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Newfoundland and Labrador Region

Canadian Science Advisory Secretariat
Science Advisory Report 2024/016

NAFO SUBDIVISION 3PS ATLANTIC COD (*GADUS MORHUA*) STOCK ASSESSMENT IN 2023

CONTEXT

The Fisheries Management Branch of Fisheries and Oceans Canada (DFO) has requested that the 3Ps Atlantic cod stock be assessed relative to reference points that are consistent with the DFO Precautionary Approach, provide harvest advice, and inform the rebuilding plan for this stock. This Science Advisory Report is from the November 6–10, 2023, regional peer review on 3Ps Atlantic Cod Assessment. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SCIENCE ADVICE

Status

- The 2024 Spawning Stock Biomass (SSB) is projected to be below the Limit Reference Point (LRP) with a greater than 99% probability. The stock remains in the Critical Zone.

Trends

- The stock has been in the Critical Zone since 2000, with SSB remaining at or near time series lows without trend since 2009. SSB in 2024 is projected to be 35.5 kt (95% Confidence Interval [CI] = 27.1–46.8), which is 54% (95% CI = 41–71%) of the LRP (66 kt).

- Recruitment is impaired and has remained well below the time series average since 1993.

- Natural mortality (M) increased from the early 2000s and has varied without trend at a relatively high level since 2008. The population weighted M estimate for ages 5–8 in 2023 is 0.35.

- Fishing mortality (F) has been declining since 2000. The population weighted F estimate for ages 5–8 in 2023 is 0.02.

Ecosystem and Climate Change Considerations

- Ocean temperatures in 3Ps were at record highs in 2021–22. Ongoing warming and associated increased dominance of silver hake indicate that this ecosystem continues to experience structural changes. The impact of these changes are not fully understood but have been associated with reductions in stock productivity.

Stock Advice

- Given the low status and productivity of the stock, continued fishery removals delay recovery prospects. Removals from all sources should be at the lowest possible level until the stock clears the Critical Zone.

March 2024

- Under the adopted management procedure, stock growth in the short term (2027) will not be achieved with a high (>75%) probability. Under no removals a high probability of growth is achieved. Other levels of removals were not evaluated in this meeting. The stock remains in the Critical Zone in all cases.

- The age structure of the fishery is no longer consistent with that applied in the previous testing and adoption of the management procedure. The consequence of this change for stock rebuilding should be examined.

BASIS FOR ASSESSMENT

Assessment Details

Year Assessment Approach was Approved

2019 (Varkey et al. 2022)

Assessment Type

Full Assessment

Most Recent Assessment Date

1. Last Full Assessment: 2021 (DFO 2021)

2. Last Interim Year Update: N/A; this stock is assessed annually

Assessment Approach

1. Broad category: Stock assessment model

2. Specific category: State-space age-based stock assessment model

This state-space stock assessment model (Hybrid) uses indices of abundance from research trawl and sentinel surveys. The model includes a time varying component for natural mortality that is informed by a condition-linked mortality index externally estimated from biological sampling data. Fisheries data used in the model include landings and catch-at-age. This model estimates stock trends since 1959. A complementary State-Space Model (SAM) is also examined in this assessment as a consistency check and shows similar trends to the Hybrid assessment model.

Stock Structure Assumption

Stock structure and migration patterns of Atlantic cod in NAFO Subdivision 3Ps are complex. Cod mix with adjacent stocks at the margins of the stock boundary, some offshore components migrate seasonally to inshore areas while some remain offshore throughout the year. Additionally, there are inshore components of this stock. All stock components are managed collectively as a single stock with one LRP.

Reference Points

The LRP was determined based on visual evaluation of recruitment and SSB scatter to determine the point below which only low recruitment has been observed, and was supported by break-point analyses (Figure 1). The LRP was set at 66 kt.

