Fisheries and Oceans Canada | Pêches et Océans Canada

Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat (CSAS)

Research Document 2024/002

Newfoundland and Labrador Region

Assessing the Status of the Cod (*Gadus morhua*) Stock in NAFO Subdivision 3Ps in 2019

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January 2024

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

ISSN 1919-5044
ISBN 978-0-660-69194-7 Cat. No. Fs70-5/2024-002E-PDF

Correct citation for this publication:

Ings, D.W., Varkey, D., Babyn, J., Regular, P.R., Champagnat, J., Kumar, R., Morgan, M.J., Healey, B.P., Rideout, R.M., and Vigneau, J. 2024. Assessing the Status of the Cod (*Gadus morhua*) Stock in NAFO Subdivision 3Ps in 2019. DFO Can. Sci. Advis. Sec. Res. Doc. 2024/002. v + 116 p.

Aussi disponible en français :

*Ings, D.W., Varkey, D., Babyn, J., Regular, P.R., Champagnat, J., Kumar, R., Morgan, M.J., Healey, B.P., Rideout, R.M., et Vigneau, J. 2024. Évaluation de l'état du stock de morue franche (*Gadus morhua*) de la sous-division 3Ps de l'OPANO en 2019. Secr. can. des avis sci. du MPO. Doc. de rech. 2024/002. v + 123 p.*

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ABSTRACT

The status of the Atlantic Cod (*Gadus morhua*) stock in the Northwest Atlantic Fisheries Organization (NAFO) Subdivision 3Ps was assessed during a Fisheries and Oceans Canada (DFO) Regional Peer Review Process meeting held November 19–22, 2019.

Total landings for the 2018–19 management year (April 1–March 31) were 4,742 t or 79% of the Total Allowable Catch (TAC).

Survey abundance and biomass estimates from the DFO research vessel (RV) spring survey were below average during 2016 to 2019. Sentinel gillnet catch rates have been very low and stable since 1999. Sentinel line-trawl catch rates have been below average for the past eight years and the 2018 catch rate was the lowest in the time-series.

A new integrated state space model resulting from the 2019 3Ps Cod Framework was used to assess the status of the stock and estimate fishing mortality.

A new biomass limit reference point (LRP) was determined for the stock based on the relationship between spawning stock biomass (SSB) and recruitment estimated from the model. The LRP is 66,000 t of SSB. Using the new assessment model, SSB at January 1, 2020, is estimated to be 16 kt (12 kt–21 kt). The stock is in the Critical Zone (24% of B_{lim} [18–32%]) as defined by the DFO Precautionary Approach (PA) Framework. The probability of being below B_{lim} is >99.9%. The estimated fishing mortality rate (ages 5–8) has ranged between 0.12 and 0.21 since 2010 and in 2019 was 0.21 (0.15–0.30), with an assumed catch of 4,453 t. Natural mortality was estimated to be 0.49 (0.41–0.58) (ages 5–8) in 2019. Values during the last four years are the highest in the time series. Recruitment (age 2) estimates have been below the long-term average since the mid-1990’s. Projection of the stock to 2022 was conducted assuming fishery removals to be within +/-30% of current levels, assuming a catch of 4,453 t for 2019, and with no catch. Under these scenarios, there is a probability >99% that the stock will remain below B_{lim} between 2020 and the beginning of 2022. The probability of stock growth to 2022 from 2019 is less than 1% or less across catch scenarios (+/-30% of current levels) and is 16% 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 3Ps remain above normal, and the spring bloom continues to be reduced in magnitude. Zooplankton biomass in 3Ps was near normal in 2017 and 2018 after four years of low production, with an increased proportion of smaller species. Data were unavailable from 2019. Ongoing warming trends, together with an increased dominance of warm water fishes, indicate that this ecosystem continues to experience structural changes. Reduced growth and condition indicate that cod productivity in 3Ps is reduced.

INTRODUCTION

This document gives an account of the 2019 assessment of the Atlantic Cod (*Gadus morhua*) stock in NAFO Subdivision (Subdiv.) 3Ps, located off the south coast of Newfoundland, Canada (Figures 1 and 2). The French overseas territory of St. Pierre et Miquelon also lies within the boundaries of NAFO Subdiv. 3Ps and only Canada and France have fished in this area since the extension of jurisdiction by each country to 200 miles in the late-1970s. The stock is jointly managed by Canada and France through formal agreements.

A Regional Peer Review Process meeting was conducted during November 2019 (DFO 2019) with participation from DFO scientists, IFREMER (Institut français de recherche pour l'exploitation de la mer), DFO Fisheries Management, academia, the Canadian fishing industry, non-governmental organizations, and the province of Newfoundland and Labrador (NL).

Various sources of information on 3Ps cod were available to update the status of this stock. Commercial landings through October 2019 were presented. The results of the 2019 DFO RV survey were reviewed in detail and compared to previous survey results. A new population model was used for the first time. In addition to the scientific data from Canadian RV surveys that were used in the 2018 assessment of the stock, the new model incorporated additional survey data: the French RV survey, the industry association GEAC survey, and the Sentinel survey. The complete series of survey data used in the model are bottom trawl surveys (Canada, 1983–2019; France, 1978–92; GEAC 1997–2007), the Sentinel Survey (1995–2018) utilizing gillnets and line-trawls near the coast and landings data. This model also incorporates uncertainty in the commercial landings and natural mortality estimates are informed by a modeled index of cod condition. Similar to the previous model used for providing advice for the stock, the new model provides estimates of biomass, and recruitment for the stock. However, an advantage of the new model is its ability to estimate fishing and natural mortality. Additional sources of information presented included data from the Science logbooks for vessels less than 35 feet (1997–2018), logbooks from vessels greater than 35 feet (1998–2018) and observer sampling. Information from tagging experiments in Placentia Bay (and more recently Fortune Bay), were also available.

ASSESSMENT

TOTAL ALLOWABLE CATCHES AND COMMERCIAL CATCH

Total Allowable Catch

The cod stock in Subdiv. 3Ps was subject to a moratorium on all fishing from August 1993 to the end of 1996. Excluding these years, the TAC has varied considerably over time, ranging from 70,500 t in 1973, the initial year of TAC regulation, to 5,980 t in the ongoing 2019/20 season (Figure 3a). Beginning in 2000, TACs have been established for seasons beginning April 1 and ending March 31 of the following year (during January–March 2000, an interim TAC was set to facilitate this change). The TAC was set at 11,500 t for five consecutive management years (2009/10–2013/14) and was subsequently increased to 13,225 t for the 2014/15 management year. In 2015/16, Canada adopted a Conservation Plan and Rebuilding Strategy (CPRS) for 3Ps cod that included a harvest control rule (HCR) for suggesting the TAC level for the upcoming year. In 2015/16 and 2016/17, this rule suggested TACs of 13,490 t and 13,043 t respectively, and Canada and France agreed to accept these TAC values. In 2017/18 and subsequent seasons it was not considered prudent to provide management advice based on the HCR. Canada and France agreed on TACs of 6,500 t for the 2017/18 season and 5,980 t for both the 2018/19 and 2019/2020 seasons. Under the terms of the 1994 Canada-France agreement, the Canadian and French shares of the TAC are 84.4% and 15.6%, respectively.

Commercial Catch

Prior to the moratorium, Canadian landings for vessels <35 ft (see “Can-NL fixed” in Table 1) were estimated mainly from purchase slip records collected and interpreted by Statistics Division, DFO. Shelton et al. (1996) emphasized that these data may be unreliable. Post moratorium landings for Canadian vessels <35 ft come mainly from a dock side monitoring program initiated in 1997. Landings for Canadian vessels >35 ft come from logbooks. Non-Canadian landings (only France since 1977) were compiled from national catch statistics reported by individual countries to NAFO. In recent years, French landings have been provided directly by French government officials.

Cod in the 3Ps management unit were heavily exploited in the 1960s and early 1970s by non-Canadian fleets, mainly from Spain and Portugal, with reported landings peaking at about 87,000 t in 1961 (Figure 3a). After extension of Canadian jurisdiction in 1977, cod catches averaged between 30,000 t and 40,000 t until the mid-1980s when increased fishing effort by France led to increased total reported landings, with catches increasing to about 59,000 t in 1987. Subsequently, reported catches declined gradually to 36,000 t in 1992. Catches exceeded the TAC throughout the 1980s and into the 1990s. The Canada France boundary dispute at this time led to fluctuations in the French catch during the late 1980s. Under advice from the Fisheries Resource Conservation Council, a moratorium was imposed on all directed cod fishing in August 1993 after only 15,216 t had been landed. Access by French vessels to Canadian waters was restricted in 1993.

Since 1997, most of the TAC has been landed by Canadian inshore fixed gear fishermen (where inshore is typically defined as unit areas 3Psa, 3Psb, and 3Psc; refer to Figure 1), with remaining catch taken mainly by the mobile gear sector fishing the offshore, i.e., unit areas 3Psd, 3Pse, 3Psf, 3Psg, and 3Psh (Table 1, Figures 3a, and 3b).

Line trawl (i.e., longline) catches dominated the fixed gear landings over the period 1977–93, reaching a peak of over 20,000 t in 1981 and typically accounting for 40–50% of the annual total for fixed gear (Table 2, Figure 4). In the post moratorium period, line trawls have accounted for 7–26% of the fixed gear landings. Gillnet landings increased steadily from about 2,300 t in 1978 to a peak of over 9,000 t in 1987 and remained relatively stable until the moratorium. Gillnets have been the dominant gear used for the inshore catch since the fishery reopened in 1997, with gillnet landings exceeding 50% of the TAC for the first time in 1998. Gillnets have typically accounted for 70–80% of the fixed gear landings since 1998. Gillnets accounted for a lower percentage of the fixed gear landings in 2001 (60%), partly due to a temporary management restriction in their use that was removed part way through the fishery following extensive complaints from industry. Gillnets have also been used extensively in offshore areas in the post moratorium period. Cod trap landings from 1975 until the moratorium varied considerably, ranging from approximately 1,000–7,000 t. Since 1998, trap landings have been reduced to negligible amounts (<120 t). Hand line catches were a small component of the inshore fixed gear fishery prior to the moratorium (about 10–20%) and accounted for about 6% of landings on average for the post moratorium period. However, hand line catch for 2001 showed a substantial increase (to 17% of total fixed gear) and this may reflect the temporary restriction in use of gillnets described above. Increases in the proportion of hand-line catch in some years (e.g., 2009, 2013) are likely due to buyers paying a higher price for hook-caught fish than for gillnet landings.

The 2013–14 (April 1 to March 31) conservation harvesting plan places various seasonal and gear restrictions on how the 3Ps cod fishery in Canadian waters could be pursued and these restrictions continue to apply to the fishery. For example, unit areas 3Psa and 3Psd were closed from November 15 to April 15 of the following year to avoid potential capture of migrating cod from the Northern Gulf stock (NAFO Divisions 3Pn4RS) and all of 3Ps was closed from April 1 to May 14, a closure intended to protect spawning aggregations. Full details of these and other measures, which may differ among fleet sectors, are available from the DFO Fisheries and Aquaculture Management (FAM) branch in St. John's. The spatial-temporal details of reported landings are reported in Table 3 and shown in Figure 5. Of particular note is the recent reduction in landings from unit areas offshore and the increasing proportion of the total landings from 3Psc (Placentia Bay).

Inshore landings were low early in 2018 (Table 3), arising mostly from by-catch of cod in other fisheries. The vast majority of landings from the inshore areas (3Psa, 3Psb, and 3Psc) were taken in June-November, with highest landings in June and July, particularly in 3Psc. The inshore (3Psa, 3Psb, and 3Psc) consistently accounted for most of the reported landings. These have typically been highest in Placentia Bay (3Psc), ranging from 1,500 t to almost 11,650 t with 26–55% of the annual 3Ps catch coming from this unit area alone. In 2018/19 the landings from 3Psc were 2,660 t, representing 59% of the 3Ps total. Most of the offshore landings have come from 3Psh and 3Psf (Halibut Channel and the southeastern portion of St. Pierre Bank; Figure 2). Unit areas 3Psd, 3Pse and 3Psg have accounted for a very small portion of the total catch in recent years. Catches in these areas thus far in 2019–20 have again been very low. The breakdown of landings by unit area excludes landings by France from 2009 to present. Resource managers from France have reported that the majority of these landings are taken in either 3Psf or 3Psh, but the exact unit area is unavailable.

CATCH AT AGE

Estimates of numbers-at-age for the Canadian catch during 2018 were available for the 2019 3Ps cod Regional Assessment Process. Note that the catch-at-age time series was reconstructed for the 2019 framework meeting and the reconstructed series was used in the assessment. The amount of landings sampled is highly variable among gear types and years, but generally the otter trawl fleet is sampled well compared to other fleets while inshore and offshore line trawl landings are sampled poorly (Table 4). There was sampling for more than half of the landings from gillnets and handlines.

During 2018 the landings were composed mostly of age 5–8 fish, which is typical of fisheries dominated by gillnet catches (Figure 6; for detailed catch-at-age estimates for 2018, see Table 5; for the complete time series (1959 to 2018) of available catch numbers at age (ages 3–14 shown) for the 3Ps cod fishery, see Table 6. Age seven fish representing the 2011 cohort was dominant in the 2018 catch.

WEIGHT AT AGE

The time series of available mean weights-at-age in the 3Ps fishery (including landings from the commercial and recreational fisheries and the sentinel surveys) are given in Table 7a and Figure 7. Estimates of mean weights-at-age are derived from sampling of the catches stratified by gear type, unit area and month. Seasonal age length keys are applied to length frequency data to age the catch and calculate proportions at age. Weights-at-age are calculated using a length-weight relationship for cod that has been applied to all cod stocks in the NL Region (Varkey et al. 2022). Beginning of the year weights-at-age calculated from commercial annual mean weights-at-age using the geometric mean method (Rivard 1980) are given in Table 7b. These data are no longer used for stock weights as selectivity of the fishery has changed over time. The stock weights used for the assessment are the beginning of the year weights-at-age based on the RV survey given in Table 7c and Figure 8.

For young cod (ages 3–6), weights-at-age computed in recent years tend to be higher than those in the 1970s and early 1980s (Tables 7a, 7b Figures 7–8). The converse is generally true for older fish. Sample sizes for the oldest age groups (>10) have been low in recent years due to the scarcity of old fish in the catch. The current extremely low weights-at-age for ages greater than 10 could be related to these low sample sizes. Interpretation of trends in weights-at-age computed from fishery data is difficult because of among-year variability in the proportion at age caught by gear, time of year, and location.

RESEARCH VESSEL SURVEYS

Stratified-random surveys have been conducted in the offshore areas of Subdiv. 3Ps during the winter-spring period by Canada since 1972 and by France over 1978–92. The two surveys were similar with regard to the stratification scheme used, sampling methods and analysis, but differed in the type of fishing gear and the daily timing of trawls (daylight hours only for French surveys). Canadian surveys were conducted using the RVs *CCGS A.T. Cameron* (1972–82), *CCGS Alfred Needler* (1983–84; 2009–present), and *CCGS Wilfred Templeman* (1985–2008). From the limited amount of comparable fishing data available, it has been concluded that the three vessels had similar fishing power and no adjustments were necessary to achieve comparable catchability factors, even though the *CCGS A.T. Cameron* was a side trawler. Cadigan et al. (2006) found no significant differences in catchability for several species, including cod, between the *Wilfred Templeman* and *Alfred Needler* research vessels. The *CCGS Teleost* has also been used during exceptional events (e.g., severe mechanical issues on regular survey vessel), and any potential vessel effect is unaccounted for. Surveys by France were conducted using the RVs *Cyros* (1978–91) and *Thalassa* (1992) and the results are summarized in Bishop et al. (1994).

The Canadian RV surveys from 1983 to 1995 employed an Engel 145 high-rise bottom trawl. In 1996, RVs began using the Campelen 1800 shrimp trawl. The Engel trawl catches for 1983–95 were converted to Campelen 1800 shrimp trawl-equivalent catches using a length-based conversion formulation derived from comparative fishing experiments (Warren 1996; Warren et al. 1997; Stansbury 1996, 1997).

The stratification scheme used in the DFO RV bottom-trawl survey in 3Ps is shown in Figure 9. Canadian surveys have covered strata ranging down to 300 fathoms (ftm) in depth (1 fathom = 1.83 meters) since 1980. Five new inshore strata were added to the survey in 1994 (stratum numbered 779–783) and a further eight inshore strata were added in 1997 (numbered 293–300) resulting in a combined 18% increase in the surveyed area. Beginning in the 2007 assessment, new indices using survey results from the augmented survey area were presented for the first time. Two survey time series are constructed from the catch data from Canadian surveys. The index from the expanded surveyed area that includes new inshore strata is referred to as the “All Strata <300 ftm” index and the time series extends from 1997 onwards. The original smaller surveyed area is referred to as the “Offshore” survey index and the time series that incorporates a random stratified design extends from 1983 to present.

The timing of the survey has varied considerably over the period (Table 8). In 1983 and 1984, the mean date of sampling was in April, in 1985 to 1987 it was in March, and from 1988 to 1992 it was in February. Both a February and an April survey were carried out in 1993; subsequently, the survey has generally been carried out in April. The change to April was aimed at reducing the possibility of stock mixing with cod from the adjacent northern Gulf (3Pn4RS) stock in the western portion of 3Ps. The stock mixing issue is described in more detail in previous assessments (e.g., Brattey et al. 2007). Due to extensive mechanical problems with the research vessel 48 of 178 planned sets were completed in 2006. Therefore, results for 2006 for the full survey area are not considered comparable to the remainder of the time-series. All subsequent surveys were considered complete. The 2019 survey completed 169 of the intended 178 fishing sets (Figure 10) with sampling in all index strata.

Abundance, Biomass, and Distribution

Trends in the abundance index and biomass index from the RV survey are shown for the offshore (i.e., index strata only: those strata of depth ≤300 ftm, excluding the new inshore strata) and the all strata area (Figure 11). The trawlable abundance index is quite variable for most of the time-series. The 2013 estimate was particularly high but was followed by a subsequent large decline during 2014–19, with the 2019 estimate being below average. The trawlable biomass estimate has been variable for much of the post-moratorium period but shows a general declining trend over 1998–2019, with the exception of a high value of 83,000 t in 2013. The survey biomass estimate for 2019 was 22,491 t, below the time series average.

The trends and degree of variability in the combined inshore/offshore survey are almost identical to those of the offshore survey (Tables 9 and 10, Figure 11) in spite of the 18% increase in surveyed area. However, the combined inshore/offshore survey showed notably higher biomass and abundance during two years; in 2005 and 2017, values were comparatively higher for the inshore/offshore index due mainly to large estimates (due to a single large set) from inshore stratum 294 and 295, respectively.

Survey indices of cod in 3Ps 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, and degree of aggregation) which may be unrelated to absolute stock size. The time series for abundance and biomass from 1983 to 1999 show considerable variability, with strong year effects, for example, the 1995, 1997 and 1998 surveys when compared to those from adjacent years. There are strong indications that the 2013 survey may have been influenced by a year effect. A clear sign of a year-effect is the fact that 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. The number of fish in a cohort cannot increase as it ages (without immigration) and when analyses suggest that such an increase has occurred it is considered evidence for a year effect.

Surveys in 3Ps are prone to single large fishing sets that heavily influence the survey indices and are often largely responsible for the year-effects mentioned previously. An extreme example is the 1995 survey, where a single large catch contributed 87% of the total biomass index. In 2013, a large single catch of larger fish on Burgeo Bank (Figure 13) resulted in >50% of the overall biomass being located in this particular area and causing a large spike in the survey indices for that year. A similar phenomenon occurred in the 2015 and 2016 surveys with a single large set in the Burgeo Bank area accounting for 38% and 60%, respectively, of the biomass index in those years. The fact that single large fishing sets have heavily influenced survey indices throughout the history of this stock, including three out of the last six years, is a concern for the assessment. The recent sporadic appearance of high numbers of fish on Burgeo Bank is not fully understood. Méthot et al. (2005) used otolith microchemistry to investigate the stock affinity of fish collected on Burgeo Bank in 2001 and suggested that approximately half of the fish in this area in April (which also equates to the time of the DFO RV survey) were fish that originated from the Northern Gulf of St. Lawrence. The presence of Northern Gulf fish within the 3Ps stock area at the time of the RV survey could bias the assessment of 3Ps cod.

To further investigate survey trends for different portions of the stock area, the stratification scheme was divided (Figure 15) into areas referred to as ‘inshore’ (strata 293–298, and 779–783), ‘Burgeo’ (strata 306–309, and 714–716), and ‘eastern’ (remaining strata) and the trends in biomass and abundance in each of these regions were examined based on the combined inshore/offshore survey data. The proportions were variable, with typically 30–70% observed in the larger eastern area, 15–60% in the Burgeo area, and around 10–25% in the inshore area. For the inshore region in 2019, biomass and abundance were similar during 2018 and 2019, at low levels similar to those observed in 2015 and 2016. After four years of declines, both abundance and biomass increased in the Eastern region during 2018, but declined again in 2019 (Figure 16), whereas the Burgeo indices increased slightly in 2019, following four years of decline.

Age Composition

Survey numbers at age are obtained by applying an age-length key (ALK) to the numbers of fish at length in the samples. The current sampling design for cod in Subdiv. 3Ps requires that an attempt be made to obtain 2 otoliths per centimeter of fish length from each of the following locations: Northwest St. Pierre Bank (strata 310–314, 705, 713), Burgeo Bank (strata 306–309, 714–716), Green Bank-Halibut Channel (strata 318 319, 325 326, 707–710), Placentia Bay (strata 779–783) and remaining area (strata 315–317, 320–324, 706, 711–712). This spatial stratification ensures sampling is distributed over the surveyed area. The otoliths are then combined into a single ALK and applied to the survey data. These data can be extrapolated into trawlable population abundance at age by multiplying the mean numbers per tow at age by the number of trawlable units in the survey area. This is obtained by dividing the area of the survey by the area swept by the trawl. For the “offshore” survey in 3Ps, the survey area is 16,732 square nautical miles including strata out to 300 ftms (and excluding the relatively recent inshore strata added in 1997). The swept area for a standard 15-min tow of the Campelen net is 0.00727 square nautical miles. Thus, the number of Campelen trawlable units in the 3Ps survey is $16{,}732 \div 0.00727 = 2.3 \times 10^6$. For the expanded survey area, there are approximately 2.7×10^6 trawlable units.

The mean numbers per tow at age in the DFO RV survey are given in Tables 11a and 11b and results for ages 1–15 are shown in the form of standardized proportion at age per year (SPAY) “bubble” plots in Figure 17. Cod up to 20 years old were not uncommon in survey catches during the 1980’s, but the age composition became more contracted through the late 1980’s and early 1990’s. In fact, few cod aged 15 or older have been sampled during surveys in the past two decades and none have been sampled in the last three years.

Over 2007–11, survey results indicated the 2006 year-class was much greater than average (at ages 1 through 5). However, subsequent surveys suggested the numbers at age for the 2006 year-class at older ages to be near or below average. The age 1 survey index for the 2012 survey, representing the 2011 year-class, was much greater than the time-series average. Although the relative strength of this year class has been revised downward to some degree in subsequent surveys it continued to look strong and is now fully selected to the fishery. More recently, abundance of the 2016 and 2017 year-class appears higher than average, but they too may be subject to revision with the addition of subsequent survey data. An examination of age-disaggregated spatial plots for the 2019 survey indicated that these year-classes were distributed through much of the waters inshore of St. Pierre Bank and in the Halibut Channel/southern portion of St. Pierre Bank (Figure 18).

Size-at-Age (Mean Length and Mean Weight)

The sampling protocol for obtaining lengths-at-age and weights-at-age has varied over time (Lilly 1998) but has consistently involved stratified sampling by length. For this reason, calculation of mean lengths and weights included weighting observations by population abundance at length (Morgan and Hoenig 1997), where the abundance at length (3-cm size groups) was calculated by areal expansion of the stratified arithmetic mean catch at length per tow (Smith and Somerton 1981). Only data from 1983 onward are presented and only data from the offshore index strata.

Mean lengths-at-age were updated using the 2019 survey data (Table 12, Figure 19). For ages older than age 3 there was a general decline in length-at-age from the early 1980s to the mid-1990s (Figure 19). 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. For ages 6–9 although there is inter-annual variability (for example see age 9 in 2018) there has been a general decline in mean length since the mid-2000s.

Annual variation in mean length at age was examined using deviation from the average as a proportion over the time series for each age. The average mean length at age from 1983 to 2019 was calculated for each age. Deviation was calculated for each age in each year by subtracting the mean for the age for the time series from the annual observation for that age and then dividing this by the mean for that age. Ages 3 to 9 were included. Mean length at age was greater than average in the mid-1980s. It showed a declining trend until the mid-1990s when it was below average. Mean length-at-age subsequently increased. Length-at-age has been lower than average in 9 of the last 13 years, being well below average in most of the last seven years. Much of the increase seen in 2018 is the result of a very large estimate of age 9 length in that year.

Values for mean weight-at-age were updated with data from the 2019 survey (Table 13, Figure 20). There was an increase in weight-at-age from the mid-1990s through the mid-2000s, but data from 2007–19 surveys suggest that mean weight-at-age was mainly lower than the mid-2000s. Mean weight-at-age was greater than average in the mid-1980s and generally declined to very low levels in the mid-1990s (Figure 20). As with mean length-at-age, mean weights-at-age increased after that time to about 2000. Weight-at-age in 9 of the last 13 years has been below average. The time series for four selected ages (3, 5, 7 and 9) are shown in Figure 20, along with their average and five-year running means. There has been a downward trend in weight-at-age since about 2010 for ages 7 and 9, with the trend starting a few years later for age 5. Weight-at age for all three ages remain below average in 2019.

Condition

Relative gutted condition (relative K) and relative liver condition (relative LK) were calculated from survey data. It has been shown that the timing of the survey affects estimates of condition for 3Ps cod (Lilly 1998) and so only estimates from April surveys beginning in 1993 were calculated. A length versus gutted weight relationship was estimated, and the condition index is then observed condition divided by the condition predicted from the length weight regression for a fish of that length. Relative liver condition was calculated in a similar fashion using a liver weight length regression. However, evaluation of the model fit indicated that a simple linear regression did not provide an adequate fit to the liver weight data. In addition, liver weight data for fish under 30 cm and greater than 120 cm were highly variable; therefore, the analyses were restricted to fish 30–120 cm in length. Regression equation is as follows:

$$\log(liver\ weight) = intercept + \beta_1 \log(length) + \beta_2(\log(length))^2 \quad (1)$$

Both gutted and liver condition increased to about 1998 and then were lower until 2004 with a spike in 2005 (Figure 21). Gutted condition reached a low in 2008 but increased steadily to reach above average levels in 2013, however it declined again and was below average from 2014–19, with 2016 being the lowest in the time series. Liver condition has been below average in 9 of the last 13 years, with 2017 being the lowest and 2019 the second lowest in the time series.

In conclusion, mean length-at-age, mean weight-at-age and both indices of condition have mostly been below average since 2014.

Maturity

The sampling design used to gather biological data to study maturation trends and an overview of maturity and fecundity research relating to 3Ps cod can be found in Brattey et al. (2008).

Annual estimates of age at 50% maturity (A50) for females from the 3Ps cod stock, collected during annual winter/spring DFO RV surveys, were calculated as described by Morgan and Hoenig (1997). A50 was estimated for each cohort and trends are shown in Figure 22a; parameter estimates and associated standard errors for the 1954 to 2013 cohorts are given in Table 14, and the model did not adequately fit data for subsequent cohorts (2014–16) as most of these fish remain immature. A50 declined rapidly for cohorts from the 1980s and remained low for cohorts from the 1990s. There was a slight increase in A50 to ~5.5 years for cohorts of the early 2000s but values for the most recent cohorts are once again near 5 years (Figure 22a). Given that the estimation is conducted by cohort, estimates for the most recent cohorts may be revised slightly in future years as additional data are collected. Males show a similar trend in A50 over time (data not shown) but tend to mature about one year earlier than females.

Annual estimates of the proportion mature at age are shown in Table 15; these were obtained from the cohort model parameter estimates in Table 14. The estimates of proportion mature for ages 4–7 show an increasing trend (i.e., increasing proportions of mature fish at young ages) through the late-1970s and 1980s, particularly for ages 5, 6, and 7 (Figure 22b). Due to the low A50, the proportions mature at age are quite high.

The time series of maturities for 3Ps cod shows a long-term trend as well as considerable annual variability. Such variations can have substantial effects on estimation of spawner biomass. Further, the age composition of the spawning biomass may have important consequences in terms of producing recruits (see Brattey et al. 2008).

ERHAPS SURVEYS BY FRANCE

The new assessment model incorporates bottom trawl data from the ERHAPS (Evaluation des Ressources Halieutiques de la région 3PS) surveys by France that were conducted from 1978 to 1992 using the same stratification scheme as the Canadian offshore RV survey. There was a change in vessel in 1992 and there was no comparative fishing to compare the catchabilities of the two vessels. Therefore, the assessment uses only data from 1978 to 1991. The ERHAPS survey was conducted in February-March using a Lofoten trawl in daylight hours only. When strata were missed during the survey, adjustments to the results of the survey were made using a multiplicative model. For further details, see (Champagnat and Vigneau in prep[1]).

GROUNDFISH ENTERPRISE ALLOCATION COUNCIL SURVEY

GEAC (presently Atlantic Groundfish Council) conducted a fall survey (November-December) within 3Ps from 1997 to 2007 using the same stratification scheme as the Canadian offshore RV survey (McClintock 2011). Twenty-four strata were sampled annually. An Engels 96 high lift trawl was used to conduct 30-minute tows. In the eleven-year survey period, coverage was incomplete in 1997, the survey was not conducted in 2006, and in 2007 a different vessel was used, and several additional strata were included. Eight years of data from this series (1998–2005) were included in the new assessment model.

ASSESSMENT MODEL DESCRIPTION

From 2009 to 2018, the NAFO Subdivision 3Ps cod stock was assessed using a SURBA (SURvey Based Assessment) model (Cook 1997, Cadigan 2010, DFO 2019) fit to the Canadian RV survey. An assessment framework was held from October 8–10, 2019 (DFO in prep[2]). At this meeting, a range of state-space models for assessing the status of the 3Ps cod stock were examined. Candidate models developed within three different state-space modelling approaches SAM (State-space Assessment Model, Nielsen and Berg 2014), 3PsSSAM (State-Space Assessment Model for 3Ps Cod, DFO in prep[3]), and HYBRID (Varkey et al. 2022), and were developed and several model formulations within each of these modelling approaches were presented and reviewed. The goal was to adopt one of the candidate models for assessing the status of the 3Ps cod stock. The assessment framework meeting decided that the a formulation of the HYBRID modelling approach will be used for assessing the stock in 2019 (Varkey et al. 2022). The HYBRID model is named as such because it uses a variety of features from SAM (mainly the use of random effects for modelling N and F matrices) and the Northern Cod Assessment Model (Cadigan 2016), mainly the inclusion of expert opinion on reliability of landings time series through the use of censored likelihood. Further, HYBRID uses time-varying natural mortality which is modelled as a function of scaled fish condition-based index. This model has the following main features:

1. includes all the available surveys (Table 16) (Canadian RV survey [1983–2019], French ERHAPS survey [1978–91], industry trawl survey [1998–2005], and gillnet [1995–2018] and linetrawl [1995–2018] sentinel surveys),
2. two types of commercial data—fisheries catch-at-age is fit using continuation ratio logits, and the fisheries landings are fit via censored likelihood,
3. Multivariate normal (MVN) random walk for F with age 2 decoupled from the MVN correlation and with a discontinuity in the random walk at the moratorium,
4. time-varying M and,
5. the model starts in 1959 which is the first year for which landings data are available.

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[1] Champagnat, J., and Vigneau, J. In prep. ERHAPS: a French survey for cod in 3Ps. IFREMER.

[2] DFO. In prep. Proceedings of the Framework Project on Population Models for Northwest Atlantic Fisheries Organization (NAFO) Subdivision 3Ps Atlantic Cod; November 19-22, 2019. DFO Can. Sci. Advis. Sec. Proceed. Ser.

