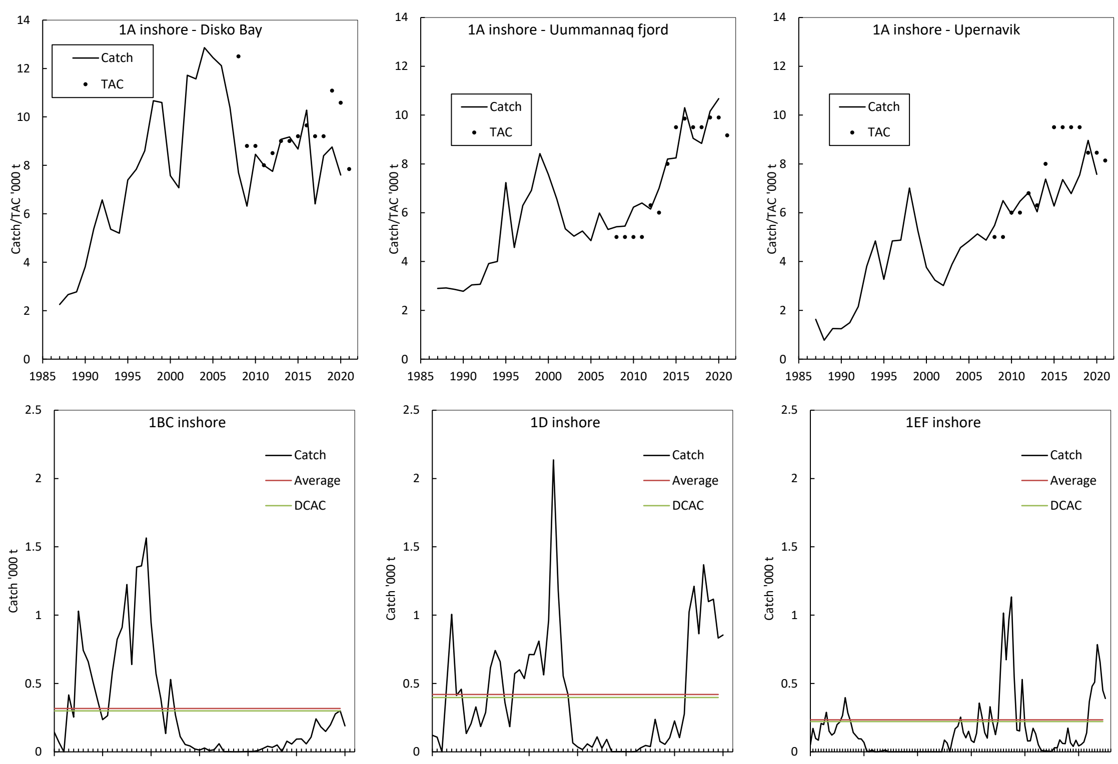


Figure 2.1. Greenland halibut in Subarea 1 (inshore): Catches and TAC.

b) Data overview

Length frequencies from factory landings. Length frequencies from factory landings has been used to calculate the mean length in the landings by season and gear. From 2010 an annual mean length in the landings is calculated accounting for season, gear, and in the Disko Bay also fishing area (Figure 2.2).

In the **Disko Bay** (1A inshore), mean length in the landings gradually decreased for more than a decade in both the winter and summer longline fishery and in the overall mean length weighted by gear and fishing ground. Glacier ice limits the access to the deep areas of the Ilulissat Icefjord (Kangia) during the summer, causing the difference between the summer and winter fishery mean length. From 2010 the mean length in the landings accounts for amounts caught within and outside the Ilulissat icefjord.

In the **Uummannaq** fjord (1A inshore) the mean length in the landings gradually decreased after 1993 to 2018. From 2018 to 2020 the mean length in the landings has remained stable around 57 cm. In the fjords near **Upernavik** (1A inshore)**,** the mean length in the commercial landings decreased from 1993 to 1998. From 1999 to 2009, the mean length in the longline fishery remained constant, but has since then gradually decreased further. In the fjords in the Sisimiut/Maniitsoq area (1BC inshore) very little data is available. Greenland halibut landed from the fjords near **Nuuk** (1D inshore), the mean length in the commercial landings gradually decreased from the 1970s to the 1980s and again since 2011 (Figure 2.2). Very little data is available from the fjords between Paamiut and Qaqortoq (1EF inshore).

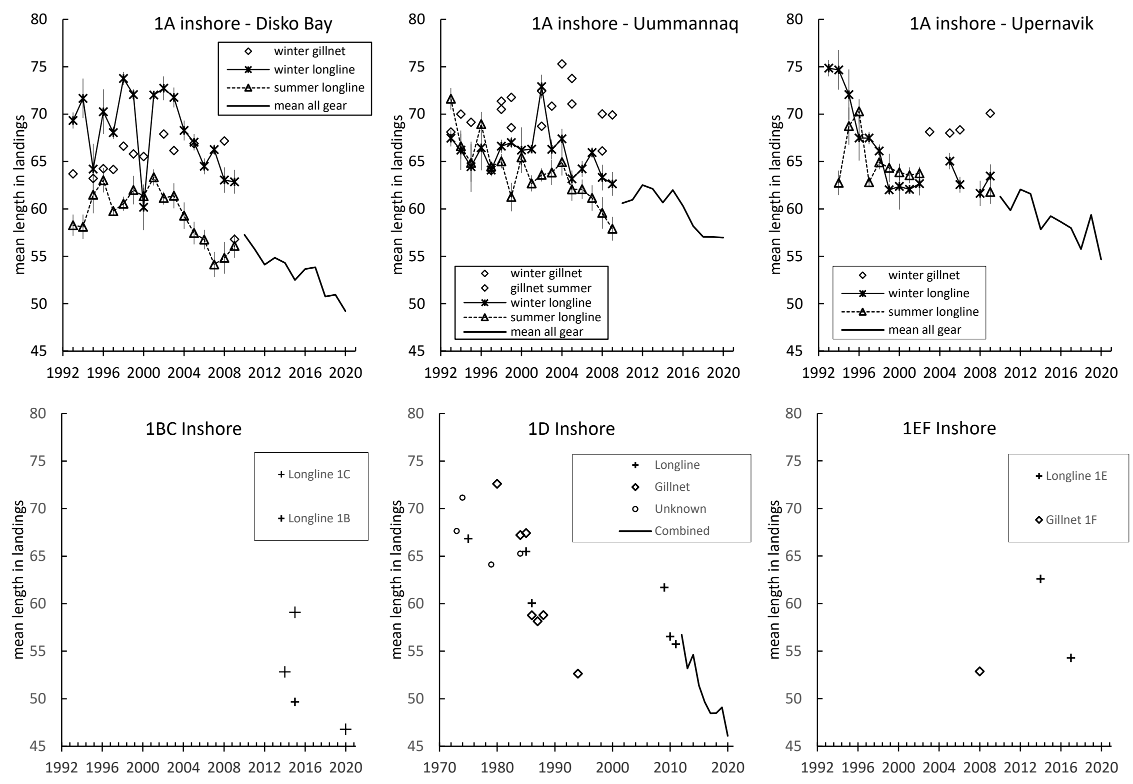


Figure. 2.2. Greenland halibut in Division 1A inshore: mean length in landings from longline fishery by season (summer and winter) and overall mean taking account of fishing ground, season and gear.

Catch-per-Unit Effort. Logbooks have been mandatory for vessels larger than 30 ft since 2008. A general linear model (GLM) with year, month and boat as factors was applied to fit the longline and gillnet Catch-Per-Unit-Effort (logCPUE) available. Only longline setting with more than 200 hooks were included to omit outlier values and limit the influence of data potential gear errors on the analysis. CPUE observations were log-transformed prior to the GLM analysis. Least-mean square estimates were used as standardized CPUE series. (Figure 2.3).

In **the Disko Bay,** the standardized CPUE series show a decreasing trend since 2009. In **Uummannaq**, the initial years (2008-2010) were based on fewer observations. From 2011, the CPUE index decreased gradually, and the three most recent years are the lowest observed in the time series. In **Upernavik,** the CPUE index has gradually decreased with a substantial decrease in 2020. In this area, the CPUE index is more variable likely related to variability in winter ice and summer glacier ice conditions from year to year. In the **Nuuk** area (1D inshore) the CPUE index shows a gradual decrease from 2012. The CPUE has not been calculated for the 1BC inshore or 1EF inshore areas as less logbook information is available from these areas.

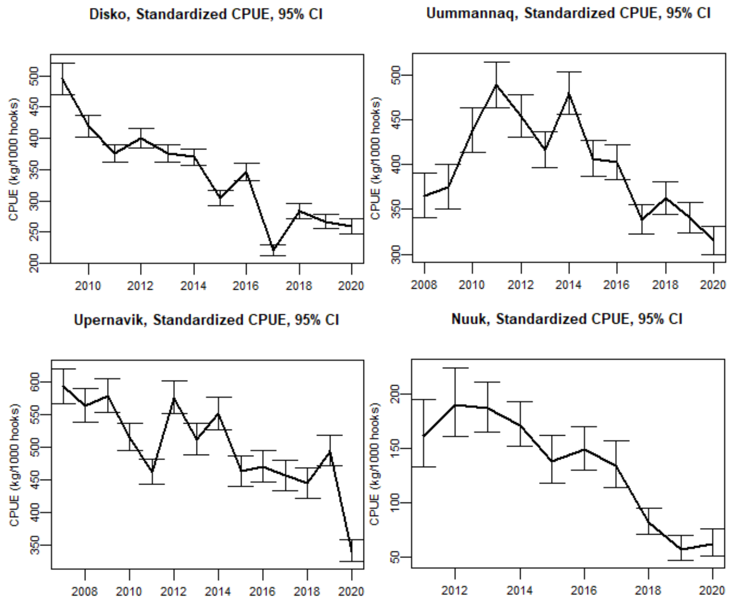


Figure 2.3 Standardized mean and 95% CI of longline CPUE in Disko bay (left), Uummannaq (center) and Upernavik (right).

Research survey data

The Greenland shrimp and fish survey (NAFO Div. 1A-F from 100 to 600 m). The survey covers the nursery areas offshore in Divisions 1A-1B and the Disko Bay. Therefore one- and two-year-old Greenland halibut typically provides the majority of the abundance index. Separate abundance and biomass indices and length frequencies has been calculated for the Disko bay part of the survey (Figure 2.4). The survey indicated an increasing abundance during the 1990's and high abundances were found from 1998 to 2005. After 2006, the abundance indices returned to the lower levels with the exception of the high abundances (mainly age 1) identified in 2011 and 2013. The biomass indices in the trawl survey indicate a steady increase during the 1990's, with a substantial increase observed in 2003 and 2004. After the gear change in 2005, the biomass index gradually decreased and stabilized at a lower level since 2013.

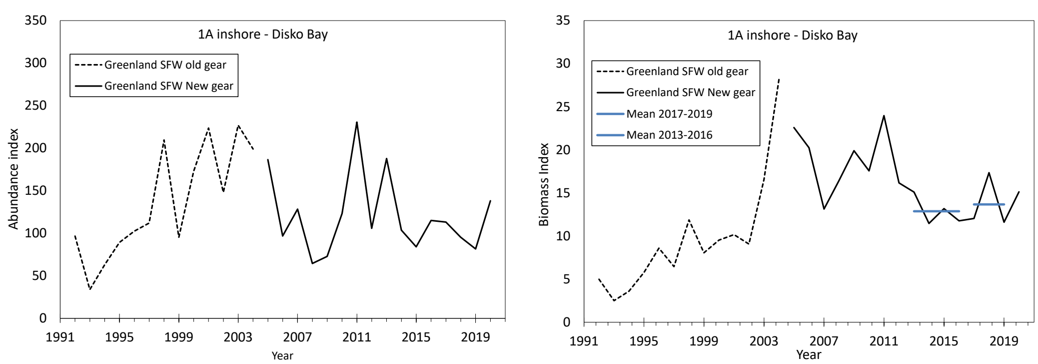


Figure 2.4. Greenland halibut in the Disko Bay (1A inshore): Abundance and biomass indices from the Greenland shrimp and fish trawl survey.

The Greenland shrimp and fish survey Inshore (1D inshore). A fixed station survey in the fjords near **Nuuk** (godthåbsfjord and Ameralik fjord) with the RV Sanna was initiated in 2015. From 2017 to 2020 both indices have been stable with the exception of the higher 2019 indices value (Figure 2.5). Length distributions in the survey indicates good recruitment with a dominance of the 2014, 2015 and 2016 YC.

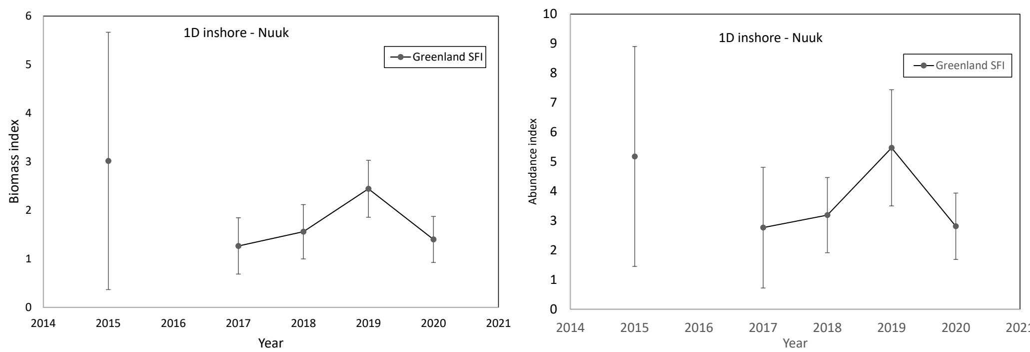


Figure 2.5. Greenland halibut in Division 1D inshore: Abundance and biomass indices in inshore trawl survey in Division 1D.

The 1A Disko Bay gillnet survey. The survey indicated low levels of pre-fishery recruits in 2006 and 2007 returning to above average levels in 2008 to 2011 (Figure 2.6). From 2013, the Gillnet survey NPUE and CPUE gradually decreased and remained below average levels until 2018. In 2019 and 2020, the survey was limited to stations in the important commercial areas. The apparent correlation between the gillnet survey NPUE and the number of Greenland halibut larger than 35 cm in the trawl survey implies a level of agreement between the gillnet survey and the trawl survey, although both surveys show large year to year variation. In 2019 and 2020 this apparent correlation does not continue. In these years the southern gillnet stations which normally have lower catch-per-effort were not covered. A larger mesh size added in 2016 did not impact the overall length distribution or CPUE in the Disko bay, indicating few larger individuals in the surveyed area (larger than 55 cm). The high NPUE and CPUE observed in 2020 were mainly Greenland halibut between 40 and 50 cm (2015 YC), but also higher than usual Greenland halibut around 30 cm were observed (2017 YC).

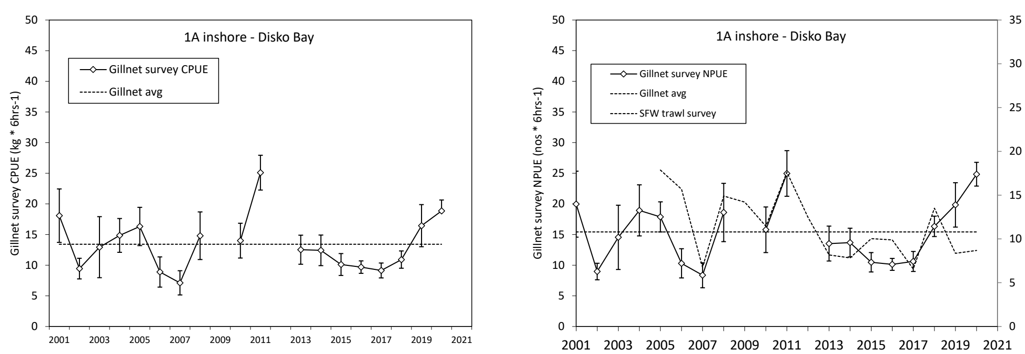


Figure 2.6. Greenland halibut in Division 1A inshore: Gillnet survey CPUE and NPUE +/-SE.

The 1A Uummannaq gillnet survey. The 2020 survey CPUE returned to the level observed prior to 2018. The gradual decrease in CPUE from 2015 to 2019, can also be seen as a as a gradual decrease in the number of large Greenland halibut as the CPUE decreases at a higher rate than NPUE. The high NPUE observed in 2020 was mainly caused by unusually high numbers of small Greenland halibut from 40cm to 50cm in the survey.

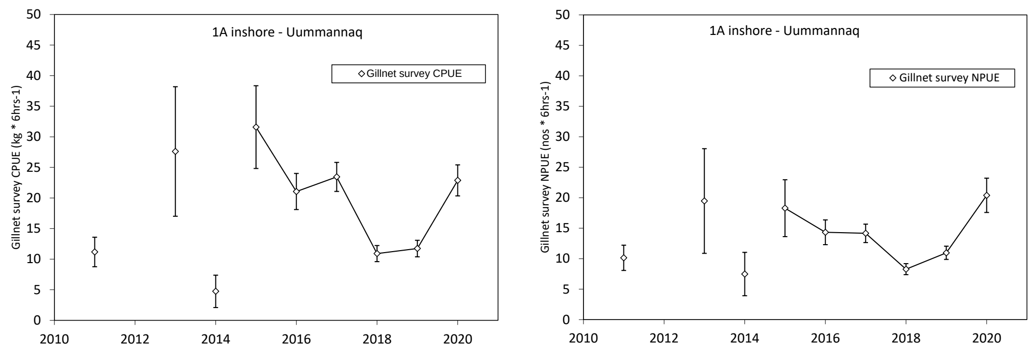


Figure. 2.7. Greenland halibut in Division 1A inshore: Gillnet survey CPUE and NPUE +/-SE.

The 1A Upernavik gillnet survey. The gillnet survey decreased slightly from 2015 to 2019. In 2020 a substantial increase in both NPUE and CPUE was observed. The increase is mainly caused by higher numbers of Greenland halibut from 40 to 55cm. Also, higher than usual numbers of 30 cm Greenland halibut (around 3 years) were observed (Figure 2.8).

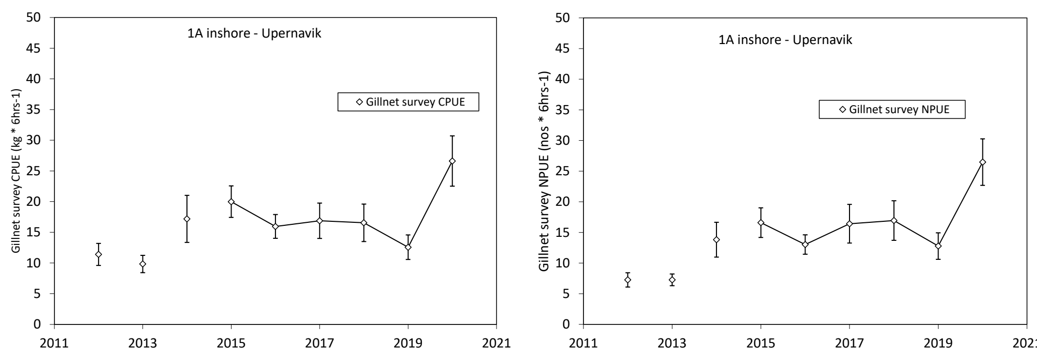


Figure 2.8. Greenland halibut in Division 1A inshore: Gillnet survey CPUE and NPUE +/-SE.

c) Conclusion

1A inshore - Disko Bay

The ICES Harvest Control Rule 3.2 for data limited stocks combined with the survey index from the Greenland shrimp and fish survey, has been used to formulate the advice since 2016. In 2020, catch advice was reduced to 4346 t. Although the DLS approach increased by 6%, a precautionary buffer was applied.

Since the most recent assessment, the CPUE based on longline logbooks and the mean individual length in the landings continued within the decreasing trend. The Greenland shrimp and fish survey in the Disko Bay increased slightly in 2020. The Gillnet survey increase in CPUE and NPUE in 2020 also increased. The increase was mainly caused by increasing numbers of Greenland halibut between 40cm to 50cm. However, the disconnection between the indices of the trawl and the gillnet survey calls for some caution when interpreting the survey results. Based on the updated indices there is no basis for a reassessment.

1A inshore - Uummannaq

Accounting for the decrease in the mean individual length in the landings since the stable 2010-2013 period, advice was reduced to 5153 t in 2020.

Since the most recent assessment, the Gillnet survey CPUE and NPUE has increased. The increase was mainly caused by an increase in Greenland halibut from 40cm to 50cm observed in 2020. In 2020, the commercial CPUE based on longline logbooks decreased further. The mean length in the landings has gradually decreased since 1993 but stabilized since 2018. With the updated indices there is no basis for a reassessment of the stock.

1A inshore - Upernavik

In 2020, advice was reduced to 5068 t, accounting for the decreasing mean individual size in the landings since 2010-2013.

Since the most recent assessment, the mean individual length in landings continued within the decreasing trend and the CPUE based on longline logbooks has decreased further. In 2020 a substantial across station increase in both NPUE and CPUE was observed. The increase was mainly caused by higher numbers of Greenland halibut from 40 to 55cm and higher than usual numbers of 30 cm Greenland halibut (around 3 years). Based on the updated indices there is no basis for a reassessment of the stock.

1BC inshore – Sisimiut/Maniitsoq area

Depletion Corrected Average Catch has been used to estimate a sustainable level of Catch of 300 t annually.

In 2020 total catch remained below 300 t. Based on the available data there is no basis for a reassessment of the stock.

1D inshore - Nuuk area

Depletion Corrected Average Catch has been used to estimate a sustainable level 398 t annually. In 2020, the SC recommended a gradual reduction of catches to this level, corresponding to 647 t in 2021 and 522 t in 2022.

Since the most recent assessment, the mean length in the landings and the Catch-per-Unit-Effort based on longline logbooks continued to decrease. The Greenland shrimp and fish survey inshore in division 1D showed presence of pre-fishery recruits. Based on the updated indices there is no basis for a reassessment of the stock.

1EF inshore – Paamiut/Qaqortoq area

In 2020, Depletion Corrected Average Catch was used to estimate a sustainable level of Catch of 222 t annually and advice was given to gradually reduce catches to this level over a period of three years (2021-2023). Based on the available data there is no basis for a reassessment of the stock.

These stocks will next be assessed in 2022

3. Demersal Redfish (*Sebastes* spp.) in SA 1

Interim Monitoring Report (SCR Doc. 88/12, 96/36, 07/88, 20/012 21/003 011 013 014; SCS Doc. 21/11)

a) Introduction

There are two demersal redfish species of commercial importance in NAFO Subarea 1, golden redfish (*Sebastes norvegicus*) and demersal deep-sea redfish (*Sebastes mentella*). Connectivity to other redfish stocks off East Greenland, the Irminger Sea, the Newfoundland and Labrador Shelf, and Iceland is unclear.

Fisheries and Catches

Both redfish species (*S. norvegicus, S. mentella*) are included in the catch statistics. Greenland operates the quota uptake by categorising the catches in three types of redfish: redfish caught by bottom trawl and longlines on the bottom are considered *Sebastes norvegicus* (REG) and redfish caught pelagic are considered *Sebastes mentella* (REB), however species identification does not occur in these fisheries*.* Redfish caught as by-catch in the shrimp fishery are considered *Sebastes sp.* (RED).

The fishery targeting demersal redfish in SA1 increased during the 1950s and peaked in 1962 at more than 60,000 t. Catches then decreased and have remained below 1000 tons per year after 1986 with few exceptions. However, official catches are uncertain with evidence of overreported catches from 1974-1977 (cod and other species reported as redfish) and underreporting of redfish taken as bycatch in the shrimp fishery. Studies of bycatch in the shrimp fishery estimated catch of redfish to be more than 14 000 t in 1988 and 4000 t in 1994. To reduce the bycatch in the shrimp fishery, 22mm sorting grids have been mandatory since 2002. Sorting grids and poor recruitment have since then limited the bycatch of redfish in the shrimp fishery to very low levels (add recent mean). In 2020, reported bycatches from shrimp trawlers increased from 1t in 2019 to 62 t; based on size (typically <20 cm) these redfish would be primarily recruits. Total reported by-catch in offshore fisheries targeting shrimp and Greenland halibut were 94t. Besides these, 101 t of commercially sized redfish were landed to factories mainly taken as bycatch in the fishery in the fjords (figure 4.1).

Recent catches ('000 tons) are as follows:

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TAC	1	1	1	1	1	1	1	1	0	0	0
STATLANT 21	0.2	0.12	0.16	0.25	0.19	0.16	0.23	0.19	0.10	0.21	
STACFIS	0.2	0.16	0.17	0.17	0.26	0.17	0.24	0.19	0.14	0.20	

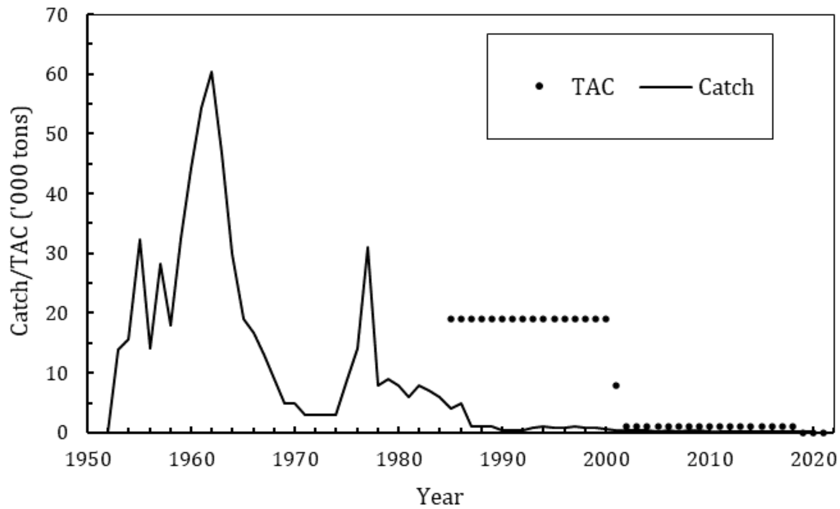


Figure. 3.1. Demersal redfish in Subarea 1: catches and TAC.

b) Data overview

i) Commercial fishery data

Mean length of golden redfish catches from sampling of EU-Germany commercial catches during 1962-90 revealed significant mean size reductions from 45 to 35 cm during the historic intensive fishery. No length distribution is available since 1990. There are no data available to estimate the size composition of catches of deep-sea redfish. Since redfish are currently taken as bycatch and landed in small amounts, little data of recent species or size composition in the landings are available. Logbooks and factory landings data were available.

ii) Research survey data

Indices for the demersal redfish stocks in Subarea 1 are estimated from 5 offshore surveys and 2 inshore surveys. The EU-Germany survey (RV Walther Herwig III) covers the shelf from 0-400m in East Greenland south of 66N and in West Greenland divisions 1C to 1F, from 1982. The Greenland deep-sea survey covers the shelf from 400-1500 m in divisions 1C and 1D. This survey has been carried out from 1997 to 2017 with the R/V Pâmiut. The survey was cancelled in 2018 and 2020 but updated in 2019 with a chartered vessel. The Greenland shrimp and fish survey (RV Pâmiut until 2017 and chartered vessels from 2018) covers the shelf in East Greenland south of 67N (since 2008) and South of 72N in West Greenland (1A-1F, since 1992) from 0-600m. The Greenland shrimp and fish survey has a more appropriate depth and geographical coverage with regards to redfish distribution and covers the important nursery areas in division 1B. However, no separation of redfish species was made prior to 2006. The effect of the vessel change was examined in both offshore Greenland surveys and it was found that the changes had a minimal effect at depth< 700 m, where the redfish occurs. The Gillnet survey in the Disko bay (1A) and a trawl survey in the Godthåb and Ameralik fjord (1D) provide information on species composition in the inshore areas. Besides the recent surveys, another index is available from a joint Greenland-Japan offshore survey (RV Shinkai Maru) occurred from 1987 to 1995 in divisions 1B to 1D from 400m to 1500m.

Golden redfish (*Sebastes norvegicus*)

The EU-Germany survey biomass index decreased in the 1980s and was at a very low level in the 1990s (figure 4.2). Increasing biomass indices of golden redfish were observed from 2005 to 2015 and decreasing thereafter. The Greenland shrimp and fish survey biomass index increased gradually from 2006 to 2016 and decreased thereafter. High indices in 2016 and 2019 are due to single hauls of large adults providing the majority of the total biomass estimate in those years. The EU-Germany survey and the Greenland shrimp and fish survey show similar overall trends with decreasing indices in the recent 5 to 6 years. The Greenland deep-sea survey and the historic Greenland-Japan survey is less informative due to shallower distribution of Golden redfish, and the inshore surveys have low indices for Golden redfish.

Demersal deep-sea redfish (*Sebastes mentella*)

The EU-Germany survey biomass index has fluctuated at a low level throughout the time series (figure 4.3). The fluctuating trend is likely caused by poor overlap with the depth distribution of adult deep-sea redfish. The Greenland-Japan survey biomass index gradually decreased from 1987 to 1995 and the low indices continued in the Greenland deep-sea survey from 1997 to 2006 (figure 4.3). From 2006, the Greenland deep-sea survey and the Greenland shrimp and fish survey biomass indices show similar trends. Biomass indices were low in both surveys in 2006 and gradually increased from 2007 to 2013 (figure 4.3). Both surveys had decreasing biomass indices since 2013 (excluding outlier years in 2016). The high 2016 biomass index in the Greenland shrimp and fish survey was caused by a single haul in division 1D of large redfish between 25 and 40 cm and is not considered reflective of population trends. About 80-95% of the redfish biomass in the trawl survey in Division 1D inshore since 2015 has been deep-sea redfish.

Juvenile redfish (<20cm both species combined)

The EU-Germany survey regularly found juvenile redfish from 1984 to 2000. After 2000, the abundance of juvenile redfish in the survey gradually decreased to a low level (figure 4.4). The Greenland shrimp and fish survey abundance of redfish (mainly recruits <20cm) decreased substantially from 1992 to 2004. In the Greenland shrimp and fish survey, the abundance of both species combined can be regarded as a recruitment index, since the survey initially had high numbers of small redfish in the fine meshed shrimp trawl used for the survey. From 1992 to 1999, high numbers of redfish recruits were observed annually, but the index gradually decreased and remained low until 2004. The decrease continued after the gear change in 2005 (figure 4.4). The increase in abundance in 2016 was primarily due to large redfish from a single large haul, and not recruits. Length distributions of redfish in the surveys showed a complete lack of new year classes from 2008 to 2019, but in 2020 a new year-class (YC) of redfish is observed. This YC is reflected in the increase in the abundance in the Greenland SFW juvenile index (Figure 4.4).

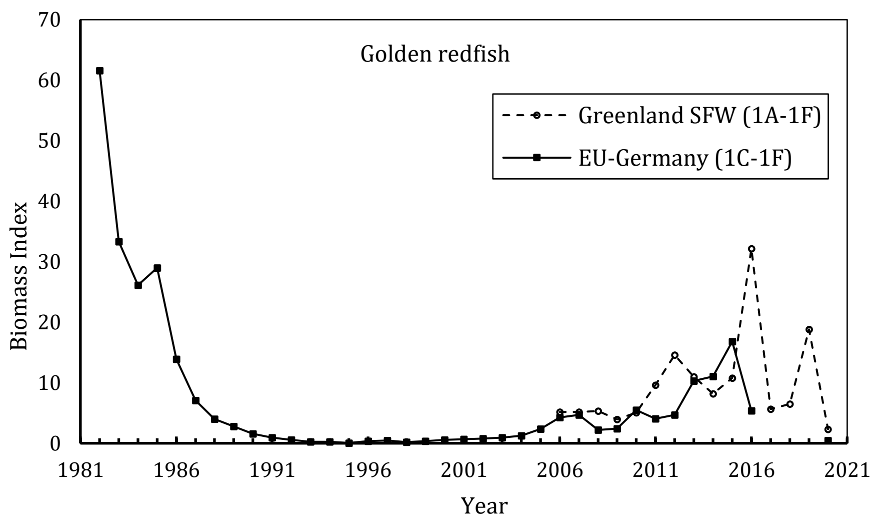


Figure. 3.2. Golden redfish biomass indices in the EU-Germany survey and the Greenland shrimp and fish survey (SFW).

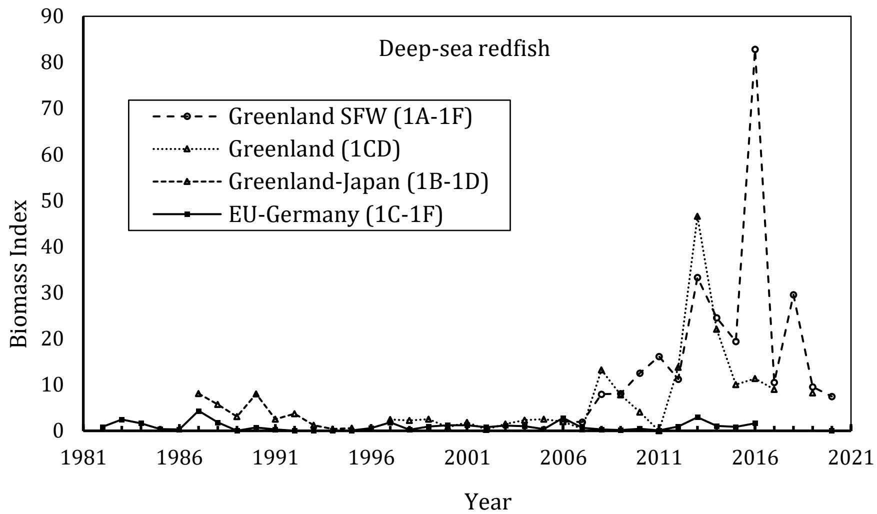


Figure. 3.3. Demersal deep-sea redfish survey biomass from the Greenland shrimp and fish survey (SFW), the Greenland deep-sea survey, the EU-Germany survey and the Greenland-Japan survey.

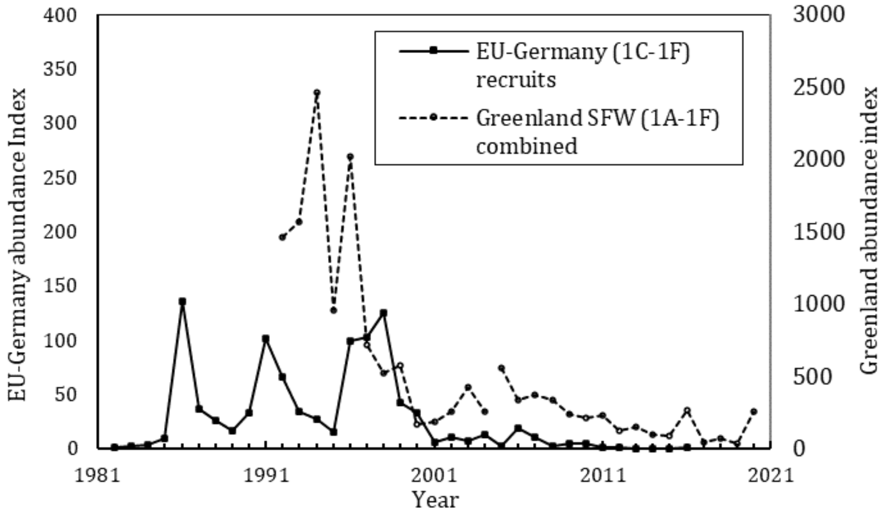


Figure. 3.4. Juvenile redfish abundance indices for the EU-Germany survey (*Sebastes sp.* <17cm), and the Greenland shrimp and fish survey (*Sebastes sp.* all sizes combined).

c) Conclusion

Golden redfish - *Sebastes norvegicus*

The stock was assessed in 2020 for the 2021-2023 period and current advice is "No directed fishery". With the updated indices there is no basis for a reassessment. Recruitment has been at a low level from 2008-2018 and the biomass indices in the surveys are in a decreasing trend.

Deep-sea redfish - *Sebastes mentella*

The stock was assessed in 2020 for the 2020-2023 period and current advice is "No directed fishery". With the updated indices there is no basis for a reassessment. Recruitment has been at a low level from 2008-2018 and the biomass indices in the surveys are in a decreasing trend.

This stock will next be assessed in 2023.

4. Wolffish in Subarea 1

Interim Monitoring Report (SCR Doc. 80/VI/72 77 96/036 07/88 20/040, 21/003 014 ; SCS Doc. 21/11)

a) Introduction

Three species of wolffish are common in Greenland. Only Atlantic wolffish (*Anarhichas lupus*) and spotted wolffish (*Anarhichas minor*) are of commercial interest. Northern wolffish (*Anarhichas denticulatus*) is an unwanted discarded bycatch. Atlantic wolffish has a more southern distribution and seems more connected to the offshore banks and the coastal areas. Spotted wolffish can be found further north in West Greenland than Atlantic wolffish both in the fjords and offshore. Atlantic wolfish has a shallower depth distribution (50-400m) than spotted wolffish (50-600m).

Fisheries and catches.

Wolffish are primarily taken as a bycatch in other fisheries. A directed wolfish fishery typically occurs when quota ceilings has been reached for more economically important species. Although spotted wolffish and Atlantic wolffish are easily distinguishable from one another, the two species are rarely separated in catch statistics. The commercial fishery for wolffish in West Greenland increased during the 1950s and wolffish was initially targeted in the coastal areas. With the failing cod fishery off West Greenland, trawlers started targeting Atlantic wolffish on the banks off West Greenland and from 1974-1976 reported landings from trawlers were around 3,000 tons per year (Figure 5.1). After 1980, the cod fishery gradually stopped in West Greenland and catches of wolffish also decreased during this period. To minimize by-catch in the shrimp fishery, offshore trawlers targeting shrimp have been equipped with 22mm grid separators since 2002 and a inshore (Disko Bay) trawlers by 2011. Since 2015, reported catches have been at a lower level. The decrease is likely related to more profitable species being targeted. In 2020, 231 t of wolffish was landed to factories mostly taken as bycatch in inshore small boat fisheries and 20 t was reported from offshore vessels.

Recent nominal catches (000 tons) for Atlantic wolffish and Spotted wolffish.

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Atlantic wolffish TAC					1.00	1.00	1.00	1.000	0	0	0
Spotted wolffish TAC					1.03	1.03	1.02	0.975	0	0	0
Combined wolffish TAC	1	1	1	1	2.03	2.03	2.03	1.975	0	0	0
STATLANT 21	0.75	1.01	858	0.91	0.40	0.24	0.24	0.27	0.19	0.24	
STACFIS	0.78	1.01	858	0.91	0.40	0.20	0.24	0.26	0.19	0.25	

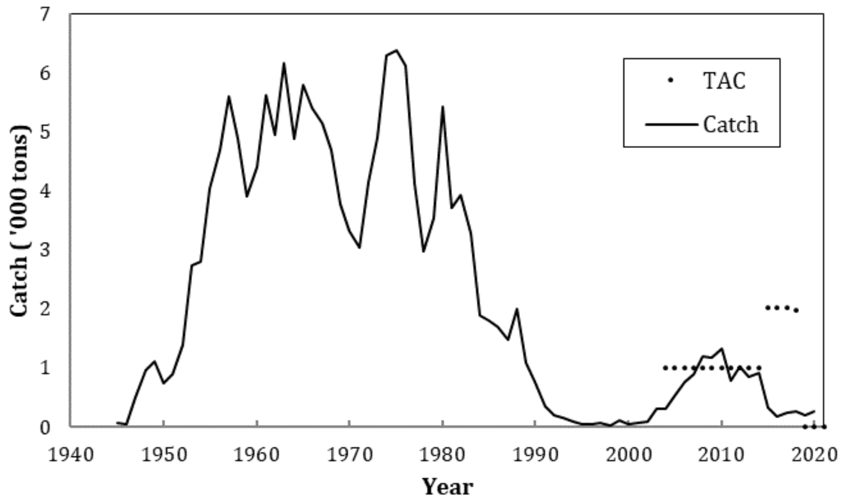


Figure 4.1. Wolffish in NAFO Subarea 1: Catches and TACs for Atlantic wolffish and spotted wolffish combined from 1945 to 2021.

b) Input data

i) Research survey data

The EU-Germany survey covers the Greenland shelf from 67 N off West Greenland to 66N off East Greenland at depths from 0-400m (RV Walther Herwig III. The survey started in 1982. In recent years not all strata have been covered particularly in divisions 1C and 1D. The Greenland shrimp and fish survey (Greenland-SFW covers the Greenland shelf from 72N off West Greenland to 67N off East Greenland at depths from 50-600m. The survey started in 1991 with RV Paamiut. The gear was changed in the Greenland-SFW survey in 2005, thus interrupting the survey index. RV Pâmiut was decommissioned in 2017 and commercial vessels using Pâmiut gear has been used to update indices since 2018. Analysis of trawl performance between Paamiut and the chartered commercial vessels, have indicated that the indices are comparable. The Greenland-SFW survey has a more appropriate geographical coverage in relation to wolffish than the EU-Germany survey. Both surveys cover the main depth distribution of wolffish.

Atlantic wolffish:

The EU-Germany survey biomass index decreased significantly in the 1980s (Figure 5.2. From 2002 to 2005 biomass index increased to above average levels, but thereafter returned to the low levels observed during the 1990s. The index was not updated from 2016 to 2019, due to low coverage and survey cancellation. Abundance index in the EU-Germany survey decreased from the beginning of the time series, in 1982 to 1984, since then it remained stable with slightly increasing level from 2002 until 2005. After 2005, the abundance index decreased to below average levels. This decrease may be related to a gradual reduction of the surveyed area (figure 5.2.

The Greenland-SFW survey biomass index was at low levels during the 1990s but increased slightly from 2002 and until the gear change in 2004. After 2005 the biomass index has continued to increase (figure 5.2. Abundance indices in the Greenland-SFW survey increased until the gear change in 2004 (Figure 5.2. From 2005 the increasing trend has continued. The increasing abundance and biomass in the Greenland SFW survey has partly been observed in divisions 1A-B, thus outside the EU-Germany survey area.

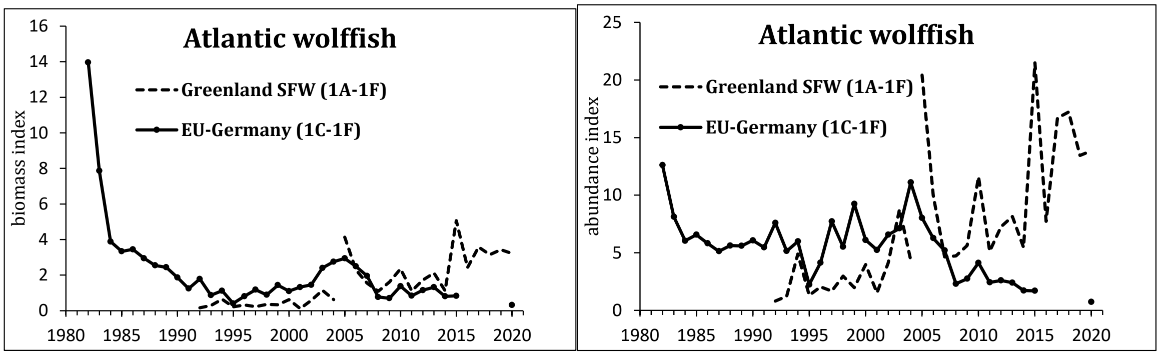


Figure. 4.2. Atlantic wolffish survey biomass index (left) and abundance index (right) from the surveys.

Spotted wolffish:

The EU-Germany survey biomass index decreased from 1982 to 1984 and remained at low levels during the 1990s (figure 5.3). From 2004, the survey biomass increased, and the recent indices were at the level observed at the beginning of the 1980s. Although highly variable, the abundance index has gradually increased since the mid 1990s (figure 5.3).

The Greenland SFW survey biomass index was at low levels during the 1990s but has gradually increased from 2002. After the gear change in 2005, survey biomass index has continued to increase (figure 5.3). The abundance index gradually increased both before and after the gear change (Figure 5.3).

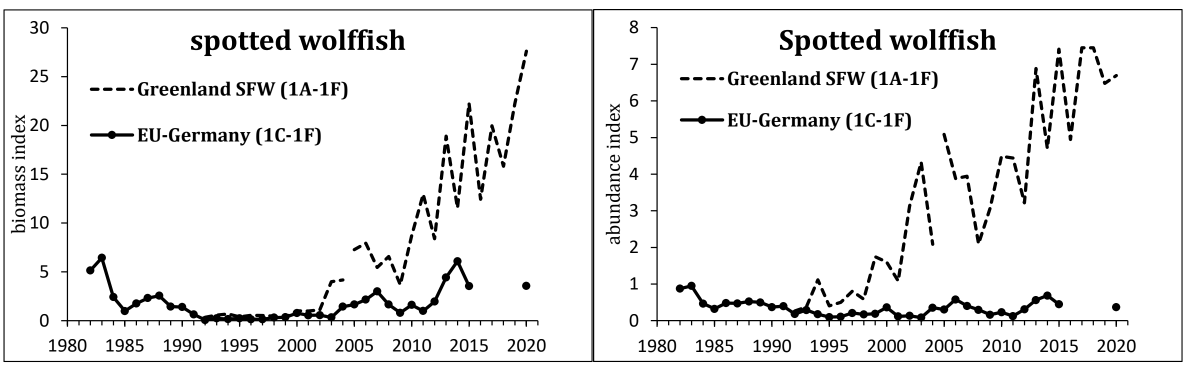


Figure. 4.3. Spotted wolffish survey biomass index (left) and abundance index (right) from the Greenland SFW and the EU-Germany survey.

Assessment results

Atlantic wolffish

This stock underwent full assessment in 2020, with the advice that there should be no directed fishery targeting Atlantic wolffish in NAFO Subarea 1. With the updated indices there is no basis for a reassessment in 2021, since the biomass indices of the EU-Germany survey remain below the initial values.

Spotted wolffish

This stock underwent full assessment in 2020. The ICES Harvest Control Rule 3.2 for data limited stocks combined with the survey index from the Greenland-SFW survey has been used to formulate the advice since 2017. For 2021-2023 annual catch advice was increased and not to exceed 1158 t. With the updated indices there is no basis for a reassessment in 2021. The survey indices remain within the increasing trend.

These stocks will next be assessed in 2024.

B. STOCKS ON THE FLEMISH CAP (NAFO DIVISION 3M)

Recent Conditions in Ocean Climate and Lower Trophic Levels

- *After being below normal between 2015 and 2017, the ocean climate index in 3M, has been normal since 2018;*
- *Spring bloom initiation was near normal in 2020 for a second consecutive year;*
- *Spring bloom magnitude was below normal in 2020 after three consecutive years of above-normal production;*
- *The abundance of copepod and non-copepod zooplankton was near normal in 2020 after having remained mostly above normal from 2015 to 2018;*
- *Zooplankton biomass was near normal in 2020 and has remained mostly near or below normal since its record-high in 2016.*

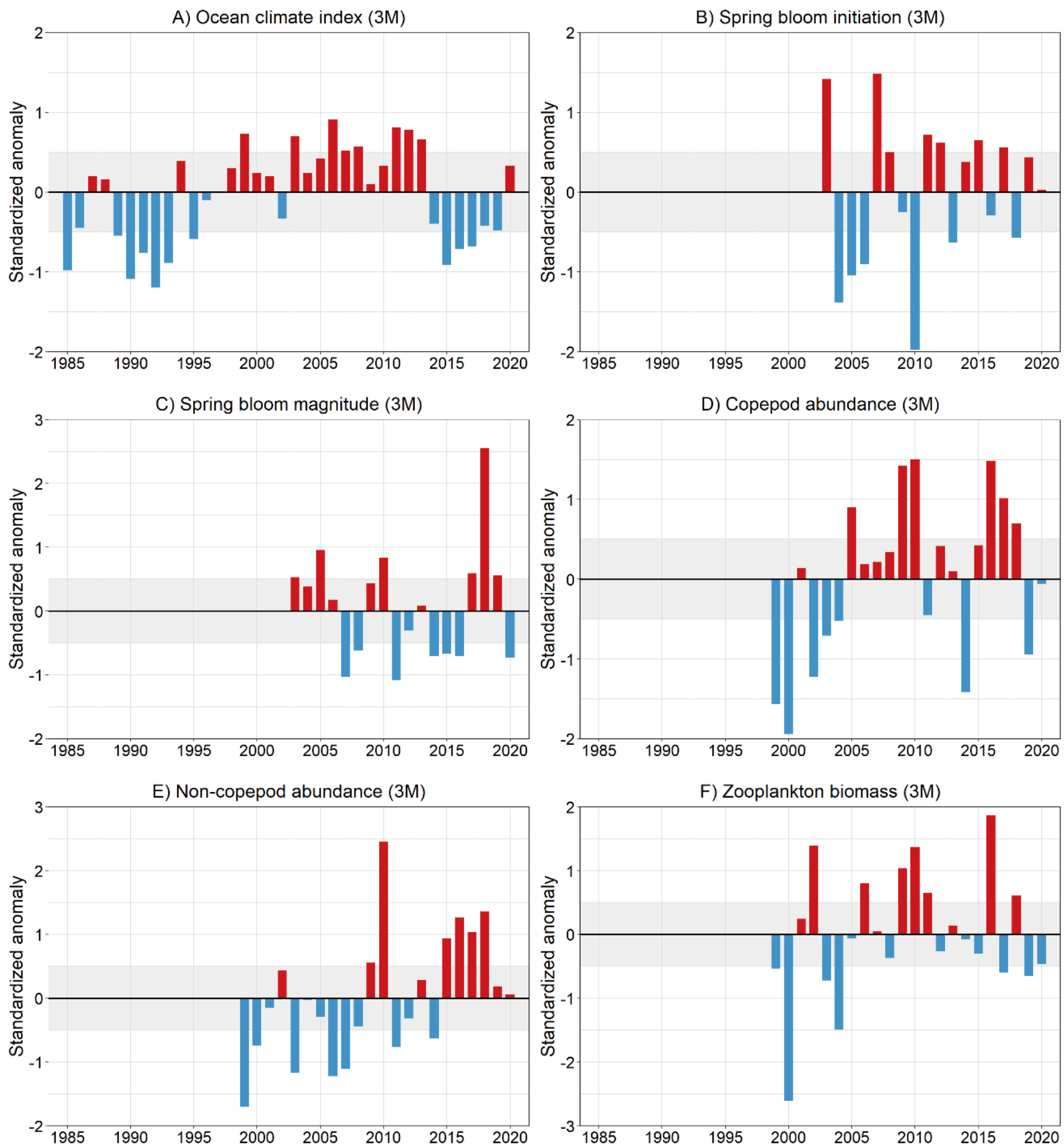


Figure B1. Environmental indices for the Flemish Cap (NAFO Div. 3M). The ocean climate index (A) for the Flemish Cap is the average of 3-time series of standardized ocean temperature anomalies of sea surface temperatures (SSTs), hydrographic section observations, and summer mean bottom temperature over the cap. Positive/negative anomalies indicate values above/below (or late/early timing) the long-term average for the reference period. Anomalies were calculated using the following reference periods: 1981-2010 for ocean climate index, 2003-2020 for spring bloom initiation and magnitude, and 1999-2020 for zooplankton abundance and biomass indices. Anomalies within ±0.5 SD (grey rectangle) are considered near-normal conditions.

Environmental Overview

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 (Figure B1). 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 Division 3M (Figure B1.A) has remained mostly above normal between the late 1990's and 2013. After the record-high of 2011, the index gradually decreased reaching in 2015 its lowest value since 1993. After been below normal between 2015-2017, the index was normal between 2018 and 2020. Spring bloom initiation has been oscillating between early and late timing between 2003 and 2020 but has remained mostly near or later than normal since 2011 (Figure B1.B). Spring bloom magnitude (total production) was below normal in 2020 after three consecutive years of above-normal production (Figure B1.C). In general, late bloom onsets are associated with limited production (Figure B1.B-C). The abundance of copepod and non-copepod zooplankton show general increasing trends throughout the 1999-2020 time series (Figure B1.D-E). However, copepod abundance decreased to below or near-normal levels over the past two years after having remained above normal from 2016 to 2018 (Figure B1.D). Similarly, the abundance of non-copepod zooplankton decreased to near-normal in 2019-2020 after four consecutive years of above-normal levels (Figure B1.E). Total zooplankton biomass on the Flemish Cap has remained mostly below to near normal since 2015 with the exception of the record-high biomass observed in 2016 (Figure B1.F).

5. Golden Redfish (*Sebastes norvegicus*) in Divisions 3M

Interim Monitoring Report

(SCR Doc. 19/035, 21/005, 21/034; SCS Doc. 21/04, 21/05, 21/06, 21/09, 21/13)

a) Introduction

There are three species of redfish that are commercially fished on Flemish Cap; deep-sea redfish (*Sebastes mentella*), golden redfish (*Sebastes norvegicus*) and Acadian redfish (*Sebastes fasciatus*). The term beaked redfish is used for *S. mentella* and *S. fasciatus* combined. Because of difficulties with identification and separation, all three species are reported together as 'redfish' in the commercial fishery. All stocks have both pelagic and demersal concentrations and long recruitment process to the bottom. Redfish species are long lived with slow growth.

The separation of the three species is very difficult and therefore it is impossible to implement separation at the level of catch reporting. This separation is made in the EU research survey. This requires extensive sampling effort by trained experts to examine internal features of individual redfish. The percentage per depth range of the three species in the EU Flemish Cap surveys, was used to separate the Div. 3M commercial catches into golden and beaked redfish. This method is also applied in assessments of beaked redfish.

i) Description of the fishery

Catches of golden redfish in Division 3M increased from 1,158 tonnes in 2006 to a peak of 7662 tonnes in 2009. In 2010, catches decreased and remained relatively stable until 2014 between 2000 and 3000 tonnes. After 2014, catches decreased continuously, being from 2016 to 2019 at residual levels. In 2020 provisional catches of golden redfish are 78 tonnes. EU-Portugal, EU-Spain, the Russian Federation and EU-Estonia are responsible for the bulk of the redfish landings over the last two decades.

Recent catches and TACs ('000 t) are as follows:

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TAC[1]	6.5	6.5	6.5	6.7	7.0	7.0	10.5	10.5	8.6	8.4
STATLANT 21[1]	5.4	6.8	6.4	6.9	6.6	7.1	10.5	10.4	8.6	
STACFIS Total catch[1,2]	6.2	7.8	7.4	6.9	6.6	7.1	10.5	10.5	8.8	
STACFIS Catch[3]	1.9	2.6	2.9	1.7	0.4	0.3	0.1	0.3	0.1	

[1] TAC, STATLANT 21 and STACFIS Total catch refer to all three redfish species combined.

[2] STACFIS total catch on 2011-2014 based on the average 2006-2010 bias.

[3] STACFIS golden redfish catch estimate, based on golden redfish proportions on observed catch.

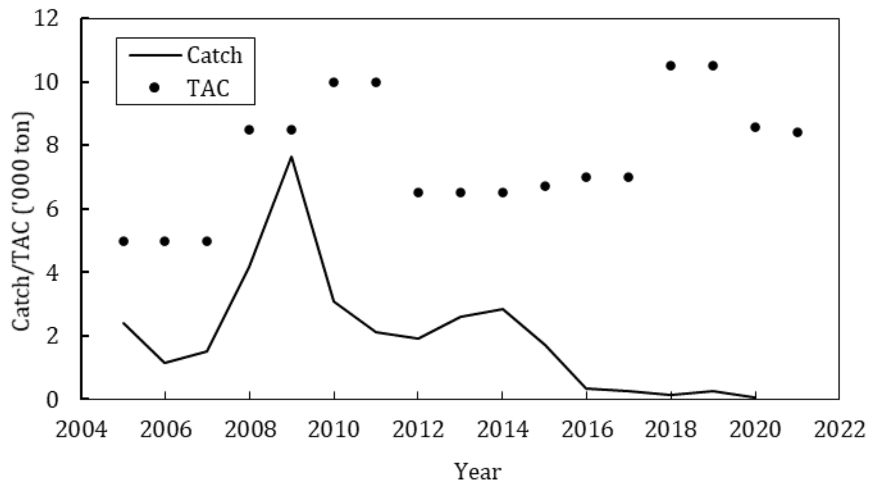


Figure 5.1. Golden redfish in Div. 3M: Golden redfish catches and TACs of all three redfish species combined.

b) Data Overview

i) Research surveys

The 1988-2020 EU survey biomass and abundance indices for golden redfish are presented in Figure 7.2. Besides some sporadic small peaks, the survey stock abundance and biomass oscillated since the beginning (1988) of the series till 2003 at low levels. From 2004 to 2008 both measured a huge increase that could not be explained only by recruitment. Since then, biomass and abundance declined and in 2020 are at low levels. Survey results are noisy, with the characteristic variance of redfish indices, but broad trends show through the noise.

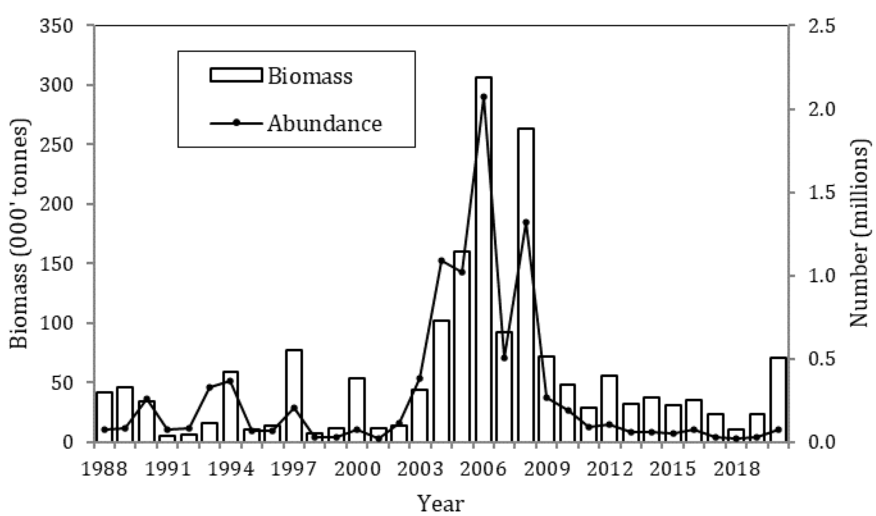


Figure 5.2. Golden redfish in Div. 3M: EU biomass and abundance indices, 1988-2020.

c) Conclusions

The perception of the stock status has not changed.

Given the current situation of the stock, it was not considered appropriate to apply any assessment model or to give advice for golden redfish separately. Nevertheless, as in previous years, advice for golden redfish is given indirectly based on the Div. 3M beaked redfish assessment (advice of 3M redfish applies the current percentage of golden redfish). SC will continue to monitor the golden redfish stock status and provide advice as part of the beaked redfish advice.

The next assessment of the stock is planned when the dynamic of the stock changes.

6. Cod 3M (*Gadus morhua*) in Division 3M

(SCS Doc. 21/05, 21/10, 21/13 and SCR Doc. 21/05, 21/17)

a) Introduction

The cod fishery on Flemish Cap has traditionally been a directed fishery by Portuguese trawlers and gillnetters, Spanish pair-trawlers and Faroese longliners. Cod has also been taken as bycatch in the directed redfish fishery by Portuguese trawlers. Estimated bycatch in shrimp fisheries is low. Large numbers of small fish were caught by the trawl fishery in the past, particularly during 1992-1994. Total annual catches from 1996 to 2010 were very small compared with previous years.

The mean reported catch was 32 000 t from 1963 to 1979 with high inter annual variability. Reported catches declined after 1980, when a TAC of 13 000 t was established, but Scientific Council regularly expressed its concern about the reliability of some catches reported in the period since 1963, particularly those since 1980. Alternative estimates of the annual total catch since 1988 were made available in 1995 (Figure 5.1), including non-reported catches and catches from non-Contracting Parties.

Catches exceeded the TAC from 1988 to 1994 but were below the TAC from 1995 to 1998. In 1999 the directed fishery was closed, and catches were estimated in that year as 353 t, most of them taken by non-Contracting Parties according to Canadian Surveillance reports. Fleets of non-Contacting Parties did not participate in the fishery since 2000. Annual bycatches between 2000 and 2005 were estimated to be below 60 t, increasing to 339 and 345 t in 2006 and 2007, respectively. In 2008 and 2009 catches increased to 889 and 1 161 t, respectively. From the reopening of the fishery in 2010, catches increased until 2013 to the TAC value, and remained at this level since.

Recent catches ('000 tonnes) are as follow:

,000 tons	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TAC	5.5	10.0	9.3	14.1	14.5	13.8	13.9	13.9	11.1	17.5	8.5	1.5
STATLANT 21	5.2	10.0	9.1	13.5	14.4	12.8	13.8	13.9	10.5	13.0	NA	
STACFIS	9.3	12.8	12.8	14.0	14.3	13.8	14.0	13.9	11.5	17.5	8.5	

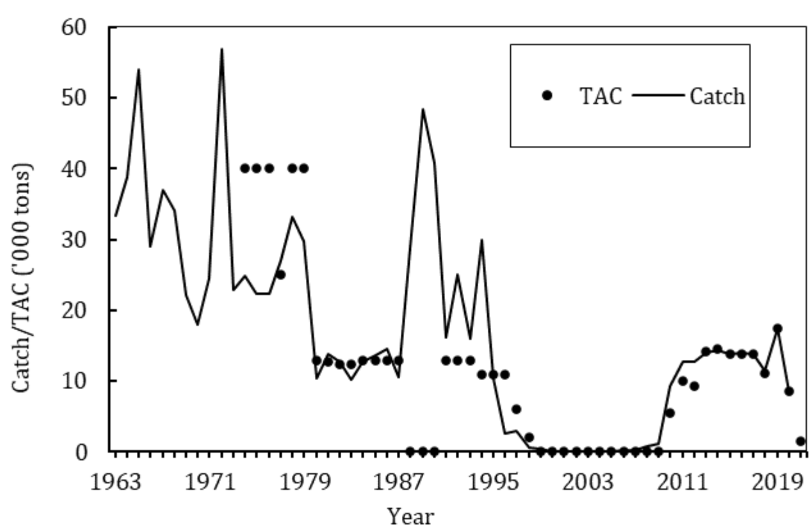


Figure 6.1. Cod in Division 3M: STACFIS catches and TAC.

b) Data Overview

i) Research survey data

Canadian survey. Canada conducted research surveys on Flemish Cap from 1978 to 1985 on board the R/V *Gadus Atlantica*, fishing with a lined Engels 145 otter trawl. The surveys were conducted annually in January-February covering depths between 130 and 728 m.

From a high value in 1978, a general decrease in biomass and abundance can be seen until 1985, reaching the lowest level in 1982 (Figure 5.2).

EU survey. The EU Flemish Cap survey has been conducted since 1988 in summer with a Lofoten gear type. The survey indices showed a general decline in biomass going from a peak value in 1989 to the lowest observed level in 2003. Biomass index increased from 2004 to 2014 and has decreased since. The growth of several strong year classes over 2005 to 2012 contributed to the increase in the biomass. Abundance rapidly increased between 2005 and 2011, decreasing since 2012 broken with an increase in 2020. The difference in timing of the peaks in biomass and abundance over 2011-2018 is driven by the very large 2009 and 2010 year classes.

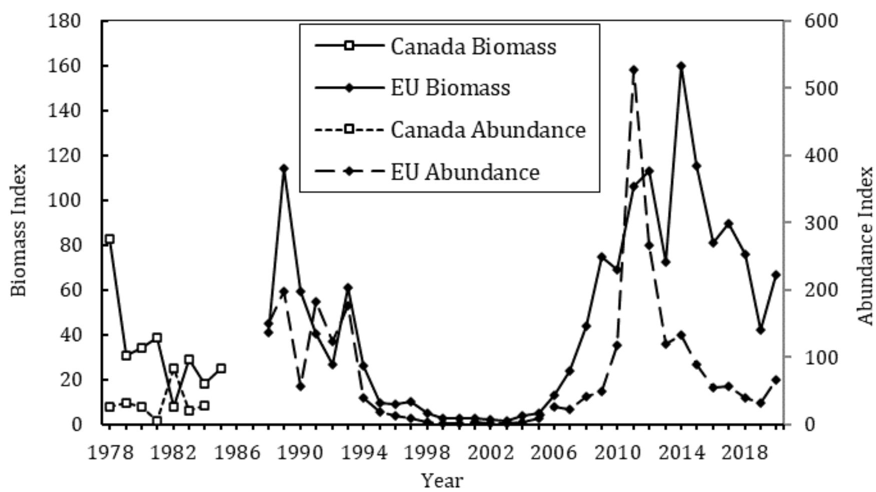


Figure 6.2. Cod in Division 3M: Survey abundance and biomass estimates from Canadian survey (1978-1985) and EU Flemish Cap survey (1988-2020).

ii) Recruitment

The recruitment index (age 1) from the Canadian survey was estimated at low levels except for 1982 and 1983. After several series of above average recruitments during 1988-1992, the EU Flemish Cap survey indicated poor recruitments during 1996-2004, even obtaining an observed zero value in 2002. From 2005 to 2012 increased recruitments were observed. In particular, the age 1 index in 2011 is by far the largest in the EU series (Figure 6.3; note that the level of both surveys is different in the two y-axis). From 2013 the recruitment index dropped to a level similar to the beginning of the recovery of the stock, with 2015 to 2018 being among the lowest levels observed in the series, and a promising increase in 2019 and 2020.

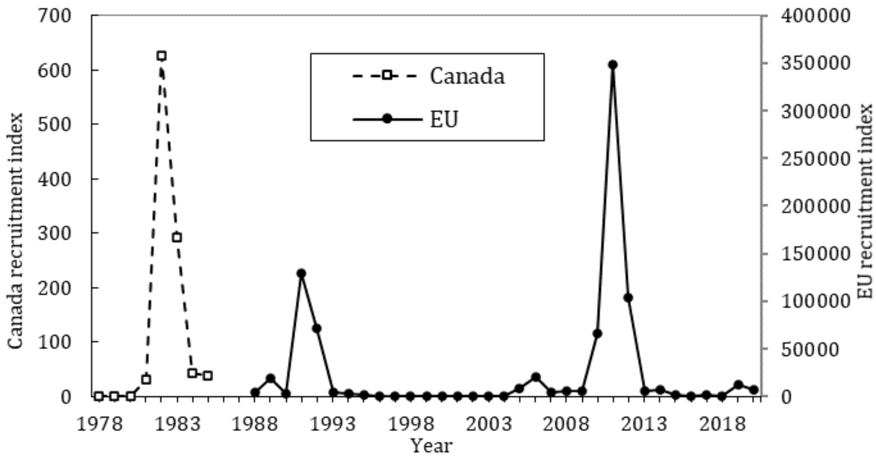


Figure 6.3. Cod in Division 3M: Number at age 1 in the Canadian survey (1978-1985) and EU survey (1988-2020).

iii) Fishery data

In 2020 seven countries fished cod in Div. 3M, trawlers from EU-Estonia, EU-Portugal, EU-Spain, Japan and Russia and longliners from Faroe Islands and Norway.

Length and age compositions from the commercial catches are available from 1972 to 2020 with the exception of the 2002 to 2005 period. Since 2010, length information was available for the major participants in the fishery. In 2020 there were length distributions from EU-Estonia, EU-Portugal, Faroe Islands and Norway (Figure 6.4). The mean in the length composition for EU-Estonia was 65 cm, being 62 cm for EU-Portugal, 79 cm for Norway and 69 cm for Faroes. The mean in the total commercial catch length distribution was 64 cm with a length range of 26-130 cm. Since 2013, the commercial catch at age data has been generated using ALKs from the EU survey. Since 2015, ages 5 to 8+ have been the most abundant in the catch.

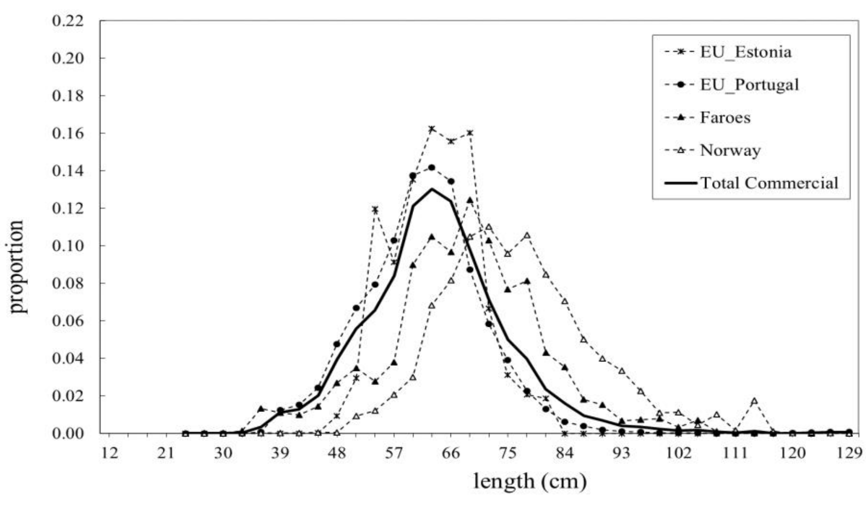


Figure 6.4. Cod in Division 3M: Length distribution of the commercial catches in 2020.

iv) Biological parameters

The 2020 indices were derived from the 2020 EU survey ALK. Mean weight-at-age in the stock and in the catch have been decreasing continuously since the reopening of the fishery, reaching the minimum for ages 4 to 8 in 2015-2017. In 2020, a quite high increase with respect to 2019 can be seen in the ages 4+, decreasing for ages 2 and 3 (Figures. 5.5 and 5.6).

Maturity ogives are available from the EU Flemish Cap survey for almost all years between 1988 and 2020. These were modelled using a Bayesian framework with missing values replaced with interpolations from adjacent years. There was a continuous decline of the A50 (age at which 50% of fish are mature), going from above 5 years old in the late 1980s to just below 3 years old in 2002 and 2003. Since 2005 there has been an increase in the A50, concurrently with the increase of the survey biomass, with the value in 2020 at the levels observed before 1990 (4.8 years old) (Figure 5.7).

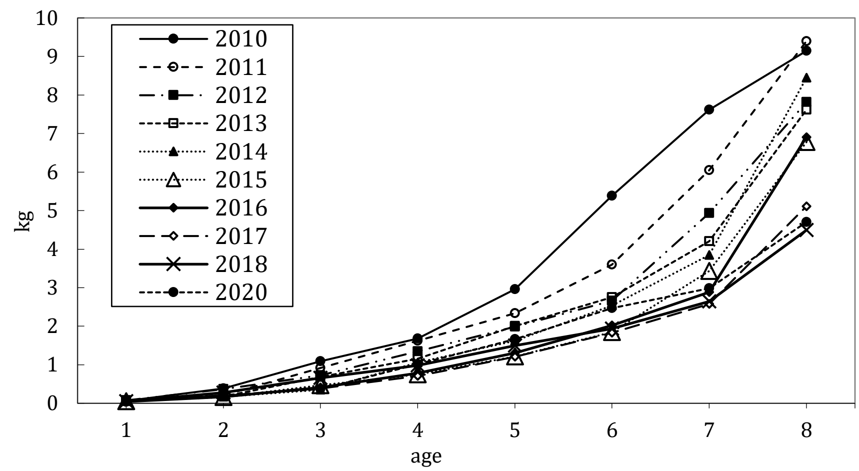


Figure 6.5. Cod in Division 3M: Mean weight-at-age in the stock for the 2010-2020 surveys.

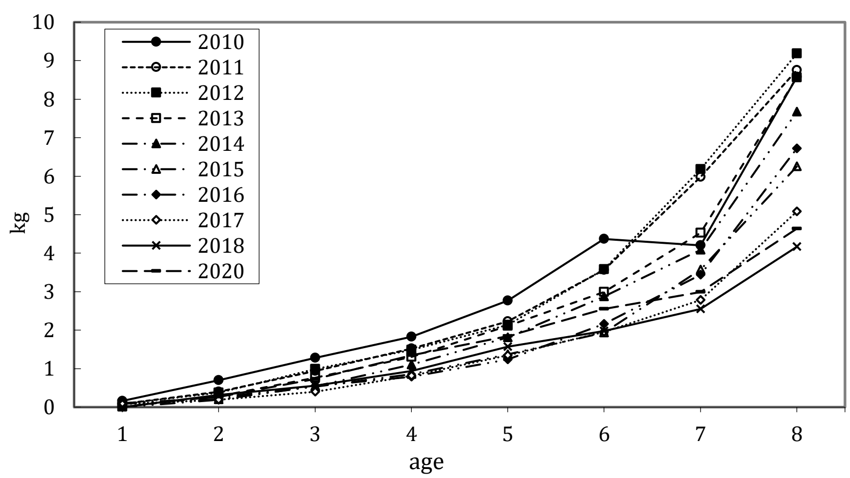


Figure 6.6. Cod in Division 3M: Mean weight-at-age in the catch for 2010-2020.

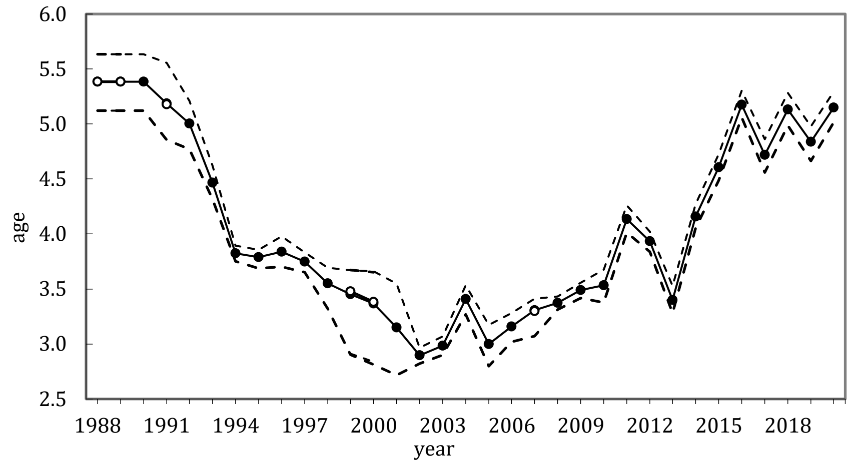


Figure 6.7. Cod in Division 3M: Age at 50% maturity (median and 90% confidence intervals) from Canadian survey (1978-1985) and EU-Flemish Cap survey (1988-2020). Interpolated years are represented in white circles.

c) Estimation of Parameters

A Bayesian SCAA model, introduced at the 2018 benchmark, was used as the basis for the assessment of this stock with data from 1988 to 2020. Input data and settings are as follows:

Catch data: catch numbers and mean weight at age for 1988-2020, except for 2002-2005, for which only total catch is available. STACFIS estimates for total catch were used.

Tuning: numbers at age from EU Flemish Cap survey (1988-2020).

Ages: from 1 to 8+

Catchability analysis: dependent on stock size for age 1, estimated independently for ages 1 to 3 and for 4+ as a group.

Natural Mortality: M was set via a lognormal prior constant over years and variable through ages. Prior median is the same as last year assessment.

Additional priors: for recruitment in all the years, for the number-at-age for ages 2-8+ in the first year, for a year factor for F (f), for selectivity (rC), and for the natural mortality.

Likelihood components: for total catch, for catch numbers-at-age and numbers-at-age of the survey.

The model components are defined as follows:

Input data	Model component	Parameters
R 1988-2020	$LN(medrec, cvrec)$	*medrec*=45000, *cvrec*=10
N(1988,a), a=2-8+	Ages 2-7 $LN\left(median = medrec \times e^{-\sum_{age=1}^{a-1} M(age)+medFsurv(age)}, cv = cvsurv\right)$ Ages 8+ $LN\left(median = medrec \times \frac{e^{-\sum_{age=1}^{A-1}(M(age)+medFsurv(age))}}{1-e^{-M(A+)+medFsurv(A+)}}, cv = cvsurv\right)$	*medFsurv*(1,…,7)={0.0001, 0.1, 0.5, 0.7, 0.7, 0.7, 0.7} *cvsurv*=10
f(y) y=1988-2020	Year 1988 $LN(median = medf,\ cv = cvf)$ Years 1989-2020 $LN(median = AR(1)\,over\ f,\ cv = cvf)$	*medf*=0.2, *cvf*=4
rC(y,a), a=2,8+ 1988-2020	Year 1988 $LN(median = medrC(a),\ cv = cvrC(a))$ Years 1989-2020 $LN(median = last\ year\ rC,\ cv = cvrCcond)$	*medrC*(a)=c(0.01,0.3,0.6,0.9,1,1,1), *cvrC*(a)=c(4,4,4,4,4,4) *cvrCcond*=0.2
Total Catch 1988-2020	$LN\left(median = \sum_{age=1}^{A+} mu.C(y,age)\,wcatch(y,age),\ cv = cvcW\right)$ $mu.C(y,a) = N(y,a)\left(1-e^{-Z(y,a)}\right)\frac{F(y,a)}{Z(y,a)}$	*cvCW=0.077*
Catch Numbers at age, a=2,8+ 1988-2020	$LN(median = mu.C(y,a),\ cv = cv.C)$	*cv.C*=0.2
EU Survey Indices (I) 1988-2020	$I(y) \sim LN(median = \mu(y,a),\ cv = cvEU)$ $\mu(y,a) = q(a)\left(N(y,a)\frac{e^{-\alpha Z(y,a)} - e^{-\beta Z(y,a)}}{(\beta-\alpha)Z(y,a)}\right)^{\gamma(a)}$ $\gamma(a)\begin{cases}\sim N(\text{mean}=1, \text{variance}=0.25),\ if\ a=1\\ =1,\ if\ a \geq 2\end{cases}$ $\log(q(a)) \sim N(\text{mean}=0, \text{variance}=5)$	I is the survey abundance index q is the survey catchability at age N is the stock abundance index *cvEU*=0.3 α = 0.5, β = 0.58 (survey made in July) Z is the total mortality
M	$M \sim LN(medM, cvM)$	*MedM*=c(1.26,0.65,0.44,0.35,0.30,0.27,0.24,0.24) *cvM*=0.15

d) Assessment Results

Total Biomass and Abundance: As a consequence of lower recruitment since 2015, the median total aggregate abundance has declined in recent years (since 2012) by 76% to levels observed prior to the closure of the fishery. Median biomass has also declined, but to a lesser extent (by 62%) as the strong year classes of 2009 to 2011 have grown and dominate the biomass (Figure 5.8).

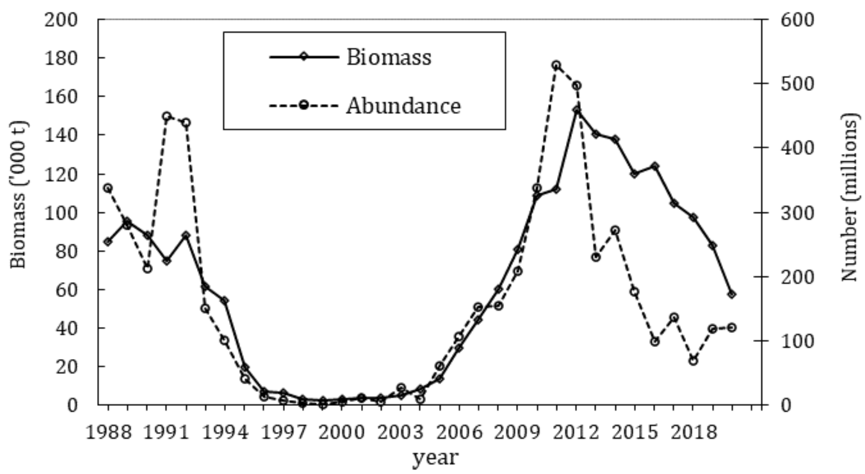


Figure 6.8. Cod in Div. 3M: Biomass and Abundance estimates.

Spawning stock biomass: Estimated median SSB over B_{lim} (Figure 5.9) increased since 2005 to the highest value of the time series in 2017. This increase is due to several abundant year classes. The SSB has decreased since then. The probability of being below B_{lim} (median value of 15 408 t; see below, section g) in 2021 is very low (<1%). SSB in 2021 was calculated using the numbers estimated by the assessment at the beginning of 2021, applying the maturity ogive and mean weight at age in stock from 2020.

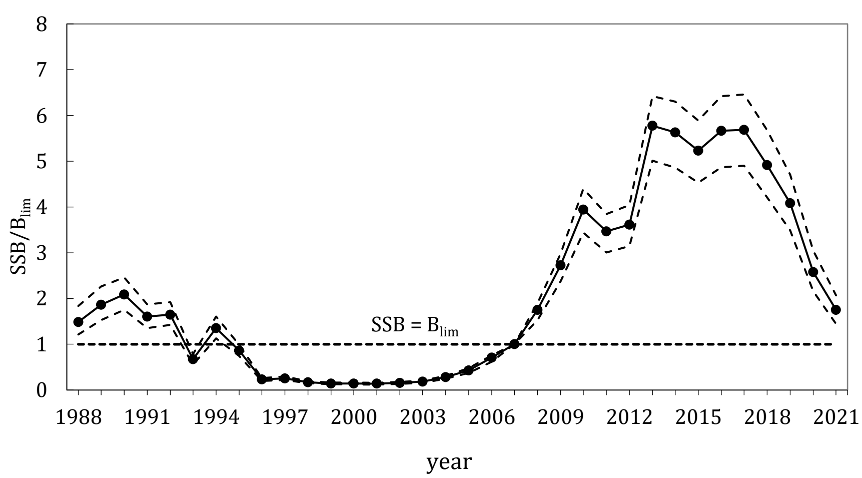


Figure 6.9. Cod in Div. 3M: Median and 80% probability intervals SSB/B_{lim} estimates. The horizontal dashed line corresponds to SSB = B_{lim}.

Recruitment: After a series of recruitment failures between 1996 and 2004, recruitment estimates (age 1) were higher in 2005-2012, especially in 2011 and 2012. Between 2015 and 2018 recruitment was very low, with an increase in 2019 and 2020 (Figure 5.10).

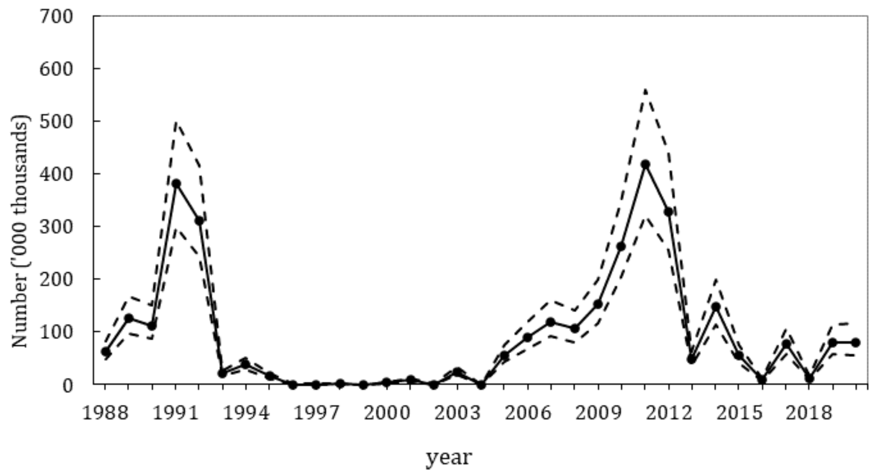


Figure 6.10. Cod in Div. 3M: Recruitment (age 1) estimates and 80% probability.

Fishing mortality: F increased in 2010 with the re-opening of the fishery although it has been below F_{lim} (0.191, see below, section g). However, in 2019 and 2020 it increased substantially and is now very close to F_{lim} (Figure 5.11).

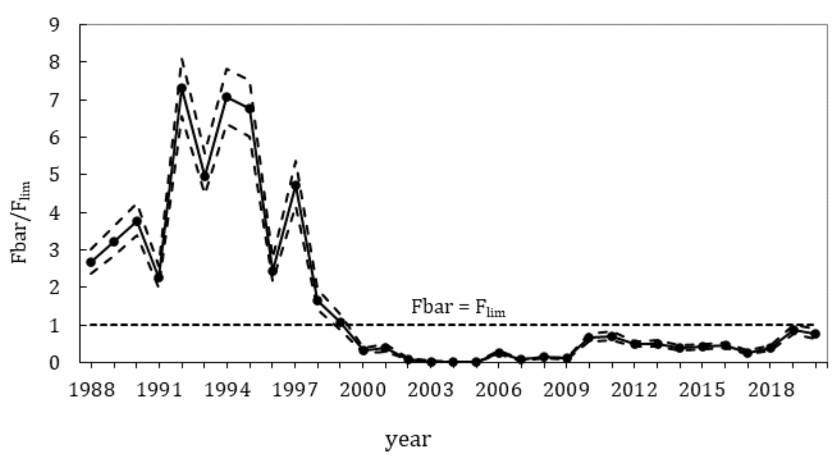


Figure 6.11. Cod in Div. 3M: F_{bar} (ages 3-5) estimates and 80% probability intervals. The horizontal dashed line corresponds to $F = F_{lim}$.

Natural mortality: The posterior median of M by age estimated by the model was:

Age	1	2	3	4	5	6	7	8
Posterior	1.38	0.60	0.35	0.24	0.26	0.39	0.33	0.41

e) Retrospective analysis

A five-years retrospective analysis with the Bayesian model was conducted by eliminating successive years of catch and survey data. Figures 5.12 to 5.14 present the retrospective estimates for age 1 recruitment, SSB and F_{bar} at ages 3-5.

Retrospective analysis shows revisions in the recruitment, mainly regarding the highest values of recruitment in the years 2009 to 2011, and in year 2019. This year the 2019 recruitment has been revised to a lowest value. But no patterns are evident in recent years (Figure 5.12). These revisions lead to revisions in the SSB. There is very little evidence of a retrospective pattern in F, although the 2019 one was revised to a lowest value (Figures 5.13 and 5.14).

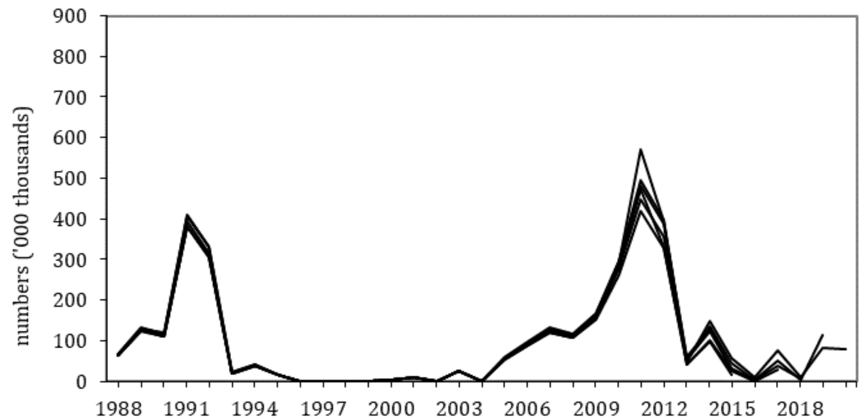


Figure 6.12. Cod in Div. 3M: Retrospective results for recruitment.

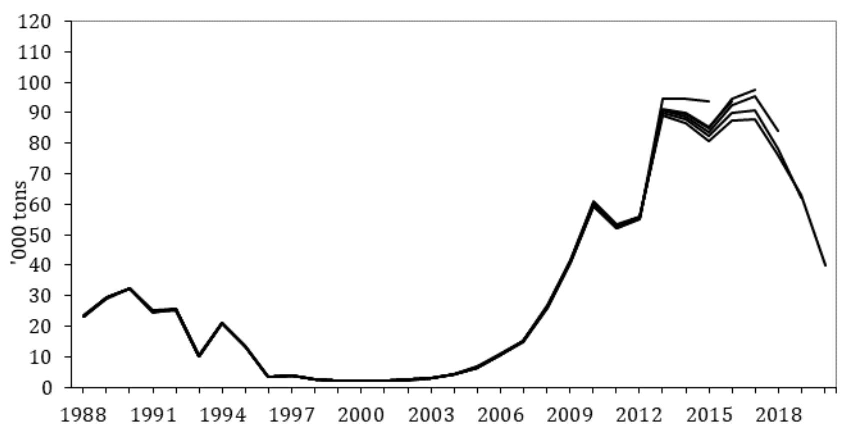


Figure 6.13. Cod in Div. 3M: Retrospective results for SSB.

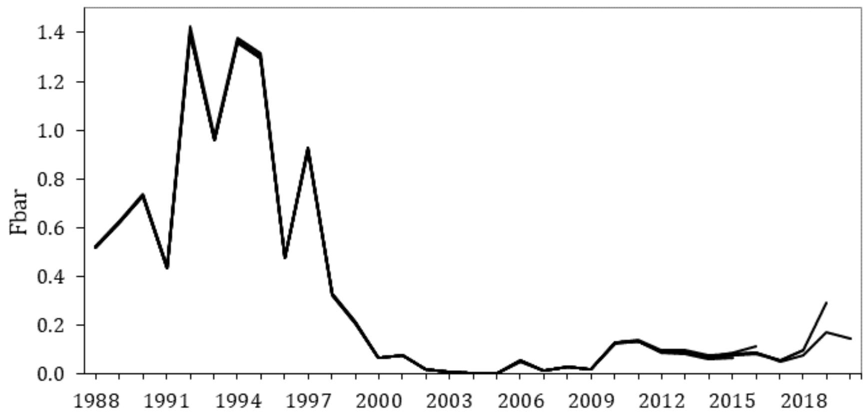


Figure 6.14. Cod in Div. 3M: Retrospective results for average fishing mortality.

f) State of the stock

SSB has been declining rapidly since 2017 but is still estimated to be above B_{lim} (median 15 408 t). This decline is expected to continue in the next couple of years due to poor recruitment between 2015 and 2018.

Fishing mortality has remained below F_{lim} (median 0.196) since the fishery reopened in 2010. However, in 2019 and 2020 it increased substantially and is now close to F_{lim}.

g) Reference Points

B_{lim} was estimated as the 2007 SSB, being its median value 15 408 tons (Figure 5.15). F_{lim} was estimated based on $F_{30\%SPR}$ calculated with the mean 2018-2020 input data as 0.196 (median value) (Figure 5.16).

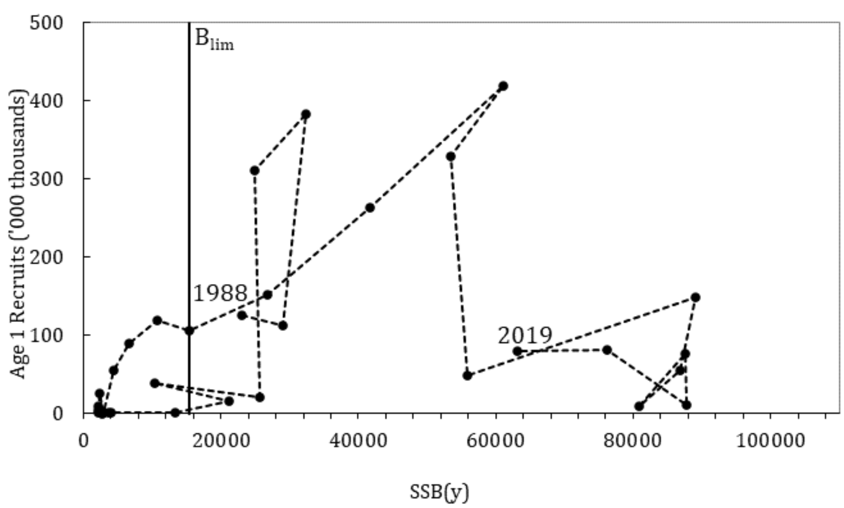


Figure 6.15. Cod in Div. 3M: Stock-Recruitment age 1 (posterior medians) plot. B_{lim} is plotted in the graph.

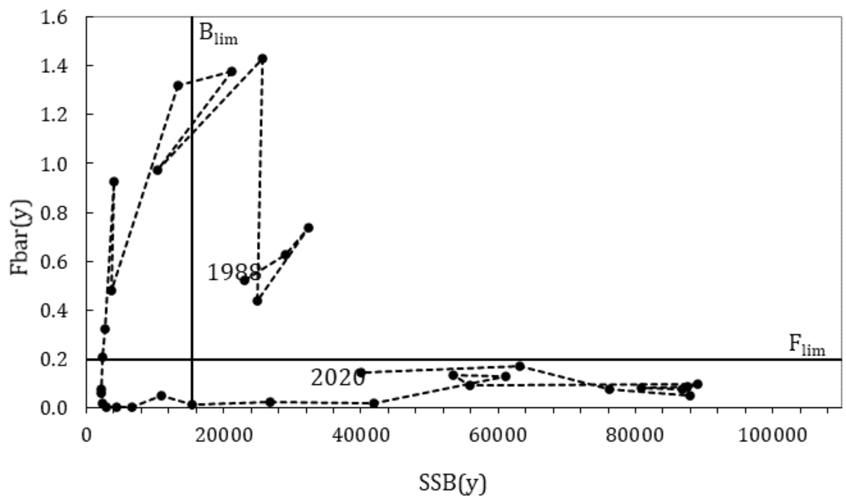


Figure 6.16. Cod in Div. 3M: Stock-F_{bar}(3-5) (posterior medians) plot. B_{lim} and F_{lim} are plotted in the graph.

h) Stock projections

The same method as last year was used to calculate the projections and the risk. Stochastic projections of the stock dynamics from 2021 to the start of 2024 were conducted. The variability in the input data is taken from the results of the Bayesian assessment. Input data for the projections are as follows:

Numbers aged 2 to 8+ in 2021: estimated from the assessment.

Recruitments for 2021-2024: Recruits per spawner were drawn randomly from 2017-2019.

Maturity ogive for 2021-2024: Mean of the last three years (2018-2020) maturity ogive.

Natural mortality for 2021-2024: 2020 natural mortality from the assessment results.

Weight-at-age in stock and weight-at-age in catch for 2021-2024: Mean of the last three years (2018-2020) weight-at-age.

PR at age for 2021-2024: Mean of the last three years (2018-2020) PRs.

F_{bar}*(ages 3-5)*: Eight scenarios were considered:

(*Scenario 1*) $F_{bar}=F_{sq}$ (median value = 0.131).

(*Scenario 2*) $F_{bar}=0$ (no catch).

(*Scenario 3*) $F_{bar}=3/4F_{lim}$ (median value = 0.147).

(*Scenario 4*) $F_{bar}=1/2F_{lim}$ (median value = 0.098).

(*Scenario 5*) Catch in 2022-2023=1500 tons.

(*Scenario 6*) Catch in 2022-2023=1875 tons.

(*Scenario 7*) Catch in 2021-2022=2250 tons.

(*Scenario 8*) Catch in 2021-2022=3000 tons.

All scenarios assumed that the Yield for 2021 is the established TAC (1 500 t).

Although advice is given only for 2022, projection results are shown to 2024 to illustrate the medium-term implications. F_{bar} is the mean of the F at ages 3-5 and used as the indicator of overall fishing mortality; F_{sq} is the status quo F calculated as the mean of the last three years F_{bar} (2018-2020).

The results indicate that under all scenarios with F_{bar}>0, total biomass during the projected years will decrease, whereas the SSB is projected to increase slightly in 2024 (Table 1). The probability of SSB being below B_{lim} in 2023 is high (≥13%) in the scenarios with $F_{bar}=F_{sq}$ and $F_{bar}=3/4F_{lim}$, while being very low (≤10%) in the rest of the cases (Table 2). The probability of SSB in 2024 being above that in 2021 ranges between <1% and 90%, depending on the scenario.

Under all scenarios, the probability of F_{bar} exceeding F_{lim} is less than or equal to 2% in 2022 and 2023.

SC notes that projections of risk, in particular more than one year ahead (Table 2), will inherently include more uncertainty than projected median stock sizes (Table 1). The risks are typically derived from the tails of a probability distribution which are less precisely estimated compared to the median (centre) of the same distribution.

Results of the projections are summarized in the following table:

	B		SSB		Yield
	Median and 80% CI				
F_{bar} = Fsq (median = 0.131)					
2021	45787	(40635 - 51559)	27058	(23458 - 31446)	1500
2022	42969	(37884 - 48389)	24420	(21335 - 27970)	6525
2023	34733	(29703 - 40345)	18598	(15605 - 21773)	5291
2024	29999	(24718 - 36318)	19822	(16344 - 23723)	
F_{bar} = 0					
2021	45787	(40635 - 51559)	27058	(23458 - 31446)	1500
2022	42969	(37884 - 48389)	24420	(21335 - 27970)	0
2023	41143	(36076 - 46765)	24071	(21037 - 27322)	0
2024	42102	(36620 - 48376)	30514	(27027 - 34628)	
F_{bar} = 3/4F_{lim} (median = 0.147)					
2021	45787	(40635 - 51559)	27058	(23458 - 31446)	1500
2022	42969	(37884 - 48389)	24420	(21335 - 27970)	7160
2023	34111	(29091 - 39726)	18092	(15086 - 21246)	5694
2024	28966	(23642 - 35277)	18923	(15516 - 22770)	
F_{bar} = 1/2F_{lim} (median = 0.098)					
2021	45787	(40635 - 51559)	27058	(23458 - 31446)	1500
2022	42969	(37884 - 48389)	24420	(21335 - 27970)	5000
2023	36238	(31192 - 41834)	19854	(16887 - 23067)	4254
2024	32578	(27213 - 38900)	22092	(18612 - 25996)	
Catch = 1500 tons					
2021	45787	(40635 - 51559)	27058	(23458 - 31446)	1500
2022	42969	(37884 - 48389)	24420	(21335 - 27970)	1500
2023	39661	(34603 - 45288)	22807	(19826 - 26087)	1500
2024	38994	(33591 - 45246)	27691	(24211 - 31752)	
Catch = 1875 tons					
2021	45787	(40635 - 51559)	27058	(23458 - 31446)	1500
2022	42969	(37884 - 48389)	24420	(21335 - 27970)	1875
2023	39291	(34238 - 44913)	22482	(19454 - 25735)	1875
2024	38216	(32795 - 44488)	27028	(23511 - 31085)	
Catch = 2250 tons					
2021	45787	(40635 - 51559)	27058	(23458 - 31446)	1500
2022	42969	(37884 - 48389)	24420	(21335 - 27970)	2250
2023	38923	(33871 - 44544)	22151	(19150 - 25412)	2250
2024	37438	(32028 - 43736)	26354	(22862 - 30373)	
Catch = 3000 tons					
2021	45787	(40635 - 51559)	27058	(23458 - 31446)	1500
2022	42969	(37884 - 48389)	24420	(21335 - 27970)	3000
2023	38196	(33139 - 43808)	21520	(18528 - 24739)	3000
2024	35865	(30453 - 42155)	24986	(21477 - 28888)	

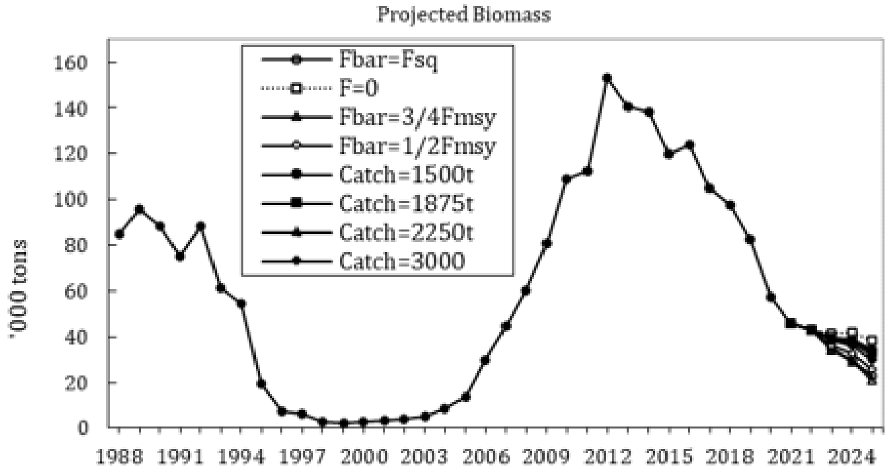


Figure 6.17. Cod in Div. 3M: Projected Total Biomass under all the Scenarios.