1. Limit Reference Point (LRP): 66 kt (DFO 2020)

2. Upper Stock Reference (USR): N/A; not defined

3. Removal Reference (RR): N/A; not defined

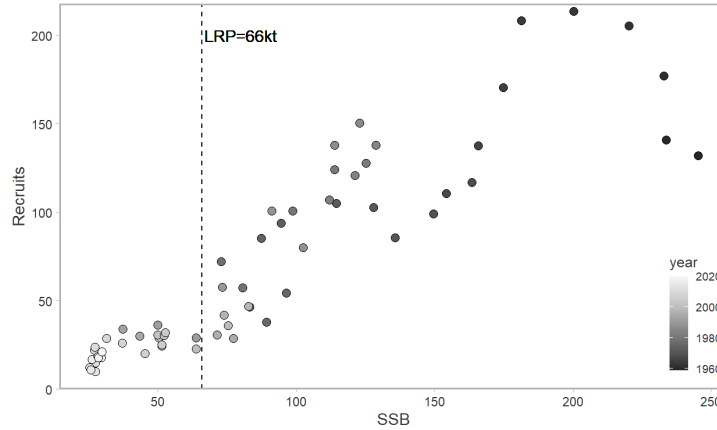4. Target (TRP): N/A; not defined

Figure 1. Recruitment (age 2) and spawning stock biomass estimates with LRP (dashed lined). Data are from 1959 to 2020 (SSB) and 1961 to 2022 (recruitment).

Harvest Decision Rule

A Management Procedure (MP) has been adopted for this stock starting in the 2023/24 fishing season with a fixed level of fishing mortality (F) while the stock is in the Critical Zone. In the calculation of total fishery removals, F across ages is scaled to the average fishery selectivity from 2019–21, with F = 0.065 at the fully selected ages (9+) (DFO 2023).

Data

- DFO Canadian RV survey (1983–2005, 2007–19, 2021–22)*

- France ERHAPS survey (1978–91)*

- GEAC industry survey (1997–2005)*

- Sentinel line trawl and gill net surveys (1995–2022)*

- Commercial fishery landings and catch at age (1959–2022)*

- Newfoundland and Labrador Climate Index (1950–2022)

- Atlantic Zone Monitoring Program biogeochemical and plankton data (2008–22)

- Mark-recapture reporting rates (2001–22)

- Newfoundland & Labrador comparative fishing data (2021–23)

- Pinniped aerial surveys (2021)
  * *data sources used directly in the assessment model*

Data changes since last assessment: Results from comparative fishing experiments indicate no conversion factor is required for Atlantic cod indices in the DFO Research Vessel (RV) Survey between the outgoing vessels (Canadian Coast Guard Ship [CCGS] *Teleost* and CCGS *Alfred Needler*) and new Offshore Fishery Science Vessels CCGS *Capt Jacques Cartier* and CCGS *John Cabot*.

The 2023 spring DFO RV Survey in 3Ps was not undertaken, primarily due to limited vessel availability. Without this index, population estimates for 2023 in the current model run had to be projected. This increases our uncertainty of stock dynamics and status in 2023, and projections forward.

Mark-recapture data were used to estimate recreational fishery catches. Based on these, catch bounds in the assessment model were increased from 1.1 to 1.3 for years 2020 onward.