Results from this formulation of the HYBRID model are presented here for the assessment of this stock. An alternate version of the HYBRID model with time-invariant M was available for comparison (if required). The assessment framework meeting also concluded that the SURBA model was not a reliable model to represent the status of the stock. The assessment framework meeting also decided that the SAM model (Champagnat et al. in prep[3]) be retained for comparison with the accepted assessment model (results from SAM model are presented in Appendix A).

In the final year of the assessment (2019), only the Canadian RV spring survey is available, as the 2019 sentinel survey is still ongoing at the time of the assessment. In the next assessment year, the sentinel survey estimates for 2019 will be included. The stock-status for 2019 is presented using partial data after analysis of the impact of staggering between surveys (i.e., not having all the ongoing surveys in the terminal year versus having all the ongoing surveys in the terminal year of the assessment). The analysis showed that inclusion of the additional year from the Canadian RV survey, improved the recruitment estimates in the projections. Projections of the stock-status are produced until 2022.

State Equation

The state equation follows the parameterization of state equation in the SAM (Nielsen and Berg 2014). The matrices of *log N* (log abundance) are treated as random variables and represent the underlying unobserved state. Age *A* in the model spans from 2 to 14+ and the plus group is represented by *A*. Years (*y*) in the model span from 1959 to 2019. First year abundances (for ages 3 to *A*) are estimated as part of the random variable matrix for $log\ N_{a,y}$. Recruitment (first age—age 2—in all years) is modelled to follow a random walk with standard deviation σ_R. The process error is normally distributed with standard deviation σ_P. Age-specific fishing mortality ($F_{a,y}$) and natural mortality ($M_{a,y}$) are used to model the exponential decay in the cohort.

$$log\ N_{2,y} = log\ N_{2,y-1} + \eta_{2,y};\ \eta_{2,y} \sim N(0, \sigma_R) \qquad (2)$$

$$log\ N_{a,y} = log\ N_{a-1,y-1} - F_{a-1,y-1} - M_{a-1,y-1} + \eta_{a,y}; 3 \le a < A-1;\ \eta_{3:A,y} \sim N(0, \sigma_P\ ) \qquad (3)$$

$$log\ N_{A,y} = log\begin{pmatrix} N_{A,y-1} * \exp\left(-F_{A,y-1} - M_{A,y-1}\right) + \\ N_{A-1,y-1} * \exp\left(-F_{A-1,y-1} - M_{A-1,y-1}\right) \end{pmatrix} + \eta_{A,y};\ A = 14+ \qquad (4)$$

Parameterization of F - Time Varying Fisheries Selectivity in the Model

To account for some of the temporal dynamics in the fishery, time varying selectivity was incorporated into the model. The primary gears used in the fishery for 3Ps cod varied considerably over time with the fishery changing from a predominately offshore fishery heavily exploited by non-Canadian fleets in the 1960s and early 1970s to a fishery based mostly inshore in the later years. Since 1997, most of the TAC has been landed by Canadian inshore

[3] Champagnat, J., Vigneau, J., Varkey, D.A., Regular, P.R., Ings, D.W., Babyn, J., and Morgan, M.J. In prep. Development of a State Space Assessment Model for 3Ps Cod. DFO Can. Sci. Advis. Sec. Res. Doc.

fixed gear fishermen with the remaining catch taken mainly by the mobile gear sector fishing the offshore.

Therefore, we modeled the $F_{a,y}$ matrix is a MVN random walk over years, similar to the implementation in SAM (Nielsen and Berg 2014). We added breaks to the MVN random walk at the beginning of the fishing moratorium. Further, the standard deviation for age 2 is de-coupled from the older ages in the fishery (ages 3+). Correlation in the random walks between ages is enabled through MVN deviations. For the covariance matrix of MVN deviations, we adopt a simple autoregressive (AR1) process for the correlation (ρ) such that similar age groups develop similar trends in the fishing mortality.

$$\log\left(F_{2:A,y}\right) = \log\left(F_{2:A,y-1}\right) + e_{2:A,y};\ e_{2:A,y} \sim MVN_{2:A}(0, \Sigma) \tag{5}$$

$$\Sigma_{a,\bar{a}} = \rho^{|a-\bar{a}|}\sigma_a^2 \tag{6}$$

Each element in Σ is a function of the standard deviation of the random walk and the estimated correlation coefficient. This parameterization of *F* allows for flexibility for the shape of the selectivity function over the two-dimensional space of ages and years. Selectivity is derived as:

$$s_{a,y} = \frac{F_{a,y}}{\sum_a F_{a,y}} \tag{7}$$

Parameterization of Natural Mortality *M*

When information on natural mortality is unavailable, a base assumption in fisheries stock assessments has been that natural mortality is invariant over age and year and often assigned a value of M=0.2 (Hilborn and Liermann 1998). For neighboring cod stocks (Northern cod 2J3KL and Flemish cap 3M), *M* is estimated to be higher than 0.2 (Cadigan 2016, and the two most recent assessments for 2J3KL and 3M), and for this reason, *M*=0.3 was chosen as the base level. Analysis of tagging data for 3Ps cod also suggested *M* levels to be higher than 0.2; although the tagging data is limited to the post-moratorium time period (Varkey et al. 2022, see Appendix B). Previous assessments also indicated an increase in total mortality (Ings et al. 2019a, Ings et al. 2019b).

The model applies time-varying $M_{a,y}$, where a trend based on fish condition is applied to a base level M (M_{base} = 0.3).

$$M_{a,y} = M_{base}\exp\left(\delta_{a,y}\right) \tag{8}$$

The $\delta_{a,y}$ term is covariate associated estimation such that the resulting *M* follows the trend in the covariate X_y.

$$\delta_{a,y} = mpar_a * X_y \tag{9}$$

Estimates of *mpar* close to zero suggest none/little influence of covariate on *M*, a positive *mpar* indicates that *M* follows the trend in the covariate and a negative *mpar* indicates an *M* trend opposite to the trend in the covariate. Here, the covariate X_y is a normalized index of *Mc,* a condition-based index of *M*.

$$X_y = \frac{Mc_y - \mu_{Mc}}{\sigma_{Mc}}$$	**10**

This scaling allows the treatment of the covariate as an anomaly resulting in estimates above or below the baseline M_{base} provided, similar to the scaling for temperature anomaly for time-varying carrying capacity (Kumar et al. 2013). The mean (μ_{Mc}) and standard deviation (σ_{Mc}) are calculated for the reference period 1978 to 2012, the first 35 years of data; therefore, the normalization of *Mc* is based on a reference period from 1978 to 2012. The *mpar* parameter was estimated by two age groups (immature and mature) to allow different age groups to respond differently to the trends in fish condition. A similar implementation of time-varying *M* is for Kootenay lake kokanee population by Kurota et al. (2016). Hence the final equation for *M* is:

$$M_{a,y} = M_{base} \exp\left(mpar_a * \left(\frac{Mc_y - \mu_{Mc}}{\sigma_{Mc}}\right)\right)$$	**2**

Likelihoods

Surveys

We fit the model to four surveys:

1. the Canadian RV survey,
2. the French ERHAPS survey,
3. the GEAC survey, and
4. sentinel survey.

$I_{a,y,s}$ represents the expected index-at-age in survey *s*, *ts***Z* (where instantaneous rate of total mortality $Z = F + M$) represents an adjustment to total mortality to account for the timing of survey in the year (ex., *ts*=0.5 for a survey in June; the model year is January to December, although the management year is April to March). The observation error standard deviation $\sigma_{ag,s}$ can be estimated separately for age-group '*ag*' and survey '*s*'.

$$\log \hat{I}_{a,y,s} = \log q_{a,s} + \log N_{a,y} - ts_{y,s} * Z_{a,y} + e_{a,y,s};\ e_{a,y,s} \sim N(0, \sigma_{ag,s})$$	**3**

The Canadian RV survey provides continuous (except 2006) records of mean numbers per tow (MNPT) throughout the time series, however survey timing shifted in the early 1990s, and inshore strata were added at the same time as the fishery reopened in 1997. We use an inshore-offshore adjustment (offset for *q*) which is applied only to fish aged 8 and older. The average fraction of fish age 8 and older in the inshore area was less than 5% in the DFO-RV combined inshore-offshore index (Figure 23). The catchability for fish aged 2 to 7 are estimated independently for the offshore and the combined inshore-offshore survey. For fish aged 8 and older, the catchability in the offshore index series (DFO-RV-OFF) is calculated as the catchability of the combined inshore-offshore series (DFO-RV-IO) plus an offset. The offset for *q* at age is calculated as the median of the log ratio of the index-at-age for the combined inshore-offshore region versus the same for the offshore region (equation 13). A comparison of several approaches to adjust for the addition of inshore strata and estimate catchability for the RV survey series were explored in Varkey et al. 2022. This adjustment was adopted based on fewer assumptions required on the ratio of fish present in the inshore versus offshore and based on better performance in retrospective analyses.

$$log\ q_{8:A,DFO\ RV\ OFF\ 1983:1996} = log\ q_{8,DFO\ RV\ IO\ 1997:2018} + \log q_{offset\ 8:A} \quad (4)$$

$$log\ q_{offset\ 8:A} = median\left[-log\left(\frac{I_{DFO\ RV\_IO\ 8:A}}{I_{DFO\ RV\_OFF\ 8:A}}\right)\right] \quad (5)$$

Fisheries Catch-at-Age

Catch is predicted using the Baranov catch equation:

$$\hat{C}_{a,y} = N_{a,y}\left(1 - \exp(-Z_{a,y})\right)^{F_{a,y}}\Big/_{Z_{a,y}} \quad (6)$$

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. Continuation ratio logits (CRLs) (Cadigan 2016) are the logit transformation of the conditional probability $\pi_{a,y}$ of proportions at age $P_{a,y}$ in a given year.

$$\hat{P}_{a,y} = \frac{\hat{C}_{a,y}}{\sum_2^A \hat{C}_{a,y}} \quad (7)$$

$$\pi_{a,y} = Prob(age = a | age \geq a) = \frac{\hat{P}_{a,y}}{\sum_a^A \hat{P}_{a,y}}, 2 \leq a \leq A \quad (8)$$

$$\hat{X}_{a,y} = \log\left(\frac{\pi_{a,y}}{1 - \pi_{a,y}}\right), 2 \leq a \leq A - 1 \quad (9)$$

The observed CRLs $X_{a,y}$ are calculated similarly from the proportions at age in the observed catch-at-age data. When the estimated catch-at-age was equal to zero, it was replaced by the minimum value in the observed catch-at-age. The continuation ratio logits are fit using a normal likelihood.

$$X_{a,y} = \hat{X}_{a,y} + \epsilon_{a,y}, \epsilon_{a,y} \sim N(0, \sigma_c) \quad (10)$$

The standard deviations for the catch-age-CRLs are estimated separately for age groups 2, 3–4, 5–8, 9+ age groups. The decision was based on the comparison of performance of several models at the assessment framework (Varkey et al. 2022).

Fisheries Landings

We applied a censored likelihood for landings time series similar to the application in Cadigan (2016), which allow the provision for including asymmetrical bounds to specify uncertainty. LB_y and UB_y indicate the lower and upper bounds on landings for a given year, $L_{obs\ 1:Y}$ indicate the reported landings time series, L_y indicates the predicted landings for the year. Φ_N is the cumulative distribution function (CDF) for a $N(0,1)$ random variable, σ_L is fixed at 0.02, a small value to ensure that predicted landings are unlikely to be estimated outside the provided bounds (Cadigan 2016).

$$l(L_{obs\ 1:Y}|\theta) = \sum_{y=1}^{Y} log \left\{ \Phi_N \left[\frac{\log\left({UB_y}/{L_y} \right)}{\sigma_L} \right] - \Phi_N \left[\frac{\log\left({LB_y}/{L_y} \right)}{\sigma_L} \right] \right\}, 1 \leq y \leq Y \qquad (20)$$

At the assessment framework meeting in October 2019, the history of the fishery and associated monitoring programs was presented (Carruthers and Ings pers. comm.) The information presented confirmed that at different periods, the available data on landings could be biased higher or lower. For example, it is uncertain if the catch by foreign fleets were reported accurately before the implementation of the Canadian Exclusive Economic Zone. Similarly, there is considerable uncertainty during period of quota negotiation between Canada and France (1987 to 1989). Although the stock was in moratorium during 1993 to 1996, there is uncertainty about bycatch in these years. Information from interviews with current and retired fish harvester (Carruthers and Ings pers. comm.) suggested that discarding and depredation could have led to underreporting after the fishery reopened in 1997 to early 2000s.

The ensuing discussion at the framework meeting was used to determine agreed-upon updated lower and upper bounds for our best understanding of the uncertainty in the landings. The bounds used in the model reflect our current understanding on uncertainty in the fisheries landings (Figure 24).

MODEL FITS AND DIAGNOSTICS

An evaluation of the model fits (Figure 25–Figure 30) shows that in the recent years, it underestimates the DFO RV index for the younger ages (Figure 25). The standardized residuals for the DFO RV survey also show the underestimation of the recent cohorts. Although the model underestimates the early years of the standardized sentinel indices, the fits to the recent data are reasonably good (Figure 27–Figure 28). The terminal year (2018) of the standardized indices for the line-trawl sentinel survey data (Figure 28) are the lowest in the time-series for fish aged 3–5 years and these data points influence the model to predict lower levels of recruitment for the years producing these cohorts. The model fits well to all indices for ages 6 and higher, which contribute the bulk of the spawning stock biomass, indicating that both the surveys point to the current low levels of the stock. Estimated survey standard deviations show that the sentinel line-trawl survey has more influence than the other surveys in the model fit (Table 17). There was considerable debate about uncertainty in the recruitment estimates resulting from the different signals being obtained from the DFO RV survey and the sentinel surveys. At the assessment meeting, we explored different approaches to weight the surveys. It was found that when the sentinel surveys were given a lower weight, the model fits tend to resemble the DFO RV survey more closely in the recent years. However, an objective approach to weighting could not be determined so the decision was made to not add arbitrary weighting to the surveys in the model fitting and estimation exercise. More in-depth research into the data gathered from both the surveys is needed to better understand the role of these surveys in the assessment model and how they related to the stock as a whole.

LIMIT REFERENCE POINTS

At the assessment framework meeting in October 2019, it was agreed that the existing LRP of using the SSB in 1994, from which there has been a sustained recovery, is a very poor biological LRP. A guideline for reference points and stock status zones according to the

Canadian PA Framework highlights three zones for stock status: a critical zone, a cautious zone, and a healthy zone (Figure 31). A biomass-based limit reference point (referred to as B_{lim}) is expected to protect the stock not only from impact of high fishing pressure but also from ‘prolonged periods of adverse environmental conditions’ (Rosenberg and Restrepo 1996). At International Credential Evaluation Service (ICES), B_{lim} is defined as ‘a deterministic biomass limit below which a stock is considered to have reduced reproductive capacity’.

We evaluated the spawning stock biomass and recruitment estimates obtained from the new assessment model for analysis of a stock-recruit relationship. A parametric fit to standard stock recruitment relationships (Beverton-Holt, Ricker, and Hockey stick) were explored and none of these attempts were successful. We were able to fit a model with time-varying estimates of slope at origin for the Beverton-Holt model.

$$R_y = \frac{a_y S_y}{1 + b S_y} \qquad \textbf{21}$$

The slope at origin *a* represents the maximum juvenile survival rate at low stock sizes. Such a model produced a new stock recruit curve for every year on account of the time varying estimates a_y in the exploration. The application of such an analysis to the estimation of an LRP was not feasible on account of annual variation in parameter estimates.

We performed a breakpoint analysis with R package ‘strucchange’ (Zeileis et al. 2002). The breakpoint function detects changes in the structure of relationship between two variables. We applied this approach to the scatterplot of spawning stock biomass and recruitment estimates from the accepted assessment model. The analysis detected breakpoints at SSB levels (149, 79, and 74 K) in the spawner-recruit scatter below an SSB of 70 K, the recruitment levels were always below 50 million (see Figure 32).

In the SSB estimates from the model, there was a gap between 70 K and 65 K. No recruitment estimates were available within this range. The assessment meeting noted that the lowest SSB below which estimated recruitment was below 50 million was 65 K. Hence a LRP of 66,000 tonnes of SSB was adopted.

MODEL OUTPUTS

Model results indicated that SSB declined from the beginning of the time-series in 1959 (195 kt) to values near the LRP by the mid-1970s (Figure 33). Subsequently, SSB increased and was estimated to be above 100 kt over 1980–88, but this period was followed by a continuous decline to a low of 39 kt in 1993. The SSB was below the LRP from 1991–94. During the first two years (1993–95) of the moratorium, SSB increased; then, SSB was stable at about 80 kt over 1995–99. During the early 2000s, SSB was also relatively stable, but at values that were just below the LRP. The SSB decreased further since the early 2000s and in 2019, SSB is 24% of the LRP.

Recruitment (Figure 34) peaked in 1965–66 at approximately 200 million age 2 fish, then generally declined until the mid- to late-1970s when there were about 35 million age two cod in the population. During most of the 1980s, recruitment was variable between 70 and 150 million fish. From 1993 onward, recruitment was generally low at values around 25–40 million fish with particularly low values (6–7 million) during 2016–17. In 2019, recruitment was estimated to be 13.8 million. In the estimation of recruitment, the model is influenced more by the sentinel surveys than by the RV survey.

The new assessment model provides estimates of both fishing *F* and natural mortality *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 (Figure 35). Then, fishing mortality estimates generally increased again until the moratorium in 1993. Average F was near zero (<0.02) during the moratorium (1993–97) when removals were only from bycatch. The estimated fishing mortality rate has ranged between 0.12 and 0.21 since 2010 and in 2019 was 0.21 (0.15–0.30) (Figure 35), with an assumed catch of 4,453 t (Figure 35). F at ages 2 and 3 is very small (<0.01), fishing pressure begins to get noticeable at age 4 (~0.1) and increases to 0.2 and higher for older ages (ages 5+) (Figure 36). In 2019, the highest fishing mortality is on ages 6 and 7, followed by the older ages.

Generally, natural mortality (M) was between 0.27 and 0.33 during the 1980 to 2010 period, but values subsequently increased considerably and the values have increased considerably in the last seven years (Figure 37). M was estimated to be 0.49 (0.41–0.58) (ages 5–8) in 2019 which corresponds to approximately 35% of the stock being removed annually by sources other than reported landings. The time varying trend in M is flat for ages 2 to 5 and the M trend follows the condition-based index for older ages (6+) (Figure 38).

MODEL PROJECTIONS

The model is projected forward with the following assumptions:

1. Catch weights-at-age, stock weights-at-age, selectivity, condition-based M indices, and recruitment are the average of respective values from 2017–19.
2. Maturity is the projected maturity for years 2020–22 from the cohort-based maturity model.
3. Catch for 2019/20 was estimated at 4,453 t.

Projection of the stock to 2022 was conducted assuming fishery removals to be within ±30% of current values, assuming a catch of 4,453 t for 2019, and with no catch (Figure 39). SSB at January 1, 2020, is estimated to be 16 kt (12–21 kt). The stock is in the Critical Zone (24% of B_{lim} (18–32%) as defined by the DFO PA Framework. Under these scenarios, there is a high probability (>99%) that the stock will remain below B_{lim} through to the beginning of 2022 (Table 18). The probability of stock growth to 2022 is 1% or less across catch scenarios (+/-30% of current levels) and is 16% when there are no removals. Stock natural mortality estimates are at their highest levels in the terminal three years of the assessment (Figure 37) and these levels are much higher than the corresponding estimates of fishing mortality (Figure 35). In all catch scenarios explored, the projected F levels are lower than projected M (Figure 38, Figure 40). The high estimates of M have a large influence on the probabilities of growth in the projection.

IMPACT OF HAVING NO SENTINEL DATA IN TERMINAL YEAR

At the time of the assessment (November 2019), the 2019 sentinel survey was still ongoing and consequently sentinel indices for 2019 were not available. Considering the important impact of sentinel line trawl series on the assessment results, some analysis were performed to evaluate the potential bias induced. A SAM model was developed along with the accepted assessment model and used to investigate various parameterizations and potential influences of decisions made during model development. The SAM model was developed with the stock assessment package (Nielsen and Berg 2014 and Berg and Nielsen 2016) and has been described extensively in Champagnat et al. (in prep[4]; run 143).

To explore the impact of having no Sentinel data in the terminal year, two runs of the SAM models going up to 2017 (data available at the time the study was undertaken) are compared:

1. one with all data going until 2017, and

2. one with all data going until 2017 except the sentinel indices going until 2016.

First the impact on stock status perception is assessed (Figure 42): the two runs displayed some differences in both SSB and F but those are small, and the confidence intervals overlap.

Then the impact on projection was estimated (Figure 43; Table 19) by comparing the estimates and confidence intervals from the two runs cited above and one starting in 2016, with all the data going into 2016. This illustrates roughly our situation before the assessment: having a complete input model up to 2018, or a model going until 2019 but with sentinel indices one year behind. The projection displays some differences in the estimates for the three runs, but confidence intervals mostly overlap. On the contrary, recruitment exhibits more important differences between projection starting in 2016 or 2017, the inclusion of last year data (especially the RV recruitment index) impacts the recruitment estimates. Therefore, it is preferable to run projections from a model even with Sentinel data missing in the terminal year.

OTHER DATA SOURCES

Other sources of information were considered in the assessment to provide perspectives on stock status in addition to the DFO survey indices. These sources of information include data from the Sentinel survey (1995–2018), science logbooks for vessels less than 35 feet (1997–2018), logbooks from vessels greater than 35 feet (1998–2018) and observer sampling. Information from tagging experiments in Placentia Bay (and more recently Fortune Bay), was 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 the various data sources track only certain subareas/ components versus the entire distribution of the stock.

Science Logbooks (<35 Ft Sector)

A science logbook was introduced to record catch and effort data for vessels <35 ft in the re-opened fishery in 1997. Return of this logbook at season's end is mandatory (L. Slaney, Resource Management Branch, DFO, pers. comm.). Prior to the moratorium, the only data for vessels <35 ft came from purchase slips, which provided limited information on catch and no information on effort. Since the moratorium, catch information comes from estimated weights and/or measured weights from the dockside monitoring program. Catch rates have the potential to provide a relative index of temporal and spatial patterns of fish density, which may relate to the overall biomass of the stock. Prior to the fall assessment meeting, there were about 194,000 records in the database. As with the analysis of results from the Sentinel program, we consider data to 2018 only, and exclude the current (in-progress) year. The number of annual logbook records has declined over time, even over multi-year periods having common TAC. In addition, the percentage of the total cod catch for the <35 ft sector represented in the logbooks has decreased over time, from about 70% in 1997 to about 20% in 2016 but has increased to 60–65% since then.

We present a catch rate index for data pertaining to the inshore fishery, i.e., unit areas 3Psa, 3Psb, and 3Psc. An initial screening of the data was conducted, and observations were not used in the analysis if the amount of gear or location was not reported (or reported as offshore / outside of 3Psa, 3Psb or 3Psc), more than 30 gillnets were used, or <100 or >4,000 hooks were used on a line trawl. Upper limits for the amount of gear considered are applied to eliminate outlying records and exclude <1% of the available data for each gear type. As observed in previous assessments, preliminary examination of the logbook data indicated that soak time for gillnets is most commonly 24 hours with 48 hours the next most common time period. In comparison, line trawls are typically in the water for a much shorter period of time-typically 2 hours with very few sets more than 12 hours.

The screening criteria described above have resulted in a substantial fraction of <35 ft catch not being available for analysis. For example, in 2018 only 26% of the <35 ft gillnet catch and 28% of the <35 ft linetrawl catch is included in the CPUE (catch per unit effort) standardization. These values are lower than usual and reflect both the low reporting rate and an increasing portion of logbooks records with invalid entries for the location fished. This occurs when logbook entries do not record a fishing location as shown on the map included in this logbook. (These are denoted as fishing areas 29–37 and illustrated in Figure 44). Most of these instances are generated from logbooks which report the location fished as either “10” or “11”-these references correspond to “species fishing areas” (e.g., Lobster Area 10) which are relatively large and include more than one of the fishing locations illustrated in Figure 44. Therefore, it is not possible to resolve these entries to the finer-scale areas indicated in the logbook, and, consequently, a substantial fraction of the catch and effort data from smaller vessels is excluded by our selection criteria.

As in previous assessments, effort was treated as simply the number of gillnets, or hooks for line trawls (1,000s), deployed in each set of the gear; soak times were not adjusted as the relationship between soak time, gear saturation and fish density is not known. Catch rates from science logbooks are expressed in terms of weight (whereas those from the sentinel fishery are expressed in terms of numbers); commercial catches are generally landed as head on gutted and recorded in pounds; these were converted to whole weight (in kg) by multiplying by a gutted-to-whole weight conversion factor (1.2) and converting pounds to kilograms (2.203).

The frequency distribution of catches per set is skewed to the right for both gears (not shown). For gillnets, catches per net are typically around 15 kg with a long tail on the distribution extending to about 75–100 kg per net. The distribution of catches for line trawls was similarly skewed, with median catches of about 180 kg/1,000 hooks; but extending out to 500–600 kg/1,000 hooks.

The catch from 3Ps was divided into cells defined by gear type (gillnet and line trawl), location (numbered 29–37, as described above) and year (1997–2018). Initially, unstandardized CPUE results were computed and examined; in this preliminary analysis, plots of median annual catch rate for gillnets and line trawl were examined for each year location. Catch rates for gillnets tend to be higher in areas 29–32 (Placentia Bay and south of Burin Peninsula) than elsewhere. Gillnet catch rates in 2018 were relatively high at most locations except in Placentia Bay where more average catch rates were observed (Figure 44). For line trawl, most data come from areas west of the Burin Peninsula and the results in areas 29–33 are based on low sample sizes and show more annual variability (Figure 45). In 2018, line trawl catch rates were among the lowest observed in Francois-Burgeo, Connaigre and Fortune Bay, but catch rates were about average elsewhere.

Prior to modeling, the data were aggregated within each gear year month location cell, and the aggregated data were weighted by its associated cell count. Catch per unit effort data were standardized to remove site (fishing area) and seasonal (month, year) effects. A Generalized Linear Model with a log link and Gamma distribution was used to estimate year and month within location and there was no intercept. Effort was used as an offset. Note that sets with effort and no catch are valid entries in the model.

In the present assessment, the model adequately fitted data from gillnets and line trawls and two standardized annual catch rate indices were produced, one for each gear type. All effects included in the model were significant.

Standardized gillnet catch rates declined over 1998–2000 and have subsequently been low but stable at approximately 20 kg/net (Figure 46). For line trawls, temporal patterns differ from those in of gillnets, with much inter-annual variation since 2000. After peaking in 2006, line trawl catch rates generally declined to 2010, and remained near the time-series average in 2014 (Figure 47). The catch rates estimated for 2016 to 2018 were the lowest in the time-series but it was based on a low number of logbook returns.

The observed trends in commercial catch rate indices for the inshore fishery are influenced by many factors. There have been substantial annual changes in the management plans in the post moratorium period (Brattey et al. 2003). In addition, gillnets and line trawls can at times be deployed to target local aggregations. For inshore fisheries, catch rates can also be strongly influenced by annual variability in the extent and timing of inshore as well as along shore cod migration patterns. Similarly, the changes in management regulations, particularly the switch from a competitive fishery to Individual Quotas (IQs) and for some vessels the need to fish cod as bycatch to maximize financial return, can have a strong influence on catch rates that is unrelated to stock size (DFO 2006). Consequently, inshore commercial catch rate data must be interpreted with caution. Despite these issues, the initial declines in gillnet and line trawl catch rates following the re-opening of the fishery in 1997 were cause for concern. The remarkable consistency in gillnet catch rates since 1998 despite the changes in resource abundance and management regulations has not yet been explained. The recent decrease in modeled catch rates for line trawls since 2015 is difficult to explain, but it may be related to the low sample sizes. Also, the age structure of the inshore line trawl catch differed from all the other gears and indicates that the 2011 cohort was not as well represented in line trawls as in other gear types.

Logbooks (>35 Ft Sector)

Standardized catch rate indices for gillnets and otter trawls were updated for vessels greater than 35 ft based on logbook data. This logbook series is administered with follow up by DFO staff when logbooks are not returned promptly and return rates, calculated as the proportion of landings represented by logbooks to sector landings, have been considerably higher than those for the <35 ft sector.

For gillnets, data were screened to select deployments between 12 and 24 hours and a minimum of five data entries was arbitrarily set for including cells (year, area, quarter) in models. The number of vessels in the logbook database, which were subsequently used in the catch rate model, decreased by half over the time-series with only 48 vessels reporting in 2018. This decline was due to a reduction in the number of vessels participating in the fishery over time. The amount of gillnet landings covered by the logbooks was more than 50% over the last decade (Table 20). The model standardizes catch rates to account for spatial and seasonal effects. Results indicated that catch rates were higher in magnitude (Figure 48) than those from vessels less than 35 ft (Figure 46), but the pattern over time was similar. Catch rates in the >35 ft fleet initially (1998 to 2000) declined by about half and remained stable at those levels to 2017. However, catch rates from the >35 foot fleet in 2018 were higher than those observed since 2000. Such an increase was not observed for the <35 foot fleet in 2018.

A standardized index for the otter trawl fleet had been developed with data screened to exclude tows less than 15 minutes and longer than 10 hours. As most of the fishery occurs during fall and winter, only tows conducted between October and March were retained for analyses and a minimum of five entries per cell (year, area, quarter) was included in modeling. CPUE was calculated as catch weight per hour of towing. However, due to privacy concerns and consistent with policy, the catch rate analyses for otter trawlers is not presented.

Attempts to standardize catch rates from line trawls revealed diagnostic issues with the models tested (normality violations) and further exploration would be required to develop a catch rate series for the >35' sector. Data screening for line trawls removed deployments longer than 24 hours as sets of longer duration were infrequent and not consistent with the known fishing procedures in the area. Also, only line trawls with a minimum of 150 hooks were retained in the analyses to reduce the potential number of mistakes in effort recordings. Standardization was attempted across years, areas, and seasons. However, significant interactions between areas and quarters complicated analyses, indicating that seasonal catch rates differ among unit areas.

Observer Sampling

Information collected at sea by observers on Canadian vessels fishing for cod (1997–2018) were reviewed for the potential to create standardized catch rate indices for gillnets, line trawls and otter trawls. Preliminary analyses of the line trawl effort data in 2018 revealed issues associated with changes in recording protocols over time that have not been resolved. Therefore, no standardized estimates of catch rates by line trawls were developed based on observer data. Also, there was insufficient data to develop a standardized catch rate index for the otter trawl fleet.

To develop a standardized catch rate index for gillnets based on observer sampling, data were screened to remove deployments longer than five days. Data exploration indicated substantial variations in observer coverage over time and among unit areas, and the proportion of the landings observed was low (<2%) during most years (Table 21). Standardization accounted for area and seasonal effects. Generally, the results of standardizing the gillnet data were broadly consistent with those from both logbook series up to 2017. Catch rates were observed to decline by about half over 1998 to 2000 and remain relatively stable up to 2017, but during 2018, catch rates increased to the highest in the time-series, although the confidence interval associated with this estimate is large. This increase is inconsistent with either logbook series (Figure 49).

Tagging Experiments

Tagging of adult (>45 cm fork length) cod in Subdiv. 3Ps was initiated in 1997 and has continued through 2019. The geographical coverage of tagging since 2007 has been 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 with tagging conducted annually in 3Psc (Placentia Bay) during 2007 to 2015 plus 2017, in 3Psb (Fortune Bay) during 2012 to 2018 (plus 2007) and in 3Psa only during 2007, 2013 and 2017 (Table 22). Although exploitation rates based on tagging of cod in these inshore areas may not be applicable to other areas, or to the stock as a whole, these inshore regions account for a significant portion (~50%) of the overall annual landings from the stock. Dedicated efforts were made in 2019 to expand the areas where fish were tagged, and tagging was conducted in all the three inshore subareas in 2019 (3Psa, 3Psb, 3Psc).

Tag reporting rates have remained relatively stable in offshore areas in recent years, but there has a downward trend in the rates for inshore areas since 2012 (Figure 50). The general pattern of cod tag returns remains unchanged with most of the fish tagged in 3Ps being harvested in 3Ps (Figures 51, 52). Recent tagging suggests exploitation of 3Ps cod in neighbouring stock areas (Divs. 3KL) is minimal and not a major issue for management. No new information was available to evaluate mixing in the western part of the stock (3Pn or 4R). The timing of tagging experiments with respect to the annual commercial fishery complicates analysis aimed at developing exploitation rates, although analytical work is underway to try and address these complications.