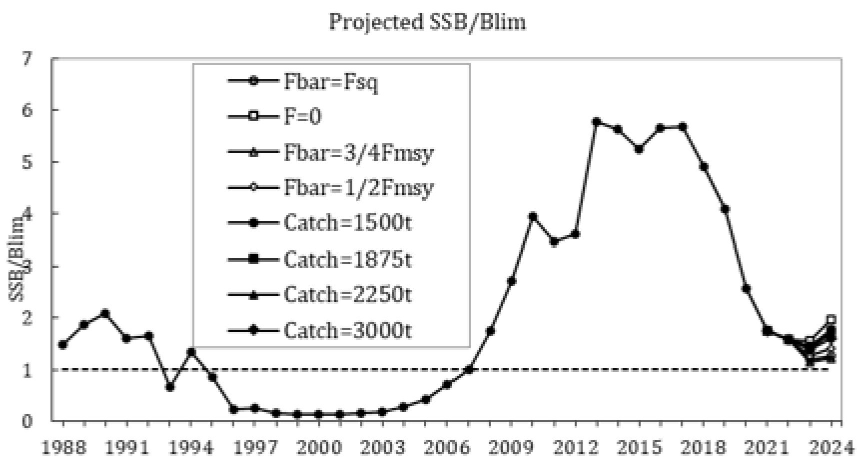


Figure 6.18. Cod in Div. 3M: Projected SSB under all the Scenarios

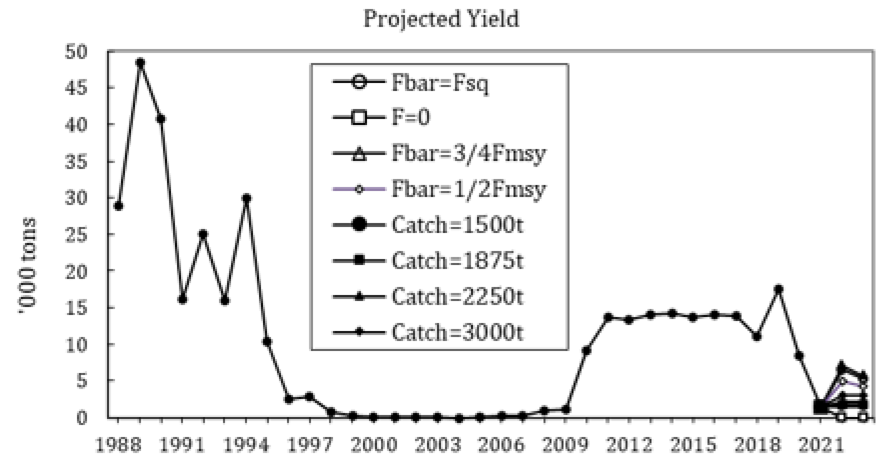


Figure 6.19. Cod in Div. 3M: Projected removals under all the Scenarios

The risk of each scenario is presented in the following table:

	Yield			P(SSB < B_{lim})				P(F_{bar} > F_{lim})			
	2021	2022	2023	2021	2022	2023	2024	2021	2022	2023	P(SSB_{24} > SSB_{21})
$F_{bar} = F_{sq} = 0.131$	1500	6525	5291	<1%	<1%	13%	8%	<1%	<1%	<1%	1%
$F_{bar} = 0$	1500	0	0	<1%	<1%	<1%	<1%	<1%	<1%	<1%	90%
$F_{bar} = 3/4F_{lim} = 0.147$	1500	7160	5694	<1%	<1%	17%	13%	<1%	1%	2%	<1%
$F_{bar} = 1/2F_{lim} = 0.098$	1500	5000	4254	<1%	<1%	5%	1%	<1%	<1%	<1%	4%
Catch = 1500 tons	1500	1500	1500	<1%	<1%	1%	<1%	<1%	<1%	<1%	58%
Catch = 1875 tons	1500	1875	1875	<1%	<1%	1%	<1%	<1%	<1%	<1%	48%
Catch = 2250 tons	1500	2250	2250	<1%	<1%	1%	<1%	<1%	<1%	<1%	36%
Catch = 3000 tons	1500	3000	3000	<1%	<1%	2%	<1%	<1%	<1%	<1%	20%

i) Research recommendations

STACFIS **recommended** that *an age reader comparison exercise be conducted.*

STATUS: An age-readers Workshop was held in November 2017 in order to reconcile the differences among age-readers of this stock. Much progress in understanding where the differences between the commercial and survey ALKs come from was made but still needs more research to completely know the problem. No progress since then was made. NAFO reiterates this recommendation.

STACFIS **encouraged** to *all Contracting Parties to provide length distribution samples from the commercial vessels fishing 3M cod*.

STATUS: NAFO reiterates this recommendation.

The next full assessment for this stock will be in 2022.

7. Redfish (*Sebastes mentella* and *Sebastes fasciatus*) in Division 3M

(SCR Doc. 21/05, 034 SCS Doc. 21/05, 06, 09,13

a) Introduction

There are three species of redfish that are commercially fished on Flemish Cap; deep-sea redfish (*Sebastes mentella*), golden redfish (*Sebastes marinus = S. norvegicus*) and Acadian redfish (*Sebastes fasciatus*). The term beaked redfish is used for *S. mentella* and *S. fasciatus* combined. Because of difficulties with identification and separation, all three species are reported together as 'redfish' in the commercial fishery. All stocks have both pelagic and demersal behaviour as well as a long recruitment process to the bottom, extending to lengths up to 30-32 cm. All redfish species are long lived with slow growth. Female sexual maturity is reached at a median length of 26.5 cm for Acadian redfish, 30.1 cm for deep-sea redfish and 33.8 cm for golden redfish.

b) Description of the fishery

The redfish fishery on Division 3M increased from 20 000 tons in 1985 to 81 000 tons in 1990, falling continuously since then till 1998-1999, when a minimum catch around 1 000 tons has been recorded as by-catch of the Greenland halibut fishery. This drop of the 3M redfish catches was related with the simultaneous decline of stock biomass and fishing effort deployed in this fishery during the first half of the 1990’s. In the 2000s catches recorded a stepwise increase, from an average level of 3 000 tons (2000-2004) to 8 000 tons (2005-2017). In 2018-2019 catches were around 10,500 tons (2018-2019 TAC of 10,500 tons) and in 2020 was 8,800 tons (2020 TAC of 8,590 tons), sticking to the changes in TACs. EU-Portugal, EU-Spain, the Russian Federation and EU-Estonia states are responsible for the bulk of the redfish landings over the last two decades.

From July 2004 to July 2006 Flemish Cap EU survey showed a 3.5 fold increase in bottom biomass of both golden and Acadian redfish. Cod stock and cod by-catch also went up, and the Flemish Cap cod fishery reopened in 2010. Redfish catch responded positively to those events and since the mid 2000’s is a blend of by-catch from cod fishery (depths above 300m, a mixture of golden and beaked redfish), catch from bottom trawl directed fishery (depths between 300-700m, primarily beaked redfish), and by-catch again from Greenland halibut fishery (bellow 700m, 100% deep sea redfish).

STACFIS catch estimates were available till 2010. Over 2006-2010 an average annual bias of 15% plus was recorded between STACFIS catch estimate and STATLANT nominal catch. In order to mitigate the lack of independent catch data a 15% surplus has been added to the STATLANT catch of each fleet between 2011 and 2014. For 2015 the annual catch was given by the Daily Catch Reports (DCR’s) by country provided by the NAFO Secretariat. For 2016 catch was calculated using the CDAG Estimation Strategy (NAFO Regulatory Area Only). The 2017 to 2020 catch estimates were obtained with the application of the CESAG method. The 1989-2020 catch estimates from those different sources are accepted as the 3M redfish landings.

Recent TACs, catches are as follows -catch ('000 t) are as follows:

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TAC	6.5	6.5	6.5	6.7	7.0	7.0	10.5	10.5	8.6	8.4
STATLANT 21	5.4	6.8	6.4	6.9	6.6	7.1	10.5	10.4	8.6	
STACFIS Total catch [1]	6.2	7.8	7.4	6.9	6.6	7.1	10.5	10.6	8.8	
STACFIS Catch [2]	6.3	5.2	4.6	5.2	6.2	6.9	10.3	10.2	8.7	

[1] STACFIS total catch on 2011-2014 based on the average 2006-2010 bias.

[2] STACFIS beaked redfish catch estimate, based on beaked redfish proportions on observed catch.

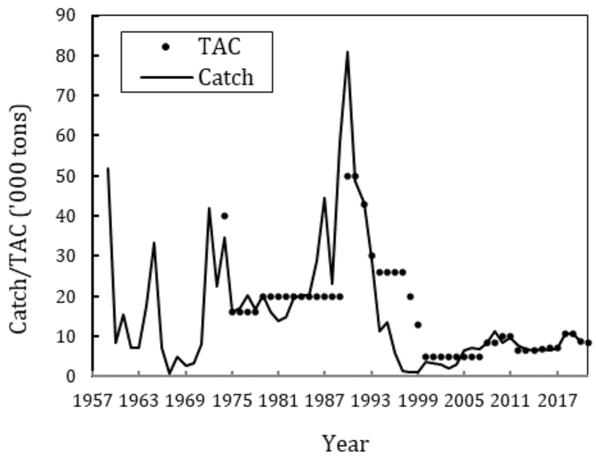


Figure 7.1. Redfish in Div. 3M: total catches and TACs.

c) Input Data

The 3M redfish assessment is focused on beaked redfish, regarded as a management unit composed of two populations from two very similar species: the Flemish Cap *S. mentella* and *S. fasciatus*. The reason for this approach is the historical dominance of this group in the 3M redfish commercial catch. During the entire series of EU Flemish Cap surveys beaked redfish also represents the majority of redfish survey biomass (78%).

d) Commercial fishery and by-catch data

Sampling data. Usually Portuguese beaked redfish length sampling was applied to the beaked redfish catch of other bottom trawl fleets with the exception of the Russian, Spanish and Japanese fleets for the years where respective length sampling data are available. However, in 2015 and 2016, most of the Portuguese sampling effort was made on beaked redfish catch from shallower depths than the ones traditionally associated with the redfish fishery, while Spanish sampling still came from 300-700m bottoms where most of the beaked redfish catch is expected to occur. So Spanish sampling substitute the Portuguese sampling as regards the length distributions for other countries estimated catches on those years. Depth distribution of Portuguese redfish catches went back to normal on 2017-2018 and so Portuguese length sampling return to be applied to other countries but Spain and Russia from 2017 to 2020, including Russia on 2018 and Spain in 2020.

The available 1998-2020 3M beaked redfish commercial length weight relationships from the Portuguese commercial catch were used to compute the mean weights of all commercial catches and corresponding catch numbers at length.

Redfish by-catch in numbers at length for the Div. 3M shrimp fishery is available for 1993-2004, based on data collected on Canadian and Norwegian vessels. No bycatch information has been available from 2005 onwards when the fishery was very low and hence bycatch was assumed to be negligible, and a moratoria to the Div.3M shrimp fishery was in place from 2010-2019. The commercial and bycatch length frequencies were summed to establish the total removals at length. These were converted to removals at age using the EU survey *S. mentella* age length keys (ALK) from 1988-2017 and *S. mentella* + *S. fasciatus* ALKs from 2018-2020 with both sexes combined. Annual length weight relationships derived from Portuguese commercial catch were used for determination of mean weights-at-age.

The 1999-2002 and 2005 cohorts dominated the overall catch through most years of the 2001-2012 interval. The 2009-2011 cohorts are the most abundant in the catch between 2014 and 2016. Larger sizes corresponding to older ages, and 11 and 12 years old fish (from 2005-2006 cohorts) were the most abundant in the catch in 2017. However most abundant ages return to much younger redfish in 2018, with ages 6 and 7 (2012-2011 cohorts) being the most abundant in the catch. In 2019 and 2020 larger sizes in the catch correspond to fish aged 8+ years older (from cohorts as old as that of 2004) dominated catches.

i) Research survey data

EU Flemish Cap bottom trawl survey

Survey biomass was calculated based on the abundance at length and annual length weight relationships from the EU bottom trawl survey for the period 1988-2020.

Age compositions for Div. 3M beaked redfish EU survey stock and mature female stock from 1989 to 2020 were obtained using the EU survey *S. mentella* age length keys (ALK) from 1988-2017 and *S. mentella* + *S. fasciatus* ALKs from 2018-2020. Mean weights-at-age were determined using the EU survey annual length weight relationships.

Gonads from Flemish Cap beaked redfish were collected since 1994 though not every year. Maturity at length ogives from 1994 were used in previous assessments. New maturity at length ogives were estimated based on microscopic inspection of histological sections of gonads collected throughout 16 years between 1994 and 2020. Maturity data were combined for both species within each year and fitted to a logistic function. For the years in between, where data was missing, curve parameters were estimated as the weighted average of the adjacent years where maturity ogives were available. The new maturity at length results were used in the present assessment.

Survey results. The survey stock abundance and biomass declined in the first years of the survey and remained low until 2003. A sequence of above average year classes (2001-2005), including the strongest of the survey series (2002), with high survival rates and coupled to a sudden but major increase of the size of the *S. fasciatus* component, lead the exploitable beaked redfish stock as a whole to a maximum in 2006. Both spawning stock and exploitable biomass were high in mid 2000s early 2010s. While exploitable biomass and abundance declining since 2012, spawning stock biomass (SSB) has remained high until 2017 (Figure. 7.2). There has been very low recruitment at age four in most recent years but the entry of the 2016 year class (that its strength needs to be checked in next years) and the growth of the existing exploitable stock halted the downward trend, on the exploitable biomass, in 2019 and even reversed in 2020. As recruitment has not yet entered the SSB, its decline has not been halted.

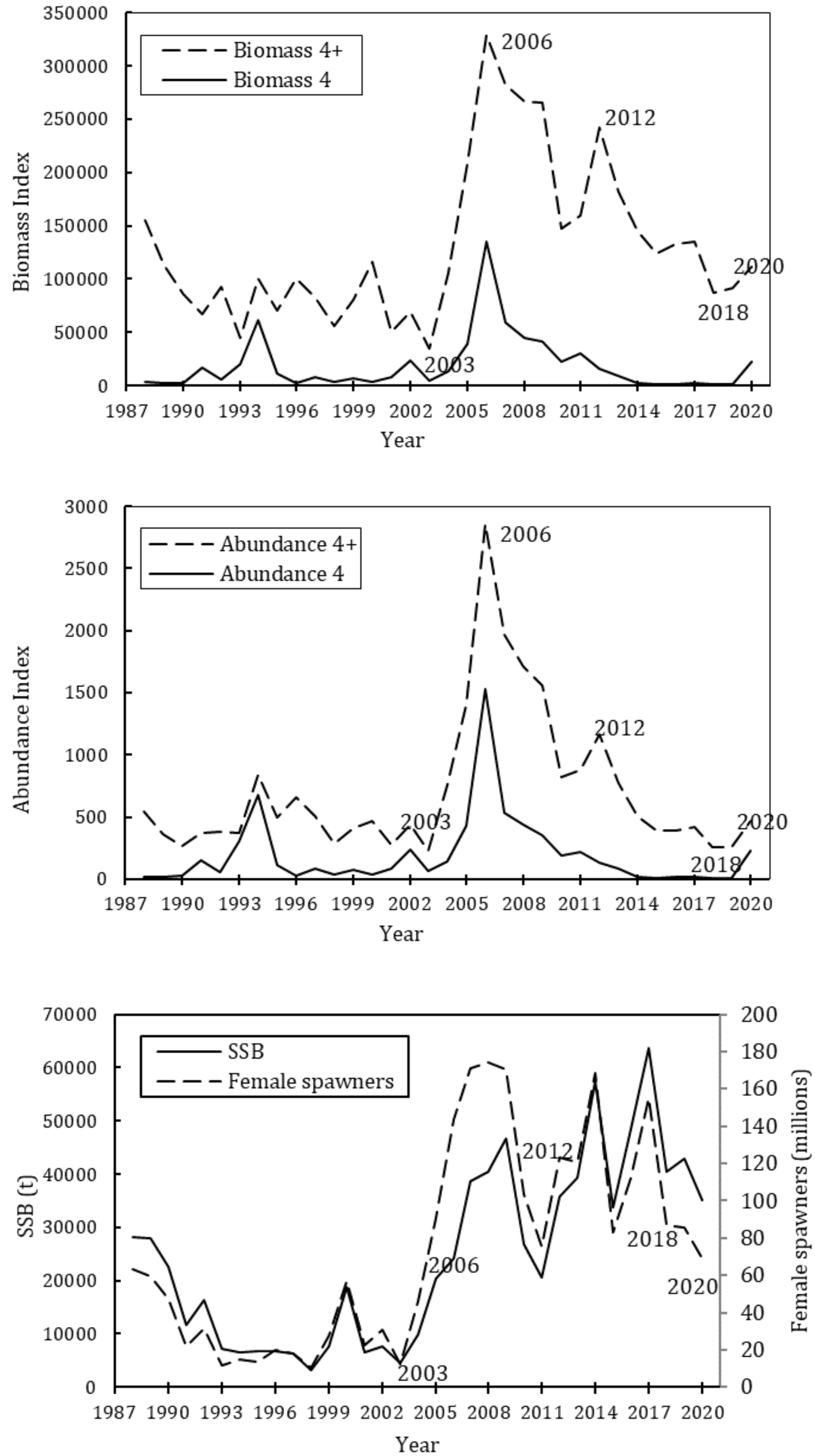


Figure 7.2. Beaked redfish in Div. 3M: exploitable biomass, female spawning biomass /abundance and recruitment at age 4 abundance from EU surveys (1988-2020).

ii) Natural mortality

In the mid 2000's, the Flemish Cap cod stock started recovering, not only in terms of abundance but also in terms of individual growth, leading to a continuous and steep increase of cod biomass between 2006 and 2012. There is a strong possibility that important increases in redfish consumption by cod are associated with this recovery leading to anomalously high levels (M> 0.1) of beaked redfish natural mortality, from 2006-2010.

Attempts to track changes on natural mortality have been made on previous assessments since 2011 for a range of M candidates between 0.1 - 0.4. Having 2006 as the starting year for the sensitivity analysis, time windows of variable width were considered where the best M option should minimize the $SS\ log\ q_{age}$ residuals and maximize correlation between exploitable survey abundance and XSA abundance. So far the approach to the actual magnitudes of M has been strictly dependent of beaked redfish survey indices, which in turn should capture the dynamics of the ensemble of the two redfish populations at times of very low recruitment, low exploitation and high predation.

In 2015, STACFIS recommended that, *in order to quantify the most likely redfish depletion by cod on Flemish Cap and be able to have an assessment independent approach to the magnitude of such impact ...work continue to investigate recent changes in natural mortality*.

In order to include an independent approach to natural mortality in the 2017 sensitivity M framework, the beaked redfish natural mortality has been estimated by a number of different published models derived from cross-species comparative analyses, either by size/age-independent and size/age-dependent methods.

e) Estimation of Parameters

The Extended Survivors Analysis (XSA) (Shepherd, 1999)[31] was used to estimate stock size. The month of peak spawning (larval extrusion) for Div. 3M *S. mentella*, was taken to be February, and was used for the estimate of the proportion of fishing mortality and natural mortality before spawning. EU survey abundance at age was used for calibration. The XSA model specifications are the same as in the assessments since 2015, and are given below:

Catch data from 1989 to 2020, ages 4 to 19+

Fleets	**First year**	**Last year**	**First age**	**Last age**
EU summer survey (Div. 3M)	1989	2020	4	18

Tapered time weighting not applied

Catchability independent of stock size for all ages

Catchability independent of age for all ages up to age 15

Terminal year survivor estimates not shrunk towards a mean F

Oldest age survivor estimates not shrunk towards the mean F of previous ages

Minimum standard error for population estimates from the last true age of each cohort age = 0.5

Before 2006, M remained at 0.1. The rationale to select the best options for natural mortality between 2006 and 2017 are thoroughly explained in the sensitivity analysis sections of previous assessments (NAFO SCS Doc. 17/16REV). A natural mortality of 0.4 was tuned to ages 4-6 between 2006 and 2010 and extended to all ages in 2009-2010 to reflect cod predation. Since then natural mortality was assumed to be again an age independent parameter, and on 2011-2012 declined to 0.125, a level much closer to what is considered the

[31] SHEPHERD, J. G. 1999. Extended survivors analysis: an improved method for the analysis of catch-at-age data and abundance indices. *ICES J. Mar. Sci.*, **56**(5): 584-591.

magnitude of natural mortality on redfish stocks (0.1). However, from 2013-2014 the best fit to survey data implied again a marginal increase of *M* to 0.14.

The best *M* option found for the 2017 and 2019 XSA assessment was a natural mortality of 0.1 on 2015-2016 and 2017-2018 respectively, previous natural mortality levels kept from the past 3M beaked redfish assessments.

The sensitivity analysis preceding the 2021 XSA assessment considered four *M* candidates, equal for all ages, for the 2019-2020 period (*M* = 0.08; 0.1; 1.2 and 1.4) since no major changes is seem, besides decline, in the cod stock status during these years.

The goodness of fit of the model runs to survey data is measured by the following diagnostics

1. Lower *SS log* q_{age} residuals on 2019-2020 together with
2. Lower *SS log* q_{age} residuals back to 2011 (*M* started to decline from the anomalous high 2006-2010 levels) and
3. Higher correlation between exploitable (4+) survey abundance and XSA abundance over recent years (2011-2020).

Diagnostics results for these sets of runs are shown below.

$M_{2019\text{-}2020}$	**0.08**	**0.1**	**0.12**	**0.14**
SS log q $\text{residuals}_{2019\text{-}2020}$	10.86	10.86	10.86	10.86
SS log q $\text{residuals}_{2011\text{-}2020}$	41.63	41.63	41.63	41.63
XSA *versus* SURVEY r^2 $_{2011\text{-}2020}$	0.8877	0.8868	0.8859	0.8850
Survivors Average Int. *s.e*	0.3176	0.3179	0.3183	0.3186
Survivors Average Ext. *s.e*	0.1839	0.1865	0.1889	0.1913

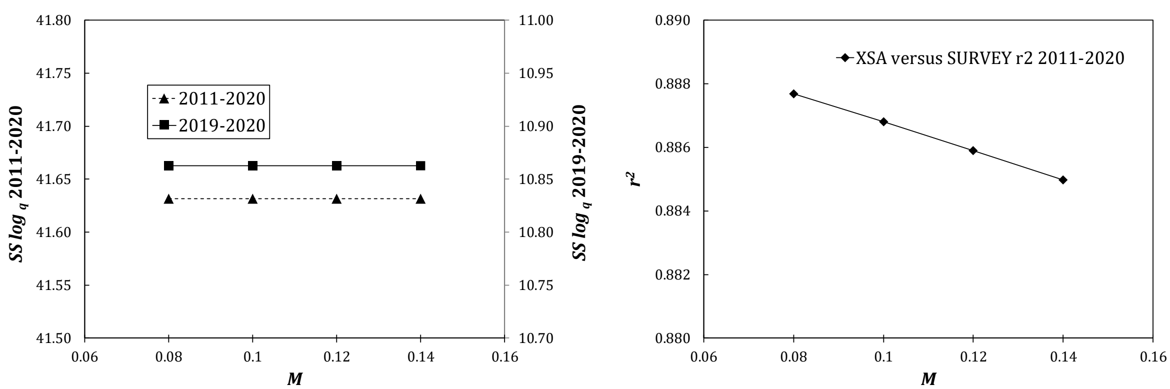


Figure 7.3. Beaked redfish in Div. 3M: goodness of fit diagnostics of XSA_{2021} for several 2019-2020 *M* options. Left panel is SS log q's 2019-2020 and 2011-2020, right panel is r^2 between XSA_{2021} and 4+ survey results.

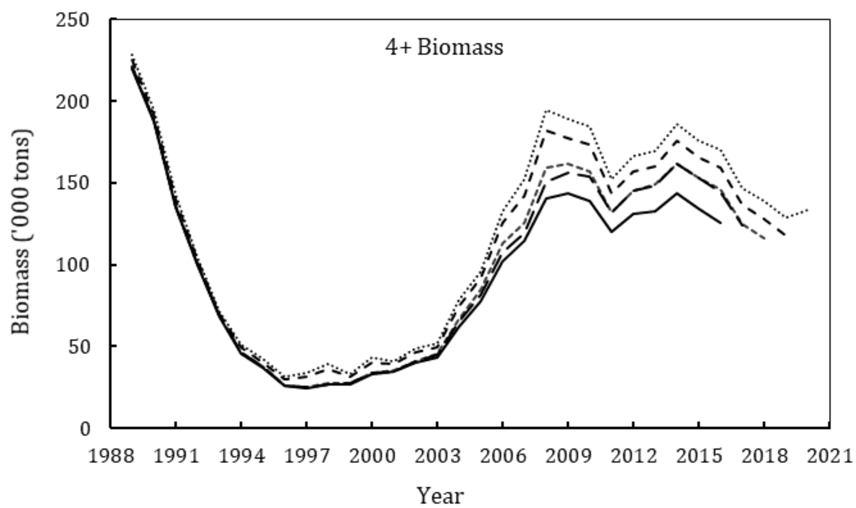
Both *SS* log q_{age} and (survey/XSA) correlation results showed that an average 2019-2020 natural mortality level within 0.08 and 0.10 deliver better diagnostics of the model fit than levels of *M* equal or greater to 0.12. Furthermore, the best results are achieved with the lowest value of *M* in the ranking (0.08). However, the primary aim of this exercise was not to track a best value for the most recent *M* level, but to find out if there was evidence that natural mortality has increased from the former level of 0.1, adopted since the 2017 assessment as the best option for average M, or not. From the results of the present sensitivity analysis that hypothesis has not been confirmed.

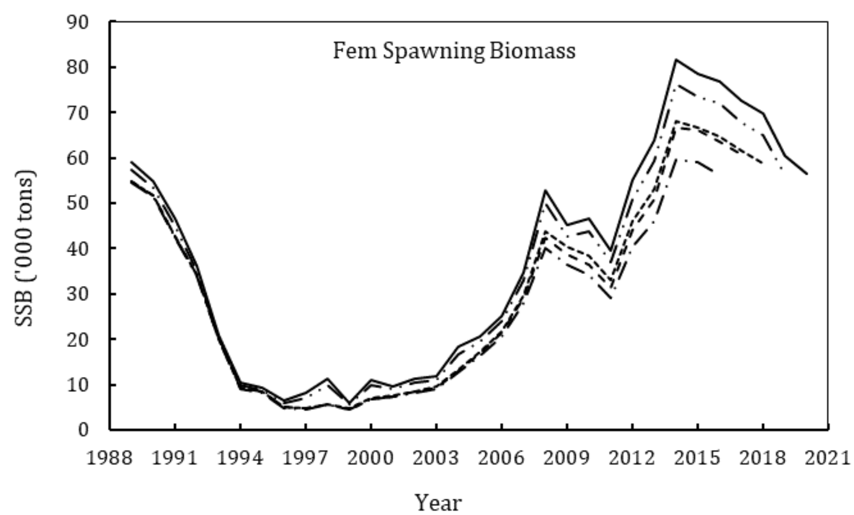
So, the 2021 XSA assessment run with average *M* on 2019 and 2020 kept at 0.10.

f) Assessment Results

The 2021 XSA diagnostics kept the main features from past assessments: high variability associated with mean catchabilities and survivors, namely at younger ages, together with a similar patchwork of *log q age* residuals that remains with only small changes from its predecessors. However, on most recent years a clear annual pattern of positive residuals appears again in older ages, not showing though, the magnitudes of the older times.

A retrospective XSA$_{2020\text{-}2016\ (\text{last year})}$ was carried out for checking patterns and magnitude of bias on the main results of recent assessments back in time (Fig. 7.4). Retrospective patterns are observed on exploitable, female spawning biomass and recruitment (underestimate) and average fishing mortality (overestimate) for most recent years. The last year of the recruitment, should be taken carefully as it has to be confirmed in the next years.





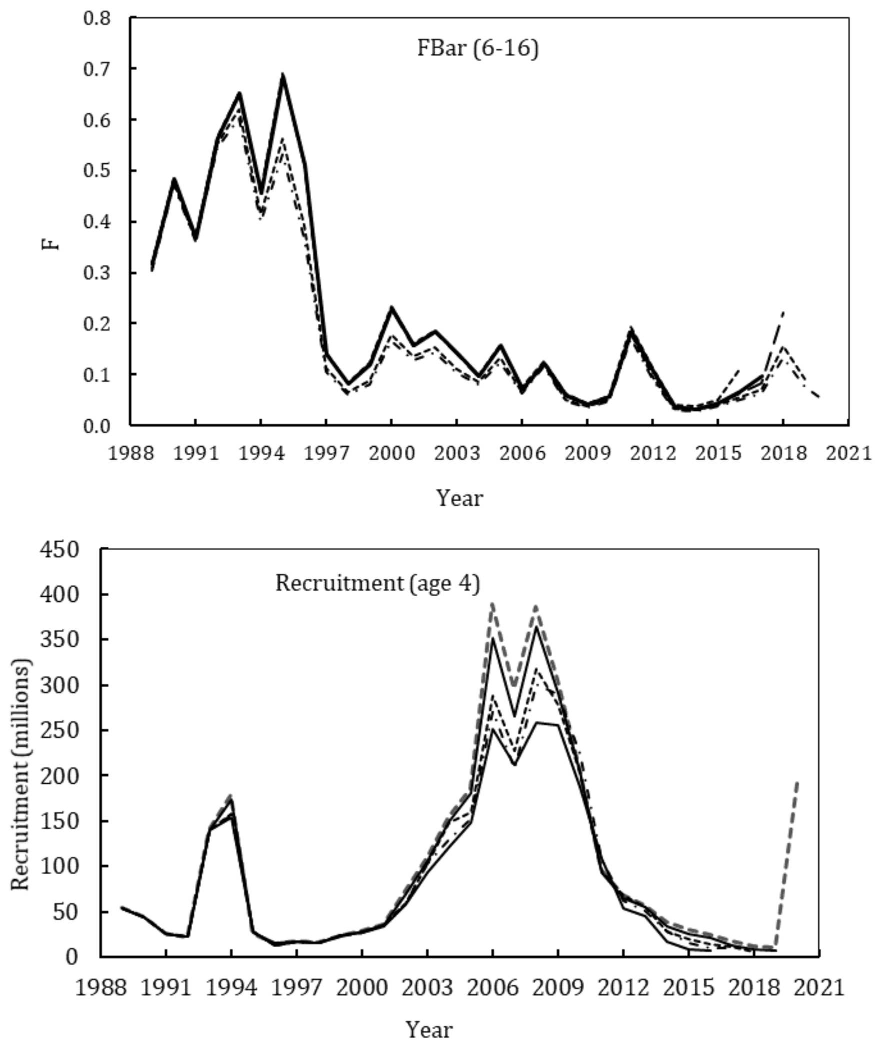


Figure 7.4. Beaked redfish in Div. 3M: XSA retrospective analysis, last year 2020-2016: exploitable 4+ biomass, female spawning stock biomass, average fishing mortality (ages 6-16) and recruitment (age 4).

Taking into account the consistency of present assessment with the previous ones, the 2021 XSA assessment was accepted with 2019-2020 natural mortality at 0.1.

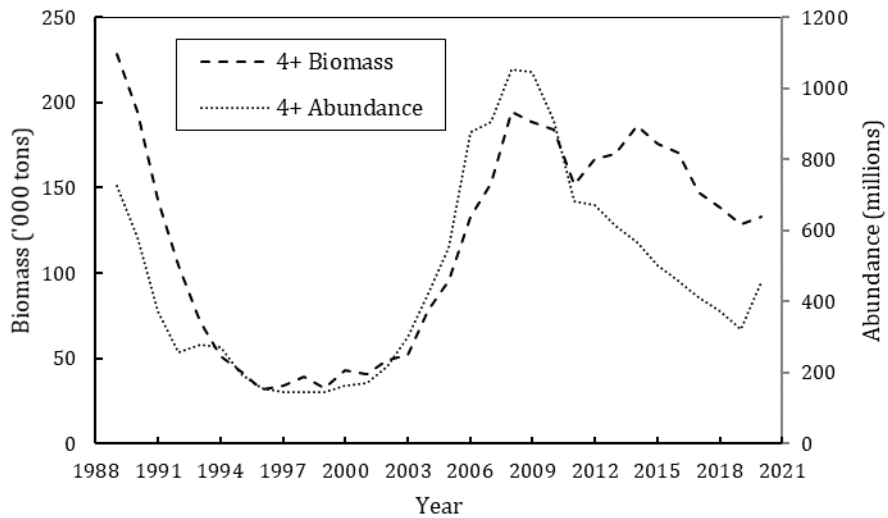


Figure 7.5. Beaked redfish in Div. 3M: age 4+ biomass and age 4+ abundance from XSA.

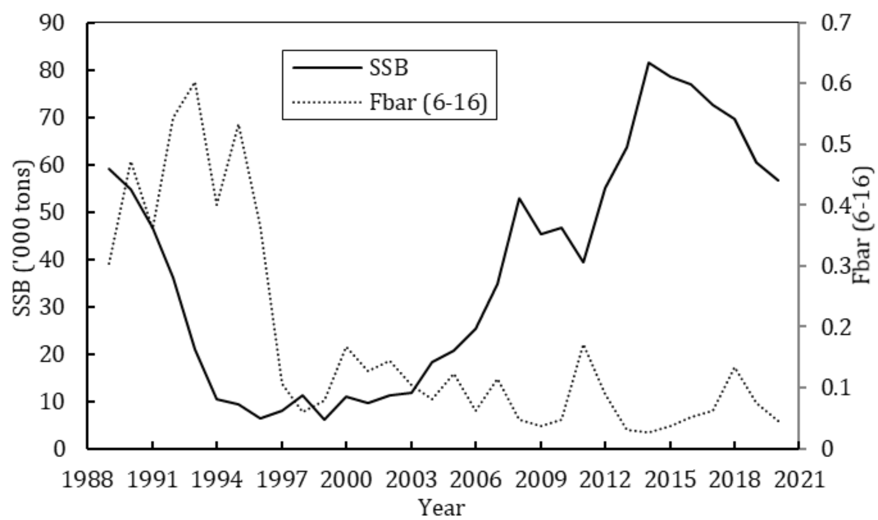


Figure 7.6. Beaked redfish in Div. 3M: female spawning biomass and fishing mortality trends from XSA.

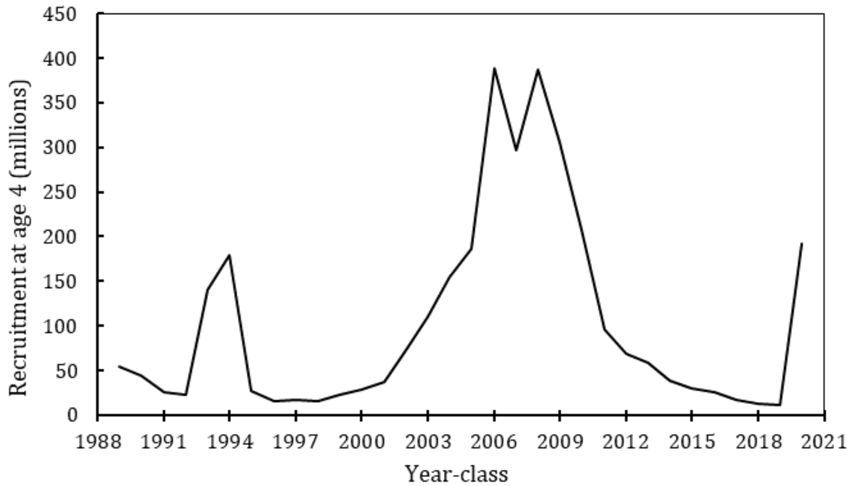


Figure 7.7. Beaked redfish in Div. 3M: recruitment at age 4.

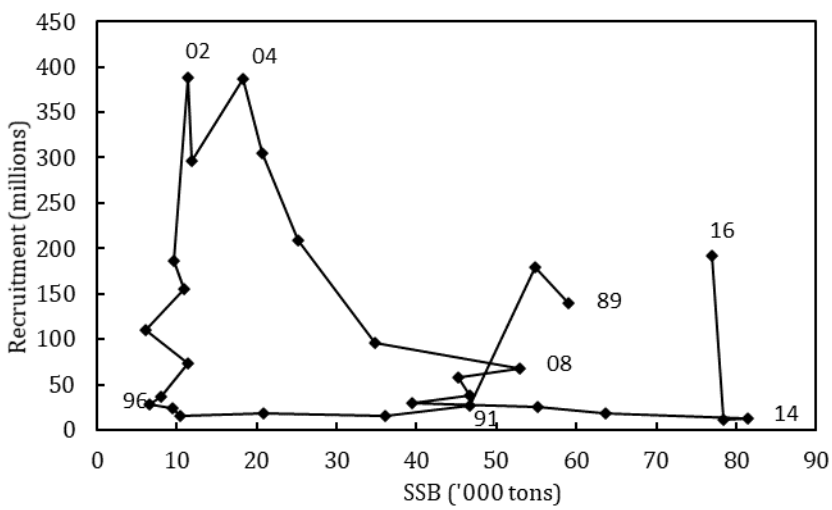


Figure 7.8. Beaked redfish in Div. 3M: Stock/Recruitment plot (labels indicate age class).

Biomass and abundance (Fig. 7. 5): Experienced a steep decline from the 1989 until 1996. The exploitable stock was kept at a low level until the early 2000s, following years of low recruitment. Above average year classes coupled with high survival rates allowed a rapid growth of biomass and abundance since 2003 and sustained the biomass at high levels until 2014. Biomass and abundance have declined from its highest level in 2014. These declines were halted in 2020.

Spawning stock biomass (Fig. 7.6): SSB showed an increasing trend since the late 1990s to 2014. SSB has declined continuously from its highest level in 2014.

Fishing Mortality (Fig. 7.6): Between 1989-1993 very high commercial catches led to high fishing mortalities through the first half of the 1990's. Fishing mortality fell until 1997 and fluctuated between low and average levels since then. Fishing mortality remains relatively low compared to the 1980s and 1990s.

Recruitment (Fig. 7.7 and 7.8): Recruitment at age 4 increased with a sequence of above average year classes from 1999 until 2007, some of them the highest observed in the series (2002-2006). However, recruitment to exploitable stock is declining continuously since 2009 and was in 2017-2019 at an historic minimum level.

After an extended period of declining recruitment, the recruitment estimate for 2020 is high but associated with high uncertainty, and its magnitude needs to be confirmed in future assessments.

State of the stock: SSB has declined continuously from its highest level in 2014. After an extended period of declining recruitment, the recruitment estimate for 2020 is high but associated with high uncertainty, and its magnitude needs to be confirmed in future assessments. Fishing mortality remains relatively low compared to the 1980s and 1990s.

g) Yield per recruit analysis

In order to get proxies of $F_{0.1}$ and F_{max} in line with the most recent partial recruitment (*PR*) results, a new yield per recruit analysis (*ypr*) was performed.

The *PR* vector is given by the 2018-2020 average of the relative *F* at ages 4-18. *M*'s were kept at 0.10 through ages and years but with an associated *CV* correspondent to an allowed variability of natural mortality between 0.08 and 0.12 (the *M* range associated with best sensitivity analysis diagnostics). All input weight at age and maturity at age vectors were averages from the most recent three years. In order to reduce the weight of the plus group on the final results, ages were virtually extended to age 29 with a plus group set at age 30. Mean weights and female maturity were kept constant and were the ones of the XSA 19 plus group.

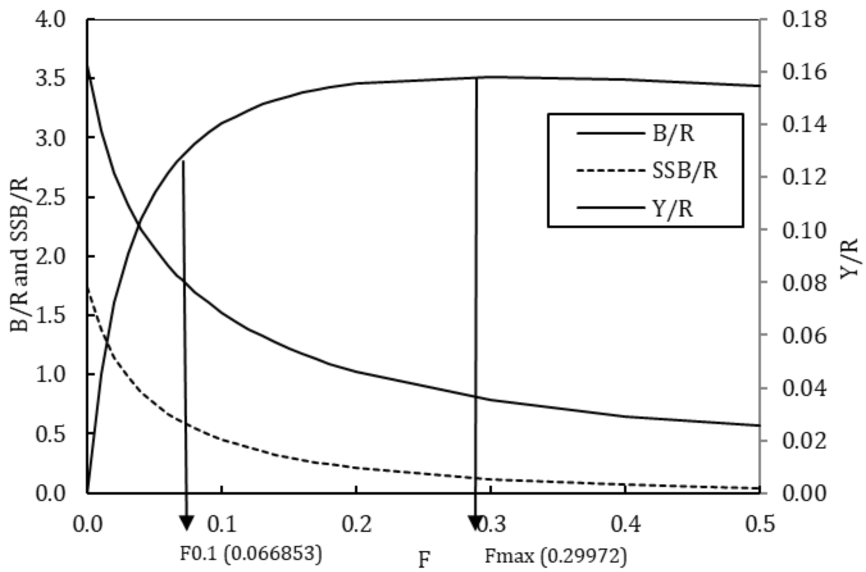


Figure 7.9. Beaked redfish in Div. 3M: yield per recruit analysis at M=0.10 (2018-2020 average inputs)

As regards $F_{0.1}$ the 2021 *ypr* result (Figure 7.9) was below from the previous ones of 2017 and 2019. $F_{0.1}$ is at 0.0669 (0.0911 in 2019 assessment; 0.086 in 2017 assessment) and F_{max} is at 0.2997 (0.1883 in 2019 assessment; 0.163 in 2017 assessment). F_{max} is considered to be estimated with high uncertainty associated and therefore not accepted. The $F_{0.1}$ value have been used for short term projections. The results regarding $F_{0.1}$ and F_{max} are at the moment candidates to 3M beaked redfish fishing mortality reference points that still need to be confirmed in near future.

h) Short term projections

Short term (2022-2024) projections were carried out for female spawning stock biomass (SSB) and catch, under most recent level of natural mortality and considering six options for fishing mortality as follows:

1. No fishing, F_0
2. $F_{0.1}$
3. $F_{statusquo}$
4. F=M=0.1
5. 1.25 TAC
6. 0.75 TAC

Projections assume that redfish catches (all species) in 2021 is equal to the RED TAC ($F_{statusquo}$ is defined as the corresponding F). Recruitment entering in 2021 to 2023 given by the geometric mean of the most recent recruitments (age 4 XSA, 2017-2019).

Stochastic projections of yield and female spawning stock biomass (SSB) under the six F options were initialized with abundance for ages 5 and older at the beginning of 2022. The coefficients of variation for population at age at the beginning of 2022, were set as the internal standard errors from XSA diagnostics. For 2022 and 2023, recruitment was randomly resampled with residuals from the geometric mean of 2017-2019 recruitments (age 4 XSA, 2017-2019). All other inputs at age are the last three year averages with associated errors at age.

Short term projections are summarized on the table below:

Table 7.1. Short term projections for female SSB (50%ile at the beginning of 2021, 90%ile, 50%ile and 10%ile at the beginning of 2022-2024), yield of beaked redfish predicted for 2022 and 2023 (50%ile) under several *F* options and TAC for all three redfish species, based on beaked redfish proportions on observed catch.

***F*=0**

Year	SSB Median and 80% CI	Yield	TAC
2021deterministic	54264	8271	8448
2022	49021 (45226 - 54929)	0	0
2023	48718 (44682 - 54634)	0	0
2024	48557 (44044 - 55328)		

***F0.1*=0.0669**

Year	SSB Median and 80% CI	Yield	TAC
2021deterministic	54264	8271	8448
2022	49021 (45226 - 54929)	10704	10933
2023	43311 (39721 - 48611)	10937	11171
2024	38147 (34488 - 43820)		

***F*=*M*=0.1**

Year	SSB Median and 80% CI	Yield	TAC
2021deterministic	54264	8271	8448
2022	49021 (45226 - 54929)	15506	15837
2023	40898 (37522 - 45931)	14898	15217
2024	34029 (30695 - 39319)		

***FsqTAC*= 0.0558**

Year	SSB Median and 80% CI	Yield	TAC
2021deterministic	54264	8271	8448
2022	49021 (45226 - 54929)	9027	9220
2023	44164 (40476 - 49546)	9415	9616
2024	39674 (35891 - 45447)		

1.25 TAC (*F*= 0.0644)

Year	SSB Median and 80% CI	Yield	TAC
2021deterministic	54264	8271	8448
2022	49021 (45226 - 54929)	10339	10560
2023	43497 (39888 - 48815)	10610	10837
2024	38481 (34787 - 44163)		

0.75 TAC (*F*=0.0376)

Year	SSB Median and 80% CI	Yield	TAC
2021deterministic	54264	8271	8448
2022	49021 (45226 - 54929)	6204	6337
2023	45578 (41810 - 51106)	6697	6840
2024	42303 (38374 - 48389)		

Average beaked redfish proportion in the 2019-2020 3M redfish catch 0.979

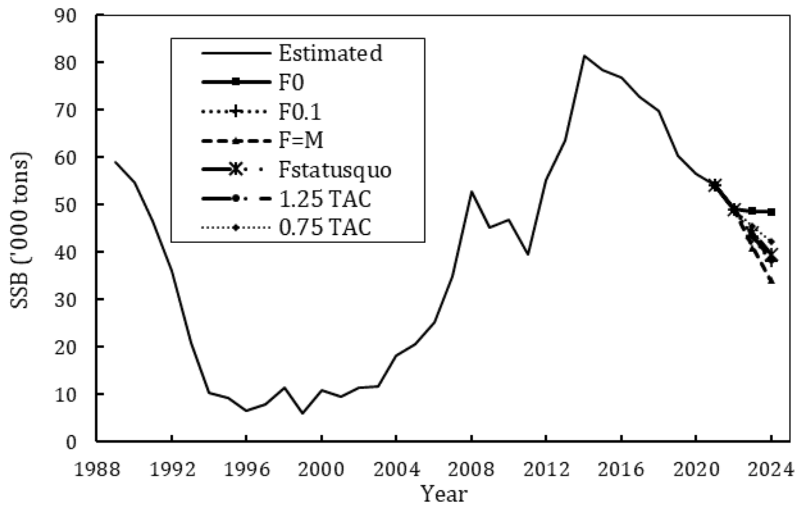


Figure 7.10. Beaked redfish in Div. 3M: SSB trajectory (1989-2020) and 2022-2024 projections (50%ile) under several *F* options

Projection results indicate a 10% decline from 2021 to 2022 (i.e., interim year under $F_{statusquo}$). Thereafter, the stock remains stable if there is no fishing (*F*=0). Results for the six projection scenarios show biomass declines of 11% (for *F*=0), 30% (for $F_{0.1}$), 37% (for *F*=*M*), 27% (for $F_{statusquo}$), 29% (for 1.25 TAC) and 22% (for 0.75 TAC) between 2021 and 2024.

With the exception of the *F*=0 scenario, all projection scenarios, the SSB is projected to decline, and to be at around the average for the assessment time-series (since the late 1980s) by 2024.

	$F_{0.1}$	*F=M*	*Fsq*	1.25 TAC	0.75 TAC
P(SSB_{2022}>SSB_{2021})	<10%	<10%	<10%	<10%	<10%
P(SSB_{2023}>SSB_{2021})	<10%	<10%	<10%	<10%	<10%
P(SSB_{2024}>SSB_{2021})	<10%	<10%	<10%	<10%	<10%

The probability of SSB arrive at the beginning of 2024 greater than it was at the beginning of 2021 is less than 10% regardless the *F* option in place, not taking in consideration the scenario F=0.

i) Reference Points

There are no accepted limit reference points for this stock. Yield per recruit reference points are used in the projections and may be candidate reference points for this stock.

j) Research recommendations

STACFIS **recommends** that *input data should be investigated in order to reduce the retrospective pattern of the XSA assessment, such as the ALKs used. Other assessment models, taking in account the ones used, on redfish stocks, with the same problem of more than one species, in the Golf St. Laurence and NAFO Div. 0, should be explored.*

The next full assessment for this stock is planned to be in 2023.

8. American Plaice (*Hippoglossoides platessoides*) in Div.3M

Interim Monitoring Report (SCR Doc. 21/05; SCS Doc 21/05, 09)

a) Introduction

The stock declined during the late 1980s and since 1996 there has been no directed fishing. Total estimated STACFIS/CESAG bycatch in 2020 was to be 187 tons (Figure 8.1).

Recent catches and TACs ('000 t) are as follows:

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TAC	ndf	ndf	ndf	ndf	ndf	ndf	ndf	ndf	ndf	ndf
STATLANT 21	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	
STACFIS	0.1	0.2	0.2	0.3	0.2	0.2	0.2	0.3	0.2	

Ndf: No directed fishing.

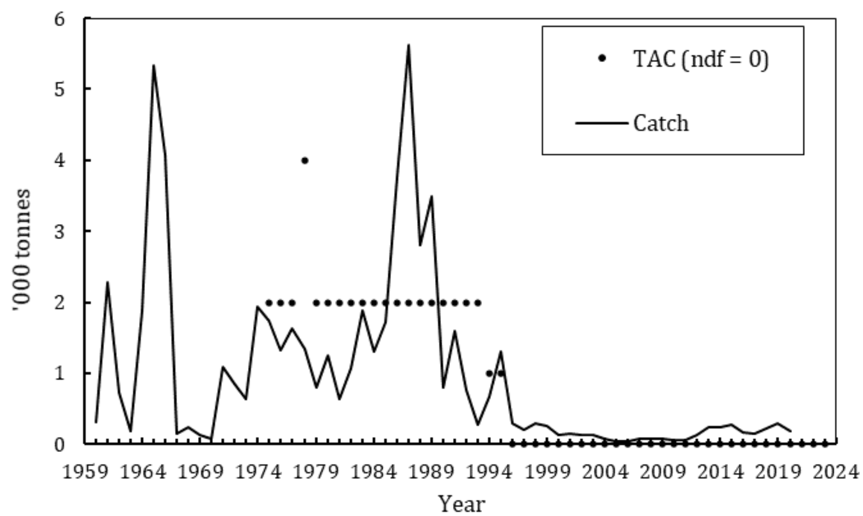


Figure 8.1. American plaice in Div. 3M: STACFIS catches and TACs. No directed fishing is plotted as 0 TAC.

b) Data Overview

The EU bottom trawl survey on Flemish Cap was conducted during 2020. In recent years (2017-2020) the biomass estimate has been relatively stable at levels observed in the mid 1990´s, prior to the fishery closure (Figure 8.2).

All of the 1991 to 2005 year-classes are estimated to be weak. Since 2006 recruitment improved, particularly the 2006, 2012, 2015 and 2018 year classes (Figure 8.3).

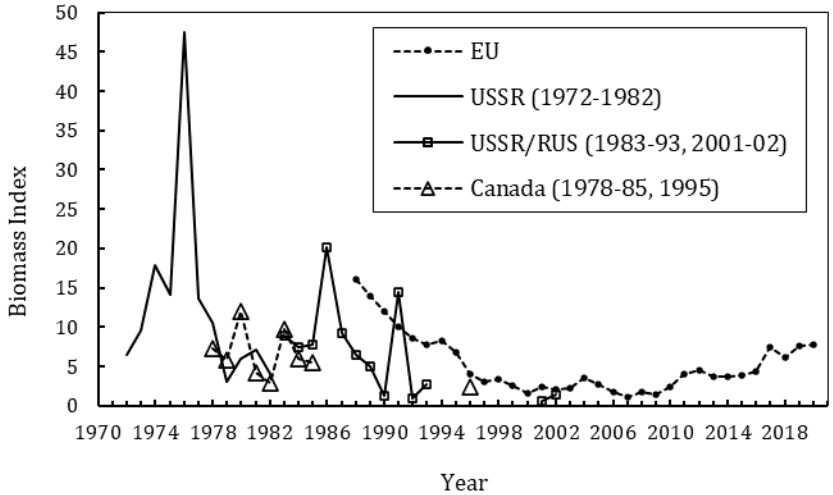


Figure 8.2. American plaice in Div. 3M: trends in survey biomass indices. EU survey data prior to 2003 have been converted to *RV Vizconde Eza* equivalents.

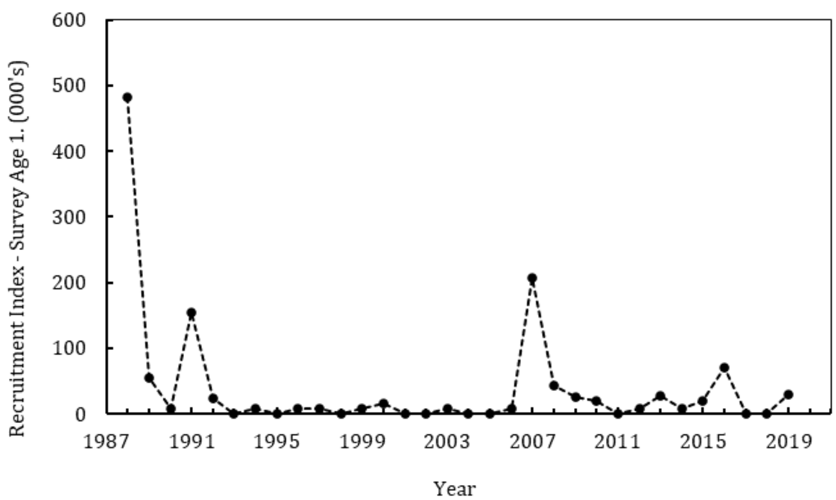


Figure 8.3. American plaice in Div. 3M: Recruitment index, trends in survey age 1 abundance.

c) Conclusion

Catches since 1996 have been low, below 300 t, and although survey biomass has been gradually increasing with signs of improvement in recruitment since 2007 (2006 year-class was particularly strong), the stock remains at a relatively low level. There is no major change to the perception of the stock status and the previous advice of no directed fishing is still valid.

The next full assessment for this stock is planned for 2023.

C. STOCKS ON THE GRAND BANKS (NAFO Divisions 3LNO)

Recent Conditions in Ocean Climate and Lower Trophic Levels

- *In 2020, subareas 2, 3 and 4 were all above normal, making the cumulative anomaly the 5th warmest since 1980;*
- *Spring bloom initiation and magnitude were, on average, near normal in subareas 2-3-4 in 2020;*
- *Mean copepod abundance was above normal in 2020 and especially higher in subareas 2-3 compared to subarea 4;*
- *Mean abundance of non-copepod zooplankton remained above normal across subareas 2-3-4 for a 5th consecutive year and was generally higher in subareas 2-3 compared to subarea 4;*
- *Mean zooplankton biomass was near normal in 2020 for a 5th consecutive year and was higher in in subarea 2 compared to subareas 3-4.*

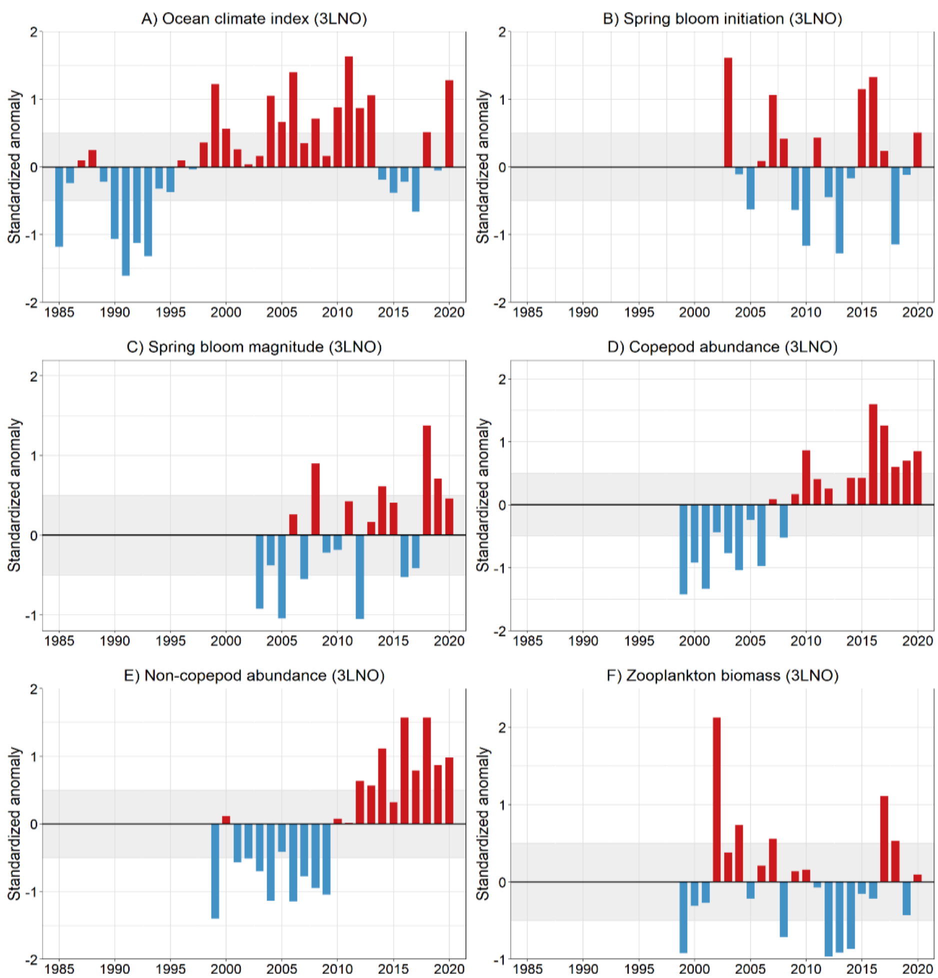


Figure C1. Environmental indices for NAFO Divisions 3LNO. The ocean climate index (A) is the average of 12 individual time series of standardized ocean temperature anomalies: SSTs for Divs. 3L, 3N and 3O, vertically average ocean temperature (0-176 m) at Station 27, mean temperature and CIL volumes over standard hydrographic sections Seal Island, Bonavista and 3L portion of Flemish Cap, and mean bottom temperature in 3LNO for spring and fall. Positive/negative anomalies indicate values above/below (or late/early timing) the long-term average for the reference period. Anomalies were calculated using the following reference periods: 1981-2010 for ocean climate index, 2003-2020 for spring bloom initiation and magnitude, and 1999-2020 for zooplankton abundance and biomass indices. Anomalies within ±0.5 SD (grey rectangle) are considered near-normal conditions.

Environmental Overview

The water mass characteristic of the Grand Bank is 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 C1.A) has remained mostly above normal between the late 1990s and 2013, reaching a peak in 2011. The index has returned to normal conditions between 2014 and 2019 (except for 2017 that was below normal). In 2020, the ocean climate index was back to above normal value, reaching the third highest value of the entire time series started in 1985 (only 2011 and 2006 were warmest). The initiation of the spring bloom has remained near or earlier than normal on the Grand Bank since 2017 after the two notably late blooms observed in 2015 and 2016 (Figure C1.B). Spring bloom magnitude (total production) decreased to near normal in 2020 after two consecutive years of above-normal production (Figure C1.C). Spring bloom production has remained mostly near or above normal since the record low observed in 2012 (Figure C1.C). The abundance of copepod and non-copepod zooplankton show clear increasing trend since the beginning of the time series in 1999 with anomalies transitioning form negative to positive around 2010 (Figure C1.D-E). Both copepod and non-copepod abundance remained above normal in 2020 for a 5th consecutive year with 4th highest anomaly of the time series (Figure C1.D-E). Zooplankton biomass drastically declined on the Grand Bank between 2002 and 2014 but has increased to near or above-normal levels since 2015 (Figure C1.F).

9. Cod (*Gadus morhua*) in NAFO Div. 3NO

(SCR Docs. 21/04; SCS Docs. 21/05, 06, 08, 09, 10, 13.)

a) Introduction

This stock has been under moratorium to directed fishing since February 1994. Total bycatch during the moratorium increased from 170 t in 1995, peaked at about 4 800 t in 2003 and has been between 400 t and 1100 t since that time. The bycatch in 2020 was 588 t.

Recent TACs and catches ('000 tons) are as follows:

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TAC	ndf	ndf	ndf	ndf	ndf	ndf	ndf	ndf	ndf	ndf
STATLANT 21	0.7	1.1	0.7	0.5	0.6	0.6	0.3	0.5	0.3	
STACFIS	0.7	1.1	0.7	0.6	0.7	0.6	0.4	0.5	0.6	

ndf : No directed fishery

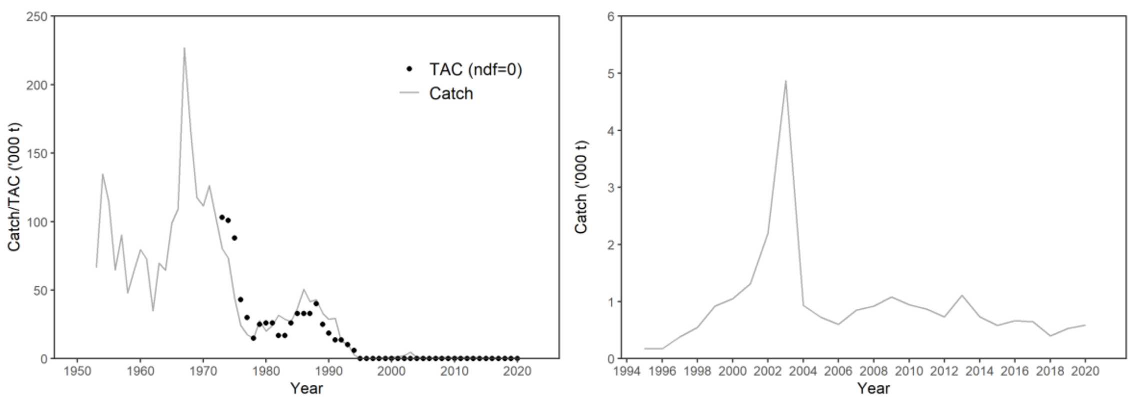


Figure 9.1. Cod in Div. 3NO: total catches and TACs. Panel at right highlights catches during the moratorium on directed fishing.

b) Data Overview

This assessment utilizes commercial catch at age data for 1959-2019 along with data from Canadian spring (1984-2019), autumn (1990-2019), and juvenile (1989-1994) surveys. As per previous assessments, trends in the EU-Spain survey were presented but not used as input to the assessment model. Catch at age could not be estimated for 2020 due to a lack of commercial sampling and so this assessment estimates stock size in 2020 rather than 2021.

i) Commercial fishery data

Catch-at-age. The calculation of catch numbers and weights at-age in recent years has been complicated by low sampling of bycatch. This has led to concern over the reliability of catch at age estimates and ultimately added an unquantified level of uncertainty to the assessment results. Specifically, there were no length data available for catches from the 280 mm mesh otter trawl fishery by EU-Spain in 2018-19. Length frequencies for Canadian catches were applied to the EU-Spain (280 mm) catches. In 2019 there was also no sampling of EU-Portugal catches and there was no sampling of catches for other contracting parties in 2018-19. In these instances, EU-Spain length frequencies from the 130 mm mesh otter trawl fishery were applied to catches. The catch-at-age for all fleets was constructed by applying Canadian survey age length keys. Results indicate that the most abundant ages in the commercial catch were 4-6 in 2018, and 3-5 in 2019. There was no estimate of catch at age for 2020 due to a lack of commercial sampling.

ii) Research survey data

Canadian bottom trawl surveys. The spring survey biomass index declined from 1984 to 1995 and has generally remained low since that time (Figure 9.2). There was an increase in biomass during 2011-2014 but indices have subsequently declined again and the 2019 biomass index is among the lowest in the time series. Trends in biomass are similar for the spring and autumn surveys and trends in abundance and biomass are similar except for 2011-2014, when biomass increased while abundance remained stable (Figure 9.2).

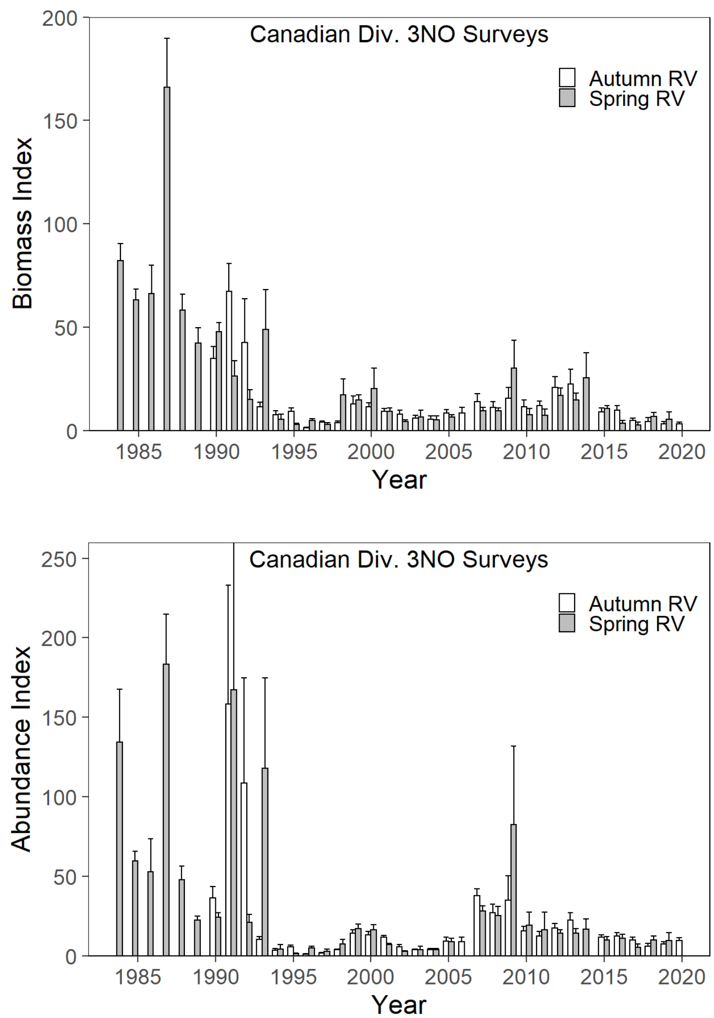


Figure 9.2. Cod in Div. 3NO: survey biomass and abundance indices (+ 1 sd) from Canadian Spring and autumn surveys.

Canadian juvenile surveys. The index increased from 1989 to 1991, and declined steadily from 1992 to 1994 (Figure 9.3).

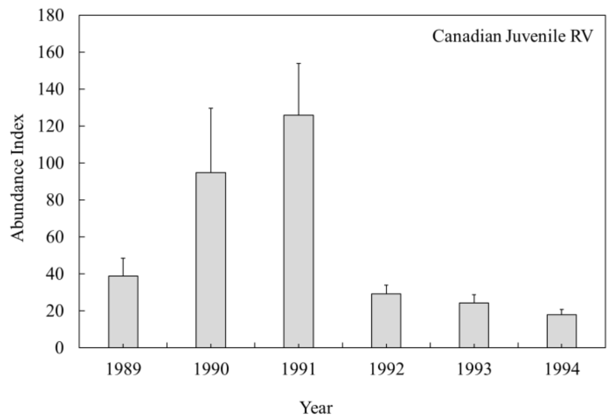


Figure 9.3. Cod in Div. 3NO: survey abundance index (+ 1 sd) from Canadian Juvenile surveys.

EU-Spain Div. 3NO surveys. The biomass index was relatively low and stable from 1997-2005 with the exception of 1998 and 2001 (Figure 9.4). There was a considerable increase in the index from 2008-2011, followed by a decline to 2013. In 2014, the index increased to the highest value in the time series but has continually decreased in subsequent years.

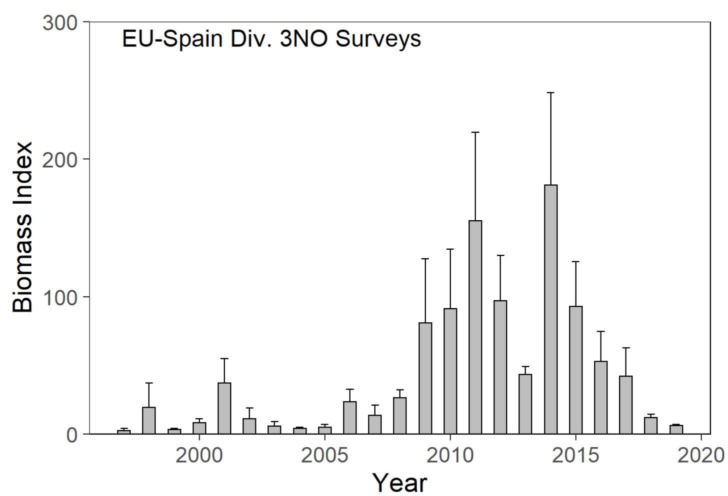


Figure 9.4. Cod in Div. 3NO: survey biomass index (+ 1 sd) from EU-Spain Div. 3NO surveys.

iii) Biological Studies

Maturity-at-age

Annual proportion mature is modeled by cohort. The estimated age at 50% maturity (A50) ranged between 5.6 and 7.4 years for cohorts produced from the 1950s to 1980s. Age at 50% maturity declined for cohorts between 1980 and the late 1990s from approximately 6.8 to 4.5 years. Since that time estimates of A50 have been variable, with the most recent estimable cohorts (2012-2014) ranging from 5.2 to 5.7 years.

c) Estimation of Parameters

Sequential population analysis (SPA)

An ADAPT was applied to catch-at-age calibrated with the Canadian spring, autumn and juvenile survey data (ages 2-10). The SPA formulation estimated numbers at ages 3-12 in 2020, age 12 from 1994-2019 and survey catchabilities at ages 2-10 for each survey. In the estimation, an *F*-constraint was applied to age 12 from 1959-93 by assuming that fishing mortality was equal to the average fishing mortality over ages 6-9. Natural mortality was assumed fixed at 0.2 for all years and ages. The mean square error of the model fit was 0.624.

d) Assessment Results

Biomass: The SPA results calibrated with the three Canadian survey indices indicate that the spawning stock was at an extremely low level in 1994 and remained stable at a low level to 2010. SSB increased to 2015 but has subsequently declined sharply and the 2020 estimate of 7279 t represents only 12% of B_{lim} (60 000 t).

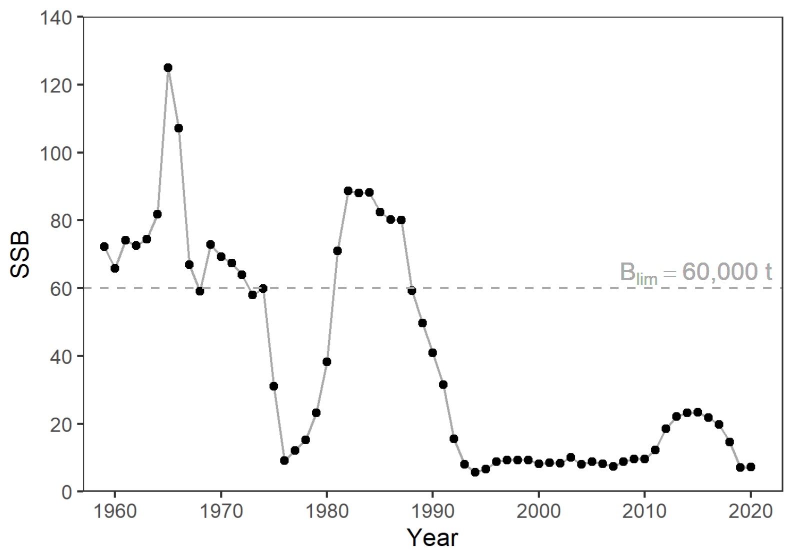


Figure 9.5. Cod in Div. 3NO: time trend of spawner stock biomass (SSB) from the SPA.

Recruitment: The 2006 year class was estimated to have the highest level of recruitment in the past two decades, with a level comparable to those from the mid - late 1980s but well below historic values (Figure 9.6). Estimated recruitment has not been strong for subsequent year classes.

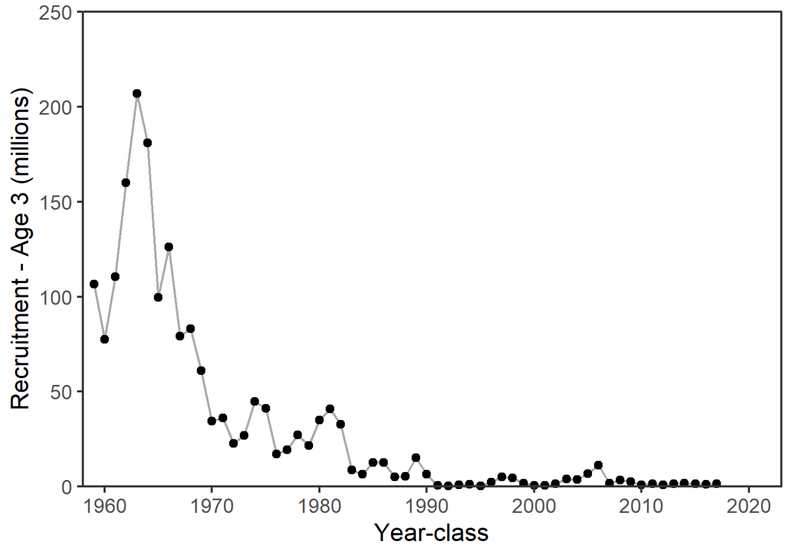


Figure 9.6. Cod in Div. 3NO: time trend of recruitment (age 3) from the SPA.

Fishing mortality: Fishing mortality was low in the early years of the moratorium but then increased and peaked in 2003 (Figure 9.7). Fishing mortality over the past decade has been amongst the lowest values in the time series and well below F_{lim}.

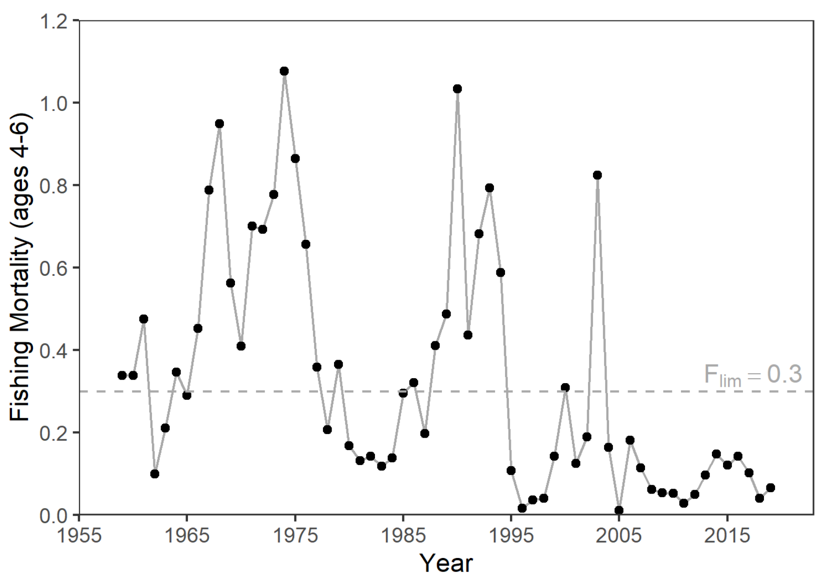


Figure 9.7. Cod in Div. 3NO: time trend of average fishing mortalities from the SPA.

e) State of the Stock

The spawning biomass increased noticeably between 2010 and 2015 but has subsequently declined sharply and the 2020 estimate of 7279 t represents only 12% of B_{lim} (60,000 t). The relatively strong 2006 year class left the population after 2018, which had some influence on the most recent SSB estimates but did not influence overall stock status. Subsequent year classes are much weaker, suggesting that the medium-term prospects for the stock are not good. Fishing mortality values over the past decade have been low and well below F_{lim} (0.3). Lack of catch-at-age data in 2020 prevented the estimation of stock size for 2021, however it should not be markedly different than the 2020 estimate.

f) Retrospective Analysis

A retrospective analysis was conducted to investigate whether there were systematic trends in the estimates of population size. A 5-year period was chosen to evaluate, whereby a complete year of data was removed in succession from the model but the formulation remained the same. Retrospective patterns were relatively small, but with a tendency for overestimation of SSB (Figure 9.8).

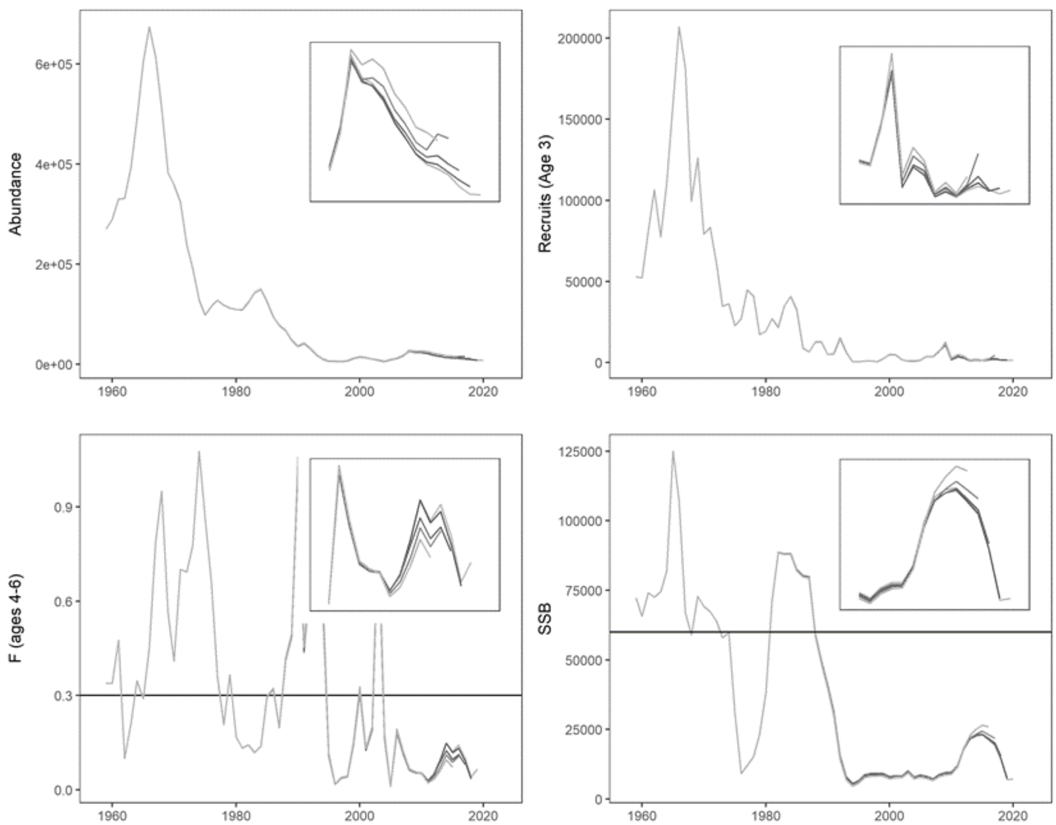


Figure 9.8. Cod in Div. 3NO: Five-year retrospective analysis of total abundance, age 3 recruitment, average F on ages 4-6, and SSB.

g) Reference Points

Mean fishing mortality for ages 4-6 in 2019 was estimated to be 0.07, well below the F_{lim} of 0.3 (Figure 9.9). The current estimate of B_{lim} is 60,000 t, the point below which only poor recruitment has been observed. SSB in 2020 is estimated to be 7279 t which is 12% of B_{lim}.

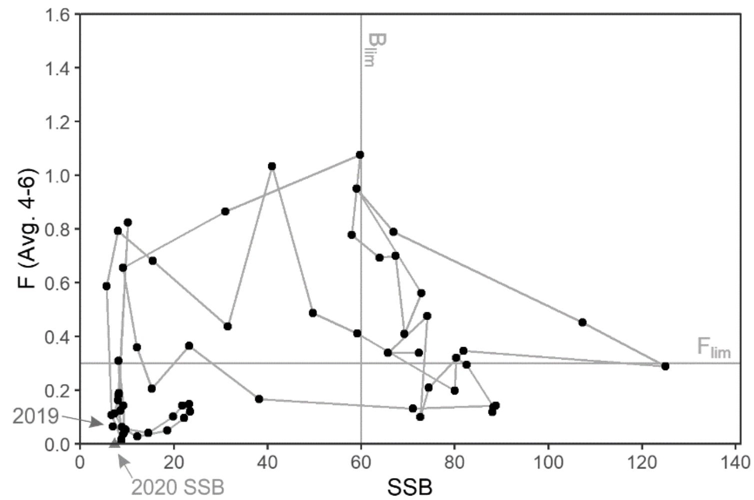


Figure 9.9. Cod in Div. 3NO: stock trajectory (1959-2019) within the NAFO PA framework.

h) Short-Term Considerations – Stochastic Projections

A decision was made to not project the stock forward because of the limited age range (ages 2-12) considered in the model, as well as potential diagnostic issues (including directional retrospective patterns, trends in residuals in recent years). Limitations of the current assessment model suggest a need to explore more flexible models capable of dealing with uncertainty in model inputs (e.g. catch at age) and that do not impose assumptions about stationary natural mortality. Although projections of the stock were not performed, the poor strength of year classes subsequent to 2006 suggests that the medium-term prospects for the stock are not good.

The next assessment of this stock will be in 2024.

Research Recommendations:

STACFIS **recommends** *investigating the potential use of a plus group in the assessment of Divs. 3NO cod.*

STATUS: Numerous attempts to incorporate a plus group within the ADAPT-based assessment of this stock all produced unsatisfactory results, either because of failure of models to converge, computational issues, or poor model fits. More flexible assessment models may be explored in the future to handle a broader age structure, as well as address issues of uncertainty in the catch at age data, and assumption with respect to constant natural mortality.

STACFIS **recommends** *continuing to monitor the consistency in trends between the Canadian and EU-Spain surveys.*

STATUS: Trends in the EU-Spain survey data were generally similar to the Canadian-Spring and Autumn surveys. However, the inclusion of the EU-Spain survey in the current ADAPT-based assessment as an additional tuning index resulted in overall poorer model fit. It was not considered to be an improvement over the currently accepted model formulation.

STACFIS **recommends** *investigating the removal of the pre-1995 Canadian autumn assessment points for an improvement in model fit / residual pattern.*

STATUS: The removal of the pre-1995 Canadian autumn assessment points did not improve the model fit / residual patterns and is not considered to result in an improvement over the currently accepted model formulation.

STACFIS **recommends** *examining the selectivity pattern (i.e. flat-topped vs. dome-shaped)*

STATUS: Analyses demonstrated that selectivity was flat-topped during the portion of the time series with a directed fishery (1959-2013), but that selectivity for the by-catch fishery during the moratorium period (1994-2019) was dome-shaped.

10. Redfish (*Sebastes mentella* and *Sebastes fasciatus*) in Divisions 3L and 3N

Interim Monitoring Report (SCR Doc. 20/033REV2, 21/004, SCS Doc. 21/04, 05, 06, 09,13)

a) Introduction

There are two species of redfish that have been commercially fished in Div. 3LN, the deep-sea redfish *(Sebastes mentella)* and the Acadian redfish *(Sebastes fasciatus*). The external characteristics are very similar, making them difficult to distinguish, and as a consequence they are reported collectively as "redfish" in the commercial fishery statistics and the surveys.

Catches declined to low levels in the early 1990s. From 1998-2009 a moratorium was in place. During that time catches were taken as by-catch primarily in Greenland halibut fisheries. With the reopening of the fishery in 2010 catches increased steadily, with removals of 13,100 t in 2019 and 11,100 t in 2020. A management strategy has been adopted for this stock based on a stepwise rule with biennial catch increases over the years 2015 to 2020, this management strategy was extended for more two years 2021 and 2022 (NAFO/COM Doc. 20-01, NCEM)

Recent nominal catches and TACs ('000 t) for redfish are as follows:

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TAC	6.0	6.5	6.5	10.4	10.4	14.2	14.2	18.1	18.1	18.1
STATLANT 21	4.3	6.2	5.7	10.2	8.5	11.9	11.5	13.0	11.7	
STACFIS	4.3	6.2	5.7	9.9	8.7	11.8	11.3	13.1	11.1	

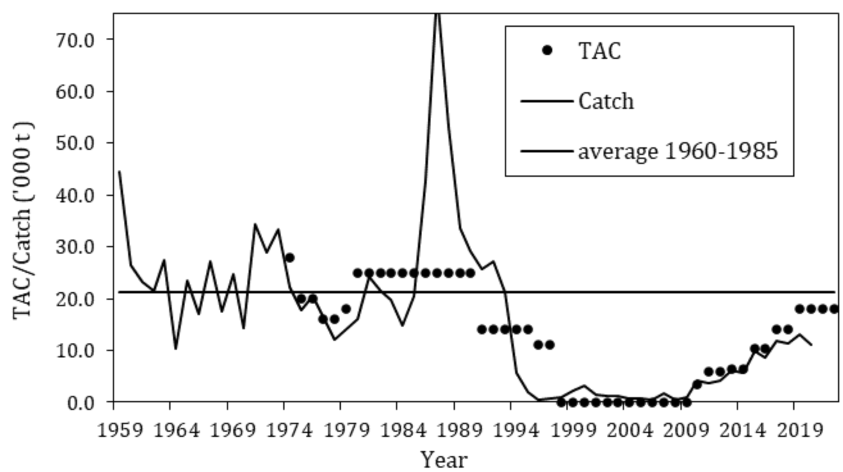


Figure 10.1. Redfish in Divs. 3LN: catches and TACs (No directed fishing is plotted as zero TAC).

b) Data Overview

i) Research surveys

All of the available surveys in Div. 3L and Div. 3N have been incorporated in the most recent assessment framework for this stock. These surveys are updated for 2020 and standardized in order to be presented on Figure 10.2. Due to COVID-19, the only survey carried out in 2020 was the Canadian Autumn survey.

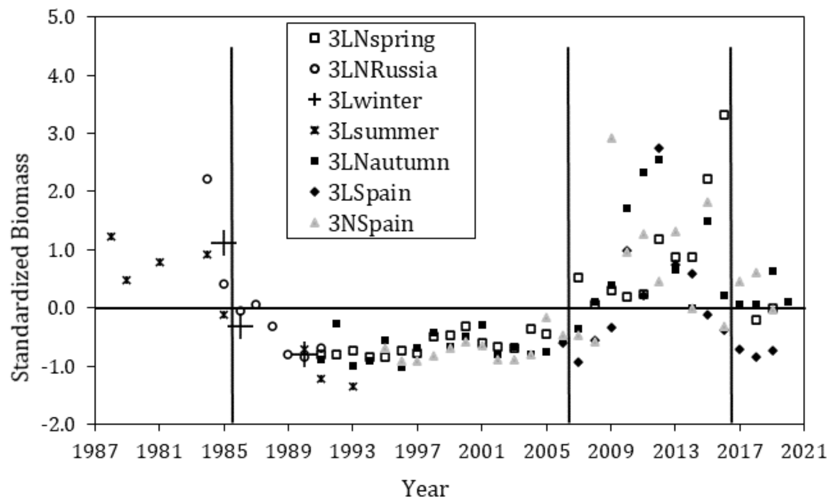


Figure 10.2. Redfish in Div. 3LN: standardized survey biomass (1978-2020). Each series is standardized to the mean and unit standard deviation. Surveys labeled as 3LNspring, 3Lautumn, 3Lwinter, 3Lsummer and 3LNautumn were conducted by Canada.

From the late 1970s to the beginning of the 1990s Canadian surveys in Div. 3L and Russian bottom trawl surveys in Div. 3LN suggest that stock size suffered a substantial reduction. Redfish bottom biomass from surveys in Div. 3LN remained well below average level over the 1990's and early 2000's. Clear increases of survey biomass are evident in 2007-2015, but biomass declined and/or stabilized between 2016 and 2020.

c) Estimation of Stock Parameters

i) Relative exploitation

Ratios of catch to the Canadian 3LNspring survey biomass were calculated and are considered a proxy of fishing mortality (Figure 10.3). The spring survey series was chosen since it is usually carried out on Div. 3L and Div. 3N from May to the beginning of June, and can give an index of the average biomass at the middle of each year.

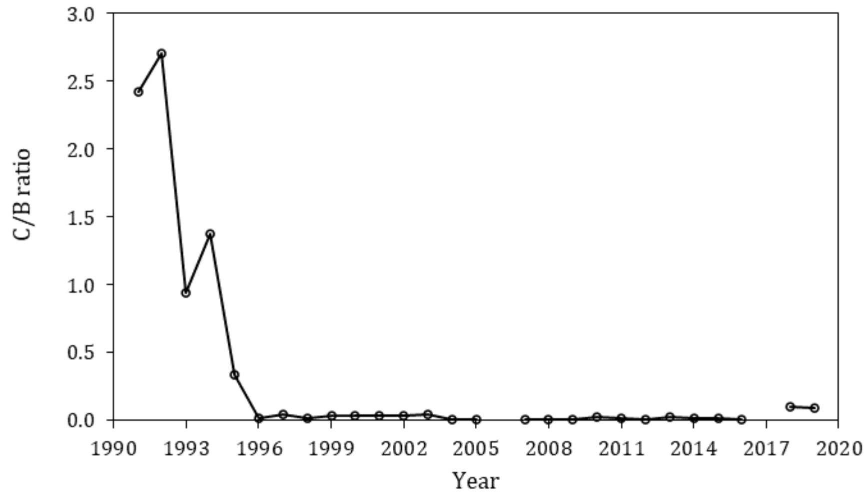


Figure 10.3. Redfish in Div. 3LN: C/B ratio using commercial catch and Canadian spring survey biomass (1991-2019).

Catch/Biomass ratio declined from 1991 to 1996. From 1996 to 2016 this proxy of fishing mortality is at a level close to zero, with a marginal increase in 2018 and 2019 (no survey spring data available for 3L 2006 or 2017 and 3LN 2020).

d) Conclusions

There is nothing to indicate a substantial change in the status of the stock given by the most recent surveys and the 2020 assessment.

The next full assessment of this stock is planned for 2022.

11. American Plaice (*Hippoglossoides platessoides*) in Divisions 3LNO

(SCS Doc. 21/05, 21/06, 21/06; SCR Doc. 20/008, 20/013, 21/004, 21/010, 21/025, 21/032 21/035,)

a) Introduction

The majority of American plaice catch has been taken by offshore otter trawlers. There was no directed fishing in 1994 and this stock has been under moratorium since 1995. Landings from by-catch increased until 2003, after which they began to decline. STACFIS agreed catch estimates were 1 002t in 2018, 1 245t in 2019, and 1 171t in 2020 (Figure 11.1). Recently, American Plaice have been taken as by-catch mainly in the Canadian Yellowtail Flounder fishery, EU-Spain and EU-Portugal skate, and redfish fisheries.

Recent nominal catches and TACs ('000 t) are as follows:

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TAC	ndf	ndf	ndf	ndf	ndf	ndf	ndf	ndf	ndf	ndf
STATLANT 21	1.3	2.2	1.4	1.1	1.7	1.2	0.8	1.2	1.1	
STACFIS	2.1[1]	3.0[1]	2.3[1]	1.1[2]	1.7[2]	1.2[3]	1.0[3]	1.2[3]	1.2[3]	

ndf No directed fishing.

[1]Catch was estimated using fishing effort ratio applied to 2010 STACFIS catch.

[2] Catch was estimated using STATLANT 21 data for Canadian fisheries and Daily Catch Records for fisheries in the NRA.

[3]Catch was obtained from CESAG catch estimates

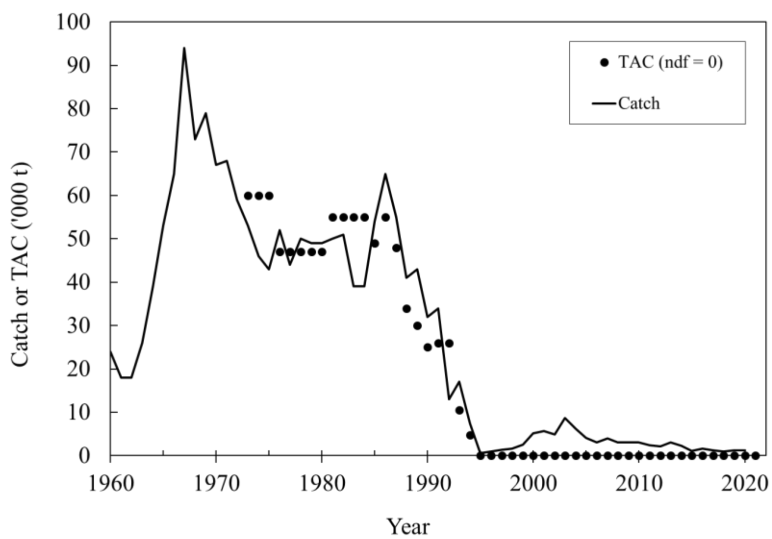


Figure 11.1. American Plaice in Div. 3LNO: estimated catches (line) and TACs (points). No directed fishing is plotted as 0 TAC.

b) Input Data

Biomass and abundance data were available from: annual Canadian spring (1985-2019) and autumn (1990-2020) bottom trawl surveys of Div. 3LNO, and EU-Spain surveys in the NAFO Regulatory Area of Div. 3NO (1995-2019). EU-Spain surveys in 1995 and 1996 were incomplete and are not considered further. The Canadian spring survey in 2006 did not adequately cover many of the strata in Divisions 3NO. In 2015 and 2017, the Canadian spring survey did not adequately cover all of the strata in Div. 3L. Likewise, in 2004, coverage of strata from Div. 3L in the Canadian autumn survey was incomplete, and in 2014 there was no coverage of Divs. 3NO. Therefore the 2006, 2015 and 2017 Canadian spring survey and the 2004 and 2014

Canadian autumn survey results were not used in the assessment. There was no Canadian spring survey or EU-Spain survey in Div. 3NO in 2020 due to COVID-19 restrictions.

Age data are collected on the Canadian surveys, and age-length keys from the CAN-Spring survey in Div. 3N are used to age catches in the EU-Spain 3NO survey.

i) Commercial fishery data

Catch and effort.

Catch estimates since 2017 have been obtained from CESAG estimates. There was no recent catch per unit effort data available.

Catch-at-age.

There was no aging data from American plaice bycatch in 2020, therefore ALKs from 2019 were used to age the 2020 commercial catch. Length sampling of bycatch in the Canadian (2018-2019), EU-Spain (2018-2020), and EU-Portugal (2018-2020) fisheries were used to update catch at age for this assessment. Total catch-at-age for all years was produced by applying Canadian survey age-length keys to length frequencies collected each year by countries with adequate sampling and adding the results to the catch-at-age calculated for Canada. This total was adjusted to include catch for which there were no sampling data from Contracting Parties such as Japan, Estonia, Russia, and United States. Issues have been reported regarding the quality and coverage of commercial sampling in recent years.

ii) Research survey data

Canadian stratified-random bottom trawl surveys.

Spring survey biomass and abundance estimates for Div. 3LNO declined substantially during the late 1980s and early 1990s. Both biomass and abundance generally increased from 1996 to 2014 but have declined since (Figure 11.2). In 2019, spring biomass was the lowest value since 1995 and the second lowest in the time series.

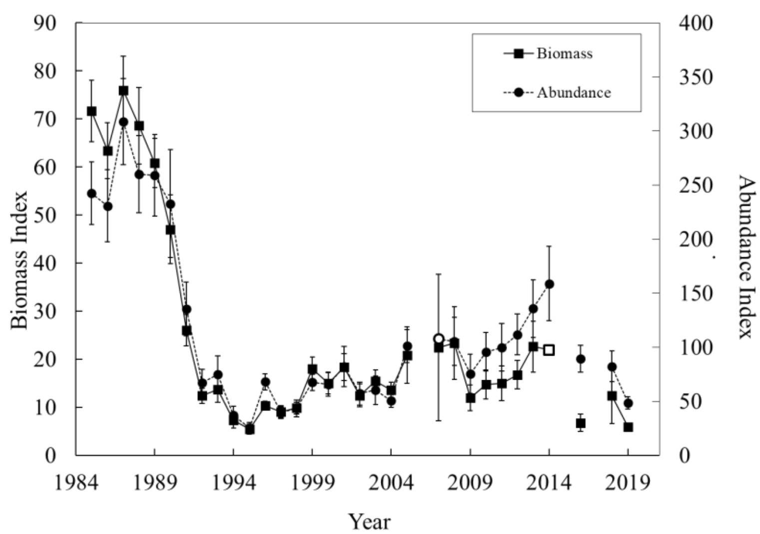


Figure 11.2. American Plaice in Div. 3LNO: biomass and abundance indices with approximate 95% confidence intervals from Canadian spring surveys. Data prior to 1996 are Campelen equivalents and since then are Campelen. Open symbols represent years where CIs extend to negative values.

Autumn survey biomass and abundance indices declined from 1990 to the early-mid 1990s. Both indices showed an increasing trend from 1995 to 2015, but have since declined (Figure 11.3). The trends observed are similar to the Canadian spring surveys.

