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Newfoundland and Labrador Region
Canadian Science Advisory Secretariat
Science Advisory Report 2021/031

STOCK ASSESSMENT OF NAFO SUBDIVISION 3PS COD

Image: Atlantic Cod *Gadus morhua.*

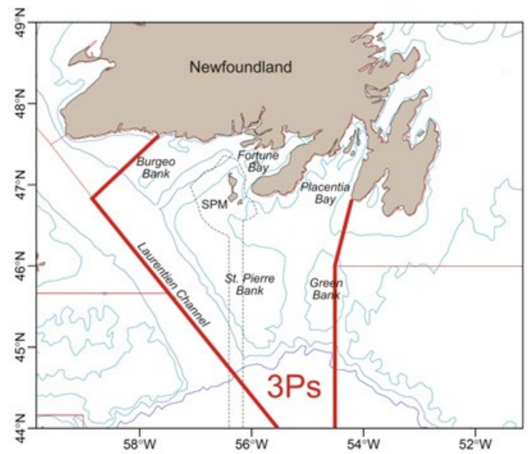

Figure 1: Subdivision 3Ps management area and economic zone around the French islands of St. Pierre et Miquelon (SPM, dashed line).

Context:

In the Northwest Atlantic, Atlantic Cod are distributed from Greenland to Cape Hatteras and are managed as 12 stocks. The Northwest Atlantic Fisheries Organization (NAFO) Subdivision (Subdiv.) 3Ps stock off southern Newfoundland extends from Cape St. Mary's to just west of Burgeo Bank, and over St. Pierre Bank and most of Green Bank (Fig. 1).

The distribution of Subdiv. 3Ps cod does not conform well to management boundaries and the stock is considered a complex mixture of inshore and offshore sub-components. These may include fish that move seasonally between adjacent areas as well as fish that migrate seasonally between inshore and offshore. The extent to which the different components contribute to the fisheries is not fully understood.

Female cod from this stock have generally matured at younger ages since the mid-1990s. About 50% of the females are mature by age 5 (~47 cm) in these more recent cohorts, compared to only about 10% at age 5 (~55 cm) among cohorts present in the 1970s-1980s.

Catches from this stock have supported an inshore fixed gear fishery for centuries and are of vital importance to the area. Fish are caught offshore by mobile and fixed gear, and inshore by fixed gear only. Spanish and other non-Canadian fleets heavily exploited the stock in the 1960s and early-1970s. French catches increased in the offshore throughout the 1980s. A moratorium on fishing initiated in August, 1993 ended in 1997 with a quota set at 10,000 t. Beginning in 2000, the management year was changed to begin on 1 April. The Total Allowable Catch (TAC) for the 2019-20 management year was set at 5,980 t. Under the terms of a 1994 Canada-France agreement, Canada holds 84.4% of the TAC, while the remainder (15.6%) is held by France (St. Pierre et Miquelon).

The present assessment is the result of a request for science advice from the Resource Management Branch of Fisheries and Oceans Canada (DFO, Newfoundland and Labrador [NL] Region). The main objectives were to evaluate the status of the stock and to provide scientific advice concerning conservation outcomes related to various fishery management options.

This Science Advisory Report is from the November 2-6, 2020 regional advisory meeting on the Assessment of Northwest Atlantic Fisheries Organization (NAFO) Subdivision 3Ps Atlantic Cod. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule] as they become available.

SUMMARY

- The stock was assessed using an integrated state-space model, which incorporates landings and catch at age (1959-2019), time-varying natural mortality informed by trends in cod condition, and includes abundance indices from research surveys using bottom trawls conducted by Canada (1983-2005, 2007-19), France (1978-91), industry (Groundfish Enterprise Allocation Council [GEAC],1998-2005), and standardized catch rate indices from the Sentinel gillnet and line-trawl surveys (1995-2019). There was no 2020 Canadian bottom trawl survey.
- Spawning Stock Biomass (SSB) at January 1, 2021 is projected to be 25 kt (18 kt-35 kt) with an assumed catch of 2,702 t in 2020. The stock is in the Critical Zone (38% of the Limit Reference Point (LRP); 27-53%) as defined by the DFO Precautionary Approach (PA) Framework. The probability of being below the LRP is >99.9%. The stock has been below the LRP since the early-2000s.
- The estimated fishing mortality rate (F) for ages 5-8 declined from 0.16 in 2015 to 0.11 in 2019. With an assumed catch of 2,702 t in 2020, F is projected to be 0.07 (0.05-0.09) in 2020.
- Natural mortality (M) for ages 5-8 has increased during the last decade, reaching 0.43 (0.35-0.52) in 2019.
- Recruitment (age 2) estimates up to 2019 have been below the long-term average since the mid-1990s.
- Projection of the stock to 2023 was conducted assuming fishery removals to be within +/-60% of an assumed catch of 2,702 t for 2020 and with no catch. Under these scenarios, there is a probability >99% that the stock will remain below the LRP between 2021 and the beginning of 2023.
- The probability of stock growth to 2023 ranges between 39% and 78% across catch scenarios (+/- 60% of current levels), and is 88% when there are no removals.
- Natural mortality plays an important role in projections for this stock. If natural mortality rates are appreciably different from those used, projected outcomes will differ from values reported above.
- Bottom temperatures in Subdiv. 3Ps remained above normal between 2009 and 2019, but no data were available for 2020. No zooplankton data were available for 2019 and 2020. Satellite imagery indicates that the timing and magnitude of the spring phytoplankton bloom were normal in 2020, after two consecutive years of early onset and above-normal production.
- Ongoing warming trends, together with an increased dominance of warm water fishes, indicate that this ecosystem continues to experience structural changes. Reduced condition is indicative of diminished productivity in Subdiv. 3Ps cod.
- Consistency with the DFO decision-making framework incorporating the PA requires that removals from all sources must be kept at the lowest possible level until the stock clears the Critical Zone.

INTRODUCTION

Oceanography and Ecosystem Overview

Oceanographic conditions in Subdiv. 3Ps are influenced by the Labrador Current from the east, the warmer and saltier Gulf Stream waters from the south, as well as the complex bottom topography in the region and local atmospheric climate conditions. Near-bottom temperatures, while showing significant variability from one year to the next, have experienced a general warming trend in some areas since 1990.

Satellite remote sensing data indicated that the timing of onset and duration of the spring phytoplankton bloom in Subdiv. 3Ps were normal in 2020. Surface production was also normal during 2020, following three consecutive years of above normal production. No zooplankton data were available for 2019 and 2020.

No data were available on the biomass or abundance of the fish community in Subdiv. 3Ps during 2020. The overall biomass of this fish community was relatively stable from the mid-1990s to 2019, whereas the overall abundance increased due mainly to an increase in small planktivorous (plankton-eating) fishes (e.g., Sandlance *Ammodytes sp.*) during that period. There was an increased dominance of warm water species such as Silver Hake (*Merluccius bilinearis*) since 2010, linked to an ongoing warming trend. Cod in Subdiv. 3Ps have a variable diet. Snow Crab was a dominant prey for cod in 2013-16. Since 2017, cod diet has had an increase in the fish fraction, suggesting that food availability may be highly variable. These changes in species composition and cod diet are evidence that the structure of the Subdiv. 3Ps ecosystem may be changing. Although the full impacts of these changes on cod are unknown, they imply that at least some aspects of the Subdiv. 3Ps ecosystem likely remains in a reduced productivity state.

Only a very small proportion of the Grey Seal (*Halichoerus grypus*) population in Atlantic Canada utilizes Subdiv. 3Ps for any part of the year. Preliminary data from satellite tracking studies indicate that of those seals that do summer in Subdiv. 3Ps, the majority spend a few months in the area while staying most of the year on the Scotian Shelf or in the Gulf of St. Lawrence. The available data indicate that Atlantic Cod are rarely seen in the diets of Grey or Harbour Seals (*Phoca vitulina*) in Subdiv. 3Ps.

History of the Fishery

In the 1960s and early-1970s, the stock was heavily exploited by non-Canadian fleets, mainly from Spain, with catches peaking at 87,000 t in 1961 (Fig. 2).

After the extension of jurisdiction in 1977, landings increased to peak at almost 59,000 t in 1987 due to increased landings by France. Landings then decreased sharply to about 40,000 t over 1988-91 before decreasing further to 36,000 t in 1992.

A moratorium was imposed in August 1993 and at that time, 15,000 t of the 20,000 TAC had been landed. Although offshore landings fluctuated, the inshore fixed gear fishery reported landings around 20,000 t each year from 1959 to the moratorium.