CONCLUSIONS AND ADVICE

A new integrated state space model resulting from the 2019 3Ps Cod Framework was used to assess the status of the stock and estimate fishing mortality. This model incorporates catch (1959–2019), time varying natural mortality informed by trends in cod condition and includes abundance indices from bottom trawl surveys conducted by Canada (1983–2005, 2007–19), France (1978–91), industry (GEAC, 1998–2005), and standardized catch rate indices from the Sentinel gillnet and line-trawl surveys (1995–2018). An advantage of the new model over the population model used previously, is the ability to estimate fishing and natural mortality.

A new biomass LRP was determined for the stock based on the relationship between SSB and recruitment estimated from the model. The LRP is 66,000 t of SSB.

SSB at January 1, 2020, is estimated to be 16 kt (12–21 kt). The stock is in the Critical Zone (24% of B_{lim} [18-32%]), as defined by the DFO PA Framework. The probability of being below B_{lim} is >99.9%. The new model and the revision of the basis for defining the LRP has led to a change in the perception of status of this stock. The stock is now estimated to have been below Blim since the early 2000’s. The estimated fishing mortality rate (ages 5–8) has ranged between 0.12 and 0.21 since 2010 and in 2019 was 0.21 (0.15–0.30), with an assumed catch of 4,453 t. Natural mortality was estimated to be 0.49 (0.41–0.58) (ages 5–8) in 2019. Values during the last four years are the highest in the time series. Recruitment (age 2) estimates have been below the long-term average since the mid-1990s. Projection of the stock to 2022 was conducted assuming fishery removals to be within +/-30% of current levels, assuming a catch of 4,453 t for 2019, and with no catch. Under these scenarios, there is a probability >99% that the stock will remain below B_{lim} between 2020 and the beginning of 2022. The probability of stock growth to 2022 is less than 1% or less across catch scenarios (+/-30% of current levels) and is 16% 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 3Ps remain above normal, and the spring bloom continues to be reduced in magnitude. Zooplankton biomass in 3Ps was near normal in 2017 and 2018 after four years of low production, with an increased proportion of smaller species. Data were unavailable from 2019. Ongoing warming trends, together with an increased dominance of warm water fishes, indicate that this ecosystem continues to experience structural changes. Reduced growth and condition indicate that cod productivity in 3Ps is reduced.

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

SOURCES OF UNCERTAINTY

Although the RV survey of Subdivision 3Ps includes coverage of 45 index strata, the majority of the survey indices for cod are typically attributed primarily to only a small number of those strata. In some years, the high estimates in some strata were a result of a single large survey tow. For example, in three of the last four years, a large survey tow on Burgeo Bank has had a major influence on survey indices (e.g., 60% of the biomass index in 2016 resulted from a single survey tow in stratum 309). The RV survey uses a stratified-random design which assumes fish density to be uniform within a stratum and hence single large survey tows have the potential to bias survey (and hence assessment) results.

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, etc.) 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 as it ages (without immigration), such results are usually considered clear evidence for a year effect. Year effects in the survey data have the potential to bias results, mask trends in the data and contribute to retrospective patterns.

Fish sampled on Burgeo Bank have represented a large portion of the survey estimates of cod in Subdivision 3Ps in recent years. However, the origin of fish in this area is not certain, with previous reports suggesting that a large portion of the fish in this area in April (the time of the RV survey) may in fact be fish from the Northern Gulf of St. Lawrence that migrate seasonally into the Burgeo Bank area. If this is true it would suggest an overestimation of recent indices for the 3Ps stock.

ACKNOWLEDGMENTS

This assessment is supported by the extensive efforts by DFO personnel who participate in collection of data during annual research surveys or sampling of the 3Ps commercial cod fishery. Additionally, data processing by L. Simms and the age reading efforts of Fred Tulk, Gillian Forbes, Marty Snooks, and Jamie Thomson are gratefully acknowledged.

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TABLES

Table 1. Reported landings of cod (t) from NAFO Subdiv. 3Ps by country and for fixed and mobile gear sectors. Landings are presented by calendar year but note that since 2000 the TAC has been established for April 1–March 31. Catch estimates for 2019 are incomplete since the fishing year was in progress at the time of the assessment. See Healey et al. (2014) for pre-1980 data.

Year	Canada NL (Mobile)	Canada NL (Fixed)[2]	Canada Mainland (All gears)	France SPM (Inshore)	France SPM (Offshore)	France Metro (All gears)	Others (All gears)	Total	TAC
1980	2,809	29,427	715	214	1,722	2,681	-	37,568	28,000
1981	2,696	26,068	2,321	333	3,768	3,706	-	38,892	30,000
1982	2,639	21,351	2,948	1,009	3,771	2,184	-	33,902	33,000
1983	2,100	23,915	2,580	843	4,775	4,238	-	38,451	33,000
1984	895	22,865	1,969	777	6,773	3,671	-	36,950	33,000
1985	4,529	24,854	3,476	642	9,422	8,444	-	51,367	41,000
1986	5,218	24,821	1,963	389	13,653	11,939	7	57,990	41,000
1987	4,133	26,735	2,517	551	15,303	9,965	-	59,204	41,000
1988	3,662	19,742	2,308	282	10,011	7,373	4	43,382	41,000
1989	3,098	23,208	2,361	339	9,642	892	-	39,540	35,400
1990	3,266	20,128	3,082	158	14,771	-	-	41,405	35,400
1991	3,916	21,778	2,106	204	15,585	-	-	43,589	35,400
1992	4,468	19,025	2,238	2	10,162	-	-	35,895	35,400
1993	1,987	11,878	1,351	-	-	-	-	15,216	20,000
1994	82	493	86	-	-	-	-	661	0
1995	26	676	60	59	-	-	-	821	0
1996	60	836	118	43	-	-	-	1,057	0
1997	108	7,594	79	448	1,191	-	-	9,420	10,000
1998	2,543	13,609	885	609	2,511	-	-	20,156	20,000
1999	3,059	21,156	614	621	2,548	-	-	27,997	30,000
2000	3,436	16,247	740	870	3,807	-	-	25,100	20,000
2001	2,152	11,187	856	675	1,675	-	-	16,546	15,000
2002	1,326	11,292	499	579	1,623	-	-	15,319	15,000
2003	1,869	10,600	412	734	1,645	-	-	15,260	15,000
2004	1,595	9,450	790	465	2,113	-	-	14,414	15,000
2005	1,863	9,537	818	617	1,941	-	-	14,776	15,000
2006	1,011	9,590	675	555	1,326	-	-	13,157	13,000
2007	1,339	9,303	294	520	1,503	-	-	12,959	13,000
2008	982	8,654	377	467	1,293	-	-	11,773	13,000
2009	1,733	5,870	193	282	1,684	-	-	9,762	11,500
2010	1,419	5,244	196	76	1,364	-	-	8,299	11,500
2011	1,392	4,046	300	456	682	-	-	6,876	11,500
2012	658	3,596	277	265	291	-	-	5,087	11,500
2013	378	2,680	174	366	768	-	-	4,366	11,500
2014	614	4,199	637	279	1,158	-	-	6,887	13,225
2015	1415	3,706	175	440	724	-	-	6,460	13,490
2016	1,930	3,343	239	324	1,360	-	-	7,196	13,043
2017	1,387	4,413	239	51	552	-	-	6,641	6,500
2018[1]	387	4,108	80	21	126	-	-	4,722	5,980

[1]Provisional catches
[2]1996–2006 includes recreational and sentinel catch. 2007–18 does not include recreational catch.

Table 2. Reported fixed gear catches of cod (t) from NAFO Subdiv. 3Ps by gear type (includes non-Canadian and recreational catch). See Healey et al. (2014) for pre-1980 data.

Year	Gillnet	Longline	Handline	Trap	Total
1980	5,493	19,331	2,545	2,077	29,446
1981	4,998	20,540	1,142	948	27,628
1982	6,283	13,574	1,597	1,929	23,383
1983	6,144	12,722	2,540	3,643	25,049
1984	7,275	9,580	2,943	3,271	23,069
1985	7,086	10,596	1,832	5,674	25,188
1986	8,668	11,014	1,634	4,073	25,389
1987	9,304	11,807	1,628	4,931	27,670
1988	6,433	10,175	1,469	2,449	20,526
1989	5,997	10,758	1,657	5,996	24,408
1990	6,948	8,792	2,217	3,788	21,745
1991	6,791	10,304	1,832	4,068	22,995
1992	5,314	10,315	1,330	3,397	20,356
1993	3,975	3,783	1,204	3,557	12,519
1994	90	0	381	0	471
1995	383	182	0	5	570
1996	467	158	137	10	772
1997	3,760	1,158	1,172	1,167	7,258
1998	10,116	2,914	308	92	13,430
1999	17,976	3,714	503	45	22,237
2000	14,218	3,100	186	56	17,561
2001	7,377	2,833	2,089	57	12,357
2002	7,827	2,309	775	119	11,030
2003	8,313	2,044	546	35	10,937
2004	7,910	2,167	415	15	10,508
2005	8,112	2,016	626	6	10,760
2006	7,590	2,698	314	2	10,603
2007[2]	7,287	2,374	445	11	10,116
2008[2]	6,636	2,482	341	21	9,480
2009[2]	4,052	1,644	612	36	6,344
2010[2]	4,013	1,182	296	2	5,493
2011[2]	2,910	882	221	19	4,032
2012[2]	3,089	670	192	10	3,961
2013[2]	1,939	457	270	14	2,680
2014[2]	2,760	1,066	331	38	4,195
2015[2]	3,065	326	299	9	3,699
2016[2]	2,779	283	268	10	3,340
2017[2]	3,658	352	359	23	4,392
2018[2]	1,964	114	115	0	2,193
2019[123]	-	-	-	-	-

[1]provisional
[2]excluding recreational catch
[3]As of September 28, 2017.

Table 3. Reported Canadian (NL + Mar) monthly landings (t) of cod per unit area in NAFO Subdiv. 3Ps.

Year	Month	Inshore			Offshore					Total
		3Psa	3Psb	3Psc	3Psd	3Pse	3Psf	3Psg	3Psh	
2015	Jan	59.3	99.6	90.6	0.0	0.0	7.2	1.2	429.4	687.3
2015	Feb	58.6	18.3	34.4	4.6	0.0	0.0	15.6	210.2	341.8
2015	Mar	3.2	0.8	14.3	0.4	0.0	1.1	6.5	470.4	496.7
2015	Apr	3.3	0.5	4.3	0.0	0.0	0.0	0.2	4.6	12.8
2015	May	38.4	37.0	59.9	0.0	0.0	0.0	0.1	0.5	135.9
2015	Jun	35.3	51.7	280.2	0.5	0.2	8.2	0.0	0.2	376.4
2015	Jul	20.5	53.2	469.7	27.6	0.3	10.7	0.0	0.1	582.1
2015	Aug	7.4	20.1	222.6	18.9	0.0	77.6	8.1	0.1	354.8
2015	Sep	1.4	23.3	129.2	33.2	15.6	230.4	39.8	0.0	472.9
2015	Oct	4.3	37.9	189.0	2.0	31.3	226.9	46.5	24.3	562.2
2015	Nov	23.7	23.6	294.8	5.1	0.0	223.6	34.1	106.3	711.3
2015	Dec	63.6	150.4	127.0	0.5	32.9	0.0	0.0	187.2	561.6
2015	**Total**	**319.1**	**516.4**	**1,916.0**	**93.0**	**80.4**	**785.7**	**152.2**	**1,433.2**	**5,295.9**
2016	Jan	18.5	89.9	93.5	0.1	4.2	0.0	1.4	567.5	775.2
2016	Feb	29.0	56.2	37.0	0.7	0.0	4.7	14.3	941.9	1,083.9
2016	Mar	0.6	1.1	5.4	8.3	0.0	0.0	37.7	255.2	308.4
2016	Apr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.3	5.3
2016	May	34.1	41.8	51.2	0.0	0.0	0.0	0.0	19.0	146.2
2016	Jun	54.4	91.5	286.5	2.4	0.3	9.8	3.5	27.9	476.4
2016	Jul	30.8	56.0	456.0	14.4	0.7	10.8	5.8	9.3	583.9
2016	Aug	4.7	22.9	130.5	3.9	7.6	89.1	48.4	2.2	309.5
2016	Sep	7.5	9.1	83.4	40.2	5.2	121.1	41.1	1.5	309.0
2016	Oct	4.3	13.4	135.0	34.9	3.9	100.9	45.0	2.1	339.5
2016	Nov	59.5	115.1	423.2	63.3	28.9	56.5	21.6	74.0	842.2
2016	Dec	19.2	96.3	101.2	0.0	0.0	1.9	0.0	163.5	382.2
2016	**Total**	**262.5**	**593.4**	**1,803.1**	**168.3**	**51.0**	**394.9**	**218.9**	**2,069.4**	**5,561.6**
2017	Jan	128.9	129.6	159.4	0.9	15.2	15.3	20.5	530.1	1,000.0
2017	Feb	41.9	106.0	67.1	4.3	0.0	0.0	110.3	344.8	674.3
2017	Mar	23.7	0.0	1.8	19.5	0.0	0.5	0.4	100.8	146.6
2017	Apr	0.0	0.0	0.1	0.0	0.0	0.0	0.0	5.1	5.2
2017	May	19.4	58.6	47.2	0.5	0.2	0.0	0.3	0.5	126.8
2017	Jun	47.1	123.0	444.5	0.2	1.1	0.0	0.0	0.0	615.9
2017	Jul	8.7	57.5	989.2	0.9	0.0	3.1	0.4	3.9	1,063.6
2017	Aug	9.7	30.2	208.9	0.7	0.3	1.0	0.7	0.0	251.4
2017	Sep	6.6	17.2	139.4	10.3	25.7	131.8	15.8	2.9	349.7
2017	Oct	4.7	26.4	307.6	10.7	143.5	80.4	25.8	1.5	600.6
2017	Nov	4.9	58.8	304.6	4.4	59.0	12.4	1.0	27.5	472.7
2017	Dec	23.0	188.8	143.7	0.0	0.0	24.0	110.9	141.8	632.2
2017	**Total**	**318.7**	**796.0**	**2,813.3**	**52.4**	**245.1**	**268.6**	**286.0**	**1,159.0**	**5,939.0**
2018	Jan	56.5	94.4	75.7	0.0	6.6	0.0	47.1	129.3	409.7
2018	Feb	22.7	70.4	8.1	4.7	0.5	0.0	5.7	56.4	168.5
2018	Mar	6.2	0.0	0.0	18.9	0.0	0.0	6.0	59.5	90.5
2018	Apr	0.0	0.0	0.0	0.1	0.0	0.0	0.2	3.5	3.8
2018	May	19.6	36.8	50.3	1.3	0.0	0.0	0.5	3.3	111.9
2018	Jun	38.5	77.3	416.0	1.2	0.9	1.9	0.6	11.0	547.4
2018	Jul	8.3	51.2	785.4	24.8	0.0	14.7	0.9	15.7	901.1
2018	Aug	4.2	27.8	206.4	1.0	14.4	19.2	5.0	2.1	280.2
2018	Sep	4.3	29.0	138.5	2.6	69.7	10.0	51.1	0.8	306.0
2018	Oct	2.5	21.3	240.7	0.1	18.4	44.2	14.9	0.3	342.5
2018	Nov	9.2	53.7	551.5	7.2	25.6	30.5	0.3	0.1	678.1
2018	Dec	38.0	375.5	229.2	1.7	9.6	0.0	60.8	20.3	735.0

Year	Month	Inshore			Offshore					Total
		3Psa	3Psb	3Psc	3Psd	3Pse	3Psf	3Psg	3Psh	
2018	**Total**	**210.2**	**837.4**	**2,701.9**	**63.7**	**145.8**	**120.6**	**193.1**	**302.1**	**4,574.7**
2019	Jan	3.9	14.7	42.1	1.5	0.0	0.0	176.7	237.0	475.9
2019	Feb	3.0	0.0	0.0	5.2	0.0	0.0	11.7	82.8	102.7
2019	Mar	0.9	0.0	0.0	7.6	0.0	0.0	6.2	45.7	60.4
2019	Apr	16.5	0.0	1.7	0.0	0.0	0.0	2.8	1.1	22.1
2019	May	22.1	68.9	37.5	0.5	0.0	0.0	0.2	2.2	131.3
2019	Jun	25.6	85.9	483.8	1.1	0.0	6.8	0.2	0.0	603.5
2019	Jul	3.3	47.2	662.3	0.6	0.1	2.8	0.1	1.0	717.4
2019	Aug	2.2	35.4	150.2	0.3	0.0	0.0	0.0	6.2	194.3
2019	Sep	1.4	37.1	83.8	0.0	0.0	0.0	0.0	0.0	122.3
2019	Oct	-	-	-	-	-	-	-	-	-
2019	Nov	-	-	-	-	-	-	-	-	-
2019	Dec	-	-	-	-	-	-	-	-	-
2019	**Total**	78.9	289.2	1,461.3	12.8	0.0	9.2	188.1	330.9	2,370.4

*French catch (2015 = 1,164 t, 2016 = 1,132 t, 2017 = 602 t, 2018 = 118 t, 2019 =93 t) excluded since unit area not available.

Table 4. Summary of sampling conducted on 3Ps cod landings during 2018.

-		Landings		Number of	
Gear	**Reported (t)**	**Sampled (t)**	**Unsampled (%)**	**Length frequencies**	**Otoliths**
Inshore	-	-	-	-	-
Handline	257	85	67	781	11
Gillnet	3,204	2,621	18	13,017	1,036
Line trawl	252	46	82	7,413	430
Offshore	-	-	-	-	-
Gillnet	373	10	3	293	0
Line trawl	47	0	0	0	0
Otter trawl	538	237	44	3,469	290

Table 5. Estimates of average weight, average length and the total numbers and weight of 3Ps cod caught at age from Canadian and French landings during 2018 (Excludes recreational catch).

Year	Age	Average Weight (kg)	Average Length (cm)	Total Catch	Total Catch std error	Total Catch CV	Total Catch Weight (t)*
2018	1	-	-	-	-	-	-
2018	2	0.31	33.4	9	0	0.35	2.826
2018	3	0.69	43.1	1,560	0.18	0.12	1,073.28
2018	4	1.41	53.5	26,655	6.88	0.26	37,690.17
2018	5	1.55	55.1	102,286	13.39	0.13	158,441.014
2018	6	1.90	59.3	424,847	27.47	0.06	808,908.688
2018	7	2.15	61.5	1,032,906	30.37	0.03	2,218,682.088
2018	8	2.34	63.0	316,226	19.47	0.06	738,703.936
2018	9	3.29	69.1	111,150	13.91	0.13	365,238.9
2018	10	3.15	68.2	49,037	7.44	0.15	154,515.587
2018	11	3.62	71.8	15,468	2.96	0.19	56,056.032
2018	12	5.37	82.1	5,242	1.15	0.22	28,149.54
2018	13	5.81	83.8	1,247	0.57	0.45	7,240.082
2018	14	6.42	87.0	1,176	0.89	0.75	7,552.272
2018	15	10.11	103.0	125	0	0.01	1,264

Year	Age	Average Weight (kg)	Average Length (cm)	Total Catch	Total Catch std error	Total Catch CV	Total Catch Weight (t)*
2018	16	11.32	106.0	435	0.11	0.25	4,922.025
2018	17	-	-	-	-	-	-
2018	18	-	-	-	-	-	-
2018	19	-	-	-	-	-	-
2018	20	-	-	-	-	-	-

SOP = 0.97.

Table 6. Numbers-at-age (000s) for the commercial cod fishery in NAFO Subdiv. 3Ps from 1959 to 2018 (ages 3–14+ shown). Recreational catches excluded for 2007 onward (see text).

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14+
1959	1,001	13,940	7,525	7,265	4,875	942	1,252	1,260	631	545	44	1
1960	567	5,496	23,704	6,714	3,476	3,484	1,020	827	406	407	283	110
1961	450	5,586	10,357	15,960	3,616	4,680	1,849	1,376	446	265	560	91
1962	1,245	6,749	9,003	4,533	5,715	1,367	791	571	187	140	135	389
1963	961	4,499	7,091	5,275	2,527	3,030	898	292	143	99	107	284
1964	1,906	5,785	5,635	5,179	2,945	1,881	1,891	652	339	329	54	233
1965	2,314	9,636	5,799	3,609	3,254	2,055	1,218	1,033	327	68	122	165
1966	949	13,662	13,065	4,621	5,119	1,586	1,833	1,039	517	389	32	75
1967	2,871	10,913	12,900	6,392	2,349	1,364	604	316	380	95	149	55
1968	1,143	12,602	13,135	5,853	3,572	1,308	549	425	222	111	5	506
1969	774	7,098	11,585	7,178	4,554	1,757	792	717	61	120	67	220
1970	756	8,114	12,916	9,763	6,374	2,456	730	214	178	77	121	181
1971	2,884	6,444	8,574	7,266	8,218	3,131	1,275	541	85	125	62	57
1972	731	4,944	4,591	3,552	4,603	2,636	833	463	205	117	48	45
1973	945	4,707	11,386	4,010	4,022	2,201	2,019	515	172	110	14	29
1974	3,025	8,265	7,080	4,780	2,457	1,625	1,053	490	241	63	42	22
1975	675	3,301	2,557	4,655	5,357	874	778	233	169	51	20	4
1976	443	4,161	7,601	3,178	2,251	796	222	84	47	29	13	3
1977	552	7,718	7,976	4,409	1,008	308	276	108	48	57	26	12
1978	216	4,474	5,347	3,004	1,509	513	253	318	77	58	35	17
1979	130	1,669	12,064	4,567	1,839	720	252	49	36	4	3	4
1980	188	1,597	4,846	7,864	3,447	1,080	366	107	77	43	13	41
1981	1,074	3,616	2,745	3,914	5,210	1,663	576	190	142	127	22	6
1982	190	4,447	4,337	1,757	3,063	3,560	672	208	54	16	7	6
1983	754	2,733	9,536	3,008	1,471	1,050	1,256	293	109	49	21	6
1984	359	4,241	4,984	4,852	1,695	533	436	354	47	25	6	2
1985	160	2,839	7,950	5,406	4,994	1,624	606	654	267	98	18	8
1986	1,442	8,677	8,914	9,077	3,822	2,204	832	306	198	78	46	21
1987	636	2,517	7,779	7,902	6,605	1,823	1,298	466	141	131	144	136
1988	375	3,474	3,455	7,380	4,912	1,448	619	423	229	119	79	100
1989	1,104	6,967	4,991	2,056	2,393	1,606	960	528	314	110	57	67

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14+
1990	1,241	5,902	6,370	3,463	1,843	1,705	1,239	749	129	109	34	110
1991	425	7,592	5,925	3,873	1,615	756	875	784	333	181	197	221
1992	1,370	3,087	6,052	4,004	1,339	449	206	251	211	177	119	438
1993	278	3,712	2,035	3,156	1,334	401	89	38	52	13	14	5
1994	1	30	152	72	79	41	19	2	2	0	0	0
1995	0	0	39	102	34	26	5	0	0	0	0	0
1996	2	16	19	77	117	38	13	8	1	0	0	0
1997	14	455	1,345	602	769	922	254	113	124	7	13	1
1998	83	298	964	1,605	946	1,512	1,371	233	110	55	16	3
1999	49	677	1,333	2,139	2,479	1,155	901	849	203	127	23	14
2000	23	408	828	1,539	1,573	1,696	589	507	977	133	45	45
2001	76	576	844	1,162	1,172	796	720	269	186	199	25	17
2002	112	591	1,416	1,283	1,009	788	451	372	112	79	81	11
2003	18	363	1,051	2,063	1,278	644	353	277	156	58	46	84
2004	66	144	714	1,826	1,855	665	281	165	82	44	14	39
2005	70	427	634	1,106	1,653	1,236	598	157	114	45	25	39
2006	47	279	927	992	911	1,155	727	324	95	40	24	29
2007	63	279	756	1,122	875	540	575	485	178	54	42	42
2008	9	212	642	1,314	1,069	653	351	329	208	110	27	38
2009	20	131	914	1,037	841	469	223	102	93	66	45	28
2010	8	404	590	1,301	741	399	208	80	24	68	34	20
2011	28	152	922	912	893	362	169	64	27	21	8	15
2012	10	80	202	723	646	398	143	64	22	32	4	11
2013	10	166	458	393	495	361	149	56	22	16	4	8
2014	6	59	785	796	367	564	218	132	28	32	5	3
2015	2	289	298	893	610	262	303	72	32	7	3	4
2016	2	78	912	649	797	385	102	128	38	21	10	3
2017	0	18	262	1,408	512	472	211	74	46	11	18	7
2018	2	27	102	425	1,033	316	111	49	15	5	1	2
2019	2	18	82	382	1,038	333	105	53	23	6	1	1

Table 7a. Mean annual weights-at-age (kg) calculated from lengths-at-age based on samples from commercial fisheries (including food fisheries and sentinel surveys where available) in Subdiv. 3Ps in 1959–2019. The weights-at-age from 1976 are extrapolated back to 1959.

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14
1959	0.28	0.69	1.08	1.68	2.4	3.21	4.1	5.08	6.03	7	8.05	9.16
1960	0.28	0.69	1.08	1.68	2.4	3.21	4.1	5.08	6.03	7	8.05	9.16
1961	0.28	0.69	1.08	1.68	2.4	3.21	4.1	5.08	6.03	7	8.05	9.16
1962	0.28	0.69	1.08	1.68	2.4	3.21	4.1	5.08	6.03	7	8.05	9.16
1963	0.28	0.69	1.08	1.68	2.4	3.21	4.1	5.08	6.03	7	8.05	9.16
1964	0.28	0.69	1.08	1.68	2.4	3.21	4.1	5.08	6.03	7	8.05	9.16
1965	0.28	0.69	1.08	1.68	2.4	3.21	4.1	5.08	6.03	7	8.05	9.16
1966	0.28	0.69	1.08	1.68	2.4	3.21	4.1	5.08	6.03	7	8.05	9.16
1967	0.28	0.69	1.08	1.68	2.4	3.21	4.1	5.08	6.03	7	8.05	9.16
1968	0.28	0.69	1.08	1.68	2.4	3.21	4.1	5.08	6.03	7	8.05	9.16
1969	0.28	0.69	1.08	1.68	2.4	3.21	4.1	5.08	6.03	7	8.05	9.16
1970	0.28	0.69	1.08	1.68	2.4	3.21	4.1	5.08	6.03	7	8.05	9.16
1971	0.28	0.69	1.08	1.68	2.4	3.21	4.1	5.08	6.03	7	8.05	9.16
1972	0.28	0.69	1.08	1.68	2.4	3.21	4.1	5.08	6.03	7	8.05	9.16
1973	0.28	0.69	1.08	1.68	2.4	3.21	4.1	5.08	6.03	7	8.05	9.16
1974	0.399	0.624	1.064	1.813	2.429	3.349	3.927	4.832	5.438	7.558	9.337	8.466
1975	0.543	0.827	1.281	1.75	2.355	3.182	3.509	5.381	4.971	6.417	10.185	10.185
1976	0.537	1.005	1.455	2.284	3.032	4.267	5.439	7.395	7.426	9.873	11.45	16.628
1977	0.606	0.684	1.367	1.992	2.765	3.703	4.684	5.452	6.701	6.741	9.225	11.753
1978	0.545	0.763	1.111	2.03	2.888	3.929	4.612	6.058	7.233	6.981	9.747	10.954
1979	0.422	0.668	1.056	1.692	2.694	3.776	4.125	5.942	7.65	10.423	10.032	10.987
1980	0.511	0.776	1.147	1.715	2.357	3.561	5.474	7.193	7.219	9.872	9.566	8.527
1981	0.516	0.877	1.366	1.839	2.303	3.359	4.893	6.991	7.52	10.414	8.871	12.302
1982	0.462	0.809	1.171	1.82	2.396	2.819	3.756	4.853	6.814	8.394	8.805	11.688
1983	0.583	0.853	1.472	2.019	2.525	3.099	3.523	4.952	6.486	7.968	10.613	12.076
1984	0.671	1.201	1.485	2.105	2.741	4.26	5.369	6.314	8.081	10.55	7.704	8.682
1985	0.588	0.821	1.2	1.783	2.626	3.373	5.149	5.941	6.74	7.94	11.32	7.876
1986	0.532	0.691	1.15	1.744	2.327	3.075	4.96	6.132	6.293	7.489	9.41	12.003
1987	0.472	0.701	1.251	1.707	2.27	3.248	4.299	5.523	6.867	7.072	7.73	10.514

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14
1988	0.63	0.799	1.016	1.637	2.169	3.122	4.256	5.976	6.885	7.342	8.277	9.126
1989	0.559	0.79	1.166	1.709	2.441	3.531	4.58	6.081	6.529	7.448	7.889	8.98
1990	0.543	0.753	1.346	1.932	2.562	2.958	3.923	3.959	6.185	7.509	7.836	7.231
1991	0.435	0.7	1.135	1.877	2.608	3.234	4.382	5.15	6.894	8.143	8.065	10.071
1992	0.459	0.665	1.023	1.658	2.514	3.251	4.665	7.621	7.861	9.296	11.49	13.43
1993	0.417	0.848	1.344	1.945	2.08	2.652	3.701	4.286	7.307	6.585	7.378	7.435
1994	0.417	0.848	1.344	1.945	2.08	2.652	3.701	4.286	7.307	6.585	7.378	7.435
1995	0.4965	0.681	1.966	2.21	2.499	2.434	2.513	-	-	-	-	-
1996	0.576	0.878	1.383	1.879	2.389	2.709	3.862	4.374	8.354	6.57	10.112	13.097
1997	0.519	0.984	1.153	1.417	2.285	3.233	3.903	3.863	4.585	9.272	5.847	12.044
1998	0.598	0.984	1.736	1.982	2.361	3.158	4.087	3.994	4.439	4.458	5.717	5.459
1999	0.789	0.924	1.543	2.263	2.52	2.784	3.822	5.389	4.985	5.333	6.041	7.166
2000	0.442	1.23	1.219	1.949	2.763	2.808	3.337	4.858	6.799	6.719	6.717	8.679
2001	0.722	1.063	1.478	1.964	2.579	3.379	3.347	3.538	5.472	8.75	7.591	8.118
2002	0.586	1.053	1.531	1.972	2.289	3.013	4.023	3.627	3.751	6.198	9.153	7.133
2003	0.673	0.971	1.531	2.067	2.316	2.621	3.836	4.581	4.066	5.251	7.968	10.317
2004	0.619	0.996	1.409	2.091	2.479	2.709	2.901	4.45	6.298	5.331	6.88	8.703
2005	0.681	0.967	1.381	1.832	2.438	2.87	3.165	3.37	4.944	6.296	6.136	8.697
2006	0.643	1.012	1.53	1.898	2.175	2.732	3.405	3.89	3.213	5.147	7.014	7.387
2007	0.642	1.085	1.517	1.991	2.3	2.556	3.535	4.912	5.425	4.765	6.897	8.299
2008	0.912	0.961	1.349	1.949	2.202	2.522	2.717	4.073	5.214	5.041	5.257	8.153
2009	0.722	0.952	1.446	1.933	2.385	2.506	2.423	3.257	5.567	7.026	8.189	8.303
2010	0.805	1.128	1.334	1.966	2.161	2.523	2.605	2.85	5.562	7.751	9.753	10.329
2011	0.845	1.017	1.355	1.574	2.125	2.386	2.745	2.598	2.769	2.864	4.728	7.567
2012	0.836	0.965	1.418	1.982	2.019	2.206	2.82	3.305	3.559	2.665	2.849	2.897
2013	0.819	1.149	1.487	1.732	2.034	2.067	2.56	2.733	2.926	3.104	2.364	2.583
2014	0.93	1.03	1.832	2.046	2.097	2.731	2.49	3.281	3.826	2.644	4.532	4.873
2015	0.766	1.144	1.532	2.067	2.416	2.727	2.991	3.116	3.997	5.79	5.072	-
2016	0.837	1.184	1.506	1.787	2.261	2.385	2.958	3.575	4.038	4.749	4.14	7.625
2017	0.481	0.852	1.338	1.816	1.932	2.361	2.528	2.396	3.937	4.07	3.654	3.158
2018	0.688	1.414	1.549	1.904	2.148	2.336	3.286	3.151	3.624	5.37	5.806	6.422
2019	0.741	1.373	1.437	1.848	2.067	2.198	2.85	2.833	3.212	4.406	5.497	7.543

Table 7b. Beginning of the year weights-at-age (kg) calculated from commercial annual mean weights-at-age. The values for 1976 are extrapolated back to 1959. Weights at age 3 in 2018, and age 14 in 2018 are the geometric means of the prior three years.