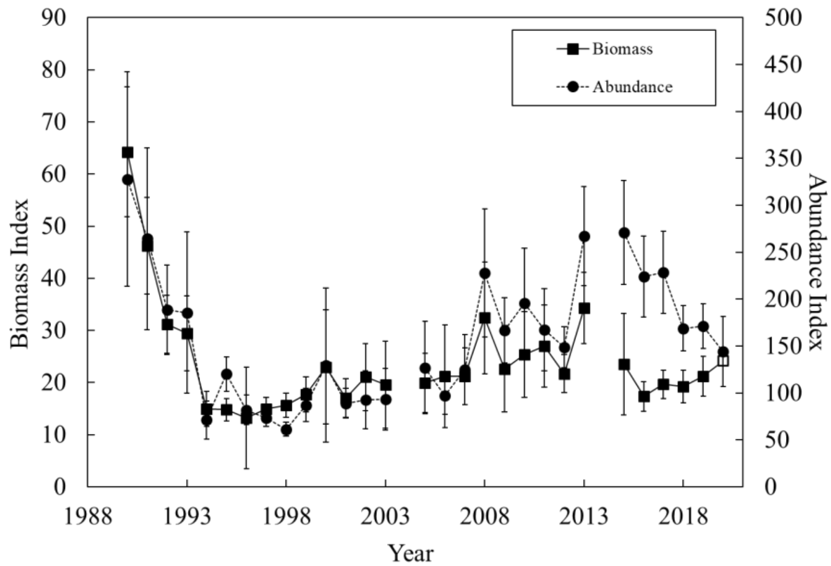


Figure 11.3. American Plaice in Div. 3LNO: biomass and abundance indices with approximate 95% confidence intervals from autumn surveys. Data prior to 1996 are Campelen equivalents and since then are Campelen. Open symbols represent years where CIs extend to negative values.

Stock distribution for Canadian Surveys.

The largest portion of this stock has historically been located in Div. 3L, however the highest declines in survey indices in the early 1990s were experienced in this Division. Biomass has been more heavily concentrated in Div. 3N since 2000, but this Division showed the greatest decline over 2013-2016, and indices in Div. 3N were at or below levels of Div. 3L in 2019-2020. There was a substantial increase in abundance in Div. 3L from 2010 to 2015 associated with ages ≤5. Abundance has declined since.

EU-Spain Div. 3NO Survey.

Numbers at age (1997 to 2019) were used in the assessment model. In 2001, the vessel (CV *Playa de Menduiña*) and gear (*Pedreira*) were replaced by the RV *Vizconde de Eza* using a *Campelen* trawl. Annual Canadian spring RV age length keys were applied to EU-Spain length frequency data (separate sexes, mean number per tow) to get numbers at age. This method could not be applied to 2006 estimates, as the Canadian spring survey was incomplete. The combined 1997-2005 age length keys were applied to the 2006 data. In 2015 and 2017, Canadian spring surveys were not completed, so ALKs from the previous year (2014 and 2016, respectively) were applied. Estimates of both indices from the EU-Spain survey varied without trend from the start of the time series to 2013 but have declined since then (Figure 11.4). The 2019 values for abundance and biomass were the lowest in the time series.

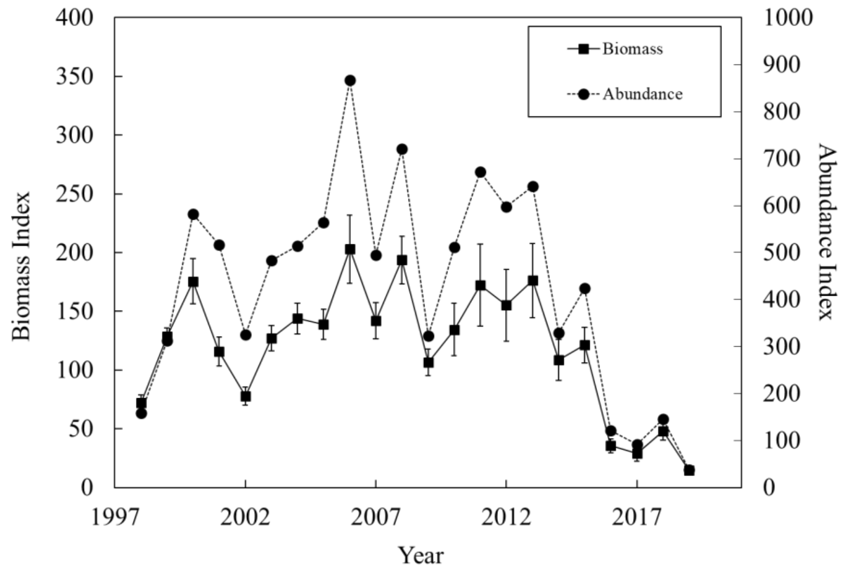


Figure 11.4. American Plaice in Div. 3LNO: biomass and abundance indices from the EU-Spain Div. 3NO survey (Data prior to 2001 are Campelen equivalents and since then are Campelen).

iii) Biological studies

Maturity.

Age at 50% maturity (A_{50}) was calculated for male and female American Plaice for Div. 3LNO using Canadian spring survey data. A_{50} has declined since the 1960s and 1970s from 6 to 4 years for males and 11 years to 8 years for females for the most recent cohort.

Size-at-age.

Mean weights-at-age and mean lengths-at-age were calculated for male and female American Plaice for Div. 3LNO using Canadian spring survey data from 1990 to 2016. Means were calculated accounting for the length stratified sampling design. Although there is variation in both length and weight-at-age there is little indication of any long-term trend for either males or females. Size at age was not updated in 2020.

c) Estimation of Parameters

An analytical assessment using the ADAPTive framework is used for this stock. This virtual population analysis (VPA) is conducted with catch-at-age and survey information from the following:

- Catch at age (1960-2020) (ages 5-15+);
- Canadian spring RV survey (1985-2019) (no 2006, 2015, 2017, 2020 values) (ages 5-14);
- Canadian autumn RV survey (1990-2020) (no 2004 or 2014 values) (ages 5-14); and
- EU-Spanish Div. 3NO survey (1998-2019) (no 2020 value) (ages 5-14).

In this base formulation, there is a plus group at age 15 in the catch-at-age and the ratio of *F* on the plus group to *F* on the last true age was set at 1.0 across all years. Natural mortality (*M*) was assumed to be 0.2 on all ages except from 1989-1996, where *M* was assumed to be 0.53 on all ages. While results from the base model are considered to be indicative of stock trends, the absolute magnitude of population estimates from this model was not accepted by STACFIS given a large retrospective pattern that consistently and significantly overestimates SSB and underestimates F.

Several additional formulations of the ADAPT VPA with increases in the natural mortality assumption since at least 2005 were also considered (Table 11.1). All M-case scenarios examined resulted in model fit with a lower MSE and less pronounced residual patterns when compared to the Baserun, indicating improved model fit.

Two previously published models for this stock were also updated with data to 2020: a state-space model and a spatial SURBA. Both models represent significant advances in modelling Grand Bank American plaice, however further work is required before either can be considered by STACFIS as an assessment model for this stock.

Table 11.1. Description of M-case scenarios used for testing sensitivity of the ADAPT VPA to M assumptions

Run name	Description	MSE	M levels where they differ from the Baserun
Baserun	M=0.2, except M=0.53 from 1989-1996	0.613	N/A
M-est 2005-2020	Within the model, estimate a single value of M for 2005-2020 within the model	0.521	0.391 (2005-2020)
M-est Blocks	Within the model, estimate a three values of M, one for each of the periods of 2005-2009, 2010-2014, 2015-2020,	0.417	0.169 (2005-9) 0.551 (2010-14) 0.566 (2015-20)
M0.53	Fix M at an increased level since 2005, level based on previous period of high M currently used in the Baserun model	0.596	0.53 (fixed since 2005)
M0.4	Fix M at an increased level since 2010, level and period based on M-est Blocks run	0.325	0.4 (fixed since 2010)

d) Retrospective patterns

A five year retrospective analysis was conducted on the base formulation of the VPA by sequentially removing one year of data from the input data set (Figure 11.10). There is a large retrospective pattern present in this assessment which indicates that abundance and SSB have generally been overestimated and F underestimated.

Similar retrospective analyses were completed for the M0.53 and M0.4 ADAPT VPA runs, the SSURBA, and the SSM.

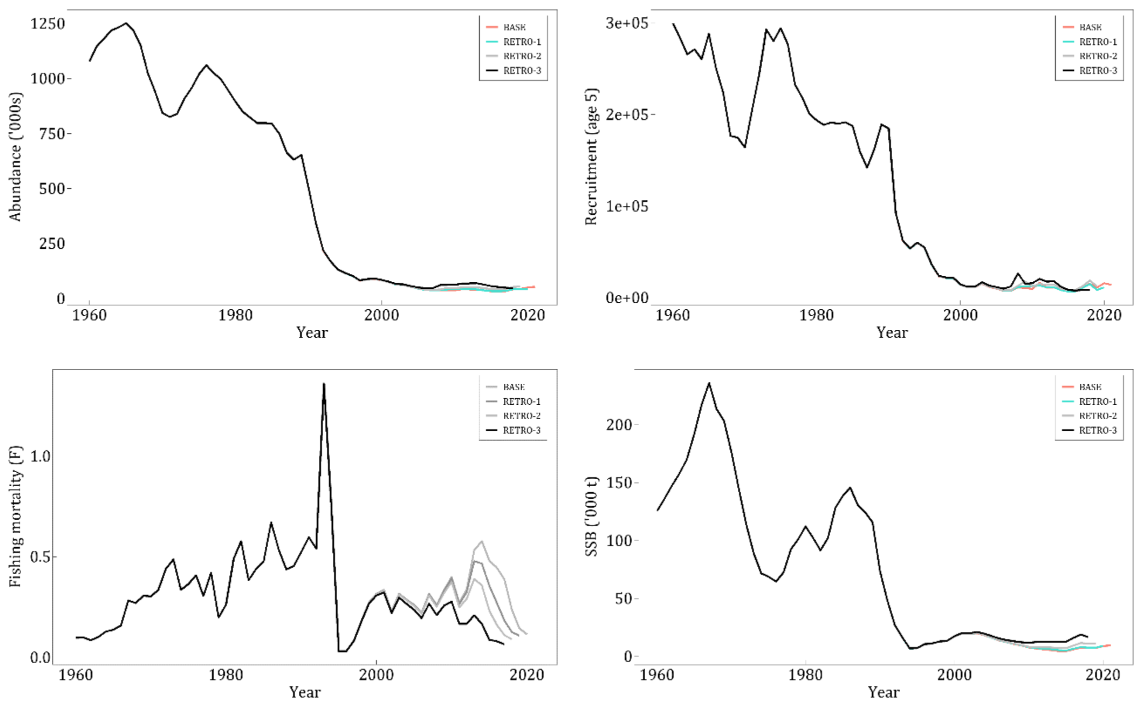


Figure 11.5. American Plaice in Div. 3LNO: retrospective analysis of population numbers, recruitment (age 5), average *F* (ages 9-14), and SSB from the baserun of the VPA.

e) Assessment Results

The *Baserun* assessment model for this stock was accepted by STACFIS as illustrative of stock trends, but due to the significant retrospective pattern the absolute values of SSB, recruitment, and fishing mortality could not be determined. Overall stock trends were consistent across models and support the conclusions of stock status from the base ADAPT. It is clear that SSB remains well below B_{lim}, and models suggest increases in both natural and fishing mortality since the early 2000s.

All models show the population declining from highs in the mid-1960s to a low in the mid-1990s. Spawning stock biomass (SSB) has shown 2 peaks, one in the mid-1960s and another in the early to mid-1980s, however SSB declined to a very low level in 1994 and 1995 (Figure 11.6). SSB increased slightly to the early 2000s and has since varied at a low level.

Stock weights at age have generally declined since the early 2000s, but have increased slightly over the last three years

Estimated recruitment at age 5 was variable between models, with some models indicating recent peaks in recruitment around 2010 and again around 2016 while others indicate below average recruitment since around 2000 (Figure 11.9). Recent recruitment estimates were very sensitive to M assumptions.

There is a tendency to overestimate SSB and underestimate F in the base assessment model, and this pattern carried over across other models examined. Given this instability in the model, no projections were completed.

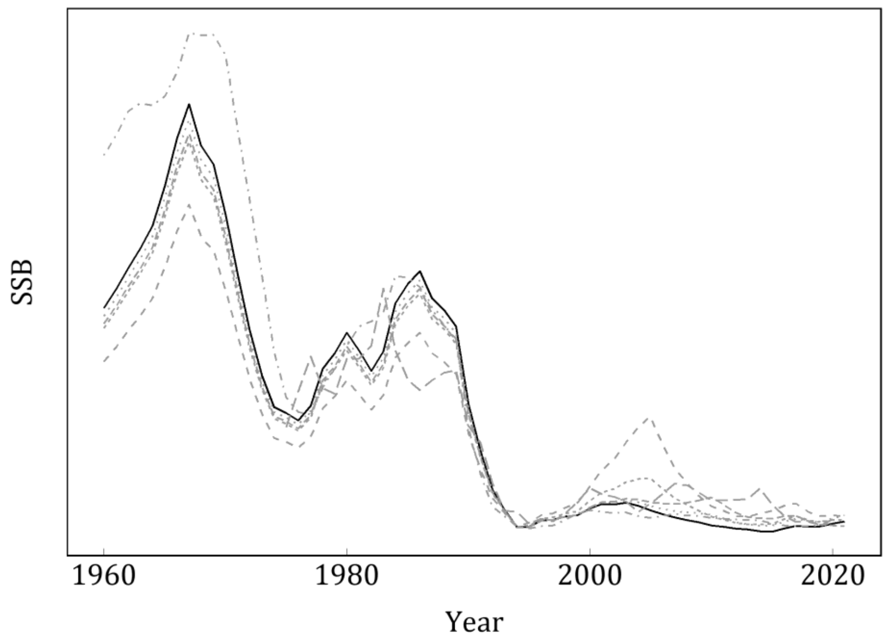


Figure 11.6. American Plaice in Div. 3LNO: SSB from all VPA formulations, the SSM, and the SSURBA. Each series is scaled to its average from 1975-2020. The solid black line indicates the ADAPT baserun.

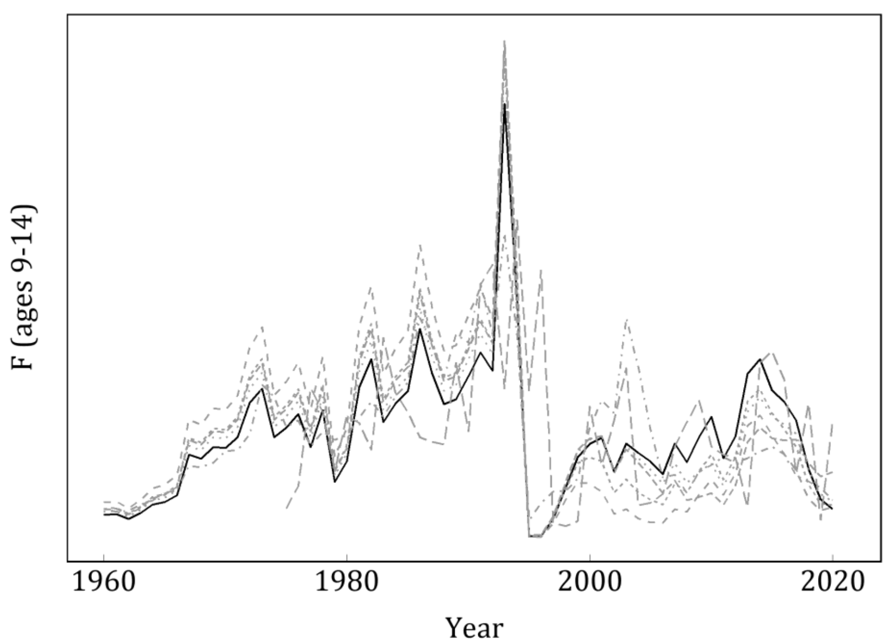


Figure 11.7. American Plaice in Div. 3LNO: Average fishing mortality from all VPA formulations, the SSM, and the SSURBA. Each series is scaled to its average from 1975-2020. The solid black line indicates the ADAPT baserun.

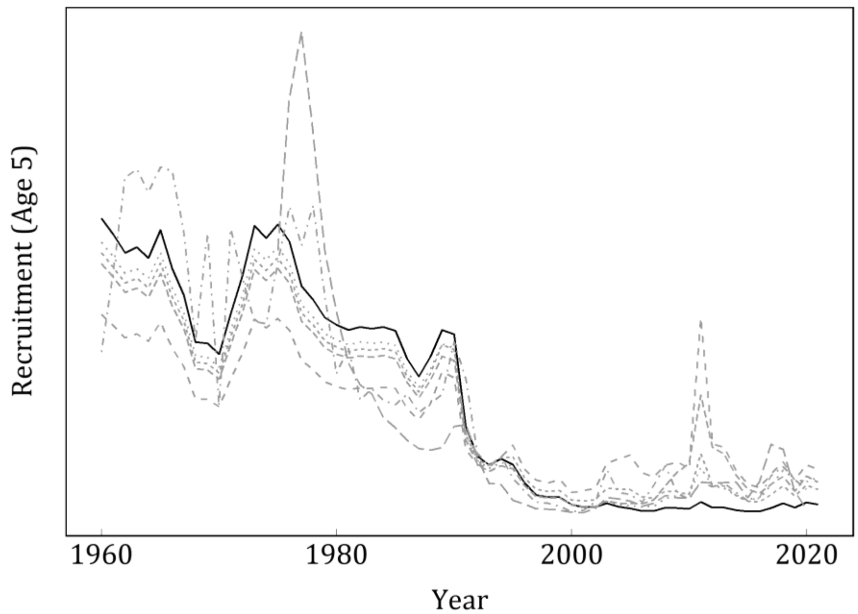


Figure 11.8. American Plaice in Div. 3LNO: relative recruits at age 5 from all VPA formulations, the SSM, and the SSURBA. Each series is scaled to its average from 1975-2020. The solid black line indicates the ADAPT baserun.

f) State of the Stock

The stock remains low compared to historic levels and is presently considered to be below B_{lim}.

Spawning stock biomass: SSB remains low compared to historic levels and remains below the B_{lim} for this stock of 50 000 t. Probability that $B<B_{lim}$ cannot be determined.

Recruitment:

Recruitment has been very low in the last two decades.

Fishing mortality:

Fishing mortality increased from the late 1990s to 2015 and has subsequently declined.

g) Precautionary Reference Points

An examination of the stock recruit scatter from the 2018 assessment of this stock shows that good recruitment has rarely been observed in this stock at SSB below 50 000 t and this is currently the best estimate of B_{lim}. In 2011 STACFIS adopted F_{lim} of 0.3 consistent with stock history and dynamics for this stock.

h) Short Term Considerations

Due to model instability, projections were not completed for this stock. There is considered to be low potential for stock growth. The next full assessment of this stock is expected to be in 2024.

i) Research Recommendations

STACFIS **recommended** that *investigations be undertaken to compare ages obtained by current and former Canadian age readers.*

STATUS: Work is ongoing. This recommendation is reiterated.

STACFIS **recommends** that *investigations be undertaken to examine the retrospective pattern and take steps to improve the model.* STACFIS **recommended** that *investigations be undertaken to reexamine which survey indices are included in the model.*

STATUS: Sensitivity analysis was completed examining the impact of changing the model assumptions about natural mortality. Previous work examined sensitivity to the F-ratio on the plus group and the stepwise exclusion of various survey indices. These exploratory runs had varying impacts on the retrospective pattern and residuals in the model. Efforts to reduce the retrospective pattern in the model have been unsuccessful. These recommendations are therefore replaced with the following:

STACFIS **recommends** that *a benchmark process be undertaken to develop a new assessment framework for this stock.*

12. Yellowtail Flounder (*Limanda ferruginea*) in Divisions 3L, 3N and 3O

(SCR 21/004, 21/018, 21/019, 20/009; SCS 21/05, 21/06, 21/09, 21/13)

a) Introduction

There was a moratorium on directed fishing from 1994 to 1997, and small catches were taken as by-catch in other fisheries. The fishery was re-opened in 1998 and catches increased from 4 400 t to 14 100 t in 2001 (Fig 12.1). Catches from 2001 to 2005 ranged from 11 000 t to 14 000 t. Since then, catches have been below the TAC and in some years, have been very low. The low catch in 2006 was due to corporate restructuring and a labour dispute in the Canadian fishing industry. Industry related factors continued to affect catches which remained well below the TAC in since 2007. However, from 2013 to 2018, catches were higher, ranging from 6 900 t to 10 700 t and in 2019 and 2020 were 75% and 87% of the TAC (12 800 t and 14 800 t respectively).

Recent catches and TACs ('000 tons) are as follows:

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TAC	17	17	17	17	17	17	17	17	17	17
STATLANT 21	3.1	10.7	8.0	6.7	8.3	9.2	8.6	12.3	14.0	
STACFIS	3.1	10.7	8.0	6.9	9.3	9.2	8.7	12.8	14.8	

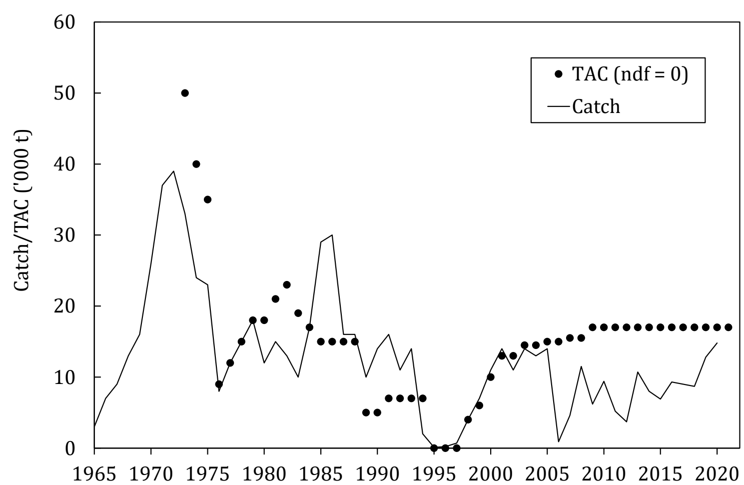


Figure 12.1. Yellowtail flounder in Div. 3LNO: catches and TACs. No directed fishing is plotted as 0 TAC.

b) Data Overview

i) Research survey data

Canadian stratified-random spring surveys. Although variable, the spring survey biomass index increased from 1995 to 1999 and since fluctuated at a high level to 2012. The spring biomass index then declined to 2016, but increased to 2018 before declining again in 2019. The 2006 and 2015 surveys did not cover the stock area and are not considered representative and there was no spring survey in 2020.

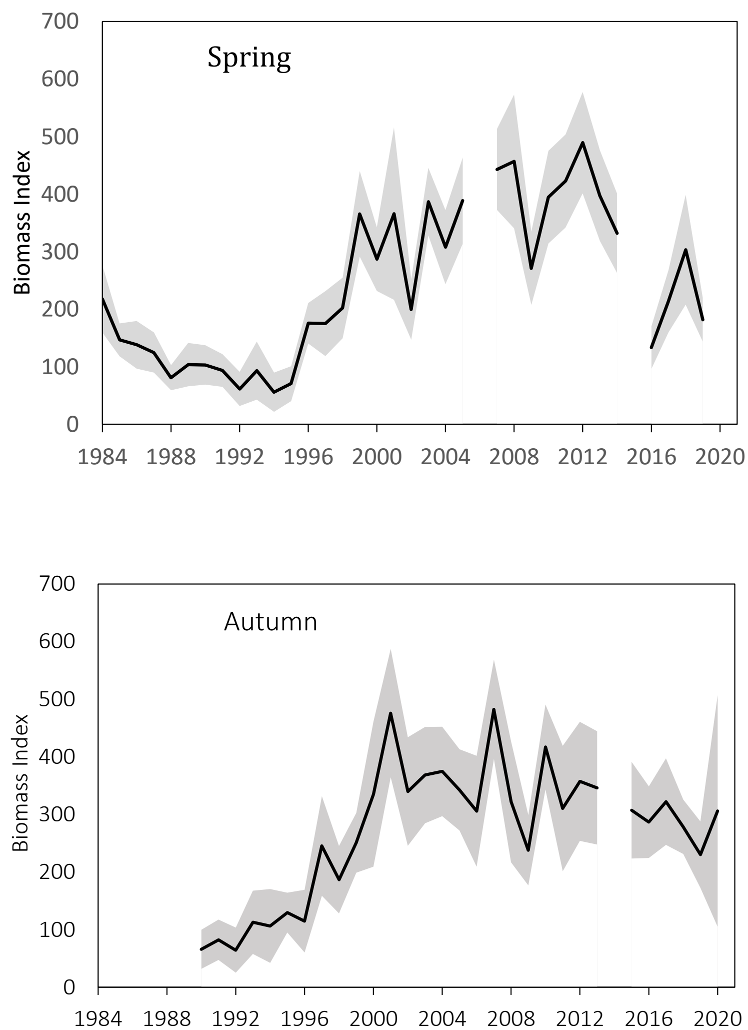


Figure 12.2. Yellowtail flounder in Div. 3LNO: indices of biomass with approximately 95% confidence intervals, from Canadian spring and autumn surveys. Values are Campelen units or, prior to autumn 1995, Campelen equivalent units. The 2014 Canadian autumn, 2015 and 2016 spring surveys were incomplete and there was no spring survey conducted in 2020.

Canadian stratified-random autumn surveys. The autumn survey biomass index for Div. 3LNO increased steadily from the early-1990s to 2001, and although variable, it remained relatively high since then (Figure 12.2). This survey did not show the sharp decline in biomass seen in the other surveys during the recent years, however a slight declining trend from 2001 to 2020 is evident. The 2014 survey was incomplete due to problems with the research vessel, and results are not considered representative.

EU-Spain stratified-random spring surveys in the NAFO Regulatory Area of Div. 3NO. The biomass index of yellowtail flounder increased sharply up to 1999 and remained relatively stable until 2013. Since then, biomass estimates have declined and the 2017 estimate is lower than those seen in nearly two decades (Figure 12.3). Results are in general agreement with the Canadian series which covers the entire stock area.

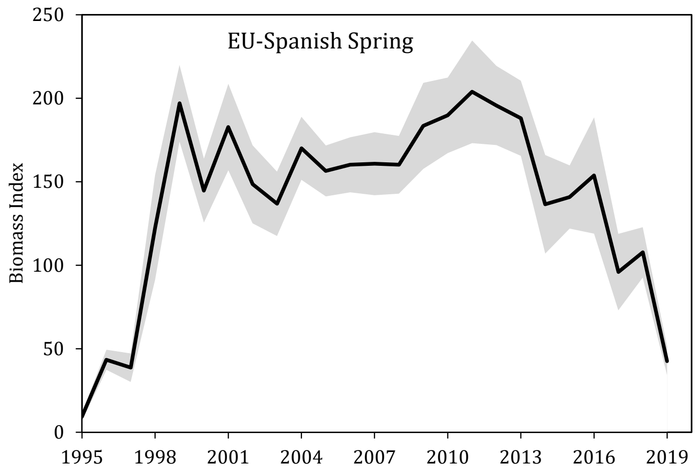


Figure 12.3. Yellowtail flounder in Div. 3LNO: index of biomass from the EU-Spain spring surveys in the Regulatory Area of Div. 3NO ±1SD. Values are Campelen units or, prior to 2001, Campelen equivalent units. There was no survey conducted in 2020.

c) Stock distribution. In all surveys, yellowtail flounder were most abundant in Div. 3N, in strata on the Southeast Shoal and those immediately to the west (360, 361, 375 & 376), which straddle the Canadian 200 mile limit. Yellowtail flounder appeared to be more abundant in the Regulatory Area of Div. 3N in the 1999-2017 surveys than from 1984-1995, and the stock has continued to occupy the northern portion of its range in Div. 3L, similar to the mid-1980s when overall stock size was also relatively large. The vast majority of the stock is found in waters shallower than 93 m in both seasons.

d) Estimation of Parameters.

A Schaefer surplus production model in a Bayesian framework was used for the assessment of this stock. The input data were catch from 1965-2020, Canadian spring survey series from 1984-2019 (no 2006, 2015 nor 2020), the Canadian autumn survey series from 1990-2020 (no 2014), Canadian Yankee survey series (1971-1982), Russian survey series (1984-1991) and Spanish survey (1995-2019). The model set up was nearly identical to that used in the 2018 assessment, with the exceptions that 3 chains were used in the estimation (2 in 2018) and 500K iterations were performed, increased from the 200K iterations in 2018. Model results and fit were very similar to the previous assessment.

The priors used in the model were:

Initial population size	Pin~dunif(0.5, 1)	uniform(0.5 to 1)
Intrinsic rate of natural increase	r ~ dunif(0.01,1)	uniform (0.01 to 1)
Carrying capacity	K~dlnorm(2.703,0.2167)	lognormal (mean, precision)

Survey catchability	q ~dgamma(1,1)	gamma(shape, rate)
Process error	sigma ~ dunif(0,5) isigma2= sigma^{-2}	uniform(0 to 5)
Observation error	tau~dgamma(1,1) itau2 = 1/tau	gamma(shape, rate)

e) Assessment Results

Recruitment: Total numbers of juveniles (<22 cm) from spring and autumn surveys by Canada and spring surveys by EU-Spain are given in Figure 12.4 scaled to each series mean. High catches of juveniles seen in the autumn of 2004 and 2005 were not evident in either the Canadian or EU-Spain spring series. Although no clear trend in recruitment is evident, the number of small fish has increased in the Canadian spring and fall surveys from 2015, and from 2017 to 2020, is above the 1996-2020 average. The spring survey by EU-Spain has shown lower than average numbers of small fish since 2006.

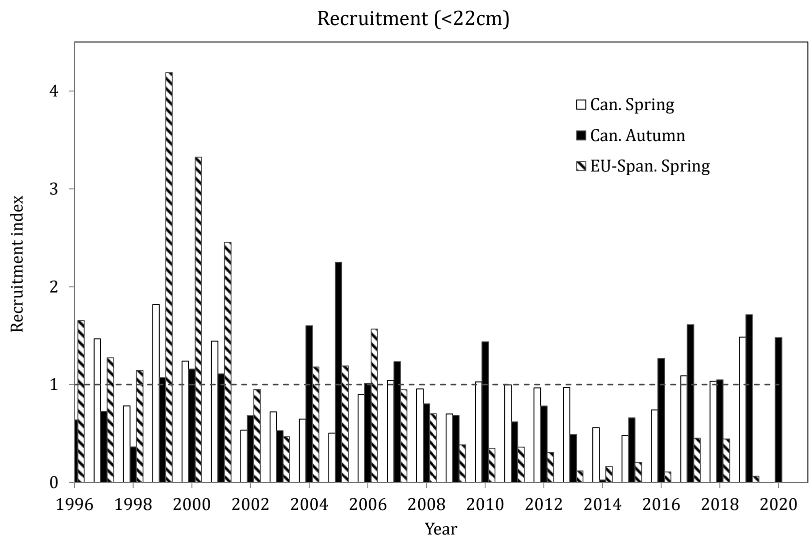


Figure 12.4. Yellowtail flounder in Div. 3LNO: Juvenile abundance indices from spring and autumn surveys by Canada and spring surveys by EU-Spain. Each series is scaled to the 1996-2020 average (horizontal line). There were no surveys in spring 2020 be either Canada or Spain.

Bayesian Stock Production Model: The surplus production model results indicate that stock size increased rapidly after the moratorium in the mid-1990s, levelled off from 2001-2012, and although it has declined in recent years, has remained above B_{msy}. Estimates from the model suggests that a maximum sustainable yield (*MSY*) of 18 730 tons can be produced by total stock biomass of 89 790 tons (B_{msy}) at a fishing mortality rate (F_{msy}) of 0.21.

Biomass: The analysis showed that relative population size (B/B_{msy}) was below 1.0 from 1973 to 1997. Relative biomass from the production model increased from 1994 to 2001, remained stable until 2012 and then declined to 2019, although it is estimated to be 1.4 times B_{msy} in 2020 (Figure 12.5).

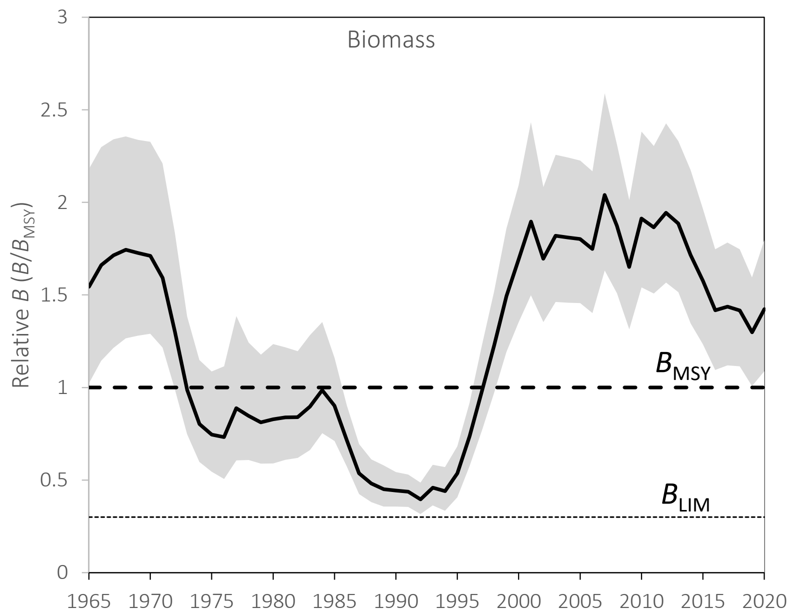


Figure 12.5. Yellowtail flounder in Div. 3LNO: relative biomass trends with approximate 90% confidence intervals.

Fishing Mortality: Relative fishing mortality rate (F/F_{msy}) was above 1.0, in particular from the mid-1980s to early-1990s when the catches exceeded or doubled the recommended TACs (Figure 12.6). *F* has increased from 2012 to 2020, however has been below F_{msy} since 1993. *F* in 2019 and 2020 averaged about 54% of F_{msy}.

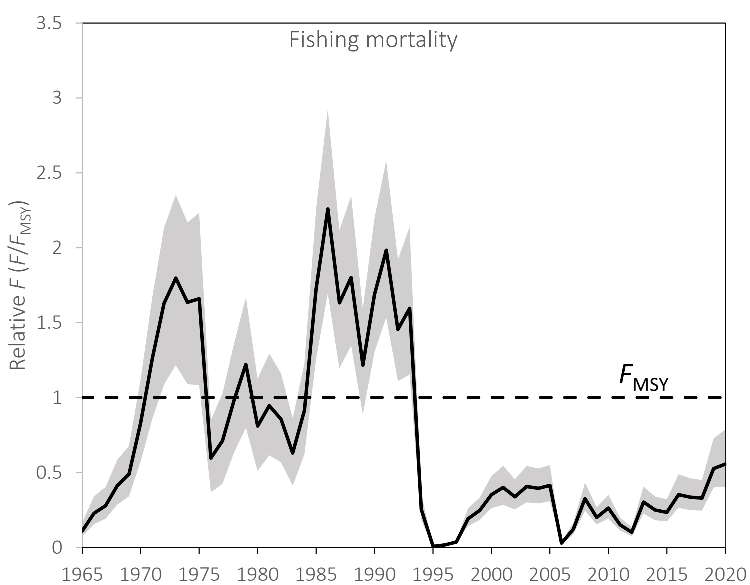


Figure 12.6. Yellowtail flounder in Div. 3LNO: relative fishing mortality trends with approximate 90% confidence intervals.

f) State of the Stock

The stock size has steadily increased since 1994 and is presently 1.4 times B_{msy} (B_{msy}=89.79). There is very low risk (<1%) of the stock being below B_{msy} or F being above F_{msy}. Recent recruitment appears to be higher than average.

In many years since the moratorium (1994-97), the catch remained below the estimated surplus production levels and has been low enough to allow the stock to grow. In 2020 the catch is very near the surplus production level (Fig 12.7).

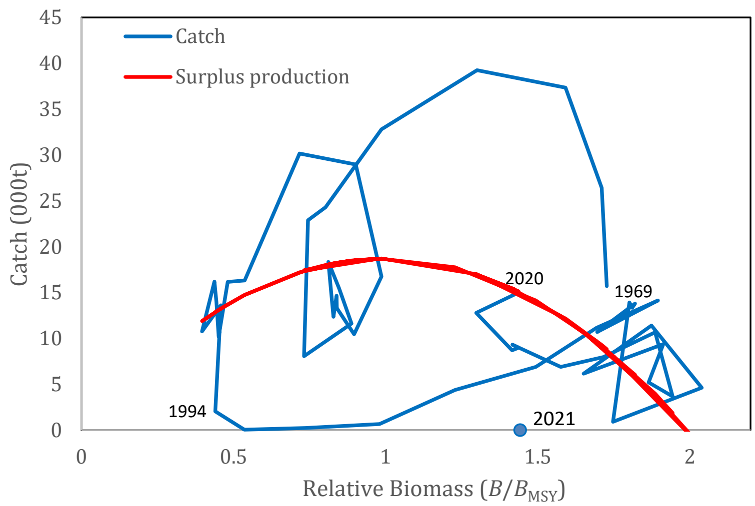


Figure 12.7. Yellowtail flounder in Div. 3LNO: catch trajectory.

g) Medium Term Considerations:

Medium-term projections were carried forward to the year 2025 for two catch scenarios in 2021: $Catch_{2021}$=average 2019 and 2020 and $Catch_{2021}$=TAC=17 000 t. Constant fishing mortality was applied from 2022-2025 at several levels of F (F=0, $F_{status\ quo}$, 2/3 F_{msy}, and 85% F_{msy}, and F_{msy}). Results were similar for both scenarios.

F_{msy} was estimated to be 0.21. Fishing at F_{msy} would first lead to a considerable yield in 2022, but yields are then projected to decline in the medium term with catch at 2/3 F_{msy}, 85% F_{msy} , and F_{msy} (Table 12.1; Figure 12.8). At the end of the projection period, the risk of biomass being below B_{lim} is less than 1% in all cases.

The probability that $F > F_{lim=Fmsy}$ in 2022-2025 was less than 0.01 for the F=0 projections (Table 12.2). For the $F_{status\ quo}$ projections, this probability was less than 0.04 in the medium term for both scenarios. At 2/3 F_{msy}, the probability that $F > F_{lim}$ was between 0.05 and 0.11 in the medium term. Projected at the level of 85% F_{lim}, the probability that $F > F_{lim}$ ranges between 0.26 and .30 and for F_{msy} projections, this probability increased to 0.50. For biomass projections, in all scenarios for 2022-2025, the probability of biomass being below B_{lim} was less than 0.01. The probability that biomass in 2025 is greater than B_{2021} is 0.48, 0.41, 0.32 and 0.26 for $F_{status\ quo}$, 2/3 F_{msy}, 85% F_{msy}, and F_{msy} respectively, in the $Catch_{2021}$=TAC=17 000 t scenario.

Table 12.1. Medium-term projections for yellowtail flounder with two catch options in 2021. Estimates and 90% confidence interval for yield and relative biomass B/B_{msy}, are shown, for projected F values of F=0, $F_{status\ quo}$, 2/3 F_{msy}, 85%F_{msy} and F_{msy}.

Projections with Catch$_{2021}$= avg catch 2019-2020 (13 800 t)

Year	Yield ('000t) median	Projected relative Biomass(B/B_{msy}) median (90% CL)
	F =0	
2022	0.00	1.43 (0.95, 2.01)
2023	0.00	1.59 (1.06, 2.21)
2024	0.00	1.72 (1.15, 2.34)
2025		1.8 (1.24, 2.42)
	$F_{status\ quo}$ = 0.112	
2022	14.35	1.43 (0.95, 2.01)
2023	14.31	1.43 (0.93, 2.03)
2024	14.29	1.43 (0.91, 2.02)
2025		1.43 (0.89, 2.03)
	2/3 F_{MSY} = 0.139	
2022	17.81	1.43 (0.95, 2.01)
2023	17.27	1.39 (0.9, 1.98)
2024	16.93	1.36 (0.85, 1.96)
2025		1.35 (0.81, 1.95)
	85% F_{MSY} =0.177	
2022	22.68	1.43 (0.95, 2.01)
2023	21.12	1.34 (0.85, 1.92)
2024	20.16	1.28 (0.77, 1.86)
2025		1.23 (0.7, 1.84)
	F_{MSY} =0.21	
2022	26.73	1.43 (0.95, 2.01)
2023	24.10	1.29 (0.81, 1.87)
2024	22.46	1.2 (0.7, 1.79)
2025		1.14 (0.61, 1.75)

Projections with Catch$_{2021}$= TAC=17 000 t

Year	Yield ('000t) median	Projected Relative Biomass(B/B_{msy}) median (90% CL)
	F =0	
2022	0.00	1.39 (0.92, 1.97)
2023	0.00	1.56 (1.03, 2.18)
2024	0.00	1.69 (1.13, 2.32)
2025		1.78 (1.22, 2.41)
	$F_{status\ quo}$ = 0.112	
2022	13.99	1.39 (0.92, 1.97)
2023	14.06	1.4 (0.91, 2)
2024	14.12	1.41 (0.89, 2.01)
2025		1.42 (0.88, 2.02)
	2/3 F_{MSY} = 0.139	
2022	17.36	1.39 (0.92, 1.97)
2023	16.98	1.37 (0.87, 1.96)
2024	16.73	1.35 (0.83, 1.94)
2025		1.33 (0.8, 1.94)
	85% F_{MSY} =0.177	
2022	22.11	1.39 (0.92, 1.97)
2023	20.77	1.31 (0.83, 1.9)
2024	19.92	1.26 (0.75, 1.85)
2025		1.22 (0.69, 1.83)
	F_{MSY} =0.21	
2022	26.05	1.39 (0.92, 1.97)
2023	23.70	1.27 (0.79, 1.85)
2024	22.20	1.19 (0.68, 1.78)
2025		1.13 (0.59, 1.75)

Table 12.2. Yield (000 t) and risk (%) of B_y<B_{msy} and F_y>F_{msy} (F_{lim}=F_{msy}) at projected F values of F=0, $F_{status\ quo}$, 2/3 F_{msy}, 85% F_{msy} and F_{msy} for two catch scenarios in 2021 (average 2019-2020=13 800 t and TAC= 17 000 t).

	Yield ('000t)			**P(F>F$_{lim}$)**				**P(B<B$_{lim}$)**				**P(B<B$_{MSY}$)**				
Catch$_{2021}$=13 800t	**2022**	**2023**	**2024**	**2022**	**2023**	**2024**	**2025**	**2022**	**2023**	**2024**	**2025**	**2022**	**2023**	**2024**	**2025**	**P(B$_{2025}$>B$_{2021}$)**
F =0	0.00	0.00	0.00	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	7%	3%	2%	1%	83%
$F_{status\ quo}$ = 0.112	14.35	14.31	14.29	2%	3%	3%	3%	<1%	<1%	<1%	<1%	7%	8%	9%	9%	50%
2/3 F_{MSY} = 0.139	17.81	17.27	16.93	8%	8%	10%	10%	<1%	<1%	<1%	<1%	7%	10%	12%	14%	42%
85% F_{MSY} =0.177	22.68	21.12	20.16	26%	27%	28%	29%	<1%	<1%	<1%	<1%	7%	13%	18%	23%	33%
F_{MSY} =0.209	26.73	24.10	22.46	50%	50%	50%	50%	<1%	<1%	<1%	<1%	7%	16%	25%	32%	27%

	Yield ('000t)			**P(F>F$_{lim}$)**				**P(B<B$_{lim}$)**				**P(B<B$_{MSY}$)**				
Catch$_{2021}$=17 000t	**2022**	**2023**	**2024**	**2022**	**2023**	**2024**	**2025**	**2022**	**2023**	**2024**	**2025**	**2022**	**2023**	**2024**	**2025**	**P(B$_{2025}$>B$_{2021}$)**
F =0	0.00	0.00	0.00	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	9%	4%	2%	1%	82%
$F_{status\ quo}$ = 0.112	13.99	14.06	14.12	2%	3%	3%	4%	<1%	<1%	<1%	<1%	9%	9%	10%	10%	48%
2/3 F_{MSY} = 0.139	17.36	16.98	16.73	8%	9%	10%	11%	<1%	<1%	<1%	<1%	9%	11%	13%	15%	41%
85% F_{MSY} =0.177	22.11	20.77	19.92	27%	28%	29%	30%	<1%	<1%	<1%	<1%	9%	14%	20%	24%	32%
F_{MSY} =0.209	26.05	23.70	22.20	50%	50%	50%	50%	<1%	<1%	<1%	<1%	9%	18%	27%	34%	26%

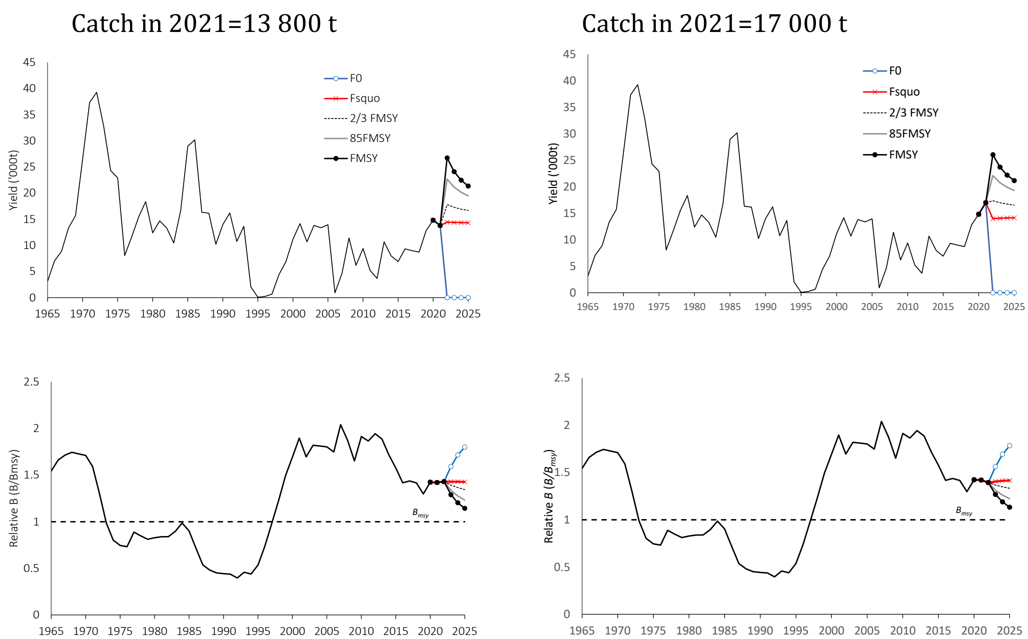


Figure 12.8. Yellowtail flounder in Div. 3LNO: stochastic projections from 2022-2025 at five levels of F (F=0, $F_{\text{status quo}}$, 2/3 F_{msy}, 85% F_{msy} and F_{msy}). Top panels shows projected yield and lower panels are projected relative biomass ratios (B/B_{msy}).

h) Reference Points:

The stock is presently 1.4 times B_{msy} (B_{msy}=89.79) and F is below F_{msy} (Figure 12.9). Scientific Council considers that 30% B_{msy} is a suitable limit reference point (B_{lim}) for stocks where a production model is used. At present, the risk of the stock being below B_{lim} = 30% B_{msy} is very low (<1%).

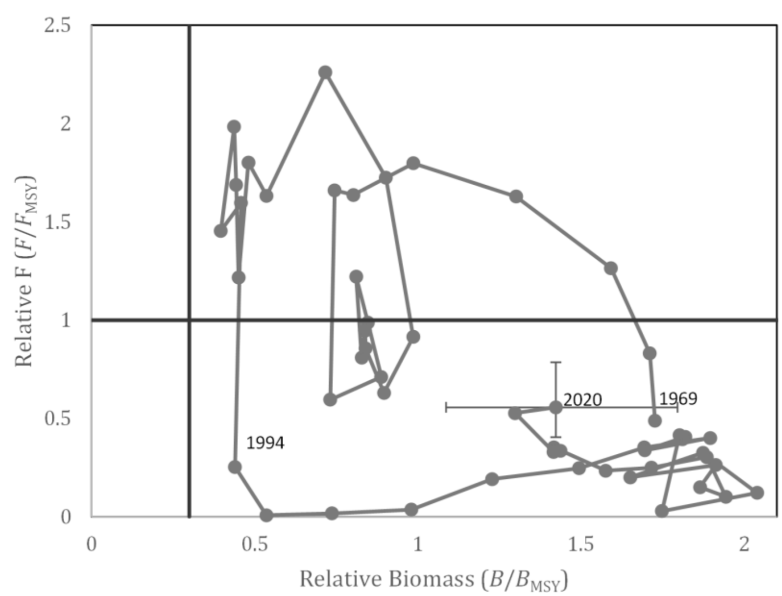


Figure 12.9. Yellowtail flounder in Div. 3LNO: stock trajectory estimated in the surplus production analysis, under a precautionary approach framework.

Currently the biomass is estimated to be above B_{lim} and F, below F_{lim} (=F_{msy}) with high probability, so the stock is in the safe zone as defined in the NAFO Precautionary Approach Framework.

The next assessment is planned for 2024.

i) Special Comment

Concerns have been raised that the projections from the stock production model may be optimistic, as ecosystem and fish productivity conditions have shown decline while the entire process error distribution (i.e. representative of both positive and negative conditions) is carried forward in the projections and risk-based advice. Nevertheless, the stock is estimated to be 1.4X B_{msy} and F is projected to remain below F_{lim} in the medium term ($P<0.01$ at all F projections for 2022-2025).

13. Witch Flounder (*Glyptocephalus cynoglossus*) in Divisions 3N and 3O

Interim Monitoring Report (SCR Docs, 20/002, 009, 046; SCS 20/06, 07, 09, 11, 13; SCS 21/08, 09, 06)

a) Introduction

From 1972 to 1984, reported catch of witch flounder in NAFO Divs. 3NO ranged from a high of about 9 200 t in 1972 to a low of about 2 400 tonnes (t) in 1980 and 1981 (Figure 13.1). Catches increased to around 9 000 t in the mid-1980s but then declined steadily to less than 1 200 t in 1995. A moratorium on directed fishing was imposed in 1995 and remained in effect until 2014. During the moratorium, bycatch averaged below 500 t. The NAFO Fisheries Commission reintroduced a 1 000 t TAC for 2015 and in 2015 set a TAC for 2016, 2017, and 2018 at 2 172 t, 2 225 t, and 1 116 t respectively. Not all Contracting Parties with quota resumed directed fishing for witch flounder until 2019, when participation in the fishery was more representative. Catch since 2015 has been below the TAC. In 2020, total catch was estimated to be 655 t.

Recent catches and TACs ('000 tones) are as follows:

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TAC	ndf	ndf	ndf	1.0	2.2	2.2	1.1	1.2	1.2	1.2
STATLANT 21	0.3	0.3	0.3	0.4	1.0	0.6	0.6	0.9	0.7	
STACFIS	0.3	0.3	0.3	0.4	1.1	0.7	0.7	0.9	0.7	

ndf = no directed fishery.

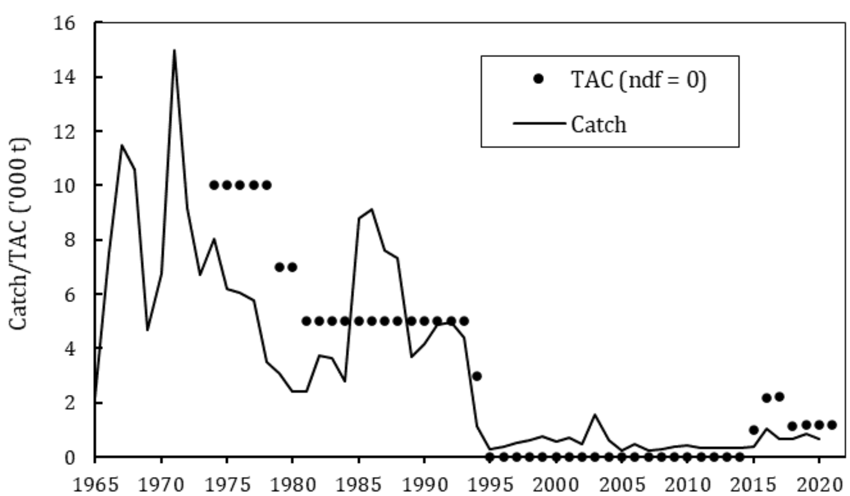


Figure 13.1. Witch flounder in Divs. 3NO (1960-2021): Catch and TAC ('000 tonnes).

b) Data Overview

i) Research survey data

Canadian spring RV survey. Due to substantial coverage deficiencies, values from 2006 are not presented, and there was no survey in 2020. The biomass index, although variable, had shown a general decreasing trend from 1985 to 1998, a general increasing trend from 1998 to 2003, and a general decreasing trend from 2003 to 2010. From 2010 to 2013 the index increased to values near the series high from 1987 (Figure 13.2). Biomass indices declined substantially from a high in 2013 to a value 51% of the time series average in 2015. Biomass indices have been relatively stable since 2015 (Figure 13.2).

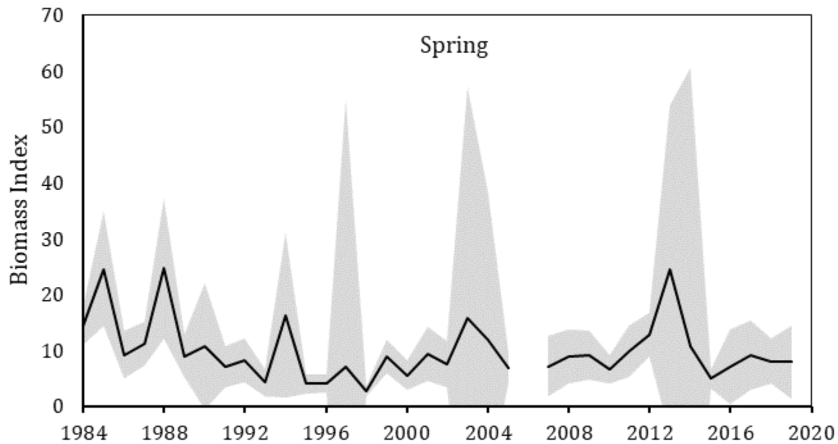


Figure 13.2. Witch flounder in NAFO Divs. 3NO: survey biomass indices from Canadian spring surveys 1984-2019 (95% confidence limits are given). Values are Campelen units or, prior to 1996, Campelen equivalent units. No survey was conducted in 2020.

Canadian autumn RV survey. Due to operational difficulties there was no 2014 autumn survey. The biomass indices showed a general increasing trend from 1996 to 2009 but declined to 54% of the time series average in 2016 (Figure 13.4). Biomass indices increased slightly from 2016 to 2019, then decreased in 2020.

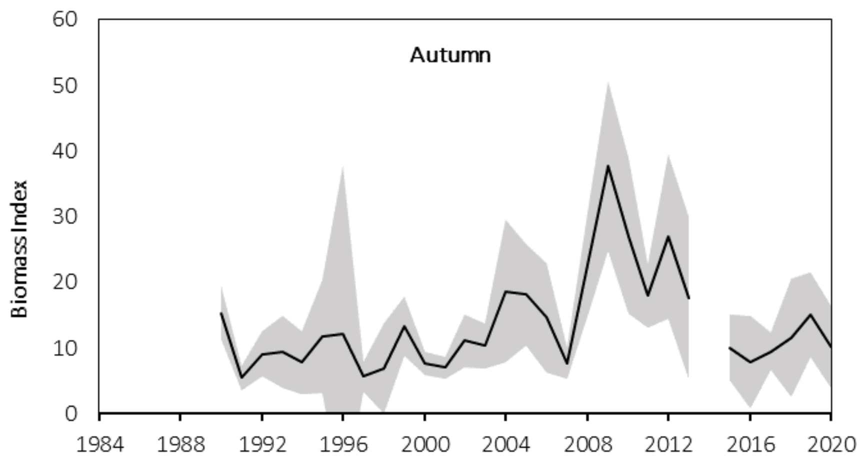


Figure 13.3. Witch flounder in Divs. 3NO: biomass indices from Canadian autumn surveys 1990-2020 (95% confidence limits are given). Values are Campelen units or, prior to 1996, Campelen equivalent units.

EU-Spain RV spring survey. Surveys have been conducted annually from 1995 to 2019 by EU-Spain in the NAFO Regulatory Area in Divs. 3NO to a maximum depth of 1,450 m (since 1998). In 2001, the vessel (*Playa de Menduiña*) and survey gear (Pedreira) were replaced by the R/V *Vizconde de Eza* using a Campelen trawl (NAFO SCR 05/25). Data for witch flounder prior to 2001 have not been converted and therefore data from the two time series cannot be compared. In the Pedreira series, the biomass increased from 1995-2000 but declined in 2001. In the Campelen series, the biomass has been variable, but relatively stable over the time series, however the 2019 estimate is the lowest in the series. No survey was conducted in 2020 (Figure 13.5).

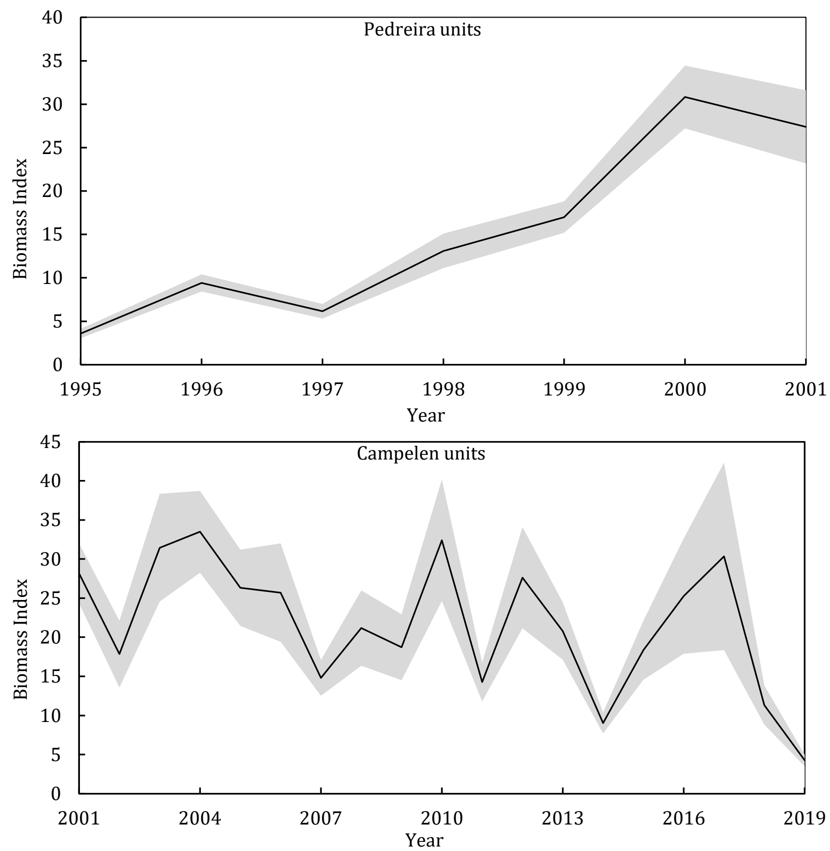


Figure 13.4. Witch flounder in Divs. 3NO: biomass indices from EU-Spanish Div. 3NO spring surveys (± 1 standard deviation). Data from 1995-2001 is in Pedreira units; data from 2001-2019 are Campelen units. Both values are presented for 2001. No survey was conducted in 2020.

c) Stock distribution. Analysis of distribution data from the surveys show that this stock is mainly distributed in Div. 3O along the southwestern slopes of the Grand Bank. In most years the distribution is concentrated toward the slopes but in certain years, an increased percentage may be distributed in shallower water. A 2014 analysis of Canadian biomass proportions by depth aggregated across survey years (spring 1984-2014 and autumn 1990-2014) indicated that in Div. 3N both spring and autumn biomass proportions were fairly evenly distributed over a depth range of 57-914 m while those in 3O were more restricted to a shallower depth range of 57-183m. Distributions of juvenile fish (less than 21 cm) were slightly more prevalent in shallower water during autumn surveys. It is possible however, that the juvenile distribution may be more related to the overall pattern of witch flounder being more widespread in shallower waters during the post-spawning autumn period, although other stocks show a pattern of juvenile fish occupying shallow and/or inshore areas. In years where all strata were surveyed to a depth of 1462 m in the autumn survey, generally less than 5% of the Divs. 3NO biomass was found in the deeper strata (731-1462 m).

d) Recruitment: With the exception of the growth of the stock following improved recruitment in the late 1990s, it is unclear if the recruitment index (survey number of fish<21 cm; figure 13.5) is representative. Nevertheless, the recruitment index in 2019 was the highest in the time series. The small fish did not appear in the 2020 Canadian autumn survey, however, and the recruitment index was again below average.

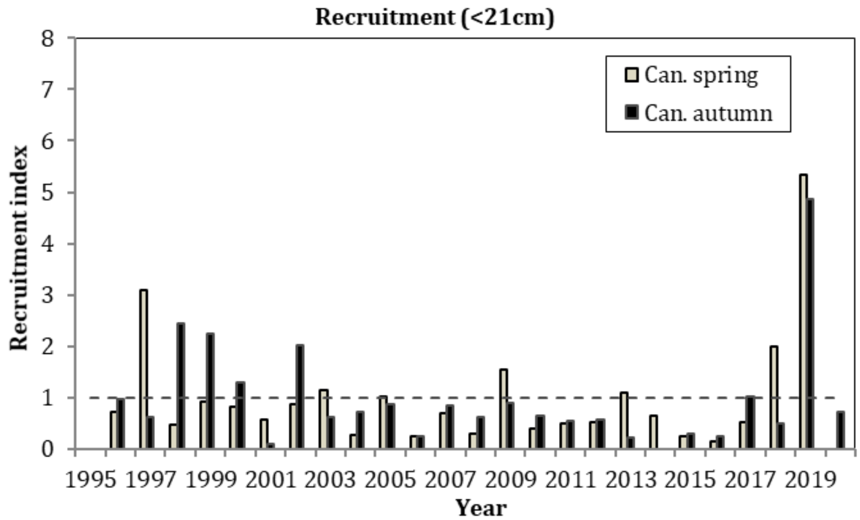


Figure 13.5. Recruitment index of witch flounder (<21cm) from spring and autumn Canadian RV surveys in NAFO Divs.3NO 1996-2020. No survey data available in autumn 2014 or spring 2006 or 2020.

e) Conclusion:

The most recent (2020) analytical assessment using a Bayesian stock production model concluded that the stock size increased from 1994 to 2013 and then declined during 2013-2015 and has since increased slightly. In 2020 the stock was at 44% B_{msy}. (59 880t). There was 14% risk of the stock being below B_{lim} and a 4% risk of F being above F_{lim} (F_{msy}=0.063). Although only the fall survey of NAFO Divs. 3NO was conducted in 2020, and the survey index showed a slight decline, it does not indicate a significant change in the status of the stock.

The next full assessment of this stock is planned for 2022.

14. Capelin (*Mallotus villosus*) in Div. 3NO - 2021

(SCR Doc. 21/029, SCS Doc. 21/06)

a) Introduction

The fishery for capelin started in 1971 and catch was highest in the mid-1970s with a maximum catch of 132 000 t in 1975. The directed fishery was closed in 1992 and the closure has continued through 2020 (Figure 14.1). No catches have been reported for this stock since 1993 except 1 t of Spanish catch in 2014 and 5 t Estonian catch in 2016.

Recent catches and TACs ('000 tones) are as follows:

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TAC	ndf	ndf	ndf	ndf	ndf	ndf	ndf	ndf	ndf	ndf
STATLANT 21	0	0	0	0	0	0	0	0	0	
STACFIS	-	-	-	0	4	11	2	2	1	

ndf = no directed fishery.

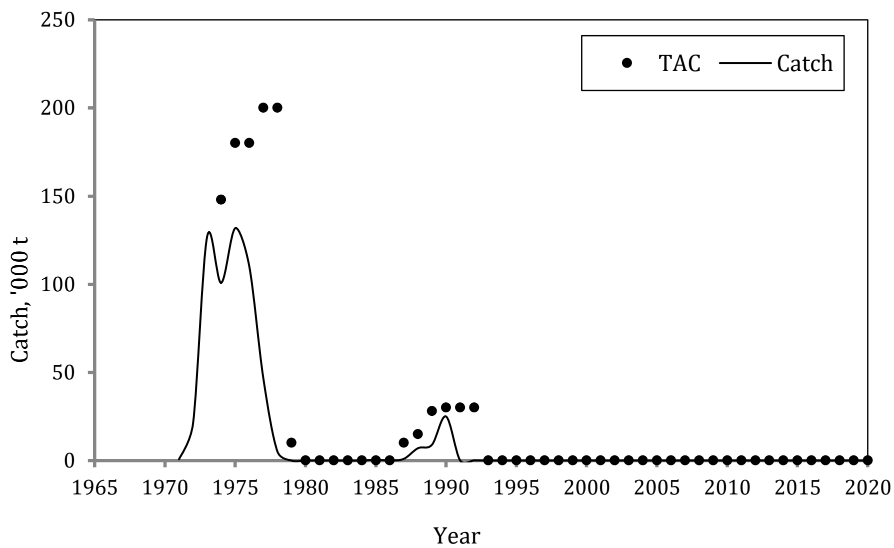


Figure 14.1. Capelin in Div. 3NO: catches and TACs.

b) Data Overview

Acoustic surveys of the capelin stock in Divisions 3NO were conducted by the USSR/Russia in 1975-1994 and Canada in 1981-1992. Now, it is difficult to compare the results of these surveys since most of Russian suveys covered Divisions 3LNO. Maximum stock size was registered in 1988 and then an abrupt decline was observed after 1990 (Figure 14.2).

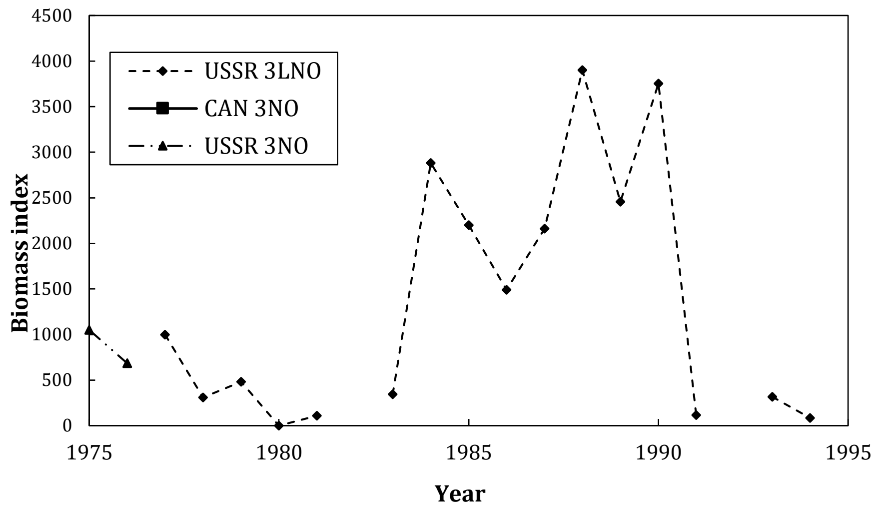


Figure 14.2. Estimate of capelin stock according to the data of Russian and Canadian acoustic survey in 1975-1994.

Trawl acoustic surveys of capelin on the Grand Bank previously conducted by Russia and Canada on a regular basis have not been repeated since 1995. In recent years, STACFIS has repeatedly recommended investigation of the capelin stock in Div. 3NO utilizing trawl-acoustic surveys to allow comparison with historical time series. However, this recommendation has not been acted upon. The only indicator of stock dynamics currently used for stock assessment is capelin biomass data obtained during Canadian stratified-random spring trawl surveys. In 1996-2019, when a Campelen trawl was used as a sampling gear, survey biomass index of capelin in Div. 3NO varied from 3.8 to 227 th. t (Figure 14.3), and the average value for this period is 43.4 th. t. In 2005, survey biomass index of capelin in Div. 3NO was 3.9 th. t, the lowest level since 1996; estimates in 2006 are not compatible because of poor cover in that year. In 2008 the biomass index sharply increased to 114 th. t and decreased in next three years to the level of 4.1 th. t in 2011. In 2013 biomass index was 74.9 th. t and it's considerably increased in 2014 to the highest level of the entire period – 227 th. t. In 2016 biomass indices declined to the historical minimum 3.8 thousand tonnes. For 2017, an increase to 78.7 th. t was observed, followed by the steady decrease with biomass reaching 17.2 th. t in 2018-2019. In 2020, the spring survey was not performed due to the pandemic.

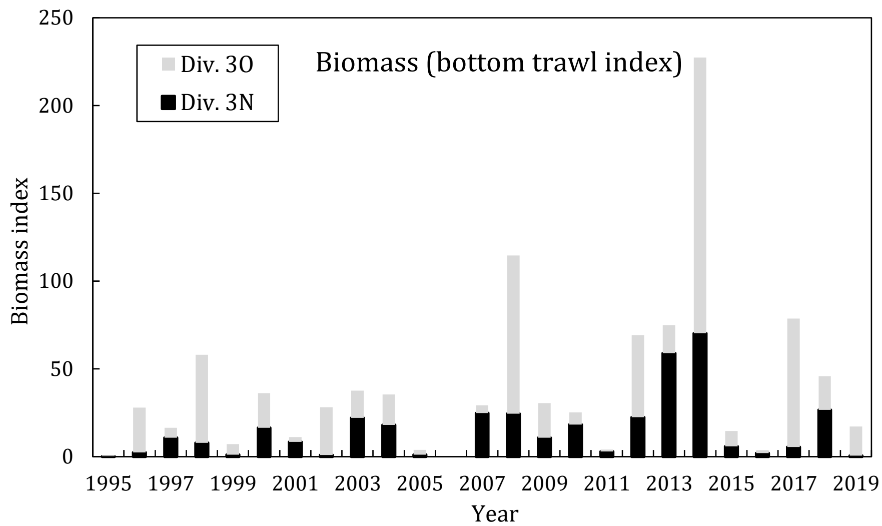


Figure 14.3. Capelin in Div. 3NO: survey biomass index from Canadian spring surveys in 1996-2019.

c) Estimation of Stock Parameters

Since interpolation by density of bottom trawl catches to the area of strata for pelagic fish species such as capelin can lead to significant deviation of the total biomass, the average value of all non-zero catches was used as an index for evaluation of the stock biomass in 1990-2019. However, if the proportion of zero and non-zero catches change, the index may not be comparable between years.

Survey catches were standardized to 1 km^2 for Engel and Campelen trawl data. Trawl sets which did not contain capelin were not included in the account. The confidence intervals around the average catch index were obtained by bootstrapping of standardized catch values. According to data from 1996-2019, the mean catch varied between 0.006 and 2.009 t/km^2. In 2019 this value was 0.006 t/km^2 (Figure 14.3).

Bottom-trawling is not a satisfactory basis for a stock assessment of a pelagic species and survey results are indicative only.

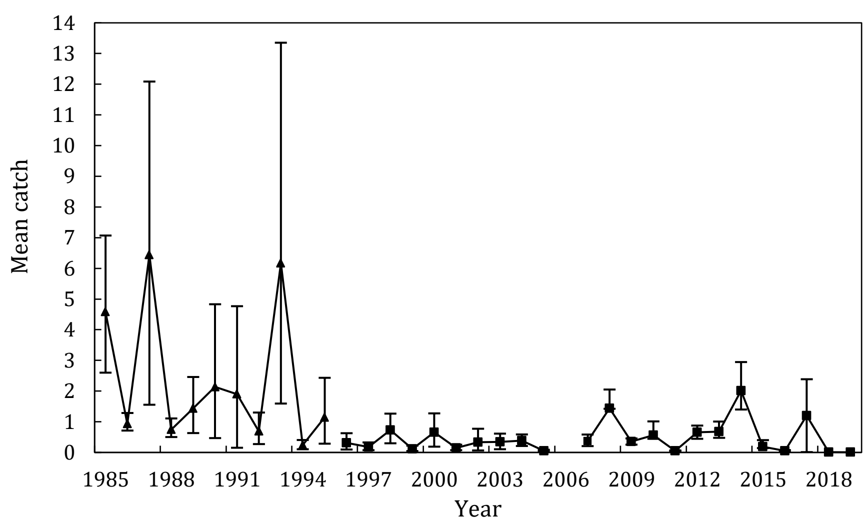


Figure 14.4. Capelin in Div. 3NO: mean catch from Canadian spring surveys in 1985-2019. Estimates prior to 1996 are from Engel and from 1996-2019 are from Campelen.

d) Assessment Results

Acoustic surveys series terminated in 1994 indicated a stock at a low level. Biomass indices from bottom trawl surveys since then have not indicated a change in stock status since then.

e) Precautionary Reference Points

STACFIS is not in a position to determine biological reference points for capelin in Div. 3NO.

f) Research recommendations

STACFIS reiterates its **recommendation** that *initial investigations to evaluate the status of capelin in Div. 3NO should utilize trawl acoustic surveys to allow comparison with the historical time series.*

This stock is expected next to be fully assessed in 2024.

15. Redfish (Sebastes mentella and Sebastes fasciatus) in Division 3O

Interim Monitoring Report (SCR Doc. 21/04; SCS Doc. 21/05, 06, 08, 09)

a) Introduction

There are two species of redfish that have been commercially fished in Div. 3O; the deep-sea redfish *(Sebastes mentella)* and the Acadian redfish *(Sebastes fasciatus*). The external characteristics are very similar, making them difficult to distinguish, and as a consequence, they are reported collectively as "redfish" in the commercial fishery statistics and RV surveys. Within Canada's fishery zone, redfish in Div. 3O have been under TAC regulation since 1974 and with a minimum size limit of 22 cm since 1995. Catch was only regulated by mesh size in the NRA of Div. 3O prior to the Fisheries Commission adopting a TAC in 2004. Initially, TAC was implemented at a level of 20 000 tons for 2005-2008 and has remained at that level. This TAC applies to the entire area of Div. 3O. The stock was most recently assessed in 2019.

Nominal catches have ranged between 3 000 tons and 35 000 tons since 1960 and have been highly variable with several distinct periods of rapid increase and decrease (Figure 15.1). Up to 1986 catches averaged 13 000 tons, increased rapidly and peaked at 35 000 tons in 1988, then declined to 5 100 tons by 1997. Catches totaled 20 000 tons in 2001, then it declined to 4 000 tons in 2008. Catch was relatively stable between 6100 t and 9000 t during the recent period (2013 to 2020). Catch was 7300 tons in 2020.

Recent catches and TACs ('000 t) are as follows:

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TAC	20	20	20	20	20	20	20	20	20	20
STATLANT 21	7.0	7.8	7.5	7.9	8.6	7.3	6.1	6.6	7.3	
STACFIS	7.0	7.8	7.5	8.4	9.0	7.5	6.1	6.5	7.3	

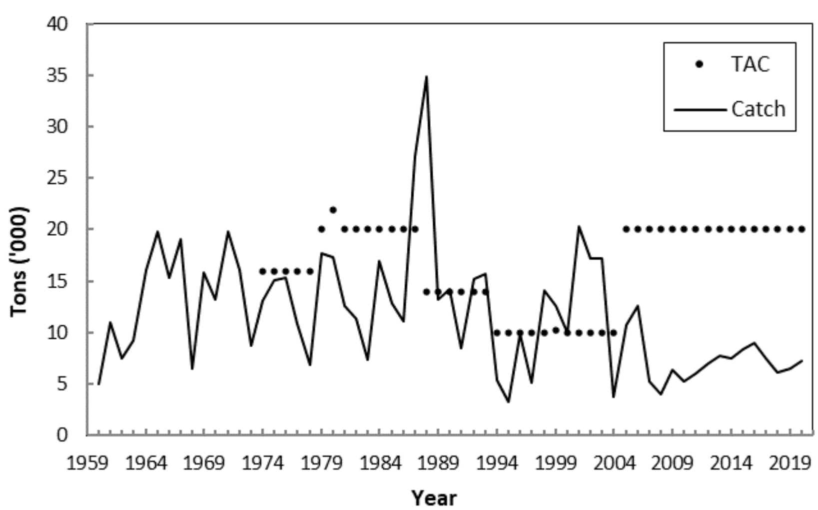


Figure 15.1. Redfish in Div. 3O: Catches and TACs. TACs prior to 2004 were applied only to Canadian waters.

b) Data Overview

Surveys

Only the Canadian autumn survey was conducted during 2020 as the Canadian spring and the EU-Spain surveys were cancelled due to the COVID 19 pandemic. The Canadian spring survey index was generally at or above the time-series mean during two periods, the mid to late 1990s and during 2009 to 2015. The 2018 and 2019 values were well below the time-series average. The Canadian autumn surveys and the EU-Spain survey generally support the Canadian spring survey index pattern, with similar normalized biomass values observed for 2019 in the Canadian spring and autumn surveys. However, the EU-Spain value was well below the mean in 2018 and 2019. The 2020 value for the Canadian autumn survey was similar to that observed in 2019, also below the mean of the time-series (Figure 15.2).

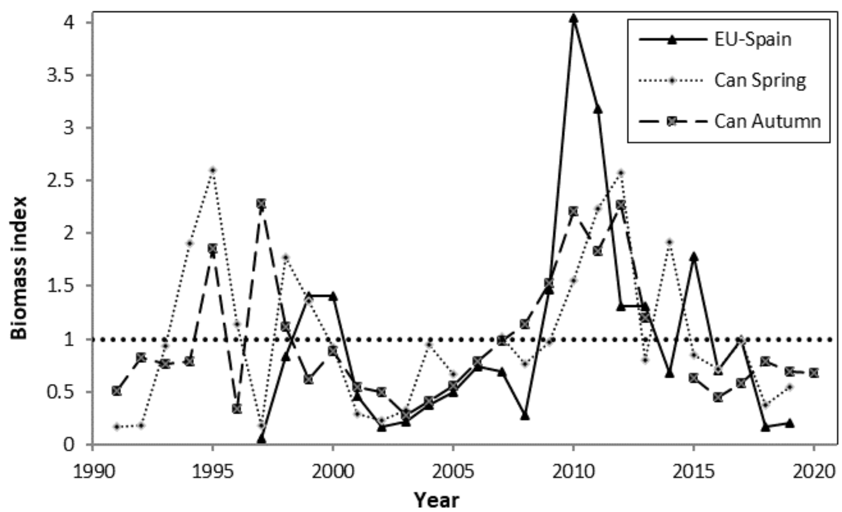


Figure 15.2. Redfish in Div. 3O: Survey biomass indices from Canada and EU-Spain (Campelen equivalent estimates prior to autumn 1995 in the Canadian Surveys and prior to 2001 in the EU-Spain survey. Indices were normalized by dividing by their time-series means over 1997-2020.

c) Estimation of Stock Parameters

There is no assessment model for this stock and survey indices are used to assess stock status.

d) Catch/Biomass ratio

A fishing mortality proxy was derived from the ratio of catch in year "n" to the average of the Canadian spring (year n) and autumn (year = n-1) survey biomass. Since 1998, the fishing mortality proxy was highest from 2001 to 2003, with a secondary peak in 2006, and lowest during the period 2007 to 2014. The fishing mortality proxy increased during the 2014 to 2016 period but values have remained stable since 2016, below the 2006 secondary peak.

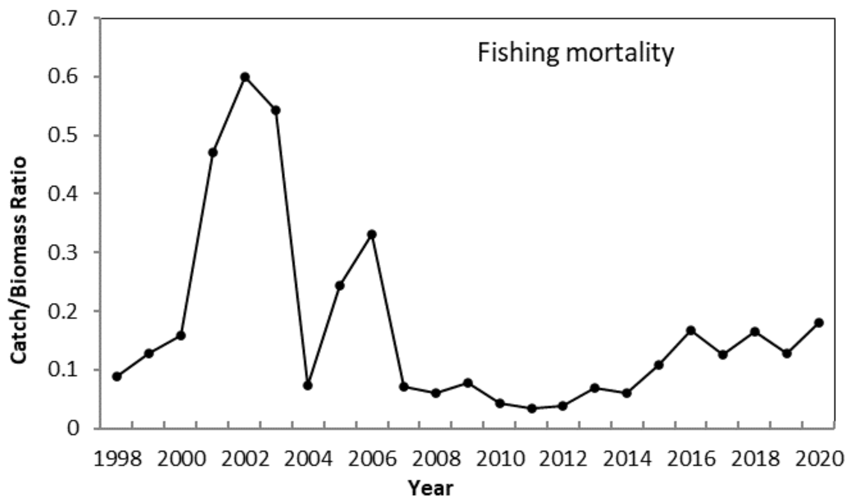


Figure 15.3. Redfish in Div. 3O: Catch/survey biomass ratios for Div. 3O. Biomass was calculated as the average survey biomass between Canadian spring (n) and autumn (n-1) for year (n) in which catch was taken. The 2006 and 2020 values of biomass come from the autumn surveys and the 2014 value comes from the spring survey.

e) Conclusion

Catches increased from 2010 to 2016 as a dominant recruitment pulse entered the fishery but catch has decreased since then. All three survey indices (Canadian spring and autumn, and EU-Spain) were near the time-series peaks during 2010 to 2011, but values have generally decreased since 2012, and all index values for 2019 were below their time-series averages. The 2020 index value for the Canadian autumn survey was similar to the 2019 value, below the time-series average. There were no Canadian spring or EU-Spain surveys in 2020. Persistent and high variability in the biomass indices makes it difficult to reconcile year-to-year changes. The fishing mortality proxy was at the lowest levels of the time series during 2007 to 2014, but moderately higher values have been observed since then. Given the high variability in the survey indices and the long life span of redfish, there is nothing to indicate a change in the status of the stock.

The next full assessment of the stock is scheduled for 2022.

f) Research Recommendations

In 2019, STACFIS **recommended** that *for Redfish in Div. 3O*, *work continue on developing an assessment model for the stock. Aging should be conducted for redfish sampled during select years to support model development.*

STATUS: No progress has been made.

16. Thorny Skate (*Amblyraja radiata*) in Divisions 3L, 3N, 3O and Subdiv. 3Ps

Interim Monitoring Report (SCR Doc.20/10; 21/04; SCS Doc. 21/06,08,09)

a) Introduction

Thorny Skate on the Grand Banks was first assessed by Canada for the stock unit 3LNOPs. Subsequent Canadian assessments also provided advice for Divs. 3LNOPs. However, Subdivision 3Ps is presently managed as a separate unit by Canada and France in their respective EEZs, and Divs. 3LNO in the NAFO Regulatory Area (NRA) is managed by NAFO. Based on this species' continuous distribution and the lack of physical barriers between Divs. 3LNO and Subdiv. 3Ps, Thorny Skate in Divs. 3LNOPs is considered to constitute a single stock.

Catch History

Commercial catches of skates contain a mix of skate species. However, Thorny Skate dominates, comprising about 95% of skate species taken in Canadian and EU-Spain catches. Thus, the skate fishery on the Grand Banks can be considered a fishery for Thorny Skate. In 2005, NAFO Fisheries Commission established a Total Allowable Catch (TAC) of 13 500 t for Thorny Skate in the NRA of Divs. 3LNO. This TAC was lowered to 12 000 t for 2010-2011, and to 8 500 tons for 2012. The TAC was further reduced to 7 000 t for 2013-2021. In Subdiv. 3Ps, Canada established a TAC of 1 050 tons in 1997, which has not changed.

Catches from the NRA of Divs. 3LNO increased in the mid-1980s with the commencement of a directed fishery for Thorny Skate. The main participants in this new fishery were EU-Spain, EU-Portugal, USSR, and the Republic of Korea. Catches from all countries in Divs. 3LNOPs over 1985-1991 averaged 17 058 t; with a peak of 28 408 t in 1991 (STATLANT-21). From 1992-1995, catches of Thorny Skate declined to an average of 7 554 t; however, there are substantial uncertainties concerning reported skate catches prior to 1996. Average STACFIS-agreed catch for Divs. 3LNO in 2015-2019 was 3 497 t and 690 t in Subdiv. 3Ps. STACFIS catch in 2020 totaled 4 321 t for Divs. 3LNO and 783 t for Subdiv. 3Ps.

Recent catches and TACs ('000 t) are as follows:

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Divs. 3LNO:										
TAC	8.5	7	7	7	7	7	7	7	7	7
STATLANT-21	4.3	4.4	4.5	3.3	3.5	4.2	0.1	3.7	4	
STACFIS	4.3	4.4	4.5	3.4	3.5	4.5	2.4	3.7	4.3	
Subdiv. 3Ps:										
TAC	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
STATLANT-21	0.4	0.3	0.2	0.2	0.7	0.6	1.1	0.9	0.8	
Divs. 3LNOPs:										
STATLANT-21	4.6	4.6	4.7	3.6	4.1	4.8	2.3	4.6	4.8	
STACFIS	4.6	4.6	4.7	3.7	4.1	5.1	3.5	4.6	5.1	

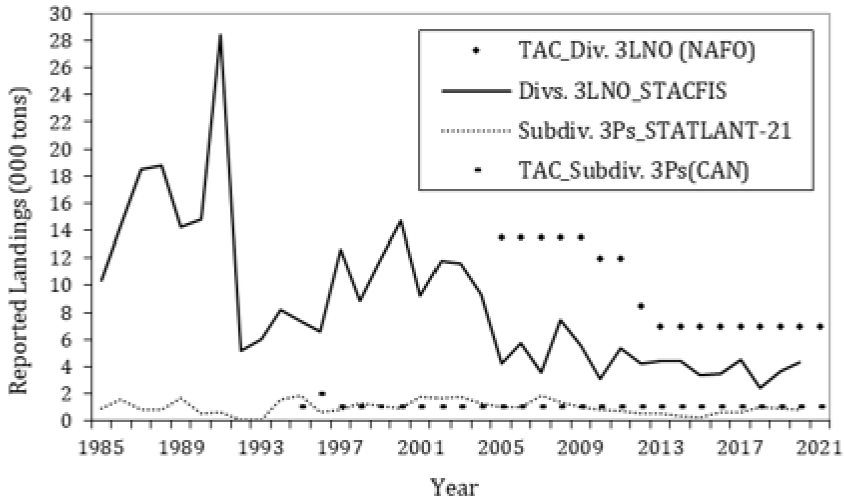


Figure 16.1. Thorny Skate in Divs. 3LNO and Subdiv. 3Ps, 1985-2020: reported landings and TAC.

b) Data Overview

i) Research surveys

Canadian spring surveys. Stratified-random research surveys have been conducted by Canada in Divs. 3LNO and Subdiv. 3Ps in spring; using a Yankee 41.5 otter trawl in 1972-1982, an Engel 145 otter trawl in 1984-1995, and a Campelen 1800 shrimp trawl in 1996-2019. Due to COVID-19 the survey was not conducted in 2020. Subdiv. 3Ps was not surveyed in 2006, nor was the deeper portion (>103 m) of Divs. 3NO in that year, due to mechanical difficulties on Canadian research vessels. In 2015 and 2017, several strata were not sampled in Div. 3L, thus impacting biomass and abundance estimates of Thorny Skate.

Indices for Divs. 3LNOPs in 1972-1982 (Yankee trawl) fluctuated without trend (Figure 16.2a).

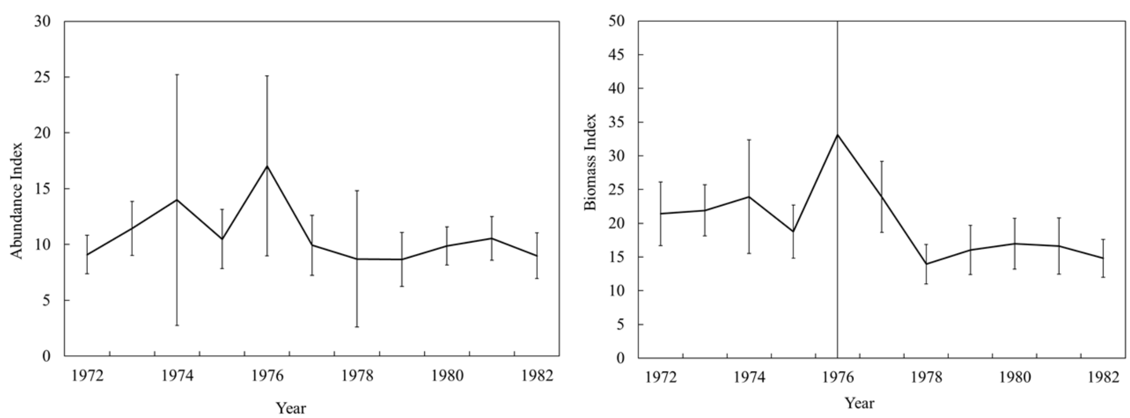


Figure 16.2a. Thorny Skate in Divs. 3LNOPs, 1972-1982: abundance (left panel) and biomass (right panel) indices from Canadian spring surveys.

Survey coverage was poor in the Canadian spring survey of Div. 3L in 2017. The missing strata typically contain ~10% on average of the total biomass in years when these strata are surveyed; therefore, the 2017 biomass index may be an underestimate (Figure 16.2b). Total survey biomass in Divs. 3LNOPs has fluctuated, but remained stable at low levels since 2007. Recent biomass estimates are above B_{lim}.

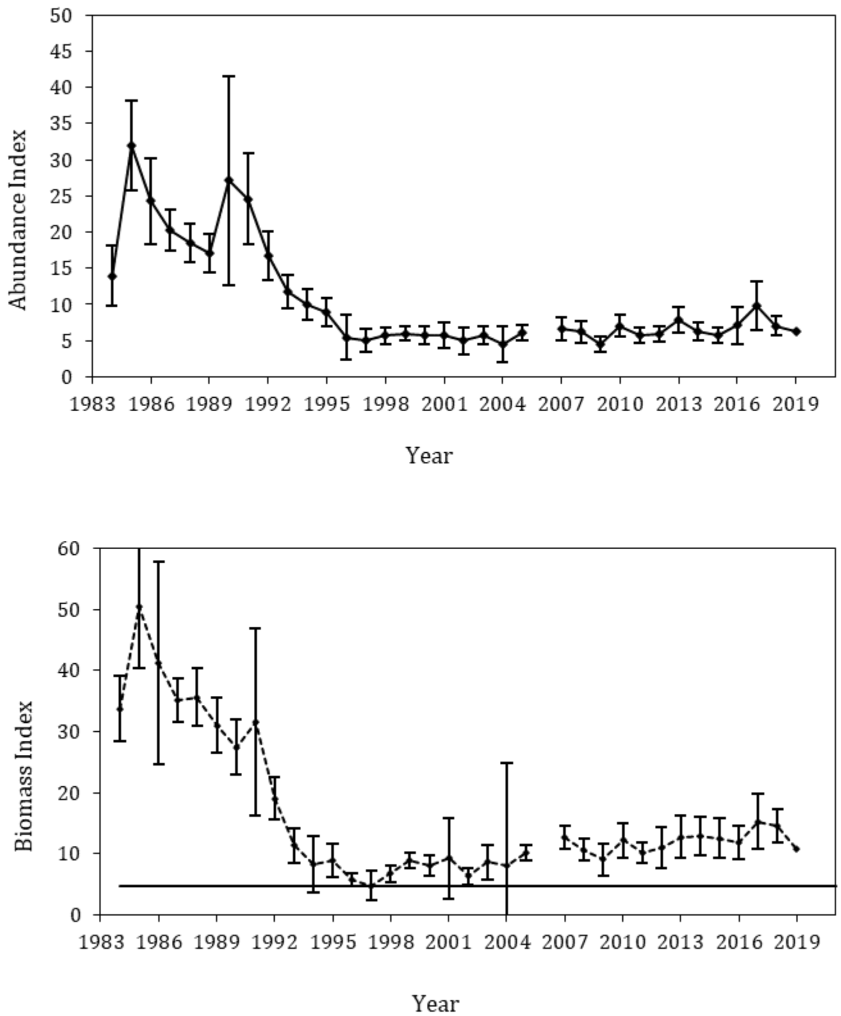


Figure 16.2b. Thorny Skate in Divs. 3LNOPs, 1984-2019: abundance (top panel) and biomass (bottom panel with B_{lim} shown [blue horizontal line]) indices from Canadian spring surveys. The survey in NAFO Div. 3L was incomplete in 2015 and 2017.

Canadian autumn surveys. Stratified-random research surveys have been conducted by Canada in Divs. 3LNO in the autumn, using an Engel 145 otter trawl in 1990-1994 and a Campelen 1800 shrimp trawl in 1995-2020, to depths of ~1 450 m.

Autumn survey indices, similar to spring estimates, declined during the early 1990s. Catch rates have been stable at very low levels since 1995 (Figure 16.3). Biomass and abundance indices for the autumn 2020 survey were similar to those observed in 2019, but were highly uncertain. Divs. 3NO were not sampled in 2014 due to mechanical difficulties on Canadian research vessels. Autumn indices of abundance and biomass are, on average, higher than spring estimates. This is expected, because Thorny Skates are found deeper than the maximum depths surveyed in spring (~750 m), and are more deeply distributed during winter/spring.

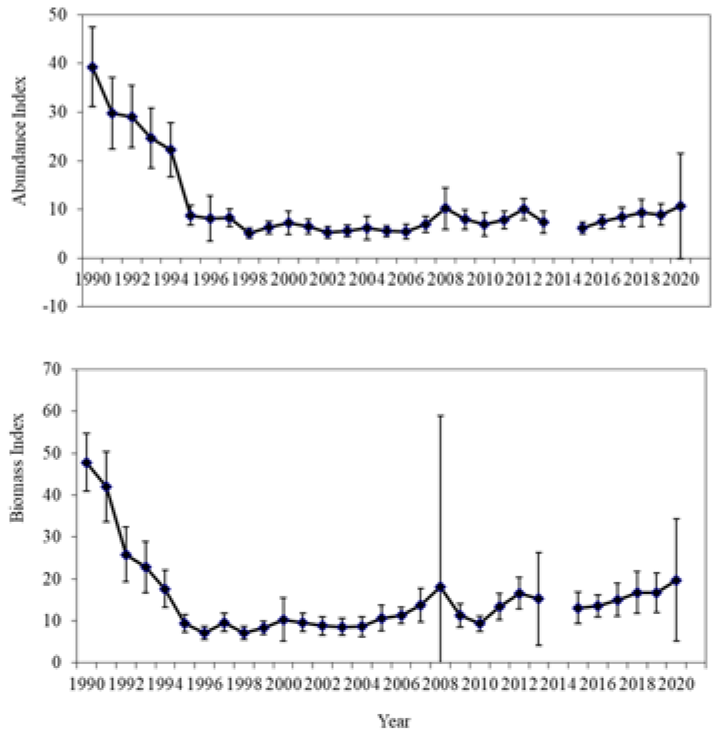


Figure 16.3. Thorny Skate in Divs. 3LNOPs: 1990-2020: abundance (top panel) and biomass (bottom panel) indices from Canadian autumn surveys.

EU-Spain Divs. 3NO Survey. EU-Spain survey indices (Campelen or equivalent) are available for 1997-2019. The survey only occurs in the NAFO Regulatory Area, thus not sampling the entire Divisions. The biomass trajectory from the EU-Spain surveys was similar to that of the Canadian spring surveys until 2006 (Figure 16.4). Since 2007, the two indices diverged with an overall increase in the Canadian survey and a decline in the EU-Spain index to its lowest level in 2019.

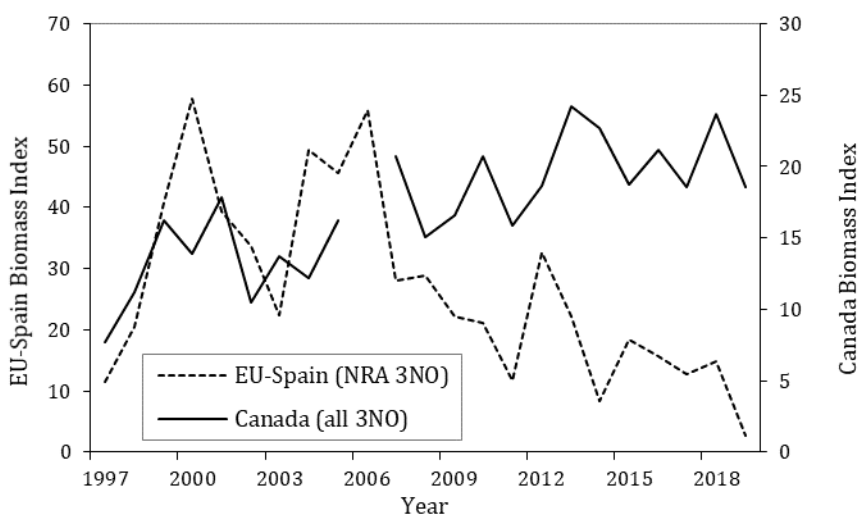


Figure 16.4. Thorny Skate in Divs. 3LNOPs: biomass indices from the EU-Spain survey and the Canadian spring survey in 1997-2019.

EU-Spain Div. 3L survey. EU-Spain survey indices (Campelen trawl) are available for 2003-2019 (excluding 2005). The survey only occurs in the NAFO Regulatory Area (Flemish Pass), thus not sampling the entire Division. Both the EU-Spain and Canadian autumn Div. 3L biomass indices generally declined from 2007-2011, while the Canadian spring index was more variable during this period (Figure 16.5). The Canadian autumn biomass index followed an increasing trend since 2011, while the Canadian spring index fluctuated at lower levels. The EU-Spain index has been following a declining trend since 2015.

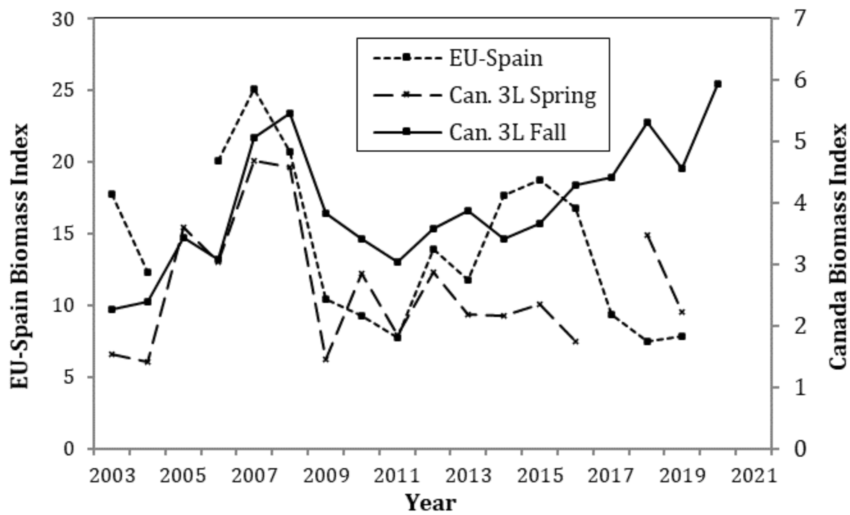


Figure 16.5. Thorny Skate in Div. 3LNOPs: Biomass indices from EU-Spain Div. 3L survey and the Canadian spring and autumn surveys of Div. 3L in 2003-2020.

c) Conclusion

With an update of abundance and biomass indices to 2020, there is nothing to indicate a significant change in the status of this stock.