The fishery reopened in May 1997 with a TAC of 10,000 t, which increased to 30,000 t by 1999. In 2000, the management year was changed to begin on 1 April. The TAC was set at 5,980 t and 2,691 t for the 2019-20 and 2020-21 management periods respectively.

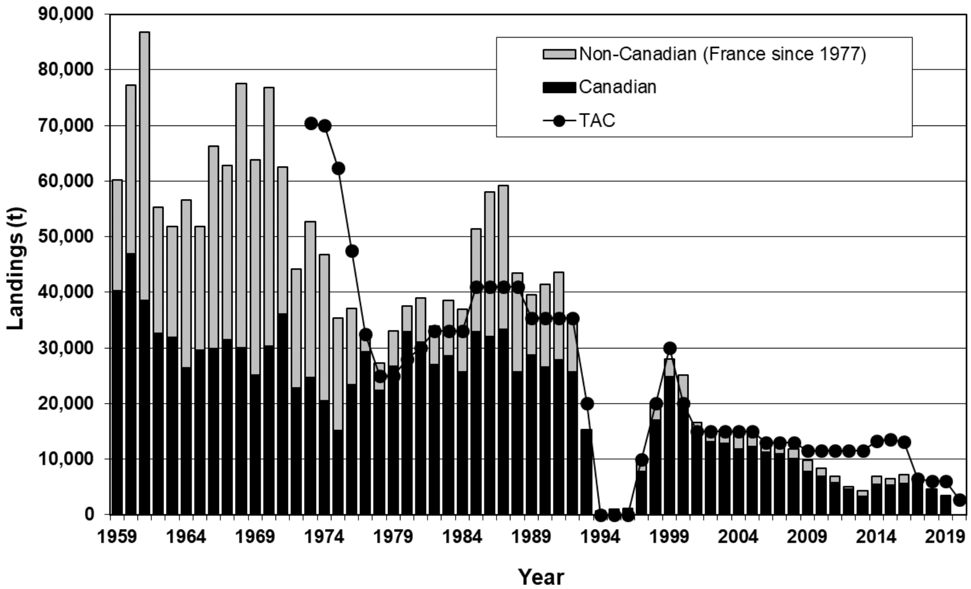

Figure 2: Reported annual landings and TACs (t) in 1959-2019. Values are based on calendar year in 1959-2000 and on management year (1 April-31 March) since then. Landings for 2020 (2020-21 season) are incomplete and not displayed.

Species Biology

Stock structure and **migration patterns** of Subdiv. 3Ps cod are complex. Cod in Subdiv. 3Ps mix with adjacent stocks at the margins of the stock boundary. Some offshore components of the stock migrate seasonally to inshore areas, and there are inshore components that are shoreward of the DFO spring research trawl survey area. These features add uncertainty to the assessment of stock status. However, since 1994, additional information has been obtained from various sources, including tagging, acoustic telemetry, and the Sentinel Survey. This information has provided a basis for several measures to investigate the potential impact of these factors (i.e., stock structure and migration patterns) on the assessment. Survey timing was shifted to April (beginning in 1993) and winter fishery closures in some areas have been imposed to reduce the potential for migrant non-3Ps cod being sampled by surveys and included in commercial catches. The DFO spring trawl survey covers most of the stock area so survey trends are thought to broadly reflect those of this stock.

Spawning is spatially widespread in Subdiv. 3Ps, occurring close to shore as well as on Burgeo Bank, St. Pierre Bank, and in the Halibut Channel. Timing of spawning is variable and extremely protracted, with spawning cod present from March until August in Placentia Bay. Detailed examination of fish collected from Halibut Channel (in the southern portion of 3Ps) in March and April of 2015 and 2016 suggested that spawning in this area began in April. Also, it was noted that for these fish, all females initially categorized as spent were likely skipping spawning; therefore, previous estimates of spawning time may be biased and estimated to be earlier than actual spawning times.

Maturation in female cod was estimated by cohort. The proportion of female cod maturing at ages 4-6 is higher for all cohorts subsequent to the 1985 cohort. The reasons for this change toward earlier age at maturity are not fully understood but may have a genetic component that is partly a response to high levels of mortality including fishing. Males generally mature about one year younger than females but show a similar trend over time.

Growth, calculated from length-at-age in research trawl survey samples, has varied over time. For cod older than age 3 there was a general decline in length-at-age from the early-1980s to the mid-1990s. For most ages, there was an increase in length-at-age from the mid-1990s through the mid-2000s, followed by a period of lower length-at-age in recent years. Length-at-age has been lower than average in 9 of the last 13 years (2007-19), being well below average in most of the last seven years.

Condition (or condition factor) is a measure of fish weight relative to length and is considered a proxy for energy reserves. Comparison of post-1992 condition with that observed during 1985-92 is difficult because survey timing has changed. Condition varies seasonally and tends to decline during winter and early spring. There were signs of improved fish condition during 2008-2013, but condition has been below average in 8 of the last 13 years (2007-19), with 2017 being the lowest and 2019 the second lowest in the time-series.

Estimates of condition (GSI, HSI, Fulton) from Sentinel sampling during 2019 changed little from 2018 and the direction of change was inconsistent among condition factors. Data from 2020 were unavailable as the Sentinel survey was ongoing at the time of the assessment meeting.

ASSESSMENT

Resource Status

Sources of Information

A state-space stock assessment model developed during 2019 was used to assess stock status. This model uses indices of abundance from research trawl surveys conducted by Canada (1983-2005, 2007-19), France (1978-1991) and an industry organization (GEAC; 1997-2005), plus the Sentinel survey (1995-2019). Also included is a time-varying component for natural mortality that is based on proportion of cod in poor condition. Data on cod condition were added for 2019, and supplemental data from the Sentinel survey was also added for 2016 and 2017. Fisheries data used in the model included landings and catch-at-age data from 1959 to 2019. The fisheries landings and catch-at-age data were revised from the 2019 assessment as only provisional estimates were available for 2019, since that year’s fishery was ongoing at the time of the assessment. In the model fitting exercise, the magnitude of the catch total weights (i.e., landings) and the age-composition information in the catch-at-age data were fitted separately. The age-composition information in the catch-at-age was fitted using continuation ratio logits. Our confidence in the magnitude of fisheries landings data has varied over the time-periods in the history of the fishery and the model uses censored likelihood on landings bounds that were developed based on a literature review and fisher interviews (Fig. 3). The assessment model estimates stock trends from 1959 to January 1, 2021. Although additional sources of information are presented (see “Other Data Sources” below), only the indices listed above were selected as the input data for the model.

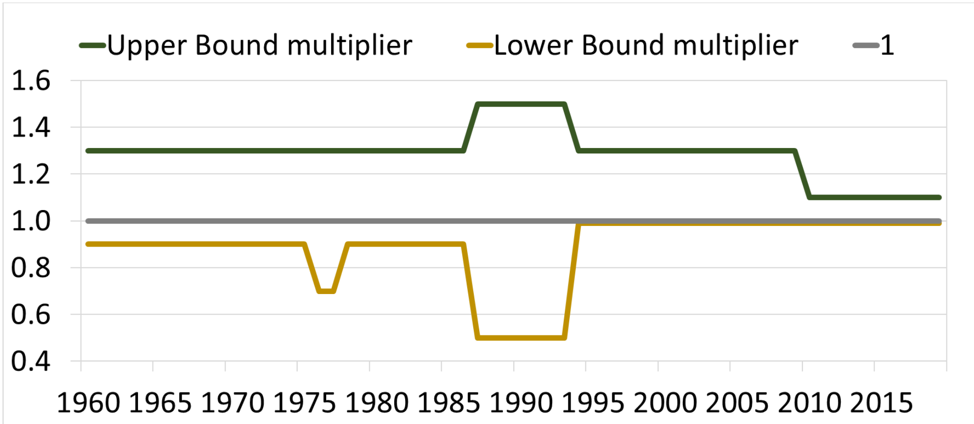

Figure 3: Landings bounds by year decided at the Framework meeting for 3Ps cod in October 2019.

Surveys

Canadian Research trawl Survey

Canadian research bottom **trawl surveys** have been conducted in Subdiv. 3Ps since 1972; however, surveys from 1972 to 1982 had poor coverage. The surveyed area was increased by 18% due to the addition of strata closer to shore in 1994 and 1997. The survey was not completed in 2006 due to mechanical issues with the research vessel. There was no survey during 2020 due to impacts of the COVID-19 pandemic.

