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Northwest Atlantic Fisheries Organization

# Report of the Scientific Council Meeting

28 May -12 June 2020
By correspondence

**NAFO**
**DARTMOUTH, NOVA SCOTIA, CANADA**
**2020**

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# REPORT OF SCIENTIFIC COUNCIL MEETING
# 28 May -12 June 2020

Chair: Carmen Fernandez Rapporteur: Tom Blasdale

## I. PLENARY SESSIONS

The Scientific Council (SC) met by correspondence from 28 May to 12 June 2020 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 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.

Dr. Hugues Benoît participated as an external reviewer for the work on Greenland halibut in NAFO Subareas 0 and 1 and also provided expertise on the Commission request on survivability of discards. Dr. Andrew Kenny participated invited by the SC chair to provide expertise on various requests focused on ecosystem aspects.

The Executive Committee met on several occasions 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 28 May 2020. The provisional agenda was **adopted** and the Scientific Council Coordinator was appointed the rapporteur. The opening session was adjourned at 12:30 on 28 May 2020.

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 work, therefore, focused on items identified as priority level 1 in the SC report from April 2 (SCS Doc. 20/04) and as described in the agenda attached in Appendix V. The meeting also managed to provide responses to some requests identified as priority level 2.

SC plans to hold an additional meeting, by correspondence, during September 15-17, aiming to address some of the requests deferred from the June meeting. However, SC noted that changes might still occur, e.g. depending on potential feedback that might be received from the Commission. Details of the SC plan of work for September are described in Section XI of this report.

The stock of witch flounder in NAFO Div. 3NO was assessed by SC this year of its own accord, and advice provided for 2021 and 2022. This was necessary to avoid a conflict in the multi-year assessment schedule in 2021, when 3LNO Yellowtail Flounder and 3NO Witch Flounder had both been planned (the same Designated Expert is responsible for both stocks). In recognition of the fact that the Commission has agreed a TAC for 2021, a second set of projections is provided in the summary sheet this year, where this second set of projections assume that catches in 2021 are equal to the TAC and considers alternative catch options only for 2022.

The concluding session was called to order at 08:00 on 12 June 2020.

The Council considered and **adopted** the Scientific Council Report of this meeting of 28 May -12 June 2020. 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 14:00 h on 12 June 2020.

The limitations of meeting by correspondence also implied that the reports of the Standing Committee on Fisheries Environment (STACFEN) and the Standing Committee on Fisheries Science (STACFIS) could only be formally **adopted** by correspondence, at a later date in June (STACFEN report) or July (STACFIS report) 2020. These reports are included as Appendices I and IV, respectively.

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

The Agenda, List of Research (SCR) and Summary (SCS) Documents, and List of Representatives, Advisers and Experts, are given in Appendix 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 2019

Recommendations from 2019 are considered in the relevant sections of this report.

## III. FISHERIES ENVIRONMENT

The Council **adopted** the Report of the Standing Committee on Fisheries Environment (STACFEN) by correspondence as presented by the Chair, Miguel Caetano. The full report of STACFEN is in Appendix I.

STACFEN made the following recommendations, which were **endorsed** by the Scientific Council:

- STACFEN **recommends** consideration of Secretariat support for an invited speaker to address emerging issues and concerns for the NAFO Convention Area during the 2021 STACFEN Meeting.

Contributions from invited speakers may generate new insights and discussion within the committee regarding integration of environmental information into the stock assessment process.

- NAFO usually convenes a symposium on environmental issues every 10 years, with the last one 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*.

Further discussions are encouraged between STACFEN and STACFIS members on environmental data integration into the various stock assessments.

## 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

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 in 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 Div. 3M, advice for 2021 will be drafted during a WebEx scheduled to occur prior to the Annual Meeting of 21 – 25 September 2020. The WebEx meeting will last 1 day and will likely be on September 11 or September 14 (subject to confirmation). For Northern shrimp in Divs. 3LNO, SC provided advice (in 2019) for 2020 and 2021.

### 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 2020 for 2021

**Recommendation for 2021**

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 1 000 tonnes in 2021 results in a very low probability (≤10%) of SSB being below $B_{lim}$ in 2022 and a very low probability of exceeding $F_{lim}$. For any catch over 1 000 tonnes, the probability of being below $B_{lim}$ exceeds the NAFO Precautionary Approach guidelines.

### 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 $B_{msy}$ | 🟡 | Stock above $B_{lim}$ in 2020. $B_{msy}$ is unknown |
| Eliminate overfishing | 🔴 | $F>F_{lim}$ in 2019 |
| Apply Precautionary Approach | 🟢 | $F_{lim}$ and $B_{lim}$ defined |
| Minimise harmful impacts on living marine resources and ecosystems | 🟡 | VME closures in effect, no specific measures |
| Preserve marine biodiversity | ⚪ | Cannot be evaluated |

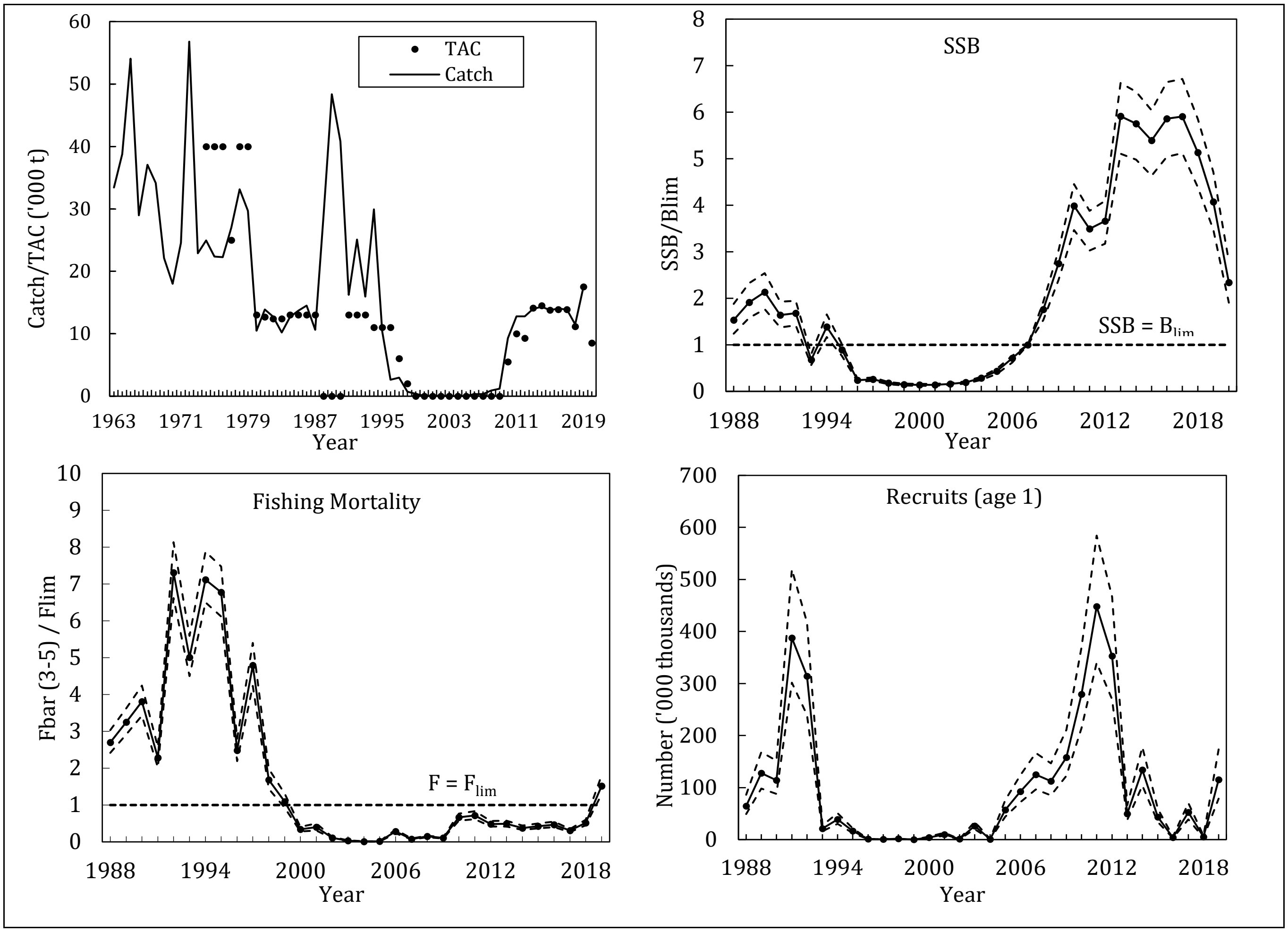
| | |
|---|---|
| 🟢 | OK |
| 🟡 | Intermediate |
| 🔴 | Not accomplished |
| ⚪ | Unknown |

### Management unit

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

### Stock status

Current SSB is estimated to be above $B_{lim}$ (median 15 271 t) although it is declining rapidly and is expected to continue its decline in the near future due to poor recruitment between 2015 and 2018. $F$ increased in 2010 with the re-opening of the fishery although until 2018 it was below $F_{lim}$ (median 0.191). In 2019, $F$ increased to a level above $F_{lim}$.



**Reference points**

*$B_{lim}$ = $SSB_{2007}$*: Median = 15 271 tonnes of spawning biomass (Scientific Council, 2020).

*$F_{lim}$ = $F_{30\%SPR}$*: Median = 0.191 (Scientific Council, 2020)

## Projections

| | B | | SSB | | Yield |
|---|---|---|---|---|---|
| | Median and 80% CI | | | | |
| $F_{bar}$=3/4$F_{lim}$ (median=0.143) | | | | | |
| 2020 | 48777 | (42258 - 55350) | 35725 | (30140 - 41365) | 8531 |
| 2021 | 35857 | (30252 - 41757) | 23121 | (18576 - 27867) | 5595 |
| 2022 | 26786 | (21764 - 32499) | 15472 | (11920 - 19144) | 4622 |
| 2023 | 19902 | (15130 - 25556) | 14280 | (10838 - 18316) | |
| $F_{bar}$=0 | | | | | |
| 2020 | 48777 | (42258 - 55350) | 35725 | (30140 - 41365) | 8531 |
| 2021 | 35857 | (30252 - 41757) | 23121 | (18576 - 27867) | 0 |
| 2022 | 32245 | (27255 - 37930) | 20159 | (16445 - 23914) | 0 |
| 2023 | 28937 | (24157 - 34759) | 22321 | (18764 - 26370) | |
| Catch=1000 tons | | | | | |
| 2020 | 48777 | (42258 - 55350) | 35725 | (30140 - 41365) | 8531 |
| 2021 | 35857 | (30252 - 41757) | 23121 | (18576 - 27867) | 1000 |
| 2022 | 31265 | (26251 - 36956) | 19317 | (15655 - 23065) | 1000 |
| 2023 | 27176 | (22347 - 32982) | 20743 | (17192 - 24760) | |
| Catch=3000 tons | | | | | |
| 2020 | 48777 | (42258 - 55350) | 35725 | (30140 - 41365) | 8531 |
| 2021 | 35857 | (30252 - 41757) | 23121 | (18576 - 27867) | 3000 |
| 2022 | 29305 | (24278 - 35017) | 17616 | (13964 - 21334) | 3000 |
| 2023 | 23596 | (18837 - 29285) | 17549 | (14040 - 21560) | |

| | Yield | | | $P(B < B_{lim})$ | | | | $P(F > F_{lim})$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2020 | 2021 | 2022 | 2020 | 2021 | 2022 | 2023 | 2020 | 2021 | 2022 | $P(B_{23} > B_{20})$ |
| 3/4Flim = 0.143 | 8531 | 5595 | 4622 | <1% | 1% | 50% | 62% | 4% | 5% | 6% | <1% |
| F=0 | 8531 | 0 | 0 | <1% | 1% | 6% | 1% | 4% | 0% | 0% | <1% |
| Catch=1000t | 8531 | 1000 | 1000 | <1% | 1% | 10% | 4% | 4% | <1% | <1% | <1% |
| Catch=3000t | 8531 | 3000 | 3000 | <1% | 1% | 24% | 24% | 4% | <1% | <1% | <1% |

Although advice is given only for 2021, projection results are shown to 2023 to illustrate the medium-term implications.

The results indicate that under all scenarios, total biomass during the projected years will decrease sharply, while the SSB will increase slightly in 2023 with the $F$=0 and the Catch=1 000 tonnes scenarios. The probability of SSB being below $B_{lim}$ in 2022 and 2023 is very high (≥24%) in the scenarios with $F_{bar}$=3/4$F_{lim}$ and Catch=3 000 tonnes, while being very low (≤10%) in the rest of the cases. The probability of SSB in 2023 being above that in 2020 is <1%.

Under all scenarios, the probability of F exceeding $F_{lim}$ is less than or equal to 6% in 2021 and 2022.

### Assessment

A Bayesian SCAA model was used as the basis for the assessment of this stock with data from 1988 to 2019.

The next full assessment for this stock will be in 2021.

*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.

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

| ,000 tons | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TAC | 5.5 | 10.0 | 9.3 | 14.1 | 14.5 | 13.8 | 13.9 | 13.9 | 11.1 | 17.5 | 8.5 |
| STATLANT 21 | 5.2 | 10.0 | 9.1 | 13.5 | 14.4 | 12.8 | 13.8 | 13.9 | 10.5 | 13.0 | |
| STACFIS | 9.3 | 12.8 | 12.8 | 13.985 | 14.3 | 13.8 | 14.0 | 13.9 | 11.5 | 17.5 | |

### 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, seapens and coral.

### Special comment

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

### Sources of information

SCS Doc. 20/06, 20/07, 20/08, 20/09 and SCR Doc. 20/11, 20/31.

## American plaice in Division 3M

Advice June 2020 for 2021 – 2023

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**Recommendation 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.

### Management objectives

No explicit management plan or management objectives defined by the Commission. Convention general principles are applied.

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

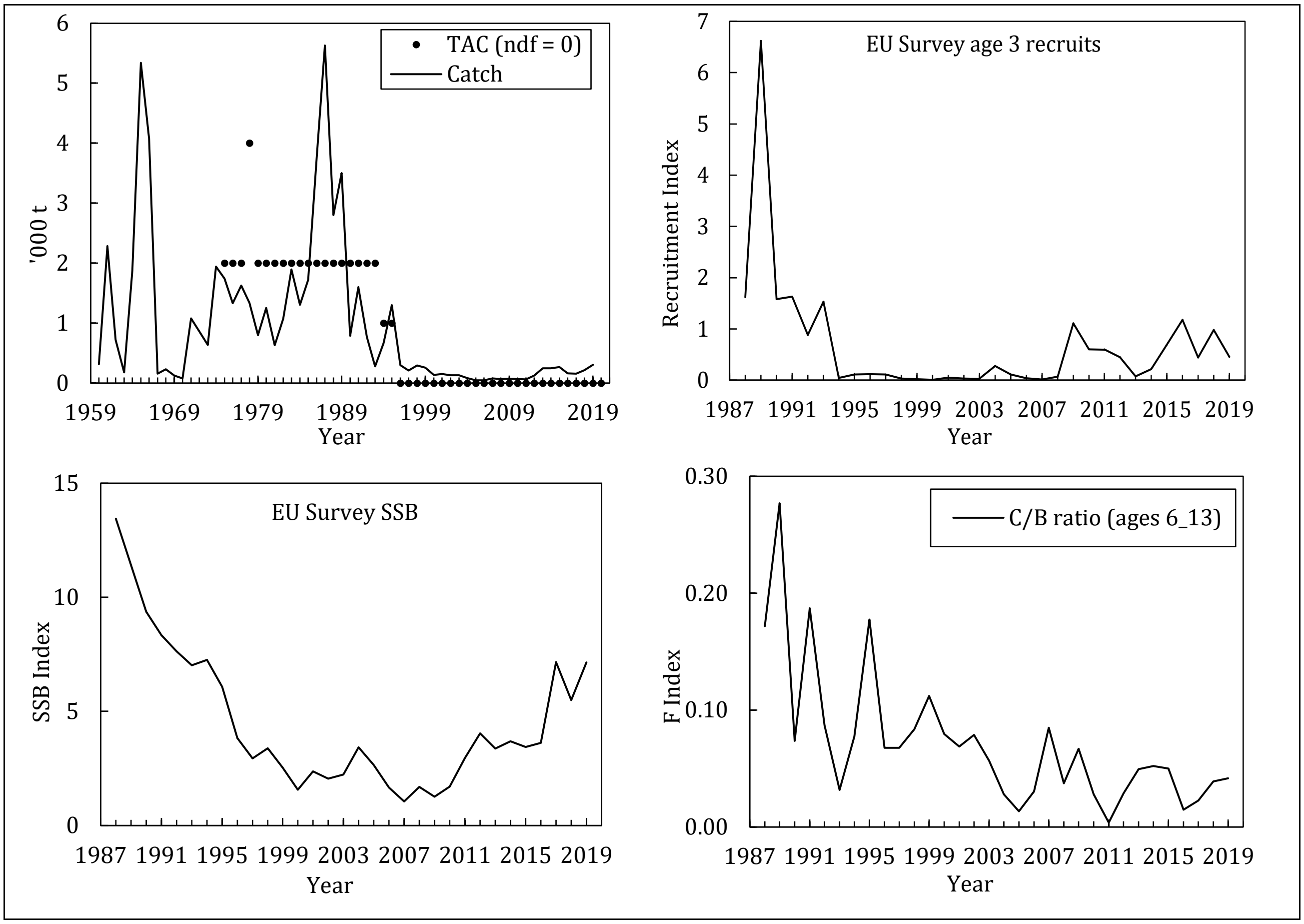
| | |
|---|---|
| 🟢 | OK |
| 🟡 | Intermediate |
| 🔴 | Not accomplished |
| ⚪ | Unknown |

### Management unit

The American plaice stock in Flemish Cap (Div. 3M) is considered to be a distinct population.

### Stock status

The stock has increased in recent years due to improved recruitment (at age 3) since 2009, and recovered to the levels of the mid 1990s, when the fishery was closed. Both catches and F remain low, although slightly higher catches are observed since 2013.



**Reference points**

Scientific Council is not in a position to provide proxies for biomass or fishing mortality reference points at this time.

**Projections**

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

**Assessment**

This assessment is based upon a qualitative evaluation of research vessel survey series and bycatch data from commercial fisheries.

The next full assessment is planned for 2023.

*Human impact*

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

*Biological and environmental interactions*

The stock occurs mainly at depths shallower than 600 m on Flemish Cap. Main stomach contents are echinoderms, shrimp and hyperiids.

**Fishery**

American plaice is caught as bycatch in otter trawl fisheries, mainly the cod and redfish fisheries. From 1979 to 1993 a TAC of 2 000 tonnes was in effect for this stock. A reduction to 1 000 tonnes was agreed for 1994 and 1995 and a moratorium was agreed to thereafter.

Recent catch estimates and TACs (‘000 tonnes) 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** | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | |
| **STACFIS** | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.2 | 0.2 | 0.2 | 0.3 | |

ndf - no directed fishing.

### Effects of the fishery on the ecosystem

No directed fishery. General impacts of fishing gear on the ecosystem should be considered.

### Special comments

No special comments

### Sources of information

SCR Doc. 05/29; 20/11, 39; SCS Doc. 18/8, 13; 19/9; 20/7, 9, 13

## Thorny skate in Divisions 3LNO and Subdivision 3Ps

Advice June 2020 for 2021-2022

**Recommendation for 2021-2022**

The stock has been stable at recent catch levels (approximately 3 511 tonnes, 2015 - 2019). However, given the low resilience of this species and higher historic stock levels, Scientific Council advises no increase in catches.

### Management objectives

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

| *Convention objectives* | *Status* | *Comment/consideration* |
|---|---|---|
| Restore to or maintain at $B_{msy}$ | 🟡 | $B_{msy}$ unknown, stock at low level |
| Eliminate overfishing | 🟡 | $F_{msy}$ unknown, fishing mortality is low |
| Apply Precautionary Approach | 🟢 | $B_{lim}$ defined from survey indices |
| Minimise harmful impacts on living marine resources and ecosystems | 🟡 | No specific measures, general VME closures apply |
| Preserve marine biological diversity | ⚪ | Cannot be evaluated |

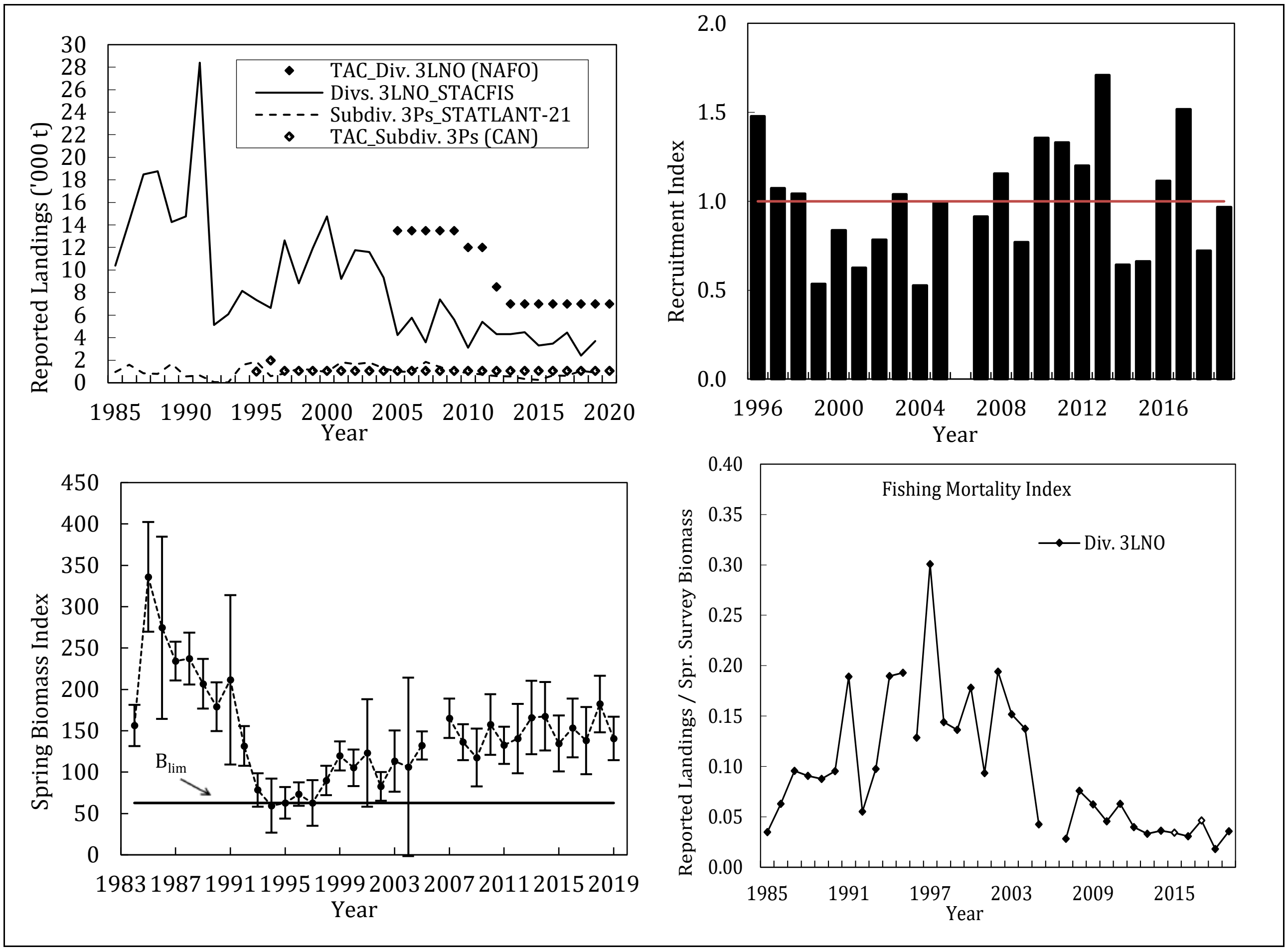
| | |
|---|---|
| 🟢 | OK |
| 🟡 | Intermediate |
| 🔴 | Not accomplished |
| ⚪ | Unknown |

### Management unit

The management unit is confined to NAFO Div. 3LNO, which is a portion of the stock that is distributed in NAFO Div. 3LNO and Subdivision 3Ps.

### Stock status

The stock is currently above $B_{lim.}$ The probability that the current biomass is above $B_{lim}$ is >95%. Total survey biomass in Divs 3LNOPs has remained stable since 2007 but is still lower than the levels observed at the end of the 1980s. Recruitment in 2017 was above average but declined to below average in 2018 and was average in 2019. Fishing mortality is currently low.



## Reference points

*B<sub>lim</sub>* defined from survey indices as *B<sub>loss</sub>* (NAFO SCS 15/12)

## 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. The next full assessment of this stock will be in 2022.

*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*

Thorny skate are found over a broad range of depths (down to 840 m) and bottom temperatures (-1.7 - 11.5ºC). Thorny skate feed on a wide variety of prey species, mostly on crustaceans and fish. Recent studies have found that polychaete worms and shrimp dominate the diet of thorny skates in Div. 3LNO, while hyperiids, snow crabs, sand lance, and euphausiids are also important prey items.

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

### Fishery

Thorny skate is caught in directed gillnet, trawl and long-line fisheries. In directed thorny skate fisheries, Atlantic cod, monkfish, American plaice and other species are landed as bycatch. In turn, thorny skate are also caught as bycatch in gillnet, trawl and long-line fisheries directing for other species. The fishery in NAFO division 3LNO is regulated by quota. Catches are well below the TAC because Canada has not been fishing on this stock.

Recent catch estimates and TACs (‘000 tonnes) are:

| | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **2018** | **2019** | **2020** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Div. 3LNO:** | | | | | | | | | | |
| TAC | 12 | 8.5 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| STATLANT 21 | 5.5 | 4.3 | 4.4 | 4.5 | 3.3 | 3.5 | 4.2 | 1.5 | 3.7 | |
| STACFIS | 5.4 | 4.3 | 4.4 | 4.5 | 3.4 | 3.5 | 4.5 | 2.4 | 3.7 | |

### 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

The life history characteristics of thorny skate result in low rates of population growth and are thought to lead to low resilience to harvesting if the stock becomes depleted to low levels.

### Sources of Information

SCR Doc. 14/23.15/40,20/04,10,14,41; SCS Doc. 20/07,09,13

### Monitoring of Stocks for which Multi-year Advice was Provided in 2018 or 2019

Interim monitoring for northern shortfin squid (*Illex illecebrosus*) in Subareas 3+4 will be carried out in September 2020). Interim monitoring updates of other stocks assessed in prior years were conducted and Scientific Council reiterates its previous advice as follows:

**Recommendation for redfish in Divisions 3M for 2020 and 2021:** SC advises that catches should not exceed $F_{0.1}$ level given the recent very low productivity of the stock. This corresponds to a TAC of 4 319 tonnes in 2020 and 4 624 tonnes in 2021.

**Recommendation for cod in Divisions 3NO for 2019–2021:** No directed fishing in 2019 to 2021 to allow for stock rebuilding. By-catches 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.

**Recommendation for American plaice in Divisions 3LNO for 2019-2021:** *SSB* remains below $B_{lim}$, therefore Scientific Council recommends that, in accordance with the rebuilding plan, there should be no directed fishing on American plaice in Div. 3LNO in 2019, 2020, and 2021. Bycatches of American plaice should be kept to the lowest possible level and restricted to unavoidable bycatch in fisheries directing for other species.

**Recommendation for yellowtail flounder in Divisions 3LNO for 2019-2021:** At a fishing mortality of 85% $F_{msy}$, catches of 24 900 tonnes, 22 500 tonnes, and 21 100 tonnes in 2019 to 2021, respectively, have less than a 30% risk of exceeding $F_{lim}$. At these yields the stock is projected to have an 82% probability of remaining above $B_{msy}$.

**Recommendation for capelin in Divisions 3NO for 2019-2021:** No directed fishery.

**Recommendation for redfish in Division 3O for 2020-22:** 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 white hake in Divisions 3NO and Subdivision 3Ps for 2020-2021:** Given the absence of strong recruitment, SC recommends catches of white hake in Divs. 3NO should not increase. Average annual catches over 2014 to 2018 were 406 tonnes.

**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.

**Special Requests for Management Advice**

Due to time constraints, Scientific Council was not able to address Commission requests number 3, 4, 9, 10, 13, 14, 16 and 18 during the June meeting. These requests will be addressed, to the extent possible, in September during the Annual Meeting and/or in an additional meeting (by correspondence) during September 15-17. Scientific Council members will work intersessionally to complete the work as far as possible prior to the September meeting.

Request number 15 was addressed by Scientific Council during the SC/NIPAG meeting in November 2019 and the response can be found in SCS Doc. 19/23.

### *i) Greenland halibut in SA2 + Divs. 3KLMNO: conduct an update assessment, compute the TAC using the agreed HCR and determine whether exceptional circumstances are occurring (COM request #2)*

The Commission requests the Scientific Council to conduct an update assessment of Greenland halibut in Subarea 2+Div. 3KLMNO and 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 2021 derived from the HCR is 16 498 tonnes.

SC advises that Exceptional Circumstances are not occurring.

The SC conducted update assessments, given the addition of three more years of data (2017-2019) to the base case SCAA and SSM models. Estimates of quantities such as recruitment, exploitable biomass, and average *F* hardly changed from values estimated in 2017.

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 tonnes in 2018. All data inputs used to calculate the TAC for 2021 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 $\mathrm{TAC}_y$ is the TAC recommended for year $y$, $\gamma$ 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),

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

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

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 of 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 $i$ ($\sigma^i$) estimated in the SCAA base case operating model. Missing survey values are treated as missing in the calculation of 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 $\alpha$ 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 tonnes |
| $\gamma$ | 0.15 |
| q | 3 |
| $\alpha$ | 0.972 |
| $\lambda_{up}$ | 1 |
| $\lambda_{down}$ | 2 |
| X | -0.0056 |
| $\Delta_{up}$ | 0.1 |
| $\Delta_{down}$ | 0.1 |

**Table i.2.** Data used in the calculation of the TAC for 2021. The weights given to each survey in obtaining composite indices of abundance (target rule) and composite trends (slope rule) are proportional to the inverse squared values of the survey error standard deviations $\sigma^i$ listed below.

| | Canada Fall 2J3K | Canada Fall 3LNO | Canada Spring 3LNO | EU-Spain 3NO | EU 3M 0-1400m |
|---|---|---|---|---|---|
| 2011 | 26.74 | 2.21 | 1.05 | 7.09 | 26.15 |
| 2012 | 23.50 | 1.71 | 1.94 | 7.37 | 19.20 |
| 2013 | 29.65 | 2.59 | 0.73 | 5.46 | 19.11 |
| 2014 | 33.34 | | 0.66 | 6.24 | 23.92 |
| 2015 | 22.29 | 0.87 | | 9.49 | 47.52 |
| 2016 | 18.54 | 1.31 | 0.66 | 8.80 | 28.30 |
| 2017 | 15.10 | 1.25 | | 16.63 | 42.66 |
| 2018 | 17.05 | 1.89 | 1.88 | 7.88 | 29.80 |
| 2019 | 16.28 | 1.87 | 1.45 | 8.82 | 16.89 |
| $s^{i}_{2020}$ | -0.07 | 0.19 | 0.30 | -0.03 | -0.20 |
| $J^{i}_{\text{current, 2020}}$ | 16.15 | 1.67 | 1.66 | 11.11 | 29.79 |
| $J^{i}_{\text{target}}$* | 26.34 | 1.79 | 1.06 | 6.93 | 26.42 |
| $\sigma^{i}$ | 0.22 | 0.26 | 0.49 | 0.38 | 0.21 |
| | | $TAC_{2020}$ | 16 926 tonnes | $TAC^{target}_{2021}$ | 16 940 tonnes |
| | | $s_{2020}$ | -0.03 | $TAC^{slope}_{2021}$ | 16 056 tonnes |
| | | $J_{2020}$ | 1.01 | $TAC_{2021}$ | 16 498 tonnes |

* A mis-specification of α (previously 0.927, corrected 0.972) meant that incorrect $J_{target}$ values were applied to calculate the TAC for 2019 and 2020. This error had a negligible impact on the TAC calculations (< 0.5%; SCR Doc. 20/042). Correct $J_{target}$ values are used here.

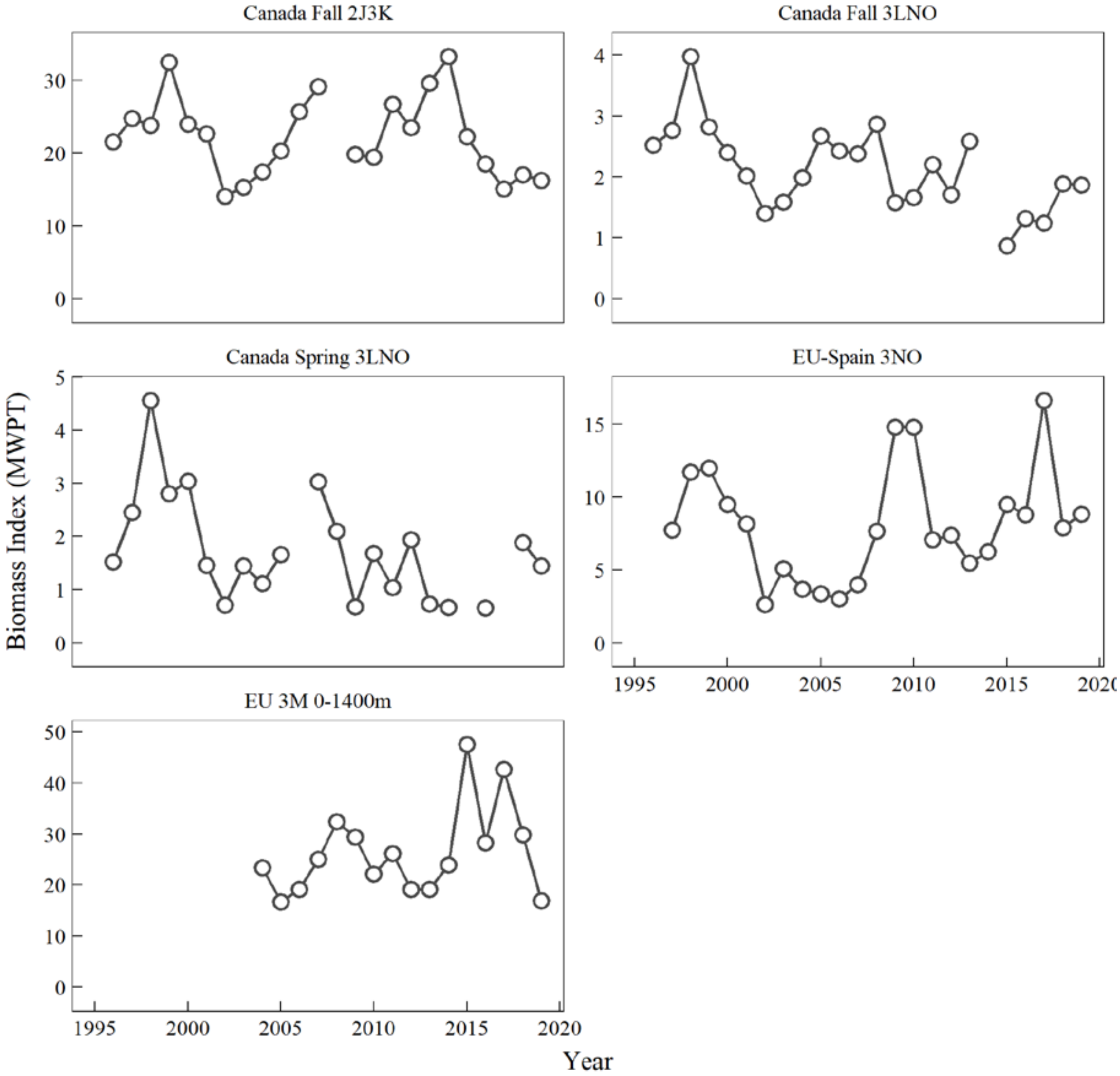


**Figure. i.1.** Input for the Greenland Halibut in Subarea 2 + Divisions 3KLMNO Harvest Control Rule. Survey data come from Canadian fall surveys in Divs. 2J3K, Canadian spring surveys in Divs. 3LNO (2015 and 2017 surveys were incomplete and not used in the calculation of the TAC using the HCR), Canadian fall surveys in Divs. 3LNO, EU Flemish Cap surveys (to 1400m depth) in Div. 3M and EU-Spain surveys in 3NO.

### Exceptional Circumstances

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);*

SC notes that the Canadian fall 2J3K was incomplete in 2019. Areas that were missed are inhabited by Greenland halibut. However, the unavailability of the strata missed in 2019 had minimal impact on the mean weight per tow indices used in the HCR (see SCR Doc. 20/004). It was therefore agreed that the 2019 Canadian fall 2J3K index would be included in the calculation of the TAC using the HCR. Therefore, Exceptional Circumstances do not presently arise from missing survey data.

*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). Incomplete documentation regarding the SSM projections have precluded the same comparison using the SSM probability envelopes in 2019. Consequently, a thorough review of the SSM MSE simulations has been conducted and several issues have been identified and resolved (summarized below). A provisional reconstruction of the SSM base case simulation is presented in Figure i.3 and the composite survey indices are 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 the 90% probability envelope from the reconstructed SSM projections, SC considers that this does not constitute Exceptional Circumstances.

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

The TAC established for 2020 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 three years are within the 80% probability envelopes from the base case SCAA operating model except for the EU 3M survey and the EU-Spain 3NO survey in 2017, both of which were above the 90% but within the 95% probability envelope (Figure i.2). Likewise, most recent survey indices are within the 80% probability envelopes from the reconstructed SSM projections, however, some observations are above the 95% envelopes (EU 3M 0-1400m in 2017, Canada Spring 3LNO in 2018 and EU-Spain 3NO in 2017; Figure i.3). All indices from 2019 are within the 80% probability envelopes from both models. This does not constitute Exceptional Circumstances.

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

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

The TAC for 2019 was 16 521 tonnes. The catch in 2019 was 16 481 tonnes (<0.3% difference). SC considers that this does not constitute Exceptional Circumstances.

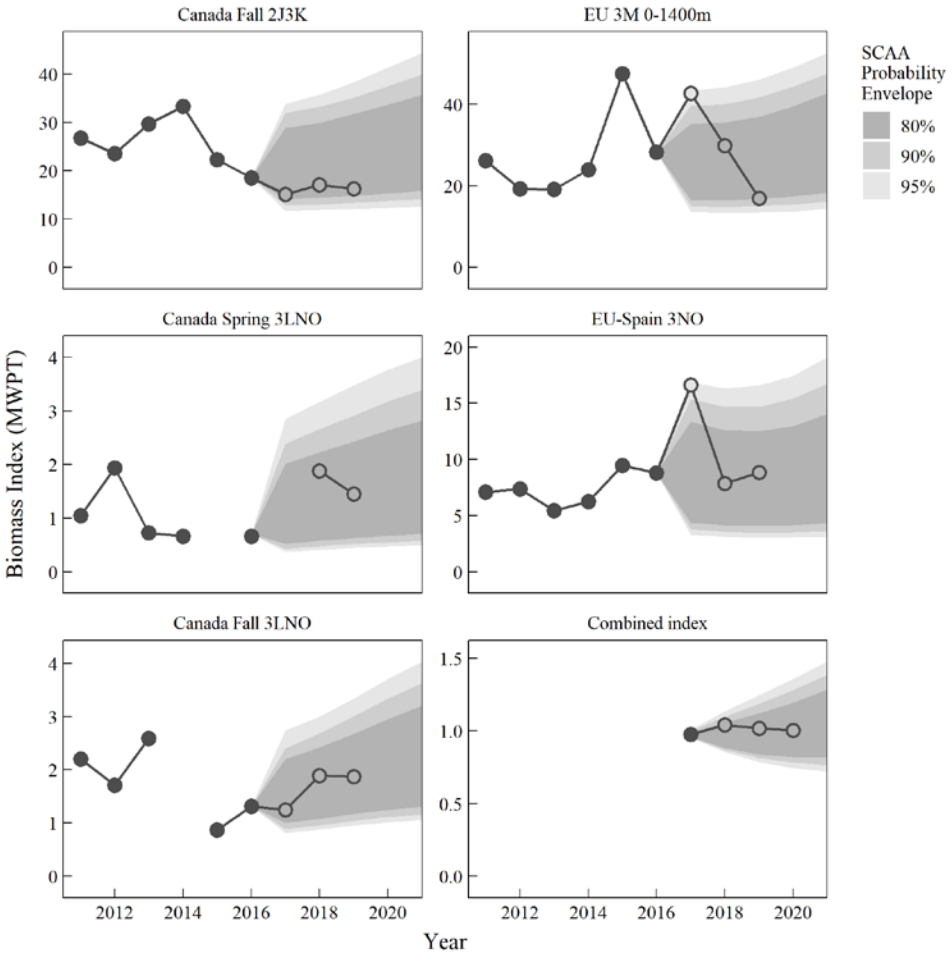


**Figure. i.2.** Greenland Halibut in Subarea 2 + Divisions 3KLMNO. Mean weight per tow from Canadian fall surveys in Divs. 2J3K, Canadian spring surveys in Divs. 3LNO (2015 and 2017 surveys incomplete and not used in the calculation of the HCR), Canadian fall surveys in Divs. 3LNO, EU Flemish Cap surveys (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.

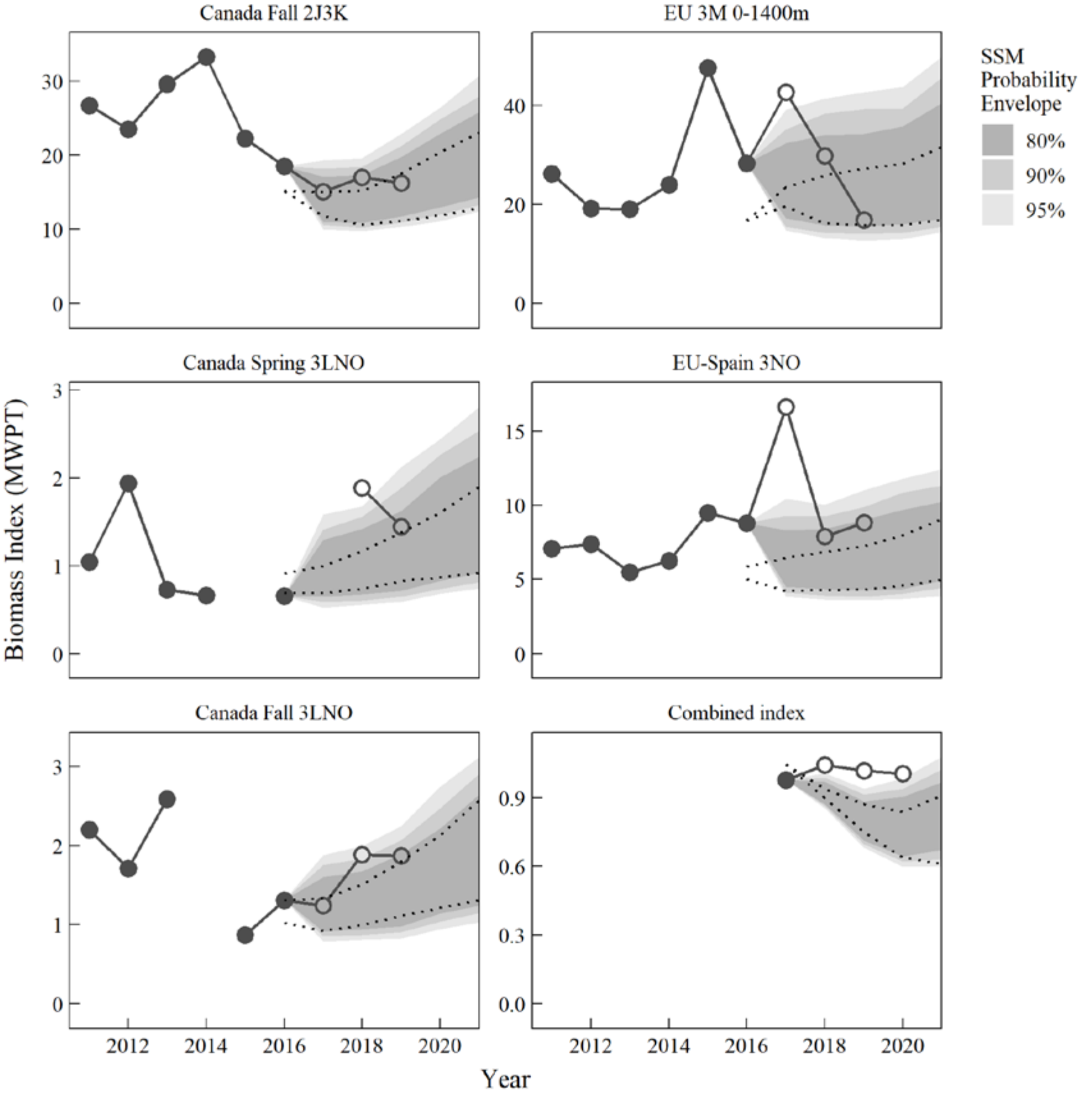


**Figure. i.3.** Greenland Halibut in Subarea 2 + Divisions 3KLMNO. Mean weight per tow from Canadian fall surveys in Divs. 2J3K, Canadian spring surveys in Divs. 3LNO (2015 and 2017 surveys incomplete and not used in the calculation of the HCR), Canadian fall surveys in Divs. 3LNO, EU Flemish Cap surveys (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 a provisional reconstruction of the SSM base case simulation are shown. Index values observed from 2017 onward are shown using open circles. The dotted lines are 95% probability envelopes from the initial SSM base case simulation, which are now known to have been incorrect (see text).

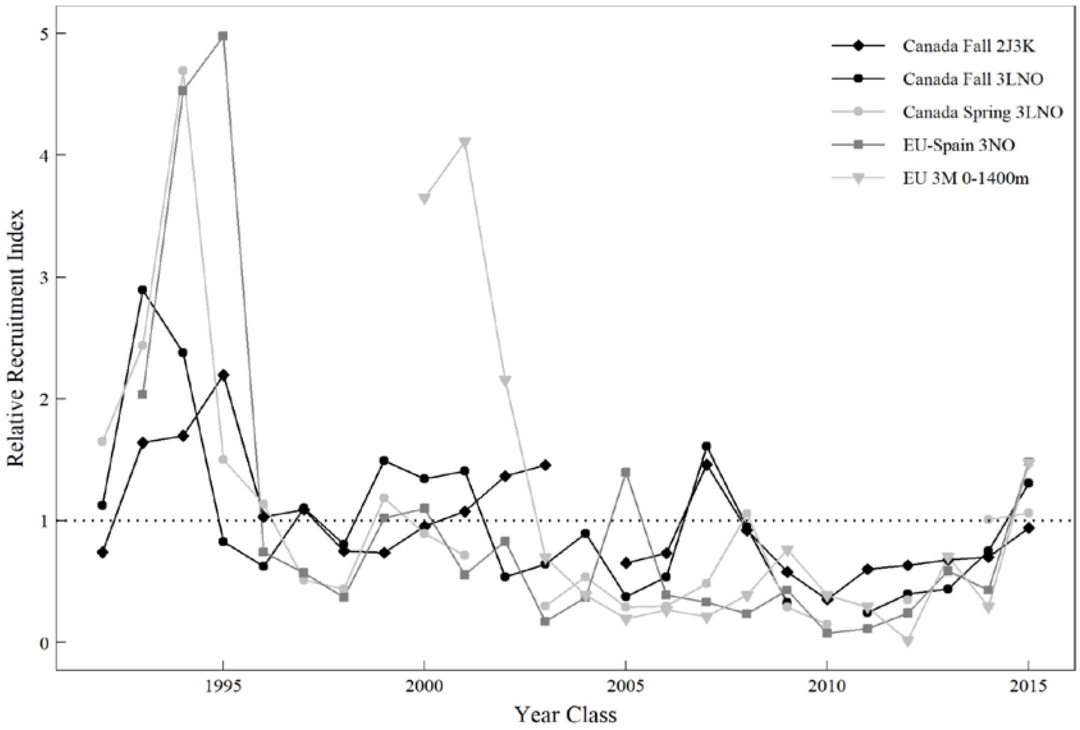


**Figure. i.4.** Greenland Halibut in Subarea 2 + Divisions 3KLMNO. Relative recruitment (age 4) indices from Canadian fall surveys in Div. 2J3K, Canadian spring surveys in Div. 3LNO, Canadian fall surveys in Div. 3LNO, EU-Spain survey in 3NO and EU survey of Flemish Cap. Each series is scaled to its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

### Update assessment

In addition to the agreed annual indicators of Exceptional Circumstances, SC agreed to evaluate assessment-based indicators of Exceptional Circumstances following an update assessment of the stock. Specifically:

- *A comparison of assessment model outputs for recruitment, exploitable biomass, and fishing mortality with operating model projections (base case) will also be taken into account qualitatively. Notwithstanding some technical issues regarding the comparison of the simulated distributions against updated assessments, it was agreed that SC will compare the estimated median of the assessment with the 95% Confidence Interval from the base case of SSM and SCAA for the above quantities. Expert judgement will determine whether Exceptional Circumstances are occurring* (SCS Doc. 18/19).

Following the addition of three more years of data (2017-2019) to the base case SCAA and SSM models, estimates of quantities such as recruitment, exploitable biomass, and average F have hardly changed from values estimated in 2017 (i.e. there were no large retrospective revisions in the estimates prior to 2016; Figures i.5 and i.6). Recent estimates from the SCAA are broadly consistent with predictions from the 2017 MSE process; specifically, all estimates are within the 95% probability envelopes with the exception of average F, which in 2017 fell below the 95% probability envelope (Figure i.5). Fishing mortality in the last two years has increased to slightly below $F_{MSY}$ in 2019. Current estimates of recruitment, exploitable biomass and average F all fall within the 95% probability envelopes from the reconstructed SSM simulation (Figures i.6). SC considers that this does not constitute Exceptional Circumstances.

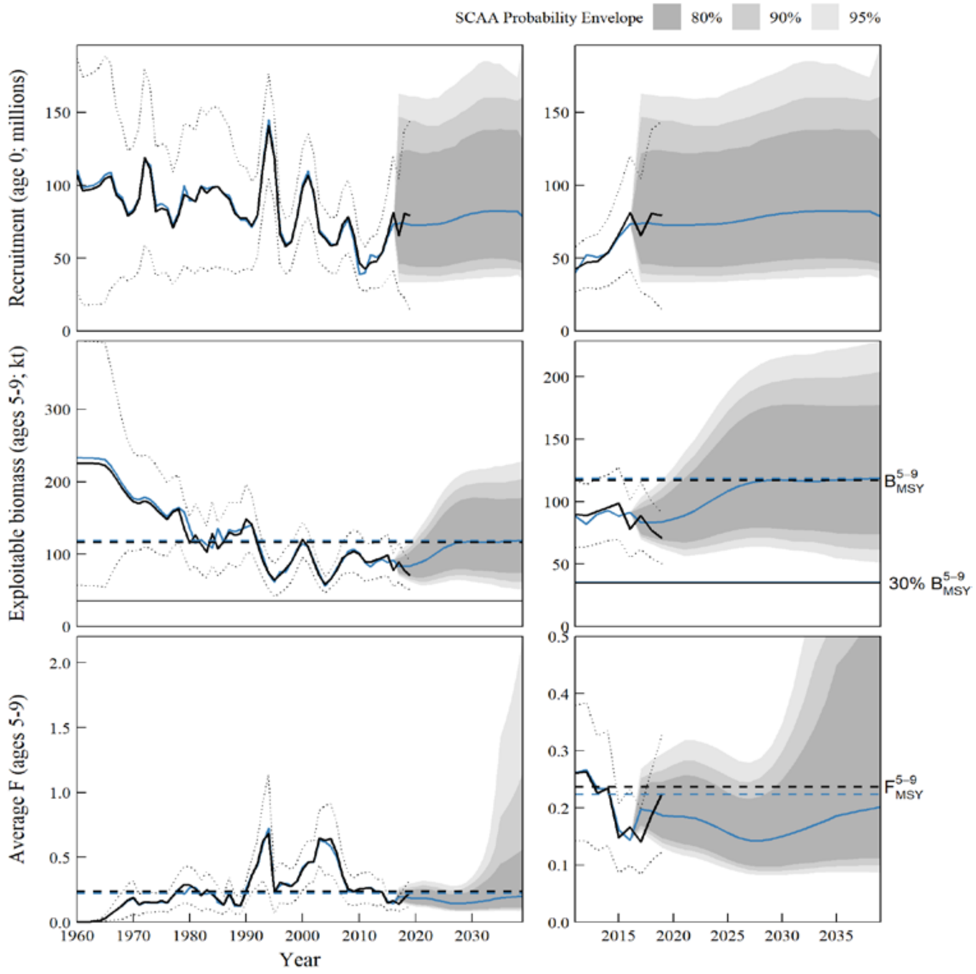


**Figure. i.5.** Greenland Halibut in Subarea 2 + Divisions 3KLMNO. Base case SCAA model: Trends in recruitment (age 0; millions), exploitable biomass (ages 5-9; kt), and average F (ages 5-9). Blue lines represent values from the 2017 MSE with the base case SCAA, whereas black lines indicate values from 2020 update assessment. Shown are: historical (1960-2019) estimates with 95% CIs (thin dotted lines) from the 2020 update assessment, as well as medians and 80%, 90% and 95% probability envelopes (grey shaded areas) projected from the 2017 MSE simulations (with the base case SCAA) under the adopted HCR. Finally, horizontal lines indicate reference points ($B_{MSY}^{5-9}$, 30% $B_{MSY}^{5-9}$, $F_{MSY}^{5-9}$) from both the 2017 MSE base case SCAA (blue) and those calculated from the 2020 update assessment (black).

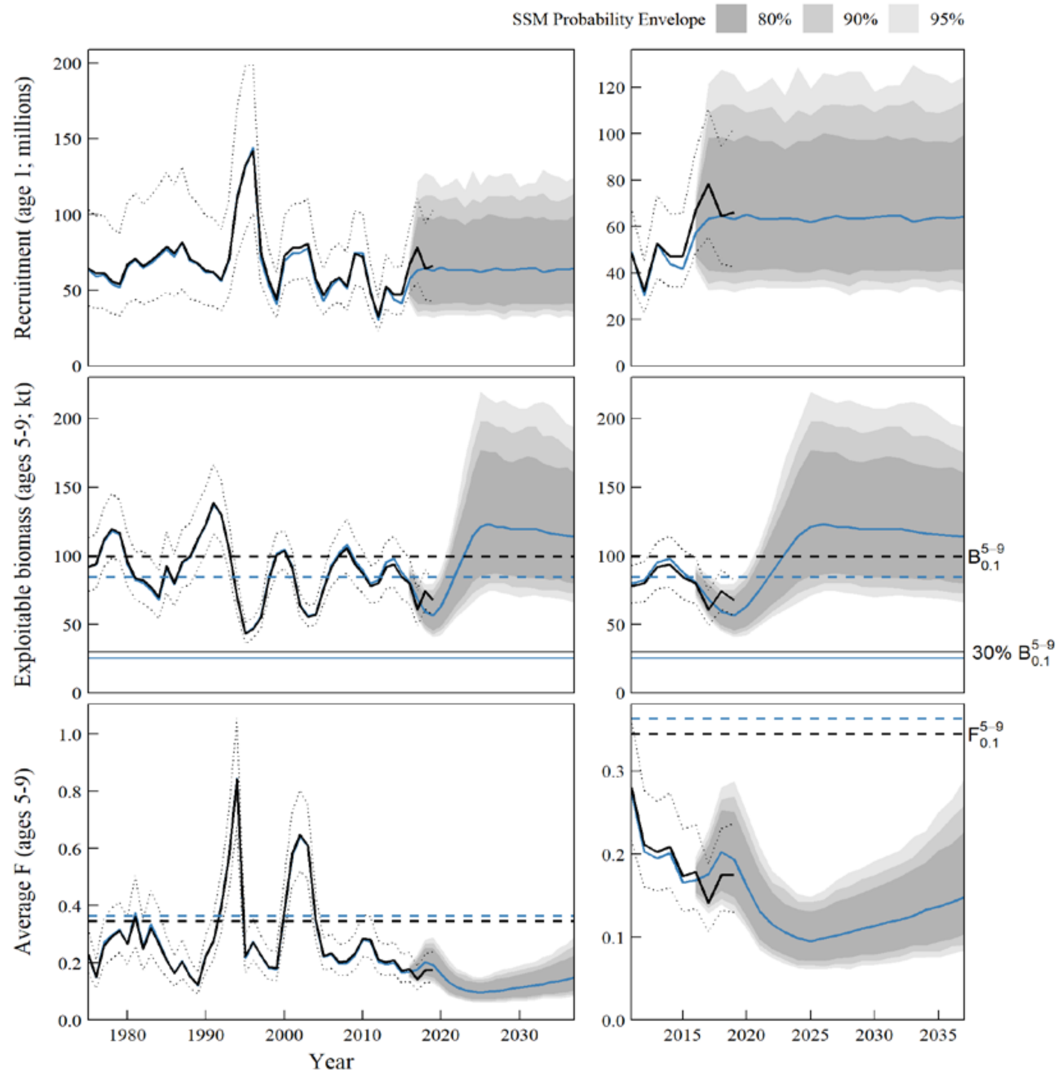


**Figure i.6.** Greenland Halibut in Subarea 2 + Divisions 3KLMNO. Base case SSM model: Trends in recruitment (age 1; millions), exploitable biomass (ages 5-9; kt), and average F (ages 5-9). Blue lines represent values from the 2017 MSE (reconstituted following correction of errors) with the base case SSM, whereas black lines indicate values from 2020 update assessment. Shown are: historical (1960-2019) estimates with 95% CIs (thin dotted lines) from the 2020 update assessment, as well as medians and 80%, 90% and 95% probability envelopes (grey shaded areas) projected from the 2017 MSE simulations (with the base case SSM) under the adopted HCR. Finally, horizontal lines indicate reference points ($B_{0.1}^{5-9}$, 30% $B_{0.1}^{5-9}$, $F_{0.1}^{5-9}$) from both the preliminary reconstruction of the 2017 MSE base case SSM (blue) and those calculated from the 2020 update assessment (black).

## Revisiting the SSM MSE simulations

Unexpected discrepancies between terminal survey indices and the projections from the SSM was the first sign that there were critical flaws in the implementation of the SSM portion of the MSE. These discrepancies are shown in Figure i.3; the dotted lines are the original SSM projections and they should start at the 2016 observations. A lack of documentation prevented SC from verifying the calculations at the June 2019 meeting and, as such, the probability envelopes from the SSM projections could not be used at that meeting to assess exceptional circumstances. This issue triggered a review of the code used to provide the SSM MSE simulations and the following issues were identified:

1. **Observation error:** the simulation began in 2016 at indices predicted by the SSM rather than the actual observation, and future indices were simulated without observation error.
2. **Process error:** the simulation was initialized without process error in the first year (2016), implying that numbers at age in the first year were known without error, and error applied in the projections were sampled from the process errors estimated by the SSM instead of being sampled from a normal distribution.
3. **HCR:** both the target and slope based components of the accepted HCR were mis-specified. Target values were calculated by year rather than by survey and using predicted indices rather than the actual observations. For the slope-based rule, the variance instead of the inverse variance was applied when calculating the weighted measure of recent survey trends. Finally, indexing errors meant that indices from the wrong years were being used to calculate the TAC.

These issues change the structure and function of the model. In an attempt to reconstruct the intended projections, the issues above were rectified and revised probability envelopes were calculated for the base case operating model; these values are used in Figure i.3 and Figure i.6. The original and reconstructed SSM probability envelopes are compared in Figure i.7. Two main differences are noticeable. First, the addition of observation error creates wider probability envelopes in the current simulation for all the survey indices. Second, yields reached higher levels in the original simulations, leading to a decline in biomass. This difference is likely caused by the mis-specification of the HCR in the original simulation.

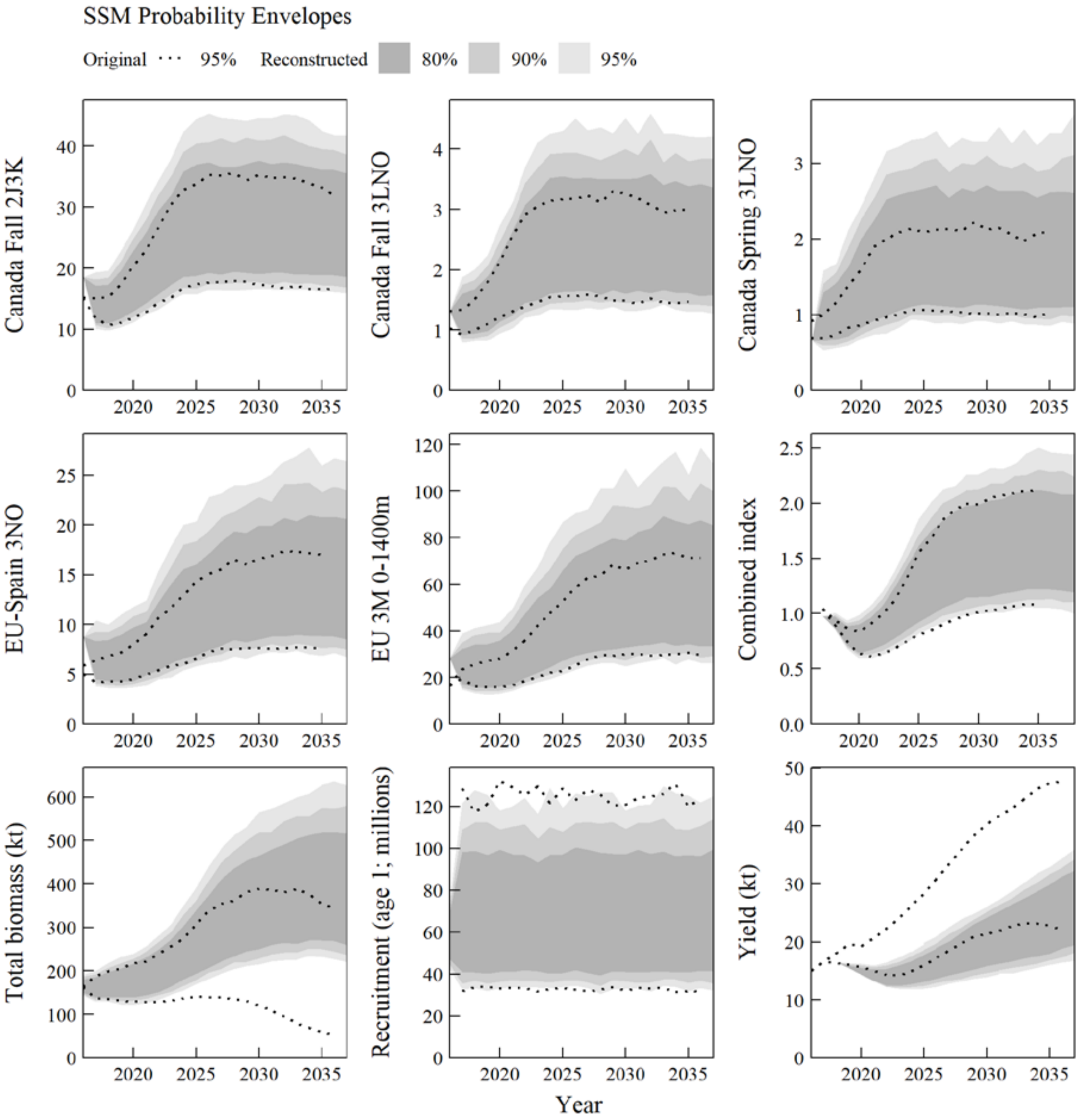


**Figure. i.7.** Greenland Halibut in Subarea 2 + Divisions 3KLMNO. Probability envelopes from the original (dotted lines; 95% probability envelope only) and reconstructed (shaded areas; 80%, 90% and 95% probability envelopes) SSM base case simulations of the Canadian and EU survey indices, combined index, total biomass (kt), recruitment (age 1; millions), and yield (kt). The original simulations are now known to have been incorrect (see text).

Performance statistics were also revisited following the revision of the simulation. Reference points were required for this task; however, it was not possible to verify or reproduce the reference points used in the initial MSE because of a lack of documentation on the agreed approach. Revised reference points were therefore calculated and, assuming mean levels of age 1 recruitment estimated by the SSM, deterministic equilibrium estimates of $F_{0.1}$ and $B_{0.1}$ were preliminarily chosen as proxies for $F_{MSY}$ and $B_{MSY}$, respectively. Performance statistics from the original simulation are also shown in Table i.3 and, as expected given the projections, there appears to be greater yields in this simulation as well as a greater risk of not reaching biomass targets. Relatively poor performance is likely a reflection of mis-specifications of the accepted HCR, which, under the reconstructed simulations, appears to be performing well.

With the reference point gaps filled, SC notes that these further base case SSM simulations were found to meet all performance criteria (Table i.3).

**Table i.3.** Performance statistics from the original and reconstructed SSM MSE simulations applying the HCR adopted in 2017. Statistics from the original simulation are likely flawed as several implementation errors have been identified (see text). Note that $B_{0.1}^{5-9}$ and $F_{0.1}^{5-9}$ were estimated using the reconstructed 2017 base case SSM simulations, and these values were used as proxies for $B_{MSY}$ and $F_{MSY}$, respectively. The basis of the original 2017 estimates of $B_{MSY}$ and $F_{MSY}$ are unknown. Also note that all other $B$ and $F$ metrics pertain to ages 5-9, except for those with $sp$ as a superscript which represents ages 10+.

| Management objective | Perf. stats | Criteria | Original | | Reconstructed | |
|---|---|---|---|---|---|---|
| 1. Restore to within a prescribed period of time or maintain at $B_{\mathrm{MSY}}$ | $B_{2037}$ / $B_{\mathrm{MSY}}$ | Median (80% PI) | 1.00 | (0.64, 1.50) | 1.35 | (0.94, 1.90) |
| | $B_{2037} < B_{\mathrm{MSY}}$ | Proportion ≤ 0.5 | 0.50 | | 0.14 | |
| | $B_{2022} < 0.8\ B_{\mathrm{MSY}}$ | Proportion ≤ 0.25 | 0.57 | | 0.13 | |
| | $B_{2037} < 0.8\ B_{\mathrm{MSY}}$ | Proportion ≤ 0.25 | 0.27 | | 0.03 | |
| 2. The risk of failure to meet the $B_{\mathrm{MSY}}$ target and interim biomass targets within a prescribed period of time should be kept moderately low | $B_{\mathrm{lowest}}$ / $B_{\mathrm{MSY}}$ | Median (80% PI) | 0.56 | (0.43, 0.69) | 0.64 | (0.52, 0.76) |
| | $B_{2022}$ / $B_{2018}$ | Proportion < Ω = 0.25 | 0.13 | | 0.07 | |
| 3. Low risk of exceeding $F_{\mathrm{MSY}}$ (for each year $y$ between 2018 to 2037, if more than 30% of the simulations had $F_y > F_{\mathrm{MSY}}$, count 1, i.e. maximum value for this metric is 20) | ( $F_{2018\text{-}2037} > F_{\mathrm{MSY}}$ ) > 0.3 | Count | 8.00 | | 0.00 | |
| 4. Very low risk of going below an established threshold (for each year $y$ between 2018 to 2037, if more than 10% of the simulations had $B_y < 0.3\ B_{\mathrm{MSY}}$ , then we count (i.e. maximum value for this metric is 20) | $B^{sp}_{2037}$ / $B^{sp}_{2018}$ | Median (80% PI) | 1.59 | (0.92, 2.54) | 2.17 | (1.46, 3.24) |
| | $B_{2037}$ / $B_{2018}$ | Median (80% PI) | 1.58 | (0.96, 2.61) | 1.91 | (1.27, 2.93) |
| | ( $B_{2018\text{-}2037} < 0.3\ B_{\mathrm{MSY}}$ ) > 0.1 | Count | 0.00 | | 0.00 | |
| | $B_{\mathrm{lowest}}$ / $B_{\mathrm{MSY}} < 0.3$ | Proportion ≤ 0.1 | 0.01 | | 0.00 | |
| 5. Maximize yield in the short, medium and long term | avC: 2018-2020 | Median (80% PI) | 16.49 | (16.38, 16.66) | 15.55 | (15.48, 15.94) |
| | avC: 2018-2037 | Median (80% PI) | 19.03 | (15.94, 24.97) | 18.53 | (15.83, 21.38) |
| 6. The risk of steep decline of stock biomass should be kept moderately low | $B_{2022} < 0.75\ B_{2018}$ | Proportion < β = 0.11 | 0.00 | | 0.00 | |
| 7. Keep inter annual TAC variation below 'an established threshold' | AAV: 2018-2037 | Median (80% PI) | 3% | (2%, 5%) | 5% | (4%, 6%) |
| 8. Proportion of the catch consisting of 10+ fish | Average 2018-2037 | Median (80% PI) | 0.12 | (0.11, 0.13) | 0.21 | (0.18, 0.25) |

### *ii) Continue the evaluation of scientific trawl surveys in VME closed areas (COM request #3)*

Due to time constraints, SC was not able to address this request during the June meeting and it is deferred until September 2020 or June 2021.

### *iii) Identify discard species/stocks with high survivability rates (COM request #4)*

Due to time constraints, SC was not able to address this request during the June meeting and it is deferred until September 2020.

### *iv) continue to refine work under the ecosystem approach (COM request #5)*

The Commission requests the Scientific Council to continue to refine its work under the Ecosystem Approach and report on these results to both the WGEAFFM and WGRBMS.

**Scientific Council responded:**

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). In practice, work toward implementing Tier 1 principles has involved, among other things, the development of guidance for aggregated total catches based on Ecosystem Production Potential (EPP) models. To address existing concerns about the reliability of this approach, SC conducted a detailed review of the EPP model, the process used to derive the Fishery Production Potential (FPP), the adjustment for ecosystem productivity conditions that renders the current FPP (FPPc), and the associated Total Catch Index (TCI) which serves as an operational metric in the guidance for total catches.

Results indicate that the EPP model provides a good approximation to ecosystem production, that it is necessary to consider basic food web structure and energy pathways to adequately track how primary production becomes fisheries production, and that this model can provide a first order approximation to the production potential of trophic guilds relevant to fisheries. SC also notes that total FPP estimates are consistent with MSY estimates from aggregate biomass surplus production models from 12 Northern hemisphere marine ecosystems, including the Newfoundland Shelf. This coherence with independent analyses gives further support to FPP and TCI as a reliable basis for the provision of strategic (3-5yr) guidance. Furthermore, the results also indicate that catches above TCI levels are more often associated with negative biomass trends in functional guilds, particularly when catches were 2-5 times greater than TCI guidance. This indicates that TCIs perform reasonably well at mapping catch levels associated with negative trends in growth of functional guilds among ecosystem units.

SC notes that the overall results of the analyses are promising, and **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 is organized around two general components dealing with a) sustainability of the fisheries exploitation (i.e. impacts on fished stocks) and b) the effects of fishing on other ecosystem elements (i.e. impacts of fishing on habitats).

Defining sustainable exploitation levels within an ecosystem approach is addressed through a three-tiered process. Tier 1 outlines the need to provide ecosystem-level guidance dealing with total fisheries exploitation based on the overall productivity and state of the ecosystems being fished. Tier 2 is the stage where models of multispecies interactions would be used to inform the allocation of fisheries production among a set of target stocks, taking into account predation and competition. Tier 3 involves single-species stock assessment, where the harvest rates derived in Tiers 1–2 are further examined to ensure single-species sustainability. Taken together, exploitation levels are defined by sequentially examining sustainability at nested levels of ecological organization (i.e. ecosystem, multispecies, and stock).

In practice, work toward implementing Tier 1 of the NAFO Roadmap has involved, among other things, the development of guidance for aggregated total catches based on a model of Ecosystem Production Potential (EPP). The NAFO Commission (COM) and Scientific Council (SC) joint Working Group on the Ecosystem Approach Framework to Fisheries Management (WGEAFFM) has raised concerns about the underlying reliability of the Ecosystem Production Potential (EPP) model. Given these concerns, consolidating previous analyses with a clear outline of the underlying assumptions of the EPP model and their potential impact on predictions, SC committed to:

1. Assess whether the 25th percentile of the Fishery Production Potential (FPP) distribution is an appropriate precautionary metric to define Total Catch Indices (TCI; i.e. fishery overall production capability).
2. Explore development of a dynamic version of the EPP model to develop projections and further inform the assessment of ecosystem-level risks.
3. Assess whether the historical biomass and proportional distribution of functional feeding groups is an appropriate representation of a fully functional/high productivity ecosystem state.
4. Evaluate whether ecosystem productivity (i.e. from lower to upper trophic levels, as possible) has changed following major changes in ecosystem status.
5. Undertake sensitivity assessment of the sources of uncertainty in EPP model projections.
6. Contrast sustainable exploitation rates from EPP and other approaches (e.g. maximum sustainable yield) and investigate alternative scenarios in the distribution of exploitation rates among functional groups.

In support of SC work on this topic, WGESA addressed these points at its 2019 meeting. While some specific elements still remain to be fully explored due to workload issues and availability of resources (e.g. dynamic version of EPP model), the substance of the concerns raised was thoroughly investigated.

Ecosystem Production Potential (EPP) models are simple network models that track the production generated by primary producers up the food web with the premise that the primary production generated by phytoplankton is the ultimate limit for fish production in the marine ecosystem (Figure iv.1). Estimates of EPP are based on 10,000 Monte Carlo simulations that yield a distribution of expectations for all model nodes (i.e. trophic levels, functional feeding guilds).

The EPP model assumes that the ecosystem is fully functional, i.e. that there is sufficient biomass in each node to fully utilize the production flowing into the node, and hence making the node's own production fully available to upper trophic level nodes. If this is not the case, the actual production in the node would be constrained by its ability to process/utilize lower trophic levels production, and hence, the realized ecosystem production would be less than that estimated by the EPP model. This would mean that ecosystem productivity is somewhat impaired, and the ecosystem is not fully functional.

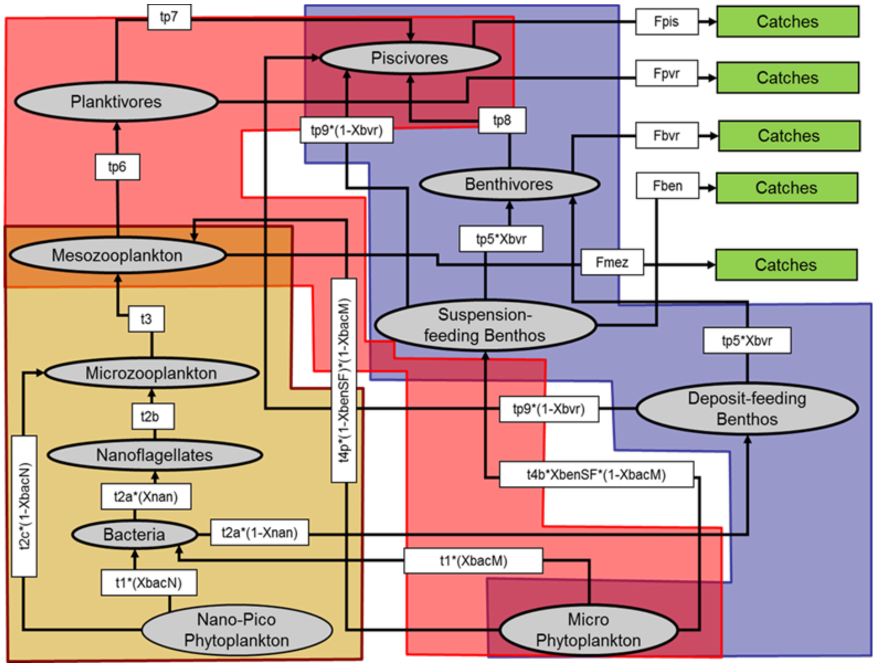


**Figure iv.1.** Structure of the EPP model. Ovals represent nodes [functional feeding guilds], and arrows indicate the trophic flows between nodes. The boxed equations along the flows indicate the parameters/factors in each flow (i.e. transfer efficiency, transfer efficiency multiplied by fraction available, or exploitation rate). The red, blue, and brown backgrounds indicate the pelagic, benthic, and microbial loop energy pathways. The current model allows fishing on five (5) nodes [functional guilds], mesozooplankton, planktivores, suspension feeding benthos, benthivores, and piscivores, but mesozooplankton are not harvested in NAFO ecosystems. The EPP model is implemented as a Monte Carlo simulation to account for the uncertainty in all inputs and model parameters. Transfer efficiencies outside the microbial loop are modeled using beta distributions derived from a compilation of 35 models of Arcto-Boreal ecosystems and 58 models of Temperate ecosystems. The main model input is size-partitioned primary production derived from remote sensing data and associated analyses.

Total ecosystem production is highly dominated by production associated with the microbial loop, with production associated with fisheries being orders of magnitude less than that of lower trophic levels. Four nodes in the EPP model contain species targeted or of potential importance to fisheries: piscivores, benthivores (e.g. many flatfish, small fish taxa, shellfish), plantktivores (e.g. capelin, herring, juvenile groundfish) and suspension-feeding benthos (e.g. scallops, clams).

SC notes that correlations of biomass fluctuations among nodes and within pathways reveal that energy flow within microbial loop and pelagic pathways is highly coherent but much more diffuse in the benthic pathway. Production of mesozooplankton and deposit feeding benthos is strongly linked to production of microplankton, and production of important fishable nodes (i.e. planktivores, benthivores, and piscivores) is strongly linked with these two lower trophic levels. From a fisheries perspective, SC notes that it is necessary to consider food web structure and energy pathways to adequately track how primary production (PP) affects fisheries production.

A comprehensive examination of the structural uncertainty of the EPP model focussed on topological changes affecting the microbial loop because it dominates ecosystem productivity, and can therefore affect all trophic nodes relevant to fisheries. Weakening the microbial loop boosts suspension-feeding benthos production, but has negative impacts on deposit-feeding benthos. A stronger microbial loop generally reduces productivity in the pelagic pathway, and consequently planktivores and piscivores. SC notes that overall, the EPP model captures basic ecosystem features reasonably, and hence can provide a first order approximation to the production potential of trophic guilds relevant to fisheries.

**Application of EPP to fisheries advice**

Using these estimates for the provision of fisheries advice in NAFO requires: [1] defining what is a sustainable catch level (FPP) in the context of an EPP model; [2] evaluating the level of ecosystem functionality and, if required, scale the model results based on the current ecosystem state; and [3] presenting results in line with NAFO management principles and frameworks.

Iverson's (1990) study supports the hypothesis that fish production is "controlled by the amount of new nitrogen incorporated into phytoplankton biomass" (e.g. upwelling, winter mixing), the *f*-ratio. Because of the strong reliance of production of the principal fishable nodes (i.e. planktivores, benthivores and piscivores) on energy flow from microplankton that is highly dependent on new nitrogen, through mesozooplankton and suspension feeding benthos nodes, Rosenberg et al. (2014) compiled estimates of the fraction of microplankton for 54 Large Marine Ecosystems around the world and concluded that the upper limit for sustainable fishing in the context of the EPP model is of ~20%. On this basis, estimates of FPP were produced for three Ecosystem Production Units (EPU) within the NAFO Convention Area: the Newfoundland Shelf (2J3K – 577,000 tonnes), the Grand Bank (3LNO – 889,000 tonnes) and the Flemish Cap (3M – 157,000 tonnes). SC notes that traditional groundfish and shellfish fisheries represent slightly less than half of these total yields, with piscivores yielding around 10% of total (Figure iv.2).

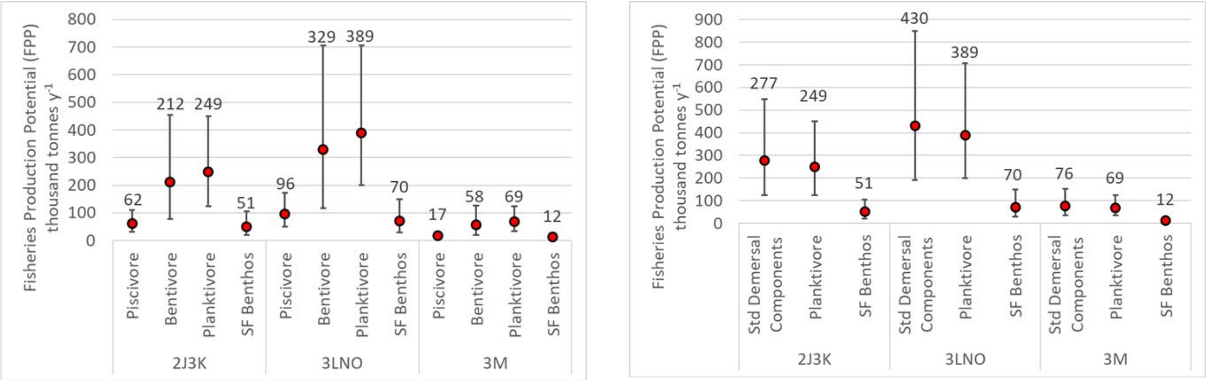


**Figure iv.2.** Fisheries Production Potential (FPP) for the Newfoundland Shelf (2J3K), Grand Bank (3LNO), and Flemish Cap (3M) EPUs. Left: FPP by fishable node (i.e. functional guild), Right: FPP with piscivore and benthivore nodes aggregated into Standard Demersal Components (SDC). Red dots indicate the medians, whiskers the 10-90% range, and the numbers above are the numerical value of the medians. Differences in magnitude among EPUs are mostly the result of the areal extent of different ecosystems. All estimates assume full ecosystem functionality.

SC notes that estimates of total FPP (2J3K – 2.27 t $km^{-2}$ $yr^{-1}$, 3LNO – 2.82 t $km^{-2}$ $yr^{-1}$, 3M – 2.72 t $km^{-2}$ $yr^{-1}$) are consistent with MSY estimates from aggregate biomass surplus production models from 12 Northern hemisphere marine ecosystems, including the Newfoundland Shelf (1-5 t $km^{-2}$ $yr^{-1}$). Exploitation rates ($F_{msy}$) were mostly close to 0.2 $yr^{-1}$ (range: 0.1-0.4 $yr^{-1}$) (Bundy et al., 2012), consistent with the sustainable fishing at F=20% as derived from the *f*-ratio.

While FPP estimates assume that the ecosystem is fully functional and relatively stable, real ecosystems are often far from equilibrium (Figure iv.3). The Flemish Cap appears to have maintained a relatively stable total biomass over time. However, the Newfoundland Shelf (2J3K) and Grand Bank (3LNO) EPUs currently have total biomass levels that are far lower than the ones observed in the 1980s. As a result, FPP estimates need to be adjusted to reflect their reduced productivity state based on the assumption of an overall constant production/biomass ratio. Trajectories of total RV Biomass, as fractions of the median of total RV Biomass between 1981-1985 for 2J3K and 1985-1987 for 3LNO, were used to define a penalty scheme to adjust FPP estimates (Figure iv.3), assuming that these ecosystems were fully functional prior to the reduction in their productivity, to yield estimates of Current Fisheries Production Potential (FPPc).

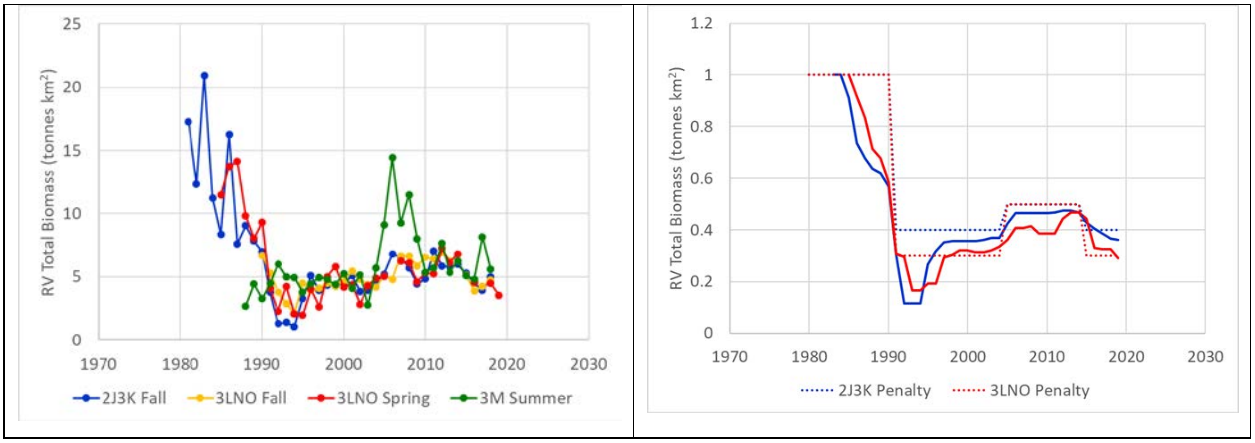


**Figure iv.3.** Left panel: Total RV Biomass Density indices for the Newfoundland Shelf (2J3K) (Fall), the Grand Bank (3LNO) (Spring and Fall), and Flemish Cap (3M) (Summer). The 2J3K and 3LNO series have been scaled pre-1995/1996 to correct for changes in the survey gear in DFO surveys. Right panel: Running medians of penalty scheme (full lines), where 1 corresponds a fully functional ecosystem, used to adjust FPP estimates for current productivity state, with the abstracted penalty scheme (dotted lines) that was applied to the analyses.

The NAFO Precautionary Approach (PA) states that the probability of exceeding a maximum sustainable exploitation rate should be low, nominally characterized by a low probability at around 20% (NAFO, 2004 – note the PA is currently under review). Following a similar rationale, a simple way to ensure that the probability of exceeding FPPc is low is to use the 25th percentile of the FPPc distribution as the operational threshold for evaluating if total catches are within the ecosystem-level sustainability envelope, which provides guidance for the Total Catch Index (TCI). On average, the current 50th percentile of the FPPc distribution is 50% greater than the value of the 25th percentile (range: 39-68%).

### Total Catch Indices (TCIs) and Guidance for Total Catches

It is important to recognize that estimates of FPPc and TCIs are intended as strategic metrics capturing signals integrated over a period of time (e.g. 3-5 years), and that changes in ecosystem trends and productivity are not solely related to fishing. For TCIs to provide effective guidance for total catches for each functional guild, fishing above these levels should erode ecosystem functionality with consequent declines in biomass at the functional guild level. This expectation was evaluated by comparing standardized growth rates for the piscivore and benthivore guilds for 3 EPUs (Newfoundland Shelf (2J3K), Grand Bank (3LNO) and Flemish Cap (3M)) with the corresponding catch/TCI ratios. SC notes that results of the analysis indicate that catches above TCI levels are more often associated with negative biomass trends in functional guild biomass, particularly when catches are 2-5 times greater than the TCI guidance. Catch levels below the TCI guidance show a fairly even distribution of positive and negative biomass trends, indicative that factors other than fisheries are also affecting productivity of fishery guilds (Figure iv.4).

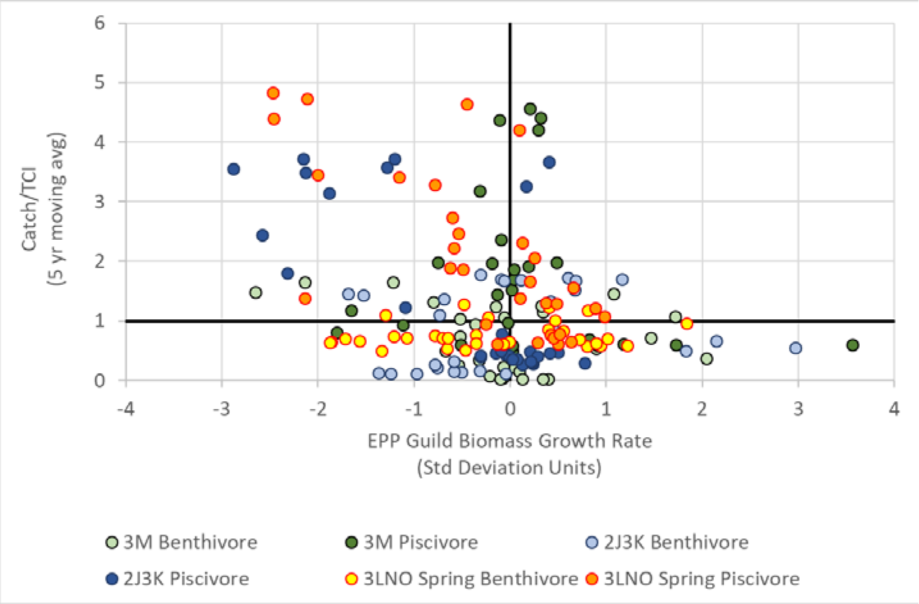


**Figure iv.4.** Relationship between functional guild biomass trends (growth rate) and catch levels expressed as a fraction of the corresponding Total Catch Index (TCI) for the piscivore and benthivore guilds in the Newfoundland Shelf (2J3K), Grand Bank (3LNO) and Flemish Cap (3M) EPUs from 1981 onwards. Catch/TCI levels below 1 indicate sustainable exploitation levels from the perspective of TCI.