The next full assessment of this stock is planned for 2022.

17. White Hake (*Urophycis tenuis*) in Divisions 3N, 3O, and Subdivision 3Ps

(SCR Doc.20/10; 21/04,22; SCS Doc. 21/05,06,08,09)

a) Introduction

The advice requested by Fisheries Commission is for NAFO Div. 3NO. On the Grand Bank, white hake are near the northern limit of their range, concentrating along the southwest slope of the Grand Bank and experience episodic recruitment. Previous studies indicated that white hake constitute a single unit in Div. 3NOPs, and that fish younger than 1 year, 2+ juveniles, and mature adults distribute at different locations in Div. 3NO and Subdiv. 3Ps. This movement of fish of different life stages between areas must be considered when assessing the status of white hake in Div. 3NO. Therefore, an assessment of Div. 3NO white hake is conducted with information on Subdiv. 3Ps included.

Canada commenced a directed fishery for white hake in 1988 in Div. 3NO and Subdiv. 3Ps. All Canadian landings prior to 1988 were as bycatch in various groundfish fisheries. EU-Spain and EU-Portugal commenced a directed fishery in 2002, and Russia in 2003, in the NAFO Regulatory Area (NRA) of Div. 3NO; resulting in the 2003-2004 peak. There were no directed fisheries by EU-Spain in 2004 or by EU-Spain, EU-Portugal, or Russia in 2005-2018. In 2003-2004, 14% of the total landings of white hake in Div. 3NO and Subdiv. 3Ps were taken by Canada, but increased to 93% by 2006; primarily due to the absence of a directed fishery for this species by other countries.

A TAC in Div. 3NO for white hake was first implemented by Fisheries Commission in 2005 at 8 500 tons, and then reduced to 6000 t for 2010-2011. The TAC in Div. 3NO for 2012 was 5000 t, and 1000 t for 2013-2021. Canada has implemented a TAC of 500 t for Subdiv. 3Ps for 2018-2024.

From 1970-2009, white hake landings in Div. 3NO fluctuated, averaging approximately 2000 t, exceeding 5000 t in only three years during that period. Landings peaked in 1987 at approximately 8100 t (Figure 17.1). With the restriction of fishing by other countries to areas outside Canada's 200-mile limit in 1992, non-Canadian landings fell to zero. Landings were low in 1995-2001 (422-t average), then increased to 6718 t in 2002 and 4823 t in 2003; following recruitment of the large 1999 year-class. STACFIS-agreed catches decreased to an average of 333 t in 2009-2018. Catch in 2019 was reported as 304 t and 343 t in 2020.

Commercial catches of white hake in Subdiv. 3Ps were less variable, averaging 1114 t in 1985-93, then decreasing to an average of 619 t in 1994-2002 (Figure 17.1). Subsequently, catches increased to an average of 1174 t in 2004-2007, then decreased to a 300-t average in 2009-2018. Catch in 2019 was reported as 274 t, and 116 t in 2020.

Recent catches and TACs ('000 t) are as follows:

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Divs. 3LNO:										
TAC	5	1	1	1	1	1	1	1	1	1[1]
STATLANT-21	0.1	0.2	0.3	0.4	0.4	0.5	0.3	.3	0.3	
STACFIS	0.1	0.2	0.3	0.5	0.4	0.5	0.4	0.3	0.3	
Subdiv. 3Ps:										
TAC							0.5	0.5	0.5	0.5
STATLANT-21	0.2	0.2	0.4	0.3	0.4	0.3	0.3	0.3	0.1	

[1]May change in-season. See NAFO FC Doc. 19/01

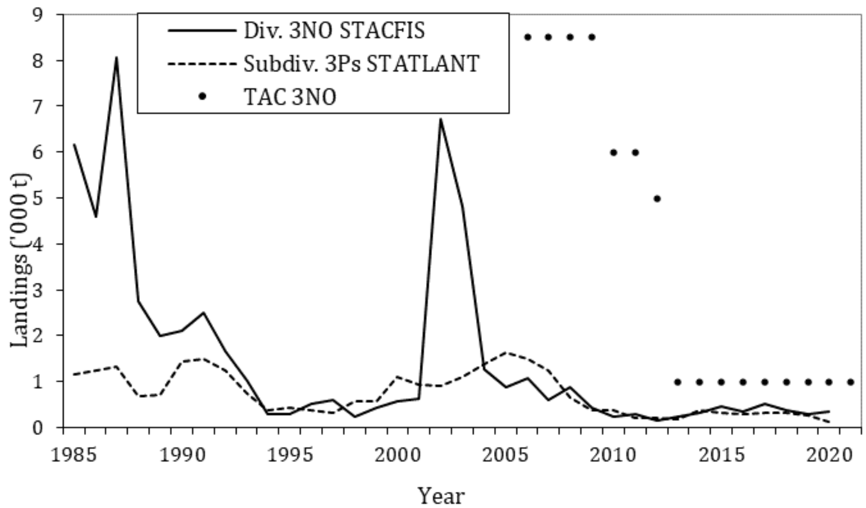


Figure 17.1. White hake in Div. 3NO and Subdiv. 3Ps: Total catch of white hake in NAFO Division 3NO (STACFIS), and Subdivision 3Ps (STATLANT-21A). The Total Allowable Catch (TAC) in the NRA of Div. 3NO is also indicated on the graph.

b) Input Data

i) Commercial fishery data

Length composition. Length frequencies were available for Canada (1994-2018), EU-Spain (2002, 2004, 2012, 2014-2018), EU-Portugal (2003-2004, 2006-2016), and Russia (2000-2007, 2013-2016). Different length ranges appeared to be highly variable depending on gear types, years and areas. In the Canadian directed fishery in 2016, the length range caught by longlines in Div. 3O was 36-114 cm. In 2015-2017, the Canadian Witch Flounder trawl fishery (152-155 mm mesh) in Div. 3O caught 34-110 cm White Hakes, and a contracted range of 42-82 cm fish (147 mm mesh) in 2019. Bycatch in the 2019 Atlantic Halibut longline fishery in Div. 3O contained 41-103 cm White Hakes; although possibly not representative of catch composition due to small sample size. In Subdiv. 3Ps, the Canadian Atlantic Halibut longline fishery in 2017-2018 caught 41-120 cm White Hakes. In 2019, the Witch Flounder trawl fishery (145 mm mesh) caught 41-90 cm fish in Subdiv. 3Ps.Sizes reported from bycatch in commercial trawls fishing in the NRA of Div. 3NO by EU-Spain were 29-104 cm (130 mm mesh) in 2017, and 18-87 cm fish in 2018. Spanish trawlers caught a contracted range of 31-71 cm fish in 2019, and 23-77 cm White Hakes in 2020. Although 14-106 cm fish were reported by EU-Spain using 280 mm mesh trawls in 2017, White Hake was not sampled from this gear in 2018-2020. EU-Portugal reported 27-76 cm fish in 2015-2016 (130 mm mesh), but did not sample this species in 2017-2020. Russia reported 32-84 cm White Hakes in 2015, and 30-107 cm fish in 2019-2020. Russia sampled few White Hakes over 2016-2018.

ii) Research survey data

Canadian stratified-random bottom trawl surveys. Data from spring research surveys in NAFO Div. 3N, 3O, and Subdiv. 3Ps were available from 1972 to 2019, there was no survey in 2020 due to COVID-19. In the 2006 Canadian spring survey, most of Subdiv. 3Ps was not surveyed, and only shallow strata in Div. 3NO (to a depth of 77 m in Div. 3N; to 103 m in Div. 3O) were surveyed; thus the survey estimate for 2006 was not included. Data from autumn surveys in Div. 3NO were available from 1990 to 2020, due to mechanical difficulties the survey was not completed in 2014. Canadian spring surveys were conducted using a Yankee 41.5 bottom trawl prior to 1984, an Engel 145 bottom trawl from 1984 to 1995, and a Campelen 1800 trawl thereafter. Canadian autumn surveys in Div. 3NO were conducted with an Engel 145 trawl from 1990 to 1994, and a Campelen 1800 trawl from 1995-2020. There are no survey catch rate conversion factors between trawls for white hake; thus each gear type is presented as a separate time series.

Abundance and biomass indices of white hake from the Canadian spring research surveys in Div. 3NOPs are presented in Figure 17.2a. From 2007-2018, the population remained at a level similar to that previously observed in the Campelen time series for 1996-1998. The dominant feature of the white hake abundance time series was the very large peak observed over 2000-2001. In recent years, spring abundance of white hake increased in 2011, but declined to relatively stable levels over 2012-2018. Biomass of this stock increased in 2000, generated by the very large 1999 year-class. Subsequently, the biomass index decreased until 2009, and has since increased in 2014, biomass declined slightly over 2015 - 2018.

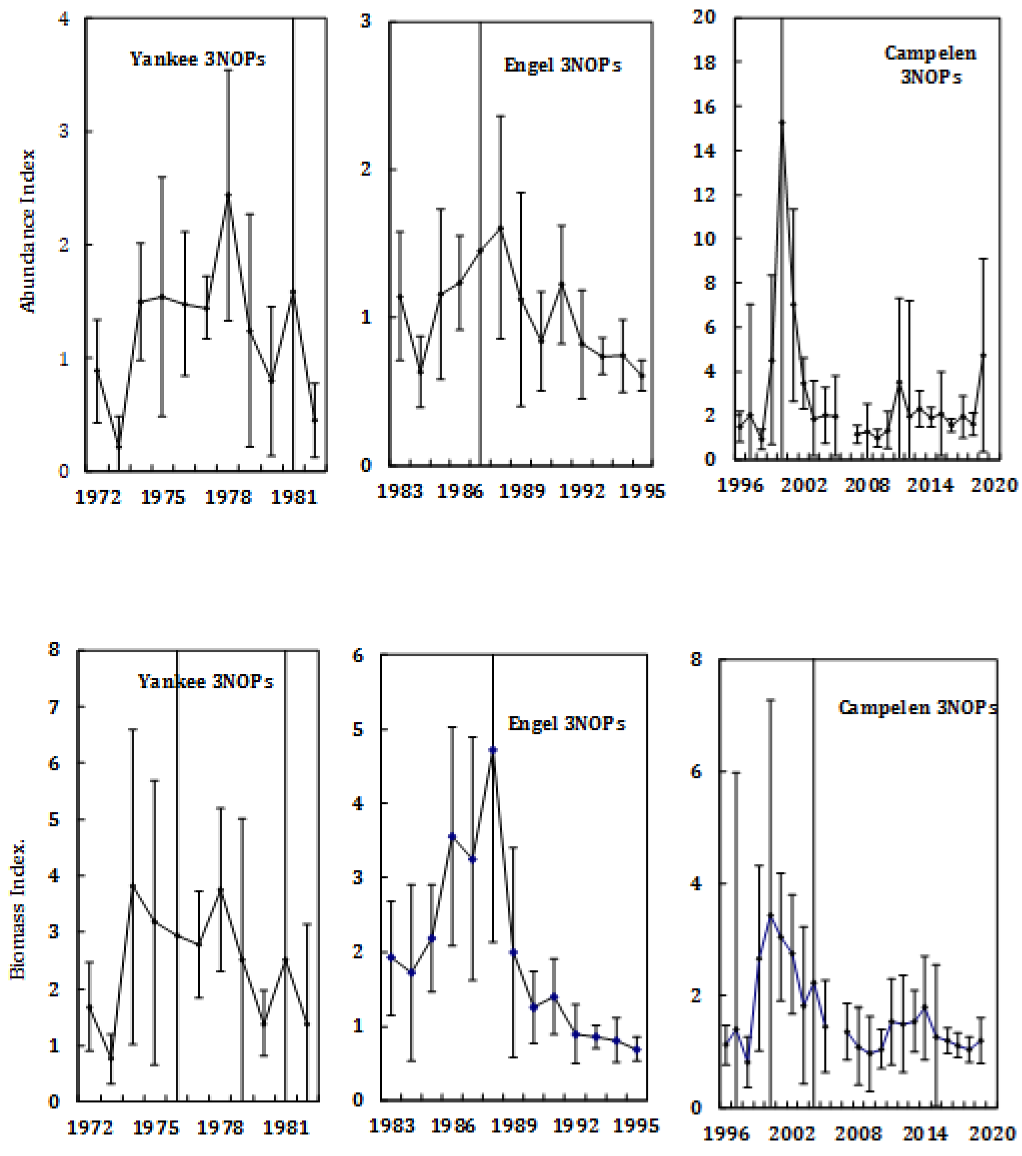


Figure 17.2a. White hake in Div. 3NO and Subdiv. 3Ps: abundance (top panels) and biomass (bottom panels) indices from Canadian spring research surveys, 1972-2020. Estimates from 2006 are not shown, since survey coverage in that year was incomplete. Yankee, Engel, and Campelen time series are not standardized, and thus are presented on separate panels. Error bars are 95% confidence limits. The bounds of the error bars in 1976, 1981, 1987, 2000, 2012, and 2015 in some panels extend above/below the graph limits.

Canadian autumn surveys of Div. 3NO have the peak in abundance represented by the very large 1999 year-class (Figure 17.2b). Autumn indices then declined to levels similar to those observed during 1996-1998 until 2010. In 2011-2013, both biomass and abundance appear to have slightly increased then declined over 2015-2018. This survey was not completed in 2014.

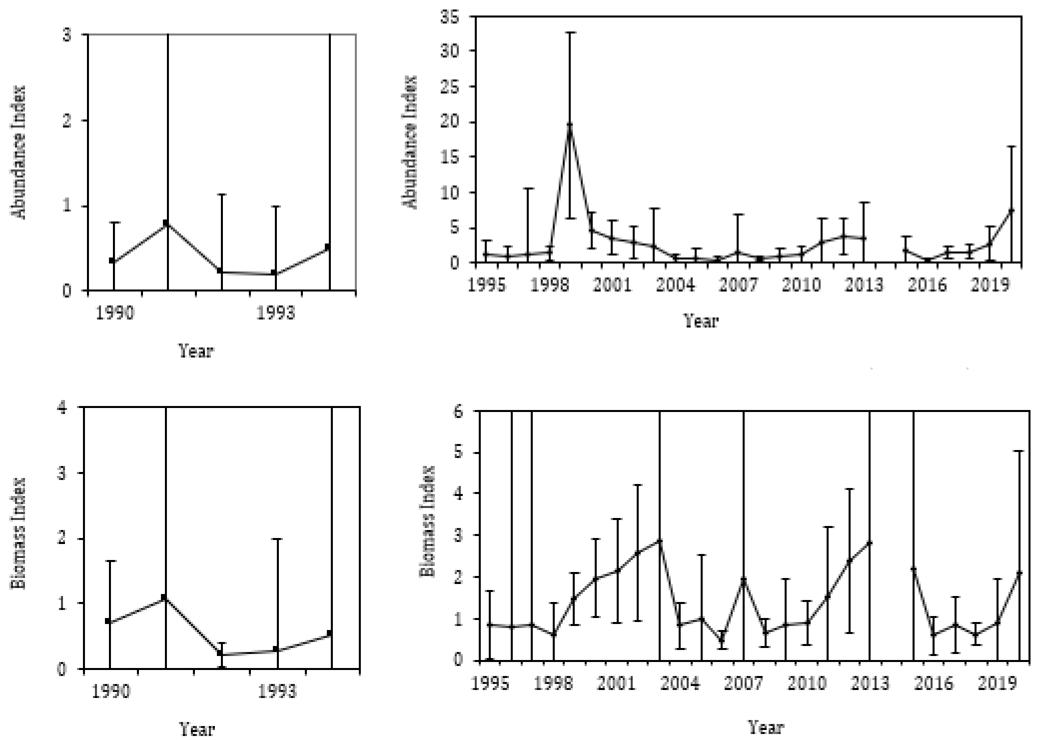


Figure 17.2b. White hake in Div. 3NO: abundance (top panel) and biomass indices (bottom panel) from Canadian autumn surveys, 1990-2020. Engel (☐, 1990-1994) and Campelen (♦, 1995-2020) time series are not standardized. Estimates from 2014 are not shown, since survey coverage in that year was incomplete. Error bars are 95% confidence limits. The bounds of the error bars in 1990-1994, 2002-2009, 2013, 2015, 2019 and 2020 in some panels extend above/below the graph limits.

EU-Spanish stratified-random bottom trawl surveys in the NRA. EU-Spain biomass indices in the NAFO Regulatory Area (NRA) of Div. 3NO were available for white hake from 2001 to 2019, the survey was not conducted in 2020 due to COVID-19 (Figure 17.3). EU-Spain surveys were conducted with Campelen gear (similar to that used in Canadian surveys) in the spring to a depth of 1400 m. This survey covers only a small portion of the total stock area. The EU-Spain biomass index was highest in 2001, then declined to 2003, peaked slightly in 2005, and then declined to its lowest level in 2008. In 2009-2013, the EU-Spain index indicated a gradually increasing trend relative to 2008, which is similar to that of the Canadian spring survey index (Figure 17.3). However, the EU-Spain biomass index declined in 2014, followed by an increase over 2015-2016 to the highest level since 2005, while the Canadian index declined to its 2007 level. The EU-Spain index declined in 2017 and 2018 to a similar level as observed in 2014.

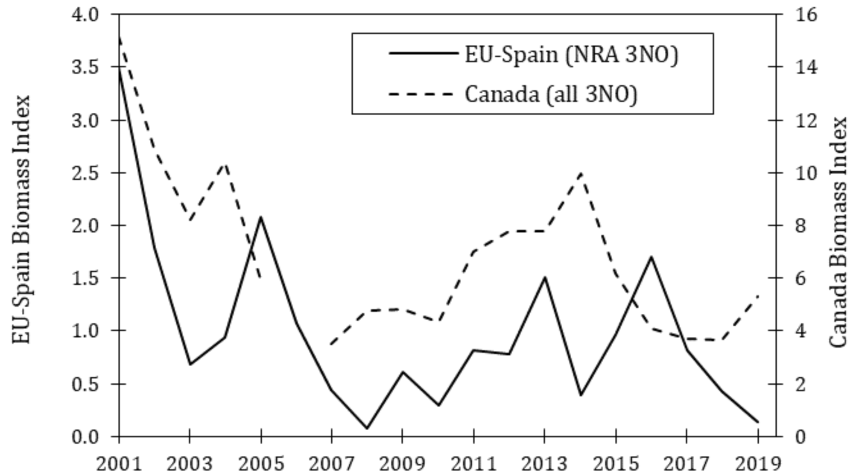


Figure 17.3. White hake in the NRA of Div. 3NO: Biomass indices from EU-Spain Campelen spring surveys in 2001-2019 compared to Canadian spring survey indices in all of Div. 3NO. Estimates from 2006 Canadian survey are not shown, since survey coverage in that year was incomplete.

iii) Biological studies

Distribution. White hake in Div. 3NO and Subdiv. 3Ps are confined largely to an area associated with the warmest bottom temperatures (4-8°C) along the southwest edge of the Grand Banks, edge of the Laurentian Channel, and southwest coast of Newfoundland.

White hake distribute in different locations during various stages of their life cycle. Fish <26 cm in length (1st year fish) occur almost exclusively on the Grand Bank in shallow water. Juveniles (2+ years) are widely spread, and a high proportion of white hake in the Laurentian Channel area of Subdiv. 3Ps are juveniles. Mature adults concentrate on the southern slope of the Bank in Div. 3NO, and along the Laurentian Channel in Subdiv. 3Ps.

Life stages. Canadian spring survey trends in abundance for 1996-2020 were staged based on length as one-year-olds (≤26 cm; YOY), 2+ juveniles (27-57 cm), and mature adults (58+ cm; Figure 17.5). Recruitment of one-year-old male and female white hake was highest in 2000, and has since been variable at a very low level. However in 2019, there was a significant increase in both male and female White hakes less than 27cm in length. Immature white hake older than two years have dominated the population. There are currently no indications of increased abundance of mature white hake.

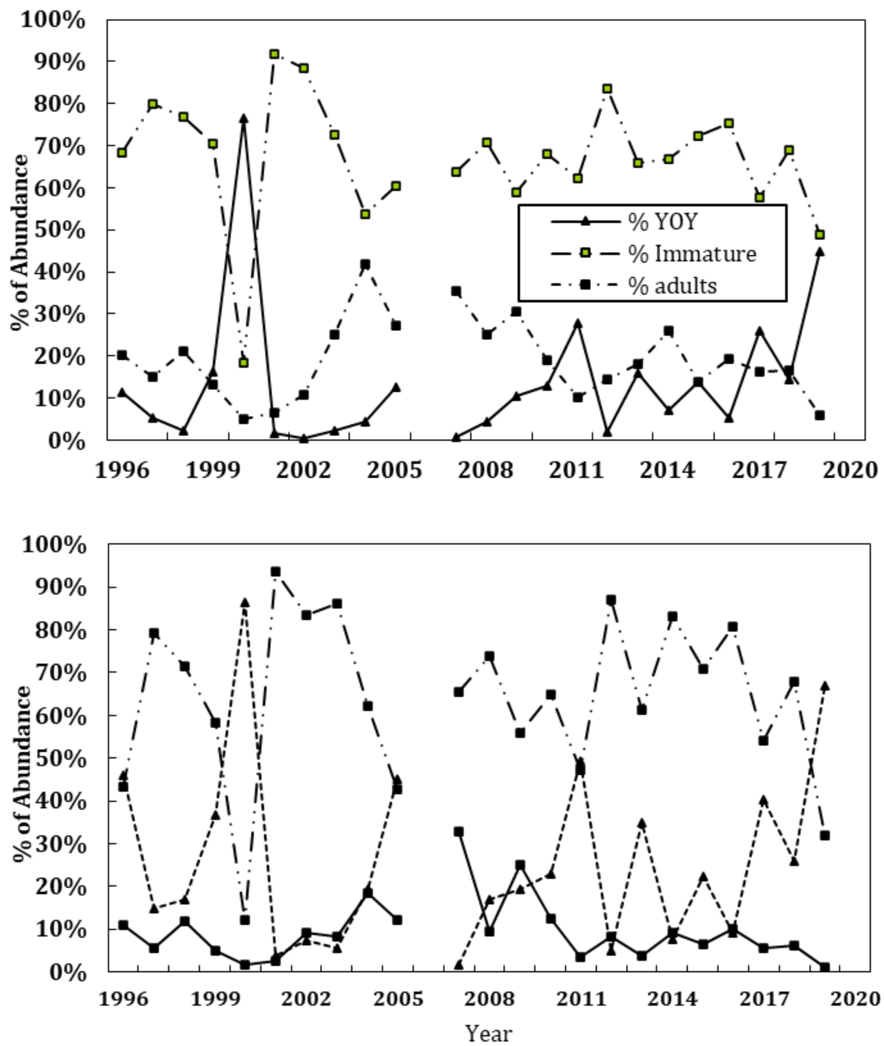


Figure 17.4. White hake in Div. 3NO and Subdiv. 3Ps: proportion of stages in terms of abundance by sex (female, upper panel; male, lower panel) from Canadian Campelen spring survey data in 1996-2020. Estimates from 2006 and 2020 are not available due to incomplete surveys.

c) Recruitment

In Canadian spring research surveys, the number of white hake less than 27 cm in length is assumed to be an index of recruitment at Age 1. The recruitment index in 2000 was very large, but no large value has been observed during 2001-2018 (Figure 17.6). Recruitment was higher in 2019, but is not comparable to the very high recruitment observed in 2000.

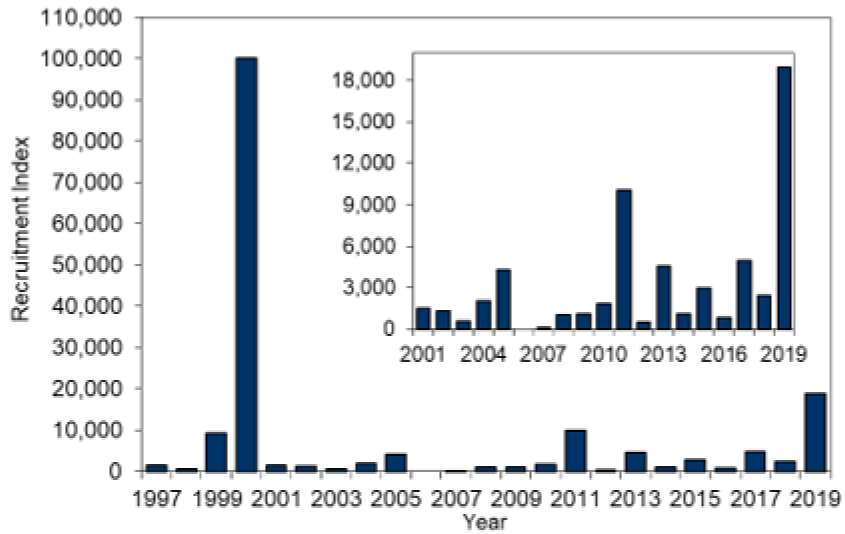


Figure 17.5. White hake in Div. 3NO and Subdiv. 3Ps: recruitment index for age 1 males and females (combined) from Canadian Campelen spring surveys in Div. 3NO and Subdiv. 3Ps in 1997-2019. Estimates from 2006 are not shown, since survey coverage in that year was incomplete and no survey occurred in 2020. Inset plot depicts 2001-2019 on a smaller scale.

In Canadian fall research surveys, the number of white hake less than 27 cm in length was large in 1999, but no large value has been observed during 2000-2019 (Figure 17.6). The number of White hakes less than 27 cm in length was higher in 2020, but not comparable to the very high value observed in 1999.

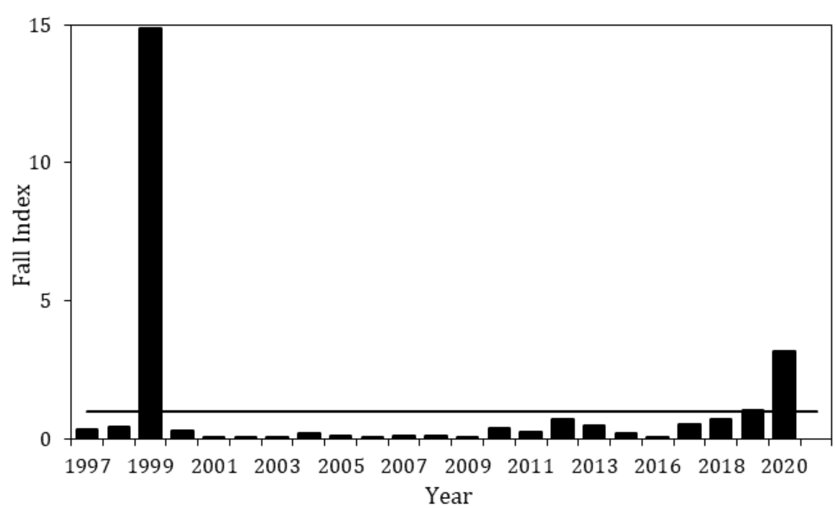


Figure 17.6. Standardized White hake (≤26 cm) from Canadian fall surveys in Div. 3NO in 1996-2020.

d) Assessment Results

This stock is assessed based upon a qualitative evaluation of stock survey biomass trends and recruitment indices.

Biomass. Biomass of this stock increased in 1999 and 2000, generated by the large recruitment observed in those years. Subsequently, the biomass index decreased and has since remained variable but lower.

Recruitment. Recruitment in 2000 was very large, but no large year class has been observed since then. Recruitment was higher in 2019, but not comparable to the very high recruitment observed in 2000.

Relative *F* (commercial landings/Canadian spring survey biomass). Using STACFIS-agreed commercial landings and Canadian spring survey biomass index, estimates of relative *F* were calculated for white hake in Div. 3NO and Div. 3NOPs. Relative fishing mortality (Rel. *F*) has fluctuated, but increased considerably in 2002-2003 (Figure 17.7). Relative *F* estimates have been low since 2010.

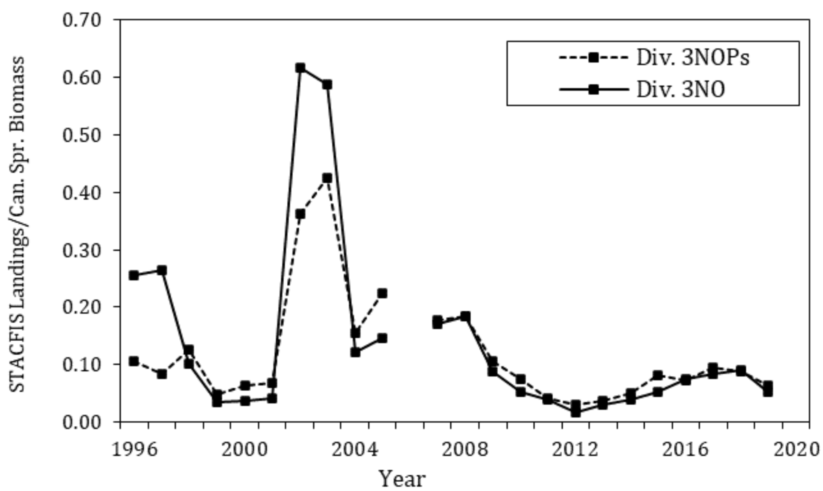


Figure 17.7. White hake in Div. 3NO and Subdiv. 3Ps: estimates of relative *F* from STACFIS-agreed commercial landings/Canadian Campelen spring survey biomass (1996-2020). Estimates from 2006 and 2020 are not shown due to missing surveys.

e) State of the stock.

The assessment is considered data limited and is associated with a relatively high uncertainty. Biomass of this stock increased in 1999 and 2000, generated by the large recruitment observed in those years. Subsequently, the biomass index decreased and has since remained variable but lower. No large recruitments have been observed since 2000. Fishing mortality is low.

f) Reference Points

No precautionary reference points have been established for this stock.

g) Research Recommendations

STACFIS **recommended** that *age determination should be conducted on otolith samples collected during annual Canadian surveys (1972-2020); thereby allowing age-based analyses of this population.*

Otoliths are being collected, and aging has begun. STACFIS reiterates this recommendation.

STACFIS **recommended** that *survey conversion factors between the Engel and Campelen gear be investigated for this stock.*

No progress, STACFIS reiterates this recommendation.

STACFIS **recommended** that *work continue on the development of population models and reference point proxies.*

Various formulations of a surplus production model both in a state-space (SPICT) and in a Bayesian framework were explored and work is continuing.

The next full assessment of this stock is planned for 2023.

D. WIDELY DISTRIBUTED STOCKS: SA 2, SA 3 AND SA 4

Recent Conditions in Ocean Climate and Lower Trophic Levels

- *In 2020, subareas 2, 3 and 4 were all above normal, making the cumulative anomaly the 5th warmest since 1980;*
- *Spring bloom initiation and magnitude were, on average, near normal in subareas 2-3-4 in 2020;*
- *Mean copepod abundance was above normal in 2020 and especially higher in subareas 2-3 compared to subarea 4;*
- *Mean abundance of non-copepod zooplankton remained above normal across subareas 2-3-4 for a 5th consecutive year and was generally higher in subareas 2-3 compared to subarea 4;*
- *Mean zooplankton biomass was near normal in 2020 for a 5th consecutive year and was higher in in subarea 2 compared to subareas 3-4.*

Environmental Overview

The water mass characteristics of Newfoundland and Labrador Shelf are typical of sub-polar waters with a sub-surface temperature range of -1-2°C and salinities of 32-33.5. Labrador Slope Water flows southward along the shelf edge and into the Flemish Pass region, this water mass is generally warmer and saltier than the sub-polar shelf waters with a temperature range of 3-4°C and salinities in the range of 34-34.75. On average bottom temperatures remain <0 °C over most of the northern Grand Banks, but increase to 1-4°C in southern regions and along the slopes of the banks below 200 m. North of the Grand Bank, in Div. 3K, bottom temperatures are generally warmer (1-3 °C) except for the shallow inshore regions where they are mainly <0 °C. In the deeper waters of the Flemish Pass and across the Flemish Cap bottom temperatures generally range from 3-4 °C. Throughout most of the year the cold, relatively fresh water overlying the shelf is separated from the warmer higher-density water of the continental slope region by a strong temperature and density front. This winter-formed water mass is generally referred to as the Cold Intermediate Layer (CIL) and is considered a robust index of ocean climate conditions. In general, shelf water masses undergo seasonal modification in their properties due to the seasonal cycles of air-sea heat flux, wind-forced mixing and ice formation and melt, leading to intense vertical and horizontal gradients particularly along the frontal boundaries separating the shelf and slope water masses.

Temperature and salinity conditions in the Scotian Shelf, Bay of Fundy and Gulf of Maine regions are determined by many processes: heat transfer between the ocean and atmosphere, inflow from the Gulf of St. Lawrence supplemented by flow from the Newfoundland Shelf, exchange with offshore slope waters, local mixing, freshwater runoff, direct precipitation and melting of sea-ice. The Nova Scotia Current is the dominant inflow, originating in the Gulf of St. Lawrence and entering the region through Cabot Strait. The Current, whose path is strongly affected by topography, has a general southwestward drift over the Scotian Shelf and continues into the Gulf of Maine where it contributes to the counter-clockwise mean circulation. The properties of shelf waters are modified by mixing with offshore waters from the continental slope. These offshore waters are generally of two types, Warm Slope Water, with temperatures in the range of 8-13 °C and salinities from 34.7-35.6, and Labrador Slope Water, with temperatures from 3.5 to 8 °C and salinities from 34.3 to 35. Shelf water properties have large seasonal cycles, east-west and inshore-offshore gradients, and vary with depth.

Ocean Climate and Ecosystem Indicators

A cumulative climate index for NAFO sub-areas 2, 3 and 4 (from the Labrador Shelf to the Scotian Shelf) is presented in Figure D1.A. After a somewhat cold period from the late 1980s to the early 1990s, the index has remained relatively high since about the mid-2000's, with 2006, 2010 and 2012 being respectively the second, third and first warmest anomalies since 1985. After a recent return to near-normal values between 2014 and 2019 (mostly driven by cooler temperatures in SA 2 and 3) the index was back to a positive anomaly in 2020 (5th warmest year since 1980).

Mean timing of the spring bloom initiation across subareas 2-3-4 remained mostly near normal between 2003 and 2020 with few overall early onsets in 2006 and 2010, and one year where blooms were delayed across the region in 2015 (Fig D1.B). Overall spring bloom mean production also remained mostly near normal throughout the time series except for the above-normal spring productions observed in 2003 and 2006 and for the below-normal production of 2008 (Figure D1.C). Spring bloom production was lower in subarea 2 compared to subareas 3 and 4 in 2018 and 2019 and was near-normal in all subareas in 2020 (Fig D1.C). Mean copepod abundance across subareas 2-3-4 rapidly increased between 1999 and 2006 before leveling off to near normal levels until 2015 (Figure D1.D). Copepod abundance was especially high in subarea 2 in 2020 (Figure D1.D). Anomalies have been mostly positive in all three subareas since 2010 with above normal levels observed in 2016 and 2020 (Figure D1.D). Mean abundance of non-copepod zooplankton increased in all subareas in the early 2010s and has remained above normal since 2016 (Figure D1.E). In general, the abundance of non-copepods was comparatively higher in subareas 2 and 3 than in subarea 4 between 2016 and 2020 (Figure D1.E). Mean zooplankton biomass in the region decreased from above normal in 2002 to below normal in 2015 (Fig D1.F). Biomass has since remained at near-normal level, especially due to an increase in subarea 2 and 3 (Figure D1.F).

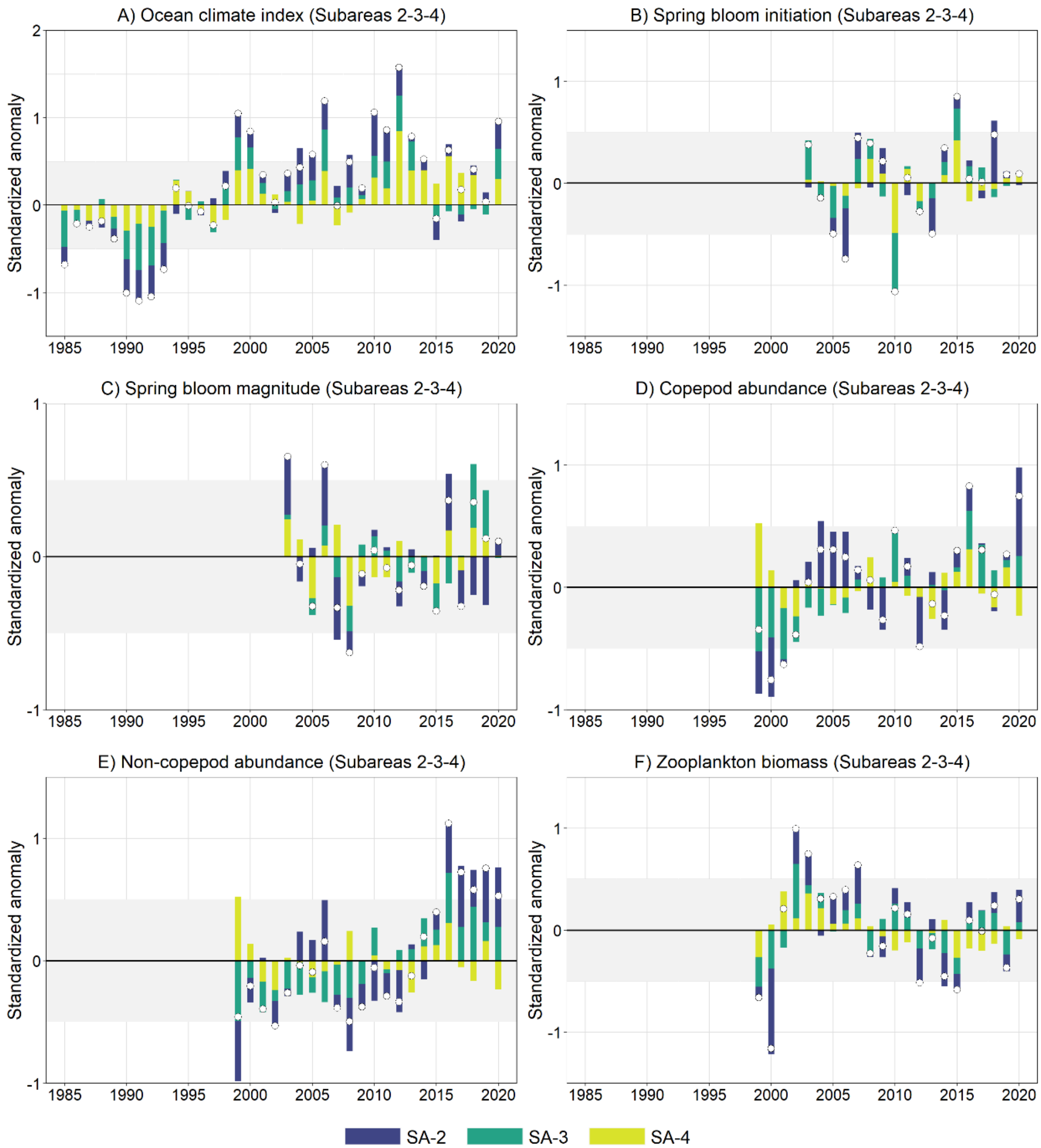


Figure D1. Environmental indices for NAFO Subareas 2-3-4. Anomalies for ocean climate index (A) are the result of the average of 8, 16 and 12 individual time series respectively for SA 2, 3 and 4. Mean positive/negative anomalies (open white circles) indicate conditions above/below (or late/early timing) the long-term average for the reference period. Color bar height indicate the relative contribution of each subarea to the mean anomaly. Anomalies were calculated using the following reference periods: 1981-2010 for ocean climate index, 2003-2020 for spring bloom initiation and magnitude, and 1999-2020 for zooplankton abundance and biomass indices. Anomalies within ±0.5 SD (grey rectangle) are considered near-normal conditions.

18. Roughhead Grenadier (*Macrourus berglax*) in Subareas 2 and 3

Interim Monitoring Report (SCS 21/05, SCS 21/06, SCS 21/09 and SCR 98/57, 21/04, 21/05, COM-SC CESAG-WP 21-04)

a) Introduction

Roughhead grenadier is distributed throughout NAFO Subareas 0 to 3 in depths between 300 and 2 000 m. However, there is little information on the number of populations and for assessment purposes, NAFO Scientific Council considers roughhead grenadier within Subareas 2 and 3 as a single stock.

A substantial part of the grenadier catches in Subarea 3 previously reported as roundnose grenadier was actually roughhead grenadier. However, catch statistics going back to 1987 have been corrected and approved by STACFIS (NAFO SCR 98/57). Catches were highest in 1998 and 1999 at approximately 7 000 t. In the period 2007-2012, catches for Subarea 2+3 roughhead grenadier were stable at levels around one thousand tons. Catches subsequently declined and since 2016 have varied around 400 t (Figure 18.1). Most of the catches were taken in Divs. 3LMN by Spain, Portugal, Estonia and Russia fleets. Less than 2% of the yearly catch has been taken in Subarea 2 and since 2015 all catches are from Subarea 3. There is no TAC for this stock.

Recent catches ('000 tons) are as follow:

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
STATLANT 21	1.0	1.3	0.4	0.6	0.2	0.1	0.1	0.1	0.2	0.2
STACFIS	1.0	1.3	0.4	0.6	0.2	0.3	0.4	0.5	0.4	0.4

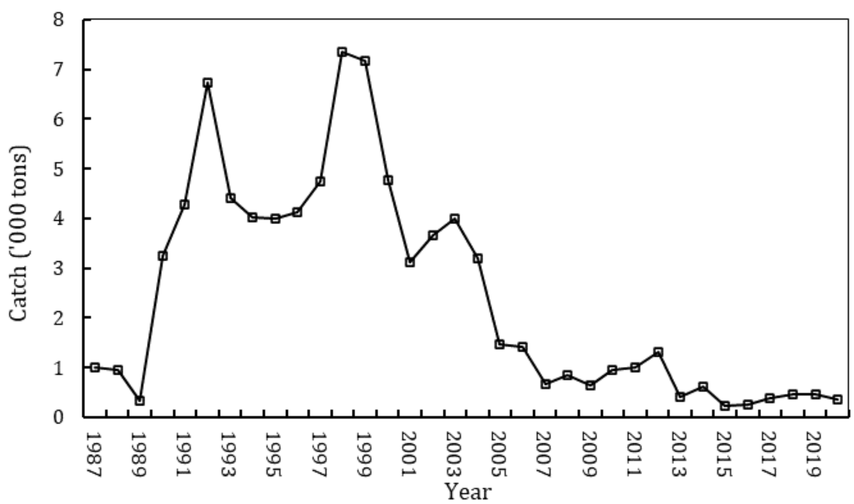


Figure 18.1. Roughhead grenadier in Subareas 2+3: STACFIS catches.

b) Data Overview

i) Surveys

There are no survey indices available covering the total distribution, in depth and area, of this stock. According to other information, this species is most abundant at depths ranging from 800 to 1500 m, therefore, the best indicator of stock status should be the survey series extending to 1500 meters. Figure 18.2 presents the biomass indices for the following series: Canadian fall 2J3K Engel (1978-1994) and Campelen (1995-2020), EU-Esp 3NO (1997-2019), EU-Esp 3L (2006-2019) and EU Flemish Cap (FC) (to 1400 m; 2004-2020). Coverage deficiencies within the Canadian 2J3K fall survey was such that the 2008, 2018 and 2019 biomass estimates could not be considered comparable to that of the other years. In 2020 the following surveys have not been carried out due to the COVID-19 global pandemic: EU 3NO and EU 3L. Survey biomass indices showed a general increasing trend in the period 1995-2004. Since then the EU 3NO and 3L surveys have been variable but with a generally decreasing trend. The EU FC survey also went through a period of decline but since 2013 has been relatively stable. In contrast, the Canadian 2J3K fall survey has experienced increasing trend throughout the time series.

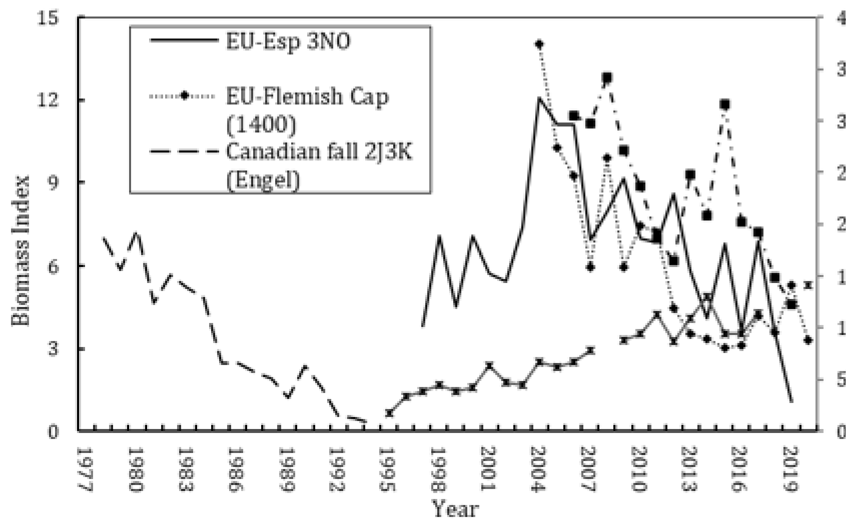


Figure 18.2. Roughhead grenadier in Subareas 2+3: Survey biomass indices.

The catch-biomass (C/B) ratios showed a clear declining trend from 1995-2005 and since then have been stable at low levels, with the exception of the 2019 ratio for the EU-Esp 3NO survey (Figure 18.3). The C/B ratio remained low since 2008 despite the decline in many of the survey biomass indices because catch levels since 2007 have been very low.

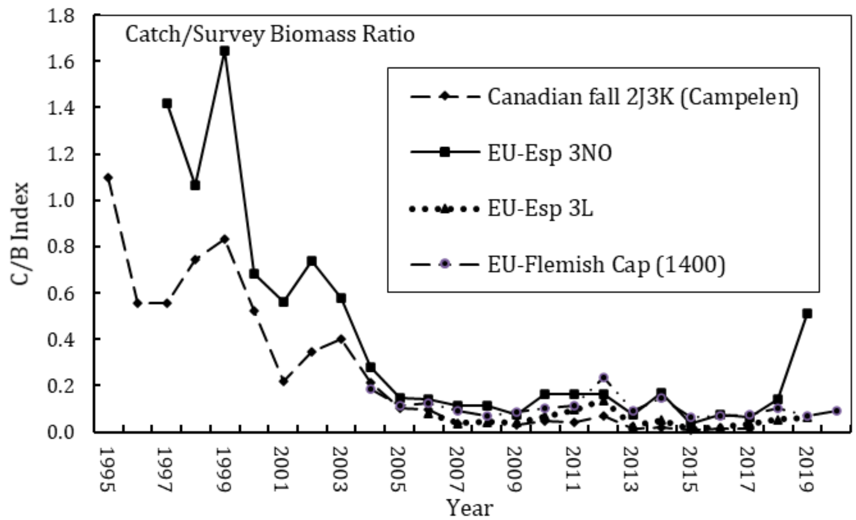


Figure 18.3. Roughhead grenadier in Subareas 2+3: catch/biomass indices based upon Canadian fall 2J3K (Campelen), EU-Esp 3NO, EU-Esp 3L and EU-Flemish Cap (to1400 m depth) surveys.

c) Conclusion

Although the indices are variable, there has been a generally decreasing trend since 2005, with the exception of the EU Flemish Cap survey which has been relatively stable since 2013 and the Canadian fall 2J3K survey which has been slowly increasing throughout the time series. Fishing mortality indices (C/B) have remained at low levels since 2005 with the exception of the of the EU-Esp 3NO survey in 2019.

Based on this review of the indices, there is no change in the status of the stock.

Interim reports will be used to monitor this stock until conditions in stock status change to warrant a full assessment.

19. Greenland Halibut (*Reinhardtius hippoglossoides*) in SA 2 + Divs. 3KLMNO

Interim monitoring report (SCR Doc. 17/26, 19/31, 20/47, 21/04, 21/05, 21/13, 21/26; FC Doc. 03/13, 10/12, 13/23, 16/20; Com Doc 17/17)

a) Introduction

Fishery and Catches: TACs prior to 1995 were set autonomously by Canada; subsequent TACs have been established by NAFO Fisheries Commission (FC). Catches increased sharply in 1990 due to a developing fishery in the NAFO Regulatory Area in Divs. 3LMNO and continued at high levels during 1991-94. The catch was only 15 000 to 20 000 t per year in 1995 to 1998. The catch increased after 1998 and by 2001 was estimated to be 38 000 t, the highest since 1994. The estimated catch for 2002 was 34 000 t. The 2003 catch could not be precisely estimated, but was believed to be within the range of 32 000 t to 38 500 t. In 2003, a fifteen year rebuilding plan was implemented by Fisheries Commission for this stock (FC Doc. 03/13). Though much lower than values of the early 2000s, estimated catch over 2004-2010 exceeded the TAC by considerable margins. TAC over-runs have ranged from 22%-64%, despite considerable reductions in effort. The STACFIS estimate of catch for 2010 was 26 170 t (64% over-run). In 2010, Fisheries Commission implemented a survey-based Management Procedure, which incorporates a harvest control rule (HCR) (FC Doc. 10/12) to generate annual TACs over at least 2011-2014. In 2013 Fisheries Commission extended this management approach to set the TACs for 2015–2017 (FC Doc. 13/23), but did not apply the HCR in 2017, rather setting the TAC equal to the 2016 TAC (FC Doc. 16/20). TACs since 2018 have been based on the HCR adopted in 2017 (Com Doc 17/17). Catch exceeded the TAC in every year from 2004 to 2014 but was similar to the TAC in 2015 through to 2020. The TAC in 2020 was 16 926 t and 16 307 t were caught. The TAC for 2021 is 16 498 t.

Recent catches and TACs ('000 t) are as follows:

	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
TAC	16.3[1]	15.5[1]	15.4[1]	15.6[1]	14.8[1]	14.8[2]	16.5[3]	16.5[3]	16.9[3]	16.5[3]
STATLANT 21	15.4	15.5	15.7	15.0	13.0	14.7	16.2	16.1	--	--
STACFIS	23.0	20.0	21.4	15.3	14.9	14.8	16.6	16.5	16.3	--

[1] TAC generated from HCR

[2] TAC equal to 2016

[3] TAC generated from HCR adopted in 2017

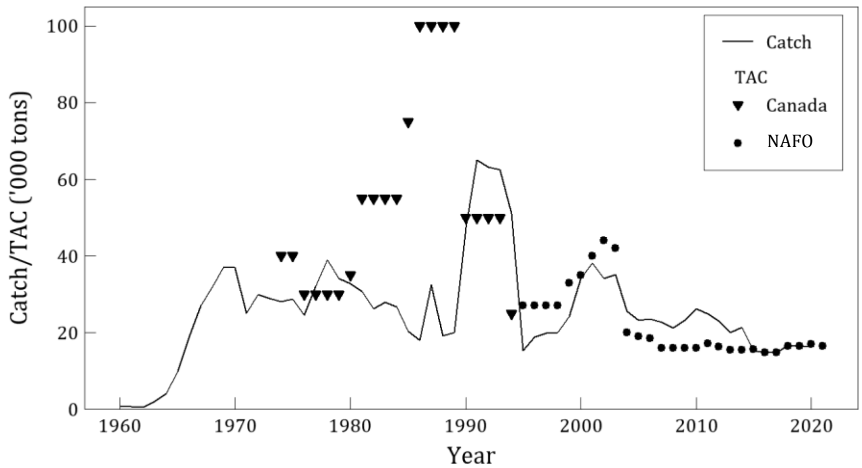


Figure 19.1. Greenland halibut in Subarea 2 + Divs. 3KLMNO: TACs and STACFIS catches.

b) Input Data

Abundance and biomass indices were available from research vessel surveys by Canada in Divs. 2+3KLNO (1978-2020), EU in Div. 3M (1988-2020) and EU-Spain in Divs. 3NO (1995-2019). Different years are examined to represent population trends from the different surveys. For the Canadian autumn survey in Divs. 2J3K the years are 1978-2020 (excluding 2008); from the Canadian spring survey in Divs. 3LNO 1996-2019 (excluding 2006, 2015, and 2017 due to survey coverage issues; the survey was not conducted in 2020 due to the COVID-19 pandemic); for the Canadian autumn survey in Divs. 3LNO to 730 m from 1996-2020 (excluding 2014 when the survey was incomplete); for the survey in Div. 3M to 700 m 1988-2020, and to 1400 m 2004-2020; and for the survey by EU-Spain in Divs. 3NO 1997-2019 (this survey was not conducted in 2020 due to the COVID-19 pandemic). Commercial catch-at-age data were available from 1975-2020.

i) Commercial fishery data

Catch-at-age: Length samples from the 2020 fishery were provided by Canada, EU-Spain, EU-Portugal, Russia, France and Japan. Ageing data from the Canadian and French (2J) fisheries were applied to the Canadian and French catches respectively while data from the Canadian autumn research survey was applied to length data for other countries. Catch-at-age estimates for countries other than Canada and France were scaled to provide estimates for countries without length sampling.

ii) Research survey data

STACFIS reiterated that most research vessel survey series providing information on the abundance of Greenland halibut are deficient in various ways and to varying degrees. Variation in divisional and depth coverage creates problems in comparing results from different years (SCR Doc. 19/31). A single survey series which covers the entire stock area is not available. A subset of standardized (depth and area) stratified random survey indices have been used to monitor trends in resource status and are described below.

Canadian stratified-random autumn surveys in Divs. 2J and 3K: Abundance and biomass indices from the Canadian autumn survey of Divs. 2J3K have shown a series of increases and decreases since 1996 (Figure 19.2). The abundance index decreased between 1996-2005, increased between 2005-2011 and, following a decrease in 2012, the index has remained relatively low and stable. The biomass index has fluctuated since 1996, with local maxima around 1999, 2007 and 2014, and local minima around 2002, 2010 and 2017; the index has been relatively low since 2017.

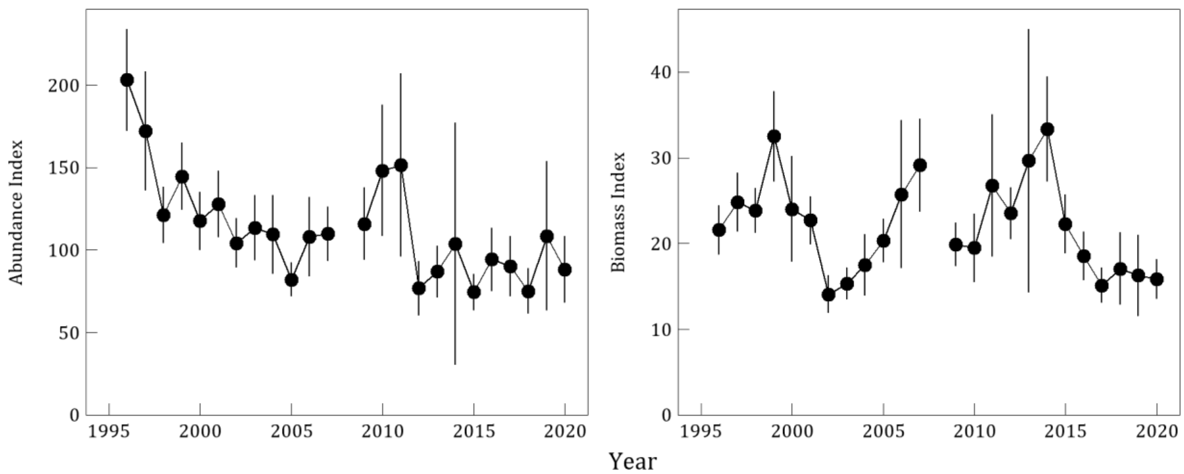


Figure 19.2. Greenland halibut in Subarea 2 + Divs. 3KLMNO: abundance (left) and biomass (right) indices (with 95% CI) from Canadian autumn surveys in Divs. 2J and 3K. The 2008 survey was not completed.

Canadian stratified-random spring surveys in Divs. 3LNO: Abundance and biomass indices from the Canadian spring surveys in Divs. 3LNO (Figure 19.3) declined from relatively high values in the late 1990s and has been relatively low in most years thereafter. In 2013, 2014, and 2016, both abundance and biomass were below the time series average. The 2015 and 2017 surveys were incomplete and are not considered representative of the population. Abundance and biomass indices from 2018 and 2019 have increased from 2016 levels. This survey was not conducted in 2020 due to the COVID-19 pandemic.

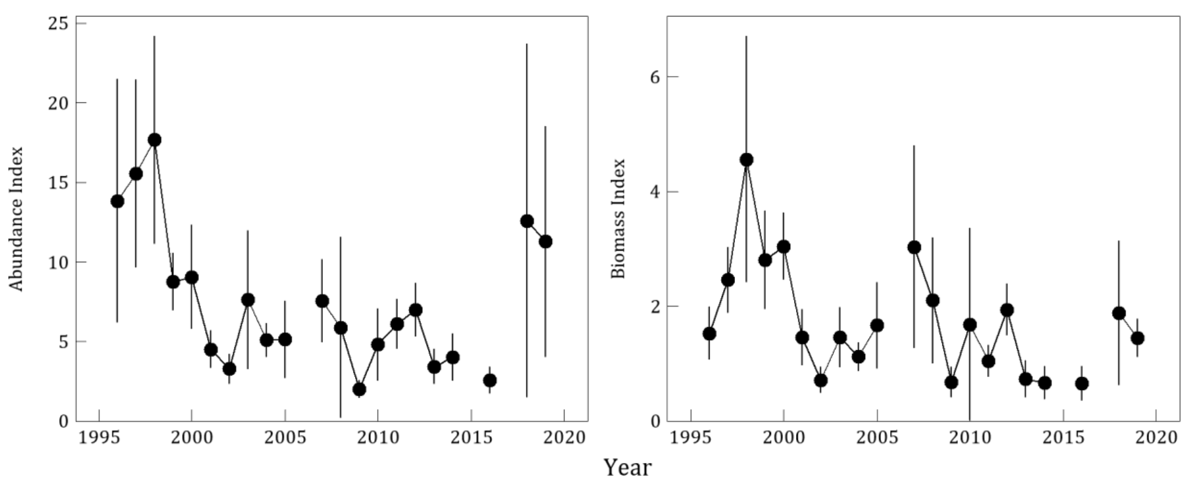


Figure 19.3. Greenland halibut in Subarea 2 + Divs. 3KLMNO: abundance (left) and biomass (right) indices (with 95% CI) from Canadian spring surveys in Divs. 3LNO.

Canadian stratified-random autumn surveys in Divs. 3LNO: Time series of abundance and biomass were developed from the Canadian autumn surveys from 1996-2020 to a depth of 730 m. The abundance index from the Canadian autumn surveys in Divs. 3LNO (Figure 19.4) declined from relatively high values in the late 1990s and has been relatively low in most years thereafter. The biomass index declined from 1998 to 2002 and then increased to 2005, to a level near that of the beginning of the time series. Abundance and biomass indices have been increasing since 2015; the abundance index has increased above levels observed between 1999-2010 and the biomass index has reached levels near those between 2005-2008. The 2014 survey was incomplete and is not considered compatible with the rest of the series.

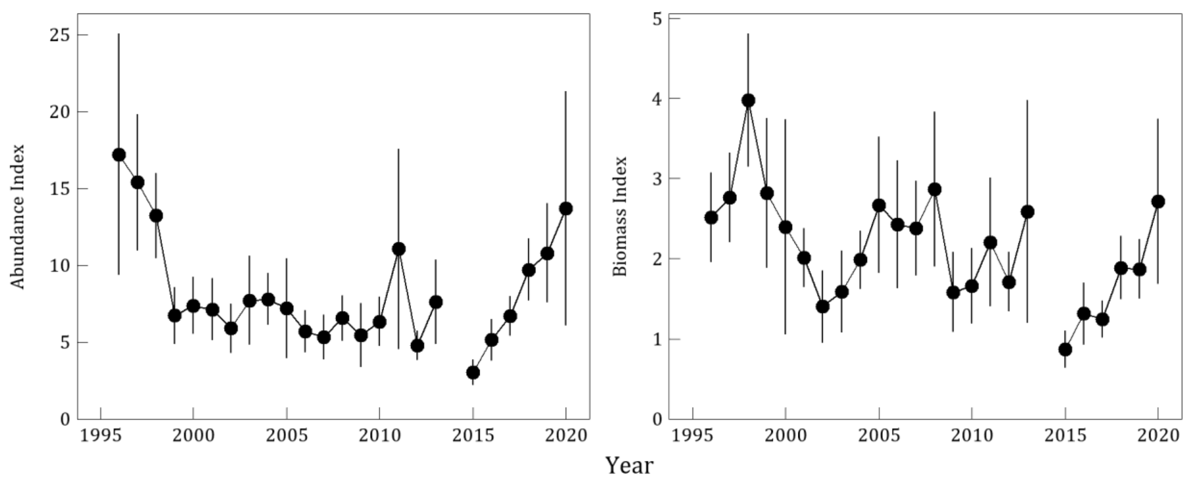


Figure 19.4. Greenland halibut in Subarea 2 + Divs. 3KLMNO: abundance (left) and biomass (right) indices (with 95% CI) from Canadian autumn surveys in Divs. 3LNO.

EU stratified-random surveys in Divs. 3M (Flemish Cap): Surveys conducted by the EU in Div. 3M during summer indicate that the Greenland halibut biomass index in depths to 730 m increased to a maximum value in 1998 (Figure 19.5). This biomass index declined continually over 1998-2002. The 2002-2008 results were relatively stable, with the exception of an anomalously low value in 2003. From 2009 to 2013 the index decreased to its lowest observed value. From 2014 to 2017 the index remained well below the series average. The Flemish Cap survey was extended to cover depths down to 1460 m beginning in 2004. Biomass estimates over the full depth range doubled over 2005-2008 but then declined to below the time series average in 2012 and 2013. From 2015-2017 the index has been variable but above the average of the time series, with 2015 and 2017 being the highest in the series. The index has since declined, dropping to a time series low in 2020.

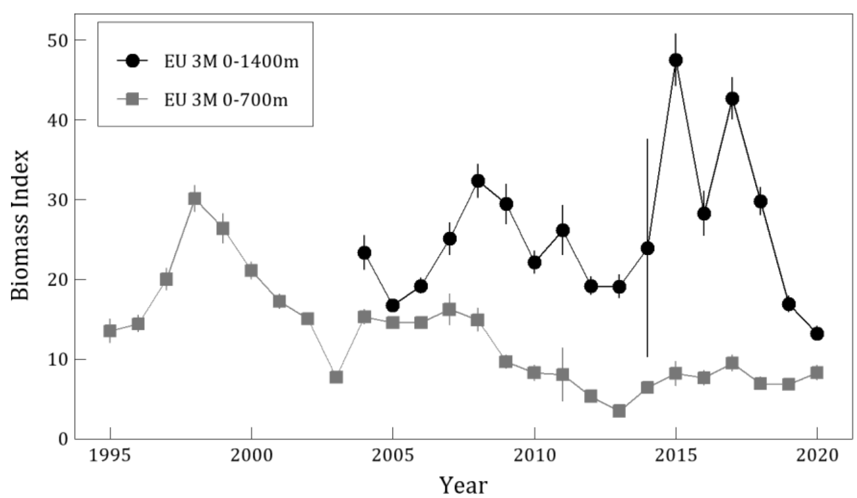


Figure 19.5. Greenland halibut in Subarea 2 + Divs. 3KLMNO: Biomass index (± 1 S.E.) from EU Flemish Cap surveys in Div. 3M. Grey squares: biomass index for depths <730 m. Black circles: biomass index for all depths <1460 m.

EU-Spain stratified-random surveys in NAFO Regulatory Area of Divs. 3LNO: The biomass index for the survey of the NRA in Divs. 3NO generally declined over 1999 to 2006 (Figure 19.6) but increased four-fold over 2006-2009. The survey index has increased since 2013 to a time series high in 2017; however, the index declined closer to the time series average in 2018 and 2019. The biomass index for the survey of the NRA in Div. 3L increased from 2006 to 2008. After declining to lower levels in 2011 and 2012 it increased to a time series high in 2017, declining substantially in 2018 and increased again in 2019. This survey was not conducted in 2020 due to the COVID-19 pandemic.

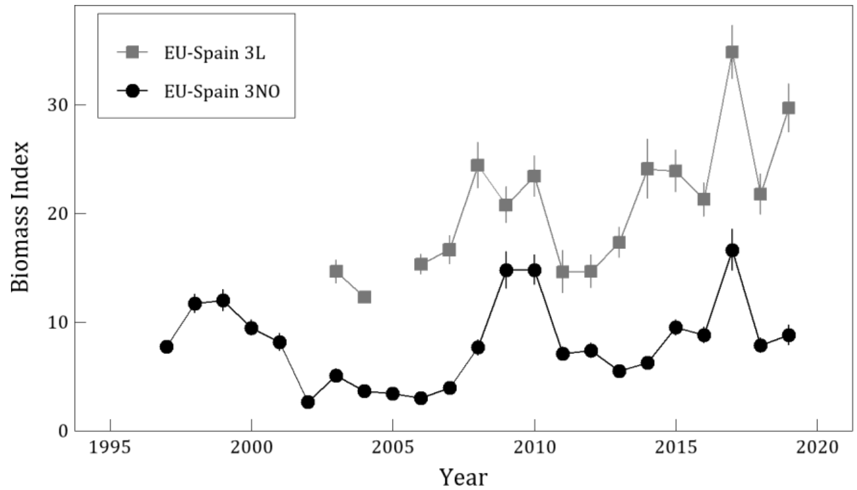


Figure 19.6. Greenland halibut in Subarea 2 + Divs. 3KLMNO: biomass index (±1 SE) from EU-Spain spring surveys in the NRA of Divs. 3NO and Div. 3L.

Summary of research survey data trends. These surveys provide coverage of the majority of the spatial distribution of the stock and the area from which the majority of catches are taken. Over 1995-2007, indices from the majority of the surveys generally provided a consistent signal in stock biomass (Figure 19.7). Results since 2007 show greater divergence which complicates interpretation of overall status; the overall trend since 2007 is unclear.

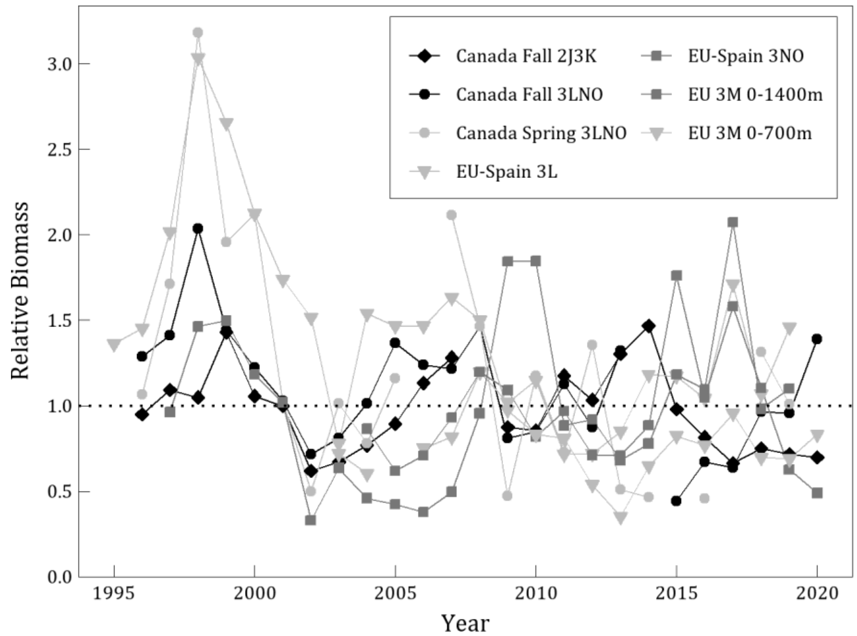


Figure 19.7. Greenland halibut in Subarea 2 + Divs. 3KLMNO: Relative biomass indices from Canadian autumn surveys in Divs. 2J3K, Canadian spring surveys in Divs. 3LNO, Canadian autumn surveys in Divs. 3LNO, EU survey of Div. 3M, and EU-Spain surveys of the NRA of Divs. 3NO. Each series is scaled to its average and the average line is shown as thin dotted line.

Recruitment from surveys. Abundance indices at age 4 from surveys were examined as a measure of recruitment. Year classes from all surveys were above average between 1993-1994 and below average between 2009-2013. After three very large year classes of 2000-2002 in the EU survey of Div. 3M, abundance at age 4 fell below average for 12 years. With the exception of observations from the Canada Fall 2J3K survey, estimates of the most recent year class (2015 and 2016) are above the time series average.

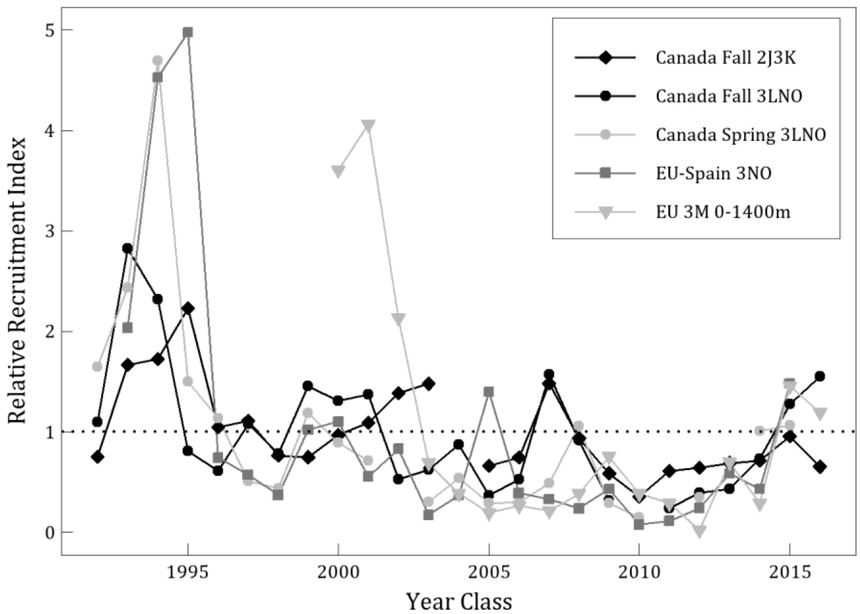


Figure 19.8. Greenland halibut in Subarea 2 + Divs. 3KLMNO: Relative recruitment indices from Canadian autumn surveys in Divs. 2J3K, Canadian spring surveys in Divs. 3LNO, and EU survey of Div. 3M. Each series is scaled to its average, which is shown using a dotted line.

c) Assessment Results

Biomass: Survey indices since 2007 are variable which complicates the interpretation of overall status. The five surveys that are used in the HCR show differing trends over this period. In 2020, only one out of four available survey indices was above its time series mean.

Recruitment: Results of all surveys indicate that recruitment (age 4) has recently returned to average levels following a series of below average years.

State of the stock: Though divergent trends in the survey indices complicate interpretations of the state of the stock, the survey indices are not deviating significantly from expectations under the accepted management procedure. Most survey indices are within the 95% probability envelopes from the base case SCAA (SCR Doc. 17/26; Figure 19.9) and revamped SSM simulations (SCR Doc. 20/47; Figure 19.10). The composite index suggests that the stock is stable, and the most recent value is within the 80% probability envelope from both models.

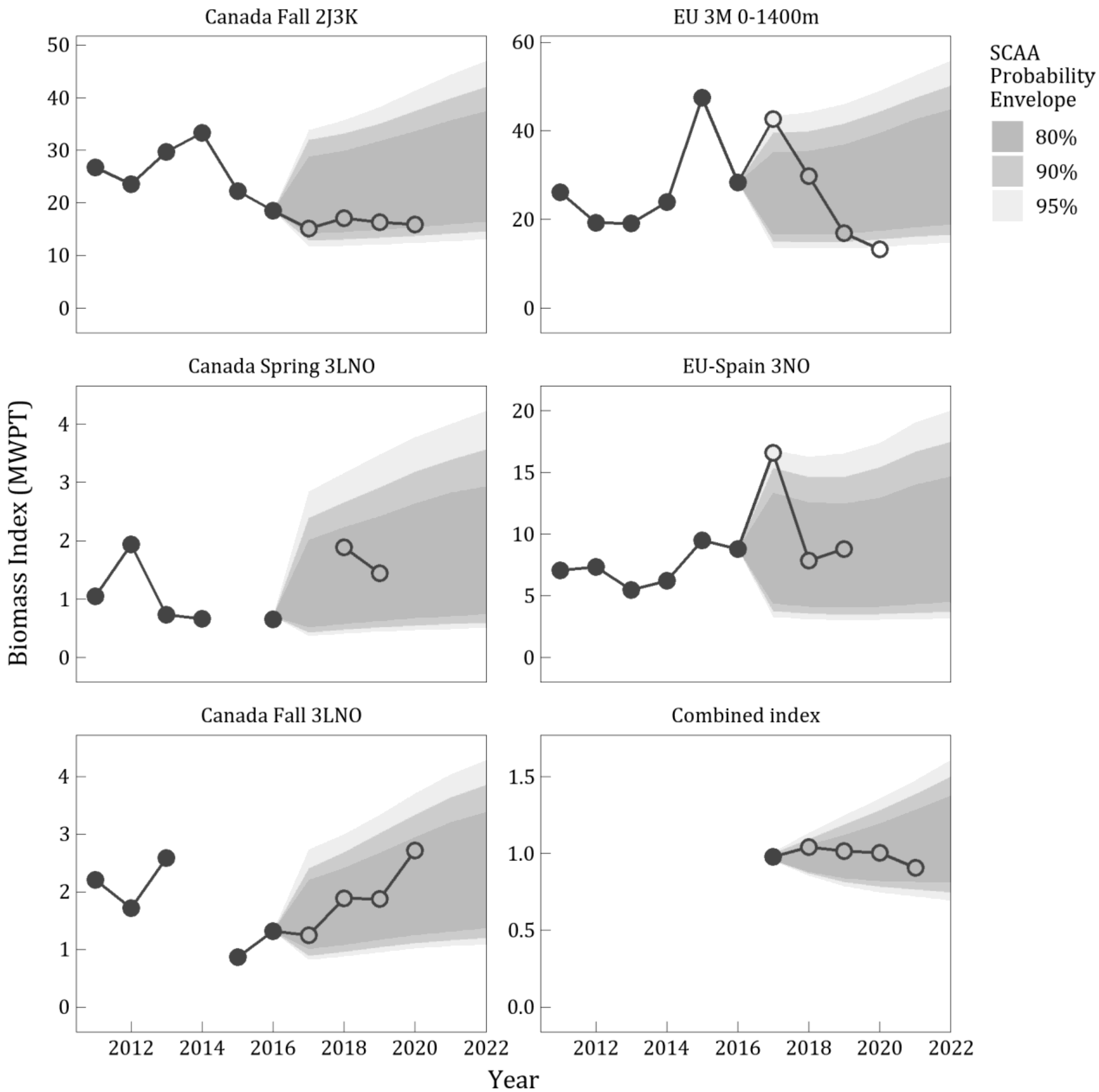


Figure 19.9. Greenland Halibut in Subarea 2 + Divs. 3KLMNO. Mean weight per tow from Canadian autumn surveys in Divs. 2J3K, Canadian spring surveys in Divs. 3LNO, Canadian autumn surveys in Divs. 3LNO, EU Flemish Cap surveys (to 1400m depth) in Div. 3M and EU-Spain surveys in 3NO. The figure also shows the combined index used in the target based component of the HCR. For the survey and combined indices, 80%, 90% and 95% probability envelopes from the SCAA base case simulation are shown. Index values observed from 2017 onward are shown using open circles.

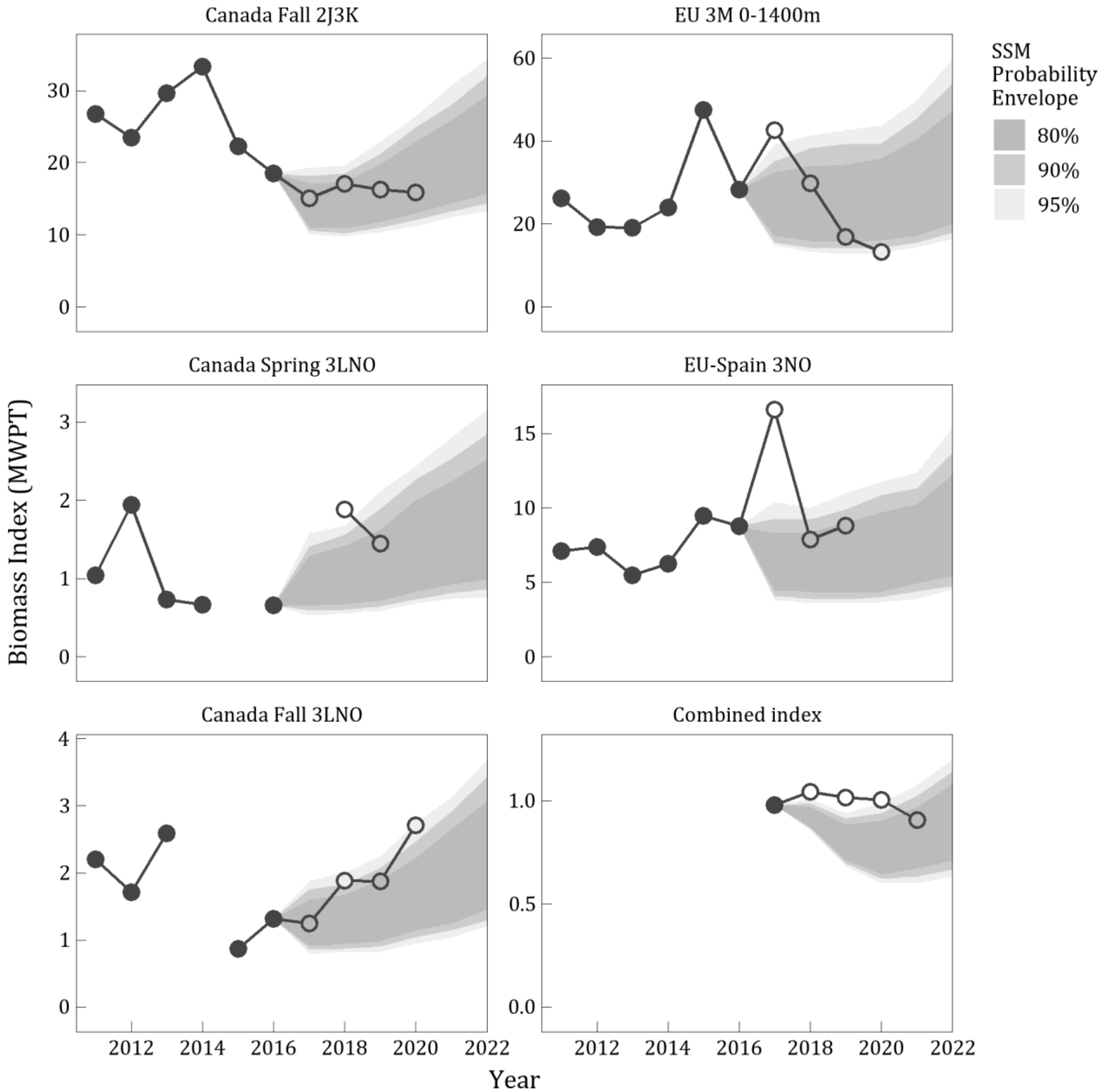


Figure 19.10. Greenland Halibut in Subarea 2 + Divs. 3KLMNO. Mean weight per tow from Canadian autumn surveys in Divs. 2J3K, Canadian spring surveys in Divs. 3LNO, Canadian autumn surveys in Divs. 3LNO, EU Flemish Cap surveys (to 1400m depth) in Div. 3M and EU-Spain surveys in 3NO. The figure also shows the combined index used in the target based component of the HCR. For the survey and combined indices, 80%, 90% and 95% probability envelopes from the SSM base case simulation are shown. Index values observed from 2017 onward are shown using open circles.

d) Reference points

Precautionary approach reference points have not been determined for this stock. STACFIS recommends that reference points are investigated during the next full assessment and MSE review process. The next full assessment and MSE review is planned for 2023.

e) Research recommendation

The divergence in survey indices could be the result of movement of fish or because of transient age effects as a result of changing recruitment when different surveys cover differing age-ranges. STACFIS recommends that tagging and/or telemetry studies be undertaken to help elucidate movement of 2+3KLMNO Greenland halibut.

20. Northern shortfin squid (Illex illecebrosus) in SA 3+4

Deferred to the NAFO Annual Meeting in September 2021.

21. Splendid alfonsino (Beryx splendens) in Subareas 6

Interim Monitoring Report (SCR 15/06, 20/36 and COM-SC CESAG-WP 21-04)

a) Introduction

Alfonsino is distributed over a wide area which may be composed of several populations. Alfonsino is an oceanic demersal species which forms distinct aggregations, at 300–950 m depth, on top of seamounts in the North Atlantic. Stock structure in NAFO Area is unknown. Until more complete data on stock structure is obtained it is considered that separate populations live on each seamount of Div 6G.

Most published growth studies suggest maximum life span between 10 and 20 years. The observed variability in the maximum age / length depends on the geographic region. Sexual maturation was found to begin at age 2 and at a mean length of 18 cm. By age 5–6 years, all individuals were mature at 25–30 cm fork length. On the Corner Rise Seamounts, alfonsino were observed to spawn from May-June to August-September.

As a consequence of the species' association with seamounts, their life-history, and their aggregation behaviour, this species is easily overexploited and can only sustain low rates of exploitation.

Description of the Fishery

Historically, catches of alfonsino in the NAFO Regulatory Area (NRA) have been reported from Div. 6E-H, although the bulk of those catches were made in the Corner Rise area Div. 6G. The development of the Corner Rise fishery was initiated in 1976. Commercial aggregations of alfonsino on the Corner Rise have been found on three seamounts. Two of them named "Kükenthal" (also known as "Perspektivnaya") and "C-3" ("Vybornaya") are located in NRA. One more bank named "Milne Edwards" ("Rezervnaya") is located in the Central Western Atlantic.

Russian vessels fished these areas during some periods between 1976 and 1999 using pelagic trawls. A directed commercial fishery had been conducted since 2005 by Spanish vessels. Since 2006 virtually all the effort has been made in the Kükenthal seamount with pelagic trawl gear.

Fishery was closed in 2020 based on scientific advice that the stock was depleted.

Recent catches (tons), effort and CPUE (Kg/hr fished) for the alfonsino fishery on Kükenthal Peak are as follows:.

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Catch (t)	152	302	114	118	122	127	51	2	1	0
Effort (days on ground)	9	22	17	15	13	16	12	8	8	0
Effort (hours fished)	68	165	87	117	92	116	68	33	33	0
CPUE (Kg/hour)	2235	1830	1310	1009	1326	1095	750	61	42	
Effort (vessels)	1	1	1	2	2	1	1	1	1	0

b) Data Overview

c) Commercial fishery data

The Russian fishery started in 1976 with a catch of 10 200 t (Figure. 22.1). Thereafter the catches ranged between 10 and 3 500 t. There was no fishing effort from 1988-1993, 1998 and 2000 – 2003. From 2005 to 2019, an alfonsino directed fishery in Kükenthal seamount was conducted by Spanish vessels using a pelagic trawl gear, where catches have ranged between 1 and 1 187 t, with no fishery in 2008. In 2020 based on scientific advice that the stock was depleted the fishery was closed and alfonsino catches were zero.

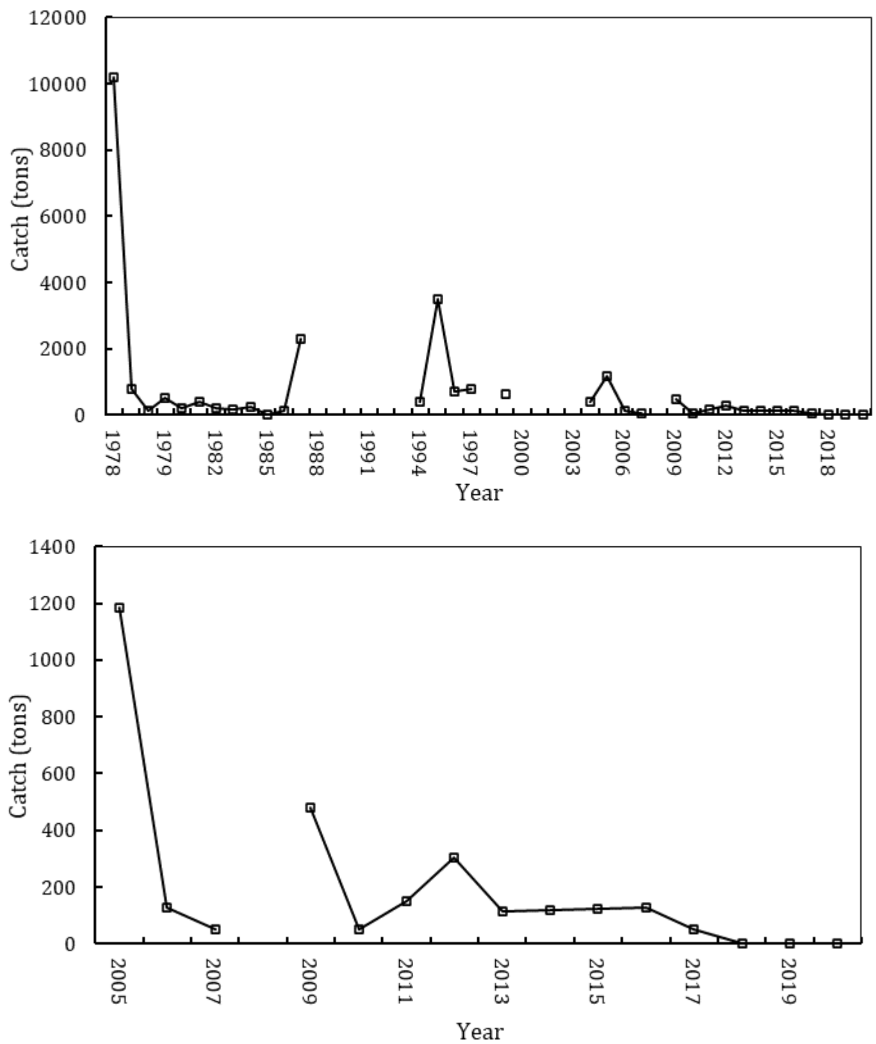


Figure 21.1. Alfonsino catches from Div. 6G. Top panel illustrates the whole catch series (1978-2020) and bottom panel illustrates the catch series since 2005.

The available commercial length distributions in percentage by year (2007, 2009, 2012 and 2016-2019) are presented in Figure 22.2. It can be observed in the period 2007-2018 that these length distributions have a slight decrease in the mode over time. Catches in this period are in the 30-50 cm range with a mode around or bigger than 40 cm. The 2019 length distribution shows a smaller range with a mode around 38 cm.

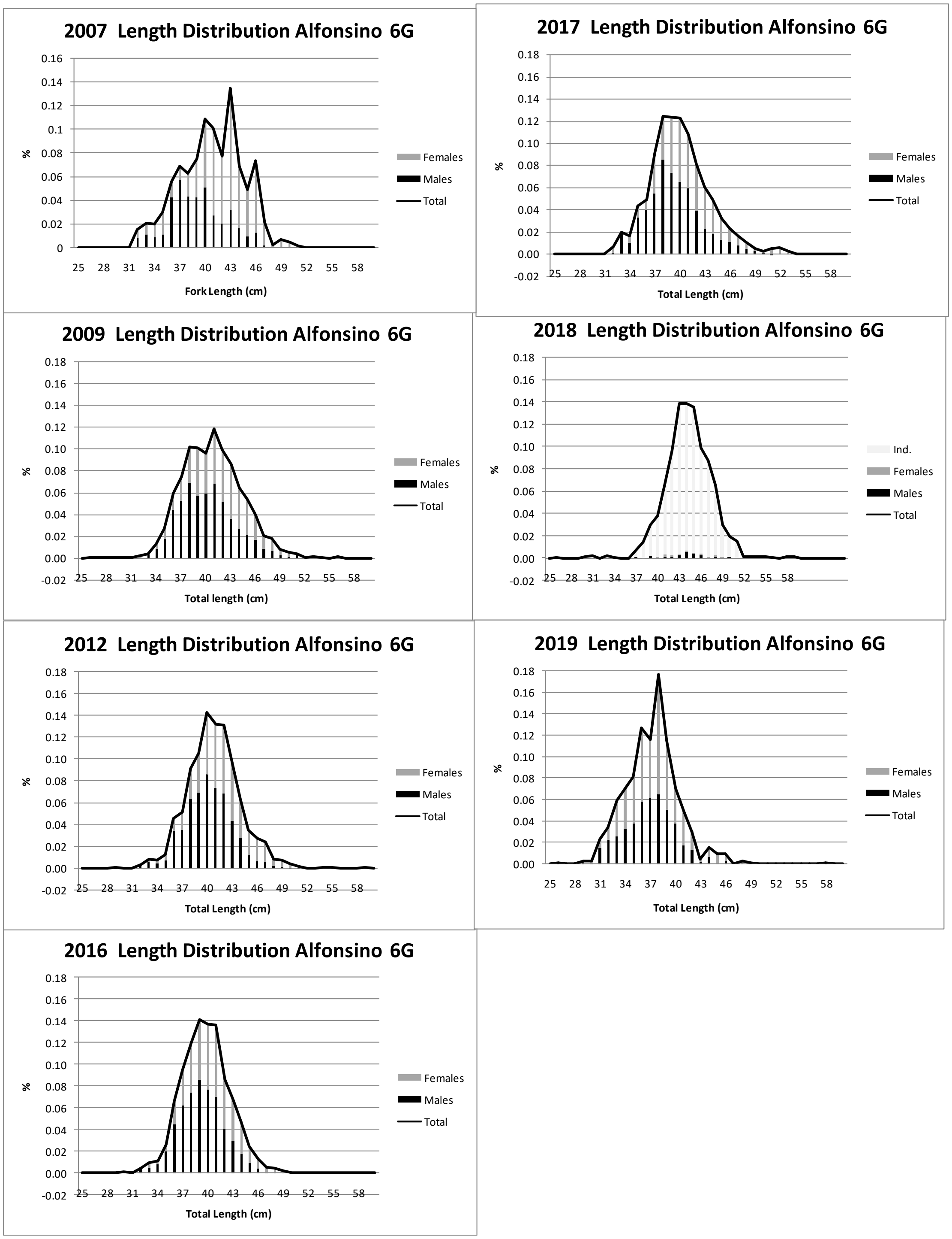


Figure 21.2. Length distributions of alfonsino catches from Div. 6G.

i) Surveys

The only information available is the retrospective data from Russian research, exploratory and fishing cruises presented by Vinnichenko (2015). This data covers the period ending in 1995. The alfonsino biomass estimated on Corner Rise with this data was around 11 000-12 000 t. It should be taken into consideration that the data with a time limitation of mainly 20-30 years were used for the calculations mentioned above. Based on this information; the greatest biomass of mature alfonsino (distribution depths of 400-950 m) was registered on the "Kükenthal" seamount. On the "C-3" and "Milne Edwards" seamounts, the biomass was much lower.

An acoustic survey plan to collect alfonsino data and estimate its biomass has been presented to the SC for discussion (SCR 20/36). The SC concluded that the presented acoustic survey plan could be appropriate to recollect fishery independent information that can help the future evaluation of this stock.

d) Conclusion

No analytical or survey based assessment were possible. The most recent assessment, in 2019, concluded that the stock appears to be depleted. There is no new information available to update the evaluation carried out in 2019 and ratified in the IMR of 2020. The only new information available is that the fishery was closed in 2020 and the catches were zero tons.

e) Special comments

Periods of decline in catches have been observed several times in the past after several years of fishing. In the past, catches have increased after a period of low/no removals; however, it is unknown if this corresponded to stock recovery. In the absence of new data (eg. from an exploratory fishery or survey) there will be no basis to update the present assessment.

Research Recommendations

SC **recommended** in 2019 that *fishery independent information should be collected on this stock, especially important given that the fishery is closed and there will not be CPUE or any other fishery independent information to monitor whether there is any recovery.* For this purpose, an acoustic survey plan has been presented and discussed by the SC. The SC concluded that the presented acoustic survey plan could be appropriate to recollect fishery independent information that can help the future evaluation of this stock.

IV. OTHER MATTERS

1. FIRMS Classification for NAFO Stocks

Due to lack of time, STACFIS did not review the assessments of stocks managed by NAFO in June 2021. This task has been deferred to the September SC meeting.

2. Other Business

No additional items were discussed.

V. ADJOURNMENT

The meeting was adjourned on 11 June 2021.

PART B: REPORT OF THE SCIENTIFIC COUNCIL (IN CONJUNCTION WITH NIPAG) MEETING

8 September 2021
by WebEx

Recommended Citation:
NAFO. 2021. Report of the Scientific Council (in conjunction with NIPAG) Meeting, 08 September 2021, via WebEx. NAFO SCS Doc. 21/18.

REPORT OF THE SCIENTIFIC COUNCIL (IN CONJUNCTION WITH NIPAG) MEETING
8 September 2021, via WebEx

Chair: Carmen Fernández Rapporteur: Tom Blasdale

I. PLENARY SESSIONS

Scientific Council, in conjunction with the NAFO/ICES *Pandalus* Assessment Group, met by WebEx on 8 September 2021, to formulate management advice for northern shrimp in NAFO Divisions 3M and 3LNO. Representatives attended from Canada, Denmark (in respect of the Faroe Islands and Greenland), the European Union, Norway and Ukraine. A full list of participants is included in Appendix V.

The Chair, Carmen Fernandez, opened the meeting 08:00 Halifax time (12:00 UTC) 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

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

III. NAFO/ICES PANDALUS ASSESSMENT GROUP

In September 2021, NIPAG fully assessed two stocks of relevance to NAFO: northern shrimp in NAFO Division 3M and Northern shrimp in NAFO Divisions 3LNO. Northern shrimp in Subareas 0 and 1, and northern shrimp in Denmark Strait and off East Greenland will be assessed in the November 2021 NIPAG meeting, as will northern shrimp in the Barents Sea, northern shrimp in the Skagerrak and Norwegian Deep, and northern shrimp in the Fladen ground. The September 2021 NIPAG report is presented as Appendix I in this report.

IV. MANAGEMENT ADVICE

1. Request for Advice on TACs and Other Management Measures

Requests from the NAFO Commission for advice on Northern Shrimp in Division 3M and Northern Shrimp in Divisions 3LNO were addressed during this meeting. Requests from coastal states will be addressed in November 2021 (see section V.1, Scheduling of Future Meetings).

a) Northern Shrimp in Division 3M

Advice September 2021 for 2022

Recommendation

The stock is now below B_{lim} i.e. it has now entered the collapse zone defined by the NAFO PA framework. The indications of improved recruitment observed in 2020 did not translate into an increase in stock biomass. There are indications of worsening recruitment in the 2021 survey data.

To be consistent with the precautionary approach, Scientific Council advises that no directed fishery should occur in 2022.

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}	Red	Stock below B_{lim}. B_{msy} is unknown.
Eliminate overfishing	White	F_{lim} not defined.
Apply Precautionary Approach	Yellow	B_{lim} defined. No fishing mortality reference point defined
Minimise harmful impacts on living marine resources and ecosystems	Green	VME closures in effect, sorting grids mandatory
Preserve marine biodiversity	White	Cannot be evaluated

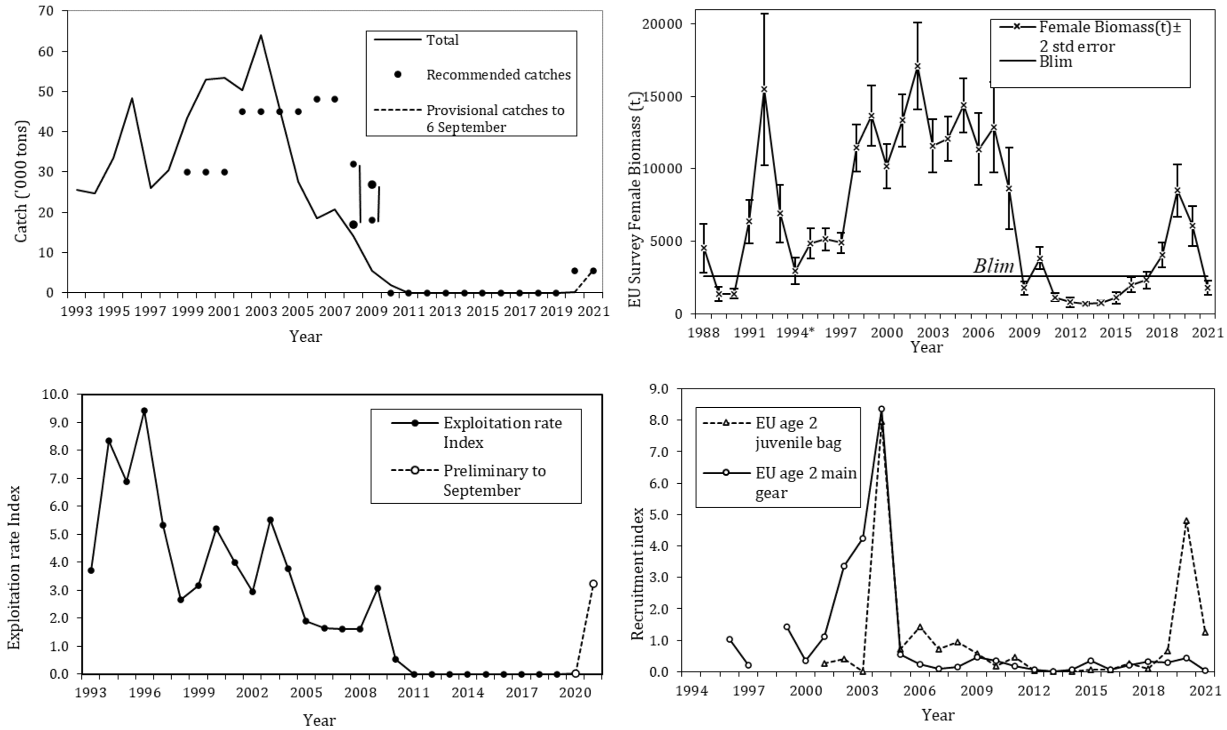
Green: OK
Yellow: Intermediate
Red: Not accomplished
White: Unknown

Management unit

The Northern Shrimp stock on Flemish Cap is considered to be a separate population.