Survey indices based on strata <550 m (<300 ftm) are presented for the expanded DFO research survey area since 1997 (inshore plus offshore; denoted by “All index strata”) as well as for the offshore only strata (“Offshore index strata”) in Figures 5 and 6. Any near-shore aggregations in April would not be measured by the DFO research survey. The majority of the area shoreward of the DFO research survey lies within inner and western Placentia Bay. There is no recent evidence that a large fraction of the stock is shoreward of the DFO research survey in April.

The **biomass index** from the offshore strata was variable but exhibited a downward trend from the mid-1980s to the early-1990s (Fig. 4). Values for most of the post-moratorium period from 1997 to 2004 were higher than those of the early-1990s, but not as high as those of the 1980s. Biomass estimates in recent years have generally been low, with nine of the last twelve years being below the 1997-2019 average. Survey catches in 2019 were generally low, with higher catches only in strata in the Halibut Channel, near Burgeo Bank and in Fortune Bay. Survey biomass from the expanded index (“All index strata”) showed similar trends to the offshore-only index.

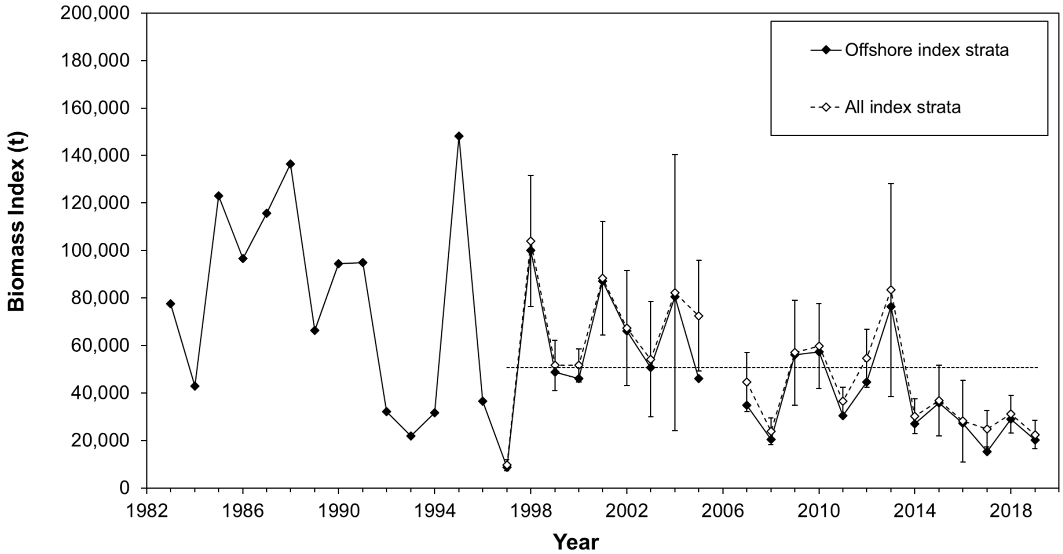

Figure 4: DFO research survey biomass indices (t). Error bars are ± one standard deviation for all index strata; dashed line is the time-series average of the all index survey.

The offshore DFO research survey abundance index is variable, but values during the 1990s were generally lower than those from the 1980s (Fig. 5). Abundance was low during the 2000s but somewhat higher over 2010-15, with four of the six years at or above average. In particular, the 2013 estimate was very high with a high measure of uncertainty. In 2019, abundance levels were below the 1997-2019 average, similar to those observed in 2018 and during the 2000s.

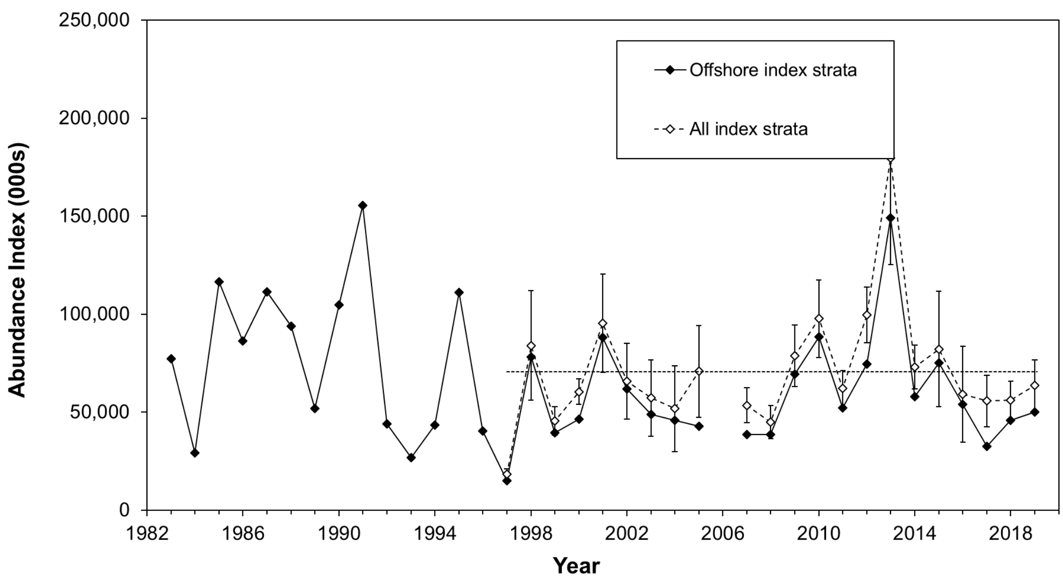

Figure 5: DFO research survey abundance indices. Error bars are ± one standard deviation for the combined survey; dashed line is the time-series average of combined survey index.

Age Composition

Catches during the 2019 DFO research survey consisted mainly of cod aged 2-4 (71% of abundance index). No strong year classes have been observed in the survey data since the 2011 cohort. The abundance of cod older than age 7 is relatively low.

France (ERHAPS) Research Vessel Survey

France conducted a bottom trawl research survey in Subdiv. 3Ps during February-March of 1978 to 1992 (Bishop et al. 1993). The vessel changed in 1992 and, since data from the two vessels could not be converted, the 1992 data were excluded from the assessment model. The ERHAPS survey used the same stratification scheme as the Canadian survey. However, only the offshore strata were sampled. A Lofoten otter trawl was used during daylight hours to conduct 30 minute tows and data for unsampled strata were estimated from a multiplicative model based on the results of the Canadian survey for the same strata.

GEAC Industry Survey

An industry-led bottom trawl survey was conducted from 1997 to 2005 and in 2007 (see McClintock 2011 and references therein). This survey also used the stratification scheme of the Canadian and French surveys but the 1997 and 2007 data were excluded from the model because of coverage and vessel issues. An Engel trawl was used, although it did not have a cod-end liner. Tows were 30 minute duration.

Sentinel Survey

Fixed-gear Sentinel surveys have been conducted at sites along the south coast of Newfoundland from St. Bride’s to Burgeo from 1995 through 2019. Gillnet results were primarily from sites in Placentia Bay whereas line-trawl results came mostly from sites west of the Burin Peninsula. The Sentinel survey for 2020 is still ongoing; hence, the data for 2020 are incomplete and not included in the modeling reported below.

The Sentinel survey data were standardized to remove site and seasonal effects to produce annual indices of the total and age-specific catch rates (Fig. 6).

The standardized total annual catch rate for gillnets was highest from 1995 to 1997, but progressively lower in 1998 and 1999, and remained quite low from 2000 to 2019 (Fig. 6, upper panel). Line-trawl catch rates were high in 1995 with a steady decline to 1999, but were subsequently fairly constant through 2009 (Fig. 6, lower panel). Between 2013 and 2018, values were the lowest in the time-series, but the 2019 index value was higher, due primarily to catches of relatively high numbers of older (ages 8-10) cod.