SC notes that the overall results of all analyses are promising and indicate that TCIs perform reasonably well at mapping catch levels associated with negative trends in growth of functional guilds among ecosystem units. SC **recommends** that, *as an interim measure in the implementation of the Roadmap (Koen-Alonso et al. 2019), 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.* Furthermore, SC **recommends** that *priority be given for the development of dynamic multispecies models to a) complement the recommended simulation-based analyses and investigate the consequences of time-dependent dynamics on the operational reliability of the TCIs as guidance for ecosystem-level advice, and b) contribute toward implementation of the Tier-2 level of the Roadmap (Koen-Alonso et al. 2019, and NAFO references therein).*

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### *v) assessment of NAFO bottom fisheries in 2021 (COM request #6)*

In relation to the assessment of NAFO bottom fisheries in 2021, the Scientific Council should:

- Assess the overlap of NAFO fisheries with VME to evaluate fishery specific impacts in addition to the cumulative impacts;
- 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 (Article 18 of the FAO International Guidelines for the Management of Deep Sea Fisheries in the High Seas) including the three FAO functional SAI criteria which could not be evaluated in the current assessment (recovery potential, ecosystem function alteration, and impact relative to habitat use duration of VME indicator species).
- Continue to work on non-sponge and coral VMEs (for example bryozoan and sea squirts) to prepare for the next assessment.

**Scientific Council responded:**

SC made further progress in assessing the overlap of NAFO fisheries with VME through an analysis of haul-by-haul log-book data in combination with VMS data for 2018 and in establishing VMS data analysis procedures to generate standardized vessel trawl-track data products. Such analysis significantly improves the spatial definition of specific fishing areas within the NAFO footprint.

Furthermore, SC has made progress in developing models and methodological approaches which assess the functional significance of VMEs, including the definition and development of SAI assessment metrics that can be applied to assess all six FAO SAI assessment criteria.

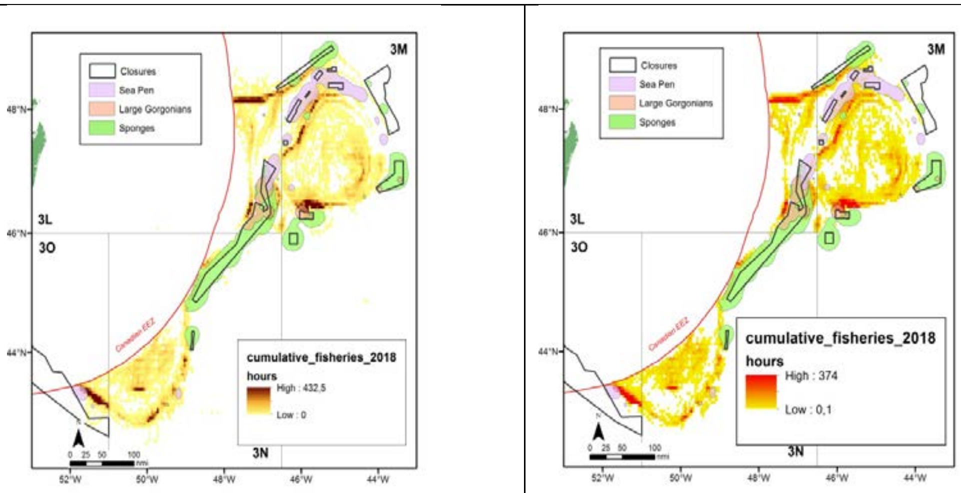
SC concludes that the weighting of assessment metrics that contribute to the SAI criteria will most likely be determined by expert judgement in the overall assessment of SAI.

Updated analysis (including new data) has been performed on non-coral and non-sponge VME indicator species which was presented in response to COM Request #7 (review of VME) in the present report.

SC noted and agreed that the spatial extent of the present VME and SAI assessment is restricted to the NRA. SC agrees that in preparation for the next review (after 2021) of VME fishery closures, VMEs and SAI, the precise spatial scope for the assessment must be defined and agreed.

### a) Overlap of NAFO fisheries with VME (analysis undertaken by EU NEREIDA research).

Following methods reported by SC in 2019 (SCS19-20) an updated analysis using 2018 VMS and haul-by-haul logbook data were integrated to provide a more accurate map of fishing effort (Figure v.1), which greatly reduces the number of spurious VMS pings included in the analysis. For the assessment of the overlap of specific fisheries with VME (as part of the SAI assessment in 2021) all available logbook and VMS data in the NRA from 2016. This is distinct from the SAI analysis which will use all available VMS data from 2010 – 2019 to assess VME impacted, at risk and protected. This information will be presented in addition to basic information related to each directed fishery defined by stock and gear type (as defined previously), e.g., the types of fishing conducted, range of vessel powers (kW), range of vessel lengths, depth range of fishing, gear type including typical dimensions, target and bycatch species and the spatial distribution of fishing effort. SC will further consider this requirement in September in order to finalize the specification of data and information to be included in the directed fishery summaries.



(A) Simple speed filter

(B) Logbook haul-time filter

**Figure v.1.** Cumulative fishing effort maps (hours fished per cell) from 2018 VMS and logbook data produced by two different methods. (A): VMS data was filtered for speeds within 1-5 knots, (B): VMS was filtered if it was within the reported fishing time interval in the logbook.

### b) 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

During the 1st assessment of bottom fisheries conducted by SC in 2016 (SCS 16/14 Rev) a table of SAI assessment metrics was developed and applied in accordance with the FAO guidelines for the assessment of SAI (FAO, 2009). One of the limitations of this approach, noted previously by SC, is that all metrics applied to each VME have equal weight, when it is likely that some of the metrics are likely to have greater significance for the assessment of SAI than others. In addition, the *rationale* for assigning the categories of 'high, moderate and low' to VME-specific metric values was not clear.

#### *Consideration of the ranking of SAI assessment metrics*

The SAI assessment is based on the consideration of the six criteria defined by the FAO VME Guidelines, namely: **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; and **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.

A full list of SAI assessment metrics was compiled, including metrics to assess the functional aspects of VME (FAO SAI criteria IV – VI) for which the 2016 assessment was more limited (SCS 16/14). SC then evaluated the full list of metrics against the FAO criteria, noting 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 4 criteria (Table v.1). SC concludes that the weighting of assessment metrics that contribute to the SAI criteria will most likely be determined by expert judgement in the overall assessment of SAI.

**Table v1.** Full list of SAI criteria (FAO, 2009) with respect to an expanded list of assessment metrics to be applied to the reassessment of bottom fisheries in 2021. Full definitions of metrics can be found in (WGESA 2019)

**SAI criteria FAO**

| Assessment Metrics | I | II | III | IV | V | VI |
|---|---|---|---|---|---|---|
| Area/Biomass at low risk | x | x |  | x |  |  |
| Area/Biomass impacted | x | x |  |  |  | x |
| Area/Biomass at high risk | x | x |  |  |  |  |
| Number of overlapping VMEs |  |  | x |  | x |  |
| Index of VME sensitivity |  |  | x | x |  |  |
| Index of fishing stability | x | x |  |  |  |  |
| Index of risk of VME fragmentation | x | x |  |  |  |  |
| Index of functional sensitivity |  |  | x | x | x |  |
| Functional Area at low risk | x | x |  | x |  |  |
| Functional Area impacted | x | x |  |  | x | x |
| Functional Area at high risk | x | x |  |  | x |  |
| VME connectivity | x | x | x | x |  |  |

***Consideration of the assignment of 'high, moderate and low' categories to VME specific metric values***

In the 1st assessment of SAI (SCS 16/14 Rev), three categories of assessment were applied to each metric value, namely, 'high, moderate and low'. The limits used to define the categories were selected to highlight the relative differences between the VME specific metrics. SC notes that this issue has been addressed in relation to the review of VMEs (see SC response to COM Request #7 in the present report) and the definition of categories used to assess the status of VMEs. Therefore, to ensure consistency between the review of VME and the assessment of SAI the same categories will be applied to the assessment of SAI in 2021.

### c) Maintain effort to assess all six of the FAO criteria

SC continues to develop and refine methodological approaches that can provide an estimate of the rates of VME recovery and resilience, such estimates will address FAO criteria **iv**. This criterion requires that a functional ecosystem scale be defined, and SC endorsed the use of the Ecosystem Production Units (EPU) as the basic spatial scale for defining the VME and the assessment of ecosystem-level impacts, while recognizing that smaller units may be ecologically justified for some assessment metrics, and that larger scales may be necessary for some analyses involving connectivity. SC noted and agreed that the spatial extent of the present VME and SAI assessment is restricted to the NRA. SC agrees that in preparation for the next review (after 2021) of VME fishery closures, VMEs and SAI that the precise spatial scope for the assessment must be defined and agreed.

The approaches being developed rely on: i. developing empirical models which utilise observed cumulative VME indicator biomass in response to observed levels of fishing effort, ii. developing a spatially explicit agent-based model to simulate the life history of sea pens, and iii. direct statistical testing of the impact of fishing on ecosystem functions such as biodiversity, bioturbation, benthic pelagic coupling, and habitat provision.

SC noted that the sensitivity analysis performed on the empirically driven resilience model suggests that estimates of fishing ***trawl-line density*** and the ***speed of trawling*** are particularly important in determining the impact and subsequent estimates of recovery time for sea pen VMEs. Therefore, SC has initiated new VMS data assessment procedures to ensure standardized VMS fishing effort (trawl track-based) data products can be generated.

SC notes the progress made to initiate the application of biological traits analysis to help determine the functional significance of VMEs in the NAFO regulatory area and to help address FAO criteria **v**. VME biological traits and associated habitat functions, rather than the VME species themselves, will be used to define and quantify the significance of potential bottom fishing impacts in conjunction with the same analysis performed on specific VMEs.

The following workplan has been proposed to finalize the development of the full list of assessment metrics in readiness for their application to assess bottom fishing SAI on VMEs in 2021:

1. Define KDE polygons and thresholds for functions (bioturbation, nutrient cycling, structure forming, functional diversity).
2. Up-date cumulative biomass *vs* fishing effort plots for ALL VMEs using new fishing effort and biomass data.
3. Create new cumulative functional (biomass) *vs* fishing effort plots for each function (bioturbation, nutrient cycling, structure forming, functional diversity) from trawl data.
4. Calculate SAI using VME and Functional polygon areas and biomass to quantify the 3 risk/impact categories (low risk, high risk, impacted).
5. Assess the spatial/temporal relationship between fish, invertebrates, VME indicator species and VMEs using multivariate approaches.
6. Up-date description of NRA fisheries – maps and tables.
7. Develop new VME fragmentation index.
8. Connectivity of VMEs Index.
9. VME buffer zones.
10. Up-date literature review of VME recovery rates.

### *vi) Re-assessment of VME closures (COM request #7)*

The Commission requests Scientific Council to conduct a re-assessment of VME closures by 2020, including area #14.

**Scientific Council responded:**

In following the 5-year cycle defined in the NCEM, an update of VME information, and a review of the VME closures in the NRA was undertaken. The VME update included the review of general information, incorporation of new data acquired since the last review in 2014, and the use of this information for delineating updated VME polygons. The assessment of the adequacy of the closures involved the same general criteria used in the first review, but improved on it by incorporating connectivity into the evaluation, and by developing a structured approach to the assessment criteria based on coverage and connectivity which is consistent with the approach being used for the next assessment of SAI in 2021.

Results indicate that Black Coral does form aggregations in the NRA. Accordingly, SC **recommends** the *inclusion of this taxa in the NCEM VME indicator species list.*

*The review of the adequacy on closures indicates that large gorgonian and sponge VMEs have generally incomplete to good protection by closures, and management action on these VMEs is* **recommended as desirable to beneficial**. *Conversely, black coral and sea pen VME have poor protection, and erect bryozoans, sea squirt and small gorgonian VMEs have inadequate protection by closures; management action for these VMEs is* **recommended as essential.** SC also reviewed the closures for VME elements (i.e. seamounts), and in line with the changes already implemented for the New England seamounts, SC **recommends** *updating the boundaries of the closures for the Corner Rise and Newfoundland seamounts to better capture the connectivity within these seamount chains.*

SC agrees that in preparation for the next review (after 2021) of VME fishery closures, VMEs and SAI, the precise spatial scope for the assessment must be defined and agreed

The current review of VME fishery closures and VME follows the same methodological approach as applied during the 1st review conducted by NAFO in 2014 (SCS14-17). The principal data source used for the present assessment was the scientific research vessel trawl catches (Table vi.1) in the NRA. The present data set includes an additional 2394 trawl catch samples since the last assessment was conducted.

**Table vi.1.** Data sources from contracting party research vessel surveys.

| Programme | Period | NAFO Division | Gear | Mesh size in codend liner (mm) | Trawl duration (min) | Average wingspread (m) |
|---|---|---|---|---|---|---|
| EU Spain 3NO Survey | 2002 - 2019 | 3NO | Campelen 1800 | 20 | 30 | 24.2 – 31.9 |
| EU Flemish Cap Survey | 2003 - 2019 | 3M | Lofoten | 35 | 30 | 13.89 |
| EU Spain 3L Survey (IEO) | 2003 - 2019 | 3L | Campelen 1800 | 20 | 30 | 24.2 – 31.9 |
| Canada 3LN) Multi-species Surveys | 1995 - 2019 | 3LNO | Campelen 1800 | 12.7 | 15 | 15 - 20 |

Definitions, used by SC in the present assessment, for VME (i.e. a habitat), VME indicator species (i.e. a taxa that defines the habitat) and VME elements (i.e. features that are known or likely to contain a VME), follow those as used in the 1st review (SCS14-17). The principal method used to quantitatively determine the location and spatial extent of VMEs is kernel density estimate analysis (KDE) which is our current best approach to determining the location and spatial extent of VMEs. This analysis identifies “hotspots” in the biomass distribution derived from research vessel trawl survey data, by looking at natural breaks in the spatial distribution associated with changes in local density. These natural breaks allow defining of significant area polygons (Scientific Council Report 19/058). Following previously established practice (SCS14-17) species distribution models were used to modify the boundaries of the KDE polygons where they extended into unsuitable habitat (low probability of occurrence).

KDE analysis was applied to the following VME indicator species, including Black Coral:

1. Large sized sponges
2. Sea pens
3. Large gorgonian coral
4. Small gorgonian coral
5. Sea squirts
6. Erect bryozoans
7. Black coral

SC notes although Black Coral was assessed as meeting the vulnerable characteristics which define a VME indicator species in 2008 (SCS 08/10), it was not included in the initial formal list of VME indicator species in the NCEM (2013). This was because at that time the limited available data indicated that Black Coral did not form clear spatial aggregations and therefore significant concentrations of Black Coral could not be defined. However, since 2014 the addition of more than 2000 trawl survey samples into the present analysis reveals that Black Coral does indeed form spatial aggregations in the NRA and, therefore, significant concentrations of Black Coral can now be defined and VME identified. SC **recommends** that *Black Coral be added to the NCEM list of VME indicator species.*

SC conducted the review in two parts, namely; i. an assessment of the adequacy of protection for each VME type (including Black Corals), and ii. a review of the adequacy of the current closures (including sea pen Area 14).

In 2014, the adequacy of closures themselves was mainly evaluated based on coverage, while a broader set of criteria was used to help define priorities for management actions, e.g.:

1. the proportion of the VME area/biomass that is protected.
2. areas with no current protection.
3. multiple VME presence, e.g. overlapping VMEs.
4. proximity to an existing closed area as this may imply continuity of the habitats.
5. proximity to high fishing activity which could endanger the VME (increased risk of impact).

Many of these criteria were later included in the assessment of SAI (SCS 16/14).

Based on the experience gained during the first cycle of review of closures and assessment of SAI, and to address earlier concerns about the need for a more systematic approach to evaluate closures, SC developed a structured set of criteria to assess the adequacy of closures, and the associated need for management action. These criteria were based on expert judgement and were developed prior to the evaluation of closures to prevent any possible bias. The developed framework included, in addition to coverage, information on VME connectivity, and was constructed to ensure consistency with the approach being implemented to assess SAI (Table vi.2).

**Table vi.2.** Definition of categories used to assess the protection status of VMEs. Status definitions (Assessment) 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.

| Assessment | Proportion of VME Protected | Projected Connectivity Among Closures | Recommended Management Action |
|---|---|---|---|
| Good | > 60% VME | Good connectivity among closures | Beneficial |
| Adequate | > 60% VME | Limited connectivity or redundancy | |
| Incomplete | 60% - 30% VME | Good connectivity among closures | Desirable |
| Limited | 60% - 30% VME | Limited connectivity or redundancy | |
| Poor | 30% - 15% VME | Limited connectivity or redundancy | Essential |
| Inadequate | < 15% VME | Limited connectivity or redundancy | |

### Assessment of adequacy of VME protection across all closures

In general, there was good spatial congruence between the 2013 and 2019 analyses as can be observed by comparing the spatial extent of VME polygons for the two assessment periods (Figure vi.1). Most VMEs have increased in area (Table vi.3) with the exception of erect bryozoans where a change in the KDE search radius enabled by the new data reduced the VME area, but this is considered to be as a result of significant additional data, and that it is likely that no actual increase or decrease in the area or biomass of VME has been realized between the two assessment periods. The increase in area for the small gorgonian corals is supported by new data from the 3O surveys and associated with an increase in KDE search radius.

SC also notes that Black Coral VME tends to overlap with sea pen VME, especially in areas off the Flemish Cap.

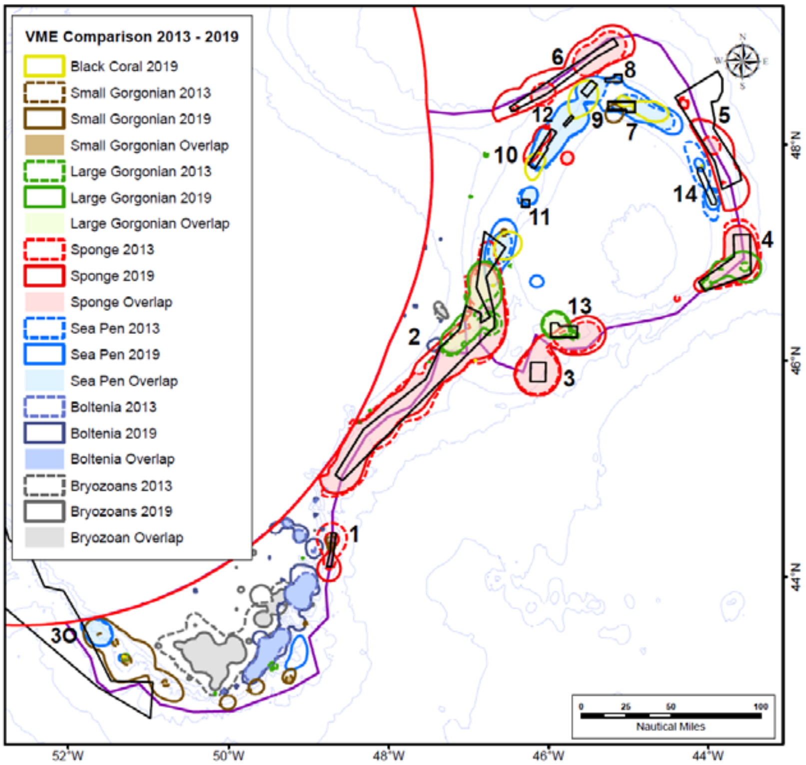


**Figure vi.1**. Overview map of the location of VME taxa (large-sized sponges, sea pens, small gorgonian corals, large gorgonian corals, erect bryozoans, sea squirts (*Boltenia ovifera*), and black corals) in the NRA, colour coded by taxon. For all taxa the polygons determined from the 2013 analysis are shown in dashed line and compared with those from the 2019 analyses in solid lines. Areas of overlap are shaded. The closed areas are indicated in black outline and their numbers shown near the closure. Solid purple line is the fishing footprint.

**Table vi.3.** Significant concentration threshold (kg) from research vessel catches and total area (km²) of VME polygons derived from kernel density estimation and species distribution modelling techniques in 2019 and 2013. Also shown is the percent change in polygon area between 2019 and 2013 and the proportion of VME area and biomass protected inside the closed areas in 2019 and also area and biomass protected inside closed areas and any part of the VME located outside of the fishing footprint (Area 14 is included in this calculation; removing it would result in only a small decrease in area/biomass of sea pen and black coral protection). This distinction reflects the difference in protection granted by closures (full protection) from locations outside the fishing footprint, which could eventually become open to fishing under an exploratory fishing protocol.

| Common Name | Research Vessel Catch Threshold (kg) | | Area of VME in (km²) | | Change in Area between 2019 & 2013 (%) | Proportion of VME Area Protected by Closed Areas in 2019 (%) | Proportion of VME Biomass Protected by Closed Areas in 2019 (%) | Proportion of VME Area Protected by Closed Areas and/or outside the Fishing Footprint in 2019 (%) | Proportion of VME Biomass Protected by Closed Areas and/or outside the Fishing Footprint in 2019 (%) |
|---|---|---|---|---|---|---|---|---|---|
| | **2019** | **2013** | **2019** | **2013** | | | | | |
| Large-sized sponges | 100 | 75 | 24,218 | 19,824 | 22 | 39 | 57 | 64 | 70 |
| Sea pens | 1.3 | 1.4 | 8,498 | 6,983 | 22 | 17 | 18 | 17 | 18 |
| Large gorgonian corals | 0.6 | 0.6 | 5,007 | 3,506 | 43 | 55 | 57 | 61 | 58 |
| Small gorgonian corals | 0.2 | 0.15* | 4,540 | 307 | 1,377 | 4 | 1 | 4 | 1 |
| Sea squirts | 0.35 | 0.3 | 4,077 | 2,193 | 86 | 0 | 0 | 0 | 0 |
| Erect bryozoans | 0.2 | 0.2 | 3,491 | 6,587 | -47 | 0.14 | 0.01 | 0.14 | 0.01 |
| Black corals** | 0.4 | - | 2,631 | - | - | 17 | 16 | 17 | 17 |

Applying the assessment criteria (Table vi.2) to these results, in conjunction with the assessment criteria described previously, an overall assessment for each VME type was performed (Table vi.4).

**Table vi.4.** Re-assessment of NAFO VME types. Overall assessment and recommendations for management action (see Table vi.3) for each VME type considering their overall protection, ranked by assessment and need for management action based on the biomass protected inside closed areas and any part of the VME located outside of the fishing footprint.

| VME Type | Overall Assessment (biomass) | Recommended Management Action |
|---|---|---|
| Small Gorgonian Corals | Inadequate | Essential |
| Sea Squirts (Boltenia ovifera) | Inadequate | Essential |
| Erect Bryozoans | Inadequate | Essential |
| Black Coral | Poor | Essential |
| Sea Pens | Poor | Essential |
| Large Gorgonian Corals | Incomplete | Desirable |
| Large-Sized Sponges | Good | Beneficial |

SC noted that the spatial extent of the present VME assessment is restricted to the NRA, which in the case of VME present on the tail of the Grand Bank (e.g. sea squirts and erect bryozoans) may be insufficient to perform a complete assessment of their spatial extent and adequacy of the VME closures. SC agrees that in preparation for the next review (after 2021) of VME fishery closures, VMEs and SAI that the precise spatial scope for the assessment must be defined and agreed.

### Assessment of adequacy of VME closures by region

For each of the existing closed areas in the NRA an assessment of the effectiveness of the closure, with justification, has been undertaken by SC (SCS Doc. 19/25).

*Division 3O Coral Closure and Area 1 Tail of the Bank*

SC notes that the 3O closure was the first coral closure in NAFO and delineated through an *ad hoc* process that involved assessing available records, expert knowledge, and management considerations (SCS 13/24). This closure extends into depths not commonly covered by research surveys. Records of VME indicator taxa within this closure typically encompass the shallower areas inside Canadian waters, but there are no similar records in the NRA portion of the closure, which only contains VME elements (i.e. canyons) likely to contain VMEs (Figure vi.2, SCS 14/17). However, sea pen and small gorgonian VME overlap in this region and are found immediately adjacent to the existing 3O closure shallow boundary along with cerianthid anemone records, and smaller large gorgonian coral and black coral VME (Figure vi.2). The absence of protection for erect bryozoans, sea squirts, sea pens and small gorgonian corals in this region is notable. It appears that there are areas with limited fishing activity in close proximity to parts of the VMEs (Figure vi.3 and Figure vi.4).

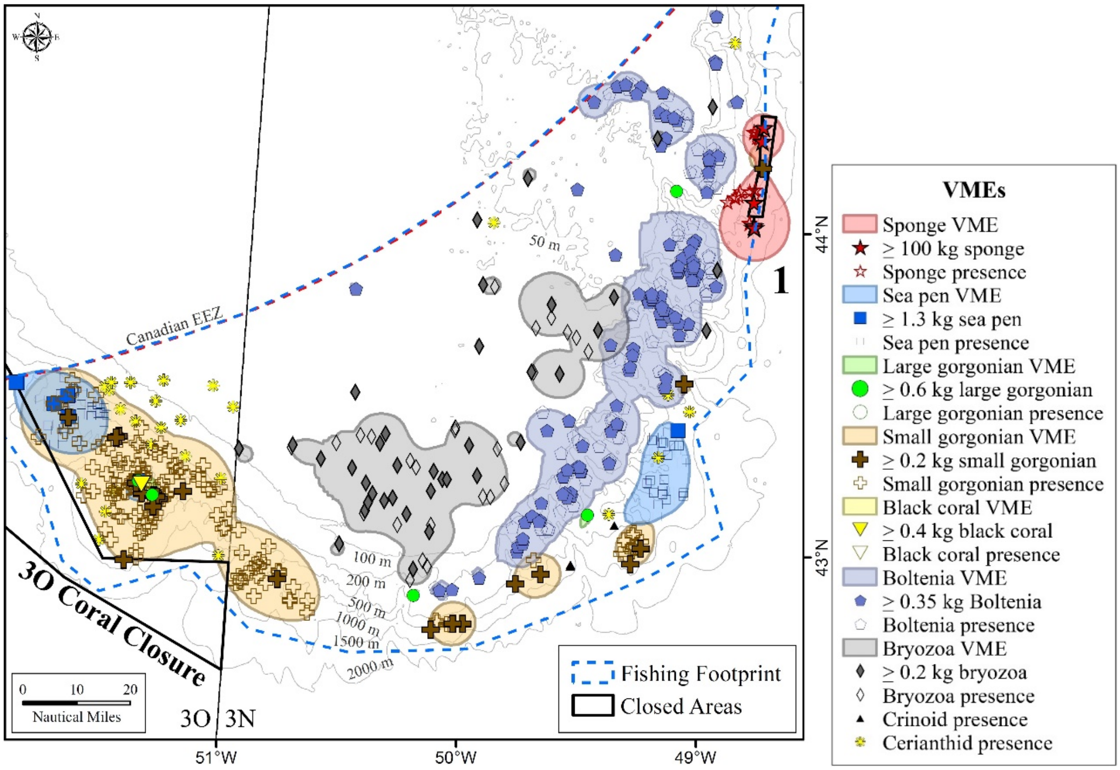


**Figure vi.2.** Area of 3O Coral Closure and Area 1. VMEs and VME indicator species.

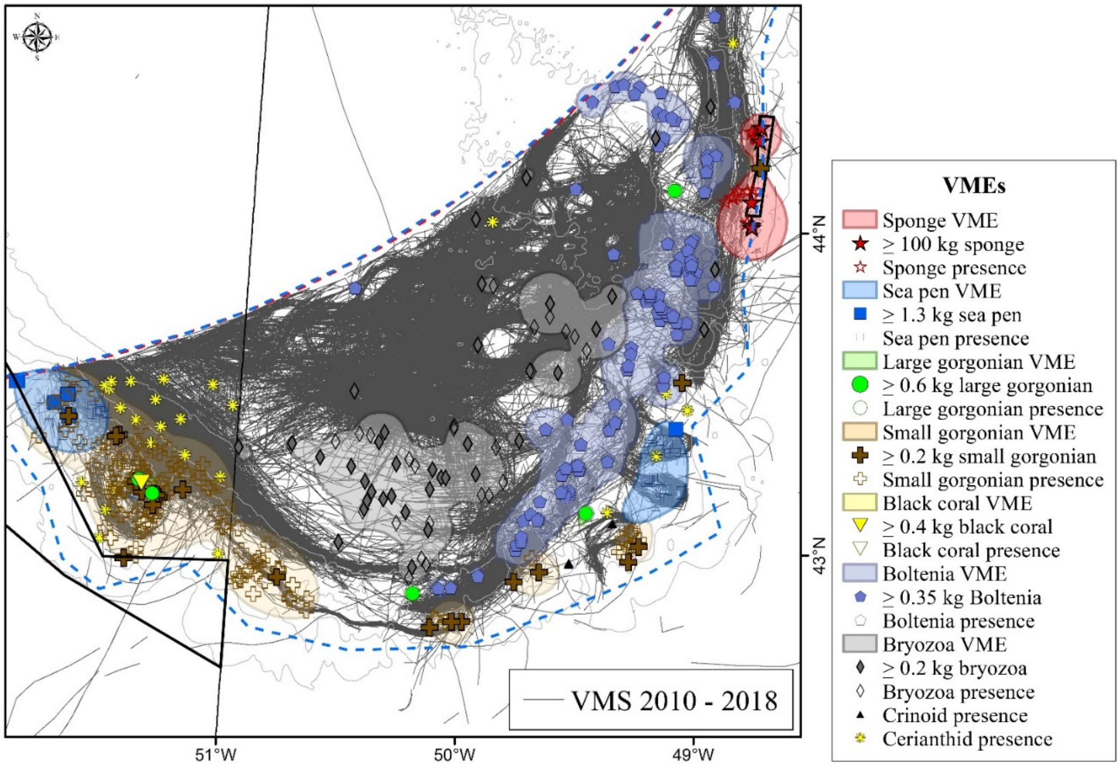


**Figure vi.3.** Area of 3O Coral Closure and Area 1. VMEs and VME indicator species with VMS fishing data (2010-2018)

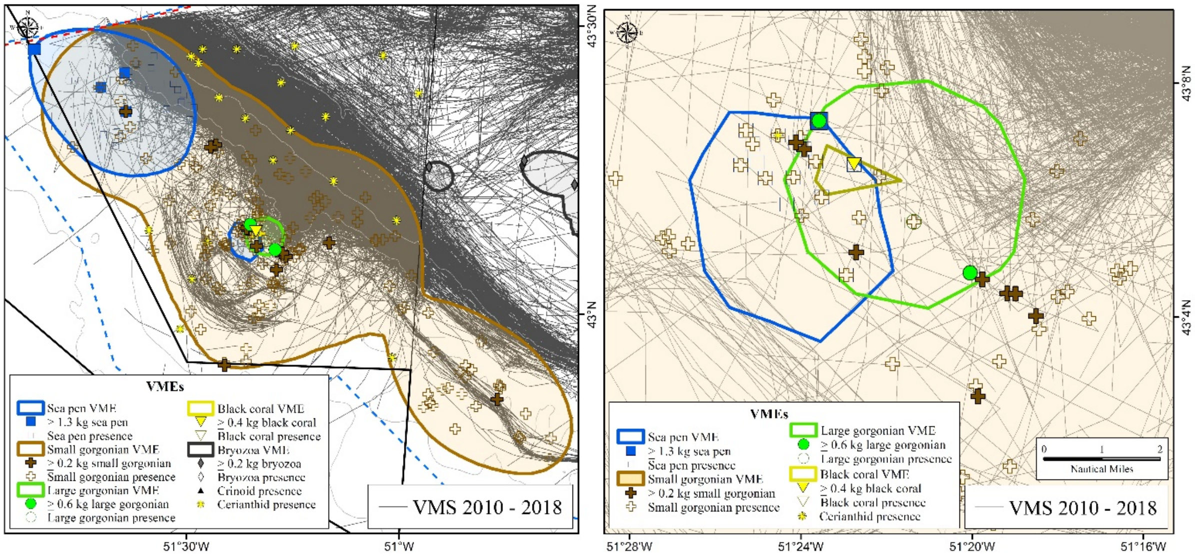


**Figure vi.4.** Area of 3O Coral Closure. Close up of VME and VME indicator species with VMS fishing data (2010-2018). The area of overlap between VMEs for sea pens, large gorgonian corals and black corals in the small gorgonian coral VME is shown in the right panel.

### *Areas 4-12 Flemish Cap and Sackville Spur Including Area 14*

SC notes that Areas 7, 9, 10, 12, 14 all have two or three types of VME overlapping within their boundaries or surrounds and are comparatively small in area (when compared to sponge and large gorgonian VME closures, Areas 4, 5 and 6) (Figure vi.5a). The connectivity between Areas 7, 9, 10, 12, 14 is limited and Area 7 and Area 14 are locations where the glass sponge *Asconema foliata* is also predicted to occur with high probability (Figure vi.5c) as is predicted high species density (Figure vi.5d). Significant areas of sea pen and black coral VME remain unprotected and in areas of very low fishing activity (based upon VMS data analysed between 2010 – 2018) (Figure vi.5b).

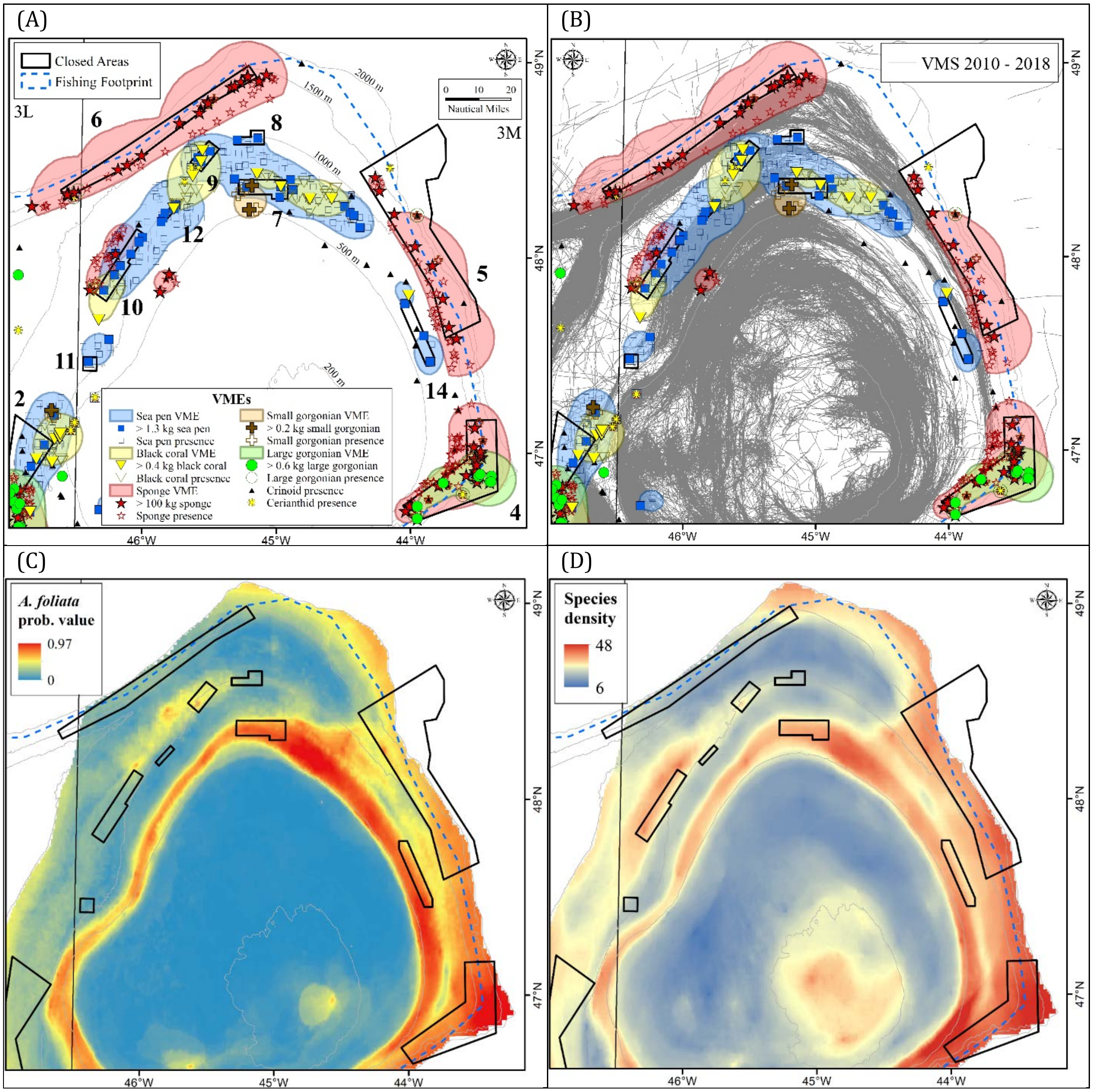


**Figure vi.5**. Areas 4-12 Flemish Cap and Sackville Spur Including Area 14. (A) distribution of VMEs and VME indicator species. (B) distribution of VMEs and VME indicator species in relation to VMS fishing data (2010-2018). (D) Asconema foliata glass sponge probability of occurrence. (D) predicted species density (number of benthic invertebrate taxa per RV trawl set).

### *Seamounts*

In accordance with changes made to the New England seamount closure in 2017 (Figure vi.6), SC has revised the boundaries of the Corner Rise and Newfoundland seamount closures to maintain connectivity across the seamount chains and to complete the protection of all vulnerable seamounts in the NRA. The 2019 General Bathymetric Chart of the Oceans (GEBCO) was used to draw the bathymetric contour lines to inform which seamounts previously identified (Kim and Wessel, 2011) were shallower than 2000 m depth (Figures vi.7 and vi.8). For the Orphan Knoll seamount closure new research with ROVs has reconfirmed the presence of VMEs (EU Horizon 2020 project SponGES). SC concludes that the available information supported the continued designation of all existing seamount areas as VMEs.

The proposed boundary changes for the seamount closures represent a net increase of 10706 km$^2$ for the Corner Rise seamount closure, and a net decrease of 1826 km$^2$ for the Newfoundland seamount closure. These areas were calculated using a NAD 83 Zone 22 projection.

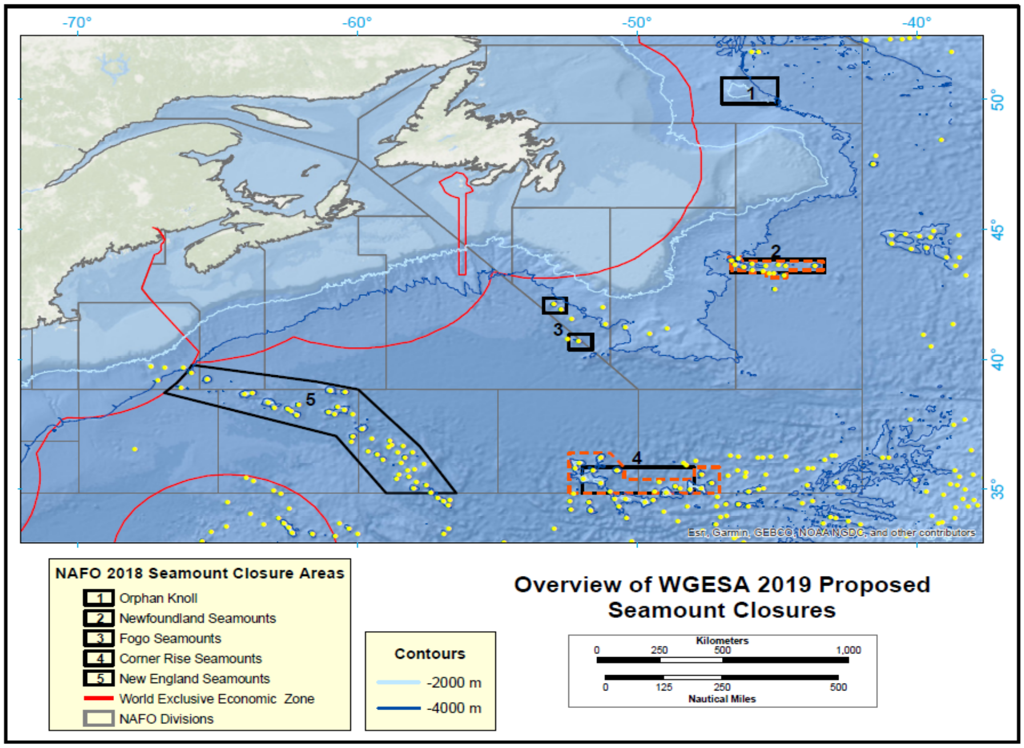
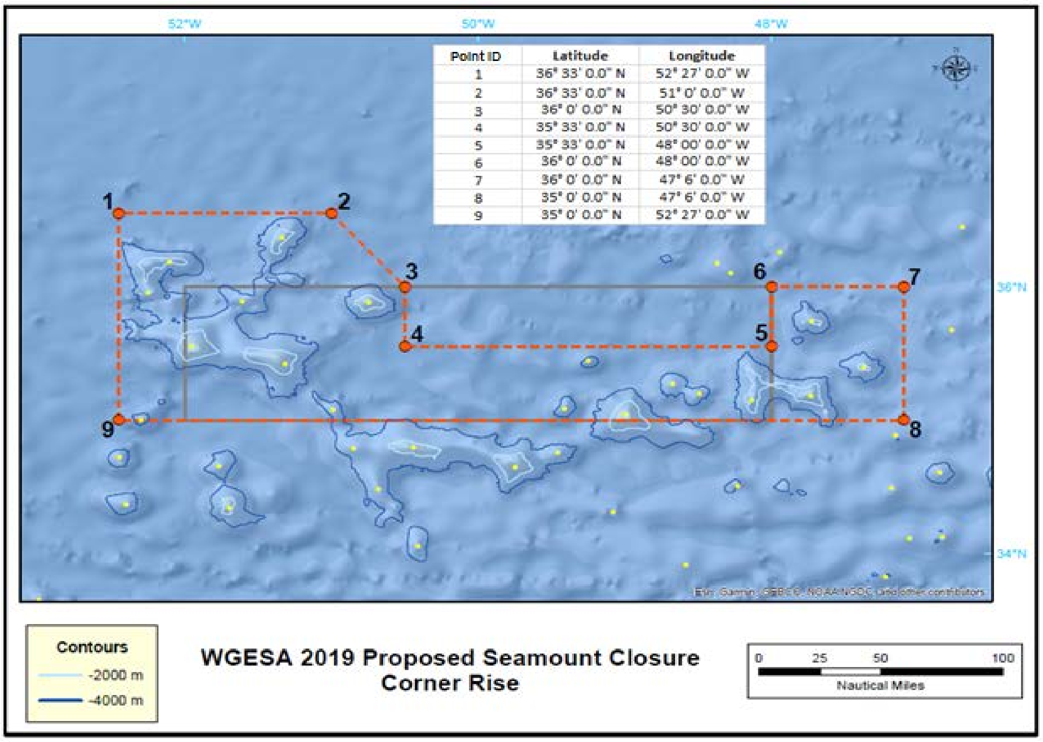
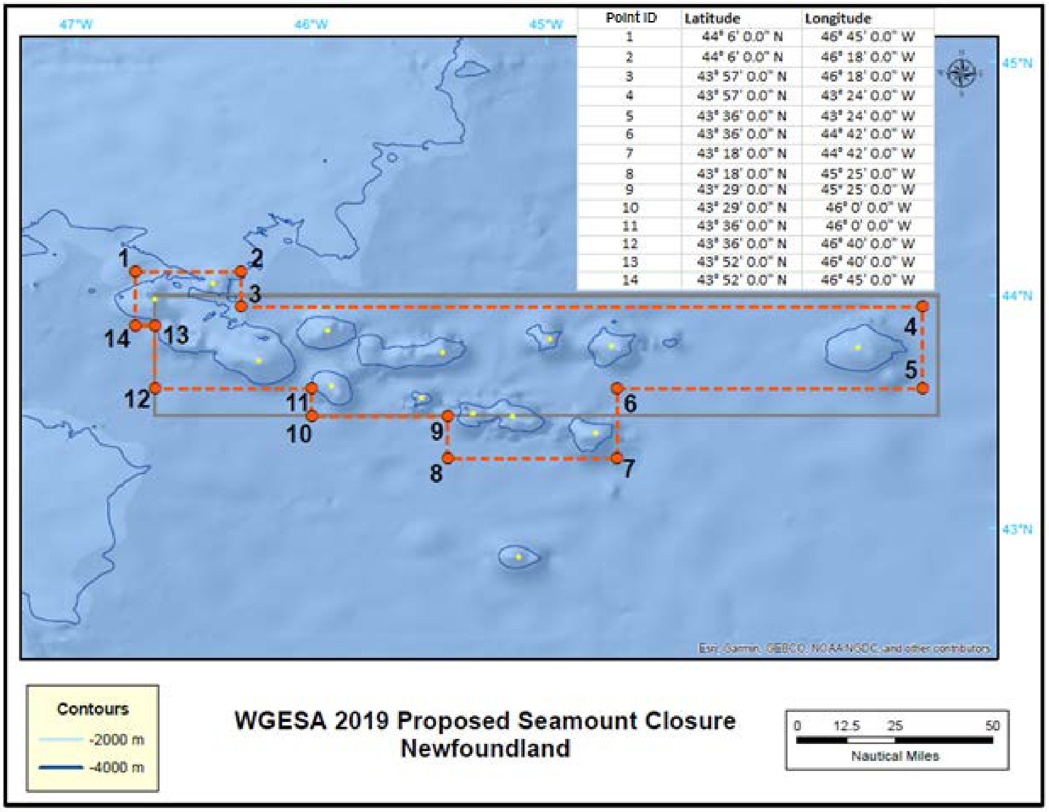


**Figure vi.6.** Location of the 5 seamount areas in NAFO with closures indicated in black outline. SC recommended changes to Areas 2 (Newfoundland Seamounts) and 4 (Corner Rise Seamounts). Yellow dots represent all the seamounts (source Kim and Wessel, 2011).



| Point ID | Latitude | Longitude |
|---|---|---|
| 1 | 36° 33' 0.0" N | 52° 27' 0.0" W |
| 2 | 36° 33' 0.0" N | 51° 0' 0.0" W |
| 3 | 36° 0' 0.0" N | 50° 30' 0.0" W |
| 4 | 35° 33' 0.0" N | 50° 30' 0.0" W |
| 5 | 35° 33' 0.0" N | 48° 00' 0.0" W |
| 6 | 36° 0' 0.0" N | 48° 00' 0.0" W |
| 7 | 36° 0' 0.0" N | 47° 6' 0.0" W |
| 8 | 35° 0' 0.0" N | 47° 6' 0.0" W |
| 9 | 35° 0' 0.0" N | 52° 27' 0.0" W |

**Figure vi.7.** Close up of the current closed area to protect VMEs on the Corner Rise Seamounts (grey outline), with proposed boundary changes to capture the unprotected seamounts nearby (red dashed line). Yellow dots indicate seamounts (source Kim and Wessel, 2011), light blue line represents the 2000 m depth contour, the dark blue line represents the 4000 m depth contour. Associated co-ordinates for the new boundary are listed. Note that the seamounts to the south of the bounding box are in the WECAFC area where they are listed as VMEs.



| Point ID | Latitude | Longitude |
|---|---|---|
| 1 | 44° 6' 0.0" N | 46° 45' 0.0" W |
| 2 | 44° 6' 0.0" N | 46° 18' 0.0" W |
| 3 | 43° 57' 0.0" N | 46° 18' 0.0" W |
| 4 | 43° 57' 0.0" N | 43° 24' 0.0" W |
| 5 | 43° 36' 0.0" N | 43° 24' 0.0" W |
| 6 | 43° 36' 0.0" N | 44° 42' 0.0" W |
| 7 | 43° 18' 0.0" N | 44° 42' 0.0" W |
| 8 | 43° 18' 0.0" N | 45° 25' 0.0" W |
| 9 | 43° 29' 0.0" N | 45° 25' 0.0" W |
| 10 | 43° 29' 0.0" N | 46° 0' 0.0" W |
| 11 | 43° 36' 0.0" N | 46° 0' 0.0" W |
| 12 | 43° 36' 0.0" N | 46° 40' 0.0" W |
| 13 | 43° 52' 0.0" N | 46° 40' 0.0" W |
| 14 | 43° 52' 0.0" N | 46° 45' 0.0" W |

**Figure vi.8.** Close up of the current closed area to protect VMEs on the Newfoundland Seamounts (grey outline), with proposed boundary changes to capture the unprotected seamounts nearby (red dashed line). Yellow dots indicate seamounts (source Kim and Wessel, 2011), blue line represents the 4000 m depth contour. Associated co-ordinates for the new boundary are listed.

*Overall assessment by region and need of management action*

The assessment has been conducted on a regional basis and the results are ranked and summarized in Table vi.5, with emphasis on the VMEs of concern.

**Table vi.5.** Re-assessment of NAFO closed areas. Overview of recommendations and need for management action for VMEs of concern (see Table vi.3) for regionally-specific assessments of the effectiveness of the closed areas, all ranked by need for management action.

| Existing VME Closure | Overall Assessment (biomass) | Recommended Management Action | Comments (VME of concern) |
|---|---|---|---|
| Division 3O Coral Closure and Area 1 Tail of the Bank | Inadequate | Essential | Small Gorgonian<br>Bryozoans<br>Sea squirts |
| Areas 4-12* Flemish Cap and Sackville Spur Including Area 14 | Poor | Essential | Black Coral and Sea Pen |
| Area 2 Flemish Pass, Areas 3, 13* Beothuk Knoll | Incomplete | Desirable | Large Gorgonians |
| Seamounts | Incomplete | Desirable | - |

* Areas 1, 3-6,13 are focused on Sponges and are of less concern (Table vi.3). Large Gorgonians in Area 4 are within the closed area.

The highest priority regions for management action, where fishery closures to protect VME are assessed to be 'inadequate' or 'poor', are, i. Division 3O Coral Closure and Area 1 Tail of the Bank, and ii. Areas 4-12 Flemish Cap and Sackville Spur Including Area 14.

### *vii) continue progress on the NAFO PA Framework review (COM request #8)*

*The Commission requests the Scientific Council to continue progression on the review of the NAFO PA Framework.*

**Scientific Council responded:**

SC compared the PA frameworks from a number of jurisdictions in the North Atlantic (PA Revision, ToR 3), and laid out a plan to address the other two Terms of Reference. In the development of the various framework components, consideration will be given to solutions for the full range of data availability with the goal that most of the PA framework elements could be adopted for all stocks. While this revision of the NAFO PAF is intended to retain its single-species focus, whenever appropriate, the proposed solutions will be informed by the ecosystem principles contained in the NAFO Roadmap for an Ecosystem Approach. SC emphasized that continued progression on the review is dependent on commitments from Contracting Parties to provide the necessary resources.

In response to the Commission request to continue progression of the review of the NAFO PA Framework, which the Commission has identified as high priority, the SC, after meeting by WebEx, agreed to resume the work of the SC Precautionary Approach Working Group (WG-PAF). The WG-PAF was created by recommendation of the WG-RBMS in 2015.

**Scope of the review of the NAFO Precautionary Approach Framework (PAF) adopted by the Fisheries Commission (FC-Doc. 15-19) and discussed by the SC Precautionary Approach Working Group as its Terms of Reference (SCS Doc. 16/15).**

1. To clarify the following elements:
    a. To confirm/review the NAFO PA reference points definition in page 3 NAFO/FC Doc. 04/18.
    b. To confirm/review the NAFO management strategies and courses of action, including risk levels, on page 3 NAFO FC/Doc. 04/18
    c. Distinction between MSY and limit/target related reference points.
    d. Analysis in support of the development of other reference points (e.g. targets, buffers).
    e. To review the methods for the calculation and interpretation of risk and the quantification and qualification of uncertainties related to them.
    f. For stocks where risk analyses are not possible, provide options on how to establish buffer reference points on a stock by stock basis.
    g. Determine the conditions for when/if reference points should change and/or be re-evaluated.
2. Consider how a revised PA can fit within an ecosystem approach.
3. In reviewing the NAFO PAF the WG will also take into consideration other precautionary approach frameworks with a focus in the north Atlantic.

SC reviewed the progress of the WG-PA to date. This review included consideration of PA frameworks in other jurisdictions of the Atlantic to inform the considerations required under ToR 3. This work provided summary comparisons among PA Frameworks from the North Atlantic (eg. ICES, Canada, USA, with NAFO), and compiled information, ideas, and illustrative proposals on how SC could approach the update of the NAFO PAF. This was the first step in revising NAFO's PAF. Based on the ensuing discussion, SC laid out a plan to address the other two Terms of Reference.

ToR 1 is focused on operational and implementation aspects and does not inform context and/or objectives. The context and objectives provided by the NAFO Convention, and the documents referred within it, remain valid. Six NAFO principles support the objective of ensuring long term sustainable use of fishery resources. These principles include promoting the optimum utilization and long-term sustainability of fishery resources, adopting measures to ensure that fishery resources are maintained at or restored to levels capable of producing maximum sustainable yield and adopting measures to minimize harmful impact on living resources and marine ecosystems.

ToR 2 asks for consideration of how a revised PAF can fit within an Ecosystem Approach, which is consistent with the new convention which calls for an Ecosystem Approach to Fisheries Management (EAFM). The NAFO Roadmap provides the template that NAFO is following to implement an ecosystem approach. Therefore, SC WG-PA will consider these principles when addressing ToR 1, trying to develop meaningful connection points between ToR 1 and ToR 2 whenever possible.

While PA frameworks are generally constructed around the "best assessment" concept, meaning that advice is based on the model that is understood to best represent the stock dynamics, NAFO and other jurisdictions are increasingly using Management Strategy Evaluation (MSE) to design and test management procedures which are more robust to model/structural uncertainty in order to achieve PA objectives. NAFO SC expects to continue carrying out MSEs to address the objectives of any revised PA framework, based on needs, and where time and resources permit.

Items in ToR 1 can be defined under three general headings, dealing with:

- Mapping objectives. This involves items a), c), and g), where conceptual questions are presented that address how the framework would represent basic convention objectives. Item a) reviews definitions, item c) explores the role of MSY-based reference points as limits and /or targets, and item g) asks about the conditions under which the reference points may need changing (keeping them constant may hinder the ability of the framework to achieve its objectives).

- Structural aspects of the framework. This involves items b) and d), which ask about the structure of the framework; which reference points are to be considered, how they are going to be used, and how risk is considered in the design of the framework.
- Quantification of uncertainty and risk. This involves items e) and f), which directly address the analytical methods in which risk is estimated and applied, including tiered approaches taking into account data quality/availability. This last point is also related to the structural aspects described under the previous heading. Where probabilities are estimated to inform on risk, these should be based on the statistical estimation of imprecision for the best assessment, or through the development of management procedures within MSE exercises.

The review of the PA framework will be approached in a structured and sequential way by addressing conceptual issues first, and second addressing the more operational aspects. The overarching EAFM umbrella will be given consideration at every step, by examining how the proposed solutions align with the principles laid out in the NAFO Roadmap. This will allow for the development of an updated PA framework in which there would be connection points to the ideas embedded in the Roadmap. Without being prescriptive, that could constitute the basic link between ToR 1 and 2 and foster a parallel treatment of both ToRs.

In the development of the various framework components, consideration will be given to solutions for the full range of data availability with the goal that most of the PA framework elements could be adopted for all stocks.

More specifically:

a) Discuss MSY reference points first, both in relation to being a limit or target, and taking into account the conditions when MSY reference points should change and/or be re-evaluated. To the extent possible, this exercise will include early exploration of how the ecosystem analyses related with setting $F_{msy}$ across fisheries, that single species $F_{msy}$ depend on species interactions, and changes in productivity.
b) Define whether or not fishing mortality and biomass reference points need to be functionally related. This is a key element in terms of consistency within the framework; if the answer is yes, the logic is self-evident, but if not, there needs to be a solid rationale (e.g. why the $F$ that renders $B_{lim}$ is not $F_{lim}$).
c) Implement a *weight of evidence* approach to tabulate the arguments for and against alternative options. The evidence and rationale to support the various options should be articulated to inform and document the discussion and decisions.
d) The structural elements can be addressed based on the results of the conceptual discussion. Once a conclusion has been reached on whether $F_{msy}/B_{msy}$ are targets or limits, the other reference points and structural/operational elements can be developed accordingly. At this stage, practical considerations could be the focus, for example, what elements of the existing framework have worked (or not), or which ones may be redundant given current techniques (e.g. do we need buffers if advice is based on estimated risk/uncertainty?).
e) Consider quantity/quality of data availability as part of the revision of the PA framework, and the possibility of defining assessment tiers based on data availability.

The revised PA will attempt to integrate the ecosystem approach elements where possible now, and be designed in such a way that ecosystem approach elements can be added more fulsomely at a later stage, when the ecosystem approach is further developed and NAFO has some experience integrating it into decision making. It was also recognized that a number of the overarching concepts apply equally to both ToRs, which will foster some initial integration of ecosystem approach aspects in this revised framework. It is anticipated that ToRs 1 and 2 will not be fully integrated simultaneously in the current PA revision, but will be more so with each new iteration of the NAFO PA framework.

Under this approach, the questions posed can be sequentially explored, where the early answers provide constraints for the subsequent questions as follows:

Mapping objectives

a) Should MSY-based reference points conceptually be considered targets or limits?
b) Do fishing mortality and biomass reference points need to be logically connected within the framework? For example, does $F_{lim}$ need to be directly linked to $B_{lim}$? (According to the cross jurisdictional analysis $F_{lim}$ can be related to $F_{msy}$ and to the biomass objective, as opposed to the biomass limit).
c) Should $B_{lim}$ be defined as is currently done (0.3*$B_{msy}$ or based on an impaired recruitment argument)? While this approach is common to most PAs, is it consistent with results from prior questions?
d) Is there a need for a target biomass to be defined or is $F_{target}$ sufficient?

Structural aspects

a) Determine the actions to be taken based on reference $B_{target}$ as well as on $B_{lim}$, as it is done now in the NAFO PA.
b) Consider defining a biomass level below $B_{target}$ and above $B_{lim}$ to define an overfished state. This type of biomass reference exists in other PA frameworks.
c) Consideration of appropriate reference points for fishing mortality.

Quantification of uncertainty and risk

a) Consider the estimation issues associated with the use of low probabilities that rely on tails of probability distribution of biomass and mortalities. It may be more appropriate to work with means/medians of distributions (i.e. the risk tolerance could be established in development of the biomass reference points and how far they are from each other).
b) The PA should consider all 3 tiered levels of stocks (eg. 1. Analytical assessment; 2. Survey-based assessment; 3. Catch information only) defined according to the availability of the data.

SC would ask that the Commission understand that dedicated resources must come from Contracting Parties, in terms of money, people and time, and that this plan likely requires the engagement of external expertise as well as dedicated SC members with experience in NAFO PA application.

Implementation of the revised PA framework is both a science and management responsibility. SC is taking the first step at a proposed work plan and scoping the issues that need resolving, but the development of the revised PA framework will require iterative steps between SC, WG-RBMS, and the Commission.

**Initial work plan**

A small group of scientists would be responsible for carrying out this work during a 2-year period going from November 2020 to October 2022. They would have to dedicate substantial work time over this period of time and would report to SC. This group would include some current SC members, possibly other scientists from Contracting Parties, and likely an external contractor(s), given SC workload concerns.

Proposed work plan:

- Review of and proposal for ToRs related to mapping objectives. Deadline for results to SC: June 2021
- Review of and proposal for ToRs related to structural aspects and quantification of uncertainty and risk. Deadline for results to SC: November 2021
- Both 1 and 2 would need to cover the data continuum, so that the framework could be applied to all NAFO stocks (data rich and data poor).
- Workshop of SC (including the group of scientists), around March 2022, to address the entire ToR and make a proposal of revision of the NAFO PA framework (to be later reviewed by the WG-RBMS).
- WG-RBMS 2022, based on the SC review work, would propose a new framework for the NAFO PA, to be considered by the NAFO Commission in September 2022.
- Consider broad associated implications for stocks managed using a Management Procedure (HCR) based on a MSE.

After approval of the framework by the NAFO Commission, a second SC workshop would be held to develop the guidelines (including the group of scientists) to support the implementation of the new NAFO PA framework, (between September 2022 and April 2023). The workshop would include case studies for reference points for, at least, several data-rich and data-poor stocks.

### *viii) Identify areas and times where bycatch and discards of Greenland sharks have a higher rate of occurrence (COM request #9)*

Due to time constraints, SC was not able to address this request during the June meeting and it is deferred until September 2020.

### *ix) Develop a 3-5 year work plan (COM request #10)*

Due to time constraints, SC was not able to address this request during the June meeting and it is deferred until September 2020.

### *x) Update assessment and projections for 3LN redfish (COM request #11)*

The Commission requests that Scientific Council do an update assessment for 3LN redfish and five year projections (2021 to 2025) to evaluate the impact of annual removals at 18 100 tonnes against the performance statistics from NCEM Annex I.H: If this level of catch does not result in fulfilling these performance statistics, SC should advise the level of catch that would.

**Scientific Council responded:**

SC conducted an update assessment of Redfish in Division 3LN followed by five-year projections (2021 to 2025) to evaluate the impact of annual removals at 18 100 tonnes on stock biomass and fishing mortality in relation to $B_{lim}$, $B_{msy}$ and $F_{msy}$ by 2026. At the beginning of 2020 the stock was in the safe zone, with a probability of biomass being above $B_{msy}$ > 90%, and with the probabilities of biomass being below $B_{lim}$ and fishing mortality being above $F_{msy}$ less than 1%.

Annual catch of 18 100 tonnes during 2021 - 2025 will maintain biomass above $B_{msy}$ at the beginning of 2026 with very high probability (> 90%). Also the probability of $B_{2026} < B_{lim}$ or $F_{2025} > F_{msy}$ is <1% if the 2020 HCR TAC is maintained during 2021-2025.

However, the probability of $B_{2026} > B_{2020}$ is close to being very low (12%), and most likely in the medium term this catch level will trigger a marginal biomass decline already suggested by the majority of recent observed data. In general, recent recruitment appears to be low. Despite these circumstances, the stock is projected to remain in the safe zone.

Scientific Council will continue to assess this stock on a 2 year schedule.

### *xi) ecosystem summary sheet for 3LNO (COM request #12)*

The Commission request that the Scientific Council present the Ecosystem Summary Sheet for 3LNO for presentation to the Commission at the 2020 Annual Meeting.

**Scientific Council responded:**

SC **recommends** that *the NAFO Secretariat request the information (i.e. percentage of non-NAFO managed stocks that are in condition of supporting fisheries; trends in abundance of stocks under moratoria; fraction of VME biomass/area under protection; level of fishing effort exerted within unprotected VME habitats; tonnage of discards in each and across fisheries) from Canada and ICCAT (International Commission for the Conservation of Atlantic Tunas) for stocks in or migrating through the 3LNO Ecosystem Production Unit.*

SC **will 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. The workshop should involve a simultaneous meeting of SC to agree on recommendations from the assessment of ecosystem status.

The amended NAFO Convention came into force in 2017 and commits the organization to apply an ecosystem approach to fisheries management in the Northwest Atlantic through implementation of its Roadmap for an

Ecosystem Approach to Fisheries (EAF) (Koen-Alonso et al. 2019, and NAFO references therein). The NAFO Roadmap requires integrating information beyond single-species, providing managers with an integrative perspective at the ecosystem level. Development of Ecosystem Summary Sheets (ESSs) is part of this process. Analogous to current Stock Summary Sheets, ESSs are intended to provide a synoptic perspective on the state of NAFO ecosystems and their management regime, aligning with the general principles adopted by NAFO in chapter III of the amended NAFO Convention. Assessment of Ecological Features and Management Measures are grouped under corresponding elements of the Convention Principles. In addition, the ESSs are to report on other considerations outside the mandate of the NAFO Convention.

ESSs are intended as a tool for strategic assessment, advice, and planning, and should be updated every 3-5 years. The assessment considers average state over the last 5 years (S – Status) and the trend during that period (T – Trend) (Tables xi.1 and xi.2).

The ESS for the 3LNO Ecosystem Production Unit (EPU) has been completed based on material from the 2019 meetings of Scientific Council and the Working Group on Ecosystem Science and Assessment. SC is still developing methodologies to assess the frequency and magnitude of observations of VME-defining taxa and benthic communities within the VME habitat outside defined VME protection zones. Trends in key benthic species and communities from regular surveys will be available in the future for a limited period (2010 onward) but the data are currently being curated. Trends in marine mammal abundance could not be evaluated because the status of most species are not assessed. No quantitative data on seabird abundance was available to the working group. Discard levels across fisheries were only available for the most recent period (2015-2018).

Metrics to assess non-NAFO Fisheries and non-NAFO VME protection are currently being developed and will be reported in future assessments. SC **recommends** that *the NAFO Secretariat request the information (i.e. percentage of non-NAFO managed stocks that are in condition of supporting fisheries; trends in abundance of stocks under moratoria; fraction of VME biomass/area under protection; level of fishing effort exerted within unprotected VME habitats; tonnage of discards in each and across fisheries) from Canada and ICCAT (International Commission for the Conservation of Atlantic Tunas) for stocks in or migrating through the 3LNO EPU.*

SC agreed to a consensus draft ESS for the 3LNO EPU. However, SC noted that the performance review panel recommended that we continue to peer review our methods and make these assessments available. Owing to the complexity of the information contained in the ESS and the diverse expertise required to provide peer review of its content, SC **will move toward** undertaking a joint Workshop with ICES (International Council for the Exploration of the Seas) as part of a review of North Atlantic ecosystems. ICES currently performs integrated ecosystem assessments (IEAs) for a number of ecoregions. The workshop should involve a simultaneous meeting of SC to agree on recommendations from the assessment of ecosystem status.

## References

Koen-Alonso, M., P. Pepin, M.J. Fogarty, A. Kenny, and E. Kenchington. 2019. The Northwest Atlantic Fisheries Organization Roadmap for the development and implementation of an Ecosystem Approach to Fisheries: structure, state of development, and challenges. *Marine Policy*. 100:342-352.

**Table xi.1.** Colour scheme for the ecological features of the ecosystem summary sheet and the corresponding criteria for assignment to each category for the status and trends. Time series for the contributing elements were standardized to zero mean and unit standard deviation relative to an appropriate reference period.

| | Ecological Features | |
|---|---|---|
| | Status | Trend |
| Green | The state over the last 5 years is consistent with conditions observed/estimated during high productivity/high resilience periods (mean > 0.5 SD) | The trend over the last 5 years indicates consistent improving of the state/condition<br>(trend > 1 SD/5 y or >20% increase in state) |
| Yellow | The state over the last 5 years is consistent with conditions observed/estimated during average productivity/average resilience periods | The trend over the last 5 years does not indicate any consistent change of the state/condition |
| Red | The state over the last 5 years is consistent with conditions observed/estimated during low productivity/low resilience periods (mean < -0.5 SD) | The trend over the last 5 years indicates consistent deterioration of the state/condition<br>(trend < -1 SD/5 y or >-20% decline in state) |
| Grey | Unknown - insufficient data to assess or assessment pending | Unknown - insufficient data to assess or assessment pending |

**Table xi.2.** Colour scheme for the management measures of the ecosystem summary sheet and the corresponding criteria for assignment to each category for the status and trends.

| | Management Measures | |
|---|---|---|
| | Status | Trend |
| Green | Good. Current management measures are delivering the desired results. | Good. Management measures over the last 5 years are improving conditions; moving towards/maintaining the desired results. |
| Yellow | Uncertain. Current management measures appear to have limited ability to deliver the desired results. | Uncertain. Management measures over the last 5 years are not improving conditions; no clear movement towards achieving the desired results. |
| Red | Poor. Current management measures appear insufficient to deliver the expected results or no management measure is in place. | Poor. Management measures over the last 5 years are not effective or no management measure is in place; conditions are moving away/deteriorating from the desired results. |
| Grey | Unknown - insufficient data to assess or assessment pending | Unknown - insufficient data to assess or assessment pending |

## 3LNO Ecosystem Status Summary Sheet

| **ECOLOGICAL FEATURES** | | | | | |
|---|---|---|---|---|---|
| **Convention Principle** | | | | | **Comment** |
| **A** | **Ecosystem status and trends (long-term sustainability)** | | **S** | **T** | **Summary of multiple trends/state** |
| | 1 | Physical Environment | 🟨 | 🟨 | Near or slightly above normal over the last 5 years but no clear trend over the last 5-yr |
| | 2 | Primary Productivity | 🟩 | 🟨 | Nutrient indices are near normal, phytoplankton standing stocks has recovered from a prolonged below normal state and are now above normal. All indices are dominated by cyclic changes with no clear trend. |
| | 3 | Secondary Productivity | 🟨 | 🟨 | Zooplankton biomass is now above normal following a prolonged period below normal state. The abundance of large zooplankton taxa has been below normal since 2013. |
| | 4 | Fish productivity | 🟥 | 🟥 | Total finfish and shellfish biomass has been declining since 2013-14. Overall biomass is below pre-collapse levels. Average weight of individuals in the survey has declined since the early 2000s. |
| | 5 | Community composition | 🟨 | 🟨 | Shellfish has declined in relative dominance, but piscivores have yet to regain their pre-collapse dominance. |
| **B** | **Ecosystem productivity level and functioning** | | **S** | **T** | **Summary of multiple trends/state** |
| | 1 | Current Fisheries Production Potential | 🟥 | 🟥 | Since 2013-2014, total biomass declined from 50% to ~30% of the estimated pre-collapse level. |
| | 2 | Status of key forage components | 🟥 | 🟥 | Reduced levels of capelin, sand lance, and shrimp. |
| | 3 | Signals of food web disruption | 🟨 | 🟥 | Diet variable, declining trend in stomach content weights. |
| **E** | **State of biological diversity** | | **S** | **T** | **Summary of multiple trends/state** |
| | 1 | Status of VMEs | 🟨 | 🟨 | Additional survey data between 2013 and 2019 has improved the delineation of VMEs and resulted in a general increase in both VME area and biomass. These changes are not thought to represent changes in population densities. |
| | 2 | Status of non-commercial species | 🟨 | 🟩 | Based on 22 non-commercial species from the multispecies surveys, 40% are below 20% of their historical maximum biomass levels. This has declined from higher levels in 2015. |

| **MANAGEMENT MEASURES** | | | | | |
|---|---|---|---|---|---|
| **Convention Principle** | | | | | **Comment** |
| **C/D** | **Apply Precautionary Principle** | | **S** | **T** | **Summary of metrics on level of management action** |
| | 1 | Total Catch Indices (TCI) and catches | 🟥 | 🟥 | Piscivores catches have exceeded the 25th percentile of the Fishery Production Potential estimates since 2015; catches of suspension feeding benthos exceed it in 2018. |
| | 2 | Multispecies and/or environmental interactions | 🟥 | 🟥 | No explicit consideration of species interactions and/or environmental drivers in stock assessments. |
| | 3 | Production potential of single species | 🟨 | 🟨 | Only 60% of NAFO managed stocks are in condition of supporting fisheries; some stocks have declining trends. |
| **D/E** | **Minimize harmful impacts of fishing on ecosystems** | | **S** | **T** | **Summary of metrics on level of management action** |
| | 1 | Level of protection of VMEs by closed areas or outside fishing footprint | 🟥 | 🟥 | Biomass and area of VMEs has increased between 2013 and 2019 as a result of improved delineation of areas of high concentration with increased data. The fraction of biomass under protection by closed areas has declined and is generally low. Several VMEs have limited protection. Fishing with bottom contacting gears does not intrude in closed areas. Part of the VMEs are located outside the fishing footprint. |
| | 2 | Level of protection of exploited species | 🟨 | 🟨 | Total Catch Index (TCI) guidelines, based on the 25th percentile of the Fishery Production Potential model estimates, have been developed. LRPs or HCRs are available for 70% of managed stocks. No multispecies assessments are in place. |
| **D/F** | **Assess significance of incidental mortality in fishing operations** | | **S** | **T** | **Summary of metrics on level of management action** |
| | 1 | Discard level across fisheries | 🟨 | 🟨 | Total discards increased during 2014-2018, with the greatest tonnage occurring in the Greenland halibut fishery. In terms of percentage of total catch from a fishery, discards were generally greater than 40% in the Atlantic halibut fishery. For each stock, the percentage of reported discards relative to total catch for that stock was generally less than 8%. |

| | | | | | |
|---|---|---|---|---|---|
| | 2 | Incidental catch of depleted and protected species | 🟩 | 🟩 | Wolffish are the most prevalent incidental catch taxa in fisheries in the EPU. Generally the incidental catch of wolffish in 3LNO fisheries is very low (less than 0.01% of survey biomass) but highly variable. |
| **OTHER CONSIDERATIONS (outside mandate of NAFO Convention)** | | | | | |
| **Human Activities other than fisheries** | | | **S** | **T** | **Comment** |
| | 1 | Oil and gas activities | | | As of 2019, there are four offshore production fields on the Grand Bank and extensive exploration activities along the eastern shelf break and Flemish Pass. The total area of licenses[1] has increased 8.3-fold from 2014 to 2019. There have been ten reported incidents between 2015 and 2019, with a major oil spill in 2018, and one that extended into the NRA in 2019. A proposed development project in the Flemish Pass overlaps with fishing grounds. It is expected, based on current exploration leases and development projections that oil and gas exploration activities may increase in the NRA until at least 2030. |
| | 2 | Pollution | | | There is low occurrence and density of seabed litter in 3L. The primary source of litter is from both NAFO-managed and non-NAFO managed fisheries. Data for 3NO are not currently available. Standardized protocols for litter data collection have been developed and await approval and implementation during EU surveys. |
| **Fisheries not managed by NAFO** | | | **S** | **T** | **Comment** |
| | | *Non-NAFO fisheries*<br>*(coastal states and other RFMOs)* | | | *To the extent possible compile the description, indicators and/or reporting level to be developed in collaboration with coastal states and/or other RFMOs* |
| | | *Level of protection of VMEs (coastal states and other RFMOs)* | | | *To the extent possible compile the description, indicators and/or reporting level to be developed in collaboration with coastal states and/or other RFMOs* |

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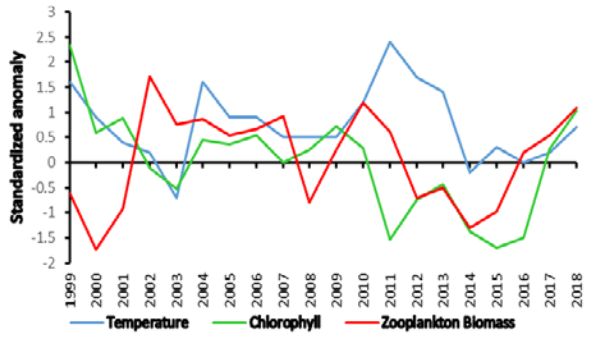
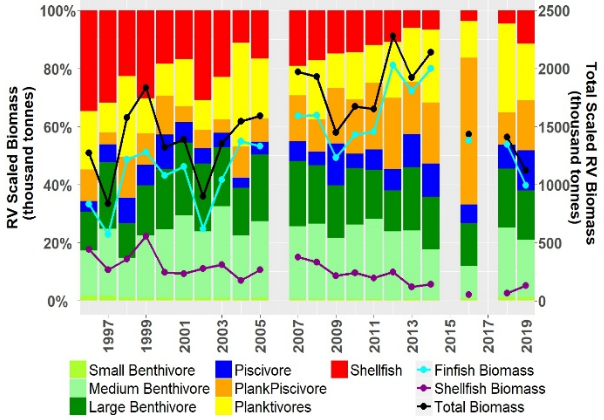
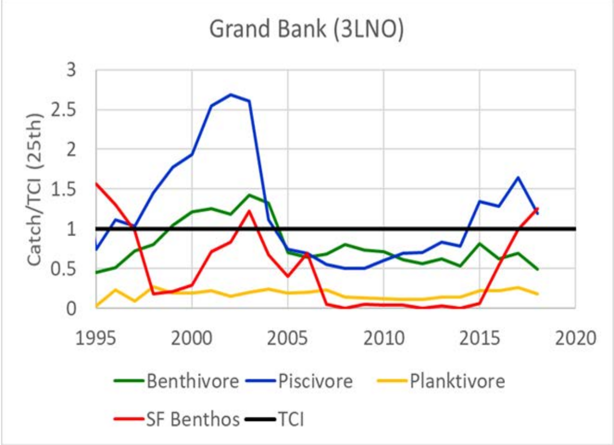
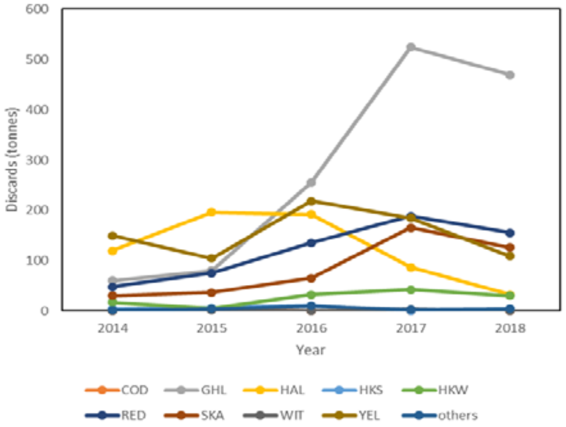
[1] License types: Exploration, Significant Discovery and Production

| **PHYSICAL ENVIRONMENT AND LOWER TROPHIC LEVELS** | **FISH COMMUNITY COMPOSITION AND BIOMASS** |
|---|---|
|  |  |
| **ECOSYSTEM AGGREGATE CATCHES** | **BY-CATCH IMPACTS** |
|  |  |

## 3LNO Ecosystem Status Narrative

The Grand Bank (3LNO) EPU is currently experiencing low productivity conditions and declines in biomass of upper trophic levels and fish stocks. Although reduced productivity appears to be driven by bottom-up processes, current aggregate catches for piscivore species have been increasing during the last 10 years and exceed the TCI guidance. Reductions in piscivore catch levels should be considered; most piscivore catches consist of redfish, Greenland halibut, and Atlantic cod.

### ECOLOGICAL FEATURES

### Ecosystem Status and Trends

The last 5 years have been characterized by increased levels of nutrients, phytoplankton indices, and total zooplankton biomass. Small-sized zooplankton have significantly increased in abundance but the larger, lipid-rich taxa that are the preferred prey of forage fish have been below normal since 2013. Since 2013, total fish biomass has lost the gains built-up since the mid-1990s. Fishes have increased their dominance in the community at the expense of shellfish since 1995, but the piscivore functional group has not regained its pre-collapse dominance.

### Ecosystem productivity level and functioning

The Grand Bank is experiencing low productivity conditions. Multispecies surveys indicate that after the regime shift in the late 1980 and early 1990, this ecosystem never regained its pre-collapse biomass level. Improved conditions between the mid-2000s and early 2010s allowed a build-up of total biomass up to ~50% the pre-collapse level. This productivity was associated with good environmental conditions for groundfish, and modest increases in forage species, principally capelin. Since 2013, forage species have declined, and a reduction in total multispecies biomass to ~30-40% of pre-collapse levels has occurred across all fish functional groups. Although variable, diet composition of cod suggests reduced contributions of forage species, and average stomach content weights of cod and Greenland halibut have shown declines, suggesting poor foraging conditions.

### State of biological diversity

Biological diversity is a multi-faceted concept. Out of its many dimensions, assessment of its state is being limited here to Vulnerable Marine Ecosystems (VMEs) and the number of non-commercial fish species considered depleted owing to availability of appropriate analyses. Although identification and delineation of VMEs is being done for the NRA, it is difficult to assess their status given the absence of a defined baseline and the unquantified impacts from historical fishing activities. The status of non-commercial species indicates that 40% of 22 taxa have biomasses that are below 20% of their historical maximum biomass for the period 1985-2018, but demonstrates an improvement from higher levels in 2015.

### MANAGEMENT MEASURES

### Precautionary Principles

The NAFO Roadmap addresses sustainability of fishing at three nested levels of ecosystem organization: ecosystem, multispecies and stock levels. Catches of piscivore species have been increasing since 2007 and were above their Total Catch Index guidance (TCI – defined as the 25th percentile of the Fishery Production Potential model estimates) from 2015-onward. Piscivore catches are mostly composed of redfish, Greenland halibut, Atlantic cod, and white hake. Catches of suspension feeding benthos (mostly surf clams) were above their TCI guidance in 2018.

Sixty percent of the NAFO managed stocks in the Grand Bank are open to directed fishing, and some of the stocks not supporting fisheries are showing declining trends in abundance indices. Impacts of either species interactions or environmental drivers are not currently being considered in the provision of single species harvest advice or management of those fisheries.

### Minimize harmful impacts of fishing on ecosystems

Minimization of harmful impacts of fishing on benthic communities has been focused on the protection of VMEs. Many coral and sponge VMEs on the Grand Bank are currently protected with dedicated closures. However, the 3O coral closure does not provide protection for the identified VMEs in that area as appropriate depths were not included within the boundary of the closure. Closures protect 59% of the large-sized sponge VME biomass, 22% of sea pen VME biomass and 56% of large gorgonian coral VME biomass in 3LNO. Non-coral and non-sponge VMEs were identified and areas of high concentration have been delineated on the tail of the Grand Bank. Only 18% of black coral biomass are currently protected by closures for other taxa, and less than 1% or less of small gorgonian corals, sea squirts and erect bryozoans biomass are protected. The fishing footprint offers some protection beyond the boundaries of the closed areas for large-sized sponges and large gorgonians.

At the ecosystem level, Total Catch Indices for this ecosystem have been developed, while at the stock level 70% of managed stocks have LRPs or HCRs. Although some studies are available, there are no multispecies assessments to inform on considerations of trade-offs among fisheries and no stock-assessment explicitly considers either species interactions or environmental factors as drivers.

### Assess significance of incidental mortality in fishing operations

Total discards demonstrated a general increase during the period 2014-2018, peaking at ~1200 tonnes in 2017 in the NRA. Total discards were greatest in the fishery for Greenland halibut. As a fraction of total catches, discards were generally below 8% of the total catch. Discards proportions were highest in the fisheries for Atlantic halibut and white hake.

Generally the incidental catch of at-risk wolffish in 3LNO fisheries is very low (less than 0.01% of survey biomass) but highly variable. While wolffish are caught in many different gear types, historically landings were greater in bottom trawl gear than in gillnet or longline gears. In addition, while of Northern and Spotted Wolffish dominate the catches in NAFO division 3L, Atlantic Wolffish are the dominant species in NAFO divisions 3NO.

## OTHER CONSIDERATIONS

### Human activities other than fishing

As of 2019, there are four offshore production fields on in 3LNO and intense exploration activities along the eastern shelf break and Flemish Pass. The total area of licenses[2] has increased 8.3-fold from 2014 to 2019. There have been several reported incidents between 2015 and 2019, with a spill of 250,000 L in 2018 and one extending into the NRA in 2019. A proposed development project in Flemish Pass overlaps fishing grounds. It is expected, based on current exploration leases and development projections that oil and gas exploration activities will increase until at least 2030.

There is low occurrence and density of seabed litter in 3L, with NAFO and non-NAFO fisheries the primary source. Data for 3NO are not currently available. Standardized protocols for seabed litter data collection have been developed and await approval and implementation during EU surveys.

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[2] License types: Exploration, Significant Discovery and Production. Exploration licences represent the greatest contributors to total area of oil and gas activities.

### *xii) Review submitted protocols for a survey methodology to inform the assessment of splendid alfonsino (COM request #13)*

Due to time constraints, SC was not able to address this request during the June meeting and it is deferred until September 2020.

### *xiii) 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) (COM request #14)*

Due to time constraints, SC was not able to address this request during the June meeting and it is deferred until September 2020.

### *xiv) Provide updates on relevant research related to the potential impact of activities other than fishing in the Convention Area (COM request #16)*

Due to time constraints, SC was not able to address this request during the June meeting and it is deferred until September 2020.

### *xv) Measures to improve the productivity of 3M Cod (COM request #17)*

The Commission requests the Scientific Council to provide advice on gear, including sorting grids, area and time-based measures that can be used to protect and improve the productivity of the 3M cod stock.

**Scientific Council responded:**

The SC responded to the Commission in 2015 and 2019 regarding sorting grids to reduce possible by-catches and discards. No new advice is provided here with respect to sorting grids.

Area/season closures have been suggested as a tool to support fisheries management, particularly for areas/seasons where key life history stages are highly aggregated (e.g. spawning aggregations). In the case of 3M cod, most of the catch occurs during the first quarter of the year, and is comprised primarily of spawning fish. SC advises that a seasonal closure (no directed fishery on 3M cod during the first quarter of the year) would protect spawning activity, reducing the number of spawning fish that are captured and allowing them to spawn before becoming available to the fishery. However, there is no clear evidence that protecting spawning fish directly translates into increased recruitment/productivity. In addition, changes in the behavior of the fishing fleets in response to a seasonal closure, and the resulting impact on the overall ecosystem (e.g. changes in the fishing grounds, by-catch of juveniles and other species, and impacts on benthic habitats), would need to be closely monitored in order to ensure that any such closure was not having unintended negative consequences. The scale of these consequences is expected to be lower for low TACs. The implementation of these measures should be accompanied by a clear definition of the objectives (to determine if and how closure effectiveness could be monitored) and a monitoring plan to study the impact that these measures may have on the fishery and ecosystem.

In 2014, the Fisheries Commission requested the Scientific Council *to analyse and provide advice on management measures that could improve selectivity in the Div. 3M cod and Div. 3M redfish fisheries in the Flemish Cap in order to reduce possible by-catches and discards.* Based on an examination of work carried out in the Barents Sea, Scientific Council responded that *the implementation of sorting-grids in the Div. 3M cod fishery gear will reduce catch of small and immature individuals of cod. These devices would to a large extent prevent catches of individuals less than the Minimum Landing Size (41 cm) and have the advantage also of reducing redfish by-catches and thereby reduce discards. It is estimated that by introducing sorting grids, the actual Fmsy value and the equilibrium yield (catches) would increase but it should have a small impact in the equilibrium Spawning Stock Biomass. To quantify these improvements more precisely, selectivity experiments with the modified gears need to be performed in the Flemish Cap area* (NAFO, 2015).

In 2020, the SC analyzed data from the commercial cod fishery in Div. 3M. These analyses suggest that catches of cod in Div. 3M are made mainly in the first quarter of the year and are comprised primarily of spawning fish. The cod trawl fishery in the first quarter is concentrated in a fairly small area where catch rates (CPUE) are higher and fish mean sizes are larger than in other areas/seasons, likely representing a major spawning area. This concentration of catches in a given area is less clear in the cod longline fishery.

Area/season closures have been suggested as a tool to support fisheries management, particularly for areas/seasons where key life history stages are highly aggregated (e.g. nursery or spawning areas). In the case of 3M cod, the fact that the directed fishery primarily targets spatially-limited spawning aggregations in the first quarter of the year suggests that a seasonal closure of this area could reduce the number of fish captured during spawning. Nevertheless, there are different works that indicate that, even in these cases, it is better and more practical, from the point of view of its implementation and control, to have seasonal closures rather than small area closures. However, the consequences that such closures may ultimately have on the productivity of the 3M cod stock, the behavior and economics of the fishing fleets, and the resulting impact on the overall ecosystem, are largely unknown. Implementation of a spawning closure would likely result in fishing effort being reallocated to other areas/seasons, which could influence other key life stages (e.g. juveniles), species (e.g. incidental catches), and/or impacts on benthic habitats (i.e. by forcing the fishery into areas/seasons that were previously less fished and/or require increased effort to achieve a comparable catch). The scale of these consequences, however, is expected to be lower for low TACs and will be directly dependent on the level of effort. The implementation of these measures should be accompanied by a clear definition of the objectives (to determine if and how closure effectiveness could be monitored) and a monitoring plan to study the impact that these measures may have on the fishery and ecosystem.

### *xvi) Information on sea turtles, sea birds, and marine mammals that are present in NAFO Regulatory Area (COM request #18)*

Due to time constraints, SC was not able to address this request during the June meeting and it is deferred until September 2020.

## 2. Coastal States

### a) Request by Denmark (on behalf of Greenland) for advice on management in 2020 of certain stocks in Subareas 0 and 1 (Annex 2)

The Scientific Council responded:

**Demersal redfish in Subarea 1** Advice June 2020 for 2021 - 2023

**Recommendation 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.

### Management objectives

No explicit management plan or management objectives have been defined by the Government of Greenland.