Stock status

After an upward trend that started in 2014, the stock has decreased since 2019, and it is now below B_{lim}. The strong age 2 recruitment observed in 2020 did not translate into the expected high stock biomass in 2021 and recruitment decreased strongly in 2021. The exploitation rate index estimated from the preliminary catch data until the beginning of September 2021 increased markedly due to the resumed fishery and the decline of biomass index.



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).

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.

Further exploration of data and assessment possibilities will occur during the next year with participation in a joint benchmark process with ICES in early 2022.

The next assessment will take place prior the NAFO Annual Meeting in September 2022.

Human impact

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

Biological and Environmental Interactions

Multispecies models (Pérez-Rodríguez et al. 2016, Pérez-Rodríguez and D. González-Troncoso 2018), suggest that, predation by cod and redfish, together with fishing were the main factors driving the shrimp stock to the collapse after 2007. In the most recent years, decreasing redfish and cod stocks have likely resulted in reduced predation mortality on shrimp.

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.

Fishery

This fishery is effort-regulated. The effort allocations were reduced by 50% in 2010 and 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. Recent catches and agreed effort by the NAFO Commission were as follows:

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
NIPAG	2000	0	0	0	0	0	0	0	0	0	79	5811[1]
STATLANT 21	1976	0	0	0	0	0	0	0	0	0	0	
Effort (Agreed Days)	5227	0	0	0	0	0	0	0	0	0	2640	2640
Effort days used	37										21	423[1]
SC Recommended Catches (tonnes)	ndf	ndf	ndf	ndf	ndf	ndf	ndf	ndf	ndf	ndf	5448	5448

[1] preliminary catch and effort to September 6th 2021

Effects of the fishery on the ecosystem

The fishery was closed to directed fishing from 2011 to 2019.

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 recommends 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. 19/23

SC notes that only about 16% of the allocated effort has been used until September 2021, but catches have already exceeded the advised catch for 2021. If all fishing days were used, the catches advised by SC would be expected to be greatly exceeded.

Source of Information

SCR Doc. 21/038

b) Northern Shrimp in Divisions 3LNO

Advice September 2021 for 2022-2023

Recommendation

No directed fishery in 2022 and 2023 as the stock is below B_{lim} with no indication of short-term recovery.

Management objectives

No explicit management plan or management objectives have been 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 General Principles	*Status*	*Comment/consideration*
Restore to or maintain at Bmsy	🔴	*Stock below Blim*
Eliminate overfishing	🟢	*No directed fishery*
Apply Precautionary Approach	🟡	*Blim is defined. No fishing mortality reference point defined*
Minimise harmful impacts on living marine resources and ecosystems	🟢	*No directed fishery*
Preserve marine biodiversity	⚪	*Cannot be evaluated*

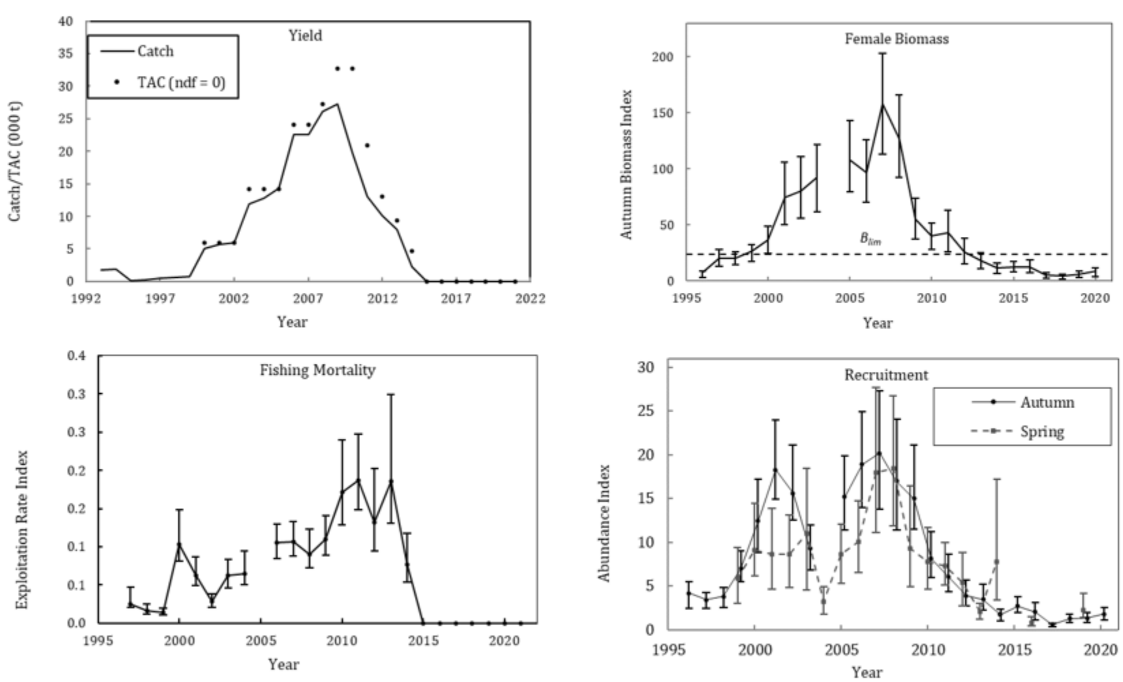
🟢 OK
🟡 Intermediate
🔴 Not accomplished
⚪ Unknown

Management Unit

The stock in Div. 3LNO is assessed and managed as a discrete population (see special comments).

Stock Status

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



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).

Projections:

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

Assessment

Based upon a qualitative evaluation of trends in stock biomass, fishing mortality proxy and recruitment. Input data are research survey indices and fishery catches.

Next full assessment is planned for 2023.

Human impact

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

Biological and Environmental Interactions

After reaching record-high conditions in 2010-2011 (warmest conditions since 1980), the bottom temperature in 3LNO had cooled down to near-normal conditions in 2014-2018 and a warming trend has been emerging since. Direct effects of temperature on shrimp distribution, recruitment, growth and survival are poorly understood.

Predation (by cod, Greenland halibut and redfish), low abundance of high energy prey (such as capelin) and environmental factors (including phytoplankton bloom dynamics) appear to be important drivers of the decline of Northern Shrimp in Divs. 2J3KL.

Fishery

The fishery, until 2014, was a directed bottom trawl fishery and there is little or no bycatch of shrimp in other trawl fisheries. The fishery in Div. 3LNO is regulated by quota.

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Enacted TAC[1]	13 108	9393	4697	ndf	ndf	ndf	ndf	ndf	ndf	ndf
STATLANT 21	10 099	7919	2282	0	0	0	0	0	0	
NIPAG[2]	10 108	8647	2289	0	0	0	0	0	0	

[1] Includes autonomous TAC as set by Denmark in respect of Faroes and Greenland.

[2] NIPAG catch estimates have been updated using various data sources (see p. 13, SCR. 14/048).

Effects of the fishery on the ecosystem

The fishery was closed to directed fishing beginning in 2015.

Special Comments

Shrimp in Div. 3LNO are genetically distinct from those in Div. 3M and the Gulf of Maine, but not from those further north. Work is ongoing to investigate the contribution of stocks north of Div. 3L to the production of Div. 3LNO shrimp.

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

Sources of information

http://www.dfo-mpo.gc.ca/Library/352955.pdf

V. OTHER MATTERS

1. Scheduling of Future Meetings

a) Scientific Council meetings

i) Scientific Council, September 2021

The Annual Meeting will be held by WebEx from 20 to 24 September 2021.

ii) Scientific Council, June 2022

Scientific Council June 2022 meeting will be held in Halifax, Nova Scotia, Canada, from 3 to 16 June 2022.

iii) Scientific Council, (in conjunction with NIPAG), September 2022

The Scientific Council shrimp advice meeting will be held in Copenhagen, Denmark, from 12 to 17 September 2022.

iv) Scientific Council, September 2022

The Annual meeting will be held in Lisbon, Portugal, from 19 to 23 September 2022.

b) NAFO/ICES Joint Groups

i) ICES – NAFO Working Group on Deep-water Ecosystem, 2022

Dates and location to be determined.

ii) ICES/NAFO/NAMMCO WG-HARP

The date and location of the next ICES/NAFO/NAMMCO Working Group on Harp and Hooded Seals (WGHARP) meeting are unknown.

iii) NIPAG, November 2022

The Scientific Council shrimp advice meeting will be held in Copenhagen, Denmark, from 12 to 17 September 2022.

2. Topics for Future Special Sessions

No special session was proposed.

3. Other Business

No other business was discussed.

VI. ADOPTION OF SCIENTIFIC COUNCIL AND NIPAG REPORTS

VII. ADJOURNMENT

APPENDIX I. REPORT OF THE NAFO/ICES *PANDALUS* ASSESSMENT GROUP (NIPAG)

Co-chairs: Katherine Sosebee and Ole Ritzau Eigaard

I. OPENING

The NAFO/ICES *Pandalus* Assessment Group (NIPAG) met by WebEx on 8 September 2021, to review stock assessments northern shrimp in NAFO Divisions 3M and 3LNO. Representatives attended from Canada, Denmark (in respect of the Faroe Islands and Greenland), the European Union, Norway, and Ukraine. The NAFO Scientific Council Coordinator and Scientific Information Administrator were also in attendance. A full list of participants is included in Appendix V.

The Co-chairs Katherine Sosebee and Ole Ritzau Eigaard opened the meeting 08:00 Halifax time (12:00 UTC) 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 2019 and 2020

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

2. Review of Catches

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

III. STOCK ASSESSMENTS

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

(SCR Docs. 21/038, 21/047)

Environmental Overview

Recent Conditions in Ocean Climate and Lower Trophic Levels

- After being below normal between 2015 and 2017, the ocean climate index in 3M has been normal since 2018;
- Spring bloom initiation was near normal in 2020 for a second consecutive year;
- Spring bloom magnitude was below normal in 2020 after three consecutive years of above-normal production;
- The abundance of copepod and non-copepod zooplankton was near normal in 2020 after having remained mostly above normal from 2015 to 2018;
- Zooplankton biomass was near normal in 2020 and has remained mostly near or below normal since the 2016 record high.

Recent Conditions in Ocean Climate and Lower Trophic 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 sub-surface 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 Division 3M (Figure 1.1.A) has remained mostly above normal between the late 1990s and 2013. After the record-high of 2011, the index gradually decreased reaching in 2015 its lowest value since 1993. After been below normal between 2015-2017, the index was normal between 2018 and 2020. Spring bloom initiation has been oscillating between early and late timing between 2003 and 2020 but has remained mostly near or later than normal since 2011 (Figure. 1.1.B). Spring bloom magnitude (total production) was below normal in 2020 after three consecutive years of above-normal production (Figure. 1.1.C). In general, late bloom onsets are associated with limited production (Figure. 1.1.B-C). The abundance of copepod and non-copepod zooplankton show general increasing trends throughout the 1999-2020 time series (Figure. 1.1.D-E). However, copepod abundance decreased to below or near-normal levels over the past two years after having remained above normal from 2016 to 2018 (Figure. 1.1.D). Similarly, the abundance of non-copepod zooplankton decreased to near-normal in 2019-2020 after four consecutive years of above-normal levels (Figure 1.1.E). Total zooplankton biomass on the Flemish Cap has remained mostly below to near normal since 2015 with the exception of the record-high biomass observed in 2016 (Figure 1.1.F).

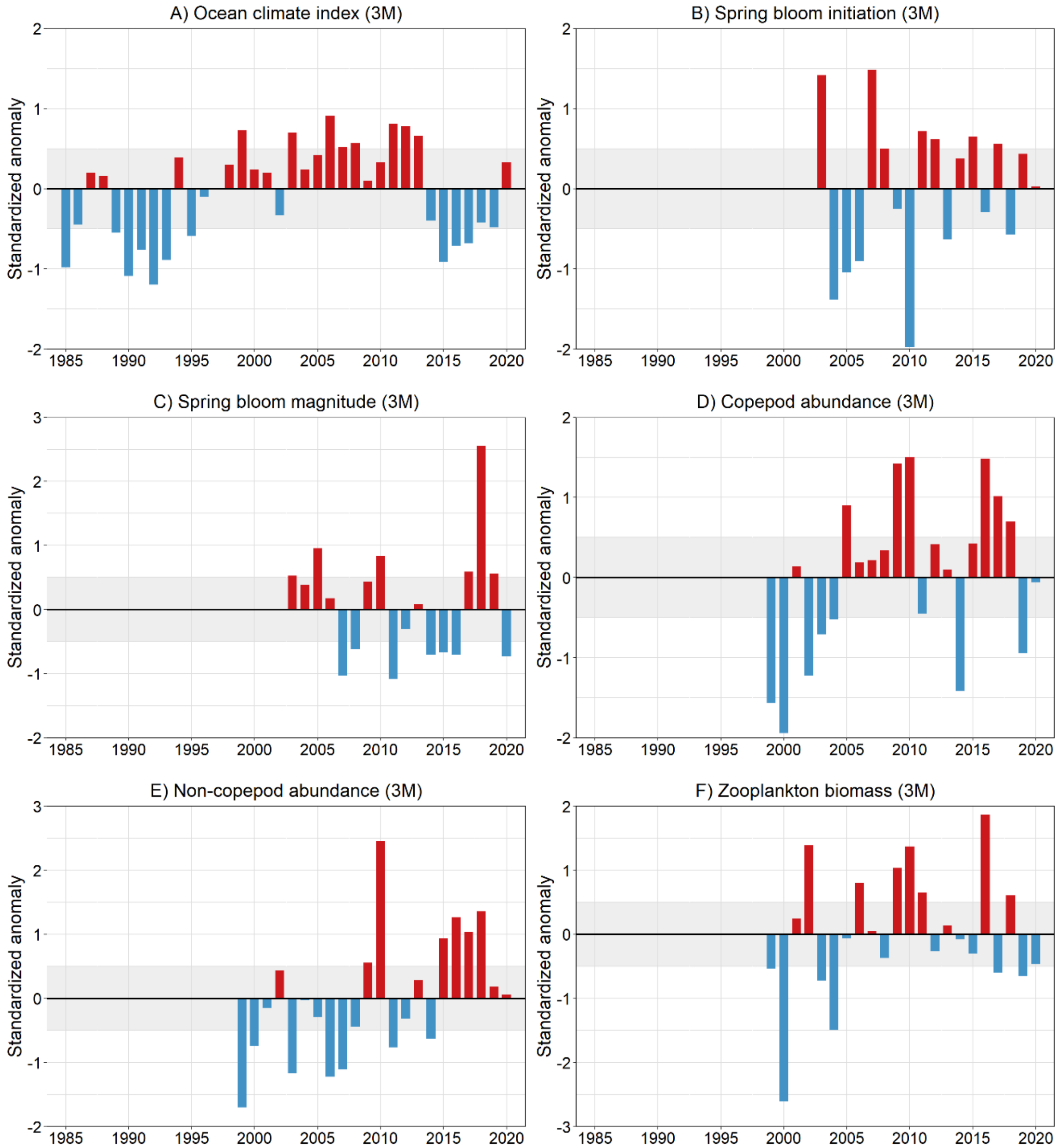


Figure 1.1. Environmental indices for the Flemish Cap (NAFO Div. 3M). The ocean climate index (A) for the Flemish Cap is the average of 3-time series of standardized ocean temperature anomalies of sea surface temperatures (SSTs), hydrographic section observations, and summer mean bottom temperature over the cap. Positive/negative anomalies indicate values above/below (or late/early timing) the long-term average for the reference period. Anomalies were calculated using the following reference periods: 1981-2010 for ocean climate index, 2003-2020 for spring bloom initiation and magnitude, and 1999-2020 for zooplankton abundance and biomass indices. Anomalies within ±0.5 SD (grey rectangle) 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. Since 2020 the fishery was resumed.

Fishery and catches: This stock is under effort regulations. The fishery was reopened in 2020 after nine years under moratorium with 2640 fishing days. The effort directed to the shrimp fishery and catches in 2020 were very low (19 days and 79 t) but increased in the first half of 2021.

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

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
NIPAG	2000	0	0	0	0	0	0	0	0	0	79	3691[1]
STATLANT 21	1976	0	0	0	0	0	0	0	0	0	0	
SC Recommended Catches	ndf	ndf	ndf	ndf	ndf	ndf	ndf	ndf	ndf	Ndf	5448	5448
Effort[2] (Agreed Days)	5227	0	0	0	0	0	0	0	0	0	2640	2640

1 Preliminary in the first half of 2021
2 Effort regulated

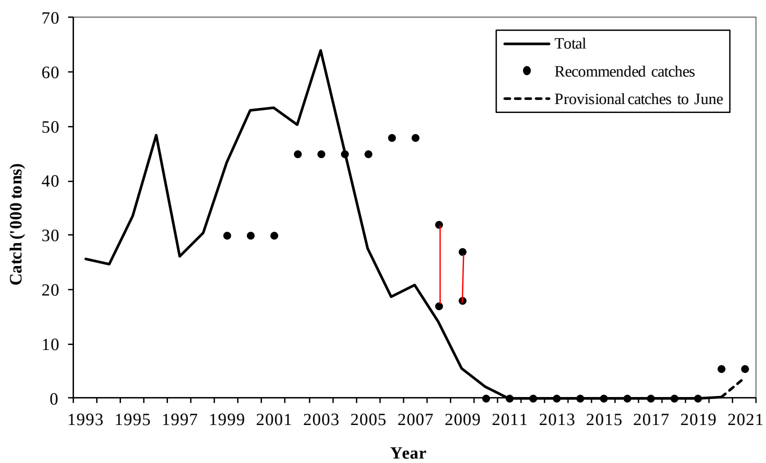


Figure. 1.2. Shrimp in Div. 3M: Catches (t) of shrimp on Flemish Cap and catches recommended in the period 1993-2021.

b) Input Data

i) Commercial fishery data

Time series of size and sex composition data were available mainly from Iceland and Faroes between 1993 and 2005. Because of the moratorium catch and effort data have not been available from 2011 to 2019, and therefore the standardized CPUE series has not been extended.

In 2020 and 2021, although the shrimp fishery was resumed, the length and sex composition from commercial catches were not available.

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 2021. A new vessel was introduced in 2003 which continued to use the same trawl employed since 1988. In addition, there were differences in cod-end mesh sizes utilized in the 1994 and 1998 surveys that have likely resulted in biased estimates of total survey biomass. Nevertheless, for this assessment, the series prior to 2003 were converted into comparable units with the new vessel using the methods accepted by STACFIS in 2004 (NAFO 2004 SC Rep., SCR Doc. 04/077).

c) Assessment

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

SSB: The survey female biomass index was stable at a high level from 1998 to 2007, and subsequently declined until 2014. Since 2015 the 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 $B_{lim.}$ In 2021 the biomass decreased for the second consecutive year and it is now bellow B_{lim}.

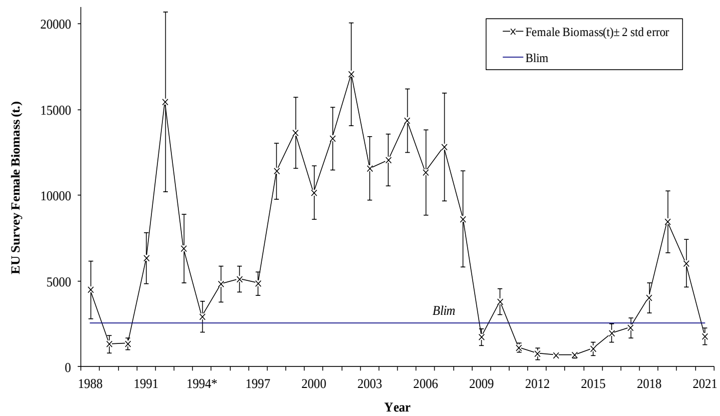


Figure. 1.3. Shrimp in Div. 3M: Female biomass index from EU trawl surveys, 1988-2021. Error bars are 2 std. err.

Recruitment: Age estimation was carried out using Rmix library from the preliminary shrimp length distribution and growth rates in the first three years allow the identification of cohorts. Considering the abundance at age 2 as indicator of recruitment, all year-classes from the 2002 cohort to 2017 have been weak from the main gear and from small mesh juvenile bag attached to the net (Figure 1.4). The recruitment index (age 2) in 2021was the second lowest of the historical series and the 2018 year class (age 3) was not stronger than expected suggesting the worsening of future recruitments in the next years.

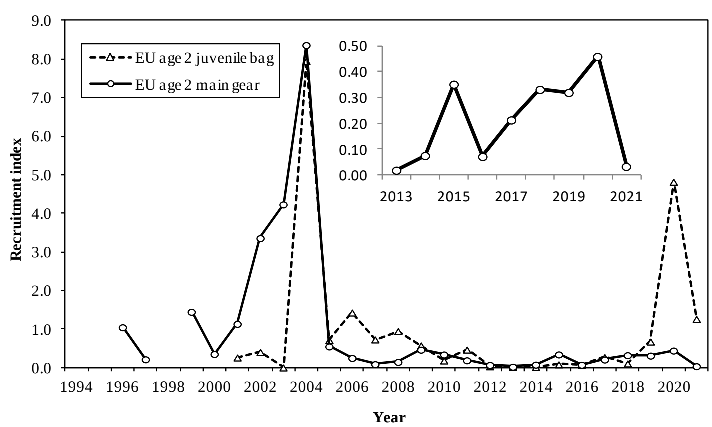


Figure. 1.4. Shrimp in Div. 3M: Abundance indices at age 2 from the EU survey. Each series was standardized to its mean.

Exploitation rate: Because of low catches, followed by the moratorium, the exploitation rate index declined to zero and has remained at that level since 2011 to 2020. In 2020, the fishery was resumed but the effort directed to shrimp fisheries and catches were residual resulting in a very low exploitation rate (0.01). In 2021 the exploitation rate increased notably (2.1) due to the increase in the catches (provisional catches until June of 3 691 t) and the decrease in the UE survey index.

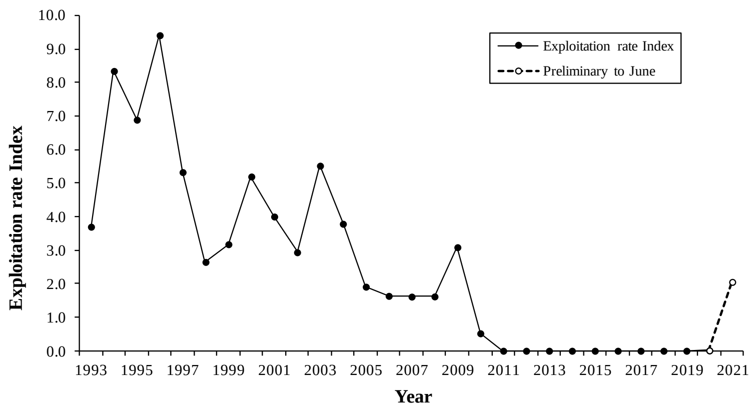


Figure 1.5. Shrimp in Div. 3M exploitation rate index as derived by catch divided by the EU survey biomass index of the same year.

d) State of the stock

After an upward trend started in 2014, the stock has decreased from 2020, and it is now bellow B_{lim}. Recruitment has declined sharply after a general upward trend in the last years and there are not indications of improved recruitment in 2022. Also the exploitation rate increased markedly due to the low level of biomass estimated in 2021 and the relative high catches carried out from the first half of the year . As a consecuence of the decrease in biomass levels and the weak recruitments in the short term, there are serious concerns that the stock will remains at low levels.

e) Reference Points

A limit reference point for fishing mortality has not been defined. 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).

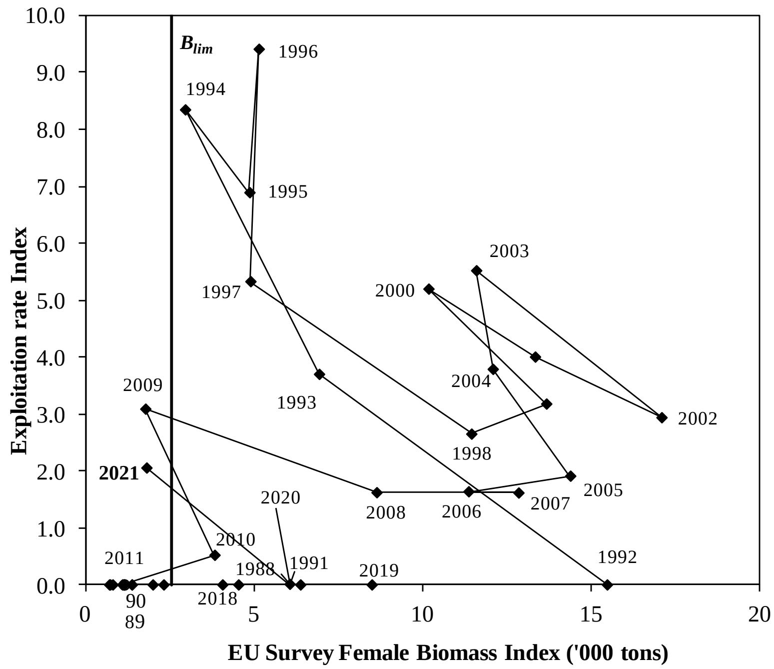


Figure 1.6. Exploitation rate index plotted against female biomass index from EU survey. Line denoting B_{lim} is drawn where biomass is 15% of the maximum point in 2002.

f) Ecosystem considerations

The drastic decline of shrimp biomass around 2008-2010 correlates with an increase of both cod and redfish in Div. 3M. It is uncertain whether this represents a causal relationship and/or covariance as a result of some environmental factor.

Multispecies models (Pérez-Rodríguez et al. 2016, Pérez-Rodriguez and D. González-Troncoso 2018), suggest that predation by cod and redfish, together with fishing, have been the main factors driving the shrimp stock to the collapse after 2007. In the most recent years, decreasing redfish and cod stocks have likely resulted in reduced predation mortality on shrimp, consistent with a period of increase in the shrimp stock.

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.

Preliminary data from EU summer survey show that in 2021 redfish and cod stocks decreased and therefore the decrease of shrimp biomass this year was not related with the recovery of redfish and cod stocks and it is probably due to the resumed exploitation of the shrimp fishery since 2020.

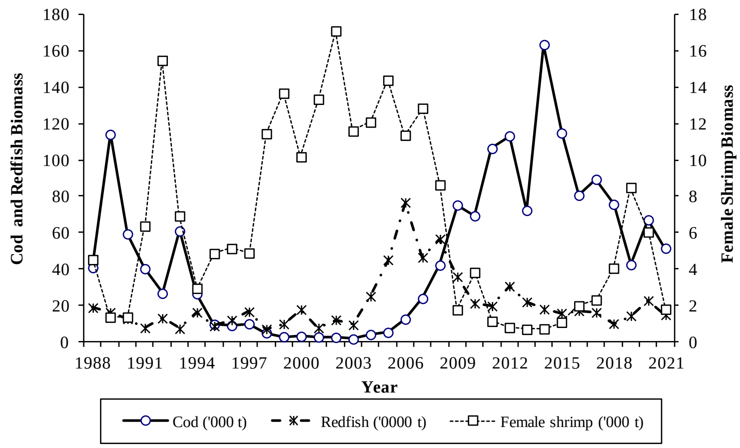


Figure 1.7. Shrimp in Div. 3M: Cod, Redfish and Female shrimp biomass from EU trawl surveys, 1988-2021. 2021 cod and redfish data are preliminary.

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: progress will be updated at NIPAG 2021

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: progress will be updated at NIPAG 2021

The next assessment will take place prior the NAFO Annual Meeting in September 2022.

References

Pérez-Rodirguez, A. and D. González-Troncoso. 2018. Update of the Flemish Cap multispecies model GadCap as part of the EU SC05 project: "Multispecies Fisheries Assessment for NAFO", NAFO SCR Doc.18/024, serial No.N6808

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

(SCR Doc. 04/012)

Environmental Overview

Recent Conditions in Ocean Climate and Lower Trophic Levels

- The ocean climate index in Subarea 0-1 was normal in 2020;
- The initiation of the spring bloom was delayed for a second consecutive year in 2020;
- Total spring bloom production (magnitude) was near normal in 2020.

Recent Conditions in Ocean Climate and Lower Trophic Levels

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 counterpoised by the warmer waters 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 2.1.A). After being in 2019 at its highest value since the record high of 2010, the index was normal in 2020. 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 but several notable late bloom onsets were recorded during the late 2010s (Figure 2.1.B). In 2020, the initiation of the spring bloom was later than normal for a second consecutive year. Spring bloom magnitude (total production) remained mostly below to near-normal between 2003 and 2020 except for a few highly productive blooms in 2006, 2015 and 2018 (Figure 2.1.C). The late bloom onsets of 2019 and 2020 are associated to below-normal or near-normal total production for the corresponding years (Figure 2.1.B-C).

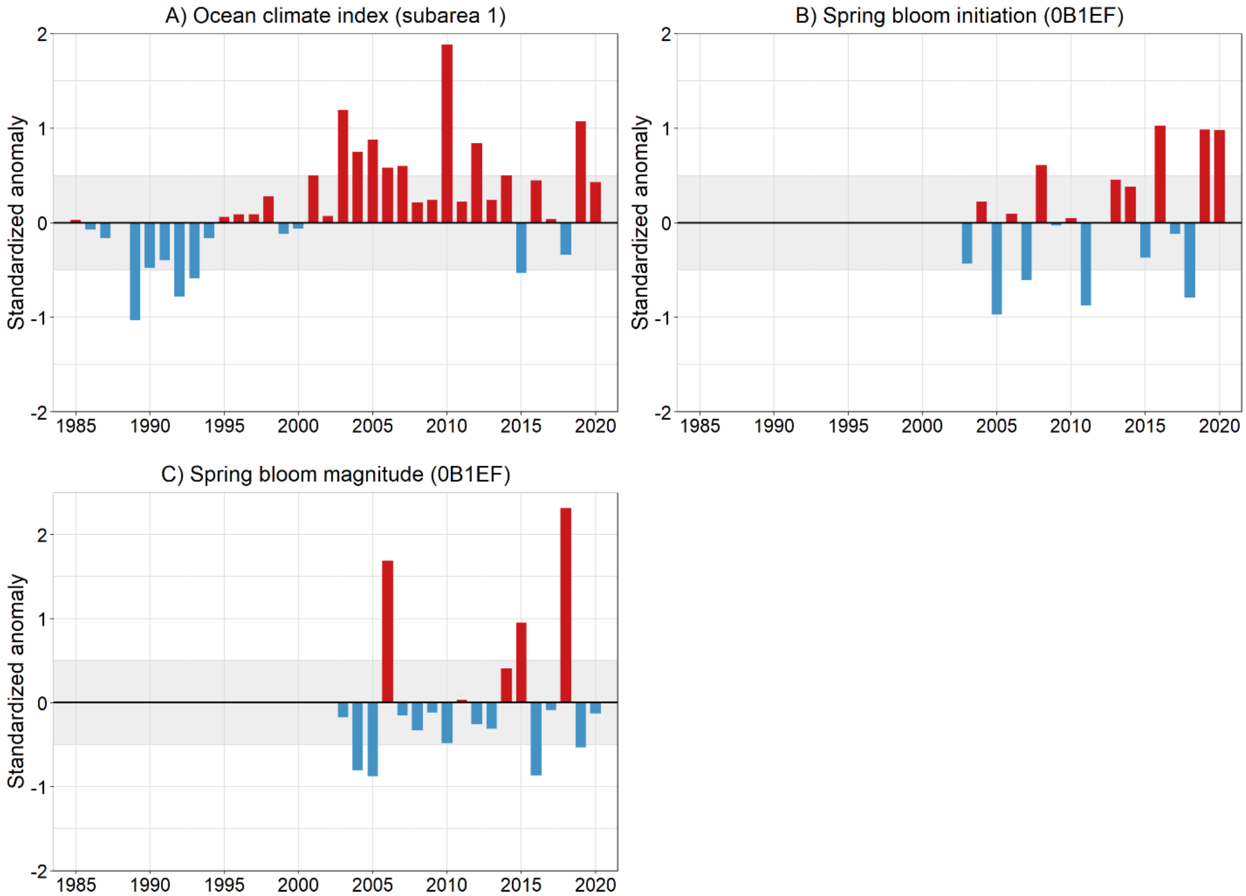


Figure 2.1. Environmental indices for NAFO Subarea 0 and 1. The climate index (A) for Subarea 0 and 1 is the average of 10 individual time series. These includes standardized anomalies of 4 SSTs time series, 4 temperature time series at 3 hydrographic stations and 2 air temperatures time series (see text for details). Phytoplankton spring bloom initiation (B) and magnitude (C) indices for the 2003-2020 period are derived from three satellite boxes covering NAFO Divs. 0B and 1EF (see text for details). Positive/negative anomalies indicate values above/below (or late/early timing) the long-term average for the reference period. Anomalies were calculated using the following reference periods: 1981-2010 for ocean climate index, 2003-2020 for spring bloom initiation and magnitude. Anomalies within ±0.5 SD (grey rectangle) are considered near-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 2021 (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 Div. 3LNO (total) are as follows:

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TAC[1]	13108	9393	4697	ndf	ndf	ndf	ndf	ndf	ndf	ndf
STATLANT 21	10099	7919	2282	0	0	0	0	0	0	
NIPAG[2]	10108	8647	2289	0	0	0	0	0	0	

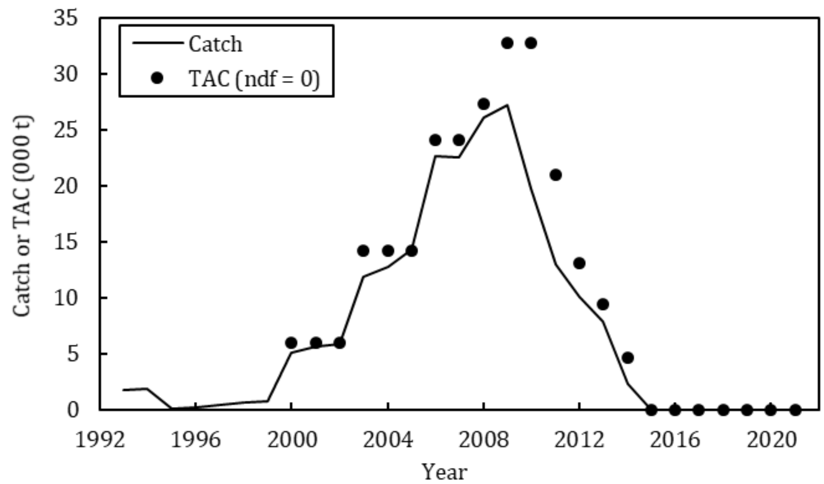


Figure 2.2. Shrimp in Div. 3LNO: Catches and TAC. The TAC illustrated includes the autonomous quotas set by Denmark (in respect of the Faroe Islands and Greenland). No directed fishing is plotted as zero TAC.

b) Input data

i) Commercial fishery data

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

ii) Research survey data

Canadian multi-species trawl survey. Canada has conducted stratified-random surveys in Div. 3LNO, using a Campelen 1800 shrimp trawl for spring (1999–2019) and autumn (1996–2020). The autumn survey in 2004, and the spring surveys in 2015, 2017-2018 and 2020-2021 were incomplete and therefore could not be used to produce biomass indices for Div. 3LNO. The autumn 2014 survey only surveyed Div. 3L, however since about 95% of the biomass in Div. 3LNO comes from Div. 3L annually, it was considered useful as a proxy for Div. 3LNO for 2014.

Spanish multi-species trawl survey. EU-Spain has been conducting a stratified-random survey in the NAFO Regulatory Area (NRA) part of Div. 3L since 2003 and in the NRA part of Div. 3NO since 1995. Data are collected with a Campelen 1800 trawl. There were no EU-Spain Div. 3L surveys in 2005 or 2021 and no Div. 3LNO survey in 2020.

c) Assessment results

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

Biomass indices. In Canadian surveys, about 95% of the biomass was found in Div. 3L, distributed mainly along the northeast slope in depths from 185 to 550 m. Total, fishable (shrimp with carapace length > 17mm) and female (SSB) biomass and abundance indices follow the same trend throughout the survey time series. There was an overall increase in both the autumn and spring indices to 2007 after which they decreased by over 95% to 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 have increased slightly since 2018, they are still amongst the lowest levels in the autumn time-series.

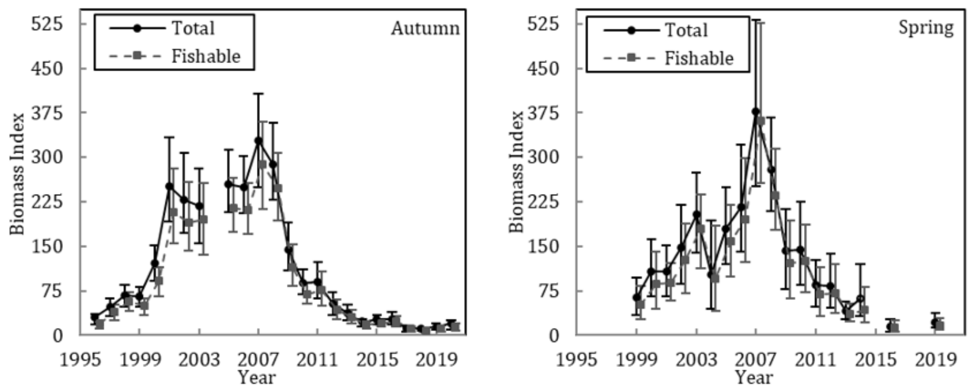


Figure 2.3. Shrimp in Div. 3LNO: Total and fishable biomass index estimates from Canadian autumn and spring multi-species surveys (with 95% confidence intervals). The 2014 autumn index is for Div. 3L only. There are no available biomass index estimates for spring 2015, 2017-2018 or 2020-2021.

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

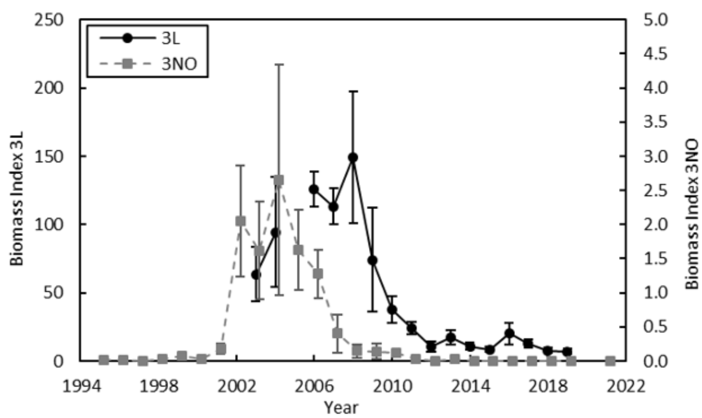


Figure 2.4. Shrimp in Div. 3LNO: Total biomass index estimates from EU - Spain multi-species surveys (± 1 SE) in the NAFO Regulatory Area (NRA) of Div. 3LNO. There are no available biomass index estimates for 2020 and only Div. 3NO was surveyed in 2005 and 2021.

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

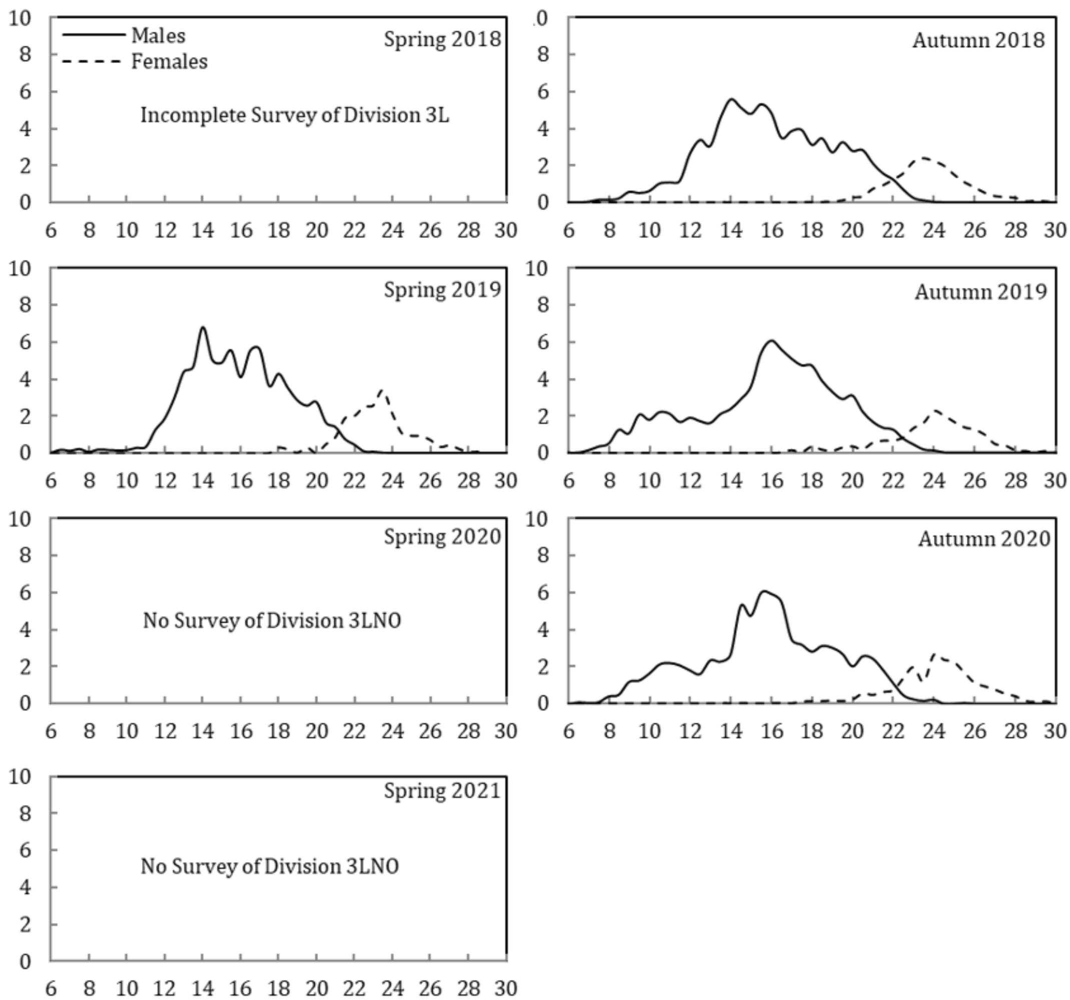


Figure 2.5. Shrimp in Div. 3LNO: Composition of survey catches (percentage at length) from Canadian spring and autumn multi-species survey data. No data for spring 2017-2018 or 2020-2021.

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

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

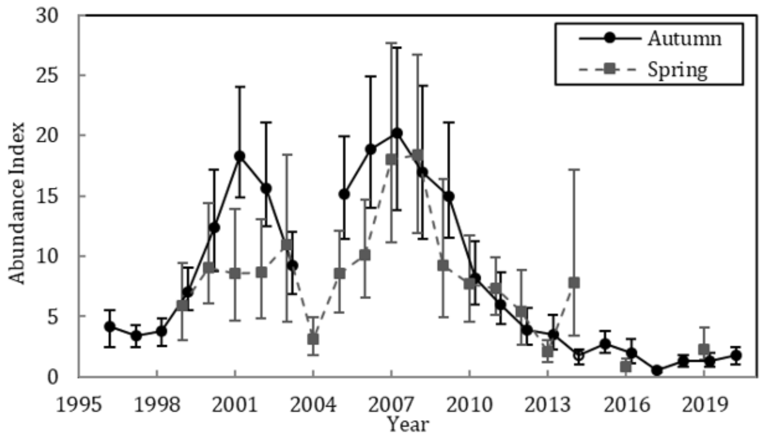


Figure 2.6. Shrimp in Div. 3LNO: Indices of recruitment-sized shrimp based on abundance of shrimp with 11.5 – 17 mm carapace lengths from Canadian spring and autumn multi-species surveys. Error bars represent 95% confidence intervals. The autumn index for 2014 is for Div. 3L only.

Exploitation index. An index of exploitation was derived by dividing the catch in a given year by the fishable biomass index from the previous autumn survey. The exploitation index generally increased throughout the course of the fishery until dropping sharply in 2014 (Figure 2.7). Since there was no directed fishing in 2015-2021, the exploitation index is zero for that period of time. Mortality due to bycatch during other fisheries is unknown.

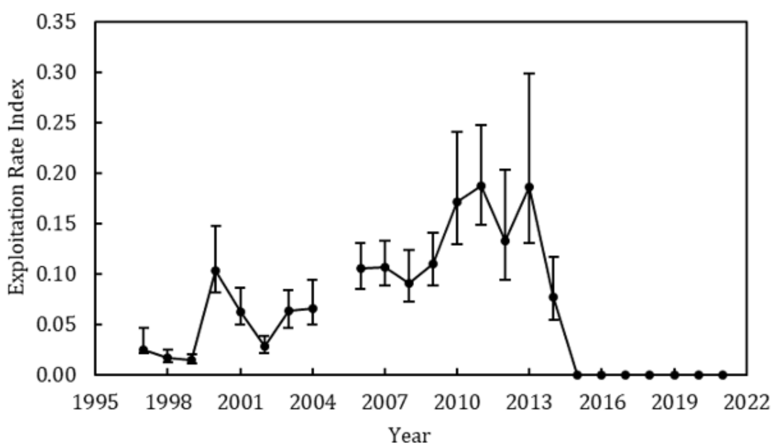


Figure 2.7. Shrimp in Div. 3LNO: Exploitation indices calculated as a year's catch divided by the previous year's autumn fishable biomass index. Error bars (calculated based on estimates of fishable biomass index) indicate 95% confidence intervals.

d) Reference points.

The point at which a valid index of female spawning stock size has declined to 15% of its highest observed value is considered to be B_{lim} (SCS Doc. 04/12). In 2021 the risk of being below B_{lim} was greater than 95% (Figure 2.8). A limit reference point for fishing mortality has not been defined.

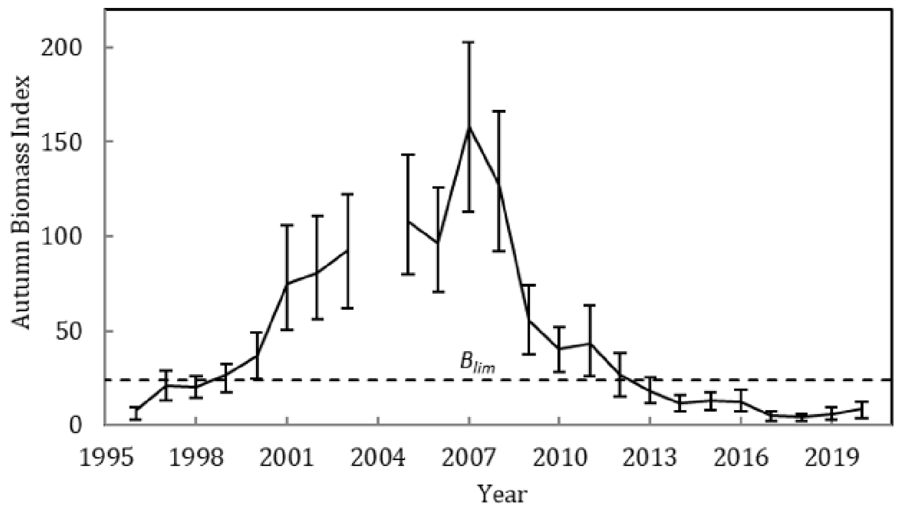


Figure 2.8. Shrimp in Div. 3LNO: Autumn female spawning stock biomass index (SSB) and B_{lim}. B_{lim} is defined as 15% of the maximum autumn female biomass over the time-series. Error bars indicate 95% confidence intervals. The autumn index for 2014 is for Div. 3L only.

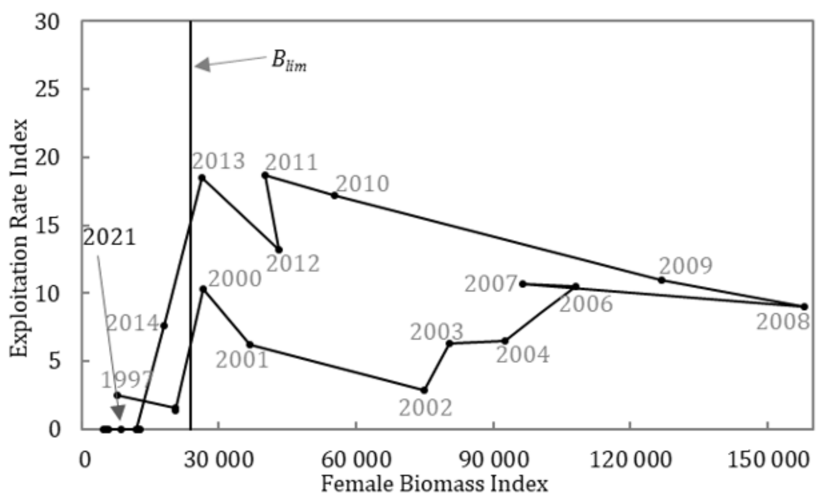


Figure 2.9. Shrimp in Div. 3LNO: Exploitation rate vs female SSB index from Canadian autumn survey. Vertical line denotes B_{lim}.

e) State of the stock

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

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

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

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

f) Ecosystem considerations

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

g) Research recommendations

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

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

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

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

References

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

PART C: REPORT OF THE SCIENTIFIC COUNCIL MEETING

20 – 24 September 2021, via WebEx

Recommended Citation:

NAFO. 2021. Report of the Scientific Council, 20 - 24 September 2021, via WebEx. NAFO SCS Doc. 21/17.

Scientific Council Annual Meeting Participants

20- 24 September 2021

SC participants from left to right:

First row: Tom Blasdale, Karen Dwyer, Margaret Treble, Laura Wheeland, Mariano Koen-Alonso

Second row: Mark Simpson, Diana González Troncoso, Ricardo Alpoim, Adolfo Merino, Irene Garrido

Third row: Liivika Näks, Lisa Readdy, Miguel Caetano, Herlé Goraguer, Kenji Taki

Fourth row: Carmen Fernández, Valerii Paramonov, Carsten Hvingel, Konstantin Fomin, Andrew Kenny

Fifth row: Kathy Sosebee

Missing from photo: Leigh Edgar, Ellen Kenchington, Martha Krohn, Brian Healey, José Miguel Casas Sanchez, Pablo Durán Muñoz, Fernando González-Costas, Mar Sacau-Cuadrado, Sergey Melnikov, Anna Ridiger

REPORT OF SCIENTIFIC COUNCIL MEETING

20-24 September 2021

Chair: Carmen Fernández Rapporteur: Tom Blasdale

I. PLENARY SESSIONS

The Scientific Council (SC) and its Standing Committees met by correspondence from 20 to 24 September 2021 to consider the various matters in its agenda. Representatives attended from Canada, the European Union, France (in respect of St. Pierre et Miquelon), Japan, Norway, the Russian Federation, Ukraine, the United Kingdom and the United States of America. The Executive Secretary, Scientific Council Coordinator and other members of the Secretariat were in attendance.

The Council was called to order at 08:00 Halifax time (11:00 UTC) on 20 September 2021. The provisional agenda was **adopted,** and the Scientific Council Coordinator was appointed the rapporteur. The opening session was adjourned at 13:00 on 20 September 2021.

The final session was called to order at 08:00 on 24 September 2021. The Council considered and **adopted** the reports of the STACFEN, STACPUB, STACREC and STACFIS Standing Committees and agreed that the report of this meeting would be finalized by correspondence. The meeting was adjourned at 13:00 hours on 24 September 2021.

The Agenda, List of Research (SCR) and Summary (SCS) Documents, and List of Representatives, Advisers and Experts, are given in Appendices V-VIII.

The Council's considerations on the Standing Committee Reports and other matters addressed by the Council follow in Sections II-XV.

II. REVIEW OF SCIENTIFIC COUNCIL RECOMMENDATIONS

There were no Scientific Council recommendation requiring immediate attention at this meeting. A detailed review of recommendations was deferred to the June 2022 meeting.

III. JOINT SESSION OF COMMISSION AND SCIENTIFIC COUNCIL

The Commission and Scientific Council met in joint sessions on 20 and 21 September to discuss the 2018 NAFO performance review, the Scientific Council's response to requests for advice from the Commission, the reports of the joint SC/Commission Working Groups and other matters of common interest.

1. Implementation of 2018 Performance Review Recommendations

The President referred to the COM Working Paper 21-17 that outlined the status of the implementation of the recommendations of the 2018 Performance Review Panel.

As agreed at the 2019 Annual Meeting, the NAFO Secretariat will provide an annual update on progress the Organization has made in addressing the recommendations of the 2018 Performance Review Panel on the basis of the "*Action Plan for the Implementation of the Recommendations from the 2018 Report of the NAFO Performance Review Panel*" (COM Doc. 19-32).

2. Presentation of scientific advice by the Chair of the Scientific Council

a) Response of the Scientific Council to the Commission's request for scientific advice

The Chair of the Scientific Council (SC), Carmen Fernández (EU), presented this year's scientific advice. The advice represents the response of SC to the request from the Commission (COM Doc. 20-16). The scientific advice on fish stocks and on other topics were formulated mainly during the SC meeting in June 2021 (SCS Doc. 21-14REV), except for the shrimp stocks in 3M and in 3LNO, which were formulated on 08 September 2021 during the NAFO/ICES *Pandalus* Assessment Group (NIPAG) meeting.

The advice relating to risk-based management strategies, ecosystem approach to fisheries management, and bycatch and discards was taken on by working groups at their subsequent meetings (see meeting summaries by the working group chairs, later in this section of the SC report). A summary of the SC advice on fish stocks in which the Commission took management actions at this meeting is presented in the table below. The detailed advice and responses to the Commission requests are contained in the above-mentioned documents.

Fish Stock	SC Advice
3M Cod	Yield of less than or equal to 5000 tonnes in 2022 results in a very low probability (≤10%) of SSB being below B_{lim} in 2023 and a very low probability of exceeding F_{lim}. However, given the present low level of the SSB and projected decline of total biomass under any fishing scenario, in order to promote growth in SSB, SC advises catches of no more than 3000 tonnes in 2022.
3M Redfish	SC advises that catches do not exceed $F_{0.1}$ level, given the life history of the stock. This corresponds to a TAC of 10 933 t in 2022 and 11 171 t in 2023.
3M Shrimp	To be consistent with the precautionary approach, SC advises that no directed fishery should occur in 2022.
3NO Cod	No directed fishing in 2022 to 2024 to allow for stock rebuilding.
3LNO American plaice	In accordance with the rebuilding plan, there should be no directed fishing on American plaice in Div. 3LNO in 2022, 2023 and 2024. Bycatch of American plaice should be kept to the lowest possible level and restricted to unavoidable bycatch in fisheries directing for other species.
3LNO Yellowtail founder	Fishing mortality up to 85% F_{msy}, corresponding to catches of 22 100 t, 20 800 t, and 19 900 t in 2022 to 2024 respectively, have risk of no more than 30% of exceeding F_{lim}.
3NOPs White hake	For 2022-2023. Catches of white hake in 3NO should not increase. Average annual total catches of the most recent five years were around 400 tonnes.
3NO Capelin	For 2022-2024. No directed fishery.
2+3KLMNO Greenland halibut	The TAC for 2022 derived from the HCR is 15 864 t. This is 4% lower than the 2021 TAC (16 498 t). Exceptional Circumstances are not occurring. The disruption of the 2021 Canadian Spring 3LNO survey, in addition to the years 2020 and 2017, will trigger Exceptional Circumstances next year.
3LNO Shrimp	No directed fishery in 2022 and 2023 as the stock is below B_{lim} with no indication of short-term recovery.

b) Feedback to the Scientific Council regarding the advice and its work during this meeting

A feedback question pertaining to 3M cod was forwarded to SC. Specifically, it requests SC to re-run projections for this stock with actual catches taken by the Faroe Islands 3M cod survey (630.6 tonnes) included in the assumed catches for 2021. The SC response to the question is presented in section VIII.2 of this report.

c) Other issues as determined by the Chairs of the Commission and the Scientific Council

The SC Chair brought forward two issues:

1) SC noted that with the information currently available, SC considers the Faroe Islands 3M cod survey initiative conducted in June 2021 did not fulfil the requirements of a valid scientific survey and more closely resembles a commercial fishery. SC further noted that protocols from Article 4 in the Conservation and Enforcement Measures (NAFO COM Doc 21/01) do not require review of proposed survey research plans and confirmation of their scientific validity by SC. In this regard, SC **recommends** that *the Commission amend this*

procedure to include a scientific review of proposed research surveys in the NRA to ensure scientific best practices are followed (COM-SC WP 21-15).

In reaction to this recommendation, Denmark (in respect to Faroe Islands and Greenland) issued a statement. It is presented in COM-SC WP 21-16.

The deliberations in addressing the issue of the Faroese survey continued at the Commission. They are reflected in the agenda items 21.a and 28 in this report.

2) In presenting the SC response to the Commission request pertaining to the development of a 3–5-year work plan and recalling the discussions at the Joint Commission-Scientific Council Working Group on Risk-based Management Strategies (WG-RBMS) meeting in August 2021, the SC Chair raised concern with regards the prioritization of SC tasks. SC presented a detailed schedule and timeline outlining resource requirements in the performance of all its tasks, among which three major tasks are the PA framework review, a review and evaluation of the Greenland halibut management strategy, and the development and evaluation of a management strategy for 3LN redfish. SC noted that the PA framework review is already underway, and that it expects the Greenland halibut process to take two years and the 3LN redfish process to take three years. Given the current workload and resources available, SC indicated that it cannot perform these three major tasks simultaneously and proposed that one of the two Management Strategy Evaluations (Greenland halibut or 3LN redfish) be postponed. Further discussion on this issue is reflected in section III.3.b of this report.

3. Meeting Reports and Recommendations of the Joint Commission–Scientific Council Working Groups

a) Working Group on Improving Efficiency of NAFO Working Group Process (E-WG), 2020

The Executive Secretary referred to COM-SC Working Paper 21-06, which is the recommendation from the Joint Commission-Scientific Council Efficiency Working Group. The Working Group recommended three (3) two-week periods where intersessional meetings by STACTIC and other Working Groups may be held, namely:

- 21 February to 04 March 2022,
- 25 April to 06 May 2022, and
- 08 to 19 August 2022.

Contracting Parties are not obliged to schedule meetings during these periods, but these dates may help in future planning of intersessional meetings.

The recommendations of the Working Group were adopted by the Commission. The Commission also agreed that this Working Group continue in 2022 under the same terms of reference.

b) Joint Commission–Scientific Council Working Group on Risk-based Management Strategies (WG-RBMS), February and August 2020

The co-Chairs Fernando González (EU) and Ray Walsh (Canada) presented the August 2021 meeting report (COM-SC Doc 21-04) and the recommendations (COM-SC WP 21-07):

Key discussion items include, among others:

- PAF Review,
- Greenland halibut Management Strategy Evaluation (MSE),
- 3LN Redfish MSE,
- Prioritization of the three tasks above.

The recommendations of WG-RBMS were **adopted** by the Commission (COM-SC WP 21-08 Rev).

The co-Chairs also highlighted the issue of the prioritization among the two MSEs and the PAF review. No consensus was reached at the WG-RBMS meeting. While SC expressed that it would be extremely difficult to perform the tasks simultaneously, Canada, on the other, indicated that it had allocated funding for a position dedicated to the 3LN redfish MSE review, and considers that this will ease the workload on SC allowing both MSEs to proceed simultaneously.

At this session, the detailed schedule and timeline presented by SC outlining resource requirements in the performance of its tasks, including the PAF review and the simultaneous performance of the two MSEs, was further discussed. Canada informed about its deliverables in advancing the review of 3LN redfish MSE (COM-SC Working Paper 21-12).

Further discussion on this issue continued again at the respective sessions of the Commission and SC. To further inform the discussion and help with the decision, SC noted the following, pertaining to the Greenland halibut Harvest Control Rule (COM WP 21-44):

1) The Greenland halibut Harvest Control Rule in the current NAFO CEM (COM. Doc. 21-01) was scientifically tested through an MSE process extending beyond 2023 (until 2037).

2) The management regime includes the HCR plus a protocol to deal with exceptional circumstances which is applied annually. In addition, update assessments based on the base-case SCAA and SSM models are done every 3 years. These update assessments were last conducted in 2020 and therefore would be repeated in 2023.

Therefore, the SC concluded a short-term extension of this management regime beyond 2023 does not pose any problem from a scientific perspective, and can be reliably applied, but is not recommended to extend for more than 3 years before a full review of the MSE is conducted.

c) Joint Commission–Scientific Council Working Group on Ecosystems Approach Framework to Fisheries Management (WG-EAFFM), August 2020

The co-Chairs Andrew Kenny (EU) and Elizabethann Mencher (USA) presented the July 2021 meeting report (COM-SC Doc. 21-03) and the recommendations (COM-SC WP 21-08).

Key discussion items include, among others:

- Significant Adverse Impact (SAI)
- Vulnerable Marine Ecosystem (VME) closures
- EAF Roadmap and the 2022 Workshop
- Review of Chapter II – NCEM measures.

The recommendations of WG-EAFFM were **adopted** by the Commission

In addition, the proposal revising the boundaries of Fogo, Corner Rise and Newfoundland Seamount mount closures was adopted by the Commission.

d) Joint Commission–Scientific Council Catch Estimation Strategy Advisory Group (CESAG), April 2020

The co-Chairs of CESAG, Katherine Sosebee (USA) and Temur Tairov (Russian Federation), presented the April meeting report (COM-SC Doc. 21-02) and the recommendations (COM-SC WP 21-09).

Key discussion items, among others:

- 2020 catch estimates conducted by the Secretariat and forwarded to SC
- Observer program best practices.

The recommendations of CESAG were **adopted** by the Commission.

4. Formulation of Request to the Scientific Council for Scientific Advice on the Management in 2023 and Beyond of Certain Stocks in Subareas 2, 3, 4 and 6 and Other Matters

In accordance with the procedure outlined in FC Doc. 12-26, a steering committee was formed to assist in the drafting of the Commission request. The committee consisted of the SC Coordinator and representatives from Canada and EU.

The Commission request to SC was developed and presented by the committee was adopted by the Commission (COM WP 21-20). Request items pertaining to fish stock assessments, 2+3KLMNO Greenland halibut and 3LN redfish MSE processes, Precautionary Approach Framework (PAF) are considered the priority items for the June 2022 Scientific Council meeting subject to resources and COVID-related restrictions.

IV. FISHERIES ENVIRONMENT

The Council adopted the Report of the Standing Committee on Fisheries Environment (STACFEN) as presented by the Chair, Miguel Caetano. The full report of STACFEN is in Appendix I.

V. PUBLICATIONS

The Council adopted the Report of the Standing Committee on Publications (STACPUB) as presented by the Chair, Margaret Treble. The full report of STACPUB is in Appendix II.

VI. RESEARCH COORDINATION

The Council adopted the Report of the Standing Committee on Research Coordination (STACREC) as presented by the Chair, Karen Dwyer. The full report of STACREC is in Appendix III.

VII. FISHERIES SCIENCE

The Council adopted the Report of the Standing Committee on Fisheries Science (STACFIS) as presented by the Chair, Katherine Sosebee. The full report of STACFIS is at Appendix IV.

VIII. REQUESTS FROM THE COMMISSION

1. Requests deferred from the June Meeting

i) Continue the evaluation of scientific trawl surveys in VME closed areas (COM request #3)

Although progress on this request has occurred in the last months, time constraints prevented the SC from discussing and preparing a response during this meeting. Therefore, it was deferred to the June 2022 meeting.

2. Requests Received from the Commission during the Annual Meeting

From United Kingdom regarding 3M cod:

Feedback Request

Scientific surveys normally harvest relatively small quantities of fish to derive information about stock status. In the case of the 2021 Faroese longline survey on Flemish Cap, the survey catches amount to 630.6t, equating to an additional 42% of the agreed TAC for 2021 of 1,500t. In order to take account of the impact of this catch on the advice provided for 2022, the UK proposes the following request to the SC:

The Commission requests that the SC run additional projections assuming a total catch level of 2,130.6t in 2021, to be made available to CPs as soon as possible during the Annual Meeting.

Scientific Council responded:

In June 2021, projections with a catch in 2021 equal to the approved TAC = 1500t were run, given the results in Tables 1a and 2a as in the advisory sheet of the 3M cod. New projections incorporating the catches in the Faroese survey during June 2021 (630.6t), so with a catch in 2021 = 2130.6t, were performed with the same scenarios as in June 2021, given the results shown in Tables 1b and 2b.

Increasing the catches in 2021, the Yield in 2022 onwards declines slightly in all the scenarios with projecting Fs, the risk of SSB being below Blim is slightly higher and the probability of the SSB in 2024 being above SSB in 2021 is lower.

While risks of the stock declining below Blim in the next 2 years remain similar with the two levels of catch, the additional catches increase the probability that the stock will decline.

Table 1a. Results with a catch in 2021 of 1500t.

	B		SSB		Yield
	Median and 80% CI				
F_{bar} = Fsq (median = 0.131)					
2021	45787	(40635 - 51559)	27058	(23458 - 31446)	1500
2022	42969	(37884 - 48389)	24420	(21335 - 27970)	6525
2023	34733	(29703 - 40345)	18598	(15605 - 21773)	5291
2024	29999	(24718 - 36318)	19822	(16344 - 23723)	
F_{bar} = 0					
2021	45787	(40635 - 51559)	27058	(23458 - 31446)	1500
2022	42969	(37884 - 48389)	24420	(21335 - 27970)	0
2023	41143	(36076 - 46765)	24071	(21037 - 27322)	0
2024	42102	(36620 - 48376)	30514	(27027 - 34628)	
F_{bar} = 3/4F_{lim} (median = 0.147)					
2021	45787	(40635 - 51559)	27058	(23458 - 31446)	1500
2022	42969	(37884 - 48389)	24420	(21335 - 27970)	7160
2023	34111	(29091 - 39726)	18092	(15086 - 21246)	5694
2024	28966	(23642 - 35277)	18923	(15516 - 22770)	
F_{bar} = 1/2F_{lim} (median = 0.098)					
2021	45787	(40635 - 51559)	27058	(23458 - 31446)	1500
2022	42969	(37884 - 48389)	24420	(21335 - 27970)	5000
2023	36238	(31192 - 41834)	19854	(16887 - 23067)	4254
2024	32578	(27213 - 38900)	22092	(18612 - 25996)	
Catch = 1500 tons					
2021	45787	(40635 - 51559)	27058	(23458 - 31446)	1500
2022	42969	(37884 - 48389)	24420	(21335 - 27970)	1500
2023	39661	(34603 - 45288)	22807	(19826 - 26087)	1500
2024	38994	(33591 - 45246)	27691	(24211 - 31752)	
Catch = 1875 tons					
2021	45787	(40635 - 51559)	27058	(23458 - 31446)	1500
2022	42969	(37884 - 48389)	24420	(21335 - 27970)	1875
2023	39291	(34238 - 44913)	22482	(19454 - 25735)	1875
2024	38216	(32795 - 44488)	27028	(23511 - 31085)	
Catch = 2250 tons					
2021	45787	(40635 - 51559)	27058	(23458 - 31446)	1500
2022	42969	(37884 - 48389)	24420	(21335 - 27970)	2250
2023	38923	(33871 - 44544)	22151	(19150 - 25412)	2250
2024	37438	(32028 - 43736)	26354	(22862 - 30373)	
Catch = 3000 tons					
2021	45787	(40635 - 51559)	27058	(23458 - 31446)	1500
2022	42969	(37884 - 48389)	24420	(21335 - 27970)	3000
2023	38196	(33139 - 43808)	21520	(18528 - 24739)	3000
2024	35865	(30453 - 42155)	24986	(21477 - 28888)	

Table 1b. Results with a catch in 2021 of 2130.6t (=1500 + 630.6).

	B		SSB		Yield
	Median and 80% CI				
F_{bar} = Fsq (median = 0.131)					
2021	45786	(40483 - 51538)	27071	(23429 - 31417)	2131
2022	42271	(37161 - 47408)	23874	(20789 - 27401)	6390
2023	34327	(29418 - 39829)	18272	(15306 - 21461)	5218
2024	29732	(24494 - 35909)	19570	(16108 - 23461)	
F_{bar} = 0					
2021	45786	(40483 - 51538)	27071	(23429 - 31417)	2131
2022	42271	(37161 - 47408)	23874	(20789 - 27401)	0
2023	40614	(35672 - 46166)	23620	(20612 - 26889)	0
2024	41588	(36298 - 47813)	30092	(26522 - 34166)	
F_{bar} = 3/4F_{lim} (median = 0.147)					
2021	45786	(40483 - 51538)	27071	(23429 - 31417)	2131
2022	42271	(37161 - 47408)	23874	(20789 - 27401)	7015
2023	33716	(28813 - 39207)	17754	(14808 - 20916)	5630
2024	28653	(23481 - 34842)	18644	(15219 - 22524)	
F_{bar} = 1/2F_{lim} (median = 0.098)					
2021	45786	(40483 - 51538)	27071	(23429 - 31417)	2131
2022	42271	(37161 - 47408)	23874	(20789 - 27401)	4901
2023	35791	(30868 - 41296)	19511	(16496 - 22691)	4205
2024	32279	(26951 - 38463)	21792	(18255 - 25694)	
Catch = 1500 tons					
2021	45786	(40483 - 51538)	27071	(23429 - 31417)	2131
2022	42271	(37161 - 47408)	23874	(20789 - 27401)	1500
2023	39131	(34196 - 44679)	22355	(19318 - 25569)	1500
2024	38516	(33179 - 44695)	27308	(23764 - 31342)	
Catch = 1875 tons					
2021	45786	(40483 - 51538)	27071	(23429 - 31417)	2131
2022	42271	(37161 - 47408)	23874	(20789 - 27401)	1875
2023	38764	(33827 - 44305)	22065	(18991 - 25288)	1875
2024	37749	(32396 - 43904)	26607	(23104 - 30608)	
Catch = 2250 tons					
2021	45786	(40483 - 51538)	27071	(23429 - 31417)	2131
2022	42271	(37161 - 47408)	23874	(20789 - 27401)	2250
2023	38399	(33459 - 43930)	21723	(18688 - 24960)	2250
2024	36966	(31635 - 43121)	25919	(22429 - 29956)	
Catch = 3000 tons					
2021	45786	(40483 - 51538)	27071	(23429 - 31417)	2131
2022	42271	(37161 - 47408)	23874	(20789 - 27401)	3000
2023	37665	(32721 - 43186)	21095	(18085 - 24336)	3000
2024	35411	(30063 - 41567)	24536	(21050 - 28527)	

Table 2a. Risk with a catch in 2021 of 1500t.

	Yield			P(SSB < B_{lim})				P(F_{bar} > F_{lim})			
	2021	2022	2023	2021	2022	2023	2024	2021	2022	2023	P(SSB_{24} > SSB_{21})
F_{bar} = F_{sq} = 0.131	1500	6525	5291	<1%	<1%	13%	8%	<1%	<1%	<1%	1%
F_{bar} = 0	1500	0	0	<1%	<1%	<1%	<1%	<1%	<1%	<1%	90%
F_{bar} = 3/4F_{lim} = 0.147	1500	7160	5694	<1%	<1%	17%	13%	<1%	1%	2%	<1%
F_{bar} = 1/2F_{lim} = 0.098	1500	5000	4254	<1%	<1%	5%	1%	<1%	<1%	<1%	4%
Catch = 1500 tons	1500	1500	1500	<1%	<1%	1%	<1%	<1%	<1%	<1%	58%
Catch = 1875 tons	1500	1875	1875	<1%	<1%	1%	<1%	<1%	<1%	<1%	48%
Catch = 2250 tons	1500	2250	2250	<1%	<1%	1%	<1%	<1%	<1%	<1%	36%
Catch = 3000 tons	1500	3000	3000	<1%	<1%	2%	<1%	<1%	<1%	<1%	20%

Table 2b. Risk with a catch in 2021 of 2130.6t (=1500t + 630.6t).

	Yield			P(SSB < B_{lim})				P(F_{bar} > F_{lim})			
	2021	2022	2023	2021	2022	2023	2024	2021	2022	2023	P(SSB_{24} > SSB_{21})
F_{bar} = F_{sq} = 0.131	2131	6390	5218	<1%	<1%	15%	9%	<1%	<1%	<1%	<1%
F_{bar} = 0	2131	0	0	<1%	<1%	<1%	<1%	<1%	<1%	<1%	87%
F_{bar} = 3/4F_{lim} = 0.147	2131	7015	5630	<1%	<1%	20%	15%	<1%	1%	2%	<1%
F_{bar} = 1/2F_{lim} = 0.098	2131	4901	4205	<1%	<1%	6%	2%	<1%	<1%	<1%	3%
Catch = 1500 tons	2131	1500	1500	<1%	<1%	1%	<1%	<1%	<1%	<1%	52%
Catch = 1875 tons	2131	1875	1875	<1%	<1%	1%	<1%	<1%	<1%	<1%	41%
C=2250	2131	2250	2250	<1%	<1%	1%	<1%	<1%	<1%	<1%	32%
Catch = 3000 tons	2131	3000	3000	<1%	<1%	2%	<1%	<1%	<1%	<1%	16%

3. Update on progress on the NAFO PA Framework review (COM request #8)

Com. Request #8: Continue progress on the NAFO PA Framework review

The Commission requests the Scientific Council to continue progression on the review of the NAFO PA Framework in accordance to the PAF review work plan approved in 2020 (NAFO COM-SC Doc. 20-04)

Scientific Council responded:

SC reported on further progress made on addressing the mapping of objectives deliverable (ToR 1a, c, and g of the PA-WG), to consider how the objectives and general principles of the NAFO Convention can be represented in the Precautionary Approach Framework (PAF). SC recommends that there are three general conditions for re-evaluating reference points in a revised PAF. These include: 1) when the context and quality of information substantially changes; 2)when there is strong evidence of a shift in productivity regime and it is understood, has persisted, is expected to continue, if the stock is viable if managed with the revised reference points and if there is sufficient information to estimate these revised points; 3) when new information indicates that management procedures based on current reference points do not perform well for meeting the objectives and principles of the NAFO convention, or alternative management procedures based on new reference points are expected to perform better for meeting the objectives.

In any case, uncertainty in reference points should be estimated and the relative risks of current and revised reference points for stock assessment and fishery management (e.g., simulation testing) should be communicated.

Work on ToR 1 a and c were presented to Scientific Council in June and to WG-RBMS in August, and recommendations endorsed by both groups. In September, work was presented by the PA-WG to the SC on ToR 1g to determine the conditions for when/if reference points should change and/or be re-evaluated. Collectively, ToR 1 a, c, and g support the task Mapping Objectives in accordance with the PA-WG tasks and timetable (COM-SC Doc. 20-04), and deliverable 1 will be therefore considered to be complete.

PA-WG recommends that there are three general conditions for re-evaluating reference points:

1. *The decision to estimate either MSY reference points or proxies should be reconsidered when the content and quality of information substantially changes.*
2. *Reference points should be re-evaluated when there is strong evidence of a shift in productivity regime, the mechanism of the shift is understood, the current productivity has persisted, the current productivity is expected to continue, the stock would be viable if managed with the revised reference points, and there is sufficient information to estimate revised reference points. Evidence that current reference points are unsustainable is sufficient to revise reference points. Operational stock assessments should routinely test for a shift back to greater productivity.*
3. *Reference points can be revised when new information indicates that management procedures based on current reference points do not perform well for meeting the objectives and principles of the NAFO convention, or alternative management procedures based on new reference points are expected to perform better for meeting the objectives.*

In any case, uncertainty in reference points should be estimated and the relative risks of current and revised reference points for stock assessment and fishery management (e.g., simulation testing) should be communicated.

The Scientific Council supported these recommendations.

The mapping deliverable will be published as an SCR or SCS in the near future.

IX. MEETING REPORTS

a) Joint Commission – Scientific Council Working Group on the Ecosystem Approach Framework to Fisheries Management (WG-EAFFM)

This joint working group met by correspondence during 14–16 July and 20-21 July 2021 and was co-chaired by Elizabethann Mencher (USA) and Andrew Kenny (UK). The Scientific Council was advised of progress of this group by the co-chairs in their presentation of the report to the joint session of Commission and Scientific Council (see section III of this report).

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

This joint working group met by correspondence during 24–26 August 2021 and was co-chaired by Fernando González (EU) and Ray Walsh (Canada). The Scientific Council was advised of progress of this group by the co-chairs in their presentation of the report to the joint session of Commission and Scientific Council (see section III of this report).

c) Joint Commission-Scientific Council Catch Estimation Strategy Advisory Group (CESAG).

CESAG met by correspondence on 13 April 2021, co-chaired by Katherine Sosebee (Scientific Council, USA) and Temur Tairov (Commission, Russian Federation). The Scientific Council was advised of progress of this group by the co-chairs in their presentation of the report to the joint session of Commission and Scientific Council (see section III of this report).

d) ICES/NAFO Working Group on Deep-water Ecology (WG-DEC)

WG-DEC met by correspondence during 7-11 June 2021 and was attended by Ellen Kenchington (Canada) representing NAFO. Consideration of the report of WG-DEC was deferred to the June 2022 SC meeting.

e) ICES/NAFO/NAMMCO Working Group on Harp and Hooded Seals (WG-HARP)

Discussion of this working group was deferred to June 2022.

X. REVIEW OF FUTURE MEETING ARRANGEMENTS

1. Scientific Council meetings

a) Scientific Council (in conjunction with NIPAG), 1 to 5 November 2021

The Scientific Council shrimp advice meeting will be held by WebEx from 1 to 5 November 2021.

b) WG-ESA, 16- 25 November 2021

The Working Group on Ecosystem Science and Assessment (WG-ESA) will meet by WebEx, from 16 to 25 November 2021.

c) Scientific Council, June 2022

Scientific Council June 2022 meeting will be held from 3 to 16 June 2022, in Halifax, Nova Scotia, Canada.

d) Scientific Council (in conjunction with NIPAG), 2022

Dates and location to be determined.

e) Scientific Council, September 2022

The Annual meeting will be held from 19 to 23 September 2022, in Lisbon, Portugal.

2. NAFO/ICES Joint Groups

a) NIPAG, 1 to 5 November 2021

The Scientific Council shrimp advice meeting will be held from 1 to 5 November 2021, by WebEx.

b) ICES – NAFO Working Group on Deep-water Ecosystem, 2022

Dates and location to be determined.

c) ICES/NAFO/NAMMCO WG-HARP

The date and location of the next ICES/NAFO/NAMMCO Working Group on Harp and Hooded Seals (WGHARP) meeting are unknown.

XI. FUTURE SPECIAL SESSIONS

No future special sessions were discussed.

XII. OTHER MATTERS

1. Initial SC considerations to address COM Req. 5.a. "Independent scientific Review of Tier 1 and its proposed application"

The Commission's Request 5 for Scientific Advice on Management in 2023 and Beyond (Com. Doc 21-20) reads:

The Commission requests that Scientific Council continue work on the sustainability of catches aspect of the Ecosystem Road Map, including:

> *a. In consultation with WG-EAFFM via co-chairs, convene independent experts to do a scientific review of; a) the estimation of fisheries production potential and total catch indices, and b) the adequacy of this analysis for their proposed use within the NAFO roadmap (Tier 1), while considering how species interactions are expected to be addressed in the future (Tier 2) within the overall Roadmap structure. The outcomes of this review would need to be tabled in June at Scientific Council to be available in advance of the planned workshop in 2022.*
>
> *b. Work to support the WG EAFFM workshop in 2022, which will explore ecosystem objectives and further develop how the Roadmap may apply to management decision making.*
>
> *c. Continue its work to develop models that support implementation of Tier 2 of the EAFM Roadmap*

In view of this request from the Commission, the SC discussed in the final day of its meeting how to address part a. and expressed the following initial considerations.

This request has one important logistical constraint which needs to be considered in the planning of the scientific review: the results of this review will need to be available before the WGEAFFM Ecosystem Objectives Workshop currently scheduled to take place in August 2022. This review is to be conducted as an SC process, which means that the review will need to be presented, discussed, and adopted/endorsed by SC at its June 2022 meeting. Given this tight timeline, the planning and organization process needs to begin immediately.

In line with similar external reviews conducted by SC (e.g. stock-assessments in support of benchmark processes), SC considers that this review needs to be overseen by WG-ESA, where the work being reviewed was originally produced, and its results documented in the final WG-ESA Report next year. This review should also be tabled at SC for full discussion and consideration, and to allow for the formal response to the COM request to be produced.

The selection of independent experts to conduct the review is therefore an urgent requirement for SC. To expedite the selection of experts it is suggested that, in the first instance, SC compile a short list of potential suitable reviewers which would then be shared with WG-EAFFM. This should be undertaken as soon as possible to enable enough time for the appointment process to be completed before the end of the year. WG-ESA would prepare material for review at its November 2021 meeting in consultation with the chairs of SC. The selected experts would then be invited (and at the same be given material to review) to an intersessional (WebEx/Teams) meeting of WG-ESA in the new year (probably in April) where they would be able to question the research, ask for clarifications if needed, and through this exercise, fully inform themselves about the nature of the research and its intended use in a management context. The invited experts would be expected to provide short written reviews in addition to their comments within 1 week after the session, and these reviews would then be appended to the WG-ESA Report to be finalised by the end of May 2022. We expect the outcome of the review to be presented to SC in June 2022 by one of the reviewers who would also be invited to the WG-EAFFM Ecosystem Objectives workshop in August 2022.

Given the nature of the work under review, the range of expertise expected to be covered in selecting independent reviewers should include ecosystem modelling, quantitative stock-assessment, and the boundary of science-management in a fisheries and/or ecosystem approaches context. This range of expertise would ideally be covered among the 3 independent reviewers required for this process (e.g. one stock-assessment expert, one ecosystem modelling expert and one expert on the science-management interface as it pertains to fisheries and/or ecosystem approaches).

While the Terms of Reference for this review need to be consulted with WG-EAFFM via its co-chairs, based on the request, a set of ToRs for discussion are:

a) Conduct a scientific review of the analysis used for the estimation of fisheries production potential and total catch indices,

b) evaluate the adequacy of this analysis for its proposed use within the NAFO roadmap (Tier 1), while considering how species interactions are expected to be addressed in the future (Tier 2) within the overall Roadmap structure.

2. Presentation of NAFO Scientific Merit Awards

a) Presentation of NAFO Scientific Merit Award to Pierre Pepin

NAFO Scientific Council (SC) was pleased to recognize Pierre Pepin (Canada)'s impact to SC work through a Scientific Merit Award. This award celebrates the many contributions Pierre has made in advancing the development and implementation of an ecosystem approach to fisheries within NAFO as a member of the SC Working Group on Ecosystem Science and Assessment (WG-ESA) and Scientific Council since 2010, as well as during his tenure as WGESA co-chair (2016-2021).

During this time, Pierre has also provided a leading voice in many of the joint initiatives within NAFO trying to breach the gap between scientists and managers, especially within the joint COM-SC Working Groups on the Ecosystem Approach Framework to Fisheries Management (EAFFM) and Rebuilding Plans and Management Strategies (RBMS).

Pierre's scientific expertise, sharp mind, and strategic vision will be sorely missed at SC, as well as his dry humour and his never-ending passion for improving the way in which we use science to make better management decisions.

b) Presentation of NAFO Scientific Merit Award to Carmen Fernández

On behalf of Scientific Council, the SC Vice-Chair and incoming Chair, Karen Dwyer (Canada), thanked the outgoing SC Chair, Carmen Fernández (EU), for her leadership. Scientific Council would like to recognize Carmen Fernández through the Scientific merit award for her four years of service as chair of SC and chair of STACREC, as well as chair of the WG-RBMS. Carmen has also played a leadership role in a number of scientific works and initiatives in the SC.

Carmen has piloted the SC boat for the last two years, bringing it to good port under the tremendous conditions of COVID-19. During these two years, the SC has met by videoconference and under her leadership it has managed to carry out a huge amount of work. One of Carmen's distinctive features was her high work capacity and scientific rigor in all her work. Another of Carmen's strengths is her ability to communicate the most complex scientific issues to managers in a clear and simple way. We are sure that the Commission will also miss her in the future.

The SC loses a brilliant scientist and a great colleague and bids her farewell with great sorrow, wishing her all the best in her new position and hoping to see her in the future working again in the SC.

3. SC co-Chair for CESAG

Kathy Sosebee (USA) informed SC that she is willing to continue as co-chair, subject to agreement from her institute. However, she noted that the Commission co-chair will also be from the USA and therefore SC may wish to consider electing a new co-chair in the future.

XIII. ADJOURNMENT

The meeting was adjourned at 13:00 on 24 September 2021.

APPENDIX I. REPORT OF THE STANDING COMMITTEE ON FISHERIES ENVIRONMENT (STACFEN)

Chair: Miguel Caetano

Due to ongoing restriction relating to the COVID-19 pandemic, the Committee met on 27 May 2021 by correspondence and videoconference to consider environment-related topics and report on conclusions to the Scientific Council. Representatives attended from Canada, Denmark (in respect of Faroe Islands and Greenland), the European Union, Japan, the Russian Federation, Ukraine, the United Kingdom and the United States of America. The Executive Secretary, Scientific Council Coordinator and other members of the Secretariat were in attendance.

1. Opening

The Chair opened the meeting by welcoming participants to this June 2021 meeting of STACFEN.

The Committee noted the following documents would be reviewed: SCR Doc. 21/002, 21/006, 21/007, 21/009, 21/010 21/023, 20/036, 20/037.

2. Appointment of Rapporteur

Due to the meeting characteristics, it was established that no rapporteur was appointed.

3. Adoption of the Agenda

Due to the meeting characteristics a general agenda was established by the SC.

4. Review of Recommendations in 2020

STACFEN **recommended** *consideration of Secretariat support for an invited speaker to address emerging issues and concerns for the NAFO Convention Area during the 2022 STACFEN Meeting. Contributions from invited speakers may generate new insights and discussions within the committee regarding integration of environmental information into the stock assessment process.*

STATUS: STACFEN was unable to secure a guest speaker for the June 2021 meeting due to ongoing restriction relating to the COVID-19 pandemic. This recommendation is **reiterated** and STACFEN will endeavour to have an invited speaker next year.

NAFO usually convenes a symposium on environmental issues every 10 years. The last one was held in 2011 as "ICES/NAFO Symposium on the Variability of the North Atlantic and its Marine Ecosystems during 2000-2009". STACFEN suggested that the forthcoming ICES Symposium (2021) could take the place of the next NAFO symposium. STACFEN therefore recommended that Scientific Council support participation and possible co-sponsorship.

STATUS: NAFO agreed to co-sponsor the symposium "4th Decadal Variability of the North Atlantic and its Marine Ecosystems: 2010-2019" which is advertised as an ICES-NAFO event. The symposium was postponed to April 2022 due to restrictions related to the Covid-19 pandemic. STACFEN therefore **recommends** that *Scientific Council support participation in the event.*

Further discussions are encouraged between STACFEN and STACFIS members on environmental data integration into the various stock assessments.

5. Oceanography and Science Data (OSD) Report for 2020 SCR 21/007

The Marine Environmental Data Section (MEDS) of the Oceans Science branch, as the Regional Environmental Data Center for NAFO, provided the annual inventory of environmental data collected in the NAFO Convention Area to the NAFO subcommittee for the environment (STACFEN). Inventories and maps of physical oceanographic observations such as ocean profiles, near surface thermosalinographs, drifting buoys, currents, waves, tides and water level measurements for the year 2020 are reported.

Data and information from NAFO member countries were provided by their designated data centre. The data of highest priority are those from the standard oceanographic sections and stations, as described in NAFO SCR DOC. 88-01. Data that have been formatted and archived at MEDS are available to all members on request or are available from DFO institutes. Requests can be made by telephone (613) 990-6065, by e-mail to info@dfo-mpo.gc.ca, by completing an online order form on the MEDS web site at http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/request-commande/form-eng.asp. The following table summarizes counts for 2020 by data type.

Data observed in NAFO Convention Area in 2020

Data Type	**Platform Type**	**Counts/Duration**
Oceanographic profiles	Autonomous drifting (Argo)	4234* profiles from 178 platforms
	Moorings (Viking)	154* profiles from 4 platforms
	Gliders	4086* profiles from 5 platforms
	Ship	2771 profiles (1042 CTD; 1273 CTD*; and 456 bottle profiles) from at least 16 ships
Surface/near-surface observations	Ship (thermosalinograph)	1438* obs. from 1 ship
	Drifting buoys	1141888* obs. from 311 buoys
	Moored buoys	258546* obs. from 20 buoys**
	Fixed platforms	100204* obs. from 3 platforms
	Water level gauges	12 sites, avg. ~1 year each

*Data formatted for real-time transmission
** All Canadian wave buoys described in this report measure waves, and the moorings measuring CTD oceanographic profiles in this table are also equipped with surface buoys measuring waves.

Data observed prior to 2020 in NAFO Convention Area and acquired between January 2020 and May 2021

Data Type	**Platform Type**	**Counts/Duration**
Oceanographic profiles	Ship	4801 profiles (1489 CTD + 3302 bottle + 10 XBT profiles) from 15 ships

6. Highlights of Climate and Environmental Conditions by NAFO Subarea for 2020 (SCR Doc. 21/023)

i) SUBAREA 0 AND 1, GREENLAND AND DAVIS STRAIT

Recent Conditions in Ocean Climate and Lower Trophic Levels

- The ocean climate index in Subarea 0-1 was normal in 2020;
- The initiation of the spring bloom was delayed for a second consecutive year in 2020;
- Total spring bloom production (magnitude) was near normal in 2020.

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 counterpoised by the warmer waters 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 1A). After being in 2019 at its highest value since the record high of 2010, the index was normal in 2020. 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 but several notable late bloom onsets were recorded during the late 2010s (Figure 1B). In 2020, the initiation of the spring bloom was later than normal for a second consecutive year. Spring bloom magnitude (total production) remained mostly below to near-normal between 2003 and 2020 except for a few highly productive blooms in 2006, 2015 and 2018 (Figure 1C). The late bloom onsets of 2019 and 2020 are associated to below-normal or near-normal total production for the corresponding years (Figure 1B-C).

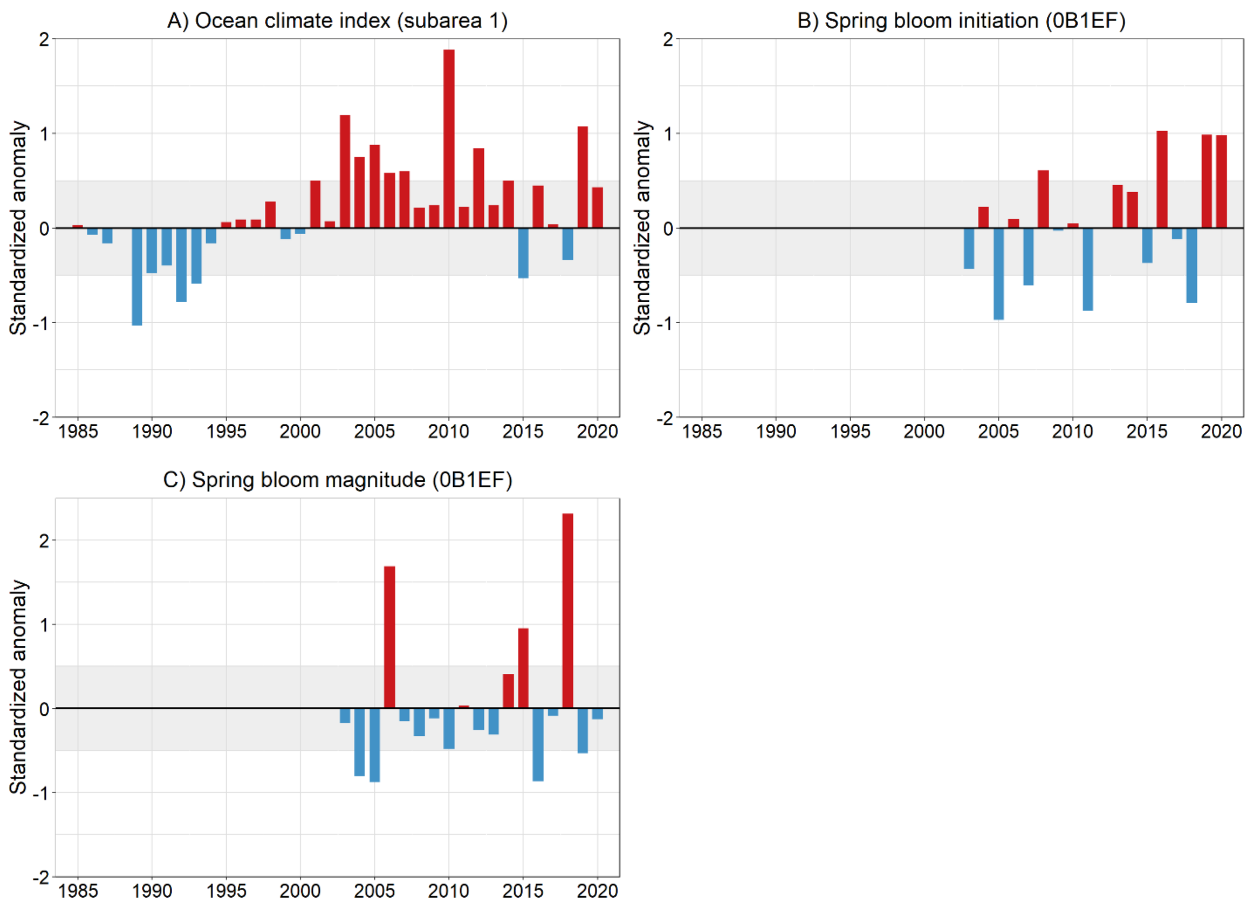


Figure 1. Environmental indices for NAFO Subarea 0 and 1. The climate index (A) for Subarea 0 and 1 is the average of 10 individual time series. These includes standardized anomalies of 4 SSTs time series, 4 temperature time series at 3 hydrographic stations and 2 air temperatures time series (see text for details). Phytoplankton spring bloom initiation (B) and magnitude (C) indices for the 2003-2020 period are derived from three satellite boxes covering NAFO Divs. 0B and 1EF (see text for details). Positive/negative anomalies indicate values above/below (or late/early timing) the long-term average for the reference period. Anomalies were calculated using the following reference periods: 1981-2010 for ocean climate index, 2003-2020 for spring bloom initiation and magnitude. Anomalies within ±0.5 SD (grey rectangle) are considered near-normal conditions.

ii) DIVISION 3M, FLEMISH CAP

Recent Conditions in Ocean Climate and Lower Trophic Levels

- After being below normal between 2015 and 2017, the ocean climate index in 3M has been normal since 2018;
- Spring bloom initiation was near normal in 2020 for a second consecutive year;
- Spring bloom magnitude was below normal in 2020 after three consecutive years of above-normal production;
- The abundance of copepod and non-copepod zooplankton was near normal in 2020 after having remained mostly above normal from 2015 to 2018;
- Zooplankton biomass was near normal in 2020 and has remained mostly near or below normal since the 2016 record-high.

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 sub-surface 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 (Figure 1). 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 Division 3M (Figure 2A) has remained mostly above normal between the late 1990s and 2013. After the record-high of 2011, the index gradually decreased reaching in 2015 its lowest value since 1993. After been below normal between 2015-2017, the index was normal between 2018 and 2020. Spring bloom initiation has been oscillating between early and late timing between 2003 and 2020 but has remained mostly near or later than normal since 2011 (Figure 2B). Spring bloom magnitude (total production) was below normal in 2020 after three consecutive years of above-normal production (Figure 2C). In general, late bloom onsets are associated with limited production (Figure 2B-C). The abundance of copepod and non-copepod zooplankton show general increasing trends throughout the 1999-2020 time series (Figure 2D-E). However, copepod abundance decreased to below or near-normal levels over the past two years after having remained above normal from 2016 to 2018 (Figure 2D). Similarly, the abundance of non-copepod zooplankton decreased to near-normal in 2019-2020 after four consecutive years of above-normal levels (Figure 2E). Total zooplankton biomass on the Flemish Cap has remained mostly below to near normal since 2015 with the exception of the record-high biomass observed in 2016 (Figure 2F).