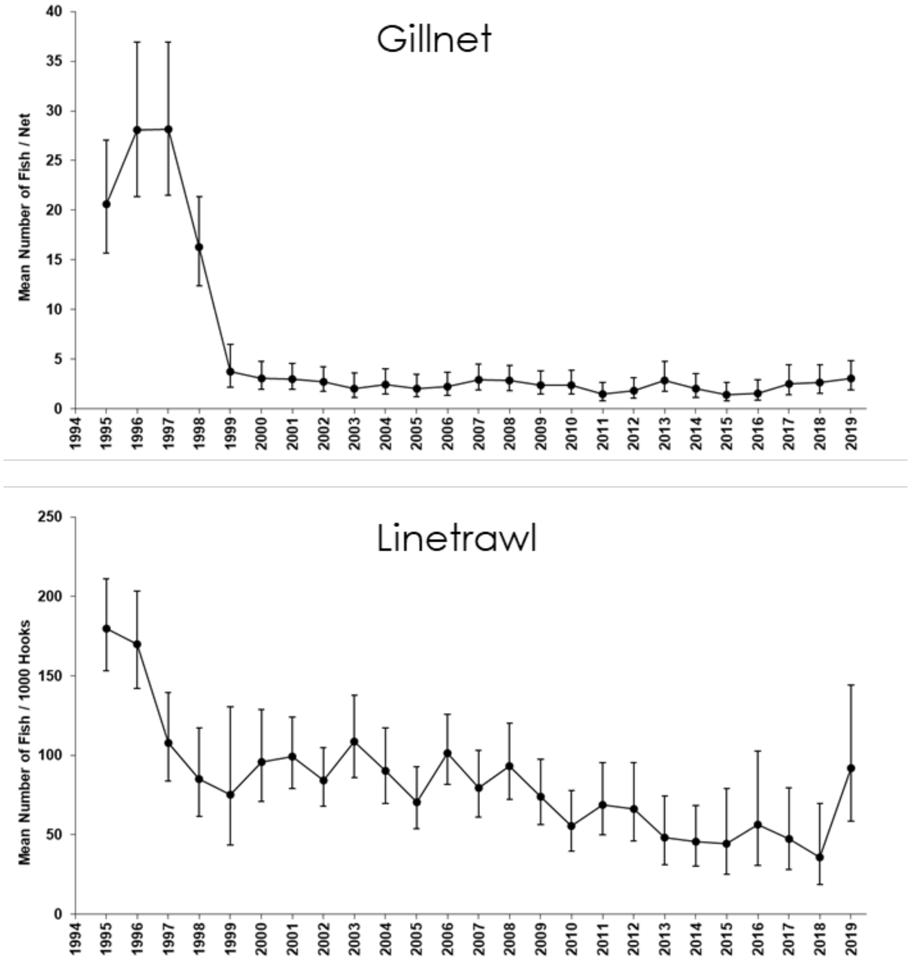

Figure 6: Standardized catch rates from the Sentinel survey using gillnets (upper panel) and line-trawls (lower panel).

The standardized age-specific catch rates for Sentinel gillnets and line-trawls showed similar trends with the relatively strong 1989 and 1990 year-classes replaced subsequently by weaker year-classes resulting in an overall decline in catch rates. Although the magnitude of the Sentinel catch rates was generally constant for more than a decade, the 1997 and 1998 year-classes were consistently evident in both age disaggregated Sentinel indices. In addition, the 2004 year-class appeared to be well-represented only within line-trawl results. Comparison of Sentinel catch rates and the DFO research survey index at times show inconsistent age compositions; these differences are not fully understood. As an example, the 2006 year-class ranked above average in the DFO survey, but did not appear particularly strong in either Sentinel index even though fish in this year-class were available to these gears. The 2011 year class, which appeared as the strongest in the DFO survey, appeared prominently in the 2019 Sentinel survey. The 2012 year-class also appeared strong in both the DFO survey and the 2019 line-trawl data from the Sentinel survey.

Spawning Biomass

Model results indicated that SSB for Subdiv. 3Ps cod declined from the beginning of the time-series in 1959 (195 kt) to values near the LRP (DFO 2009) by the mid-1970s (Fig. 7). Subsequently, SSB increased and was estimated to be approximately 100 kt over 1980 to 1988, but this period was followed by a continuous decline to a low of 40 kt in 1993. The SSB was below the LRP from 1991 to 1994 (Fig. 7). The SSB was stable at about 80 kt over 1995 to 1999. During the early 2000s, SSB was relatively stable, but at values that were just below the LRP. Since then, the SSB decreased further and SSB was 44% and 40% of the LRP in 2019 and 2020, respectively. With the projected catch of 2,702 t for calendar year 2020, the SSB at the beginning of 2021 will be 25 kt (38% of the LRP).

In the 2019 assessment, the estimate of SSB for January 1, 2020 was 16 kt (12-21 kt); in the 2020 assessment, this estimate was revised to 26 kt (20-35 kt). This is a large revision from 24% to 40% of the LRP in 2020 due in part to the rare event of missing the spring bottom trawl survey in 2020 coupled with increased interannual variation in the Sentinel line trawl index (Fig. 6). While this revision appears to be large and is outside of the 95% confidence intervals, it is important to note that these estimates were not exact and also based on different suites of data. Impacts of inter-annual variations in data inputs on future revisions of SSB estimates will be monitored. For the 2020 assessment, there were revisions to the 2019 landings and catch at age data in the 2020 assessment. Also, fish condition data from the Sentinel survey (2016, 2017, and 2019) were added to inform natural mortality, plus catch rates from the 2019 Sentinel survey were included. Line-trawl catch rates increased considerably between 2018 and 2019. The inclusion of these data in the model led to an upward revision of the status of the stock. Many more older fish were caught in the 2019 Sentinel line-trawl survey, which resulted in an update of the biomass of several year-classes in the stock. The 2018 Sentinel line-trawl indices were at time-series lows for ages 3 to 5, while the 2019 indices were comparatively much higher for several age-groups. Although this index covers only a small portion of the stock, it shows good internal consistency and for this reason, the model is sensitive to the Sentinel line-trawl index. Conversely, the DFO research survey covers most of the stock area, but has comparatively less internal consistency. A brief examination of the Sentinel data sets did not reveal any short-term changes in fishing patterns at different sites that would undermine the validity of using the Sentinel indices for 2019. The line-trawl series is particularly influential in the model and catch rates are known to be tempered by data from the DFO spring bottom trawl survey.

Revisions to recent SSB estimates were apparent in retrospective testing that compared the 2020 and 2019 assessments (assessment “retro”), but this is not indicative of model performance issues; the model “retro” was much smaller (5 kt revision for January 1, 2019) than the assessment retro (10 kt revision). The assessment retrospective pattern occurred because not all of the data were available to do the typical updates in the terminal and penultimate years of the model. The model uses both the DFO and the Sentinel Survey data to ascertain the current status of the stock, and information on landings and catch-at-age to determine the terminal year F. Annually, the assessment occurs during fall. At this time, all data from the DFO spring survey and preliminary landings are available for the terminal year, but catch at age estimates and the Sentinel data are unavailable because annual sampling is ongoing for both data series. Sentinel data for the penultimate year are updated, though. During future assessments with only partial updates of data, revisions of model estimates may be expected. In the next assessment, if new bottom trawl data from spring 2021 and Sentinel data from 2020 are added to the model, downward revisions of recent SSB estimates may occur.

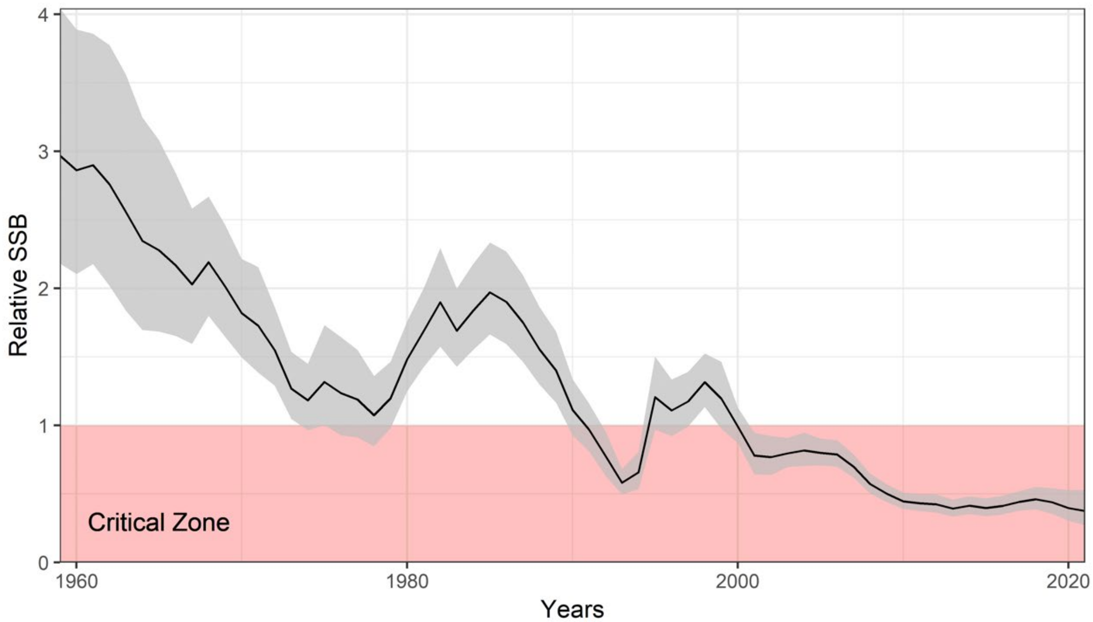

Figure 7: Estimates of SSB for the period 1959 to 2021, relative to the LRP (median estimate with 95% confidence interval). This reference point represents the boundary between the Critical and Cautious zones of DFO's Precautionary Approach framework.