### Management unit

These two species are managed together as a single unit. Survey data reveal an almost continuous distribution of both species from East Greenland to West Greenland; both areas had geographically distinct fisheries historically. However, the degree of connectivity between the two areas is unknown.

### Stock status

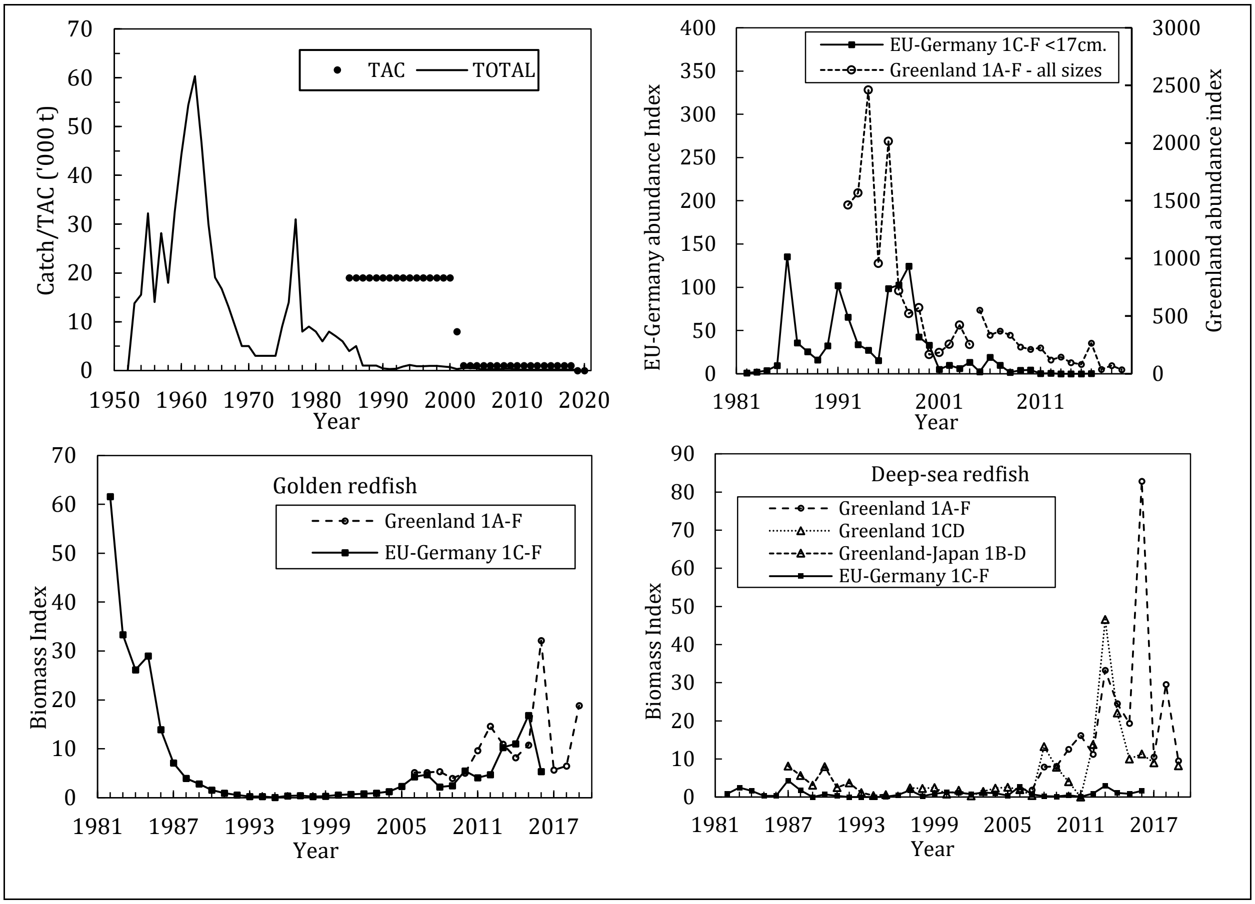
Catches of the stock have been very low since the 1990s.

*Golden redfish*

Survey indices indicate that the biomass remains far below historical levels. Recruitment has been poor for two decades and failing during the most recent decade. The overall stable biomass in recent years is the result of somatic growth or immigration balancing the limited fishery and natural mortality in the remaining stock.

*Deep-sea redfish*

Both the Greenland Shrimp and Fish survey (Div. 1A-F) and the Greenland deep-sea survey (Div. 1CD) indicate a decreasing biomass index of deep-sea redfish in the recent 4-7 years. Recruitment has been poor for two decades. No new incoming year classes have been identified during the trawl surveys in either East Greenland (EU-Germany survey), West Greenland offshore (EU-Germany survey and survey in Div. 1A-F), or inshore (Survey in Div. 1A-F) during the recent decade.



**Reference points**
Could not be established.

**Assessment**

No analytical assessment was performed. The assessment was based upon a qualitative evaluation of survey indices, length composition in surveys, and historical fishery. The assessment is considered data-limited and with relatively high uncertainty, as surveys do not fully cover the distribution of the stock

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

***Environmental impact***
Unknown

**Fishery**

The proportions of golden and deep-sea redfish in the historical catches are unknown. The catches of redfish peaked in the 1960s at 60 000 tonnes, but gradually decreased during the 1970s and 1980s. A significant unreported bycatch of redfish was likely taken during the 1980s and 1990s in the fishery targeting shrimp. With the implementation of sorting grids in the shrimp fishery in 2002, catches and bycatch of redfish are considered to be very low.

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

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **TAC** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| **STATLANT 21** | 0 | 0.2 | 0.12 | 0.16 | 0.25 | 0.19 | 0.16 | 0.23 | 0.19 | 0.095 | |
| **STACFIS** | 0.3 | 0.2 | 0.16 | 0.17 | 0.17 | 0.26 | 0.17 | 0.24 | 0.19 | 0.14 | |

### Effects of the fishery on the ecosystem

There is currently no significant directed fishery in West Greenland. Recent landings of redfish are bycatches taken in other fisheries: mainly longline, gillnet or jigging in the inshore and coastal areas, and trawl in the offshore areas.

### Basis for Advice

Survey indices were used to evaluate the stock.

### Special comments

The higher biomasses of both redfish species observed in the surveys since around 2008 could be a consequence of either increased survival of redfish after the implementation of sorting grids in the shrimp fishery and/or migration of redfish from nearby areas. Current stock delineation may not be appropriate.

Although the Shrimp and Fish survey experienced vessel changes in 2018 and 2019, the indices are considered to be comparable with those from earlier years. The deep-sea survey in 1CD also experienced a vessel change in 2019, for which it has been shown that gear performance parameters remained constant with both vessels at depths < 700 m. Since both redfish are found mainly at depths < 600 m during this survey, results are also considered comparable.

This stock will be monitored by interim monitoring report until such time as monitoring suggests a major change.

### Sources of Information

SCR Doc. 20/003, 006, 012, 016 and 045; SCS Doc. 20/12.

## Wolffish in Subarea 1

Advice June 2020 for 2021 - 2023

**Recommendation 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.

**Management objectives**

No explicit management plan or management objectives have been defined by the Government of Greenland.

**Management unit**

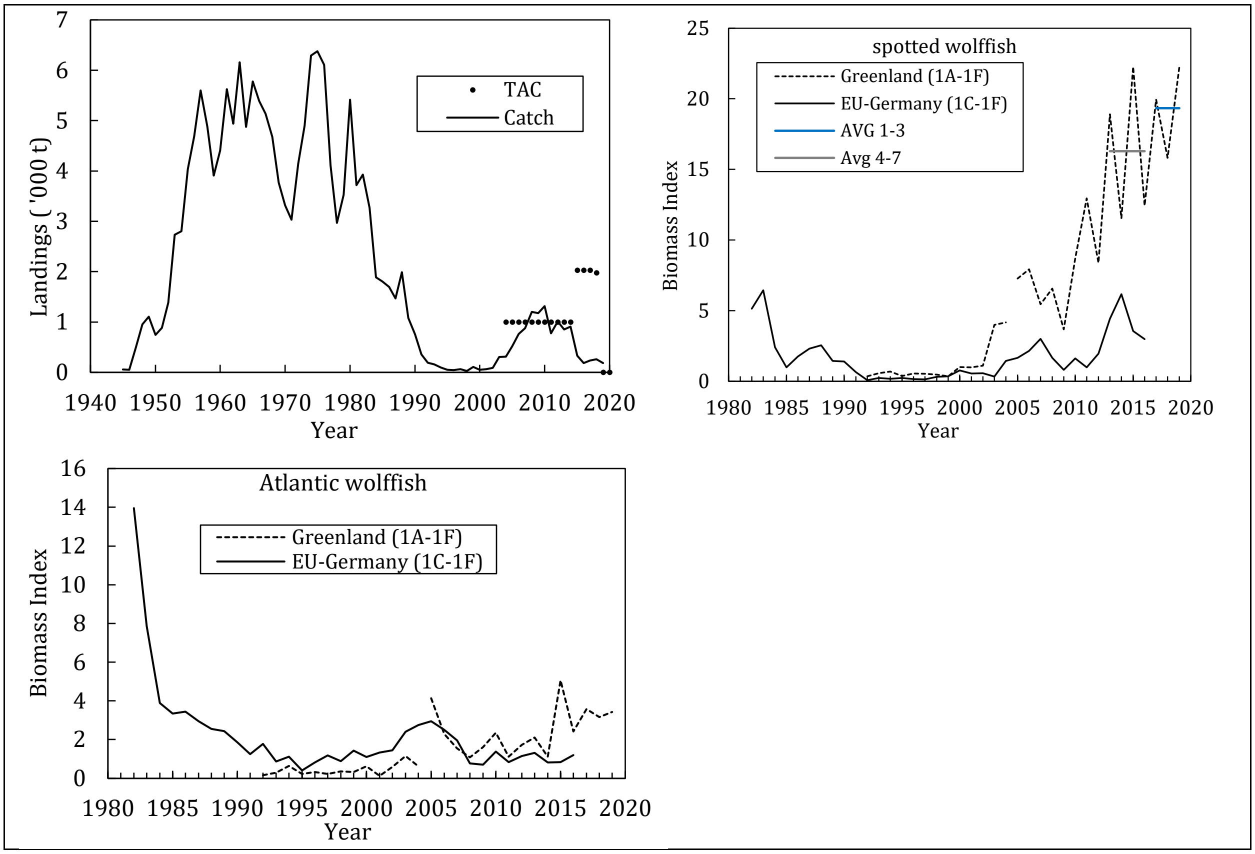
Atlantic wolffish is known to be more connected to the offshore banks in South and West Greenland and is considered a single unit.

Spotted wolffish is found in all areas, both inshore and offshore, but is known to be the dominating species in the coastal regions and the fjords in South, West and North Greenland. It is presumed to be a single stock.

**Stock status**

Atlantic wolffish: The survey biomass and abundance indices continued to increase in the Greenland Shrimp and Fish survey; however, the EU-Germany indices remain low (to 2016). As the EU-Germany survey and the Greenland shrimp and fish survey in the overlapping period were around the same level, it seems reasonable to assume that the biomass remains below the level of the 1980s.

Spotted wolffish: Survey indices suggest continued stock growth. Although the catches were below the TAC from 2015-2018, there is no indication that the decreasing catches were related to a decrease in the stock. The average biomass index in the Greenland Shrimp and Fish survey is 19% higher in the recent 3 years (2017-2019) compared to the preceeding 4 year period.



**Reference points**
Could not be established.

**Assessment**

No analytical assessment was performed. The assessment is based upon a qualitative evaluation of survey indices, length composition in surveys, and fishery data. The assessment is considered data limited and with relatively high uncertainty, as surveys do not fully cover the distribution of the stock.

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

*Environmental impact*
Unknown

**Fishery**

Wolffish are primarily taken in a directed longline fishery or as a bycatch in longline, gillnet or trawl fisheries. Prior to 2015, TACs were set for wolffish with species combined, but since 2016 separate TACs have been set for spotted and for Atlantic wolffish. The proportions of Atlantic wolffish and spotted wolffish in the catches are unknown, but there is little doubt that spotted wolffish constitutes the majority of recent landings, since the fishery takes place in the coastal areas and the fjords, where spotted wolffish is known to be the dominating species. Furthermore, the majority of the Atlantic wolffish observed in surveys are smaller than normal commercial sizes, whereas spotted wolffish between 70 and 110 cm are plentiful.

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

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Atlantic wolffish TAC** | | | | | 1.0 | 1.0 | 1.0 | 1.0 | 0 | 0 |
| **Spotted wolffish TAC** | | | | | 1.025 | 1.025 | 1.025 | 1.025 | 0 | 0 |
| **Wolffish TAC** | 1.0 | 1.0 | 1.0 | 1.0 | 2.025 | 2.025 | 2.025 | 2.025 | 0 | 0 |
| **STATLANT 21** | 0.8 | 1.0 | 0.9 | 0.9 | 0.4 | 0.2 | 0.3 | 0.3 | 0.2 | |
| **STACFIS** | 0.8 | 1.0 | 0.9 | 0.9 | 0.4 | 0.2 | 0.3 | 0.3 | 0.2 | |

**Effects of the fishery on the ecosystem**

Wolffish in the area are targeted with longlines, selecting mainly adult fish and with low environmental impact.

**Basis for Advice**

**Atlantic wolffish**
Survey indices were used to evaluate the stock.

**Spotted wolffish**
Survey indices were used to evaluate the stock. The ICES Harvest Control Rule (HCR) 3.2 for data limited stocks was used as a basis for giving TAC advice; the ratio of the mean of the survey index over the last three years (2017-2019) and over the preceding four years (2013-2016) is equal to 1.1877. The survey index used in this calculation was the Greenland Shrimp and Fish survey as its distribution was appropriate to the distribution of the stock. Application of this HCR starts from the previously advised catch (975 tonnes), resulting in catches of no more than 975 x 1.1877 = 1158 tonnes.

**Special comments**
The ICES HCR for data limited stocks was first applied to spotted wolffish in 2017. A 1st year 'precautionary buffer' of 20% reduction was applied in 2017.

The harvest control rule is based on modifying the previous advice based on the stock trends observed in the survey. If advised catches are not taken, this can lead to increases in recommended catches as long as the stock increases. If the divergence between the observed and advised catches continues, this could lead to unsustainable advice, and therefore application of this rule may need to be reevaluated in the future.

The two species are not usually separated in the landings. Given the different status of the Atlantic and spotted wolffish stocks, SC recommends speciation of the landings for these two species.

**Sources of Information**

SCR Doc. 14/028, 20/006, 012, 040; SCS Doc. 20/12.

## Greenland halibut in Division 1A inshore - Upernavik

Advice June 2020 for 2021 – 2022

**Recommendation for 2021 - 2022**

Scientific Council recommends that catch should not exceed 5 068 tonnes. This is a reduction over the previous advice accounting for the reduction in mean individual size in the recent catches

### Management objectives

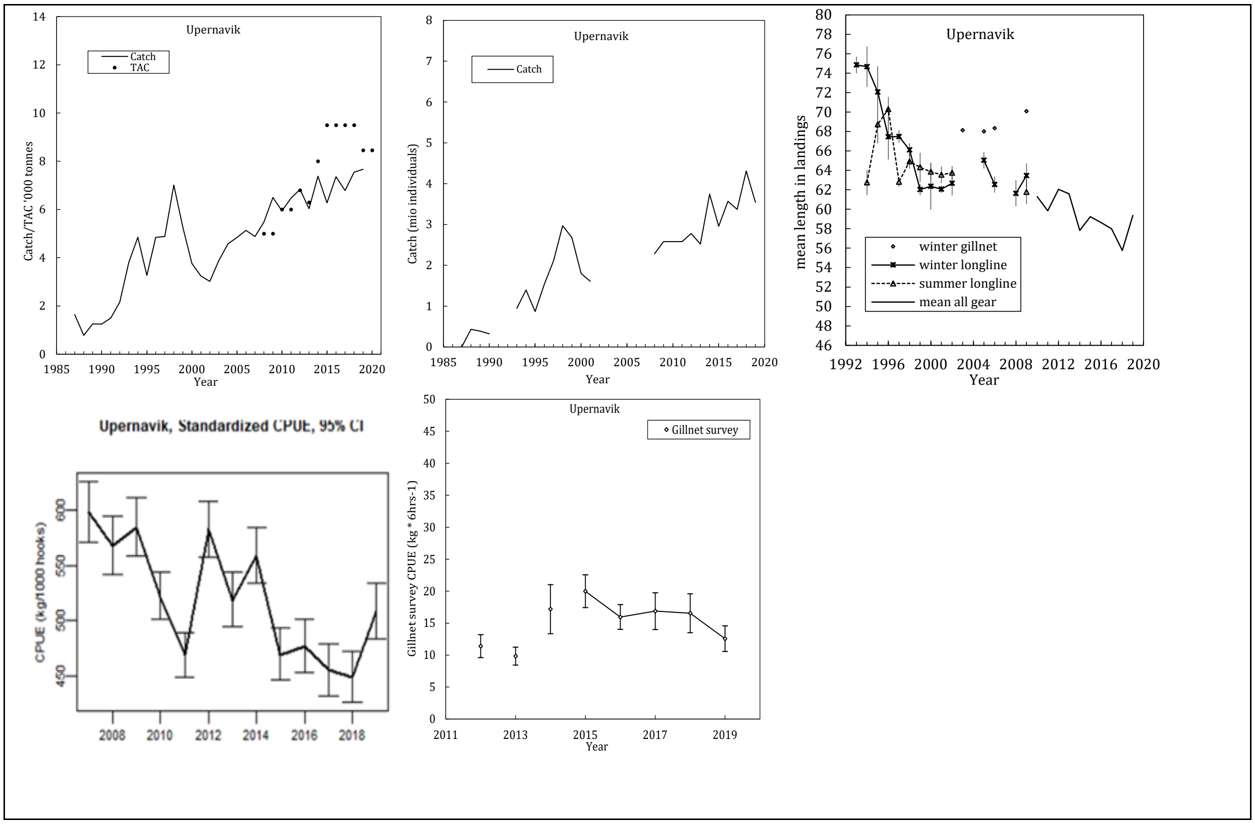
No explicit management plan or management objectives have been defined by the Government of Greenland.

### Management unit

The three stocks in Div. 1A inshore fjords (Disko Bay, Uummanaq and Upernavik) are believed to recruit from the Subarea 0+1 offshore spawning stock (in the Davis Strait) and there is little migration between the separate areas and the stock in SA 0+1 offshore. Separate advice is given for each management unit in Subarea 1A inshore.

### Stock status

The catch in tonnes and in numbers of fish has been record high since 2014. Mean length in the fish landings decreased in the 1990s but stabilized from 1999 to 2009. Since then, until 2018, length in the fish landings has decreased from 74-76 cm to 56-58 cm. The mean length increased in 2019, but this value is questionable because the sample size was smaller than usual. The standardized longline CPUE index decreased until 2018 reaching the lowest value of the time series. CPUE increased in 2019 but remains within the decreasing trend for year to year variation. The gillnet survey has shown some stability since 2015. The decrease observed in 2019 is uncertain due to a lower number of stations than usual.



## Reference points

Could not be established.

## Assessment

No analytical assessment was performed. Survey indices, commercial CPUE, and mean length in the landings were considered the best information to monitor the stock.

*Human impact*

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

*Environmental impact*

Unknown

## Fishery

Catches increased from the mid 1980s and peaked in 1998 at a level of 7 000 t. Landings then decreased sharply, but during the past 15 years, they have gradually returned to a higher level. Average catch in the most recent 5 years has been 7 169 t.

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

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| **TAC** | 6.5 | 6.5 | 8 | 9.5 | 9.5 | 9.5 | 9.5 | 9.5 | 8.5 | 8.5 |
| **STACFIS** | 6.5 | 6.8 | 6 | 7.4 | 6.3 | 7.4 | 6.8 | 7.5 | 7.6 | |

## Effects of the fishery on the ecosystem

Greenland halibut in the area is targeted with longlines and gillnets. Both gears select adult fish with large body size and do not retain recruits or small-sized fish. Ghost fishing by lost gillnets has been observed, but its effects are unknown.

## Special comments

The ICES Harvest Control Rule 3.2 for data-limited stocks could not be used since the survey time series was too short to be applied.

Recruits are mainly received from the offshore stock in SA 0 + 1 offshore.

## Sources of Information

SCR Doc. 20/006, 016 , 043; SCS Doc. 20/012.

## Greenland halibut in Division 1A inshore - Uummannaq

Advice June 2020 for 2021 – 2022

**Recommendation 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.

### Management objectives

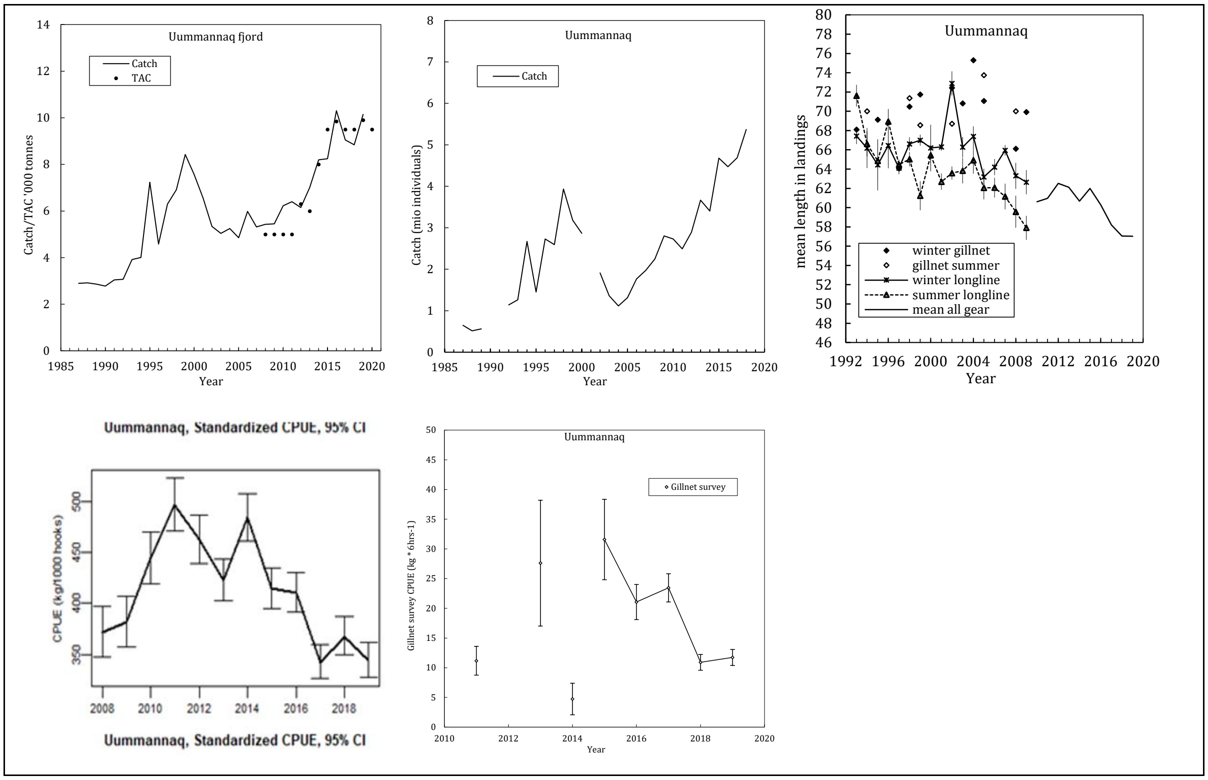
No explicit management plan or management objectives has been defined by the Government of Greenland.

### Management unit

The three stocks in Div. 1A inshore fjords (Disko Bay, Uummanaq, and Upernavik) are believed to recruit from the Subarea 0 + 1 offshore spawning stock (in the Davis Strait), and there is little migration between the separate areas and the stock in SA 0 + 1 offshore. Separate advice is given for each area, within the specific management unit, in Subarea 1A inshore.

### Stock status

The catch in tonnes and numbers of fish has been increasing since 2009, reaching record high values in 2016 and 2019. Mean length in the landings has gradually decreased. From 2011, the standardized commercial longline CPUE index decreased gradually, being 2017 and 2019 the years with the lowest values observed in the time series. The gillnet survey has shown a substantial decrease in CPUE due to a lower number of large fish in the survey, until 2018, and it remained almost stable in 2019.



**Reference points**

Could not be established.

**Assessment**

No analytical assessment was performed. Mean length in the landings, commercial CPUE, and survey indices were considered the best information to monitor the stock.

*Human impact*

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

*Environmental impact*

Unknown

**Fishery**

Catches in the Uummannaq fjord gradually increased from the 1980s, reaching 8425 t in 1999, but then decreased and remained between 5000 t and 6000 t from 2002 to 2009. Since 2009 catches gradually increased, reaching 10 243 t in 2019, the second-highest value of the time series.

Recent catch estimates (‘000 tonnes) are as follows:

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| **TAC** | 6 | 6 | 7.4 | 8.4 | 9.5 | 9.9 | 9.5 | 9.5 | 9.9 | 9.5 |
| **STACFIS** | 6.4 | 6.1 | 7 | 8.2 | 8.2 | 10.3 | 9 | 8.8 | 10.2 | |

**Effects of the fishery on the ecosystem**

Greenland halibut in the area is targeted with longlines and gillnets. Both gears select adult fish with large body size and do not retain recruits or small-sized fish. Ghost fishing by lost gillnets has been observed, but its effects are unknown.

**Special comments**

The ICES Harvest Control Rule 3.2 for data-limited stocks was not be used since the survey time-series is still relatively short.

Recruits are mainly received from the offshore stock in SA 0 + 1 offshore.

**Sources of Information**

SCR Doc. 20/006, 016, 043; SCS Doc. 20/12.

## Greenland halibut in Division 1A inshore - Disko Bay

Advice June 2020 for 2021 – 2022

### Recommendation for 2021 - 2022

The Scientific Council advises that the TAC should not exceed 4346 tonnes.

### Management objectives

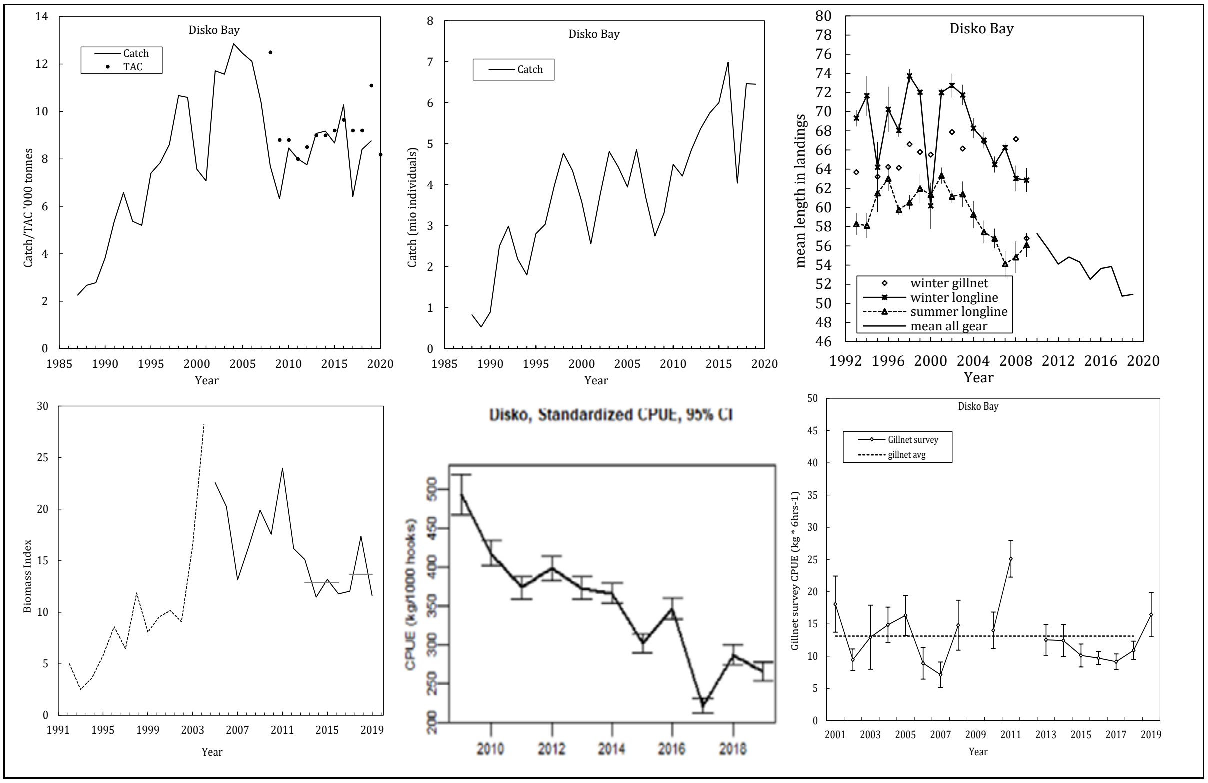
No explicit management plan or management objectives has been defined by the Government of Greenland.

### Management unit

The three stocks in Div. 1A inshore (Disko Bay, Uummanaq and Upernavik) are believed to recruit from the SA 0+ 1 offshore spawning stock (in the Davis Strait), and there is little migration between the separate areas and the stock in SA 0 + 1 offshore. Separate advice is given for each area, within the specific management unit, in Subarea 1A inshore.

### Stock status

Mean length of the fish landed has gradually decreased over 10 to 15 years. Although the catches have remained at a level of around 8 400 t per year in the recent decade, the number fish caught has gradually increased due to a decrease in the size in the landings. The number of fish landed remains high. The trawl survey biomass index has gradually decreased since 2009, with few years falling outside the decreasing trend. The commercial CPUE for longline vessels has decreased by about 50% since 2009. The Gillnet survey CPUE, originally designed for pre-fishery recruits, indicate stable recruitment at higher ages. The gillnet survey index in 2019 was above the average levels, but the comparability of the 2019 value with the earlier time series is questionable.



**Reference points**

Could not be established.

**Assessment**

No analytical assessment was performed. Mean length in the landings, survey indices and commercial CPUE was considered the best information to monitor the stock.

The next assessment is planned for 2022.

*Human impact*

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

*Environmental impact*

Since 1997 bottom temperatures have remained stable at a level of 2-3 degrees in the Disko Bay.

**Fishery**

Catches increased in the 1980s, peaked from 2004 to 2006 at more than 12 000 tonnes, but then decreased substantially. From 2009, catches gradually increased, reaching 8 759 tonnes in 2019.

Recent catch estimates (‘000 tonnes) are as follows:

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| TAC | 8 | 8 | 9 | 9 | 9.2 | 9.7 | 9.2 | 9.2 | 11.1 | 8.2 |
| **STACFIS** | 8 | 7.8 | 9.1 | 9.2 | 8.7 | 10.8 | 6.4 | 8.4 | 8.8 | |

**Effects of the fishery on the ecosystem**

Greenland halibut in the area is targeted with longlines and gillnets. Both gears select adult fish with large body size and do not retain recruits or small sized fish. Ghost fishing by lost gillnets has been observed but its effects are unknown.

**Basis for advice**

The application of the ICES guidance on data limited stocks (DLS) method 3.2 (ICES 2012a and 2012b, ICES 2014) using the Greenland Shrimp and Fish survey (Div. 1A-F) was accepted by SC in 2016, as the basis for giving TAC advice on Greenland halibut in the Disko Bay. This method was applied again to provide the following advice advice for the next two years. This rule was developed and tested as an empirical approach that uses the trend in the stock response to fishing pressure (ICES 2012a, Jardim et al. 2015). The empirical basis was given a generic expression

$C_{y+1}=advice_{recent}*r$

where r=index mean for 2017-2019/index mean for 2013-2016 = 1.061

Should changes in excess of +- 20% be generated using this rule, a 20% cap is applied. In 2016 or 2018, no precautionary buffer was applied. Since both the mean length in the fish landings and the commercial CPUE’s have decreased in both 2018 and 2019 and stock status relative to reference points is unknown, a PA buffer (i.e. a 0.8 factor) was applied this year. This results in the following advised catch:

$advice_{recent}$ = 5120 tonnes (catch advised for 2019 and 2020).

Catch in 2021 and 2022 = $advice_{recent}$* r * PA buffer = 5120 tonnes * 1.061 * 0.8 = 4346 tonnes

Multi-year advice is recommended when applying this index-ratio based rule. Also, Greenland has requested advice for as many years as is considered appropriate. A two year advice cycle is suggested at this time.

**Special comments**

Although the index provided by the Greenland shrimp and fish trawl survey experienced vessel changes in 2018 and 2019, the results are considered to be comparable with those from earlier years.

Recruits are mainly received from the offshore stock in SA 0 + 1 offshore.

**Sources of Information**

SCR Doc. 20/006, 016, 043; SCS Doc. 20/012.

**Greenland halibut in Subarea 1 Division 1BC inshore** Advice June 2020 for 2021 – 2022

**Recommendation for 2021 and 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).

### Management objectives

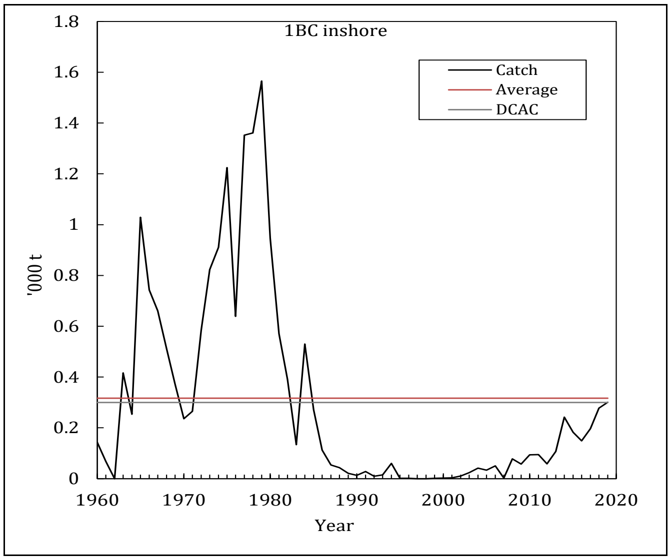
No explicit management plan or management objectives have been defined by the Government of Greenland.

### Management unit

The stocks are believed to recruit from the offshore spawning stock in Subarea 0+1 (the Davis Strait) or offshore spawning stock in ICES Subareas 5, 6, 12 and 14 (East Greenland-Iceland-Faroes). There is little migration of adults between the fjords and the stock in SA 0 + 1 offshore. Fjords are assigned to a NAFO division based on the location of the mouth of each fjord. Combined catch advice is given for all fjords within the specified management unit.

### Stock status

The catch was at a low level for two decades from the end of the 1980's. During the recent decade the catch has gradually increased to the estimated sustainable level of catch.



### Reference points

The Depletion Corrected Average Catch method was used to estimate a sustainable level of catch.

### Projections

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

### Assessment

The assessment is considered data limited and as such associated with a relatively high uncertainty. The assessment is based upon a catch history from 1960 to 2019. During this period the stock has gone through a period of intensive fishery and 3 decades of rebuilding. There are currently no survey data and commercial data is limited.

The next assessment is planned for 2022.

*Human impact*

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

*Biological and environmental interactions*

No specific studies were reviewed during this assessment.

**Fishery**

Catches increased in the area from the 1960's reaching more than 1,000 tonnes in 1965. Catches decreased thereafter but returned to a higher level from 1973 to 1980. After this intense fishing period, catches decreased and were almost non-existing for two decades from 1987. From 2008, catches have gradually increased, reaching 300 tonnes in 2019.

A TAC has not previously been set for the stocks in Divisions 1B to 1F inshore. The fishery has never been quota regulated.

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

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| **TAC** | | | | | | | | | | |
| **STACFIS** | 95 | 58 | 107 | 242 | 183 | 149 | 197 | 278 | 301 | |

**Effects of the fishery on the ecosystem**

Greenland halibut in the area is targeted with longlines only in deep water and on muddy bottom. The gear is light with low risk of bycatch of birds and marine mammals and with low impact on the seabed.

**Special comments**

Until 2020 this stock was considered to be part of the stock in SA 0 + 1 offshore .

Available data until June 1st indicated a 30% reduction in catch compared to 2019, but the catches remain within the level observed within the recent 4 seasons. ICES DLS Guidance report 2012 p. 19-21 suggest a method to provide advice from the sustainable level catch estimated by the DCAC model. The method uses two scenarios and an adaptation period of 3-5 years following a ”fast down”– ”slow up” (catches should decrease to the DCAC value quickly if they are above it and could increase slowly towards it if below) approach taking into account that stocks with a low biomass cannot sustain MSY.

**Sources of information**

SCR Doc. 20/006 020 038 043; SCS Doc. 20/012.

**Recommendation for 2021 and 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.

### Management objectives

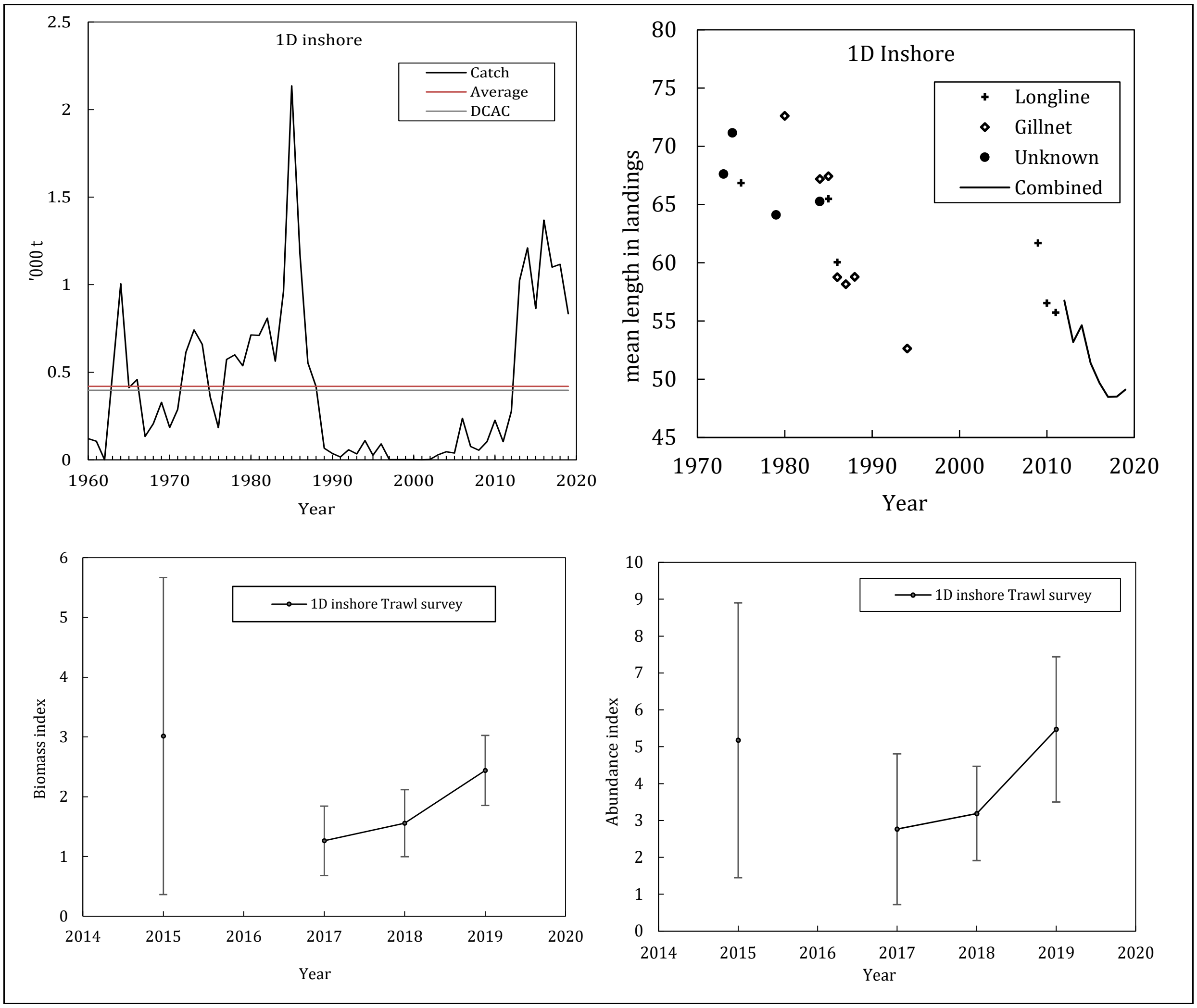
No explicit management plan or management objectives have been defined by the Government of Greenland.

### Management unit

The stock in the fjords in Division 1D are believed to recruit from the offshore spawning stock in ICES Subareas 5, 6, 12 and 14 (East Greenland-Iceland-Faroes). There is little migration of adults between the fjords and the stock in SA 0 + 1 offshore. The stock is furthermore believed to be constituted of several isolated fjord stocks, with little migration between the fjords. Fjords are assigned to a NAFO division based on the location of the mouth of each fjord. Combined catch advice is given for all fjords within the specified management unit.

### Stock status

The catch was at a low level for two decades from the end of the 1980's. Since 2013 the catches have been about twice as high as the DCAC estimated sustainable level of catch. During this period, a decrease in size composition in the catch has been observed. The trawl survey for Greenland halibut in the fjords in 1D indicated a decrease in the number of fish in the commercial size range since 2015. However, the biomass indices in the survey increased from 2017 to 2019, due to higher numbers of pre fishery recruits in the range 30-40 cm. The survey furthermore indicated presence of recruits in the area although the stocks are believed to be dependent on recruitment from the stock in ICES Subareas 5, 6, 12 and14.



## Reference points

The Depletion Corrected Average Catch method was used to estimate a sustainable level of catch.

## Projections

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

## Assessment

The assessment is considered data limited and as such associated with a relatively high uncertainty. The assessment is based upon a catch history from 1960 to 2019. During this period the stock has gone through a period of intensive fishery and 3 decades of rebuilding. The assessment is further supported by a trawl survey (since 2015) and length frequencies from the fishery are available from 1973 to present.

The next assessment is planned for 2022.

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

*Biological and environmental interactions*
No specific studies were reviewed during this assessment

### Fishery

Catches in 1D inshore were around 500 tonnes annually from 1966 to the end the 1980’s, peaking in 1985 with 2,136 tonnes. After this intense fishing period, the fishery was virtually non-existing for two decades. From 2003 catches gradually increased, reaching 1,369 tonnes in 2016. In 2019, the catch decreased to 834 tonnes from 1117 tonnes in the preceding year. A TAC has not previously been set for the stock in Division 1D inshore. The fishery has never been quota regulated.

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

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| **TAC** | | | | | | | | | | |
| **STACFIS** | 104 | 277 | 1,024 | 1,211 | 864 | 1,369 | 1,100 | 1,117 | 834 | |

### Effects of the fishery on the ecosystem

Greenland halibut in the area is targeted with longlines only in deep water and on muddy bottom. The gear is light, with low risk of bycatch of birds and marine mammals and with low impact on the seabed.

### Special comments

Until 2020 this stock was considered to be part of the stock in SA 0 + 1 offshore.

ICES DLS Guidance report 2012 p. 19-21 suggests a method to provide advice from the sustainable level catch estimated by the DCAC model. The method uses two senarios and an adaptation period of 3-5 years following a ”fast down” – ”slow up” (catches should decrease to the DCAC value quickly if they are above it and could increase slowly towards it if below) approach taking into account that stocks with a low biomass cannot sustain MSY.

Available data until June 1st indicated a 7.5% reduction in catch in 2020 compared to 2019. Assuming the same degree of catch reduction through the year, the full year catch for 2020 is estimated to be 771 tonnes. SC recommends reducing catches from the 2020 level to the DCAC estimated catch (398 tonnes) by 2023, a decrease of 124 tonnes per year over the next three years. This results in catches of 647 tonnes in 2021 and 522 tonnes in 2022

### Sources of information

SCR Doc. 20/ 003, 006, 020, 038, 043; SCS Doc. 20/012.

**Greenland halibut in Subarea 1 Division 1EF inshore** Advice June 2020 for 2021 – 2022

### Recommendation for 2021 and 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).

### Management objectives

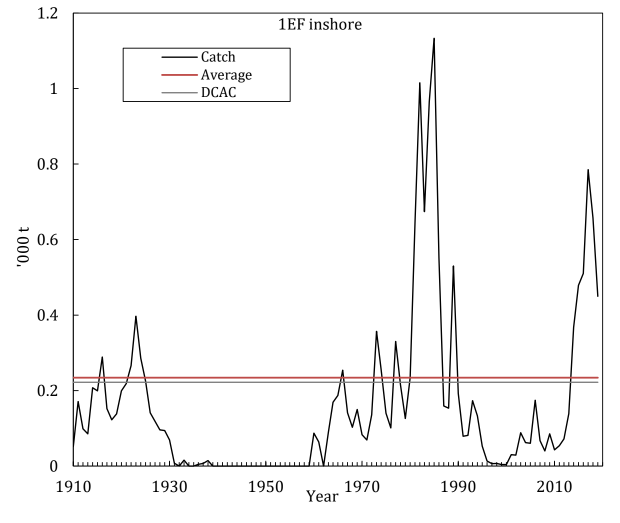
No explicit management plan or management objectives have been defined by the Government of Greenland.

### Management unit

The stocks in the fjords in Division 1EF are believed to recruit from the offshore spawning stock in ICES Subarea 14 (Denmark Strait). There is little migration of adults between the fjords and offshore stocks in SA 0 and 1. The stock is furthermore believed to be constituted of several isolated fjord stocks with little migration between the fjords. Fjords are assigned to a NAFO division based on the location of the mouth of each fjord. Combined catch advice is given for all fjords within the specified management unit.

### Stock status

The catch was at a low level for two decades from the end of the 1980's. Since 2014 the catches have been about 2-3 times higher than the DCAC estimated sustainable level of catch.



### Reference points

The Depletion Corrected Average Catch method was used to estimate a sustainable level of catch.

### Projections

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

### Assessment

The assessment is considered data limited and as such associated with a relatively high uncertainty. The assessment is based upon a catch history from 1910-1930 and 1960 to 2019. During this period the stock has gone through 3 periods of fishery and 2 periods of low catches. There are currently no survey data and commercial data is limited.

The next full assessment is planned for 2022.

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

*Biological and environmental interactions*
No specific studies were reviewed during this assessment.

## Fishery

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 1,000 tonnes per year from 1982 to 1985. From 1990 and the following two decades the average catches were just around 60 t per year, but since 2014 annual catches have been at 400-800 tonnes per year. A TAC has not previously been set for the stocks in Divisions 1B to 1F inshore. The fishery has never been quota regulated.

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

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| **TAC** | | | | | | | | | | |
| **STACFIS** | 54 | 72 | 139 | 368 | 479 | 510 | 785 | 657 | 450 | |

## Effects of the fishery on the ecosystem

Greenland halibut in the area is targeted with longlines only in deep water and on muddy bottom. The gear is light, with low risk of bycatch of birds and marine mammals and with low impact on the seabed. Bycatch of Greenland sharks can be a concern in the area.

## Special comments

Until 2020 this stock was considered to be part of the stock in SA 0 + 1 offshore

ICES DLS Guidance report 2012 p. 19-21 suggest a method to provide advice from the sustainable level catch estimated by the DCAC model. The method uses two scenarios and an adaptation period of 3-5 years following a ”fast down” – ”slow up” (catches should decrease to the DCAC value quickly if they are above it and could increase slowly towards it if below) approach taking into account that stocks with a low biomass cannot sustain MSY.

Available data until June 1st indicated a 50% reduction in catch in 2020 compared to 2019. Assuming the same degree of catch reduction through the year, the full year catch for 2020 is assumed to be 218 tonnes. This is very close to the estimated DCAC value (222 tonnes). If the observed catch in 2020 was substantially higher than this value, then a stepped reduction in catch should be implemented so as to reach 222 tonnes by 2023. Catch in Division 1E is currently far below the most recent 4 seasons, whereas Division 1F is similar to the low 2019 season.

## Sources of information

SCR Doc. 20/006, 020, 038, 043; SCS Doc. 20/012.

**Request by Canada and Denmark (Greenland) for Advice on Management in 2020** ***(Annex 2, Item 3; Annex 3, Item 1)***

Scientific Council responded:

## Greenland halibut in Subarea 0+1 (offshore)

Advice June 2020 for 2021 – 2022

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### Recommendation for 2021 and 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.

### Management objectives

Canada and Greenland adopted a total allowable catch (TAC) of 36 370 t for 2019 and 2020. Canada requests that 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.

| ***Convention objectives*** | ***Status*** | ***Comment/consideration*** |
|---|---|---|
| Apply Precautionary Approach | 🟢 | Stock well above $B_{lim}$ |
| Minimise harmful impacts on living marine resources and ecosystems | 🟡 | Fishing closures are in effect in SA0 and Div. 1A. No specific measures. |

🟢 OK

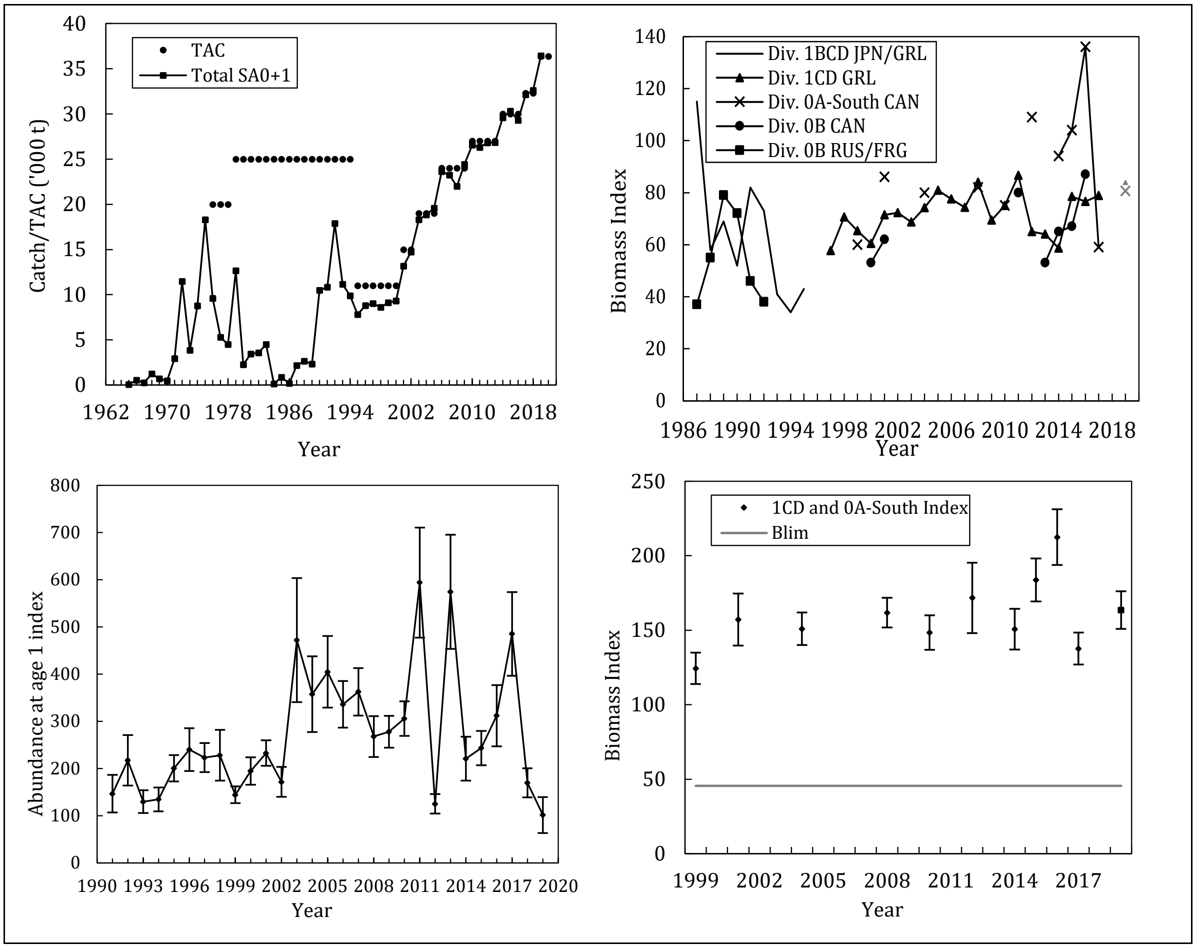
🟡 Intermediate

### Management unit

The Greenland halibut stock in Subarea 0 + 1 (offshore) is part of a larger population complex distributed throughout the Northwest Atlantic. From 2020, separate assessments are made on the inshore management units.

### Stock status

The combined 1CD and 0A-South biomass index has been above $B_{lim}$ throughout the time series, 1999 to 2017. The combined biomass index is not available for 2018, and the 2019 value is not used to assess stock status because its comparability with the earlier time series is questionable. The index of age 1 in the last two years is considerably lower than in previous years, however, there have been high abundances in 2011, 2013 and 2017. It is unclear if the age 1 abundance index is representative of future recruitment but it is considered to contribute to the perception of overall stock status.



## Reference points

Age-based or production models were not available for estimation of precautionary reference points. In 2014 a preliminary proxy for $B_{lim}$ was set as 30% of the mean for the combined 0A-South + 1CD survey biomass index for years 1999 to 2012.

## Assessment

The assessment is qualitative with input from research surveys (total biomass and abundance indices, an index of age 1 fish, and length frequency distributions) and fishery length frequencies.

The next assessment is expected to be in 2022.

*Human impact*

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

*Biology and Environmental interactions*

No specific studies were reviewed during this assessment

## Fishery

Catches were first reported in 1964. Catches increased from 1989 to 1992 due to a new trawl fishery in Div. 0B with participation by Canada, Norway, Russia and Faeroe Islands and an expansion of the Div. 1CD fishery with participation by Japan, Norway and Faeroe Islands. Catch declined from 1992 to 1995 primarily due to a reduction of effort by non-Canadian fleets in Div. 0B. Since 1995 catches have been near the TAC and increasing in step with increases in the TAC, with catches reaching a high of 36 446 tonnes in 2019.

Recent catch and TACs ('000 tonnes)

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| **TAC** | 27 | 27 | 27 | 30 | 30 | 30 | 32.3 | 32.3 | 36.4 | 36.4 |
| **SA 0** | 13.2 | 13.3 | 13.4 | 14.9 | 15.4 | 14.1 | 15.9 | 16.4 | 18.4 | |
| **SA 1** | 13.1 | 13.5 | 13.5 | 14.7 | 14.9 | 15.2 | 16.2 | 16.2 | 18.0 | |
| **Total STACFIS**[1] | 26.3 | 26.8 | 26.9 | 29.6 | 30.3 | 29.3 | 32.1 | 32.6 | 36.4 | |

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

### Effects of the fishery on the ecosystem

No specific information available. General impacts of bottom trawl gear on the ecosystem should be considered.

### Basis for Advice

A quantitative assessment of risk at various catch options is not possible for this stock; therefore, it is not possible to quantitatively evaluate the sustainability of the TAC. There was no biomass index available for 2018 and there is uncertainty in the comparability of the 2019 estimate, therefore, the ICES Harvest Control Rule 3.2 for data limited stocks was not applied. TAC advice in 2020 is based on a qualitative review of available data.

### Special comments

The research vessel that had been used to conduct 0A-South and 1CD surveys from 1997 to 2017 was retired and there was no survey in 2018. A survey was conducted in 2019 with a commercial vessel, however, data reviewed suggest the change in vessel had an effect on the catchability at depths > 700 m, where Greenland halibut are known to be abundant. In addition the earlier timing of the 0A-South survey in 2019 likely resulted in an unknown portion of the stock being beyond the survey area. As a result the comparability between 2019 and previous surveys is questionable and the results were not recommended for use in the 2020 assessment.

Although the survey used to provide the age 1 abundance index also experienced vessel changes in 2018 and 2019, the results are considered to be comparable with those from earlier years.

### Sources of information

SCR 20/06, 07, 12, 15, 18, 19, 32, 34, 37; SCS Doc. 20/10, 12, 13)

### 2020 Canadian Request:

*Canada again encourages the Scientific Council to continue exploring opportunities to develop risk-based advice, including the implications of catch differing from the TAC (e.g. +/- 5-15%) on the stock's long-term trajectory.*

Response: A quantitative assessment of risk at various catch options is not possible for this data limited stock that is assessed using a qualitative assessment of biomass and abundance indices. Whereas differences of up to 5% are unlikely to pose a risk to the stock at this time, systematic exceedances of the TAC may not be sustainable in the medium to long term.

### 2020 Denmark (Greenland) Request for advice:

*The Scientific Council is requested to consider the possibility for providing a separate advice for 1 B-1 F inshore.*

Response: Scientific Council reviewed data on Greenland halibut tagging research, parasitology and historical catches by month for fjord areas within Divisions 1B-F. Offshore movement appears to be limited and linked primarily to areas in the Denmark Strait. In addition, these inshore fjord fisheries have undergone cycles in catch levels on the scale of 1 to 2 decades, suggesting local depletion of offshore recruitment in sink, or primarily sink stocks. Scientific Council concluded that advice could be provided for these inshore stock components, separate from the larger Subarea 0 and 1 offshore stock component. Advice for divisions 1B-1F inshore is given in section VII.2.a.

## 3. Scientific Council Advice of its own accord

### a) Witch flounder in Divisions 3NO

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**Recommendation 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.

**Management objectives**

The Commission adopted a total allowable catch (TAC) of 1 175 tonnes for 2020 and 2021. Convention General Principles are applied.

| ***Convention General Principles*** | ***Status*** | ***Comment/consideration*** |
|---|---|---|
| Restore to or maintain at $B_{msy}$ | 🔴 | Probability of $B_{2020} < B_{msy} = 97\%$ |
| Eliminate overfishing | 🟢 | $F < F_{msy}$ |
| 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 |

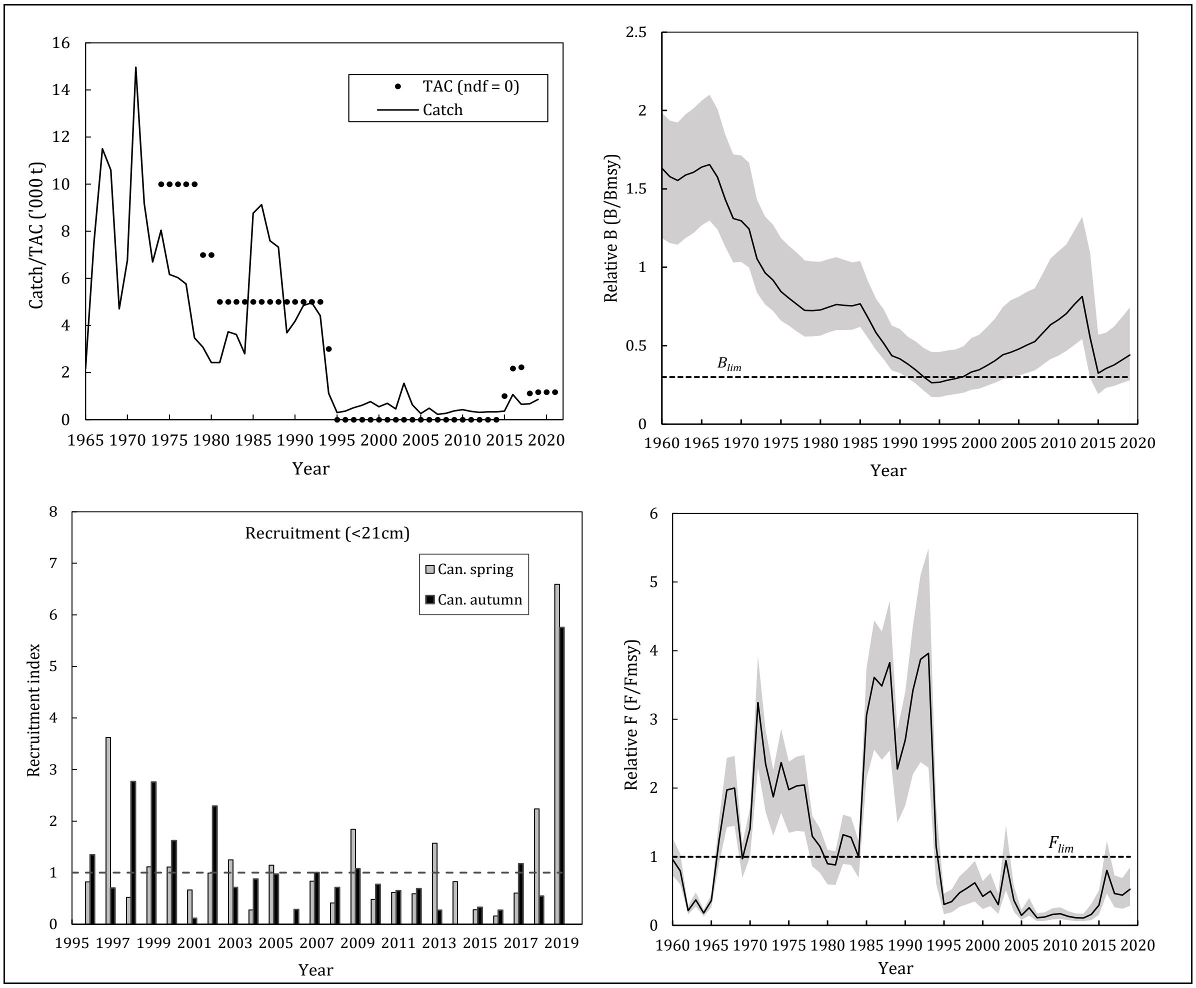
| | |
|---|---|
| 🟢 | OK |
| 🟡 | Intermediate |
| 🔴 | Not accomplished |
| ⚪ | Unknown |

**Management unit**

The management unit is NAFO Divisions 3NO. The stock mainly occurs 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, a higher percentage may be distributed in shallower water.

**Stock status**

The stock size increased from 1994 to 2013, then declined during 2013-2015 and has since increased slightly. In 2020 the stock is at 44% $B_{msy}$ (59 880 tonnes). There is 14% risk of the stock being below $B_{lim}$ and a 4% risk of $F$ being above $F_{lim}$ ($F_{msy}$=0.063). With the exception of the growth of the stock following improved recruitment in the late 1990s, it is unclear if the recruitment index is representative. Nevertheless, the recruitment index in 2019 is the highest in the time series.



## Reference points

Reference points are estimated from the surplus production model. Scientific Council considers that 30% $B_{msy}$ is a suitable biomass limit reference point ($B_{lim}$) and $F_{msy}$ a suitable fishing mortality limit reference point for stocks where a production model is used.

## Projections and risk analyses.

The probability of *F* exceeding $F_{lim}$ in 2020 is 16% at a catch of 1 175 tonnes (TAC 2020). The probability of *F* being above $F_{lim}$ ranged from 2% to 50% for the catch scenarios tested. The population is projected to grow under all scenarios and the probability that the biomass in 2023 is greater than the biomass in 2020 is greater than 60% in all scenarios. The population is projected to remain below $B_{msy}$ through to the beginning of 2023 for all levels of *F* examined with a probability of greater than 88%. The probability of projected biomass being below $B_{lim}$ by 2023 was 7% to 11% in all catch scenarios examined and was 4% by 2023 in the *F*=0 scenario.

A second set of projections assuming that the catch in both 2020 and 2021 was equal to the adopted TAC (1 175 tonnes) was also conducted. The probability of projected biomass being below $B_{lim}$ by 2023 was 8% to 10% in all catch scenarios examined and was 7% by 2023 in the *F*=0 scenario.

Projected yield (tonnes) and the risk of $F > F_{lim}$, $B<B_{lim}$ and $B<B_{msy}$ and probability of stock growth ($B_{2023}>B_{2020}$) under projected F values of $F$=0, $F_{2019}$, 2/3 $F_{msy}$, 85% $F_{msy}$, and $F_{msy}$, and two levels of catch (800 tonnes and 1 175 tonnes), for the two sets of projections, are presented in the following tables.

**Projections with catch in 2020 = TAC (1 175 t)**

| Year | Yield (t) median | Projected relative Biomass($B/B_{msy}$) median (80% CL) |
|---|---|---|
| *F0* | | |
| 2021 | 0 | 0.49 ( 0.30, 0.89) |
| 2022 | 0 | 0.53 ( 0.32, 0.97) |
| 2023 | | 0.58 ( 0.35, 1.06) |
| *Catch 800 t* | | |
| 2021 | 800 | 0.49 ( 0.30, 0.90) |
| 2022 | 800 | 0.52 ( 0.31, 0.97) |
| 2023 | | 0.54 ( 0.31, 1.03) |
| $F_{2019}$ = 0.033 | | |
| 2021 | 957 | 0.49 ( 0.30, 0.89) |
| 2022 | 1011 | 0.52 ( 0.31, 0.96) |
| 2023 | | 0.55 ( 0.32, 1.03) |
| *Catch 1 175t* | | |
| 2021 | 1175 | 0.49 ( 0.30, 0.90) |
| 2022 | 1175 | 0.52 ( 0.31, 0.97) |
| 2023 | | 0.54 ( 0.31, 1.03) |
| 2/3 $F_{msy}$ = 0.042 | | |
| 2021 | 1212 | 0.49 ( 0.29, 0.89) |
| 2022 | 1281 | 0.51 ( 0.30, 0.96) |
| 2023 | | 0.54 ( 0.31, 1.02) |
| 85% $F_{msy}$ =0.054 | | |
| 2021 | 1554 | 0.49 ( 0.30, 0.89) |
| 2022 | 1615 | 0.51 ( 0.30, 0.95) |
| 2023 | | 0.53 ( 0.30, 1.01) |
| $F_{msy}$ =0.063 | | |
| 2021 | 1823 | 0.49 ( 0.30, 0.88) |
| 2022 | 1879 | 0.50 ( 0.29, 0.94) |
| 2023 | | 0.52 ( 0.29, 0.99) |

**Projections with catch in 2020 and 2021 = TAC (1 175t)**

| Year | Yield (t) median | Projected relative Biomass($B/B_{msy}$) median (80% CL) |
|---|---|---|
| *F0* | | |
| 2021 | 1175 | 0.49 ( 0.30, 0.89) |
| 2022 | 0 | 0.52 ( 0.31, 0.96) |
| 2023 | | 0.56 ( 0.33, 1.05) |
| *Catch 800 t* | | |
| 2021 | 1175 | 0.49 ( 0.30, 0.89) |
| 2022 | 800 | 0.52 ( 0.31, 0.96) |
| 2023 | | 0.56 ( 0.33, 1.04) |
| $F_{2019}$ = 0.033 | | |
| 2021 | 1175 | 0.49 ( 0.30, 0.89) |
| 2022 | 1006 | 0.52 ( 0.31, 0.96) |
| 2023 | | 0.55 ( 0.32, 1.03) |
| *Catch 1 175t* | | |
| 2021 | 1175 | 0.49 ( 0.30, 0.90) |
| 2022 | 1175 | 0.52 ( 0.31, 0.97) |
| 2023 | | 0.54 ( 0.31, 1.03) |
| 2/3 $F_{msy}$ = 0.042 | | |
| 2021 | 1175 | 0.49 ( 0.30, 0.89) |
| 2022 | 1285 | 0.52 ( 0.31, 0.96) |
| 2023 | | 0.54 ( 0.31, 1.02) |
| 85% $F_{msy}$ =0.054 | | |
| 2021 | 1175 | 0.49 ( 0.30, 0.89) |
| 2022 | 1638 | 0.52 ( 0.31, 0.96) |
| 2023 | | 0.54 ( 0.31, 1.01) |
| $F_{msy}$ =0.063 | | |
| 2021 | 1175 | 0.49 ( 0.30, 0.89) |
| 2022 | 1928 | 0.52 ( 0.31, 0.96) |
| 2023 | | 0.53 ( 0.30, 1.01) |

| Catch 2020=1 175 t | Yield (t) | | $P(F>F_{lim})$ | | $P(B<B_{lim})$ | | | $P(B<B_{msy})$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2023 | 2021 | 2022 | 2023 | $P(B_{2023}>B_{2020})$ |
| F0 | 0 | 0 | 0% | 0% | 11% | 7% | 4% | 93% | 91% | 88% | 74% |
| Catch $_{2021}$ & Catch$_{2022}$=800t | 800 | 800 | 2% | 2% | 11% | 9% | 7% | 93% | 91% | 89% | 68% |
| $F_{2019}$ = 0.033 | 957 | 1011 | 6% | 7% | 11% | 9% | 8% | 93% | 91% | 89% | 67% |
| Catch $_{2021}$ & Catch$_{2022}$= 1 175t | 1175 | 1175 | 15% | 13% | 11% | 9% | 8% | 93% | 91% | 89% | 65% |
| 2/3 $F_{msy}$ = 0.042 | 1212 | 1281 | 17% | 18% | 11% | 10% | 9% | 93% | 91% | 89% | 66% |
| 85% $F_{msy}$ =0.054 | 1554 | 1615 | 35% | 36% | 11% | 10% | 10% | 93% | 91% | 90% | 63% |
| $F_{msy}$=0.063 | 1823 | 1879 | 50% | 50% | 11% | 11% | 11% | 93% | 92% | 90% | 61% |

| Catch2020 and 2021= 1 175 t | Yield (t) | | $P(F>F_{lim})$ | | $P(B<B_{lim})$ | | | $P(B<B_{msy})$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2023 | 2021 | 2022 | 2023 | $P(B_{2023}>B_{2020})$ |
| F0 | 1175 | 0 | 15% | 0% | 11% | 9% | 7% | 93% | 91% | 88% | 70% |
| Catch$_{2022}$=800t | 1175 | 800 | 15% | 2% | 11% | 9% | 8% | 93% | 91% | 89% | 67% |
| $F_{2019}$ = 0.033 | 1175 | 1006 | 15% | 7% | 11% | 9% | 8% | 93% | 91% | 89% | 66% |
| Catch$_{2021}$ & Catch$_{2022}$= 1 175t | 1175 | 1175 | 15% | 13% | 11% | 9% | 8% | 93% | 91% | 89% | 65% |
| 2/3 $F_{msy}$ = 0.042 | 1175 | 1285 | 15% | 18% | 11% | 9% | 9% | 93% | 91% | 89% | 65% |
| 85% $F_{msy}$ =0.054 | 1175 | 1638 | 15% | 36% | 11% | 9% | 9% | 93% | 91% | 89% | 64% |
| $F_{msy}$=0.063 | 1175 | 1928 | 15% | 50% | 11% | 9% | 10% | 93% | 91% | 90% | 63% |

**Assessment**

This stock is assessed utilizing a surplus production model in a Bayesian framework. Full assessments were conducted in 2017, 2018 and 2019. Due to workload issues and the schedule of stocks assessed on a multi-year basis, which would create considerable difficulties for assessing the stock in 2021, a full assessment was conducted in 2020 by SC of its own accord.

The input data were catch from 1960-2019, the Canadian spring survey series from 1984-1990, the Canadian spring survey series from 1991-2019 (no 2006) and the Canadian autumn survey series from 1990-2019 (no 2014).

The next assessment is planned for 2022.

*Human impact*

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

*Biological and environmental interactions*

Witch flounder in NAFO Divs. 3NO are distributed mainly along the tail and southwestern slopes of the Grand Bank. The Southern Grand Bank (3NO) EPU is currently experiencing low productivity conditions and biomass has declined across multiple trophic levels and stocks since 2014.

**Fishery**

The fishery was reopened to directed fishing in 2015 and is exploited by otter trawl. Prior to the reopening, witch flounder were caught primarily as bycatch in bottom otter trawl fisheries for yellowtail flounder, redfish, skate and Greenland halibut.

Recent catch estimates and TACs (‘000 tonnes) are:

| | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **2018** | **2019** | **2020** |
|---|---|---|---|---|---|---|---|---|---|---|
| **TAC** | ndf | ndf | ndf | ndf | 1.0 | 2.2 | 2.2 | 1.1 | 1.2 | 1.2 |
| **STATLANT 21** | 0.4 | 0.3 | 0.3 | 0.3 | 0.4 | 1.0 | 0.6 | 0.6 | 0.9 | |
| **STACFIS** | 0.4 | 0.3 | 0.3 | 0.3 | 0.4 | 1.1 | 0.7 | 0.7 | 0.9 | |

ndf = no directed fishery.

**Effects of the fishery on the ecosystem**

No specific information available. General impacts of bottom trawl gear on the ecosystem should be considered.

**Special comments**

**Sources of Information**

SCR 20/002, 20/009, 20/046; SCS 20/06, 20/07, 20/09, 20/11, 20/13

## VIII. REVIEW OF FUTURE MEETINGS ARRANGEMENTS

### 1. Scientific Council (in conjunction with NIPAG) September 2020 (date to be determined)

Scientific Council (in conjunction with NIPAG) will meet by WebEx in September, before the Annual Meeting, to update the assessment of 3M shrimp and provide advice for 2021. The meeting will last 1 day and will likely take place on either September 11 or September 14, subject to confirmation. For 3LNO shrimp, SC provided advice in 2019 for both 2020 and 2021 (SCS Doc. 19/21).

### 2. Scientific Council, September 2020

Regular September meeting:

The Scientific Council September 2020 meeting is scheduled to be held in Halifax, Nova Scotia, Canada, from 21 to 25 September 2020. Due to the ongoing COVID-19 pandemic, it is possible that this meeting may be held by correspondence.

Extra September meeting (by correspondence):

SC plans to hold an additional meeting, by correspondence, during September 15-17, aiming to address some of the requests deferred from the June meeting. However, SC noted that changes might still occur, e.g. depending on potential feedback that might be received from the Commission

Details of the SC plan of work for September are described in Section XI.

### 3. Scientific Council (in conjunction with NIPAG), 27 October to 2 November 2020

The Scientific Council shrimp advice meeting will be held from 27 October to 2 November 2020, venue to be determined.

### 4. WG-ESA, 19- 28 November, 2020

The Working Group on Ecosystem Science and Assessment (WG-ESA) will meet at the NAFO Secretariat, Nova Scotia, Canada, from 17 to 26 November 2020.

### 5. Scientific Council, June 2021

Scientific Council June 2020 meeting will be held in Halifax. Nova Scotia, Canada from 28 May to 10 June 2021,

### 6. Scientific Council (in conjunction with NIPAG), 2021

Dates and location to be determined.

### 7. Scientific Council, September 2021

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.

### 8. NAFO/ICES Joint Groups

#### a) NIPAG, 27 October to 2 November 2020

The joint NAFO/ICES *Pandalus* Assessment Group meeting will be held will be held from 27 October to 2 November 2020, venue to be determined.

#### NIPAG, 2021

Dates and location to be determined.

#### ICES – NAFO Working Group on Deep-water Ecosystem, 2021

Dates and location to be determined.

#### WG-HARP

The date and location of the next ICES/NAFO/NAMMCO Working Group on Harp and Hooded Seals (WGHARP) meeting are unknown.

### 9. Commission- Scientific Council Joint Working Groups

### a) WG-RBMS August 2020

The joint SC-Commission Working Group on Risk Based Management Systems (WG-RBMS) will be held by correspondence on 20-21 August 2020.

### WG-EAFFM August 2020

The joint SC-Commission Working Group on the Ecosystem approach to Fisheries Management (WG-EAFFM) will be held by correspondence on 17-19 August 2020.

SC noted that, following the withdrawal of the UK from the European Union, Andy Kenny is not presently able to serve as co-Chair for this group, given that the UK is not a Contracting Party of NAFO at this point. As an interim measure, it was agreed that the SC Chair will act as WG-EAFFM co-Chair for this meeting only.

### CESAG

The next meeting of the Catch Estimation Strategy Advisory Group (CESAG) will be in February 2021 via WebEx.

## IX. ARRANGEMENTS FOR SPECIAL SESSIONS

### 1. Topics of Future Special Sessions

The following proposal for a symposium in 2021, was presented to SC by the STACFEN Chair. The idea would be to offer sponsorship as well as participation in the organization of the event, if possible and if this was agreeable to ICES. SC expressed support for this proposal and endorsed the recommendation made by STACFEN in this regard (see Section III of this report).

**Proposal:**

**Subject**

Budget availability to co-sponsor a symposium on STACFEN-oceanography at 2021

**Background**

STACFEN has organized or co-organized a symposium every 10 years, focused on the significant environmental changes on a decade scale. The link https://www.nafo.int/Science/Research/Conferences allows viewing the history of NAFO symposia. In 2002 a symposium regarding decadal oceanographic conditions in the NAFO Convention Area was organized: https://www.nafo.int/Science/Conferences/mini-symposium-on-hydrographic-variability-in-nafo-waters-june-2002 whereas in 2011 the following symposium was organized jointly with ICES http://www.ieo-santander.net/ices-symposium2011/conference_abstracts.php

Following the same time scale, another symposium should occur in 2021. ICES is again organizing a Symposium with focus on Decadal Hydro-Biological Variability of the North Atlantic for the decade 2010-2019, to be held in Bergen-Norway in October 2021. This brings the possibility of mirroring the joint NAFO/ICES structure of 2011.

**Symposium description**

The ICES Symposium will be the 4th one of an ICES series and will contribute to the recently promoted United Nations Decade of Ocean Science for Sustainable Development (2021-2030). It will summarize the status at the beginning of the decade and looking forward into the coming decade. In general, the main challenge will be to summarize and explain the hydro-biological variability observed during the decade of 2010-2019 in relation to longer time variability or change, and to quantify the interactions between the variability and change in the ocean environment with variability in plankton, fish, mammals and seabirds in the North Atlantic marine ecosystems. The symposium will be organized in three thematic sessions: Development of ocean climate; Impacts of climate variability on marine ecosystems; and The coming decade.

**Benefits for the NAFO community**

The joint organization brings added value for the knowledge of decadal oceanographic variations in the NAFO area integrated into the North Atlantic region. One of the direct advantages is to promote evaluation of the oceanographic changes in the wider spatial context of the North Atlantic. The participation of NAFO researchers in the organizing committee will promote a wider interplay between different scientific approaches relevant to NAFO-STACFEN. Furthermore, contributions from participants may generate new insights and discussion within STACFEN regarding the integration of environmental information into the stock assessment process. The co-sponsorship may allow a discount on the registration fees for some NAFO participants.

If the SC considers that a presentation of work bringing up-to-date climate information in the main NAFO stock areas to the Commission at their annual September meeting in 2021 would be relevant, then the work developed for the above-cited symposium would form the basis of that presentation.

**Amount requested**

Ten thousand (10 000) Canadian dollars is the approximate value to co-sponsor a symposium.

## X. MEETING REPORTS

### 1. Working Group on Ecosystem Science and Assessment (WG-ESA) - SCS Doc. 18/23

The report of the meeting of the Working Group on Ecosystem Science and Assessment (WG-ESA) held 19-28 November 2019 in Dartmouth, Nova Scotia was presented by its co-Chairs Pierre Pepin (Canada) and Andrew Kenny (formerly EU).

### 2. ICES/NAFO/NAMMCO Working Group on Harp and Hooded Seals (WGHARP)

The report of the 2019 meeting is available and main findings will be presented to SC in September.

## XI. REVIEW OF SCIENTIFIC COUNCIL WORKING PROCEDURES/PROTOCOL

### a) General plan of work for September:

A brief discussion took place at the end of the June SC meeting, in which SC concluded that it would be appropriate to schedule an extra 3-day meeting in September, by correspondence, in the week immediately prior to the NAFO Commission Annual Meeting. The extra meeting would aim to provide responses to some of the requests that could not be addressed in June.

The table below contains the plan of work agreed by SC, albeit noting that changes might still occur, e.g. depending on potential feedback that might be received from the Commission.

Points of note:

- "September (extra)" means extra SC meeting, to be held by correspondence on September 15-17; results would be available for presentation to the Commission at the Annual Meeting.
- "September (regular)" means regular SC September meeting (September 21-25); results would not be available for presentation to the Commission at the Annual Meeting.
- The work marked as "September (extra)" should be conducted intersessionally and presented in the September (extra) meeting. To make efficient use of this extra but short meeting (lasting only 3 days), SC agreed that the work should be presented in very advanced form, including, whenever possible, already a first draft of the SC response. SC identified teams of scientists to lead the work on each of these requests, but also agreed that no substantial additional amount of work would be expected from anyone between June and September. Therefore, the requests in the table will be addressed based on the material currently available plus, potentially, a small amount of additional development that the scientists involved may be able to undertake before September.
- This plan will be communicated in a letter to the Commission, for their information and potential feedback.

| REQUEST NUMBER | SC RESPONSE SCHEDULED FOR: | NOTES: |
|---|---|---|
| 4 (Discard survival) | September (extra) | A draft SC response has already been prepared. It is available on SharePoint (Working Folders ➔ 4_COMReq). No further work required for September. |
| 18 (Sea mammals, turtles, birds) | September (extra) | A simple response will be prepared, similar to WGESA's approach (2019 report) for sea mammals and turtles |
| 13 (Alfonsino survey) | September (extra) | SCR 20-036 and presentation are already available on SharePoint. The SC response needs to be prepared. |
| 14 (assessments cod and witch 2J3KL & Pelagic S. mentella ICES) | September (extra) | Some background materials are available on SharePoint (Working Folders ➔ 14_COMReq). Background materials must be completed.<br>Reasonably in-depth presentations of the assessments and advice should be provided for SC's consideration and a summary response prepared by SC. |
| 9 (Areas and times with high bycatch and discards of Greenland shark) | September (extra) | SC will aim to conduct some analyses based on recently digitised records and a response needs to be prepared. |
| 10 (3-5 yr workplan) | September (extra & regular) | Needs updating with main items identified for next 3 years |
| 16 (Updates from research on activities other than fishing) | September (extra) | Work has been conducted by WGESA (2019 report). The SC response needs to be prepared. |
| 3 (Excluding scientific trawl surveys from VME closed areas) | September (extra) or June 2021 ?? (flexible) | Work from SC and WGESA is available from earlier years. The work needs to be finalised (in September 2020 or June 2021) |
| | | |
| Items on which SC has to work in September (regular): | | |
| PAF review | Further elaboration of work plan for the next 1-2 years | |
| | | |
| Other outstanding matters from June: | | |
| STACREC report | To be reviewed and adopted in September (regular). | |
| STACPUB report | To be reviewed and adopted in September (regular). | |

## XII. OTHER MATTERS

### 1. A tribute to Vladimir Babayan (10.03.1945 – 10.06.2020)

Scientific Council was informed of the passing of Russian colleague, Vladimir Konstantinovich Babayan a Russian eminent scientist in fisheries science, age 75, on June 10, 2020 in Moscow.

Vladimir was born on March 10, 1945 in Krasnodar, Russia. He graduated from the Moscow State Institute of Electronic Engineering (MIEM) in 1969. In 2002 he defended his thesis: «Methodology improving for total allowable catch (TAC) estimating using the example of Okhotomorkiy pollock».

Vladimir began to work at Russian Federal Research Institute of Fisheries and Oceanography (VNIRO) in 1970. Over 50 years of professional activity Vladimir devoted to improving the methodological and mathematical support for the stock assessment and sustainable use of aquatic living resources. He made a great personal contribution to the development and implementation of a modern sustainable fisheries methodology in Russian fisheries management system.

On the account of V. Babayan more than 80 scientific works of both conceptual and important practical importance, large number of copyright certificates and packages used in the calculation of TAC. His monograph «A Precautionary approach to assessment of total allowable catch» (2000) is a fundamental work in the stock assessment field and made a huge contribution to Russian fisheries science.

The high level of professional competence, excellent knowledge of English and diplomacy allowed to Vladimir to take part at working groups and scientific committees meetings of ICSEAF, ICES, NAFO and the International Commission on Aquatic Bioresources of the Caspian Sea. Many years he was the head of Russian delegation in NAFO Scientific Council meeting. Thanks to extensive knowledge and experience, Vladimir for many years led the Russian Annual Workshop of stock assessment methodology.

Vladimir Babayan was not only an outstanding scientist and leader, but an irreplaceable mentor and friend who could give a valuable advice in any situation. His untimely death is an incalculable loss for relatives and friends, scientists, colleagues and pupil over the world. The bright memory of Vladimir, as a wise, extremely honest and non-indifferent person and a real professional in science, will keep in our hearts forever.

### 2. Budget Items

SC budget will be reviewed intersessionally by the SC Chair and Secretariat for inclusion in the Secretariat's budget paper for the Annual meeting in September 2020. An indicative budget required to co-sponsor a symposium on STACFEN-oceanography in 2021 has been noted in Section IX of this report.

## 3. Designated Experts

The list of Designated Experts can be found below:

### 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 | Antonio Avila de Melo | amelo@ipma.pt |
| Redfish in Div. 3LN | Antonio Avila de Melo | amelo@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 |

## XIII. ADOPTION OF COMMITTEE REPORTS

The limitations of meeting by correspondence implied that the reports of the Standing Committee on Fisheries Environment (STACFEN) and the Standing Committee on Fisheries Science (STACFIS) could only be formally adopted by correspondence, later in the month of June (STACFEN report) or July (STACFIS report). The adopted reports are included as Appendices I and IV, respectively.

The reports of 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 12 June 2020, 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 2 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 14:00 on 12 June 2020.

# XVII. 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 28th May 2020 by correspondence and videoconference to consider environment-related topics and report to it by the Scientific Council. Representatives attended from Canada, Denmark (in respect of Faroe Islands and Greenland), European Union (Estonia, Portugal, Spain), Japan, Russian Federation, Ukraine and US.

## 1. Opening

The Chair opened the meeting by welcoming participants to this June 2020 Meeting of STACFEN.

*The Committee noted the following documents would be reviewed: SCR Doc. 20/017, 20/018, 20/019, 20/020, 20/024, 20/035, 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 it was established by SC a general agenda.*

## 4. Review of Recommendations in 2018

STACFEN **recommends** *consideration of Secretariat support for an invited speaker to address emerging issues and concerns for the NAFO Convention Area during the 2019 STACFEN Meeting.*

STATUS: STACFEN was unable to secure a guest speaker for the June 2020 meeting due to ongoing restriction relating to the COVID-19 pandemic. This recommendation is **reiterated** and STACFEN will endeavor to have an invited speaker next year.

Contributions from past speakers have generated new insights and discussion within the committee regarding the integration of environmental information into the stock assessment process.

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 2019 SCR 20/024

The Marine Environmental Data Section (MEDS) of the Oceans Science Branch of Fisheries and Oceans Canada serves as the Regional Environmental Data Center for NAFO. As part of this role, MEDS provides an annual inventory of environmental data collected in the NAFO Convention Area to the NAFO subcommittee for the environment (STACFEN), including 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 previous calendar year. Reporting includes data and information from NAFO member countries where these are provided to the data center. The data of highest priority are those from the standard sections and stations, as described in NAFO SCR DOC., No. 1, Serial N 1432, 9p. 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 2018 by data type.

***Data observed in NAFO Convention Area in 2019***

| **Data Type** | **Platform Type** | **Counts/Duration** |
|---|---|---|
| Oceanographic profiles | Autonomous drifting (Argo) | 4348* profiles from 184 platforms |
| | Moorings (Viking) | 1151* profiles from 6 platforms** |
| | Gliders | 3038* profiles from 11 platforms |
| | Ship | 3226 profiles (826 CTD; 1830 CTD*; and 570 XBT* profiles) from at least 21 ships |
| Surface/near-surface observations | Ship (thermosalinograph) | 12904* obs. from 1 ship |
| | Drifting buoys | 307473* obs. from 184 buoys |
| | Moored buoys | 242445* obs. from 20 buoys** |
| | Fixed platforms | 60312* 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 2018 in NAFO Convention Area and acquired between January 2019 and May 2020***

| **Data Type** | **Platform Type** | **Counts/Duration** |
|---|---|---|
| Oceanographic profiles | Ship | 8996 profiles (3869 CTD + 1258 bottle + 175 XBT profiles) from 17 ships |

*Data formatted for real-time transmission

## 6. Highlights of Climate and Environmental Conditions by NAFO Sub-Area for 2019

Summary information on recent ocean climate conditions and lower tropic levels was compiled for Sub-area 0+1, Division 3M, Divisions 3LNO and Sub-areas 2, 3 and 4. This information, together with relevant ocean climate and ecosystem indicators is presented in the respective sections of the STACFIS report (Appendix IV).

## 7. Review of the physical, biological and chemical environment in the NAFO Convention Area during 2019

The winter North Atlantic Oscillation (NAO) index is the difference in winter (December, January and February) Sea Level atmospheric Pressures (SLP) between a high SLP region near the Azores and low SLP region near Iceland. It generally considered as a measure of the strength of the winter westerly and northwesterly winds over the Northwest Atlantic. A high (positive phase) NAO index occurs from an intensification of the Icelandic Low and Azores High. This favors strong northwest winds, cold air and sea temperatures and heavy ice conditions on the Newfoundland Shelf regions. Analysis has shown that variability in the NAO can account for a significant portion of the variability in key ocean climate indices, including Labrador Sea convection and the Cold-Intermediate-Layer water mass overlying much of the Newfoundland and Labrador continental Shelf.