A data and analysis correction led to a revision of estimated recent stock weights compared to those used in the previous assessment.
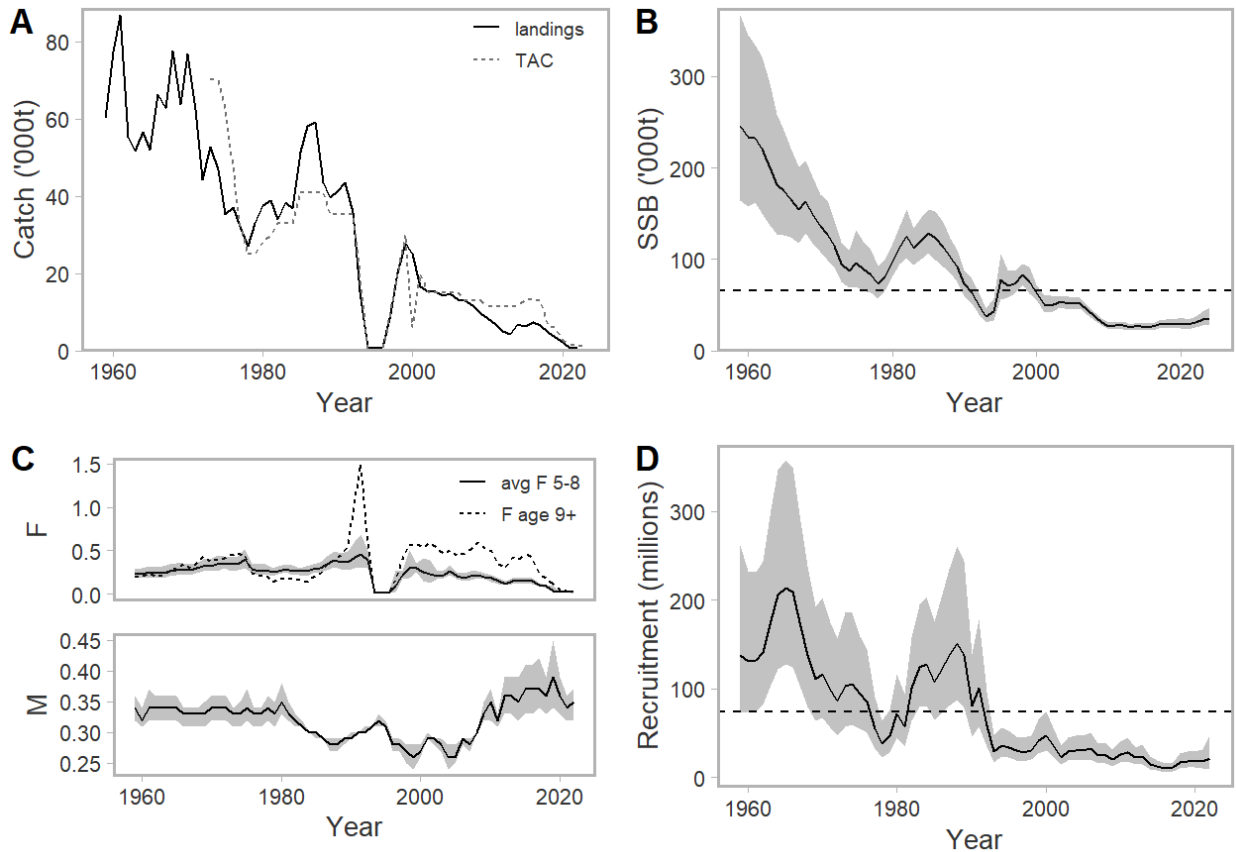
ASSESSMENT

Figure 2. A) Reported annual landings (solid) and Total Allowable Catch (TAC) (dashed). B) Estimates of SSB (black line = median estimate; grey area = 95% confidence interval) relative to the LRP (dashed line; LRP = 66 kt SSB). C) Top: Average Fishing (F) mortality (solid line = ages 5–8; dashed line = fully selected, ages 9+) estimates with 95% confidence intervals. Bottom: Average Natural (M) mortality (ages 5–8) estimates with 95% confidence intervals. D) Estimated recruitment (median estimate of age-2 abundance, with 95% confidence interval); the dashed horizontal line is the time-series median (74 million).

Historical and Recent Stock Trajectory and Trends

Table 1. Median estimates of 3Ps cod population size and mortality rates over the last five years from the Hybrid assessment model. (-) indicates estimate is not available for this year.

Year	Biomass (000 t) (95%CI)	Abundance (millions)	Recruits, age 2 (millions)	Average M (ages 5–8)	Average F (ages 5–8)	F ages 9+ (fully selected)
2019	28.6	60.0	18.4	0.39	0.09	0.19
2020	29.8	63.1	17.8	0.36	0.04	0.11
2021	28.7	64.5	17.7	0.34	0.02	0.05
2022	30.9	66.3	21.0	0.35	0.02	0.04
2023	34.1	69.5	-	-	-	-

Biomass

The SSB was below the LRP (66 kt) from 1991 to 1994, with a low in 1993 around 38 kt. The stock increased through the mid to late 1990s while a moratorium on directed fishing was in place (1993–97), but by 1999 started declining again following a re-opening of the fishery. From 2001–06 SSB was relatively stable at values that averaged near 50 kt. Further decreases followed and SSB has been near 30 kt since 2008. With an assumed catch of 1,304 t for the 2023 calendar year (i.e., the TAC), SSB in the beginning of 2024 is estimated to be 35.5 kt, which is 52% of the LRP.