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14
1959	0.178	0.440	0.863	1.347	2.008	2.776	3.628	4.564	5.535	6.497	7.507	8.587
1960	0.178	0.440	0.863	1.347	2.008	2.776	3.628	4.564	5.535	6.497	7.507	8.587
1961	0.178	0.440	0.863	1.347	2.008	2.776	3.628	4.564	5.535	6.497	7.507	8.587
1962	0.178	0.440	0.863	1.347	2.008	2.776	3.628	4.564	5.535	6.497	7.507	8.587
1963	0.178	0.440	0.863	1.347	2.008	2.776	3.628	4.564	5.535	6.497	7.507	8.587
1964	0.178	0.440	0.863	1.347	2.008	2.776	3.628	4.564	5.535	6.497	7.507	8.587
1965	0.178	0.440	0.863	1.347	2.008	2.776	3.628	4.564	5.535	6.497	7.507	8.587
1966	0.178	0.440	0.863	1.347	2.008	2.776	3.628	4.564	5.535	6.497	7.507	8.587
1967	0.178	0.440	0.863	1.347	2.008	2.776	3.628	4.564	5.535	6.497	7.507	8.587
1968	0.178	0.440	0.863	1.347	2.008	2.776	3.628	4.564	5.535	6.497	7.507	8.587
1969	0.178	0.440	0.863	1.347	2.008	2.776	3.628	4.564	5.535	6.497	7.507	8.587
1970	0.178	0.440	0.863	1.347	2.008	2.776	3.628	4.564	5.535	6.497	7.507	8.587
1971	0.178	0.440	0.863	1.347	2.008	2.776	3.628	4.564	5.535	6.497	7.507	8.587
1972	0.178	0.440	0.863	1.347	2.008	2.776	3.628	4.564	5.535	6.497	7.507	8.587
1973	0.178	0.440	0.863	1.347	2.008	2.776	3.628	4.564	5.535	6.497	7.507	8.587
1974	0.178	0.440	0.863	1.347	2.008	2.776	3.628	4.564	5.535	6.497	7.507	8.587
1975	0.178	0.440	0.863	1.347	2.008	2.776	3.628	4.564	5.535	6.497	7.507	8.587
1976	0.180	0.440	0.863	1.347	2.008	2.776	3.628	4.564	5.535	6.497	7.507	8.587
1977	0.488	0.436	0.947	1.417	2.118	2.865	3.667	4.500	5.484	6.385	7.840	9.367
1978	0.374	0.620	0.857	1.508	2.135	2.825	3.745	4.650	5.054	6.529	7.238	8.750
1979	0.309	0.541	0.841	1.335	2.112	3.003	3.586	5.158	6.010	6.511	8.283	9.166
1980	0.422	0.543	0.857	1.295	2.023	3.030	4.458	5.467	6.878	7.777	8.747	9.555
1981	0.379	0.641	0.975	1.426	1.954	2.848	3.962	5.538	7.176	8.118	8.514	9.444
1982	0.329	0.608	0.961	1.533	2.061	2.574	3.576	4.798	5.925	7.992	8.838	9.784
1983	0.433	0.615	1.012	1.526	2.143	2.774	3.295	4.439	5.885	7.226	9.312	10.106
1984	0.582	0.777	1.084	1.619	2.292	3.119	3.935	4.578	5.504	7.701	9.728	10.229
1985	0.577	0.749	1.131	1.583	2.353	3.014	4.350	5.343	5.829	6.569	9.417	10.834
1986	0.452	0.687	1.001	1.504	2.086	2.975	3.846	5.255	6.099	7.299	7.603	10.809
1987	0.463	0.645	0.953	1.387	2.062	2.709	3.693	4.688	5.840	6.573	7.857	8.194
1988	0.556	0.678	0.916	1.422	1.881	2.597	3.288	4.644	5.354	6.397	7.216	7.947
1989	0.539	0.714	0.975	1.333	1.938	2.704	3.464	4.306	5.597	6.399	7.152	8.070
1990	0.510	0.736	1.014	1.465	1.998	2.598	3.771	4.574	5.735	6.914	7.789	8.965
1991	0.558	0.660	1.003	1.487	2.094	2.670	3.327	4.225	5.681	6.983	8.103	8.987
1992	0.377	0.645	0.882	1.351	1.968	2.618	3.472	4.522	5.211	7.042	8.936	10.131
1993	0.234	0.559	0.865	1.239	1.822	2.507	3.543	4.221	5.095	6.936	7.317	9.255

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14
1994	0.525	0.538	0.941	1.415	1.744	2.417	3.185	4.359	5.202	6.032	7.130	7.434
1995	0.378	0.724	1.132	1.626	2.143	2.390	3.083	3.931	4.323	5.116	6.590	7.918
1996	0.584	0.716	1.123	1.793	2.264	2.695	2.998	3.734	4.554	4.470	5.494	7.447
1997	0.480	0.778	1.133	1.667	2.267	2.861	3.195	3.375	4.300	5.540	6.337	8.825
1998	0.509	0.793	1.187	1.635	2.128	2.789	3.619	3.786	4.035	4.889	6.377	9.118
1999	0.619	0.755	1.265	1.904	2.277	2.612	3.486	4.636	4.540	4.934	5.656	6.816
2000	0.478	0.792	1.118	1.801	2.516	2.668	2.981	4.245	5.898	5.528	5.818	6.891
2001	0.567	0.792	1.136	1.621	2.307	3.055	3.003	3.300	5.071	7.502	6.826	7.220
2002	0.439	0.837	1.254	1.714	2.121	2.827	3.838	3.534	3.659	5.815	8.750	7.774
2003	0.573	0.746	1.265	1.806	2.186	2.474	3.465	4.533	4.092	4.544	6.876	9.593
2004	0.464	0.810	1.154	1.790	2.295	2.532	2.740	4.406	5.644	4.749	6.164	8.288
2005	0.506	0.744	1.155	1.586	2.237	2.692	2.941	3.042	4.679	6.424	5.384	7.482
2006	0.455	0.802	1.209	1.640	1.997	2.599	3.159	3.309	3.189	4.633	6.369	6.436
2007	0.419	0.729	1.207	1.744	2.082	2.343	3.203	4.126	4.370	3.902	5.903	7.620
2008	0.535	0.738	1.125	1.665	2.089	2.347	2.581	3.768	5.076	5.400	4.931	7.736
2009	0.474	0.822	1.226	1.615	2.135	2.349	2.538	3.107	4.703	6.063	6.495	6.709
2010	0.491	0.825	1.178	1.755	2.089	2.478	2.618	2.768	4.501	6.782	8.204	8.921
2011	1.132	0.822	1.223	1.492	2.088	2.340	2.650	2.712	2.859	3.935	7.445	9.962
2012	0.623	0.993	1.216	1.636	1.813	2.172	2.580	2.998	3.093	2.720	3.487	4.958
2013	0.482	0.956	1.208	1.609	2.041	2.031	2.363	2.860	3.176	3.417	2.557	3.236
2014	0.853	0.818	1.478	1.798	1.966	2.404	2.274	2.896	3.412	2.892	3.726	3.518
2015	0.658	1.011	1.289	1.948	2.213	2.358	2.815	2.808	3.746	4.841	3.789	3.836
2016	0.669	0.971	1.314	1.677	2.198	2.422	2.803	3.289	3.552	4.544	5.204	6.398
2017	0.721	0.754	1.239	1.681	1.849	2.335	2.485	2.684	3.827	4.394	4.288	3.773
2018	0.721	0.904	1.280	1.764	2.080	2.371	2.696	2.916	3.707	4.589	4.389	4.524

Table 7c. Beginning of the year weights-at-age (stock weights in kg) modeled from the weights-at-age derived from the Canadian RV survey.

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14
1959	0.295	0.685	1.239	1.822	2.463	3.225	4.228	5.495	6.771	8.526	9.988	11.696
1960	0.295	0.685	1.239	1.822	2.463	3.225	4.228	5.495	6.771	8.526	9.988	11.696
1961	0.295	0.685	1.239	1.822	2.463	3.225	4.228	5.495	6.771	8.526	9.988	11.696
1962	0.295	0.685	1.239	1.822	2.463	3.225	4.228	5.495	6.771	8.526	9.988	11.696
1963	0.295	0.685	1.239	1.822	2.463	3.225	4.228	5.495	6.771	8.526	9.988	11.696
1964	0.295	0.685	1.239	1.822	2.463	3.225	4.228	5.495	6.771	8.526	9.988	11.696
1965	0.295	0.685	1.239	1.822	2.463	3.225	4.228	5.495	6.771	8.526	9.988	11.696
1966	0.295	0.685	1.239	1.822	2.463	3.225	4.228	5.495	6.771	8.526	9.988	11.696

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14
1967	0.295	0.685	1.239	1.822	2.463	3.225	4.228	5.495	6.771	8.526	9.988	11.696
1968	0.295	0.685	1.239	1.822	2.463	3.225	4.228	5.495	6.771	8.526	9.988	11.696
1969	0.295	0.685	1.239	1.822	2.463	3.225	4.228	5.495	6.771	8.526	9.988	11.696
1970	0.295	0.685	1.239	1.822	2.463	3.225	4.228	5.495	6.771	8.526	9.988	11.696
1971	0.295	0.685	1.239	1.822	2.463	3.225	4.228	5.495	6.771	8.526	9.988	11.696
1972	0.291	0.642	1.135	1.647	2.235	3.085	4.260	5.623	6.827	8.398	9.693	11.414
1973	0.286	0.624	1.090	1.601	2.155	2.799	3.805	5.172	6.429	7.952	9.199	10.854
1974	0.295	0.676	1.176	1.712	2.337	3.008	3.847	5.147	6.574	8.293	9.600	11.274
1975	0.308	0.734	1.355	1.949	2.636	3.428	4.339	5.448	6.836	8.838	10.402	12.095
1976	0.297	0.753	1.441	2.201	2.949	3.807	4.892	6.085	7.190	9.152	11.045	12.844
1977	0.268	0.651	1.322	2.105	3.010	3.861	4.944	6.242	7.321	8.799	10.494	12.539
1978	0.249	0.560	1.075	1.827	2.722	3.719	4.732	5.956	7.107	8.506	9.605	11.796
1979	0.261	0.603	1.073	1.757	2.790	3.951	5.313	6.610	7.821	9.484	10.623	12.690
1980	0.275	0.635	1.170	1.757	2.676	4.009	5.545	7.276	8.500	10.219	11.600	13.466
1981	0.275	0.624	1.128	1.724	2.377	3.385	4.927	6.673	8.255	9.826	11.106	12.852
1982	0.274	0.657	1.179	1.779	2.504	3.248	4.520	6.468	8.255	10.380	11.591	13.319
1983	0.250	0.607	1.146	1.703	2.369	3.150	4.009	5.493	7.435	9.679	11.462	12.855
1984	0.244	0.581	1.106	1.746	2.392	3.151	4.120	5.165	6.699	9.235	11.287	12.835
1985	0.232	0.562	1.043	1.669	2.428	3.164	4.113	5.302	6.297	8.327	10.782	12.521
1986	0.219	0.531	0.996	1.552	2.284	3.163	4.079	5.222	6.365	7.715	9.592	11.948
1987	0.221	0.505	0.935	1.477	2.110	2.946	4.030	5.079	6.105	7.593	8.648	11.229
1988	0.224	0.518	0.902	1.417	2.051	2.776	3.830	5.097	6.012	7.392	8.635	10.727
1989	0.225	0.546	0.971	1.431	2.060	2.831	3.800	5.110	6.364	7.681	8.837	10.809
1990	0.201	0.482	0.884	1.313	1.762	2.401	3.281	4.304	5.425	6.944	7.884	9.579
1991	0.206	0.445	0.799	1.248	1.697	2.167	2.955	3.953	4.856	6.289	7.567	8.902
1992	0.241	0.503	0.817	1.264	1.815	2.359	3.038	4.078	5.123	6.465	7.854	9.336
1993	0.242	0.573	0.912	1.259	1.796	2.478	3.272	4.164	5.246	6.755	7.991	9.723
1994	0.220	0.520	0.938	1.244	1.580	2.161	3.038	3.971	4.735	6.125	7.409	9.015
1995	0.223	0.501	0.903	1.379	1.686	2.056	2.864	3.968	4.826	5.891	7.126	8.793
1996	0.231	0.503	0.857	1.316	1.866	2.207	2.755	3.780	4.866	6.057	6.900	8.722
1997	0.249	0.551	0.922	1.343	1.917	2.632	3.185	3.896	4.963	6.527	7.553	9.204
1998	0.256	0.577	0.995	1.414	1.923	2.674	3.759	4.439	5.051	6.576	8.031	9.525
1999	0.273	0.597	1.056	1.539	2.040	2.705	3.839	5.248	5.779	6.721	8.113	9.850
2000	0.274	0.588	1.000	1.484	2.014	2.606	3.521	4.854	6.217	7.008	7.577	9.584

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14
2001	0.270	0.596	0.994	1.423	1.965	2.605	3.423	4.471	5.766	7.537	7.890	9.561
2002	0.256	0.600	1.035	1.450	1.921	2.579	3.446	4.356	5.323	6.995	8.482	9.378
2003	0.246	0.566	1.038	1.502	1.947	2.501	3.383	4.353	5.167	6.450	7.875	9.070
2004	0.261	0.566	1.023	1.596	2.143	2.697	3.510	4.590	5.574	6.761	7.842	9.435
2005	0.268	0.600	1.023	1.573	2.276	2.976	3.826	4.850	6.024	7.469	8.415	10.115
2006	0.252	0.572	1.007	1.454	2.078	2.932	3.924	4.902	5.888	7.442	8.590	10.083
2007	0.228	0.540	0.958	1.439	1.930	2.690	3.890	5.049	5.973	7.293	8.588	10.024
2008	0.201	0.469	0.857	1.299	1.803	2.343	3.328	4.639	5.710	6.871	7.832	9.349
2009	0.221	0.470	0.838	1.327	1.854	2.484	3.286	4.487	5.918	7.358	8.225	9.722
2010	0.236	0.521	0.846	1.306	1.905	2.577	3.520	4.487	5.820	7.769	8.977	10.294
2011	0.243	0.505	0.846	1.170	1.656	2.342	3.233	4.270	5.195	6.840	8.516	9.672
2012	0.248	0.534	0.844	1.209	1.539	2.126	3.074	4.112	5.191	6.407	7.861	9.386
2013	0.210	0.511	0.834	1.117	1.478	1.848	2.618	3.678	4.712	6.047	6.966	8.703
2014	0.211	0.462	0.858	1.200	1.494	1.951	2.500	3.439	4.608	5.981	7.140	8.670
2015	0.209	0.469	0.772	1.238	1.610	1.975	2.637	3.284	4.301	5.844	7.057	8.588
2016	0.204	0.449	0.758	1.079	1.616	2.078	2.612	3.392	4.014	5.339	6.757	8.228
2017	0.203	0.439	0.723	1.061	1.415	2.095	2.759	3.365	4.143	4.984	6.176	7.833
2018	0.217	0.463	0.752	1.081	1.493	1.970	2.979	3.786	4.361	5.452	6.096	7.990
2019	0.204	0.454	0.723	1.019	1.381	1.890	2.545	3.730	4.501	5.287	6.162	7.619
2020	0.210	0.471	0.790	1.098	1.459	1.950	2.701	3.509	4.847	5.932	6.478	7.985
2021	0.212	0.483	0.822	1.196	1.562	2.041	2.758	3.692	4.520	6.336	7.215	8.383
2022	0.217	0.487	0.844	1.241	1.693	2.169	2.861	3.742	4.720	5.868	7.658	8.517

Table 8. Details of annual DFO research vessel surveys of 3Ps.

Year	Vessel	Start Date	End Date	Days	Sets	Sets w/ Cod	% w/ cod
1983	AN 9	23-Apr-83	8-May-83	15	164	117	0.71
1984	AN 26	10-Apr-84	17-Apr-84	7	93	59	0.63
1985	WT 26	8-Mar-85	25-Mar-85	17	109	78	0.72
1986	WT 45	6-Mar-86	23-Mar-86	17	136	88	0.65
1987	WT 55–56	13-Feb-87	22-Mar-87	37	130	95	0.73
1988	WT 68	27-Jan-88	14-Feb-88	18	146	106	0.73
1989	WT 81	1-Feb-89	16-Feb-89	15	146	90	0.62

Year	Vessel	Start Date	End Date	Days	Sets	Sets w/ Cod	% w/ cod
1990	WT 91	1-Feb-90	19-Feb-90	18	108	66	0.61
1991	WT 103	2-Feb-91	20-Feb-91	18	158	104	0.66
1992	WT 118	6-Feb-92	24-Feb-92	18	137	63	0.46
1993.1	WT 133	6-Feb-93	23-Feb-93	17	136	52	0.38
1993.4	WT 135	2-Apr-93	20-Apr-93	18	130	63	0.48
1994	WT 150–151	6-Apr-94	26-Apr-94	20	166	73	0.44
1995	WT 166–167	04-Apr-95	28-Apr-95	24	161	65	0.40
1996	WT 186–187	10-Apr-96	01-May-96	22	148	105	0.71
1997	WT 202–203	02-Apr-97	23-Apr-97	22	158	104	0.66
1998	WT 219–220	10-Apr-98	05-May-98	25	177	113	0.64
1999	WT 236–237	13-Apr-99	06-May-99	23	175	128	0.73
2000	WT 313–315	08-Apr-00	11-May-00	34	171	136	0.80
2001	WT 364–365, Tel 351	07-Apr-01	29-Apr-01	23	173	134	0.77
2002	WT 418–419	05-Apr-02	27-Apr-02	21	177	117	0.66
2003	WT 476–477	05-Apr-03	02-May-03	23	176	117	0.66
2004	WT 523, WT 546, Tel 522	11-Apr-04	11-May-04	30	177	107	0.60
2005	WT 617–618, AN 656	17-Apr-05	09-May-05	22	178	134	0.75
2006	WT 688	13-Apr-06	18-Apr-06	5.1	48	43	-
2007	WT 757–759	04-Apr-07	02-May-07	29	178	135	0.76
2008	WT 824–827	10-Apr-08	23-May-08	44	169	115	0.68
2009	AN 902–904	08-Apr-09	13-May-09	35	175	137	0.78
2010	AN 930–932	08-Apr-10	08-May-10	31	177	132	0.75
2011	AN 401–403	07-Apr-11	08-May-11	32	174	131	0.75
2012	AN 415–417	31-Mar-12	26-Apr-12	27	177	137	0.77
2013	AN 430–432	26-Mar-13	23-Apr-13	29	179	133	0.74
2014	AN 445–446, Tel 130	05-Apr-14	10-May-14	36	156	105	0.67
2015	AN 450–452	11-Apr-15	10-May-15	30	173	116	0.67

Year	Vessel	Start Date	End Date	Days	Sets	Sets w/ Cod	% w/ cod
2016	Tel 157,158,169	02-Apr-16	01-May-16	30	157	110	0.70
2017	AN 476–478	06-Apr-17	08-May-17	33	179	121	0.68
2018	AN 494–496	28-Apr-18	27-May-18	30	167	115	0.69
2019	AN 506–508	30-Mar-19	4-May-19	35	169	106	0.63

*Table 9. Cod abundance estimates (000's of fish) from DFO bottom-trawl research vessel surveys in NAFO Subdiv. 3Ps.**

Strata	Depth (fathoms)	sq. mi.	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
314	<30	974	287	328	1,223	563	172	89	395	1,280	1,680	22
320	<30	1,320	1,260	1,603	4,213	1,189	893	363	715	1,483	3,841	838
293	31–50	159	55	284	503	1,312	186	56	66	93	973	197
308	31–50	112	16,893	3,058	1,167	878	4,437	28,379	131	3,821	1,425	169
312	31–50	272	112	337	1310	854	4,247	75	792	599	1,553	206
315	31–50	827	767	1,405	3,705	2,243	11,141	211	2,476	228	2,844	861
321	31–50	1,189	1,823	2,608	393	549	307	157	613	474	8,289	1,276
325	31–50	944	7,970	8,019	519	2,194	2,708	1,217	200	114	730	487
326	31–50	166	11	627	11	57	11	23	38	23	0	0
783	31–50	229	515	228	126	110	63	72	142	16	221	44
294	51–100	135	713	59	2,658	1,476	845	1,401	716	1,576	2,646	1,367
297	51–100	152	4,242	2,781	3,922	1,547	1,181	1,241	554	1,302	920	5,499
307	51–100	395	7,758	4,945	3,412	1,902	2,010	7,480	1,793	5,868	3,152	6,466
311	51–100	317	9,627	1,979	3,212	17,063	2,847	1,352	2,209	2,965	5,152	2,384
317	51–100	193	3,215	330	7,022	12,721	0	199	1,739	942	27	5,031
319	51–100	984	20,120	10,120	35,549	40,494	15,851	20,338	13,826	11,624	6,071	22,102
322	51–100	1,567	820	2,546	3,162	11,202	8,400	1,376	1,616	1,026	8,969	2,867
323	51–100	696	15,274	8,179	3,067	1,332	2,489	7,854	3,452	112	394	447
324	51–100	494	417	3,590	646	610	510	680	234	158	731	702
781	51–100	446	293	506	813	5,031	1,166	756	205	622	2,491	1,242
782	51–100	183	22	566	327	512	1,032	277	138	566	793	712
295	101–150	209	2,441	nf	971	1,639	1,776	2,444	1,495	13,451	1,279	1,624
298	101–150	171	585	0	6,764	134	125	141	118	3,093	12	12
300	101–150	217	194	917	43	637	254	68	388	968	95	90
306	101–150	363	714	1,382	706	877	574	433	136	233	133	316
309	101–150	296	236	529	308	49,273	145	41	22,517	38	0	5,366
310	101–150	170	143	129	35	1,695	86	386	82	53	35	160
313	101–150	165	259	21	11	164	571	23	227	261	0	20
316	101–150	189	10	12	17	65	0	45	30	23	15	0
318	101–150	129	18	9	9	237	21	35	68	9	0	27

Strata	Depth (fathoms)	sq. mi.	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
779	101–150	422	0	503	5,955	12,283	7,372	192	348	318	581	916
780	101–150	403	0	388	526	3,587	1,002	127	698	147	249	1,285
296	151–200	71	32	3,581	2,269	2,338	103	161	347	893	15	587
299	151–200	212	42	58	39	110	188	0	29	33	15	0
705	151–200	195	36	29	0	13	63	13	27	13	0	13
706	151–200	476	258	131	98	16	0	35	147	646	64	15
707	151–200	74	23	16	15	173	12	22	5	9	nf	31
715	201–300	1,074	63	53	18	26	0	3,600	117	149	nf	23
716	151–200	128	180	130	676	2,330	264	551	148	0	0	0
708	151–200	539	26	30	28	199	nf	59	nf	327	nf	8
711	201–300	126	44	29	3,850	16	0	16	41	63	669	87
712	201–300	593	15	34	65	0	20	17	40	0	0	17
713	201–300	731	56	0	134	36	0	0	20	17	0	50
714	201–300	851	55	70	79	0	0	169	92	29	16	0
Total	Offshore	-	88,490	52,275	74,660	148,972	57,779	75,237	53,926	32,588	45,788	49,991
Total	In/Offshore	-	97,625	62,146	99,575	179,689	73,072	82,172	59,170	55,667	56,077	62,198
std	Offshore	-	24,153	8,209	12,294	53,762	10,415	29,521	24,399	5,429	9,423	-

*See Fig. 14 for location of strata. The survey was not completed in 2006. See Brattey et al. (2007) for pre-2005 data.

*Table 10. Cod biomass estimates (t) from DFO bottom-trawl research vessel surveys in NAFO Subdiv. 3Ps.**

Strata	Depth (fathoms)	sq. mi.	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
314	<30	974	43	100	200	69	30	52	98	269	230	8
320	<30	1,320	603	500	1,695	1,618	759	69	363	1,113	1,444	1,580
293	31–50	159	15	19	46	52	10	13	5	6	64	23
308	31–50	112	8,343	1,558	426	732	1,408	13,903	49	2,184	692	56
312	31–50	272	37	78	206	234	904	30	125	104	1,081	71
315	31–50	827	235	1,295	1,585	544	4,726	180	796	83	1,611	452
321	31–50	1,189	2,054	1,639	150	114	140	56	130	78	7,413	257
325	31–50	944	4,194	2,831	269	547	923	385	18	12	197	31
326	31–50	166	19	140	4	25	3	5	7	3	0	0
783	31–50	229	31	25	7	19	27	1	25	2	31	2
294	51–100	135	55	7	315	73	47	111	45	67	1,185	85
297	51–100	152	1,224	2,110	1,863	528	227	285	138	175	348	1,668
307	51–100	395	4,100	3,258	1,563	650	951	2,185	565	3,137	1,412	3,345
311	51–100	317	2,414	394	348	1,512	684	108	310	178	4,020	274
317	51–100	193	2,436	31	2,849	970	0	67	325	29	12	862
319	51–100	984	20,494	10,024	28,365	20,804	12,559	11,071	4,507	6,151	2,756	8,662

Strata	Depth (fathoms)	sq. mi.	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
322	51–100	1,567	439	1,395	206	607	1,439	201	182	77	6,343	217
323	51–100	696	10,070	4,602	655	127	1,220	4,048	1,676	11	135	33
324	51–100	494	39	653	86	175	97	112	21	20	86	34
781	51–100	446	33	44	55	151	70	114	15	44	149	94
782	51–100	183	1	328	30	101	42	51	9	22	32	23
295	101–150	209	519	Nf	477	117	204	453	260	6,718	171	124
298	101–150	171	250	0	3,903	37	79	43	59	1,732	32	0
300	101–150	217	111	480	94	200	74	14	138	510	77	37
306	101–150	363	630	932	649	501	268	244	74	120	256	231
309	101–150	296	282	333	210	44,380	25	14	17,005	18	0	3,591
310	101–150	170	82	105	17	306	74	152	28	39	31	103
313	101–150	165	213	14	21	39	315	12	87	341	0	15
316	101–150	189	7	7	29	23	0	75	30	12	4	0
318	101–150	129	32	38	15	438	51	50	76	7	0	59
779	101–150	422	0	168	1,246	4,719	1,875	34	15	19	54	54
780	101–150	403	0	71	21	284	178	13	80	3	10	138
296	151–200	71	5	2,702	1,863	589	29	33	131	236	1	69
299	151–200	212	26	63	29	9	275	0	21	29	11	0
705	151–200	195	47	36	0	49	141	18	88	8	0	1
706	151–200	476	153	180	126	17	0	53	110	597	107	19
707	151–200	74	20	24	71	154	27	21	6	17	nf	47
715	151–200	1,074	101	74	16	45	0	2,033	181	288	nf	39
716	151–200	128	124	111	1,102	1,476	307	311	178	0	0	0
708	201–300	539	16	30	32	269	nf	109	nf	334	nf	13
711	201–300	126	33	25	3,546	4	0	7	21	61	1,026	135
712	201–300	593	10	22	55	0	9	9	31	0	0	5
713	201–300	731	101	0	124	16	0	0	7	17	0	31
714	201–300	851	55	59	87	0	0	160	119	48	48	0
Total	Offshore	-	57,429	30,487	44,706	76,447	27,057	35,740	27,211	15,356	28,905	16,828
Total	In/Offshore	-	59,698	36,505	54,656	83,327	30,195	36,905	28,154	24,920	31,068	22,491
std	Offshore	-	18,906	5,042	11,579	44,705	6,964	14,899	17,255	3,512	7,956	-

*See Fig. 14 for location of strata. The survey was not completed in 2006. See Brattey et al. (2007) for pre-2005 data.

Table 11a. Mean numbers per tow at age (1–15 only) in Campelen units for the Canadian research vessel bottom trawl survey of NAFO Subdiv. 3Ps (offshore index strata only).

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Total
1983	6.42	10.01	6.52	1.14	3.72	1.62	0.48	0.89	1.61	0.75	0.36	0.14	0.06	0.05	0.04	33.81
1984	0.30	5.40	2.33	1.55	0.63	2.11	0.77	0.37	0.46	0.71	0.18	0.15	0.06	0.03	0.00	15.03
1985	0.38	7.74	14.88	12.57	9.96	3.28	2.66	0.79	0.48	0.42	0.42	0.49	0.21	0.12	0.03	54.43
1986	0.20	6.62	5.65	6.48	7.95	6.33	2.13	1.47	0.84	0.29	0.24	0.29	0.17	0.10	0.06	38.82
1987	1.09	8.48	5.67	4.97	13.82	8.31	3.35	1.29	0.69	0.28	0.23	0.16	0.17	0.16	0.06	48.73
1988	0.42	9.13	5.93	2.96	2.84	6.50	5.84	3.65	1.49	0.84	0.74	0.35	0.16	0.15	0.09	41.09
1989	0.49	6.50	4.66	3.17	1.51	1.16	2.15	1.21	0.67	0.37	0.41	0.13	0.11	0.05	0.09	22.68
1990	0.00	1.48	9.82	14.49	10.89	5.67	3.84	3.14	1.15	0.71	0.32	0.16	0.12	0.09	0.01	51.88
1991	1.30	27.69	5.03	10.00	11.24	5.75	2.84	1.58	1.19	0.74	0.56	0.22	0.11	0.07	0.04	68.36
1992	0.00	1.80	6.95	2.11	4.15	2.03	1.03	0.53	0.26	0.24	0.08	0.04	0.01	0.01	0.02	19.26
1993 (Feb)	0.00	0.00	1.83	4.03	0.71	2.96	0.68	0.33	0.13	0.09	0.11	0.03	0.04	0.01	0.01	10.96
1993 (Apr)	0.00	0.00	1.99	4.04	1.49	1.35	0.47	0.10	0.04	0.03	0.04	0.01	0.00	0.01	0.01	9.58
1994	0.00	1.63	1.46	4.31	6.10	1.73	1.62	0.50	0.08	0.04	0.03	0.02	0.01	0.01	0.00	17.54
1995	0.00	0.31	1.16	1.67	13.08	19.65	4.40	5.75	2.19	0.25	0.20	0.01	0.07	0.03	0.00	48.77
1996	0.90	1.08	3.67	3.62	1.32	2.69	2.91	0.54	0.46	0.09	0.09	0.02	0.00	0.00	0.00	17.39
1997	0.22	1.53	2.33	1.04	0.50	0.28	0.30	0.24	0.14	0.05	0.02	0.00	0.00	0.00	0.00	6.65
1998	0.52	0.97	6.79	8.42	5.60	3.99	1.96	2.50	2.79	0.43	0.30	0.06	0.03	0.00	0.00	34.36
1999	1.24	2.54	2.55	2.38	2.58	2.34	1.72	0.44	0.79	0.60	0.09	0.02	0.02	0.00	0.00	17.31
2000	1.25	3.33	5.36	3.10	2.17	1.82	1.20	0.89	0.35	0.31	0.53	0.12	0.00	0.01	0.00	20.44
2001	0.57	2.26	12.41	12.29	4.36	2.04	1.26	0.77	0.71	0.38	0.50	0.94	0.12	0.06	0.03	38.70
2002	0.58	1.10	3.90	8.28	5.85	3.04	2.04	0.99	0.53	0.37	0.08	0.12	0.19	0.01	0.00	27.08
2003	0.52	1.46	1.78	4.08	6.55	3.94	1.50	0.72	0.33	0.18	0.19	0.05	0.11	0.01	0.01	21.43
2004	0.20	1.90	2.07	1.71	2.08	4.05	4.24	1.26	0.81	0.67	0.79	0.15	0.10	0.02	0.07	20.12
2005	0.77	1.43	6.73	4.96	1.60	0.89	0.79	0.71	0.28	0.05	0.17	0.08	0.03	0.03	0.09	18.61
2007	3.18	1.73	4.84	3.11	1.48	0.76	0.44	0.22	0.47	0.42	0.12	0.09	0.08	0.05	0.01	17.00
2008	0.47	4.39	4.51	3.32	1.92	1.12	0.47	0.32	0.12	0.15	0.10	0.04	0.03	0.01	0.00	16.97
2009	0.40	1.43	9.25	6.67	5.70	3.09	1.79	0.99	0.21	0.17	0.21	0.38	0.14	0.02	0.00	30.45
2010	0.60	2.13	7.65	15.71	6.70	4.06	1.47	0.29	0.10	0.04	0.04	0.09	0.01	0.00	0.00	38.89
2011	0.15	4.70	6.55	2.46	5.08	1.92	1.41	0.48	0.10	0.08	0.00	0.02	0.01	0.01	0.00	22.97
2012	5.32	2.94	8.88	5.82	3.22	3.38	1.75	0.96	0.17	0.26	0.02	0.04	0.00	0.01	0.02	32.79
2013	1.58	18.42	11.49	16.61	6.43	4.50	3.09	2.36	0.56	0.28	0.07	0.01	0.00	0.01	0.00	65.41
2014	0.85	3.33	11.33	4.74	2.22	1.15	0.43	0.94	0.48	0.07	0.00	0.01	0.00	0.01	0.00	25.56
2015	0.11	4.55	9.11	12.60	3.32	1.36	1.07	0.36	0.50	0.06	0.01	0.00	0.00	0.00	0.00	33.05
2016	0.98	2.40	6.10	5.27	5.45	2.31	0.81	0.25	0.14	0.16	0.01	0.00	0.00	0.00	0.00	23.87
2017	1.30	2.42	2.77	2.25	2.42	2.12	0.55	0.32	0.09	0.03	0.05	0.00	0.00	0.00	0.00	14.30
2018	0.89	4.53	4.55	2.77	1.90	2.46	2.58	0.26	0.22	0.20	0.15	0.01	0.00	0.00	0.00	20.52

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Total
2019	0.63	5.32	6.85	4.72	1.96	1.02	0.94	0.31	0.11	0.05	0.04	0.00	0.01	0.00	0.00	21.95

*Data are adjusted for missing strata. The survey in 2006 was not completed and there were two surveys in 1993 (February and April).