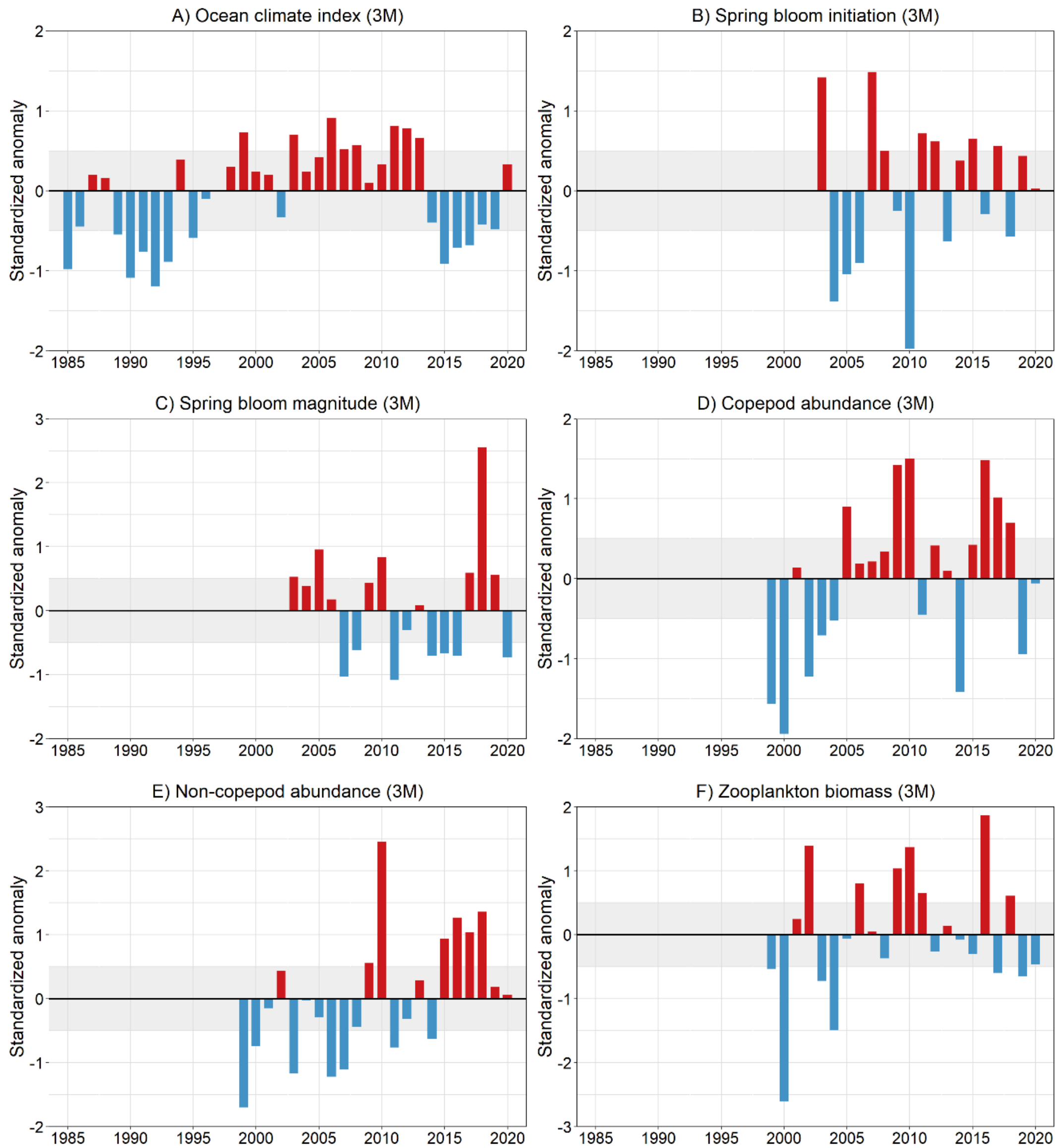


Figure 2. Environmental indices for the Flemish Cap (NAFO Div. 3M). The ocean climate index (A) for the Flemish Cap is the average of 3-time series of standardized ocean temperature anomalies of sea surface temperatures (SSTs), hydrographic section observations, and summer mean bottom temperature over the cap. Positive/negative anomalies indicate values above/below (or late/early timing) the long-term average for the reference period. Anomalies were calculated using the following reference periods: 1981-2010 for ocean climate index, 2003-2020 for spring bloom initiation and magnitude, and 1999-2020 for zooplankton abundance and biomass indices. Anomalies within ±0.5 SD (grey rectangle) are considered near-normal conditions.

iii) DIVISION 3LNO, GRAND BANKS

Recent Conditions in Ocean Climate and Lower Trophic Levels

- In 2020, the ocean climate in NAFO Divs. 3LNO - Grand Bank, was at its warmest value since the record-high of 2011, and at its third highest value since the time series started in 1985;
- Spring bloom initiation was near normal in 2020 for a 2nd consecutive year;
- Spring bloom magnitude decreased to near normal in 2020 after two consecutive year of above-normal production;
- The abundance of copepod and non-copepod zooplankton remained above normal in 2020 for a 5th consecutive year;
- Zooplankton biomass was near normal in 2020 for a second consecutive year following the above-normal levels observed in 2017 and 2018.

The water mass characteristic of the Grand Bank is 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 3A) 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 2017 that was below normal). In 2020, the ocean climate index was back to above-normal value, reaching the third highest value of the entire time series started in 1985 (only 2011 and 2006 were warmest). The initiation of the spring bloom has remained near or earlier than normal on the Grand Bank since 2017 after the two notably late blooms of 2015 and 2016 (Figure 3B). Spring bloom magnitude (total production) decreased to near normal in 2020 after two consecutive years of above-normal production (Figure 3C). Spring bloom production has remained mostly near or above normal since the record low observed in 2012 (Figure 3C). The abundances of copepod and non-copepod zooplankton show clear increasing trends since the beginning of the time series in 1999 with anomalies transitioning from negative to positive around 2010 (Figure 3D-E). Both copepod and non-copepod abundances remained above normal in 2020 for a 5th consecutive year with the 4th highest anomaly of the time series (Figure 3D-E). Zooplankton biomass drastically declined on the Grand Bank between 2002 and 2014 but has increased to near or above-normal levels since 2015 (Figure 3F).

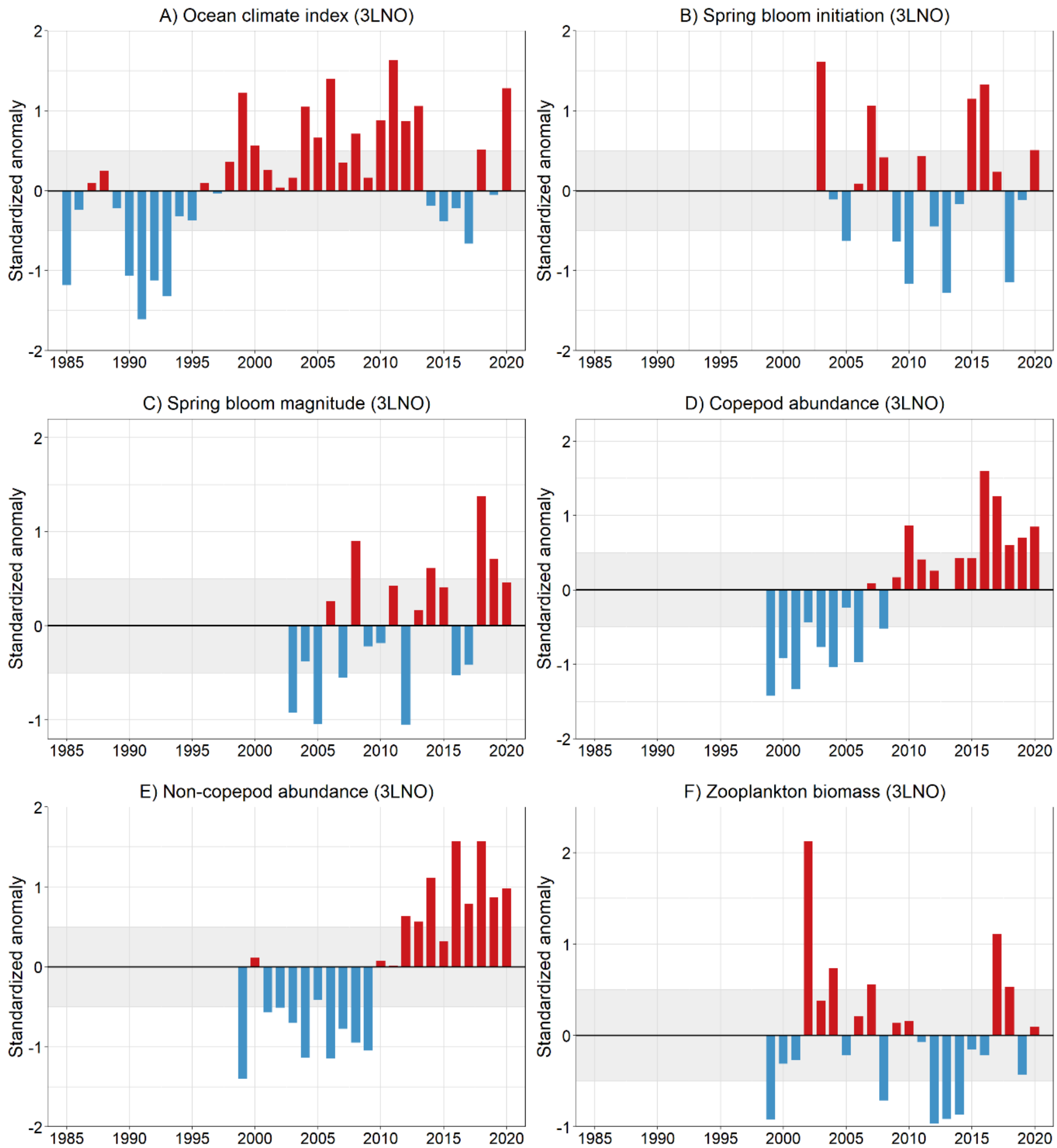


Figure 3. Environmental indices for NAFO Divisions 3LNO. The ocean climate index (A) is the average of 12 individual time series of standardized ocean temperature anomalies: SSTs for Divs. 3L, 3N and 3O, vertically average ocean temperature (0-176 m) at Station 27, mean temperature and CIL volumes over standard hydrographic sections Seal Island, Bonavista and 3L portion of Flemish Cap, and mean bottom temperature in 3LNO for spring and fall. Positive/negative anomalies indicate values above/below (or late/early timing) the long-term average for the reference period. Anomalies were calculated using the following reference periods: 1981-2010 for ocean climate index, 2003-2020 for spring bloom initiation and magnitude, and 1999-2020 for zooplankton abundance and biomass indices. Anomalies within ±0.5 SD (grey rectangle) are considered near-normal conditions.

iv) SUBAREAS 2, 3 AND 4, NEWFOUNDLAND AND LABRADOR SHELF, SCOTIAN SHELF AND GULF OF MAINE

Recent Conditions in Ocean Climate and Lower Trophic Levels

- In 2020, subareas 2, 3 and 4 were all above normal, making the cumulative anomaly the 5th warmest since 1980;
- Spring bloom initiation and magnitude were, on average, near normal in subareas 2-3-4 in 2020;
- Mean copepod abundance was above normal in 2020 and especially higher in subareas 2-3 compared to subarea 4;
- Mean abundance of non-copepod zooplankton remained above normal across subareas 2-3-4 for a 5th consecutive year and was generally higher in subareas 2-3 compared to subarea 4;
- Mean zooplankton biomass was near normal in 2020 for a 5th consecutive year and was higher in subarea 2 compared to subareas 3-4.

The water mass characteristics of Newfoundland and Labrador Shelf are typical of sub-polar waters with a sub-surface temperature range of -1-2°C and salinities of 32-33.5. Labrador Slope Water flows southward along the shelf edge and into the Flemish Pass region. This water mass is generally warmer and saltier than the sub-polar shelf waters with a temperature range of 3-4°C and salinities in the range of 34-34.75. On average bottom temperatures remain <0°C over most of the northern Grand Banks but increase to 1-4°C in southern regions and along the slopes of the banks below 200 m. North of the Grand Bank, in Div. 3K, bottom temperatures are generally warmer (1-3°C) except for the shallow inshore regions where they are mainly <0°C. In the deeper waters of the Flemish Pass and across the Flemish Cap bottom temperatures generally range from 3-4°C. Throughout most of the year the cold, relatively fresh water overlying the shelf is separated from the warmer higher-density water of the continental slope region by a strong temperature and density front. This winter-formed water mass is generally referred to as the Cold Intermediate Layer (CIL) and is considered a robust index of ocean climate conditions. In general, shelf water masses undergo seasonal modification in their properties due to the seasonal cycles of air-sea heat flux, wind-forced mixing and ice formation and melt, leading to intense vertical and horizontal gradients particularly along the frontal boundaries separating the shelf and slope water masses.

Temperature and salinity conditions in the Scotian Shelf, Bay of Fundy and Gulf of Maine regions are determined by many processes: heat transfer between the ocean and atmosphere, inflow from the Gulf of St. Lawrence supplemented by flow from the Newfoundland Shelf, exchange with offshore slope waters, local mixing, freshwater runoff, precipitation and melting of sea-ice. The Nova Scotia Current is the dominant inflow, originating in the Gulf of St. Lawrence and entering the region through Cabot Strait. The Current, whose path is strongly affected by topography, has a general south-westward drift over the Scotian Shelf and continues into the Gulf of Maine where it contributes to the counter-clockwise mean circulation. The properties of shelf waters are modified by mixing with offshore waters from the continental slope. These offshore waters are generally of two types, Warm Slope Water, with temperatures in the range of 8-13°C and salinities from 34.7-35.6, and Labrador Slope Water, with temperatures from 3.5 to 8°C and salinities from 34.3 to 35. Shelf water properties have large seasonal cycles, east-west and inshore-offshore gradients, and vary with depth.

Ocean Climate and Ecosystem Indicators

A cumulative climate index for NAFO subareas 2, 3 and 4 (from the Labrador Shelf to the Scotian Shelf) is presented in Figure 4A. After a somewhat cold period from the late 1980s to the early 1990s, the index has remained relatively high since about the mid-2000's, with 2006, 2010 and 2012 being respectively the second, third and first warmest anomalies since 1985. After a recent return to near-normal values between 2014 and 2019 (mostly driven by cooler temperatures in SA 2 and 3) the index was back to a positive anomaly in 2020 (5th warmest year since 1980).

Mean timing of the spring bloom initiation across subareas 2-3-4 remained mostly near normal between 2003 and 2020 with few early onsets in 2006 and 2010, and one year when blooms were delayed across the region in 2015 (Figure 4B). Mean spring bloom production also remained mostly near normal throughout the time series except for the above-normal productions observed in 2003 and 2006 and for the below-normal production of 2008 (Figure 4C). Spring bloom production was lower in subarea 2 compared to subareas 3 and 4 in 2018 and 2019 and was near normal in all subareas in 2020 (Figure 4C). Mean copepod abundance across subareas 2-3-4 rapidly increased between 1999 and 2006 before levelling off to near-normal levels until 2015 (Figure 4D). Copepod abundance was especially high in subarea 2 in 2020 (Figure 4D). Anomalies have been mostly positive in all three subareas since 2010 with above-normal levels observed in 2016 and 2020 (Figure 4D). Mean abundance of non-copepod zooplankton increased in all subareas in the early 2010s and has remained above normal since 2016 (Figure 4E). In general, the abundance of non-copepods was comparatively higher in subareas 2 and 3 than in subarea 4 between 2016 and 2020 (Figure 6E). Mean zooplankton biomass in the region decreased from above-normal in 2002 to below-normal in 2015 (Figure 4F). Biomass has since remained at a near-normal level, especially due to an increase in subarea 2 and 3 (Figure 4F).

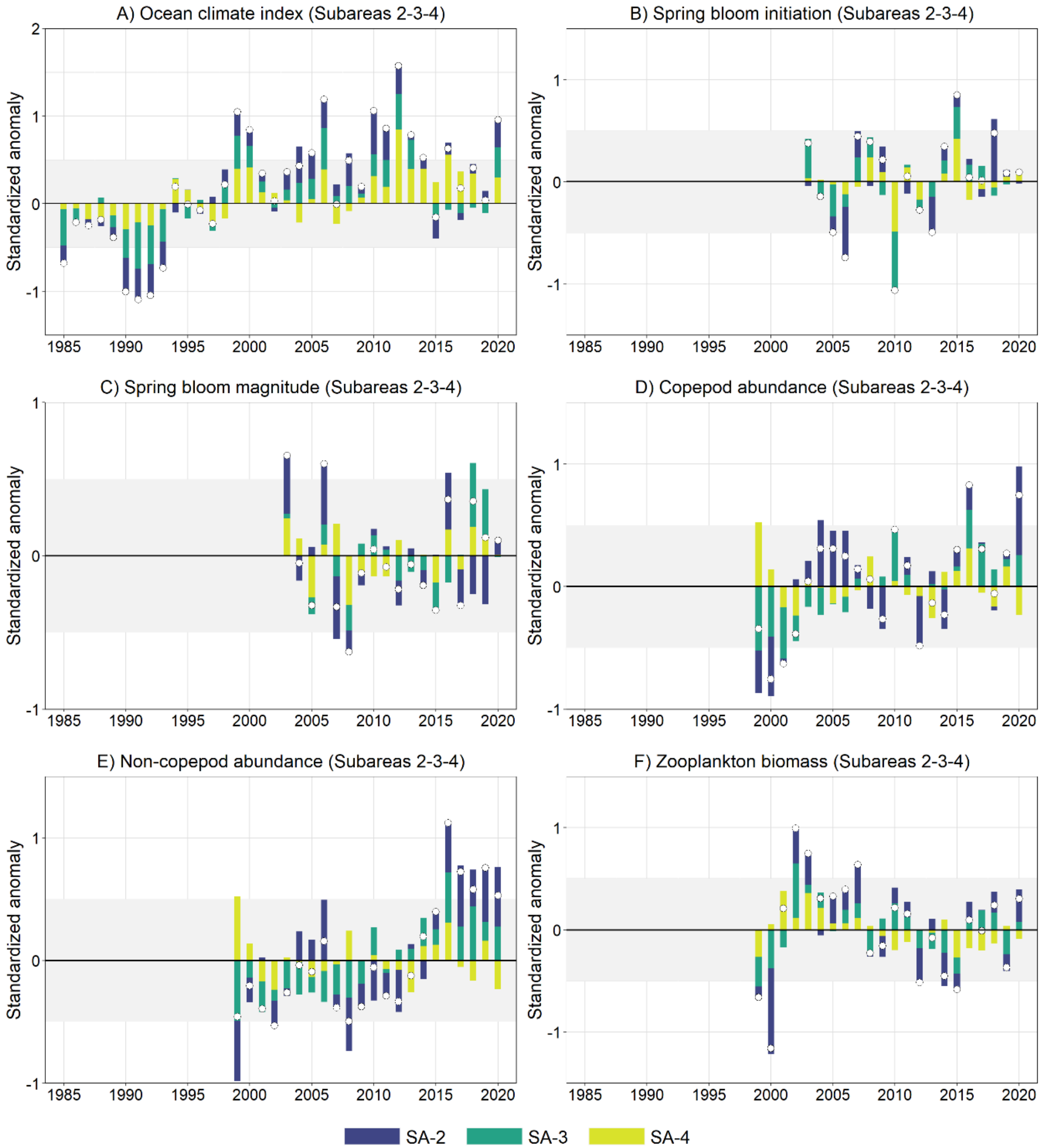


Figure 4. Environmental indices for NAFO Subareas 2-3-4. Anomalies for ocean climate index (A) are the result of the average of 8, 16 and 12 individual time series respectively for SA 2, 3 and 4. Mean positive/negative anomalies (open white circles) indicate conditions above/below (or late/early timing) the long-term average for the reference period. Colour bar height indicate the relative contribution of each subarea to the mean anomaly. Anomalies were calculated using the following reference periods: 1981-2010 for ocean climate index, 2003-2020 for spring bloom initiation and magnitude, and 1999-2020 for zooplankton abundance and biomass indices. Anomalies within ±0.5 SD (grey rectangle) are considered near-normal conditions.

7. Review of the physical, biological and chemical environment in the NAFO Convention Area during 2019

a) Subarea 1. Report on hydrographic conditions off Southwest Greenland May/June 2020 (SCR Doc. 21/002).

Hydrographic conditions were monitored at 10 hydrographic standard sections in June 2020 across the continental shelf off West Greenland. Three offshore stations have been chosen to document changes in hydrographic conditions off Southwest Greenland. The coastal water showed temperatures below the long-term mean south of the Sisimiut section. After some years with a relative saline Subpolar Mode Water mass, salinity dropped below its long-term mean.

b) Subarea 1. Hydrographic conditions off West Greenland in 2020 (SCR Doc. 21/006).

An overview of the atmospheric and hydrographic conditions off West Greenland in autumn 2020 is presented. In winter 2019/2020, the NAO index was positive for the seventh consecutive winter. The annual mean air temperature at Nuuk Weather Station in West Greenland was -0.8 °C in 2020, which was 0.6 °C above the long-term mean (1981-2010). The core properties of the water masses of the West Greenland Current (WGC) are monitored at two standard NAFO/ICES sections across the western shelf and continental slope of Greenland near Cape Desolation and Fyllas Bank. However, the Cape Desolation Section had to be abandoned due to time constraints in autumn 2020. The water properties between 0 and 50 m depth at Fyllas Bank Station 4 are used to monitor the variability of the fresh Polar Water component of the West Greenland Current. In 2020, the temperature of this water mass was 2.92 °C, which was 0.28 °C above its long-term mean (1983-2010). The salinity decreased in 2020 and was 0.38 below its long-term mean.

c) Subareas 1 and 2. Meteorological, Sea Ice, and Oceanographic Conditions in the Labrador Sea during 2020 (SCR Doc. 21/037)

In the Labrador Sea, the coldest and freshest North Atlantic basin south of the Greenland-Iceland-Scotland Ridge, wintertime surface heat losses result in the formation of dense waters that play an important role in ventilating the deep ocean and driving the global ocean overturning circulation. Even though in the winter of 2020, the central Labrador Sea lost more heat to surface cooling than in the previous winter, the loss remained near-normal for a third straight year. The recent reduction in the seasonal cooling of the Labrador Sea contrasts a 27-year record high winter heat lost in 2015. The 2020 winter (Dec-Mar) NAO index was above-normal and the highest after reaching its record high in 2015. However, the sea level pressure pattern was not associated with strong westerly winds along the Labrador coast. This led to, respectively, near-normal and above-normal winter and spring air temperatures in the Labrador Basin domain. Both winter and spring sea surface temperatures in the Labrador Basin were above-normal. Winter sea ice extent was below-normal in the Davis Strait, Northern Labrador Shelf and Labrador Shelf regions. Spring sea ice extent was also below-normal in all three regions. With respect to temperature anomalies averaged annually over the central Labrador Sea, the upper 100 m layer was the coldest in the 2002-2020 period in 2015 and 2018. After 2018, this layer attained above-normal annual temperatures in 2019-2020, reaching a 2011-2020 temperature high in 2019, then slightly cooling yet remaining above-normally warm through 2020. The intermediate, 200-2000 m, layer of the Labrador Sea started to cool immediately after hitting a record warm point of the 1972-2020 period in 2011. This cooling trend was mainly driven by strengthening and progressively deepening winter convection in 2012 and during 2014-2018. The key factor that has contributed to the recurrent deepening of convective mixing in the three straight winters following the winter of 2015 was not as much air-sea heat exchange as the water column preconditioning set by convective mixing in the previous years. Such multiyear persistence of deepening winter convection, continuing through the winter of 2018, when it exceeded 2000 m in depth, has resulted in the most voluminous, densest and deepest formation of Labrador Sea Water since 1994. In the winter of 2019, the situation has however changed with winter convection not generally exceeding 1400 m and the intermediate layer starting to warm to the point of fully reversing the seawater density trend to negative. Even though, wintertime mixing reached marginally deeper in 2020 (by 100 m or so), and the intermediate layer slightly cooled, the negative density trend prevailed. Between 2018 and 2020, the annual mean intermediate layer density reduced by about 0.01 kg/m^3. Overall, the changes in the depth of winter convection and intermediate layer properties between these years imply that the effect of the water column preconditioning on winter convection has weakened since 2018. Vertical distributions of dissolved oxygen and CFC (anthropogenic gases used as tracers of convectively-formed water masses in the ocean) concentrations in the central Labrador Sea based on quality controlled drift-corrected measurements assembled since 1990 follow very closely multiyear events of recurrently persistent renewal of dense deep Labrador Sea water in the Atlantic Ocean. Bedford Institute of Oceanography North Atlantic model simulations suggest that the transport of the Labrador Current generally decreased between 1995 and 2014, increased between 2014 and 2019, and slightly decreased in 2020. The Atlantic meridional overturning circulation index based on this model demonstrates a general weakening trend since mid-1990s until 2004, then slight strengthening lasting until 2011, then weakening again until the overturning weakest point was reached in 2019. The overturning circulation started to strengthen in 2020, but it is too early to associate this short-term increase with a reversal of the current negative trend in the Atlantic meridional overturning circulation.

d) Subareas 2, 3 and 4. Environmental and Physical Oceanographic Conditions on the Eastern Canadian shelves during 2020 (SCR Doc. 21/009).

Oceanographic and meteorological observations in NAFO Subareas 2, 3 and 4 during 2020 are presented and referenced to their long-term averages. The winter North Atlantic Oscillation (NAO) index, a key indicator of the direction and intensity of the winter wind field patterns over the Northwest Atlantic was positive for a 7^{th} consecutive year (since 2012, only 2013 was negative). The air temperatures across the NW Atlantic were about normal in the Arctic and in Labrador, and warmer than average in Newfoundland and in sites on the coast of the Scotian Shelf and the Gulf of Maine. Winter average sea ice conditions were below normal on the Newfoundland and Labrador for the first time since from 2013. Annual sea surface temperature (SST) across the NAFO Subareas 2, 3 and 4 were above normal overall for the zone for the first time since 2014. While SSTs remained below normal in parts of the Scotian Shelf in October, they were above normal on the Labrador and Newfoundland Shelf, reaching series records in 3MNO in October. The year ended with December record highs on the Scotian Shelf. The spatially averaged bottom temperature was above normal across the zone except in NAFO Divisions 2J and 3K where they were near normal. There were, however, no spring measurements in 3Ps and 3LNO due to a cancelled survey. The Labrador Current weakened to normal during 2019 and 2020 on the NL slope and has been below normal fairly consistently since 2014 on the Scotian slope.

e) Subareas 2, 3 and 4. Biogeochemical oceanographic conditions in the Northwest Atlantic during 2020 (SCR Doc. 21/010).

Biogeochemical variables collected in 2020 from coastal high-frequency monitoring stations and seasonal sampling of standard oceanographic sections covering NAFO Subareas 2-4 are presented and referenced to earlier periods when available. We review spatial and inter-annual variations in phytoplankton spring bloom indices as well as vertically integrated nitrate, chlorophyll *a*, zooplankton abundance, and zooplankton biomass inventories collected by the Atlantic Zone Monitoring Program (AZMP) and ships of opportunity in 2020. Spring bloom timing, duration, and magnitude were mostly near normal across the Canadian NW Atlantic except for the early and exceptionally long bloom observed on the Georges Bank. In general, nitrate and chlorophyll inventories remained near or above normal on the Newfoundland and Labrador shelves, Flemish Cap, Grand Bank and Gulf of St. Lawrence, and below to near normal on the Scotian Shelf. The abundance of copepod and non-copepod zooplankton increased or remained high on the Newfoundland and Labrador shelves and the Grand Bank, but generally decreased in the Gulf of St. Lawrence and on the Scotian Shelf. The abundance of large *Calanus finmarchicus* copepods increased on the northern Newfoundland and Labrador shelves and western Scotian Shelf and decreased on the Flemish Cap and the Grand Bank. The abundance of small *Pseudocalanus* spp. copepods increased on the Newfoundland and Labrador shelves, but drastically decreased almost everywhere else. Trends in total zooplankton biomass indicated an increase for the Newfoundland and Labrador shelves, and an overall decrease for the Gulf of St. Lawrence compared to 2019.

f) Subareas 5 and 6. Hydrographic Conditions on the Northeast United States Continental Shelf in 2020 (SCR Doc. 21/036).

A brief overview is presented of the atmospheric and oceanographic conditions on the Northeast U.S. Continental Shelf during 2020. Hydrographic monitoring typically conducted by the operational oceanography programs of the Northeast Fisheries Science Center (NEFSC) were suspended for the entirety of 2020 due to the global pandemic. Time series measurements from a handful of moored buoys in the Gulf of Maine and Southern New England Shelf were examined in their place. All observations point to warmer than average conditions across the region, including in the Cold Intermediate Layer in the eastern Gulf of Maine. Moored measurements in Northeast Channel during fall indicate that warm and salty conditions persist, suggesting that the slope water entering the Gulf of Maine continues to be dominated by southern sources as they have for the past decade.

8. The Formulation of Recommendations Based on Environmental Conditions

STACFEN **recommends** *consideration of Secretariat support for an invited speaker to address emerging issues and concerns for the NAFO Convention Area during the 2022 STACFEN Meetin*g.

Contributions from invited speakers may generated new insights and discussion within the committee regarding integration of environmental information into the stock assessment process.

STACFEN **recommends** that *further discussions take place between STACFEN and STACFIS members on environmental data integration into the various stock assessments.*

9. National Representatives

The National Representatives for hydrographic data submissions was updated by the Secretariat: E. Valdes (Cuba), Di Wan (Canada), **Vacant** (Denmark), **Vacant** (France), **Vacant** (Germany), **Vacant** (Japan), H. Sagen (Norway), **Vacant** (Portugal), E. Tel (Spain), L. J. Rickards (United Kingdom), and P. Fratantoni (USA), **Vacant** (Russian Federation).

10. Other Matters

No other subject was discussed.

11. Adjournment

The Chair thanked STACFEN members for their excellent contributions and the Secretariat for their support and contributions.

The meeting was adjourned at 10:00 on 27 May 2021.

APPENDIX II. REPORT OF THE STANDING COMMITTEE ON PUBLICATIONS (STACPUB)

Chair: Margaret Treble Contributor: Alexis Pacey

The Committee met by Webex, on 24 September 2021, to consider publications and communications related topics and report on various matters referred to it by the Scientific Council. Representatives attended from Canada, European Union (France, Portugal, and Spain), Japan, the Russian Federation, United Kingdom, Ukraine, Norway and the United States of America. The Scientific Council Coordinator was in attendance as were other members of the Secretariat staff.

1. Opening

The Chair opened the meeting by welcoming the participants.

2. Appointment of Rapporteur

Alexis Pacey (NAFO Secretariat) was appointed rapporteur.

3. Adoption of Agenda

The Agenda as given in the Provisional Agenda distributed prior to the meeting was adopted.

4. Review of Recommendations in 2020

The recommendations made by STACPUB for the work of the Scientific Council as **endorsed** by the Council, are as follows:

STACPUB reiterates the recommendation from 2018 and **recommends** that *the Secretariat and Chair of STACPUB work to develop guidelines for SCS documents.*

> *STATUS: This has been completed*. The guidelines are on the NAFO website: https://www.nafo.int/Library/Science/SC-Documents.

STACPUB **recommends** that *the Secretariat continue to investigate solutions that would be compatible with reference management software.*

> *STATUS*: *This has been completed – A solution was found and has been implemented.* The Crossref DOIs of each article are linked by integrating DataCite coding and enabling our SQL server to connect each DOI to various reference management software programs. Two simple buttons were created to assist in downloading the citations. The copy function remains as is for users who do not have reference management software. In conjunction with this project, increasing visibility of reports and PDFs of journal articles has been completed.

STACPUB **recommends** that *the Associate Editors be surveyed to determine if they would agree to have the expertise categories removed from their profiles on the JNAFS website.*

> *STATUS*: *This has been completed* – The expertise categories have been removed from the Associate Editor profiles on the JNAFS website, as well as on the introductory page of the NAFO website.

5. Review of Publications

a) Journal of Northwest Atlantic Fishery Science (JNAFS)

Volume 51, Regular issue, was published and printed in December 2020, containing five articles. Currently, Volume 52 has 7 articles; one published, two in review with associate editors, two in revision/re-submit stage with the authors, one in production, and one new submission, not assigned yet to an Associate Editor.

In February 2021 an e-mail promoting JNAFS and calling for paper submissions was sent out to contacts on the NAFO and JNAFS distribution list. Similar e-mails had also been sent in 2018 and 2019, following a suggestion made in 2017 to try to increase awareness.

The Secretariat has had an increase in the number of requests to not send out printed versions of the Journal because it can be accessed online. If we stopped printing JNAFS, or printed copies only for those that specifically request a printed copy then this could also reduce publishing costs. STACPUB **recommend** *that the Secretariat stop producing printed copies of the Journal*.

b) NAFO Scientific Council Reports

The NAFO Scientific Council Reports 2020 (Redbook) volume (462 pages) was published during May 2021 online.
No copies were printed due to meetings being held virtually. Print copies are available upon request.

c) NAFO Scientific Council Studies

There were no submissions for 2020.

d) NAFO Commission-Scientific Council Reports

These reports are found in the Meeting Proceedings of the Commission from September 2019-August 2020 (362 pages) and were printed and distributed in September 2020. Five copies were made with a spiral binding. Fewer copies were printed due to meetings being held virtually.

e) Aquatic Sciences and Fisheries Abstracts (ASFA)

Most science publications and SCR documents for 2020 have been submitted to ASFA as of 30 April, 2021. SCS documents will be indexed using the new software program, OpenASFA, developed by FAO team. Training took place during the spring of 2021 and further developments and enhancements are ongoing.

f) Website link to PDFs

The Senior Pupblications/Web Manager continues to look for improvements to our ability to have easy access to reports and JNAFS articles. This has been completed and implemented. All PDFs are found in the initial article listing and below the abstract.

6. Other Matters

a) ASFA 2020 Board Meeting

Alexis attended the ASFA Board Meeting virtually, which met 13-17 September 2021. Discussions took place around the new software, OpenASFA, partnership agreements, future plans and strategies for ASFA, such as outreach and funding, and 50th anniversary celebration of ASFA's inception. Action items and discussions from the meeting will be completed when the ASFA Secretariat finalizes the report.

7. Adjournment

Meeting adjourned 24 September 2021.

APPENDIX III. REPORT OF STANDING COMMITTEE ON RESEARCH COORDINATION (STACREC)

Chair: Karen Dwyer Rapporteur: Tom Blasdale

1. Opening

The June Scientific Council meeting was preceded by a virtual meeting on May 3, during which information on biological surveys in the NAFO Regulatory Area were presented. There was a discussion about the effects of the Covid-19 pandemic on surveys carried out in 2020 and whether the assessments in June would be affected. Future surveys for 2021 were also discussed. There was only one item discussed at the June 2021 meeting for STACREC, and this was the initiation of a longline survey of the Flemish Cap (Div. 3M) carried out by the DFG. In September the meeting was reopened to discuss the results of the longline survey.

2. Appointment of Rapporteur

The Scientific Council Coordinator, Tom Blasdale, was appointed as rapporteur for this meeting.

3. Review of previous recommendations from 2020 and new recommendations from 2021

Previous recommendations were not examined at the June meeting and no new recommendations were made in 2021 due to constraints to the meeting from Covid-19.

Survey-related recommendations (previous and new recommendations)

In 2015, STACREC **recommended** that *an analysis of sampling rates be conducted to evaluate the impact on the precision of survey estimates.* As a separate aspect, in September 2017 STACREC discussed *possibilities for combining multiple surveys in different areas and at different times of the year to produce aggregate indices*.

In September 2019, it *was agreed that a speaker on this general topic would be invited to the June 2020 SC meeting, and the STACREC chair will take the lead in arranging this invitation.* However, due to the pandemic, it was not possible to have an invited speaker in June. However, a Canadian scientist attended the ICES WKUSER (Workshop on Unavoidable Survey Effort Reduction) in January 2020 and presented information on survey coverage issues. Feedback from this meeting was presented to STACREC in May 2021.

The workshop goal was to provide best practices to deal with survey effort reduction and the need for contingency planning was also emphasized. The potential consequences of survey effort reduction were summarized, including increased uncertainty, biased outcomes, the reduced ability to detect distribution shifts, changes in productivity, etc. It was also emphasized that not all information collected may be used in stock assessment but its value in the future is unknown and may be increasingly important to address new emerging priorities.

Numerous case studies were presented from various areas of the world summarizing their surveys as well as those that provided analytical approaches to filling in gaps as well as analysis of the impacts of shortcomings.

Approaches dealing with decreasing survey coverage varied from resampling survey data to simulating distribution and abundance data, up to a complete MSE study of the impacts of changing survey coverage on stock assessment.

A follow-up meeting is planned but dates and location not yet decided.

The full report is available at: ICES. 2020. ICES Workshop on unavoidable survey effort reduction (WKUSER).

ICES Scientific Reports. 2:72. 92pp. http://doi.org/10.17895/ices.pub.7453

In 2019, STACREC made the following recommendation:

STACREC **recommends** the *following actions for future years whenever survey coverage issues arise*:

The STACREC report should contain, after the general survey presentation, a summary of the decisions and conclusions stock by stock regarding whether the survey can be used as a stock index for that year.

The mean proportion (over time) of total survey biomass in the survey strata missed that year should be calculated.

At this time, the following may be used as initial ("preliminary") guidelines based on the value of the mean proportion of total survey biomass in the survey strata missed in that year:

- If it is <10%: the survey index of that year is most likely acceptable.
- If it is between 10% and 20%: the survey index of that year is questionable and needs to be examined carefully before deciding whether it is acceptable.
- If it is >20%: the survey index of that year is most likely not acceptable. Any decision to accept it would require a clear and well justified rationale.

These are preliminary guidelines and sampling biases may also be relevant in the considerations for each specific stock and survey. In particular, the finer structure of the indices needs to be considered if they are used disaggregated by age or length in stock assessments.

It has been suggested that an added guideline might be: For age groups where there is a greater than 10% difference between total survey biomass in the survey strata missed that year in the index used (total or mean numbers), then it should be excluded from the model, if the model can handle missing values. However, there was no time to discuss this at the June 2020 meeting and therefore this discussion will be deferred to June 2021. This discussion was once again deferred to June 2022 due to lack of time at the virtual meeting.

All other recommendations will be deferred to next year (2022).

4. Fishery Statistics

a) Progress report on Secretariat activities in 2020/2021

STATLANT 21A and 21B:

In accordance with Rule 4.4 of the Rules of Procedure of the Scientific Council, as amended by Scientific Council in June 2006, the deadline dates for this year's submission of STATLANT 21A data and 21B data for the preceding year are 1 May and 31 August, respectively. The Secretariat produced a compilation of the countries that have submitted to STATLANT and made this available to the meeting. It was noted that many member states did not provide data in a timely manner, and it was recommended that the Secretariat send out a reminder before the deadline(s).

Table 1. Dates of receipt of STATLANT 21A reports for 2018-2020 and 21B reports for 2018-2020 received prior to 02 June 2021

Country/component	STATLANT 21A (deadline, 1 May)			STATLANT 21B (deadline, 31 August)		
	2018	2019	2020	2018	2019	2020
CAN-CA		9 Jun 20				
CAN-SF	29 Apr 19	17 Apr 20	30 Apr 21	30 Aug 19	2 Jul 20	
CAN-G		14 May 20	5 May 21	23 Aug 19		
CAN-NL	17 May 19	30 Apr 20	30 Apr 21	4 Sep 19	31 Aug 20	31 Aug 21
CAN-Q						
CUB						
E/BUL						
E/EST	30 Apr 19	30 Apr 20	30 Apr 21	17 Dec 19	29 Jun 20	23 Aug 21
E/DNK	1 May 19	26 May 20	27 May 21	27 Aug 19	21 Aug 20	21 Jul 21
E/FRA						
E/DEU	30 Apr 19	18 May 20	30 Apr 21	19 Sep 19	29 Jun 20	30 Aug 21
E/LVA	24 Apr 19		26 Apr 21			
E/LTU	24 Apr 19			1 July 19		3 Jul 21
EU/POL						
E/PRT	30 Apr 19	29 May 20	26 Apr 21	19 Sep 19	31 Aug 20	28 Aug 21
E/ESP		14 May 20	31 May 21	12 Dec 19	24 Jun 20	7 Jun 21
GBR						
FRO	22 May 19	3 Jun 20	12 Jan 21	18 May 19	15 Dec 20	12 Jan 21
GRL	29 Apr 19	24 Apr 20	3 May 21	22 Aug 19	25 Aug 20	30 Aug 21
ISL						
JPN	23 Apr 19	8 May 20	28 Apr 21	30 Aug 19	28 Aug 20	24 Aug 21
KOR						
NOR	25 Apr 19	27 May 20	10 May 21	26 Aug 19	4 Sep 20	1 Sep 21
RUS	14 May 19	27 May 20	30 Apr 21			30 Aug 21
USA	10 Jun 19					
FRA-SP	14 Mar 19	8 May 20	21 Jun 21			
UKR						

5. Research Activities

a) Biological Sampling

i) Report on activities in 2020/2021

STACREC reviewed the list of Biological Sampling Data for 2020 prepared by the Secretariat and noted that any updates will be inserted during the summer. The SCS Document was finalized for the September 2021 Meeting.

Report by National Representatives on commercial sampling conducted

Designated experts were asked to provide some information on whether the limitations from COVID-19 impacted the ability of observers to collect commercial information. This was agreed to be done on a stock by stock basis, but overall it was seen that although there was reduced sampling from Spanish trawlers and possibly other fleets, some sampling was available for 2020.

Canada-Newfoundland (SCS Doc. 21/08, plus information within various SC assessment documents):

Information was obtained from the various fisheries taking place in all areas from Subareas 0, 2, 3 and portions of Subarea 4. Information was included on fisheries for the following stocks/species: Greenland halibut (SA 2 + Div. 3KLMNO), Atlantic salmon (SA 2+3+4), Arctic char (SA 2), Atlantic cod (Div. 2GH, Div. 2J+3KL, Div. 3NO, Subdiv. 3Ps), American plaice (SA 2 + Div. 3K, Div. 3LNO, Subdiv. 3Ps), witch flounder (Div. 2J3KL, 3NO, 3Ps), yellowtail flounder (Div. 3LNO), redfish (Subarea 2 + Div. 3K, 3LN, 3O, 3P4V), Northern shrimp (Subarea 2 + Div. 3KLMNO), Iceland scallop (Div. 2HJ, Div. 3LNO, Subdiv. 3Ps, Div. 4R), sea scallop (Div. 3L, Subdiv. 3Ps), snow crab (Div. 2J+3KLNO, Subdiv. 3Ps, Div. 4R), squid (SA 3), thorny skate (Div. 3LNOPs), white hake (Div. 3NOPs), lobster (SA 2+3+4), capelin (SA 2 + Div. 3KL), and marine mammals (SA 2,3, and 4). Additionally, a summary of recent stock assessments and research projects on several of marine species are included in this report.

Denmark/Faroe Islands (SCS 21/10):

Data on catch rates were obtained from trawl and longline fisheries in NAFO Div. 3M for Atlantic cod from 2014 to 2019 2020 (n=1219, NAFO-observers). Length frequencies (NAFO-observers and crew members) were also available from 2014 to 2019 2020 (number of samples, n=219230). In addition, weight measurements were taken by crew members from 2014 to 2019 2020 (n=8394). The fishery has been conducted exclusively by longliners since 2017.

Denmark/Greenland (SCS 21/11):

Data on catch rates were obtained from trawl, gillnet and longline fisheries in NAFO Div 1A-F for American plaice, Arctic char, Atlantic halibut, Atlantic salmon, Atlantic cod, capelin, snow crab, Greenland cod, Greenland halibut, roundhead grenadier, roundnose grenadier, haddock, herring, lumpfish, polar cod, Arctic cod, deep-sea redfish, golden redfish, saithe, scallops, sea cucumber, Greenland shark, dogfish shark, Northern shrimp, skate, tusk, and wolffish. Length frequencies, from Greenland, were available for Greenland halibut trawl fishery in 1AB and 1CD, longline fishery in 1A, 1C and 1D inshore, and gillnet fishery in 1A inshore; and for cod trawl fishery offshore in Div. 1F; from the longline fishery in 1A, and 1D inshore, from the gillnet fishery 1A inshore, with handlines in 1C and 1D inshore, and from pound nets in 1C-D inshore. A total of 314 length samples were taken, and 52047 individuals, including Greenland halibut, cod and shrimp were measured, in NAFO Div. 1-F. A total of 1612 otoliths in Div. 1A-F from cod, Greenland halibut and herring were collected. Also, 562 DNA samples in 1F from cod and 1A, 1C, 1D and 1F from Greenland halibut were collected. A total of 31 stomachs from herring were collected.

EU-Germany (NAFO SCS Doc 21/07):

Data on catch rates were obtained from trawl catches for Greenland halibut in Div. 1C and 1D.

EU-Estonia (NAFO SCS Doc. 21/13):

Catch rate data was obtained from two fishing vessels in Subarea 3 (one for the full year and one for only 5 months). The main target species were redfish, cod and Greenland halibut. NAFO observers took length samples of these species and yellowtail flounder. The number of samples was reduced by almost half in 2020 but the number of fish measured was reduced by only one third compared to the previous year.

EU-Portugal (NAFO SCS Doc. 21/05):

Data on catch rates were obtained from trawl catches for: redfish (Div. 3LMNO); Greenland halibut (Div. 3LMN) and cod (Div. 3M). Data on length composition of the catch were obtained for: redfish (*S. mentella*) (Div. 3LMNO); American plaice (Div. 3MNO); cod (Div. 3MN); Greenland halibut, redfish (*S. marinus*) and roughhead grenadier (Div. 3LM); thorny skate and witch flounder (Div. 3M).

EU-Spain (NAFO SCS Doc. 21/06) :

A total of 10 Spanish trawlers operated in Div. 3LMNO NAFO Regulatory Area (NRA) during 2020, amounting to 1,200 days (19,051 hours) of fishing effort. Total catches for all species combined in Div. 3LMNO were 16,339 tons. Although there were NAFO observers (NAFO Observers Program) present, only one IEO scientific observer was onboard Spanish vessels during 2020, comprising a total of 31 observed fishing days, around 3% coverage of the total Spanish effort. Besides recording catches, discards and effort, this observer carried out biological sampling of the main species taken in the catch. For Greenland halibut, roughhead grenadier, American plaice and cod this includes recording weight at length, sex-ratio, maturity stages, performing stomach contents analyses and collecting material for reproductive studies. Otoliths of these four species were also taken for age determination. In 2020, 37 length samples were taken, with 4,816 individuals of different species examined to obtain the length distributions.

Due to the special COVID-19 pandemic situation that has occurred in 2020, the information available on Spanish commercial fishing activity in the NRA is quite poor.

Japan (NAFO SCS Doc. 21/04):

Since 2016, one Japanese otter trawler operated in Div. 3L and 3M. The total catch including discards was 1,765 tons. Target species (main fishing Divisions) (catch) were Greenland halibut (3L) (1,075 tons), redfish (3LM) (1,058 tons). Number of size measurements in 2020 for Greenland halibut and redfish were 2,950, and 1,900 respectively. There were no catches of yellowtail flounder in 2020.

Russia (NAFO SCS Doc. 21/09):

Catch rates were available from Greenland halibut (Divs. 1ACD, 3LMN, with bycatch statistics), Atlantic cod (Div. 3LMNO), redfish (Divs. 3LN, 3M, 3O, with bycatch statistics), yellowtail flounder (Div. 3N), skates (Div. 3LMNO), witch flounder (Div. 3LMNO), roughhead grenadier (Div. 3LM), roundnose grenadier (Div. 3LN), white hake (Div. 3NO) and Atlantic halibut (3LMNO). Length frequencies were obtained from Greenland halibut (Divs. 1A, 1D, 3LMN), redfish (*Sebastes fasciatus* in Divs. 3LN, *S. mentella* in Div. 3L), roughhead grenadier (Divs. 3LM), roundnose grenadier (Divs. 3LM), witch flounder (Divs. 3L), skates (*Amblyraja radiata* in Divs. 3LM), blue wolffish (Divs. 3LM), blue antimora (*Antimora rostrata* in Divs. 3LM), black dogfish (*Centroscyllium fabricii* in Div. 3O), threebeard rockling (*Gaidropsarus vulgaris* in Div. 3L), red hake (*Urophycis chuss* in Div. 3L), greater eelpout (*Lycodes esmarkii* in Div. 3L) and Marlin-spike grenadier (*Nezumia bairdii* in Div. 3L). Age-length distribution for Greenland halibut in Divs. 3LMN, as well as statistics on marine mammal occurrences and VME indicator species catches, are also available.

USA (SCS Doc. 21/16):
The report described catches and survey indices of 37 stocks of groundfish, invertebrates and elasmobranchs. Of note, no indices for 2020 were available due to COVID-19. Research on the environment, plankton, finfishes, marine mammals, and apex predators were described. Descriptions of cooperative research included a longline survey in the Gulf of Maine and Shark tagging. Other studies included age and growth, food habits, tagging studies, and observer trips.

b) Biological Surveys

i) Review of survey activities in 2020 and early 2021 (by National Representatives and Designated Experts)

The May 3, 2021, meeting also reviewed the survey activities and data by contracting parties prior to the Scientific Council meeting in June and to evaluate whether the survey coverage was useful for stock assessments, especially pertaining to limitations of the COVID-19 pandemic. The Canadian Spring survey was not carried out in 2020, nor was the EU-Spain 3NO or 3L surveys.

Canada – Newfoundland and Labrador (SCR Doc. 21/04):

Research survey activities carried out by Canada (Newfoundland and Labrador Region) were summarized, and stock-specific details were provided. Canada-NL conducts two stratified random multispecies bottom trawl surveys per year, both using the Campelen 1800 survey trawl. In 2020, the spring multispecies survey was cancelled due to the emerging Covid-19 pandemic. The 2020 autumn RV survey went ahead with enhanced safety protocols. The autumn survey was conducted from late-August to mid-December in Divs. 2HJ3KLNO, and successfully completed 472 out of 674 planned tows (70%), covering 174 out of 211 planned strata (82%). The autumn survey fishes to a maximum depth of 1500m in 2HJ3KL and 732m in 3NO.

The cancelling of the spring survey and the reduced coverage of the autumn survey add to a recent trend of survey coverage issues in the Canada-NL surveys. In general, extensive mechanical delays during both spring and autumn surveys in recent years have resulted in reduced survey coverage, interchange of research vessels outside of their normal area coverage pattern and have extended the time required to complete surveys of the individual divisions. The autumn survey has had particular trouble covering the deep strata in Div. 2H and Div. 3L. In addition, Divs. 3NO were completely excluded from the 2014 autumn survey. Spring surveys have generally provided good coverage of the survey area prior to 2014 but coverage of Div. 3L has been poor and incomplete in three of the last five years. Deficiencies in these surveys combined with those over 1995-2008 (see Brodie and Stansbury, 2007, Healey and Brodie, 2009) impact the assessments of many groundfish and invertebrate stocks to varying degrees, uncertainties which are typically not factored into the assessment results nor management advice. Nevertheless, recent negative trends in survey indices for several Grand Bank stocks raise concern over the status of many of the fishery resources in this area and poor survey coverage results in a higher degree of uncertainty with respect to monitoring and understanding the ecosystem changes that appear to be occurring in this area.

STACREC noted continued concern over deficiencies in the spatial coverage of the Canadian surveys in recent years, and the potential impact on the ability to detect signal from noise in regard to evaluating trends in biomass and abundance of various species. The reduced survey coverage is generally considered to have led to increased, albeit unquantified, uncertainty with respect to the provision of scientific advice. In addition to impacts on individual stock assessments, deficiencies in survey coverage also add uncertainty to the results of research on environmental (STACFEN) trends and ecosystem status, functioning and productivity (WG-ESA).

Canada – Subarea 0

There was no survey in Subarea 0 during 2020.

Denmark/ Greenland (SCR 20/02, 11, 12, 13, 14,15)

Two hydrographic cruises were carried out across the continental shelf off West Greenland to sample 10 standard sections onboard the chartered Islandic C/V Helga Maria, during the period June 6 to July 26, 2020 (NAFO 1A- B), and onboard the Royal Danish Navy vessel Hdms Lauge Koch during the period May 29 to June 2, 2020 (NAFO 1B-F). Data from three offshore stations were taken to document changes in hydrographic conditions off Southwest Greenland (NAFO Div. 1D-F). Results were presented as Scientific Council Research Document.

The Greenland Shrimp and Fish trawl survey in West Greenland in NAFO Div. 1A-F (50 - 600 m) was initiated in 1988. From 1988 to 1900, several vessels conducted the survey. From 1991 to 2017, the surveys were conducted onboard R/V Paamiut. In 2018-2020, two different charter vessels were used, Sjudarberg and Helga Maria, respectively, which used all the standard gear from the research vessel Paamiut (cosmos trawl, doors, all equipment such as bridles, etc., and Marport sensors on doors and headlines), in an effort to make the surveys as identical as possible with the previous years' surveys. The effect of the survey vessel change has been examined by looking at gear performance variables and survey length frequencies. The performance of all variables examined remained relatively stable with the three different vessels suggesting that the indices can be comparable. In 2021, the survey was carried out between June 6 – July 14, onboard C/V Helga Maria using the Cosmos gear with a mesh size 20 mesh liner in the cod-end. The survey follows a buffered stratified random sampling. A total of 251 valid hauls were conducted. Survey results including biomass and abundance indices for Greenland halibut, cod, deep see redfish, golden redfish, American plaice, Atlantic wolfish, spotted wolfish, and thorny skate were presented as Scientific Council Research Documents.

The Greenland halibut gillnet surveys in 1A inshore were initiated in 2001, in the Disko Bay. The survey normally covers four transects and each gillnet set is compiled of five different nets with different mesh size (46, 55, 60, 70 and 90 mm half mesh). From 2013 to 2015, the surveys in Uummannaq and Upernavik gradually changed from longline surveys to gillnet surveys. Surveys are conducted with the R/V Sanna. In 2020, 38, 46 and 46 gillnet stations were set in Disko Bay, Uummannaq and Upernavik, respectively. Results are presented as three Scientific Research Documents.

The Greenland halibut bottom trawl survey in 1D inshore (Nuuk, Ameralik and Qarajat fjords) was initiated in 2015. The survey has been conducted with the R/V Sanna equipped with a 1440 mesh bacalao trawl. The survey is bottom stratified with fixed stations (stations were selected where bottom conditions allow bottom trawling). A total of 18 valid stations were conducted, in 2020. Survey results, including biomass and abundance indices for Greenland halibut, shrimp, deep-sea redfish and Golden redfish, were presented as Scientific Council Research Document.

EU-Spain and EU-Portugal (SCR 21/05):

The Spanish bottom trawl survey in NAFO Regulatory Area Div. 3NO or 3L (Flemish Pass) was not conducted in 2020 due to the COVID pandemic.

The EU (Spain and Portugal) bottom trawl survey in Flemish Cap (Div. 3M) was carried out on board R/V Vizconde de Eza using the usual survey gear (Lofoten) from 30 June to 29 July 2020. The area surveyed was extended up to depths of 800 fathoms (1460 meters) following the same procedures as in previous years and 181 fishing stations planned. A total of 181 valid hauls were made (184 in total), 120 up to 730 meters depth and 61 up to 1460 meters. Survey results including abundance indices of the main commercial species and age distributions for cod, redfish, American plaice, Greenland halibut, roughhead grenadier, squid and shrimp are presented. The general indexes for this year are estimated taken into account the traditional swept area (strata 1-19, up to depths of 730 m.) and the total area surveyed (strata 1-34, up to depths of 1460 m.).

VME data from the 2020 EU (Spain and Portugal) bottom trawl groundfish survey in NAFO Regulatory Area (Div. 3M):

New data on deep-water corals and sponges were presented from the 2020 EU-Spain and Portugal bottom trawl groundfish survey. The data was made available to the NAFO WG-ESA to improve mapping of Vulnerable Marine Ecosystem (VME) species in the NAFO Regulatory Area (Divs. 3LMNO). Distribution maps of presence and catches above threshold for RV data of sponges (100 kg/tow), large gorgonians (0.6 kg/tow), small gorgonians (0.15 kg/tow) and sea pens (1.3 kg/tow) were presented.

Sponges: Sponges were recorded in 47 of the 184 tows (25.5% of the total tows analyzed), with depths ranging between 141 - 1166 m. No significant catches of sponge (≥ 100 kg/tow) were found.

Large Gorgonians: Large gorgonians were recorded in 2 of the 184 tows (1% of total tows analyzed), with depths ranging between 806 - 940 m. None of the tows had significant catches of large gorgonians (≥ 0.6 kg/tow).

Small Gorgonians: Small gorgonians were recorded in 15 tows (8.15 % of total tows analyzed), with depths ranging between 567 - 1250 m. No significant catches (> 0.2 kg/tow) were recorded.

Sea Pens: Sea pens were recorded in 59 tows (32% of total tows analyzed), with depths ranging between 182 - 1423 m. No significant catches (> 1.3 kg/tow) were recorded.

NEREIDA

Research in support of the re-assessment of NAFO Bottom Fisheries in 2021 under the EU NEREIDA project was presented in WG-ESA 2020. An update on the description and classification of the different fisheries and distribution of fishing effort in the NRA for a four-year period (2016 to 2019) was conducted. This characterization of the different demersal fisheries was done on the basis of two data sources: Haul by haul logbook information and Vessel Monitoring System (VMS) data. Two analyses were presented on the quality and coverage of VMS and logbooks data. Additionally, an overlay analysis to estimate the area of VME polygons that was overlapped by the 2016 to 2019 cumulative fishing effort and fisheries-specific effort layers was conducted.

This work was conducted as part of the NEREIDA project funded by the European Commission under Grant Agreements SI2.770786; SI2.793318 and SI2.827558.

ATLAS

Available information from EU-Spain groundfish surveys (Div. 3L, 2006-2019 period) regarding marine mammals and seabirds' distribution, behaviour and interaction with fishing were presented during 2020. The work was developed in collaboration with BIOESLE project.

Regarding seabed litter, the Spanish Institute of Oceanography (IEO) developed a protocol to be used in all the EU groundfish surveys in the NRA. It was developed in collaboration with BIOESLE and Clean Atlantic projects. The objective of the protocol is to expand the seabed litter data collection started in year 2006 in the Flemish Pass (Div. 3L) to the other areas sampled by the EU surveys: Flemish Cap (Div. 3M) and the Grand Banks (Divs. 3NO) using the same methodology and standardized forms. In 2020, data on seabed litter was collected during the EU Spain and Portugal Flemish Cap survey (Div. 3M).

An updated map showing the geographical location of oil and gas activities in NAFO Divs. 3LMN was presented during the 2020 WG-ESA. The map showed the overlap and potential conflicts between different users of the marine space (e.g. oil and gas vs. fisheries) and between users and marine environment (oil and gas vs. VMEs). Furthermore, an update on oil and gas incidents that occurred within the NAFO Convention area during 2020 year was presented. Both map and incidents list were obtained from publicly available information

USA (SCS Doc. 21/16):

The US conducted a spring survey in 2020 covering NAFO Subarea 6 aboard the FSV *Henry B. Bigelow*. Due to COVID-19 pandemic only 133 stations out of the normal 350-380 were successfully completed. No fall survey was conducted.

c) Other Research Activities

No items were reported for this section.

6. Other Matters

a) Report on data availability for stock assessments (by Designated Experts)

During the 2019 STACREC meeting, it was suggested that there should be a better organized process for requesting and submitting data for stock assessment and other processes, such as National Research Reports. There was no time to discuss this again during the 2021 meeting, but it is an item to be discussed in a future STACREC meeting.

b) Annual submissions of information to NAFO: National Research Reports, Inventories of biological surveys, List of biological sampling data, List of tag releases, RV surveys on a stock by stock basis

Discussions on the above information has been ongoing for the past two years and further discussion will continue in June 2022 (or the next face-to-face meeting).

National Research Reports: STACREC concluded that these reports are useful, and they should continue to be produced. Discussions will continue in the future on the best format for the National Research Reports. The needed direction may be towards a National Sampling Report instead of a National Research Report. It was noted that a tool, e.g. Rmarkdown, could be useful for producing consistent reports.

Further discussion will be deferred until June 2022.

List of biological sampling data: This information is annually collated into an SCS document in Excel format. It was concluded that there is utility in the information provided in the current tables and in having the information publicly available as is the case with the current SCS document. No changes were suggested at this stage.

RV surveys on a stock by stock basis: STACREC will continue to develop a format for these tables. It was agreed in 2019 that STACREC members preferred Excel spreadsheets rather than text files.

Inventories of biological surveys: STACREC recommended that this information no longer be collected in 2020 and that the SCS be discontinued after 2019, subject to confirmation in September 2019.

List of tag releases: STACREC recommended that this information no longer be collected in 2020 and that the SCS be discontinued after 2019.

c) Review of Greenland halibut deep-water surveys in Northwest Atlantic Fisheries Organization Divisions Subareas 0 and 1 offshore (SCR 21/008)

Research surveys have been conducted in Northwest Atlantic Fisheries Organization (NAFO) Subarea 1 by Greenland since 1997 and in Subarea 0 by Canada since 1999, using the R/V Paamiut fishing with an Alfredo III bottom trawl. Indices from Divs. 0A-South and 1CD are combined to provide an overall index for the Greenland halibut stock in NAFO 0+1 offshore. The surveys follow a depth stratified random sampling design and until 2003 sets were selected using a random number draw of grid cells within depth strata. In 2004, the independent and random placement of stations was replaced by a buffered random sampling to automatically avoid selecting stations in adjacent cells. The Greenlandic surveys also adopted a variance-based approach to determine the number of stations to allocate to each stratum. This method optimizes set distribution among the depth strata based on variance in Greenland halibut biomass from past surveys, instead of having the same number of stations proportional to the strata area each year. In 2021, surveys will be conducted with a new vessel (R/V Tarajoq) and a new trawl gear (Bacalao 476). These changes in vessel and gear provide an opportunity to review past practices and improve the surveys. The research document presents proposed changes in survey design and sampling protocols for review and comment by members of STACREC.

d) Faroese longline survey of cod in Div. 3M (SCWP 21/012)

During the June 2021 SC meeting, a letter from the Faroe Marine Research Institute was forwarded by the NAFO secretariat to CPs and NAFO officials, indicating that this institute would be conducting a scientific survey in NAFO Division 3M during June/July 2021. This prompted SC to request, via STACREC, a presentation about this planned survey. A presentation was given to STACREC describing this longline survey. This survey was presented by the Faeroe Islands as a complement to the EU Div. 3M bottom trawl research survey. It is a longline survey in waters less than 600 m, with approximately 100 sets with 6000 hooks each. The survey is conducted by a commercial fishing vessel without scientific personnel on board, and where catch will be recorded, identified, and sampled (length, weight and otoliths) by the fishing crew. This is primarily a cod survey, however Atlantic halibut and other bycatch (including VME species) would be expected to be caught.

In principle, a longline survey may provide additional information on the ecosystem in 3M. However, STACREC noted that the proposed survey design was insufficient (e.g. lack of proper consideration of number of hooks, stratification, catchability) to consider this as a valid scientific survey; an appropriate survey design, together with objectives and detailed survey protocols, is required to properly assess the potential scientific value of the data collected.

Moreover, in September 2021, STACREC was made aware that the catch from this survey totalled 630 t, accounting for removals equal to roughly 42% of the TAC of 1500 t. For context, the EU bottom trawl survey of Div. 3M which constitutes the most important fishery independent data for the assessment, took about 7 t in total of cod in 2021. This indicates that the Faroe Islands longline survey is not optimized for the collection of information with minimum impact, as would be the case for a typical scientific survey.

With the information currently available, STACREC considers that this initiative does not fulfil the requirements of a valid scientific survey and more closely resembles a commercial fishery.

STACREC notes that protocols from Article 4 in the Conservation and Enforcement Measures (NAFO COM Doc 21/01) do not require review of proposed survey research plans and confirmation of their scientific validity by SC. **STACREC recommends** that *the Commission amend this procedure to include a scientific review of proposed research surveys in the NRA to ensure scientific best practices are followed.*

7. Adjournment

The meeting was adjourned on September 24, 2021.

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

Chair: Katherine Sosebee Rapporteur: Tom Blasdale

I. OPENING

The Committee met by correspondence from 20 to 24 September 2021 to consider the various matters in its agenda. Representatives attended from Canada, Denmark (in respect of Faroe Islands and Greenland), the European Union, France (in respect of St. Pierre et Miquelon) Japan, Norway, the Russian Federation, the United Kingdom and the United States of America. The Executive Secretary, Scientific Council Coordinator and other members of the Secretariat were in attendance.

II. ASSESSMENTS DEFERRED FROM THE JUNE 2020 MEETING.

1. Northern Shortfin Squid (*Illex illecebrosus*) in SAs 3+4

Interim Monitoring Report (SCR Doc. 98/59, 75; 6/45; 16/21, 34REV; 19/ 42; 20/2, 10REV, 11; SCS Doc. 21/05, 06, 16)

a) Introduction

Illex illecebrosus has a lifespan of less than one year and is considered a single stock throughout its range from Newfoundland to Florida, in NAFO Subareas 2-6. However, the Subareas 3+4 and Subareas 5+6 stock components are assessed and managed separately by NAFO and the U.S.A. Mid-Atlantic Fishery Management Council, respectively. The Canada Department of Fisheries and Oceans (DFO) has no fishery management plan for the *Illex* fisheries that occur within their Exclusive Economic Zone (EEZ) in Subarea 3, the Newfoundland commercial and recreational inshore jig fisheries, and Subarea 4 (the historical Scotian Shelf bottom trawl fishery). The small *Illex* fishery that occurs off St. Pierre et Miquelon within the EEZ of France (in respect of St. Pierre et Miquelon) is also not managed. The stock assessment is data-poor and in-season stock assessments and annual biomass projections are not currently possible. Therefore, as of 2019, the SA 3+4 *Illex* assessments have been conducted in September instead of June to be able to incorporate the Div. 4VWX July survey indices for the current year. Indices of relative biomass and mean body weight were computed using data from the Div. 4VWX July surveys conducted by the DFO. These indices were used to assess stock status (i.e., whether the Subareas 3+4 stock component was at a low or high productivity level) during the current year. The Subareas 3+4 nominal catch divided by the Div. 4VWX biomass index was used to assess annual relative exploitation rates. Such rates can only be computed through year *t*-1 because squid catch data for the current year are not generally available in time for the September assessment.

b) Data Overview

Since 1999, there has been no directed fishery for *Illex* in Subarea 4 and most of the catches from Subareas 3+4 have been primarily from the Subarea 3 inshore jig fishery. However, there were no catches from Subarea 3 during 2013-2015. During 1999-2011, catches from Subareas 3+4 were low during most years (average = 1078 t), compared to catches during 1976-1981 (average = 80 645 t), and ranged between about 57 t in 2001 to 6 981 t in 2006 (Figure 1.1). During 2007-2015, catches were much lower and averaged 351 t during 2007-2011 and 27 t during 2012-2015. However, recent catches increased more than fourfold between 2017 (383 t) and 2018 (1 545 t) then gradually increased to 3 872 t in 2020, which was 54% greater than the 1982-2016 low productivity period average (2 510 t) but well below the 1976-1981 high productivity period average (80 645 t). During 2000-2020, only 3 % of the 34 000-t TAC for Subareas 3+4 was harvested on average, with a peak of 21% in 2006 and 11% in 2020. Only 11% of the Subareas 3+4 catch was harvested within the NRA during 2020. Thus, catches in Subareas 3+4 are not limited by the current NAFO quota. There is no quota for the jig fishery that occurs within Canada's EEZ.

Recent catches and TACs ('000 t) are as follows:

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
TAC SA 3+4	34	34	34	34	34	34	34	34	34	34
STATLANT 21 SA 3+4	0.2[1]	<0.1[1]	0.1[1]	0.1[1]	<0.1[1]	<0.1[1]	0.4[1]	1.4[1]	2.8[1]	3.9[1]
STATLANT 21 SA 5+6[2]	18.2	11.7	3.8	8.8	2.4	6.7	22.5	24.1		
STACFIS SA 3+4	0.1	<0.1	<0.1	<0.1	<0.1	0.2	0.4	1.5	2.9	3.9
STACFIS SA 5+6[2]	18.8	11.7	3.8	8.8	2.4	6.7	22.5	24.1	27.2	28.1
STACFIS Total SA 3-6[3]	18.9	11.7	3.8	8.8	2.4	6.9	22.9	25.6	30.1	32.0

1 Includes catches (<0.1 t to 53 t during 2011-2020) reported as 'Unspecified Squid' from Subarea 4 because they were likely *I. illecebrosus* based on the geographic distribution of this species versus *Doryteuthis pealeii*.

2 Catches from Subareas 5+6 are included because there is no basis for considering separate stocks in Subareas 3+4 and Subareas 5+6. USA STATLANT 21 catches were not reported to NAFO for any species during 2019 and 2020.

3 STACFIS Total SA 3-6 catches were computed as catches harvested in the NRA (2011-2017 from STALANT 21 database; 2018 onward from NAFO CESAG database) plus catches recorded in the USA and CA (Newfoundland and Maritimes Regions) commercial catch databases.

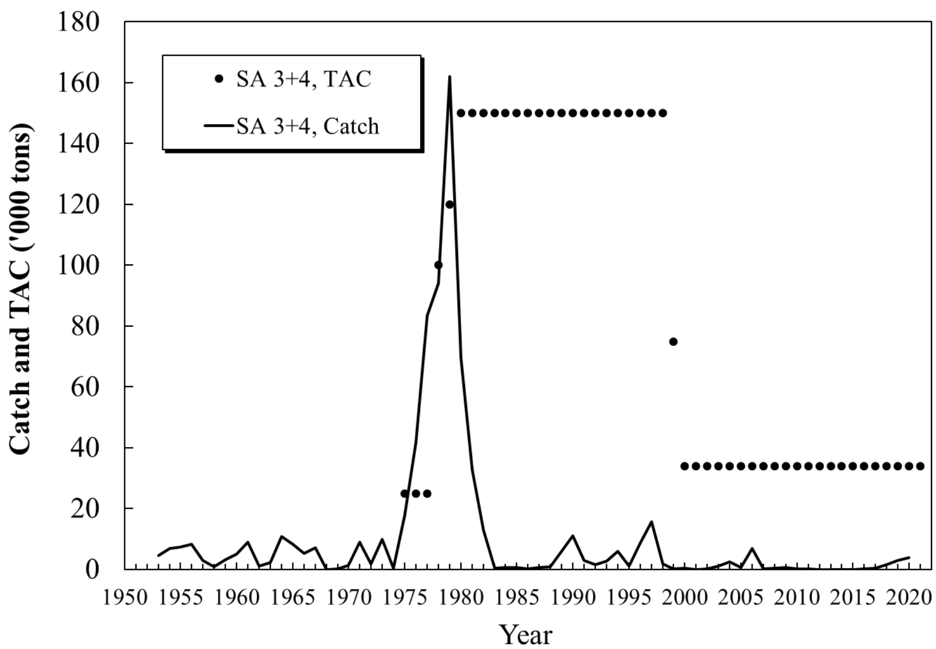


Figure 1.1. Northern shortfin squid in Subareas 3+4: nominal catches and TACs.

Relative biomass indices, derived using data from the Canadian surveys conducted during July in Div. 4VWX, exhibited several distinct periods. Biomass indices averaged 13.2 kg per tow during the high productivity period (1976-1981) and 2.6 kg per tow during the low productivity period (1982-2016). A third distinct period in biomass trend occurred from 2017 onward and consisted of very high biomass indices during two non-consecutive years followed by a large decrease in 2020. Biomass indices fluctuated widely after 2003 (Figure 1.2), but generally declined between 2004 and 2013, from a level near the high productivity period mean of 13.2 to the lowest level on record, respectively. During 2014-2016, biomass indices remained much lower than 2.6 kg per tow, but then increased in 2017 (16.1 kg per tow) to the third highest level of the time series and was greater than the 1976-1981 high productivity period average. However, during 1982-2016, each year of high biomass (i.e., 1992, 2004 and 2006) during the low productivity period was followed by a much lower biomass level. Persistence of the high 2017 biomass level could not be confirmed in 2018 because a biomass index was not computed due to inadequate sampling of a majority of the *Illex* strata due to survey vessel mechanical problems. The 2019 biomass index was twice as high (32.1) as the 2017 index and was the second highest value in the time series. However, during 2020, the biomass index (8.2) decreased to a level below the high productivity period average but remained higher than all but two of the biomass indices during 1982-2016. The 2021 biomass index could not be computed because a new survey vessel and trawl were used to conduct the 2021 July Div. 4VWX survey and there are currently no conversion factors available with which to standardize the 2021 biomass index with the rest of the time series.

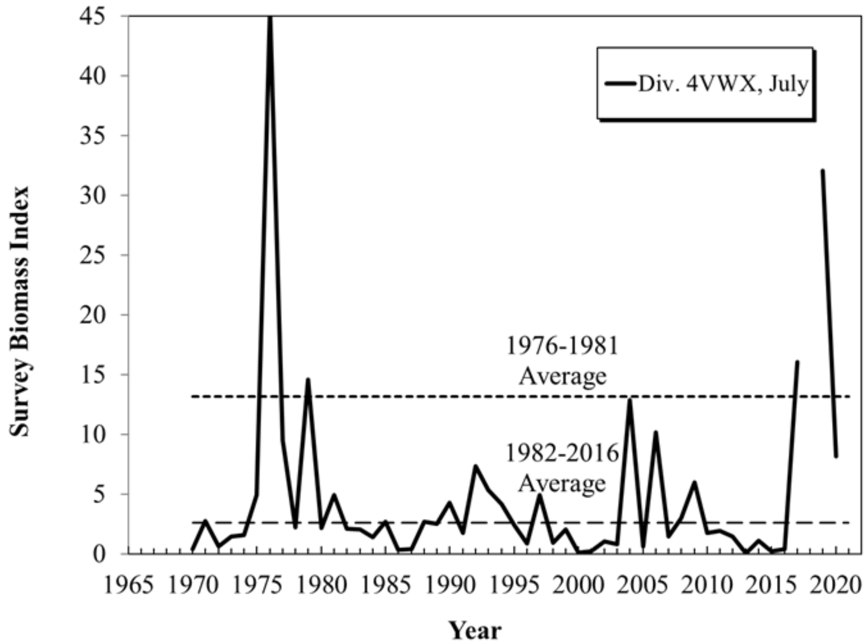


Figure 1.2. Northern shortfin squid in Subareas 3+4: survey biomass indices from the July survey in Div. 4VWX.

The mean body weight of squid caught during the July Div. 4VWX surveys averaged 150 g during the 1976-1981 high productivity period (1976-1981) and 80 g during the low productivity period (1982-2016). Mean body weight increased from the lowest level of the time series in 1983 (27 g) to the second highest level of the low productivity period (121 g) in 1999 (Figure 1.3). Between 2000 and 2006, mean body weight increased to a low productivity period peak of 137 g, but then gradually declined to 42 g in 2013. Following wide fluctuations around the low productivity average during 2014-2016, mean body weight increased to a level similar to 2006 in 2017 (134 g). For the reason explained above, mean body weight was not computed for 2018, so it is unknown whether mean body weight was above the high productivity period average for two consecutive years. During the 2019 assessment, the Scientific Council noted that the 2019 mean body weight (164 g) was above the high productivity period average for the first time since 1979 and concluded that the status of the Subareas 3+4 stock component may be moving toward a high productivity period. However, this level of high body weight did not persist for a second year and instead dropped below the high productivity period average in 2020 (123 g) but was greater than all but one year during 1982-2016. As noted in the biomass section above, there are no data available with which to compute the 2021 body weight index.

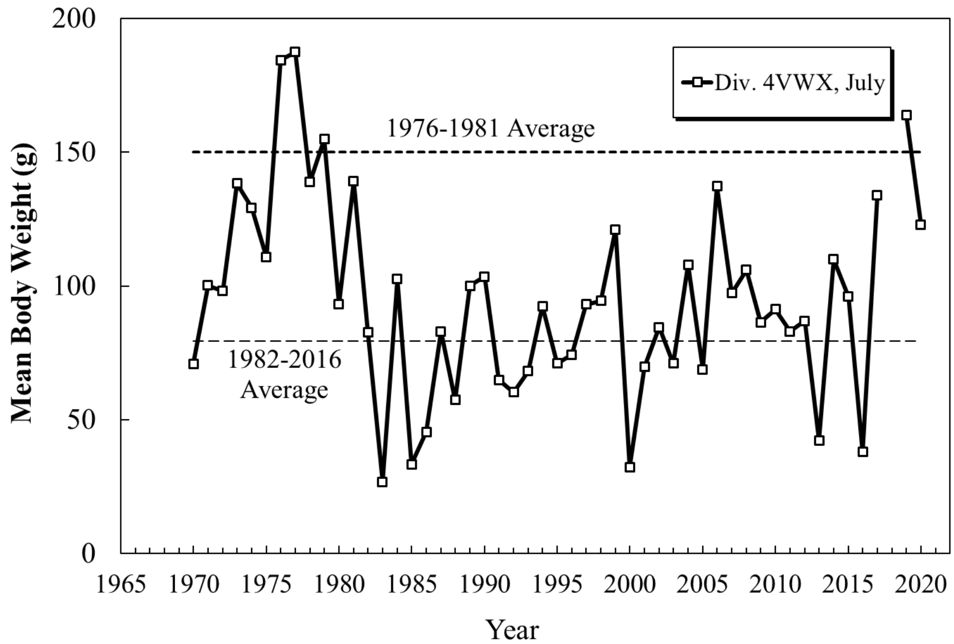


Figure 1.3. Northern shortfin squid in Subareas 3+4: mean body weights of squid from the July survey in Div. 4VWX.

Catch/biomass ratios (SA 3+4 nominal catch/Division 4VWX July survey biomass index) / 10 000) have been well below the 1982-2016 mean (0.12) during most years since 2001 and the ratio was 0.05 in 2020 (Figure 1.4). There is no Div. 4VWX biomass index available for 2021 for the reasons previously described. Although the survey index for the current year would normally be available, the Subareas 3+4 catches are never available in time for the September assessments.

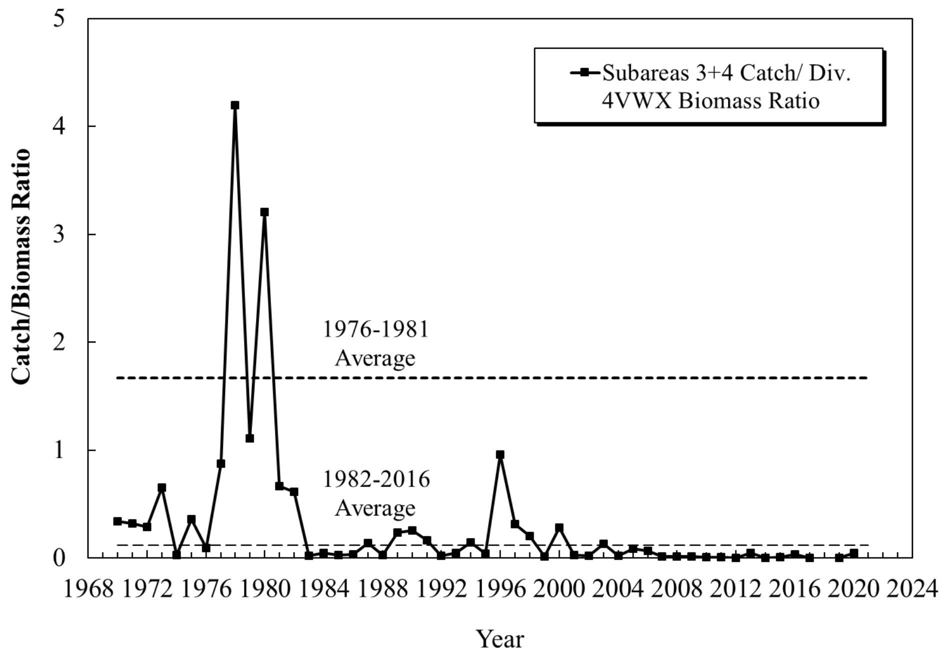


Figure 1.4. Northern shortfin squid in Subareas 3+4: catch/biomass ratios (SA 3+4 nominal catch/Division 4VWX July survey biomass index) / 10 000).

c) Conclusion

In 2020, the Scientific Council concluded (and the Commission adopted) that the large decrease in biomass and mean body size indices, from above the high productivity period average in 2019 to below it in 2020, and the continued low exploitation rates in recent years do not support an increase in the status quo catch advice (34 000 t).

Without a 2021 biomass index for the July Div. 4VWX survey, the survey in Subareas 3+4 that covers the largest area of *Illex* habitat at a time when the species has fully migrated onto the Scotian Shelf, there are no data available with which to change this advice, and therefore, the status quo catch advice of 34 000 t is recommended for 2022.

The next assessment is planned for 2022.

d) Research Recommendation

In 2013, STACFIS **recommended** that *gear/vessel conversion factors be computed to standardize the 1970-2003 relative abundance and biomass indices from the July Div. 4VWX surveys.*

STATUS: No progress has been made.

III. OTHER MATTERS

1. Nomination of Designated Experts (DE)

Kathy Sosebee (USA) will take over as DE for white hake and skate subject to agreement by her managers.

Ricardo Alpoim (EU) will continue as DE for redfish in Division 3M and provisionally for redfish in 3LN- for no more than one year. Canada will consider whether their new hire will take this over as DE for this stock.

2. Other matters

a) Review of SCR and SCS Documents

No SCRs were submitted to this meeting.

b) FIRMS Classification for NAFO Stocks

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

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

[1] Will be re-assessed at the SC shrimp meeting in October 2021
[2] Assessed as Greenland halibut in Div. 1A inshore
[3] Fishing mortality may not be the main driver of biomass for Div. 3M Shrimp and Redfish

3. Other business

No other items were discussed

IV. ADJOURNMENT

The meeting was adjourned on 24 September 2021.

PART D: REPORT OF THE NAFO/ICES *PANDALUS* ASSESSMENT GROUP (NIPAG) MEETING

1-4 November 2021

Contents

Recommended Citation

NAFO/ICES. 2021. Report of the NAFO/ICES *Pandalus* Assessment Group Meeting, 1 – 4 November 2021, WebEx. NAFO SCS Doc. 21/19.

REPORT OF THE NAFO/ICES *PANDALUS* ASSESSMENT GROUP (NIPAG)

Chair : Mark Simpson **Rapporteur :** Tom Blasdale

I. Opening

The NAFO/ICES *Pandalus* Assessment Group (NIPAG) met by WebEx on 1-4 November 2021, to review stock assessments referred to it by the Scientific Council of NAFO and by the ICES Advisory Committee. Representatives attended from Canada, Denmark (in respect of Greenland), European Union, Norway, Russian Federation and the United States of America. The NAFO Scientific Council Coordinator and Scientific Information Administrator were also in attendance.

II. General Review

1. Review of Research Recommendations in 2019 and 2020

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

2. Review of Catches

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

III. Stock Assessments

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

This stock was assessed during the 08-09 September 2021 meeting of the Scientific Council in conjunction with NIPAG (NAFO SCS Doc. 21/18. NIPAG reviewed the assessment during the present meeting. There were no further recommendations.

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

This stock was assessed during the 08-09 September 2021 meeting of the Scientific Council in conjunction with NIPAG (NAFO SCS Doc. 21/18). NIPAG reviewed the assessment during the present meeting. There were no further recommendations.

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

(SCR Docs. 04/075, 04/076, 08/006, 11/053, 11/058, 12/044, 13/054, 20/053, 20/054, 20/057, 20/058, 21/040, 21/041, 21/042)

Environmental overview (STACFEN report in SCS Doc. 21-17)

Recent Conditions in Ocean Climate and Lower Trophic Levels in NAFO OB

- The ocean climate index in Subarea 0-1 was normal in 2020;
- The initiation of the spring bloom was delayed for a second consecutive year in 2020;
- Total spring bloom production (magnitude) was near normal in 2020.

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. 3.1.A). After being in 2019 at its highest value since the record high of 2010, the index was normal in 2020. 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 but several notable late bloom onsets have been recorded during the late 2010s (Figure. 3.1.B). In 2020, the initiation of the spring bloom was later than normal for a second consecutive year. Spring bloom magnitude (total production) remained mostly below to near normal between 2003 and 2020 with the exception of a few highly productive bloom in 2006, 2015 and 2018 (Figure. 3.1.C). The late bloom onset observed in 2019 and 2020 are associated below or near normal total production for the corresponding years (Figure. 3.1.B-C).

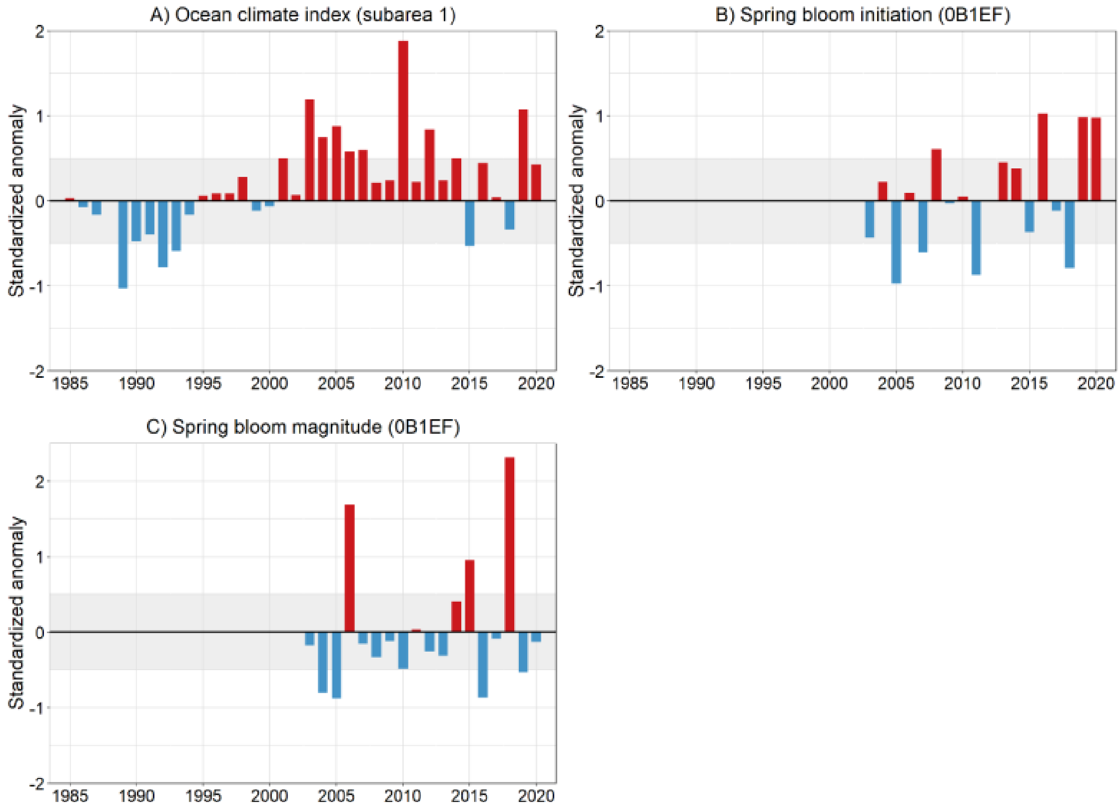


Figure 3.1. Environmental indices for NAFO Subarea 0 and 1. The climate index (A) for Subarea 0 and 1 is the average of 10 individual time series. These includes standardized anomalies of 4 SSTs time series, 4 temperature time series at 3 hydrographic stations and 2 air temperatures time series (see text for details). Phytoplankton spring bloom initiation (B) and magnitude (C) indices for the 2003-2020 period are derived from three satellite boxes covering NAFO Divisions 0B and 1EF (see text for details). Positive/negative anomalies indicate values above/below (or late/early timing) the long-term average for the reference period. Anomalies were calculated using the following reference periods: 1981-2010 for ocean climate index, 2003-2020 for spring bloom initiation and magnitude. Anomalies within ±0.5 SD (grey rectangle) are considered near normal conditions.

a) Introduction

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

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

Four fleets, one from Canada and three from Greenland (Kongelige Grønlandske Handel (KGH) fleet fishing from 1976 to 1990, the offshore fleet and coastal fleet) have participated in the fishery since the late 1970s. The Canadian fleet and the Greenland offshore fleets have been restricted by areas and quotas since 1977. The Greenland coastal fleet has privileged access to inshore areas (primarily Disko Bay and Vaigat in the north, and Julianehåb Bay in the south). Coastal licenses were originally given only to vessels under 80 tons, but in recent years larger vessels have entered the coastal fishery. Greenland allocates a quota to EU vessels in Subarea 1; this quota is usually fished by a single vessel which, for analyses, is treated as part of the Greenland offshore fleet. Mesh size is at least 40 mm in both Greenland, and Canada. Most trawlers in Greenland use mesh size at 44 mm and sorting grids, to reduce bycatch of fish are required in both of the Greenland fleets and in the Canadian fleet. Discarding of shrimps is prohibited.

The enacted TAC for Greenland Waters in 2021 was set at 115 000 t and for Canadian Waters, 15 937 t.

Greenland requires that logbooks catch is recorded as live weight. For shrimps sold to on-shore processing plants, a former allowance for crushed and broken shrimps in adjusting quota draw-downs was abolished in 2011 to bring the total catch live weight into closer agreement with the enacted TAC. Since 2012, *Pandalus montagui* has been included among the species protected by a 'moving rule' to limit bycatch and there are no licenses issued for directed fishing on it (SCR Doc. 20/054). Instructions for reporting *P. montagui* in logbooks were changed in 2011, to improve the reporting of these catches.

The table of recent catches was updated (SCR Doc. 21/040, 21/041). Total catch increased from about 10 000 t in the early 1970s to more than 105 000 t in 1992 (Figure 3.2). Actions by the Greenlandic authorities to reduce effort, as well as fishing opportunities elsewhere for the Canadian fleet, caused catches to decrease to about 80 000 t by 1998. Total catches increased to an average over 150 000 t in 2005 to 2008 but have since decreased to 72 256 t in 2015. Since 2016, the catches have been increasing in conjunction with increasing TACs and was in 2020, 113 117 t. The projected catch for 2021 is 108 000 t. The projected catch for Canada from Div. 0A in 2021 is expected to be in the region of 100 t.

Recent catches, projected catch for 2021 and recommended and enacted TACs (t) for northern shrimp in Sub-area 1 and Div. 0A (east of 60°30'W) are as follows:

	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
TAC										
Advised	90 000	80 000	80 000	60 000	90 000	90 000	105 000	105 000	110 000	115 000
Enacted[1]	114 425	100 596	97 649	82 561	96 426	101 706	114 873	119 875	125 229	130 937
Catches (NIPAG)										
SA 1	115 965	95 379	88 765	72 254	84 356	89 369	93 189	101 997	113 117	107 900[2]
Div. 0A	12	2	0	2	1 171	3 215	1 689	2 463	751	100[2]
TOTAL	115 977	95 381	88 765	72 256	85 527	92 584	94 878	104 440	113 868	108 000[2]
STATLANT 21										
SA 1	114 958	91 800	88 834	71 777	82 922	88 947	90 457	98 219	110 095	
Div. 0A	12	2	0	2	1 381	2 778	1 412	1328	204	

1Canada and Greenland set independent and autonomous TACs

2 Projected total catches for the year.

Until 1988 the fishing grounds in Div. 1B were the most important. The offshore fishery subsequently expanded southward, and after 1990 catches in Div. 1C–D, taken together, began to exceed those in Div. 1B. However, since 1998 catch and effort in southern West Greenland have continually decreased, and since 2008 effort in Div. 1F has been virtually nil (SCR Doc. 21/040). The fishery has moved north and, since 2009, about 80% of the total catch was taken in Div. 1A and 1B.

In 2002–2005 the Canadian catch was stable at 6000 to 7000 t - about 4–5% of the total - but since 2007 fishing effort has been sporadic and catches variable, averaging about 1750 t in 2007–11 and from 2012 to 2015 catches in Div. 0A did not exceed 5 t (SCR Doc. 21/040). In 2016 fishing increased in the Canadian EEZ and from 2016 to 2020, Canadian catches averaged about 1800 t.

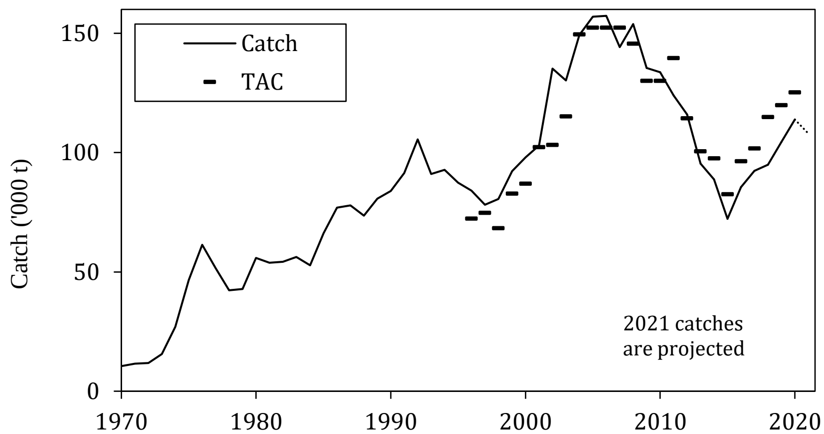


Figure 3.2. Northern shrimp in Subarea 1 and Div. 0A: Enacted TACs and total catches (2021 expected for the year).

b) Input data

i) Fisheries Data

Fishing effort and CPUE. Catch and effort data from the fishery were available from Greenland logbooks for Subarea 1 (SCR Doc. 21/040). In recent years both the distribution of the Greenland fishery and fishing power have changed significantly: for example, larger vessels have been allowed in a limited part of coastal areas; the coastal fleet has fished outside Disko Bay; the offshore fleet now commonly uses double trawls. Furthermore, quota transfers between the two fleets are now allowed. Catch data before 2004 were under-reported, which was corrected in 2008.

CPUEs were standardized by linearized multiplicative models including terms for vessel, month, gear type, year, and statistical area. Standardized CPUE series were done separately for three different fleets (Figure 3.3); the early offshore fleet fishing in Div. 1A and part of 1B (KGH-index, 1976-1990), the present offshore fleet fishing in Subarea 1 (1987-2021) and the coastal fleet fishing in coastal and inshore areas (1989-2021). 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 four years the CPUE of the coastal fleet has slightly decreased while the CPUE of the offshore fleet increased from 2016 to 2017 and dropped little from 2018 to 2020. The declining trend has stopped and half year data from 2021 indicating an increase in CPUE for both fleet components.

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.

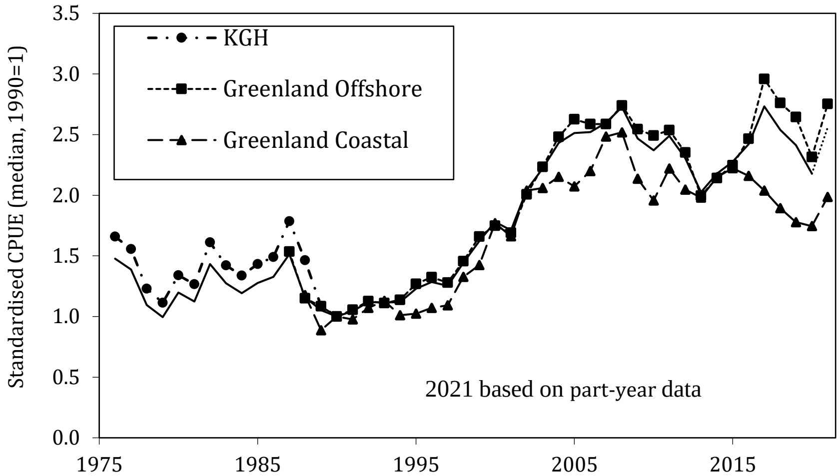


Figure 3.3. Northern shrimp in Subarea 1 and Div 0A: Standardized CPUE index series 1976–2021.

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.

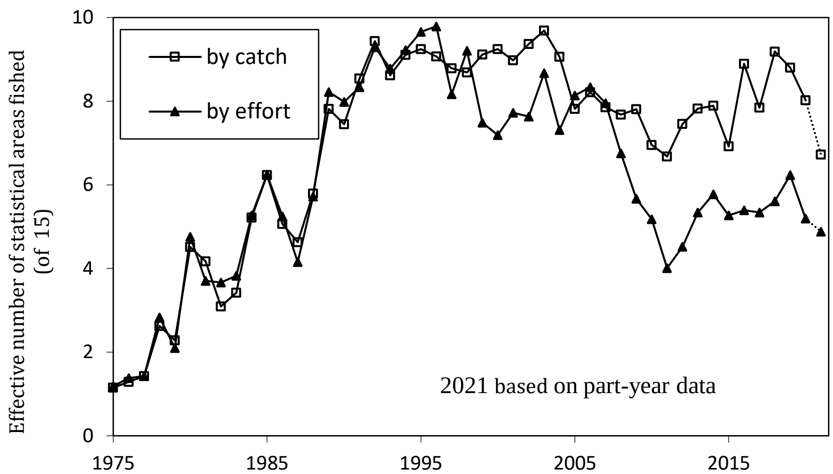


Figure 3.4. Northern shrimp in Subarea 1 and Div. 0A: Indices for the distribution of the Greenland fishery between statistical areas in 1975–2021.

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

a

No new survey data is available for 2021, due to the delay of delivery of the new Greenlandic research ship *r/v Tarajoq*.

Greenland trawl survey. Stratified semi-systematic trawl surveys designed primarily to estimate shrimp stock biomass have been conducted since 1988 in offshore areas and since 1991 also inshore in Subarea 1 (SCR Doc. 20/053). From 1993, the survey was extended southwards into Div. 1E and 1F. A cod-end liner of 22 mm stretched mesh has been used since 1993. From its inception until 1998 the survey used 60-min. tows, but since 2005 all tows have lasted 15 min. In 1988 to 2005 the *Skjervøy 3000* survey trawl used was replaced by a *Cosmos 2000* with rock-hopper ground gear, calibration trials were conducted, and the earlier data were adjusted.

In 2018 and 2019-2020, the annual trawl survey was conducted with two different chartered vessels during the same time period as the usual survey. All the standard gear from the research vessel Paamiut (such as cosmos trawl, doors, all equipment such as bridles etc., Marport sensors on doors and headlines) were used and all the standard research protocols were followed in an attempt to make the surveys as comparable as possible to earlier surveys. At least two crew members from Paamiut participated in each of the surveys. NIPAG therefore assumed that the 2018 and 2019-2020 results were directly comparable with the previous surveys, however without comparative fishing there remains some uncertainty. A more detailed description is available in SCR Docs. 20/053.

The survey average bottom temperature increased from about 1.7°C in 1990–93 to about 3.1°C in 1997–2014 but has since declined to 2.5° in 2019 and remained stable in 2020 (SCR Doc. 20/053). About 80% of the survey biomass estimate is in water 200–400 m deep throughout the time series. Since 2001 most of the biomass has been in water 200–300 m deep (SCR Doc. 20/053). The proportion of survey biomass in Div. 1E–F has been low in recent years and the distribution of survey biomass, like that of the fishery, has become more northerly.

Biomass. The survey index of total biomass remained fairly stable from 1988 to 1997. It then increased until 2003. Subsequent values were consecutively lower, with the second lowest level in the last 20 years occurring in 2014 (Figure 3.5) (SCR Doc. 20/053). Over the past 5 years biomass has increased. Offshore regions comprise 82% of the total survey biomass, and 18% is inshore in Disko Bay and Vaigat. The inshore regions have far higher densities and is almost three times as high as offshore (Figure 3.5) (SCR Doc. 20/053).