### a) Sub-area 1. Report on hydrographic conditions off Southwest Greenland June 2019 (SCR Doc. 20/019).

Hydrographic conditions were monitored at 8 hydrographic standard sections in June 2019 across the continental shelf off West Greenland. The northernmost section was not occupied due to technical problems. 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.

### Sub-area 1. Hydrographic conditions off West Greenland in 2019 (SCR Doc. 20/018).

An overview of the atmospheric and hydrographic conditions off West Greenland in autumn 2019 is presented. In winter 2018/2019, the NAO index was positive (2.09) for the sixth consecutive winter. The annual mean air temperature at Nuuk Weather Station in West Greenland was 0.4°C in 2019, which was 1.8°C above the long-term mean (1981-2010). The core properties of the water masses of the West Greenland Current 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 Fyllas Bank Section had to be abandoned due to severe weather conditions in autumn 2019. The properties of the Irminger Sea Water are monitored in the 75-200 m layer at Cape Desolation Station 3. In 2019, the water temperature and the salinity in the 75-200 m layer at this station were 5.98°C and 34.92, which was 0.26°C above and 0.01 below the long-term mean, respectively. The properties of the North Atlantic Deep Water (NADW) in the Deep Boundary Current west of Greenland are monitored at 2000 m depth at Cape Desolation Station 3. In 2019, the temperature and salinity of the NADW were 3.11°C and 34.92 and were 0.22°C and 0.01 above the long-term mean, respectively.

### Sub-areas 1 and 2. Meteorological, Sea Ice, and Physical Oceanographic Conditions in the Labrador Sea during 2019 (SCR Doc. 20/037)

The winter (December-March) NAO index in 2019 was above-normal. However, a low atmospheric pressure anomaly in the Labrador Sea in winter resulted in above-normal air temperatures, while sea surface temperatures were near-normal in winter and above-normal in spring. Sea ice extent anomalies in winter and spring were generally negative, except for a near-normal winter anomaly on the central Labrador Shelf. In the Labrador Sea, intense vertical mixing induced by high surface heat losses in winter results in the formation of a characteristic dense water mass, Labrador Sea Water, which consequently spreads across the ocean ventilating its deep layers and essentially driving the global ocean overturning circulation. The most remarkable event in the entire history of oceanographic observations in the North Atlantic was the production of a record cold dense deep gas-saturated voluminous class of Labrador Sea Water between the late 1980s and mid-1990s. Over about 20 years that followed this well-documented water mass development, the sea was gradually warming gaining more saline and less dense waters. In the winter of 2015, the Labrador Sea incurred the highest heat loss in more than two decades. However, the four following winters showed a significant reduction in the respective net surface heat losses, remaining above-normal in 2016 and 2017, and then declining to near-normal in 2018 and 2019. Despite the persistent decline in the surface cooling since 2015, the water column preconditioned by deep convection in the previous winters eased further deepening of convective mixing in the subsequent winters. As a result, in the period from 2014 to 2018, winter convection progressively deepened from 1600 to 2000 m, respectively, becoming the deepest since the winter of 1994 which in turn was the deepest (2500 m) convection on the 80-year record. In turn, the Labrador Sea Water formed by the convective mixing that deepened in each of the five winters preceding 2019 was the largest since the mid-1990s. If in the winter of 2018, convection continued to deepen despite a near-normal surface heat loss in the same winter, in the winter that followed, a comparable heat loss brought much weaker convection, reversing the multiyear trend in convection depth and implying that the effect of preconditioning of the water column by previous convections declined in the present case. Indeed, the temperature and salinity profiles collected by research vessels and profiling Argo floats in the central Labrador Sea indicate that the 2019 winter convection was shallower than in the previous five years. It reached the depth of about 1400 m in the western part of the Labrador Basin, and only about 1000 m in the central and eastern parts based on the 2019 ship survey section plots and individual Argo float profiles. Composite salinity profiles indicate the depth of winter convection on the order of 1200-1300 m. The near-normal winter convection in the winter of 2019 further added to gas (dissolved oxygen, anthropogenic gases, and carbon dioxide) uptake and consequently respective gas concentrations in the Labrador Sea in the upper 1000 m layer, while the deeper layer shows a decrease. In 2018, the upper, 15-100 m, layer of the central Labrador Sea steadily cooling since 2010 was the coldest since 2000. In the following year, this layer warmed by 0.5°C raising its temperature to above-normal. In 2011, the intermediate, 200-2000 m, layer reached its warmest state since 1972, and then started to cool. The cooling of this intermediate layer that followed was a direct result of persistently deepening convection during the winters from 2012 through 2018. The warming of the upper and intermediate layers of the Labrador Sea in the following year concurs with the reduced heat loss and shallow convection in the winter of 2019. With respect to interdecadal variability, the Labrador Sea completed a cooling cycle, 2012-2018, similar to those observed during 1987-1994 and in the late 1950s. Each of these cooling events coincided with the strengthening of winter convection and production of large volumes of Labrador Sea Water. Bedford Institute of Oceanography North Atlantic model simulations suggests that the transport of the Labrador Current decreased between 1995 and 2014, but has since increased slightly. A weakening trend of the Atlantic Meridional Overturning Circulation (AMOC) since the mid-1990s is obtained in this model hindcast. Continuing weakening of the AMOC in recent years led to the weakest AMOC since 1990.

### Sub-areas 2, 3 and 4. Environmental and Physical Oceanographic Conditions on the Eastern Canadian shelves during 2019 (SCR Doc. 20/020).

Oceanographic and meteorological observations in NAFO Sub-areas 2, 3 and 4 during 2019 are presented and referenced to their long-term (1981-2010) 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 6th consecutive year (since 2012, only 2013 was negative). The air temperatures across the NW Atlantic were warm in the Arctic, between normal and colder than normal on the Newfoundland and Labrador and Scotian Shelf, and warmer than normal in Boston on the coast of the Gulf of Maine. The sea ice volume across the Newfoundland and Labrador shelf was slightly below normal, characterized by a large negative anomaly in March-April, which also led to an early retreat on Newfoundland shelf. Annual sea surface temperature across the NAFO subareas 2, 3 and 4 was below normal overall for the zone for the first time since 1992, yet they would have been near normal if not for tropical storm Dorian that mixed heat deep into the water column. Observations from the summer Atlantic Zone Off-Shelf Monitoring Program oceanographic survey indicate that after a predominance of colder than average conditions since 2012, the volume of the cold intermediate layer (CIL, <0°C) reduced along Bonavista and Flemish Cap section in 2019 (CIL along Seal Island section was normal this year but was reduced in 2018). The spatially averaged bottom temperature in 3LNOP divisions during the spring was close to normal, except along the slopes of the Grand Banks where it was above normal. For the fall, the bottom temperature in 2HJ3KLNO divisions was also above normal, especially in 2J (+1.1 SD) and 3K (+1.0 SD). Deep water temperatures on the Scotian shelf were very warm: record high in Cabot Strait (nearly 5SD above the climatology) and Emerald Basin, and second warmest year in George Basin. The Labrador Current transport index along the Labrador and northern Newfoundland slope in 2019 was back to normal after the 2018 record high since the beginning of the time series that started in 1993.

### Sub-areas 2, 3, 4 and 5. Biogeochemical oceanographic conditions in the Northwest Atlantic (NAFO subareas 2-3-4) during 2019 (SCR Doc. 20/035).

Biogeochemical variables collected in 2019 from coastal high-frequency monitoring stations and seasonal (spring, summer and fall) sampling of standard oceanographic sections covering the Newfoundland and Labrador (NL) shelves, the Flemish Cap (FC), the Grand Bank (GB), the Southern Newfoundland, the Scotian Shelf (SS) and the Gulf of St. Lawrence (GSL) are presented and referenced to earlier periods when available. We review interannual variations in phytoplankton spring bloom indices as well as nitrate (50-150 m), chlorophyll a (0-100 m), and zooplankton abundance and biomass inventories collected during the 2019 Atlantic Zone Monitoring Program (AZMP). Spring bloom timing and duration were near normal in all regions except on the Newfoundland Shelf and the GB where earlier and longer-than-normal blooms were observed. Bloom magnitude was below normal in all regions, especially in the GSL where spring production reached a record low after several consecutive years of above-normal production. In general, nitrate inventories increased on the NL shelves and the FC in 2019 compared to the previous year but remained low on the GB and the SS. Chlorophyll inventories were mostly above normal on the NL shelves, the GB, and the GSL, and near to below normal on the SS. The abundance of copepod and non-copepod zooplankton were near to above normal in all regions although no data were available for the Labrador Shelf, the GB, and the Southern Newfoundland for this report. Copepod abundance increased from below to near or above-normal levels on the SS in 2019 compared to 2018. The abundance of large *Calanus finmarchicus* copepods was mainly near normal in 2019 which represented an increase compared to the previous year. The abundance of small *Pseudocalanus spp*. copepods was near to above normal in all regions in 2019, continuing an increasing trend observed since 1999. Zooplankton biomass was near to below normal in most regions. The low biomass on the NL shelves and the GB in 2019 contrasted with above normal-levels observed in 2018. However, biomass indices for these regions were calculated on partial datasets and the general pattern for 2019 may change when all data become available.

### Sub-areas 5 and 6. Hydrographic Conditions on the Northeast United States Continental Shelf in 2019 (SCR Doc. 20/017).

An overview is presented of the atmospheric and oceanographic conditions on the Northeast U.S. Continental Shelf during 2019. The analysis utilizes hydrographic observations collected by the operational oceanography programs of the Northeast Fisheries Science Center (NEFSC), which represents the most comprehensive consistently sampled ongoing environmental record within the region. Overall, 2019 was characterized by warmer than average water temperatures observed across the entire Northeast US Shelf, with enhanced warming observed near the bottom. Extreme warm anomalies observed in the northern Middle Atlantic Bight are linked to warm-core Gulf Stream rings and consistent with observations of increased ring formation since 2010. Deep (slope) waters entering the Gulf of Maine continue to be warmer and saltier than average, marking a full decade that southern source waters have dominated the slope water composition in the region. The Cold Intermediate Layer in the western Gulf of Maine consisted of a narrower band of colder water compared with climatology, while the underlying water mass was warmer and fresher than normal.

## 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 2021 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.

NAFO usually convenes a symposium on environmental issues every 10 years, and as 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 to support participation and possible co-sponsorship*.

Further discussions are encouraged 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), Isabelle Gaboury (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 28 May 2020.

## 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 28 May to 12 June 2020 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 and the United States of America. Observers from the Ecology Action Centre, and Food, 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).

Dr. Hugues Benoît participated as an external reviewer for the work on Greenland halibut in NAFO Subareas 0 and 1.

## II. GENERAL REVIEW

### 1. Review of Recommendations in 2019

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 20-05 (Rev) 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. Following the recommendation from STACFIS in 2018 that CESAG review the Catch Estimation Strategy to consider potential refinements, such as the inclusion of gear type, mesh size, and quarter into the strategy, the Secretariat made changes to the method in order to provide catch estimates of broken down by quarter and gear type. It is not possible to provide catch estimates disaggregated by mesh size at present because this information is not included in daily catch reports or port inspections on which the CESAG estimates are based.

In response to the suggestion of SC members last year, catch data were provided for all species.

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

The invited external reviewer for STACFIS in 2020 was Dr Hugues Benoît from Fisheries and Oceans Canada (Mont-Joli). Following discussions in Scientific Council in consultation with Dr Benoît, it was agreed that the review would focus on two stocks: Greenland halibut in Subareas 0 + 1 (offshore) and Greenland halibut in Subarea 1 (A-F) inshore. The reviews are as follows:

## Greenland halibut (Subarea 0 + 1A (offshore) and 1B-F, June 2020: Reviewer comments by Dr Hugues Benoît.

The text below constitutes a simple summary of comments provided to the assessment leads leading up to and during the assessment meeting as part of a number of interventions.

### Assessment of the offshore stock

The assessment of Greenland halibut (GH) in subareas 0 and 1 is empirical and based principally on bottom-trawl surveys in NAFO area 0 and in area 1 and information from the commercial fishery.

The surveys in 2019 were undertaken by an uncalibrated vessel and took place several weeks earlier than any previous year. The distribution of GH with respect to depth and distance from shore was different from past years and there was evidence that a potentially important portion of the stock was distributed outside the survey area. This, combined with evidence that the characteristics of the trawl while fishing were also different in 2019, led to the decision to exclude the 2019 survey from the assessment, which I fully support. Analyses of past survey data revealed that the seasonal timing of surveys has also varied, albeit to a smaller extent, in the past and appears to have been associated with differences among years in the spatial distribution of GH, likely associated with seasonal shifts in distribution. Given this sensitivity it will be important that the survey be conducted at consistent dates in the future and ideally across the range of depths occupied by GH to best ensure that an interannually consistent portion of the stock is found within the survey areas such that the survey indices remain proportional to abundance.

The assessment presented an index of young fish purported to be a recruitment index. It was pointed out that no evidence had been presented, cited or was otherwise evident in the document that the trends were related to recruitment to larger sizes/older ages. The term 'recruitment index' may therefore be misleading. Furthermore, the calculation of the index was not clear and made reference to the Peterson method, which was not familiar to me and probably others, in this context at least (it is commonly known for the analysis of mark-recapture data). Uncertainty in the estimates was not presented.

Empirical assessments often review trends in biological indicators of stock health other than survey abundance indices, such as changes in survey size composition, size ratios and maturation characteristics. I was surprised to see little mention of these characteristics even though this information is collected. Reviewing this information seems particularly relevant as the fishery appears to select for a non-negligible portion of fish that may not be mature.

Empirical assessments also typically present estimates of relative harvest rate, often as landings over survey biomass. If the survey provides a proportional index of abundance (which this survey has historically been assumed to), trends in harvest rate should reflect trends in fishing mortality. Furthermore, the magnitude of the harvest rate can, in some instances, provide an indicator of whether fishing mortality is sustainable; if survey biomass constitutes a minimum estimate and if harvest rates are low, then fishing mortality is also likely to be low.

The assessment estimates a standardize catch-per-unit-effort (CPUE) time series, although trends in it are not interpreted because it is not considered reliable. If this is the case, then why present it? Other assessment present CPUE as an index of fishery performance rather that abundance, which often serves to facilitate industry buy-in to the assessment process and to promote collaboration with the scientific team. If these considerations are not relevant for this assessment, the relevance of presenting the CPUE should be reassessed. Given that this has been a developing fishery, expertise and technology have likely improved over time rendering it next to impossible to define a consistent unit of effort. How then can one distinguish increasing innovation and increasing stock size in an increasing CPUE? Notwithstanding these considerations, the assessment did not present or mention any validation for the CPUE estimation. Could the effects of the model be considered strictly additive (i.e., no interactions )? Were model assumptions met? Was the design matrix for the vessel effects adequate and reasonably balanced? Violation of one or more of these sorts of things can impact the trend and individual standard errors for the series.

### Knowledge about the dynamics of the Greenland halibut in the fjords in NAFO subarea 1B to 1F inshore to justify treating these as a separate stock from the offshore in 0/1

Most stocks are at least roughly defined from a biological basis to reflect a population, but are often also delineated based on the practicalities of fishery management. The considerations presented at the meeting were almost exclusively biological, implying that maintaining the integrity of population processes was the key motivator for this work. However, it was somewhat difficult to assess the relevance of the different pieces of evidence brought forward because the burden of proof of stock attribution to the offshore versus inshore was neither defined or implied. For example, was it necessary to demonstrate with high probability that the inshore fish have little or association with the offshore? The question is relevant because many of the lines of evidence that were advanced could be interpreted as natal homing despite offshore spawning, and spatial discontinuities in distribution appear largely depth related rather than simply geographical. Furthermore because the tagging data were not analysed with respect to the seasons of deployment and recapture, it was not possible in my view to refute the homing hypothesis. However, if the burden of proof is reversed, or if the level of proof is lessen, then the data presented could be consistent with distinct inshore stocks, perhaps associated with offshore stocks east of Greenland.

A notable element in the working paper is a very pronounced and rapid decline in the size composition of landings in 1CD, and in other areas (if I recall correctly). The causes of these declines can be manifold, but should be of particular concern if they are related to fishing, or if they could impact future fishing opportunities. I recommend that the assessment team undertake an evaluation of the weight of evidence for different hypotheses, which could include an increase in recruitment, a decline in growth, an increase in total mortality (fishing and/or natural), and a change in selectivity and/or availability.

### Assessment of GH in the South West Greenland fjords division 1BC, 1D and 1EF

The assessment was based on the depletion-corrected average catch method (DCAC). I have little expertise in DCAC, other than what I have read generally, but offer the following general comments. Overall I think there are some important inconsistencies with the choice of approach could have been clarified:

- If the assumption that GH in these fjords constitute merely sink populations, as I understood was the proposal, then the concept of sustainable yield that is implied by the DCAC doesn't apply. You cannot recruitment overfish purely sink populations since there is no feedback from stock to recruitment; instead you are dealing with an inventory management problem of optimizing yield with respect to somatic growth, *M* and possible size-dependent market demand (economic yield-per-recruit). DCAC is therefore probably not the best method to provide catch advice.
- The DCAC is dependent on an equilibrium assumption. Possible depletion/collapse of these stocks in the 1990s and 2000s, and recent declines in size composition of catches seems inconsistent with that assumption.
- It appears that there is a fair amount of both fishery dependent and independent data for at least Disko Bay, which begs the question of why those data aren't better utilized.
- I am surprised by the choice of SD values in table 2. M is considered relatively quite uncertain, while it is probably not that badly known (given observed maximum ages for GHL in the subarea an M=0.15 is probably not unreasonable), meanwhile the Fmsy/M ratio is probably equally or less well know yet is considered relatively much more certain. Furthermore, a value of 1 for that ratio is inconsistent with accepted sustainable values, which tend to be <=0.8. Notwithstanding these comments, I didn't see any results that reflected these stochastic values, only deterministic results based on scenarios (Table 3, where I can only assume individual parameter values were altered assuming all the others were at their nominal value).
- I am not sure the following statement in the working paper is correct in general and in the present case: 'The-DCAC advice can to some extent be considered conservative, as the estimated sustainable catch will always be less the average catch for the total timeseries with unregulated fishery'. It will only be conservative if the depletion period is not included in the catch data used to make the estimate (at least based on my understanding of DCAC) and the stock is at equilibrium.

# III. STOCKS ASSESSMENTS

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

### Recent Conditions in Ocean Climate and Lower Trophic Levels

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

### Environmental Overview

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

### Ocean Climate and Ecosystem Indicators

The ocean climate index in Subareas 0-1 has been predominantly above normal or near-normal since the early 2000s, except for 2015 and 2018 that were below and slightly below normal, respectively (Figure A1.A). In 2019, the index was at its highest value since the record high of 2010, and at its thirds highest value since the beginning of the time series in 1985. Before the warm period of the last decade, cold conditions persisted in the early to mid-1990s. The timing of the spring bloom transitioned from later to earlier than normal between 1998 and 2007. Spring bloom timing has shown a general trend of increasingly later initiation since the late 2000s with few exceptions of early timing observed in 2011, 2015, and 2017. The initiation of the spring bloom (Figure A1.B) occurred later than normal for a second consecutive year in 2019. Spring bloom magnitude (Figure A1.C) was mostly near normal between 1998 and 2007. Both below and above normal spring production occurred during that period but no clear pattern was observed. There was a general trend of increasing spring production since the record low in 2007. However, spring bloom magnitude in 2019 was back to below normal with the second-lowest anomaly of the time series. In general, early blooms are associated with high spring production and vice versa (Figure A1.B, A1.C).

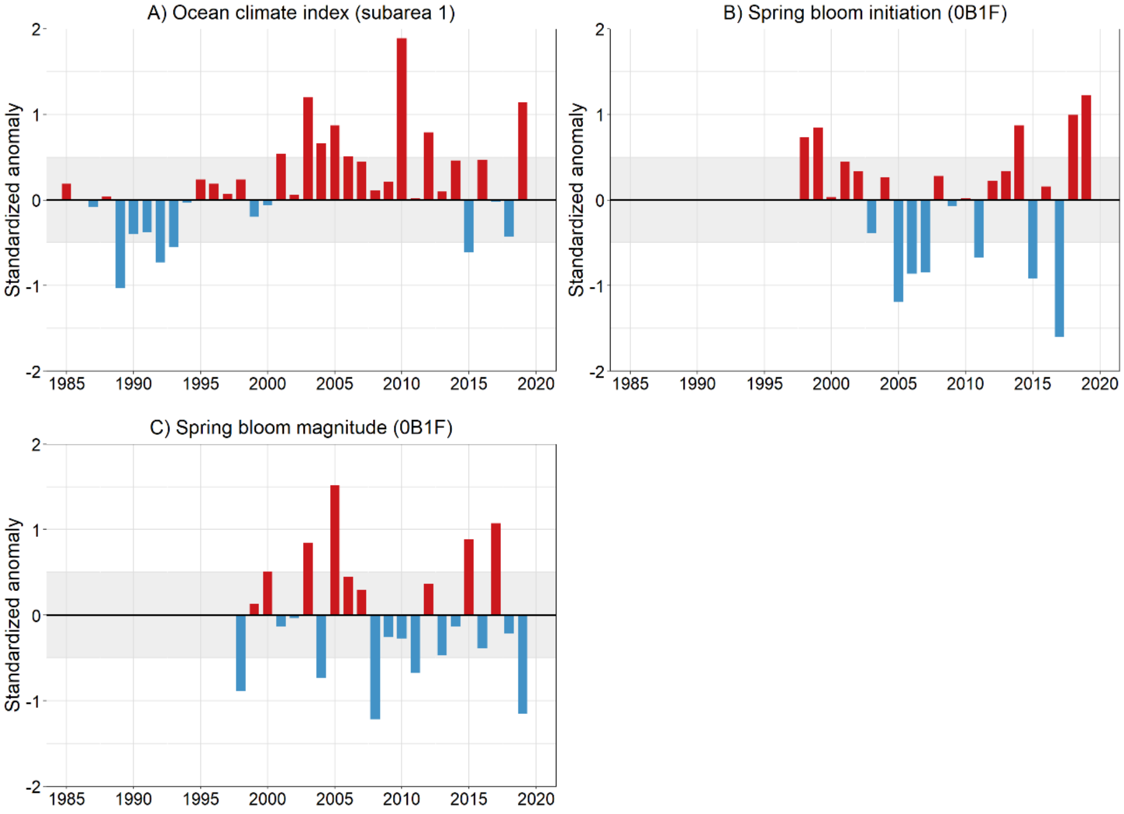


**Figure A1.** Environmental indices for NAFO Subareas 0 and 1 during 1990-2019. The climate index (A) for Subareas 0 and 1 is the average of 7 individual time series of standardized ocean temperature anomalies: sea surface temperatures (SSTs) for West Greenland Shelf, North and Central Labrador Sea and Hudson Strait, vertically average ocean temperature at Fyllas Bank Station 4 (FB-4; 0-50 m) and Cape Desolation Station 3 (CD-3; 75-200 m), as well temperature at 2000 m at CD-3, and air temperatures in Nuuk (Greenland) and Iqaluit (Baffin Island). Geographical boxes used for SSTs are presented in Cyr *et al*. (2019) and air temperature time series are presented in Cyr *et al*. (2020). FB-4 and CD-3 time series are obtained from the ICES Report on Ocean Climate (IROC; https://ocean.ices.dk/iroc/). Phytoplankton spring bloom initiation (B) and magnitude (C) indices for the 1998-2019 period are derived from three satellite boxes located in NAFO Div. 0B (Hudson Strait) and 2H1F (Labrador Sea) and 1F (Greenland Shelf) (see SCR Doc. 20/035 for box location). Positive/negative anomalies indicate above/below (or late/early timing) normal conditions, Anomalies were calculated using the following reference periods: ocean climate index: 1981-2010; spring bloom indices (magnitude and peak timing): 1998-2015. Anomalies within ± 0.5 SD (shaded area) are considered near-normal conditions.

## 1. Greenland halibut (*Reinhardtius hippoglossoides*) in Subarea 0 and 1 (offshore)

(SCR Doc. 20/06, 07, 12, 15, 18, 19, 32, 34, 37; SCS Doc. 20/10, 12, 13)

### a) Introduction

The Greenland halibut stock in Subarea 0 and 1 (offshore) is part of a larger population complex distributed throughout the Northwest Atlantic (Roy et al. 2014). The fishery distribution includes Canadian (SA0) and Greenland (SA1) waters. Canada and Greenland manage the fisheries independently and request advice from NAFO SC. The fishery came under quota regulation in 1976 when a TAC of 20 000 t was established. TAC was increased to 25 000 t in 1979. In 1994 analysis of tagging and other biological information resulted in the creation of separate management areas for inshore Div. 1A. The portion of the TAC allocated to Subarea 0+1A (offshore) and 1B-F was set at 11 000 t and the TAC remained at this level from 1995-2001, during which time the TAC was fished almost exclusively in Div. 0B and Div. 1CD. A series of surveys took place during 1999-2004 in areas of Div. 0A and 1AB that had not been surveyed before resulting in an expansion of the fishery into these northern divisions between 2001 and 2006. In 2020 analysis of tagging and fishery data resulted in the creation of separate management areas for inshore Div. 1B-F.

The assessment is qualitative, and since 2014 has been based on an index of survey biomass that combines Divisions 0A-South and 1CD surveys (ICES 2013). The surveys are conducted by the same vessel and gear during the fall which allows for a combination of the survey results. An index based harvest control rule was accepted as the basis for TAC advice in 2016.

The vessel that conducted surveys from 1997 to 2017 has been retired and a new research vessel is expected to be available in 2021. No survey was conducted in 2018 and a commercial vessel was used for the 2019 survey. This change in vessel has had an effect on gear performance such that the 2019 index is not directly comparable to previous years. Also, earlier timing for the 0A-South survey in 2019 introduced additional uncertainty to the comparability of this index. As a result the use of the previously accepted harvest control rule is compromised and the 2019 assessment and advice are based on a qualitative review of available survey and fisheries data. The absence of a continuous survey series limits the assessment and STACFIS may be unable to evaluate the impact of the advised TAC.

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

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| TAC | 27 | 27 | 27 | 30 | 30 | 30 | 32.3 | 32.3 | 36.4 | 36.4 |
| SA 0 | 13.2 | 13.3 | 13.4 | 14.9 | 15.4 | 14.1 | 15.9 | 16.4 | 18.4 | |
| SA 1 | 13.1 | 13.5 | 13.5 | 14.7 | 14.9 | 15.2 | 16.2 | 16.2 | 18.0 | |
| Total STACFIS[1] | 26.3 | 26.8 | 26.9 | 29.6 | 30.3 | 29.3 | 32.1 | 32.6 | 36.4 | |

[1] Based on STATLANT, with information from Canada and Greenland authorities used to exclude 1A-F and 0B inshore catch.

### *i) Description of the Fishery*

Bottom otter trawl gear is used by most fleets in the Subarea 1 fishery. There have been longline vessels occasionally in the offshore, however gillnet gear is not allowed. The Subarea 0 fishery is a mix of trawl and gillnet (between 30-40% of the catch in recent years) with the occasional use of longline. The trawlers in both Subareas have been using both single and double trawl configurations since about 2000. The gillnet fishery in Subarea 0 began in 2005 and has been using baited gillnets since about 2015. Baiting gillnets has been shown to increase catch rates (Bayse and Grant 2020).

Catches were first reported in 1964 and rose to 20,027 t in 1975 before declining to 2,031 t in 1986. Catches increased from 1989 to 1992 (reaching a level of 17,888 t) due to a new trawl fishery in Div. 0B with participation by Canada, Norway, Russia and Faeroe Islands and an expansion of the 1CD fishery with participation by Japan, Norway and Faeroe Islands. Catch declined from 1992 to 1995 primarily due to a reduction of effort by non-Canadian fleets in Div. 0B. Since 1995 catches have been near the TAC, increasing in step with increases in the TAC, with catches reaching a high of 36,446 t in 2019 (Figure 1.1).

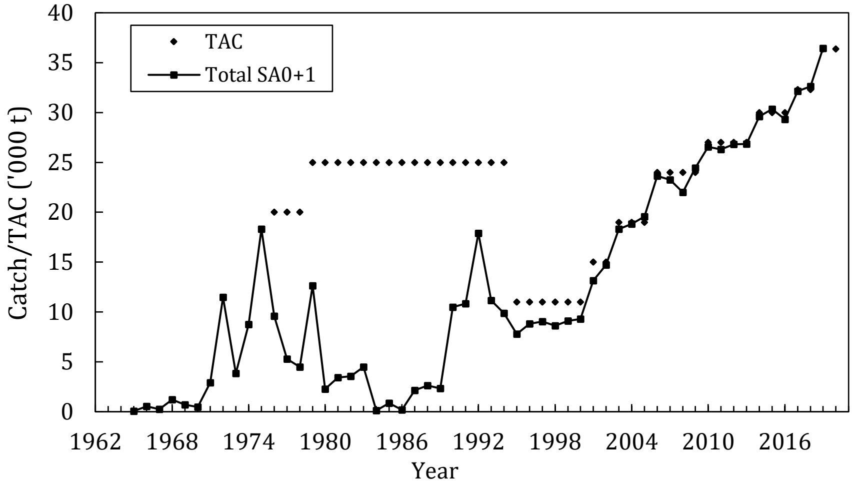


**Figure 1.1.** Greenland halibut in Subarea 0 and 1 (offshore): catches and TACs.

### b) Data Overview

#### *i) Commercial fishery*

In 2019 length frequencies were available from Greenland and Russian Federation trawl fisheries in Div. 1AB, Norway, Greenland, German, and Russian Federation trawl fisheries in Div. 1CD, and from Canadian gillnet and trawl fisheries in Div. 0AB.

The length frequency data have been combined to produce an overview for Baffin Bay (0A+1AB) and Davis Strait (0B and 1CD) portions of the stock area, given these areas have shown differences in size components in both surveys and fisheries. In 0A+1AB fisheries lengths ranged from about 20 cm to 90 cm with a mode fluctuating between 45 cm and 51 cm. In 0B+1CD fisheries lengths ranged from about 30 cm to 100 cm with a mode varying between 45 and 53 cm. Overall the SA0+1 length frequency had a mode that varied between 49 cm and 51 cm, with 51 cm observed since 2015.

Lengths sampled from the longline fishery in Subarea 1 have ranged from about 40 cm to 100 cm with a mode that has been relatively stable around 55 cm. Lengths sampled in the SA0 gillnet fishery have ranged from approximately 40 cm to 90 cm with a mode prior to 2014 of approximately 61 cm that has since varied around 59 cm.

It is not known how the technical development of fishing gear or vessel changes in the fleets have influenced the catch rates, for example, the expansion of the fishery into new grounds in the northern portion of the stock area (0A and 1AB) and the learning that takes place can affect catch rates over time. Also, the SA0 gillnet fishery began baiting gill nets around 2015 and it is currently not possible to identify which sets used bait and which did not. Such changes can influence the estimation of the catch rates, therefore, the standardized catch rates that have been presented in previous assessments are not considered informative and have not been included in the assessment. This does not preclude consideration of new research using CPUE if future assessments find it has value.

#### *ii) Research surveys*

The survey timing was earlier in the season by about 6 weeks and this could have had an effect on distribution of fish available to the surveys in 2019 compared to previous years. Generalized Additive Models (GAMs) were used to examine the abundance relative to depth and distance from shore for the survey time series (Wheeland et al. 2020). There was no indication of a difference in distribution for the 2019 1CD survey that would impact its comparability to the previous time series. However, abundance in the 0A-South survey was highest in the shallowest areas, farthest inshore. Survey biomass in the shallowest strata was significantly greater than in previous years, and fish in these strata were larger in 2019. Greenland halibut distribution is known to extend inshore, with inshore/offshore movements, therefore this analysis suggests an unknown proportion of the stock may have been beyond the 0A-South survey in 2019 and it is not considered comparable.

The effect of the vessel change on the 2019 survey was examined by looking at gear performance parameters, (e.g. net height and door distance) and survey length frequency of fish 35-70 cm and >70 cm (Nogueira and Treble 2020). Mean net height differed between the R/V Paamiut and the C/V Helga Maria by 23% – 27% and door spread by -7% and -10% in the 0A-South and 1CD surveys, respectively. Further examination of mean net height and door spread suggest the R/V Paamiut could have been fishing with better bottom contact in deep water, and this could have an effect on catchability, particularly for Greenland halibut that associated with the bottom and are known to increase in abundance with depth.

Based on these analyses the comparability of the 2019 survey indices are considered questionable and are not used in the 2020 assessment.

Surveys began in SA0 and SA1 in the mid 1980s with surveys conducted in 0B by Russia and the Democratic Republic of Germany and in 1BCD jointly by Greenland and Japan. Since 1997 surveys have been conducted in 0B and 0A-South by Canada and in 1CD by Greenland using the same research vessel (Figure 1.2).

The combined 1CD and 0A-South survey biomass was relatively stable from 1999 to 2014 (Figure 1.3). There was an increase in 2016 followed by a decrease in 2017. Abundance followed a similar trend. The overall length distribution ranges from about 5 cm to 100 cm. Modal lengths have shifted from 42 cm and 43 cm during 1999 and 2001, respectively to a high of 51 cm in 2015. Secondary modes were clearly present in 2008 and 2012-2017.

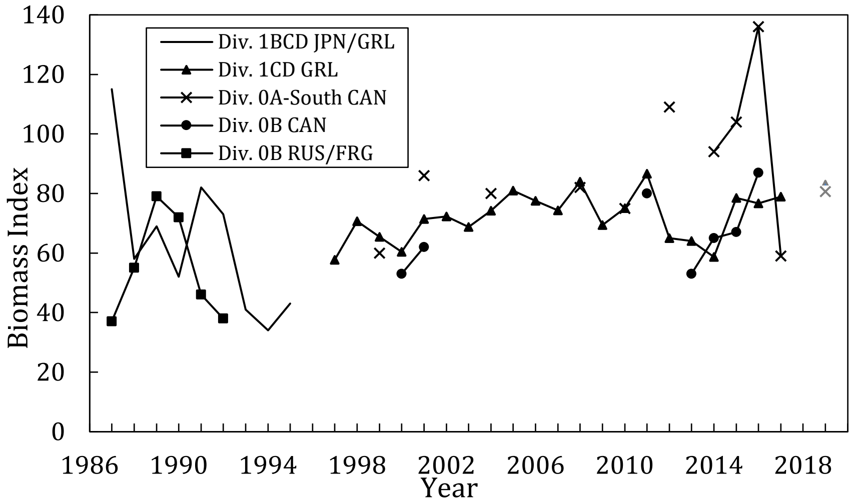


**Figure 1.2.** Greenland halibut in Subarea 0 and 1(offshore): biomass indices from bottom trawl surveys. A survey in Div. 0A in 2006 is not included due to poor coverage.

Since 1988 surveys with a shrimp trawl have been conducted off West Greenland during July-September. The survey covers the area between 59° N and 72° 30' N (Div. 1A-1F) from 50 m to 600m. This survey also experienced vessel changes in 2018 and 2019, however, the results are considered to be comparable with those from earlier years. Clear modes can be found in the length distribution at 12-15 cm and 23 cm, corresponding to ages 1 and 2, allowing for the development of an index of age 1 Greenland halibut using the Petersen method.

### c) Estimation of Parameters

Several attempts to model the stock dynamics have been tried over the years using methods such as Yield per Recruit Analysis, XSA, ASPIC and Schaefer surplus production model. None have been accepted.

## d) Assessment Results

### *i) Subarea 0 and 1 (offshore)*

*Biomass*: The 0A-South+Div. 1CD combined survey biomass index had been relatively stable from 1999 to 2014 (Figure 1.3). Since 2014 the index has been more variable with a time series high in 2016 and a level near the series low in 2017, with all values remaining above $B_{lim}$.

*Recruitment*: The general trend in estimated biomass of age 1 Greenland halibut in the offshore and inshore areas combined has been used as a proxy for recruitment. Since 2003 the index has had an overall declining trend with the exception of three years with high levels of abundance (2011, 2013 and 2017). The index of age 1 in the last two years is considerably lower than in previous years (Figure 1.4). It is unclear if the age 1 abundance index is linked to spawning stock biomass and representative of future recruitment. However, it is considered to contribute to the perception of overall stock status.

*Length distribution in surveys:* Length frequency distribution in the 1CD and 0A-South combined survey have had an increase in abundance in larger fish with modal length shifting from 49 to 51 cm during the last 10 years.

*State of the Stock*: The combined 1CD and 0A-South biomass index has been above $B_{lim}$ throughout the time series, 1999 to 2017. The combined biomass index is not available for 2018, and the 2019 value is not used to assess stock status because its comparability with the earlier time series is questionable. The index of age 1 in the last two years is considerably lower than in previous years, however, there have been high abundances in 2011, 2013 and 2017. It is unclear if the age 1 abundance index is representative of future recruitment but it is considered to contribute to the perception of overall stock status.

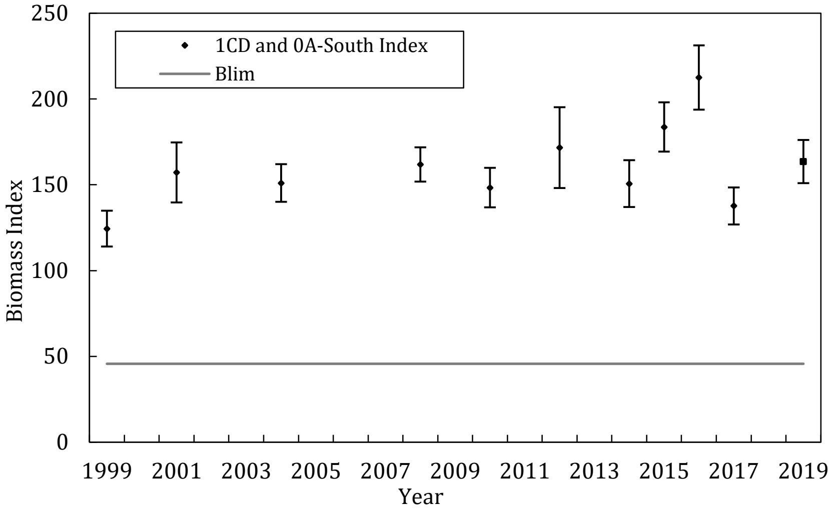


**Figure 1.3**. Greenland halibut in Subarea 0 and 1 (offshore): Biomass trends in Div. 0A-South and Div. 1CD and the proxy for $B_{lim}$.

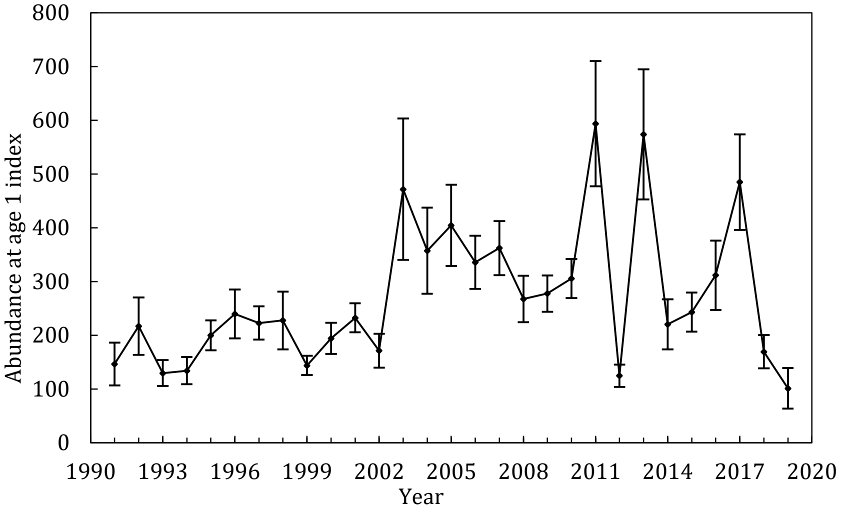


**Figure 1.4.** Greenland halibut in Subarea 0 and 1 (offshore) and Div. 1B-F: index at age 1 derived from the Greenland Shrimp and Fish Survey.

### e) Precautionary Reference Points

Age-based or production models were not available for estimation of precautionary reference points. In 2014 a preliminary proxy for $B_{lim}$ was set as 30% of the mean for the combined 0A-South + Div. 1CD survey biomass index for years 1999 to 2012 (Figure 1.5).

The next full assessment of this stock is expected to be in 2022.

### f) Recommendations:

In 2018 STACFIS **recommended** that *the CPUE data be explored and the General Linear Model examined to better understand the observed trends.*

STATUS: No progress in 2020 but will be carried forward to 2022.

There is a question as to the representativeness of the abundance at age 1 (from the 1A-F survey) as an index of recruitment, or stock status, for the SA 0 and 1 offshore stock. *STACFIS recommends* exploring the use of the overall 1A-F survey biomass as an index of stock status instead of only the age 1 portion of this survey.

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## 2. Greenland halibut Subarea 1 inshore.

(SCR Doc. 20/003 006 016 034 043 044 SCS Doc. 20/12)

### a) Introduction

The fishery in Subarea 1 inshore mainly takes place in in Division 1A in the Disko Bay, the Uummannaq fjord and the Fjords surrounding Upernavik. Further North a fishery is slowly developing in the Qaanaaq fjord. The fishery in Divisions 1B to 1F is comparably smaller than the fishery in Division 1A and never been quota regulated. The stocks are believed to depend on recruits from the offshore stocks and adults are considered isolated from the stocks in Davis Strait and Baffin Bay. Advice is given for each of the six areas on a two-year basis and a separate TAC is set for each of the inshore areas in Division 1A.

### *i) Catch history*

The inshore fishery for Greenland halibut developed in the beginning of the twentieth century, with the introduction of the longline to Greenland in 1910. Catches remained at a lower level until the 1980s, but increased substantially thereafter.

In Division 1A inshore, the fishery is conducted with longlines or gillnets from small vessels, open boats and through holes in the sea ice during the winter months. Quota regulations were introduced as a shared quota for all vessels in 2008. In 2012, the TAC was split in two components with ITQ's for vessels and shared quota for small open boats. In 2014, the Government of Greenland set "quota free" areas within each subarea, and in these areas, catches were not drawn from the total quota, although still included in landing statistics. Sorting grids have been mandatory since 2002 in the offshore shrimp fishery at West Greenland and in the inshore shrimp fishery (Disko Bay) from 2011. Trawl fishery is not allowed in the Uummannaq fjord and Upernavik area. In 2017, mesh size in gillnets were reduced to 95mm half mesh. Besides the three main areas, a fishery is slowly developing in the Qaanaaq fjord (77 degrees North). In Divisions 1B to 1F the fishery is conducted with longlines only.

***1A Disko Bay***: Catches increased in the 1980s, peaked from 2004 to 2006 at more than 12 000 t, but then decreased substantially. From 2009, catches gradually increased and reached 10 760 t in 2016, before decreasing to 6 409 t in 2017. From 2009, catches gradually increased, reaching 8 759 t in 2019. (Table 2.1 and Figure 2.1).

***1A Uummannaq***: Catches in the Uummannaq fjord gradually increased from the 1980s reaching 8 425 t in 1999, but then decreased and remained between 5 000 and 6 000 t from 2002 to 2009. After 2009 catches gradually increased reaching 10 305 t in 2016. In 2019 catches reached 10 243 t, the second-highest value of the time series (Table 2.1 and Figure 2.1).

***1A Upernavik***: Catches increased from the mid1980s and peaked in 1998 at a level of 7 000 t. Landings then decreased sharply, but during the past 15 years, they have gradually returned to the higher level. Average catch in the most recent 5 years has been 7 169 t (Table 2.1 and Figure 2.1).

**1BC Sisimiut Maniitsoq area:** Catches increased in the area from the 1960s reaching more than 1 000 t in 1965. Catches decreased thereafter but returned to a higher level from 1973 to 1980. After this intense fishing period, catches decreased and were almost non-existent for two decades after 1987. From 2008, catches have gradually increased reaching 300 t in 2019.

**1D Nuuk area:** Catches in 1D inshore were around 500 t annually from 1966 to the end the 1980s and peaking in 1985 with 2 136 t. After this intense fishing period, the fishery was virtually non-existent for two decades. From 2003 catches gradually increased, reaching 1 369 t in 2016. In 2019, the catch decreased to 834 t from 1 117 t in the preceding year.

**1EF Paamiut Qaqortoq area:** 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 1 000 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.

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

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1A Qaanaaq - Catch | 0.02 | 0.05 | 0.01 | 0.13 | 0.14 | 0.14 | 0.211 | 0.252 | 0.221 | |
| 1A Upernavik - TAC | 6.50 | 6.50 | 7.95 | 9.50 | 9.50 | 9.50 | 9.50 | 9.50 | 8.46 | 8.46 |
| 1A Upernavik - Catch | 6.47 | 6.83 | 6.04 | 7.38 | 6.27 | 7.36 | 6.78 | 7.55 | 7.67 | |
| 1A Uummannaq - TAC | 6.00 | 6.00 | 7.45 | 8.38 | 9.50 | 9.85 | 9.50 | 9.50 | 9.90 | 9.50 |
| 1A Uummannaq - catch | 6.40 | 6.13 | 7.01 | 8.20 | 8.24 | 10.30 | 9.05 | 8.84 | 10.2 | |
| 1A Disko Bay – TAC | 8.00 | 8.00 | 9.00 | 9.00 | 9.20 | 9.65 | 9.20 | 9.20 | 11.08 | 8.18 |
| 1A Disko Bay - Catch | 8.00 | 7.76 | 9.07 | 9.18 | 8.67 | 10. 76 | 6.41 | 8.40 | 8.76 | |
| 1BC Sis Man - TAC | - | - | - | - | - | - | - | - | - | - |
| 1BC Sis Man - Catch | 0.095 | 0.058 | 0.107 | 0.242 | 0.183 | 0.149 | 0.197 | 0.278 | 0.301 | |
| 1D Nuuk - TAC | - | - | - | - | - | - | - | - | - | - |
| 1D Nuuk - Catch | 0.104 | 0.277 | 1.024 | 1.211 | 0.864 | 1.369 | 1.100 | 1.117 | 0.834 | |
| 1 EF Paa – Qar -TAC | - | - | - | - | - | - | - | - | - | - |
| 1EF Paa – Qar -Catch | 0.054 | 0.072 | 0.139 | 0.368 | 0.479 | 0.510 | 0.785 | 0.657 | 0.450 | |
| STACFIS Total | 21.38 | 21.17 | 23.40 | 26.71 | 24.86 | 30.59 | 24.53 | 27.09 | 28.38 | |

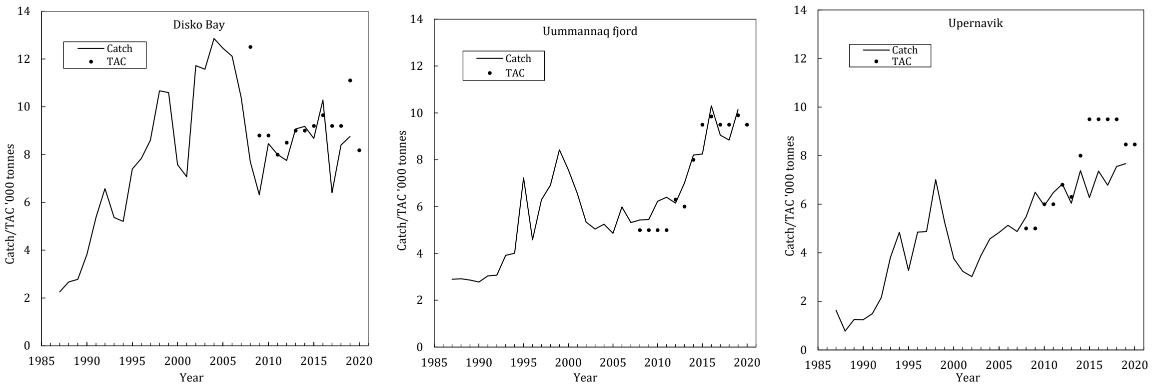


**Figure 2.1.** Greenland halibut in Division 1A inshore: Greenland halibut catches and TAC in t in Disko Bay, Uummannaq and Upernavik.

## b) Data overview

### *i) Commercial fishery data*

Length frequencies from factory landings are available since 1993. These data were used to calculate the mean length in the landings by season, gear and an annual mean accounting for season, gear and area (Figure 2.2).

**In 1A Disko Bay,** 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.

In **1A Uummannaq,** the length distributions in the commercial landings have gradually decreased since 1993, but at a higher rate in recent years. Since there is little difference between summer and winter fishing grounds, only small differences in the summer and winter length distributions are observed.

In **1A Upernavik,** 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 decreased further.

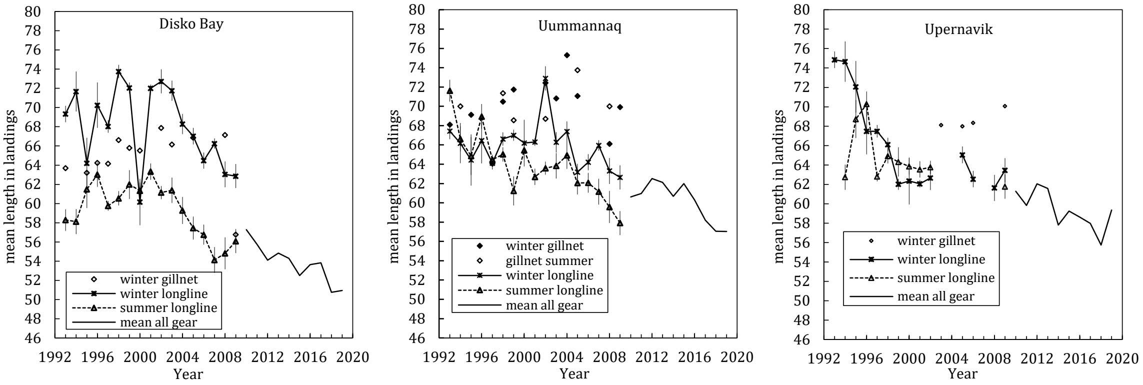


**Figure. 2.2.** Greenland halibut in Division 1A inshore: mean length in landings from longline fishery by season (summer and winter) and overall mean taking account of fishing ground, season and gear.

In **1D Nuuk** area, the mean length in the commercial landings gradually decreased from the 1970s to the 1980s and again since 2011 (Figure 2.3)

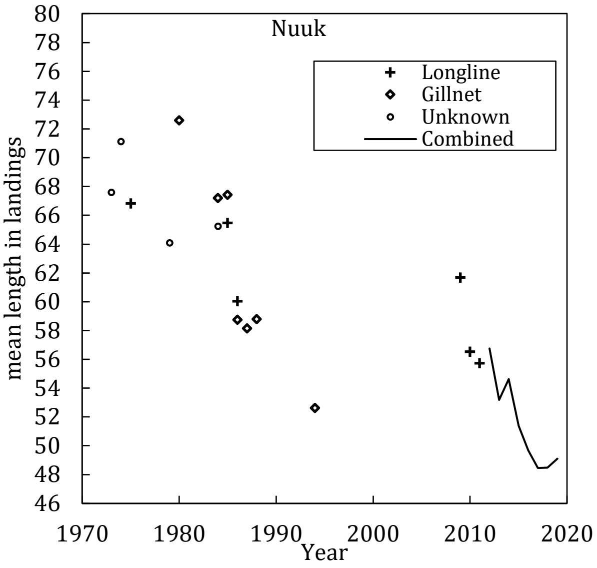


**Figure 2.3.** Greenland halibut in Division 1D inshore: mean length in landings and overall mean taking account of fishing ground, season and gear.

*Catch numbers.* Although catch in tonnes decreased in the Disko Bay in 2016, estimated catch in numbers are still at the level of the previous high catches (Figure 2.4). In both Uummannaq and Upernavik, current catch in numbers are at a record high level in recent years.

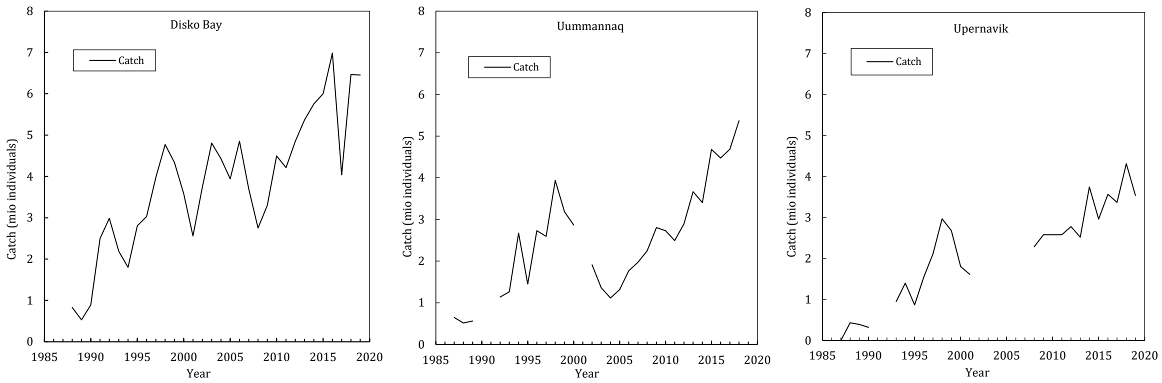


**Figure 2.4**. Greenland halibut in Division 1A inshore: Greenland halibut catch in million individuals.

The Depletion Corrected Average Catch method was used to estimate a sustainable level of catch for the areas 1BC, 1D, and 1EF (Figure 2.5). The method can be applied when a sufficiently long catch history of decades or more is available on stocks that has never experienced quota regulations.

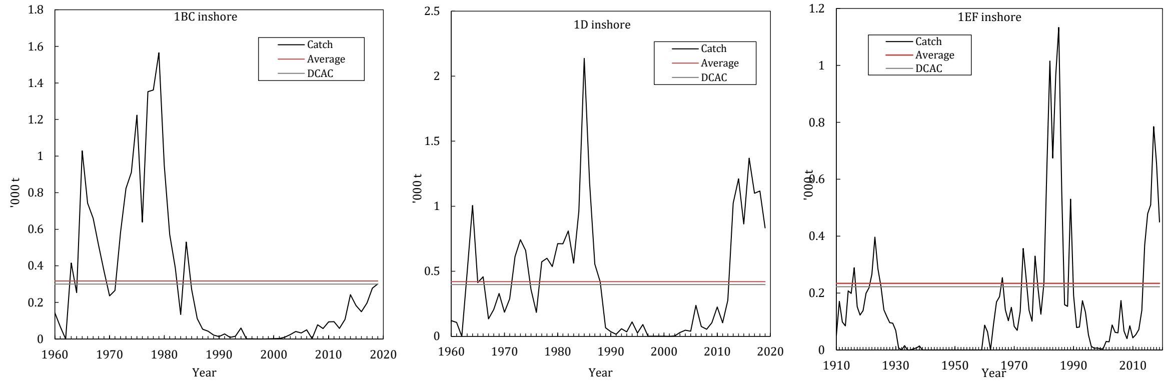


**Figure 2.5**. Greenland halibut in Division 1BC, 1D and 1EF inshore. Greenland halibut catch, estimated DCAC sustainable catch and average catch.

**CPUE index based on logbooks.** 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 logCPUE available. Due to uncertainty about mesh size, the Gillnet CPUE was not used in the assessment. Only longline setting with more than 200 hooks were included to omit obvious outlier values and limit the influence of data potential 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 2.6).

In **1A Disko Bay,** the standardized CPUE series show a decreasing trend since 2009.

In **1A 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 **1A Upernavik,** The CPUE index reveal a gradual decreasing the 2015 to 2018 indices being among the lowest observed. The index increased in 2019, although remaining within the decreasing trend observed since 2007.

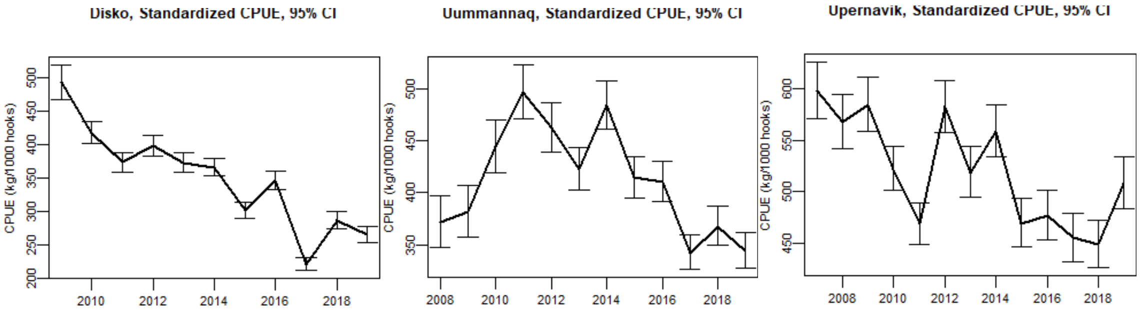


**Figure 2.6** Standardized mean and 95% CI of longline CPUE in Disko bay (left), Uummannaq (center) and Upernavik (right).

### *ii) Research survey data*

**The Greenland shrimp and fish survey** (NAFO Div. 1A-F from 100 to 600 m) also covers the Disko bay. Separate abundance and biomass indices and length frequencies has been calculated for the Disko bay part of the survey (Figure 2.7).

The **1A Disko Bay** part of Greenland Shrimp and Fish Survey indicated an increasing abundance trend during the 1990s and high abundances (mainly age 1) were found from 1998 to 2005. After 2006, the abundance indices returned to the lower levels with the exception of the high abundances 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 has been in a decreasing trend with the lowest values found in the most recent 4 years.

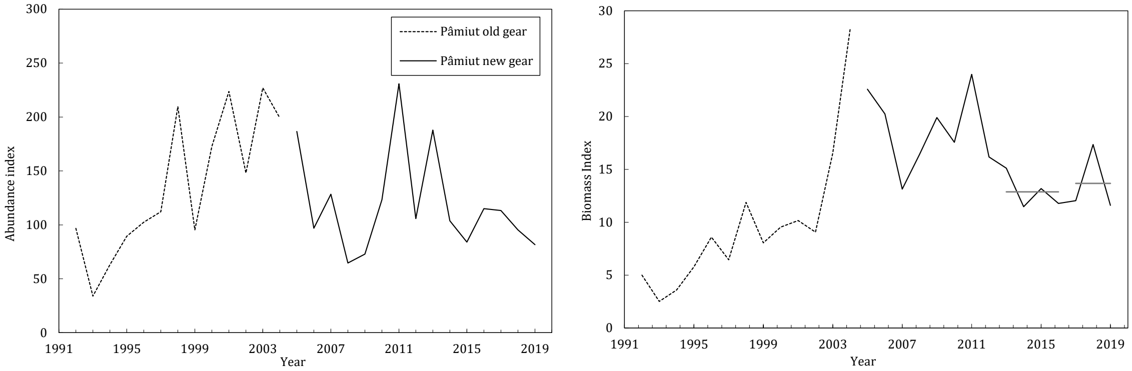


**Figure 2.7**. Greenland halibut in Division 1A inshore: Abundance and biomass indices in the Disko bay from the Greenland Shrimp Fish trawl survey.

A similar trawl survey was initiated in 2015 in the fjords near **1D Nuuk** (godthåbsfjord and Ameralik fjord). The trawl survey indicated increasing abundance and biomass in 2019, mainly due to higher numbers of pre-fishery recruits from 30 to 40 cm (Figure 2.8).

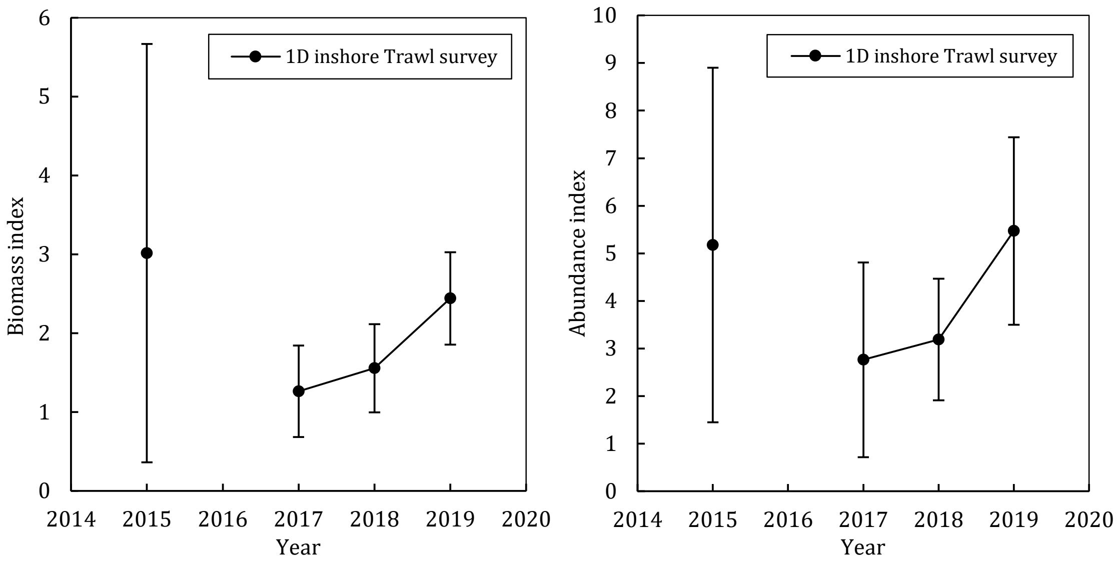


**Figure 2.8.** Greenland halibut in Division 1D inshore: Abundance and biomass indices in inshore trawl survey in Division 1D.

**Gillnet surveys** were originally designed to target pre fishery recruits at lengths from 35-55 cm. Since the survey uses gillnets with narrow selection curves and normally catches the same sized fish, but in varying numbers, there is little difference between the trends of the CPUE and NPUE indices.

The **1A Disko Bay** gillnet survey indicated low levels of pre-fishery recruits in 2006 and 2007, but returned to above average levels in 2008 to 2011 (Figure 2.9). Since 2013, the Gillnet survey NPUE and CPUE has gradually decreased and remained below average levels until 2018. In 2019, the survey was limited to stations in the important commercial areas, causing the increase in the index. 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 surveys, although both surveys show large year to year variation. A larger mesh size added in 2016 did not impact the overall length distribution in the Disko bay, indicating few larger individuals in the surveyed area (55-70 cm).

The **1A Uummannaq** gillnet survey was performed using the same method and setup as in the Disko Bay. The gillnet survey showed a substantial decrease in CPUE due to a lower number of large fish in the survey, until 2018, and it remained almost stable in 2019. (Figure 2.10)

The **1A Upernavik** gillnet survey was performed using the same method and setup as in the Disko Bay. The gillnet survey showed some stability since 2015. The decrease observed in 2019 is uncertain due to a lower number of stations than usual. (Figure 2.11)

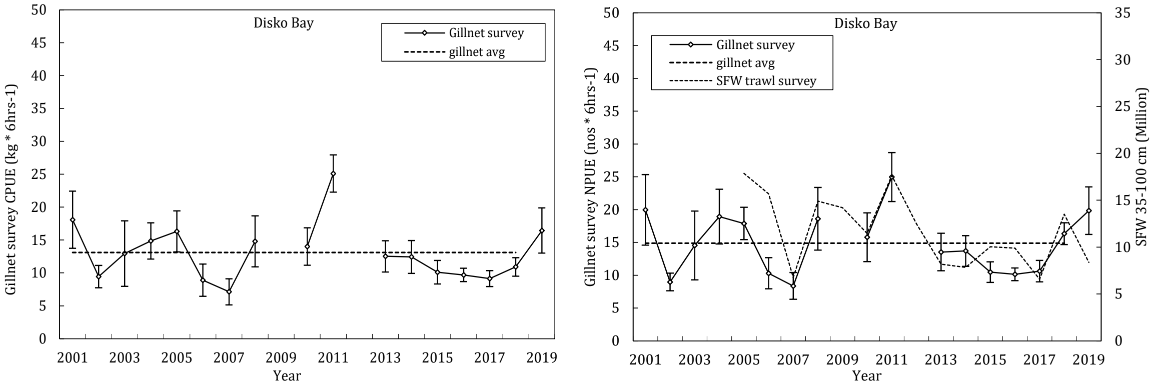


**Figure 2.9.** Greenland halibut in Division 1A inshore: Gillnet survey CPUE and NPUE +/-SE.

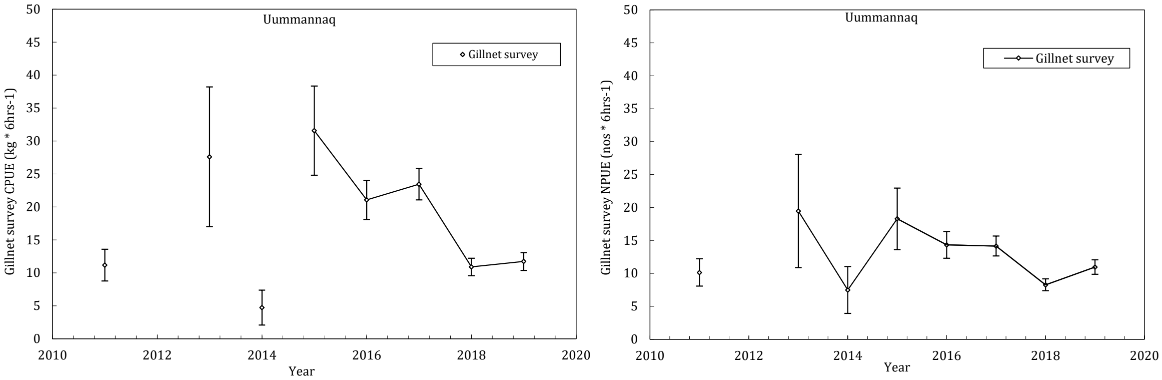


**Figure. 2.10.** Greenland halibut in Division 1A inshore: Gillnet survey CPUE and NPUE +/-SE.

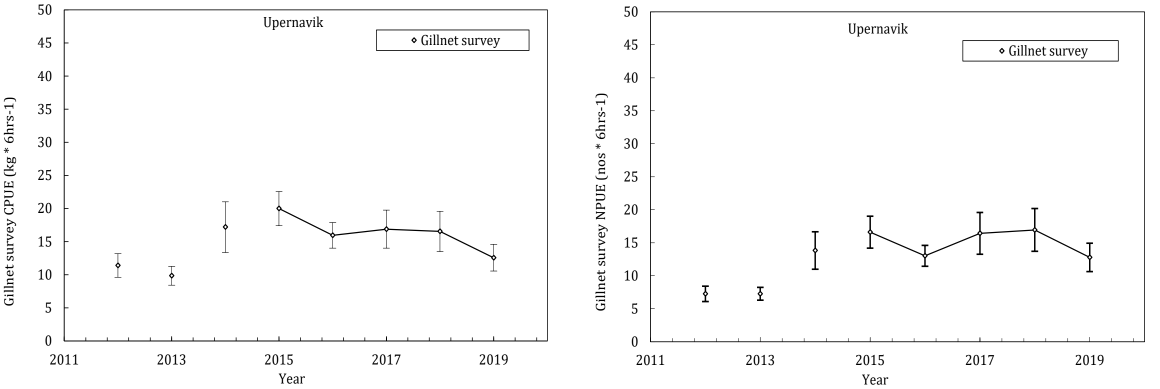


**Figure 2.11.** Greenland halibut in Division 1A inshore: Gillnet survey CPUE and NPUE +/-SE.

### *iii) Biological studies*

Based on 221 females collected in Uummannaq in 2018, length at 50% maturity ($L_{50}$) for females was estimated to be 77 cm (visual inspection as described in WKBUT 2013). This is similar to the other studies in fjords in East Greenland and larger than females from offshore areas (Gundersen et al. 2013).

### *iv) Environmental studies*

Deeper water bottom temperatures have been measured in surveys since 1991. A temperature increase from 1 C to 2-3 degrees occurred in 1997 along the west coast of Greenland and inside the Disko Bay. The temperature increase has been related to both glacier acceleration and increased growth of one-year-old Greenland halibut. Since 1997, bottom temperatures have remained stable at a level of 2 to 3 ºC in the Disko Bay.

### c) Assessment results:

Age based analysis are not available for these stocks due to the challenges concerning age determination for Greenland halibut. Therefore, the assessments were based on survey biomass index in 1A Disko Bay and commercial data in 1A Uummannaq and 1A Upernavik.

In divisions 1BC, 1D and 1EF, Depletion Corrected Average Catch was used to estimate a sustainable level of Catch. The estimation of DCAC was only possible in these areas since the stocks in the fjords south of the Disko Bay have gone through periods of increased fishery, local depletions and rebuilding without any quotas limiting the fishery.

*Assessment:* No analytical assessment could be performed for any of the stocks.

### d) State of the stock

#### 1A Disko Bay

*Biomass:* CPUE is used as an index of biomass and has gradually decreased and remained below average levels in the most recent 3-5 years. The trawl survey biomass index has gradually decreased since 2005, with the lowest values found in 4 of the most recent 5 years.

*Fishing mortality*: Unknown

*Recruitment:* The recruitment index of age one Greenland halibut has been variable in recent years with series high values observed in 2011 and 2013 and in the nearby offshore area in 2017. However, there is weak correlation between age one and older ages in subsequent years. The trawl survey indicates a steady high supply of recruits to the area and the gillnet survey indicates an annual presence of pre-fishery recruits (30-40 cm) in the Disko Bay.

*State of the stock:* Mean length of the fish landed has gradually decreased over 10 to 15 years. Although the catches have remained at a level of around 8 400 t per year in the recent decade, the number fish caught has gradually increased due to a decrease in the size in the landings. The number of fish landed remains high. The trawl survey biomass index has gradually decreased since 2009, with few years falling outside the decreasing trend. The commercial CPUE for longline vessels has decreased by about 50% since 2009. The Gillnet survey CPUE, originally designed for pre-fishery recruits, indicate stable recruitment at higher ages. The gillnet survey index in 2019 was above the average levels, but the comparability of the 2019 value with the earlier time series is questionable.

#### 1A Uummannaq:

*Biomass:* Unknown.

*Fishing mortality:* Unknown.

*Recruitment:* The recruitment index of age one Greenland halibut has been high in the nearby offshore areas in 2011, 2013 and 2017. The size distribution in the gillnet survey finds some pre-fishery recruits in the 30-40 cm size range.

*State of the stock:* The catch in tonnes and numbers of fish has been increasing since 2009, reaching record high values in 2016 and 2019. Mean length in the landings has gradually decreased. From 2011, the standardized commercial longline CPUE index decreased gradually, being 2017 and 2019 the years with the lowest values observed in the time series. The gillnet survey has shown a substantial decrease in CPUE due to a lower number of large fish in the survey, until 2018, and it remained almost stable in 2019.

**1A Upernavik:**

*Biomass:* Unknown.

*Fishing mortality:* Unknown.

*Recruitment:* The recruitment index of age one Greenland halibut has gradually been decreasing in division 1AN, west of the Upernavik area. The gillnet survey reveals pre-fishery recruits in the 30-40 cm size range at a level comparable to the Disko Bay.

*State of the stock:* The catch in tonnes and in numbers of fish has been record high since 2014. Mean length in the fish landings decreased in the 1990s but stabilized from 1999 to 2009. Since then, until 2018, length in the fish landings has decreased from 74-76 cm to 56-58 cm. The mean length increased in 2019, but this value is questionable because the sample size was smaller than usual. The standardized longline CPUE index decreased until 2018 reaching the lowest value of the time series. CPUE increased in 2019 but remains within the decreasing trend for year to year variation. The gillnet survey has shown some stability since 2015. The decrease observed in 2019 is uncertain due to a lower number of stations than usual.

**1BC Sisimiut - Maniitsoq area**

*Biomass:* Unknown

*Fishing mortality*: Unknown

*Recruitment:* Unknown. The stocks are believed to be dependent on recruitment from the spawning stock in The Davis strait.

*State of the stock:* The catch was at a low level for two decades from the end of the 1980's. During the recent decade, the catch has gradually increased to the estimated sustainable level of catch.

**1D Nuuk area**

*Biomass:* Unknown

*Fishing mortality*: Unknown

*Recruitment:* The trawl survey revealed presence of several year classes of recruits and found higher numbers of pre fishery recruits in the range 30-40 cm, in the 2019 survey.

*State of the stock:* The catch was at a low level for two decades from the end of the 1980's. Since 2013 the catches have been about twice as high at the DCAC estimated sustainable level of catch. During this period, a decrease in size composition in the catch has been observed. The trawl survey for Greenland halibut in the fjords in 1D indicated a decrease in the number of fish in the commercial size range since 2015. However, the biomass indices in the survey increased from 2017 to 2019, due to higher numbers of pre fishery recruits in the range 30-40 cm. The survey furthermore indicated presence of recruits in the area although the stocks are believed to be dependent on recruitment from the the stock ICES Subarea 5, 6, 12 and14.

**1EF Paamiut - Qaqortoq area**

*Biomass:* Unknown

*Fishing mortality*: Unknown

*Recruitment:* Unknown. The stocks are believed to be dependent on recruitment from the stock in ICES Subarea 5, 6, 12 and14

*State of the stock:* The catch was at a low level for two decades from the end of the 1980's. Since 2014 the catches have been about 2-3 times higher than the DCAC estimated sustainable level of catch.

These stocks will next be assessed in 2022

## 3. Demersal Redfish (*Sebastes* spp.) in Subarea 1

(SCR Doc. 88/12, 96/36, 07/88, 20/003 006 012 016; SCS Doc. 20/12)

### a) Introduction

There are two demersal redfish species of commercial importance in subarea 1, golden redfish (*Sebastes norvegicus*) and demersal deep-sea redfish (*Sebastes mentella*). Connectivity to other redfish stocks off East Greenland, Irminger Sea and Iceland is unclear. Survey data reveal an almost continuous distribution of both species from East Greenland to West Greenland. Historic catches show decade long occurrence of redfish in both areas.

### *i) Fisheries and Catches*

Both redfish species are included in the catch statistics since no species-specific data are available. 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). Redfish caught pelagic are considered *Sebastes mentella* (REB). Redfish caught as by-catch in the shrimp fishery are named *Sebastes sp* (RED). From offshore and inshore surveys in West Greenland, it is known that the demersal redfish on the shelf and in the fjords are a mixture of *S. marinus* and *S. mentella*.

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 1,000 tons per year after 1986 with few exceptions. However, catches are uncertain with evidence of cod being misreported as redfish and other species in the 1970s, and by-catches of redfish in the shrimp fishery likely underestimated in the 1970's to 2001. Bycatch of redfish was estimated to be more than 14,000 t in 1988 and 4,000 t in 1994 yet reported catches are much lower in these years. To reduce the amount of fish taken in the trawl fishery targeting shrimp, sorting grids have been used since 2002. Studies of bycatches and poor recruitment has since then limited the bycatch of redfish in the shrimp fishery to very low levels. In 2019, 31 t was reported as by-catch in offshore fisheries (less than 1 tons from shrimp trawlers) and 111 t were landed to factories mainly taken as bycatch in other fisheries from small vessels and open boat targeting cod and Greenland halibut (Figure 3.1).

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

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TAC | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| STATLANT 21 | 0 | 0.2 | 0.12 | 0.16 | 0.25 | 0.19 | 0.16 | 0.23 | 0.19 | 0.09 | |
| STACFIS | 0.3 | 0.2 | 0.16 | 0.17 | 0.17 | 0.26 | 0.17 | 0.24 | 0.19 | 0.14 | |

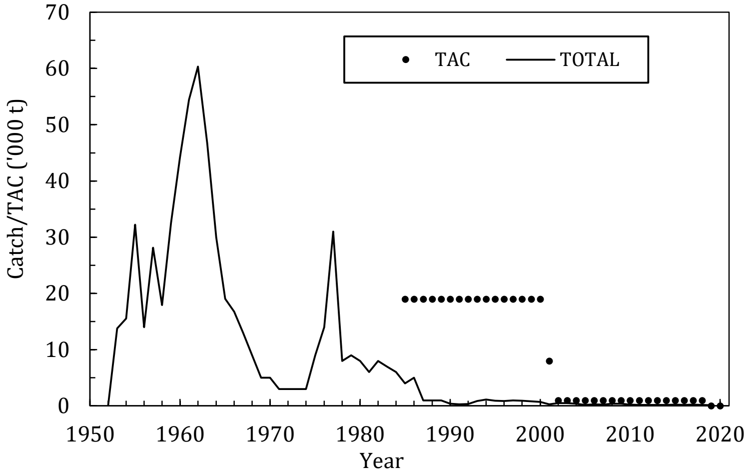


**Figure 3.1.** Demersal redfish in Subarea 1: catches and TAC.

## 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. 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*

There are five ongoing surveys of relevance for the demersal redfish stocks in Subarea 1. The EU-Germany survey (Walther Herwig III, 0-400m, NAFO 1C-F, ICES XIV, since 1992), the Greenland deep-sea survey (Pâmiut, 400-1500m, NAFO 1CD since 1998) and the Greenland shrimp and fish survey (Pâmiut, 0-600m, NAFO 1A-F, since 1992 (SFW), ICES XIV since 2007 (SFE)). 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 1B. However, no separation of redfish species was made prior to 2006 and the gear was changed in 2005 in the survey, thus breaking the index. Due to research vessel decommission, chartered commercial vessels using the research vessel gear and riggings has been used to update the indices in the Greenland shrimp and fish survey in 2018 and 2019. The EU-Germany survey has a longer time series, but have had low coverage in West Greenland since 2016. Furthermore, A gillnet survey in the Disko bay and the Uummannaq fjord in Division 1A inshore and a Trawl survey in the Godthåbs fjord and Ameralik fjord in Division 1D inshore provides information on species composition in the recent landings. Besides the recent surveys, a joint Greenland-Japan survey (Shinkai Maru, -1500m, NAFO 1B-D, 1987-1995) existed with somewhat overlapping the areas and depths as the present Greenland deep-sea survey.

*Golden redfish (Sebastes norvegicus)*

**The EU-Germany survey** biomass index (1C-F) decreased in the 1980s and was at a very low level in the 1990s (Figure 3.2). However, the survey has revealed increasing biomass indices of golden redfish (>17cm) since 2004 and peaking in 2015 when the index reached the highest level observed since 1986. In **the Greenland shrimp and fish survey,** golden redfish biomass was stable from 2006-2010 but increased gradually until 2016. The 2017 and 2018 biomass indices were however close to the 2006-2011 level. The increasing biomass observed from 2011-2016 occurred division 1E and 1F and was often caused by one or 2 hauls containing larger individuals contributing more than half the total West Greenland biomass. In 2016, a single haul in division 1E consisted of large golden redfish between 45-70 cm and provided 80% of the total biomass estimate. In 2019, the biomass index reached the second highest value observed since 2006, but this was attributed to two hauls, one in division 1C (60%) and one in division 1B (12%). the rest of the biomass being distributed from 1A including the Disko bay to 1F in South Greenland. The gillnet surveys in Division 1A inshore supported that the redfish in this area were almost exclusively Golden redfish. This was not the case in Division 1D inshore.

*Demersal deep-sea redfish (Sebastes mentella)*

**The EU-Germany survey** biomass index has fluctuated at a low level throughout the time series (Figure 3.3). 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 when the survey ended (Figure 3.3). **The Greenland deep-sea survey** (1CD) indices were at a low level from 1997 to 2007, but the biomass index has been at a higher level since 2008 (Figure 3.3). T**he Greenland shrimp and fish survey** biomass index for deep-sea redfish steadily increased after 2006 and the 2016 indices were among the highest observed (Figure 3.3). However, the high 2016 biomass index was caused by a single haul in division 1D of large redfish between 25 and 40 cm. In 2017, there were no such large hauls in the survey but the indices remain high. About 80-95% of the redfish biomass in the trawl survey in Division 1D inshore since 2015 has been deep-sea redfish.

*Juvenile redfish (both species combined)*

**The EU-Germany survey** regularly found juvenile redfish from 1984 to 2000. After 2000, the abundance of juvenile redfish has decreased to a low level and has remained low since then (Figure 3.3). **The Greenland shrimp and fish survey** initially had high levels of juvenile redfish in the survey. The total abundance of both species combined can be regarded as a recruitment index, since the Greenland Shrimp and Fish survey normally catches 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. After the gear change in 2005, the abundance index gradually decreased (Figure 3.3). Length distributions reveal that the increase in survey biomass observed in 2016 is primarily large mature redfish and not recruits. Length distributions of redfish in the surveys furthermore reveals a complete lack of new year classes since 2009 (lack of redfish less than 20 (age 1 to 4) cm since 2013) in West Greenland. The stocks in East Greenland which could potentially supply West Greenland with recruits (as known for other species such as Atlantic Cod and Haddock) reveal that new incoming year classes of redfish have not been observed since 2011 in either the Greenland Shrimp and fish survey (2008-2016) nor the EU-Germany survey in East Greenland in 2019 (not shown). Spawning females have been observed in the inshore trawl survey in division 1D in April and May.

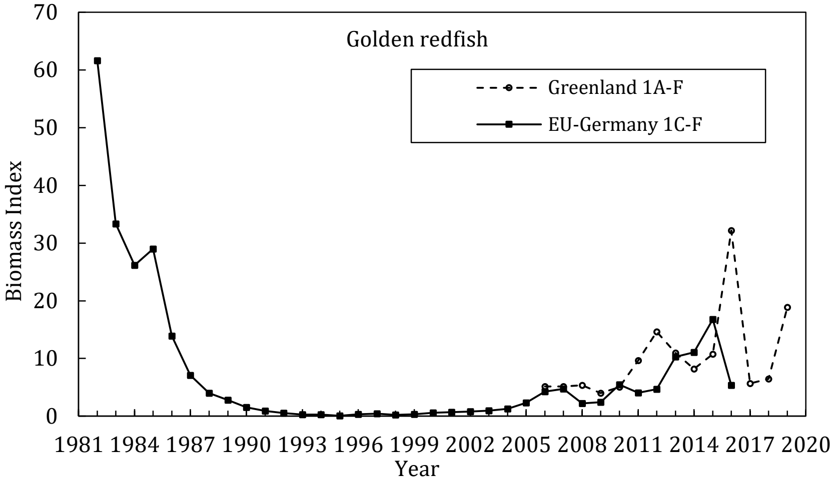


**Figure 3.2.** Golden redfish biomass indices in the EU-Germany survey (1C-F) and the Greenland shrimp and fish survey (1A-F).

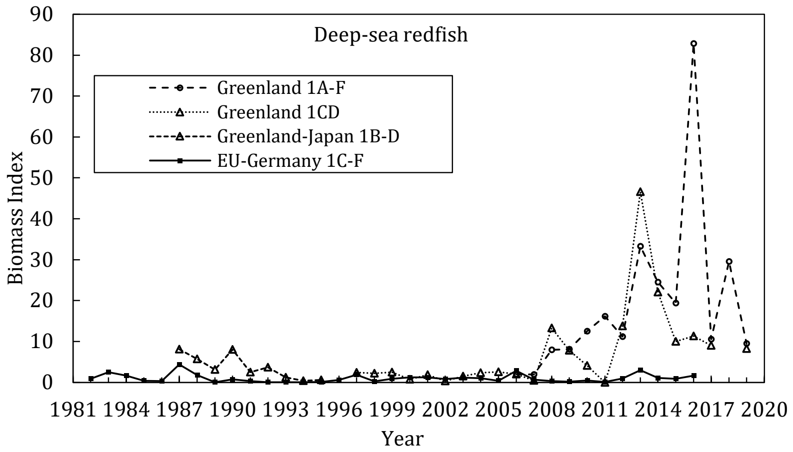


**Figure 3.3**. Demersal deep-sea redfish survey biomass from the Greenland shrimp and fish survey (1A-F), the Greenland deep-sea survey (1CD), the EU-Germany survey (1C-F) and the Greenland-Japan survey (1B-D).

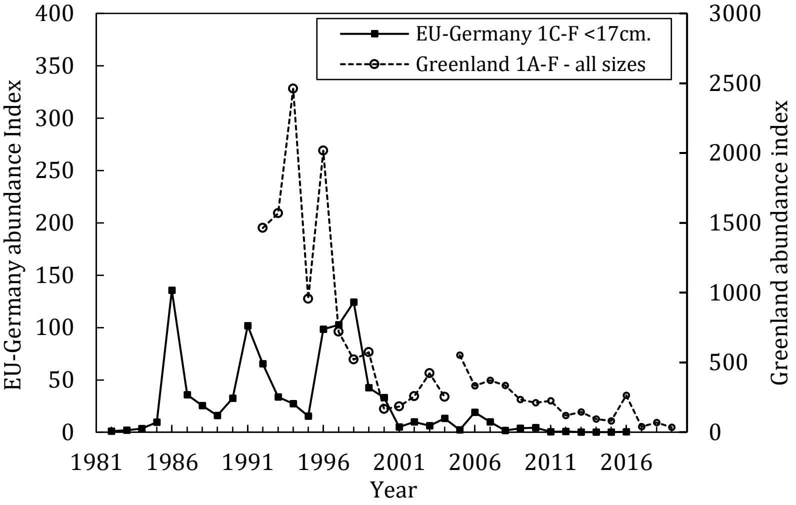


**Figure 3.4.** Juvenile redfish abundance indices (deep-sea redfish and golden redfish) for the EU-Germany survey (1C-F, <17cm), and the Greenland shrimp and fish survey (1A-F, all sizes).

## c) Assessment results

Assessment: No analytical assessment could be performed for any of the stocks.

## d) State of the stock

### Golden redfish - *Sebastes norvegicus*

*Biomass:* The EU-Germany and Greenland Shrimp and fish survey have revealed a slightly increasing biomass of golden redfish from 2005 to 2015. Updated indices in the Greenland shrimp and fish survey (until 2019) and the EU-Germany survey (until 2016) has indicated that the biomass remains near the 2015 level. It can therefore be assumed that the biomass is still far below the 1980s level.

*Fishing mortality:* Unknown

*Recruitment:* Both the EU-Germany survey and the Greenland Shrimp and Fish survey indicates poor recruitment during the past two decades. In the Greenland shrimp and fish survey, virtually no new incoming year classes have been observed during the recent decade in West Greenland and East Greenland.

*State of the stock:* Survey indices indicate that the biomass remains far below historical levels. Recruitment has been poor for two decades and failing during the most recent decade. The overall stable biomass in recent years is the result of somatic growth or immigration balancing the limited fishery and natural mortality in the remaining stock.

**Deep-sea redfish -** *Sebastes mentella*

*Biomass:* The Greenland-Japan survey indicate that the biomass decreased from 1987 to 1995. The Greenland deep survey and the Greenland Shrimp and fish survey both indicated that the biomass remained low until 2007. Both the Greenland deep-sea survey and the Greenland shrimp and fish survey agree that the biomass of deep-sea redfish increased from 2008 to 2013/2017, but the biomass indices have decreased in the recent 4-7 years.

*Fishing mortality:* Unknown

*Recruitment:* Both the EU-Germany survey and the Greenland Shrimp and Fish survey indicates poor recruitment during the past two decades. In the Greenland shrimp and fish survey, virtually no new incoming year classes have been observed during the recent decade in West Greenland and East Greenland (lack of 1-4 year old fish less than 20 cm since 2013) and inshore in Division 1D.

*State of the stock:* Both the Greenland Shrimp and Fish survey (Div. 1A-F) and the Greenland deep-sea survey (Div. 1CD) indicate a decreasing biomass index of deep-sea redfish in the recent 4-7 years. Recruitment has been poor for two decades. No new incoming year classes have been identified during the trawl surveys in either East Greenland (EU-Germany survey), West Greenland offshore (EU-Germany survey and survey in Div. 1A-F), or inshore (Survey in Div. 1A-F) during the recent decade.

This stock will next be assessed in 2023.

## 4. Wolffish in Subarea 1

(SCR Doc. 80/VI/72 77 96/036 07/88 17/036 19/008, 20/06, 20/40; SCS Doc. 20/12)

### a) Introduction

Three species of wolffish are common in Greenland. Only Atlantic wolffish (*Anarhichas lupus*) and spotted wolffish (*Anarhichas minor*) are of commercial interest, whereas 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 and both inshore and offshore but is the dominant species of wolffish in the coastal areas and inside the fjords. Atlantic wolfish has a shallower depth distribution (50-400m) than spotted wolffish (50-600m).

### *i) Fisheries and catches.*

Wolffish are primarily taken as a bycatch in other fisheries. A directed wolfish fishery typically occurs when access to more economically important species are limited. 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 4.1). After 1980, the cod fishery gradually decreased 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 grid separators since 2002 and inshore (Disko Bay) trawlers since 2011. In 2015, reported catches have decreased and the lower catch level has continued until 2019 with just 190 t. It is reasonable to assume that the decrease is related to fishery targeting more profitable species, limiting catches to exploited bycatch only.