Mortality Rates

The assessment model provides estimates of both fishing (F) and natural mortalities (M). The estimated fishing mortality rate for ages five to eight generally increased from 1959 (F=0.27) to the mid-1970s (peaked at 0.42 in 1975) leading up to the extension of jurisdiction in 1977, then declined rapidly to approximately 0.3 and remained at similar values until the mid-1980s. Then, fishing mortality estimates generally increased again until the moratorium in 1993. Average F was near zero (< 0.02) during the moratorium (1993-1997) when cod removals were only from bycatch. The estimated average fishing mortality rate for the dominant ages in the fishery (5 to 8) has generally declined from 0.16 in 2015 to 0.11 in 2019. With an assumed catch of 2,702 t for 2020, the F is projected to be 0.07 in 2020 (Fig. 8).

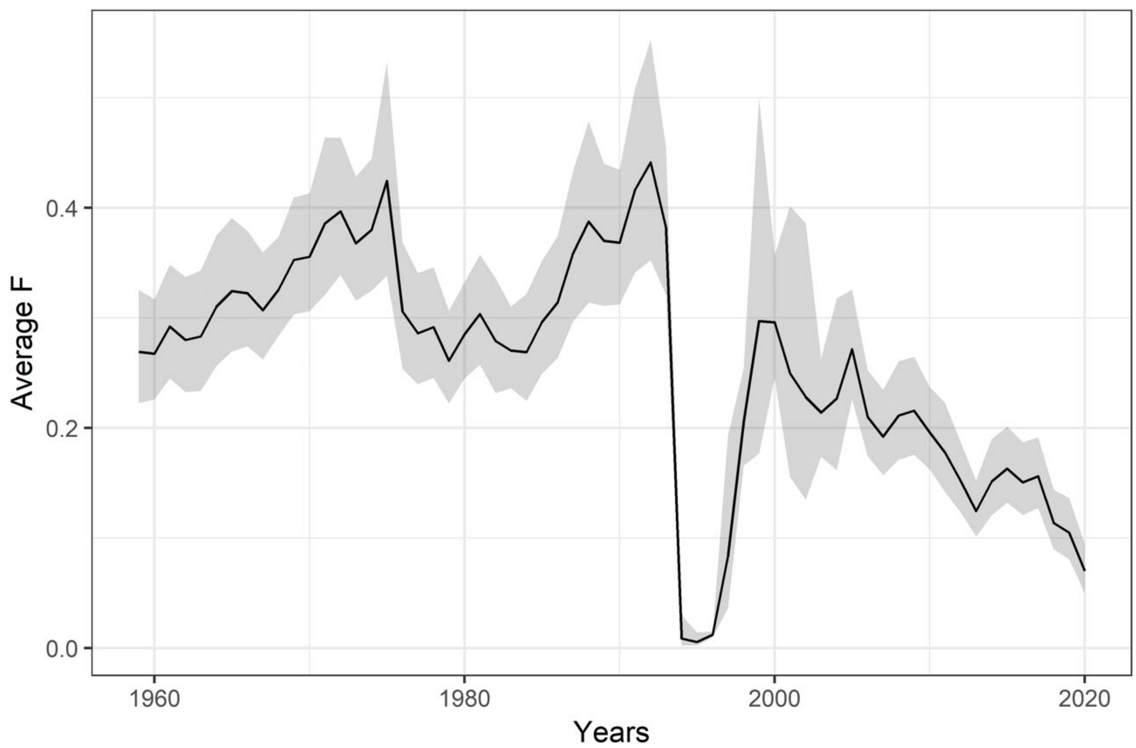

Figure 8: Average F (ages 5 to 8) estimates from 2020 assessment with 95% confidence interval.

Generally, natural mortality (M) was between 0.27 and 0.35 during the 1980 to 2010 period, but values subsequently increased considerably and the highest values in this time-series were observed during the last decade (Fig. 9). M was estimated to be 0.43 (0.35-0.52), for ages 5-8 in 2019, which corresponds to approximately 33 percent of the stock being removed annually by sources other than reported landings. Uncertainty in estimates of M was high, especially in recent years when M was above the long-term average.

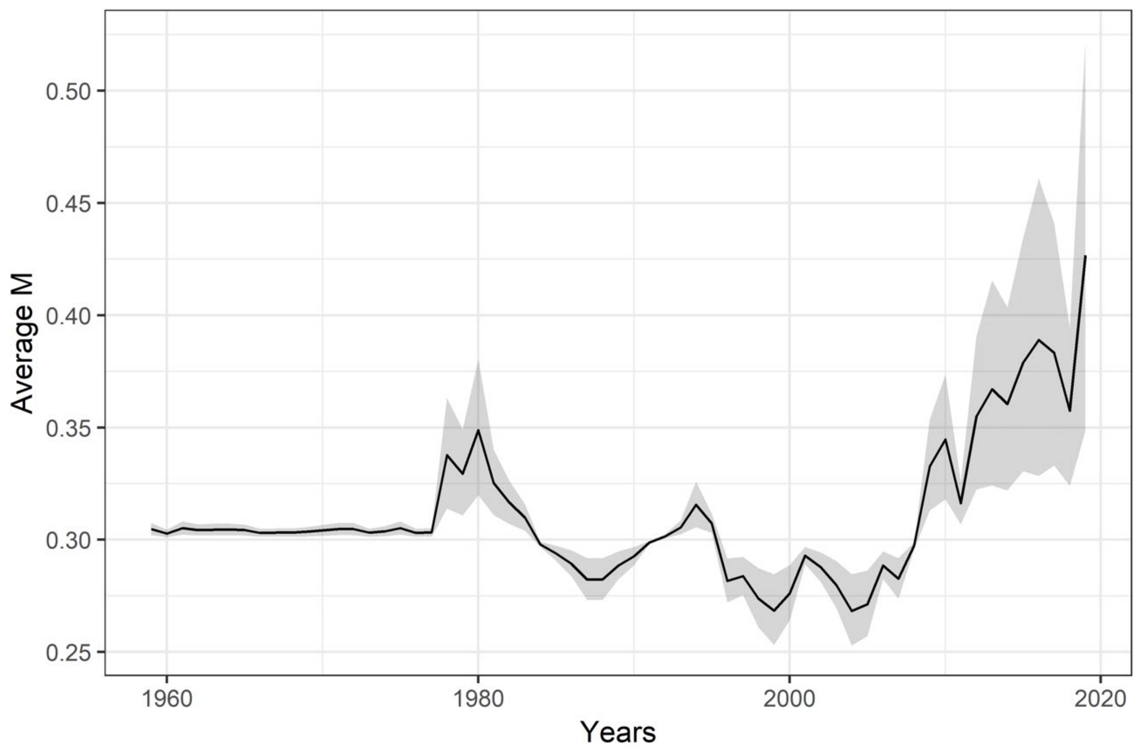

Figure 9: Average M (ages 5 to 8) estimates from 2020 assessment with 95% confidence interval.

Recruitment

Recruitment peaked in 1965-66 at approximately 200 million age two cod, then generally declined until the mid - to late 1970s when there were about 35 million age two fish in the population (Fig. 10). During most of the 1980s, recruitment varied between 70 and 150 million fish. From 1993 onward, recruitment was generally low at values around 25 to 45 million fish with particularly low values (8 to 9 million) in 2016-2017. Recruitment was estimated to have increased in the recent years, with values approaching 20 million in 2018 and 2019.