Table 11b. Mean numbers per tow at age (1–15 only) in Campelen units for the Canadian research vessel bottom trawl survey of NAFO Subdiv. 3Ps (inshore and offshore strata).

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Total
1997	0.32	1.68	2.44	1.01	0.46	0.25	0.26	0.21	0.12	0.04	0.01	0.00	0.00	0.00	0.00	6.80
1998	0.72	1.28	6.28	7.40	4.91	3.53	1.73	2.19	2.43	0.38	0.26	0.06	0.03	0.00	0.00	31.20
1999	1.31	3.05	2.52	2.26	2.41	2.12	1.54	0.39	0.68	0.52	0.07	0.02	0.02	0.01	0.00	16.92
2000	1.38	3.84	6.66	3.52	2.24	1.75	1.11	0.80	0.31	0.28	0.46	0.11	0.00	0.01	0.00	22.47
2001	0.99	2.88	11.44	10.58	3.71	1.74	1.08	0.66	0.60	0.32	0.43	0.80	0.10	0.05	0.03	35.41
2002	0.79	1.53	3.72	7.08	4.95	2.58	1.73	0.85	0.45	0.31	0.07	0.11	0.16	0.01	0.00	24.34
2003	0.61	2.62	2.24	3.67	5.88	3.51	1.34	0.63	0.28	0.16	0.17	0.04	0.09	0.01	0.01	21.26
2004	0.33	2.24	2.50	1.85	1.93	3.49	3.61	1.08	0.68	0.57	0.67	0.13	0.09	0.02	0.06	19.25
2005	0.80	1.63	7.32	7.27	3.49	2.08	1.52	1.20	0.41	0.09	0.15	0.06	0.03	0.03	0.08	26.16
2007	3.31	2.34	5.33	3.26	2.11	1.14	0.76	0.35	0.56	0.37	0.12	0.10	0.07	0.04	0.01	19.87
2008	0.55	4.09	4.30	3.27	1.99	1.22	0.50	0.34	0.12	0.14	0.08	0.04	0.02	0.01	0.00	16.67
2009	1.44	2.47	8.64	5.81	4.91	2.65	1.53	0.84	0.18	0.15	0.18	0.32	0.12	0.01	0.00	29.25
2010	0.68	2.76	7.75	13.95	5.87	3.53	1.27	0.25	0.08	0.03	0.03	0.07	0.01	0.00	0.00	36.28
2011	0.19	4.63	6.37	2.56	5.46	2.04	1.42	0.49	0.09	0.08	0.00	0.02	0.01	0.01	0.00	23.37
2012	5.50	3.99	11.21	6.37	3.34	3.39	1.76	0.94	0.16	0.25	0.01	0.04	0.00	0.01	0.02	36.99
2013	3.14	19.94	12.11	16.14	5.83	4.04	2.72	2.06	0.48	0.24	0.06	0.01	0.00	0.01	0.00	66.78
2014	1.44	5.21	11.03	4.54	2.23	1.11	0.41	0.83	0.42	0.06	0.00	0.01	0.00	0.01	0.00	27.32
2015	0.41	4.90	8.47	10.97	2.87	1.17	0.92	0.31	0.43	0.06	0.01	0.00	0.00	0.00	0.00	30.51
2016	1.07	2.58	5.98	4.62	4.71	2.00	0.69	0.22	0.12	0.14	0.01	0.00	0.00	0.00	0.00	22.13
2017	1.74	3.22	4.34	3.99	3.57	2.62	0.62	0.38	0.09	0.04	0.05	0.00	0.00	0.00	0.00	20.66
2018	1.67	5.40	4.56	2.58	1.73	2.22	2.29	0.23	0.19	0.17	0.13	0.01	0.00	0.00	0.00	21.20
2019	1.17	6.73	6.77	4.31	2.00	1.20	0.90	0.31	0.13	0.04	0.04	0.00	0.01	0.00	0.00	23.62

*Data are adjusted for missing strata. The survey in 2006 was not completed.

Table 12. Mean length-at-age (cm) of cod sampled during research bottom-trawl surveys in Subdiv. 3Ps in winter-spring 1983–2018. Shaded entries (*) are based on fewer than 5 aged fish.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12
1983	10.3	20.2	31.2	43.1	52.9	57.8	65.6	71.5	73.4	79.4	89.6	93.7
1984	12.0*	19.2	30.7	42.1	52.2	60.7	66.2	70.6	75.5	79.1	84.2	98.1
1985	-	17.9	29.1	40.3	51.2	60.2	66.4	74.2	73.9	79.4	88.9	93.0
1986	11.0*	18.8	27.1	40.3	49.0	55.7	62.1	72.2	76.4	82.8	93.3	93.9
1987	10.7	19.9	29.5	39.5	48.4	54.1	61.2	67.3	77.8	85.4	83.2	89.9
1988	9.2*	19.7	29.0	40.7	47.8	56.2	62.2	66.7	74.6	79.7	79.7	87.5
1989	12.0*	19.2	30.2	41.7	48.2	56.3	64.0	71.8	75.9	84.6	88.5	96.6
1990	-	19.9	29.9	40.1	48.3	53.7	56.6	62.3	70.1	76.2	79.1	88.7
1991	9.5	19.2	29.8	39.0	47.0	53.5	57.4	62.8	68.2	73.7	73.8	77.1
1992	-	20.7	30.4	40.9	47.4	55.3	61.2	62.4	66.7	73.3	83.9	81.8
1993	-	-	30.9	41.3	48.0	52.7	62.3	70.6	77.1	80.2*	96.0	106.0*
1994	-	19.1	32.2	39.4	48.2	50.2	53.7	59.1	68.0	87.7	79.7*	90.5
1995	-	21.2*	29.9	42.0	50.4	56.5	58.2	57.9	63.0	79.6	81.3	83.6*
1996	12.6	20.8	30.0	38.7	44.2	52.9	60.9	61.2	63.3	76.8	74.7	86.1*
1997	12.7	24.1	31.8	40.9	48.2	51.6	60.7	65.4	67.3	67.3	82.5*	-
1998	10.6	22.3	32.8	42.7	49.1	53.3	57.6	67.1	77.4	77.2	64.3	78.0*
1999	12.0	22.4	31.4	43.2	51.4	58.9	61.7	66.2	77.6	86.8	76.9	109.0*
2000	13.3	22.0	31.7	40.8	48.8	54.7	60.5	65.3	67.9	81.2	92.7	89.1
2001	10.6	21.9	33.2	40.6	47.6	51.4	57.4	68.8	77.5	75.0	85.5	96.8
2002	12.0	22.0	31.8	42.0	50.8	55.1	55.2	67.2	74.6	79.8	73.4*	86.0
2003	10.7	23.7	31.9	43.0	51.8	55.4	58.6	58.7	70.5	72.0	65.5	86.6*
2004	14.0	20.2	33.7	38.9	47.6	60.8	66.3	69.2	67.3	69.6	73.2	73.5*
2005	12.1	25.5	34.2	41.9	48.6	54.5	63.5	67.6	72.3	72.6*	99.2	103.4
2006	-	-	-	-	-	-	-	-	-	-	-	-
2007	11.1	21.2	30.7	38.1	48.9	54.9	55.8	64.9	81.7	91.6	86.9	86.6
2008	11.7	18.4	26.6	38.5	45.9	53.0	60.2	59.4	66.9	68.2	90.0	94.1
2009	12.3	19.1	31.3	38.7	46.7	55.0	60.5	63.5	72.3	76.0	83.3	87.2
2010	11.8	22.7	30.5	40.4	45.6	55.0	65.8	70.9	75.2	81.1*	92.6*	103.1
2011	14.0	23.5	30.2	40.1	47.1	49.5	56.1	61.7	73.8	53.2*	-	75.5*
2012	11.1	18.6	34.2	41.7	48.1	55.8	53.9	61.0	72.2	73.8	105.0*	107.0*
2013	12.3	20.4	27.9	41.9	47.7	47.8	53.4	54.0	63.7	55.4	97.0*	95.9*
2014	10.6	20.9	30.2	35.0	47.8	53.4	54.5	63.2	65.0	59.3*	-	80.0*
2015	11.9	20.9	30.5	39.8	45.0	53.8	56.5	56.0	64.5	72.4*	87.0*	-
2016	12.2	19.4	29.7	38.6	45.3	48.8	55.7	61.4	57.0*	72.4	96.0*	-

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12
2017	11.7	19.6	28.2	38.8	44.9	49.1	52.8	53.8	61.7*	85.5*	72.4*	-
2018	12.5	21.8	31.3	38.1	45.3	50.3	57.4	57.0	88.5	60.4*	61.1	96.0
2019	10.4	19.9	29.0	39.2	44.7	44.9	47.7	61.1	62.9	79.5	100.8*	-

Table 13. Mean round weight-at-age (kg) of cod sampled during DFO bottom-trawl surveys in Subdiv. 3Ps in winter-spring 1983–2018. Shaded entries (*) are based on fewer than 5 aged fish.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12
1983	0.01	0.07	0.23	0.72	1.30	1.65	1.86	3.55	4.04	4.90	8.85	10.27
1984	-	0.07	0.27	0.63	1.21	1.85	2.79	3.83	4.23	5.03	7.87	9.82
1985	-	-	0.21	0.51	1.04	1.57	2.28	3.21	3.14*	3.76*	-	3.97*
1986	-	0.05	0.17	0.46	0.90	1.33	2.38	3.34	5.02	4.65	6.63*	8.87
1987	-	-	0.25	0.54	0.95	1.27	1.89	2.30	4.48	6.34	6.62	5.94
1988	-	0.06	0.19	0.58	0.92	1.49	2.21	2.42	3.94	4.84	4.26	9.10
1989	-	0.06	0.24	0.61	0.90	1.33	2.36	3.78	4.51	5.82	8.28	9.06
1990	-	0.06	0.21	0.54	0.95	1.35	1.62	2.18	3.05	4.24	4.86	7.35
1991	0.01	0.05	0.22	0.46	0.87	1.32	1.70	2.35	3.09	3.96	4.05	4.91
1992	-	0.06	0.23	0.57	0.87	1.46	2.03	2.26	2.86	3.98*	5.80	5.24
1993	-	-	0.22	0.55	0.89	1.15	1.99	3.00	4.28	4.47	8.67	13.20*
1994	-	0.05	0.25	0.46	0.90	1.04	1.24	1.81	2.89	6.45	4.47*	6.75
1995	-	0.06*	0.21	0.54	1.02	1.51	1.69	1.58	2.21	4.78	5.45	5.54*
1996	0.02	0.07	0.22	0.46	0.67	1.28	2.01	2.08	2.14	4.46	3.90	6.79*
1997	0.02	0.11	0.26	0.55	0.88	1.08	1.90	2.61	2.87	3.08	5.46*	-
1998	0.01	0.09	0.28	0.66	0.94	1.27	1.64	2.79	4.66	4.44	2.53	4.19*
1999	0.01	0.10	0.28	0.65	1.13	1.71	2.00	2.55	4.56	6.57	4.26	12.39*
2000	0.02	0.09	0.27	0.56	0.95	1.33	1.90	2.38	2.90	5.44	8.35	6.78
2001	0.01	0.09	0.29	0.53	0.82	1.17	1.66	3.15	4.32	4.20	6.30	8.96
2002	0.01	0.09	0.26	0.60	1.03	1.37	1.36	2.84	4.03	4.84	3.58*	6.03
2003	0.01	0.11	0.27	0.64	1.13	1.43	1.78	1.72	2.95	3.93	2.47	5.99*
2004	0.02	0.07	0.32	0.48	0.87	1.95	2.48	2.99	2.77	3.32	3.91	4.20*
2005	0.01	0.14	0.34	0.61	0.94	1.42	2.29	3.02	4.00	4.62*	10.75	11.45
2006	-	-	-	-	-	-	-	-	-	-	-	-
2007	0.01	0.08	0.23	0.44	0.97	1.43	1.45	2.67	5.91	7.84	7.15	7.63
2008	0.01	0.05	0.16	0.48	0.77	1.22	1.87	1.78	2.63	3.03	7.38	8.58
2009	0.01	0.06	0.25	0.47	0.81	1.39	1.92	2.27	3.53	4.33	6.72	7.09
2010	0.01	0.09	0.23	0.52	0.77	1.35	2.55	3.06	4.14	6.37*	9.02*	11.15
2011	0.02	0.11	0.25	0.51	0.91	1.01	1.59	2.21	3.59	1.23*	-	4.43*

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12
2012	0.01	0.06	0.34	0.58	0.90	1.45	1.32	2.04	3.82	3.62	9.23*	13.34*
2013	0.02	0.07	0.19	0.64	0.94	0.91	1.29	1.31	2.31	1.68	9.88	10.32
2014	0.01	0.08	0.22	0.35	0.88	1.24	1.41	2.22	2.48	1.92*	-	4.68
2015	0.01	0.07	0.22	0.49	0.74	1.35	1.50	1.52	2.51	3.82*	5.67*	-
2016	0.01	0.05	0.20	0.45	0.73	0.92	1.40	2.14	1.30*	3.24	9.68*	-
2017	0.01	0.06	0.18	0.46	0.72	0.93	1.13	1.26	2.23*	5.95*	3.10*	-
2018	0.02	0.09	0.25	0.47	0.77	1.09	1.69	1.57	6.58	2.51*	2.59	9.14*
2019	0.01	0.06	0.20	0.46	0.67	0.71	0.85	2.3	2.57	5.29	10.19*	-

Table 14. Parameter estimates and SE's for a probit model fitted to observed proportions mature at age (from "combined" survey area) for female cod from NAFO Subdiv. 3Ps based on surveys conducted during 1954–2019.

Cohort	Slope	Slope SE	Intercept	Intercept SE	Cohort	Slope	Slope SE	Intercept	Intercept SE
1954	1.1094	0.2940	-8.1702	2.4445	**1984**	2.2315	0.2981	-13.4166	1.8044
1955	1.5059	0.2237	-10.2633	1.6124	**1985**	2.6988	0.3728	-16.0342	2.2010
1956	1.3174	0.3208	-9.4592	2.2216	**1986**	2.5829	0.2930	-14.0673	1.5934
1957	1.4604	0.3703	-10.3248	2.3525	**1987**	2.2526	0.2231	-11.9227	1.2350
1958	2.3929	0.5853	-16.4519	3.6202	**1988**	2.7731	0.4110	-14.0212	2.1672
1959	2.1113	0.5358	-13.0196	2.9364	**1989**	1.8846	0.1577	-9.7844	0.8110
1960	1.6741	0.2990	-10.6677	1.7584	**1990**	1.7888	0.1900	-9.2101	0.9575
1961	1.8639	0.3551	-11.4722	2.0669	**1991**	2.4874	0.4971	-13.1443	2.5618
1962	1.7141	0.2898	-10.5115	1.7043	**1992**	2.6015	0.3903	-13.0008	1.9108
1963*	-	-	-	-	**1993**	1.8954	0.2394	-9.8698	1.2957
1964	1.9272	0.2411	-12.7182	1.5667	**1994**	1.6015	0.1969	-8.1481	1.0091
1965	2.4194	0.5982	-16.4244	4.2387	**1995**	1.6523	0.2188	-8.7711	1.1242
1966	1.5492	0.2401	-10.0608	1.6025	**1996**	1.7414	0.2410	-9.3461	1.2620
1967	1.6876	0.3782	-10.0845	2.2543	**1997**	3.0797	0.4567	-14.8462	2.1742
1968	2.1397	0.2885	-13.1625	1.7869	**1998**	1.9984	0.2396	-9.6586	1.1567
1969	1.6825	0.3043	-10.3672	1.8439	**1999**	1.8423	0.2647	-9.1495	1.3103
1970	1.5265	0.2305	-8.8558	1.3136	**2000**	1.7800	0.3025	-9.2716	1.4885
1971	1.3122	0.1401	-7.8405	0.8346	**2001**	1.7588	0.2292	-8.3449	1.0333
1972	1.4117	0.1445	-8.9081	0.8853	**2002**	1.6768	0.2439	-8.8522	1.2949
1973	1.4521	0.1667	-9.3550	1.0320	**2003**	1.5873	0.2283	-9.0376	1.2856
1974	2.0042	0.1969	-13.1541	1.2944	**2004**	1.4999	0.1654	-8.3631	0.9171
1975	1.7846	0.2174	-11.1641	1.3757	**2005**	1.8575	0.2314	-10.0273	1.2522

Cohort	Slope	Slope SE	Intercept	Intercept SE	Cohort	Slope	Slope SE	Intercept	Intercept SE
1976	1.3552	0.2056	-8.5990	1.2510	**2006**	1.7505	0.1777	-8.5990	0.9036
1977	2.5066	0.3505	-15.3640	2.1732	**2007**	1.5891	0.2499	-7.5603	1.1862
1978	1.7920	0.1680	-10.7323	1.0205	**2008**	1.7560	0.2389	-8.6024	1.0569
1979	1.0297	0.1138	-6.4477	0.7670	**2009**	1.4971	0.1611	-7.6958	0.7294
1980	1.4270	0.1415	-9.4134	0.9131	**2010**	1.8573	0.2860	-9.2644	1.3954
1981	1.7431	0.1781	-11.9865	1.1846	**2011**	2.3599	0.3115	-12.2046	1.6167
1982	2.0091	0.2059	-13.3056	1.3496	**2012**	2.2602	0.4056	-12.0903	2.1402
1983	1.8944	0.2608	-11.8903	1.6045	**2013**	2.9760	0.8310	-14.9256	4.0239

*Fit not significant

Table 15. Estimated proportions mature for female cod from NAFO Subdiv. 3Ps from DFO surveys from 1978 to 2016, projected forward to 2019. Estimates were obtained from a probit model fitted by cohort to observed proportions mature at age (from "combined" survey area). Black shaded cells (*) are averages of the three closest cohorts; grey shaded cells (†) are the average of estimates for the adjacent cohorts.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14
1954	0.0004*	0.0015*	0.0050*	0.0175*	0.0607*	0.1938*	0.4701*	0.7573*	0.9135*	0.9723*	0.9914*	0.9973*	0.9992*	0.9997*
1955	0.0009	0.0015*	0.0050*	0.0175*	0.0607*	0.1938*	0.4701*	0.7573*	0.9135*	0.9723*	0.9914*	0.9973*	0.9992*	0.9997*
1956	0.0002	0.0026	0.0050*	0.0175*	0.0607*	0.1938*	0.4701*	0.7573*	0.9135*	0.9723*	0.9914*	0.9973*	0.9992*	0.9997*
1957	0.0003	0.0007	0.0078	0.0175*	0.0607*	0.1938*	0.4701*	0.7573*	0.9135*	0.9723*	0.9914*	0.9973*	0.9992*	0.9997*
1958	0.0001	0.0011	0.0032	0.0234	0.0607*	0.1938*	0.4701*	0.7573*	0.9135*	0.9723*	0.9914*	0.9973*	0.9992*	0.9997*
1959	0.0000	0.0006	0.0040	0.0142	0.0677	0.1938*	0.4701*	0.7573*	0.9135*	0.9723*	0.9914*	0.9973*	0.9992*	0.9997*
1960	0.0000	0.0000	0.0026	0.0149	0.0610	0.1804	0.4701*	0.7573*	0.9135*	0.9723*	0.9914*	0.9973*	0.9992*	0.9997*
1961	0.0001	0.0002	0.0001	0.0112	0.0535	0.2265	0.4003	0.7573*	0.9135*	0.9723*	0.9914*	0.9973*	0.9992*	0.9997*
1962	0.0001	0.0007	0.0012	0.0010	0.0464	0.1744	0.5691	0.6693	0.9135*	0.9723*	0.9914*	0.9973*	0.9992*	0.9997*
1963	0.0002	0.0004	0.0035	0.0102	0.0111	0.1733	0.4409	0.8562	0.8599	0.9723*	0.9914*	0.9973*	0.9992*	0.9997*
1964	0.0001†	0.0008	0.0028	0.0185	0.0785	0.1096	0.4745	0.7465	0.9641	0.9490	0.9914*	0.9973*	0.9992*	0.9997*
1965	0.0000	0.0005†	0.0046	0.0177	0.0914	0.4129	0.5741	0.7955	0.9166	0.9918	0.9826	0.9973*	0.9992*	0.9997*
1966	0.0000	0.0001	0.0028†	0.0252	0.1041	0.3491	0.8531	0.9365	0.9437	0.9762	0.9982	0.9942	0.9992*	0.9997*
1967	0.0002	0.0000	0.0010	0.0159†	0.1255	0.4283	0.7410	0.9796	0.9938	0.9863	0.9935	0.9996	0.9981	0.9997*
1968	0.0002	0.0009	0.0001	0.0066	0.0847†	0.4435	0.8285	0.9385	0.9975	0.9994	0.9968	0.9983	0.9999	0.9994
1969	0.0000	0.0012	0.0044	0.0012	0.0438	0.3415†	0.8157	0.9689	0.9879	0.9997	0.9999	0.9993	0.9995	1.0000
1970	0.0002	0.0001	0.0066	0.0206	0.0130	0.2396	0.7498†	0.9609	0.9950	0.9977	1.0000	1.0000	0.9998	0.9999
1971	0.0007	0.0009	0.0012	0.0344	0.0899	0.1292	0.6840	0.9489†	0.9927	0.9992	0.9996	1.0000	1.0000	1.0000
1972	0.0015	0.0030	0.0049	0.0099	0.1616	0.3174	0.6251	0.9370	0.9915†	0.9987	0.9999	0.9999	1.0000	1.0000
1973	0.0006	0.0054	0.0137	0.0257	0.0784	0.5103	0.6865	0.9493	0.9903	0.9986†	0.9998	1.0000	1.0000	1.0000

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14
1974	0.0004	0.0023	0.0198	0.0601	0.1240	0.4196	0.8492	0.9116	0.9953	0.9986	0.9998†	1.0000	1.0000	1.0000
1975	0.0000	0.0016	0.0093	0.0697	0.2274	0.4324	0.8600	0.9682	0.9798	0.9996	0.9998	1.0000†	1.0000	1.0000
1976	0.0001	0.0001	0.0067	0.0369	0.2176	0.5752	0.8038	0.9812	0.9940	0.9956	1.0000	1.0000	1.0000†	1.0000
1977	0.0007	0.0005	0.0008	0.0280	0.1359	0.5082	0.8617	0.9566	0.9978	0.9989	0.9991	1.0000	1.0000	1.0000†
1978	0.0000	0.0028	0.0030	0.0058	0.1096	0.3922	0.7933	0.9663	0.9916	0.9997	0.9998	0.9998	1.0000	1.0000
1979	0.0001	0.0000	0.0106	0.0175	0.0418	0.3447	0.7259	0.9344	0.9925	0.9984	1.0000	1.0000	1.0000	1.0000
1980	0.0044	0.0008	0.0004	0.0400	0.0961	0.2444	0.6920	0.9157	0.9815	0.9984	0.9997	1.0000	1.0000	1.0000
1981	0.0003	0.0123	0.0047	0.0048	0.1391	0.3878	0.7058	0.9057	0.9781	0.9949	0.9996	0.9999	1.0000	1.0000
1982	0.0000	0.0014	0.0336	0.0275	0.0557	0.3851	0.7905	0.9468	0.9762	0.9946	0.9986	0.9999	1.0000	1.0000
1983	0.0000	0.0002	0.0059	0.0888	0.1453	0.4196	0.7084	0.9574	0.9925	0.9943	0.9987	0.9996	1.0000	1.0000
1984	0.0000	0.0001	0.0012	0.0240	0.2143	0.5049	0.8986	0.9040	0.9926	0.9990	0.9987	0.9997	0.9999	1.0000
1985	0.0000	0.0003	0.0007	0.0066	0.0929	0.4330	0.8596	0.9909	0.9733	0.9987	0.9999	0.9997	0.9999	1.0000
1986	0.0000	0.0001	0.0020	0.0051	0.0366	0.2991	0.6814	0.9735	0.9993	0.9930	0.9998	1.0000	0.9999	1.0000
1987	0.0000	0.0000	0.0012	0.0132	0.0370	0.1783	0.6401	0.8569	0.9955	0.9999	0.9982	1.0000	1.0000	1.0000
1988	0.0001	0.0001	0.0004	0.0111	0.0818	0.2225	0.5536	0.8811	0.9437	0.9992	1.0000	0.9995	1.0000	1.0000
1989	0.0000	0.0006	0.0018	0.0053	0.0946	0.3719	0.6809	0.8763	0.9686	0.9791	0.9999	1.0000	0.9999	1.0000
1990	0.0004	0.0002	0.0057	0.0233	0.0731	0.4931	0.7975	0.9409	0.9759	0.9923	0.9925	1.0000	1.0000	1.0000
1991	0.0006	0.0024	0.0033	0.0515	0.2400	0.5396	0.9006	0.9632	0.9916	0.9957	0.9981	0.9973	1.0000	1.0000
1992	0.0000	0.0036	0.0158	0.0507	0.3408	0.8069	0.9457	0.9883	0.9943	0.9989	0.9992	0.9996	0.9990	1.0000
1993	0.0000	0.0003	0.0210	0.0957	0.4612	0.8310	0.9822	0.9962	0.9987	0.9991	0.9998	0.9999	0.9999	0.9997
1994	0.0003	0.0004	0.0034	0.1136	0.4106	0.9320	0.9791	0.9986	0.9997	0.9999	0.9999	1.0000	1.0000	1.0000
1995	0.0014	0.0023	0.0055	0.0394	0.4339	0.8210	0.9955	0.9978	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000
1996	0.0008	0.0071	0.0150	0.0695	0.3302	0.8209	0.9679	0.9997	0.9998	1.0000	1.0000	1.0000	1.0000	1.0000
1997	0.0005	0.0042	0.0341	0.0921	0.5017	0.8557	0.9648	0.9950	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1998	0.0000	0.0028	0.0216	0.1490	0.4030	0.9314	0.9862	0.9939	0.9992	1.0000	1.0000	1.0000	1.0000	1.0000
1999	0.0005	0.0002	0.0160	0.1032	0.4649	0.8180	0.9946	0.9988	0.9990	0.9999	1.0000	1.0000	1.0000	1.0000
2000	0.0007	0.0035	0.0037	0.0847	0.3753	0.8117	0.9676	0.9996	0.9999	0.9998	1.0000	1.0000	1.0000	1.0000
2001	0.0006	0.0042	0.0250	0.0740	0.3455	0.7582	0.9553	0.9950	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2002	0.0014	0.0033	0.0260	0.1591	0.6347	0.7507	0.9424	0.9907	0.9992	1.0000	1.0000	1.0000	1.0000	1.0000
2003	0.0008	0.0079	0.0192	0.1443	0.5826	0.9742	0.9450	0.9884	0.9981	0.9999	1.0000	1.0000	1.0000	1.0000
2004	0.0006	0.0041	0.0444	0.1042	0.5155	0.9115	0.9988	0.9899	0.9978	0.9996	1.0000	1.0000	1.0000	1.0000
2005	0.0010	0.0028	0.0214	0.2125	0.4082	0.8704	0.9870	0.9999	0.9982	0.9996	0.9999	1.0000	1.0000	1.0000
2006	0.0003	0.0047	0.0137	0.1048	0.6104	0.8035	0.9769	0.9982	1.0000	0.9997	0.9999	1.0000	1.0000	1.0000
2007	0.0011	0.0018	0.0206	0.0637	0.3850	0.9010	0.9604	0.9963	0.9998	1.0000	0.9999	1.0000	1.0000	1.0000
2008	0.0025	0.0061	0.0115	0.0860	0.2495	0.7701	0.9814	0.9931	0.9994	1.0000	1.0000	1.0000	1.0000	1.0000
2009	0.0011	0.0123	0.0340	0.0693	0.2966	0.6192	0.9471	0.9967	0.9988	0.9999	1.0000	1.0000	1.0000	1.0000
2010	0.0020	0.0092	0.0584	0.2141	0.3179	0.6589	0.9017	0.9914	0.9994	0.9998	0.9999	1.000	1.0000	1.0000
2011	0.0000	0.0105	0.0445	0.2182	0.5803	0.7533	0.8922	0.9813	0.9984	0.9999	0.9999	1.0000	1.0000	1.0000

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14
2012	0.0000	0.0015	0.0528	0.1896	0.5564	0.8753	0.9524	0.9726	0.9967	0.9997	0.9999	0.9999	1.0000	1.0000
2013	0.0000	0.0005	0.0151	0.2272	0.5403	0.849	0.9727	0.9924	0.9935	0.9994	0.9999	1.0000	1.0000	1.0000
2014	0.0003	0.0014	0.0055	0.1353	0.6081	0.8552	0.9621	0.9945	0.9988	0.9985	0.9999	0.9999	1.0000	1.0000
2015	0.0002	0.0017	0.0092	0.0572	0.6146	0.8912	0.9674	0.9913	0.9989	0.9998	0.9996	0.9999	1.0000	1.0000
2016	0.0002	0.0012	0.01155	0.05972	0.39849	0.94206	0.97738	0.99334	0.9981	0.9998	0.9999	0.9999	1.0000	1.0000
2017	0.0002	0.0012	0.0088	0.07332	0.30324	0.87848	0.994	0.99563	0.9987	0.9996	0.9999	1.0000	0.9999	1.0000
2018	0.0002	0.0012	0.0088	0.0634	0.34874	0.74888	0.98748	0.99941	0.9992	0.996	0.9999	0.9999	1.0000	1.0000
2019	0.0002	0.0012	0.0088	0.0634	0.3502	0.78375	0.95335	0.99884	0.9999	0.9998	0.9999	0.9999	1.0000	1.0000
2020	0.0002	0.0012	0.0088	0.0634	0.3502	0.8037	0.96083	0.99291	0.9999	0.9999	0.9999	0.9999	1.0000	1.0000
2021	0.0002	0.0012	0.0088	0.0634	0.3502	0.8037	0.9672	0.99401	0.9990	0.9999	1.0000	0.9999	1.0000	1.0000
2022	0.0002	0.0012	0.0088	0.0634	0.3502	0.8037	0.9672	0.99525	0.9991	0.9999	1.0000	1.0000	1.0000	1.0000

Table 16. Additional data sources used in the 2019 assessment compared to the 2018 assessment.