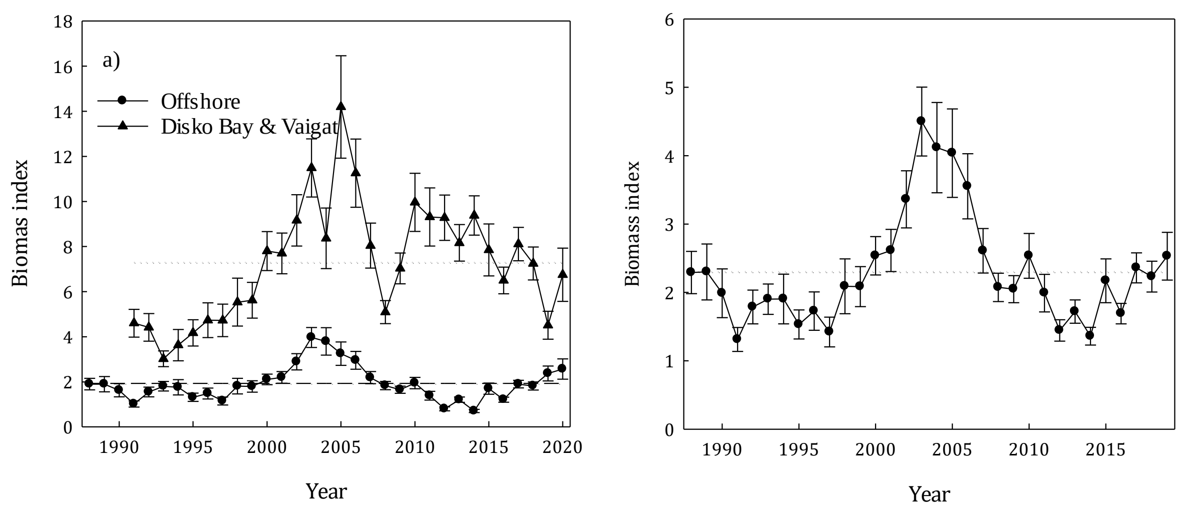


Figure 3.5. Northern shrimp in Subarea 1 and Div. 0A: Biomass index (survey mean catch rates) inshore and offshore (left panel) and overall (right panel) 1988–2020 (error bars 1 SE). Horizontal lines are the series average.

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

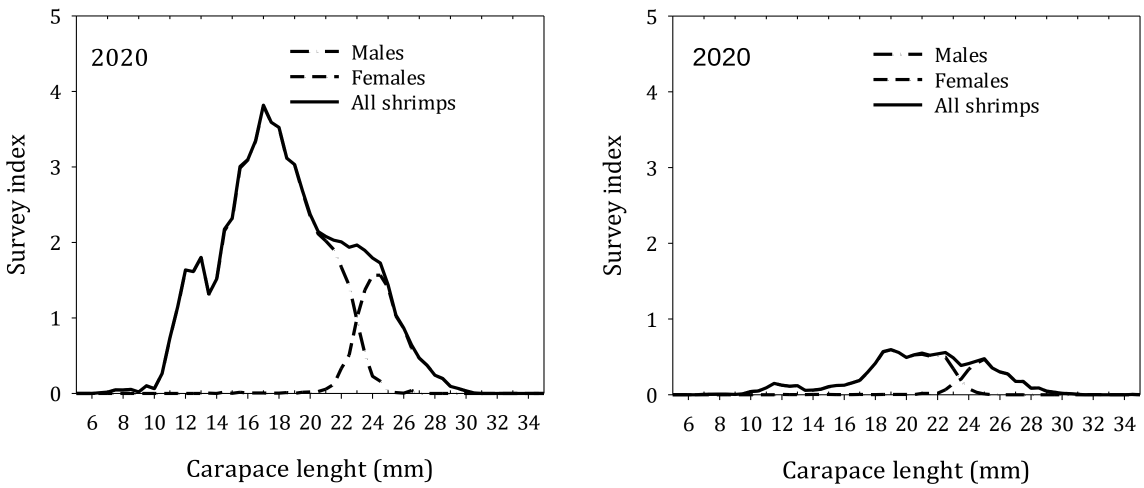


Figure 3.6. Northern Shrimp in Subarea 1 and Div. 0A: Survey mean catch rates at length in offshore regions (left) and Disko Bay & Vaigat (right) at the West Greenland trawl survey in 2020.

Recruitment. The number at age-2 (10.5 to 13.5 mm) reached a peak in 2000 and 2001 and has since declined to a much lower level, with three high values in 2015, 2019 and 2020. The pre-recruit index (14–16.5 mm, expected to recruit to next year's fishable biomass) had high values in 2002 -2005 (except in 2004) and has since fluctuated at a lower level, with relatively high values in 1999-2000 and again in 2015, 2017 and 2020 (SCR Doc. 20/053, 20/056) (Figure 3.7). Numbers of age-2 and pre-recruits in 2020 are above the 1993 to 2020 average, respectively.

Linear regression has shown a significant relationship between the number of age-2 shrimp, pre-recruits and the fishable biomass with a lag of 2, 3 or 4 years. The correlation was strongest (R^2 = 0.64) between number of age-2 shrimp and the fishable biomass 4 years later (SCR Doc. 20/053), whereas the correlation was strongest (R^2 = 0.68) between pre-recruits and fishable biomass 1 year later (SCR Doc. 20/057). Furthermore, there was also a significant relationship between number of age-2 shrimp and the number of pre-recruits 2-years later (R^2 = 0.52) (SCR Doc. 20/057).

The stock composition in Disko Bay has historically been characterized by a higher proportion of young shrimps than that offshore, exceptions were in 2017, 2019 and 2020, where younger shrimps offshore were much higher in numbers and relative to survey biomass. Both in 2019 and 2020, numbers of age 2-shrimps relative to survey biomass are much higher among offshore regions than inshore, where numbers of age-2 shrimps were record low (SCR Doc. 20/053, 20/056). Numbers of pre-recruits relative to survey biomass were considerably lower inshore than offshore regions (SCR Doc. 20/053, 20/056).

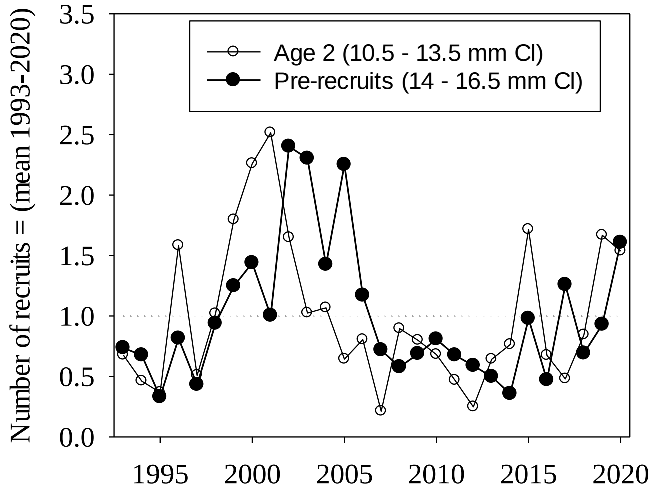


Figure 3.7. Northern shrimp in Subarea 1 and Div. 0A: Survey index of numbers at age 2 (10.5 - 13.5 mm) and index of number of pre-recruits (14-16.5 mm), 1993-2020. Indices are standardized to the series mean.

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

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

Indices of cod biomass are adjusted by a measure of the overlap between the stocks of cod and shrimps to obtain an index of 'effective' cod biomass, which is entered in the assessment model (SCR Doc. 14/062). Currently the cod stock at West Greenland is at a low level compared to the period before the collapse in the beginning of 1990s, but has since 2010 shown a slow, but progressive increases and has remained almost stable since 2015. The index of its overlap with the shrimp stock decline to an average below the serial value. This resulted in a 2020 'effective cod biomass' index of 7 kt in 2020 (Figure 3.8) (SCR Doc. 16/042, 16/047, SCR Doc. 20/056, SCR Doc. 20/058). Because of missing survey in 2021 and the need of input variables for the cod biomass and overlap factor for model performance, an average of the most recent three years was used as input data for those variables (21/042). This resulted in an estimated 2021 'effective cod biomass' index of 6 kt and in line with the most recent years.

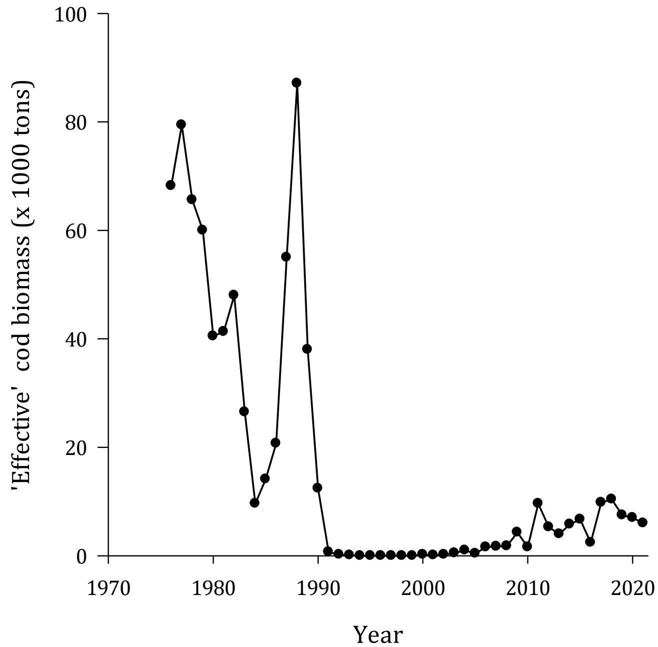


Figure 3.8. Indices of the 'effective' cod biomass in Subarea 1 and Div. 0A 1976 - 2021 (measure of the potential predation pressure by cod on shrimps).

c) Assessment

A Schaefer surplus-production model of population dynamics was fitted to series of CPUE, catch, and survey biomass indices (SCR Doc. 21/042). The model includes a term for predation by Atlantic cod. Total shrimp catches for 2021 are expected to be 108 000 t.

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

A more comprehensive description of the evaluation and changes of the model are available in SCR Doc. 18/060. These changes have been included in the assessment since 2018 and have resulted in increased stability of the model parameters and a much-improved retrospective pattern (Figure 3.10).

Estimates of stock-dynamic parameters from fitting a Schaefer stock-production model to 46 years' data are given in Table 3.1. Median values from the 2020 assessment are provided for comparison. The modelled biomass (Figure 3.9a) was relatively low and stable until the late 1990s, when it started a rapid increase, doubling by 2004. Modelled biomass steadily declined from 2004 to 2013 but has since slightly increased and have been stable over the most recent years. The median biomass has been above B_{msy} since the late 1990s except from 2013 to 2014. Mortality has generally been close to or below Z_{msy} during the modelled period (Figure 3.9b). Estimates of total mortality have increased in the most recent years. Assuming catches of 108 000 t, total mortality in 2021 is estimated to be below Z_{msy} with probability of $Z_{2021} > Z_{msy}$ = 33%. Biomass at the end of 2021 is projected to be close to the 2020 value and above B_{msy}. The probability of the biomass at the end of 2021 being below B_{msy} is 24% and the probability of being below B_{lim} is very low (<1%).

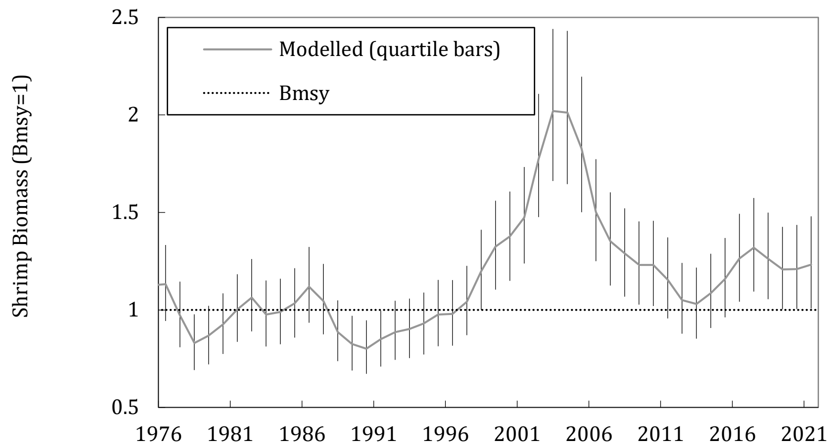


Figure 3.9a. Northern shrimp in SA 1 and Div. 0A: Relative stock biomass with quartile error bars 1976–2021. Dotted line corresponds to $B = B_{msy}$.

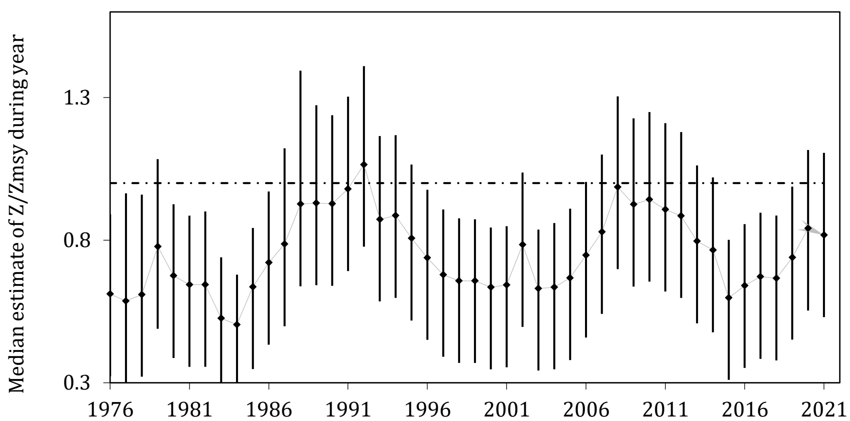


Figure3.9b. Northern shrimp in SA 1 and Div. 0A: Trajectory of the median modelled estimate of mortality relative to Z_{msy} during the year, 1976–2021 with quartile error bars.

Table 3.1. Estimates of stock-dynamic and parameters from fitting a Schaefer stock-production model to 46 years' data on the West Greenland stock of the northern shrimp in 2021. The median (2020) column shows results from last year's assessment.

	Mean	S.D.	25%	Median	75%	Est. mode	Median (2020)
Max.sustainable yield	137.3	62.9	102.1	123.4	154.6	95.6	123.0
B/Bmsy, end current year (proj.)(%)	126.2	35.3	100.7	123.2	148.0	117.2	122.5
Biomass risk, end current year(%)	24.4	43.0	–	–	–	–	–
Z/Zmsy, current year (proj.)(%)	–	–	55.6	81.8	110.6	–	89.3
Carrying capacity	3559	1972	2040	3048	4544	2026	2896
Max. sustainable yield ratio (%)	9.4	4.7	5.9	8.8	12.4	7.5	9.0
Survey catchability (%)	17.3	11.1	9.1	14.5	22.7	8.9	15.4
CPUE(1) catchability	1.0	0.6	0.5	0.8	1.3	0.5	0.9
CPUE(2) catchability	1.6	1.0	0.8	1.3	2.1	0.8	1.4
Effective cod biomass 2021 (Kt)	10.5	49.1	-2.2	6.0	17.7	-3.0	7.0
$P_{50\%}$ (prey biomass index with consumption 50% of max.)	4.5	11.3	0.2	1.3	4.7	-5.2	1.3
V_{max} (maximum consumption per cod)	1.9	2.2	0.4	0.9	2.5	-1.0	0.9
CV of process (%)	12.8	2.8	10.9	12.6	14.6	12.2	13.0
CV of survey fit (%)	18.0	3.2	15.7	17.7	19.8	17.1	17.2
CV of CPUE (1) fit (%)	7.0	1.5	5.9	6.7	7.8	6.1	6.7
CV of CPUE (2) fit (%)	7.6	2.3	5.9	6.9	8.5	5.7	7.0

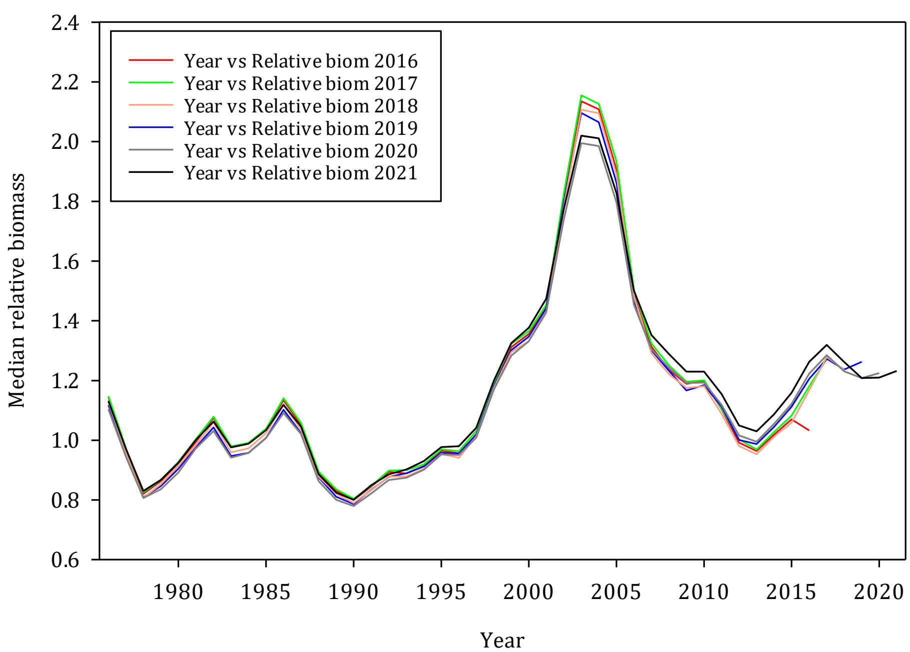


Figure 3.10. Retrospective plots of the relative biomass B/B_{msy} 2016 to 2021. Mohn's rho is estimated to –0.034.

A six-year retrospective analysis was performed (Figure 3.10) and results were found to be quite stable.

d) Reference points

B_{lim} has been established as 30% B_{msy}, and Z_{msy} (fishery and cod predation) has been set as the mortality reference point. B_{msy} and Z_{msy} are estimated directly from the assessment model (SCR Doc. 021/042).

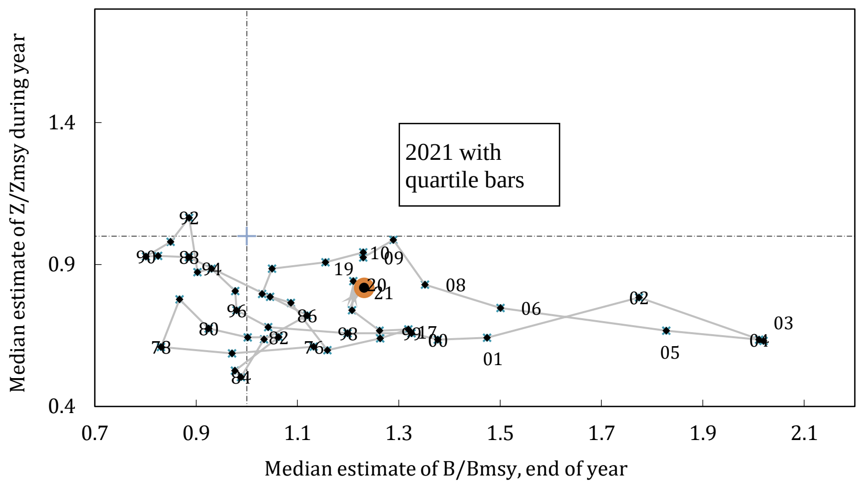


Figure 3.11. Northern shrimp in Subarea 1 and Div. 0A: Trajectory of relative biomass and relative mortality, 1976–2021.

e) State of the stock

Biomass. Biomass at the end of 2021 is above B_{msy} and the probability of being below B_{lim} is very low (<1%).

Mortality. Assuming catches of 108 000 t and an effective cod biomass of 6 kt, the probability of being above Z_{msy} is 33%.

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

State of the Stock. Biomass at the end of 2021 is above B_{msy} and the probability of being below B_{lim} is very low (<1%). The probability of mortality in 2021 being above Z_{msy} is 33%. Recruitment (number of age-2 shrimp) in 2020 was above average.

f) Projections

Three years projections for years 2022–2024 under eight catch options and subject to predation by the cod stock with an 'effective' biomass of 6 kt (the estimated value for 2021 was 6 kt) were evaluated. Additional projections assuming 'effective' cod biomasses of 5 kt, and 7 kt were conducted but results indicated small differences in risk probabilities (SCR Doc 21/042).

6 000 t cod	Catch option ('000 tons)							
Risk of:	95	100	105	110	115	120	125	130
$B_{msy} < B_{2022}$ (%)	26	26	26	26	28	27	27	27
$B_{msy} < B_{2023}$ (%)	26	27	27	27	29	30	30	30
$B_{msy} < B_{2024}$ (%)	26	28	28	29	30	32	32	34
$B_{lim} < B_{2022}$ (%)	0	0	0	0	0	0	0	0
$B_{lim} < B_{2023}$ (%)	0	0	0	0	0	0	0	0
$B_{lim} < B_{2024}$ (%)	0	0	0	0	0	0	0	0
exceeding Z_{msy} in 2022 (%)	20	23	26	30	33	37	40	43
exceeding Z_{msy} in 2023 (%)	21	24	27	31	35	38	41	44
exceeding Z_{msy} in 2024 (%)	21	25	28	31	35	38	42	45
$B < B_{msy}$ 80% 2022 (%)	9	10	10	10	10	11	10	11
$B < B_{msy}$ 80% 2023 (%)	10	11	11	11	13	13	13	14
$B < B_{msy}$ 80% 2024 (%)	11	12	12	13	14	16	16	16

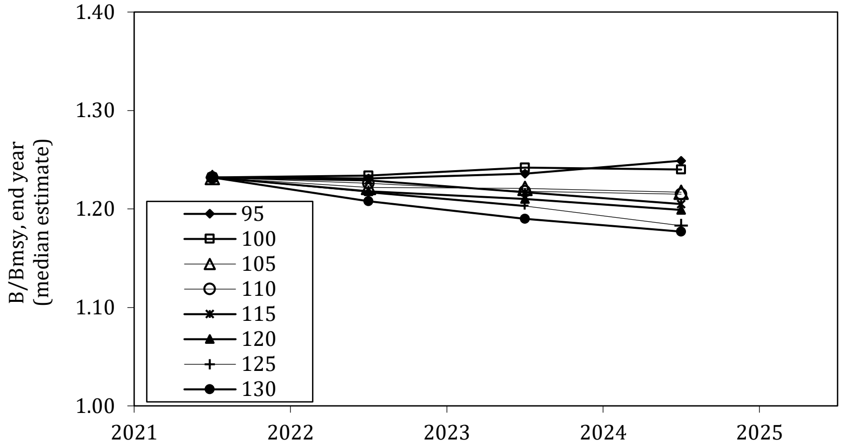


Figure 3.12. Northern shrimp in Subarea 1 and Div. 0A: Median estimates of year-end biomass trajectory for 2022–2024 with annual catches at 95 –130 kt. and an 'effective' cod stock assumed at 6 kt.

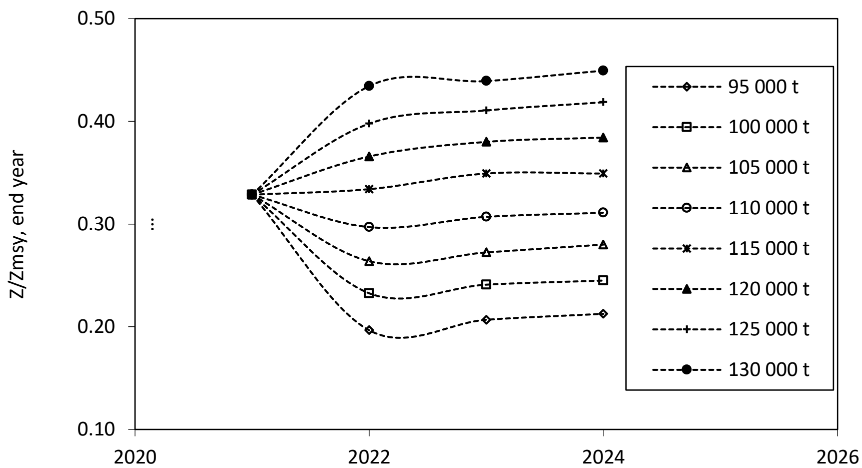


Figure 3.13. Northern shrimp in Subarea 1 and Div. 0A: Risks of transgressing mortality and biomass precautionary limits with annual catches at 95–130 kt projected for 2022–24 with an 'effective' cod stock assumed at 6 kt.

g) Research recommendations

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

Status: Done (SCR Doc. 21-041).

- NIPAG **recommends** *increasing sampling to cover the whole fleet.*
- NIPAG **recommends** that *diagnostics of the model should be further explored.*

Status: information is presented in SCR Doc. 21/042 **Completed.**

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

(SCR Docs. 04/012, 20/060, 21/040, 21/043)

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 population.

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

In the Greenland EEZ, the minimum permitted mesh size in the cod-end is 40 mm but most trawlers used 44 mm in the cod-end. The fishery is managed by catch quotas allocated to national fleets. In the Icelandic EEZ, the mesh size is 40 mm and there are no catch limits, however, there have been no catches by Iceland 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 9000 t and 15 000 t. Between 2004 and 2016 the total catch decreased to 49 t in 2016. Catches have since then increased to 3172 t in 2020 (Figure 4.1). Since 2012, no or very little fishery has taken place in the southern area.

Catches in the first half year of 2021 were 2370 based on logbooks. Since 2014, the fishing effort have been historical 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:

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021[1]
Recommended TAC, total area	12 400	12 400	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000
Actual TAC, Greenland	12 400	12 400	8 300	6 100	5 300	5 300	4 300	3 384	4 750	7 000
North of 65°N, Greenland EEZ	1 893	1 714	622	576	49	561	547	1 574	3 172	2 369
North of 65°N, Iceland EEZ	0	0	0	0	0	0	0	0	0	0
North of 65°N, total	1 893	1 714	622	576	49	561	547	1 574	3 172	2 369
South of 65°N, Greenland EEZ	215	3	0	0	0	0	0	2	0	0
TOTAL NIPAG	2 109	1 717	622	576	49	561	547	1 576	3 172	2 370

[1] Catches until June 30 2021

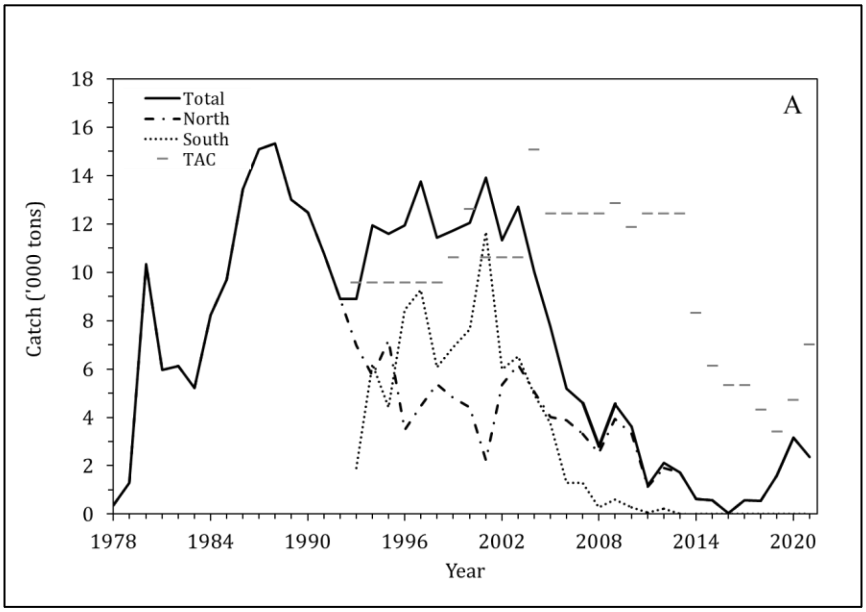


Figure 4.1. Shrimp in Denmark Strait and off East Greenland: Catch and TAC (2021 catches until June 30th).

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. 21/043).

The overall CPUE index increased from 1993 to 2009, followed by a continuous decline to a low value in 2014 and has been increasing since (Figure 4.2), reaching a record high level in 2020, which may indicate an improvement of the stock state. In 2021 the CPUE index value is the third highest in the time series, but below the 2019 and 2020 values. The estimates for recent years are based on relatively low fishing effort (from 300 fishing hours in 2016 to 3737 fishing hours in 2020) which is concentrated in a relatively small area north of 65^0N and west of 30^0W. As most of the fishing has been conducted in the northern area the overall CPUE index is dominated by the CPUE index for this area (Figure 4.2 and Figure 4.3). In the southern area a standardized catch rate series increased until 1998, and then fluctuated without a trend until 2012 (Figure 4.4). No index for the southern area has been calculated since 2012 due to a low number of hauls. In 2021 EU fleet started fishing in April which is later than previous year, where a larger portion of the catch is taken in February/March.

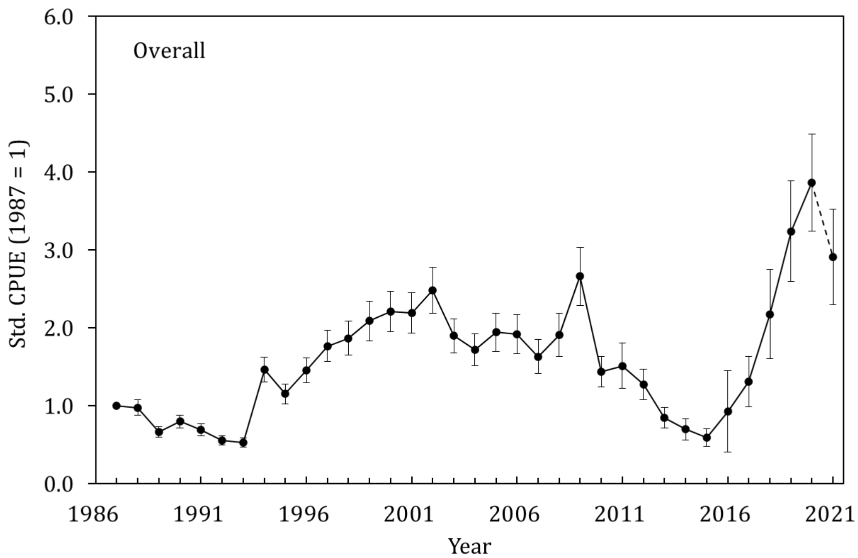


Figure 4.2. Shrimp in Denmark Strait and off East Greenland: Annual standardized CPUE index (1987 = 1) with ± 1 SE combined for the total area. 2021 data until June 30th (dotted line).

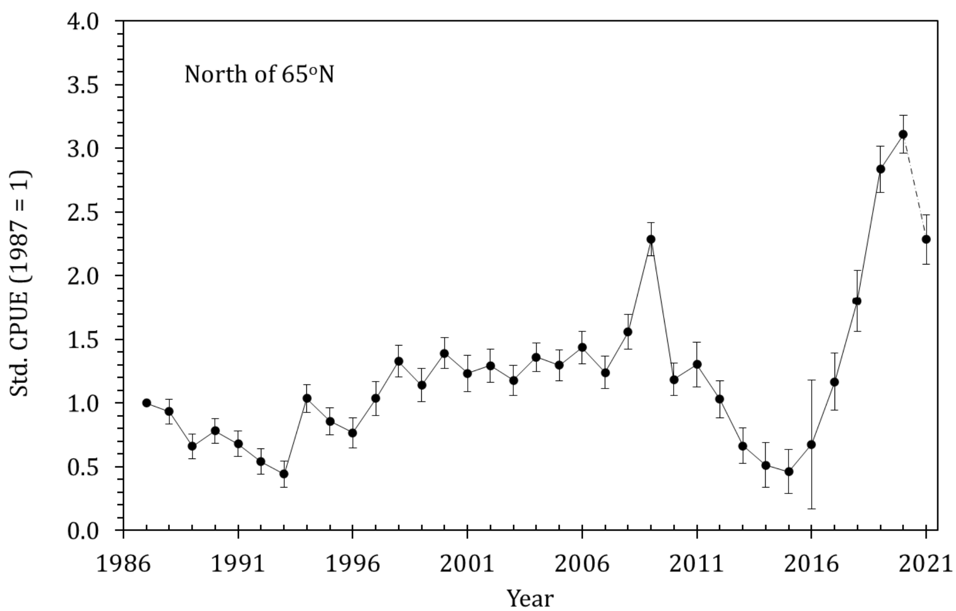


Figure 4.3. Shrimp in Denmark Strait and off East Greenland: Annual standardized CPUE (1987 = 1) with ±1 SE fishing north of 65°N. 2021 data until June 30th (dotted line).

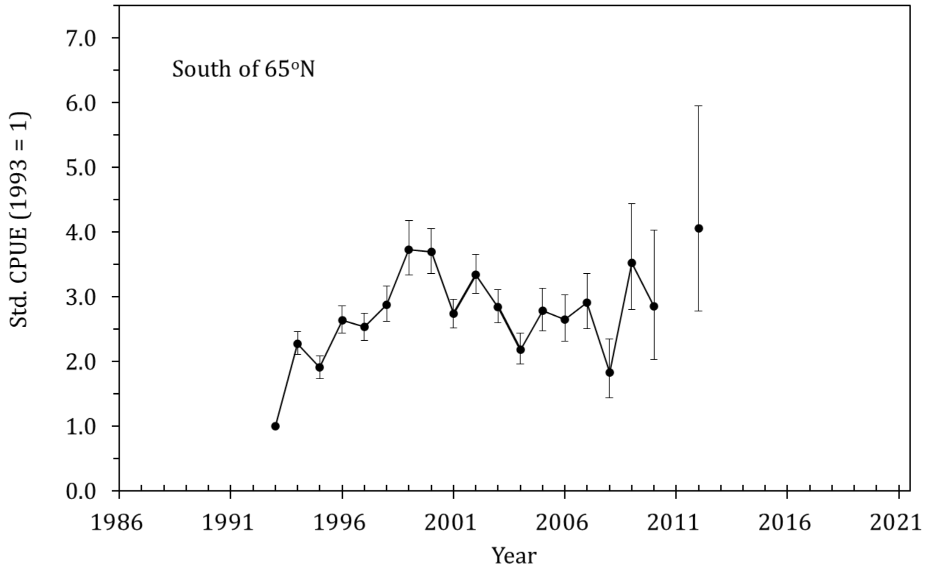


Figure 4.4. Shrimp in Denmark Strait and off East Greenland: Annual standardized CPUE (1993 = 1) with ±1 SE fishing south of 65°N (no data for the area since 2010/2012).

Standardized effort index time series (catch divided by standardized CPUE) as a proxy for exploitation rate for the total area shows a decreasing trend since 1993. Recent levels are the lowest of the time series (Figure 4.5). The 2016 to 2021 levels of exploitation rate may be biased given the issues on CPUE described above.

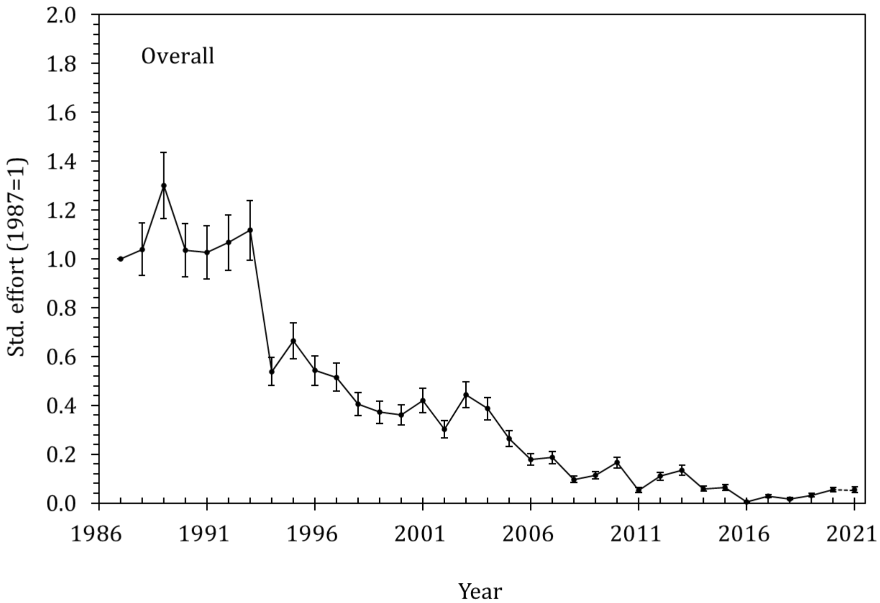


Figure 4.5. Shrimp in Denmark Strait and off East Greenland: Annual standardized effort indices, as a proxy for exploitation rate (± 1 SE; 1987 = 1), combined for the total area (2021 effort until June 30th).

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. 20/060). Due to lack of research vessel, no survey was conducted in the period 2017 to 2019. In 2020 the survey was conducted with the chartered fishing vessel *Helga Maria* using the same gear configuration (SCR Doc. 20-53 and 20-060). Lack of comparative fishing with the survey vessel used in 2020 leads to uncertainty in the survey estimates. Smaller geographical areas were also surveyed in 1985-1988 (Norwegian survey) and in 1989-1996 (Greenlandic survey). The historical surveys are not directly comparable with the recent survey due to different areas covered, survey technique and trawling gear.

Biomass. The survey biomass index decreased from 2009 to 2012 and then remained at a low level until 2016, there are no estimates for the years 2017-2019. The 2020 estimate is the highest in the timeseries (Figure 4.6). There was no survey in 2021.

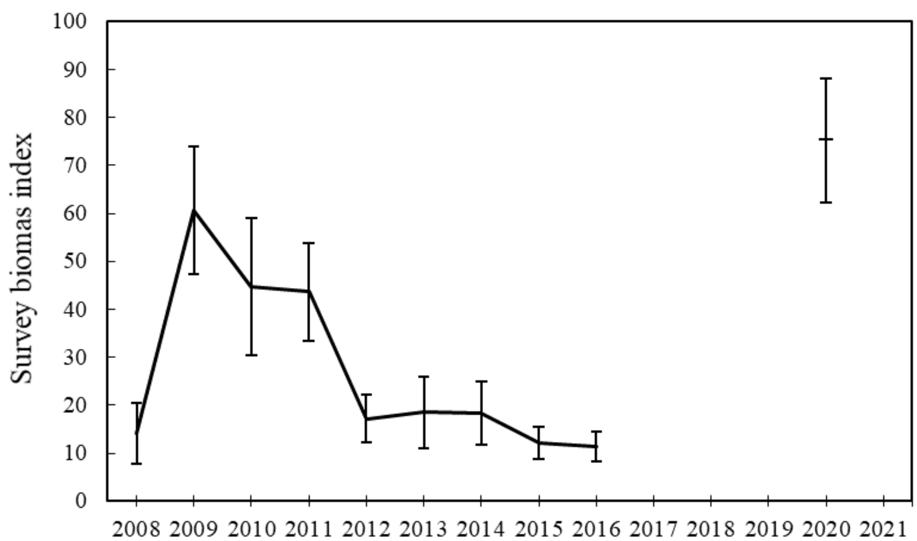


Figure 4.6. Shrimp in Denmark Strait and off East Greenland: Survey biomass index from 2008- 2016 and 2020 (± 1 SE). No survey was carried out in the period 2017 to 2019 and in 2021.

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

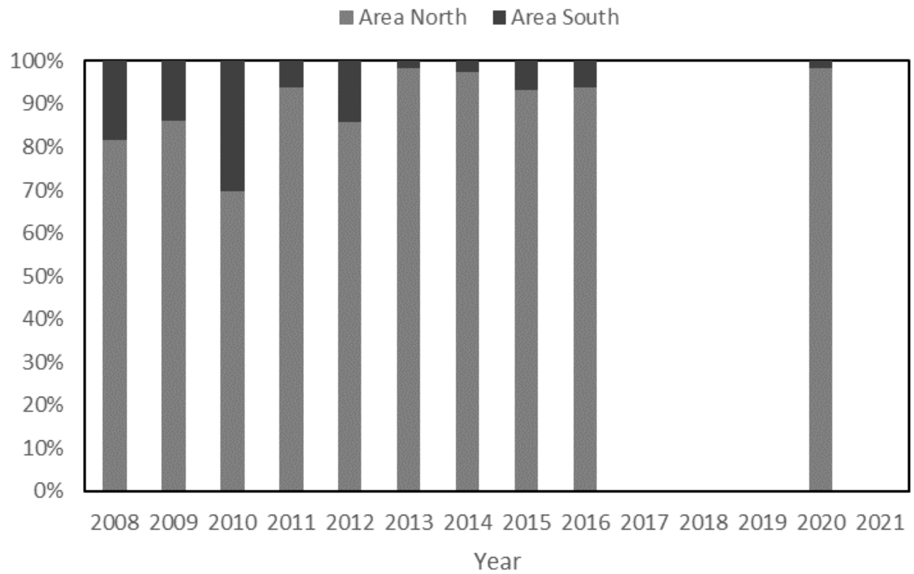


Figure 4.7. Shrimp in Denmark Strait and off East Greenland: Distribution of survey biomass north and south of 65°N (in %) from 2008-2016 and 2020. No survey was carried out in the period 2017 to 2019 and in 2021.

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% all years except 2009 and 2020. In 2020 36.9 % of the biomass was female, the second lowest in the time series (SCR Doc. 20/060). In 2020 there may have been some issues regarding the classification of primiparous and multiparous females. The analysis was carried out on the combined female biomass.

Very few males smaller than 20 mm CL are caught in the survey (Figure 4.8). Scarcity of smaller shrimp in the survey area stresses that the total area of distribution and recruitment patterns of the stock are still unknown.

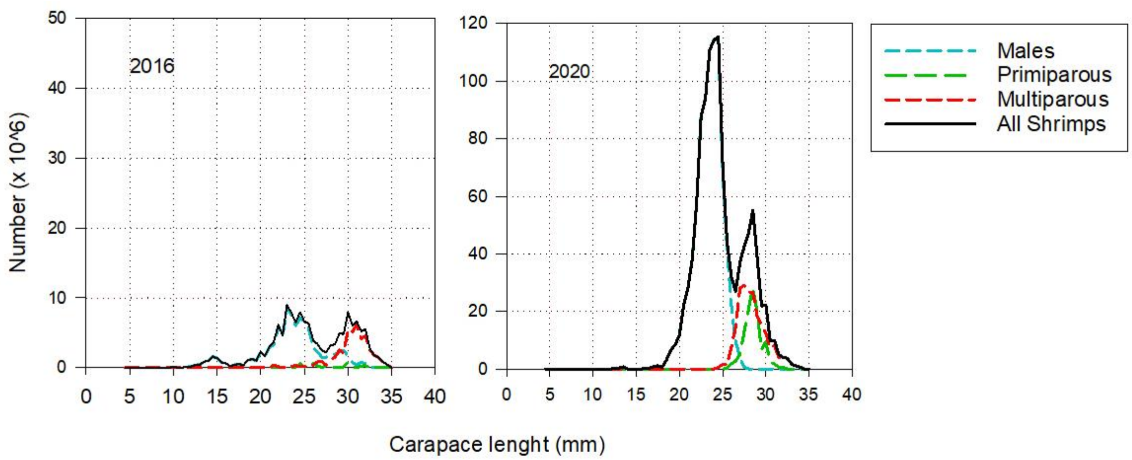


Figure 4.8. Shrimp in Denmark Strait and off East Greenland: Numbers of shrimp by length group (CL) in the total survey area in 2016 and 2020. No survey was carried out in the period 2017 to 2019 and in 2021.

c) Assessment results

Evaluation of the stock status is based upon interpretation of commercial fishery and survey data. The standardized CPUE have increase since 2015 and peaked in 2020 at a historical high level. In 2021 (until June 30th) the CPUE index value is the third highest in the time series but below the 2019 and 2020 values. The fishery in recent years is concentrated in a relatively small area north of 65⁰N and west of 30⁰W. Since 2016 only one survey in 2020 has been performed showing a record high survey biomass. The increase in CPUE since 2016 and the high survey biomass found in 2020, may indicate an improvement of shrimp density in the northern area. There was a decrease in CPUE in the first half of 2021, however, the fishery started late in 2021 and this may have impacted the fishing patterns.

During the 2021 NIPAG meeting a comprehensive sensitivity analysis of the surplus production model (SPiCT) was presented (SCR Doc. 21/044), following the recommendation of 2020 NIPAG. However, the SPiCT model was not applicable as a preliminary assessment tool this year, mainly because of the lack of survey biomass index in 2021 (and 2017 to 2019). However, it should be noted that nearly all model settings analyzed indicated B/Bmsy > 1 and F/Fmsy < 1.

d) Reference points

Scientific Council considers that 15% of the maximum survey female biomass provides a proxy for B_{lim} (SCS Doc. 17-017). In 2020 B_{lim} was recalculated based on new high survey female biomass from the 2020 survey (Figure 4.2). No fishing mortality reference point is defined.

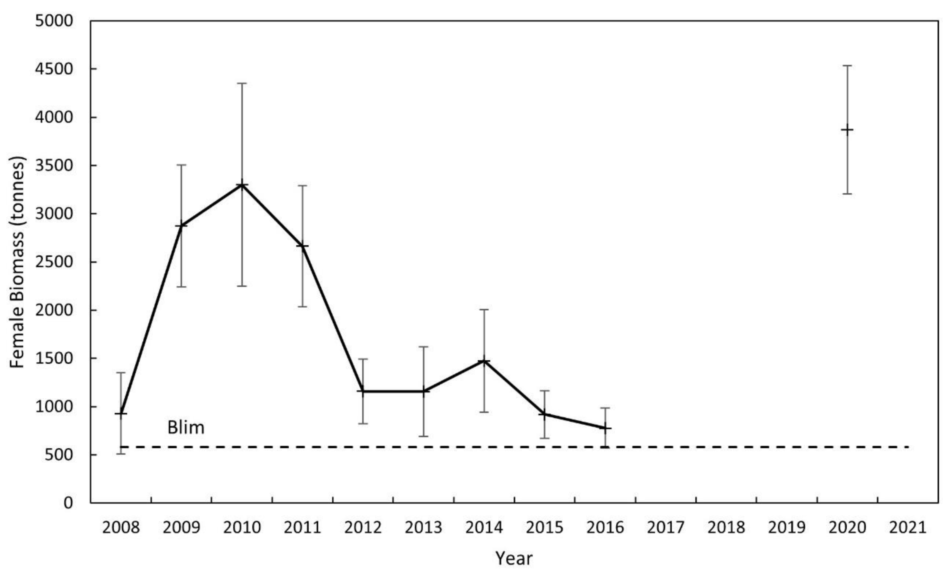


Figure 4.9. Shrimp in Denmark Strait and off East Greenland: Spawning stock biomass index (SSB) ±SE from 2008-2016 and 2020, and B_{lim} estimated as 15% of maximum survey female biomass. No survey was carried out in the period 2017 to 2019 and in 2021.

e) State of the stock

CPUE: The CPUE index declined continuously from its highest point in 2009 to a low value in 2014 and has been increasing until 2020, in 2021 there was a drop in CPUE, but the value remains at a high level. Estimates for the period 2016 to 2021 is based on fishing in a relatively small area and may not reflect the state of the total stock.

Recruitment. No recruitment estimates were available.

Biomass. The survey biomass index decreased by around 80% from 2010 to 2016. No survey was conducted in the period 2017 to 2019. The survey biomass in 2020 is the highest observed. There was no survey in 2021.

Exploitation rate. Since the mid-1990s the exploitation rate index based on standardized commercial effort has decreased, currently reaching the lowest levels seen in the time series. The 2016 to 2021 levels of exploitation rate may be biased given the issues on CPUE described above.

State of the stock. The survey biomass in 2020 is the highest observed since the beginning of the survey, in 2008. The commercial CPUE in 2021 has dropped slightly since 2020 which was the highest since the beginning of the time series, in 1986. There is no recruitment index available for this stock, few juvenile shrimps are caught in the survey area.

f) Research recommendations

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

Status: Has been completed; this recommendation should be progressed when new survey biomass and CPUE data become available

References

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

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

This stock was assessed during the 25–27 February 2019 NIPAG meeting. NIPAG reviewed the assessment during the present meeting. There were no further recommendations.

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

Background documentation (equivalent to stock annex) is found in SCR Docs. 20/65, 66, 67, 70; 08/56, 07/75, 86; 06/64.

Ecosystem overview

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

The capelin stock has increased again after a steep decline between 2017 and 2019 and has been estimated to be above B_{lim}. Cod biomass has decreased in recent years following a peak around 2013 but is still at a relatively high level. Despite the recent increase in capelin, cod abundance remaining on historically high levels may put relatively high predation pressure on shrimp. The levels of environmental and organic pollution in the Barents Sea are generally low and do not exceed threshold limits or global background levels. More detailed information can be found in ICES (2018b).

a) Introduction

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

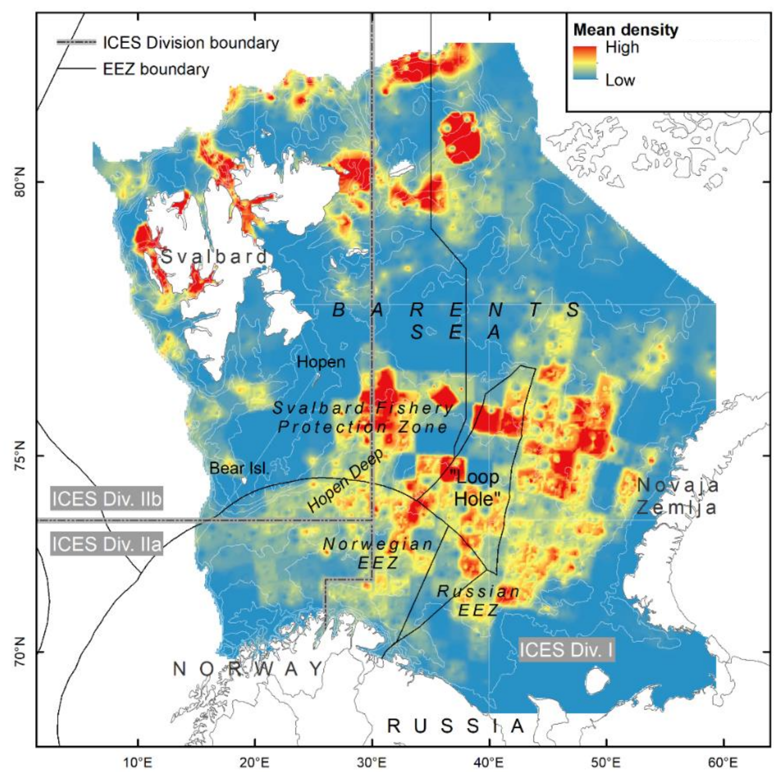


Figure 6.1. Shrimp in ICES SA 1 and 2: Stock distribution (Mean survey density index (kg/km2) from the joint Norwegian-Russian survey).

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

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

Landings. Landings have increased from 20 000 t in 2013 to more than 60 000 t in the most recent years and are predicted to reach 57 000 tons by the end of 2021.

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

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021[1]
Recommended TAC	60 000	60 000	60 000	70 000	70 000	70 000	70 000	70 000	150 000	140 000
Norway	14 158	8 846	10 234	16 618	10 896	7 010	23 126	23 925	19 118	21 000
Russia	0	1 067	741	1 151	2 491	3 849	12 561	28 081	21 265	14 000
Others	10 598	9 336	9 989	16 253	17 359	19 582	200 254	21 576	21 494	22 000
Total	24 756	19 249	20 964	34 022	30 748	30 441	55 941	73 582	61 877	57 000

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

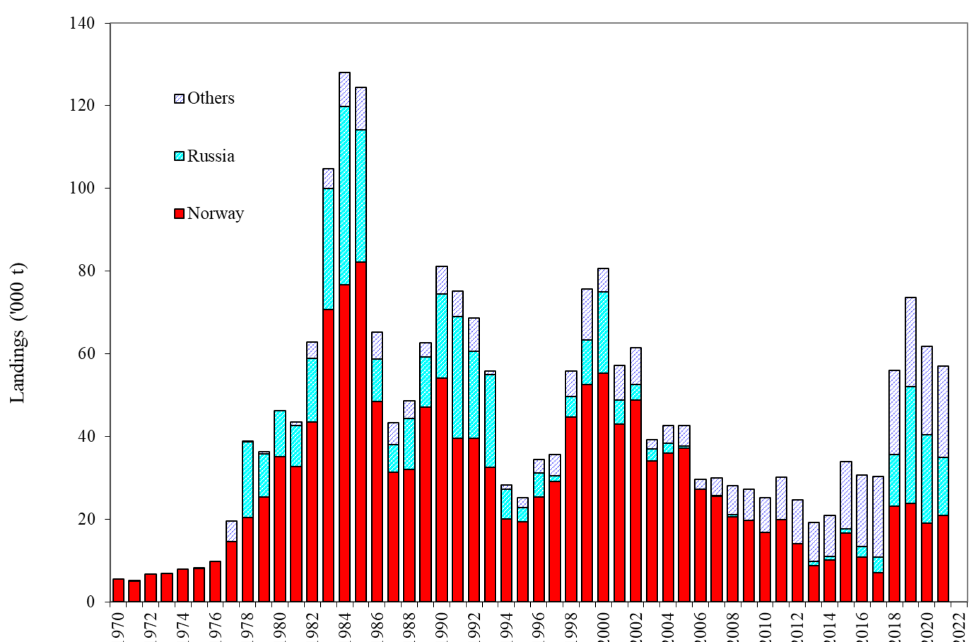


Figure 6.2. Shrimp in ICES SA 1 and 2: Total annual landings (2021 projected to the end of the year).

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

In 2017, specific information on bycatch from EU-Estonia based on onboard scientific observers was presented. They indicated 2.9% by weight of fish discards and 0.6% discards of shrimp.

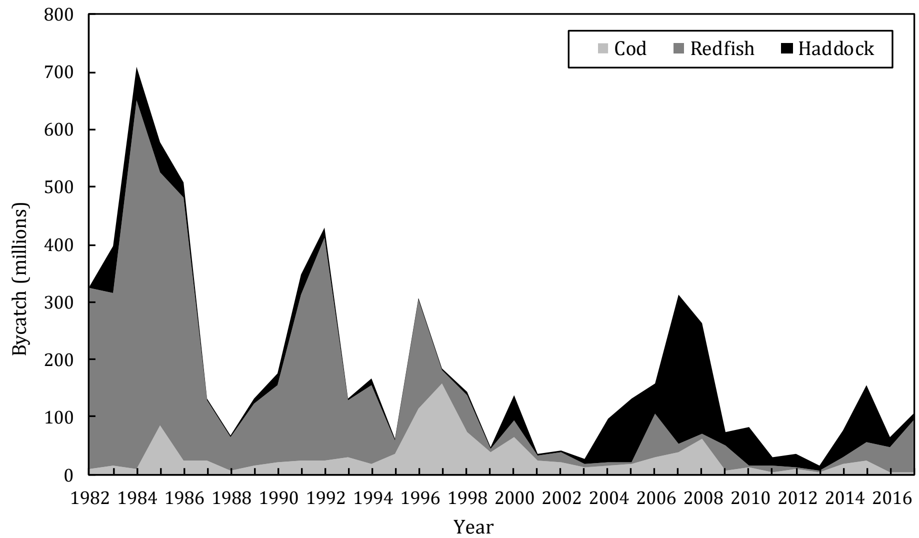


Figure 6.3. Shrimp in ICES SA 1 and 2: Estimated bycatch of cod, haddock and redfish in the Norwegian shrimp fishery (million individuals). The sorting grid was introduced in 1992 and has been mandatory since and following that, the vast majority of bycatch is assumed to have been juveniles.

b) Input data

i) Commercial fishery data

Logbook data are normally available only from the Norwegian fleet, but 2017 data was also available from the EU-Estonia fleet. In 2020 and 2021 summary catch and effort data was received from Poland, Latvia and Estonia. In addition, information was provided by Russia in SCR Doc. 21/052, including information on catch distribution and standardized catch rates.

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

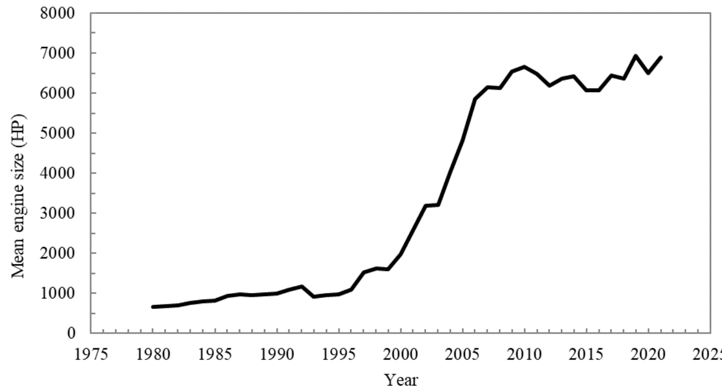


Figure 6.4. Shrimp in ICES SA 1 and 2: Mean engine power (HP) weighted by trawl-time (Norwegian vessels).

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

The fishery was originally conducted mainly in the central Barents Sea and on the Svalbard Shelf along with the Goose Bank (southeast Barents Sea). Norwegian logbook data since 2009 show decreased activity in the Hopen Deep and around Svalbard, coupled with increased effort further east in international waters (the “Loophole”) (Figure 6.5). Information from the Norwegian industry points to decreasing catch rates and more frequent area closures due to bycatch of juvenile fish on the traditional shrimp fishing grounds as the main reasons for the observed change in fishing pattern.

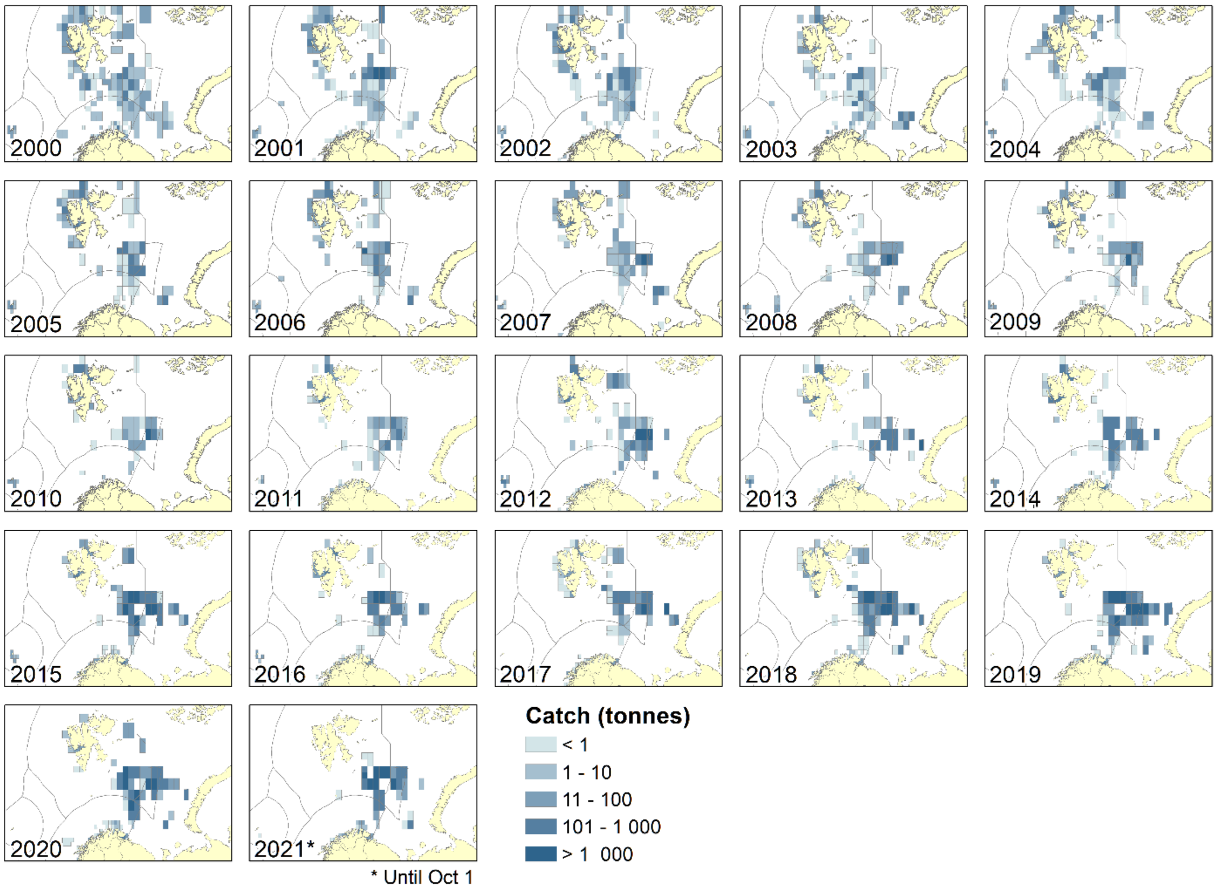


Figure 6.5. Shrimp in ICES SA 1 and 2: Distribution of catches by Norwegian vessels since 2000 based on logbook information. *2021 includes only data until October 1st.

The Soviet/Russian fishery for the northern shrimp in the Barents Sea started in 1978. Catches peaked in 1983-1985 and varied in subsequent years (Fig. 6.2) In 2009-2012, the Russian fishery for shrimp came to a full stop. Following a restructuring of the fleet catches have again increased in excess of 20 000 t in 2020.

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

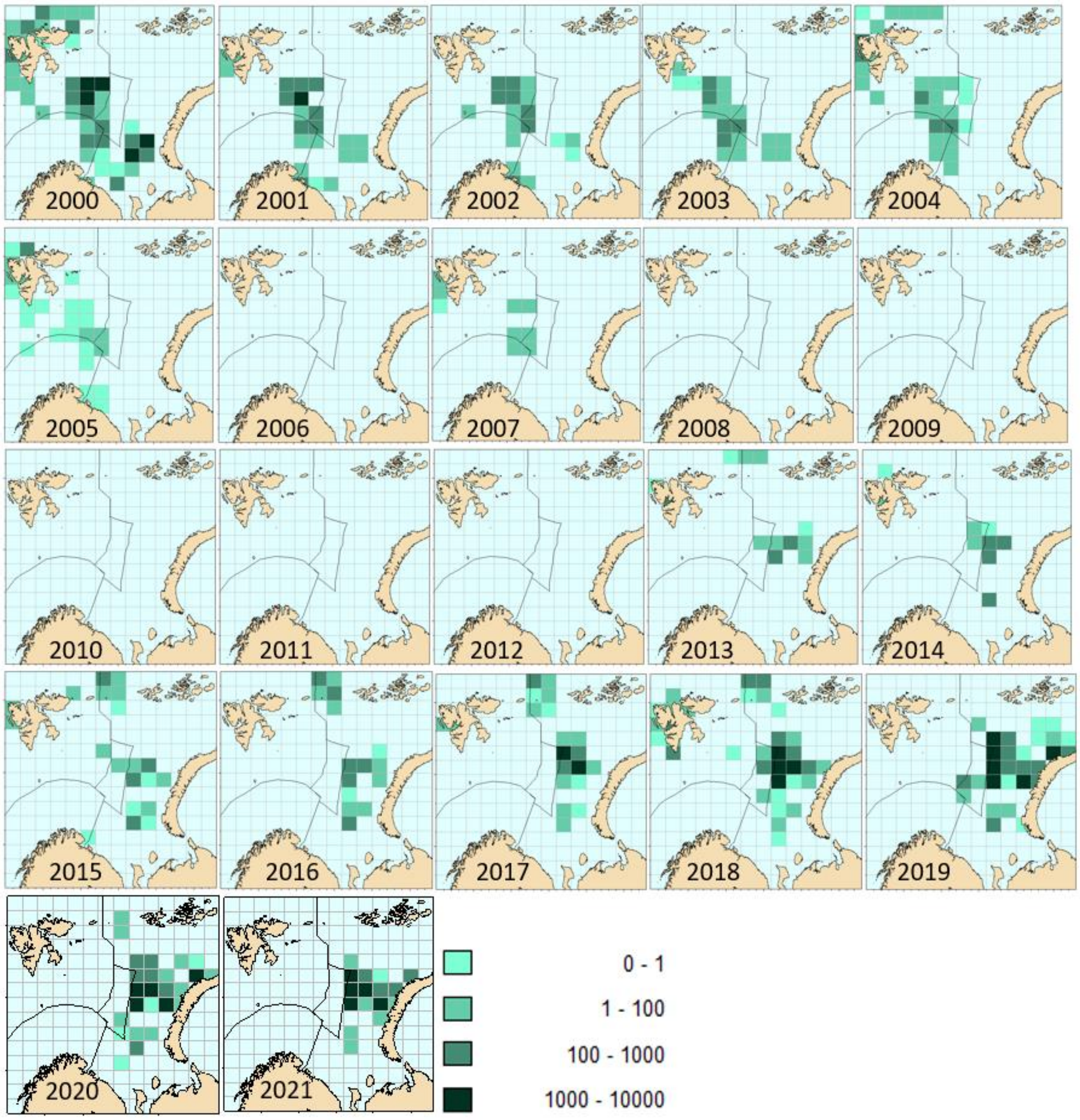


Figure 6.6. Distribution of catches by Russian vessels since 2000 based on logbook information. (2021 only data until September)

A standardized CPUE index based on a generalized linear model (GLM) that took area, depth, gear, and month into account, has been relatively stable since 2016 (Fig. 6.7). This standardized CPUE, being new and not fully evaluated by NIPAG was at this point not used as input to the assessment model. The inclusion of this index will be further considered at the up-coming benchmark in 2022.

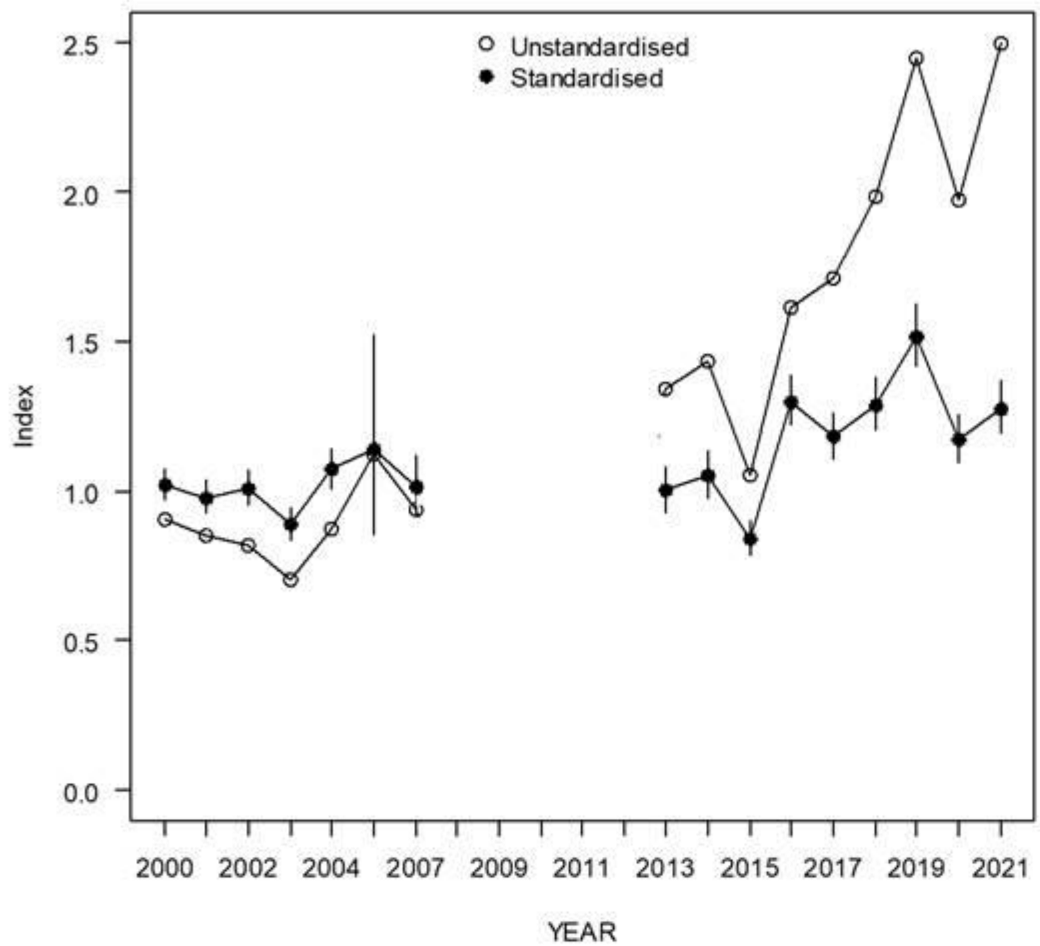


Figure 6.7. Unstandardized (geometric mean of annual observations) and standardized (year coefficients from GLM) CPUE indices for Russian shrimp fishery. Error bars indicate +2 s.e. Each series has been normalized to a geometric mean of 1. There was no Russian fishery between 2009 and 2012.

Norwegian logbook data were used in a GLM to calculate standardized annual catch rate indices (SCR Doc. 19/056). The GLM used to derive the CPUE indices included the following variables: (1) vessel, (2) season (month), (3) area (five survey strata), and (4) gear type (single, double or triple trawl). The resulting series provides an index of the fishable biomass of shrimp ≥17 mm CL, *i.e*. females and older males (Figure 6.8). The minimum commercial size in this fishery is 15mm.

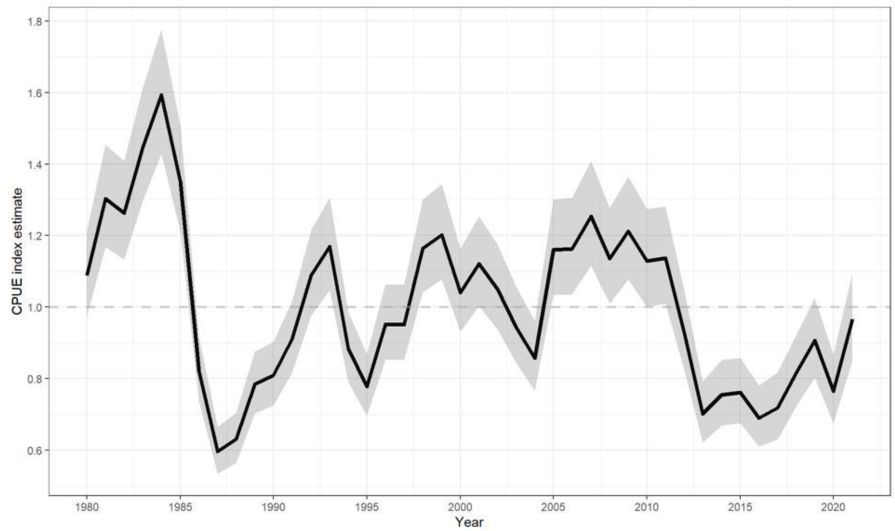


Figure 6.8. Shrimp in ICES SA 1 and 2: Standardized CPUE index based on Norwegian data. Index values are centered around the mean of the series. The shaded area marks the 95% confidence intervals.

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

The addition of the updated data set for 2020 and provisional 2021 data has slightly changed the trajectory of the standardized CPUE series for the most recent years as compared to the estimation presented at the 2020 assessment, however, the overall trend remains the same. Following the work towards the 2022 benchmark, a correction was made to the way the uncertainty was calculated which have resulted in larger (and likely more realistic) uncertainty estimates than seen in previous assessments.

ii) Research survey data

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

Biomass. The biomass indices of survey 1 and 2 have fluctuated without trend over their respective time periods covered (Figure 6.10). The most recent survey series (survey 3) has increased substantially since a low in 2016 to reach its highest value in 2019. However, the 2020 value is down again close to the 2016 value. In general, the entire survey area of the Ecosystem survey (survey 3 in Figure 6.10) is covered in all years, however, due to heavy ice conditions in 2014 the northern part of the area (stratum 3, see SCR Doc. 17/68) was not covered. For the 2004-2013 survey period this area accounts for on average 13% of the biomass (range: 8-27%). The 2014 biomass for stratum 3 was estimated by calculating the average ratio of biomass density in stratum 3 to biomass density in the remaining survey area for the 2009-2013 period and applying this average to the density of the 2014 surveyed area. Estimates of variance for stratum 3 was taken as the variance of the 2009-2013 estimates for stratum 3. A similar method incorporating 2015 to 2017 data was used to compensate for missing coverage due to vessel malfunction of stratum 5 and stratum 4 in 2018 and 2019 respectively.

In the 2020 the Russian part of the survey area (about 50%) was not finalized before the start of the 2020 assessment due to technical issues. These data have now been added (Figure 6.9) and the updated 2020 index value is similar (<1% difference) to the one estimated based on partial data last year. For this year the Russian 2021 survey data had not yet been entered in the Norwegian database and therefore not available for this assessment (Figure 6.9). The same approach as agreed on by NIPAG in 2020 (see full description in 2020 report) was applied to correct for the missing coverage, using the long-term mean biomass proportion of the strata without data compared to the total biomass to raise the total biomass. The mean proportion of the missing strata was 67.8% and total biomass, thus, increased by 32.2%.

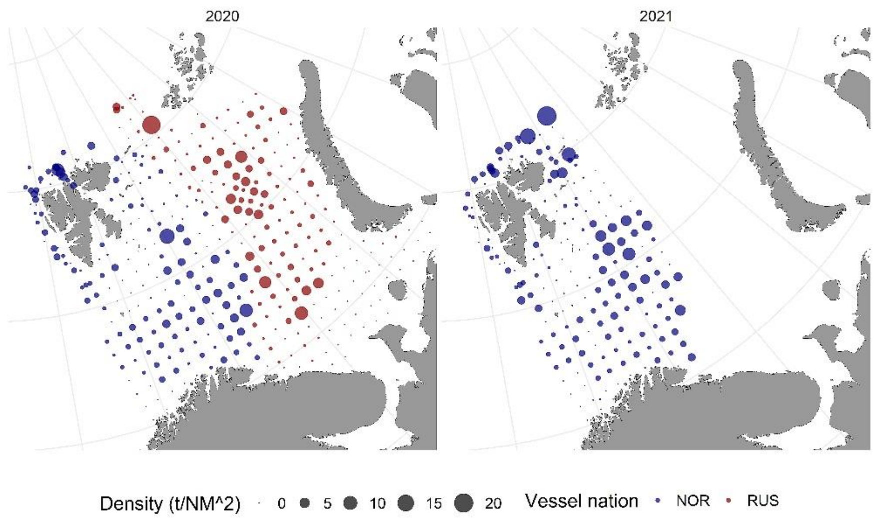


Figure 6.9. Survey data availability 2020 and 2021 of the joint Norwegian-Russian survey at the time of the 2021 NIPAG meeting. Dots are scaled to the registered catches of shrimp, colors indicate different survey vessels.

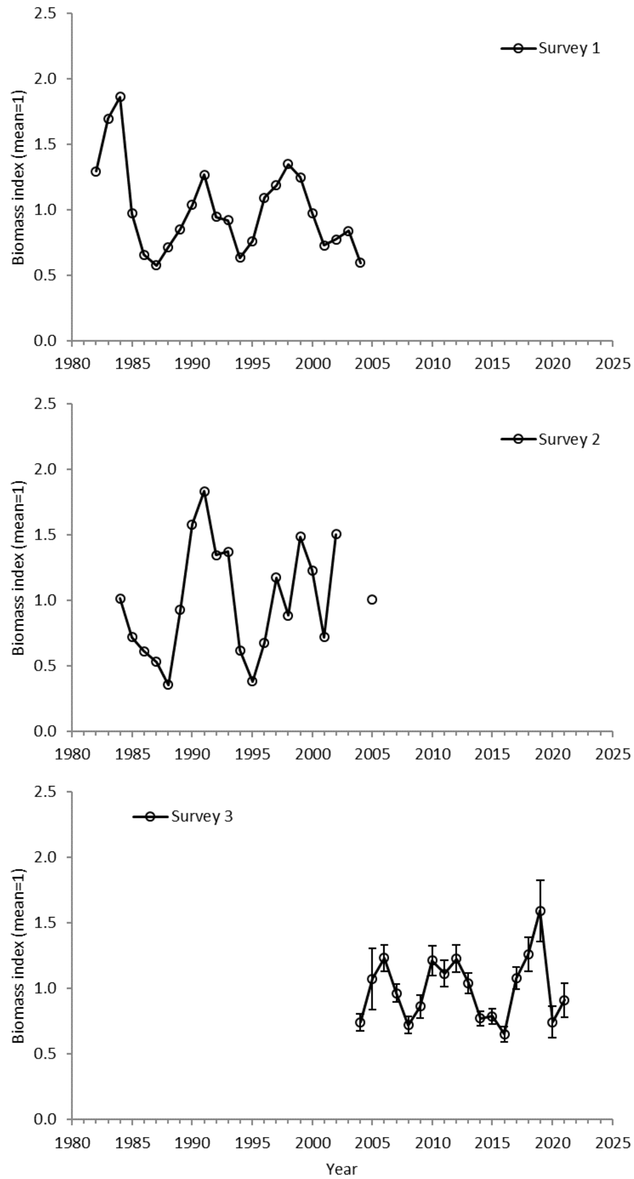


Figure 6.10. Shrimp in ICES SA 1 and 2: Indices of total stock biomass from the (1) 1982-2004 Norwegian shrimp survey, (2) the 1984-2005 Russian survey, and (3) the joint Russian-Norwegian ecosystem survey since 2004. Error bars represent 1 SE.

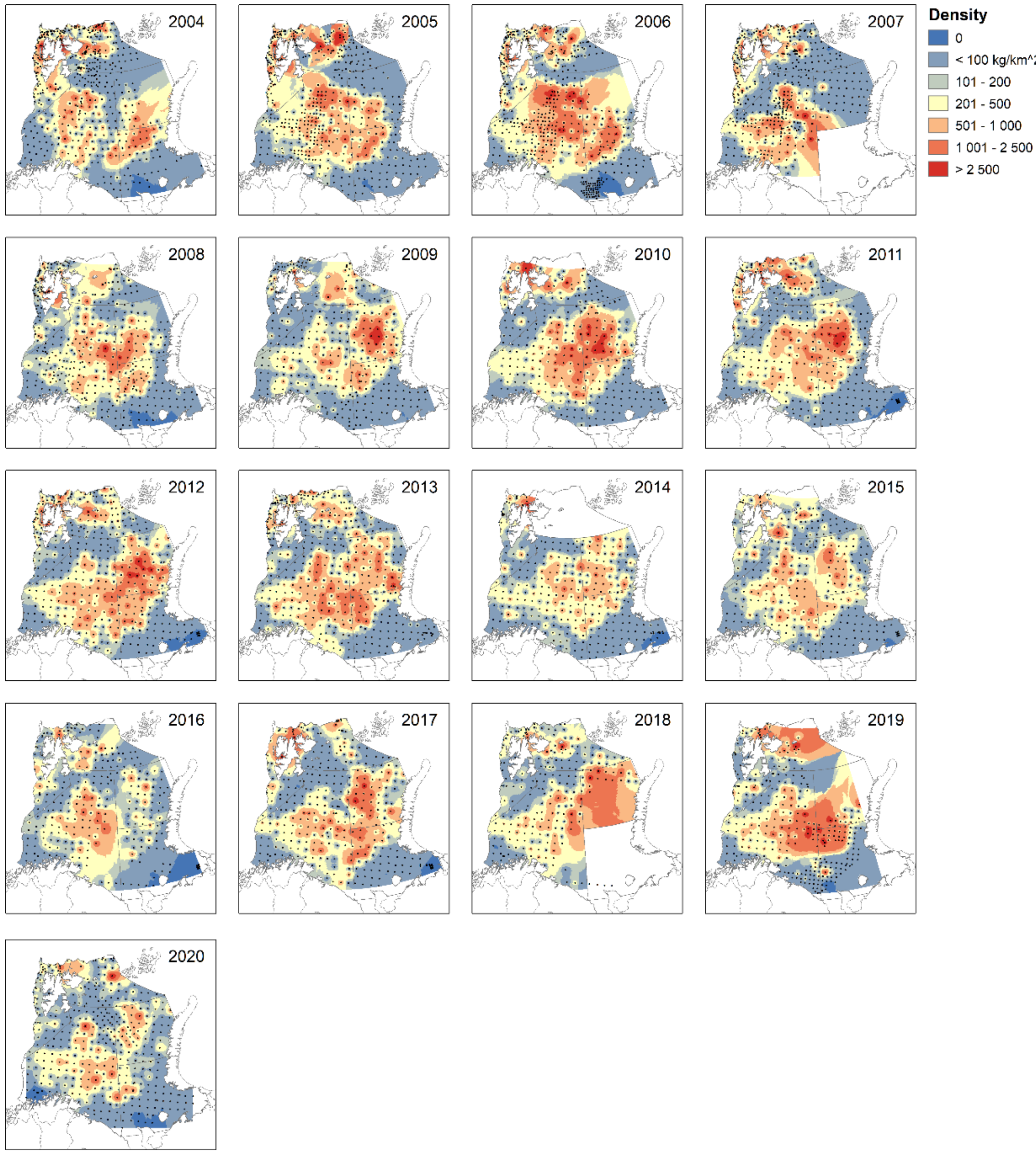


Figure 6.11. Shrimp in ICES SA 1 and 2: shrimp density (kg/km2) as calculated from the Ecosystem survey data since 2004 (no data for stratum 3 in 2014 due to ice conditions; no data for stratum 5 in 2018 and 4 in 2019 due to vessel malfunction; for survey 2021 see text.

Recruitment indices. No information is included as data are not available since 2013. Length distribution data from the Estonian fishery and survey data from the Norwegian EEZ were investigated during the meeting and these gave some indication of good recruitment in 2015 and 2019, however, NIPAG deferred further analysis to the upcoming benchmark in 2022.

c) Assessment

The modelling framework introduced in 2006 (SCR Doc. 06/064) was used for the assessment. Model settings were the same as those used in previous years. However, the observation error for the 2021 survey data point was assumed to be twice that of the remaining series, considering that the survey data did not cover the entire shrimp distribution area.

Within this model, parameters relevant for the assessment and management of the stock are estimated, based on a stochastic version of a surplus-production model. The model is formulated in a state-space framework and Bayesian methods are used to derive "posterior" probability density distributions of the parameters (SCR Doc. 20/066).

The model synthesized information from input priors, four independent series of shrimp biomass indices and one series of shrimp catch. The biomass indices were: a standardized series of annual fishery catch rates for 1980–2020 (Figure 6.6, SCR Doc. 20/067); and trawl-survey biomass indices for 1982–2004, 1984–2005 and for 2004–2020 (Figure 6.7, SCR Doc. 20/065). These indices were scaled to true biomass by individual catchability parameters, q_j, and lognormal observation errors were applied. Total reported catch in ICES Div. 1 and 2 since 1970 was used as yield data (Figure 6.2, SCR Doc. 20/067). The fishery being without major discarding problems or variable misreporting, reported catches were entered into the model as error-free.

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

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

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

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

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

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

Summaries of the estimated posterior probability distributions of selected parameters are shown in Table 6.2. Values are similar to the ones estimated in previous assessments. *K* could not be well estimated from the data alone and its posterior will depend somewhat on the chosen prior. For the estimates of relative stock size relaxing the *K*-prior did not have much effect (SCR Doc. 07/076) except for a slight increase in uncertainty. However, the posterior for *MSY* is sensitive as *K* is correlated with *MSY*: in particular, the right-hand side of the posterior distribution is widened while the left-hand side seems pretty well determined by the data. The mode of the distribution of *MSY* is around 110 kt and would likely be a best point estimate of this parameter.

Table 6.2. Shrimp in ICES SA 1 and 2: Summary of parameter estimates: mean, standard deviation (sd) and quartiles of the posterior distributions of selected parameters estimated in the 2021 assessment and the median values from the 2020 assessment.

	Mean	sd	25 %	Median	75 %	Median (2020)
MSY (ktons), maximum sustainable yield	211	117	118	191	291	204
K (ktons), carying capacity	2997	1529	1868	2699	3787	2686
r, intrinsic growth rate	0.30	0.14	0.21	0.30	0.40	0.32
q_R, catchability of survey 2	0.13	0.08	0.07	0.11	0.16	0.11
q_{Ru}, catchability of survey 1	0.32	0.21	0.18	0.26	0.40	0.27
q_E, catchability of survey 3	0.20	0.13	0.11	0.17	0.25	0.17
q_C, catchability of CPUE index	4.7E-04	3.0E-04	2.6E-04	3.8E-04	5.8E-04	3.8E-04
P_0, initial relative biomass (1969)	1.51	0.26	1.33	1.51	1.68	1.51
P_{2021}, relative biomass in 2021	1.69	0.31	1.53	1.70	1.87	1.86
σ_R, coefficient of variation for survey 2	0.18	0.03	0.16	0.18	0.20	0.17
σ_{Ru}, coefficient of variation for survey 1	0.34	0.05	0.31	0.34	0.37	0.34
σ_E, coefficient of variation for survey 3	0.18	0.03	0.16	0.18	0.20	0.19
σ_C, coefficient of variation for CPUE index	0.12	0.02	0.11	0.12	0.13	0.13
σ_P, coefficient of variation for process	0.18	0.02	0.16	0.17	0.19	0.18

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

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

The results of this year's assessment are at large consistent with those of previous years (model introduced in 2006). The conclusions on stock status drawn from the model have been found on investigation to largely be insensitive to the setting of the priors for initial stock biomass and carrying capacity (SCR Docs. 06/064 and 07/076).

Stock size and fishing mortality. A steep decline in stock biomass in the mid-1980s was noted following some years with high catches and the median relative biomass almost dropped to the *Bmsy*-level (Figure 6.12, upper). Since the late 1980s, however, the stock has varied with a slightly increasing trend. The estimated probability of stock biomass being below $B_{trigger}$ by the end of 2021 is less than 1% (Table 6.3). The median estimate of fishing mortality has remained below F_{msy} throughout the history of the fishery (Figure 6.12 lower). In 2021, there is a less than 5% probability of the *F* being above F_{msy} (Table 6.3).

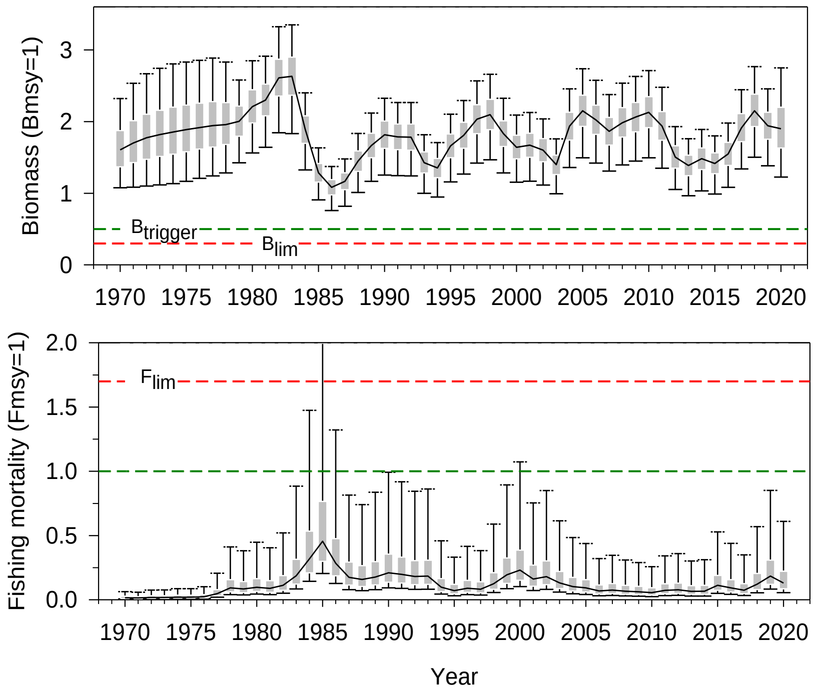


Figure 6.12. Shrimp in ICES SA 1 and 2: Estimated relative biomass (B/B_{msy}) and fishing mortality (F/F_{msy}) since 1970. Boxes represent inter-quartile ranges and the solid black line in the middle of each box is the median; the arms of each box cover the central 90% of the distribution. The broken lines indicate *MSY* and precautionary approach reference points.

Table 6.3. Shrimp in ICES SA 1 and 2: Stock status for 2020 and projected to the end of 2021 with a predicted total catch of 57000 t.

Status	2020	2021
Risk of falling below B_{lim}	0.1 %	0.1 %
Risk of falling below $B_{trigger}$	0.3 %	0.3 %
Risk of exceeding F_{MSY}	4.0 %	4.1 %
Risk of exceeding F_{lim}	1.8 %	1.8 %
Stock size (B/Bmsy), median	1.70	1.71
Fishing mortality (F/Fmsy)	0.19	0.18

Projections. Catch advice at the median of F_{msy} (ICES MSY approach) would imply no more than 289 ktons, which is outside the catch history of the fishery. Given that the right-hand side of the probability distributions of the yield at the F_{msy} is less well estimated, NIPAG considers it more appropriate to apply the mode as a point estimate of yield at F_{msy}. This mode is at 140 kt. Assuming a catch of 57 ktons for 2021, catch options up to 140 ktons for 2021 have low risks of exceeding F_{msy} (<18%), F_{lim} (<6%), and of going below $B_{trigger}$ (<1%) by the end of 2022 (Table 6.4) and all these options are likely to maintain the stock above B_{msy}.

Table 6.4. Shrimp in ICES SA 1 and 2: Predictions of risk and stock status associated with optional catch levels for 2022.

	Catch option 2022 (ktons)						Yield at Fmsy (mode)	Yield at Fmsy (median)
	60	70	80	90	100	110	140	289
Risk of falling below B_{lim}	0.1 %	0.1 %	0.1 %	0.1 %	0.1 %	0.1 %	0.3 %	1.2 %
Risk of falling below $B_{trigger}$	0.4 %	0.4 %	0.4 %	0.4 %	0.4 %	0.4 %	0.7 %	2.9 %
Risk of exceeding F_{MSY}	4.3 %	5.6 %	7.1 %	8.6 %	10.3 %	12.2 %	17.6 %	50 %
Risk of exceeding F_{lim}	2.0 %	2.5 %	3.0 %	3.8 %	4.5 %	5.3 %	7.6 %	24 %
Stock size (B/Bmsy), median	1.72	1.71	1.72	1.69	1.69	1.68	1.64	1.57
Fishing mortality (F/Fmsy),	0.18	0.21	0.24	0.27	0.31	0.34	0.45	1.00

d) Environmental and other considerations

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

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

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

Model performance. The model was able to produce good simulations of the observed data (Figure 6.13). The differences between observed values of biomass indices and the corresponding values predicted by the model were checked numerically (SCR Doc 20/066). They were found generally not to include excessively large deviations.

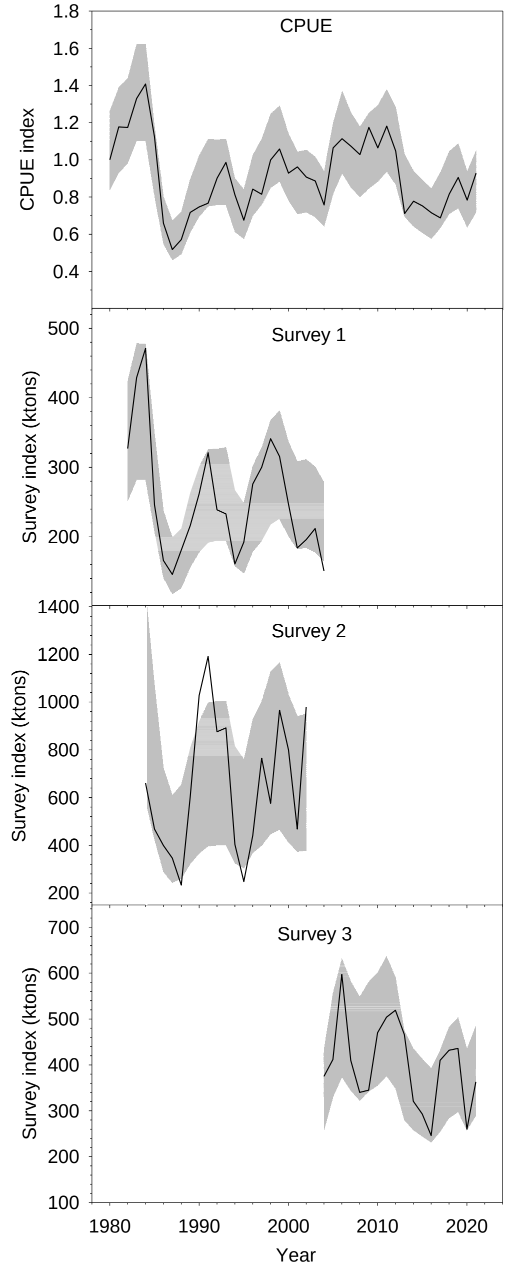


Figure 6.13. Shrimp in ICES SA 1 and 2: Observed (solid line) and estimated (shaded) series of the included biomass indices: the standardized catch-per-unit-effort (CPUE), the 1982–2004 Norwegian shrimp survey (survey 1), the 1984 to 2005 Russian survey (Survey 2) and the Joint Norwegian-Russian Ecosystem Survey (survey 3) since 2004. Grey shaded areas cover the 80% probability interval of their posteriors.

The model did tend to be pessimistic regarding the final years during the stock increase since 2015 (Figure 6.14), but all of these were well inside the updated estimated probability distributions the following year. The model only slightly underestimated the decline from 2019 to 2020. A simple calculation of Mohn's rho based on the point estimates (medians) for five years is -0.07.

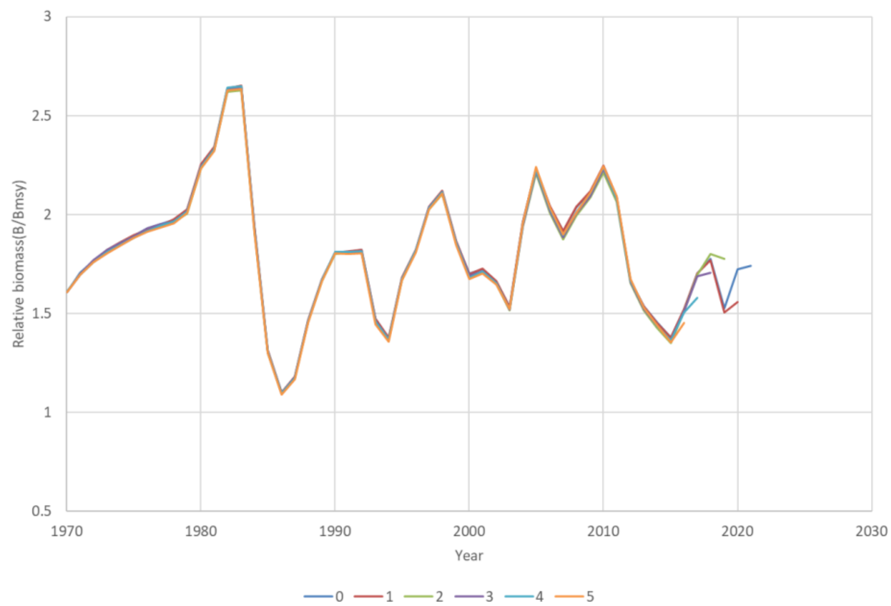


Figure 6.14. Shrimp in ICES SA 1 and 2: Retrospective plot of median relative biomass (B/B_{msy}). Relative biomass series are estimated by consecutively leaving out from 0 to 5 years of data.

e) State of the stock

Biomass. Stock biomass has been above $B_{trigger}$ throughout the history of the fishery. The probability that the biomass at the end of 2021 is below $B_{trigger}$ is less than 1%.

Mortality. Fishing mortality is likely to have remained below F_{msy} throughout the history of the fishery. In 2021 there is 2% risk of fishing mortality exceeding F_{lim}.

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

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

f) Research recommendations

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

Status: An official data call has been made and some parties have now provided aggregated data on total catch and effort. This is of limited use for the work of NIPAG and this recommendation is therefore reiterated.

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

Status: no progress. This recommendation is not reiterated.

References

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

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

7. Northern shrimp (*Pandalus borealis*) in the Fladen Ground (western part of ICES Division 27.4a)

Background documentation is found in SCR Doc. 21/046.

a) Introduction

From the 1960s up to around 2000, a significant shrimp fishery exploited the shrimp stock on the Fladen Ground in the northern North Sea. Landings from the Fladen Ground have been recorded since 1970, and total landings have fluctuated between zero and a maximum of around 9 000 t in 1987 (Fig. 7.1, Table 7.1). Historically, the Danish fleet accounted for the greatest share of these landings, while the Scottish fleet landed a smaller portion. Norway landed minor catches in some years. The fishery took place mainly during the first half of the year, with the highest activity in the second quarter. Since 1998, landings decreased steadily and since 2004, the Fladen Ground shrimp fishery has been virtually non-existent. Interview information from the fishing industry obtained in 2004 gave the explanation that the decline was caused by high fuel prices, low shrimp abundance and low prices on the small shrimp which are characteristic of the Fladen Ground. Since 2011, there have been minor Danish and Norwegian landings of shrimp from Fladen Ground, mainly taken as bycatch in the Norway pout fishery.

The Fladen Ground shrimp stock was surveyed as part of the annual Norwegian shrimp survey in the Skagerrak and Norwegian Deep in the late 1980s and early 1990s. The stock was surveyed again in January 2021. For many years, due to lack of both fishery and survey data, it was not known if the decline in the fishery reflected a decline in the stock. The last ICES advice given in 2019 advised no targeted fishery (ICES 2019). In 2021, there is an agreed quota of 660 tons which applies to the United Kingdom and European Union waters of Area 4, and the United Kingdom waters of Division 2.a.

Table 7.1. Shrimp in ICES Division 4.a West: Recent landings in metric tonnes, as used by NIPAG for the assessment.

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021[1]
Recommended TAC	*	*	*	*	*	*	*	0	0	0
Actual TAC	3 058	3 058	2 446	2 446	2 446	2 446	1 957	1 566	1 200	660
Denmark	0	0	1	19	0	1	0	2	153	277
UK (Scotland)	0	0	0	1.1	0	3.7	0	0	0	0
Sweden	0	0	0	0	0	0	0	0	0	0
Norway	0.5	0	0	0	10	6	0	6	66	0
Total	0	0	1	20.1	10	10.7	0	8	219	277

[1] Landings until October 2021.
* ICES catch advice for 2012-2018 was “no increase in catch”.