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

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| Atlantic wolffish TAC | | | | | 1.00 | 1.00 | 1.00 | 1.00 | 0 | |
| Spotted wolffish TAC | | | | | 1.025 | 1.025 | 1.025 | 1.025 | 0 | |
| Combined wolffish TAC | 1 | 1 | 1 | 1 | 2.025 | 2.025 | 2.025 | 2.025 | 0 | 0 |
| STATLANT 21 | 0.8 | 1.0 | 0.9 | 0.9 | 0.40 | 0.24 | 0.24 | 0.27 | 0.2 | |
| STACFIS | 0.78 | 1.0 | 0.9 | 0.9 | 0.40 | 0.20 | 0.24 | 0.26 | 0.2 | |

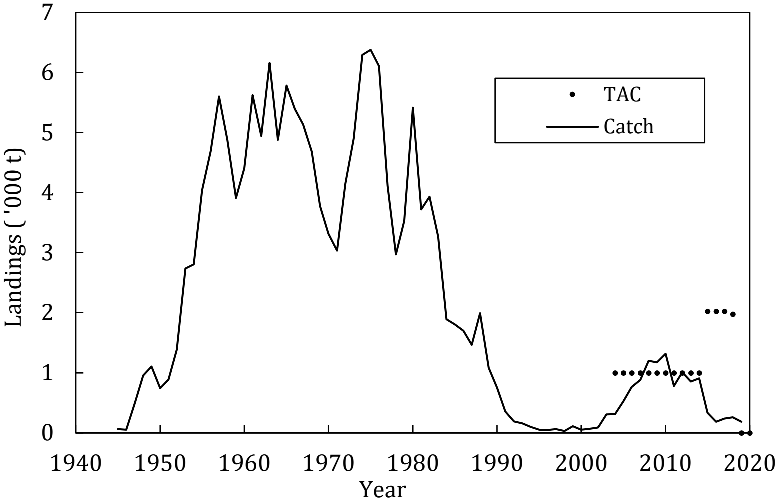


**Figure 4.1.** Wolffish in Subarea 1: Catches and TACs for Atlantic wolffish and spotted wolffish combined from 1945 to 2019.

## b) Input data

### *i) Research survey data*

The EU-Germany survey (RV Walther Herwig III, 0-400m, NAFO 1C-F, ICES XIV, since 1982) covers the southern part of the West Greenland shelf. The survey was cancelled in 2018 and had low coverage in West Greenland in 2017 and 2019.

The Greenland shrimp and fish survey (RV Pâmiut, 50-600m, NAFO 1A-F (South Greenland to 72N), 1992-2017, ICES 14 (South Greenland to 67N) 2007-2017) covers a larger geographical area and depth range. The gear was changed in the Greenland shrimp and fish 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 in 2018 and 2019. Although the Shrimp and Fish survey experiences change vessel in 2018 and 2019, analysis of trawl performance have indicated that the indices are considered to be comparable. The Greenland shrimp and fish survey has a more appropriate geographical coverage in relation to wolffish, although none covers the inshore areas. Both surveys cover the main depth distribution of wolffish.

**Atlantic wolffish:**

**The EU-Germany survey** biomass index decreased significantly in the 1980s (Figure 4.2). From 2002 to 2005 biomass index increased to above average levels, but thereafter returned to the low levels observed during the 1990s. The index has not been updated since 2016, 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 decrease in the surveyed area (Figure 4.2).

**The Greenland shrimp and fish survey** biomass indix 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 gradually increased from 2006 onwards peaking in 2015 (Figure 4.2). Abundance indices in the Greenland shrimp and fish survey increased until the gear change in 2004 (Figure 4.2). From 2005 the increasing trend has continued peaking in 2015. The increase in abundance has been observed in divisions 1A-B, outside the EU-Germany survey area.

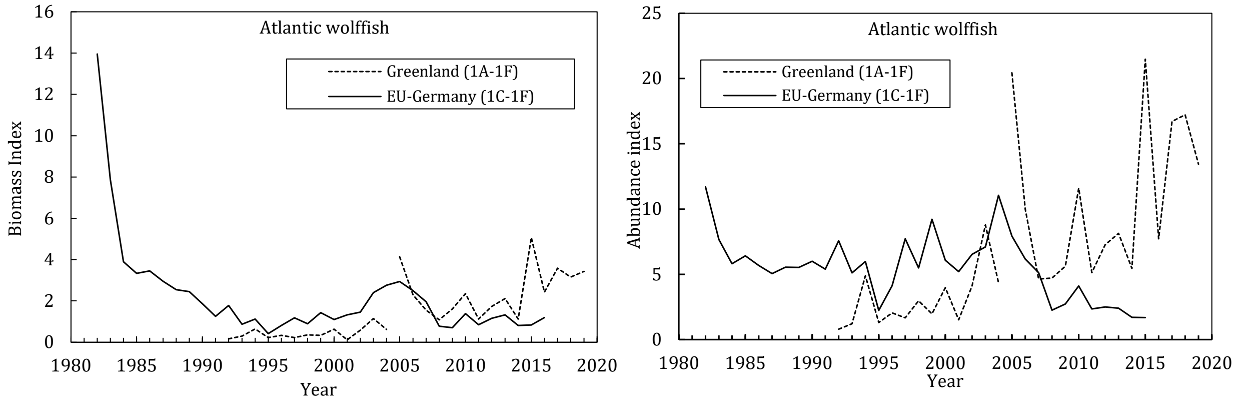


**Figure 4.2.** Atlantic wolffish survey biomass index (left) and abundance index (right) from the surveys.

**Spotted wolffish:**

**The EU-Germany survey** biomass index decreased from 1982 to 1984 and remained at low levels during the 1990s (Figure 4.3). 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 4.3).

**The Greenland shrimp and fish 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 4.3). The abundance index gradually increased both before and after the gear change. (Figure 4.3).

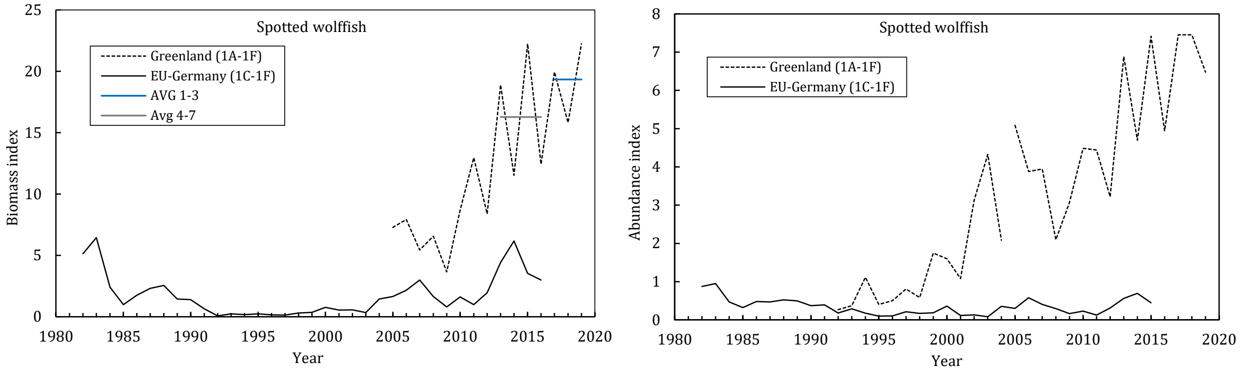


Figure. 4.3. Spotted wolffish survey biomass index (left) and abundance index (right) from the surveys.

## c) Assessment results

### Atlantic wolffish

This stock underwent full assessment in 2017, with the advice that there should be no directed fishery targeting Atlantic wolffish in Subarea 1, since the biomass index of the EU-Germany survey are far below the initial values. Although the Greenland shrimp and fish survey index is increasing, there is no major change in the perception of the stock.

*Biomass:* The biomass index of the EU-Germany survey was far below the initial values in 2016. The survey biomass and abundance indices continue to increase in the Greenland Shrimp and fish survey.

*Fishing mortality*: Unknown

*Recruitment: The higher survey abundance indices in 4 of the most recent 5 years, indicate better recruitment than during the preceding decade*

*State of the stock:* The survey biomass and abundance indices continued to increase in the Greenland Shrimp and fish survey; however, the EU-Germany indices remained low (to 2016). As the EU-Germany survey and the Greenland shrimp and fish survey in the overlapping period were around the same level, it seems reasonable to assume that the biomass remains below the level of the 1980s

**Spotted wolffish**

*Biomass:* The biomass indices of the EU-Germany survey and the Greenland shrimp and fish survey were at a low level during the 1990s. From 2004 to 2016, the biomass index has gradually increased in the EU-Germany survey. The gradually increasing biomass was also observed in the Greenland shrimp and fish survey from 2002 to 2004 and after the gear change from 2005 to 2019.

*Fishing mortality*: Unknown

*Recruitment:* The Greenland shrimp and fish survey, indicate higher numbers of recruits from 2013 to 2019 observed as increasing numbers of spotted wolffish less than 40 cm.

*State of the stock:* Survey indices suggest continued stock growth. Although the catches were below the TAC from 2015-2018, there is no indication that the decreasing catches were related to a decrease in the stock. The average biomass index in the Greenland Shrimp and fish survey is 19% higher in the recent 3 years (2017-2019) compared to the preceding 4-year period.

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

- The ocean climate index in 3M was normal between 2016 and 2019. Before that, 2015 was at its lowest value since 1993, while 2012 was marked by a record high.
- Spring bloom initiation was near normal in 2019 for a third consecutive year. Spring bloom magnitude was below normal in 2019 for the first time since 2015.
- The abundance of copepod and non-copepod zooplankton was above normal in 2019 with the 3rd and 2nd highest anomaly of the time series, respectively.
- Zooplankton biomass was below normal 2019 for the first time since 2014. It was the 3rd lowest anomaly of the time series

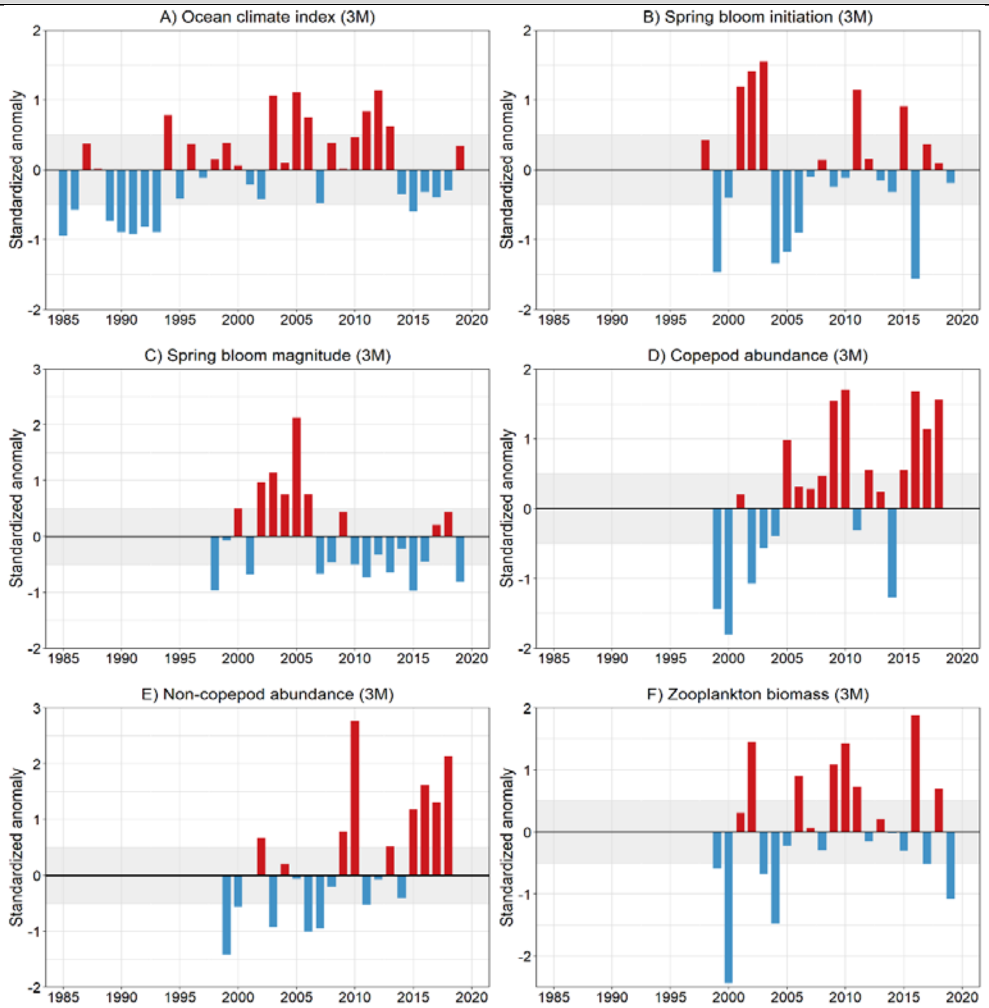


**Figure B1.** Environmental indices for Flemish Cap (in NAFO Div. 3M) during 1990-2019. The ocean climate index (A) for Flemish Cap is the average of 3 time-series of standardized ocean temperature anomalies: sea surface temperatures (SSTs) in Div. 3M, mean temperature over the offshore portion of Flemish Cap hydrographic section (stations FC-15 to FC-35) summer mean bottom temperature over the cap. SSTs and observations along the Flemish Cap hydrographic section are presented in Cyr et al. (2020). Bottom temperatures are derived using the same procedure used in Cyr et al. (2020), but only for the top 1000m of the Cap. Data used for this calculation is mostly from (although not limited to) the EU summer survey. Spring bloom initiation (B) and magnitude (C) indices for the 1998-2019 period are derived from two satellite Ocean Colour boxes (Flemish Pass, and Flemish Cap; see SCR Doc. 20/035 for box location). Zooplankton abundance (D & E) and biomass (F) indices for the 1999-2019 period are derived from a subset of 10 stations along the Flemish Cap Atlantic Zone Monitoring Program oceanographic section covering the Flemish Pass, the Flemish Cap, and the outer shelf break. Positive/negative anomalies indicate conditions above/below (or late/early timing) the long-term average for the reference period. All anomalies are mean standardized anomaly calculated with the following reference periods: ocean climate index, 1981-2010; phytoplankton indices (magnitude and peak timing): 1998-2015; zooplankton indices (copepod, non-copepod, and biomass): 1999-2015. Anomalies within ± 0.5 SD (shaded area) are considered normal conditions.

## Environmental Overview

### Ocean Climate and Ecosystem Indicators

The ocean climate index in Division 3M (Figure B1.A) has remained mostly above normal between about 2003 and 2013. After the record-high of 2012, the index gradually decreased reaching in 2015 its lowest value since 1993. The index was however normal during the period 2016-2019, with only 2019 being on the positive side. Spring bloom initiation has been oscillating between short period (2-3 years) of earlier and later timing between 1998 and 2007. The timing of the spring bloom has remained mostly near normal since with the exceptions of two late blooms in 2011 and 2015, and the earliest bloom of the time series in 2016. Spring bloom initiation (Figure B1.B) in 2019 was near normal for a 3rd consecutive year. Spring bloom magnitude (Figure B1.C) was mainly above normal through the first half of the 2000s before decreasing to near or below normal levels through 2019. Spring production was below normal in 2019 after three consecutive years of near-normal levels. The abundance of copepod (Figure B1.D) and non-copepod (Figure B1.E) zooplankton showed a general increasing trend since the beginning of the time series. Copepod abundance was above normal in 2019 for a third consecutive year after a period of near-normal levels during the early 2010s. The abundance of non-copepods was above normal in 2019 for a 4th consecutive year and presented the second highest anomaly of the time series. Zooplankton biomass (Figure B1.F) showed a generally increasing trend between 1999 and 2010. Biomass then decreased throughout the 2010s except for the record-high biomass observed in 2016 and the above normal level observed in 2018.

## 5. Cod 3M (*Gadus morhua*) in Division 3M

(SCS Doc. 20/06, 20/07, 20/08, 20/09 and SCR Doc. 20/11, 20/31)

### 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TAC | 5.5 | 10.0 | 9.3 | 14.1 | 14.5 | 13.8 | 13.9 | 13.9 | 11.1 | 17.5 | 8.5 |
| STATLANT 21 | 5.2 | 10.0 | 9.1 | 13.5 | 14.4 | 12.8 | 13.8 | 13.9 | 10.5 | 13.0 | |
| STACFIS | 9.3 | 12.8 | 12.8 | 13.985 | 14.3 | 13.8 | 14.0 | 13.9 | 11.5 | 17.5 | |

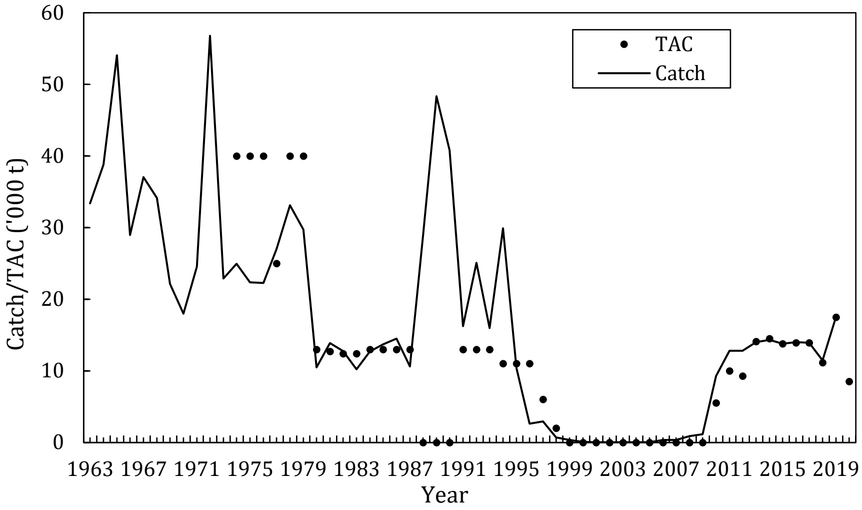


**Figure 5.1.** Cod in Division 3M: STACFIS catches and TAC.

## 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. 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.

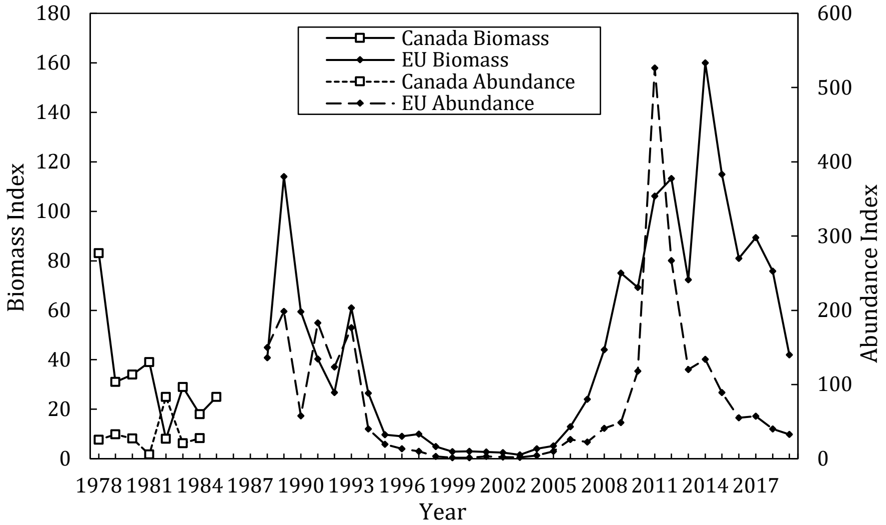


**Figure 5.2.** Cod in Division 3M: Survey abundance and biomass estimates from Canadian survey (1978-1985) and EU Flemish Cap survey (1988-2019).

### *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.

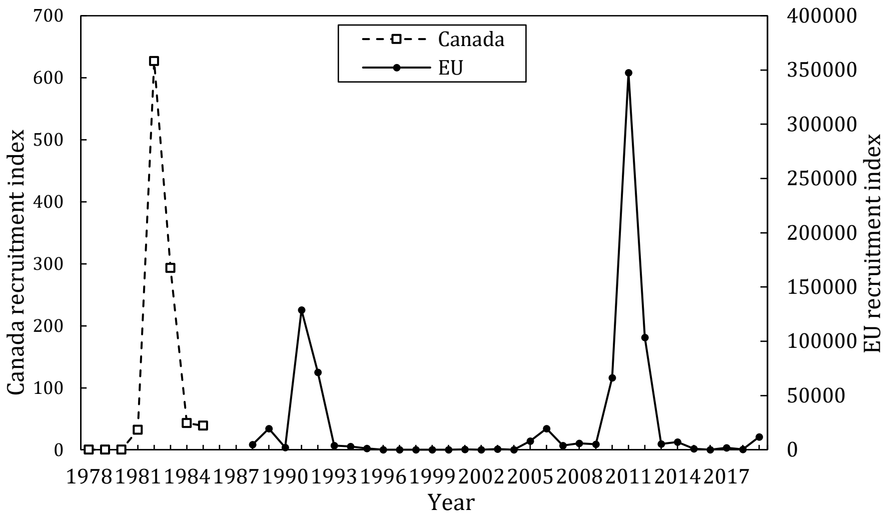


**Figure 5.3.** Cod in Division 3M: Number at age 1 in the Canadian survey (1978-1985) and EU survey (1988-2019).

### *iii) Fishery data*

In 2019 eight countries fished cod in Div. 3M, trawlers from EU-Estonia, EU-Portugal, EU-Spain, Norway, Japan, Russia and St Pierre and Miquelon and longliners from Faroe Islands.

Length and age compositions from the commercial catches are available from 1972 to 2019 with the exception of the 2002 to 2005 period. Since 2010, length information was available for the major participants in the fishery. In 2019 there were length distributions from EU-Estonia, EU-Portugal, EU-Spain, Faroe Islands and Norway (Figure 6.4). The mean in the length composition for EU-Estonia was 62 cm, being 57 cm for EU-Portugal, 65 cm for EU-Spain, 63 cm for Norway and 74 cm for the Faroese longliners. The mean in the total commercial catch length distribution was 62 cm with a length range of 35-135 cm. Since 2013, the commercial catch at age data has been generated using ALKs from the EU survey. In 2018, ages 7 and 8+ were the most abundant in the catch, being age 6 in 2019.

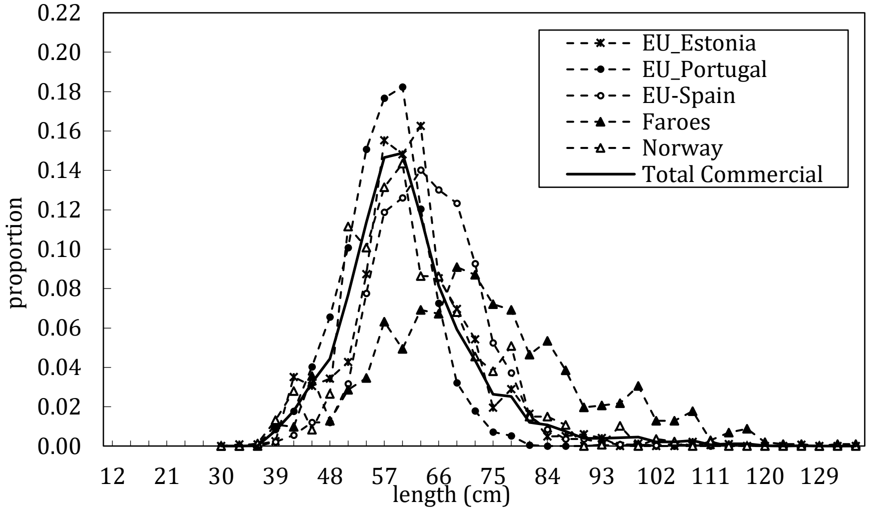


**Figure 5.4.** Cod in Division 3M: Length distribution of the commercial catches in 2019.

### *iv) Biological parameters*

The 2019 indices were derived from the 2019 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 2019, all the ages increased or remained quite stable their weight except ages 7 and 8 (Figures. 5.5 and 5.6).

Maturity ogives are available from the EU Flemish Cap survey for almost all years between 1988 and 2019. 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 2019 at the levels observed before 1990 (4.8 years old) (Figure 5.7).

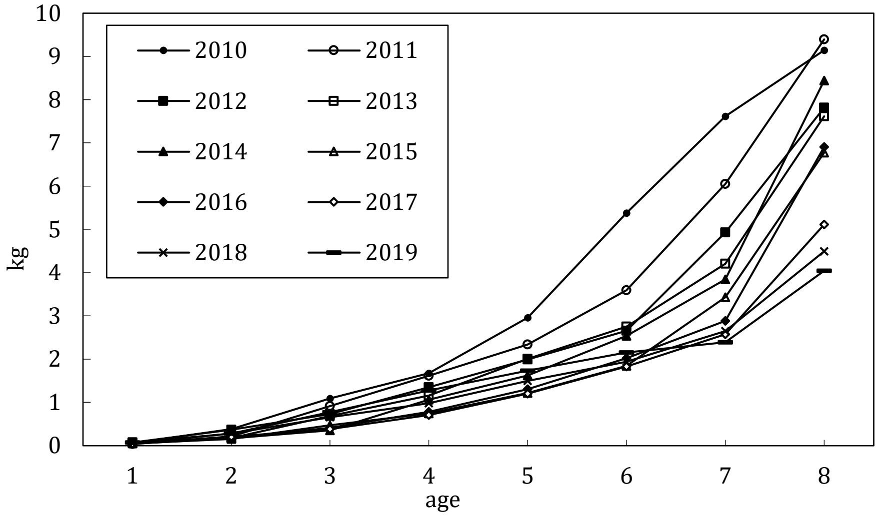


**Figure 5.5.** Cod in Division 3M: Mean weight-at-age in the stock for the 2010-2019 surveys.

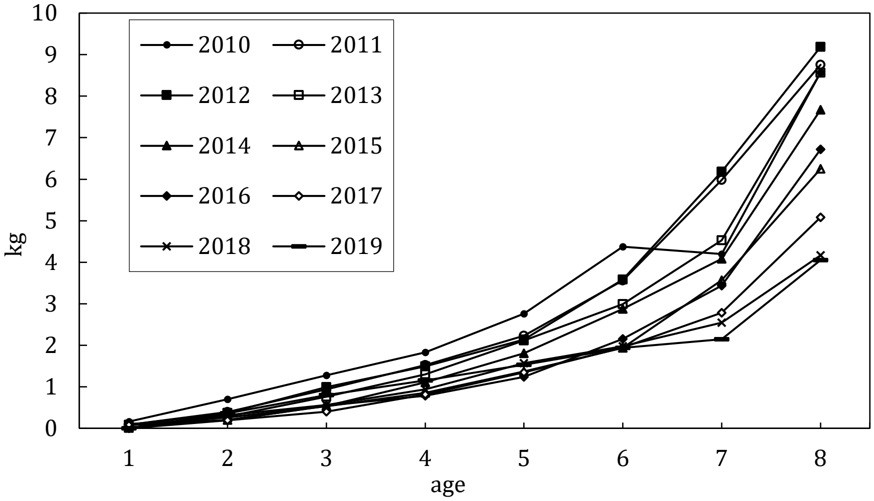


**Figure 5.6.** Cod in Division 3M: Mean weight-at-age in the catch for 2010-2019.

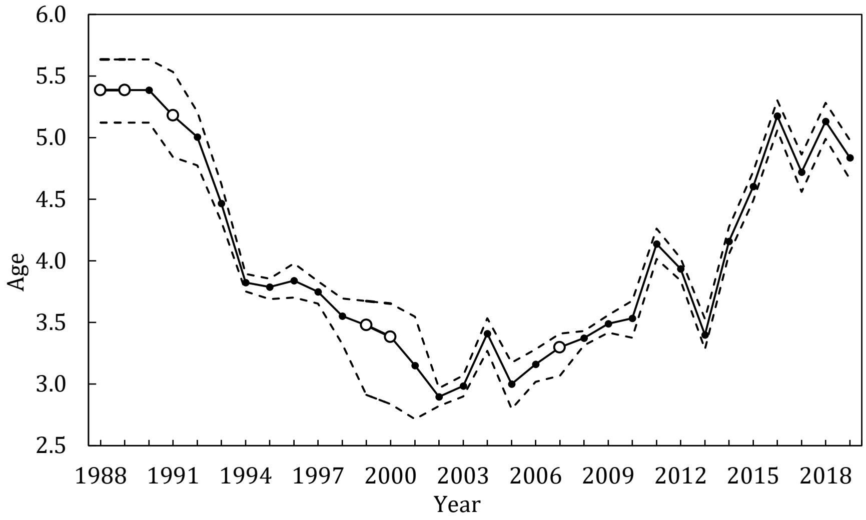


**Figure 5.7.** Cod in Division 3M: Age at 50% maturity (median and 90% confidence intervals) from Canadian survey (1978-1985) and EU-Flemish Cap survey (1988-2019). Interpolated years are represented in white circles.

### c) Estimation of Parameters

A Bayesian SCAA model was used as the basis for the assessment of this stock. Input data and settings are as follows:

*Catch data*: catch numbers and mean weight at age for 1988-2019, 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 (1988-2019).

*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<br>1988-2019 | $LN\left(medrec, cvrec\right)$ | *medrec*=45000, *cvrec*=10 |
| N(1988,a),<br>a=2-8+ | Ages 2-7<br>$LN\left(median = medrec \times e^{-\sum_{age=1}^{a-1} M\left(age\right)+medFsurv\left(age\right)}, cv = cvsurv\right)$<br>Ages 8+<br>$LN\left(median = medrec \times \frac{e^{-\sum_{age=1}^{A-1}\left(M\left(age\right)+medFsurv\left(age\right)\right)}}{1-e^{-M\left(A+\right)+medFsurv\left(A+\right)}}, cv = cvsurv\right)$ | *medFsurv*(1,…,7)={0.0001, 0.1, 0.5, 0.7, 0.7, 0.7, 0.7}<br>*cvsurv*=10 |
| *f*(y)<br>y=1988-2019 | Year 1988<br>$LN\left(median = medf\,,\ cv = cvf\ \right)$<br>Years 1989-2019<br>$LN\left(median = AR(1)\,over\ f\,,\ cv = cvf\ \right)$ | *medf*=0.2, *cvf*=4 |
| *rC*(y,a), a=2,8+<br>1988-2019 | Year 1988<br>$LN\left(median = medrC\left(a\right),\ cv = cvrC\left(a\right)\right)$<br>Years 1989-2019<br>$LN\left(median = last\ year\ rC,\ cv = cvrCcond\ \right)$ | *medrC*(a)=c(0.01,0.3,0.6,0.9,1,1,1),<br>*cvrC*(a)=c(4,4,4,4,4,4)<br>*cvrCcond*=0.2 |
| Total Catch<br>1988-2019 | $LN\left(median = \sum_{age=1}^{A+} mu.C\left(y, age\right) wcatch\left(y, age\right),\ cv = cvcW\right)$<br>$mu.C\left(y,a\right) = N\left(y,a\right)\left(1-e^{-Z\left(y,a\right)}\right)\frac{F\left(y,a\right)}{Z\left(y,a\right)}$ | *cvCW=0.077* |
| Catch Numbers at age, a=2,8+<br>1988-2019 | $LN\left(median = mu.C\left(y,a\right),\ cv = cv.C\right)$ | *cv.C*=0.2 |
| EU Survey<br>Indices (I)<br>1988-2019 | $I(y) \sim LN\left(median = \mu(y,a),\ cv = cvEU\ \right)$<br>$\mu(y,a) = q(a)\left(N(y,a)\frac{e^{-\alpha Z(y,a)} - e^{-\beta Z(y,a)}}{\left(\beta-\alpha\right)Z(y,a)}\right)^{\gamma(a)}$<br>$\gamma(a)\begin{cases}\sim N(\text{mean} = 1, \text{variance} = 0.25),\ if\ a = 1 \\ = 1,\ if\ a \geq 2\end{cases}$<br>$\log(q(a)) \sim N(\text{mean} = 0, \text{variance} = 5)$ | I is the survey abundance index<br>q is the survey catchability at age<br>N is the stock abundance index<br>*cvEU*=0.3<br>α = 0.5, β = 0.58 (survey made in July)<br>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)<br>*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 73% to levels observed prior to the closure of the fishery. Median biomass has also declined, but to a lesser extent (by 49%) as the strong year classes of 2009 to 2011 have grown and dominate the biomass (Figure 5.8).

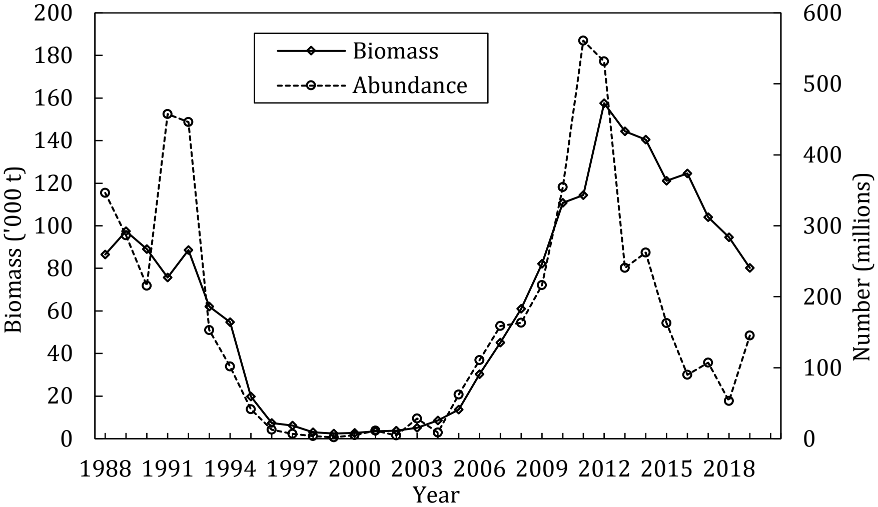


**Figure 5.8.** Cod in Div. 3M: Biomass and Abundance estimates.

*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 15 271 t; see below, section g) in 2020 is very low (1%). SSB in 2020 was calculated using the numbers estimated by the assessment at the beginning of 2020, applying the maturity ogive and mean weight at age in stock from 2019.

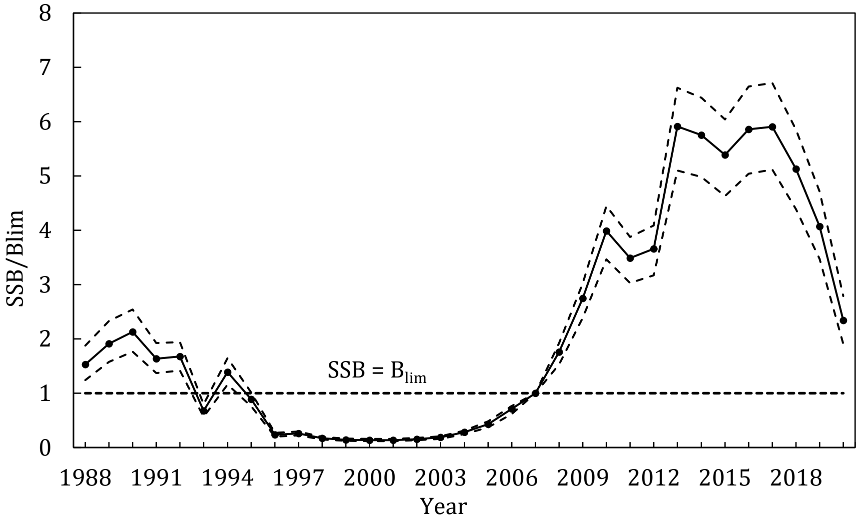


**Figure 5.9.** Cod in Div. 3M: Median and 80% probability intervals SSB/$B_{lim}$ estimates. The horizontal dashed line corresponds to SSB = $B_{lim}$.

*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 (Figure 5.10).

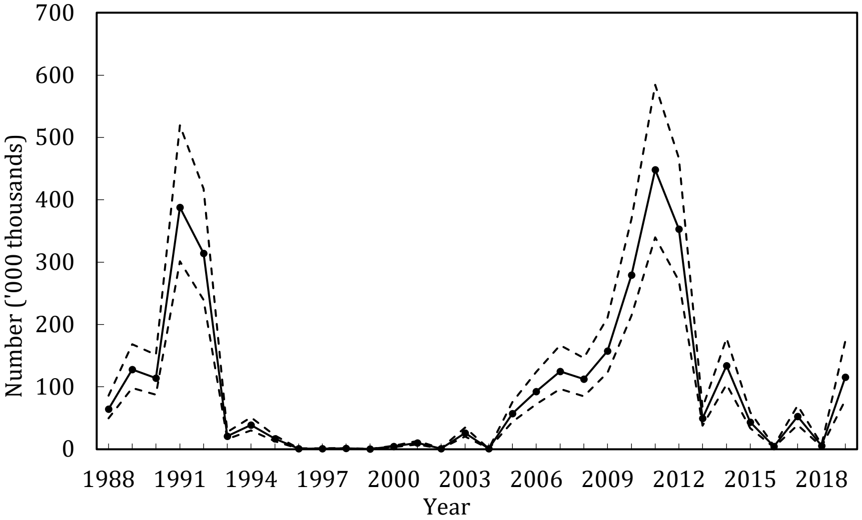


**Figure 5.10.** Cod in Div. 3M: Recruitment (age 1) estimates and 80% probability.

*Fishing mortality*: F increased in 2010 with the re-opening of the fishery although it was below $F_{lim}$ (0.191, see below, section g) until 2018. In 2019, F increased, being above $F_{lim}$ (Figure 5.11).

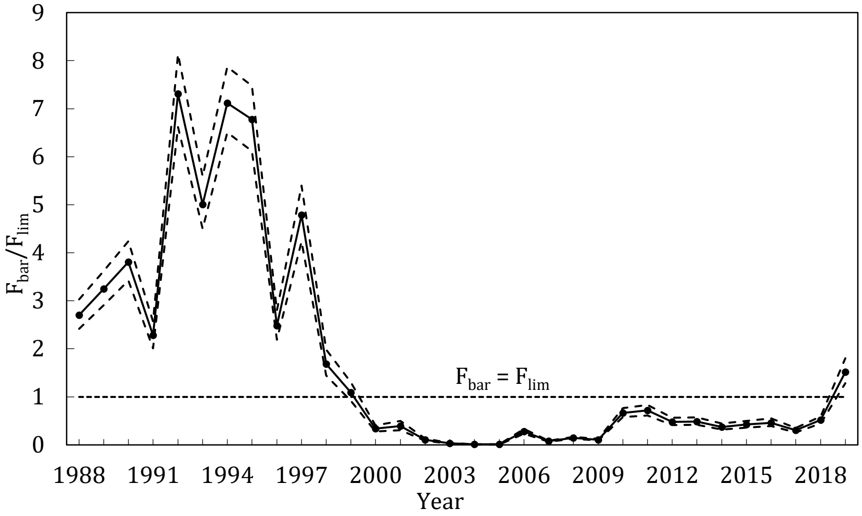


**Figure 5.11.** Cod in Div. 3M: $F_{bar}$ (ages 3-5) estimates and 80% probability intervals. The horizontal dashed line corresponds to $F = F_{lim}$.

*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 | 0.61 | 0.36 | 0.26 | 0.27 | 0.38 | 0.33 | 0.39 |

### 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, 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 (Figures 5.13 and 5.14).

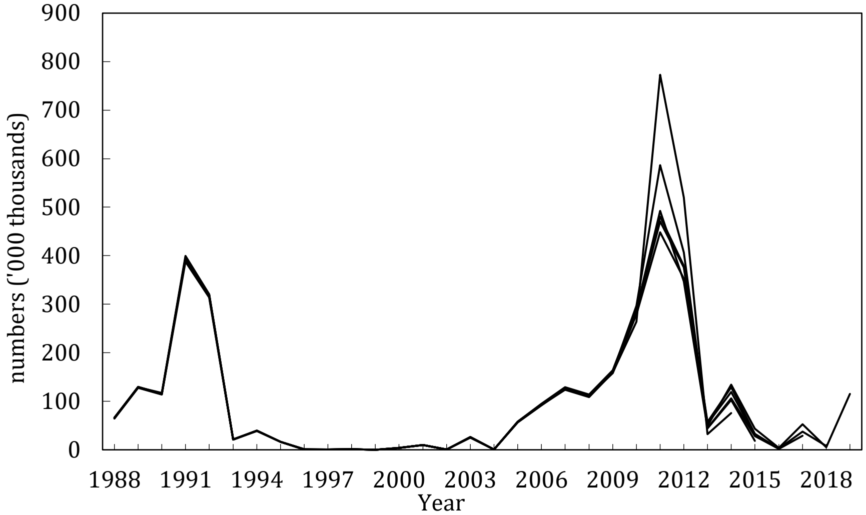


**Figure 5.12.** Cod in Div. 3M: Retrospective results for recruitment.

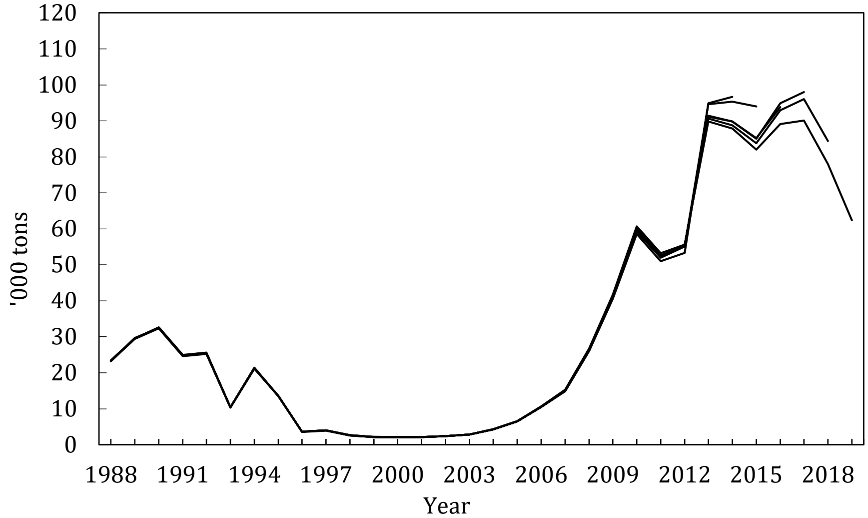


**Figure 5.13.** Cod in Div. 3M: Retrospective results for SSB.

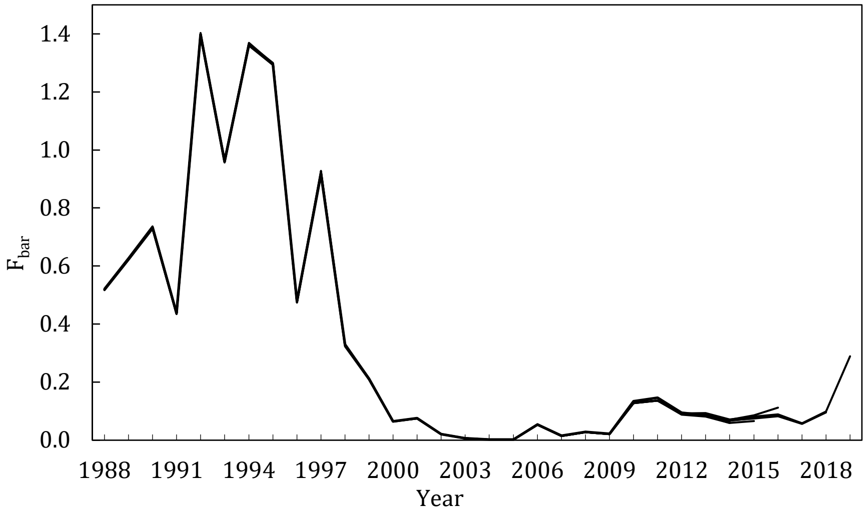


**Figure 5.14.** Cod in Div. 3M: Retrospective results for average fishing mortality.

### f) State of the stock

Current SSB is estimated to be above *B<sub>lim</sub>* (median 15 271 t) although it is declining rapidly and is expected to continue its decline in the near future due to poor recruitment between 2015 and 2018.

F increased in 2010 with the re-opening of the fishery although until 2018 it was below $F_{lim}$ (median 0.191). In 2019, *F* increased to a level above $F_{lim}$.

### g) Reference Points

$B_{lim}$ was estimated as the 2007 SSB, being its median value15 271 tons (Figure 5.15). $F_{lim}$ was estimated based on $F_{30\%SPR}$ calculated with the mean 2017-2019 input data as 0.191 (median value) (Figure 5.16).

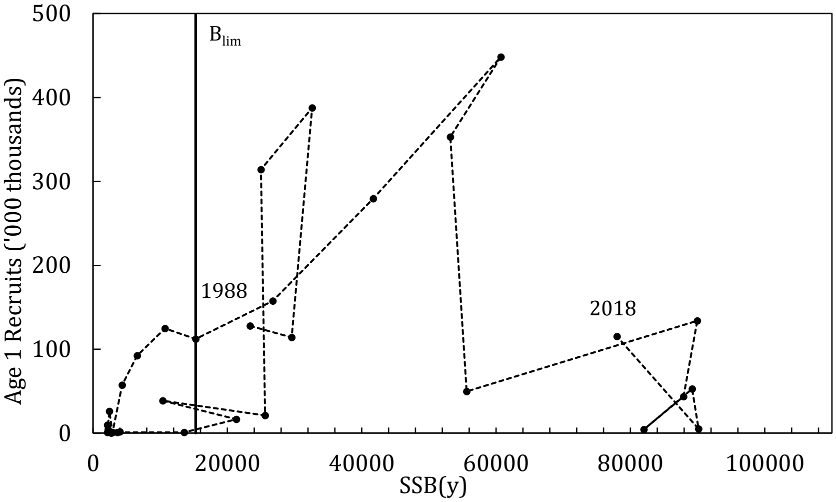


**Figure 5.15.** Cod in Div. 3M: Stock-Recruitment age 1 (posterior medians) plot. $B_{lim}$ is plotted in the graph.

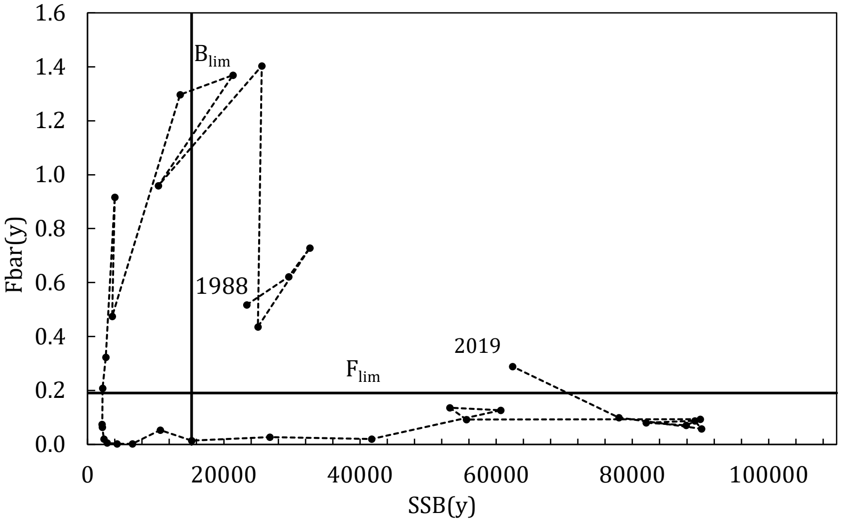


**Figure 5.16.** Cod in Div. 3M: Stock-*$F_{bar}$*(3-5) (posterior medians) plot. *$B_{lim}$* and *$F_{lim}$* are plotted in the graph.

### 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 2020 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 2020*: estimated from the assessment.

*Recruitments for 2020-2023*: Recruits per spawner were drawn randomly from 2016-2018.

*Maturity ogive for 2020-2023*: Mean of the last three years (2017-2019) maturity ogive.

*Natural mortality for 2020-2023*: 2019 natural mortality from the assessment results.

*Weight-at-age in stock and weight-at-age in catch for 2020-2023*: Mean of the last three years (2017-2019) weight-at-age.

*PR at age for 2020-2023*: Mean of the last three years (2017-2019) PRs.

*$F_{bar}$(ages 3-5)*: Four scenarios were considered:

(*Scenario 1*) $F_{bar}$=3/4$F_{lim}$ (median value = 0.143).

(*Scenario 2*) $F_{bar}$=0 (no catch).

(*Scenario 3*) Catch in 2021-2023=1000 tons.

(*Scenario 4*) Catch in 2021-2023=3000 tons.

All scenarios assumed that the Yield for 2020 is the established TAC (8 531 t).

The results indicate that under all scenarios, total biomass during the projected years will decrease sharply (Figure 6.17), while the SSB will increase slightly in 2023 and 2024 with the $F$=0 and the Catch=1000t scenarios (Figure 6.18). The probability of SSB being below $B_{lim}$ in 2022 and 2023 is very high (≥24%) in the scenarios with $F_{bar}$=3/4$F_{lim}$ and Catch=3000t, being very low (≤10%) in the rest of the cases. The probability of SSB in 2023 being above that in 2020 is <1%.

Under all scenarios, the probability of F exceeding $F_{lim}$ is less than or equal to 6%.

Under 3/4$F_{lim}$, the projected Yield has a decreasing trend in the projected years (2021-2023).

Results of the projections are summarized in the following table:

| | B | | SSB | | Yield |
|---|---|---|---|---|---|
| | Median and 80% CI | | | | |
| $F_{bar}$=3/4$F_{lim}$ (median=0.143) | | | | | |
| 2020 | 48777 | (42258 - 55350) | 35725 | (30140 - 41365) | 8531 |
| 2021 | 35857 | (30252 - 41757) | 23121 | (18576 - 27867) | 5595 |
| 2022 | 26786 | (21764 - 32499) | 15472 | (11920 - 19144) | 4622 |
| 2023 | 19902 | (15130 - 25556) | 14280 | (10838 - 18316) | 3494 |
| 2024 | 15396 | (10877 - 21078) | 13556 | (9424 - 18349) | |
| $F_{bar}$=0 | | | | | |
| 2020 | 48777 | (42258 - 55350) | 35725 | (30140 - 41365) | 8531 |
| 2021 | 35857 | (30252 - 41757) | 23121 | (18576 - 27867) | 0 |
| 2022 | 32245 | (27255 - 37930) | 20159 | (16445 - 23914) | 0 |
| 2023 | 28937 | (24157 - 34759) | 22321 | (18764 - 26370) | 0 |
| 2024 | 27386 | (22667 - 33174) | 25006 | (20842 - 29872) | |
| Catch=1000 tons | | | | | |
| 2020 | 48777 | (42258 - 55350) | 35725 | (30140 - 41365) | 8531 |
| 2021 | 35857 | (30252 - 41757) | 23121 | (18576 - 27867) | 1000 |
| 2022 | 31265 | (26251 - 36956) | 19317 | (15655 - 23065) | 1000 |
| 2023 | 27176 | (22347 - 32982) | 20743 | (17192 - 24760) | 1000 |
| 2024 | 24680 | (19993 - 30474) | 22430 | (18278 - 27230) | |
| Catch=3000 tons | | | | | |
| 2020 | 48777 | (42258 - 55350) | 35725 | (30140 - 41365) | 8531 |
| 2021 | 35857 | (30252 - 41757) | 23121 | (18576 - 27867) | 3000 |
| 2022 | 29305 | (24278 - 35017) | 17616 | (13964 - 21334) | 3000 |
| 2023 | 23596 | (18837 - 29285) | 17549 | (14040 - 21560) | 3000 |
| 2024 | 19249 | (14646 - 24980) | 17264 | (13095 - 22048) | |

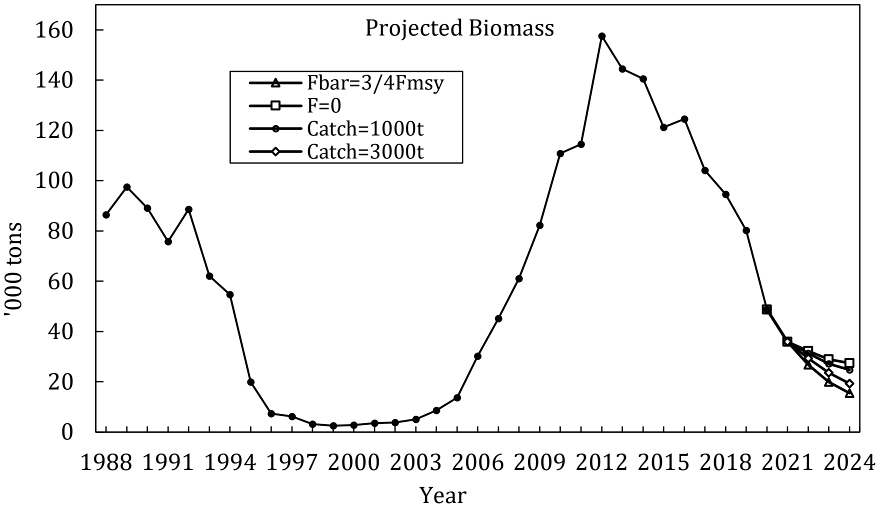


**Figure 5.17.** Cod in Div. 3M: Projected Total Biomass under all the Scenarios.

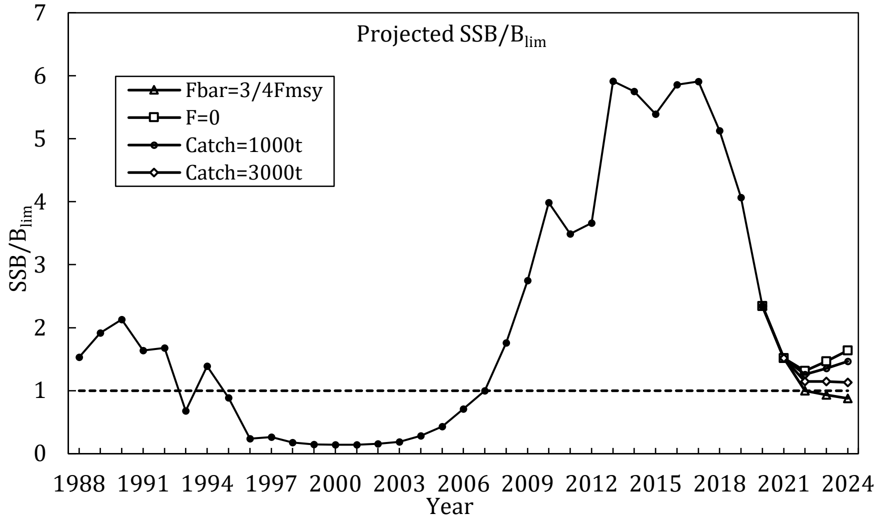


**Figure 5.18.** Cod in Div. 3M: Projected SSB under all the Scenarios

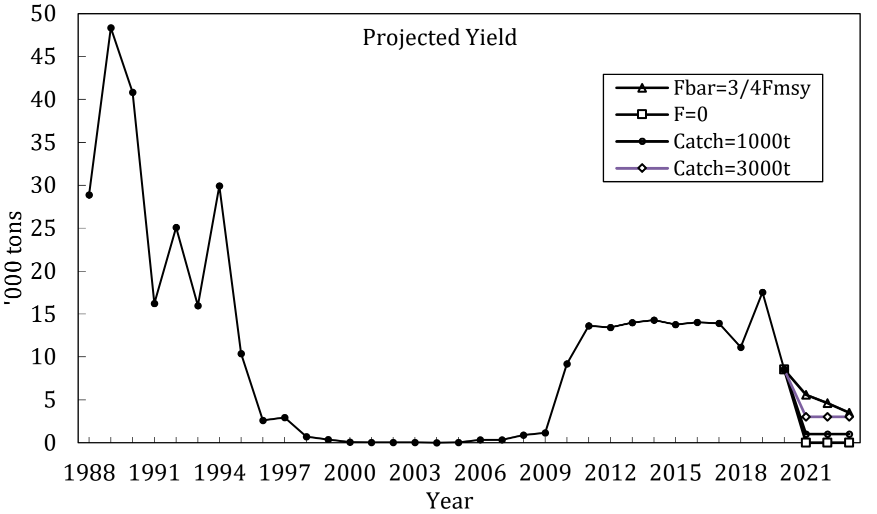


**Figure 5.19.** Cod in Div. 3M: Projected removals under all the Scenarios

The risk of each scenario is presented in the following table:

| | Yield | | | $P(B < B_{lim})$ | | | | $P(F > F_{lim})$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2020 | 2021 | 2022 | 2020 | 2021 | 2022 | 2023 | 2020 | 2021 | 2022 | $P(B_{23} > B_{20})$ |
| 3/4Flim = 0.143 | 8531 | 5595 | 4622 | <1% | 1% | 50% | 62% | 4% | 5% | 6% | <1% |
| F=0 | 8531 | 0 | 0 | <1% | 1% | 6% | 1% | 4% | 0% | 0% | <1% |
| Catch=1000t | 8531 | 1000 | 1000 | <1% | 1% | 10% | 4% | 4% | <1% | <1% | <1% |
| Catch=3000t | 8531 | 3000 | 3000 | <1% | 1% | 24% | 24% | 4% | <1% | <1% | <1% |

### 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 2021.

## 6. Beaked Redfish (*Sebastes mentella* and *Sebastes fasciatus*) in Division 3M

(SCR Doc. 19/016, 20/011; SCS Doc. 20/05, 20/06, 20/07, 20/09, 20/13)

Interim Monitoring Report

### 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.

### *i) Description of the fishery*

The redfish fishery in Div. 3M increased from 20 000 tons in 1985 to 81 000 tons in 1990, falling continuously since then until 1998-1999, when a minimum catch around 1100 tons was recorded mostly as by-catch of the Greenland halibut fishery. An increase of the fishing effort directed to Div. 3M redfish is observed 2005 onwards basically pursued by Portuguese bottom trawl and Russia bottom and pelagic trawl. Part of this fishing effort has been deployed on shallower depths above 300m and is associated with the increase of cod catches and reopening of the Flemish Cap cod fishery in 2010.

STACFIS catch estimates were available till 2010. Over 2006-2010 an average annual bias of 15% plus was recorded between SACFIS 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 - 2019 catch estimates were obtained with the application of the CESAG method. The 1989-2019 catch estimates from those different sources are accepted as the 3M redfish landings.

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

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| TAC | 10.0 | 6.5 | 6.5 | 6.5 | 6.7 | 7.0 | 7.0 | 10.5 | 10.5 | 8.6 |
| STATLANT 21 | 9.7 | 5.4 | 6.8 | 6.4 | 6.9 | 6.6 | 7.1 | 10.5 | 10.5 | |
| STACFIS Total catch[1] | 11.1 | 6.2 | 7.8 | 7.4 | 6.9 | 6.6 | 7.1 | 10.5 | 10.5 | |
| STACFIS Catch[2] | 9.0 | 6.3 | 5.2 | 4.6 | 5.2 | 6.2 | 6.9 | 10.3 | 10.2 | |

[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.

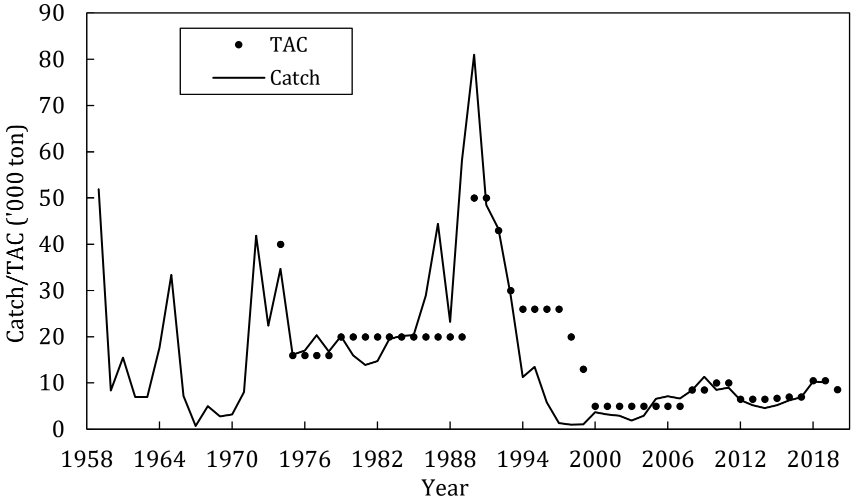


**Figure 6.1.** Redfish in Div. 3M: catches and TACs.

## b) Data Overview

### *i) Research surveys*

Flemish Cap Survey: Despite a sequence of abundant year classes and a low exploitation regime over almost twenty years, survey results suggest that the beaked redfish stock increased sharply from 2004 to 2006 and then declined rapidly over the second half of the 2000's. Such unexpected shift on the stock dynamics can only be attributed to mortality other than fishing mortality. Spawning stock biomass has remained high in recent years while exploitable biomass and abundance are declining since 2012 (Figure 6.2). There has been very low recruitment at age four in most recent years.

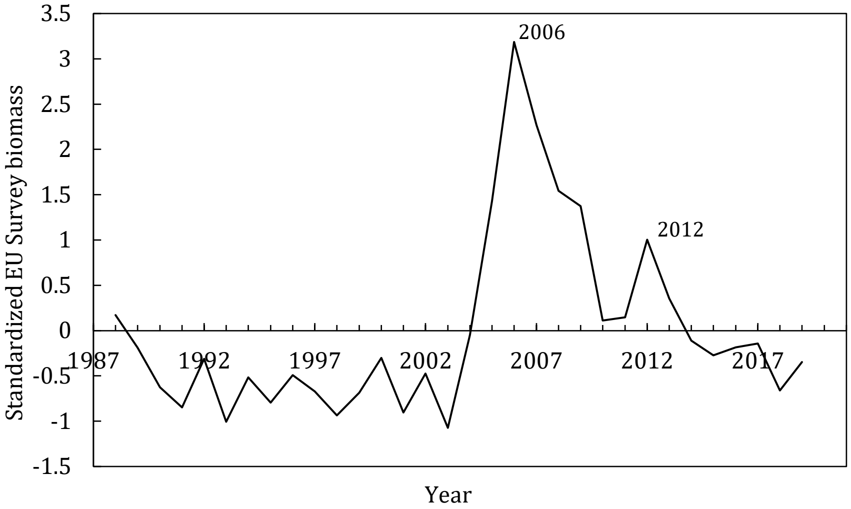


**Figure 6.2.** Beaked redfish in Div. 3M: survey standardized total biomass index (1988-2019).

### c) Conclusions

The perception of the stock status has not changed.

The next full assessment of the stock is planned for 2021.

## 7. Golden Redfish (*Sebastes norvegicus*) in Division 3M

(SCR Doc. 19/016, 19/035, 20/011; SCS Doc. 20/05, 20/06, 20/07, 20/09, 20/13)

Interim Monitoring Report

### 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 7,662 tonnes in 2009. In 2010, catches decreased and remained relatively stable until 2014 between 2,000 and 3,000 tonnes. After 2014, catches decreased continuously, being from 2016 to 2018 at residual levels (148 tonnes in 2018). In 2019 provisional catches of golden redfish are 259 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:

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| TAC[1] | 10.0 | 6.5 | 6.5 | 6.5 | 6.7 | 7.0 | 7.0 | 10.5 | 10.5 | 8.6 |
| STATLANT 21[1] | 9.7 | 5.4 | 6.8 | 6.4 | 6.9 | 6.6 | 7.1 | 10.5 | 10.5 | |
| STACFIS Total catch[2] | 11.1 | 6.2 | 7.8 | 7.4 | 6.9 | 6.6 | 7.1 | 10.5 | 10.5 | |
| STACFIS Catch[3] | 2.1 | 1.9 | 2.6 | 2.9 | 1.7 | 0.4 | 0.3 | 0.1 | 0.3 | |

[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.

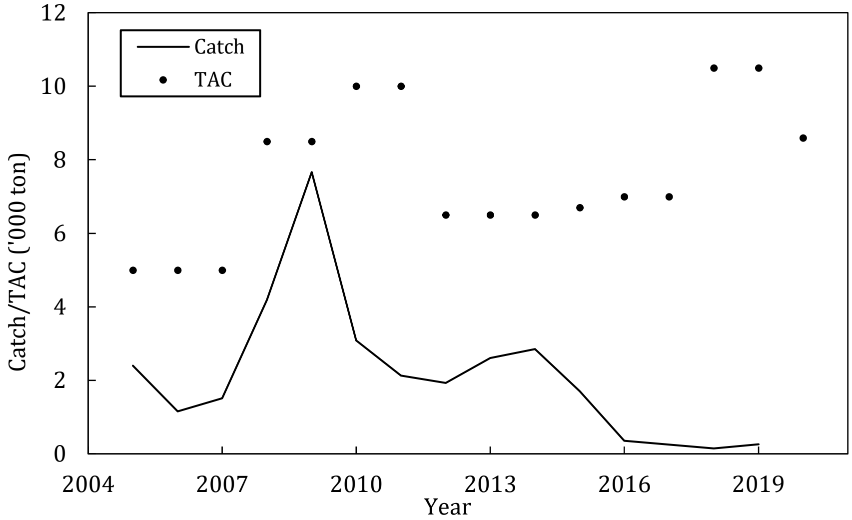


**Figure 7.1.** Golden redfish in Div. 3M: Golden redfish catches and TACs of all three redfish species combined.

## b) Data Overview

### *i) Research surveys*

The 1988-2019 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 2019 are at very low levels. Survey results are noisy, with the characteristic variance of redfish indices, but broad trends show through the noise.

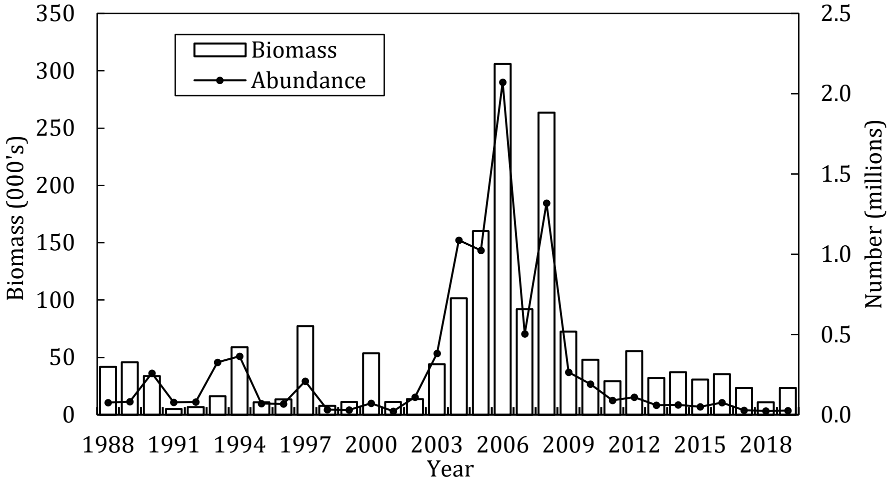


**Figure 7.2.** Golden redfish in Div. 3M: EU biomass and abundance indices, 1988-2019.

### 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.

## 8. American Plaice (*Hippoglossoides platessoides*) in Division 3M

(SCR Doc. 05/29; 20/11, 39; SCS Doc. 18/8, 13; 19/9; 20/7, 9, 13)

### a) Introduction

The American plaice stock occurs mainly at depths shallower than 600 m on Flemish Cap. Catches are taken mainly by otter trawl, primarily in a bycatch fishery since 1992.

Nominal catches during 1960 to 1973 varied with a peak of about 5 341 tonnes in 1965. Catches of this stock became regulated in 1974 and ranged from 275 tonnes (1993) to 5 600 tonnes (1987) until 1996. Since 1997 catches have remained low and declined to a historical minimum in 2012 (63 tonnes). Catches increased in recent years, oscillating between 120 and 300 tonnes and are taken as bycatch partially in the Div.3M cod fishery

From 1979 to 1993 a TAC of 2 000 tonnes was in effect for this stock. A reduction to 1 000 tonnes was agreed for 1994 and 1995 and a moratorium was agreed to thereafter (Figure 8.1).

Recent catches and TACs ('000 tonnes) 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 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | |
| STACFIS | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.2 | 0.2 | 0.2 | 0.3 | |

ndf No directed fishing.

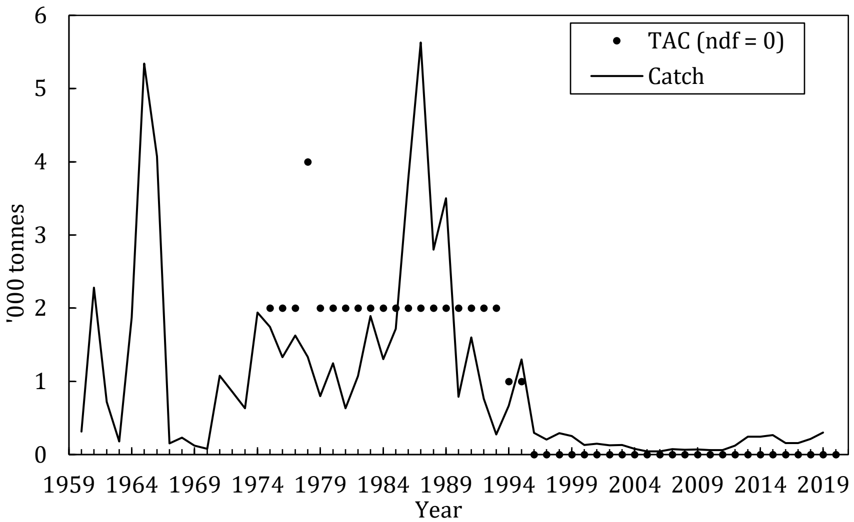


**Figure 8.1.** American plaice in Div. 3M: STACFIS catches and TACs. No directed fishing is plotted as 0 TAC.

### b) Input Data

#### *i) Commercial fishery data*

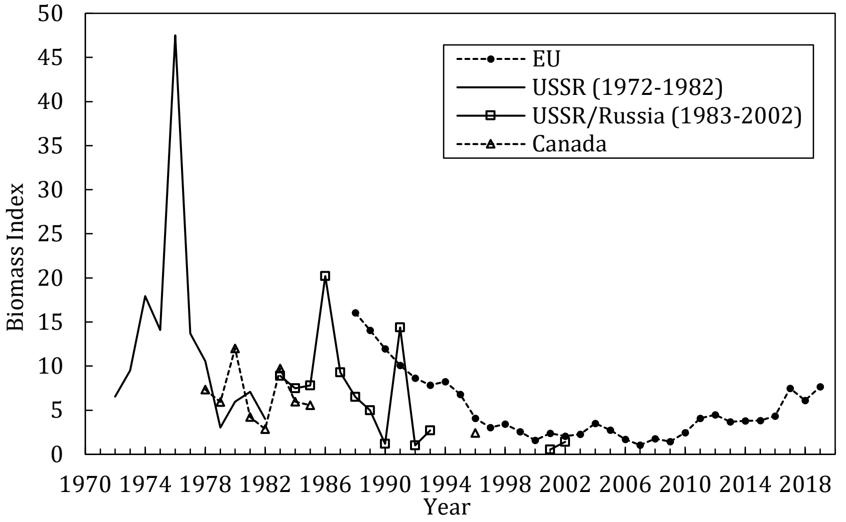
EU-Portugal provided length composition data for the 2017, 2018 and 2019 trawl catches. EU-Spain provided length composition data for the 2019 trawl catches. Russia provided length composition data for the 2017 and 2019 trawl catches, the Portuguese 2019 length frequency was not used due to the low number of individuals sampled. The length frequencies were used to estimate the length and age compositions for the 2017-2019 total catch. There is no dominant age in catches between 2017 and 2019, with catches distributed mainly between the ages of 4 to 12.

#### *ii) Research survey data*

The series of research surveys conducted by the EU since 1988 were continued in July 2019. In June 2003 a new Spanish research vessel, the RV Vizconde de Eza replaced the RV Cornide de Saavedra that had carried out the EU survey series with the exception of the years of 1989 and 1990. In order to preserve the full use of the 1988-2002 survey indices, the original mean catch per tow, biomass and abundance at length distributions for American plaice have been converted to the new vessel units so that each former time series could be comparable with the new indices obtain with the RV Vizconde de Eza. The methodology used to convert the series was accepted by STACFIS in 2005 (SCR 05/29). The results of the calibration show that the RV Vizconde de Eza is 33% more efficient than the RV Cornide de Saavedra in catching American plaice.

USSR/Russia conducted surveys from 1972 to 1993 with two additional surveys conducted in 2001 and 2002. From 1972 to 1982 the USSR survey used a fixed-station design. Since 1983 USSR/Russia adopted a stratified random survey design and the USSR surveys for 1972 to 1982 were post-stratified for comparison to the new survey series. Canada conducted research vessel surveys from 1978 to 1985, and a single survey was conducted in 1996.

Although the USSR/Russia survey series (1972-1993) shows high variability, there was a decreasing trend during 1986-93. Abundance and biomass from the USSR/Russia survey in 2001 were the lowest of the series. Canadian survey biomass and abundance between 1978 and 1985 varied without trend at a level similar to that seen in the USSR/Russia survey and in 1996 were similar to estimates from the EU survey (Figure 8.2). The EU survey series had a continuous decreasing trend in abundance and biomass from the beginning of the series to 2000 and has remained low. The 2007 abundance and biomass were the lowest of the series. Since 2008, due to improved recruitment, biomass and abundance indices increased. The EU's survey biomass shows a faster upward trend than the abundance, due to the growth of existing year classes. In recent years the stock recovered to the levels of mid 90´s, when the fishery was closed.



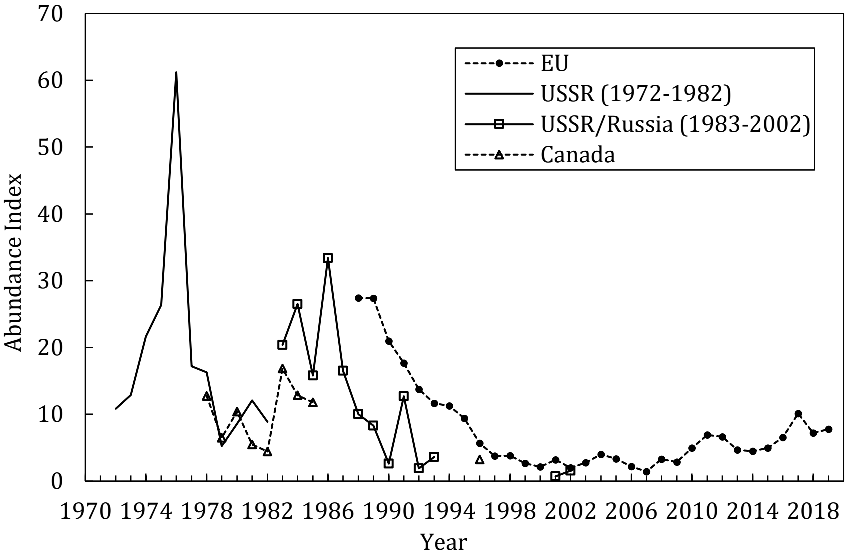


**Figure 8.2.** American plaice in Div. 3M: trends in survey biomass and abundance indices. EU survey data prior to 2003 have been converted to RV Vizconde Eza equivalents.

Ages 7, 6 and 4 corresponding to the 2012, 2013 and 2015 year-classes respectively, were dominant in the 2019 EU survey. Between 2006 and the 1990 year-class, the recruitment was very poor as shown by EU survey indices.

An index of spawning stock biomass (50% of age 5 and 100% of age 6 plus) from the EU survey series declined from 1988 to 2000 and has remained low. A minimum was recorded in 2007. During 2010-2012 the index increased and then stabilized till 2016 around 3 500 tonnes as the strong 2006 year class entered the SSB. From 2016 to 2019 this index increased to around 7 000 tonnes with the entering of new year classes. However, there are few fish aged 16 or older.

### c) Estimation of Parameters

A fishing mortality index (*F*) is given by the catch and EU survey biomass ratio for ages fully recruited to the fishery.

A partial recruitment vector for American plaice in Div. 3M was revised assuming flat topped partial recruitment and adjusting a relative mean index-at-age to a general logistic curve. This index was derived by determining the ratio between the 1988-2019 age composition of the catch and American plaice EU survey abundance. Both data sets were standardized to numbers-per-thousand prior to analysis.

In the last assessment in 2017, extensive exploratory analyses were conducted to investigate the impact of changing: 1) the first age in the assessment (age 1 or 4); 2) the first year of the tuning fleet (1998 or 1994); 3) splitting the tuning series in two (1988-1993 and 1994-2016); 4) or changing M from 0.2 to 0.15. The XSA with age 4 onwards, M=0.15 and splitting the tuning fleet showed better diagnostics, but they are highly dependent on the input sets and show a strong retrospective pattern. In this year assessment no further exploratory analysis was done and the XSA was updated by adding the 2017, 2018 and 2019 data, although it shows a better retrospective pattern, the model behavior didn´t changed and it is still highly dependent on the input sets (such as M input, since F is too low). (Figure 8.3)

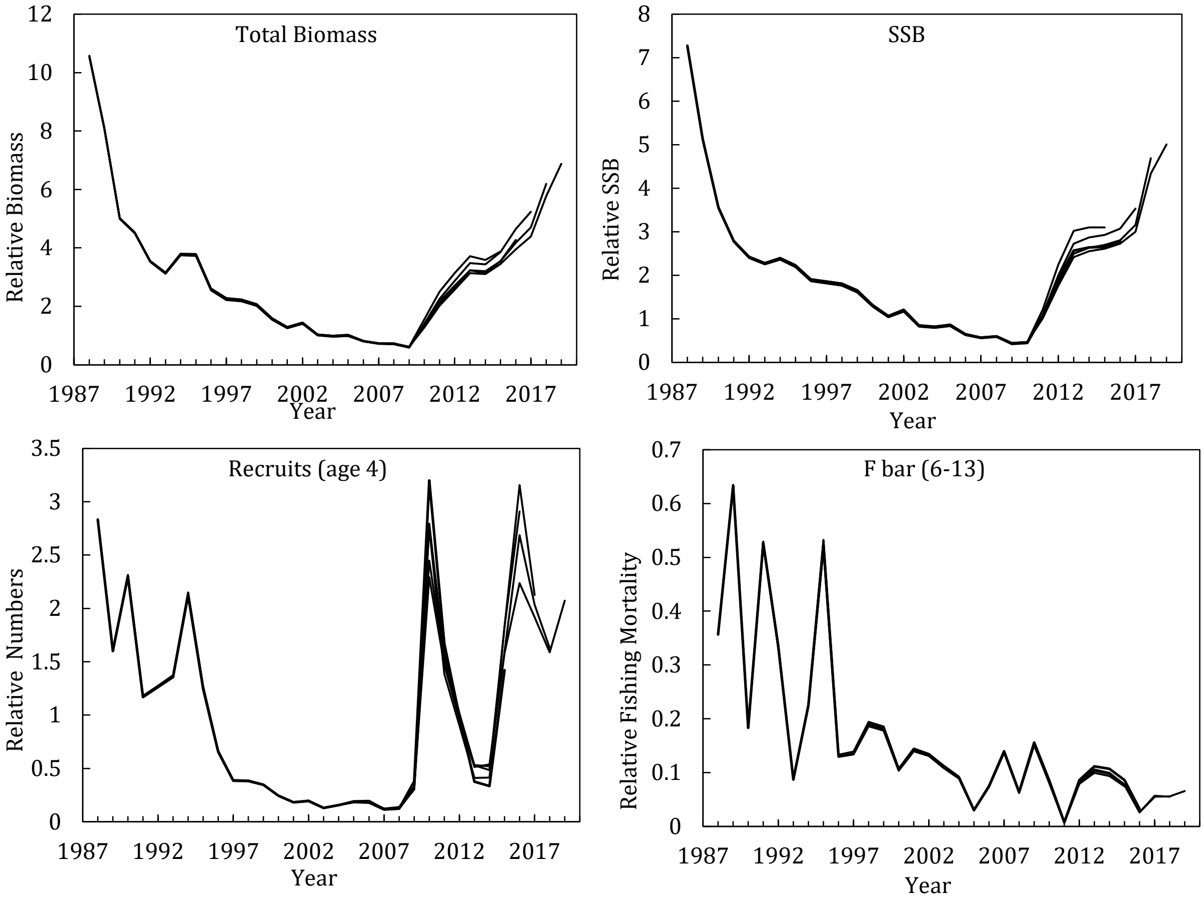


**Figure 8.3.** American plaice in Div. 3M: XSA retrospective analysis, last year 2016-2010: biomass, spawning stock biomass, average fishing mortality (ages 6-13) and recruitment (age 4).

The VPA-type Bayesian model with all data (ages 1-16+, tuning from 1988-2016) run in the last assessment was updated with the 2017-2019 data and run with M=0.1.5 with the same c.v. (0.05). The model runs used the following input sets:

*Catch data*: catch numbers and mean weight at age for 1988-2019.

*Catchability analysis*: dependent on stock size for age 4.

*Priors*: for survivors at age at the end of the final assessment year, for survivors from the last true age at the end of every year, for numbers at age of the survey and for the natural mortality.

The VPA-type Bayesian model results indicated a dependency on the chosen priors and their distribution.

None of the analyses (XSA or VPA-type Bayesian model) were accepted as a basis to estimate stock size. Nevertheless, the XSA was chosen to illustrate trends in the stock (Figure 8.4).

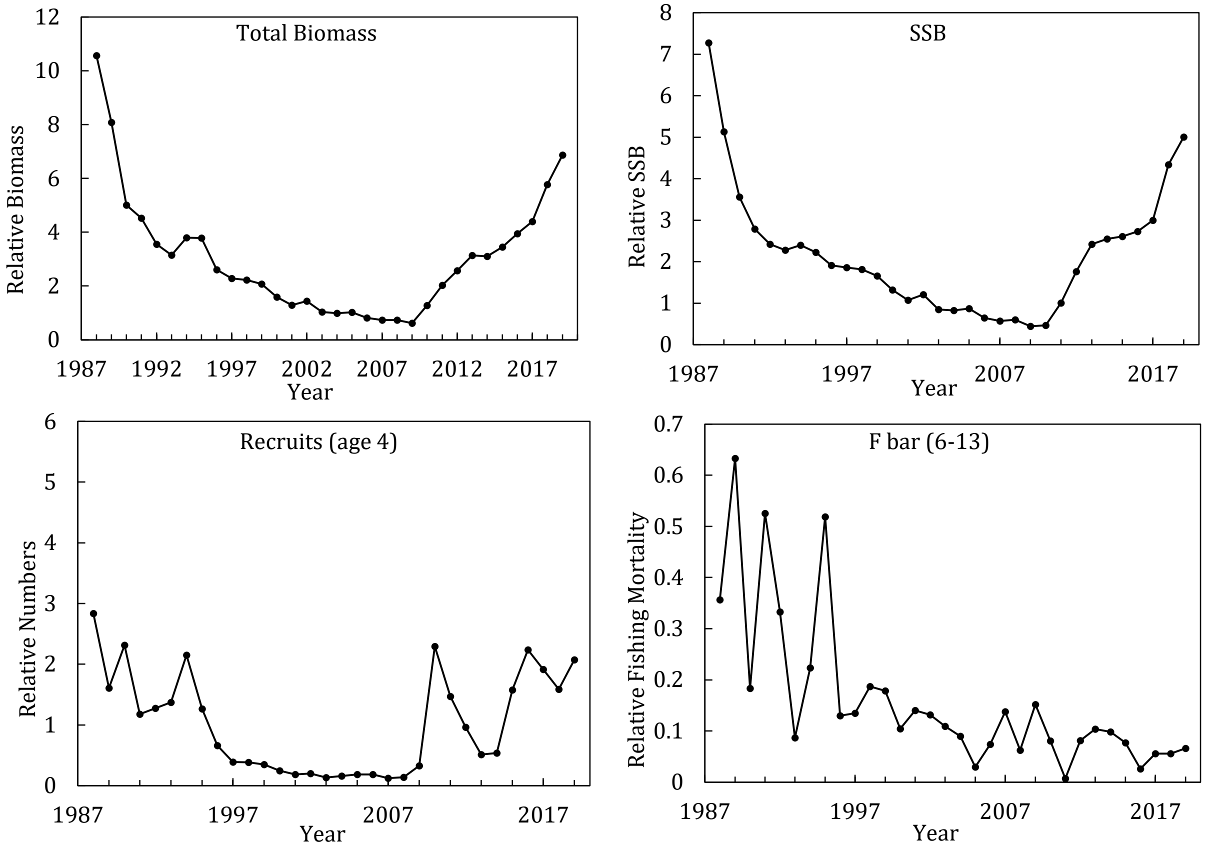


**Figure 8.4.** American plaice in Div. 3M: stock trends in the XSA exploratory assessment.

## d) Illustrative XSA and Surveys results

Both fishing mortality index (C/B) and XSA fishing mortality declined from the mid-1980s to the mid-2000s (Figure 8.5). Since 2011 fluctuated at or below 0.1. In recent years *F* has increased.

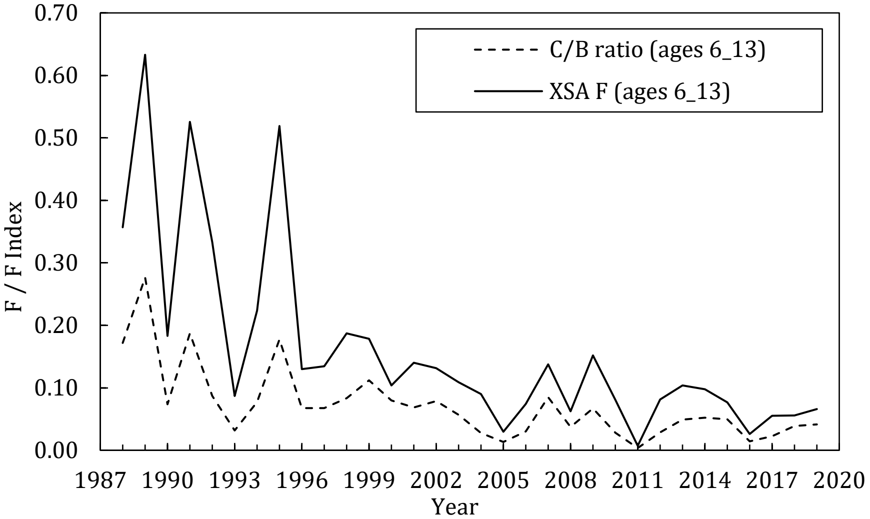


**Figure 8.5.** American plaice in Div. 3M: fishing mortality (catch/biomass) index from EU survey (ages 6-13) and XSA estimated fishing mortality (ages 6-13).

The EU survey and illustrative XSA indicates only poor recruitment from 1991 to 2005 year class. SSB recorded a minimum in 2007. During 2010-2012 SSB increased and then stabilized till 2016 as the strong 2006 year class entered the SSB. From 2016 to 2019 SSB recovered, as total biomass, to the levels of mid 90´s, when the fishery was closed (Figure 8.6). However, there are few fish aged 16 or older.

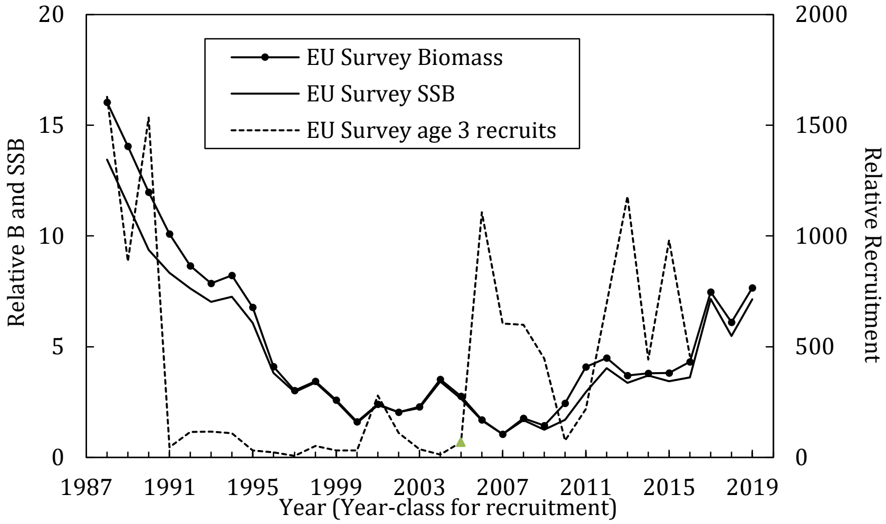


**Figure 8.6.** American plaice in Div. 3M: biomass, spawning stock biomass (SSB) and corresponding recruitment (age 3) from the EU Survey.