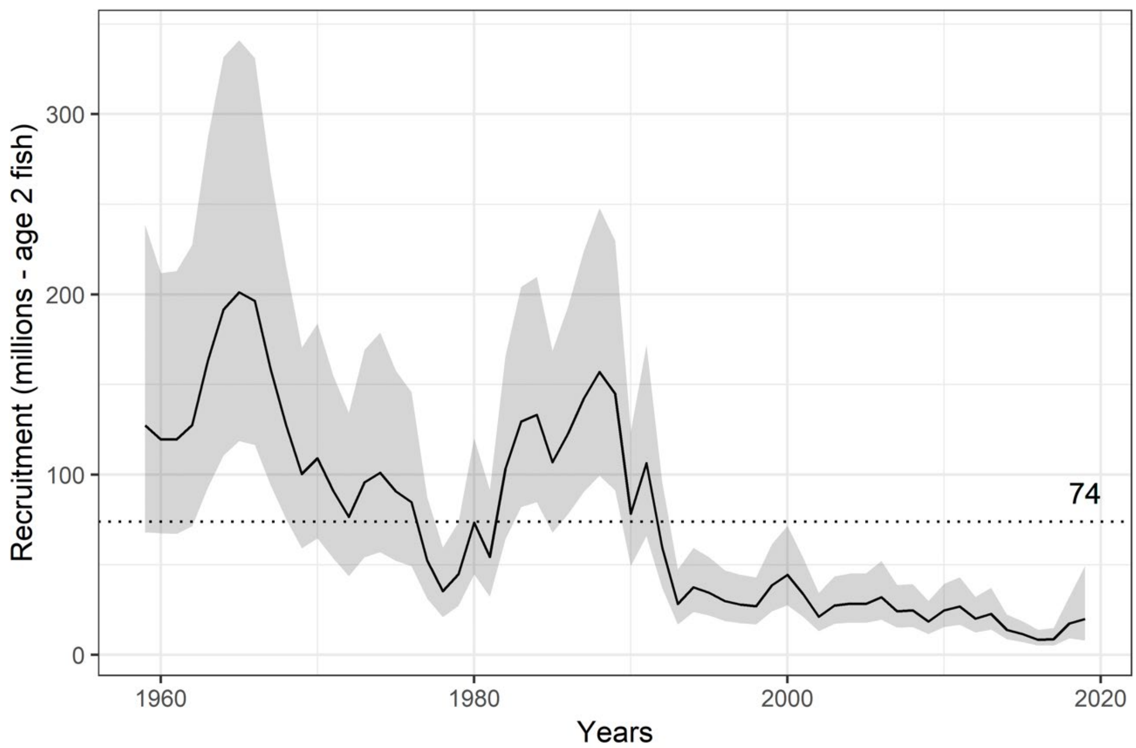

Figure 10: Estimated recruitment of age two Cod from the 2020 assessment (median estimate with 95% confidence interval). The dashed horizontal line is the time-series median.

Projection

Projection of the stock to 2023 was conducted assuming fishery removals to be within ±60% of current values, assuming a catch of 2,702 t for 2020, and with no catch. Under these scenarios, there is a high probability (>99%) that the stock will remain below the LRP between 2022 and the beginning of 2023 (Table 1). The probability of stock growth to 2023 increases as removals decrease; it is 58% in a scenario with status quo catch and 88% when there are no removals.

Table 1: Risk of projected SSB being below the LRP under 14 scenarios of catch removals (catch at status quo, ±10 to 60% status quo and no removals) over 2021-23. Status quo catch was assumed to be 2,702 t. B_y represents SSB in projection year.

Catch Multiplier	Projected Catch	Probability of growing out of the critical zone P(B_y>LRP)		Probability of growth from current levels P(By>projected B2021)	
		2022	2023	2022	2023
1.6	4323	<0.1%	<0.1%	40%	39%
1.5	4053	<0.1%	<0.1%	43%	42%
1.4	3783	<0.1%	<0.1%	44%	45%
1.3	3513	<0.1%	<0.1%	47%	49%
1.2	3242	<0.1%	<0.1%	49%	52%
1.1	2972	<0.1%	<0.1%	51%	55%
1	2702	<0.1%	<0.1%	53%	58%
0.9	2432	<0.1%	<0.1%	55%	62%
0.8	2162	<0.1%	<0.1%	57%	65%
0.7	1891	<0.1%	<0.1%	59%	67%
0.6	1621	<0.1%	<0.1%	62%	72%
0.5	1351	<0.1%	<0.1%	65%	75%
0.4	1081	<0.1%	<0.1%	66%	78%
0.001	*	<0.1%	<0.1%	75%	88%

Other Data Sources

In addition to DFO research surveys, other sources of information were considered in this assessment to provide perspectives on stock status. These sources of information included data from science logbooks for vessels less than 35 feet (1997-2019), logbooks from vessels greater than 35 feet (1998-2019), and at-sea fishery observer sampling. Information from tagging experiments in Placentia Bay (and more recently in Fortune Bay), were also available. Any differences in trends between these additional data sources and the DFO survey are difficult to reconcile, but attributed to differences in survey/project design, seasonal changes in stock distribution, differing selectivity of various gear types, or the degree to which various data sources track only certain subareas/components versus the entire distribution of the stock.

Logbooks

There is considerable uncertainty in the interpretation of fishery catch rate data. These data may be more reflective of changes in fishery performance or the nature of the fishery rather than differences in population size.

Logbooks for <35’ Vessels

Standardized annual catch rates from science logbooks for Canadian vessels (<35’ sector) fishing fixed gillnets showed a declining trend over 1998-2000, and subsequently were fairly constant near the time series average until 2019, when the lowest catch rates in the time-series were reported (Fig. 11, upper panel). Line-trawl catch rates showed a very different pattern with a greater degree of variation (Fig. 11, lower panel). After peaking in 2006, line-trawl catch rates generally declined to near the time-series average in 2009 and remained at similar levels up to 2015. Catch rates for line trawls during 2016 to 2019 were the lowest in the time series, albeit based on very low reporting rates (<40 logbooks annually) with no logbooks returned from some areas. In addition, the commercial catch rate index was based on weight of fish caught, whereas the Sentinel index was based on numbers. As with the Sentinel results, there was contrast between the two gear-types in catch rates relative to the time-series average over time. However, catch per unit effort (CPUE) was well below the time-series averages for both gillnets (27% below) and line-trawls (40% below) in 2019.

The percentage of the catch from the <35' fleet that is accounted for in standardized logbook indices has declined over time and in 2019 represented less than 30% of the catch as compared to approximately 70% at the start of the time-series in 1997. This likely affects the quality and comparability of this index over time, such that it is unclear if the CPUE trends reflect the fishery as a whole.

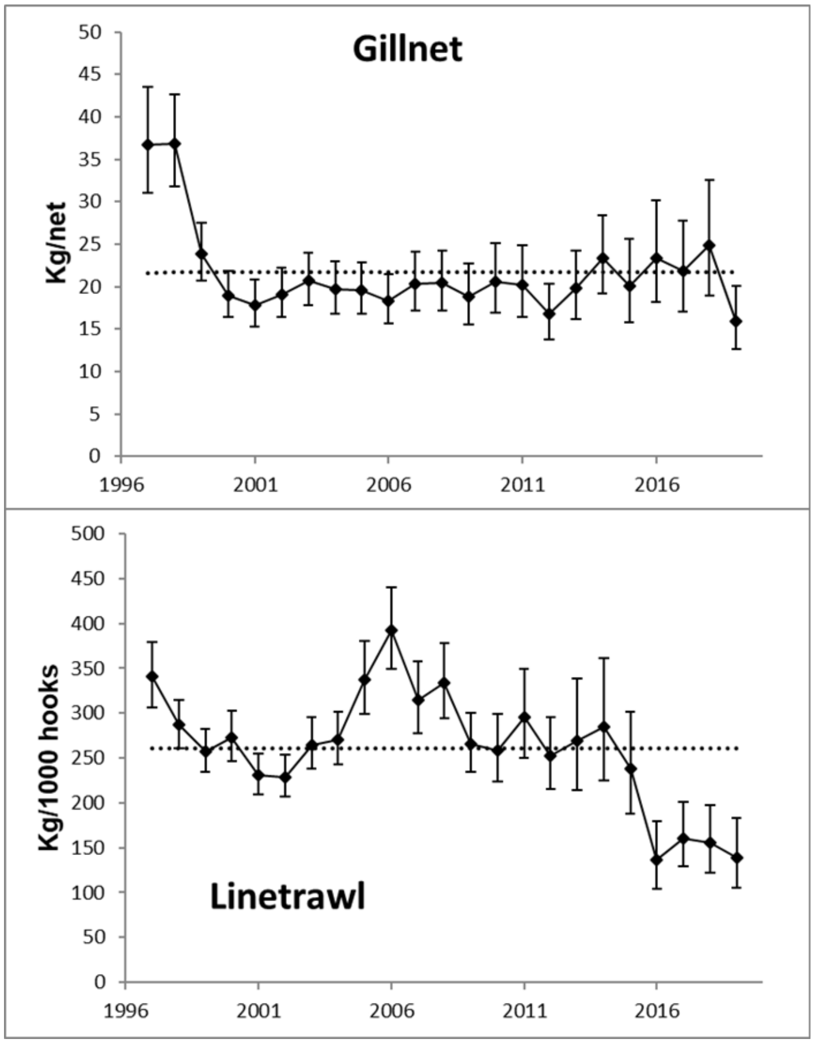

Figure 11: Standardized catch rates for gillnets (upper panel) and line-trawls (lower panel) derived from logbook data for vessels less than 35 feet. Error bars are 95% confidence intervals; dashed lines represent the time-series average.