Abundance

Abundance follows a similar trend to biomass, and is currently low – estimated at 69.5 million fish in 2023. The age structure of the population is truncated, with few fish observed 14 years or older.

Removal Rate

The population weighted F estimate (ages 5–8) was <0.02 during the moratorium (August 1993–May 1997) when removals were only from bycatch, and then rapidly increased to 0.3 in 1999 and 2000 after the reopening of the fishery. F_{5-8} has been declining since that time, coinciding with a series of reductions in TAC and participation in the fishery, and in 2022 is estimated to be 0.02.

F at the fully selected ages (F_{9+}) peaked just prior to the mortarium, reaching an estimate of 1.49 in 1992. F_{9+} was <0.02 from 1994–96, then increased following the reopening of the fishery and was high (0.3 to 0.6) from 1998 through to 2017. F_{9+} has decreased rapidly since, and is estimated at 0.04 in 2022.

Recruitment

Recruitment (age-2) estimates have been below the long-term average (74 million) since the mid-1990s and over the last decade reached historic lows (10–12 million over 2015–17). Recruitment levels are estimated near 21 million in 2022. Given low SSB, age structure of the population, small size at age, and early age at maturity, short term prospects for improved recruitment are limited.

Natural Mortality

Natural mortality (M, ages 5–8) was near 0.33 from 1959 to 1980, then declined to near 0.27 through the early 2000s. M increased considerably to the 2010s and averaged 0.36 over 2010–20 (time-series high at 0.39 in 2019). M in 2022 is estimated at 0.35.

History of Landings, TAC & Catch Advice

Table 2. TAC and landings by management year (thousand metric tonnes).

Management Year	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21*	21–22*	22–23*	23–24
TAC**	11.50	11.50	13.22	13.49	13.04	6.50	5.98	5.98	2.69	1.35	1.35	1.30
Canada	4.00	4.60	5.80	5.90	5.20	4.90	4.50	3.30	1.75	0.80	0.90	N/A
France	0.80	1.40	1.60	0.90	1.10	0.20	0.20	0.20	0.03	0.02	0.01	N/A
Totals	4.80	6.00	7.30	6.80	6.30	5.10	4.70	3.50	1.78	0.83	0.91	N/A

[*] Provisional;

[**] TAC is shared between Canada (84.4%) and France (St. Pierre et Miquelon; 15.6%).

There has been a rapid and unexpected exit of the 2011 year class from the fishery in 2023, following a dominance of this cohort in the catch since 2017. Catches were primarily composed of ages 5–6, and 6–7 in 2021 and 2022, respectively, returning to a more typical age distribution within the fishery. Recent catches are largely concentrated in the Placentia Bay area (Unit area 3Psc).

Ecosystem and Climate Change Considerations

The cold Labrador Current from the east, and warmer and saltier Gulf Stream waters from the south influence oceanographic conditions in 3Ps. Surface and bottom temperatures have experienced a general warming trend in some areas since 1990, with 2021 and 2022 being the warmest of years with available data.

Satellite remote sensing data (2003–22) indicated that the timing of onset of the spring phytoplankton bloom in 3Ps has been variable over the last four years, following a period of late blooms from 2014–18. Nitrate and chlorophyll-*a* inventories in 2022 were the highest recorded since 2008. Recent trends in zooplankton production in 3Ps cannot be determined due to data gaps in 2020 and 2021, however, zooplankton indices were near average in 2022.