## e) Assessment Results

This stock is assessed based upon a qualitative evaluation of stock survey biomass trends and recruitment indices. The XSA was used to illustrate trends in the stock.

*Biomass:* Stock biomass and SSB recorded a minimum in 2007, due to consistent year-to-year recruitment failure from the 1991 to 2005 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 (Figure 8.6).

*Fishing Mortality:* Fishing mortality index (C/B) declined from the mid-1980s to the mid-2000s and since 2000 fluctuated at or below 0.1. In recent years *F* has increased.

*Recruitment:* All of the 1991 to 2005 year-classes are estimated to be weak. Since 2006 the recruitment improved, particularly the 2006, 2012, 2013 and 2015 year classes.

*State of the Stock:* The stock has increased in recent years due to improved recruitment (at age 3) since 2009, and recovered to the levels of the mid 1990s, when the fishery was closed. Both catches and F remain low, although slightly higher catches are observed since 2013.

## f) Reference Points

STACFIS is not able to provide proxies for biomass reference points at this time.

The fishing mortality proxy (Catch/Biomass index) remains low, as the spawning stock biomass increases (Figure 8.7).

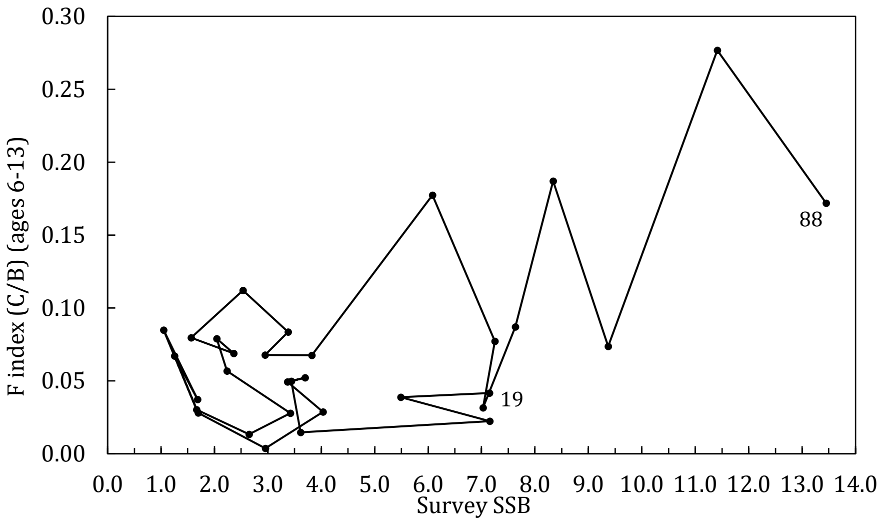


**Figure 8.7.** American plaice in Div. 3M: stock trajectory within the NAFO PA framework.

The following set of parameters was used for the yield-per-recruit analysis: M = 0.2 or 0.15; exploitation pattern described above; maturity of 50% at age 5 and 100% at age 6 plus; and an average mean weights-at-age in the catch and in the stock for the period 1988-2019. This analysis gave:

For $M = 0.2$, $F_{0.1} = 0.161$ and $F_{max} = 0.337$.

For $M = 0.15$, $F_{0.1} = 0.124$ and $F_{max} = 0.248$.

## g) Research Recommendations

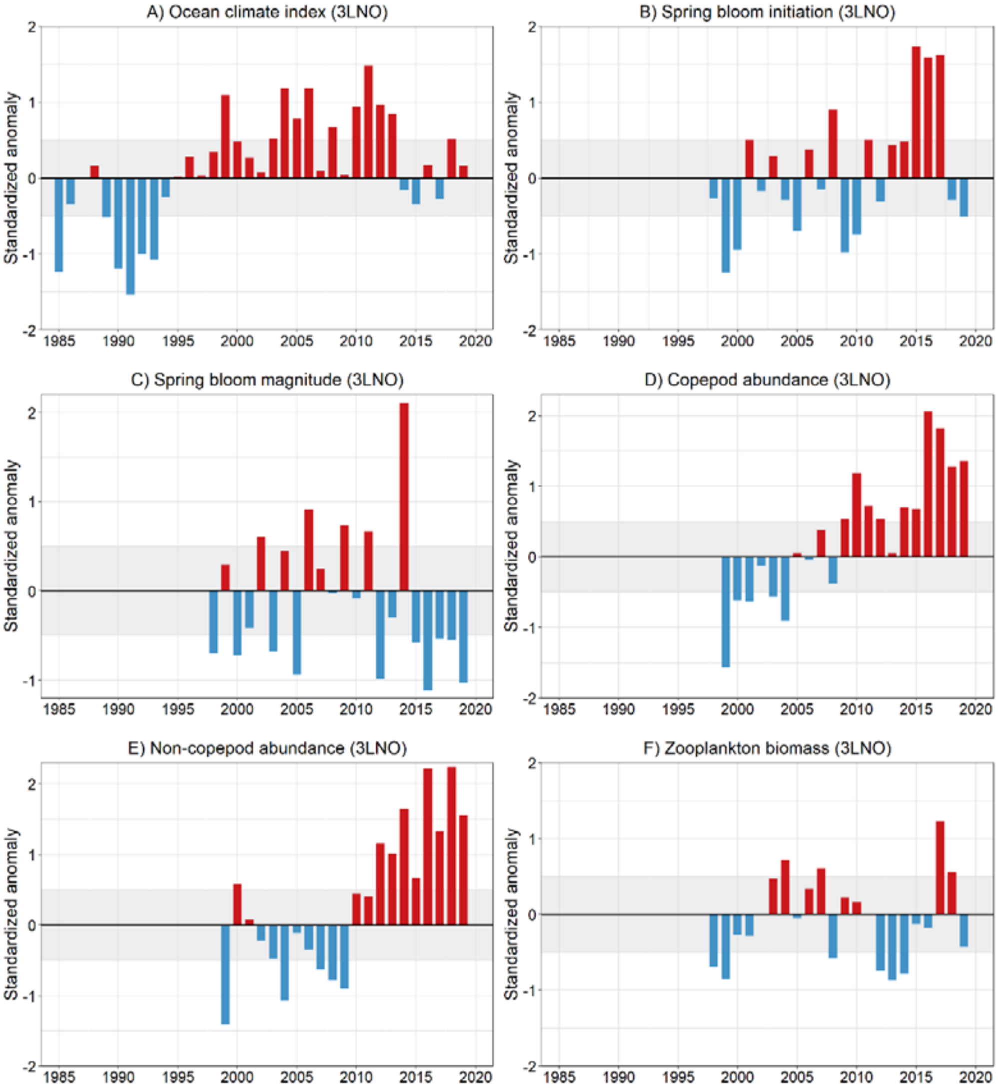
STACFIS **recommends** that *other types of models should also be explored, and that Div. 3M American plaice stock be a candidate for an assessment benchmark together with the Div. 3LNO American plaice stock or other flatfish stocks.*

This stock will be full assessed in 2023.

## C. STOCKS ON THE GRAND BANKS (NAFO DIVISIONS 3LNO)

**Recent Conditions in Ocean Climate and Lower Trophic Levels**

- After a decade of above-average ocean temperatures in NAFO Divs. 3LNO - Grand Bank, the climate index was normal between 2014 and 2019
- Spring bloom initiation was near normal in 2019 for a 2nd consecutive year after the three latest bloom of the time series. Spring bloom magnitude in 2019 was below normal with the second-lowest anomaly of the time series.
- The abundance of copepod was above normal in 2019 for a 6th consecutive year. Non-copepod abundance was also above normal for the 8th consecutive year.
- Zooplankton biomass returned to near normal in 2019 after two years of above normal levels.
- a



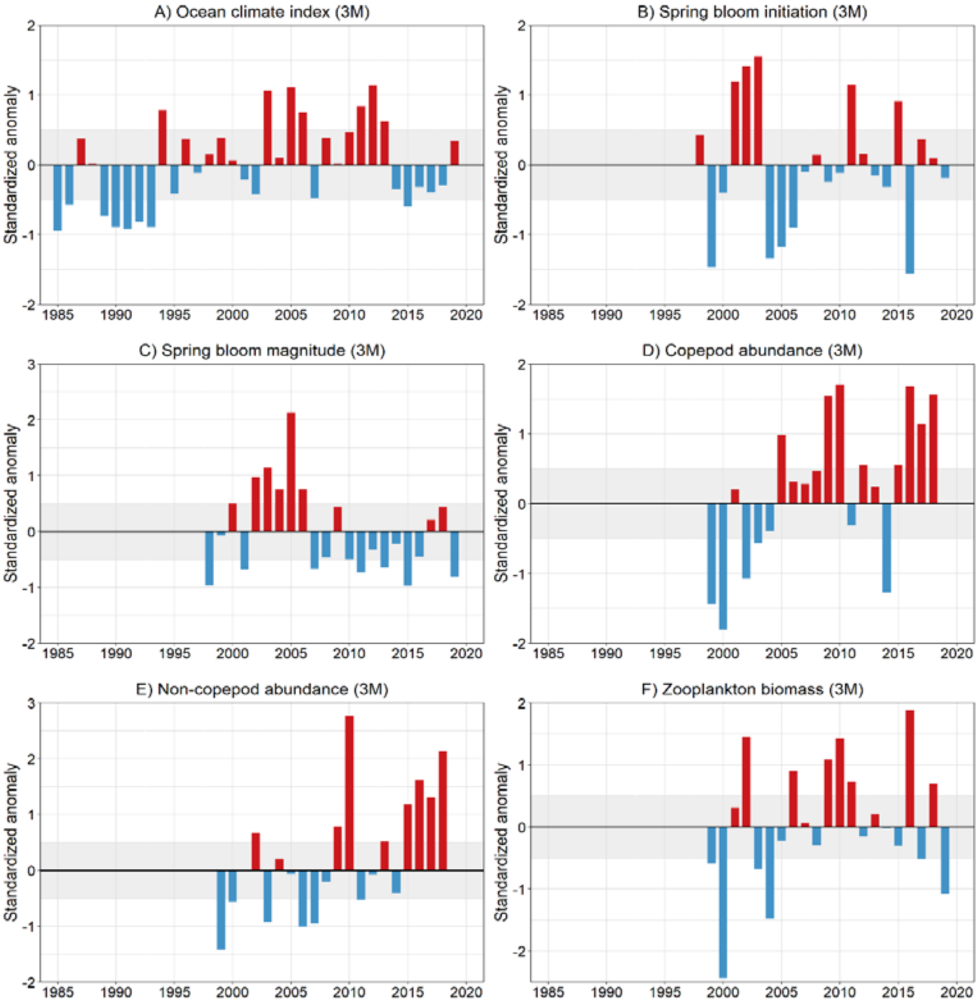


**Figure C1.** Environmental indices for NAFO Divisions 3LNO during 1990-2019. The ocean climate index (A) is the average of 12 individual time series of standardized ocean temperature anomalies: sea surface temperatures (SSTs) for Divs. 3L, 3N and 3O, vertically average ocean temperature (0-176 m) at Station 27, mean temperature and CIL volumes over standard hydrographic sections Seal Island, Bonavista and inshore Flemish Cap (FC-01 to FC-20), and mean bottom temperature in 3LNO for spring and fall. All these variables are presented in Cyr et al. (2020). Phytoplankton spring bloom magnitude (B) and duration (C) indices for the 1998-2019 period are derived from three satellite Ocean Colour boxes (Avalon Channel, Hibernia, and Southeast Shoal; see SCR Doc. 20/035 for box location). Zooplankton abundance copepod and non-copepod) and biomass (D & E) indices for the 1999-2019 period are derived from two cross-shelf oceanographic sections (Flemish Cap [3LN portion only] and Southeastern Grand Banks) and one coastal high-frequency sampling station (Station 27). Positive/negative anomalies indicate conditions above/below (or late/early initiation) the long-term average for the reference period. All anomalies are mean standardized anomaly calculated with the following reference periods: ocean climate index, 1981-2010; phytoplankton indices (magnitude and peak timing):1998-2015; zooplankton indices (abundance and biomass): 1999-2015. Anomalies within ±0.5 SD (shaded area) are considered normal conditions.

## Environmental Overview

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

## Ocean Climate and Ecosystem Indicators

The ocean climate index in Divs. 3LNO (Figure 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, with 2018 being the warmest of this 6th-year time series. A general trend towards later spring blooms (Figure C1.B) has been observed since 1998. However, spring bloom timing was back to near normal for a second consecutive year in 2019 after 3 years of late blooms. Spring bloom magnitude (Figure C1.C) oscillated between positive and negative anomalies with observable trends between 1998 and 2014. Bloom magnitude has remained below normal since 2015 with the second-lowest spring production of the time series observed in 2019. The abundance of copepod (Figure C1.D) and non-copepod (Figure C1.E) zooplankton showed strong increasing trends since the beginning of the time series. The abundance of copepods was above normal for a 6th consecutive year in 2019 with third highest anomaly of the time series. The abundance of non-copepods was also above normal for the 8th consecutive year in 2019. Zooplankton biomass (Figure C1.F) has been oscillating between periods of negative and positive anomalies throughout the time series with no strong departure from normal conditions except in 2017 when biomass reached a time series record high. Zooplankton biomass returned to near normal values in 2019 after two years of above normal levels.

## 9. Cod (*Gadus morhua*) in NAFO Division 3NO

(SCR 20/2,4,8; SCS 20/5,6,7,8,9,11,13)

Interim monitoring report

### 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 2019 was 526 t.

Recent catches and TACs ('000 tons) 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 | 0.8 | 0.7 | 1.1 | 0.7 | 0.5 | 0.6 | 0.6 | 0.3 | 0.5 | |
| STACFIS | 0.8 | 0.7 | 1.1 | 0.7 | 0.6 | 0.7 | 0.6 | 0.4 | 0.5 | |

ndf : No directed fishery

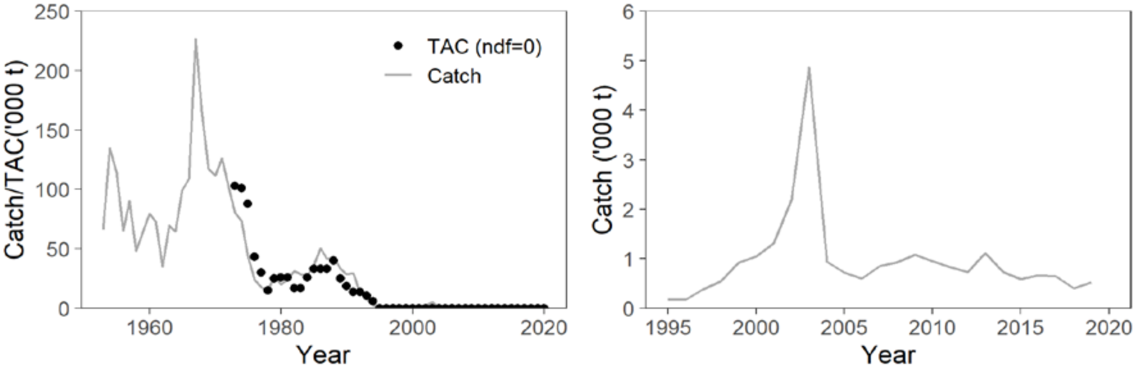


**Figure 9.1.** Cod in Div. 3NO: total catches and TACs. Panel at right highlights catches during the moratorium on directed fishing.

### b) Data Overview

**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 and the 2017-2019 biomass indices were among the lowest in the time series. The trend in the autumn survey biomass index was similar to the spring series (Figure 9.2).

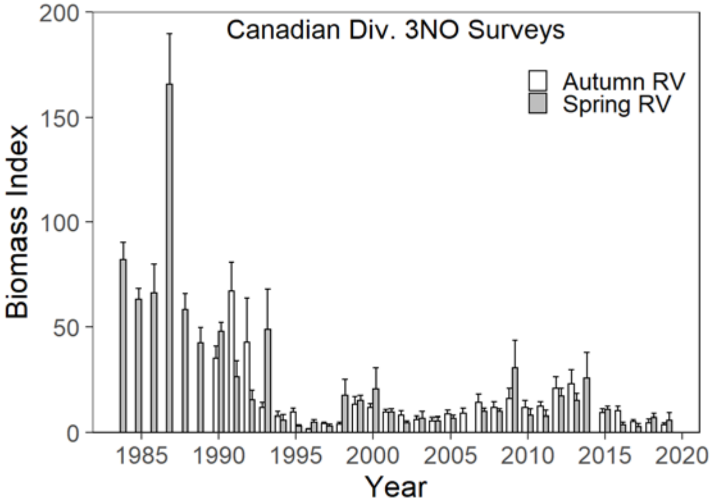


**Figure 9.2.** Cod in Div. 3NO: survey biomass index (+ 1 sd) from Canadian spring (grey) and autumn (white) research surveys.

**EU-Spain Div. 3NO surveys.** The biomass index was relatively low and stable from 1997-2008 with the exception of 1998 and 2001 (Figure 9.3). There was a considerable increase in the index from 2009-2011, 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. The 2019 index is the lowest since 2005.

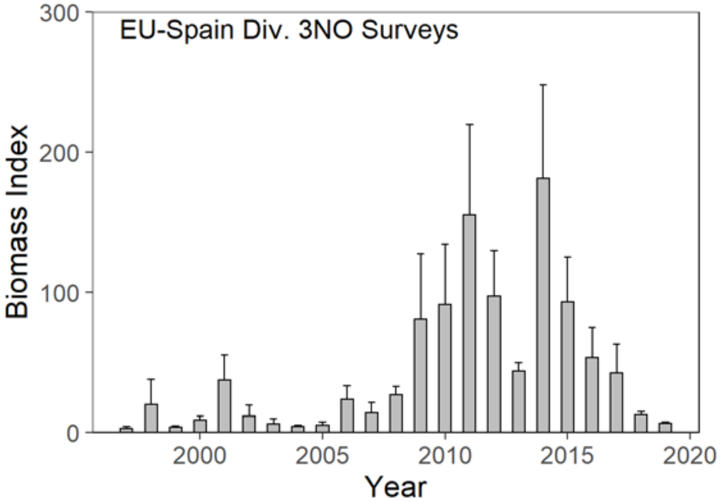


**Figure 9.3.** Cod in Div. 3NO: survey biomass index (+ 1 sd) from EU-Spain Div. 3NO surveys.

### c) Conclusion

The most recent analytical assessment (2018) concluded that SSB was well below $B_{lim}$ (60 000 t) in 2017. Canadian and EU-Spain survey indices for 2018 and 2019 have remained similar or declined relative to 2017. Overall, the 2019 indices are not considered to indicate a significant change in the status of the stock.

The next full assessment of this stock will occur in 2021.

## 10. Redfish (*Sebastes mentella* and *Sebastes fasciatus*) in Divisions 3L and 3N.

(SCR Doc. 20/002, 20/004, 2020/009, 20/014, 20/033; SCS Doc. 20/07, 20/09, 20/13)

### a) Introduction

There are two species of redfish in Divisions 3L and 3N, the deep-sea redfish (*Sebastes mentella)* and the Acadian redfish (*Sebastes fasciatus*) that have been commercially fished and reported collectively as redfish in fishery statistics. Both species, occurring on Div. 3LN and managed as a single stock, do not belong to isolated local populations but, on the contrary, are part of a large Northwest Atlantic complex ranging from the Gulf of Maine to south of Baffin Island.

Between 1959 and 1960 reported catches dropped from 44 600 to 26 600 t, oscillating over the next 25 years (1960-1985) around an average level of 21 000 t. Catches rose afterwards to a high of 79 000 t in 1987 and fell steadily to a 450 t minimum reached in 1996. Catches remained at a low level (450-3 000 t) until 2009. The NAFO Fisheries Commission implemented a moratorium on directed fishing for this stock between 1998 and 2009. The fishery reopened in 2010 with a TAC of 3 500 t. The Fisheries Commission endorsed the Scientific Council recommendations from 2011 onwards and catches increased, being at 13 050 t in 2019, the highest level recorded since 1993 (Table 1, Figure 10.1). Since the reopening in 2010, Canada, followed by Russia and EU-Portugal are the main partners of a fishery mostly deployed northwards in Div. 3L until 2018, but evenly split between the two divisions last year. A management strategy has been adopted for this stock based on a stepwise rule with biennial catch increases over the years 2015 to 2020 (NAFO/COM Doc. 18-01, NCEM)

Recent catches and TACs ('000 tons) are as follows:

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| **TAC** | 6 | 6 | 6.5 | 6.5 | 10.4 | 10.4 | 14.2 | 14.2 | 18.1 | 18.1 |
| **STATLANT 21** | 5.4 | 4.3 | 6.2 | 5.7 | 10.2 | 8.5 | 11.9 | 11.5 | 13.0 | |
| **STACFIS** | 5.4 | 4.3 | 6.2 | 5.7 | 10.2 | 8.5 | 11.8 | 11.3 | 13.1 | |

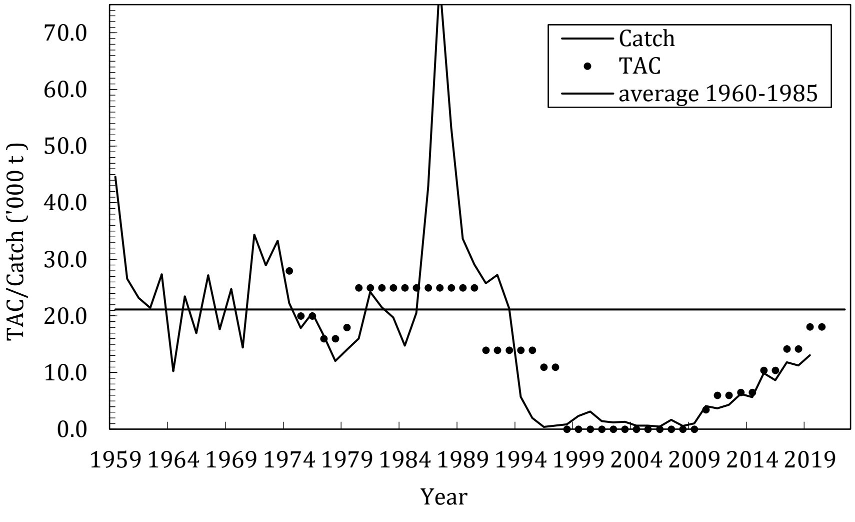


**Figure 10.1.** Redfish in Div. 3LN: catches and TACs (No directed fishing is plotted as zero TAC)

### b) Input Data

#### *i) Commercial fishery data*

Most of the commercial length sampling data available for the Div. 3LN beaked redfish stocks since 1990 comes from the Portuguese fisheries. Length sampling data from EU-Spain and from Russia were used to estimate the length composition of the by-catch for those fleets in several years. Above average mean lengths, an apparently stable catch at length with no clear trends towards smaller or larger length groups and proportions in numbers of small redfish (< 20cm) usually below 1%, are observed on most of the years of the 1990-2005 interval. Well below average mean lengths coupled with in excess of 10% of small redfish in the catch occurred afterwards on most years between 2006 and 2016, but fell to 0.7% on average over the last 3 years (2017-2019). At the same time mean length in the catch roughly increased 2.3cm, with larger sizes being recently the bulk of the catch.

An important increase in the numbers of small redfish in the catch can reflect the arrival of one or more good recruitments but, on the contrary, a noticeable decline on this indicator, as observed on recent years, can signal that year classes coming in the fishery are now below average or even weak.

### *ii) Research survey data*

From 1978 to 1993, several stratified-random bottom trawl surveys were conducted by Canada in various years and seasons in Div. 3L and in Div. 3N. Only those surveys where strata at depths greater than 366m were sampled are included.

Since 1991 two Canadian series of annual stratified-random surveys covered both Div. 3L and Div. 3N on a regular annual basis: a spring survey (May-Jun.) and an autumn survey (Sep.-Oct. 3N/Nov.-Dec. 3L for most years). No survey was carried out in spring 2006 and in autumn 2014 in Div. 3N. Again, in the spring of 2017 there were problems with 3L survey coverage and none of the 3L strata in the redfish index were sampled. Therefore, 2006 and 2017 are not included in the 3LN Canadian spring survey data set or in the 2014 autumn survey data set.

The poor coverage of Div. 3L by Canadian spring survey has little impact on redfish strata so this survey was included in the assessment. Again in the spring of 2017 there were problems with 3L survey coverage and none of the 3L strata in the redfish index were sampled, so 2017 is not included in the 3LN Canadian spring survey data set.

Since 1983 Russian bottom trawl surveys in NAFO Div. 3LMNO changed to stratified-random, following the Canadian stratification for Sub area 3. In 1992 and 1994 Russian survey was carried out only in Div. 3L. In 1995, the Russian bottom trawl series in NAFO Sub area 3 was discontinued.

In 1995 EU-Spain started a stratified-random bottom trawl spring (May-June) survey in NAFO Regulatory Area of Div. 3NO. The Div. 3N EU-Spain spring survey series (1995-2017) has been included in the assessment framework since 2010. The EU-Spain survey in Div. 3L of NAFO Regulatory Area (Flemish Pass) was initiated by EU-Spain in 2003. However only in 2006, for the first time, an adequate prospecting survey was conducted in Division 3L in terms of a representative coverage of all strata in this division. This survey is included in the assessment framework since then.

See section c) for details of which surveys are used in the assessment. Details on the two Canadian survey series, as well as on the Russian series and the two Spanish surveys can be found on previous assessment reports.

The survey biomass series used in the assessment framework and the female SSB survey series were standardized to zero mean and unit standard deviation and so presented on Figure 10.2. 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, but since 1997 those indices start to show some dynamics of increase. Clear increases of survey biomass are evident in 2007-2015 but biomass went down and/or stabilize between 2016 and 2019.

Both Canadian spring and autumn standardized female SSB survey series for Div. 3LN have trends concurrent to their correspondent biomass series from 1991-2015 (Figure 10.2). More recently (2016-2019) however all SSB indices were kept at or above average, which is not the case for survey biomass.

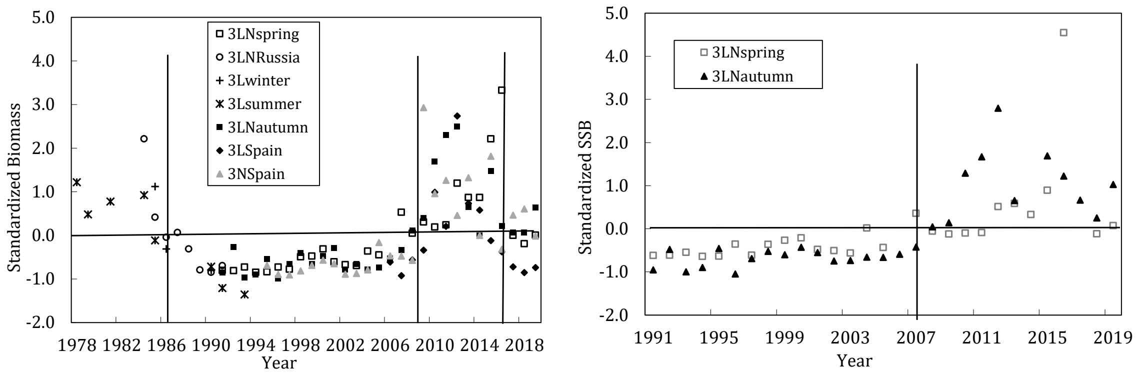


**Figure 10.2.** Redfish in Div. 3LN: standardized survey biomass (1978-2019, left panel) and female spawning biomass (1991-2019, right panel). Each series standardized to zero mean and unit standard deviation. Vertical bars indicate periods when indices cross average levels.

During the first half of the 1990's, on both surveys, the length anomalies were negative or slightly positive. Mean lengths on most of the years between 1996 and 2007 (spring survey) or 2006 (autumn survey) were above the mean, reflecting a shift on the stock length structure to larger individuals. Between 2007-2008 and 2011-2012 mean lengths generally fall and stay below average (Figure 10.3), just as observed on the commercial catch at length, suggesting the occurrence of good recruitments by the late 2000's.

On 2016-2019, from Canadian surveys, mean length in the stock increased but the numbers of fish =>20cm declined.

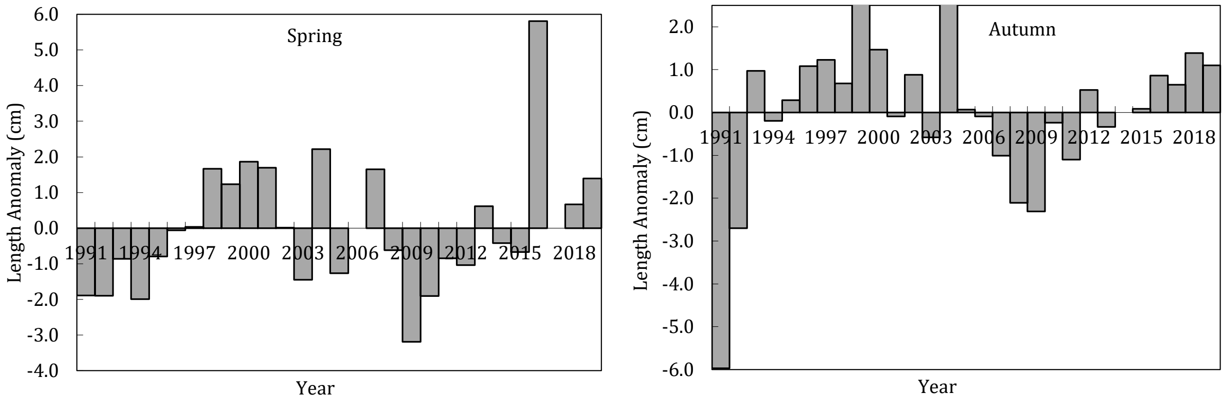


**Figure 10.3.** Redfish in Div. 3LN: annual anomalies of the mean length in the spring and autumn survey, 1991-2019.

### *iii) Recruitment*

Between 2006-2007 and 2009-2010 the recruitment index (numbers of redfish < 20cm) increased rapidly both in commercial catch and Canadian surveys, reaching by then maximum values. The recruitment index drops fast on the following years and is at lower levels since 2014-2015 (Figure 10.4).

Nevertheless, unusual high numbers of very small redfish pre recruits (5-10cm) have been observed on recent years (2015-2017) on Canadian spring and autumn surveys.

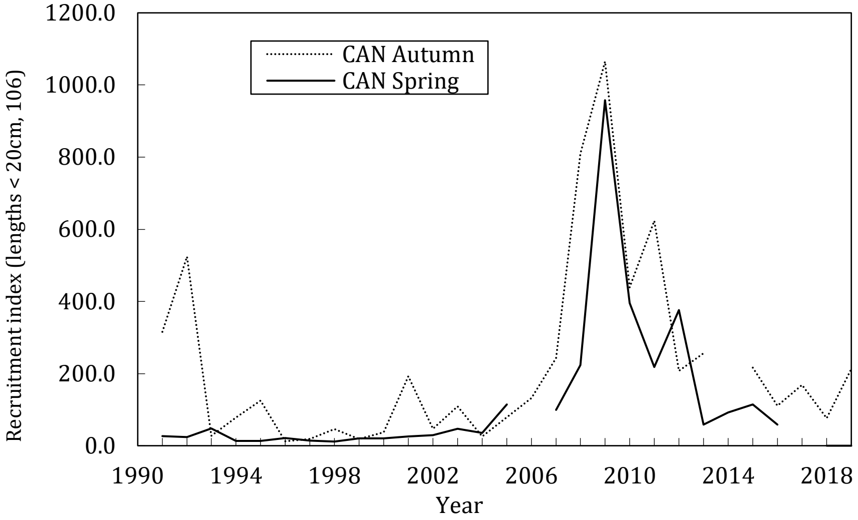


**Figure 10.4.** Redfish in Divs. 3LN: Recruitment index (lengths < 20 cm) from spring and autumn Canadian surveys in NAFO 3LN, 1991-2019.

### c) Assessment Results

A non-equilibrium surplus production model (ASPIC; Prager, 1994) is used to assess the status of the stock since 2008. Until 2012 the model was adjusted to an array of Canadian, Russian and Spanish surveys series arranged under the formulation adopted by STACFIS. However the model showed an increasingly poor fit to recent survey biomass increases observed from the second half of the 2000's onwards on all the ongoing surveys. Selective elimination of outliers, in order to get a picture in line with the perception of the stock history from commercial and survey data trends, was no longer a valid option, as reflected in a STACFIS research recommendation on this matter (NAFO, 2012).

In the 2014 assessment the purpose was to reach an inclusive approach that would incorporate most, if not all, of the surveys points available for the two divisions while at the same time delivering a "realistic" output in line with the perception of stock and fishery dynamics given by historical commercial and survey data. Following a series of exploratory analysis, the 2014 assessment had MSY fixed at a 21000 t. This *MSY proxy* is the average level of sustained catch for the 1960-1985 interval, when the stock experienced an apparent stability, suggested either by the STATLANT CPUE series or available surveys, before declining in response to a sudden rise of catch level. This framework also kept negative correlated STATLANT CPUE series and all "outliers" in their respective survey series, while Canadian autumn surveys on Div. 3L and Div. 3N were assembled in a single 3LN Canadian autumn series. While fixing the MSY level is not common, it was justified in this case as levels generated from models that freely estimated $B_{msy}$ were unrealistic (estimating MSY's of more than 100 000 tons). Therefore MSY was fixed in the model and the results are conditioned on this assumption.

The input series of this assessment are:

| | |
|---|---|
| I1 (Statlant CPUE and catch) | Statlant cpue for Div. 3LN,1959-1994 and catch for Div. 3LN 1959-2019 |
| I2 (3LN spring survey) | Canadian spring survey biomass for Div. 3LN, 1991-2005, 2007-2016, 2018-2019 |
| I3 (3LN autumn survey) | Canadian autumn survey biomass for Div. 3LN, 1991-2013, 2015-2019 |
| I4 (3LN Power russian survey) | Russian spring survey biomass for Div. 3LN , 1984-1991 (Power and Vaskov,1992) |
| I5 (3L winter survey) | Canadian winter survey biomass for Div. 3L, 1985-1986 and 1990 |
| I6 (3L summer survey) | Canadian summer survey biomass for Div. 3L, 1978-1979, 1981,1984-1985, 1990-1991and 1993 |
| I7 (3L autumn survey) | Canadian autumn survey biomass for Div. 3L, 1985-1986, 1990 |
| I8 (3N spring spanish survey) | Spanish survey biomass for Div. 3N, 1995-2019 |
| I9 (3L summer spanish survey) | Spanish survey biomass for Div. 3L, 2006-2019 |

The 1959-2010 catches used are the catches adopted by STACFIS for this stock. The 2011-2016 catches were taken from the NAFO STATLANT 21 data base. The 2017 catch was estimated with the CDAG method (COM-SC CESAG-WP 18-01 (Rev.2)) whereas the CESAG method provided the catch estimates for 2018 and 2019 (COM-SC CESAG-WP 19-03 (Revised) and COM-SC CESAG-WP 20-05 (Revised), respectively).

In this assessment the ASPIC version 7.03 (Prager, 2015) fit the logistic form of the production model (Schaefer, 1954). The model requires from the user a set of initial definitions/starting guesses/constraints that need to be specified in the input file. Control parameters are kept from the 2014 and 2016 assessments and line-by-line details of all input settings can be found on the correspondent reports. User guess catchabilities for the nine input series that support the assessment were the estimate catchabilities from 2018 ASPICfit.

ASPIC2020 run first on deterministic (FIT) mode. Key results, and relative biomass and fishing mortality trajectories are presented on Table 10.1 and Figure 10.5 respectively in comparison with the same results from previous 2016 and 2018 assessments.

**Table 10.1.** ASPIC2020 versus ASPIC 2018 and ASPIC 2016: comparison of main results from deterministic run.

| | MSY$^{(1)}$ | *B1/K* | *Fmsy* | *Flastyear/Fmsy* | *Ye* $^{(2)}$ | *Bmsy* | *B* $^{(3)}$*/Bmsy* |
|---|---|---|---|---|---|---|---|
| ASPIC 2020 | *21000* | **0.7204** | **0.1136** | 0.3917 | 13730 | **184900** | 1.5880 |
| ASPIC 2018 | *21000* | **0.6976** | **0.1122** | 0.3759 | 15600 | **187100** | 1.5070 |
| ASPIC 2016 | *21000* | 0.6874 | 0.1116 | 0.3640 | 17820 | 188200 | 1.3890 |

*(1) fixed at the starting guess*

*(2) estimate for 2016 from ASPIC2016, estimate for 2018 from ASPIC 2018 and estimate for 2020 from ASPIC 2020*

*(3) at the beginning of 2016 from ASPIC2016, at the beginning of 2018 from ASPIC 2018 and at the beginning of 2020 from ASPIC 2020*

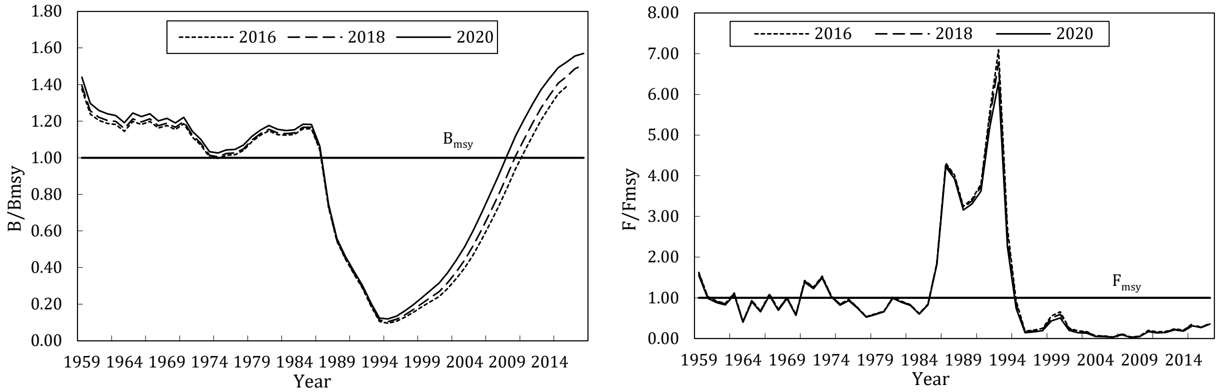


**Figure 10.5.** Redfish in Divs. 3LN*:* $B/B_{msy}$ (left) and $F/F_{msy}$ (right) from ASPIC$_{fit}$ 2020 versus ASPIC$_{fit}$ 2018 and ASPIC$_{fit}$ 2016 assessments.

In terms of biomass dynamics results showed a good nearness index, crossing twice $B_{msy}$ and presenting good contrast. As regards correlation among input series, all three short 3L survey series from the 1980's – early 1990's have good correlations with the Russian survey covering the same period of stock decline. As for the ongoing surveys, correlations among series are relatively good between Canadian 3LN spring and autumn, between the 3N and 3L Spanish surveys and also between both Spanish and Canadian 3LN autumn.

Correlation between observed series and expected model results continue to be in general average to weak. A long time interval (61 years) and a variety high number of survey data sets (8 surveys, differing in time, season and covered area) are unavoidable obstacles difficult to overcome, and will always negatively impact the diagnostics of ASPICfit compared to shorter indices with greater consistency.

To investigate whether or not there was statistical evidence of model mis-specification, the Wald-Wolfowitz runs-test was carried out on the residuals of the fits of the surplus production model to the four abundance indices that cover recent years: 3LSpain, 3NSpain, 3LNautumn and 3LNspring. The respective p-values under the null hypothesis of independence of the residuals for each of these series were respectively 0.028, 0.545, 0.216, and 0.128, i.e. only for the 3LSpain series is the hypothesis of independence of residuals rejected at the 5% level, which would in turn indicate model mis-specification. This supported the acceptance of the model.

There was good consistency within results and trends between the three last assessments (2016, 2018 and 2020) with stock biomass increasing well above $B_{msy}$ and a fishing mortality still kept well below $F_{msy}$.

A summary of estimates from bootstrap analysis are presented in Table 10.2.

**Table 10.2.** ASPIC2020 main results from bootstrap analysis

|  | ASPIC | Point | Bias-corrected approximate confidence limits |  |  |  | Inter-quartile | Relative |
|---|---|---|---|---|---|---|---|---|
| Param. name | assessment | estimate | 80% lower | 80% upper | 60% lower | 60% upper | range | IQ range |
| B1/K | 2020 | 0.7204 | 0.5817 | 1.2410 | 0.6189 | 0.9961 | 0.2944 | 0.4090 |
| MSY | 2020 | 21000 | NA | NA | NA | NA |  |  |
| Ye Last year+1 | 2020 | 15600 | 12040 | 20330 | 12890 | 19060 | 4907 | 0.3150 |
| Bmsy | 2020 | 184900 | 165100 | 222100 | 169200 | 206700 | 31160 | 0.1690 |
| Fmsy | 2020 | 0.1136 | 0.0946 | 0.1272 | 0.1016 | 0.1241 | 0.0190 | 0.1670 |
| B Last year+1/Bmsy | 2020 | 1.5880 | **1.3770** | 1.6710 | **1.4710** | 1.6540 | 0.1387 | 0.0870 |
| F Last year/Fmsy | 2020 | 0.3917 | 0.3708 | **0.4553** | 0.3751 | **0.4251** | 0.0374 | 0.0950 |
| Yield Last year+1/MSY | 2020 | 0.6540 | 0.5494 | 0.8582 | 0.5729 | 0.7788 | 0.1595 | 0.2440 |

Bootstrap results reiterate a stock at the beginning of 2020 with a very high probability (>90%) to be above $B_{msy}$ and a 2019 fishing mortality below $F_{msy}$ with a very high probability (>90%). The maximum observed sustainable yield (*MSY*) of 21 000 t can be a long term sustainable yield if fishing mortality stands at a level of 0.114/year. The correspondent $B_{msy}$ for this stock is at the level of 185 000 t.

Catch versus surplus production trajectories are presented in Figure 10.5. Between 1960 and 1985 catches form a scattered cloud of points around the surplus production curve. In 1986-1987, catches rose well above surplus production and, though declining continuously since then, were still above equilibrium yield in 1993. Catch has dropped well below surplus production in 1995 and from 2010 onwards has been slowly increasing towards surplus production. By 2019 equilibrium yield was almost reached.

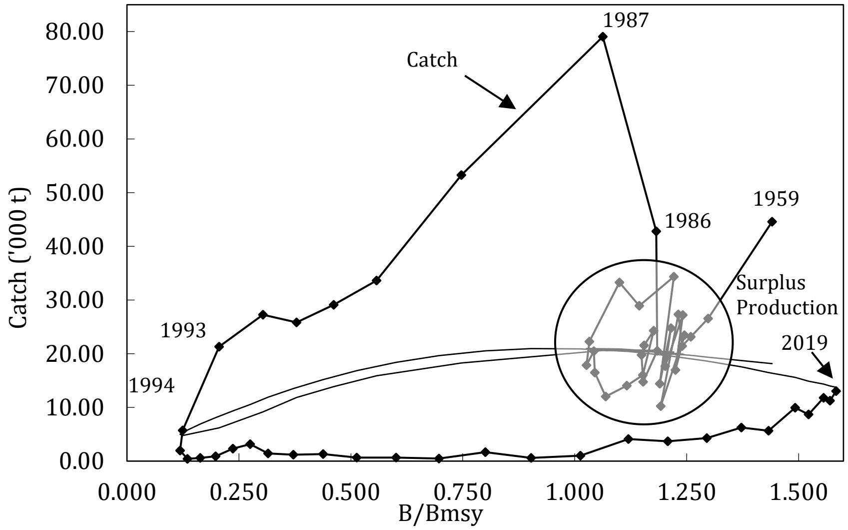


**Figure 10.6.** Redfish in Div. 3LN: Catch versus Surplus Production from ASPIC$_{fit}$ 2020.

*Biomass:* Slightly above $B_{msy}$ for most of the former years up to 1985. Declined from $B_{msy}$ in 1986 to 12% $B_{msy}$ in 1995, when a minimum stock size is recorded. Over the moratorium years biomass was allowed to recover and at the beginning of 2020 biomass is predicted to be near 1.6 x $B_{msy}$. The probability of being above $B_{msy}$ is very high (>90%). At the beginning of 2020, the probability of being below $B_{lim}$ is less than 1% (see section d).

*Fishing mortality:* Fishing mortality has been low to very low since 1996 but has moderately increased since the reopening of the fishery in 2010. On 2019 fishing mortality was estimated to be at 0.39 x $F_{msy}$, and the probability of being above $F_{msy}$ is very low. On 2019, the probability of being above $F_{msy}$ is less than 1%.

*Recruitment*: From commercial catch and Canadian survey length data (numbers of redfish < 20cm) there are no signs of recent recruitment (2014 – 2019) of above average year classes to the exploitable stock. Nevertheless, unusual high numbers of very small redfish pre recruits (5-10cm) have been observed on recent years (2015-2017) on Canadian spring and autumn surveys.

*State of stock*: The stock is currently in the safe zone of the NAFO precautionary approach framework and is estimated to be at 1.59 x $B_{msy.}$ There is a very low risk (<10%) of the stock being below $B_{lim}$. Fishing mortality is well below $F_{msy}$ (0.39 x $F_{msy}$), and the probability of being above $F_{lim}$ (= $F_{msy}$) is very low (<10%). Recent recruitment appears to be low.

## d) Short term catch projection under the actual management strategy

The Risk-Based Management Strategy (MS) for 3LN Redfish adopted by the Fisheries Commission on the 36th Annual Meeting – September 2014 (Ávila de Melo *et al*., 2014; FC Working Paper 14/23, NCEM annex I.H), was designed to reach 18 100 t of annual catch by 2019-2020 (18 100 t was the equilibrium yield in 2014 given by the 2014 assessment, carried out under the assumption of an MSY of 21 000 t). It is based on a Harvest Control Rule (HCR) that implemented a stepwise biennial catch increase, with the same amount of increase every two years, between 2015 and 2020.

Since then, the following assessments monitored the impact of the MS on the stock, though between 2015 and 2019 catches never reached the predicted TAC´s, or even the correspondent Ye's (equilibrium yields). Meanwhile, based on the results of bi-annual assessments, the biomass in recent years (2015-2020) is well above $B_{msy}$ and fishing mortalities well below $F_{msy}$ at a very high probability level (>90%).

The medium term catch projections (2021-2025) aimed to quantify the likelihood of the stock to be exploited below $F_{msy}$ until 2025 and arrive at the beginning of 2026 still above $B_{msy}$ under two catch options. The first projection drives the stock under a 2021-2025 catch at the HCR 2019-2020 TAC of 18 100 t (*status quo* HCR2020 option), while the second option drives the stock under a lower 2021-2025 catch ceiling of 13 730 t, the equilibrium yield available at present ($Ye_{2020}$ option). A second option is justified by recent observed data suggesting that stock is not growing and recruitment is poor. Both scenarios assume that the 2020 TAC of 18 100 t will be effectively taken.

ASPICP, the ASPIC auxiliary program for projections, provided point estimates (with associated bias corrected 80% and 50% confidence limits) of biomass and fishing mortality for the assessment time interval, 1959-2019, extended to the projection years, 2020-2025, with 2020 catch at the present TAC and either with the 2021-2025 catch at the HCR 2020 (18 100 t) or at 2020 *Ye* (13 730 t).

The ASPICP results for the HCR 2020 option are presented in Figure 10.7a and 10.7b, as regards relative 1959-2026 biomass and 1959-2025 fishing mortality trajectories.

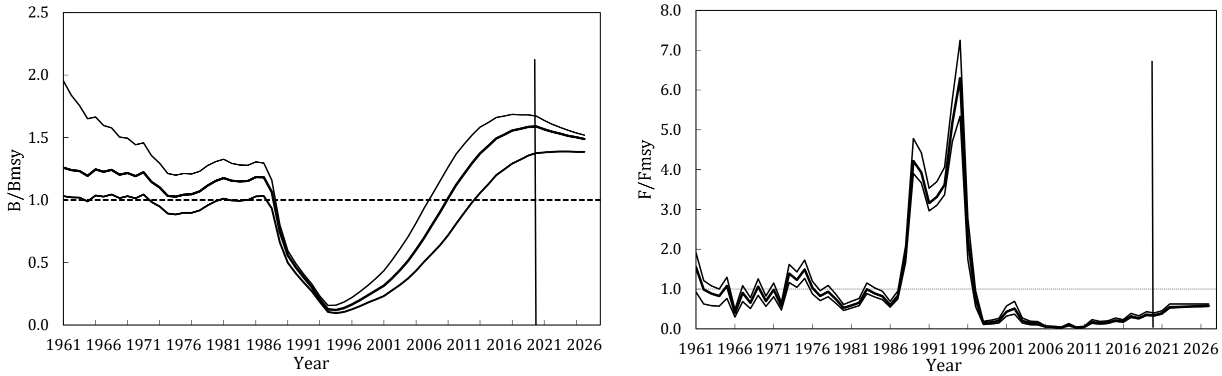


**Figure 10.7.** Redfish in Div. 3LN: B/$B_{msy}$ (left) and $F/F_{msy}$ (right) point estimates trajectories with approximate 80% bias corrected CLs from ASPICP 2020 (HCR 2020 option).

Comparisons of results with the two options are presented in Table 10.3 and Figure 10.8 (for $B_{msy}$ 2020-2026).

**Table 10.3.** Redfish in Div. 3LN: short term catch projections. The 10th, point estimate, and 90th percentiles of projected $B/B_{msy}$ , $F/F_{msy}$ are shown, for projected 2021-2025 HCR 2020 TAC or at 2020 *Ye* catch.

| **2021-2026 catch at HCR TAC 18 100 t** | percentiles | | |
|---|---|---|---|
| Year | 10 | point estimate | 90 |
| BIOMASS RELATIVE TO Bmsy | | | |
| 2020 | 1.377 | 1.588 | 1.671 |
| 2021 | 1.380 | 1.566 | 1.636 |
| 2022 | 1.385 | 1.547 | 1.606 |
| 2023 | 1.387 | 1.530 | 1.580 |
| 2024 | 1.387 | 1.514 | 1.557 |
| 2025 | 1.386 | 1.501 | 1.537 |
| 2026 | 1.385 | 1.489 | 1.520 |
| FISHING MORTALITY RELATIVE TO Fmsy | | | |
| 2020 | 0.547 | 0.547 | 0.625 |
| 2021 | 0.554 | 0.554 | 0.624 |
| 2022 | 0.561 | 0.561 | 0.622 |
| 2023 | 0.566 | 0.566 | 0.621 |
| 2024 | 0.572 | 0.572 | 0.622 |
| 2025 | 0.577 | 0.577 | 0.622 |

| **2021-2026 catch at 2020 Ye 13 730 t** | percentiles | | |
|---|---|---|---|
| Year | 10 | point estimate | 90 |
| BIOMASS RELATIVE TO Bmsy | | | |
| 2020 | 1.377 | 1.588 | 1.671 |
| 2021 | 1.380 | 1.566 | 1.636 |
| 2022 | 1.400 | 1.569 | 1.629 |
| 2023 | 1.417 | 1.571 | 1.624 |
| 2024 | 1.435 | 1.573 | 1.619 |
| 2025 | 1.450 | 1.575 | 1.615 |
| 2026 | 1.463 | 1.577 | 1.611 |
| FISHING MORTALITY RELATIVE TO Fmsy | | | |
| 2020 | 0.547 | 0.5466 | 0.6249 |
| 2021 | 0.417 | 0.4171 | 0.4702 |
| 2022 | 0.416 | 0.4164 | 0.4641 |
| 2023 | 0.416 | 0.4158 | 0.4583 |
| 2024 | 0.415 | 0.4153 | 0.4531 |
| 2025 | 0.415 | 0.4148 | 0.4488 |

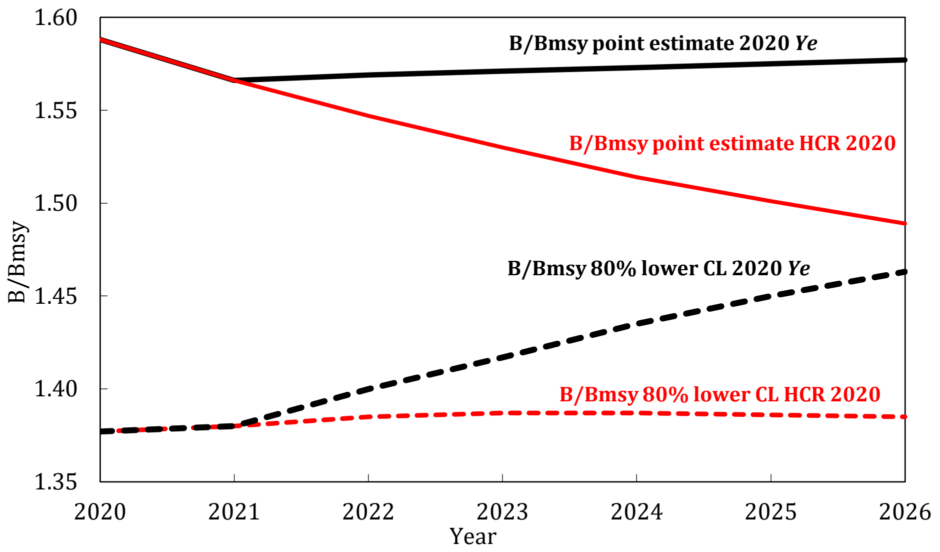


**Figure 10.8.** *B/Bmsy* 2020-2026 projections under HCR 2020 TAC versus 2020 *Ye*. Both options assume that the 2020 TAC of 18 100 t will be effectively taken.

Either the HCR 2020 TAC or catch at 2020 *Ye* on 2021 - 2025 will maintain biomass at the beginning of 2026 above $B_{msy}$ while keeping fishing mortality till the end of 2025 below $F_{msy}$ with > 90% probability (Table 10.4). Also the probability of $B_{2026} < B_{lim}$ or $F_{2025} > F_{lim}$ is <1% for both catch options. Catch on 2021-2025 at 2020 *Ye* will keep biomass roughly at its present level, and will avoid the beginning of a marginal biomass decline predicted by the HCR 2020 option (that has been already suggested by the majority of recent observed data).

**Table 10.4.** Redfish in Div. 3LN: Risk assessment under 18 100 t and 13 730 t catches in 2021-2025 scenarios.

| HCR (Yield) | | | | | | P(F>Flim) = P(F>FMSY) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
| 18100 t | 18100 t | 18100 t | 18100 t | 18100 t | 18100 t | <1% | <1% | <1% | <1% | <1% | <1% |
| 13730 t | 13730 t | 13730 t | 13730 t | 13730 t | 13730 t | <1% | <1% | <1% | <1% | <1% | <1% |

| HCR (Yield) | | | | | | P(B< Blim) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 |
| 18100 t | 18100 t | 18100 t | 18100 t | 18100 t | 18100 t | <1% | <1% | <1% | <1% | <1% | <1% | <1% |
| 13730 t | 13730 t | 13730 t | 13730 t | 13730 t | 13730 t | <1% | <1% | <1% | <1% | <1% | <1% | <1% |

| HCR (Yield) | | | | | | P(B<BMSY) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | P(B2026> B2020) |
| 18100 t | 18100 t | 18100 t | 18100 t | 18100 t | 18100 t | 1.4% | 1.4% | 1.2% | 1.1% | 1.1% | 1% | 1% | 12% |
| 13730 t | 13730 t | 13730 t | 13730 t | 13730 t | 13730 t | 1.4% | 1.4% | 1.1% | 1% | <1% | <1% | <1% | 45.6% |

## e) Reference Points

The ASPIC point estimate results were put under the precautionary framework (Figure 10.9). The trajectory presented shows a stock within $B_{msy}$ - 1.3 $B_{msy}$ under exploitation around $F_{msy}$ through 25 years in a row (1960-1985). The stock rapidly declined afterwards to well below $B_{msy}$ when fishing mortality rises to well above $F_{msy}$ (1987-1994). Fishing mortality dropped to well below $F_{msy}$ in 1996, being kept at very low to low to level ever since. Biomass gradually reaches and surpasses $B_{msy}$ several years after (2009). The stock is presently in the safe zone.

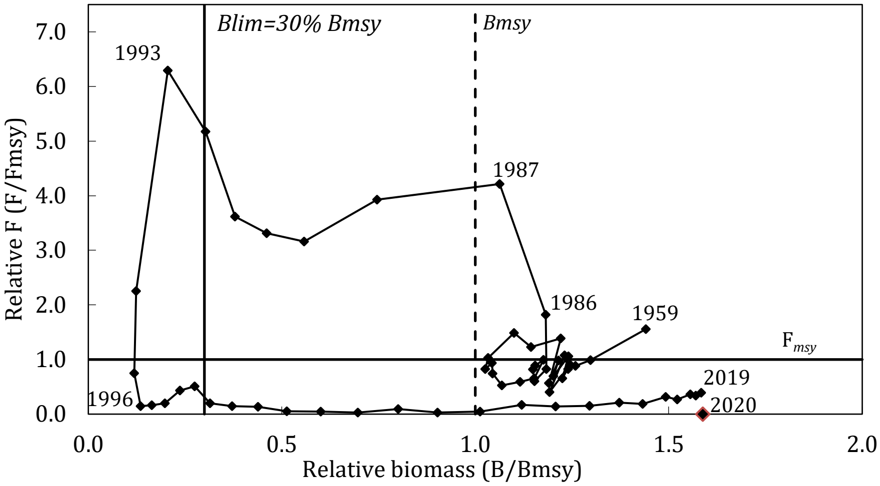


**Figure 10.9.** Redfish in Div. 3LN: stock trajectory under a precautionary framework for $\text{ASPIC}_{\text{fit}}$ 2020.

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

### f) Research recommendations

STACFIS **recommends** that *alternate models be explored for this stock.*

## 11. American plaice (Hippoglossoides *platessoides*) in NAFO Divisions 3LNO

(SCR 20/04; 20/02, 20/08, 20/13, SCS 20/07, 20/09, 20/11, 20/13)

Interim Monitoring Report

### a) Introduction

American plaice supported large fisheries from the 1960s to the 1980s. However, due to the collapse of the stock in the early 1990s, there was no directed fishing in 1994 and a moratorium was put in place in 1995. Landings from by-catch increased until 2003, after which they began to decline. The majority of the catch has been taken by offshore otter trawlers. STACFIS agreed catches were 1 002t in 2018 and 1 248t in 2019 (Figure 11.1). American plaice are taken as by-catch mainly in the Canadian yellowtail flounder fishery, EU-Spain and EU-Portugal skate, redfish and Greenland halibut fisheries.

Recent nominal catches and TACs ('000 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** | 1.2 | 1.3 | 2.2 | 1.4 | 1.1 | 1.0 | 1.1 | 0.8 | | |
| **STACFIS** | 2.4[1] | 2.1[1] | 3.0[1] | 2.3[1] | 1.1[2] | 1.7[2] | 1.2 | 1.0 | 1.2 | |

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.

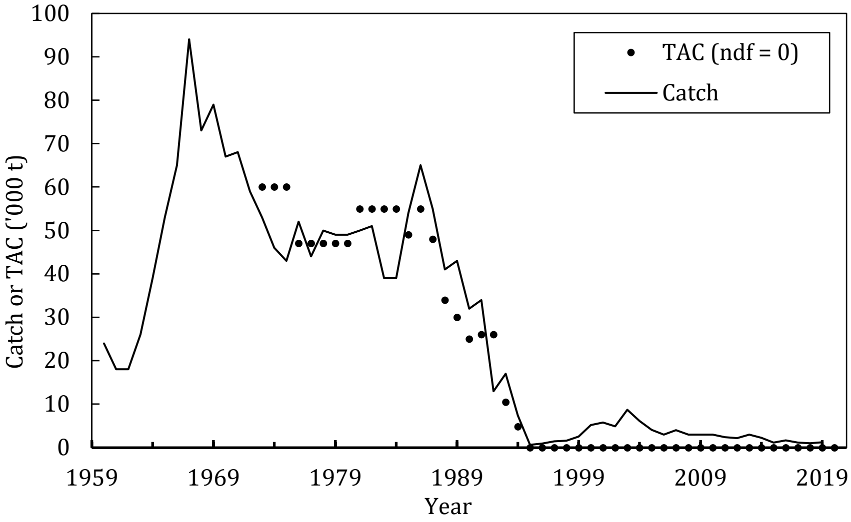


**Figure 11.1.** American plaice in Div. 3LNO: estimated catches and TACs. No directed fishing (ndf) is plotted as 0 TAC.

### b) Research Survey Data

**Canadian spring survey.** Due to coverage issues in the Canadian spring survey, indices are not available from 2006, 2015, or 2017. The 2018 spring survey was incomplete (3 missed strata in Div. 3L), but coverage is considered to be sufficient to be indicative of trends. However, the impact of the missed area on age composition should be investigated prior to use in an age structured model.

Biomass and abundance estimates from spring surveys for Div. 3LNO declined during the late 1980s-early 1990s. Biomass indices generally increased from the mid-1990s to 2014 but declined sharply after that (Figure 11.2). The abundance index follows a similar trend. Spring estimates of biomass and abundance in 2019 are the lowest since 1995 and 1998, respectively.

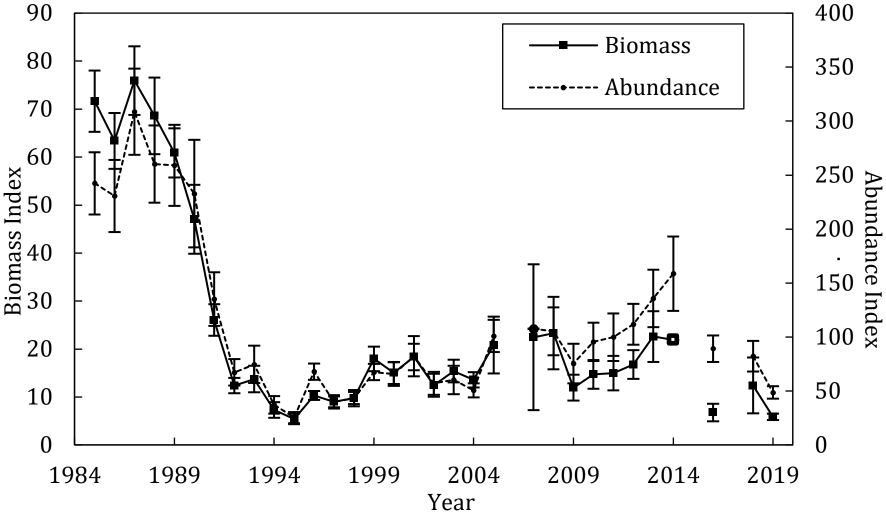


**Figure 11.2.** American plaice in Div. 3LNO: biomass and abundance indices with approximate 95% confidence intervals from Canadian spring surveys. Data prior to 1996 are Campelen equivalents and since then are Campelen. Open symbols represent years where CIs extend to negative values.

**Canadian autumn survey**. Autumn survey points for 2004 and 2014 are excluded due to incomplete coverage of Div. 3L and 3NO, respectively. Biomass and abundance indices from the autumn survey declined rapidly from 1990 to the mid-1990s, followed by an increasing trend to 2013. Abundance indices subsequently declined from 2015 to 2019. Biomass indices also declined after 2013 and have been below average since 2015.

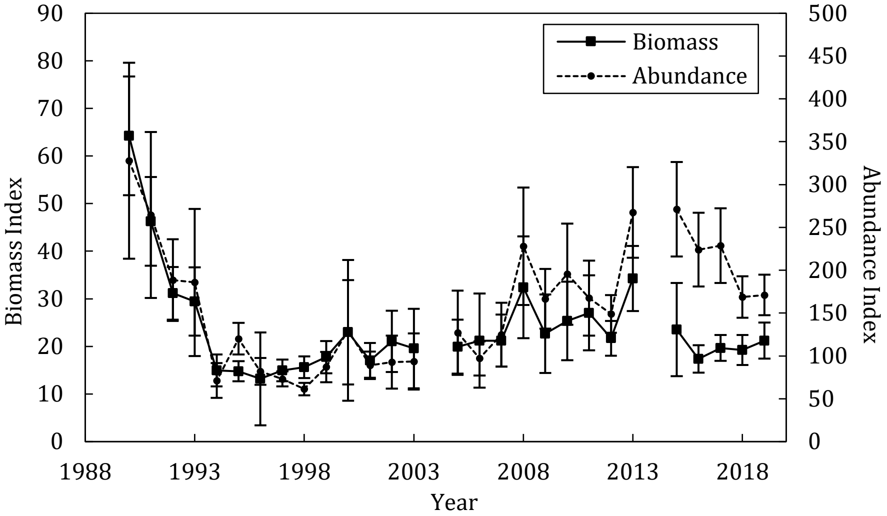


**Figure 11.3.** American plaice in Div. 3LNO: biomass and abundance indices with approximate 95% confidence intervals from Canadian autumn surveys. Data prior to 1996 are Campelen equivalents and since then are Campelen.

**EU-Spain Div. 3NO Survey**. From 1998-2019, surveys have been conducted annually by EU-Spain in the Regulatory Area in Div. 3NO. The biomass and abundance indices varied without trend for most of the time series but then declined from 2011. The 2019 estimates of biomass and abundance are the lowest in the time series.

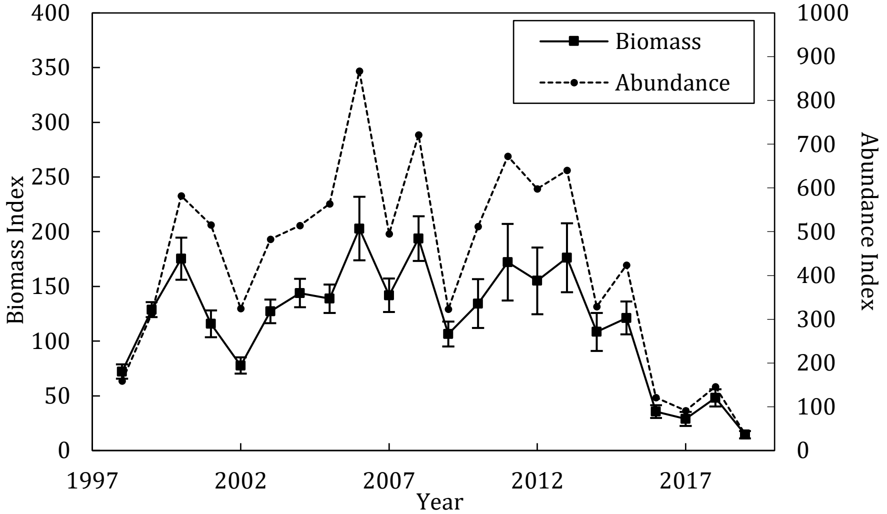


**Figure 11.4.** American plaice in Div. 3LNO: biomass and abundance indices from the EU-Spain Div. 3NO survey (Data prior to 2001 are Campelen equivalents and since then are Campelen).

**EU-Spain Div. 3L Survey.** From 2003-2019, surveys have been conducted annually by EU-Spain in the Regulatory Area in Div. 3L, with the exception of 2005. The biomass and abundance indices increased from 2010 to 2015, and have subsequently declined to 2019.

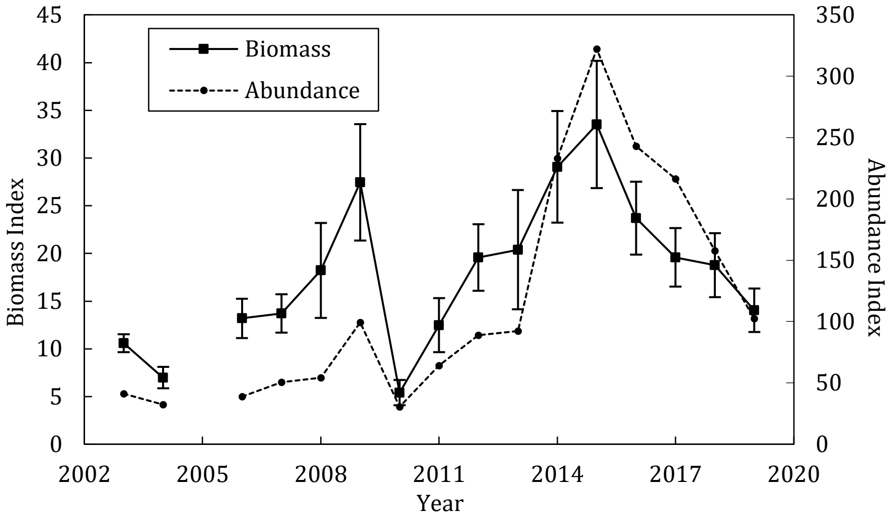


**Figure 11.5.** American plaice in Div. 3LNO: biomass and abundance indices from the EU-Spain Div. 3L survey.

### c) Conclusion

Based on available data, there is nothing to indicate a change in the status of the stock since the 2018 assessment.

The next full assessment of this stock is planned for 2021.

### d) Research Recommendations

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.*

STATUS: Sensitivity analysis was completed during the 2018 assessment examining the impact of changing the model assumptions about the F-ratio on the plus group, and this will be explored further. Work is ongoing. The recommendation is reiterated.

STACFIS **recommended** that *investigations be undertaken to reexamine which survey indices are included in the model.*

STATUS: Work is ongoing. This recommendation is reiterated.

## 12. Yellowtail Flounder (*Limanda ferruginea*) in Divisions 3LNO

(SCR 20/002, 20/009; SCS 20/05, 20/06, 20/07, 20/09, 20/11)

Interim Monitoring Report

### 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 (Figure 12.1). Catches from 2001 to 2005 ranged from 11 000 t to 14 000 t. The catch in 2006 was only 930 t, due to corporate restructuring and a labour dispute in the Canadian fishing industry. Since then, catches have continued to be influenced by industry related factors, remaining below the TAC and in some years, have been very low. In 2019, catches totalled 11 900 t.

Recent catches and TACs ('000 tones) are as follows:

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| TAC [1] | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| STATLANT 21 | 5.2 | 3.1 | 10.7 | 8.0 | 6.7 | 8.3 | 9.0 | 8.7 | 12.8 | |
| STACFIS | 5.2 | 3.1 | 10.7 | 8.0 | 6.9 | 9.3 | 9.0 | 8.7 | 12.8 | |

[1] SC recommended any TAC up to 85% $F_{msy}$ in 2009-2021.

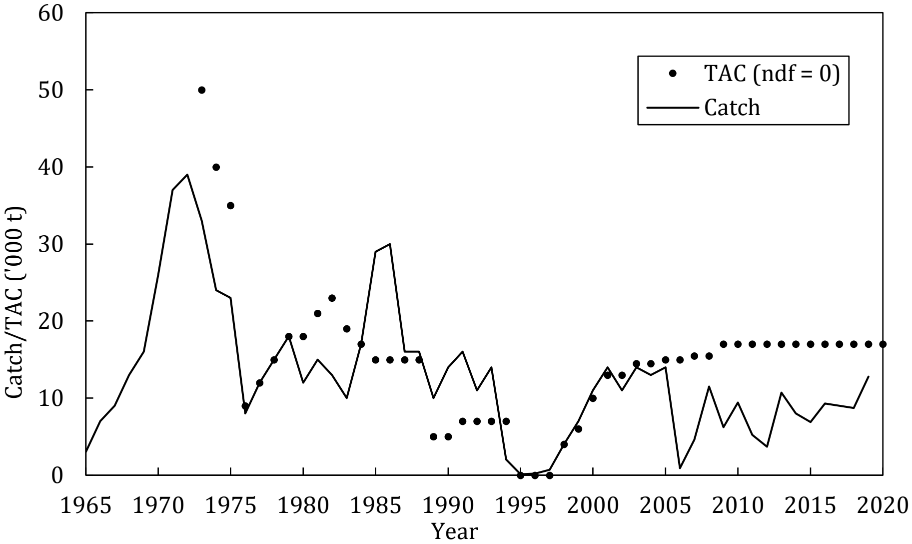


**Figure 12.1.** Yellowtail flounder in **Divs. 3LNO**: catches and TACs. No directed fishing is plotted as 0 TAC.

## 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 in 2017 and 2018. Although the 2006 and 2015 surveys did not cover the stock area, the average biomass in strata missed by these surveys in years since 1995 has been below 10% of the total biomass estimate.

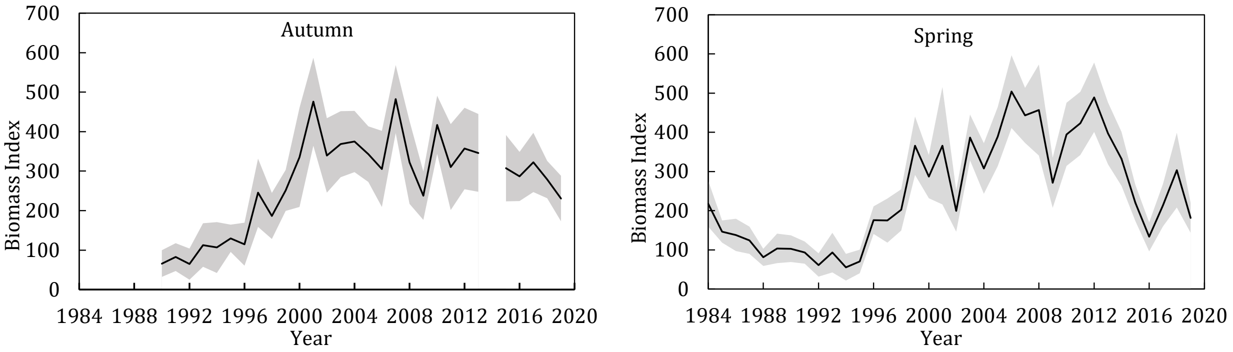


**Figure 12.2.** Yellowtail flounder in **Divs. 3LNO**: indices of biomass with approximate 95% confidence intervals, from Canadian spring and autumn surveys. Values are Campelen units or, prior to autumn 1995, Campelen equivalent units. The 2014 Canadian autumn survey was incomplete and not considered representative.

**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 has remained relatively high. (Figure 12.2). This survey did not show the decline in biomass seen in the other surveys during the recent years. The 2014 survey was incomplete due to problems with the research vessel. Ninety-three percent of the biomass estimate in surveys since 1995 was found in the strata missed in 2014, and therefore survey results in this year 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 declined to a 20 year low in 2019 (Figure 12.3). Results are in general agreement with the Canadian series which covers the entire stock area.

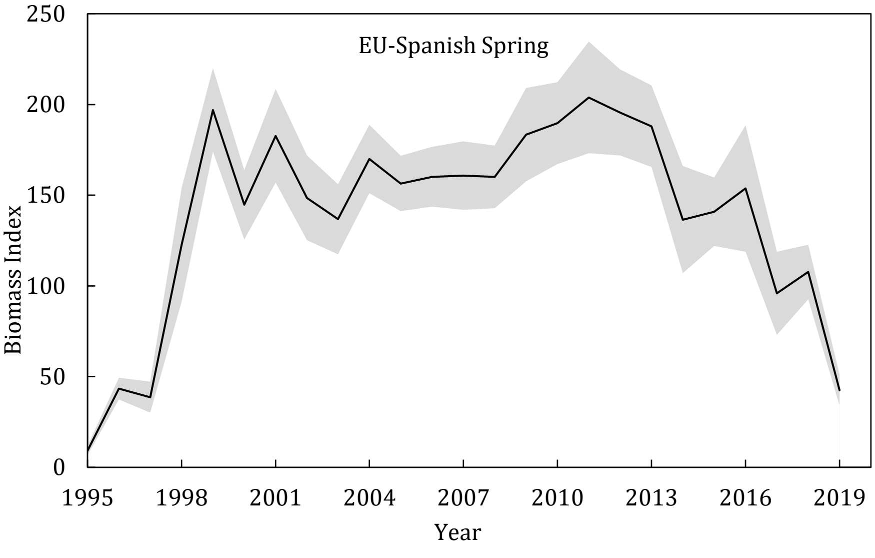


**Figure 12.3.** Yellowtail flounder in **Divs. 3LNO**: index of biomass from the EU-Spain spring surveys in the Regulatory Area of Divs. 3NO ±1SD. Values are Campelen units or, prior to 2001, Campelen equivalent units.

**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 1999-2019 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.

**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. No clear trend in recruitment is evident, although since 2007, the number of small fish in several Canadian surveys has been above average. The spring survey by EU-Spain has shown lower than average numbers of small fish since 2007.

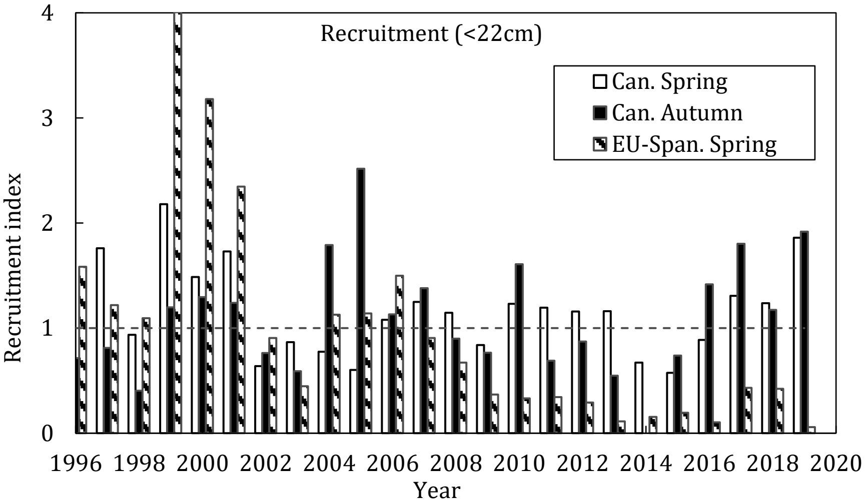


**Figure 12.4.** Yellowtail flounder **in Divs. 3LNO**: Juvenile abundance indices from spring and autumn surveys by Canada (Can.) and spring surveys by EU-Spain. Each series is scaled to its mean (horizontal line).

## c) Conclusion

The most recent (2018) analytical assessment using a Bayesian stock production model concluded that the stock size has steadily increased since 1994 and is presently 1.5 times $B_{msy}$ ($B_{msy}$=87 630 tonnes). There is very low risk (<1%) of the stock being below $B_{msy}$ or $F$ being above $F_{msy}$. Overall, the 2019 survey indices are not considered to indicate a significant change in the status of the stock.

The next full assessment of this stock is planned for 2021.

## 13. Witch Flounder (*Glyptocephalus cynoglossus*) in Divisions 3N and 3O

(SCR Docs, 20/002, 009, 046; SCS 20/06, 07, 09, 11, 13)

## 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 2019, total catch was estimated to be 862 t.

In 2019 the assessment for this stock was evaluated and endorsed by an external reviewer.

Recent catches and TACs ('000 tones) are as follows:

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| **TAC** | ndf | ndf | ndf | ndf | 1.0 | 2.2 | 2.2 | 1.1 | 1.2 | 1.2 |
| **STATLANT 21** | 0.4 | 0.3 | 0.3 | 0.3 | 0.4 | 1.0 | 0.6 | 0.6 | 0.9 | |
| **STACFIS** | 0.4 | 0.3 | 0.3 | 0.3 | 0.4 | 1.1 | 0.7 | 0.7 | 0.9 | |

ndf = no directed fishery.

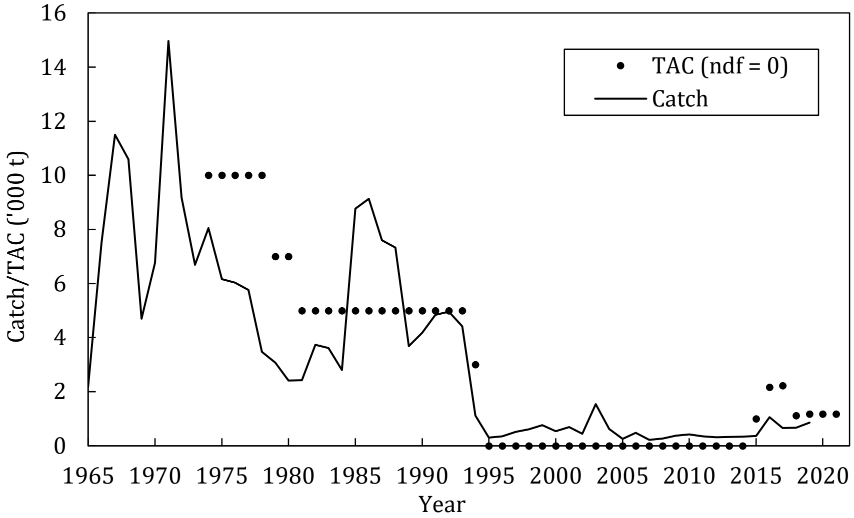


**Figure 13.1.** Witch flounder in Divs. 3NO (1960-2021): Catch and TAC (‘000 tonnes).

## b) Data Overview

### *i) Commercial fishery data*

**Length frequencies.** Length frequencies were available from observer data for Canadian witch flounder directed and bycatch fisheries in NAFO Divs. 3NO in 2019. Canadian data indicated the catch and bycatch ranged between 30 and 60 cm with a mean length of ~45 cm (Figure 13.2). Length frequencies were available from bycatches in directed fisheries for yellowtail flounder, redfish, Greenland halibut, and skate by Spain, in 2019 (Figure 13.2). The Spanish data (SCS 20/07) from Divs. 3NO indicated most of the witch flounder catch and bycatch was between 25 and 55 cm in length (Figure 13.2).

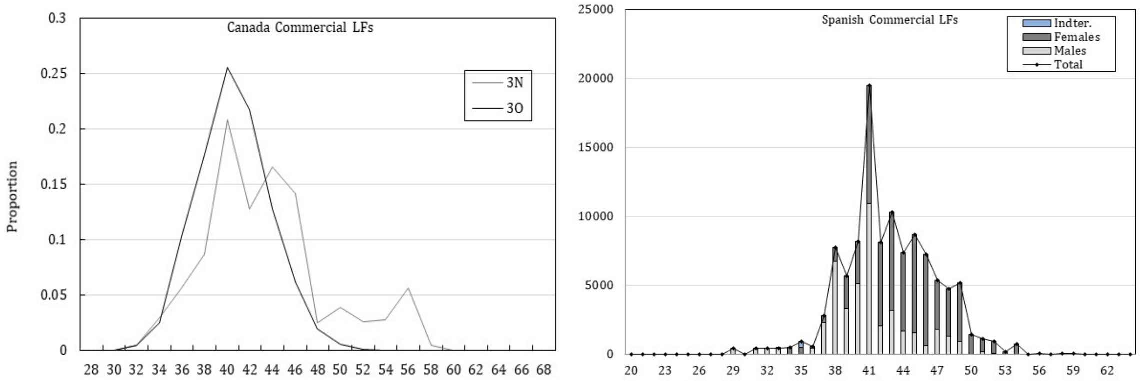


**Figure 13.2.** Witch flounder length frequency (cm) distributions for Canada and Spain (NAFO Divs. 3NO) commercial bycatch and directed fisheries in 2019.

### *ii) Research survey data*

**Canadian spring RV survey.** Due to substantial coverage deficiencies, values from 2006 are not presented. 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 13.3). 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 13.3).

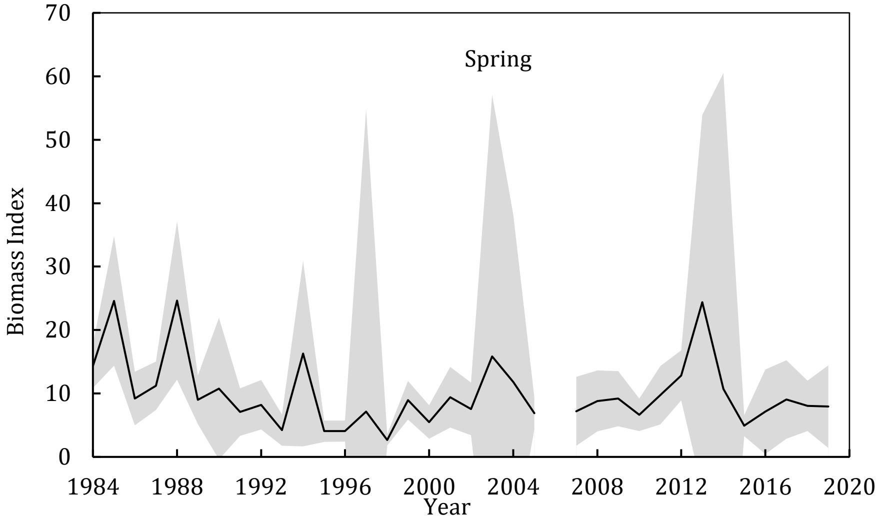


**Figure 13.3.** Witch flounder in NAFO Divs. 3NO: survey biomass indices from Canadian spring surveys 1984-2019 (95% confidence limits are given). Values are Campelen units or, prior to 1996, Campelen equivalent units.

**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 have increased slightly since 2016.

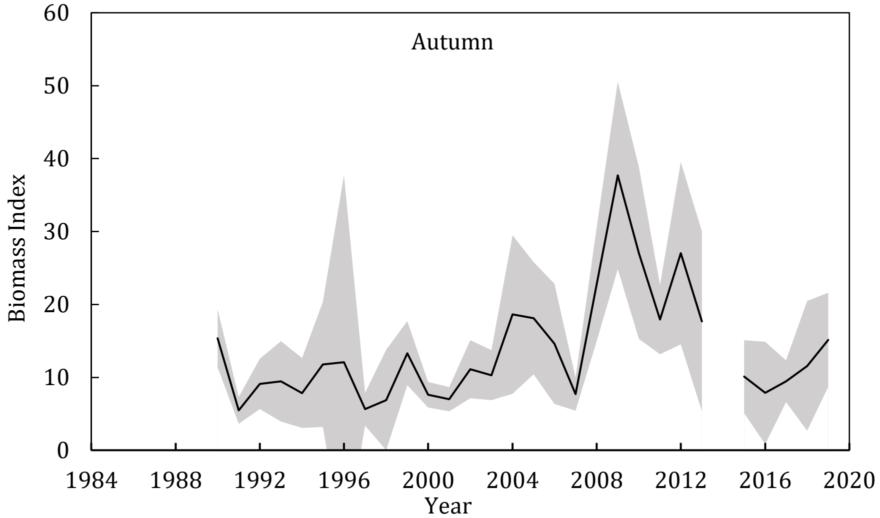


**Figure 13.4**. Witch flounder in Divs. 3NO: biomass indices from Canadian autumn surveys 1990-2019 (95% confidence limits are given). Values are Campelen units or, prior to 1996, Campelen equivalent units.

**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. (Figure 13.5).

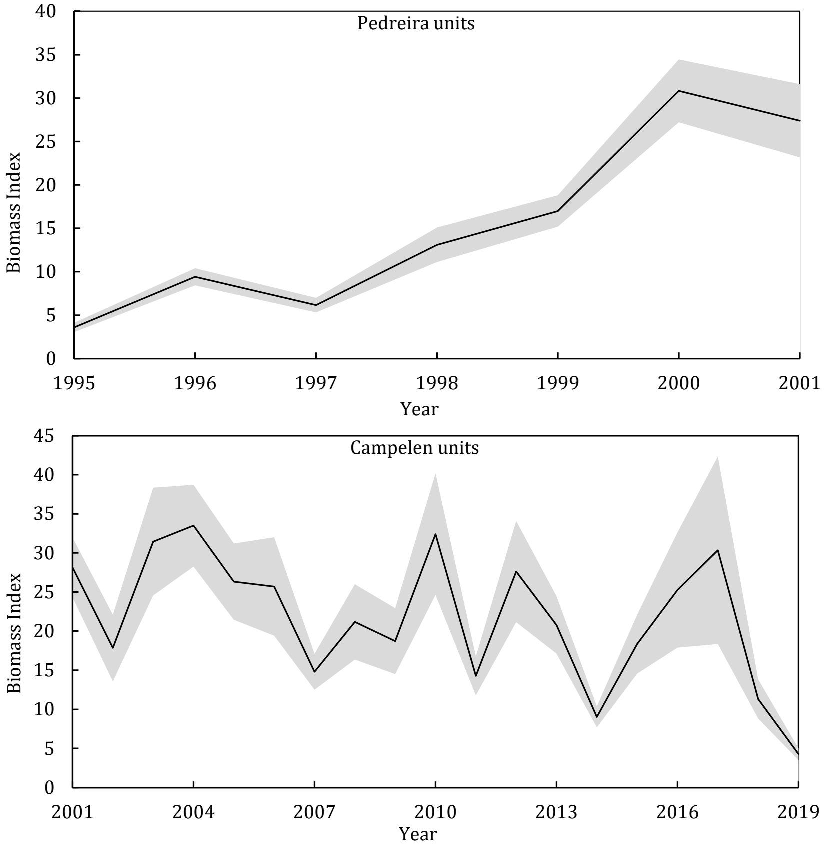


**Figure 13.5.** Witch flounder in Divs. 3NO: biomass indices from EU-Spanish Div. 3NO spring surveys (± 1 standard deviation). Data from 1995-2001 is in Pedreira units; data from 2001-2019 are Campelen units. Both values are presented for 2001.