Data	Assessment 2018	Assessment 2019
3Ps CAN-RV Spring survey	1983–2018	1983–2019
ERHAPS	-	1978–1991
Sentinel Gillnet and Line trawl	-	1995–2018
GEAC	-	1998–2005
Fisheries landings	-	1959–2019 (preliminary estimate for 2019)
Fisheries catch-at-age	-	1959–2019 (preliminary estimate for 2019)
M-index based on fish condition	-	1978–2019

Table 17. Survey standard deviation estimates from the HYBRID assessment model.

Survey	Survey standard deviation estimate
DFO RV Inshore-Offshore	0.89
DFO RV Offshore	0.68
IFREMER ERHAPS	0.71
GEAC	1.14
Sentinel gillnet	0.65
Sentinel linetrawl	0.37

Table 18. Risk of projected SSB being below B_{lim} under six scenarios of total mortality (catch at status quo, ±15% status quo and ±30% status quo and no catch) over 2020–22. Status quo catch was assumed to be 4,453 t. B_y represents SSB in projection year.

Projected Catch	Probability of growing out of the critical zone $P(B_y>B_{lim})$			Probability of growth from current levels $P(B_y>B2019)$		
-	2020	2021	2022	2020	2021	2022
$0.001*Catch_{2019}$	<0.1%	<0.1%	<0.1%	5%	7%	16%
$0.7*Catch_{2019}$	<0.1%	<0.1%	<0.1%	5%	1%	1%
$0.85*Catch_{2019}$	<0.1%	<0.1%	<0.1%	5%	1%	1%
$1.0*Catch_{2019}$	<0.1%	<0.1%	<0.1%	5%	<1%	<1%
$1.15*Catch_{2019}$	<0.1%	<0.1%	<0.1%	5%	<1%	<1%
1.3*Catch	<0.1%	<0.1%	<0.1%	5%	<1%	<1%

Table 19. Estimates of SSB, average fishing mortality and recruitment from SAM projection performed to assess the impact of having no sentinel data in the terminal year. Three runs are compared (with 2017 is assumed as the assessment year): one current run (2017ALL), one year less inputs for sentinel line trawl data (2017sentLT.y-1), and one year behind run (2016ALL).

Variable	Year	2016ALL	2017ALL	2017sentLT.y-1
SSB	2016	24.424	-	-
	2017	26.479	27.833	29.042
	2018	26.628	27.211	28.771
	2019	24.239	24.731	26.633
	2020	22.491	21.593	24.192
	2021	21.457	18.763	21.987
	2022	20.517	16.469	19.892
Fishing mortality	2016	0.177	-	-
	2017	0.13	0.148	0.139
	2018	0.18	0.18	0.165
	2019	0.203	0.209	0.186
	2020	0.226	0.257	0.218
	2021	0.239	0.31	0.253
	2022	0.243	0.344	0.271
Recruitment	2016	10.265	-	-
	2017	15.643	8.562	10.408
	2018	15.643	11.729	10.952
	2019	15.643	10.219	12.398
	2020	15.643	10.219	12.398
	2021	15.643	10.219	12.398
	2022	15.643	11.729	12.398

Table 20. Estimated catch rates for gillnets and summaries of data provided in logbooks for vessels greater than 35 feet.

Quota Year	Estimated CPUE (t/net)	Standard Error	Number of sets	Number of vessels	Landings (t)		
					Logbooks	Reported	% of reported
1998	113	3.53	1,048	128	2,495	4,237	59
1999	86	1.83	2,893	168	4,966	8,213	60
2000	71	1.81	1,734	148	2,088	4,456	47
2001	42	1.11	1,701	131	1,044	2,309	45
2002	54	1.61	1,154	115	1,085	2,600	42
2003	56	1.64	1,212	134	1,277	2,772	46
2004	53	1.50	1,367	127	1,112	2,437	46
2005	41	1.07	1,526	133	1,230	2,446	50
2006	50	1.37	1,393	134	1,439	2,564	56
2007	50	1.27	1,642	151	1,722	2,456	70
2008	48	1.25	1,599	137	1,598	2,278	70
2009	47	1.40	1,126	119	1,068	1,642	65
2010	50	1.75	805	89	902	1,469	61

Quota Year	Estimated CPUE (t/net)	Standard Error	Number of sets	Number of vessels	Landings (t)		
					Logbooks	Reported	% of reported
2011	48	1.67	788	92	1,114	1,412	79
2012	49	2.16	466	69	792	1,235	64
2013	56	2.77	364	49	443	681	65
2014	60	2.30	632	63	969	1,397	69
2015	50	1.81	718	58	1,217	1,813	67
2016	42	1.35	943	62	1,101	1,662	66
2017	55	2.03	723	55	851	1,522	56
2018	78	2.89	714	48	961	1,728	56

Table 21. Standardized catch rates for gillnets based on at sea sampling by observers. Number for sets and proportion of landings observed are also provided.

Quota year	CPUE	Standard error	Number of		Observed catch (t)	Landings (t)	% observed
			trips	sets			
1997	71.9	6.8	19	111	59.3	3,760	1.58
1998	80.1	4.8	22	350	281.7	10,102	2.79
1999	39.1	2.0	32	425	158.5	20,469	0.77
2000	31.8	1.8	20	395	131.1	10,891	1.2
2001	-	-	0	0	0	6,159	0
2002	61.3	20.3	3	8	-	-	-
2003	32.5	1.7	40	432	131.2	8,055	1.63
2004	34.8	1.8	34	457	146.7	7,353	2
2005	22.9	1.3	23	363	50.9	6,898	0.74
2006	23.7	1.7	23	217	44.9	6,877	0.65
2007	28.8	1.8	19	285	77.9	6,678	1.17
2008	31.5	1.9	30	304	58.9	6,264	0.94
2009	32.0	2.4	13	179	48.6	3,602	1.35
2010	21.8	1.6	10	212	13.9	3,709	0.37
2011	23.2	2.3	9	94	23.7	2,994	0.79
2012	15.2	2.1	5	49	9.2	2,741	0.34
2013	28.4	10.0	1	7	-	-	0.01
2014	50.4	10.3	3	21	-	-	0.67
2015	38.5	5.0	8	53	31.4	3,066	1.02
2016	20.9	2.0	7	110	13.0	3,047	0.43
2017	20.8	3.7	6	28	-	-	0.22
2018	126.3	28.6	5	17	16.6	3,334	0.50

NOTE: Landings not presented for less than five vessels.

Table 22a. Annual number of cod tagged in NAFO Subdiv. 3Ps during 2007–18 by tag type (low or high reward) and by statistical unit area.

Release Year	Low Reward ($10)	High Reward ($100)	Total Tagged in 3Psa	Total Tagged in 3Psb	Total Tagged in 3Psc	Total Tagged in 3Ps
2007	3,410	480	840	1019	2,031	3,890
2008	315	80	-	-	395	395
2009	2,006	504	-	-	2,510	2,510
2010	817	205	-	-	1,022	1,022
2011	767	196	-	-	963	963
2012	1,869	471	-	743	1,597	2,340
2013	3,153	798	554	557	2,840	3,951
2014	789	200	-	416	573	989
2015	994	256	-	514	736	1,250
2016	401	101	-	502	-	502
2017	1,467	373	100	1,136	574	1,840
2018	283	76	-	359	-	359

Table 22b. Annual number of cod tags returned from NAFO Subdiv. 3Ps during 2007–17 by tag type (low or high reward).

Recapture Year	Low Reward ($10)	High Reward ($100)	Total Returned
2007	333	67	400
2008	262	58	320
2009	245	70	315
2010	210	74	284
2011	95	35	130
2012	146	42	188
2013	179	67	246
2014	195	73	268
2015	176	63	239
2016	130	64	194
2017	186	71	257

FIGURES

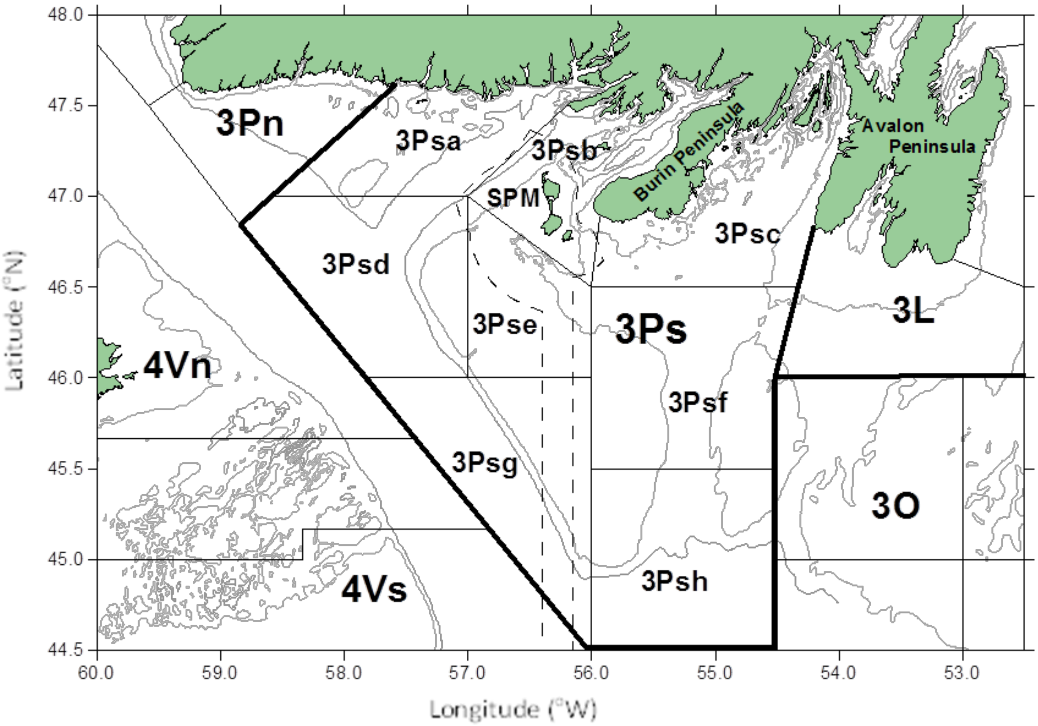


Figure 1. NAFO Subdiv. 3Ps management zone showing the economic zone around the French islands of St. Pierre et Miquelon (SPM, dashed line), the 100 m and 250 m depth contours (grey lines) and the boundaries of the statistical unit areas (solid lines).

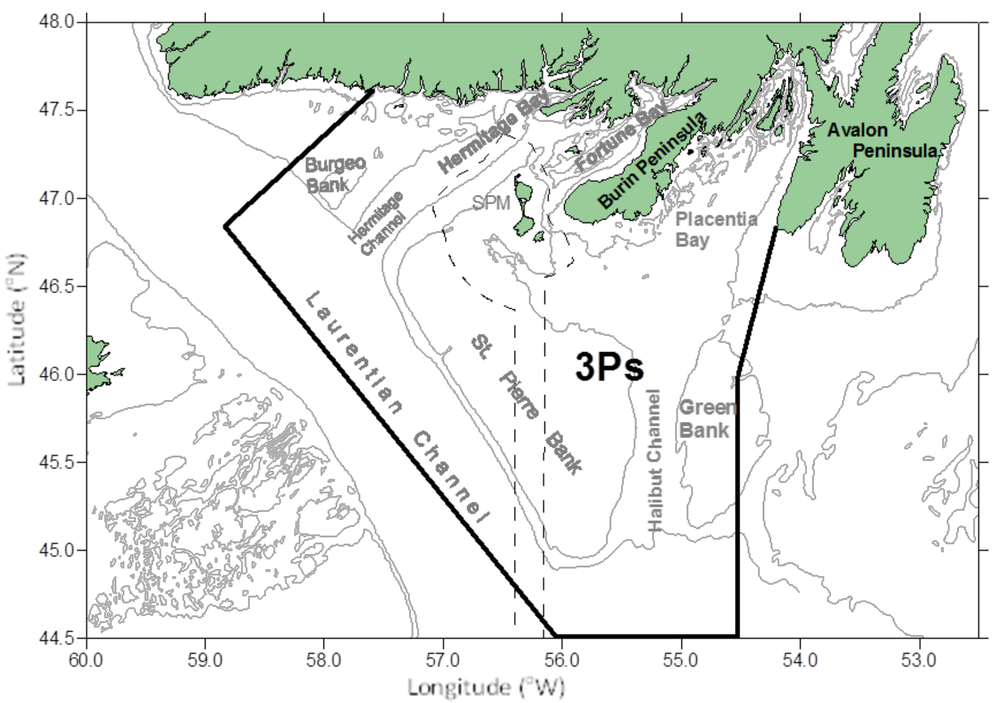


Figure 2. NAFO Subdiv. 3Ps management zone showing the economic zone around the French islands of St. Pierre and Miquelon (SPM, dashed line), the 100 m and 250 m depth contours (grey lines) and the main fishing areas.

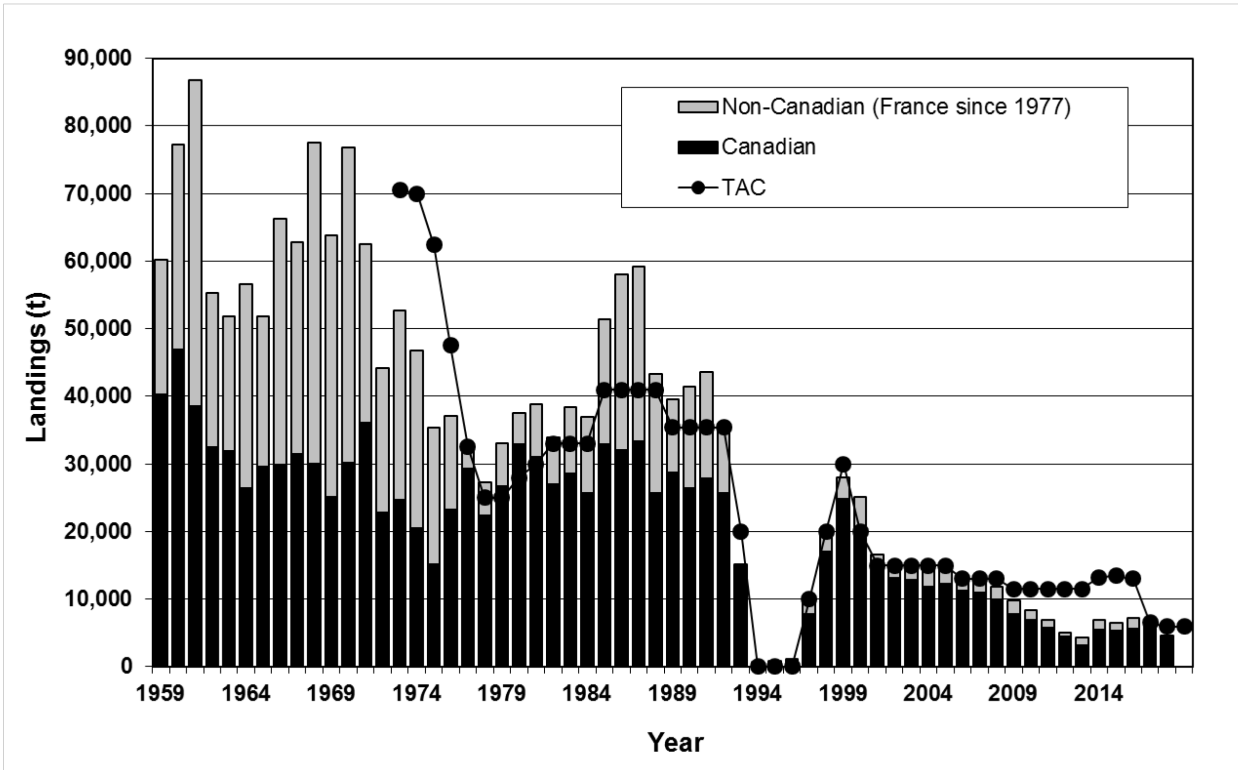


Figure 3a. Reported landings of cod by Canadian and non-Canadian vessels in NAFO Subdiv. 3Ps. Note that the 2019 fishery was still in progress at the time of the current assessment.

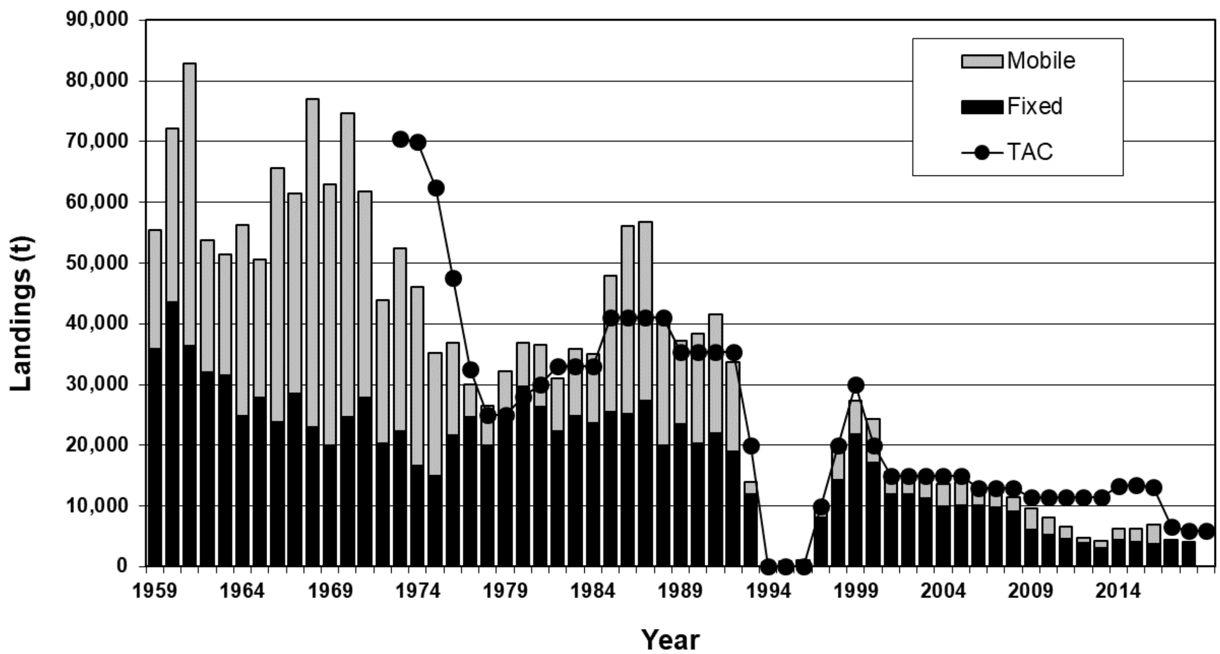


Figure 3b. Reported landings of cod by fixed and mobile gears in NAFO Subdiv. 3Ps. Note that the 2019 fishery was still in progress at the time of the current assessment.

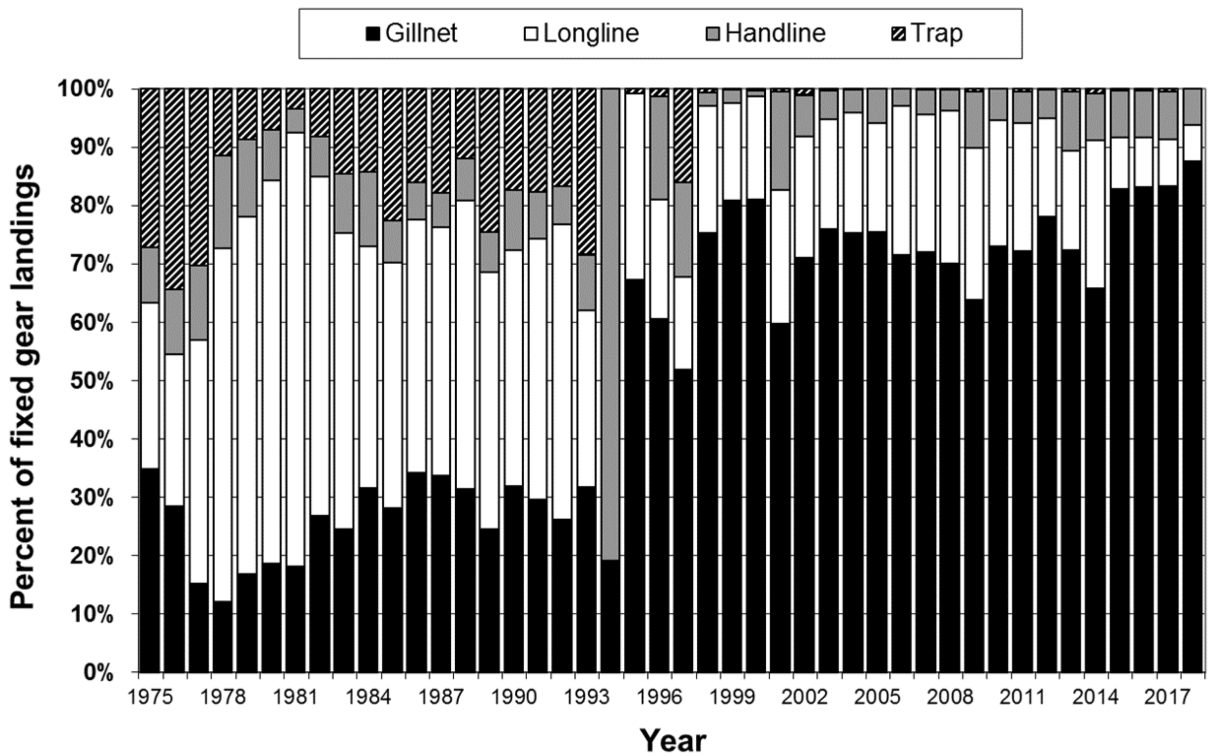


Figure 4. Percent of total fixed gear landings by the four main fixed gears used in the cod fishery in NAFO Subdiv. 3Ps. The fishery was under a moratorium during 1994–96 and values for those years are based on sentinel and by-catch landings of <800 t.

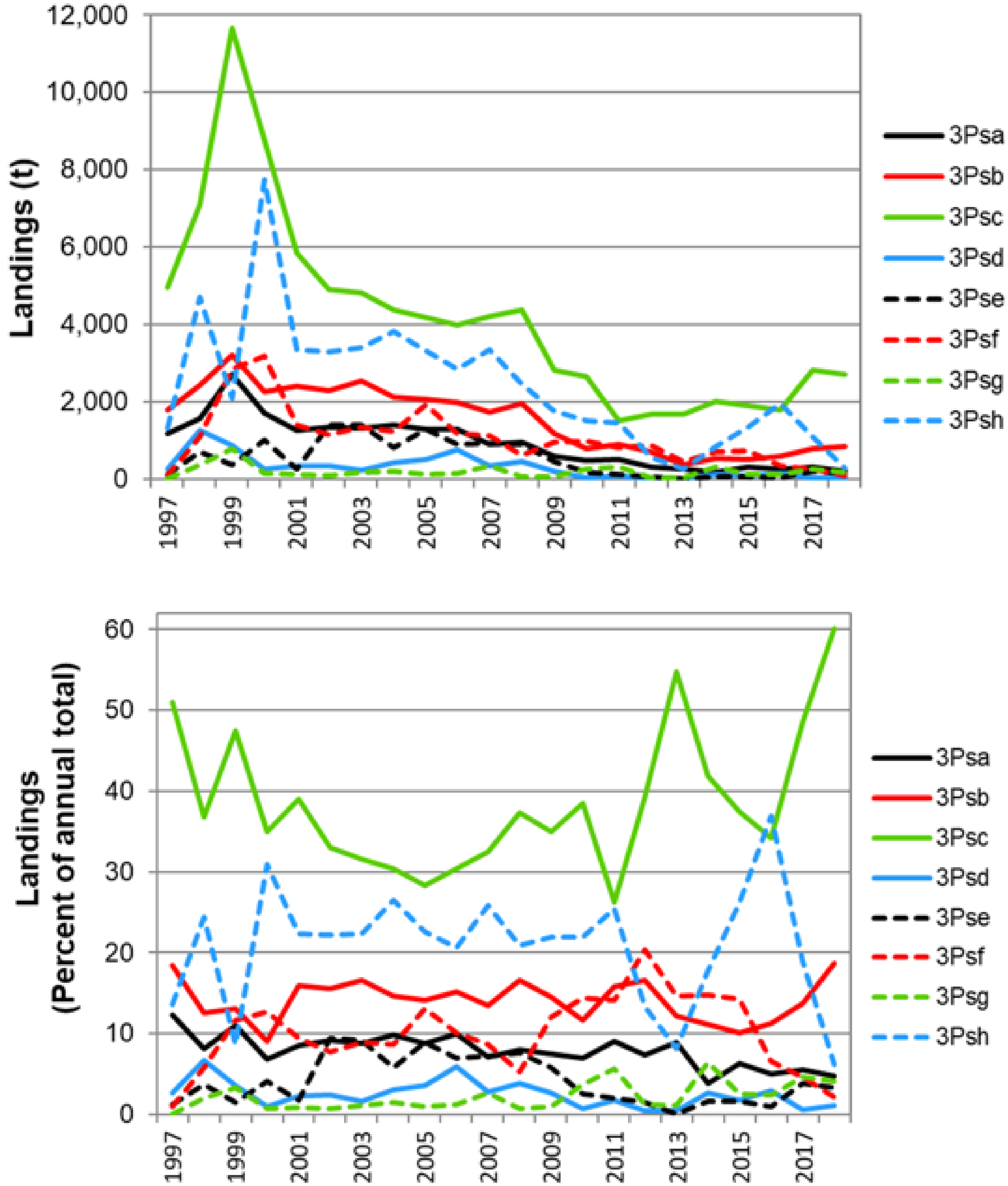


Figure 5. Breakdown of recent Canadian annual landings of 3Ps cod by statistical unit areas. Both landings (upper panel) and percent of total landings (lower panel) are presented. Unit area is not available for SPM landings. Refer to Figure 1 for locations of unit areas.

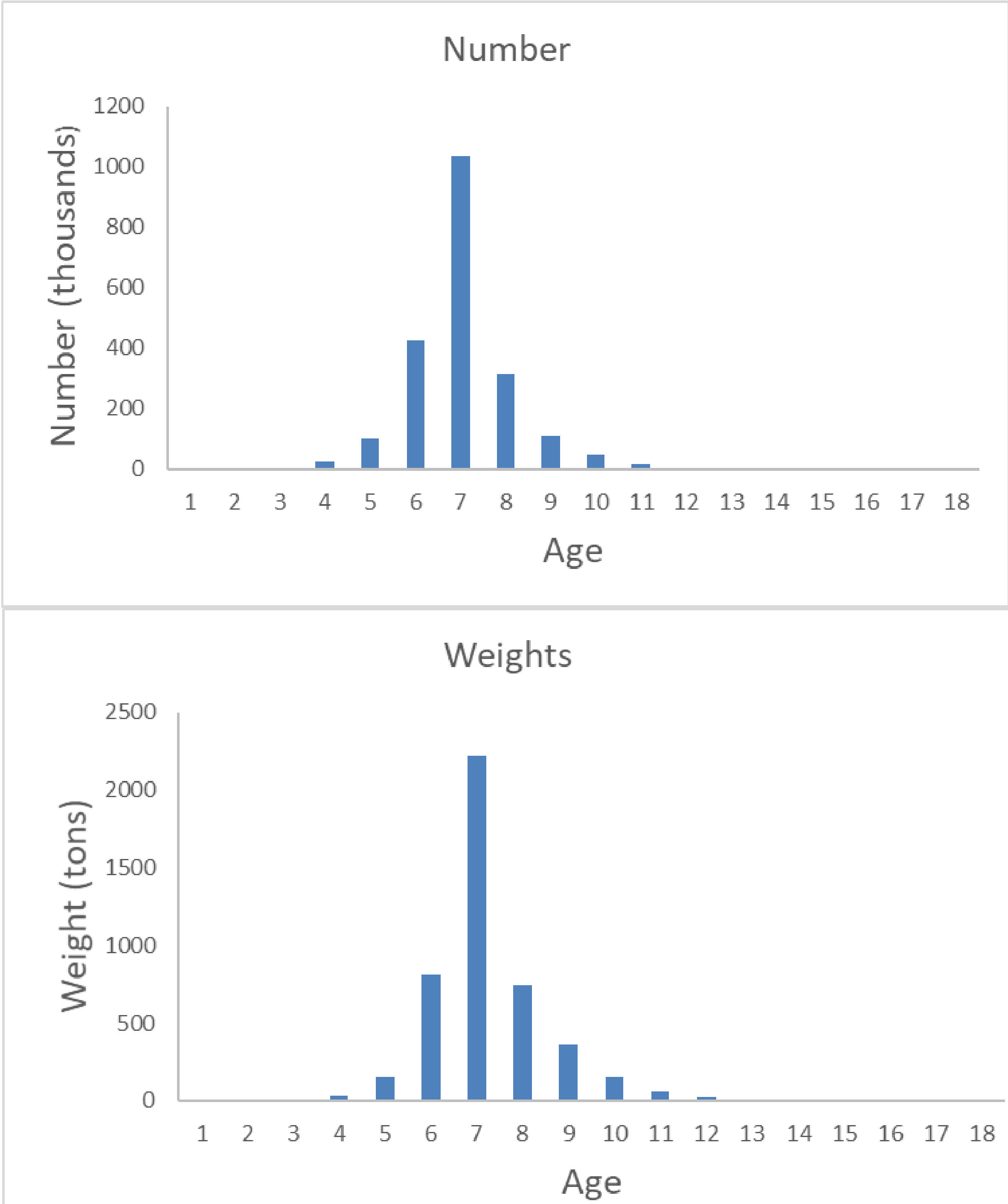


Figure 6. Catch numbers and weight at age from commercial fisheries and sentinel sampling in 2018.

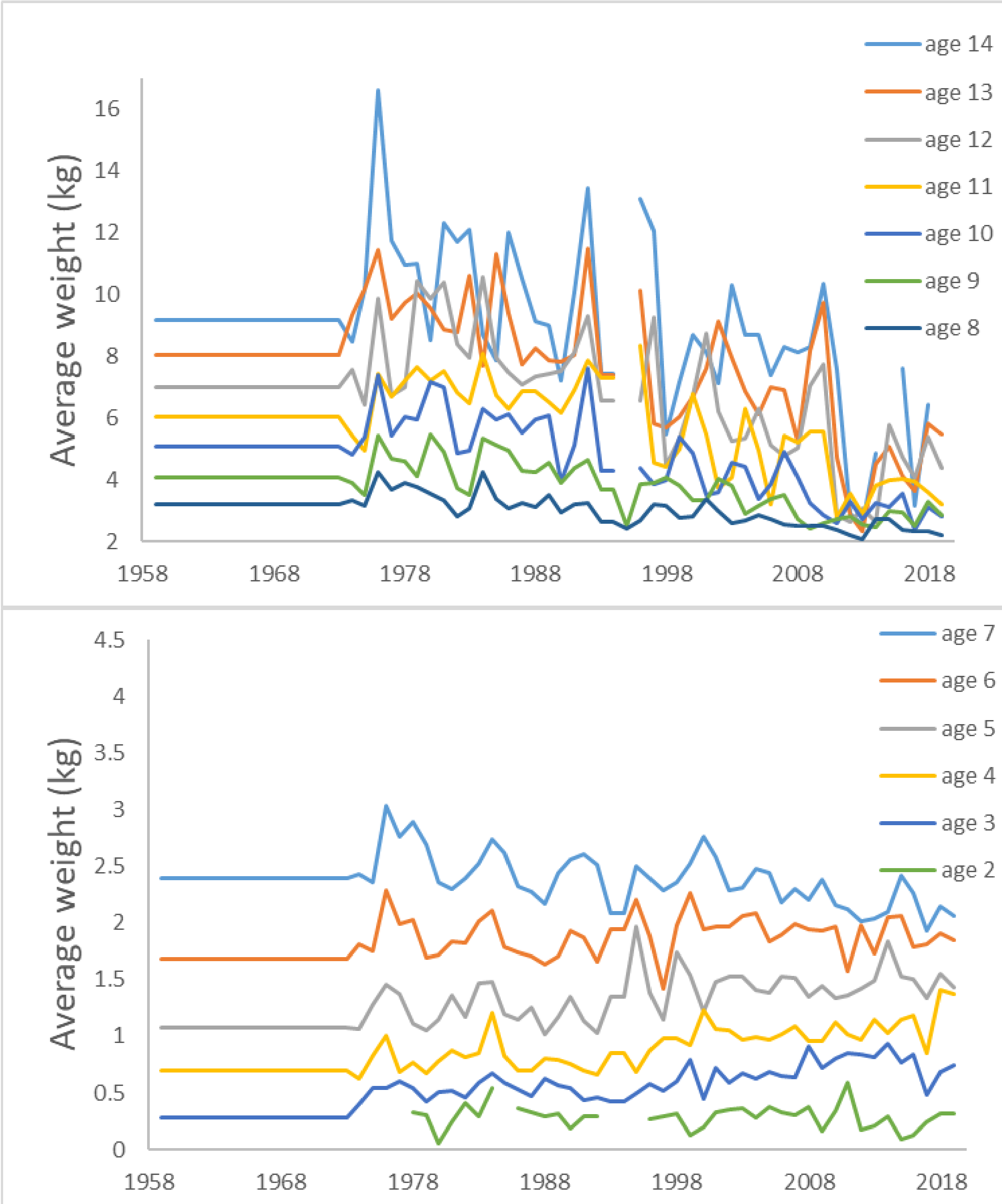


Figure 7. Mean weights-at-age calculated from mean lengths-at-age (lower panel: ages 2–7; upper panel: ages 8–14) from the commercial catch of cod in Subdiv. 3Ps during 1959 to 2018.