The structure of the ecosystem in 3Ps has been changing in recent years. Atlantic cod was the historically dominant species among predatory fishes in this ecosystem, but its dominance has been markedly reduced in recent years, coinciding with increases in warm water species such as Silver Hake (*Merluccius bilinearis*) (Figure 3).
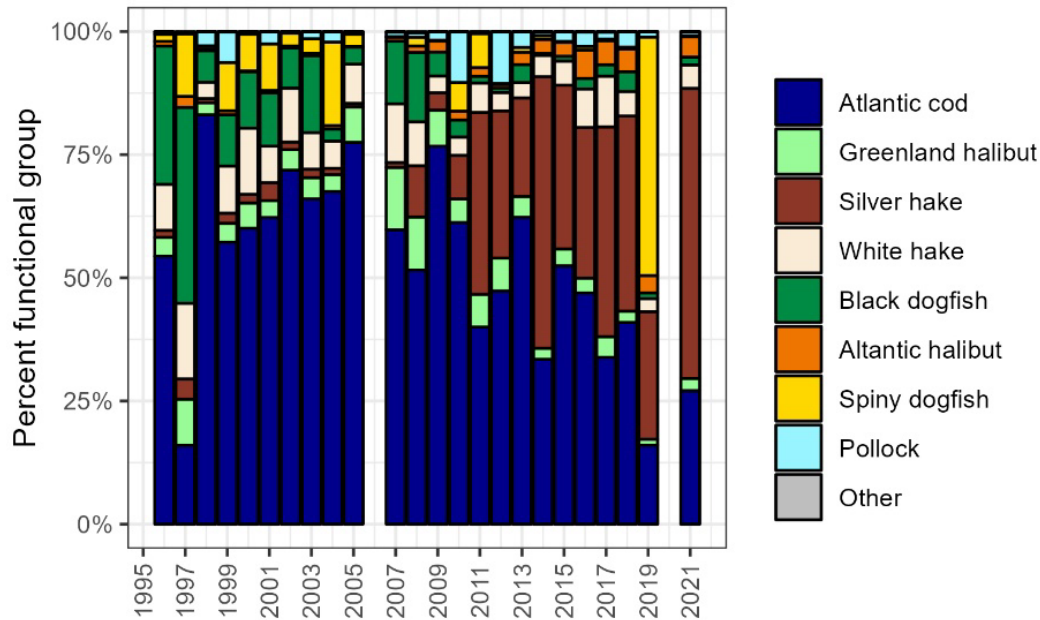
Figure 3. Species composition (proportion of total biomass) of the piscivore functional group in 3Ps from the spring DFO RV survey.

Cod diet in 3Ps has shown a variable composition over time, with comparatively low stomach content weights compared to the neighboring Grand Bank (Div. 3LNO), suggesting lower and highly variable food availability in this ecosystem. This, in conjunction with overall declines in weight-at-age and generally poor cod condition in the 2010s could indicate food limitations on cod productivity.

Among pinnipeds, Harbour Seal (*Phoca vitulina vitulina)* and Grey Seal (*Halichoerus grypus)* are typically found in 3Ps. Harbour Seals are year-round residents while Grey Seals are seasonal migrants, primarily moving into the region in the summer. Recent aerial surveys (Hamilton et al. 2023) of haulouts in 3Ps have counted 2,637 Harbour Seals (89% of total NL counts), and 380 Grey Seals (<1% of total Atlantic Canada counts). Analysis of seal scats collected in 3Ps during the summer indicate that Atlantic cod are detected in a small number of seal scats (<3%) at this time of year.

Projections

Data available for the model in the current assessment were up to 2022 given the absence of a 2023 RV survey. Stock levels to 2024 are determined based on projections under current fishing selectivity (average 2020–22), with an assumed catch of 1,304 t (i.e., the TAC) in 2023.

Projections of the stock from 2024 to 2027 were conducted assuming annual fishery removals under the adopted MP. Projections were also conducted with no fishing removals (F=0) over this period.

Under these scenarios (Table 3), there is a very high (>98%) probability that the stock will remain below the LRP through at least the start of 2027. There is a moderately high (69%)

probability of stock growth to 2027 when the MP is applied, with median estimates indicating 10% growth in SSB to 2027. There is a high (87%) probability of stock growth to 2027 when there are no removals by fishing (F=0) over this period, with median estimates indicating 23% growth in SSB to 2027. In the estimation of probability of growth, growth is defined as any increase in SSB.

Table 3. Short term (2024–27) projections of SSB and catch under the adopted MP and at F=0, including the probability of stock growth relative to current levels P(SSBy>SSB$_{2024}$) and the probability of projected SSB being above the LRP. "SSB Low" and "SSB High" indicate the lower and upper limits of the 95 percentile projection envelope.