**Abundance at length.** Abundance at length in the Canadian spring RV surveys appears to be fairly consistent since 2000 with few fish greater than 50 cm, and a mode generally around 38-40 cm (Figure 13.6). However, from 2007 to 2013 there was an increase in the number of larger fish in the 40-45 cm range except for an anomalous 30-35 cm range encountered in 2014 (Figure 13.6). Consistent with the decline in abundance observed in this survey, this size mode was smaller in amplitude from 2016 onward. Abundance at length in the Spanish spring RV surveys was fairly consistent at 33-35 cm from 2001 to 2007 (a smaller range than the Canadian surveys during the same time period). From 2008 to 2019 the size range has generally increased with more fish in the 38-43 cm range (Figure 13.6). In 2019 the mode was ~42 cm (Figure 13.6).

There were a number of distinctive peaks in the 5-15 cm range (recruitment year classes) in surveys that were evident and could be followed through successive years. This included the periods from 2007 to 2009 in the Canadian spring series and from 2005 -2006 in the Spanish spring series (Figure 13.6). A distinctive recruitment peak in the 10 cm range was evident in the 2017 Canadian autumn RV survey. Growth of this peak can be tracked through both Canadian spring and autumn surveys, and in 2019 these fish appear in a mode in the 21-26cm range. Another strong peak of fish at about 5cm is observed in the 2019 spring Canadian survey which is evident at 7-10 cm in size in the Canadian autumn survey. (Figure 13.6). The 2019 Spanish spring survey had low levels of witch flounder at all sizes.

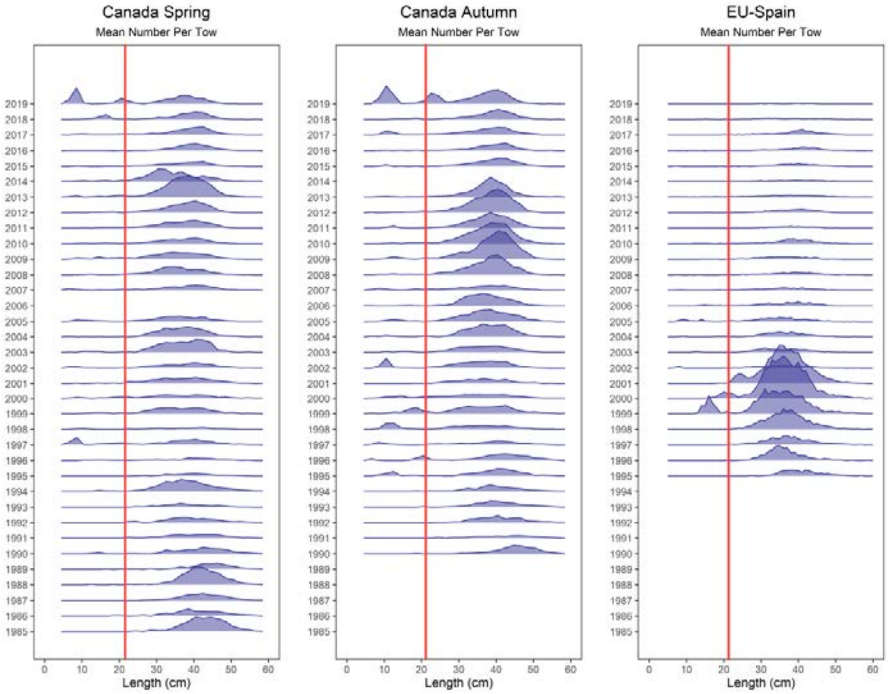


**Figure 13.6.** Length frequencies (abundance at length) of witch flounder from spring Canadian (1996-2019), autumn Canadian (1996 to 2019) and Spanish (2002-2019) RV surveys in NAFO Divs.3NO. No Canadian survey data was available in spring 2006 or autumn 2014. Vertical line represents the length at which fish are expected to be recruited to the population (21 cm).

**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).

### c) 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 1960-2019, Canadian spring survey series from 1984-1990, Canadian spring survey series from 1991-2019 (no 2006) and the Canadian autumn survey series from 1990-2019 (no 2014). The model formulation was identical to the accepted formulation from the 2019 assessment.

The priors used in the model were:

| | | |
|---|---|---|
| Median initial population size (relative to carrying capacity) | Pin~dunif(0.5, 1) | uniform(0.5 to 1) |
| Intrinsic rate of natural increase | r ~ dlnorm(-1.763,3.252) | lognormal (mean, precision) |
| Carrying capacity | K~dlnorm(4.562,11.6) | lognormal (mean, precision) |
| Survey catchability | q =1/pq<br>pq ~dgamma(1,1) | gamma(shape, rate) |
| Process error (sigma=standard deviation of process error in log-scale) | For 1960-2013 and 2017-2019<br>sigma ~ dunif(0,10)<br>precision:isigma2= sigma$^{-2}$<br>For 2014-2016<br>sigmadev <-sigma+1<br>precision: isigmadev2=sigmadev$^{-2}$ | uniform(0 to 10) |
| Observation error (tau=variance of observation error in log-scale) | tau~dgamma(1,1)<br>precision:itau2 = 1/tau | gamma(shape, rate) |

### d) State of the Stock

*Recruitment*: With the exception of the growth of the stock following improved recruitment in the late 1990s, it is unclear if this recruitment index is representative. Nevertheless, the recruitment index in 2019 is the highest in the time series.

Recruitment (defined as fish less than 21cm; Figure 13.7) in both the spring and autumn Canadian surveys, although somewhat variable, had generally been low since 2003. In 2016, recruitment approached the lowest of the time series. Recruitment in 2019 surveys, however, was the highest in the time series, at about six times the series' means.

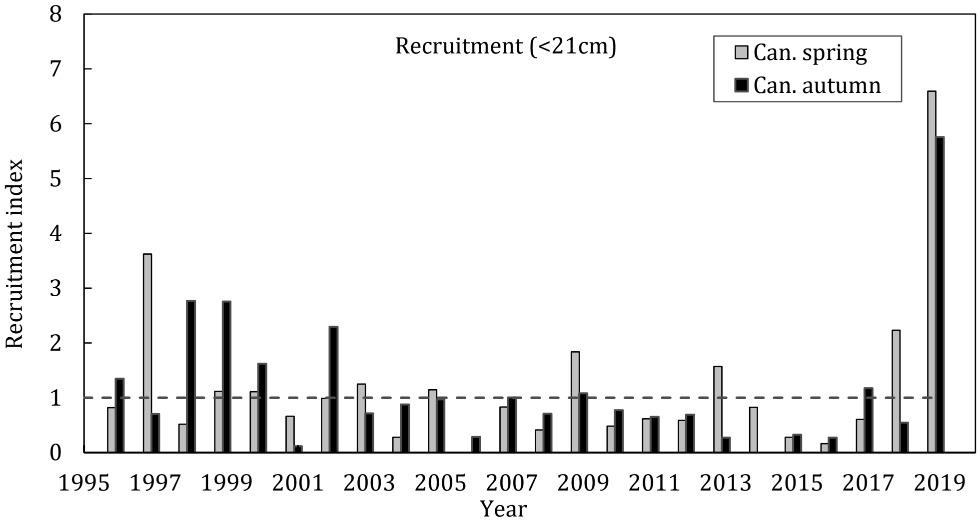


**Figure 13.7.** Recruitment index of witch flounder (<21cm) from spring and autumn Canadian RV surveys in NAFO Divs.3NO 1996-2019. No survey data available in autumn 2014 or spring 2006.

*Stock Production Model:* The surplus production model results indicate that stock size decreased from the late 1960s to the late 1990s and then increased from 1999 to 2013. There was a large decline from 2013 to 2015, with a subsequent small increase since. The model suggests that a maximum sustainable yield (*MSY*) of 3 789 (3 063 – 4 751) tonnes can be produced by total stock biomass of 59 880 (45 500 – 73 310) tonnes ($B_{msy}$) at a fishing mortality rate ($F_{msy}$) of 0.063 (0.05-0.09) (Figure 13.8).

*Biomass:* The analysis showed that relative population size (median $B/B_{msy}$) was below $B_{lim}$=30%$B_{msy}$ from 1993-1997 (Figure 13.8). Biomass in 2019 is 44% of $B_{msy}$ with a probability of being below $B_{lim}$ of 14%.

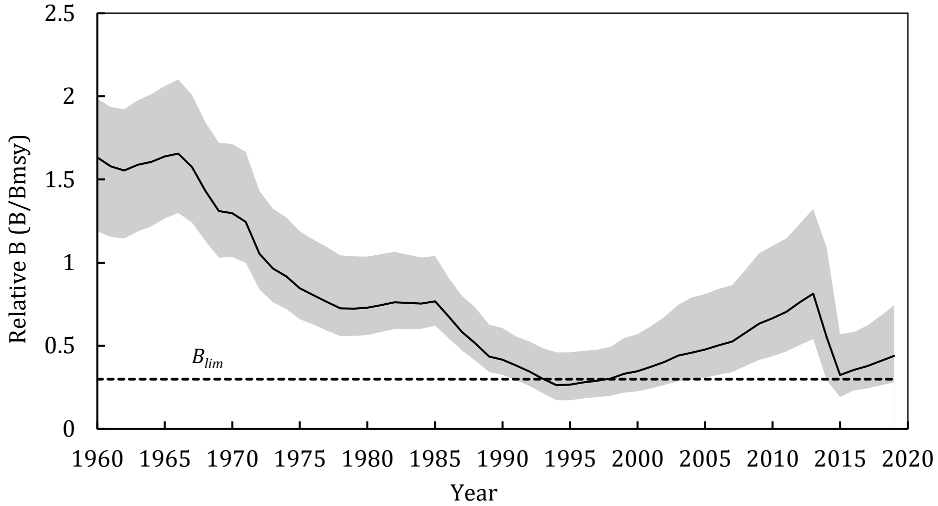


**Figure 13.8.** Witch flounder in Divs. 3NO. Median relative biomass (*Biomass*/$B_{msy}$) with 80% credible intervals from 1960-2019. The horizontal line is $B_{lim}$=30%$B_{msy}$.

*Fishing Mortality:* Relative fishing mortality rate (median $F/F_{msy}$) was mostly above 1.0 from the late 1960s to the mid-1990s (Figure 13.9). *F* has been below $F_{msy}$ since the moratorium implemented in 1995. Median *F* was estimated to be 53% of $F_{msy}$ with a low probability (4%) of being above $F_{msy}$ in 2019.

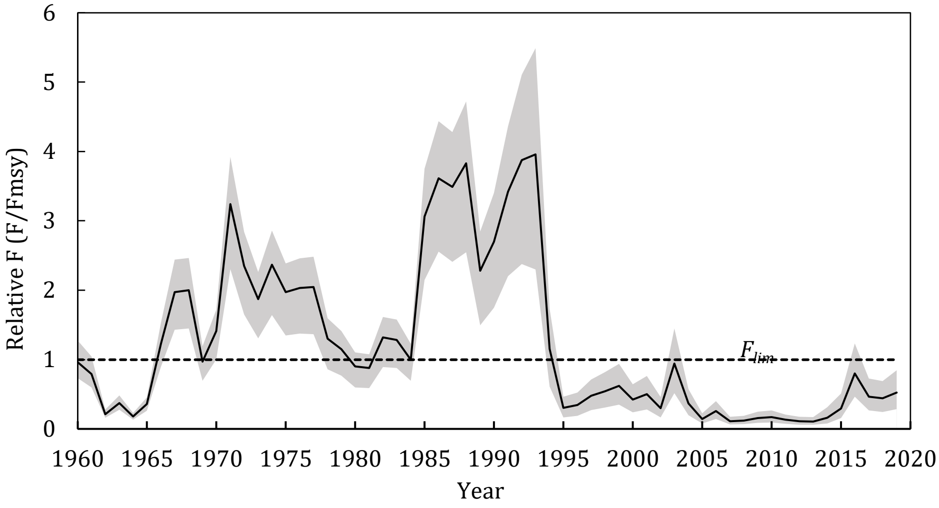


**Figure 13.9.** Witch flounder in Divs. 3NO. Median relative fishing mortality ($F/F_{msy}$) with 80% credible intervals from 1960-2019. The horizontal line is $F_{lim}$=$F_{msy}$.

*State of the stock:* The stock size increased from 1994 to 2013, then declined during 2013-2015 and has since increased slightly. In 2020 the stock is at 44% $B_{msy}$ (59 880 tonnes). There is 14% risk of the stock being below $B_{lim}$ and a 4% risk of *F* being above $F_{lim}$ ($F_{msy}$=0.063). With the exception of the growth of the stock following improved recruitment in the late 1990s, it is unclear if the recruitment index is representative. Nevertheless, the recruitment index in 2019 is the highest in the time series.

### e) Medium Term Considerations

The posterior distributions (13 500 samples) for r, K, sigma, and biomass and the production model equation were used to project the population to 2023. All projections assumed that the catch in 2020 was equal to the TAC of 1 175 t. This was followed by constant fishing mortality for 2020 and 2021 at several levels of $F$ ($F=0$, $F_{2019}$, 2/3 $F_{msy}$, 85% $F_{msy}$, and $F_{msy}$) and two levels of catch (avg 2016-2019=800 t and $\text{TAC}_{2020\ \text{and}\ 2021}$=1 175 t).

The probability that $F > F_{lim}$ in 2020 is 16% at a catch of 1 175 t. The probability of $F>F_{lim}$ ranged from 2 to 50% for the catch scenarios tested (Table 13.1, 13.2). The population is projected to grow under all scenarios (Figure 13.10) and the probability that the biomass in 2023 is greater than the biomass in 2020 is greater than 60% in all scenarios. The population is projected to remain below $B_{msy}$ through to the beginning of 2023 for all levels of $F$ examined with a probability of greater than 88%. The probability of projected biomass being below $B_{lim}$ by 2023 was 7 to 11% in all catch scenarios examined and was 4% by 2023 in the F=0 scenario.

A second set of projections was also conducted assuming that the catch in 2020 and 2021 was equal to the adopted TAC (1 175 t). The results were essentially the same as those assuming that the catch in 2020 equals the TAC. The probability of projected biomass being below $B_{lim}$ by 2023 was 8 to 10% in all catch scenarios examined and was 7% by 2023 in the $F$=0 scenario.

**Table 13.1.** Medium-term projections for witch flounder under two scenarios: catch in 2020=TAC (1 175t) and catch in 2020 and 2021=TAC (1 175 t). The 10th, 50th and 90th percentiles of catch and relative biomass $B/B_{msy}$, are shown, for projected $F$ values of $F=0$, $F_{2019}$, 2/3 $F_{msy}$, 85% $F_{msy}$, $F_{msy}$., and two levels of catch (Average 2016-2019=800 t and TAC= 1 175 t).

**Projections with catch in 2020 = TAC (1 175 t)**

| Year | Yield (t) median | Projected relative Biomass($B/B_{msy}$) median (80% CL) |
|---|---|---|
| *F0* | | |
| 2021 | 0 | 0.49 ( 0.30, 0.89) |
| 2022 | 0 | 0.53 ( 0.32, 0.97) |
| 2023 | | 0.58 ( 0.35, 1.06) |
| *Catch 800 t* | | |
| 2021 | 800 | 0.49 ( 0.30, 0.90) |
| 2022 | 800 | 0.52 ( 0.31, 0.97) |
| 2023 | | 0.54 ( 0.31, 1.03) |
| $F_{2019}$ = 0.033 | | |
| 2021 | 957 | 0.49 ( 0.30, 0.89) |
| 2022 | 1011 | 0.52 ( 0.31, 0.96) |
| 2023 | | 0.55 ( 0.32, 1.03) |
| *Catch 1 175t* | | |
| 2021 | 1175 | 0.49 ( 0.30, 0.90) |
| 2022 | 1175 | 0.52 ( 0.31, 0.97) |
| 2023 | | 0.54 ( 0.31, 1.03) |
| 2/3 $F_{msy}$ = 0.042 | | |
| 2021 | 1212 | 0.49 ( 0.29, 0.89) |
| 2022 | 1281 | 0.51 ( 0.30, 0.96) |
| 2023 | | 0.54 ( 0.31, 1.02) |
| 85% $F_{msy}$ =0.054 | | |
| 2021 | 1554 | 0.49 ( 0.30, 0.89) |
| 2022 | 1615 | 0.51 ( 0.30, 0.95) |
| 2023 | | 0.53 ( 0.30, 1.01) |
| $F_{msy}$ =0.063 | | |
| 2021 | 1823 | 0.49 ( 0.30, 0.88) |
| 2022 | 1879 | 0.50 ( 0.29, 0.94) |
| 2023 | | 0.52 ( 0.29, 0.99) |

**Projections with catch in 2020 and 2021 = TAC (1 175t)**

| Year | Yield (t) median | Projected relative Biomass($B/B_{msy}$) median (80% CL) |
|---|---|---|
| *F0* | | |
| 2021 | 1175 | 0.49 ( 0.30, 0.89) |
| 2022 | 0 | 0.52 ( 0.31, 0.96) |
| 2023 | | 0.56 ( 0.33, 1.05) |
| *Catch 800 t* | | |
| 2021 | 1175 | 0.49 ( 0.30, 0.89) |
| 2022 | 800 | 0.52 ( 0.31, 0.96) |
| 2023 | | 0.56 ( 0.33, 1.04) |
| $F_{2019}$ = 0.033 | | |
| 2021 | 1175 | 0.49 ( 0.30, 0.89) |
| 2022 | 1006 | 0.52 ( 0.31, 0.96) |
| 2023 | | 0.55 ( 0.32, 1.03) |
| *Catch 1 175t* | | |
| 2021 | 1175 | 0.49 ( 0.30, 0.90) |
| 2022 | 1175 | 0.52 ( 0.31, 0.97) |
| 2023 | | 0.54 ( 0.31, 1.03) |
| 2/3 $F_{msy}$ = 0.042 | | |
| 2021 | 1175 | 0.49 ( 0.30, 0.89) |
| 2022 | 1285 | 0.52 ( 0.31, 0.96) |
| 2023 | | 0.54 ( 0.31, 1.02) |
| 85% $F_{msy}$ =0.054 | | |
| 2021 | 1175 | 0.49 ( 0.30, 0.89) |
| 2022 | 1638 | 0.52 ( 0.31, 0.96) |
| 2023 | | 0.54 ( 0.31, 1.01) |
| $F_{msy}$ =0.063 | | |
| 2021 | 1175 | 0.49 ( 0.30, 0.89) |
| 2022 | 1928 | 0.52 ( 0.31, 0.96) |
| 2023 | | 0.53 ( 0.30, 1.01) |

**Table 13.2.** Projected yield (t) and the risk of *F*> *F*<sub></sub>$F_{lim}$, $B<B_{lim}$ and $B<B_{MSY}$ and probability of stock growth (B2023>B2020) under projected *F* values of *F=0*, $F_{2019}$, 2/3 $F_{msy}$, 85% $F_{msy}$, $F_{msy}$., and two levels of catch (Average 2016-2019=800 t and TAC= 1 175 t). Two scenarios are shown: catch in 2020=TAC (1 175t) and catch in 2020 and 2021=TAC (1 175 t).

| Catch 2020=1 175 t | Yield (t) | | $P(F>F_{lim})$ | | $P(B<B_{lim})$ | | | $P(B<B_{msy})$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2023 | 2021 | 2022 | 2023 | $P(B_{2023}>B_{2020})$ |
| F0 | 0 | 0 | 0% | 0% | 11% | 7% | 4% | 93% | 91% | 88% | 74% |
| Catch $_{2021}$ & Catch$_{2022}$=800t | 800 | 800 | 2% | 2% | 11% | 9% | 7% | 93% | 91% | 89% | 68% |
| $F_{2019}$ = 0.033 | 957 | 1011 | 6% | 7% | 11% | 9% | 8% | 93% | 91% | 89% | 67% |
| Catch $_{2021}$ & Catch$_{2022}$= 1 175t | 1175 | 1175 | 15% | 13% | 11% | 9% | 8% | 93% | 91% | 89% | 65% |
| 2/3 $F_{msy}$ = 0.042 | 1212 | 1281 | 17% | 18% | 11% | 10% | 9% | 93% | 91% | 89% | 66% |
| 85% $F_{msy}$ =0.054 | 1554 | 1615 | 35% | 36% | 11% | 10% | 10% | 93% | 91% | 90% | 63% |
| $F_{msy}$=0.063 | 1823 | 1879 | 50% | 50% | 11% | 11% | 11% | 93% | 92% | 90% | 61% |

| Catch2020 and 2021= 1 175 t | Yield (t) | | $P(F>F_{lim})$ | | $P(B<B_{lim})$ | | | $P(B<B_{msy})$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2023 | 2021 | 2022 | 2023 | $P(B_{2023}>B_{2020})$ |
| F0 | 1175 | 0 | 15% | 0% | 11% | 9% | 7% | 93% | 91% | 88% | 70% |
| Catch$_{2022}$=800t | 1175 | 800 | 15% | 2% | 11% | 9% | 8% | 93% | 91% | 89% | 67% |
| $F_{2019}$ = 0.033 | 1175 | 1006 | 15% | 7% | 11% | 9% | 8% | 93% | 91% | 89% | 66% |
| Catch$_{2021}$ & Catch$_{2022}$= 1 175t | 1175 | 1175 | 15% | 13% | 11% | 9% | 8% | 93% | 91% | 89% | 65% |
| 2/3 $F_{msy}$ = 0.042 | 1175 | 1285 | 15% | 18% | 11% | 9% | 9% | 93% | 91% | 89% | 65% |
| 85% $F_{msy}$ =0.054 | 1175 | 1638 | 15% | 36% | 11% | 9% | 9% | 93% | 91% | 89% | 64% |
| $F_{msy}$=0.063 | 1175 | 1928 | 15% | 50% | 11% | 9% | 10% | 93% | 91% | 90% | 63% |

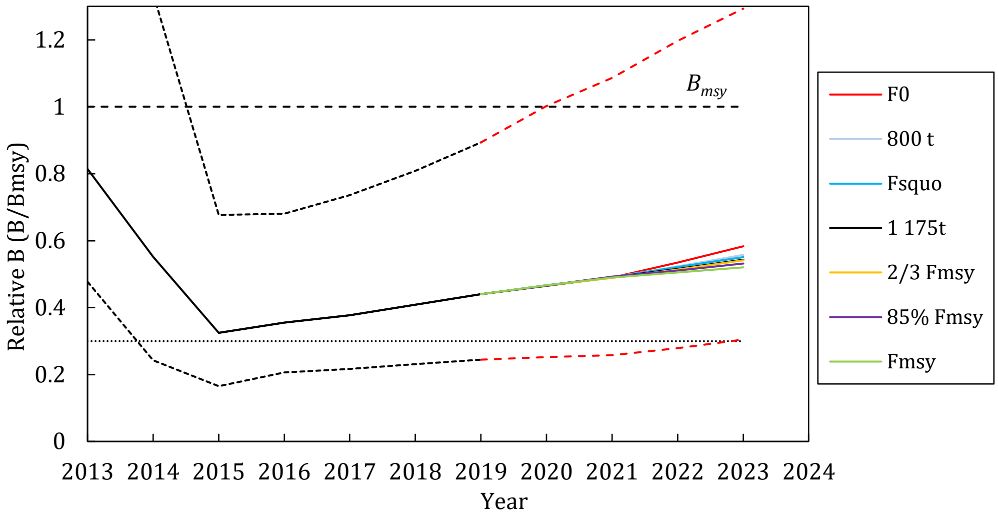


**Figure 13.10.** Witch flounder in Divs. 3NO: medium term projections of relative biomass ($B/B_{msy}$) at five levels of *F* (F=0, $F_{2019}$, 2/3 $F_{msy}$, 85% $F_{msy}$ and $F_{msy}$) and two levels of catch (avg 2016-2019=800 t and TAC 1 175 t). A catch of 1 175 t is assumed in 2020. The 10th and 90th credible intervals are included for the model results up to 2019 and for the projected period for the *F*=0 assumption.

## f) Reference Points

Reference points are estimated from the surplus production model. Scientific Council considers that 30% $B_{msy}$ is a suitable biomass limit reference point ($B_{lim}$) and $F_{msy}$ a suitable fishing mortality limit reference point for stocks where a production model is used.

At present, the risk of the stock being below $B_{lim}$ is 14% and above $F_{lim}$ is 4% (Figure 13.11).

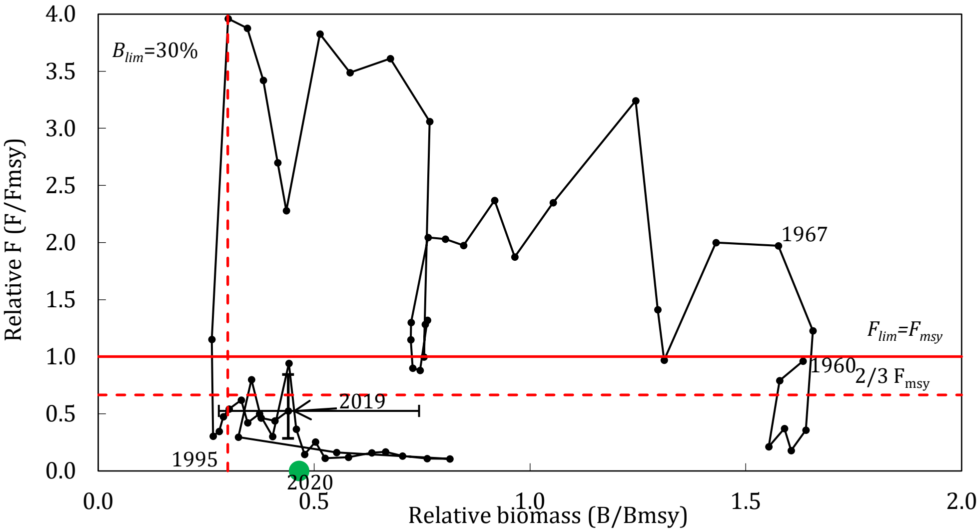


**Figure 13.11.** Witch flounder in Divs. 3NO: stock trajectory estimated in the surplus production analysis, under a precautionary approach framework.

### g) Recommendations

The next assessment will be in 2022.

## 14. Capelin (*Mallotus villosus*) in Divisions 3NO

(SCR 20-10 and SCS 20-07, 20-11)

Interim Monitoring Report

### a) Introduction

The fishery for capelin started in 1971 and catches were high in the mid-1970s with a maximum catch of 132 000 t in 1975 (Figure 14.1). The stock has been under a moratorium to directed fishing since 1992. No catches have been reported from 1993 to 2013. Small catches (mostly discards) started appearing from 2014 to 2019, with an exception of 2015.

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

| | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Recommended TAC | na | na | na | na | na | na | na | na | na | na | na | na | na |
| Catch[1] | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 5 | 1 | 2 | 2 | |

[1] No catch reported for this stock

na = no advice possible

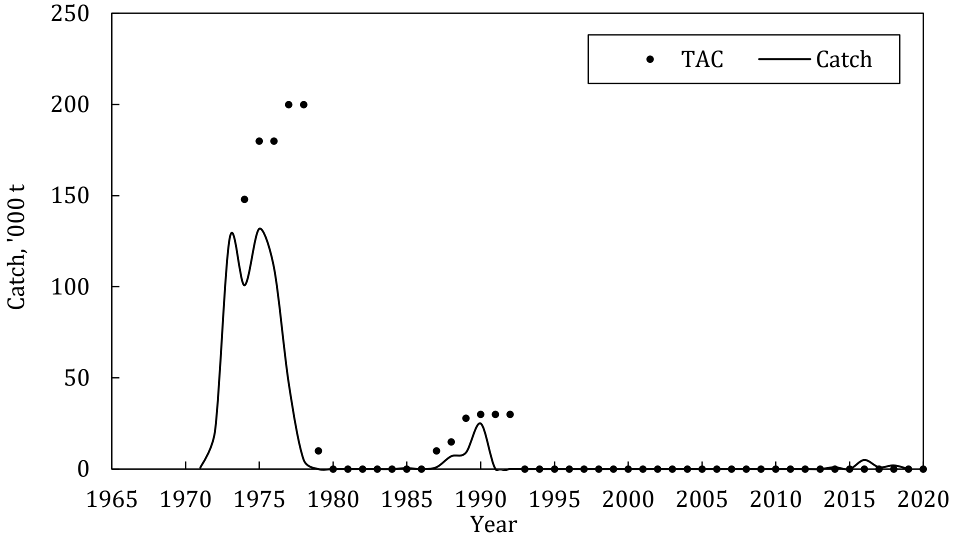


**Figure 14.1.** Capelin in Div. 3NO: catches and TACs.

### b) Data Overview

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 the 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. Available indicators of stock dynamics currently include the capelin biomass index from Canadian spring stratified-random bottom trawl surveys. This index varied greatly from 1995-2019 without any clear trend, however, three of the highest values have been observed in the most recent ten years of the time series (Figure 14.2). In 2016, the biomass indices declined to the historical minimum of 3.8 thousand tons. After increasing to 78.7 thousand tons in 2017, the index has decreased to 45.7 thousand tons in 2018. In 2019, further decrease was indicated, to 17.3 thousand tons.

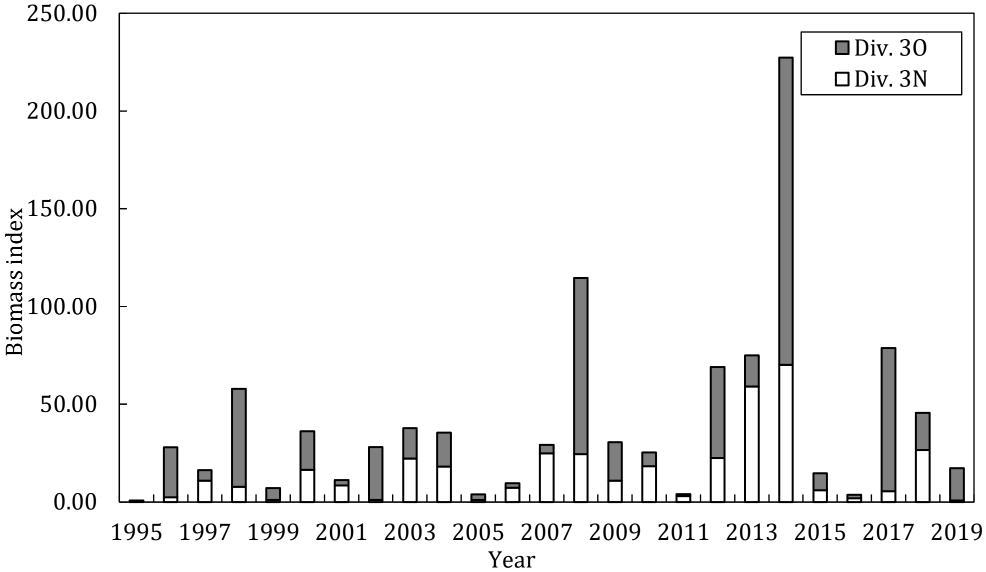


**Figure 14.2.** Capelin in Div. 3NO: survey biomass index (bottom trawl) from Canadian spring survey in 1995-2019.

Data from EU-Spain trawl surveys in Divs. 3NO for 1995-2019 are also available (Figure 14.3). Data from 1995-2000 are from the C/V "Playa de Menduíña", transformed to be comparable with the 2001-2019 R/V "Vizconde de Eza"data.

Survey estimates of capelin biomass show the maximum biomass level in 2012 (151.4 thousand tons). For the period of 2014-2017 biomass sharply declined from 85.5 thousand tons to 5.2 thousand tons. For 2018-2019, biomass has exhibited a simlar tendency to that at the early 2000s, rising to the level of 27.8-19.8 thousand tons.4

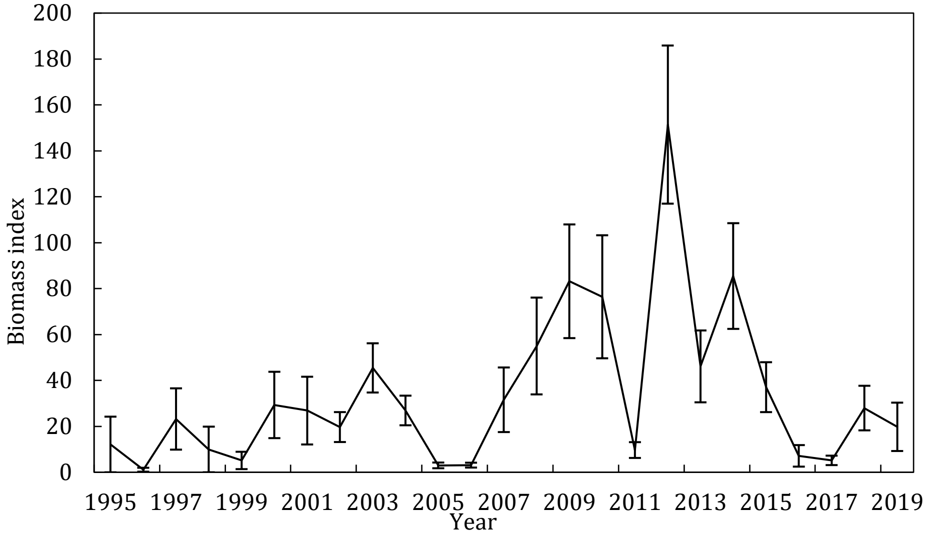


**Figure 14.3.** Biomass index and standard deviations of capelin (1995-2019) based on EU-Spain trawl 3NO surveys.

### c) Assessment Results

An acoustic survey series that terminated in 1994 indicated a stock at a low level. Biomass indices from bottom trawl surveys since that time have not indicated any change in stock status, although the validity of such surveys for monitoring the dynamics of pelagic species is questionable.

### d) Precautionary Reference Points

STACFIS is not in a position to determine biological reference points for capelin in Div. 3NO.

### e) 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.*

The next full assessment of the stock is planned for 2021.

## 15. Redfish (Sebastes mentella and Sebastes fasciatus) in Division 3O

(SCR Doc. 19/002, 009; SCS Doc. 19/ 06, 07, 09, 11, 13)

Interim Monitoring Report

### 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 magnitude 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 (Fig. 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 2019). Catch was 6500 tons in 2019.

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

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| **TAC** | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| **STATLANT 21** | 6.0 | 7.0 | 7.8 | 7.5 | 7.9 | 8.6 | 7.3 | 4.3 | | |
| **STACFIS** | 6.0 | 7.0 | 7.8 | 7.5 | 8.4 | 9.0 | 7.5 | 6.1 | 6.5 | |

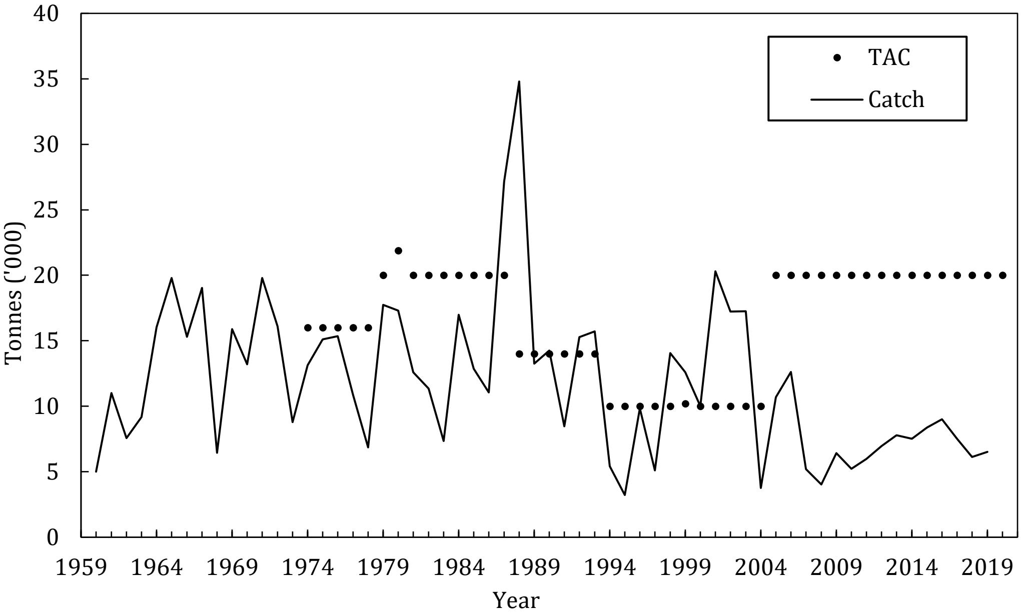


**Figure 15.1**. Redfish in Div. 3O: Catches and TACs. TACs prior to 2004 applied only to Canadian waters.

## b) Data Overview

*Surveys*

Canadian spring and autumn surveys plus the EU-Spain survey were conducted in 3O during 2019. 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 pattern of the Canadian spring survey index, 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 (Figure. 15.2).

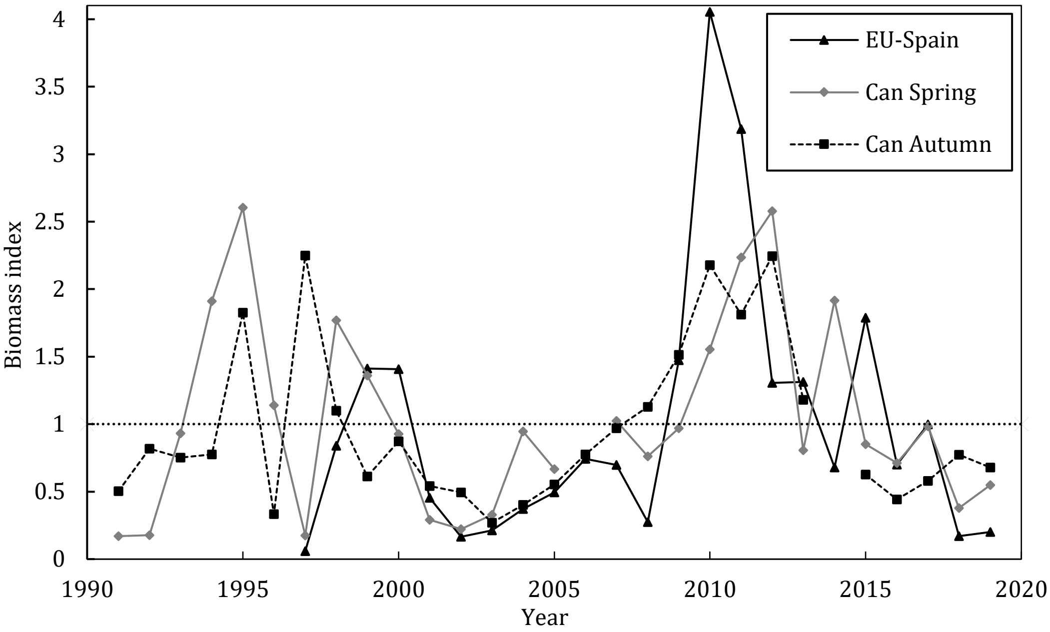


**Figure 15.2.** Redfish in Div. 3O: Survey biomass indices from Canada (Campelen equivalent estimates prior to autumn 1995) and EU-Spain. Indices were normalized by dividing by their time-series means over 1997-2019.

## c) Estimation of Stock Parameters

There is no assessment model for this stock and survey indices are used to assess stock status.

*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.

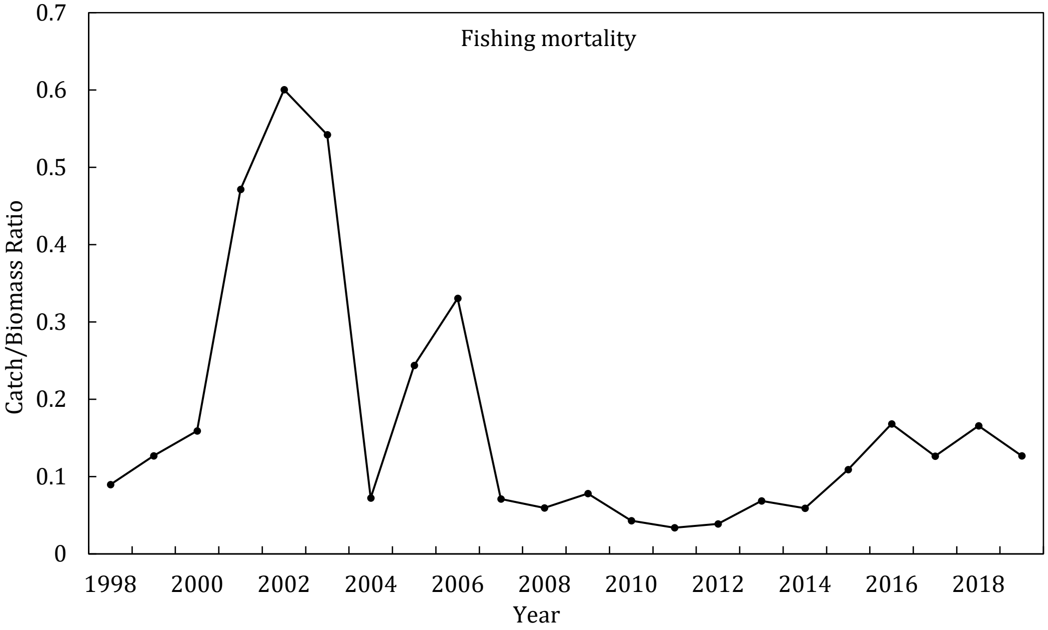


**Figure 15.3.** Redfish in Div. 3O: Catch/survey biomass ratios for Div. 3O. Biomass was calculated as the average survey biomass between spring (n) and autumn (n-1) for year (n) in which catch was taken. The 2006 and 2014 values of biomass come from the autumn and spring surveys respectively.

### d) 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 fall, 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. 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.

### e) 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 Subdivision 3Ps

(SCR Doc. 20/04,10,14,41; SCS Doc. 20/07,09,13)

### a) Introduction

Thorny skate on the Grand Banks was first assessed by Canada in 1999 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.

### *i) 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 (Figure 16.1). 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 2013-2020. 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 (Figure 16.1). The main participants in this new fishery were Spain, Portugal, USSR, and the Republic of Korea. Reported landings from all countries in Divs. 3LNOPs over 1985-1991 averaged 17 058 t; with a peak of 28 408 t in 1991 (STATLANT-21A). 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 2012-2018 was 3 831 t, and 460 t for Subdiv. 3Ps. STACFIS catch in 2019 totaled 3 697 t for Divs. 3LNO, and 889 t for Subdiv. 3Ps.

Recent catches and TACs ('000 tonnes) were as follows:

| | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **2018** | **2019** | **2020** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Divs. 3LNO:** | | | | | | | | | | | |
| TAC | 12 | 12 | 8.5 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| STATLANT-21A | 5.4 | 5.5 | 4.3 | 4.3 | 4.5 | 3.3 | 3.5 | 4.2 | 1.5 | 3.7 | |
| STACFIS | 3.1 | 5.4 | 4.3 | 4.3 | 4.5 | 3.3 | 3.5 | 4.5 | 2.4 | 3.7 | |
| **Subdiv. 3Ps:** | | | | | | | | | | | |
| TAC | 1.05 | 1.05 | 1.05 | 1.05 | 1.05 | 1.05 | 1.05 | 1.05 | 1.05 | 1.05 | 1.05 |
| STATLANT-21A | 0.9 | 0.7 | 0.6 | 0.6 | 0.3 | 0.2 | 0.7 | 0.6 | 1.1 | .9 | |
| **Divs. 3LNOPs:** | | | | | | | | | | | |
| STATLANT-21A | 6.2 | 6.3 | 4.9 | 4.9 | 4.8 | 3.6 | 4.1 | 4.8 | 2.3 | 4.6 | |
| STACFIS | 4.0 | 6.1 | 4.8 | 5.0 | 4.8 | 3.6 | 4.1 | 5.1 | 3.5 | 4.6 | |

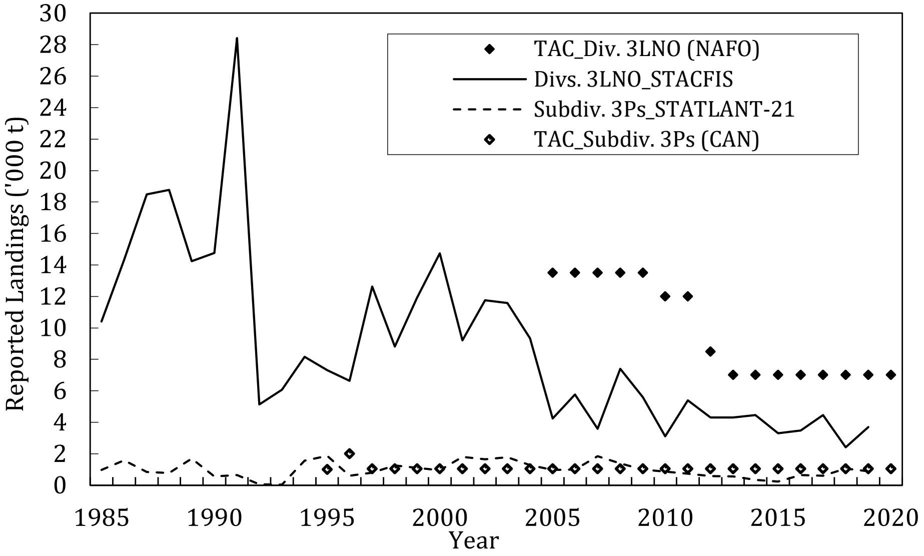


**Figure 16.1.** Thorny skate in Divs. 3LNO and Subdiv. 3Ps, 1985-2019: total reported landings and TACs.

## b) Data Overview

### *i) Commercial fisheries*

Thorny skates from either commercial or research survey catches are currently not aged.

Commercial length frequencies of skates were available for EU-Spain (1985-1991, 1997-2019), EU-Portugal (2002-2004, 2006-2011, 2013, 2017-2019), Russia (1998-2008, 2011-2012, 2015-2019), and Canada (1994-2008, 2010, 2012-2019).

From skate-directed trawl fisheries (280 mm mesh) in the NRA of Divs. 3LNO over 2012-2019, EU-Spain reported 15-100 cm TL skates, with a small number of young-of-the-year (≤21 cm) caught in 2013-2014 and 2017-2018. In 2013, EU-Portugal caught 26-85 cm skates (mode: 49-50 cm) using 280 mm mesh in Div. 3N.

In trawl fisheries targeting other species (130-135 mm mesh) in Div. 3LNO (NRA) over 2013-2019, EU-Portugal reported skate bycatch ranging from 25-88 cm TL, including modes of 46-49, 60-64, and 72-76 cm. EU-Portugal did not sample Divs. 3LNO skate bycatch in 2014-2016 and 2018, while EU-Spain have not done so since 2009. Russian trawlers in the Div. 3LN Greenland Halibut fishery reported 24-78 cm skates in 2012. In the Div. 3LO redfish fishery, Russia reported 35-89 cm skates in 2013-2016, and sampled only 5 and 14 specimens in 2017 and 2018 (respectively). In 2019, Russia reported the capture of thorny skates (31-87 cm)in Div. 3L averaging 56.1 cm. In Div. 3N and 3O respectively, Russia captured skates that comprised individuals ranging from 31-95 cm (average 64.0 cm), and 15-92 cm (average 70.7 cm). In the Div. 3L redfish fishery, skates varied between 27-93 cm in 2016-2019, including modes of 35-40, 56, 62-66, and 72-82 cm. Canadian trawlers in the Div. 3NO Yellowtail Flounder fishery in 2016-2019 caught 24-101 cm thorny skates. In 2017, skates trawled in the Div. 3O Witch Flounder fishery ranged between 42-100 cm (mode: 80 cm). Skates trawled in the Divs. 2J3KL Greenland Halibut fishery in 2018 varied between 31-88 cm (modes of 48, 53, and 63 cm).

No standardized commercial catch per unit effort (CPUE) exists for thorny skate.

### *ii) 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 1983-1995, and a Campelen 1800 shrimp trawl in 1996-2019. Subdiv. 3Ps was not surveyed in 2006, nor was the deeper portion of Divs. 3NO, 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 series) fluctuated without trend (Figure 16.2a).

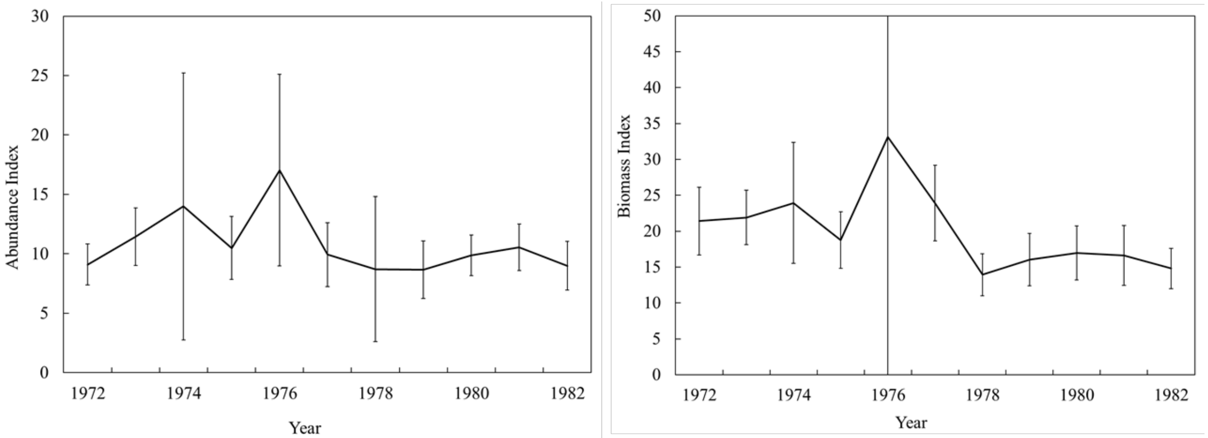


**Figure 16.2a.** Thorny skate in Divs. 3LNOPs, 1972-1982: abundance (left panel) and biomass (right panel) indices from Canadian spring surveys.

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.

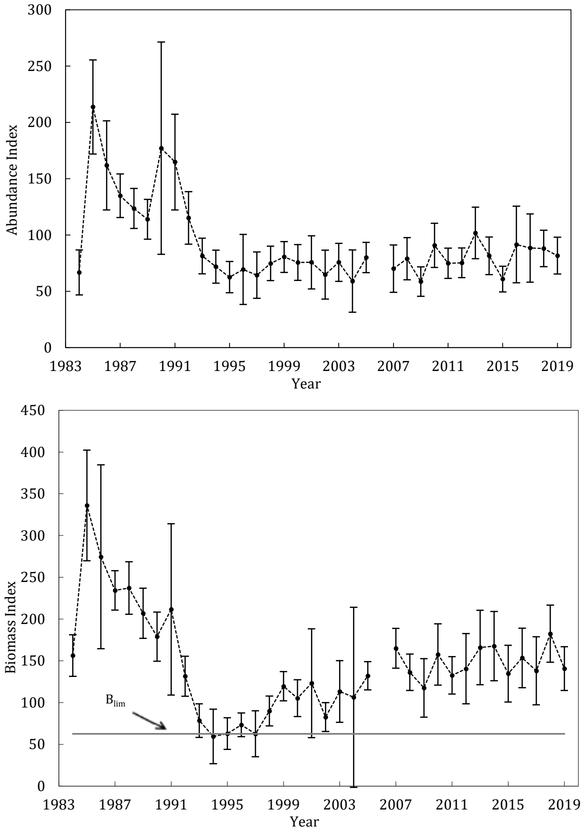


**Figure 16.2b.** Thorny skate in Divs. 3LNOPs, 1984-2019: abundance (top panel) and biomass (bottom panel) indices from Canadian spring surveys. Horizontal line represents $B_{lim}$. Surveys in 2015 and 2017 (open circles) were incomplete.

**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 1995-2019, 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). Divs. 3NO were not surveyed in 2014, nor deep-water strata (>732 m) of Div. 3L in 2015, and 2017-2018; 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.

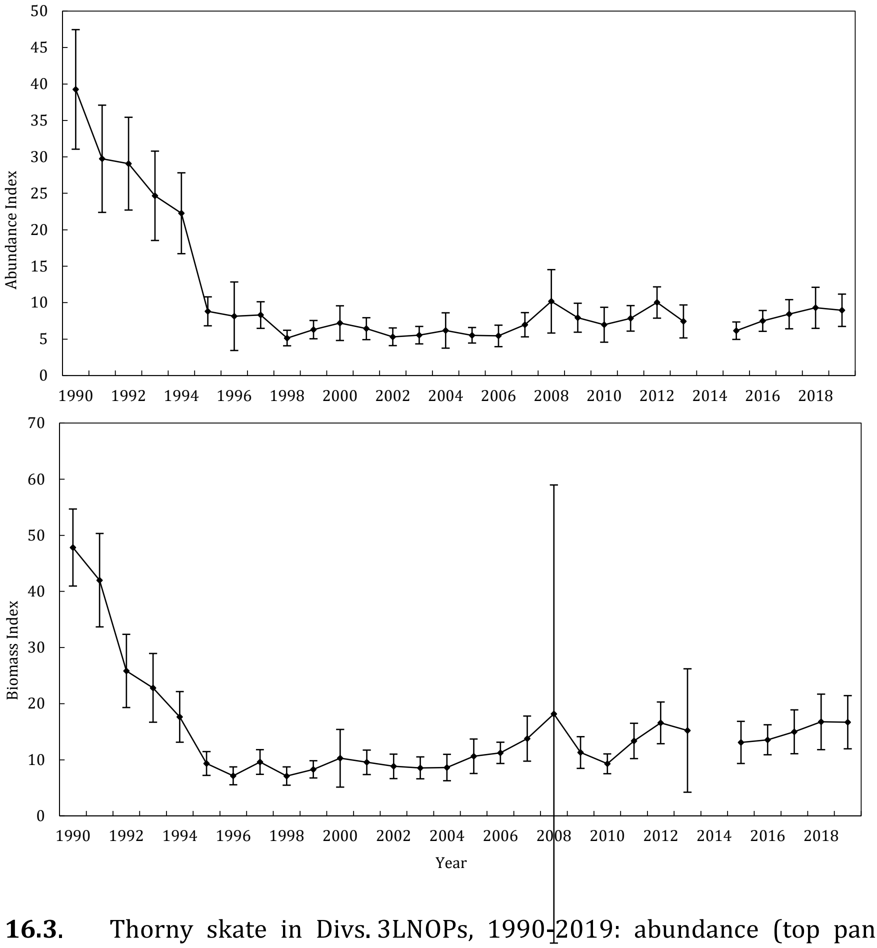


**Figure 16.3**. Thorny skate in Divs. 3LNOPs, 1990-2019: abundance (top panel) and biomass (bottom panel) indices from Canadian autumn surveys. Divs. 3NO were not sampled in 2014, nor deep-water strata of Div. 3L in 2015, and 2017-2018.

**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 declining trend in the EU-Spain index to its lowest value in 2019.

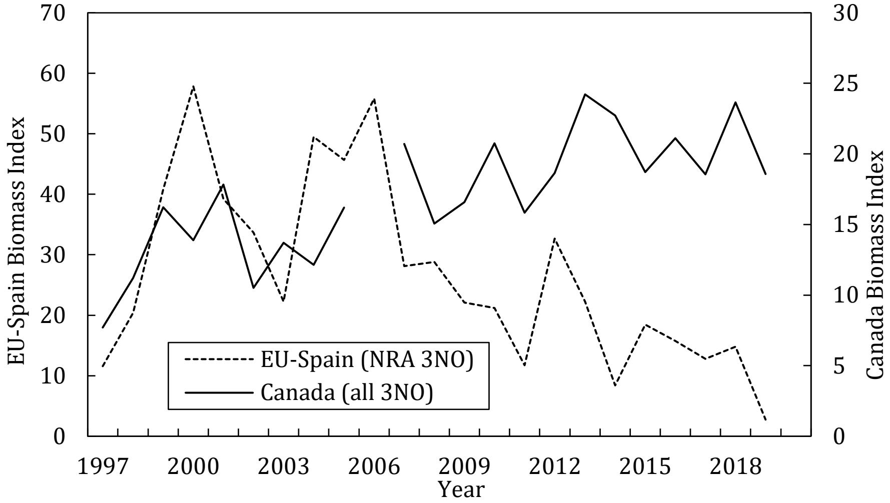


**Figure 16.4.** Thorny skate in Divs. 3LNOPs, 1997-2019: biomass indices from the EU-Spain survey and the Canadian spring survey.

**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.

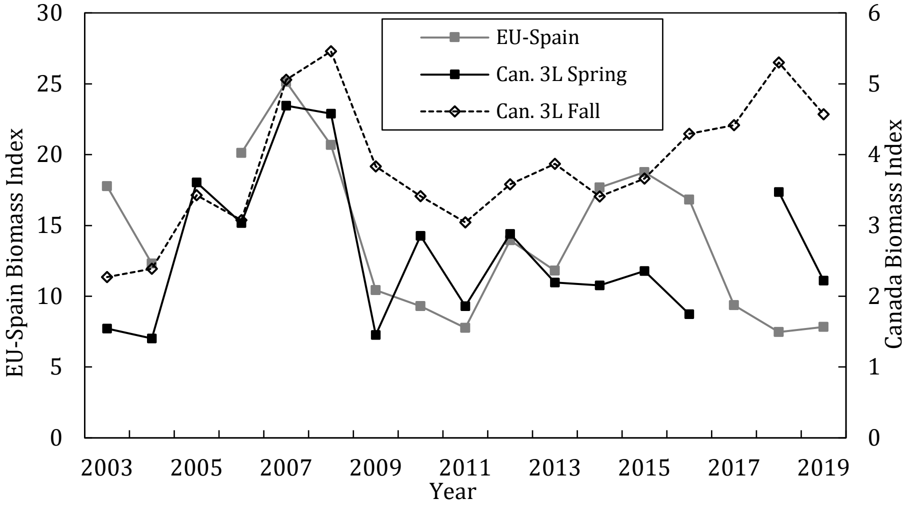


**Figure 16.5.** Thorny skate in Div. 3LNOPs, 2003-2019: Biomass indices from EU-Spain Div. 3L survey and the Canadian spring and autumn surveys of Div. 3L. The Canadian spring survey in Div. 3L was incomplete in 2015 and 2017.

### *iii) Biological studies*

Recruitment index (skate ≤21 cm TL) was below average in 1999-2002 (Figure 16.6). The index was above average during 2010-2013. Recruitment declined to below average in 2014-2015, then increased to 1.3 in 2017. This increase in 2017 was observed despite the missing Div. 3L survey strata which, in 2009-2016, contained on average 10% of the thorny skate recruits. This index was below average in 2018, and average in 2019. Life history traits of late maturity, low fecundity, and long reproductive cycles result in low intrinsic rates of increase, and impart low resilience to fishing mortality for this species.

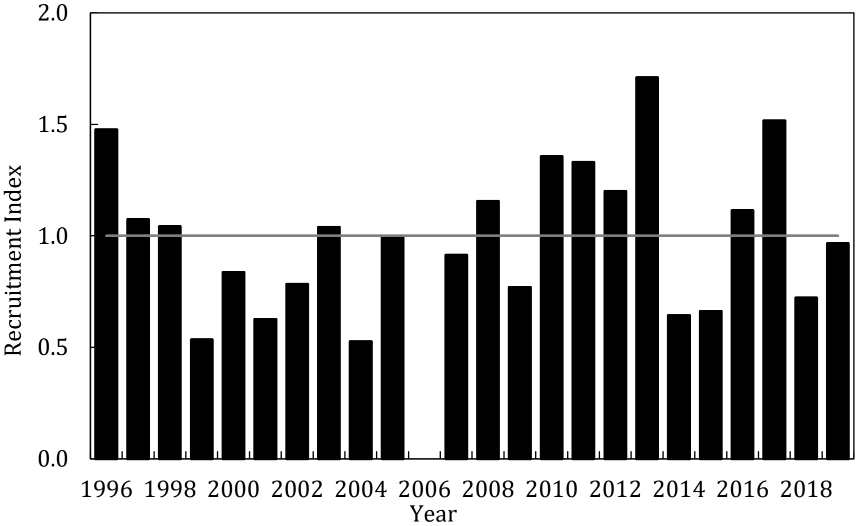


**Figure 16.6.** Thorny skate in Divs. 3LNOPs, 1996-2019: Standardized recruitment index for ≤21 cm TL males and females (combined) from Canadian Campelen spring surveys. Horizontal line depicts the standardized average recruitment for 1996-2019. The survey was incomplete in 2017.

## c) Estimation of Parameters

Relative F (STACFIS-agreed commercial landings/Canadian spring survey biomass) in Divs. 3LNO declined over the late-1990s, and is currently low. Relative fishing mortality in Subdiv. 3Ps has also been low in recent years.

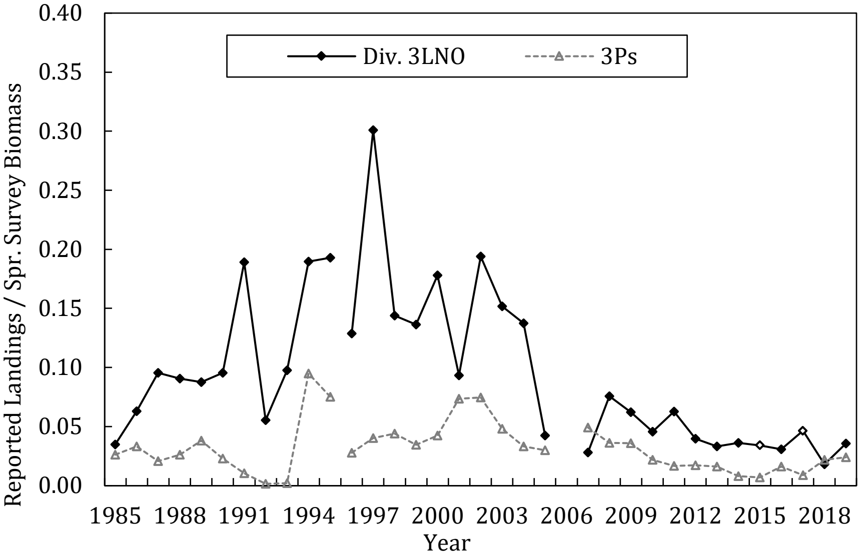


**Figure 16.7.** Thorny skate in Divs. 3LNO and Subdiv. 3Ps, 1985-2019: estimates of Relative F from STACFIS-agreed commercial landings/Canadian spring survey biomass. was incomplete in 2015 and 2017 (open circles).

## d) Assessment Results

*Assessment Results:* No analytical assessment was performed.

The Canadian spring survey is considered the primary indicator of the status of this stock, due to its spatial and temporal coverage.

*Biomass:* Biomass of this stock has remained stable at low levels since 2007. For comparable periods, the pattern from the Canadian autumn research survey was similar.

*Fishing Mortality:* Relative F (STACFIS-agreed commercial landings/Canadian spring survey biomass) in Divs. 3LNOPs declined since the mid-1990s, and is currently low.

*Recruitment:* Recruitment has been below average over 1997-2007. Recruitment was above average during 2010-2013, but declined to below average in 2014-2016. Recruitment in 2016-2017 was above average, but declined to below average in 2018, and was average in 2019.

*State of the Stock:* The stock is currently above $B_{lim.}$ The probability that the current biomass is above $B_{lim}$ is >95%. Total survey biomass in Divs 3LNOPs has remained stable since 2007 but is still lower than the levels observed at the end of the 1980s. Recruitment in 2017 was above average but declined to below average in 2018 and was average in 2019. Fishing mortality is currently low.

## e) Reference Points

Limit reference points based on $B_{loss}$, which represents the lowest value for the Canadian spring survey conducted with Campelen survey gear, were accepted in 2015 as a proxy for $B_{lim}$ (Figure 16.8).

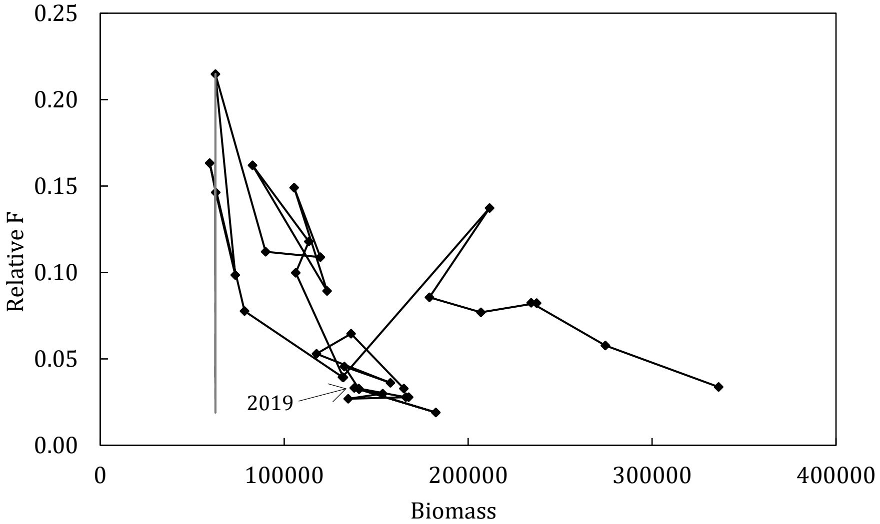


**Figure 16.8.** Thorny skate in Divs. 3LNOPs, 1985-2019: stock trajectory under a precautionary approach framework.

## f) Research Recommendations

STACFIS **recommended** that *further work be conducted on development of a quantitative stock model.*

**STATUS:** Work ongoing. STACFIS reiterated this recommendation.

The next full assessment is planned for 2022.

## 17. White hake (*Urophycis tenuis*) in Divisions 3N, 3O, and Subdivision 3Ps

(SCR Doc. 20/02,10; SCS Doc. 20/07,11)

Interim Monitoring Report

### a) Introduction

The advice requested by Fisheries Commission is for NAFO Div. 3NO. 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 within 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.

In 1988, Canada commenced a directed fishery for White Hake 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 in landings. 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 for White Hake was first implemented by Fisheries Commission in 2005 at 8 500 tons, and was then reduced to 6 000 t for 2010 and 2011. The 5 000 t TAC in Div. 3NO for 2012 was further reduced to 1 000 t for 2013-2020. Canada implemented a TAC of 500 t for Subdiv. 3Ps for 2018-2020.

From 1970-2009, White Hake catches in Div. 3NO fluctuated, averaging approximately 2 000 t, exceeding 5 000 t in only three years during that period. Catches peaked in 1987 at 8 061 t (Figure 17.1). With the restriction of fishing by other countries to areas outside Canada's Exclusive Economic Zone in 1992, non-Canadian catches fell to zero. Average catch was low in 1995-2001 (422 t), then increased to 6 718 t in 2002 and 4 823 t in 2003; following recruitment of the large 1999 year-class. STACFIS-agreed catches in Divisions 3NO decreased to an average of 333 t over the period 2009-2018. STACFIS catch in 2019 was 304 t in Div. 3NO.

Commercial catches of White Hake in Subdiv. 3Ps were less variable, averaging 1 114 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 1 374 t in 2003-2007, then decreased to a 310 t average in 2008-2018. Catch in 2019 was reported as 186 t in Subdiv. 3Ps

Recent reported landings and TACs (000 tons) in NAFO Div. 3NO and Subdiv. 3Ps are as follows:

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Div. 3NO**: | | | | | | | | | | |
| TAC | 6 | 5 | 1[1] | 1[1] | 1[1] | 1[1] | 1[1] | 1[1] | 1[1] | 1[1] |
| STATLANT 21 | 0.2 | 0.1 | 0.2 | 0.3 | .4 | .4 | .5 | .3 | .3 | |
| STACFIS | 0.2 | 0.1 | 0.2 | 0.3 | .5 | .4 | .5 | .4 | .3 | |
| **Subdiv. 3Ps**: | | | | | | | | .5 | .5 | .5 |
| STATLANT 21 | 0.2 | 0.2 | 0.2 | 0.4 | .3 | .4 | .3 | .3 | .2 | |

[1] May change in season. See NAFO FC Doc. 13/01 quota table.

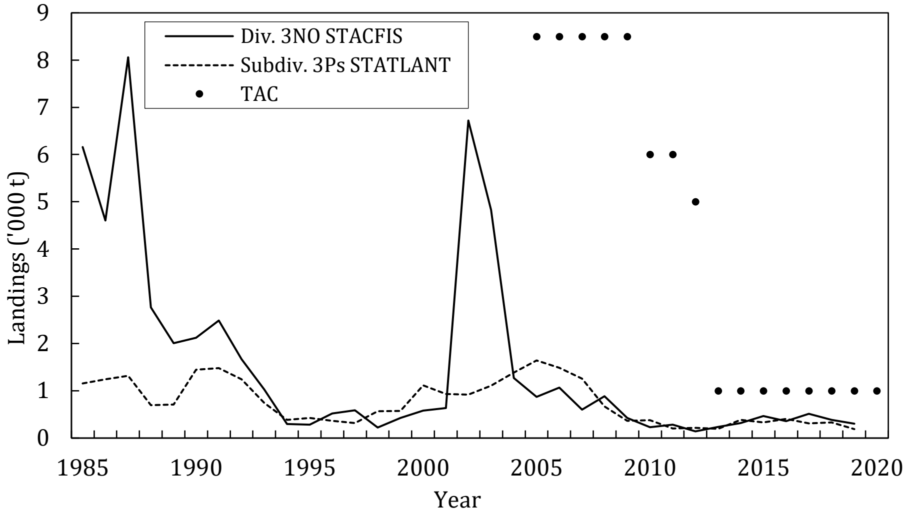


**Figure 17.1.** White Hake in Division 3NO and Subdivision 3Ps: Total catch of White Hake in NAFO Division 3NO (STACFIS) and Subdivision 3Ps (STATLANT-21A). The Total Allowable Catch (TAC) in the NRA of Divs. 3NO is also indicated on the graph.

## b) Data Overview

### *i) 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. 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 2019, 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 1995-2019. 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 2007-2019, 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. In 2019, the abundance index of white hake has exhibited a strong increase comparable to that observed in 1999. 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 been relatively stable.

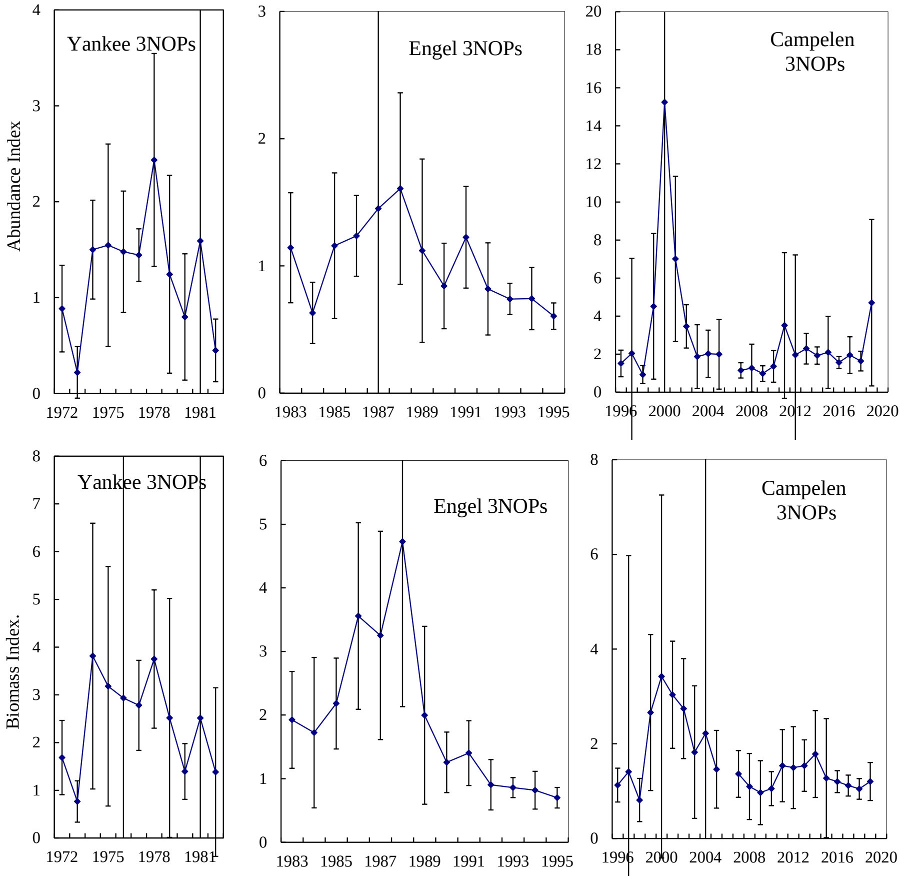


**Figure 17.2a.** White Hake in Div. 3NO and Subdiv. 3Ps: abundance (top panels) and biomass (bottom panels) indices from Canadian winter-spring research surveys, 1972-2019. Estimates from 2006 are not shown, since survey coverage in that year was incomplete. Yankee, Engel, and Campelen time series are not standardized, and are presented on separate panels. Error bars are 95% confidence limits. The bounds of the error bars 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. In recent years, both biomass and abundance appear to have been variable without trend. This survey was not completed in 2014.

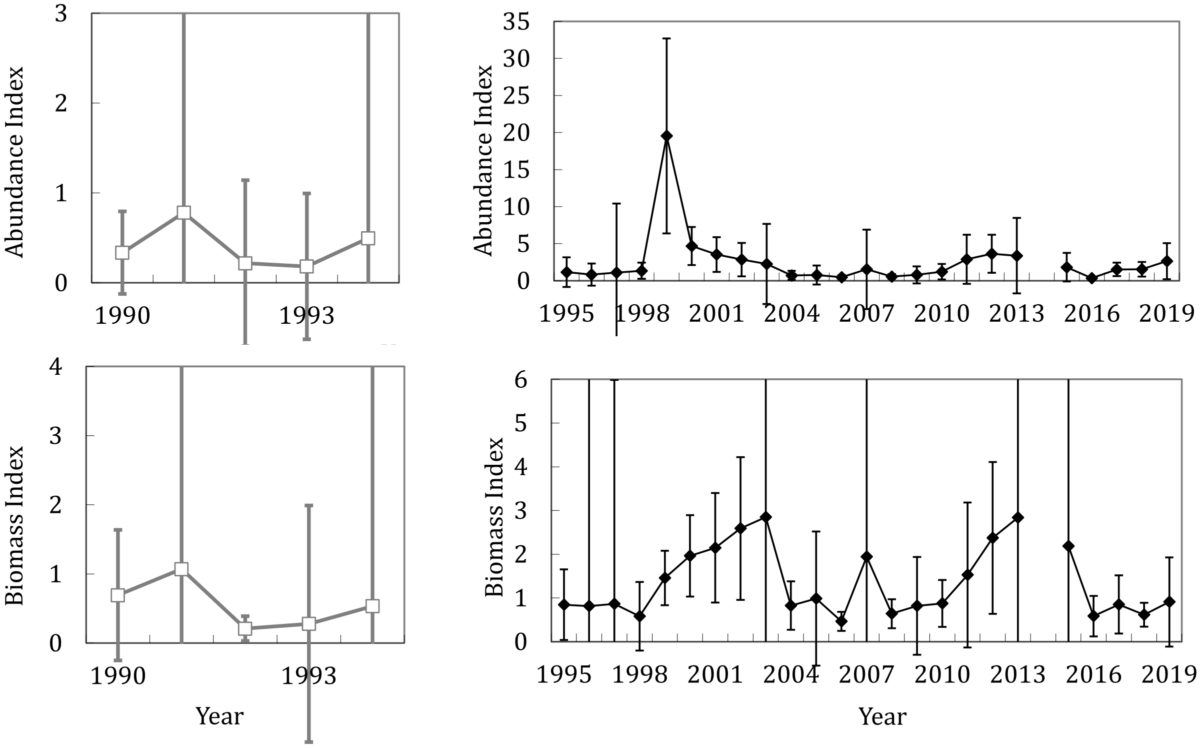


**Figure 17.2b.** White Hake in Div. 3NO: abundance (top panel) and biomass indices (bottom panel) from Canadian fall surveys, 1990-2019. Engel (□, 1990-1994) and Campelen (♦, 1995-2013) time series are not standardized. Estimates from 2014 are not shown, since survey coverage in that year was incomplete. Error bars are 95% confidence limits. The bounds of the error bars in 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 (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 1 400 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 from 2016 to 2019 to a similar level as observed in 2008, while in 2019 the Canadian index increased.

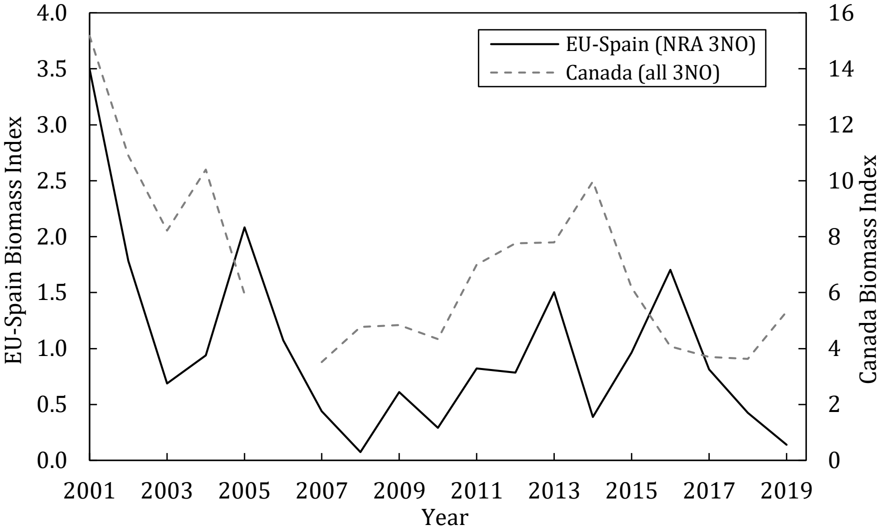


**Figure 17.3.** Biomass indices from EU-Spain spring 3NO surveys in 2001-2019 in the NRA compared to Canadian spring survey indices in all of Div. 3NO. Estimates from 2006 Canadian survey are not shown, since survey coverage in that year was incomplete.

**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 2001-2019 (Figure 17.6). Recruitment was higher in 2011 and in 2019, but not comparable to the very high recruitment observed in 2000.

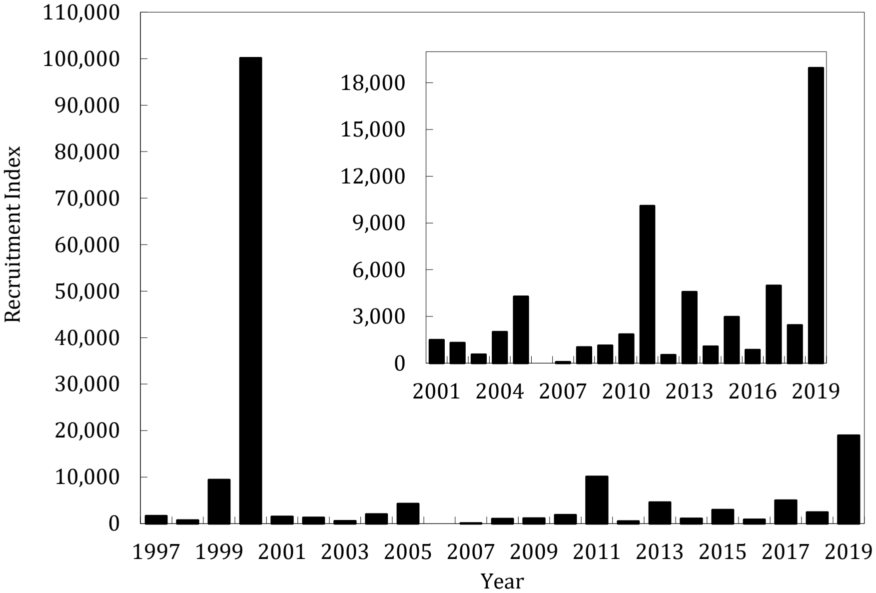


**Figure 17.4.** White Hake in Div. 3NO and Subdiv. 3Ps: recruitment index for Age 1 males and females (combined) from Canadian Campelen spring surveys in Divs. 3NO and Subdiv. 3Ps n 1997-2019. Estimates from 2006 are not shown, since survey coverage in that year was incomplete. Inset plot depicts 2001-2019 on a smaller scale.

### c) Conclusion

Based on current information there is no significant change in the status of this stock. Stock biomass remains at relatively low levels, and no large recruitments have been observed since 2000.

### d) Research Recommendations

STACFIS **recommended** that *age determination should be conducted on otolith samples collected during annual Canadian surveys (1972-2016+); thereby allowing age-based analyses of this population.*

Otoliths are being collected but have not been aged. 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 in a Bayesian framework were explored and work is continuing.

## D. WIDELY DISTRIBUTED STOCKS: SUBAREA 2, SUBAREA 3 AND SUBAREA 4

### Recent Conditions in Ocean Climate and Lower Trophic Levels

- Driven mostly by warm temperature in SA 4, the ocean climate index based on data from the Labrador Shelf to the Scotian Shelf (SA2-4) has remained mostly warmer than normal since early 2010, with its highest value in 2012. In 2019, SA-2 was normal, SA-3 below normal and SA-4 above normal.
- Spring bloom initiation anomalies in 2019 were negative (earlier bloom) on the Newfoundland Shelf and The Grand Bank (SA 3), and positive (later bloom) on the Scotian Shelf and in the Gulf of St. Lawrence (SA 4) but did not depart from normal conditions (± 0.5 SD).
- Spring bloom magnitude anomalies in 2019 were negative (lower production) on the Newfoundland Shelf and the Grand Bank (SA 3) and on the Scotian Shelf and the Gulf of St. Lawrence (SA 4) but did not depart much from normal conditions (± 0.5 SD).
- The abundance of copepod and non-copepod zooplankton showed positive anomalies across the Northwest Atlantic (SA 2-4) in 2019.
- Zooplankton biomass in 2019 showed a positive anomaly on the Labrador Shelf (SA 2), and negative anomalies on the Newfoundland Shelf, the Grand Banks, the Scotian Shelf, and in the Gulf of St. Lawrence (SA 3-4)

### Environmental Overview

The water mass characteristics of the Newfoundland and Labrador Shelf are typical of sub-polar waters with a sub-surface temperature range of -1-2ºC 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 (1-3oC) except for the shallow inshore regions where they are mainly <0oC. In the deeper waters of the Flemish Pass and across the Flemish Cap bottom temperatures generally range from 3-4oC. 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 8-13oC and salinities from 34.7-35.6, and Labrador Slope Water, with temperatures from 3.5oC to 8oC 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 2010. Years 2012, 2014, 2017, 2015 and 2016 (ranked in this order) are the warmest anomalies since 1985. In 2019, the cumulative index was however average but characterized by warm conditions in SA-4 and cold conditions in SA-3. Spring bloom initiation (Figure D1.B) oscillated between earlier (negative anomalies) and later (positive anomalies) sowing no long-term trend throughout the time series. Spring bloom timing anomalies in 2019 were negative on the Newfoundland Shelf and the Grand Banks (SA 3) and positive on the Scotian Shelf and in the Gulf of St. Lawrence (SA 4) but did not depart from normal conditions (± 0.05 SD). Spring Bloom magnitude (Figure D1.C) transitioned from mostly positive anomalies from 1998-2006 to almost exclusively negative anomalies afterwards in all subareas. Spring bloom magnitude anomalies in 2019 were negative (lower production) on the Newfoundland Shelf and the Grand Bank (SA 3) and on the Scotian Shelf and the Gulf of St. Lawrence (SA 4) but did not depart much from normal conditions (± 0.5 SD). Limited satellite coverage in SA 2 in 2019 due to sea ice and clouds did not allow calculation of spring bloom indices for that region.

The abundance of copepod (Figure D1.D) and non-copepod Figure D1.E) zooplankton showed large-scale increasing trends throughout the time series. Copepod abundance increased markedly on the Newfoundland Shelf and the Grand Banks (SA 3) during the late 2010s. Positive anomalies in copepod abundance were observed across all subareas in 2019 with the second highest cumulated index of the time series. The abundance of non-copepod has markedly increased in all subareas since the late 2000s with positive anomalies across the Northwest Atlantic since 2013, including in 2019. Large scale trend in zooplankton biomass (Figure D1.F) shows an increase during the late 1990s and early 2000s, followed by an overall decrease between 2002 and 2015. Zooplankton biomass. Zooplankton biomass has been increasing during the late 2010s, especially on the Labrador Shelf (SA 2) and on the Newfoundland Shelf and the Grand Bank (SA 3). Zooplankton abundance anomalies in 2019 were positive in SA 2 and negative in SA 2 and SA 3.

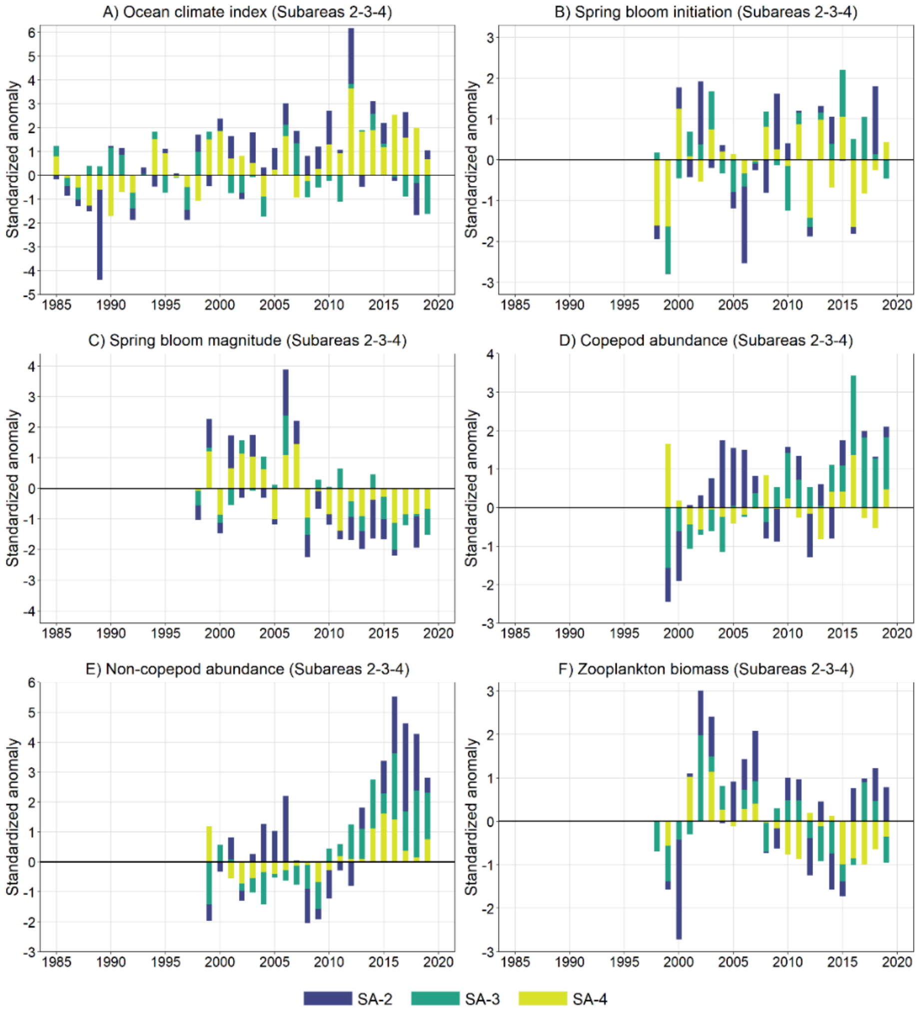


**Figure D1.** Environmental indices for NAFO Sub-areas 2 to 4 during 1990-2019. The ocean climate index (A) is presented as a stack bar plot for Subareas 2, 3 and 4. The standardized anomalies for SA2 are the result of the average of 8 individual time series: Sea surface temperatures (SST) in Divs. 2G, 2H and 2J, bottom temperatures in 2H and 2J in the fall, mean temperature and CIL volumes over the hydrographic section Seal Island and the air temperature in Cartwright (Labrador). For SA3, 16 individual time series are used: SSTs in Divs. 3K, 3L, 3M, 3N, 3O and 3P, vertically average ocean temperature at Station 27 (0-176 m), mean temperature and CIL volumes over hydrographic sections Bonavista and Flemish Cap, mean bottom temperature in 3LNO (spring and fall) and 3M (summer) and air temperature in St. John's and Bonavista (Newfoundland). For SA4, 10 individual time series are used: SSTs in Divs. 4Vn, 4Vs, 4W and 4X, vertically average ocean temperature at Station Prince-5 (0-90 m), surface (0-50 m) and bottom (150 m) temperature at Station Halifax-2, bottom temperature in 4VWX (summer), deep (150-200m) temperatures in the Northeast Channel (NEC) and nea-surface (0-30 m)temperatures in the Gulf of Maine (GoM). Most of these data are presented in Cyr *et al*. (2020), expect temperatures for NEC and GoM that have been obtained from the ICES report on ocean climate (IROC; https://ocean.ices.dk/iroc/). Phytoplankton spring bloom magnitude (B) and duration (C) indices for the 1998-2019 period are derived from 17 satellite Ocean Colour boxes distributed across NAFO subarea 2 (Hudson Strait, Northern Labrador Shelf, Hamilton Bank), 3 (St. Anthony Basin, Northeast Newfoundland Shelf, Avalon Channel, Hibernia, Flemish Pass, Flemish Cap, Southeast Shoal, Green-St. Pierre Bank), and 4 (Northwest Golf of saint Lawrence-GSL, Northeast GSL, Magdalen Shallows, Eastern Scotian Shelf, Central Scotian Shelf, Western Scotian Shelf) (see SCR Doc. 20/035 for box location). Zooplankton abundance (D) and biomass (E) indices for the 1999-2018 period are derived from 18 standard oceanographic cross-shelf sections and five high-frequency coastal sampling stations distributed across NAFO subarea 2 (Beachy Island, Makkovik Bank, Seal Island), 3 (Bonavista Bay, Flemish Cap, Southeastern Grand Banks, Station 27), and 4 (Eastern St. Lawrence, Sept-Îles, Southwest Anticosti, Bonne Bay, Central GSL, Magdalen Islands, Rimouski, Shediac Valley, Cabot Strait, Louisbourg, Halifax, Browns Bank, Halifax-2, Prince-5). Positive/negative anomalies indicate conditions above/below (or late/early initiation) the long-term average for the reference period. All anomalies are mean standardized anomaly calculated with the following reference periods: ocean climate index, 1981-2010; phytoplankton indices (magnitude and peak timing): 1998-2015; zooplankton indices (abundance and biomass): 1999-2015. Anomalies within ±0.5 SD are considered normal conditions.