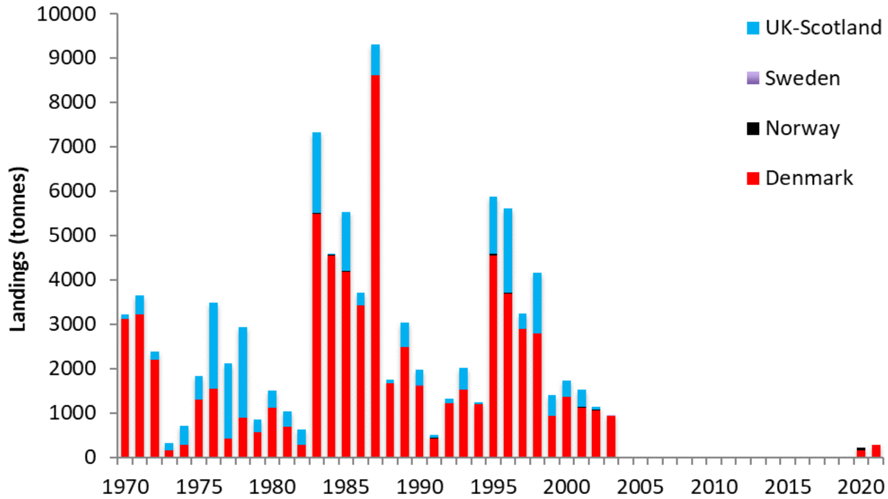


Figure 7.1. Shrimp in ICES Division 4.a West: Official landings by country, 1970-2021. The 2021-numbers are until October.

b) Input data

i) Commercial fishery data

The Danish shrimp fishery on Fladen Ground took place mainly from 1987 to 2003. Since 2004, only sporadic targeted fishery has taken place, 1 ton in 2014, 13 tons in 2015 and 24 tons in 2021. In recent years, the largest volumes of shrimp are by-caught in other small-meshed trawl fisheries such as the fishery for Norway pout. Especially in 2020 and 2021, total Danish shrimp bycatches were substantial, resembling the values experienced during the primary period of the targeted shrimp fishery in the 1990s. For the targeted Danish shrimp fishery on Fladen Ground (codend mesh size 32-69 mm) a landings-per-unit-effort (LPUE) time series has been calculated by dividing the total annual landings with the total annual kilowatt days in the fishery (Fig. 7.2). This index of stock size shows that in the three years with a significant targeted fishery since the minimum of the time series (and the stop of the fishery) in 2004, the LPUE values have been increasing, and in 2021, the value approaches the overall mean of the time series.

The Danish Norway pout landings from Fladen Ground have been sampled in harbour by the Danish Control Agency since 1989 to estimate total species composition in weight. The data cover the period from 1989 to April 2020, except for 2005 and 2007 when there was no quota and therefore no fishery. In April 2020, a change in the bycatch monitoring of the Norway pout fishery was implemented, increasing the sampling coverage. Based on the two harbour sampling schemes for the Norway pout fishery, two shrimp bycatch indices have been defined. Index #1 covers the period from 1989 to 30th of April 2020, and Index #2 covers the later period until October 2021. Index #1 is based on all industrial samples from the Norway pout fishery from the approximately 20 ICES squares which make up the distributional area of the Fladen Ground shrimp stock, whereas Index #2 is based on data from the same fishery, but for the full (slightly larger) area of the Fladen Ground Norway pout fishing grounds. The by-catch percentage was calculated as an average over all samples from a given year and plotted in the same figure (Fig. 7.2), demonstrating that the two 2020 values were almost identical (adding confidence to the comparability of the two-time series) and that the bycatch percentage increased substantially in 2020 and 2021, approaching the highest levels of the time series (values from the mid-1990s). The trend in the bycatch time series aligns with the trend in the LPUE index from the targeted shrimp fishery and supports the perception of the shrimp stock biomass having increased in recent years.

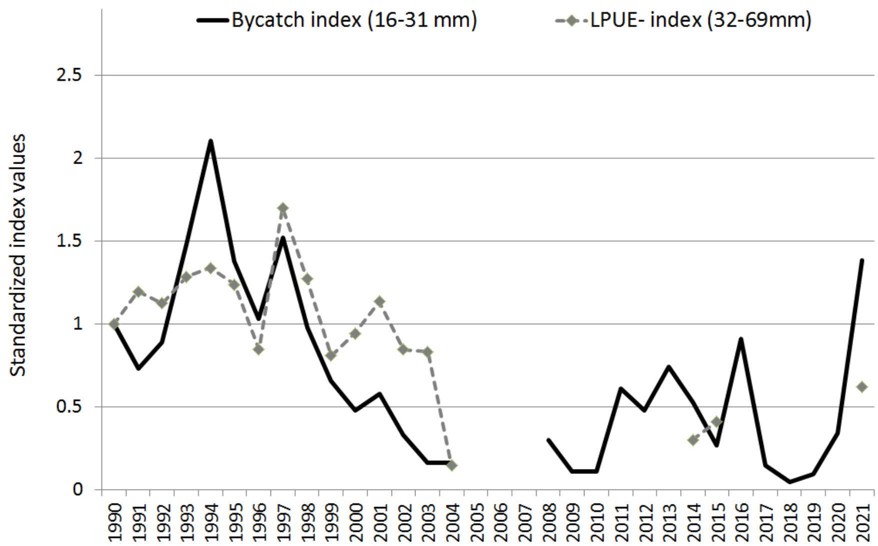


Figure 7.2. Shrimp in ICES Division 4.a West: time series of two stock size indices; one based on harbour sampling of bycatch in the Danish small meshed trawl fishery for Norway pout (codend mesh size 16-31 mm) and one based on landings and effort (LPUE) in the targeted Danish shrimp fishery. Index values are standardized to the first year of the time series (1990). The time series spans a change in the harbour sampling scheme in 2020, which is not assessed to have biased the subsequent estimates of the bycatch index (SCR Doc. 21/046).

ii) Research survey data

Abundance and density. A trawl survey for shrimp in Skagerrak and the Norwegian Deep (ICES Divisions 3.a and 4.a East) has since 1984 been conducted annually by the Norwegian Institute of Marine Research (IMR) with the objective of assessing the distribution, biomass, abundance and length distribution of the shrimp stock (Søvik and Thangstad 2021). In the late 1980s and early 1990s, IMR surveyed also the shrimp stock on the Fladen Ground. A total of seven cruises were conducted in October/November, as part of the first time series from 1984-2002 using R/V Michael Sars and the Campelen-trawl. No scientific survey has covered the shrimp stock on Fladen Ground since the mid-1990s. However, as recent bycatches of shrimp in the Danish and Norwegian Norway pout fisheries have indicated increasing densities of shrimp on the Fladen Ground, a cruise was again conducted by IMR, in January 2021. The timing of the annual shrimp survey shifted to the 1st quarter in 2006 (Søvik and Thangstad 2021). There have also been changes in the vessel used, but the gear is still the standard Campelen-trawl.

The high abundance of shrimp on the Fladen Ground perceived from the fisheries data was confirmed by the 2021-survey. In fact, the two highest trawl catches of shrimp (157 and 342 kg, in 30 minutes tows) in the whole 2021 survey were taken on Fladen Ground (Fig. 7.3). Mean abundance in 2021 was considerably higher compared with the time series 1986-1994, mainly due to the two high trawl catches, while the median was on the same level as the earlier years (Fig. 7.4). The same pattern is seen for the density of shrimp (kg per trawled nautical mile).

Recruitment. The Fladen Ground stock in the first quarter consists mainly of three year-classes (Fig. 7.5) (2021-plot). The size of the 1-group in 2021 was relatively large, indicating good recruitment to the stock in the near future. This age group has already recruited to the fishable biomass (second half of 2021). Length frequency distributions from the 1980s and 1990s indicate that the shrimp stock in the fourth quarter consists mainly of two age groups, the 1- and 2-year old shrimp. The 0-group is visible in some of the plots. The exception is the length distribution from 1986, showing 4-5 age groups with shrimp up to 30 mm carapace length.

Due to fast growth, the Fladen Ground shrimp stock is dependent on frequently good year classes to sustain high densities. It should be noted that recruitment to the neighboring stock Skagerrak and the Norwegian Deep has been low for many years (NAFO/ICES 2020). However, stock dynamics might be different on the Fladen Ground compared with in the Norwegian Deep and Skagerrak (SCR Doc. 21/046). Results from genetic investigations suggest two separate populations (Knutsen et al. 2015).

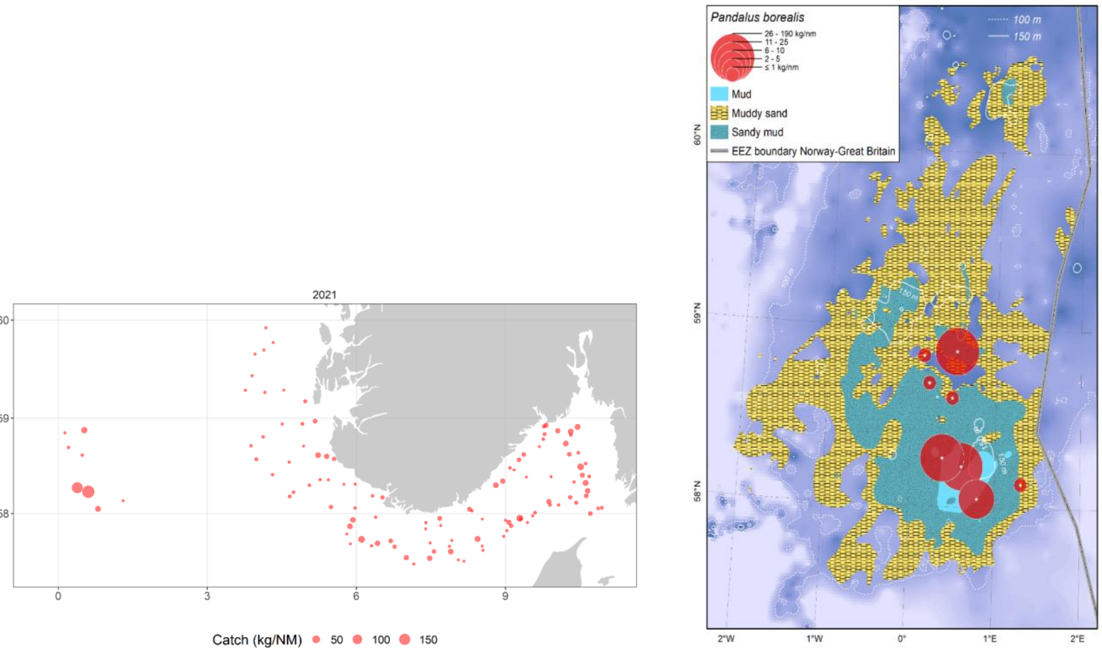


Figure 7.3. Shrimp in ICES Division 4.a west: i) the left-hand panel shows the distribution and size of trawl catches on the full IMR annual shrimp survey (both the Fladen and the Skagerrak and Norwegian Deep stocks) in January 2021, and ii) the right-hand figure shows the distribution of trawl catches on Fladen grad overlaid with sediment information, where the muddy areas give an indication of the extent of the shrimp stock.

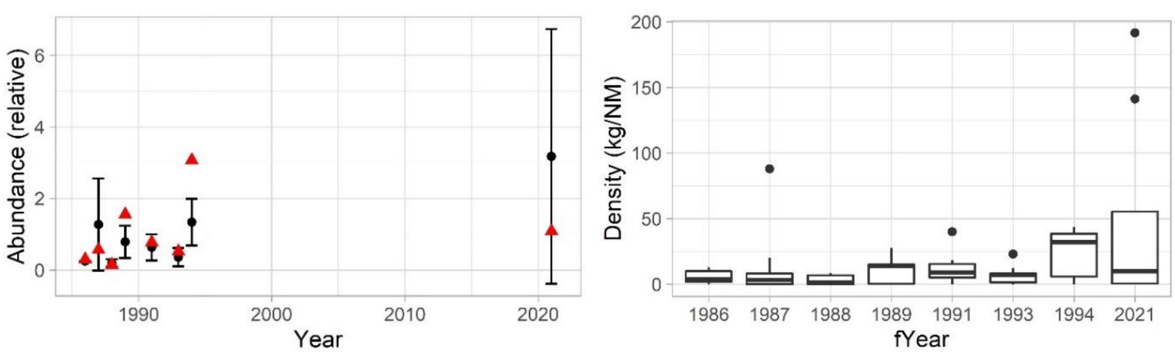


Figure 7.4. Shrimp in ICES Division 4.a West: Survey time series, 1986-1994 and 2021, abundance (relative index), mean ± 95 % confidence interval (black dots) and median (red triangles) (left), and density (kg/nm) (right), boxplot showing median (bold line), first and third quartiles (hinges, the 25th and 75th percentiles), and whiskers spanning 1.5 times the inter-quantile range above and below the hinges. Dots indicate outliers outside of the inter-quantile range.

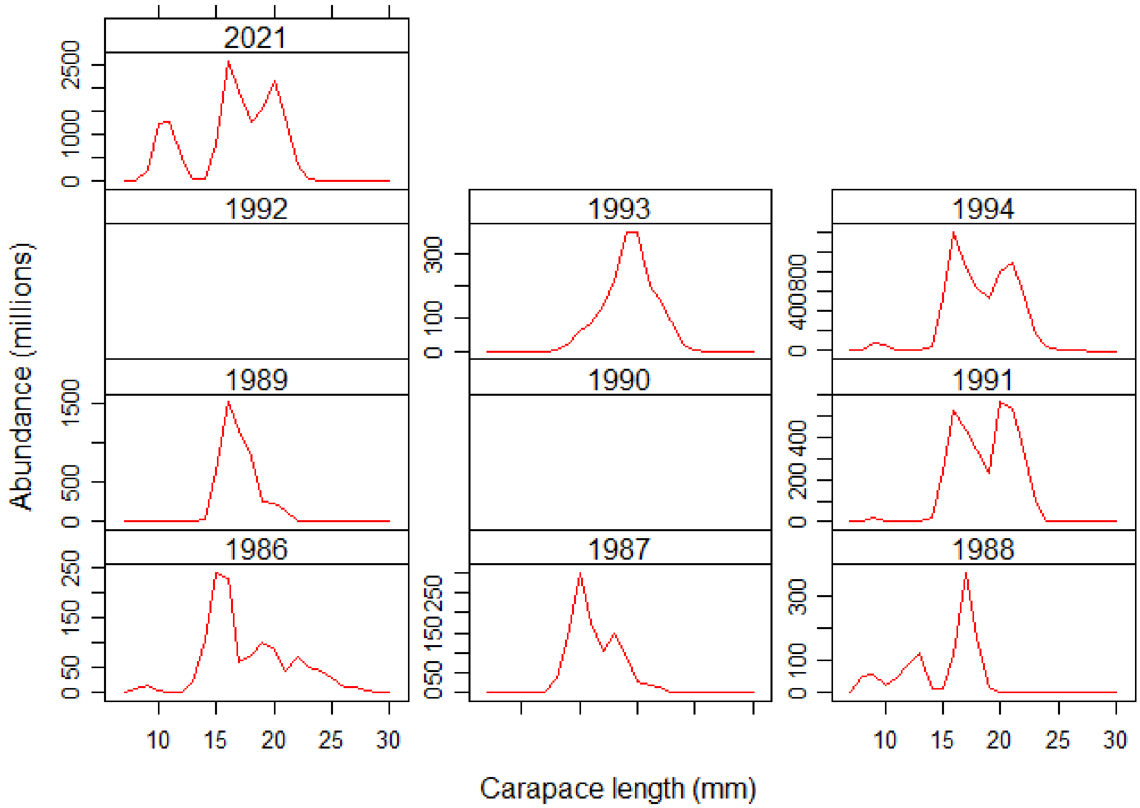


Figure 7.5. Shrimp in ICES Division 4.a West: Length frequency distributions from the annual IMR surveys in October/November 1986-1994 (no surveys in 1990 and 1992), and in January 2021. Note different y-axes.

c) Assessment

New information and analyses of historical data have substantially improved the knowledge basis for assessing the stock status of the Fladen Ground shrimp stock. Overall, the different sources of new information; Norwegian survey data, a new Danish LPUE-index and a new Danish bycatch-based stock index, all indicate that the shrimp stock on Fladen Ground has increased since 2018 and likely is at a relatively high level.

A Danish observer and self-sampling program for the targeted shrimp fishery was initiated in 2021, which provided biological data of the stock (weight, length, and sex). If a commercial shrimp fishery is continued on Fladen Ground, these 2021 data may form the start of a new commercially-based time series that together with biological data from the Norwegian survey may enable a full analytical assessment of the stock. Due to likely irregular visits to Fladen Ground by the annual IMR shrimp survey an analytical assessment will have to be based mainly on fishery data.

Reference points. There are no reference points defined for this stock.

Stock size and fishing mortality. Stock size is likely at a relative high level and fishing mortality at a relatively low level.

Projections. There are no projections for this stock.

d) Additional considerations

Environmental conditions. The Fladen Ground is a rather shallow area with depths between 100 and 150 m. The area of suitable muddy shrimp habitat is limited and surrounded by sandy bottom.

Temperature. Measurements of bottom temperature in January 2021 at the annual Norwegian shrimp survey gave values between 7.9 and 8.2 ^{0}C, indicating warm bottom water.

e) State of the stock

State of the Stock. The state of the stock relative to reference points is unknown. However, new information from the fisheries and the Norwegian shrimp survey indicate that the stock size has increased since 2018 and presently is at a relatively high level.

f) Research recommendations

NIPAG **recommends** that *a trial fishery including compulsory sampling of catches is initiated on the Fladen Ground.*

References

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(Northern North Sea, Fladen Ground)

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IV. Other matters

a) Date and place for the next NIPAG meeting

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

- In future years, advice for the Barents Sea stock will be required by late summer to accommodate the Norway/Russia Fisheries Commission meeting which takes place in October. It would be preferable to have the meeting in late November to allow inclusion of autumn survey data but, if the meeting is held earlier, it would be possible to do an update before Norway/Russia Commission meeting.
- The timing of the East Greenland survey in future years is uncertain but could most likely be in the summer. The West Greenland survey will be June/July, as usual.
- The Skagerrak stock will continue to be assessed during February/March. This will be considered as a full NIPAG meeting, and meeting times will be arranged to allow full participation in North American time zones.
- As in the last two years, the NAFO Commission will require advice for the NAFO 3M stock to be available for their Annual Meeting in September. The EU Flemish Cap survey will be completed in late July but, due to the time taken for the vessel to return to Spain and the summer holiday season, it is not expected that the data would be available before the end of August.

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

It was agreed that the main 2022 NIPAG meeting will be held 12-17 September in Copenhagen. It will be necessary to assess the 3M stock early in the meeting to allow the advice to be ready well in advance of the NAFO Annual Meeting.

There will be an additional NIPAG meeting by Webex in November, if required, to assess stocks not covered in the September meeting.

Table IV.1 Timing of key events relevant to the timing of *Pandalus* assessments currently done under NIPAG.

Management Unit	Management Cycle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	*Potential* Assessment Window
3LNO	Jan 1 - Dec 31													Mar-Sep
3M	Jan 1 - Dec 31													Aug-Sep
West Greenland (Div 0A + SA1)	Jan 1 - Dec 31													Sep-Oct
East Greenland + Denmark St	Jan 1 - Dec 31													Sep-Oct
Barents Sea	Jan 1 - Dec 31													Aug-Oct
Skaggerak & Norwegian Deep	Jan 1 - Dec 31													Feb-Mar
Fladen Ground	Jan 1 - Dec 31													Aug-Oct

Legend
- Survey Data Available
- Logbook Data Available
- Assessment Preparation Complete
- Advice is required
- TAC Decision

Table IV.2. Advice Schedule for NIPAG shrimp stocks

	November 2021	March 2022	September 2022	November 2022	March 2023	September 2023 WebEx	November 2023
3M	Produce Advice for 2022-23		Interim monitoring Report			Produce Advice for 2024-25	provisional advice 2025
3LNO	interim monitoring report		produce advice for 2020 and 2021	interim monitoring report		update if required	provisional advice 2022 and 2023
Skagerrak and Norwegian Deep	provisional advice for 1st half 2019	full advice for 2019, provisional advice 1st half 2020		review	full advice for 2020, provisional advice 1st half 2021		review
Fladen Ground	Full Advice			Full Advice			Full Advice
West Greenland	Full Advice (subject to requests from Greenland and Canada)			Full Advice (subject to requests from Greenland and Canada)			Full Advice (subject to requests from Greenland and Canada)
Denmark strait and East Greenland	Full Advice (subject to requests from Greenland)			Full Advice (subject to requests from Greenland)			Full Advice (subject to requests from Greenland)
Barents Sea	Full Advice			Full Advice			Full Advice

V. Adjournment

The NIPAG meeting was adjourned at 1300 hours on 4 November 2021. The Chair thanked all participants, especially the designated experts and stock coordinators, for their hard work. The Chair thanked the NAFO and ICES Secretariats for all of their logistical support. The report was adopted at the close of the meeting, subject to editorial changes.

PART E: REPORT OF THE SCIENTIFIC COUNCIL (IN CONJUNCTION WITH NIPAG) MEETING

1 to 4 November 2021
by WebEx

REPORT OF THE SCIENTIFIC COUNCIL (IN CONJUNCTION with NIPAG) MEETING
1- 4 November 2021, via WebEx

Chair : Mark Simpson Rapporteur : Tom Blasdale

I. PLENARY SESSIONS

Scientific Council, in conjunction with the NAFO/ICES *Pandalus* Assessment Group, met by WebEx on 1- 4 November 2021, to consider the various matters in its agenda. Representatives attended from Canada, Denmark (in respect of the Faroe Islands and Greenland), the European Union, Norway and the Russian Federation. A full list of participants is included in Appendix II.

The Chair, Mark Simpson, opened the meeting 08:00 Halifax time (12:00 UTC) by welcoming participants. The provisional agenda was adopted as circulated. The Scientific Council Coordinator was appointed as rapporteur.

II. REVIEW OF SCIENTIFIC COUNCIL RECOMMENDATIONS IN 2019 AND 2020

Recommendations from 2019 and 2020 are considered in the relevant sections of this report.

III. NAFO/ICES PANDALUS ASSESSMENT GROUP

In November 2021, NIPAG fully assessed two stocks of relevance to NAFO: northern shrimp in Subareas 0 and 1, and northern shrimp in Denmark Strait and off East Greenland. The Scientific Council summary sheets, conclusions and advice for these stocks are presented in Section IV of this report. Additionally, NIPAG reviewed assessments for two stocks for which advice was given in September 2021 (SCS Doc. 21/17): Northern shrimp in NAFO Division 3M and Northern shrimp in NAFO Divisions 3LNO. The full NIPAG report is available in NAFO SCS Doc. 21/19.

IV. MANAGEMENT ADVICE

1. Request for Advice on TACs and Other Management Measures

Requests from the NAFO Commission for advice on Northern Shrimp in Division 3M and Northern Shrimp in Divisions 3LNO were addressed during the September meeting (SCS Doc 21/17).

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

Advice November 2021 for 2022

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 2022 should not exceed 115 000 t.

With regard to the Canadian harvest strategy, Scientific Council notes that catches of 115 000 t in 2022 would result in less than 35% risk of exceeding Z_{msy} in 2022, and a 35% risk of exceeding Z_{msy} in 2023 and 2024, assuming catches at the same level as in 2022.

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 less 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***
Apply Precautionary Approach	●	Stock status is both estimated and forecast relative to precautionary reference points

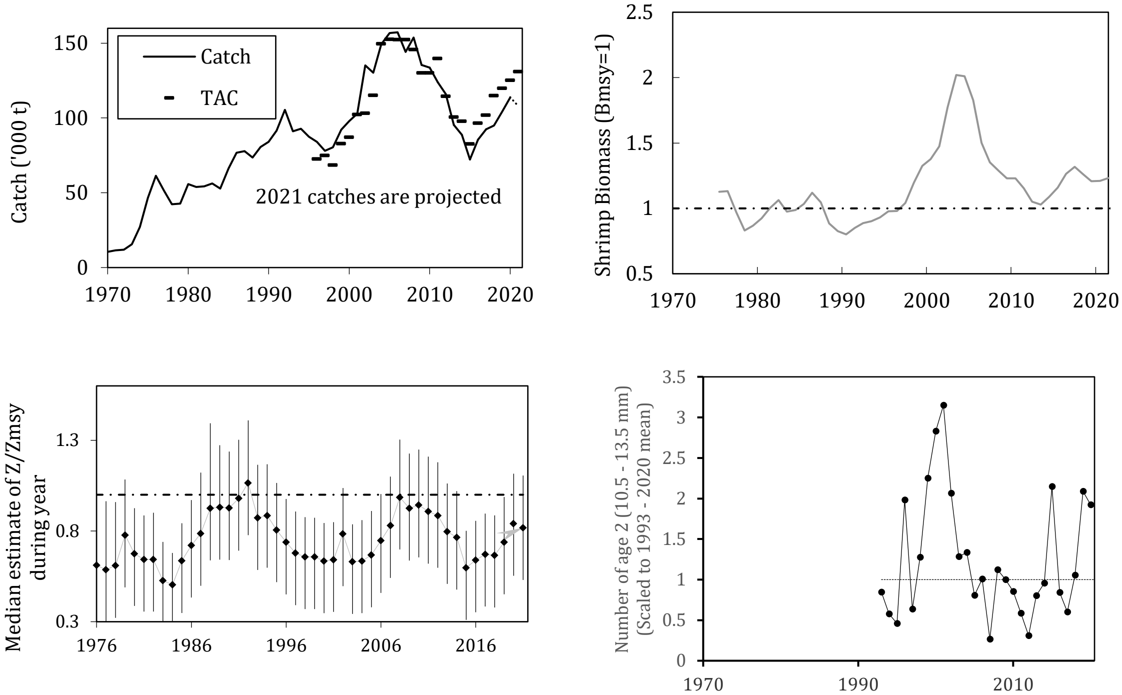
● OK

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 2020, more that 99% of the landings were from Greenland.

Stock status

Biomass at the end of 2021 is above B_{msy} and the probability of being below B_{lim} is very low (<1%). The probability of mortality in 2021 being above Z_{msy} is 33%. Recruitment (number of age-2 shrimp) in 2020 was above average.



Reference points

B_{lim} has been established as 30% B_{msy}, and Z_{msy} (fishery and cod predation) has been set as the mortality reference point (FC Doc. 04-18). B_{msy} and Z_{msy} are estimated directly from the assessment model.

Projections

Predicted probabilities of transgressing precautionary reference points in 2022 – 2024 under eight catch options and subject to predation by a cod stock with an effective biomass of 6 Kt.

6 000 t cod	**Catch option ('000 tons)**							
Risk of:	**95**	**100**	**105**	**110**	**115**	**120**	**125**	**130**
falling below Bmsy end 2022 (%)	26	26	26	26	28	27	27	27
falling below Bmsy end 2023 (%)	26	27	27	27	29	30	30	30
falling below Bmsy end 2024 (%)	26	28	28	29	30	32	32	34
falling below Blim end 2022 (%)	0	0	0	0	0	0	0	0
falling below Blim end 2023 (%)	0	0	0	0	0	0	0	0
falling below Blim end 2024 (%)	0	0	0	0	0	0	0	0
exceeding Zmsy in 2022 (%)	20	23	26	30	33	37	40	43
exceeding Zmsy in 2023 (%)	21	24	27	31	35	38	41	44
exceeding Zmsy in 2024 (%)	21	25	28	31	35	38	42	45
falling below Bmsy 80% end 2022 (%)	9	10	10	10	10	11	10	11
falling below Bmsy 80% end 2023 (%)	10	11	11	11	13	13	13	14
falling below Bmsy 80% end 2024 (%)	11	12	12	13	14	16	16	16

Assessment

Advice is based on risk analysis coming from a quantitative model. The analytical assessment was run in 2021 with revised treatment of the input data (SCR Doc. 20/053, 20/057, 21/040, 21/042) and with updated data series.

The next assessment is scheduled for 2022.

Human impact

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

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:

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Enacted TAC[1]	114 425	100 596[1]	97 649[1]	82 561[1]	96 426[1]	101 706[1]	114 876[1]	119 875[1]	125 229[1]	130 937[1]
STATLANT 21	114 970	91 802	88 834	71 779	84 303	91 725	91 869	102 706	110 229	
NIPAG	115 977	95 381	88 765	72 256	85 527	92 584	94 878	104 314	113 868	108 000[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

No survey has been conducted in the assessment area in 2021, due to delay of the new Greenlandic research ship.

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 recommend that the catch table should be given in increments of no less than 5 t due to uncertainty in calculating risk levels.

Source of Information

SCS Doc 13/04, FC Docs 04-18, SCR Docs. 20/053, 20/057, 21/040, 21/041, 21/042

b) Northern shrimp in Denmark Strait and off East Greenland

Advice November 2021 for 2022

Recommendation

There is uncertainty about the current stock status, however there is no indication of any change from last year's assessment in 2020. Therefore Scientific Council reiterates its advice that the catch in 2022 should not exceed 3000 t.

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} defined. No fishing mortality reference is defined.

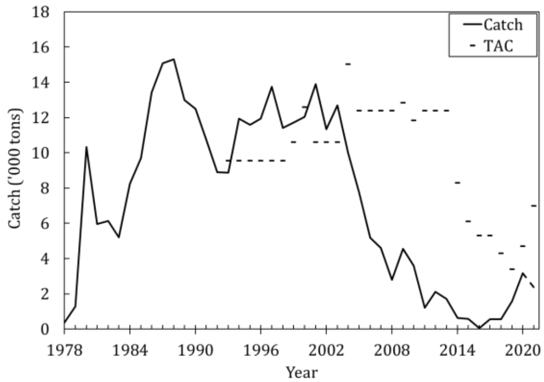
● Intermediate

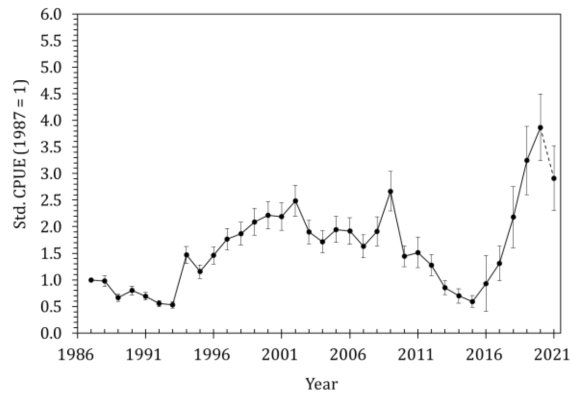
Management unit

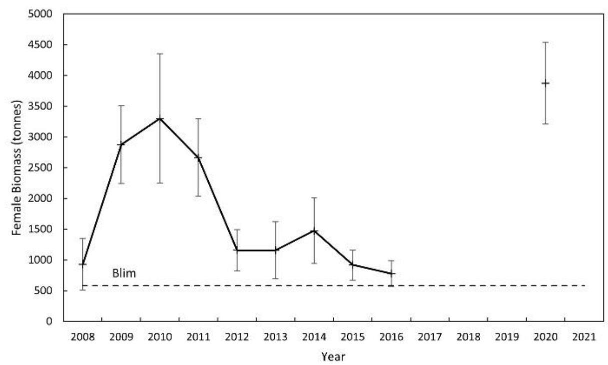
The shrimp stock is distributed off East Greenland in ICES Div. 14b and 5a and is assessed as a single population.

Stock status

There was no survey in 2021 nor in 2017 to 2019. The stock in 2020 was at a high level. The survey biomass in 2020 is the highest observed since the beginning of the survey, in 2008. The commercial CPUE in 2021 has decreased compared to 2020 but remains at a high level. There is no recruitment index available for this stock, few juvenile shrimps are caught in the survey area.







Reference points

Scientific Council considers that 15% of the maximum survey female biomass provides a proxy for *Blim* (SCS Doc. 17/17). The record high survey biomass found in 2020 results in *Blim* = 580 t.

Projections

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

Assessment

There was no survey in 2021. The most recent survey was in 2020 after three years with no survey data. The survey biomass was the highest since the survey started in 2008. The standardized commercial CPUE has increased since 2015 and was at a historical high level in 2020, it has since dropped slightly in 2021. In 2021 the fisheries started late due to a delay in licences, this may have impacted the fishing pattern. The survey biomass in 2020 is concentrated in a fairly small geographical area and the recent fishing effort is concentrated in the same general area. Recent fishing effort has been relatively low, so this CPUE may not reflect stock status for the entire stock distribution area.

A comprehensive sensitivity analyses of the surplus production model (SPiCT) was performed as recommended by NIPAG 2021 (SCR Doc 21/044). However, the SPiCT model was not applicable as a preliminary assessment tool this year but encourage future development of this modeling approach.

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

Biological and Environmental Interactions
Cod is an important predator on shrimp. The cod stock has generally been decreasing in East Greenland waters since 2014.

Fishery

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

Recent catches and TAC (t) were as follows:

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Enacted TAC	12 400	12 400	8 300	6 100	5 300	5 300	4 300	3 384	4 750	7 000
SC Recommended TAC	12 400	12 400	2 000	2 000	2 000	2 000	2 000	2 000	3 000	3 000
NIPAG	2 109	1 717	622	576	49	561	547	1 580	3 172	2 370[1]

[1] To June 30th 2021

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. 20/066, 21/043, 21/044

V. OTHER MATTERS

1. Scheduling of Future Meetings

a) Scientific Council meetings

i) WG-ESA, 16- 25 November 2021

The Working Group on Ecosystem Science and Assessment (WG-ESA) will meet at the NAFO Secretariat, Nova Scotia, Canada, from 16 to 25 November 2021.

ii) Scientific Council, June 2022

Scientific Council June 2022 meeting will be held in Halifax, Nova Scotia, Canada, from 3 to 16 June 2022.

iii) Scientific Council, (in conjunction with NIPAG), September 2022

The Scientific Council shrimp advice meeting will be held in Copenhagen from 12 to 17 September 2022.

iv) Scientific Council, September 2022

The Annual meeting will be held from 19 to 23 September 2022, in Lisbon, Portugal.

b) NAFO/ICES Joint Groups

i) ICES – NAFO Working Group on Deep-water Ecosystem, 2022

Dates and location to be determined.

ii) ICES/NAFO/NAMMCO WG-HARP

The date and location of the next ICES/NAFO/NAMMCO Working Group on Harp and Hooded Seals (WGHARP) meeting are unknown.

iii) NIPAG, November 2022

The Scientific Council shrimp advice meeting will be held in Copenhagen from 12 to 17 September 2022.

2. Topics for Future Special Sessions

No special session was proposed.

3. Other Business

No other business was discussed.

VI. ADOPTION OF SCIENTIFIC COUNCIL AND NIPAG REPORTS

The Council at its session on 4 November 2021 considered and adopted Sections III.1-4 of the "Report of the NAFO/ICES *Pandalus* Assessment Group" (NAFO SCS Doc. 21/19). The Scientific Council then considered and adopted its own report of the October 2020 meeting subject to editorial changes after the meeting.

VII. ADJOURNMENT

The meeting was adjourned at 1300 hours on 4 November 2021. The Chair thanked all participants, especially the designated experts and stock coordinators, for their hard work. The Chair thanked the NAFO and ICES Secretariats for all of their logistical support. The report was adopted at the close of the meeting, subject to editorial changes.

PART F: MISCELLANEOUS

A –NAFO SCIENTIFIC COUNCIL MEETING, 27 MAY – 11 JUNE 2021 –AGENDA

Provisional Agenda

(By correspondence and videoconference)

The meeting will be held from Monday to Friday. Weekends will not be working days.

Note:

- For STACFEN, STACPUB and STACREC (items III, IV and V below), the Committee Chairs will produce a draft of the report offline and upload it to the Scientific Council SharePoint, either in June or September, depending on workload. Scientific Council will be informed and given the opportunity to comment before the approval of these reports.
- The same working procedure will be applied to some of the STACFIS and Scientific Council items. All stock assessments and other scientific work directly used in responding to this year's requests for advice will be presented in plenary sessions by WebEx.

I. Opening (Scientific Council Chair: Carmen Fernández)
  1. Appointment of Rapporteur
  2 Presentation and Report of Proxy Votes
  3. Adoption of Agenda
  4. Attendance of Observers
  5. Appointment of Designated Experts
  6. Plan of Work
  7. Housekeeping issues

II. Review of Scientific Council Recommendations in 2020

III. Fisheries Environment (STACFEN Chair: Miguel Caetano)
  1. Opening
  2. Appointment of Rapporteur
  3. Adoption of Agenda
  4. Review of Recommendations in 2020
  5. Department of Fisheries and Oceans Canada, Oceans Science Branch, Marine Environmental Data Section (MEDS) Report for 2020
  6. Review of the physical, biological and chemical environment in the NAFO Convention Area during 2020
  7. Formulation of recommendations based on environmental conditions during 2020
  8. Other Matters
  9. Adjournment

IV. Publications (STACPUB Chair: Margaret Treble)
  1. Opening
  2. Appointment of Rapporteur
  3. Adoption of Agenda
  4. Review of Recommendations in 2020
  5. Review of Publications
     a) Annual Summary
        i) Journal of Northwest Atlantic Fishery Science (JNAFS)
        ii) Scientific Council Studies
        iii) Scientific Council Reports

6. Other Matters
7. Adjournment

V. Research Coordination (STACREC Chair: Karen Dwyer)
1. Opening
2. Appointment of Rapporteur
3. Review of Recommendations in 2020
4. Fishery Statistics
    a) Progress report on Secretariat activities in 2020/2021
        i) Presentation of catch estimates from the CESAG, daily catch reports and STATLANT 21A and 21B
5. Research Activities
    a) Biological sampling
        i) Report on activities in 2020/2021
        ii) Report by National Representatives on commercial sampling conducted
        iii) Report on data availability for stock assessments (by Designated Experts)
    b) Biological surveys
        i) Review of survey activities in 2020 and early 2021 (by National Representatives and Designated Experts)
        ii) Surveys planned for 2021 and early 2022
    c) Tagging activities
    d) Other research activities
6. Review of SCR and SCS Documents
7. Other Matters
    a) Summary of progress on previous recommendations
    b) NAFO Catch Estimates Methodology Study
8. Adjournment

VI. Fisheries Science (STACFIS Chair: Kathy Sosebee)
I. Opening
II. General Review of Catches and Fishing Activity
III. Stock Assessments
1. Greenland halibut (*Reinhardtius hippoglossoides*) in SA 0+1 offshore (monitor)
2. Greenland halibut (*Reinhardtius hippoglossoides*) Div. 1A inshore Divs. 1BC inshore, Div. 1D inshore and Divs. 1EF inshore (monitor)
3. Demersal Redfish and deep-sea redfish (*Sebastes* spp.) in SA 1 (monitor)
4. Wolffish in SA 1 (monitor)
5. Golden redfish (*Sebastes norvegicus* aka *S. marinus*) in Div. 3M (monitor)
6. Cod (*Gadus morhua*) in Div. 3M (full assessment)
7. Redfish (*Sebastes mentella* and *Sebastes fasciatus*) in Div. 3M (full assessment)
8. American plaice (*Hippoglossoides platessoides*) in Div. 3M (monitor)
9. Cod (*Gadus morhua*) in Divs. 3NO (full assessment)
10. Redfish (*Sebastes mentella* and *Sebastes fasciatus*) in Divs. 3L and 3N (monitor)
11. American plaice (*Hippoglossoides platessoides*) in Divs. 3LNO (full assessment)
12. Yellowtail flounder (*Limanda ferruginea*) in Divs. 3LNO (full assessment)
13. Witch flounder (*Glyptocephalus cynoglossus*) in Divs. 3NO (monitor)
14. Capelin (*Mallotus villosus*) in Divs. 3NO (full assessment)
15. Redfish (Sebastes mentella and Sebastes fasciatus) in Div. 3O (monitor)

16. Thorny skate (*Amblyraja radiata*) in Divs. 3LNO and Subdiv. 3PS (monitor)
17. White hake (*Urophycis tenuis*) in Divs. 3NO and Subdiv. 3PS (full assessment)
18. Roughhead grenadier (*Macrourus berglax*) in SA 2 and 3 (monitor)
19. Greenland halibut (*Reinhardtius hippoglossoides*) in SA 2 + Divs. 3KLMNO (under management strategy: (monitor, COM request #2)
20. Northern shortfin squid (*Illex illecebrosus*) in SA 3+4 (monitor)
21. Splendid alfonsino (*Beryx splendens*) in SA 6 (monitor)

IV. Other Matters
  a) FIRMS Classification for NAFO Stocks (Note: expected to be deferred to September)
  b) Other Business
V. Adjournment

VII. Management Advice and Responses to Special Requests (See Annex 1)

Because of the difficulties caused by the online meeting format, it may not be possible to address all the requests during the June meeting. The following priority order will be applied to the requests:

Priority level	**Schedule for SC addressing the request**
1	June
2	June (but could be delayed to September if no time in June – to be decided during the June meeting, depending on progress)

1. NAFO Commission (Annex 1)
  a) Request for Advice on TACs and Other Management Measures (request #1, Annex 1)
  [Priority level 1 for all of them]
    <u>For 2022</u>
    - Cod in Div. 3M
    <u>For 2022 and 2023</u>
    - Redfish in Div. 3M
    - White hake in Divs. 3NO
    <u>For 2022, 2023 and 2024</u>
    - American Plaice in Divs. 3LNO
    - Capelin in Divs. 3NO
    - Cod in Divs. 3NO
    - Yellowtail Flounder in Divs. 3LNO

  b) Monitoring of Stocks for which Multi-year Advice was provided in 2019 or 2020 (request #1)
  [Priority level 1 for all of them, except squid which is for September]
    - American plaice in Div. 3M
    - Redfish in Divs. 3LN
    - Witch flounder in Divs. 3NO
    - Redfish in Divs. 3O
    - Thorny skate in Divs. 3LNO and Subdiv. 3PS
    - Greenland halibut in SA 2 + Divs. 3KLMNO
    - Alfonsino stocks in the NAFO Regulatory Area
    - Roughhead grenadier in SA 2 and 3

- Northern shortfin squid (*Illex illecebrosus*) in SA 3+4 [note: to be done in September]

c) Special Requests for Management Advice

Request #2 [Priority level 1]: Greenland halibut in SA2 + Divs. 3KLMNO: monitor, compute the TAC using the agreed HCR and determine whether exceptional circumstances are occurring

Request #3 [Priority level 1]: Continue the evaluation of scientific trawl surveys in VME closed areas and the effect on stock assessments of excluding the surveys from these areas

Request #4 [Priority level 1]: Implement the steps of the bycatch and discards action plan relevant to SC: Task 2.2 (already responded to in September 2020 SC report); Tasks 3.1 and 3.2 for June 2021.

Request #5 [Priority level 2]: Continue to refine work on the Ecosystem Roadmap

Request #6 [Priority level 1]: Re-assessment of NAFO bottom fisheries in 2021

Request #7 [Priority level 2]: Review the proposed revisions to Annex I.E, Part VI

Request #8 [Priority level 1]: Continue progress on the NAFO PA Framework review

Request #9 [Priority level 1]: Identify areas and times where bycatch and discards of Greenland sharks have a higher rate of occurrence

Request #10 [Priority level 2]: Continue to develop a 3-5 year work plan

Request #11 [Priority level 1]: Scoping exercise for 3LN redfish MSE

Request #12 [Priority level 1]: Review submitted protocols for a survey methodology to inform the assessment of splendid alfonsino

Request #13 [Priority level 2]: Presentation of the stock assessment and the scientific advice of Cod 2J3KL (Canada), Witch 2J3KL (Canada) and *Pelagic Sebastes mentella* (ICES Divisions V, XII and XIV; NAFO 1)

Request #14 [Priority level 1]: Conduct ongoing analysis of the Flemish Cap cod fishery data by 2022

Request #15 [Priority level 1]: Consider whether other measures, such as depth restrictions, spatial and mesh changes, could reduce the catch of juvenile and immature cod across all fisheries in 3M

Request #16 [Priority level 2]: Provide updates on relevant research related to the potential impact of activities other than fishing in the Convention Area & work with other organizations (FAO, ICES…) to bring in additional expertise to inform SC's work

Request #17 [Priority level 2]: Information on sea turtles, sea birds, and marine mammals that are present in NAFO Regulatory Area

Request #18 [Priority level 2]: Ecosystem summary sheets for 3M and 3LNO & move toward joint workshop with ICES

2. Coastal States

a) Request by Denmark (Greenland) for Advice on Management in 2022 (Annex 2)
None: requests for advice on Management in 2022 were for monitoring only

b) Request by Canada and Denmark (Greenland) for Advice on Management in 2022 (Annex 2, Annex 3)
None: requests for advice on Management in 2022 were for monitoring only

VIII. Review of Future Meetings Arrangements

1. Scientific Council (in conjunction with NIPAG), 8 to 14 Sep. 2021
2. Scientific Council, 20 – 24 Sep. 2021
3. WG-ESA, Nov. 2021
4. Scientific Council, June 2022
5. Scientific Council (in conjunction with NIPAG), 2022

6. Scientific Council, Sep. 2022
7. WG-ESA, Nov. 2022
8. NAFO/ICES Joint Groups
   a) NIPAG, 2021
   b) NIPAG, 2022
   c) WG-DEC
   d) WG-HARP

IX. Arrangements for Special Sessions
1. Topics for future Special Sessions (Note: expected to be deferred to September)

X. Meeting Reports (Note: some may be deferred to September)
1. Working Group on Ecosystem Science and Assessment (WG-ESA), Nov. 2020
2. Report from ICES-NAFO Working Group on Deepwater Ecosystems (WG-DEC), 2020
3. Report from Joint COM-SC Working Group on Catch Estimation Strategy Advisory Group (CESAG), March and April 2020
4. Meetings attended by the Secretariat

XI. Review of Scientific Council Working Procedures/Protocol
1. General Plan of Work for September 2021 Annual Meeting
2. Priority actions for Scientific Council from the Performance Review Panel WG (adopted by the NAFO Commission in September 2019):
   - peer review process for the science underlying the SC advice, applied consistently to all SC science used in advice [note: to be discussed by SC in June if time permits, otherwise in September]

XII. Other Matters
1. Designated Experts
2. Election of Chairs
3. Budget items
4. Proposed MoU with the Sargasso Sea Commission
5. Other Business

XIII. Adoption of Committee Reports
1. STACFEN
2. STACREC
3. STACPUB
4. STACFIS

XIV. Scientific Council Recommendations to Commission

XV. Adoption of Scientific Council Report

XVI. Adjournment

B – NAFO SCIENTIFIC COUNCIL MEETING (IN CONJUNCTION WITH NIPAG), 08 SEPTEMBER 2021– AGENDA

By WebEx
8-9 September 2021

Daily hours (Halifax time, Canada): 08:00 to 13:00 h

I. Opening (Chair: Carmen Fernández)

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

II. Review of Recommendations in 2020

III. NAFO/ICES Pandalus Assessment Group (Co-chairs Katherine Sosebee and Ole Ritzau Eigaard)

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

1. Request for Advice on TACs and Other Management Measures (Annex I)
   a) Northern shrimp in Div. 3LNO
   b) Northern shrimp in Div. 3M

V. Other Matters

1. Scheduling of Future Meetings
2. Topics for Future Special Sessions
3. 2022 benchmark preparation
4. Other Business

VI. Adoption of Scientific Council and NIPAG Reports

VII. Adjournment

C – NAFO SCIENTIFIC COUNCIL MEETING, 20-24 SEPTEMBER 2021–AGENDA

I. Plenary Session

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

II. Review of Scientific Council Recommendations

III. Joint Session of Commission and Scientific Council

1. Implementation of 2018 Performance Review Panel recommendations
2. Presentation of scientific advice by the Chair of the Scientific Council
   a. Response of the Scientific Council to the Commission's request for scientific advice
   b. Feedback to the SC regarding the advice and its work during this meeting
   c. Other issues as determined by the Chair of the Commission and of the Scientific Council
3. Meeting Reports and Recommendations of the Joint Commission–Scientific Council Working Groups
   a. Working Group on Improving Efficiency of NAFO Working Group Process (E-WG), 2021
   b. Joint Commission–Scientific Council Working Group on Risk-based Management Strategies (WG-RBMS), August 2021
   c. Joint Commission–Scientific Council Working Group on Ecosystems Approach Framework to Fisheries Management (WG-EAFFM), July 2021
   d. Joint Commission–Scientific Council Catch Estimation Strategy Advisory Group (CESAG), 2021
4. Formulation of Request to the Scientific Council for Scientific Advice on Management in 2022 and beyond of Certain Stocks in Subareas 2, 3 and 4 and Other Matters

IV. Fisheries Environment (STACFEN Chair: Miguel Caetano)

1. Opening
2. Appointment of Rapporteur
3. Review of the report from June 2021
4. Other Matters
5. Adjournment

V. Publications (STACPUB Chair: Margaret Treble)

1. Opening
2. Appointment of Rapporteur
3. Adoption of Agenda
4. Review of the report from June 2021
5. Review of Recommendations in 2020
6. Review of Publications
   a. Annual Summary
      i. Journal of Northwest Atlantic Fishery Science (JNAFS)
      ii. Scientific Council Studies
      iii. Scientific Council Reports
7. Other Matters
8. Adjournment

VI. Research Coordination (STACREC Chair: Karen Dwyer)

1. Opening
2. Appointment of Rapporteur
3. Review of the report from June 2021
4. Review of Recommendations in 2020
5. Fishery Statistics
   a. Progress report on Secretariat activities in 2020/2021
      i. Presentation of catch estimates from the CESAG, daily catch reports and STATLANT 21A and 21B
6. Research Activities
   a. Biological sampling
      i. Report on activities in 2020/2021
      ii. Report by National Representatives on commercial sampling conducted
      iii. Report on data availability for stock assessments (by Designated Experts)
   b. Biological surveys
      i. Review of survey activities in 2020 and early 2021 (by National Representatives and Designated Experts)
      ii. Surveys planned for 2021 and early 2022
   c. Tagging activities
   d. Other research activities
7. Review of SCR and SCS Documents
8. Other Matters
   a. Summary of progress on previous recommendations
   b. Review of proposed changes to NAFO gear codes
9. Adjournment

VII. Fisheries Science (STACFIS Chair: Katherine Sosebee)

1. Opening
2. Nomination of Designated Experts
3. Other Matters
   a. Review of SCR and SCS Documents
   b. Review of FIRMS classification of NAFO stocks
   c. Other Business

VIII. Requests from the Commission

1. Requests/advice requested by the Commission (in NAFO/COM Doc. 20-16) deferred from the June 2021 Scientific Council Meeting
2. *Ad hoc* Requests from Current Meeting
3. Further progress on items related to COM requests (in NAFO/COM Doc. 20-16)
   a. COM request #8: NAFO PA Framework review
      Progress from PA-WG meetings in 2021

IX. Review of Future Meeting Arrangements

X. Future Special Sessions

1. Progress on 2021 symposium with ICES on Decadal Hydro-Biological Variability of the North Atlantic for the decade 2010-2019
2. Information concerning Flatfish Symposium 2022
3. Other potential future topics

XI. Other Matters

5. Implementation of 2018 Performance Review Panel recommendations
4. Meeting reports
   a. ICES/NAFO Working Group on Deep-water Ecology (WG-DEC)
   b. ICES/NAFO/NAMMCO Working Group on Harp and Hooded Seals (WG-HARP)

XII. Adoption of Reports

1. Committee Reports of STACFEN, STACPUB, STACFIS and STACREC
2. Report of Scientific Council

XIII. Adjournment

D – NAFO/ICES *PANDALUS* ASSESSMENT MEETING (NIPAG), 01 – 04 NOVEMBER 2021– AGENDA

By WebEx
1 to 4 November 2021

Daily hours (Halifax time, Canada): 08:00 to 13:00 h

I. Opening (chairs Mark Simpson)

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

II. General Review

1. Review of Recommendations in 2020
2. Review of Catches

III. Stock Assessments

Northern shrimp (NAFO Division 3M) (review of assessment September 2021)
Northern Shrimp (NAFO Divisions 3LNO) (review of assessment September 2021)
Northern shrimp (NAFO Subareas 0 and 1) (full assessment)
Northern shrimp (in Denmark Strait and off East Greenland) (full assessment)
Northern shrimp in the Skagerrak and Norwegian Deep (ICES Subdivision 27.3a.20 and the eastern part of Division 27.4a) (review of assessment February 2021)
Northern Shrimp in Barents Sea and Svalbard area (ICES Sub-areas I & II) (full assessment)
Northern shrimp in Fladen Ground (ICES Division IVa) (full assessment)

IV. Other Business

1. FIRMS Classification for NAFO Shrimp Stocks
2. Benchmark planning
3. Scheduling of future meetings

V. Adjournment

E – NAFO SCIENTIFIC COUNCIL (IN CONJUNCTION WITH NIPAG) MEETING, 01 – 04 NOVEMBER 2021 – AGENDA

By WebEx
1 to 4 November 2021

Daily hours (Halifax time, Canada): 08:00 to 13:00 h

I. Opening (Chair: Mark Simpson)

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

II. Review of Recommendations in 2019

III. NAFO/ICES Pandalus Assessment Group (Co-chairs Mark Simpson and Ole Ritzau Eigaard)

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

  1. Requests from Coastal States (Items 5 and 6 of Annex 3, item 2 of Annex 3)
     a. Northern shrimp (Subareas 0 and 1)
     b. Northern shrimp (in Denmark Strait and off East Greenland)

V. Other Matters

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

VI. Adoption of Scientific Council and NIPAG Reports

VII. Adjournment

THE COMMISSION'S REQUEST FOR SCIENTIFIC ADVICE ON MANAGEMENT IN 2022 AND BEYOND OF CERTAIN STOCKS IN SUBAREAS 2, 3 AND 4 AND OTHER MATTERS

(from SCS Doc. 21/01)

Following a request from the Scientific Council, the Commission agreed that items 1, 2, 8 and 11 should be the priority for the June 2021 Scientific Council meeting subject to resources and COVID-related restrictions.

1. The Commission requests that the Scientific Council provide advice for the management of the fish stocks below according to the assessment frequency presented below. In keeping with the NAFO Precautionary Approach Framework (FC Doc. 04-18), the advice should be provided as a range of management options and a risk analysis for each option without a single TAC recommendation. The Commission will decide upon the acceptable risk level in the context of the entirety of the SC advice for each stock guided and as foreseen by the Precautionary Approach.

Yearly basis	**Two-year basis**	**Three-year basis**
Cod in Div. 3M Northern shrimp in Div. 3M	Redfish in Div. 3M Northern shrimp in Div. 3LNO Thorny skate in Div. 3LNO Witch flounder in Div. 3NO Redfish in Div. 3LN White hake in Div. 3NO	American Plaice in Div. 3LNO American Plaice in Div. 3M Capelin in Div. 3NO Northern shortfin squid in SA 3+4 Redfish in Div. 3O Yellowtail flounder in Div. 3LNO Cod in Div. 3NO

To implement this schedule of assessments, the Scientific Council is requested to conduct a full assessment of these stocks as follows:

In 2021, advice should be provided for 2022 for Cod in Div. 3M and Northern shrimp in Div. 3M. With respect to Northern shrimp in Div. 3M, SC is requested to provide its advice to the Commission prior to the 2021 Annual Meeting based on the survey data up to and including 2021.

In 2021, advice should be provided for 2022 and 2023 for: Redfish in Div. 3M, Northern shrimp in Div. 3LNO, and White hake in Div. 3NO

In 2021, advice should be provided for 2022, 2023 and 2024 for: American plaice in Div. 3LNO, Capelin in Div. 3NO, Cod in Div. 3NO, Yellowtail flounder in Div. 3LNO

Advice should be provided using the guidance provided in **Annexes A or B as appropriate**, or using the predetermined Harvest Control Rules in the cases where they exist (currently Greenland halibut 2+3KLMNO).

The Commission also requests the Scientific Council to continue to monitor the status of all other stocks annually and, should a significant change be observed in stock status (e.g. from surveys) or in bycatch in other fisheries, provide updated advice as appropriate.

2. The Commission requests the Scientific Council to monitor the status of Greenland halibut in Subarea 2+Div. 3KLMNO annually to compute the TAC using the agreed HCR and determine whether exceptional circumstances are occurring. If exceptional circumstances are occurring, the exceptional circumstances protocol will provide guidance on what steps should be taken.

3. The Commission requests that the Scientific Council continue its evaluation of the impact of scientific trawl surveys on VME in closed areas, and the effect of excluding surveys from these areas on stock assessments.

4. The Commission requests the Scientific Council to implement the steps of the Action plan relevant to the Scientific Council and in particular the tasks identified under section 2.2 of the Action Plan, for progression in the management and minimization of Bycatch and discards (COM Doc. 17-26).

    - Tasks outlined in Tasks 3.1 and 3.2 of the NAFO Action Plan in the Management and Minimization of Bycatch and Discards (COM Doc. 17-26).

5. The Commission requests that Scientific Council continue to refine work on the Ecosystem Road Map:

- Continue to test the reliability of the ecosystem production potential model and other related models
- Report on these results to WG-EAFFM and WG-RBMS to further develop how it may apply to management decisions
- Develop options of how ecosystem advice could inform management decisions, an issue which is directly linked to the results of the foreseen EAFM roadmap workshop.
- Continue its work to develop models that support implementation of Tier 2 of the EAFM Roadmap."

6. The Commission requests that the Scientific Council, in preparation of the re-assessment of NAFO bottom fisheries in 2021 and discussion on VME fishery closures:

- Assess the overlap of NAFO fisheries with VME to evaluate fishery specific impacts in addition to the cumulative impacts for NRA fisheries;
- Consider clearer objective ranking processes and options for objective weighting criteria for the overall assessment of significant adverse impacts and the risk of future adverse impacts;
- Maintain efforts to assess all of the six FAO criteria including the three FAO functional SAI criteria which could not be evaluated in the current assessment.
- Provide input and analysis of potential management options, with the goal of supporting meaningful and effective discussions between scientists and managers at the 2021 WG-EAFFM meeting;
- Continue to work on the VME indicator species as listed in Annex IE, Section VI to prepare for the next assessment.

7. The Commission requests that the Scientific Council review the proposed revisions to Annex I.E, Part VI as reflected in COM-SC EAFFM-WP 18-01, for consistency with the taxa list annexed to the VME guide and recommend updates as necessary.

8. The Commission requests the Scientific Council to continue progression on the review of the NAFO PA Framework in accordance to the PAF review work plan approved in 2020 (NAFO COM-SC Doc. 20-04)

9. The Commission requests that the Scientific Council Work with WG-BDS to identify areas and times where bycatch and discards of Greenland sharks have a higher rate of occurrence in time for consideration by the Commission in 2021 to inform the development of measures to reduce bycatch in the NRA.

10. The Commission requests the Scientific Council to continue to develop a 3-5 year work plan, which reflects requests arising from the 2020 Annual Meeting, other multi-year stock assessments and other scientific inquiries already planned for the near future. The work plan should identify what resources are necessary to successfully address these issues, gaps in current resources to meet those needs and proposed prioritization by the Scientific Council of upcoming work based on those gaps.

11. The Commission requests that the Scientific Council, carry out a scoping exercise to provide guidance to the WG-RBMS on the process of conducting of a full review/evaluation of the management strategy of Div. 3LN redfish.

12. The Commission requests the Scientific Council review submitted protocols for a survey methodology to inform the assessment of Splendid Alfonsino. The Scientific Council to report on the outcome of this work at next Commission annual meeting.

13. The Commission requests that results from stock assessments and the scientific advice of Cod 2J3KL (Canada), Witch 2J3KL (Canada) and Pelagic Sebastes mentella (ICES Divisions V, XII and XIV; NAFO 1) to be presented to the Scientific Council (SC), and request the SC to prepare a summary of these assessments to be included in its annual report.

14. The Commission requests the Scientific Council, jointly with the Secretariat, to conduct ongoing analysis of the Flemish Cap cod fishery data by 2022 in order to:

    (1) monitor the consequences of the management decisions (including the analysis of the redistribution of the fishing effort along the year and its potential effects on ecosystems, the variation of the cod catch composition in lengths/ages, and the bycatch levels of other fish species, benthos in general, and VME taxa in particular), and

    (2) carry out any additional monitoring that would be required, including Div. 3M cod caught as bycatch in other fisheries during the closed period.

15. The Commission requests the Scientific Council, in its future work, to consider whether other measures, such as depth restrictions, spatial and mesh changes, could reduce the catch of juvenile and immature cod across all fisheries in 3M.

16. The Commission requests the Scientific Council to continue to monitor and provide updates resulting from relevant research related to the potential impact of activities other than fishing in the Convention Area. Further, that the Secretariat and the Scientific Council work with other international organizations, such as the FAO and ICES, to bring in additional expertise to inform the Scientific Council's work.

17. The Commission requests the Scientific Council to provide information to the Commission at its next annual meeting on sea turtles, sea birds, and marine mammals that are present in NAFO Regulatory Area based on available data.

18. The Commission requests that the Scientific Council proceed with developing the ecosystem summary sheets for 3M and 3LNO move toward undertaking a joint Workshop with ICES (International Council for the Exploration of the Sea) as part of a peer review of North Atlantic ecosystems.

ANNEX A. Guidance for providing advice on Stocks Assessed with an Analytical Model

The Commission requests the Scientific Council to consider the following in assessing and projecting future stock levels for those stocks listed above. These evaluations should provide the information necessary for the Fisheries Commission to consider the balance between risks and yield levels, in determining its management of these stocks:

- For stocks assessed with a production model, the advice should include updated time series of:
  - Catch and TAC of recent years
  - Catch to relative biomass
  - Relative Biomass
  - Relative Fishing mortality
  - Stock trajectory against reference points
  - And any information the Scientific Council deems appropriate.

Stochastic short-term projections (3 years) should be performed with the following constant fishing mortality levels as appropriate:

- For stocks opened to direct fishing: 2/3 F_{msy}, 3/4 F_{msy}, 85% F_{msy}, 90% F_{msy},95% F_{msy}, F_{msy} 0.75 X $F_{status\ quo}$, $F_{status\ qu}$,1.25 X Status quo, F=0; TAC Status quo, 85% TAC Status quo, 90% TAC Status quo, 95% TAC Status quo
- For stocks under a moratorium to direct fishing: $F_{status\ quo}$, F = 0.

The first year of the projection should assume a catch equal to the agreed TAC for that year.

Results from stochastic short-term projection should include:

- The 10%, 50% and 90% percentiles of the yield, total biomass, spawning stock biomass and exploitable biomass for each year of the projections
- The risks of stock population parameters increasing above or falling below available biomass and fishing mortality reference points. The table indicated below should guide the Scientific Council in presenting the short-term projections.

				Limit reference points														
				$P(F>F_{lim})$			$P(B<B_{lim})$				$P(F>F_{msy})$			$P(B<B_{msy})$				P(B2024 > B2020)
F in 2022 and following years*	Yield 2022 (50%)	Yield 2023 (50%)	Yield 2024 (50%)	2022	2023	2024	2022	2023	2024		2022	2023	2024	2022	2023	2024		
2/3 Fmsy	t	t	t	%	%	%	%	%	%		%	%	%	%	%	%		%
3/4 Fmsy	t	t	t	%	%	%	%	%	%		%	%	%	%	%	%		%
85% Fmsy	t	t	t	%	%	%	%	%	%		%	%	%	%	%	%		%
90% Fmsy																		
95% Fmsy																		
Fmsy	t	t	t	%	%	%	%	%	%		%	%	%	%	%	%		%
0.75 X Fstatus quo	t	t	t	%	%	%	%	%	%		%	%	%	%	%	%		%
Fstatus quo	t	t	t	%	%	%	%	%	%		%	%	%	%	%	%		%
1.25 X Status quo	t	t	t	%	%	%	%	%	%		%	%	%	%	%	%		%
F=0	t	t	t	%	%	%	%	%	%		%	%	%	%	%	%		%
TAC Status quo																		
85% TAC Status quo																		
90% TAC Status quo																		
95% TAC Status quo																		

- For stock assessed with an age-structured model, information should be provided on stock size, spawning stock sizes, recruitment prospects, historical fishing mortality. Graphs and/or tables should be provided for all of the following for the longest time-period possible:
- historical yield and fishing mortality;
- spawning stock biomass and recruitment levels;
- Stock trajectory against reference points
- And any information the Scientific Council deems appropriate

  Stochastic short-term projections (3 years) should be performed with the following constant fishing mortality levels as appropriate:

  - For stocks opened to direct fishing: $F_{0.1}$, F_{max}, 2/3 F_{max}, 3/4 F_{max}, 85% F_{max}, 75% $F_{status\ quo}$, $F_{status\ quo}$, 125% $F_{status\ quo}$,
  - For stocks under a moratorium to direct fishing: $F_{status\ quo}$, F = 0.

  The first year of the projection should assume a catch equal to the agreed TAC for that year.
  Results from stochastic short-term projection should include:

  - The 10%, 50% and 90% percentiles of the yield, total biomass, spawning stock biomass and exploitable biomass for each year of the projections
  - The risks of stock population parameters increasing above or falling below available biomass and fishing mortality reference points. The table indicated below should guide the Scientific Council in presenting the short-term projections.

				Limit reference points													
				P(F.>F_{lim})			P(B<B_{lim})			P(F>F0.1)			P(F>F_{max})			P(B2024 > B2020)
F in 2022 and following years*	Yield 2022	Yield 2023	Yield 2024	2022	2023	2024	2022	2023	2024	2022	2023	2024	2022	2023	2024	
F0.1	t	t	t	%	%	%	%	%	%	%	%	%	%	%	%	%
F_{max}	t	t	t	%	%	%	%	%	%	%	%	%	%	%	%	%
66% F_{max}	t	t	t	%	%	%	%	%	%	%	%	%	%	%	%	%
75% F_{max}	t	t	t	%	%	%	%	%	%	%	%	%	%	%	%	%
85% F_{max}	t	t	t	%	%	%	%	%	%	%	%	%	%	%	%	%
0.75 X F_{2018}	t	t	t	%	%	%	%	%	%	%	%	%	%	%	%	%
F_{2018}	t	t	t	%	%	%	%	%	%	%	%	%	%	%	%	%
1.25 X F_{2018}	t	t	t	%	%	%	%	%	%	%	%	%	%	%	%	%

ANNEX B. Guidance for providing advice on Stocks Assessed without a Population Model

For those resources for which only general biological and/or catch data are available, few standard criteria exist on which to base advice. The stock status should be evaluated in the context of management requirements for long-term sustainability and the advice provided should be consistent with the precautionary approach.

The following graphs should be presented, for one or several surveys, for the longest time-period possible:

a. time trends of survey abundance estimates
b. an age or size range chosen to represent the spawning population
c. an age or size-range chosen to represent the exploited population
d. recruitment proxy or index for an age or size-range chosen to represent the recruiting population.
e. fishing mortality proxy, such as the ratio of reported commercial catches to a measure of the exploited population.
f. Stock trajectory against reference points

And any information the Scientific Council deems appropriate.

DENMARK (ON BEHALF OF GREENLAND) REQUESTS FOR SCIENTIFIC ADVICE ON MANAGEMENT IN 2022 OF CERTAIN STOCKS IN SUBAREA O AND 1.

(from SCS Doc. 21/02)

Denmark (on behalf of Greenland) requests scientific advice on management in 2020 of Certain Stocks in NAFO Subarea 0 and 1. Denmark (on behalf of Greenland) requests the Scientific Council for advice on the following species:

1. Golden Redfish, Demersal Deep-Sea Redfish, Atlantic Wolffish and Spotted Wolffish
Advice on Golden Redfish (*Sebastes marinus*), Demersal Deep-Sea Redfish (*Sebastes mentella*), Atlantic Wolffish (*Anarhichas lupus*) and Spotted Wolffish (*Anarhichas minor*) in Subarea 1 was in June 2020 given for 2021-2023. Consequently, the Scientific Council is requested to continue its monitoring of the above stocks and provide updated advice as appropriate in the event of significant changes in stock levels.

2. Greenland Halibut, Offshore
Advice on Greenland Halibut, Offshore in Subareas 0 and 1 was in 2020 given for 2021 and 2022. Consequently, the Scientific Council is requested to continue its monitoring of the above stocks and provide updated advice as appropriate in the event of significant changes in stock levels. The Scientific Council is also asked to advice on any other management measures it deems appropriate to ensure the sustainability of these resources.

3. Greenland Halibut, Inshore, West Greenland
Advice on Greenland Halibut in Division 1A inshore, Division 1BC inshore, Division 1D inshore and Division 1EF inshore was in 2020 given for 2021-2022. Consequently, the Scientific Council is requested to continue its monitoring of the above stocks and provide updated advice as appropriate in the event of significant changes in stock levels. The Scientific Council is also asked to advice on any other management measures it deems appropriate to ensure the sustainability of these resources.

4. Northern Shrimp, West Greenland
Subject to the concurrence of Canada as regards to Subareas 0 and 1, Denmark (on behalf of Greenland) requests the Scientific Council before December 2021 to provide advice on the scientific basis for management of Northern Shrimp (*Pandalus borealis*) in Subareas 0 and 1 in 2022 in line with Greenland's stated management objective of maintaining a mortality risk of no more than 35% in the first year prediction and to provide a catch option table ranging with 5000 t increments. Future catch options should be provided for as many years as data allows for. Furthermore, Scientific Council is requested to provide a catch level corresponding to a mortality risk of exact 35% in the first year of prediction.

5. Northern Shrimp, East Greenland
Furthermore, the Scientific Council is in cooperation with ICES requested to provide advice on the scientific basis for management of Northern Shrimp (*Pandalus borealis*) in Denmark Strait and adjacent waters east of southern Greenland in 2022 and for as many years ahead as data allows for.

CANADA'S REQUEST FOR ADVICE ON MANAGEMENT IN 2022 AND BEYOND

(from SCS Doc. 21/03)

1. Greenland halibut (Subarea 0 + 1 (offshore)[1]

Advice on Greenland Halibut in Subareas 0 and 1 was provided in 2020 for 2021 and 2022. Canada requests that the Scientific Council monitor the status of this stock in 2021 and, should a significant change be observed in stock status (e.g. from surveys or in bycatch in other fisheries), provide updated advice as appropriate.

2. Shrimp (Subarea 1 and Division 0A)

Canada requests the Scientific Council to consider the following options in assessing and projecting future stock levels for Shrimp in Subarea 1 and Division 0A:

The status of the stock should be determined and risk-based advice provided for catch options corresponding to Z_{msy}, in 5000-10 000t increments (subject to the discretion of Scientific Council), with forecasts for 2022 to 2024. These options should be evaluated in relation to Canada's Harvest Strategy (attached) and NAFO's Precautionary Approach Framework, and presented in the form of risk analyses related to B_{msy}, 80% B_{msy}, B_{lim} (30% B_{msy}) and Z_{msy}.

Presentation of the results should include graphs and/or tables related to the following:

- Historical and current yield, biomass relative to B_{msy}, total mortality relative to Z_{msy}, and recruitment (or proxy) levels for the longest time period possible;
- Total mortality (Z) and fishable biomass for a range of projected catch options (as noted above) for the years 2022 to 2024. Projections should include both catch options and a range of effective cod predation biomass levels considered appropriate by the Scientific Council. Results should include risk analyses of falling below: B_{msy}, 80% B_{msy} and B_{lim} (30% B_{msy}), and of being above Z_{msy} based on the 3-year projections, consistent with the Harvest Decision Rules in Canada's Harvest Strategy; and
- Total area fished for the longest time period possible.

Please provide the advice relative to Canada's Harvest Strategy as part of the formal advice (i.e., grey box in the advice summary sheet).

[1] The Scientific Council has noted previously that there is no biological basis for conducting separate assessments for Greenland halibut throughout Subareas 0-3 but has advised that separate TACs be maintained for different areas of the distribution of Greenland halibut.

LIST OF SCR AND SCS DOCUMENTS – 2021

SCR Documents			
Serial No.	**Document No.**	**Author(s)**	**Title**
N7157	SCR Doc. 21-001	G. Søvik and T. H. Thangstad	Results of the Norwegian Bottom Trawl Survey for Northern Shrimp (*Pandalus borealis*) in Skagerrak and the Norwegian Deep (ICES Divisions 3.a and 4.a East) in 2021
N7160	SCR Doc. 21-002	John Mortensen	Report on hydrographic conditions off Southwest Greenland May/June 2020
N7163	SCR Doc. 21-003	Heino Fock, Karl-Michael Werner and Christoph Stransky	Survey Results of the German bottom trawl survey 1982-2020 with special reference to years 2016-2019
N7165	SCR Doc. 21-004REV.	R.M. Rideout, D.W. Ings, M. Koen-Alonso	Temporal And Spatial Coverage of Canadian (Newfoundland And Labrador Region) Spring And Autumn Multi-Species RV Bottom Trawl Surveys, With An Emphasis On Surveys Conducted in 2020
N7166	SCR Doc. 21-005	Diana González Troncoso, Jose Miguel Casas Sánchez and Lupe Ramiro	Results from Bottom Trawl Survey on Flemish Cap of June-July 2020
N7173	SCR Doc. 21-006	Boris Cisewski	Hydrographic conditions off West Greenland in 2020
N7174	SCR Doc. 21-007	Di Wan	MEDS STACFEN Report 2020
N7175	SCR Doc. 21-008	A.Nogueira, M.Treble , H.Benoît, and K.J. Hedges	Review of Greenland halibut deep-water surveys in Northwest Atlantic Fisheries Organization Divisions Subareas 0 and 1 offshore
N7176	SCR Doc. 21-009	F. Cyr, P. S. Galbraith, C. Layton, D. Hebert, N. Chen, G. Han	Environmental and Physical Oceanographic Conditions on the Eastern Canadian shelves (NAFO Sub-areas 2, 3 and 4) during 2020.
N7177	SCR Doc. 21-010	D. Bélanger, P. Pepin, G. Maillet	Biogeochemical oceanographic conditions in the Northwest Atlantic (NAFO subareas 2-3-4) during 2020
N7178	SCR Doc. 21-011	Rasmus Nygaard, Søren L. Post, Anja Retzel, Karl Zinglersen, Lars Heilmann, Sofie R. Jeremiassen, Signe Jeremiassen, Louise Mølgaard and Jørgen Sethsen	Biomass and Abundance of Demersal Fish Stocks in the Nuuk fjord.
N7179	SCR Doc. 21-012	Rasmus Nygaard	Survey results from the Uummannaq gillnet survey in NAFO Division 1A inshore.
N7180	SCR Doc. 21-013	Rasmus Nygaard	Trawl and gillnet survey results from the Disko Bay, NAFO Division 1A Inshore
N7181	SCR Doc. 21-014REV.	Rasmus Nygaard and Adriana Nogueira	Biomass and Abundance of Demersal Fish Stocks off West and East Greenland estimated from the Greenland Institute of Natural resources (GINR) Shrimp and Fish Survey (SFW), 1990-2020.
N7182	SCR Doc. 21-015	Rasmus Nygaard	Survey results from the Upernavik Gillnet survey, NAFO Division 1Ainshore.

N7184	SCR Doc. 21-016	Paul M. Regular, Bob Rogers, Laura Wheeland, Sean C. Anderson	NAFOdown: An R Markdown Template for Producing NAFO Scientific Council Documents
N7185	SCR Doc. 21-017	Diana González-Troncoso, Carmen Fernández and Fernando González-Costas	Assessment of the Cod Stock in NAFO Division 3M
N7186	SCR Doc. 21-018	D. Maddock Parsons & R. Rogers	2021 Assessment of Yellowtail Flounder in NAFO Divisions 3LNO using a Stock Production Model in a Bayesian Framework
N7187	SCR Doc. 21-019	D. Maddock Parsons, R. Rideout and R. Rogers	Divisions 3LNO Yellowtail Flounder (*Limanda ferruginea*) in the 2018-2020 Canadian Stratified Bottom Trawl Surveys.
N7188	SCR Doc. 21-020	Andrea M.J. Perreault, Laura Wheeland, Noel G. Cadigan	Updated state-space model for American plaice (*Hippoglossoides platessoides*) in Div. 3LNO
N7189	SCR Doc. 21-021	Irene Garrido, Diana González-Troncoso, Fernando González-Costas, Ricardo Alpoim	Analysis of 3M cod catch in all the fisheries across the Flemish Cap
N7190	SCR Doc. 21-022	M.R. Simpson and C.M. Miri	An Assessment of White Hake (*Urophycis tenuis*, Mitchill 1815) in NAFO Divisions 3N, 3O, and Subdivision 3Ps
N7191	SCR Doc. 21-023	F. Cyr and D. Bélanger	Environmental indices for NAFO subareas 0 to 4 in support of the Standing Committee on Fisheries Science (STACFIS)
N7192	SCR Doc. 21-024	Garrido, Irene, Fernando González-Costas, Diana González-Troncoso	Analysis of the by-catch of the moratorium stocks in the NRA
N7193	SCR Doc. 21-025	L. Wheeland	An exploration of the impact of natural mortality assumptions in a Virtual Population Analysis for Divisions 3LNO American Plaice
N7194	SCR Doc. 21-026	P.M. Regular, B. Rogers, M.J. Morgan	Greenland halibut (*Reinhardtius hippoglossoides*) in NAFO Subarea 2 and Divisions 3KLMNO: stock trends based on annual Canadian research vessel survey results
	SCR Doc. 21-027		-Retracted-
N7196	SCR Doc. 21-028REV.	M.R. Simpson et al.	Spatial-temporal variation in Greenland shark (*Somniosus microcephalus*) bycatch in the NAFO Regulatory Area
N7197	SCR Doc. 21-029	K. Yu. Fomin	Capelin Stock Assessment in NAFO Divisions 3NO Based on Data from Trawl Surveys
N7198	SCR Doc. 21-030	R.M. Rideout, P.M. Regular, D. Varkey	Exploration of alternative ADAPT model formulations for the assessment of Atlantic Cod in Divs. 3NO
N7199	SCR Doc. 21-031	R.M. Rideout, R. Rogers, D.W. Ings	An Updated Assessment of the Cod Stock in NAFO Divisions 3NO
N7200	SCR Doc. 21-032	Rajeev Kumar, Divya A. Varkey, Laura Wheeland	Spatial state-space survey-based stock assessment (SSURBA) model for the Grand Bank stock of American plaice

N7201	SCR Doc. 21-033	K. Hedges, M. A. Treble, A. Nogueira, J. Nielsen, and H. Fock	Greenland shark bycatch data in NAFO Subareas 0+1.
N7203	SCR Doc. 21-034	R. Alpoim	Golden Redfish 3M
N7204	SCR Doc. 21-035	L. Wheeland L. Wheeland, K. Dwyer, R. Kumar, R. Rideout, A. Perreault and B. Rogers	Assessment of American Plaice in Div. 3LNO
N7211	SCR Doc. 21-036	Paula Fratantoni	Hydrographic Conditions on the Northeast United States Continental Shelf in 2020 – NAFO Subareas 5 and 6
N7212	SCR Doc. 21-037	Igor Yashayaev, Ingrid Peterson, and Zeliang Wang	Meteorological, Sea Ice, and Oceanographic Conditions in the Labrador Sea during 2020
N7214	SCR Doc. 21-038	J.M. Casas Sanchez	Division 3M Northern shrimp (*Pandalus borealis*) – Interim Monitoring Update
N7215	SCR Doc. 21-039	Diana González Troncoso, Irene Garrido and Fernando González-Costas	Effect in survey indices of removing stations in the NAFO closed Areas in the design of the EU surveys
N7238	SCR Doc. 21-040	Burmeister and Riget	The Fishery for Northern Shrimp (*Pandalus borealis*) off West Greenland, 1970–2020
N7239	SCR Doc. 21-041	Burmeister	Catch Table Update for the West Greenland Shrimp Fishery
N7240	SCR Doc. 21-042	Burmeister and Riget	A provisional Assessment of the shrimp stock off West Greenland in 2021
N7241	SCR Doc. 21-043	Buch, Burmeister and Riget	The Fishery for Northern Shrimp (*Pandalus borealis*) in Denmark Strait / off East Greenland 1978 – 2021
N7242	SCR Doc. 21-044	Riget, Burmeister and Buch	Applying a stochastic surplus production model (SPiCT) to the East Greenland Stock of Northern Shrimp
N7243	SCR Doc. 21-045	Burmeister	Reply to the Canadian request for advice of shrimps in Subarea 0 and 1
N7245	SCR Doc. 21-046	O. Ritzau Eigaard and G. Søvik	New data and information on the northern shrimp (*Pandalus borealis*) stock in Division 4.a West (Northern North Sea, Fladen Ground)
N7246	SCR Doc. 21-047	J.M. Casas Sanchez	Northern Shrimp (*Pandalus borealis*) on Flemish Cap Surveys 2021
N7248	SCR Doc. 21-048	R. Waller, K. Cantwell, C. Lirette, F.J. Murillo, E. Kenchington	Summary of the Vulnerable Marine Ecosystem Indicators Observed in the NAFO Closed Areas on the Okeanos Explorer Expedition “2021 North Atlantic Stepping Stones: New England and Corner Rise Seamounts”
N7252	SCR Doc. 21-049	S. Wang, E. Kenchington, F.J. Murillo, C. Lirette, M. Koen-Alonso, A. Kenny, M. Sacau	Advances in the Assessment of Habitat Fragmentation and Protection in the NAFO Regulatory Area
N7253	SCR Doc. 21-050	Sacau, M., Neves, B.M., Wareham Hayes, V., and Durán-Muñoz, P.	New preliminary data on VME encounters in NAFO Regulatory Area (Divs. 3MNO) from EU; EU-Spain and Portugal Groundfish Surveys (2021) and Canadian surveys (2020 Fall)

N7195	SCR Doc. 21-051	P. Durán Muñoz and M. Sacau	Information on activities other than fishing (offshore oil and gas) in the NAFO Convention Area: Implications for the development of the Ecosystem Summary Sheets (Divisions 3LNO and 3M)
N7255	SCR Doc. 21-052	S. Bakanev	Russian fishery for the northern shrimp (*Pandalus borealis*) in the Barents Sea in 2000-2021

SCS Documents			
Serial No.	**Document No.**	**Author(s)**	**Title**
N7154	SCS Doc. 21/01	NAFO	The Commission's Request for Scientific Advice on Management in 2022 and Beyond of Certain Stocks in Subareas 2, 3 and 4 and Other Matters
N7155	SCS Doc. 21/02	Denmark (in respect of Faroe Islands and Greenland)	Denmark (on behalf of Greenland) Coastal State Request for Scientific Advice - 2022
N7156	SCS Doc. 21/03	Canada	Canada's Request to NAFO SC for Coastal State Advice - 2022
N7159	SCS Doc. 21/04	Japan	National Research Report of Japan (2021)
N7161	SCS Doc. 21/05	Portugal	Portuguese Research Report for 2020
N7162	SCS Doc. 21/06	Spain	Spanish Research Report for 2020
N7164	SCS Doc. 21/07	Germany	German Research Report for 2020
N7167	SCS Doc. 21/08	Canada	Canadian Research Report 2020
N7168	SCS Doc. 21/09	Russia	Russian Research Report for 2020
N7169	SCS Doc. 21/10	Faroe Islands	Faroese Research Report 2020
N7170	SCS Doc. 21/11	Greenland	Denmark/Greenland Research Report for 2020
N7171	SCS Doc. 21/12REV2	NAFO	List of Biological Sampling Data for 2020
N7172	SCS Doc. 21/13	Estonia	Estonian Research Report for 2020
N7205	SCS Doc. 21/14	NAFO	Report of the Scientific Council Meeting 2021
N7206	SCS Doc. 21/15	NAFO	Scientific Council 5-year work plan 2021
N7235	SCS Doc. 21/16	USA	United States Research Report for 2020
N7249	SCS Doc. 21/17	NAFO	Report of the Scientific Council Meeting, 20–24 September 2021
N7237	SCS Doc. 21/18	NAFO	Report of the NAFO/ICES *Pandalus* Assessment Meeting, 08–09 September 2021
N7250	SCS Doc. 21/19	NAFO	Report of the NAFO/ICES *Pandalus* Assessment Meeting, 01–04 Novovember 2021
N7251	SCS Doc. 21/20	NAFO	Report of the Scientific Council (in conjunction with NIPAG) Meeting 01-04 November 2021
N7256	SCS Doc. 21/21	NAFO	Report of the NAFO Working Group on Ecosystem Science and Assessment (WG-ESA) Meeting, 16–25 November 2021

LIST OF REPRESENTATIVES, ADVISERS, EXPERTS AND OBSERVERS, 2021

A	Scientific Council Meeting, 27 May - 11 June 2021
B	Scientific Council Meeting (in conjunction with NIPAG), 08 September 2021
C	Scientific Council Meeting, 20-24 September 2021
D	NAFO/ICES *Pandalus* Assessment Group Meeting, 01-04 November 2021
E	Scientific Council Meeting (in conjunction with NIPAG), 01- 04 November 2021

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MERIT AWARDS

Year	Recipient	Institute
2009	Ralph Mayo	NMFS Woods Hole, MA, USA
2010	Dr. Manfred Stein	Institut fur Seefischerei, Hamburg, Germany
2011	Dr. Vladimir Rikhter	AtlantNIRO, Kaliningrad
2013	Bill Brodie	DFO, St. John's, NL, Canada
2013	Jean-Claude Mahé	IFREMER Lorient, France
2013	Antonio Vázquez	Spain, European Union
2014	Fred Serchuk	Northeast Fisheries Science Center (NEFSC), USA
2016	Mariano Koen-Alonso	DFO, St. John's, NL, Canada
2017	Eugene Colbourne	DFO, Dartmouth, NS, Canada
2017	Don Power	DFO, St. John's, NL, Canada
2018	*No awards were presented in 2018*	
2019	Joanne Morgan	DFO, St. John's, NL, Canada
2019	Brian Healey	DFO, St. John's, NL, Canada
2019	Fernando Gonzalez-Costas	IEO, Vigo, Spain
2019	Diana Gonzalez-Troncoso	IEO, Vigo, Spain
2019	Carmen Fernández	IEO, Gijon, Spain
2019	Agurtzane Urtizberea	AZTI Pasaia Gipuzkoa, Spain
2020	António Ávila de Melo	IPMA, Lisbon, Portugal
2021	Pierre Pepin	DFO, St. John's, NL, Canada
2021	Carmen Fernández	IEO, Gijon, Spain

LIST OF RECOMMENDATIONS IN 2021

From the Scientific Council June Meeting, 27 May – 11 June 2021

The recommendation made by STACFEN for the work of the Scientific Council as endorsed by the Council, are as follows:

The report of Standing Committee on Fisheries Environment (STACFEN) was deferred until the September meeting of SC.

The recommendations made by STACPUB for the work of the Scientific Council as endorsed by the Council, are as follows:

The report of the Standing Committee on Publications (STACPUB) is deferred until the September meeting of SC.

The recommendations made by STACREC for the work of the Scientific Council as endorsed by the Council, are as follows:

The report of the Standing Committee on Research Coordination (STACREC) is deferred until the September meeting of SC.

The recommendations made by STACFIS for the work of the Scientific Council as endorsed by the Council, are as follows:

6. Cod (*Gadus morhua*) in Division 3M

STACFIS **recommends** that *an age reader comparison exercise be conducted.*

STATUS: An age-readers Workshop was held in November 2017 in order to reconcile the differences among age-readers of this stock. Much progress in understanding where the differences between the commercial and survey ALKs come from was made but still needs more research to completely know the problem. No progress since then was made. NAFO reiterates this recommendation.

STACFIS **encouraged** to all Contracting Parties to provide length distribution samples from the commercial vessels fishing 3M cod.

STATUS: NAFO reiterates this recommendation.

The next full assessment for this stock will be in 2022.

7. Redfish (*Sebastes mentella* and *Sebastes fasciatus*) in Division 3M

STACFIS **recommends** that *input data should be investigated in order to reduce the retrospective pattern of the XSA assessment, such as the ALKs used. Other assessment models, taking in account the ones used, on redfish stocks, with the same problem of more than one species, in the Golf St. Laurence and NAFO Div. 0, should be explored.*

The next full assessment for this stock is planned to be in 2023.

9. Cod (*Gadus morhua*) in Division 3NO

STACFIS **recommends** *investigating the potential use of a plus group in the assessment of Divs. 3NO cod.*

STATUS: Numerous attempts to incorporate a plus group within the ADAPT-based assessment of this stock all produced unsatisfactory results, either because of failure of models to converge, computational issues, or poor model fits. More flexible assessment models may be explored in the future to handle a broader age structure, as well as address issues of uncertainty in the catch at age data, and assumption with respect to constant natural mortality.

STACFIS **recommends** *continuing to monitor the consistency in trends between the Canadian and EU-Spain surveys.*

STATUS: Trends in the EU-Spain survey data were generally similar to the Canadian-Spring and Autumn surveys. However, the inclusion of the EU-Spain survey in the current ADAPT-based assessment as an additional tuning index resulted in overall poorer model fit. It was not considered to be an improvement over the currently accepted model formulation.

STACFIS **recommends** *investigating the removal of the pre-1995 Canadian autumn assessment points for an improvement in model fit / residual pattern.*

STATUS: The removal of the pre-1995 Canadian autumn assessment points did not improve the model fit / residual patterns and is not considered to result in an improvement over the currently accepted model formulation.

STACFIS **recommends** *examining the selectivity pattern (i.e. flat-topped vs. dome-shaped).*

STATUS: Analyses demonstrated that selectivity was flat-topped during the portion of the time series with a directed fishery (1959-2013), but that selectivity for the by-catch fishery during the moratorium period (1994-2019) was dome-shaped.

11. American Plaice (*Hippoglossoides platessoides*) in Divisions 3LNO

STACFIS **recommends** that *investigations be undertaken to compare ages obtained by current and former Canadian age readers.*

STATUS: Work is ongoing. This recommendation is reiterated.

STACFIS **recommends** that *investigations be undertaken to examine the retrospective pattern and take steps to improve the model.* STACFIS **recommends** *that investigations be undertaken to reexamine which survey indices are included in the model.*

STATUS: Sensitivity analysis was completed examining the impact of changing the model assumptions about natural mortality. Previous work examined sensitivity to the F-ratio on the plus group and the stepwise exclusion of various survey indices. These exploratory runs had varying impacts on the retrospective pattern and residuals in the model. Efforts to reduce the retrospective pattern in the model have been unsuccessful. These recommendations are therefore replaced with the following:

STACFIS **recommends** that *a benchmark process be undertaken to develop a new assessment framework for this stock.*

14. Capelin (*Mallotus villosus*) in Division 3NO

STACFIS reiterates its **recommendation** that *initial investigations to evaluate the status of capelin in Div. 3NO should utilize trawl acoustic surveys to allow comparison with the historical time series.*

This stock is expected next to be fully assessed in 2024.

15. Redfish (*Sebastes mentella* and *Sebastes fasciatus*) in Division 3O

In 2019, STACFIS **recommended** that *for Redfish in Div. 3O, work continue on developing an assessment model for the stock. Aging should be conducted for redfish sampled during select years to support model development.*

STATUS: No progress has been made.

17. White Hake (*Urophycis tenuis*) in Divisions 3N, 3O, and Subdivision 3Ps

STACFIS **recommends** that *age determination should be conducted on otolith samples collected during annual Canadian surveys (1972-2020); thereby allowing age-based analyses of this population.*

STATUS: Otoliths are being collected, and aging has begun. STACFIS reiterates this recommendation.

STACFIS **recommends** that *survey conversion factors between the Engel and Campelen gear be investigated for this stock.*

STATUS: No progress, STACFIS reiterates this recommendation.

STACFIS **recommends** that *work continue on the development of population models and reference point proxies.*

Various formulations of a surplus production model both in a state-space (SPICT) and in a Bayesian framework were explored and work is continuing.

The next full assessment of this stock is planned for 2023.

19. Greenland Halibut (Reinhardtius hippoglossoides) in SA 2 + Divs. 3KLMNO

The divergence in survey indices could be the result of movement of fish or because of transient age effects as a result of changing recruitment when different surveys cover differing age-ranges. STACFIS **recommends** that *tagging and/or telemetry studies be undertaken to help elucidate movement of 2+3KLMNO Greenland halibut*.

21. Splendid alfonsino (*Beryx splendens*) in Subareas 6

SC **recommended** in 2019 that *fishery independent information should be collected on this stock, especially important given that the fishery is closed and there will not be CPUE or any other fishery independent information to monitor whether there is any recovery. For this purpose, an acoustic survey plan has been presented and discussed by the SC. The SC concluded that the presented acoustic survey plan could be appropriate to recollect fishery independent information that can help the future evaluation of this stock.*

From the Scientific Council (in conjunction with NIPAG) Meeting, 08 September, 2021

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

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: progress will be updated at NIPAG 2021

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: progress will be updated at NIPAG 2021

The next assessment will take place prior the NAFO Annual Meeting in September 2022.

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

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

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

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

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

From the Scientific Council Meeting, 20-24 September 2021

The recommendation made by STACFEN for the work of the Scientific Council as endorsed by the Council, are as follows:

STACFEN **recommends** *consideration of Secretariat support for an invited speaker to address emerging issues and concerns for the NAFO Convention Area during the 2022 STACFEN Meeting.*

Contributions from invited speakers may generated new insights and discussion within the committee regarding integration of environmental information into the stock assessment process.

STACFEN **recommends** that *further discussions take place between STACFEN and STACFIS members on environmental data integration into the various stock assessments.*

The recommendations made by STACPUB for the work of the Scientific Council as endorsed by the Council, are as follows:

STACPUB **recommends** that *the Secretariat stop producing printed copies of the Journal.*

The recommendations made by STACREC for the work of the Scientific Council as endorsed by the Council, are as follows:

Previous recommendations were not examined at the June meeting and no new recommendations were made in 2021 due to constraints to the meeting from Covid-19.

Survey-related recommendations (previous and new recommendations)

In 2015, STACREC **recommended** that *an analysis of sampling rates be conducted to evaluate the impact on the precision of survey estimates.* As a separate aspect, in September 2017 STACREC discussed *possibilities for combining multiple surveys in different areas and at different times of the year to produce aggregate indices*.

In September 2019, it *was agreed that a speaker on this general topic would be invited to the June 2020 SC meeting, and the STACREC chair will take the lead in arranging this invitation.* However, due to the pandemic, it was not possible to have an invited speaker in June. However, a Canadian scientist attended the ICES WKUSER (Workshop on Unavoidable Survey Effort Reduction) in January 2020 and presented information on survey coverage issues. Feedback from this meeting was presented to STACREC in May 2021.

The workshop goal was to provide best practices to deal with survey effort reduction and the need for contingency planning was also emphasized. The potential consequences of survey effort reduction were summarized, including increased uncertainty, biased outcomes, the reduced ability to detect distribution shifts, changes in productivity, etc. It was also emphasized that not all information collected may be used in stock assessment but its value in the future is unknown and may be increasingly important to address new emerging priorities.

Numerous case studies were presented from various areas of the world summarizing their surveys as well as those that provided analytical approaches to filling in gaps as well as analysis of the impacts of shortcomings.

Approaches dealing with decreasing survey coverage varied from resampling survey data to simulating distribution and abundance data, up to a complete MSE study of the impacts of changing survey coverage on stock assessment.

A follow-up meeting is planned but dates and location not yet decided.

The full report is available at: ICES. 2020. ICES Workshop on unavoidable survey effort reduction (WKUSER).

ICES Scientific Reports. 2:72. 92pp. http://doi.org/10.17895/ices.pub.7453

In 2019, STACREC made the following recommendation:

STACREC **recommends** the *following actions for future years whenever survey coverage issues arise*:

The STACREC report should contain, after the general survey presentation, a summary of the decisions and conclusions stock by stock regarding whether the survey can be used as a stock index for that year.

The mean proportion (over time) of total survey biomass in the survey strata missed that year should be calculated.

At this time, the following may be used as initial ("preliminary") guidelines based on the value of the mean proportion of total survey biomass in the survey strata missed in that year:

- If it is <10%: the survey index of that year is most likely acceptable.
- If it is between 10% and 20%: the survey index of that year is questionable and needs to be examined carefully before deciding whether it is acceptable.
- If it is >20%: the survey index of that year is most likely not acceptable. Any decision to accept it would require a clear and well justified rationale.

These are preliminary guidelines and sampling biases may also be relevant in the considerations for each specific stock and survey. In particular, the finer structure of the indices needs to be considered if they are used disaggregated by age or length in stock assessments.

It has been suggested that an added guideline might be: For age groups where there is a greater than 10% difference between total survey biomass in the survey strata missed that year in the index used (total or mean numbers), then it should be excluded from the model, if the model can handle missing values. However, there was no time to discuss this at the June 2020 meeting and therefore this discussion will be deferred to June 2021. This discussion was once again deferred to June 2022 due to lack of time at the virtual meeting.

All other recommendations will be deferred to next year (2022).

Faroese longline survey of cod in Div. 3M

STACREC notes that protocols from Article 4 in the Conservation and Enforcement Measures (NAFO COM Doc 21/01) do not require review of proposed survey research plans and confirmation of their scientific validity by SC. **STACREC recommends** that *the Commission amend this procedure to include a scientific review of proposed research surveys in the NRA to ensure scientific best practices are followed.*

The recommendations made by STACFIS for the work of the Scientific Council as endorsed by the Council, are as follows:

1. Northern Shortfin Squid (*Illex illecebrosus*) in Subareas 3+4

In 2013, STACFIS **recommended** that *gear/vessel conversion factors be computed to standardize the 1970-2003 relative abundance and biomass indices from the July Div. 4VWX surveys.*

STATUS: No progress has been made.

From the NAFO/ICES *Pandalus* Assessment Group (NIPAG) Meeting, 01-04 November,2021

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

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

Status: Done (SCR Doc. 21-041).

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

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

Status: information is presented in SCR Doc. 21/042 **Completed.**

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

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

Status: Has been completed; this recommendation should be progressed when new survey biomass and CPUE data become available

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

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

Status: An official data call has been made and some parties have now provided aggregated data on total catch and effort. This is of limited use for the work of NIPAG and this recommendation is therefore reiterated.

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

Status: no progress. This recommendation is not reiterated.

7. Northern shrimp (*Pandalus borealis*) in the Fladen Ground (western part of ICES Division 27.4a)

NIPAG **recommends** that *a trial fishery including compulsory sampling of catches is initiated on the Fladen Ground.*