Logbooks for >35' Vessels

Catch rates for gillnets from vessels >35' were standardized to account for spatial and seasonal effects. For these vessels, standardized annual catch rates (Fig. 12) were higher in magnitude than those from vessels <35' (Fig. 11), but the general pattern was similar up to 2017. Both time-series showed an initial decline over 1998 to 2000 followed by fairly constant catch rates to 2017. In 2018, catch rates for gillnets from vessels >35' were the third highest in the time-series, but only a modest increase was estimated for the <35' fleet. In 2019, catch rates for the >35' fleet were lower, similar to those reported during 2000 to 2017. Over the last decade, approximately two thirds of the reported landings from vessels >35' were accounted for by the standardized gillnet index, which is slightly higher than earlier in the series when less than 50% coverage occurred frequently. Further analyses are required to develop a standardized catch rate index for line-trawls fished by vessels >35'.

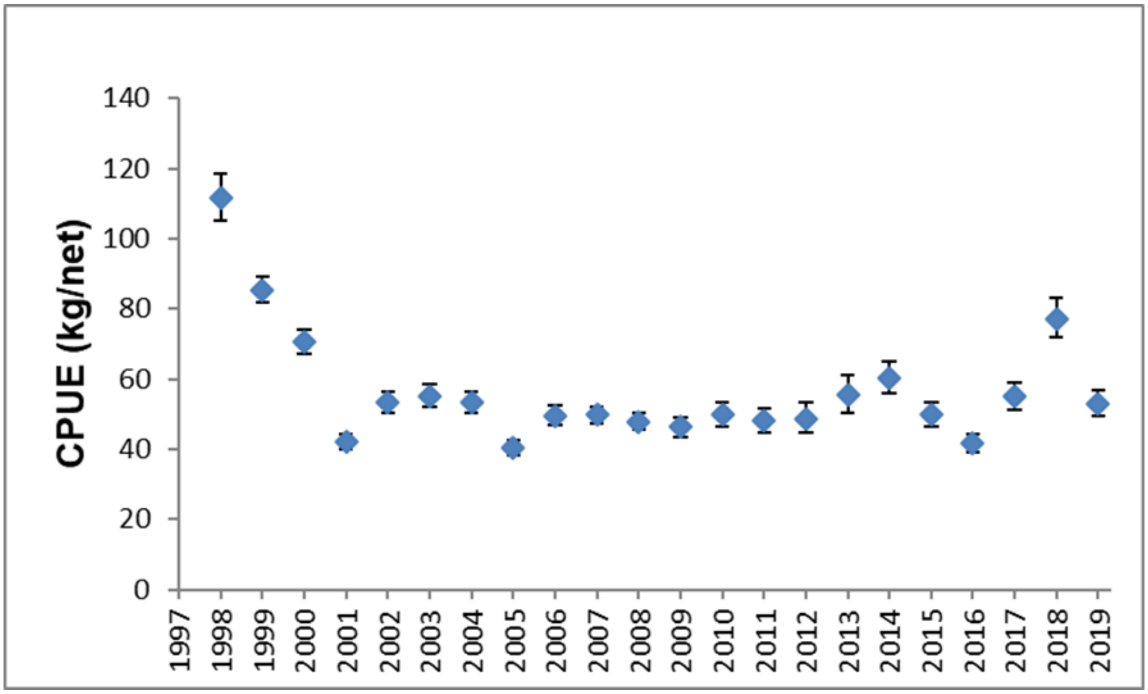

Figure 12: Standardized catch rates for gillnets derived from logbook data for vessels greater than 35 feet. Error bars are 95% confidence intervals.

Observer sampling

Data collected at sea by fisheries observers on Canadian vessels fishing for cod (1997-2019) were analyzed to calculate a standardized catch rate index for gillnets. There were substantial variations in observer coverage over time and among unit areas, as well as by fishing fleet. Although the proportion of the landings observed was low (<3%) for most years and areas, catch rates from gillnets show a pattern similar to those from logbooks and Sentinel surveys with initial declines over 1998-99, then rates remain relatively flat until 2017. Catch rates derived from the observer sampling increased to a time-series high in 2018. Catch rates during 2019 were lower, similar to those observed during 2016-17. Data on line-trawl effort were not available in time for the assessment. There was insufficient data from otter trawl to develop a standardized index.

Tagging

The geographical coverage of cod tagging since 2007 was largely limited to areas of Fortune Bay and Placentia Bay, which causes some uncertainty as to how results from these inshore areas relate to the stock as a whole. The number of cod tagged has varied annually and by area; tagging was conducted annually in 3Psc (Placentia Bay) during 2007 to 2015 plus 2017 and 2020; in 3Psb (Fortune Bay) during 2012 to 2018 plus 2007 and 2020; and in 3Psa only during 2007, 2013, and 2019. Although exploitation rates based on cod tagging in these inshore areas may not be applicable to other areas, or to the whole stock, these inshore regions accounted for a significant portion (~50%) of the overall annual landings from the stock. Dedicated efforts were made in 2019 to expand the areas where cod were tagged, and tagging was conducted in all three inshore areas in that year (3Psa, 3Psb, 3Psc).

The general pattern of cod tag returns remained unchanged with most of the fish tagged in Subdiv. 3Ps being harvested in Subdiv. 3Ps. Recent tagging suggested that exploitation of Subdiv. 3Ps cod in neighboring stock areas (Div. 3KL) is minimal and not a major issue for management. No new information was available to evaluate mixing in the western portion of the stock (Subdiv. 3Pn or Div. 4R). The timing of tagging experiments with respect to the annual commercial fishery complicated the analysis aimed at developing exploitation rates, although work is underway to try to address these complications.

In 2018, part of an array of acoustic receivers was placed in upper Placentia Bay. In 2019, this array was expanded to all waters leading to the upper reaches of Placentia Bay. In 2019, 65 cod were implanted with acoustic tags in upper Placentia Bay, and 43 of these fish have been detected by those receivers since then. This telemetry information will help to determine the timing and movements of cod that use Placentia Bay and nearby areas.

A comparison of tag returns from recreational fishers as compared to commercial harvesters indicated that removals by the recreational harvest in Subdiv. 3Ps comprised a relatively small component of the total removals in that Subdivision.

Landings

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

Management Year	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21*,**
TAC***	11.5	11.5	11.5	13.225	13.49	13.043	6.5	5.98	5.98	2.691
Canada	5.2	4.0	4.6	5.8	5.9	5.2	4.9	4.5	3.3	0.9
France	1.1	0.8	1.4	1.6	0.9	1.1	0.2	0.2	0.2	
Totals	6.3	4.8	6.0	7.3	6.8	6.3	5.0	4.7	3.5	0.9

* Provisional.
** Approximate landings to 2 October, 2020.
*** TAC is shared between Canada (84.4%) and France (St. Pierre et Miquelon; 15.6%).

Reported combined landings by Canada and France were substantially below the TAC from the 2009-10 season to 2016-17, but during the 2017-18 and 2018-19 seasons, approximately three quarters (77% and 79%, respectively) of the 5,980 t TAC was landed (Table 2). Prior to 2009-10, the TAC had been almost fully subscribed with the exception of the initial four years of TAC regulation. Industry participants have indicated multiple reasons that contributed to the recent reductions in landings, including reduced cod availability and economic factors. Of the 3,499 t landed during the 2019-20 season, 3,310 t was taken by Canada (including 14 t from Sentinel Surveys), and 189 t was landed by France.

Provisional data indicate that landings in the ongoing 2020-21 management year were 930 t as of October 2, 2020. Although incomplete, these landings to date are about 55% lower than those reported during the same period in 2019-20, but it should be noted that the TAC in 2019-20 was higher, at 5,980 t, and a number of management measures changed between fishing seasons.

During the 2019-20 season, >80% of the total landings were taken by fixed gears (dominated by gillnet) with the remainder taken by the otter trawl fleet.

To estimate landings for 2020, reported landings between January 1 and October 2, 2020 were combined with reported landings from the previous (2019) October to December period plus

2019 landings from the Maritimes and France. This estimate (2,702 t) was used in projection scenarios.