## 18. Roughhead Grenadier (*Macrourus berglax*) in Subareas 2 and 3

(SCS Doc. 18/05, 18/07, 20/07 and 20/09, and SCR 98/57, 20/02, 20/04, 20/10, 20/11 and 20/14)

Interim Monitoring Report

### a) Introduction

The stock structure of this species in the North Atlantic remains unclear because there is little information on the number of different populations that may exist and the relationships between them. Roughhead grenadier is distributed throughout NAFO Subareas 0 to 3 in depths between 300 and 2 000 m. However, for assessment purposes, NAFO Scientific Council considers the population of 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. To correct the catch statistics STACFIS (NAFO SCR 98/57) revised and approved roughhead grenadier catch statistics since 1987. In the period 2007-2012, catches for Subarea 2+3 roughhead grenadier were stable at levels around one thousand tons. In the period 2013-2019 catches were at a lower level and in the last years were around 400 ton (Figure 18.1). Most of the catches were taken in Divs. 3LMN by Spain, Portugal, Estonia and Russia fleets. In the catch series available, less than 2% of the yearly catch has been taken in Subarea 2. There is no TAC for this stock.

Recent catches ('000 tonnes) are as follow:

| | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **2018** | **2019** |
|---|---|---|---|---|---|---|---|---|---|---|
| **STATLANT 21** | 0.8 | 1.0 | 1.3 | 0.4 | 0.6 | 0.2 | 0.1 | 0.1 | 0.1 | 0.2 |
| **STACFIS** | 0.9 | 1.0 | 1.3 | 0.4 | 0.6 | 0.2 | 0.3 | 0.4 | 0.5 | 0.4 |

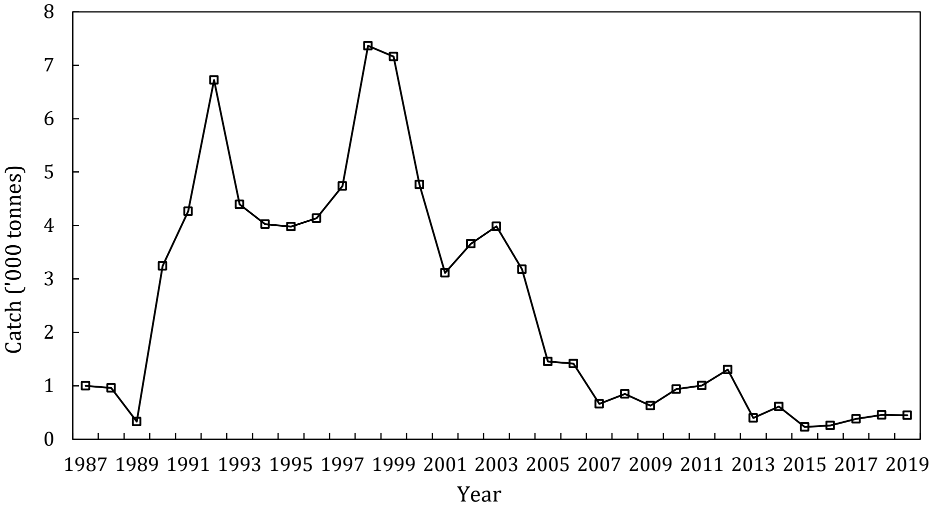


**Figure 18.1.** Roughhead grenadier in Subareas 2+3: STACFIS catches.

### 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 predominately at depths ranging from 800 to 1500 m, therefore the best survey indicators of stock biomass should be the series extending to 1500 meters depth as they cover the depth distribution of roughhead grenadier fairly well. Figure 18.2 presents the biomass indices for the following series: Canadian fall 2J+3K Engel (1978-1994) and Canadian fall 2J+3K Campelen (1995-2019,), EU 3NO (1997-2019), EU 3L (2006-2019) and EU Flemish Cap (to1400 m; 2004-2019). Survey coverage deficiencies within Divs. 2J3K were such that the 2008, 2018 and 2019 index from Canadian fall Divs. 2J3K could not be considered comparable to that of the other years. Survey biomass indices showed a general increasing trend in the period 1995-2004. Although the indices are variable across the past decade, there is a general decreasing trend with the exception of the Canadian 2J3K survey, which has increased.

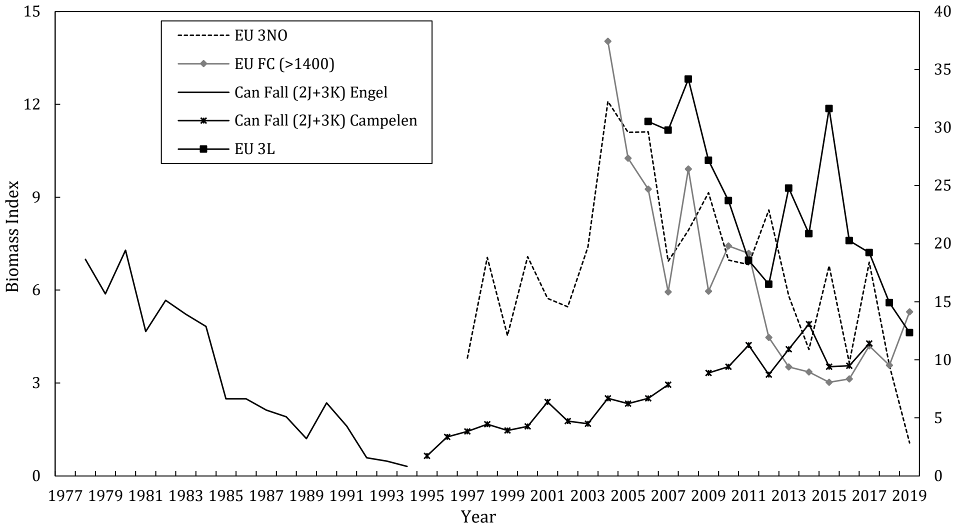


**Figure 18.2.** Roughhead grenadier in Subareas 2+3: Survey biomass indices.

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 of the 3NO survey index in the year 2019 (Figure 18.3) .The (C/B) ratio remained low since 2008 despite the decline of many of the survey biomass indices because catch levels since 2007 are very low.

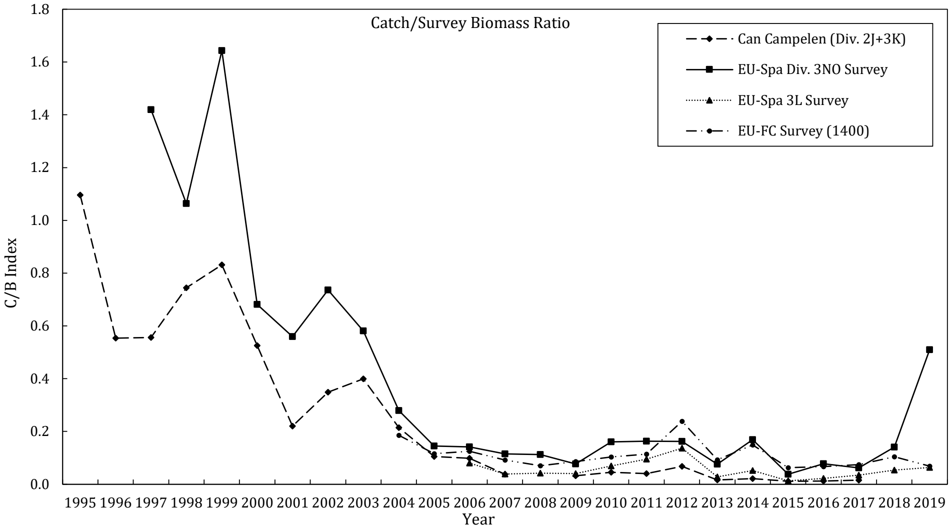


**Figure 18.3**. Roughhead grenadier in Subareas 2+3: catch/biomass indices based upon Canadian Autumn (Campelen series), EU-Spanish Div. 3NO, EU-Spanish 3L and EU-Flemish Cap (to1400 m depth) surveys.

### c) Conclusion

Although the indices are variable across the whole time series, there is a general decrease over the past decade with the exception of the Canadian 2J3K survey, which has increased. Fishing mortality indices have remained at low levels since 2005 with the exception of the of the 3NO survey index in the year 2019. Based on overall indices for the current year, there is no change in the status of the stock.

This stock will be monitored in future by interim monitoring reports until such time conditions change to warrant a full assessment.

## 19. Greenland Halibut (*Reinhardtius hippoglossoides*) in Subarea 2 + Divisions 3KLMNO

(SCR Doc. 12/19, 17/46, 20/30, 20/47, 20/48, 20/49, 20/50; SCS Doc. 18/19; FC Doc. 03/13, 10/12, 13/23, 16/20)

### a) Introduction

#### *i) 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 Div. 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 2019.

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

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| TAC | 17.2[1] | 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] |
| STATLANT 21 | 15.7 | 15.2 | 15.6 | 15.6 | 14.9 | 14.8 | 14.7 | 11.7 | -- | -- |
| STACFIS | 25.0 | 23.0 | 20.0 | 21.4 | 15.3 | 14.9 | 14.8 | 16.6 | 16.5 | -- |

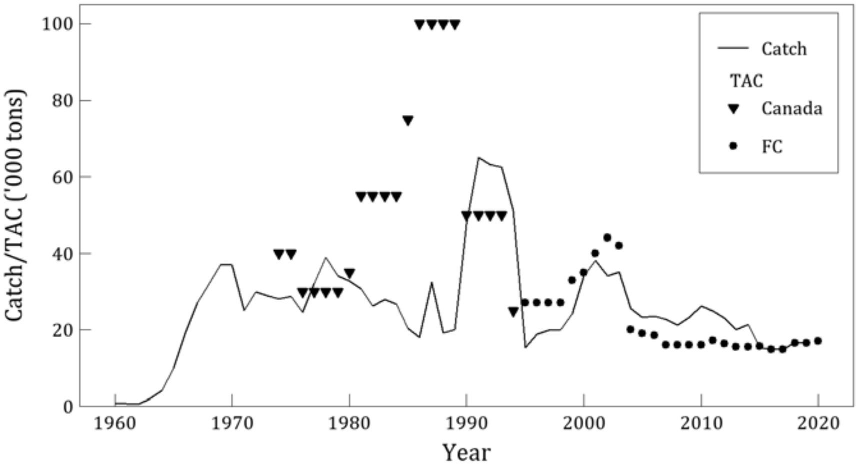


**Figure 19.1.** Greenland halibut in Subarea 2 + Div. 3KLMNO: TACs and STACFIS catches.

### b) Input Data

Abundance and biomass indices were available from research vessel surveys by Canada in Div. 2+3KLMNO (1978-2019), EU in Div. 3M (1988-2019) and EU-Spain in Div. 3NO (1995-2019). Different years are examined to represent population trends from the different surveys. For the Canadian fall survey in Divs. 2J3K the years are 1978-2019 (excluding 2008); from the Canadian spring survey in Divs. 3LNO 1996-2019 (excluding 2006 and 2015, 2017 not included due to survey coverage issues); for the Canadian fall survey to 730 m from 1996-2019 (excluding 2014 when the survey was incomplete); for the survey in Div. 3M to 700 m 1988-2019, and to 1400 m 2004-2019; and for the survey by EU-Spain in Divs. 3NO 1997-2019. Commercial catch-at-age data were available from 1975-2019.

### *i) Commercial fishery data*

**Catch-at-age and mean weights-at-age:** Length samples of the 2019 fishery were provided by EU-Spain, EU-Portugal, EU-Estonia, Russia and Japan. Ageing information was available for the Spanish and Russian fisheries, but commercial aging data from the Canadian fishery were not available in 2019 as the COVID-19 pandemic prevented the completion of otolith reading (SCR Doc. 20/49). Weights were available from EU-Spain, EU-Portugal, and EU-Estonia.

### *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. 12/19). 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 Div. 2J and 3K:** The Canadian autumn Div. 2J3K survey index provides the longest time series of abundance and biomass indices (Figure 19.2) for this resource. Biomass declined from relatively high estimates of the early 1980s to reach an all-time low in 1992. The index increased substantially due to the abundant 1993-1995 year-classes, but this increase was not sustained, with declines over 1999-2002. The index increased substantially from 2010-2014 to levels near those of the early part of the time series. However, the index declined substantially from 2015 to 2017. The abundance index was stable through the 1980s, but increased substantially in the mid-1990s, again due to the presence of the 1993-1995 year-classes. After this, abundance declined to the late 1990s and had been relatively stable except for the decline in 2005. Following improved estimates of abundance in 2010 and 2011, the 2012 to 2019 indices are considerably lower.

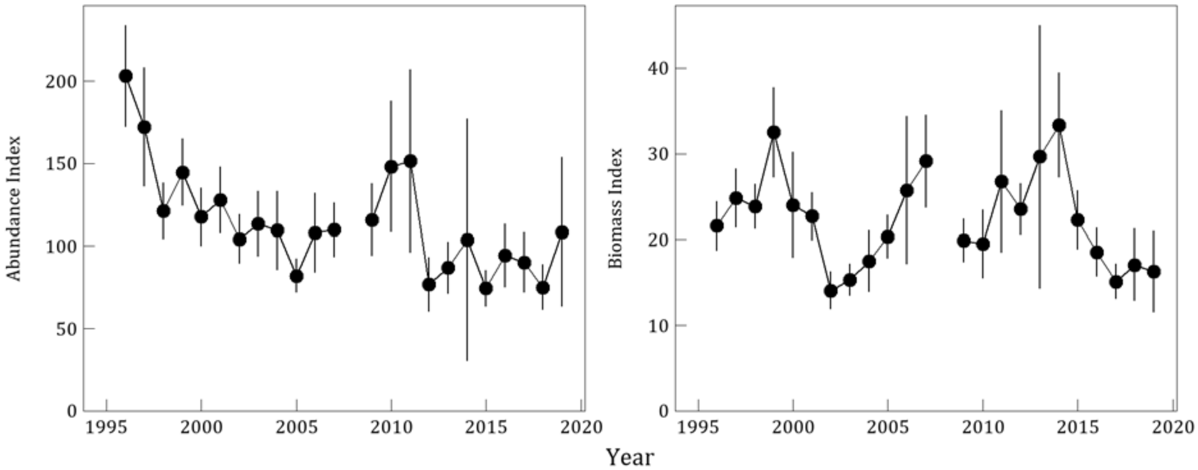


**Figure 19.2.** Greenland halibut in Subarea 2 + Div. 3KLMNO: abundance (left) and biomass (right) indices (with 95% CI) from Canadian autumn surveys in Div. 2J and 3K. The 2008 survey was not completed.

**Canadian stratified-random spring surveys in Div. 3LNO:** Abundance and biomass indices from the Canadian spring surveys in Div. 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.

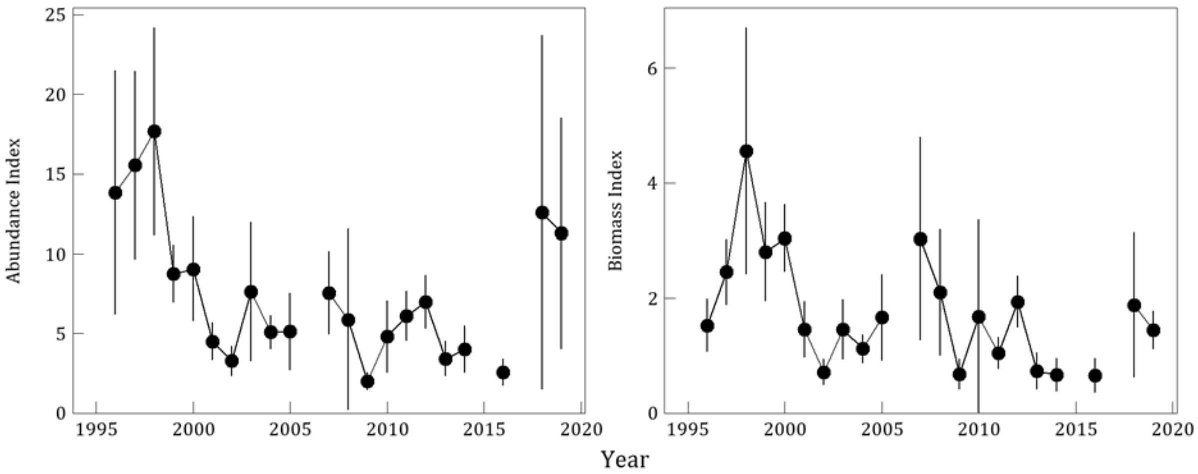


**Figure 19.3.** Greenland halibut in Subarea 2 + Div. 3KLMNO: abundance (left) and biomass (right) indices (with 95% CI) from Canadian spring surveys in Div. 3LNO.

**Canadian stratified-random autumn surveys in Div. 3LNO:** Time series of abundance and biomass were developed from the Canadian autumn surveys from 1995-2019 to a depth of 730 m. The abundance index from the Canadian autumn surveys in Div. 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 2009-2012. The 2014 survey was incomplete and is not considered compatible with the rest of the series.

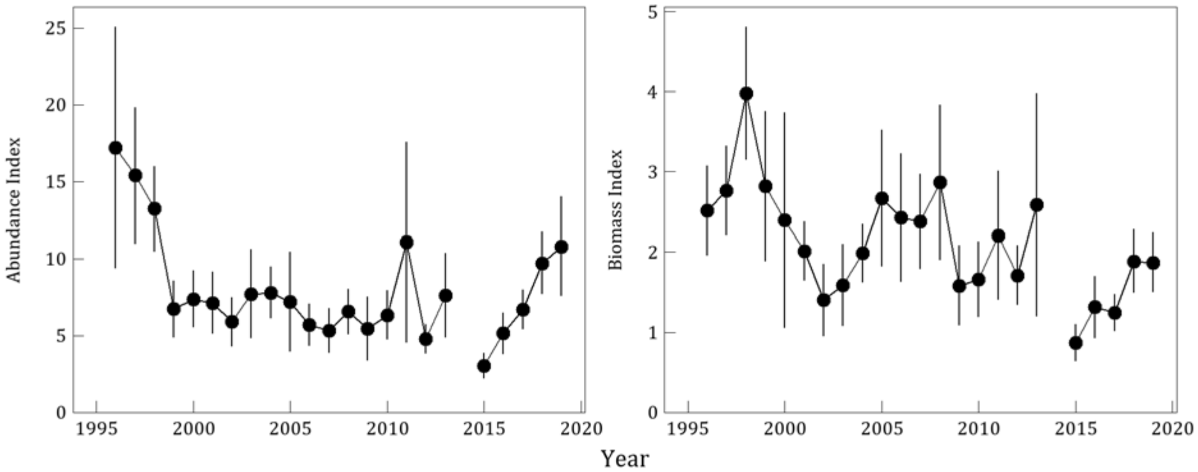


**Figure 19.4.** Greenland halibut in Subarea 2 + Div. 3KLMNO: abundance (left) and biomass (right) indices (with 95% CI) from Canadian autumn surveys in Div. 3LNO.

**EU stratified-random surveys in Div. 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 in the 1988 to 1998 period (Figure 19.5) to a maximum value in 1998. 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 below the time series average in 2019.

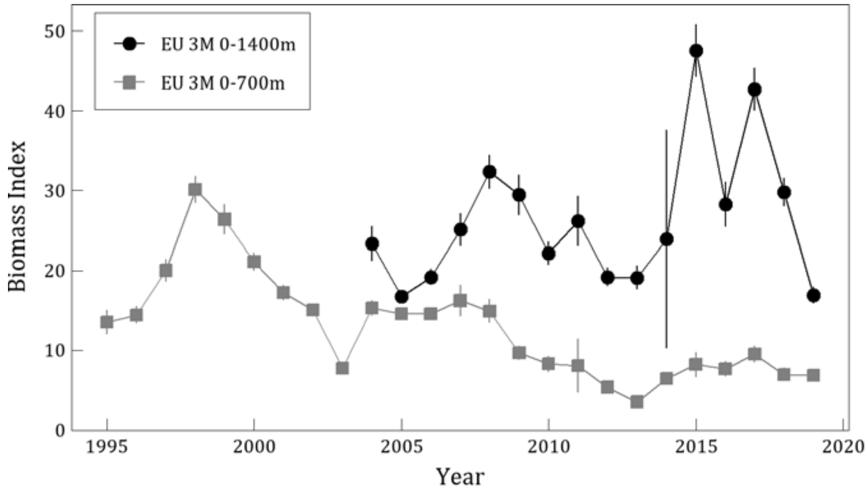


**Figure 19.5.** Greenland halibut in Subarea 2 + Div. 3KLMNO: Biomass index (± 1 S.E.) from EU Flemish Cap surveys in Div. 3M. Grey squares: biomass index for depths <730 m. Black circles: biomass index for all depths <1460 m.

**EU-Spain stratified-random surveys in NAFO Regulatory Area of Div. 3LNO:** The biomass index for the survey of the NRA in Div. 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.

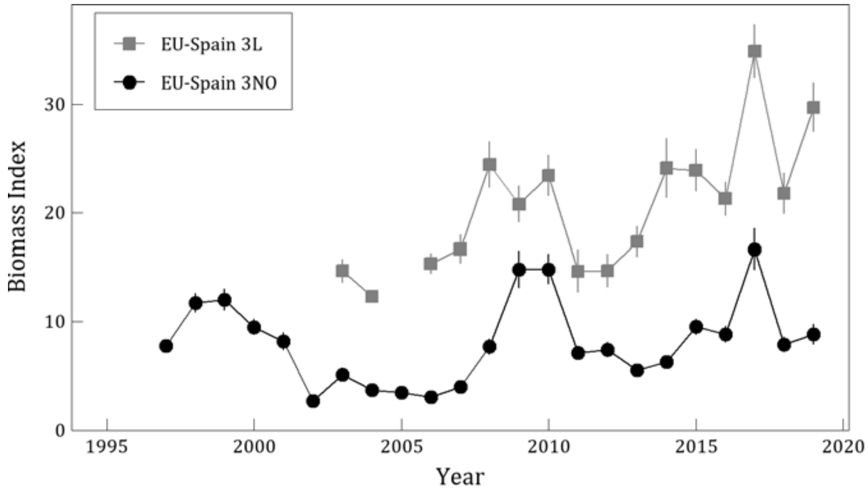


**Figure 19.6.** Greenland halibut in Subarea 2 + Div. 3KLMNO: biomass index (±1 SE) from EU-Spain spring surveys in the NRA of Div. 3NO and Div. 3L.

**Summary of research survey data trends: T**hese 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. Since 2014 there is a clear divergence with the surveys in the NRA (including 3M) having increased to well above their time series averages while the Canadian surveys have been lower than their respective time series average. The overall trend since 2007 is unclear.

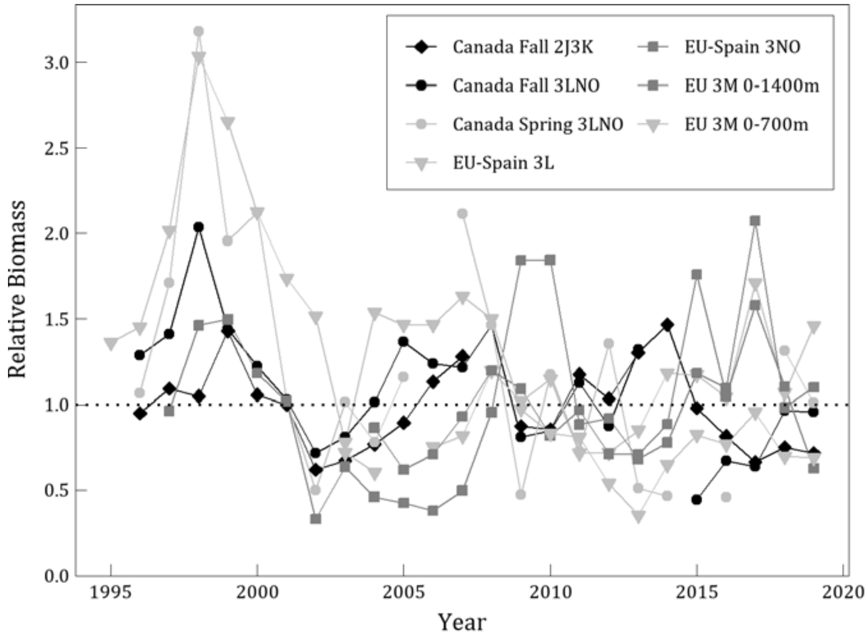


**Figure 19.7.** Greenland halibut in Subarea 2 + Div. 3KLMNO: Relative biomass indices from Canadian autumn surveys in Div. 2J3K, Canadian spring surveys in Div. 3LNO, Canadian autumn surveys in Div. 3LNO, EU survey of Flemish Cap, and EU-Spain surveys of the NRA of Div. 3NO. Each series is scaled to 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. Estimates of the most recent year class are above the time series average in four out of five surveys examined.

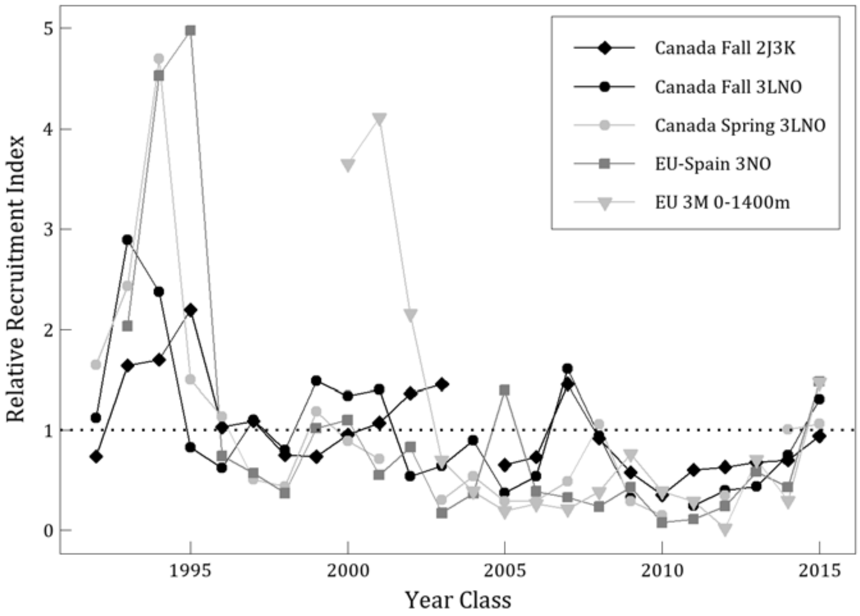


**Figure 19.8.** Greenland halibut in Subarea 2 + Div. 3KLMNO: Relative recruitment indices from Canadian autumn surveys in Div. 2J3K, Canadian spring surveys in Div. 3LNO, and EU survey of Flemish Cap. Each series is scaled to its average and the average line is shown as thin dotted line.

## c) Estimation of Parameters

Two assessment models were developed to support the management strategy evaluation (MSE) conducted in 2017 for the Greenland halibut stock in Subarea 2 + Div. 3KLMNO: 1) a statistical-catch-at-age (SCAA) model, and 2) a state-space model (SSM). For this year's update assessment, three years of data were added to the base case formulations. Both models used the following inputs: catch-at-age from 1975-2019, Canadian fall Div. 2J3K survey numbers at age 1996-2019, Canadian spring Div. 3LNO survey numbers at age 1996-2019, EU Div. 3M survey 0-700 m numbers at age 1995-2003, EU Div. 3M survey 0-1400 m numbers at age 2004-2019, EU-Spain Div. 3NO survey numbers at age 1997-2019, and Canadian fall Div. 3LNO 0-730m survey numbers at age 1996-2019. Due to concerns regarding the validity of recent catch and survey data, several tests were conducted to evaluate the sensitivity of both models to these inputs (SCR Doc. 20/30REV, 20/50). Results were virtually indistinguishable across most sensitivity tests, deviating marginally only when important and likely un-biased survey data were excluded from the SSM. Outputs from base case implementations of these model tests are given below.

### *i) Statistical catch-at-age*

The SCAA methodology is based on standard Baranov numbers-at-age dynamics fitted assuming observation error only in the data and process parameter values which are fixed over time. It is described in Appendix A of SCR Doc. 20/30REV. Key features and settings of the base case formulation include:

- In addition to the inputs specified above the SCAA used total catches over 1960-2019 and total biomass indices from the surveys specified above.
- Stock-recruit function: Beverton-Holt with an input steepness h = 0.8 and log-normal variability with $\sigma_R$ = 0.4.
- Natural mortality: fixed at $M$ = 0.12 for all ages.
- The assessment commences in 1960: initial numbers-at-age is estimated by way of two estimable parameters reflecting a number of recruits informed by a “prior” around the pre-exploitation equilibrium and a negative exponential (constant total mortality) decline.
- Maximum data plus group of 10+ (model plus group is 14+, with aggregation used in fitting to the data).
- Weight-at-age for 10+ applies to all older fish.
- Commercial selectivity-at-age is modelled by double-normal distributions.
- Periods over which the estimated commercial selectivity is unchanged: 1960-1989, 1990-1995, 1996-2003 and 2004+.
- All survey selectivities, apart from the EU 3M survey, are modelled by double normal distributions. For the EU 3M survey, selectivities are estimated separately for ages 1-9 and 4-10 depending on the depth range covered.
- The penalised negative log likelihood minimized in the model fit includes contributions from the survey indices of abundance (taken to be log-normally distributed with the associated variances and catchability coefficients estimated in the fitting process) , the proportion-at-age information (surveys and commercial catches) and annual catches, as well as penalties related to stock-recruitment residuals and the starting recruitment in 1960 (see above).
- The “sqrt(p)” approach is used for the commercial and survey proportions-at-age in the negative log-likelihood.
- The multiplicative weight given to the age-proportion data relative to the survey indices in the negative log-likelihood is $w_{CAA}$ = 0.2.

### *ii) State-space model*

The SSM is a variation of the northern cod assessment model (NCAM) developed by Cadigan (2015) that follows the style of the state-space assessment model (SAM) developed by Nielsen and Berg (2014). The core of this model is similar to other age-structured assessment models since the population dynamics involve a basic cohort model with a plus group and it fits catch using the Baranov catch equation. Key features and settings include:

- Natural mortality fixed at $M$ = 0.12.
- Variation between reported landings and their model predicted values ($\sigma_L$) = 0.1.
- Plus group age = 10.
- Starting year for the survey data = 1995.
- Starting year for the landings data = 1975.
- Zeros in mean catch at age from the survey indices and catch at age from catch statistics are replaced with 0.005 and 0.5, respectively, and these values are treated as an upper limit in the likelihood. This predicates that zero observations are not true zeros, rather they are below the detection limit of the sampling programs.
- Like all state-space models, this model attempts to differentiate process error and observation error.
- Fishing mortality is modelled as an autoregressive process with autocorrelation assumed across both ages and years. In other words, Greenland halibut of similar ages and periods are assumed to experience similar levels of fishing mortality.
- Recruitment is modelled as a random effect as there was no clear sign of a stock-recruitment relationship.
- Catch at age proportions are modelled using continuation ratio logits.

## d) Assessment Results

The primary purpose of the update assessment was to determine whether the stock is deviating from the expected trajectory while being managed using the current HCR. Specifically, SC agreed to conduct the following check to determine if Exceptional Circumstances are occurring:

*"A comparison of assessment model outputs for recruitment, exploitable biomass, and fishing mortality with operating model projections (base case) will also be taken into account qualitatively. Notwithstanding some technical issues regarding the comparison of the simulated distributions against updated assessments, it was agreed that SC will compare the estimated median of the assessment with the 95% Confidence Interval from the base case of SSM and SCAA for the above quantities. Expert judgement will determine whether Exceptional Circumstances are occurring"* (SCS Doc. 18/19).

### ***i) Statistical catch-at-age***

Following the addition of the three more years of data to the base case SCAA model, trends in the stock have hardly changed from those estimated in 2017 (SCR Doc. 20/30REV; Figure 19.9). The most recent estimates of recruitment and exploitable biomass are consistent with predictions from the 2017 MSE process (Figure 19.9). There was a small drop in average $F$ below the 95% probability envelope in the 2017; however, the 2018 and 2019 estimates fall within the 80% envelope.

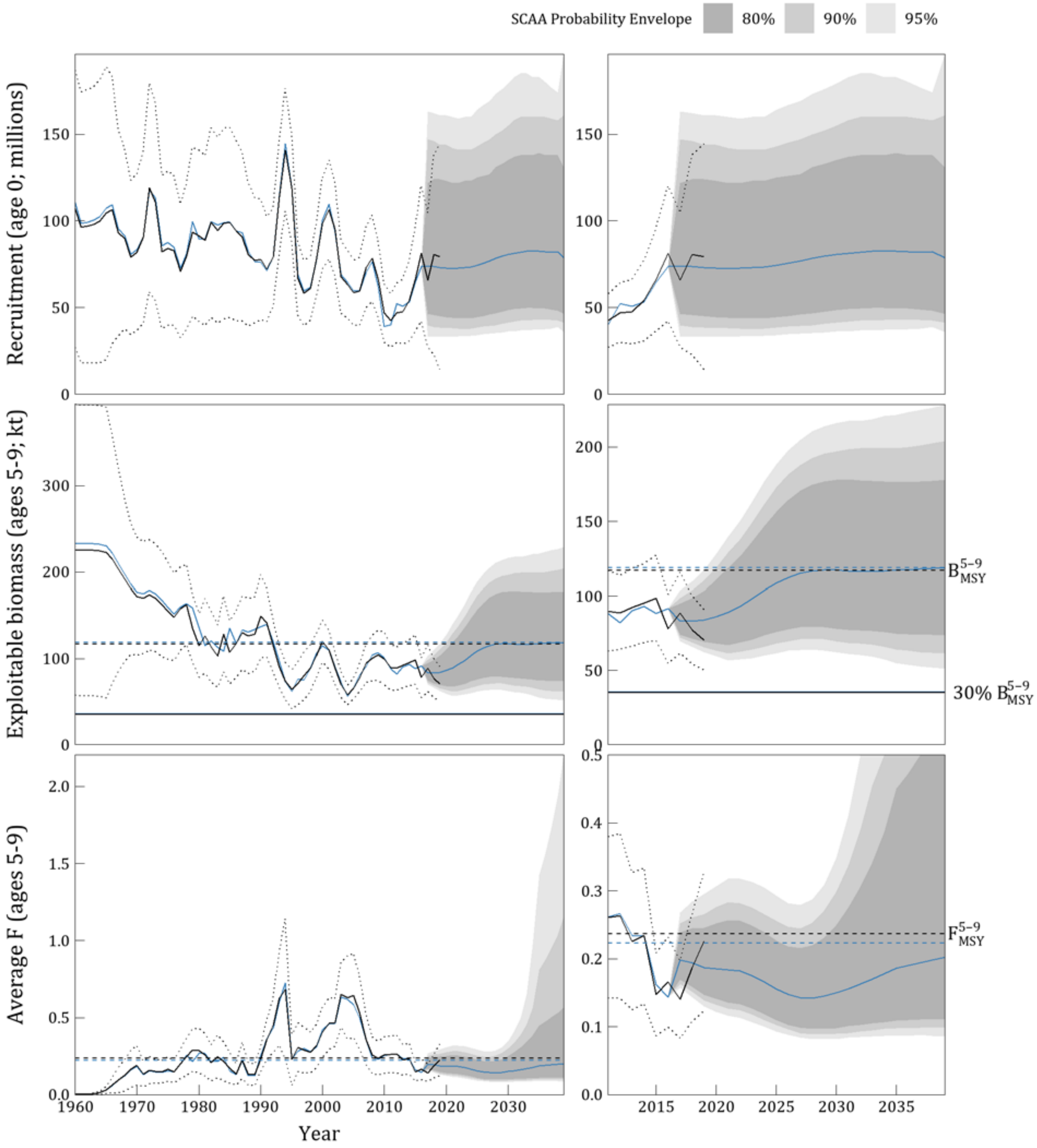


**Figure 19.9.** Greenland Halibut in Subarea 2 + Divisions 3KLMNO. Base case SCAA model: Trends in recruitment (age 0; millions), exploitable biomass (ages 5-9; kt), and average F (ages 5-9). Blue lines represent values from the 2017 MSE with the base case SCAA, whereas black lines indicate values from 2020 update assessment. Shown are: historical (1960-2019) estimates with 95% CIs (thin dotted lines) from the 2020 update assessment, as well as medians and 80%, 90% and 95% probability envelopes (grey shaded areas) projected from the 2017 MSE simulations (with the base case SCAA) under the adopted HCR. Finally, horizontal lines indicate reference points ($B_{MSY}^{5-9}$, 30% $B_{MSY}^{5-9}$, $F_{MSY}^{5-9}$) from both the 2017 MSE base case SCAA (blue) and those calculated from the 2020 update assessment (black).

### *ii) State-space model*

Like the SCAA, a retrospective analysis of the SSM indicates that model estimates are stable in recent years (SCR Doc. 20/50), including those obtained in 2017 when this model was first utilized as part of the MSE process (Figure 19.10). Unfortunately, issues identified with the initial SSM MSE simulations make comparisons with current estimates moot. Following guidance from documents produced during the MSE process, the SSM simulation code was modified in an attempt to generate the intended projection results (SCR Doc. 20/50). Using the revised simulations, it is evident that the accepted management procedure met key performance statistics. Current estimates of recruitment, exploitable biomass, and average $F$ from the base case SSM also fall within the 95% probability envelopes for the revised simulations (Figure 19.10).

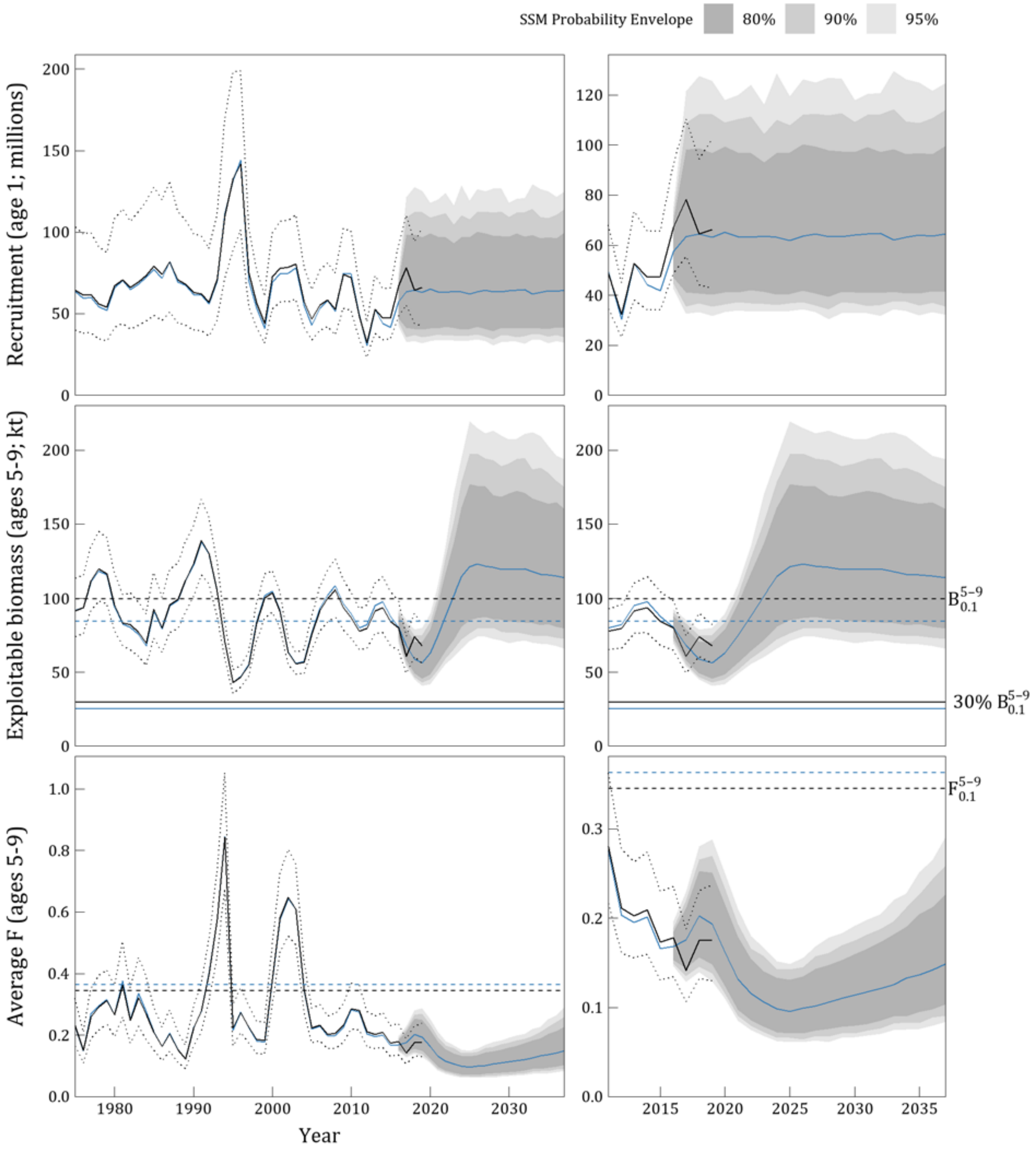


**Figure 19.10.** Greenland Halibut in Subarea 2 + Divisions 3KLMNO. Base case SSM model: Trends in recruitment (age 1; millions), exploitable biomass (ages 5-9; kt), and average F (ages 5-9). Blue lines represent values from the 2017 MSE (reconstituted following correction of errors) with the base case SSM, whereas black lines indicate values from 2020 update assessment. Shown are: historical (1960-2019) estimates with 95% CIs (thin dotted lines) from the 2020 update assessment, as well as medians and 80%, 90% and 95% probability envelopes (grey shaded areas) projected from the 2017 MSE simulations (with the base case SSM) under the adopted HCR. Finally, horizontal lines indicate reference points ($B_{0.1}^{5-9}$, 30% $B_{0.1}^{5-9}$, $F_{0.1}^{5-9}$) from both the preliminary reconstruction of the 2017 MSE base case SSM (blue) and those calculated from the 2020 update assessment (black).

## e) State of the Stock

Recent recruitment has generally increased according to both models (estimates of age 0s have increased since 2010 in the SCAA and age 1s have increased since 2012 in the SSM) and 2019 estimates are near the time series average. Current results from both the SCAA and SSM indicate that there are few signs that the stock is deviating from the expected trajectory while being managed using the current Management Procedure.

As part of the management strategy evaluation process of 2017, reference points were developed using each model to test a series of performance metrics. Though these reference points have been defined, neither have been accepted for use as $B_{lim}$. The SSM reference points, in particular, were not calculated using explicit links between stock size and recruitment and, as such, they should not be used to define the stock size below which productivity is seriously impaired. Reference points that follow definitions under NAFOs Precautionary Approach Framework require further research and review.

## f) Reference points

### *i) Statistical catch-at-age*

MSY reference points were calculated using a Beverton Holt stock recruit relationship. Reference points were estimated using data up to 2016, as part of the 2017 MSE process, and these values were updated using data up to 2019 for the update assessment of 2020. Commercial selectivity equal to the selectivity in the last commercial selectivity period for the SCAA and weight-at-age was taken as the average over the last 10 years. The maximum penalized likelihood estimates for the parameters of the stock-recruitment relationship and for selectivities were used for this evaluation. CVs for MSY and $B_{MSY}^{5-9}$ were found from the Hessian associated with the assessment. Note that these are conditional on the calculated value of $F_{MSY}^{5-9}$. For full details see SCR 17/46. The following reference points were determined using the SCAA:

| | $F_{MSY}^{5-9}$ | $B_{MSY}^{5-9}$ |
|---|---|---|
| 2017 | 0.223 | 119 kt |
| 2020 | 0.237 | 117 kt |

The 2017 values were used to evaluate several performance criteria during the 2017 MSE process.

### *ii) State-space model*

Exploratory analyses and initial modelling of the dynamics of the Greenland halibut stock from NAFO Subarea 2 and Divisions 3KLMNO showed little sign of a stock-recruitment relationship. Recruitment was therefore treated as a random effect in the SSM. This formulation, however, precluded the standard analytical approach to calculating $F_{MSY}$ from stock-recruitment curves. Yield per recruit analyses were used to determine $F_{max}^{5-9}$ and $F_{0.1}^{5-9}$: the whole time series averages of recruitment, 10 year averages of weight at age and three year averages of selectivity at age were used in the analyses. These were used to project the population out 100 years to obtain deterministic estimates of $F_{max}^{5-9}$ and $F_{0.1}^{5-9}$. An optimization function was used to profile across a range of $F^{5-9}$ values to find the point at which the yield is maximized. For full details see SCR 20/48. The following provisional reference points were determined using the SSM:

| | $F_{0.1}^{5-9}$ | $B_{0.1}^{5-9}$ |
|---|---|---|
| 2017 | 0.363 | 84 kt |
| 2020 | 0.345 | 100 kt |

The 2017 values were used as proxies for $B_{MSY}^{5-9}$ and $F_{MSY}^{5-9}$ to evaluate several preformance criteria using the revised SSM MSE simulations (SCR 20/47).

### g) 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.*

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.

### h) References

Cadigan, N. G. (2015). A state-space stock assessment model for northern cod, including under-reported catches and variable natural mortality rates. *Canadian Journal of Fisheries and Aquatic Sciences*, *73*(2), 296–308.

Nielsen, A., and Berg, C. W. (2014). Estimation of time-varying selectivity in stock assessments using state-space models. *Fisheries Research*, *158*, 96–101.

## 20. Splendid alfonsino (*Beryx splendens*) in Subareas 6

(SCR 15/06 and SCS Doc. 19/20 and 20/07 and NAFO/COM Doc. 20/01)

Interim Monitoring Report

### 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.

### *i) 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.

### *ii) 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 present, 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.

Recent catches (tonnes), effort and CPUE (Kg/hr fished) for the alfonsino fishery on Kukenthal Peak.

| Year | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Catch (t)** | 52 | 152 | 302 | 114 | 118 | 122 | 127 | 51 | 2 | 1 |
| **Effort (days)** | 4 | 9 | 22 | 17 | 15 | 13 | 16 | 12 | 8 | 8 |
| **Effort (hours fished)** | 66 | 68 | 165 | 87 | 117 | 92 | 116 | 68 | 33 | 33 |
| **CPUE (Kg/hour)** | 788 | 2235 | 1830 | 1310 | 1009 | 1326 | 1095 | 750 | 61 | 42 |
| **Effort (vessels)** | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 |

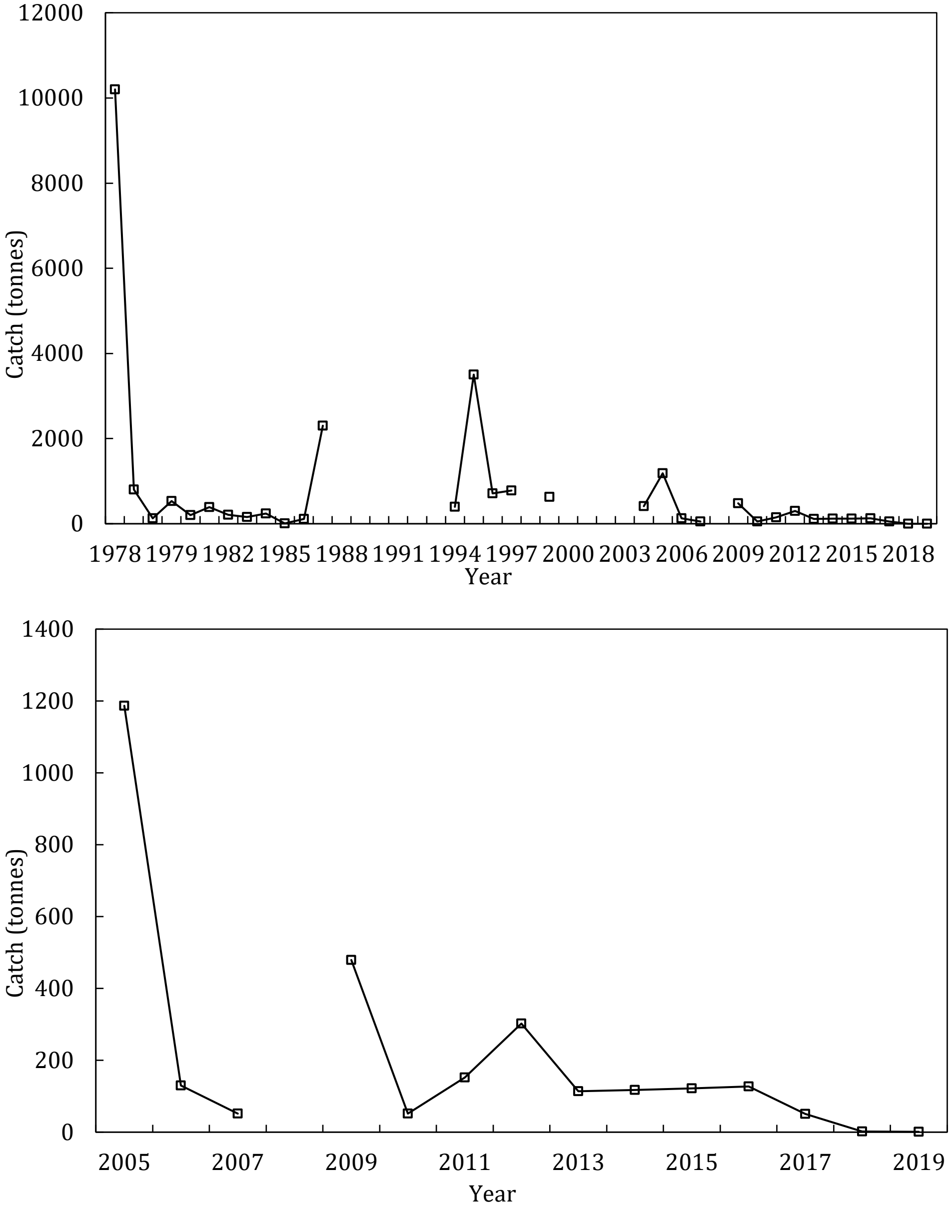


**Figure 20.1.** Alfonsino catches from Div. 6G. Top panel illustrates the whole catch series (1978-2019) and bottom panel illustrates the catch series since 2005.

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.

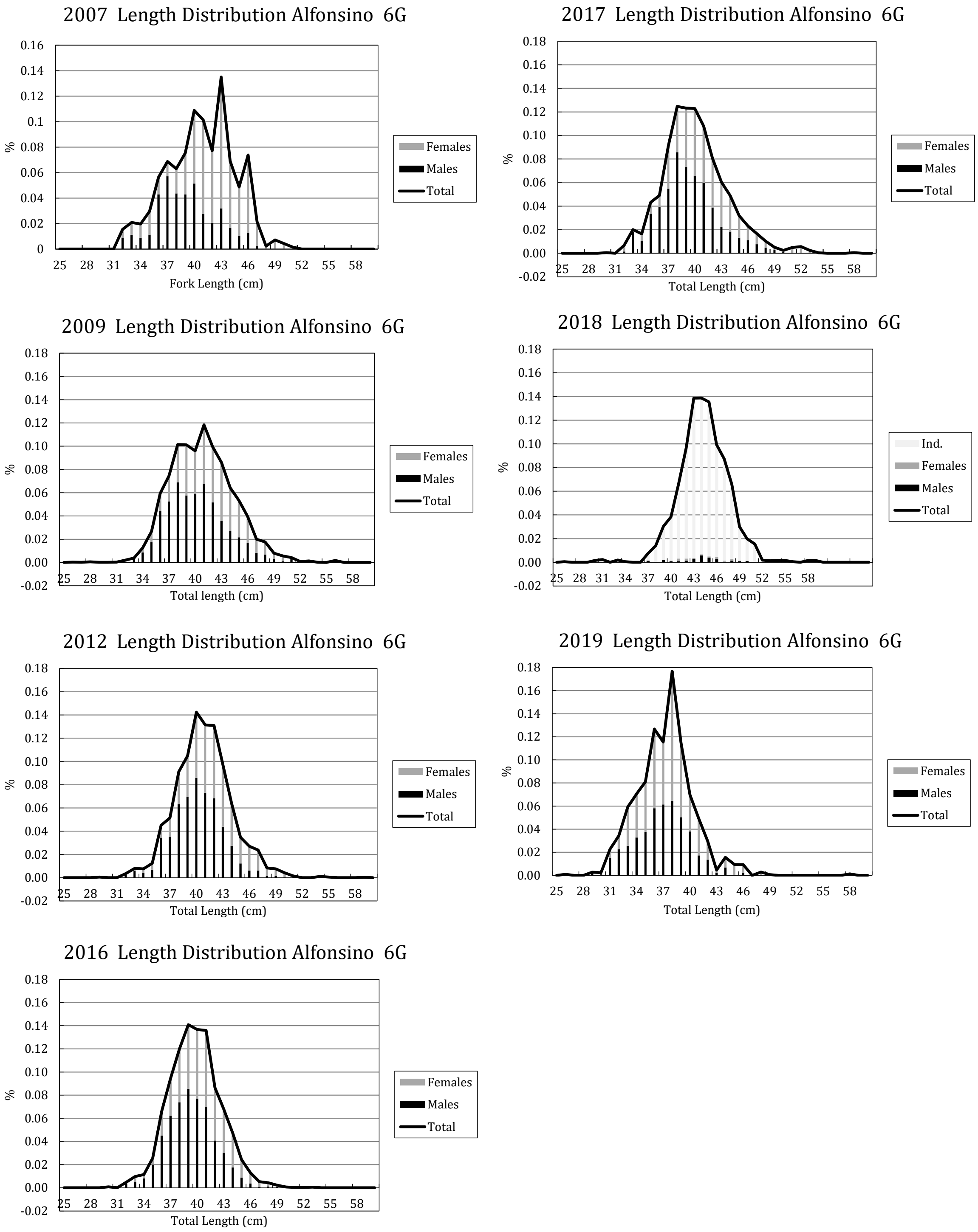


**Figure 20.2.** Length distributions of alfonsino catches from Div. 6G.

## b) Data Overview

### *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.

## c) Conclusion

No analytical or survey based assessment were possible. The most recent assessment, in 2019, concluded that the stock appears to be depleted. Overall, the 2019 information are not considered to indicate a significant change in the status of the stock.

The next full assessment of this stock will occur in 2021.

## d) 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.

## e) Research Recommendations

SC **recommended** in 2019 that *fishery independent information should be collected on this stock, and especially important given 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, a possible acoustic survey plan has been presented to be discussed by the SC.

## 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 2020. 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 12 June 2020

## APPENDIX V. AGENDA - SCIENTIFIC COUNCIL MEETING, 28 MAY-12 JUNE 2020

### (By correspondence)

***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 2019

III. Fisheries Environment (STACFEN Chair: Miguel Caetano)
  1. Opening
  2. Appointment of Rapporteur
  3. Adoption of Agenda
  4. Review of Recommendations in 2019
  5. Department of Fisheries and Oceans Canada, Oceans Science Branch, Marine Environmental Data Section (MEDS) Report for 2019
  6. Review of the physical, biological and chemical environment in the NAFO Convention Area during 2019
  7. Interdisciplinary studies
  8. Formulation of recommendations based on environmental conditions during 2019
  9. Other Matters
  10. Adjournment

IV. Publications (STACPUB Chair: Margaret Treble)
  1. Opening
  2. Appointment of Rapporteur
  3. Adoption of Agenda
  4. Review of Recommendations in 2019
  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
  3. Appointment of Rapporteur
  4. Review of Recommendations in 2019
  5. Fishery Statistics
    a) Progress report on Secretariat activities in 2019/2020
      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 2019/2020
      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 2019 and early 2020 (by National Representatives and Designated Experts)
      ii) Surveys planned for 2020 and early 2021
    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) NAFO Catch Estimates Methodology Study
  9. Adjournment

VI. Fisheries Science (STACFIS Chair: Katherine Sosebee)
  1. Opening
  2. General Review of Catches and Fishing Activity
  3. Stock Assessments
    1. Greenland halibut (*Reinhardtius hippoglossoides*) in SA 0, Div. 1A offshore and Div. 1B-F (full assessment)
    2. Greenland halibut (*Reinhardtius hippoglossoides*) Div. 1A inshore (full assessment)
    3. Demersal Redfish (*Sebastes* spp.) in SA 1 (full assessment)
    4. Demersal deep-sea redfish (*Sebastes* spp.) in SA 1 (full assessment)
    5. Wolffish in Subarea 1 (full assessment)
    6. Cod (*Gadus morhua*) in Div. 3M (full assessment)
    7. Redfish (*Sebastes mentella* and *Sebastes fasciatus*) in Div. 3M (Monitor)
    8. American plaice (*Hippoglossoides platessoides*) in Div. 3M (Full assessment)
    9. Cod (*Gadus morhua*) in NAFO Div. 3NO (Monitor)
    10. Redfish (*Sebastes mentella* and *Sebastes fasciatus*) in Divs. 3L and 3N (Update assessment: Comm request #11)
    11. Golden redfish (Sebastes norvegicus) in Div. 3M (Monitor)
    12. American plaice (*Hippoglossoides platessoides*) in Div. 3LNO (monitor)
    13. Yellowtail flounder (*Limanda ferruginea*) in Div. 3LNO (monitor)
    14. Witch flounder (*Glyptocephalus cynoglossus*) in Div. 3NO (Full assessment)

15. Capelin (*Mallotus villosus*) in Div. 3NO (monitor)
16. Redfish (*Sebastes mentella* and *Sebastes fasciatus*) in Div. 3O (monitor)
17. Thorny skate (*Amblyraja radiata*) in Div. 3LNO and Subdiv. 3PS (full assessment)
18. White hake (*Urophycis tenuis*) in Div. 3NO and Subdiv. 3PS (monitor)
19. Roughhead grenadier (*Macrourus berglax*) in Subareas 2 and 3 (monitor)
20. Greenland halibut (*Reinhardtius hippoglossoides*) in SA 2 + Div. 3KLMNO (under management strategy: Update assessment, COM request #2)
21. Northern shortfin squid (*Illex illecebrosus*) in Subareas 3+4 (monitor, deferred to September)
22. Splendid alfonsino (*Beryx splendens*) in SA 6

4. Other Matters
   a) FIRMS Classification for NAFO Stocks (Note: expected to be deferred to September)
   b) Other Business
5. Adjournment

VII. Management Advice and Responses to Special Requests (See Annex 1)

SC has agreed a priority order for the requests, with the following meaning (where September refers to a potential SC meeting taking place around September 14-18):

| **Priority level** | **Schedule for SC addressing the request** |
|---|---|
| 1 | June, as top priority |
| 2 | June, as next level of priority |
| 3 | Preferably June, but could be delayed to September if no time in June |
| 4 | September (unless progress in June was unexpectedly fast) |
| 5 | Flexible (June, September, or June 2021) |

1. NAFO Commission (Annex 1)
    a) Request for Advice on TACs and Other Management Measures (request #1, Annex 1) [note: Priority level 1 for all of them]

        For 2021
        - Cod in Div. 3M

        For 2021 and 2022
        -Thorny Skate in 3LNO
        - Witch flounder in Div. 3NO [note: SC will do this of its own accord, because of practical working arrangements in connection with change of Designated Expert]

        For 2021, 2022 and 2023
        - American Plaice in 3M

    b) Monitoring of Stocks for which Multi-year Advice was provided in 2018 or 2019 (request #1) [note: Priority level 1 for all of them, except squid]
        - Redfish in Div. 3M
        - Golden redfish in Div. 3M
        - Cod (*Gadus morhua*) in NAFO Div. 3NO
        - Yellowtail flounder in Divs. 3LNO
        - American Plaice in Divs. 3LNO
        - Capelin in Divs. 3NO
        - Alfonsino stocks in the NAFO Regulatory Area
        - Roughhead grenadier in Subareas 2 and 3
        - White hake (*Urophycis tenuis*) in Div. 3NO and Subdiv. 3PS
        - Northern shortfin squid (*Illex illecebrosus*) in Subareas 3+4 [note: to be done in September]

    c) Special Requests for Management Advice
        i) Greenland halibut in SA2 + Divs. 3KLMNO: conduct an update assessment, compute the TAC using the agreed HCR and determine whether exceptional circumstances are occurring (request #2) [note: Priority level 1]

        ii) continue the evaluation of scientific trawl surveys in VME closed areas (request #3) [note: Priority level 5]

        iii) identify discard species/stocks with high survivability rates (request #4) [note: Priority level 3]

- iv) continue to refine work under the ecosystem approach (request #5) [note: Priority level 1]
- v) assessment of NAFO bottom fisheries in 2021 (request #6) [note: Priority level 2]
- vi) re-assessment of VME closures (request #7) [note: Priority level 1]
- vii) continue progress on the NAFO PA Framework review (request #8) [note: Priority level 1]
- viii) identify areas and times where bycatch and discards of Greenland sharks have a higher rate of occurrence (request #9) [note: Priority level 3]
- ix) develop a 3-5 year work plan (request #10) [note: Priority level 4]
- x) update assessment and projections for 3LN redfish (request #11) [note: Priority level 1]
- xi) ecosystem summary sheet for 3LNO (request #12) [note: Priority level 1]
- xii) review submitted protocols for a survey methodology to inform the assessment of splendid alfonsino (request #13) [note: Priority level 3]
- xii) 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) [note: Priority level 2 (cod and witch) and 4 (redfish)]
- xiii) provide updates on relevant research related to the potential impact of activities other than fishing in the Convention Area (request #16) [note: Priority level 3]
- xiv) measures to improve the productivity of 3M Cod (request #17) [note: Priority level 2]
- xv) information on sea turtles, sea birds, and marine mammals that are present in NAFO Regulatory Area (request #18) [note: Priority level 2 (initial discussion and guidance) and 4 (finalize)]

2. Coastal States
   - a) Request by Denmark (Greenland) for Advice on Management in 2021 (Annex 2)
     - i) Golden redfish, demersal deep-sea redfish, Atlantic wolffish and spotted wolffish (Item 1) [note: Priority level 1]
     - ii) Greenland halibut, inshore, Northwest Greenland (Item 3) [note: Priority level 1]
   - b) Request by Canada and Denmark (Greenland) for Advice on Management in 2021 (Annex 2, Annex 3)
     - i) Greenland halibut in Div. 0A and the offshore area of Div. 1A, plus Div. 1B-F (Annex 2, Item 2; Annex 3, Item 1) [note: Priority level 1]

VIII. Review of Future Meetings Arrangements

1. Scientific Council, 1 day around 10–14 September, by WebEx, advice on 3M shrimp
2. Scientific Council, 21 – 25 Sep. 2020 (potentially extending to dates around 14–18 Sep.)
3. Scientific Council (in conjunction with NIPAG), 27 Oct.–02 Nov. 2020
4. Scientific Council, June 2021
5. Scientific Council, Sep. 2021
6. Scientific Council (in conjunction with NIPAG), 2021
7. WG-ESA, Nov. 2020
8. NAFO/ICES Joint Groups
   - a) NIPAG, 2020
   - b) NIPAG, 2021

  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
  1. Working Group on Ecosystem Science and Assessment (WG-ESA), Nov. 2019
  2. Report from ICES-NAFO Working Group on Deepwater Ecosystems (WG-DEC), 2019
  3. Report from ICES/NAFO/NAMMCO Working Group on Harp and Hooded Seals (WGHARP), 2019
  4. Report from Joint COM-SC Working Group on Catch Estimation Strategy Advisory Group (CESAG), March and April 2020
  5. Meetings attended by the Secretariat

XI. Review of Scientific Council Working Procedures/Protocol
  1. General Plan of Work for September 2020 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. Budget items
  3. 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

## ANNEX 1. THE COMMISSION'S REQUEST FOR SCIENTIFIC ADVICE ON MANAGEMENT IN 2021 AND BEYOND OF CERTAIN STOCKS IN SUBAREAS 2, 3 AND 4 AND OTHER MATTERS

(SCS Doc. 20/01)

Following a request from the Scientific Council, the Commission agreed that items 1, 2, 7, 8 and 11 should be the priority for the June 2020 Scientific Council meeting.

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 (rather than a single TAC recommendation) and the actual risk level should be decided upon by managers.

| Yearly basis | Two-year basis | Three-year basis |
|---|---|---|
| Cod in Div. 3M<br>Northern shrimp in Div. 3M | Redfish in Div. 3M<br>Northern shrimp in Div. 3LNO<br>Thorny skate in Div. 3LNO<br>Witch flounder in Div. 3NO<br>Redfish in Div. 3LN<br>White Hake in Div. 3NO | American Plaice in Div. 3LNO<br>American Plaice in Div. 3M<br>Capelin in Div. 3NO<br>Northern shortfin squid in SA 3+4<br>Redfish in Div. 3O<br>Yellowtail flounder in Div. 3LNO<br>Greenland halibut in Div. 2+3KLMNO<br>Cod in Div. 3NO<br>Splendid alfonsino in SA 6 |

To implement this schedule of assessments, the Scientific Council is requested to conduct a full assessment of these stocks as follows:

In 2020, advice should be provided for 2021 for Cod in 3M and Northern shrimp in 3M. With respect to Northern shrimp in 3M, SC is requested to provide its advice to the Commission prior to the 2020 Annual Meeting.

In 2020, advice should be provided for 2021 and 2022 for: Thorny Skate in 3LNO,

In 2020, advice should be provided for 2021, 2022 and 2023 for: American Plaice in 3M,

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 conduct an update assessment of Greenland halibut in Subarea 2+Div. 3KLMNO and 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 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 SC 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), giving priority in 2020 to the identification of discard species/ stocks listed in Annex I.A. and Annex I.B of the NCEM with high survivability rates.

5. The Commission requests the Scientific Council to continue to refine its work under the Ecosystem Approach and report on these results to both the WGEAFFM and WGRBMS.

6. In relation to the assessment of NAFO bottom fisheries in 2021, the Scientific Council should:

   - Assess the overlap of NAFO fisheries with VME to evaluate fishery specific impacts in addition to the cumulative impacts;
   - 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 (Article 18 of the FAO International Guidelines for the Management of Deep Sea Fisheries in the High Seas) including the three FAO functional SAI criteria which could not be evaluated in the current assessment (recovery potential, ecosystem function alteration, and impact relative to habitat use duration of VME indicator species).
   - Continue to work on non-sponge and coral VMEs (for example bryozoan and sea squirts) to prepare for the next assessment.

7. The Commission requests Scientific Council to conduct a re-assessment of VME closures by 2020, including area #14.

8. The Commission requests the Scientific Council to continue progression on the review of the NAFO PA Framework.

9. The Commission requests Scientific Council continue to work with WG- BDS and the Secretariat to identify areas and times where bycatch and discards of Greenland sharks have a higher rate of occurrence. This work will support WG-BDS in developing appropriate management recommendations, including safe handling practices for live release of Greenland sharks, for consideration by the Commission at its 2021 Annual Meeting.

10. The Commission requests Scientific Council to continue to develop a 3-5 year work plan, which reflects requests arising from the 2019 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 Scientific Council do an update assessment for 3LN redfish and five year projections (2021 to 2025) to evaluate the impact of annual removals at 18 100 tonnes against the performance statistics from NCEM Annex I.H: If this level of catch does not result in fulfilling these performance statistics, SC should advise the level of catch that would.

12. The Commission request that the Scientific Council present the Ecosystem Summary Sheet for 3LNO for presentation to the Commission at the 2020 Annual Meeting.

13. The Commission request 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.

14. The COM request that the results 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) 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.

15. The Commission to ask the Scientific Council to advise on the possible sustainable management methods for northern shrimp in Div. 3M, including quota, fishing effort, periods, reporting or other technical measures. This advice should be provided before the intersessional work by the end of this year.

16. The Commission requests 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 (for example via EU ATLAS project), and where possible to consider these results in the on-going modular approach concerning the development of Ecosystem Summary Sheets.

17. The Commission requests the Scientific Council to provide advice on gear, including sorting grids, area and time-based measures that can be used to protect and improve the productivity of the 3M Cod stock.

18. 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.

## ANNEX A: Guidance for providing advice on Stocks Assessed with an Analytical Model

The Commission request 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:

1. 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% $F_{msy}$, 75% $F_{2019}$, $F_{2019}$, 125% $F_{2019}$,
    - For stocks under a moratorium to direct fishing: $F_{2019}$, 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(B2022 > B2018) |
| F in 2019 and following years* | Yield 2020 (50%) | Yield 2021 (50%) | Yield 2022 (50%) | 2020 | 2021 | 2022 | 2020 | 2021 | 2022 | | 2020 | 2021 | 2022 | 2020 | 2021 | 2022 | | |
| 2/3 $F_{msy}$ | t | t | t | % | % | % | % | % | % | | % | % | % | % | % | % | | % |
| 3/4 $F_{msy}$ | t | t | t | % | % | % | % | % | % | | % | % | % | % | % | % | | % |
| 85% $F_{msy}$ | t | t | t | % | % | % | % | % | % | | % | % | % | % | % | % | | % |
| $F_{msy}$ | t | t | t | % | % | % | % | % | % | | % | % | % | % | % | % | | % |
| 0.75 X $F_{2018}$ | t | t | t | % | % | % | % | % | % | | % | % | % | % | % | % | | % |
| $F_{2018}$ | t | t | t | % | % | % | % | % | % | | % | % | % | % | % | % | | % |
| 1.25 X $F_{2018}$ | t | t | t | % | % | % | % | % | % | | % | % | % | % | % | % | | % |
| F=0 | t | t | t | % | % | % | % | % | % | | % | % | % | % | % | % | | % |

2. 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% $F_{2019}$, $F_{2019}$, 125% $F_{2019}$,
   - For stocks under a moratorium to direct fishing: $F_{2019}$, 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(B2022 > B2018) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F in 2019 and following years* | Yield 2020 | Yield 2021 | Yield 2022 | 2020 | 2021 | 2022 | 2020 | 2021 | 2022 | | 2020 | 2021 | 2022 | 2020 | 2021 | 2022 | | |
| 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.

## ANNEX 2: DENMARK (ON BEHALF OF GREENLAND) COASTAL STATE REQUEST FOR SCIENTIFIC ADVICE - 2021

(SCS Doc. 20/03)

Denmark (on behalf of Greenland) requests scientific advice on management in 2020 of Certain Stocks in NAFO Subarea O 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 2017 given for 2018-2020. Denmark (on behalf of Greenland) requests the Scientific Council to provide advice on appropriate TAC levels for 2021 to 2023.
2. **Greenland Halibut, offshore:** For Greenland Halibut in subareas O + 1 advice was in 2018 given for 2019 and 2020. Subject to the concurrence of Canada as regards Subareas O and 1, the Scientific Council is requested to provide advice on appropriate TAC levels for 2021 to 2022. in 1) the offshore areas of NAFO Division OA and Division 1 A plus Division 1 B and 2) NAFO Division OB plus Divisions 1C-1F. The Scientific Council is also asked to advice on any other management measures it deems appropriate to ensure the sustainability of these resources. The Scientific Council is requested to consider the possibility for providing a separate advice for 1 B-1 F inshore.
3. **Greenland Halibut, inshore, Northwest Greenland:** Advice on Greenland Halibut in Division 1 A inshore was in 2018 given for 2019-2020. Denmark ( on behalf of Greenland) requests the Scientific Council to provide advice on appropriate TAC levels for 2021 to 2022.
4. **Northern Shrimp, West Greenland:** Subject to the concurrence of Canada as regards Subarea O and 1, Denmark (on behalf of Greenland) requests the Scientific Council before December 2020 to provide advice on the scientific basis for management of Northern Shrimp (Panda/us borea/is) in Subarea O and 1 in 2021 and for as many years ahead as data allows for.
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 (Panda/us borea/is) in Denmark Strait and adjacent waters east of southern Greenland in 2021 and for as many years ahead as data allows for

# ANNEX 3. CANADA'S REQUEST FOR COASTAL STATE ADVICE - 2021

(SCS Doc. 20/02)

**1.** Greenland halibut (Subarea 0 + 1A (offshore) and 1B-F)
The Scientific Council is requested to provide an overall assessment of status and trends in the total stock area throughout its range and to specifically advise on TAC levels for 2021 and 2022[3]. The stock status should be evaluated in the context of management requirements for long-term sustainability and the advice provided should be consistent with NAFO's Precautionary Approach Framework.

Canada again encourages the Scientific Council to continue exploring opportunities to develop risk-based advice, including the implications of catch differing from the TAC (e.g. +/- 5-15%) on the stock's long-term trajectory.

**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 5,000-10,000t increments (subject to the discretion of Scientific Council), with forecasts for 2021-2025, if possible. 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 2021 to 2025 if possible. 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).

---

[3] 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.

## APPENDIX VI: PROVISIONAL TIMETABLE - SCIENTIFIC COUNCIL MEETING, 28 MAY-12 JUNE 2020

## (By correspondence)

***The meeting will be held from Monday to Friday. Weekends will not be working days.***

***All times below correspond to Halifax times***

***Every day the WebEx connection will be open at 07:30 hours***
***for participants to join and test connection and sound in advance of an 08:00 hours start***

***15-minute breaks will be included at approximately 2-hour intervals***

| **Date** | **Time** | **Provisional schedule of plenary sessions (by WebEx)** |
|---|---|---|
| **28 May** (Thursday) | 0800-0815 | SC Opening |
| | 0815-0930 | STACFEN presentation of key information for SC + discussion |
| | 0930-1030 | SC + STACFIS: round the table of status of work and available documents for each stock assessment and all other requests |
| | 1030-1045 | Break |
| | 1045-1200 | SC: WG-ESA presentation of Request #7 + discussion |
| **29 May** (Friday) | 0800-1000 | SC: WG-ESA continue Request #7 + Request #6 (if time permits) |
| | 1000-1015 | Break |
| | 1015-1200 | STACFIS (start presentation of stock assessments) |
| **01 June** (Monday) | 0800-1200 | SC: Request #2 (GHL) |
| | | STACFIS |
| **02 June** (Tuesday) | 0800-1200 | SC: Requests #8, 5, 12 |
| | | STACFIS |
| **03 June** (Wednesday) | 0800-1200 | STACFIS |
| **04 June** (Thursday) | 0800-1200 | SC: Finalize Requests #7 and #6 |
| | | SC: Requests as needed (#2 GHL?, #11, #17, #4?, #9?, #13?) |
| **05 June** (Friday) | 0800-1200 | STACFIS |
| **08 June** (Monday) | 0800-1200 | STACFIS (if needed) |
| | | SC: Requests #18 (initial discussion/guidance), #14 (cod and witch) |
| | | SC: Requests as needed |
| **09 June** (Tuesday) | 0800-1200 | SC: Finalize Requests #5, #12 |
| | | SC: Requests as needed (#16?, #3??, #10??, others) |
| **10 June** (Wednesday) | 0800-1200 | SC |
| **11 June** (Thursday) | 0800-1200 | SC (including approval of Standing Committee Reports) |
| **12 June** (Friday) | 0800-1200 | SC |

# APPENDIX VII: EXPERTS FOR PRELIMINARY ASSESSMENT OF CERTAIN STOCKS

Designated Experts for 2020:

## 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 | Antonio Avila de Melo | amelo@ipma.pt |
| Redfish in Div. 3LN | Antonio Avila de Melo | amelo@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 |

## APPENDIX VIII. LIST OF SCR AND SCS DOCUMENTS

| SCR Documents | | | |
|---|---|---|---|
| **Doc No.** | **Serial No** | **Author(s)** | **Title** |
| SCR Doc. 20-001 | N7032 | 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 2020 |
| SCR Doc. 20-002 | N7041 | R. M. Rideout and D. W. Ings | 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 2019 |
| SCR Doc. 20-003 | N7044 | 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. |
| SCR Doc. 20-004 | N7046 | R.M. Rideout | Do spatial coverage issues in the 2019 Canadian (NL) RV bottom trawl surveys influence the suitability of survey indices for use in NAFO stock assessments? |
| SCR Doc. 20-005 | N7047 | P.M Regular, R.M. Rideout, D.W. Ings | Impact of missed strata on abundance-at-age estimates of Greenland halibut from the Canadian fall 2J3K and spring 3LNO surveys in 2018 |
| SCR Doc. 20-006 | N7048 | 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), 1990-2019. |
| SCR Doc. 20-007 | N7051 | M. A. Treble | Report on Greenland halibut caught during the 2019 trawl survey in Divisions 0A |
| SCR Doc. 20-008 | N7052 | Diana González-Troncoso1, Irene Garrido2, Ana Gago1, Esther Román1 and Lupe Ramilo1 | Results for Greenland halibut, American plaice and Atlantic cod of the Spanish survey in NAFO Div. 3NO for the period 1997-2019 |
| SCR Doc. 20-009 | N7053 | Diana González-Troncoso1, Ana Gago1 and Irene Garrido2 | Yellowtail flounder, redfish (Sebastes spp.) and witch flounder indices from the Spanish Survey conducted in Divisions 3NO of the NAFO Regulatory Area |
| SCR Doc. 20-010 | N7054 | Diana González-Troncoso1, Irene Garrido2 and Ana Gago1 | Biomass and length distribution for roughhead grenadier, thorny skate, white hake and squid from the surveys conducted by Spain in NAFO 3NO |
| SCR Doc. 20-011 | N7055 | Diana González Troncoso1, Jose Miguel Casas Sánchez1 and Mónica Mandado2 | Results from Bottom Trawl Survey on Flemish Cap of June-July 2019 |
| SCR Doc. 20-012 | N7056 | Adriana Nogueira and Daniel Estévez-Barcia | Results for Greenland halibut survey in NAFO Divisions 1C-1D for the period 1997-2019 |
| SCR Doc. 20-013 | N7057 | Esther Román-Marcote, Concepción González-Iglesias and Diana González-Troncoso | Results for the Spanish Survey in the NAFO Regulatory Area of Division 3L for the period 2003-2019 |
| SCR Doc. 20-014 | N7059 | Esther Román-Marcote, Diana González-Troncoso and Marisol Alvarez | Results for the Atlantic cod, roughhead grenadier, redfish, thorny skate and black dogfish of the Spanish Survey in the NAFO Div. 3L for the period 2003-2019 |
| SCR Doc. 20-015 | N7060 | A. Nogueira and M. Treble | Comparison of vessels used and survey timing for the 1CD and 0A-South deep-water surveys and the 1A-F west Greenland shelf surveys |
| SCR Doc. 20-016 | N7061 | Rasmus Nygaard | Trawl, gillnet and longline survey results from surveys conducted by the Greenland Institute of Natural Resources in NAFO Division 1A Inshore |

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| SCR Doc. 20-017 | N7062 | Paula Fratantoni | Hydrographic Conditions on the Northeast United States Continental Shelf in 2019 – NAFO Subareas 5 and 6 |
| SCR Doc. 20-018 | N7063 | Boris Cisewski | Hydrographic conditions off West Greenland in 2019 |
| SCR Doc. 20-019 | N7065 | John Mortensen | Report on hydrographic conditions off Southwest Greenland June 2019 |
| SCR Doc. 20-020 | N7066 | F. Cyr, P. S. Galbraith, C. Layton, D. Hebert | Environmental and Physical Oceanographic Conditions on the Eastern Canadian shelves (NAFO Sub-areas 2, 3 and 4) during 2019. |
| SCR Doc. 20-021 | N7067 | Irene Garrido, Fernando González-Costas, Diana González-Troncoso, Ricardo Alpoim and Dolores Garabana | 3M cod possible technical measures: spatial / temporal closures |
| SCR Doc. 20-022 | N7068 | Durán Muñoz, P., Sacau, M., Román-Marcote, E. and García-Alegre, A. | A theoretical exercise of Marine Spatial Planning in the Flemish Cap and Flemish Pass (NAFO Divs. 3LM): implications for fisheries management in the high seas |
| SCR Doc. 20-023 | N7069 | E. Román-Marcote, P. Durán Muñoz and M. Sacau | Preliminary information from EU-Spain surveys in Div 3L regarding Commission request #18: "Provide information to the Commission at its next annual meeting on sea turtles, seabirds, and marine mammals that are present in NAFO Regulatory Area based on available data" |
| SCR Doc. 20-024 | N7070 | Isabelle Gaboury | NAFO STACFEN (MEDS) Report 2019 |
| SCR Doc. 20-030 | N7078 | Rademeyer and Butterworth | Updated SCAA Base Case Assessment for Greenland Halibut |
| SCR Doc. 20-031 | N7079 | Diana González-Troncoso1, Carmen Fernández2 and Fernando González-Costas1 | Assessment of the Cod Stock in NAFO Division 3M |
| SCR Doc. 20-032 | N7080 | L.J. Wheeland1, E. Novaczek1, M. A. Treble2, A. Nogueira3 | Impacts of survey timing on distribution and indices of Greenland halibut in NAFO Div. 0A and Divs. 1CD |
| SCR Doc. 20-033 | N7081 | A. M. Ávila de Melo 1, Nuno Brites 2, R. Alpoim 1, D. González Troncoso 3, F. González 3 and M. Pochtar 4 | The status of redfish (S. mentella and S. fasciatus) in Divisions 3LN and two medium term scenarios (when recruitment is low, Risk Based Management Strategy or common sense?) |
| SCR Doc. 20-034 | N7082 | Rasmus Nygaard, Adriana Nogueira and Karl Zinglersen | Knowledge about the dynamics of the Greenland halibut in the fjords in NAFO subarea 1B to 1F inshore |
| SCR Doc. 20-035 | N7083 | D. Bélanger1, P. Pepin1, G. Maillet1 | Biogeochemical oceanographic conditions in the Northwest Atlantic (NAFO subareas 2-3-4) during 2019 |
| SCR Doc. 20-036 | N7084 | Pablo Carrera and Fernando González-Costas | Sampling Plan for an Acoustic Survey of Kükenthal Peak (NAFO Division 6G) to Quantify Alfonsino (Beryx splendens) Biomass, Abundance and Size Composition |
| SCR Doc. 20-037 | N7085 | Igor Yashayaev, Ingrid Peterson, and Zeliang Wang | Meteorological, Sea Ice, and Physical Oceanographic Conditions in the Labrador Sea during 2019 |
| SCR Doc. 20-038 | N7086 | M. A. Treble and A Nogueira | Assessment of the Greenland Halibut Stock Component in NAFO Subarea 0 + Division 1A (Offshore) and Divisions 1B-1F |
| SCR Doc. 20-039 | N7087 | R. Alpoim1, | An Assessment of American Plaice (Hippoglossoides platessoides) in NAFO Division 3M |
| SCR Doc. 20-040 | N7088 | Rasmus Nygaard | Assessment of wolffish in NAFO subarea 1 |
| SCR Doc. 20-041 | N7089 | M.R. Simpson, and C.M. Miri | Assessment of Thorny Skate (Amblyraja radiata Donovan, 1808) in NAFO Divisions 3LNO and Subdivision 3Ps |
| SCR Doc. 20-042 | N7090 | Paul Regular, Rebecca Rademeyer, Divya Varkey, Doug Butterworth, Carmen Fernandez | Correcting mis-calculated values of J_target for use in the Greenland halibut HCR |
| SCR Doc. 20-043 | N7091 | Rasmus Nygaard | An assessment of the stocks of Greenland halibut in the South West Greenland fjords division 1BC, 1D and 1EF all |

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| | | | located in NAFO subarea 1, using the Depletion Corrected Average Catch model. |
| SCR Doc. 20-044 | N7092 | Rasmus Nygaard | Commercial data for the Greenland Halibut Stock Component in NAFO Division 1A Inshore. |
| SCR Doc. 20-045 | N7093 | Rasmus Nygaard | Assessment of Demersal Redfish in NAFO Subarea 1 |
| SCR Doc. 20-046 | N7094 | D. Maddock Parsons, B. Rogers, and R. Rideout | An assessment of the witch flounder resource in NAFO Divisions 3NO |
| SCR Doc. 20-047 | N7095 | D.A. Varkey, P.M. Regular, R. Kumar, N. Gullage, B. Healey, D.W. Ings, K. Lewis, K. Dwyer | Review and revamp of the SSM-based Management Strategy Evaluation for Greenland halibut stock in NAFO Subarea 2 and Divisions 3KLMNO |
| SCR Doc. 20-048 | N7096 | D.A. Varkey, R. Kumar, P.M Regular, N. Gullage | Performance metrics based on the state-space stock assessment model for Greenland halibut stock in NAFO Subarea 2 and Divisions 3KLMNO |
| SCR Doc. 20-049 | N7097 | D. W. Ings | Catch at age for SA 2 + Div 3KLMNO Greenland halibut during 2017 to 2019 |
| SCR Doc. 20-050 | N7098 | Paul M. Regular | Update of Base Case SSM for Greenland Halibut in NAFO Subarea 2 and Divisions 3KLMNO |

| SCS Documents | | | |
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| **Doc No.** | **Serial No** | **Author(s)** | **Title** |
| SCS Doc. 20/01 | N7034 | NAFO | The Commission's Request for Scientific Advice on Management in 2021 and Beyond of Certain Stocks in Subareas 2, 3 and 4 and Other Matters |
| SCS Doc. 20/02 | N7035 | Canada | Canada's Request for Coastal State Advice - 2021 |
| SCS Doc. 20/03 | N7036 | Denmark (on behalf of Greenland) | Denmark (on behalf of Greenland) Coastal State Request for Scientific Advice - 2021 |
| SCS Doc. 20/04 | N7038 | NAFO | Report of the NAFO Scientific Council Planning Meeting, 2 April 2020 |
| SCS Doc. 20/05 | N7039 | Japan | National Research Report of Japan (2020) |
| SCS Doc. 20/06 | N7040 | K Hubel | Estonian Research Report for 2019 |
| SCS Doc. 20/07 | N7045 | F. González-Costas, G. Ramilo, E. Román, J. Lorenzo, A. Gago, D. González-Troncoso, M. Sacau, P. Duran, M. Casas and J. L. del Rio | Spanish Research Report for 2019 |
| SCS Doc. 20/08 | N7049 | Luis Ridao Cruz | Faroese Research Report 2019 |
| SCS Doc. 20/09 | N7050 | J. Vargas, R. Alpoim, E. Santos and A. M. Ávila de Melo | Portuguese Research Report for 2019 |
| SCS Doc. 20/10 | N7058 | H. O. Fock and C. Stransky | German Research Report for 2019 |
| SCS Doc. 20/11 | N7064 | Bob Rogers and Mark Simpson | Canadian Research Report for 2019 |
| SCS Doc. 20/12 | N7076 | Greenland Institute of Natural Resources | Denmark/Greenland Research Report for 2019 |
| SCS Doc. 20/13 | N7077 | Konstantin Fomin and Maria Pochtar | Russian Research Report for 2019 |
| SCS Doc. 20/14 | N7099 | NAFO | Report of the June Scientific Council Meeting, 28 May - 12 June 2020 |

## APPENDIX IX. LIST OF PARTICIPANTS, 28 MAY – 12 JUNE 2020

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