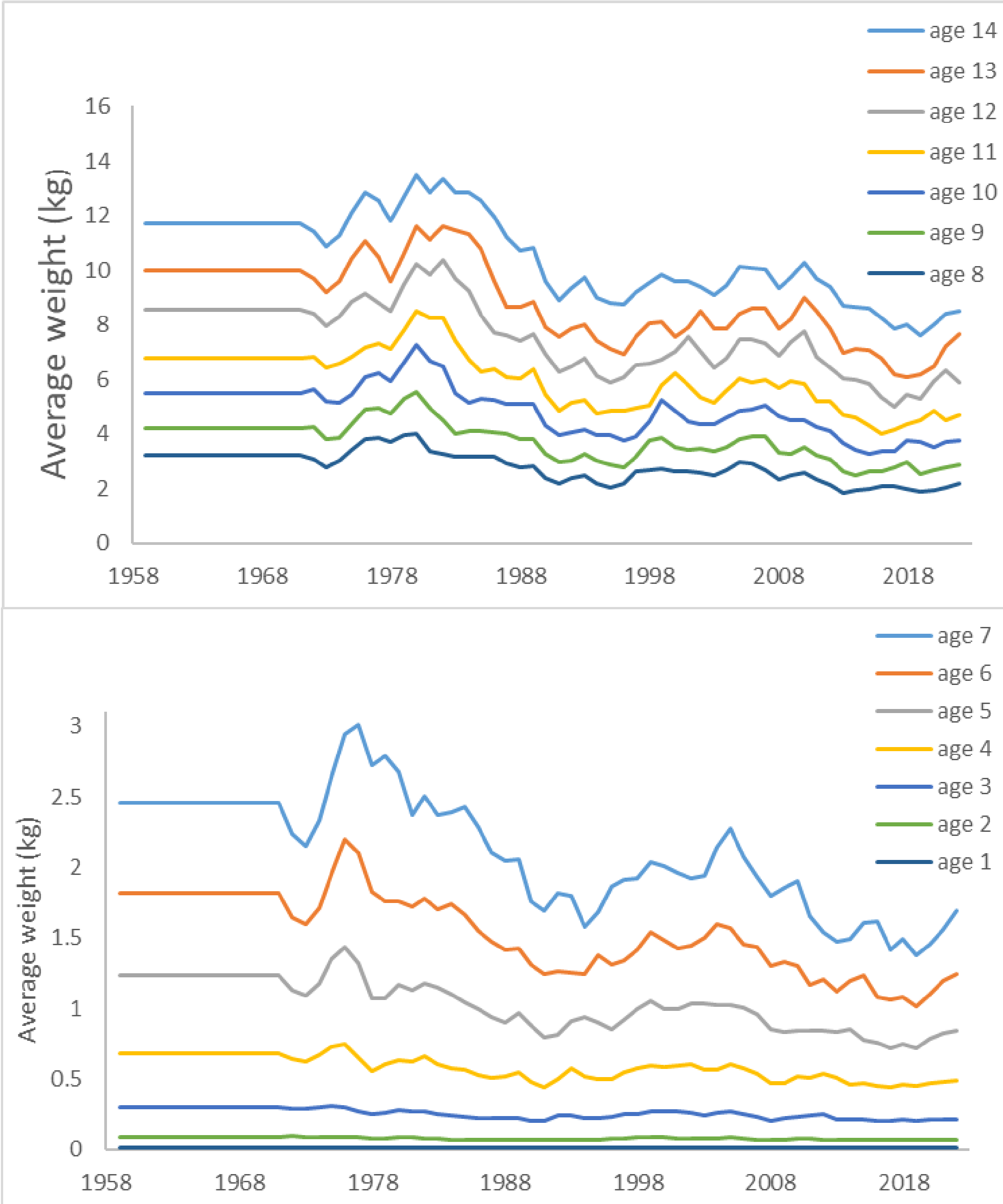


Figure 8. Beginning of year mean weights-at-age (lower panel: ages 1–7; upper panel: ages 8–14) modeled from survey weights of cod in Subdiv. 3Ps during 1959 to 2019 and projected to 2020.

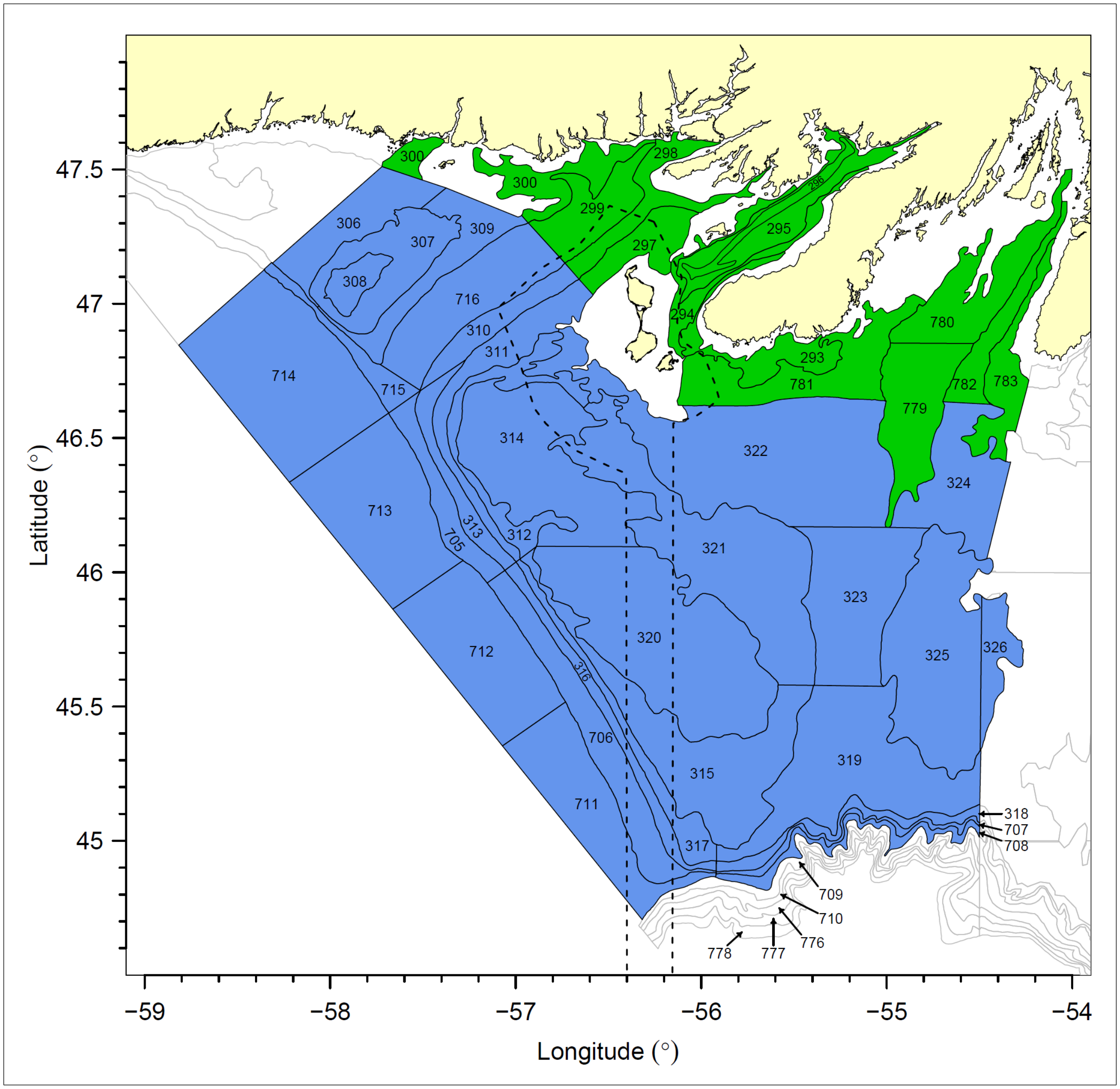


Figure 9. Stratum area boundaries and area surveyed during the DFO research vessel bottom-trawl survey of NAFO Subdiv. 3Ps. Offshore strata are shaded blue. Inshore strata were added in 1994 (strata 779–783) and 1997 (strata 293–300) and are shaded green. The dashed line represents the boundary of the French economic zone.

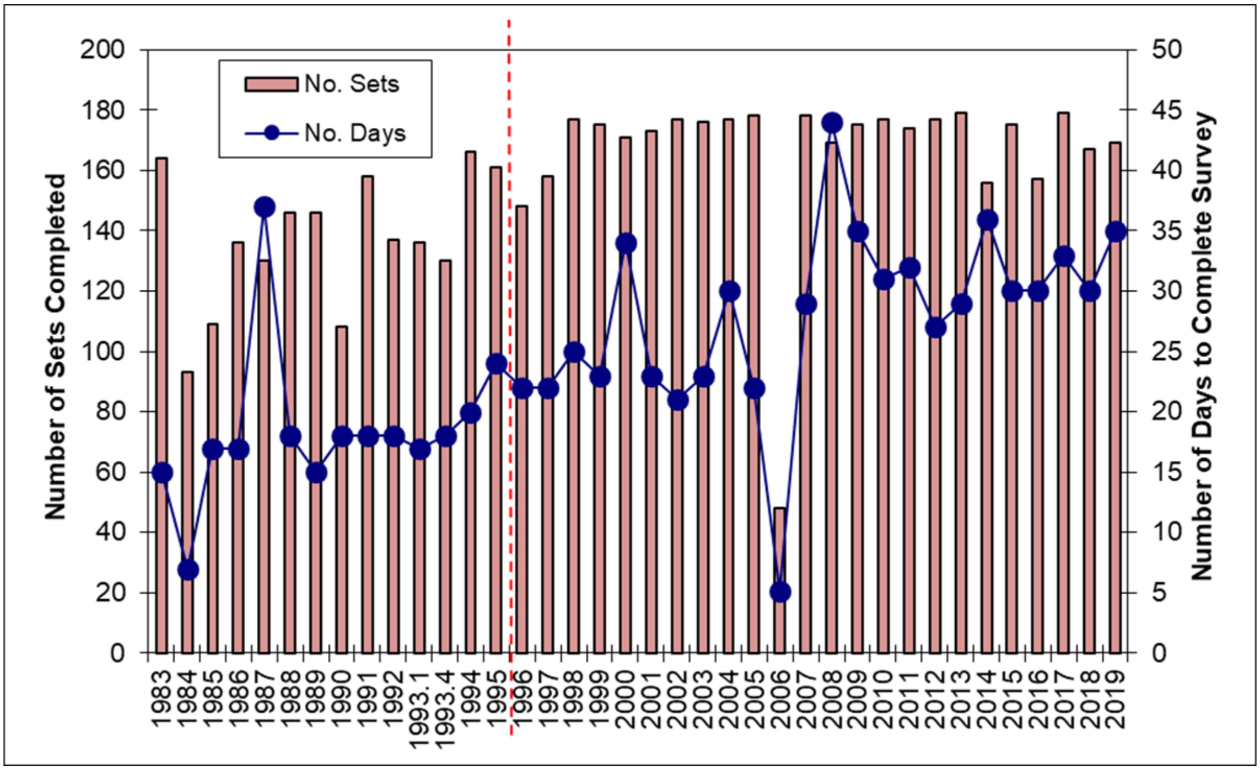
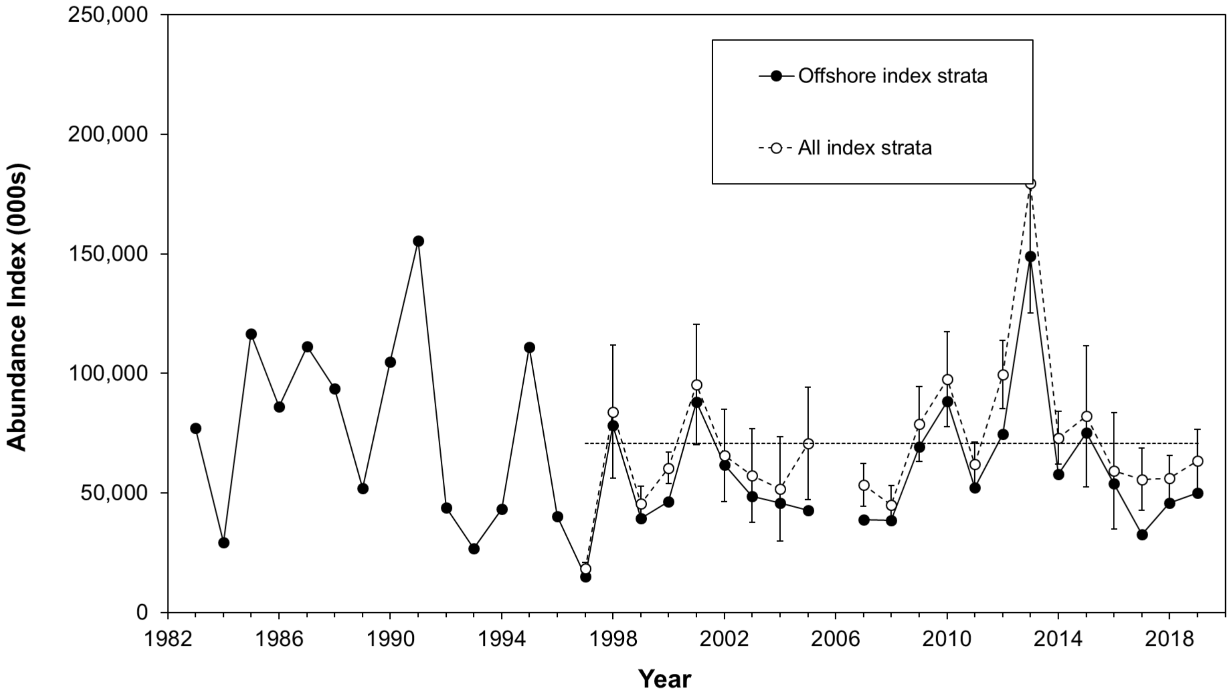


Figure 10. Number of research vessel survey sets completed during surveys of NAFO Subdiv. 3Ps, and the number of days required to complete these set. Survey coverage was expanded to present levels (i.e., covering all inshore and offshore index strata) in 1997 (dashed vertical line).



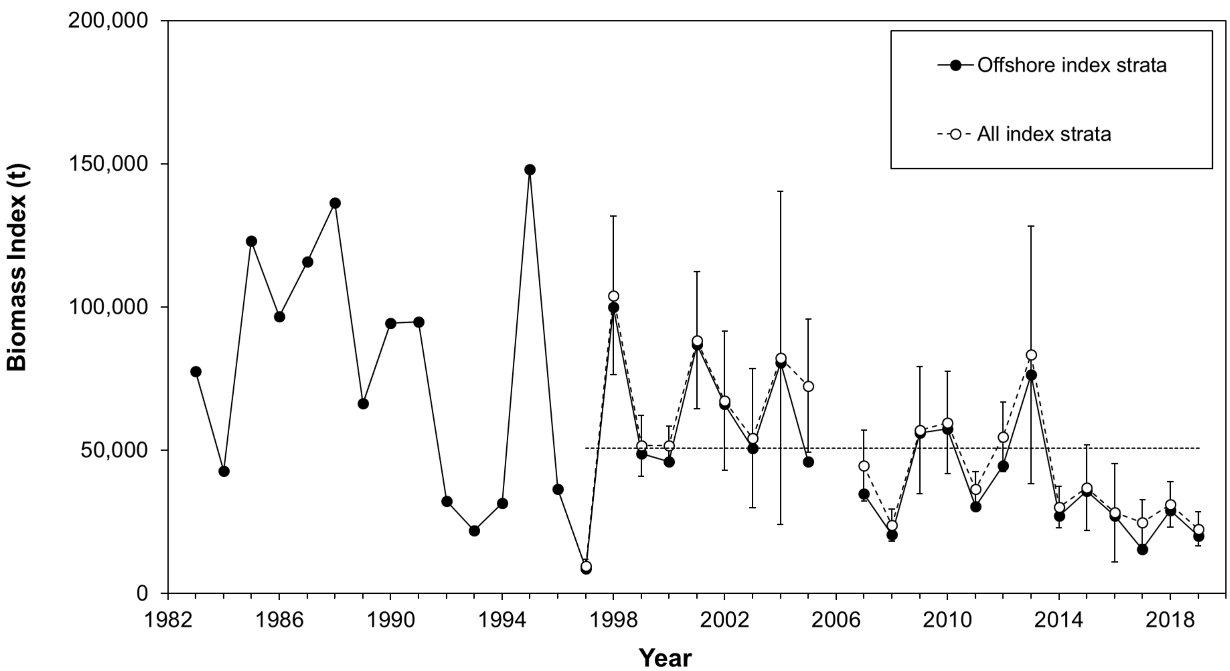


Figure 11. Abundance (upper panel) and biomass (lower panel) indices for cod in NAFO Subdiv. 3Ps from DFO research vessel bottom trawl surveys of index strata during winter/spring from 1983 to 2019. Error bars show plus/minus one standard deviation. Open symbols show values for the augmented survey area that includes additional inshore strata added to the survey in 1997. Dashed horizontal lines are means of the time-series for all index strata.

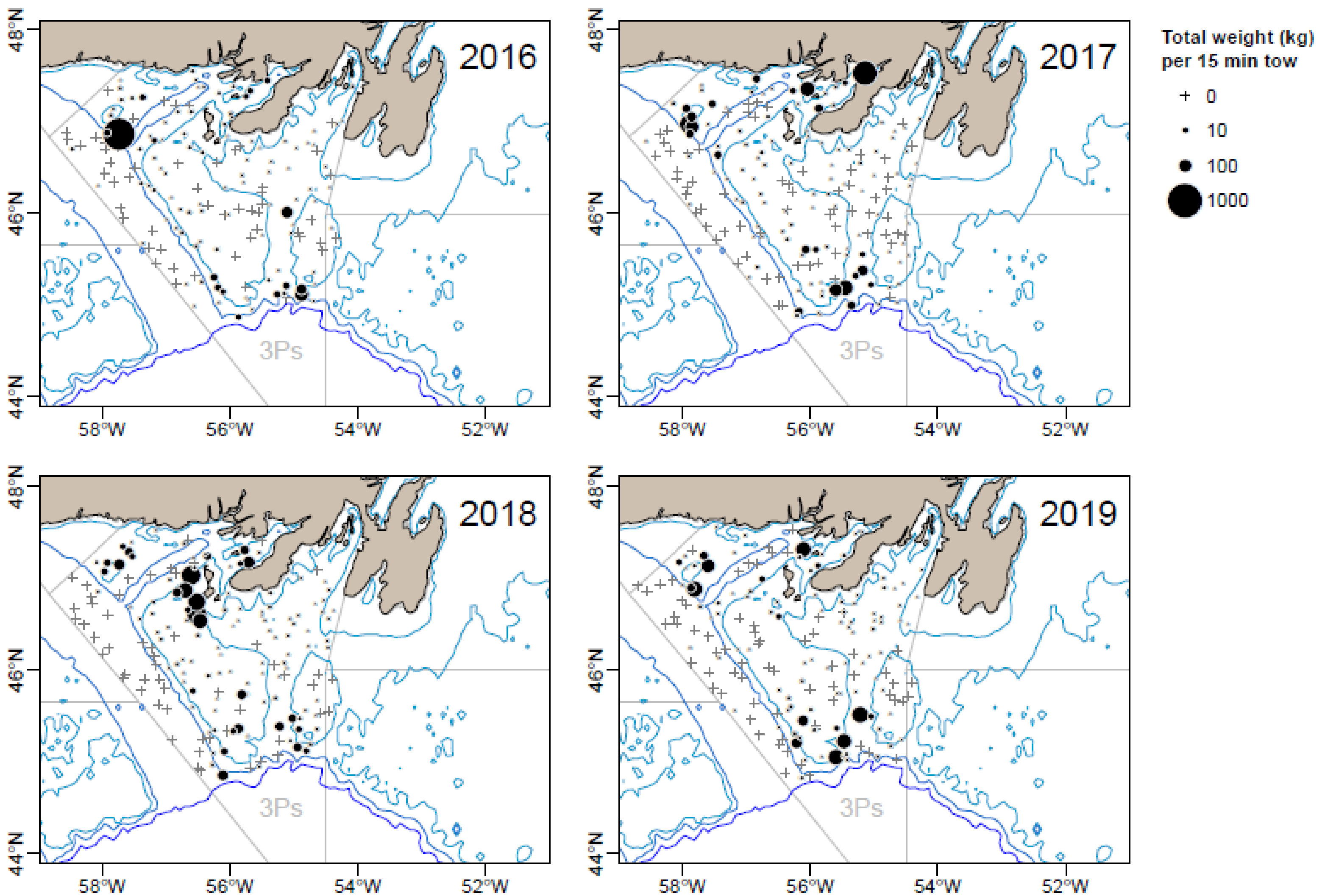


Figure 12. Age aggregated distribution of cod catches (weight per tow) from the April DFO research vessel surveys of NAFO Subdiv. 3Ps over 2016–19. Bubble size is proportional to total weight caught.

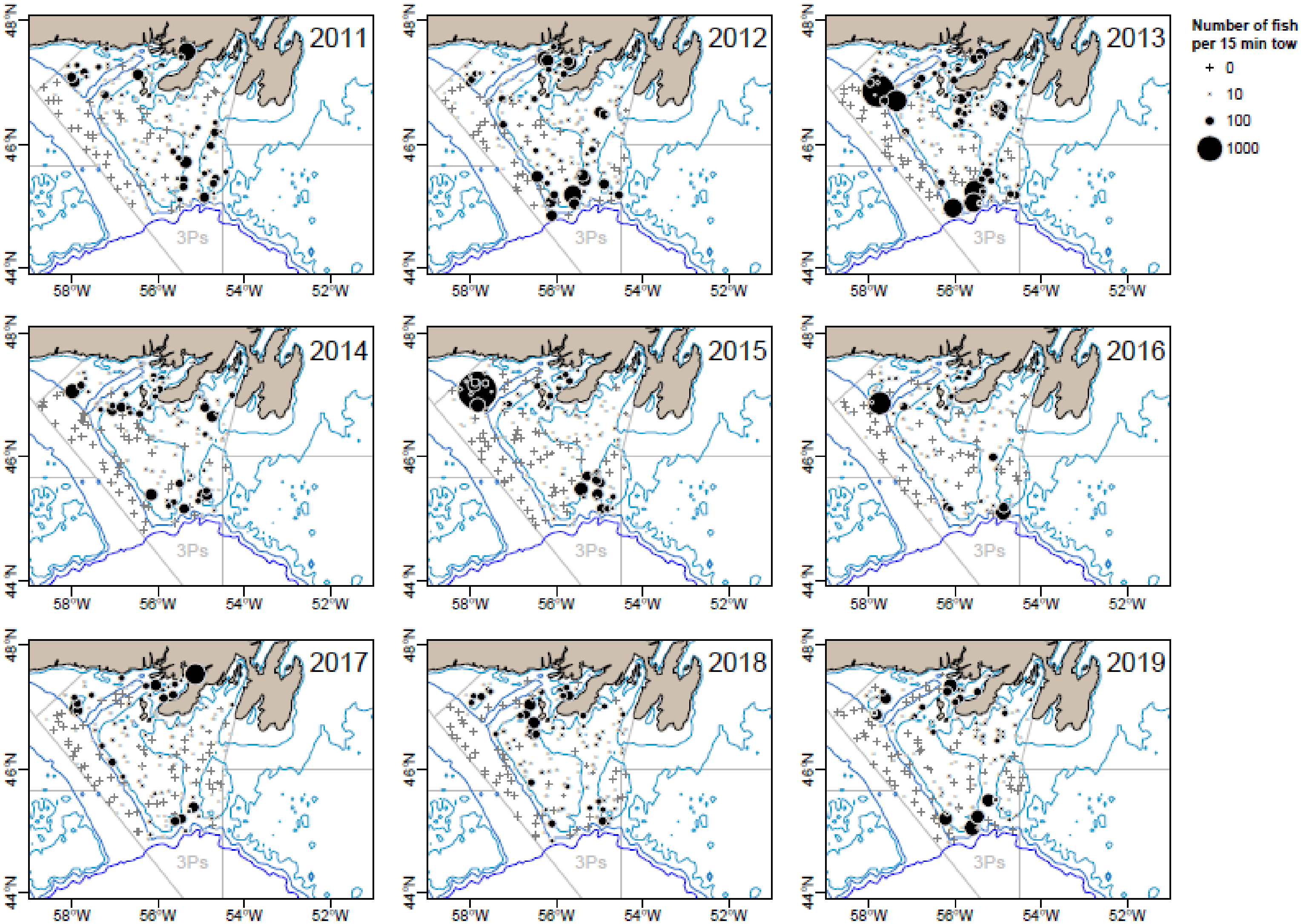


Figure 13. Age aggregated distribution of cod catches (nos. per tow) from the April DFO research vessel surveys of NAFO Subdiv. 3Ps over 2011–19. Bubble size is proportional to numbers caught.

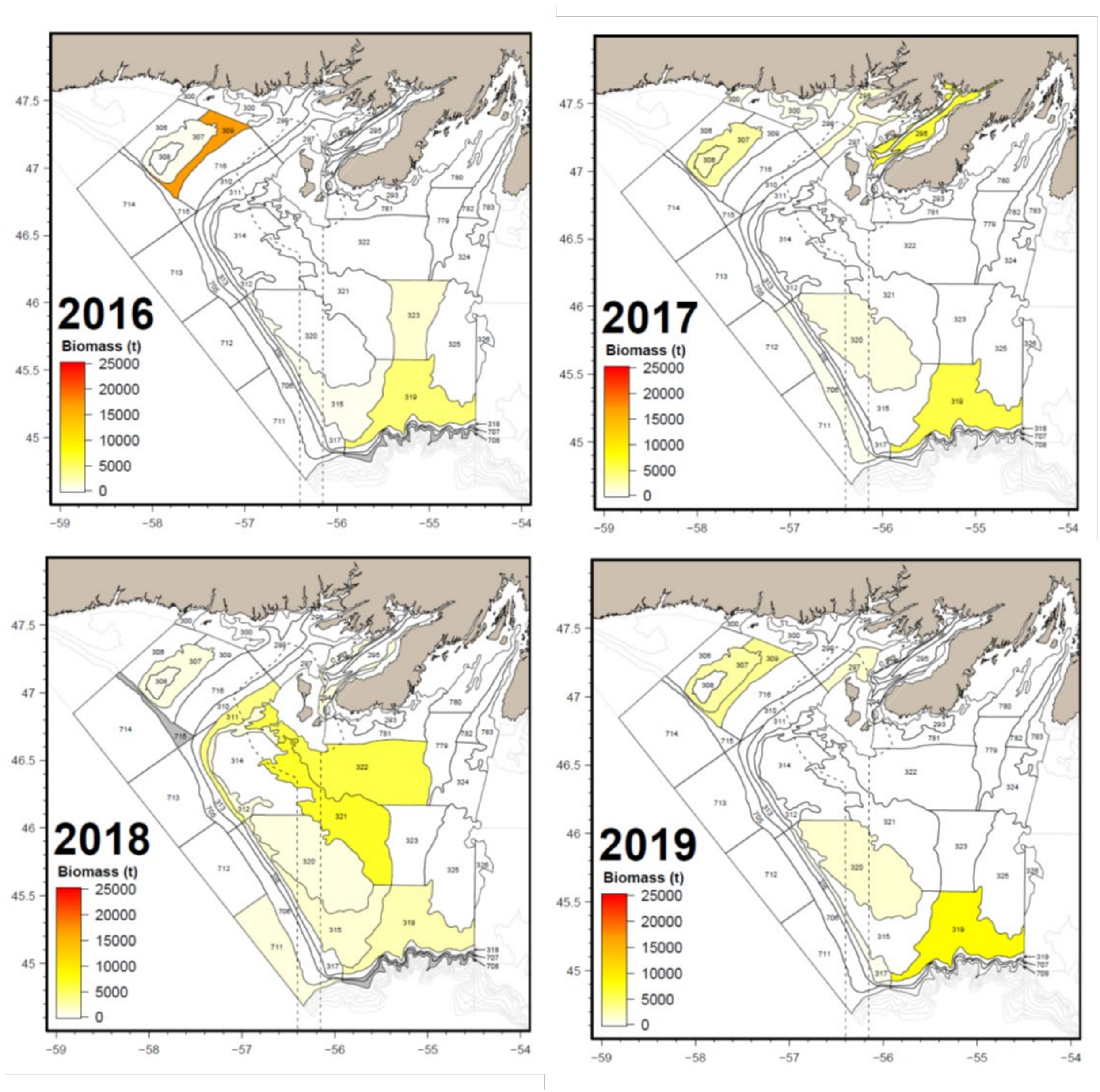


Figure 14. Stratum-specific biomass estimates of cod in Subdiv. 3Ps based on the DFO RV survey during 2016 to 2019.

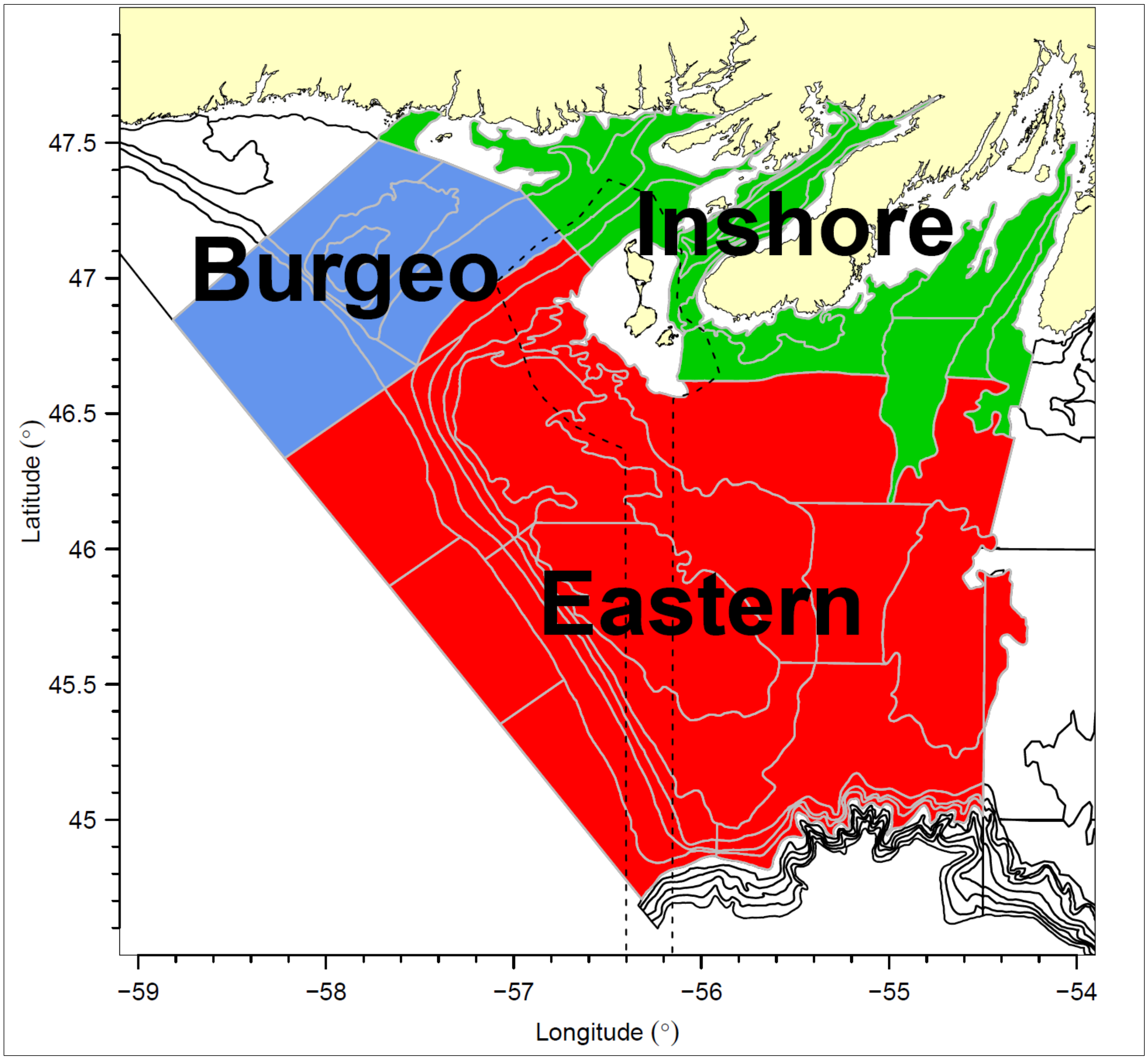


Figure 15. NAFO Subdiv. 3Ps management zone illustrating the allocation of survey strata into 'Inshore', 'Burgeo', and 'Eastern' regions. Survey trends for the three regions are depicted in Fig. 16.