Sources of Uncertainty

Advice for the upcoming fishing season was based on a one year projection to January 1, 2021, which added uncertainty to the assessment results. Typically, model estimates rather than projections are available for January 1 of the upcoming fishing season. Although the assessment model performs well in retrospective testing, model projections require assumptions about future biological states, which were estimated to be similar to recent observations (three year averages) in projection scenarios. If future conditions vary greatly from these assumptions, results will differ. Uncertainty was also increased by the lack of bottom trawl data from the DFO spring 2020 research survey, which was cancelled due to the global pandemic. This data series is known to interact with Sentinel line-trawl data within the model, thus model results can be affected greatly by the already influential line-trawl data when research survey data are not available. Upward revisions to recent (e.g., January 1, 2020) SSB estimates in the current assessment were evidence of the impact of adding one, but not the other data series to the model in the terminal year. Preliminary data suggested that adequate sampling was conducted by the Sentinel program during 2020, which should be available for the 2021 assessment. Therefore, the addition of data from the spring 2021 research survey and the 2020 Sentinel sampling to the assessment next year could potentially revise the recent SSB estimates.

The accepted population model for the stock includes Sentinel data, but the model under-estimated the index for the young ages in the Canadian survey in the post-2010 period. However, the model fits well to all other ages (6-14+) in the Canadian research survey and all ages in other surveys plus the catch at age. Model performance is greatly reduced when the Sentinel data are excluded as evidenced by strong retrospective patterns over the past five years. This issue requires further research in the context of gaining a better understanding of how data from the various sources interact within the model.

Although the DFO research survey of Subdiv. 3Ps includes coverage of 45 index strata, the majority of the survey indices for cod are typically influenced by catches from only a small number of those strata. High estimates in some of these strata are a result of a single large survey tow in particular years. For example, a large survey tow in stratum 309 on Burgeo Bank in 2016 had a major influence on survey indices (e.g., 60% of the biomass index). The presence of single large survey tows caused increased uncertainty in the DFO survey data which is not accounted for in the assessment model.

Survey indices are at times influenced by “year-effects”, an atypical survey result that can be caused by a number of factors (e.g., environmental conditions, movement, degree of aggregation) which may be unrelated to absolute stock size. There are strong indications that the 2013 survey may have been influenced by a year-effect that resulted in a large spike in the survey indices for that year. The 2013 RV survey estimated that the abundance of multiple cohorts increased compared to observations of these same cohorts at one age younger in 2012. Since the number of fish in a cohort cannot increase after it is fully recruited to the survey gear (without immigration), such results are usually considered clear evidence for a year-effect. Year-effects in the survey data have the potential to mask trends in the data for several years and contribute to retrospective patterns.

Burgeo Bank is a known seasonal mixing area for cod from Subdiv. 3Ps and from the northern Gulf of St. Lawrence (nGSL). The start of the DFO research survey was moved to April in 1993 in order to minimize the impact of migratory nGSL fish on the assessment of Subdiv. 3Ps cod. However, at least one published study suggests that a non-trivial portion of cod in the Burgeo

Bank area in April is of nGSL origin (Méthot et al. 2005). The potential presence of non-3Ps cod in this area at the time of the DFO survey, combined with the fact that a large portion of survey indices have come from the Burgeo Bank area in recent years, suggests the potential for overestimation of survey results.

CONCLUSIONS AND ADVICE

The Subdiv. 3Ps Atlantic Cod stock was assessed using an integrated state-space model, which incorporates landings and catch at age (1959-2019), time-varying natural mortality informed by trends in cod condition, and includes abundance indices from research surveys using bottom trawls conducted by Canada (1983-2005, 2007-19), France (1978-1991), industry (GEAC, 1998-2005), and standardized catch rate indices from the Sentinel gillnet and line-trawl surveys (1995-2019). There was no 2020 Canadian bottom trawl survey due to the global pandemic. SSB at January 1 2021 is projected to be 25 kt (18 kt - 35 kt) with an assumed catch of 2,702 t in 2020. The stock is in the Critical Zone, at 38% of the LRP (27-53%) as defined by the DFO PA Framework (DFO 2009). The probability of being below the LRP is >99.9%. The stock has been below the LRP since the early-2000s. The estimated fishing mortality rate (ages 5-8) declined from 0.16 in 2015 to 0.11 in 2019. With an assumed catch of 2,702 t in 2020, F is projected to be 0.07 (0.05-0.09) in 2020. Natural mortality for ages 5-8 has increased during the last decade, reaching 0.43 (0.35-0.52) in 2019. Recruitment (age 2) estimates up to 2019, have been below the long term average since the mid-1990s. Projection of the stock to 2023 was conducted assuming fishery removals to be within +/- 60% of an assumed catch of 2,702 t for 2020 and with no catch. Under these scenarios, there is a >99% probability that the stock will remain below the LRP between 2021 and the beginning of 2023. The probability of stock growth to 2023 ranges between 39% and 78% across catch scenarios (+/- 60% of current levels), and is 88% when there are no removals. Natural mortality plays an important role in projections for this stock. If natural mortality rates are appreciably different from those used, projected outcomes will differ from values reported above. Bottom temperatures in Subdiv. 3Ps remained above normal between 2009 and 2019, but no data were available for 2020. No zooplankton data were available for 2019 and 2020. Satellite imagery indicates that the timing and magnitude of the spring phytoplankton bloom were normal in 2020, after two consecutive years of early onset and above-normal production. Ongoing warming trends, together with an increased dominance of warm water fishes, indicate that this ecosystem continues to experience structural changes. Reduced condition is indicative of diminished productivity in 3Ps cod. Consistency with the DFO PA Framework (DFO 2009) requires that removals from all sources must be kept at the lowest possible level until the stock clears the Critical Zone.

OTHER CONSIDERATIONS

Management Considerations

A seasonal closure of the entire Subdiv. 3Ps stock area (typically March to mid-May) occurs annually and is intended to minimize fishing on spawning aggregations. Some harvesters have suggested that the timing of spawning has been delayed in recent years and that the timing of the closure may therefore no longer be appropriate. In 2015 and 2016, samples collected from the Halibut Channel area (in southern 3Ps) by industry (March) and from the DFO research survey (April) indicated that spawning in this area began in April. No spawning was observed in March but egg sizes suggested that at least some cod were nearing spawning at the time of capture. The original recommendation for the Subdiv. 3Ps spawning closure came with the suggestion that spawning in this stock occurs during April-June but with the acknowledgement that “spawning ground behavior typically begins in March” (FRCC 2001). Hence, the recommended (and subsequently adopted) closure time of March 1-June 30 was presumably intended to protect not only spawning but also pre-spawning aggregations. If the objective of the Subdiv. 3Ps closure is still to protect spawning and pre-spawning aggregations, then the starting date of the closure is likely still appropriate. It should be noted, however, that the current closure end date of mid-May almost certainly does not protect the full spawning period of this stock.

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SOURCES OF INFORMATION

This Science Advisory Report is from the November 2-6, 2020 regional advisory meeting on the Assessment of Northwest Atlantic Fisheries Organization (NAFO) Subdivision 3Ps Atlantic Cod. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

[1] Erratum: September 2023. Joel Vigneau's affiliation was corrected to "IFREMER" from "IFREMER-NL-GIDC-DFO Science".

Bishop, C. A., E. F. Murphy, and M. B. Davis 1993. An assessment in 1993 of the cod stock in NAFO Subdivision 3Ps. DFO Atl. Fish. Res. Doc. 93/70.

DFO 2009. A Fishery Decision-Making Framework Incorporating the Precautionary Approach.

FRCC. 2001. Conservation requirements for groundfish stocks in sub-areas 0, 2 + 3. Ottawa, Canada. 39 p.

McClintock, J. 2011. The fall 2007 NAFI Subdivision 3Ps GEAC survey: catch results for Atlantic cod (*Gadus morhua*), American plaice (*Hippoglossoides platessoides* F.), Witch flounder (*Glyptocephalus cynoglossus* L.), and Haddock (*Melanogrammus aeglefinus*). DFO Can. Sci. Advis. Sec. Res. Doc. 2010/056.

Méthot, R., M. Castonguay, Y. Lambert, C. Audet, and S. Campana. 2005. Spatio-temporal Distribution of Spawning and Stock Mixing of Atlantic Cod from the Northern Gulf of St. Lawrence and Southern Newfoundland Stocks on Burgeo Bank as Revealed by Maturity and Trace Elements of Otoliths. J. Northw. Atl. Fish. Sci. 36: 1–12.

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