F	Year	SSB/B$_{LIM}$	SSB ('000 t)	SSB Low ('000 t)	SSB High ('000 t)	Catch ('000 t)	P(SSB$_y$>SSB$_{2024}$)	P(SSB$_y$>LRP)
MP	2024	0.54	35.5	27.1	46.8	1.550	NA	<0.1%
MP	2025	0.56	36.7	27.3	49.7	1.547	59%	<0.1%
MP	2026	0.58	38.1	27.6	53.8	1.597	67%	<0.1%
MP	2027	0.59	38.9	27.4	57.4	1.628	69%	<0.1%
F=0	2024	0.54	35.5	27.1	46.8	0	NA	<0.1%
F=0	2025	0.58	38.5	28.5	52.2	0	70%	<0.1%
F=0	2026	0.63	41.5	30	58.6	0	82%	<0.1%
F=0	2027	0.66	43.6	30.6	63.8	0	87%	1.7%

A Rebuilding Plan is in development for this stock, with a proposed rebuilding target to be above the LRP with a 75% probability. As a component of the plan's development, a series of rebuilding projections examined potential stock growth under various fishing, natural mortality, and recruitment scenarios (DFO 2023). The current assessment projections of SSB under the MP applied in the 2023/24 management year (described above) fall within the 75% probability envelopes from the rebuilding projections under prevailing conditions of natural mortality and recruitment previously completed for this stock. However, median projected SSB in all years of the short-term projections under the MP fall below median values from the rebuilding projections and no longer yields a 75% probability of growth to 2027. This indicates a slower than expected rate of stock growth (Figure 4).
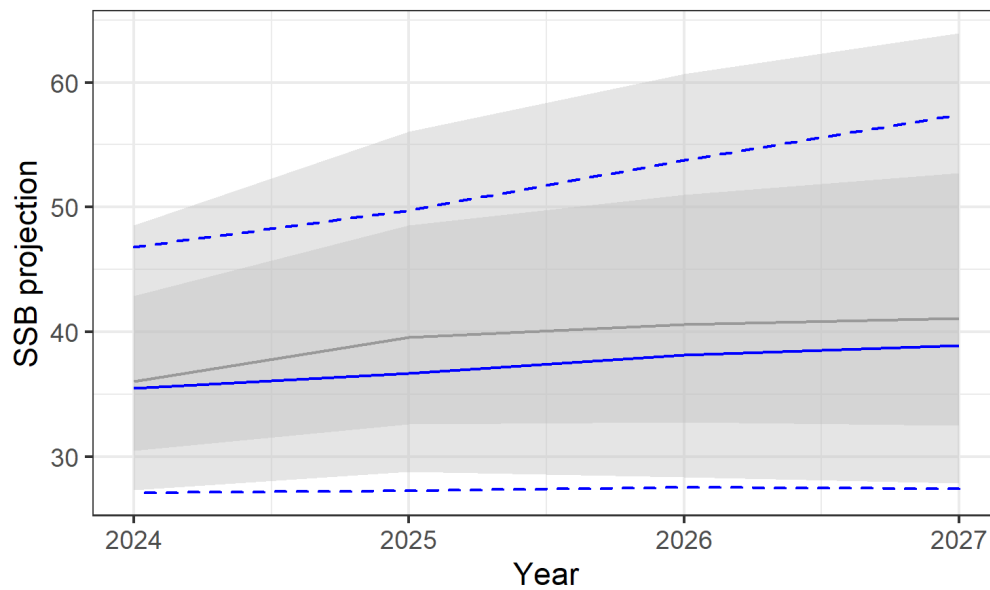
Figure 4. Current SSB projection under the adopted MP (blue line = median, dashed lines = 95% CI) compared to previous projections from testing the Rebuilding Framework under prevailing conditions (grey line = median, dark grey = 75% CI, light grey = 95% CI).

OTHER MANAGEMENT QUESTIONS

Mark-recapture data were used to estimate recreational fishery removals. While estimates show interannual variation, there is no obvious trend in removal levels. Recreational fishery catches are estimated to be between 135 t and 376 t (95% CI) with a mean of 225 t based on values from 2016 to 2022 (Figure 5), the period for which the current recreational fishery season has been in place. These are considered to be the best available estimates of current recreational catches, however there is significant uncertainty in these estimates and there are no direct measures of recreational removals.
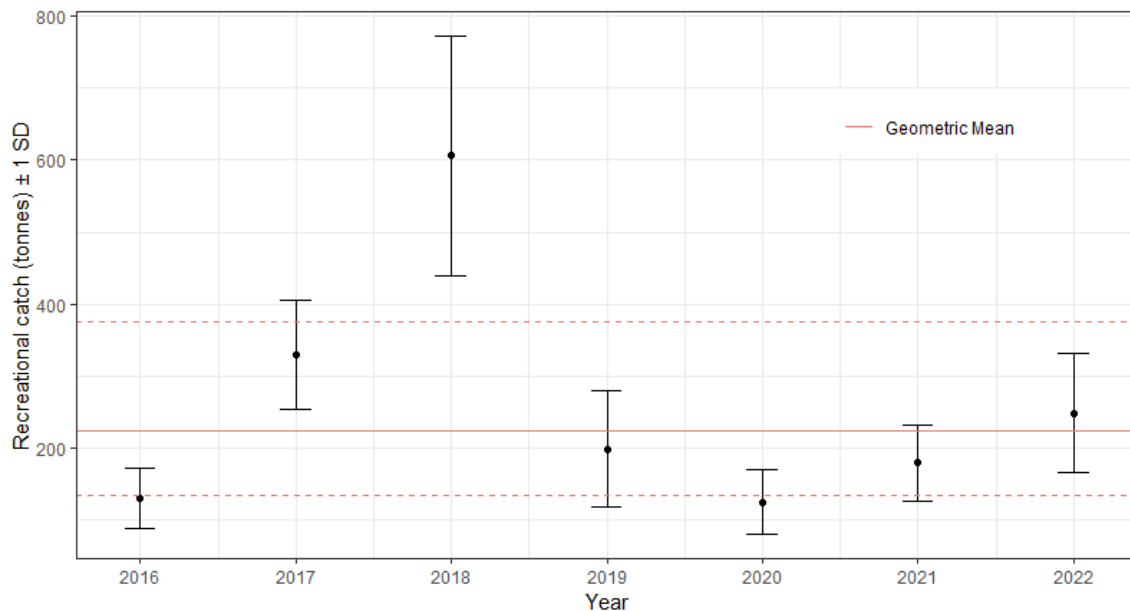
Figure 5. Annual estimates of recreational fishery removals in 3Ps. Error bars indicate one standard deviation (SD). Horizonal red line shows the time series average (225 t; geometric mean 2016–22) with dashed red lines indicating the 95% confidence interval on the estimate.

SOURCES OF UNCERTAINTY

The impact of ongoing warming in 3Ps and associated changes in community composition on the productivity of this stock are not well understood. Further work is needed to quantify the impact of these changes on habitat availability, competition, and cod biological processes.

Typically, the terminal year of this assessment is informed by the RV survey in the spring of the current year. However, the 2023 RV survey was not undertaken in 3Ps. SSB to 2024 is determined based on a projection. This increases the uncertainty in the estimate of current stock size; however, we are confident in the evaluation of stock status.

The relative influence of the sentinel indices on recent stock trends is higher in the current assessment. Given the known influence of the sentinel indices within the model, and recent diverging trends between sentinel and RV indices, it is possible that this is leading to an overestimation of current stock size.

Model-predicted process errors are negative at some ages in the recent period, which suggests unexplained mortality within the model. Projections are based on process error variance from the full model series which does not capture short-term patterns.

Research Recommendation: Revise the projection framework within the Hybrid model to incorporate short-term process error trends.

The stock structure of cod in 3Ps is complex and connections to other stock areas are not fully understood. This can lead to increased variability in indices and uncertainty in the understanding of stock productivity.

Research Recommendation: Genetic analyses and tagging and telemetry work are ongoing and should continue in order to better understand stock structure and seasonal movements.

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