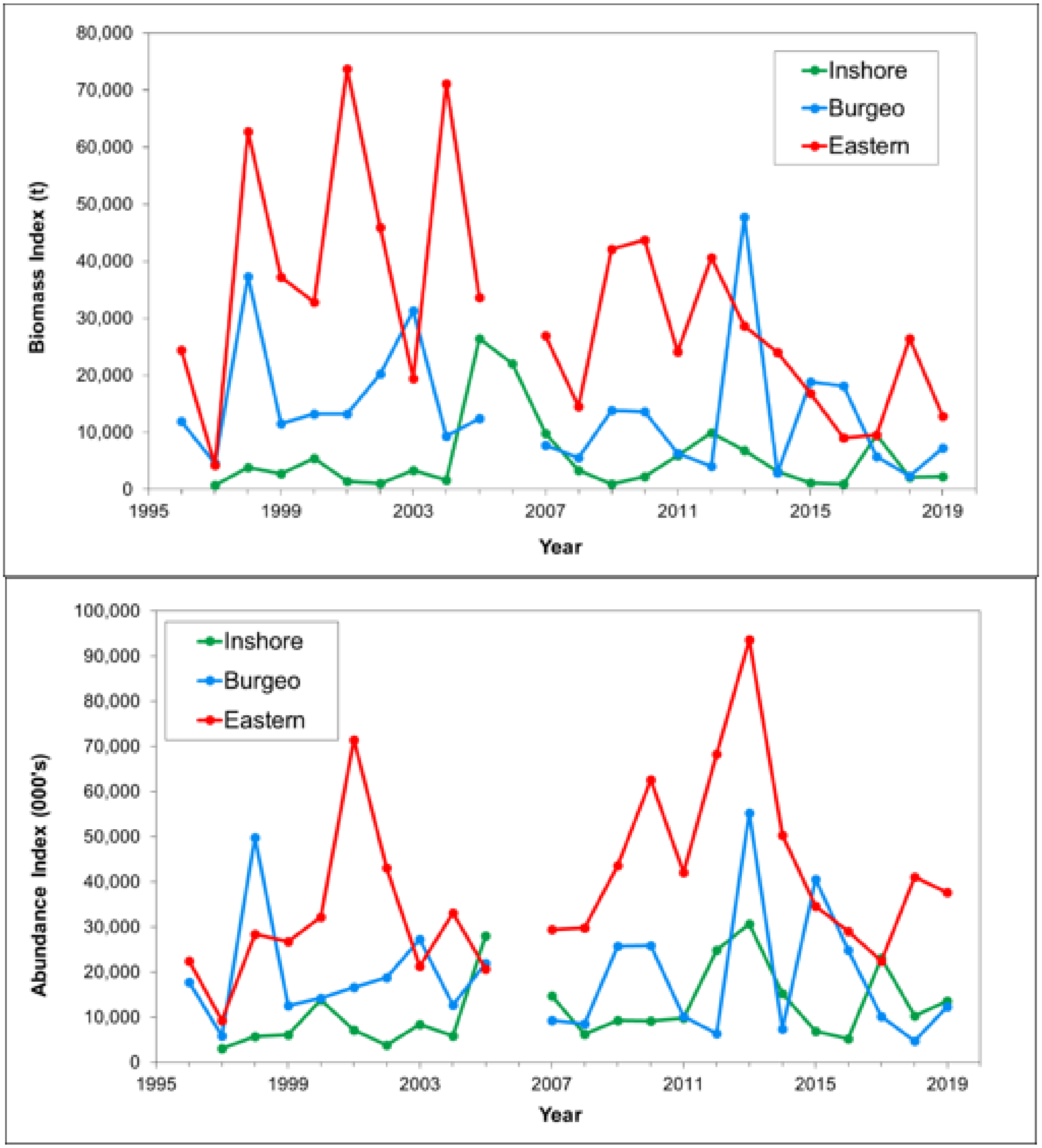


Figure 16. Total biomass (above) and abundance (below) index for cod in various regions of NAFO Subdiv. 3Ps from DFO research vessel bottom trawl surveys during winter/spring from 1997 to 2019. The 2006 survey was not completed. The Campelen trawl was used in all surveys.

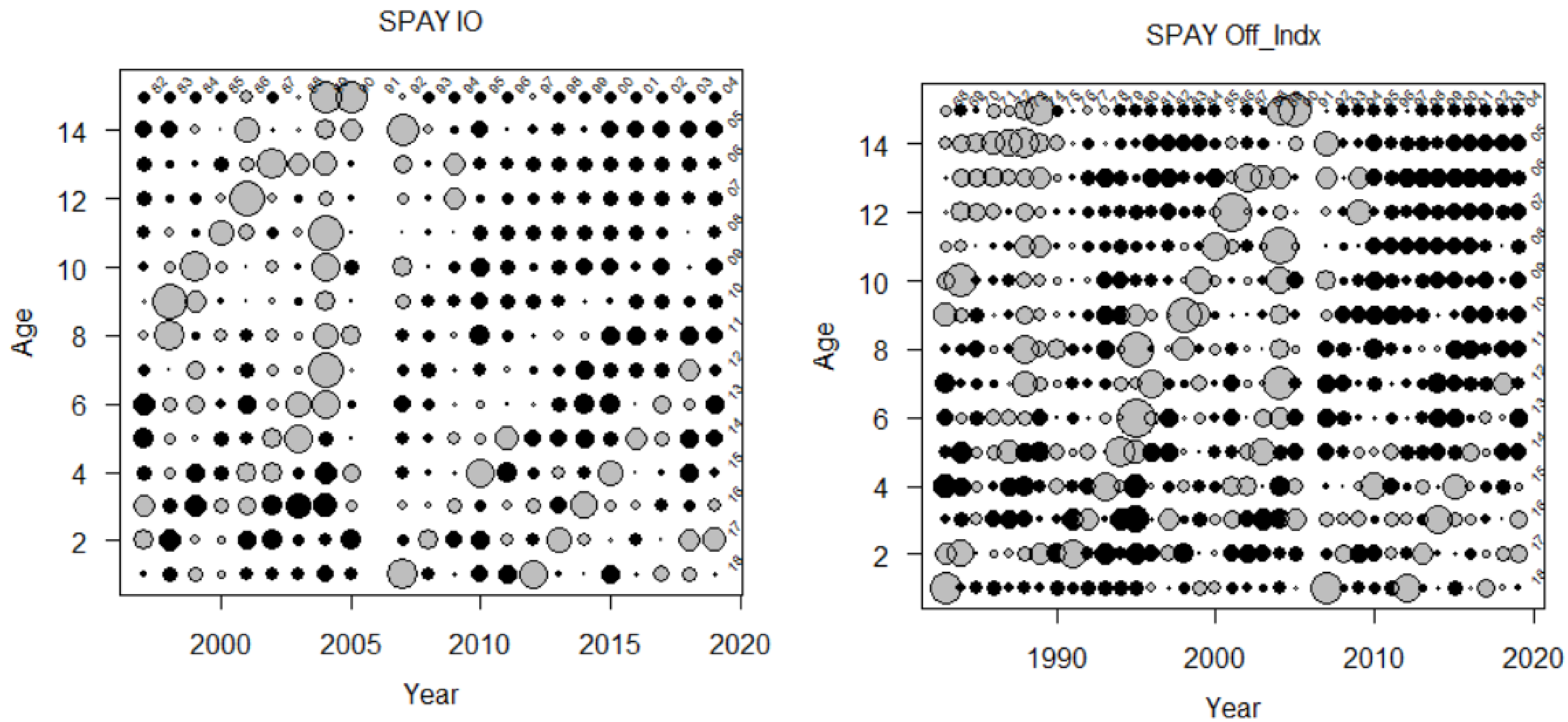


Figure 17. Standardized age-disaggregated catch rates from the spring bottom trawl survey of Subdiv. 3Ps. Catch rates (mean nos per tow) were converted to proportions within each year. Values were standardized by subtracting the mean proportion and dividing by the standard deviation of the proportions computed across years. Symbol sizes are scaled and values greater than average are shown as grey circles, average values are shown as small dots, and less than average values are shown as black circles. Labels in the upper and right margins identify cohorts. Left panel includes the 1997–2018 "All Strata <300 fm" data, and panel at right includes data which comprise the "Offshore" index (1983–2019).

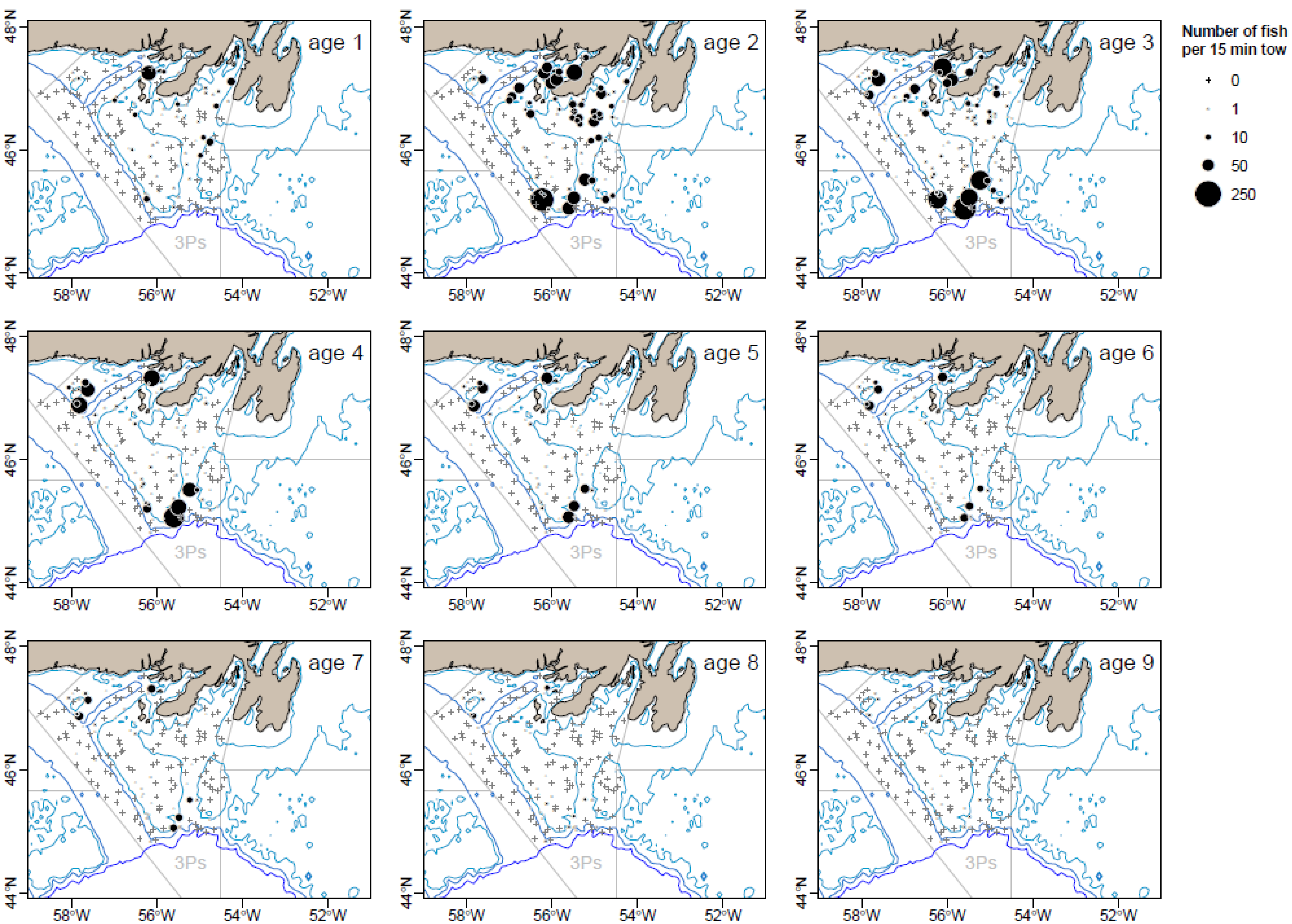
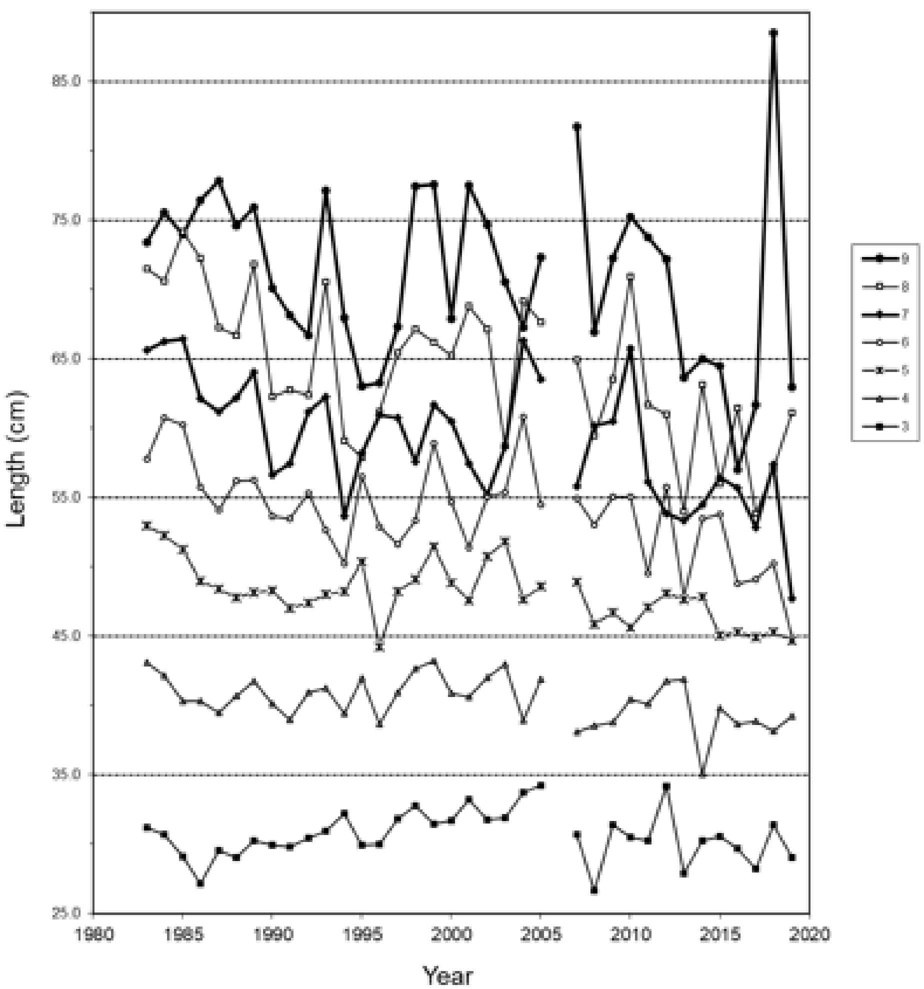


Figure 18. Age dis-aggregated distribution of cod catches (nos. per tow at age) from the Spring 2019 DFO research vessel survey of NAFO Subdiv. 3Ps. Bubble size is proportional to numbers caught.



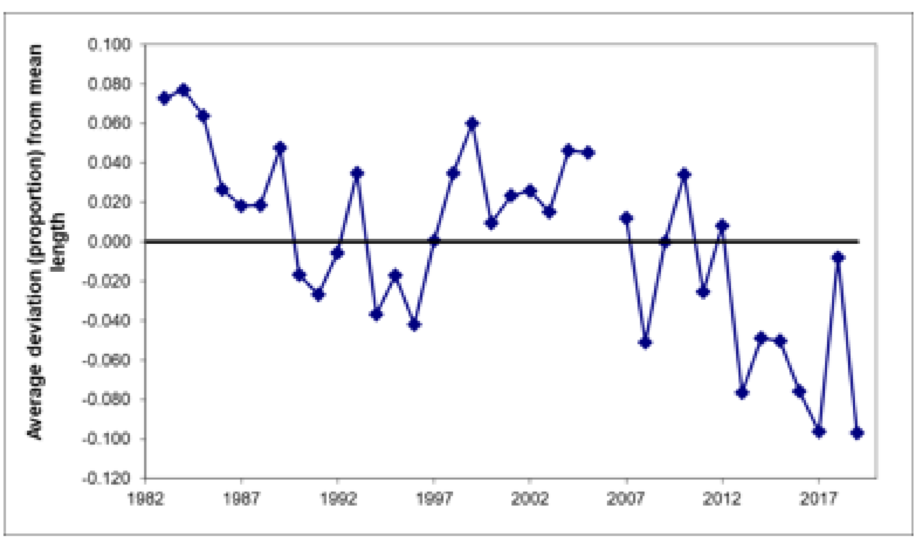
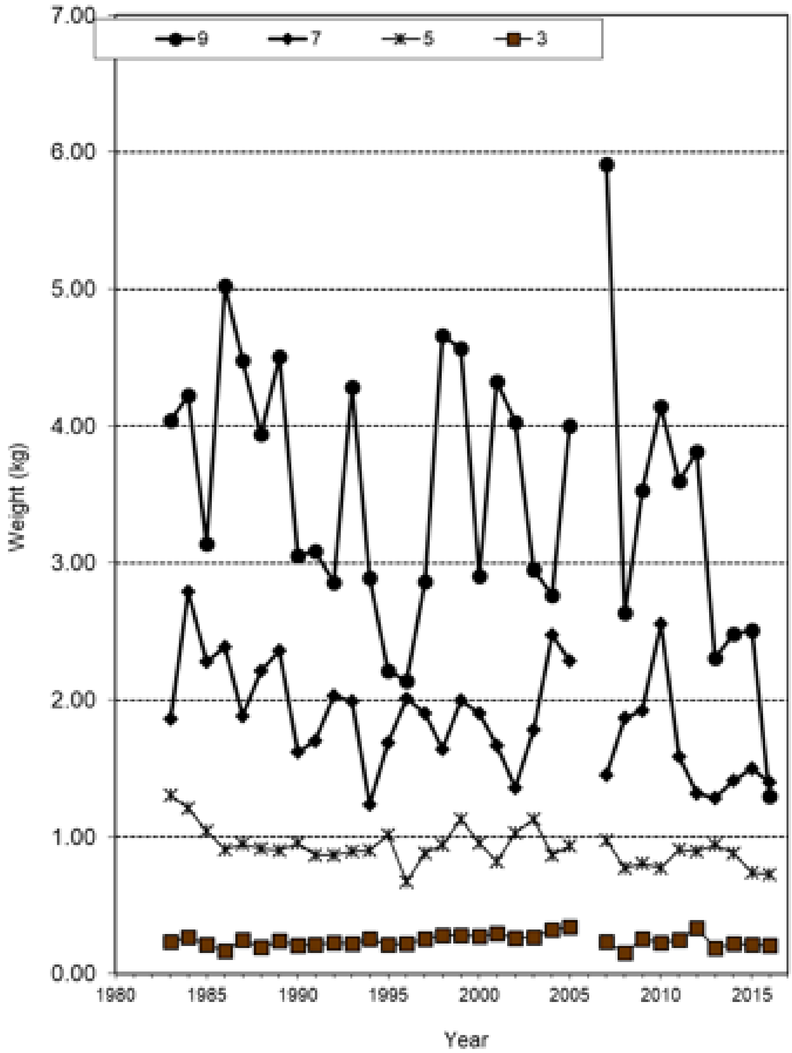


Figure 19. Mean length at ages 3–9 (above) and average proportion deviation from mean length at age for ages 3–9 combined (below) of cod in Subdiv. 3Ps during 1983–2018 from sampling during DFO bottom-trawl surveys in winter-spring.



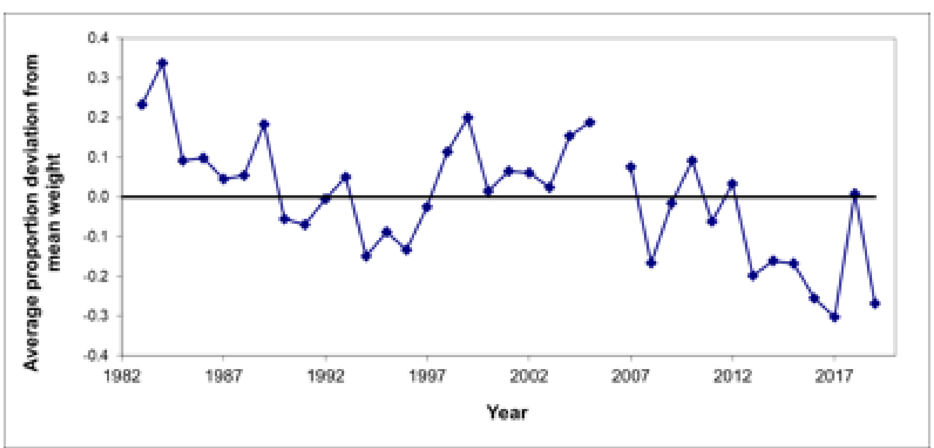


Figure 20. Mean round weight-at-age (kg) (above) and average proportion deviation from mean weight at age for ages 3–9 (below) of cod sampled during DFO bottom-trawl surveys in NAFO Subdiv. 3Ps in winter-spring 1983–2018.

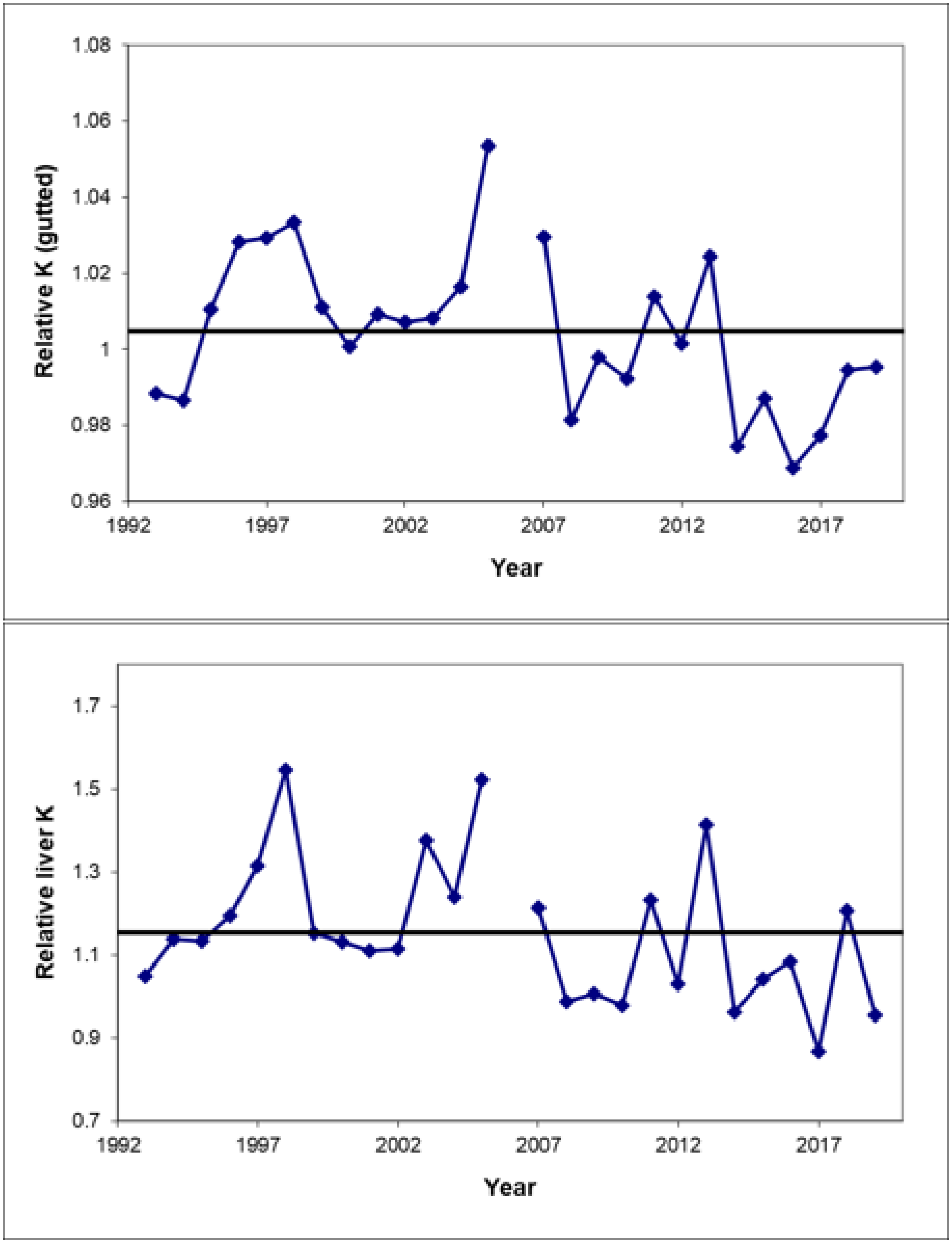


Figure 21. Relative condition indices for 3Ps cod from spring surveys over 1993–2019. Upper panel is relative gutted condition index; lower panel relative liver condition index. Horizontal line represents time-series average.

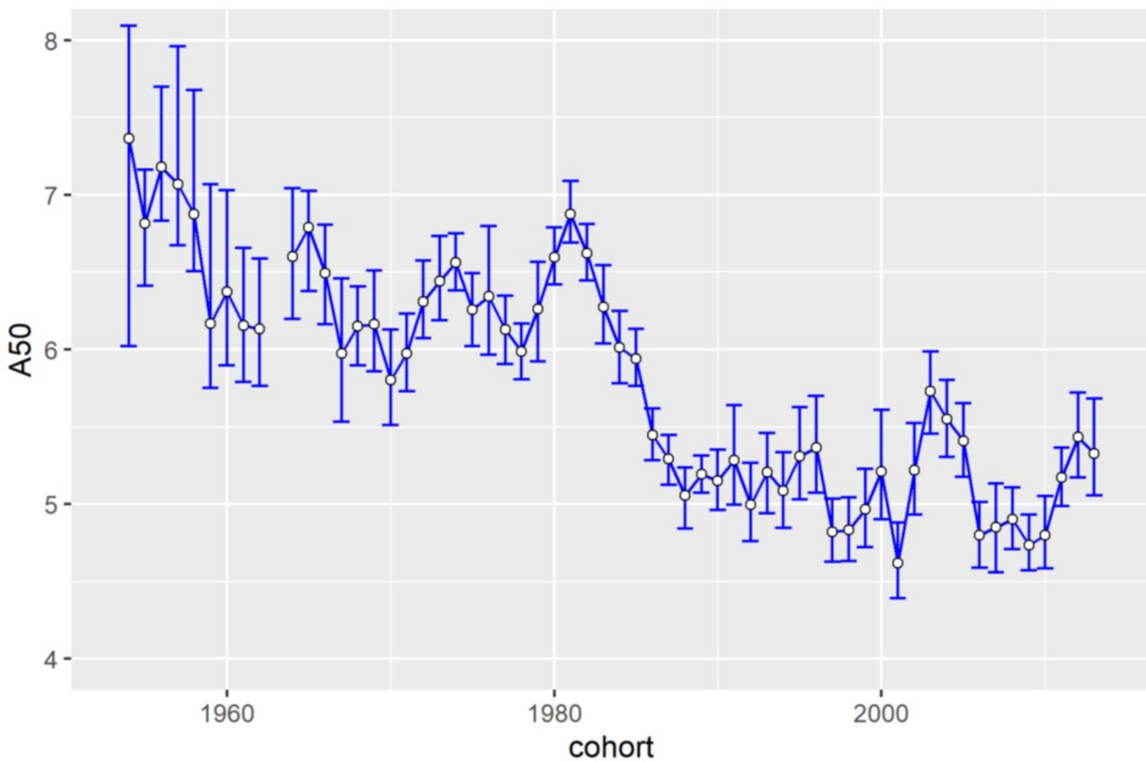


Figure 22a. Age at 50% maturity by cohort for female cod sampled during DFO research vessel bottom-trawl surveys of NAFO Subdiv. 3Ps. Error bars are 95% fiducial limits.

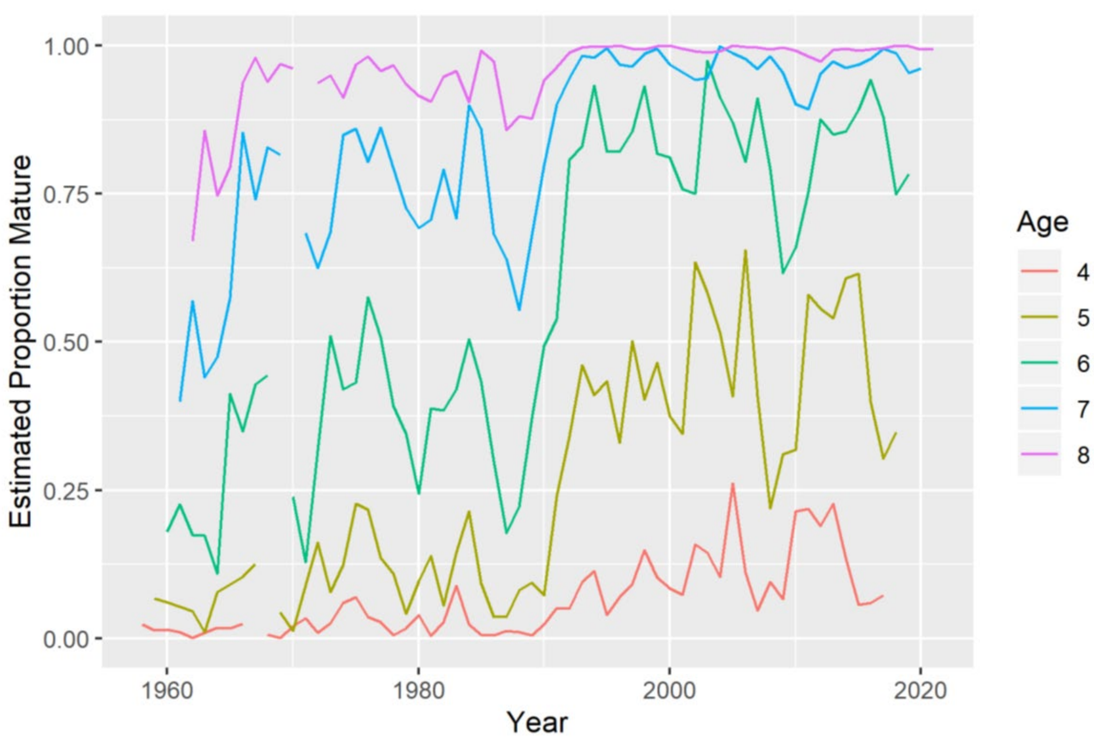


Figure 22b. Estimated proportions mature at ages 4–8 for female cod sampled during DFO research vessel bottom-trawl surveys in NAFO Subdiv. 3Ps (data from all strata surveyed).

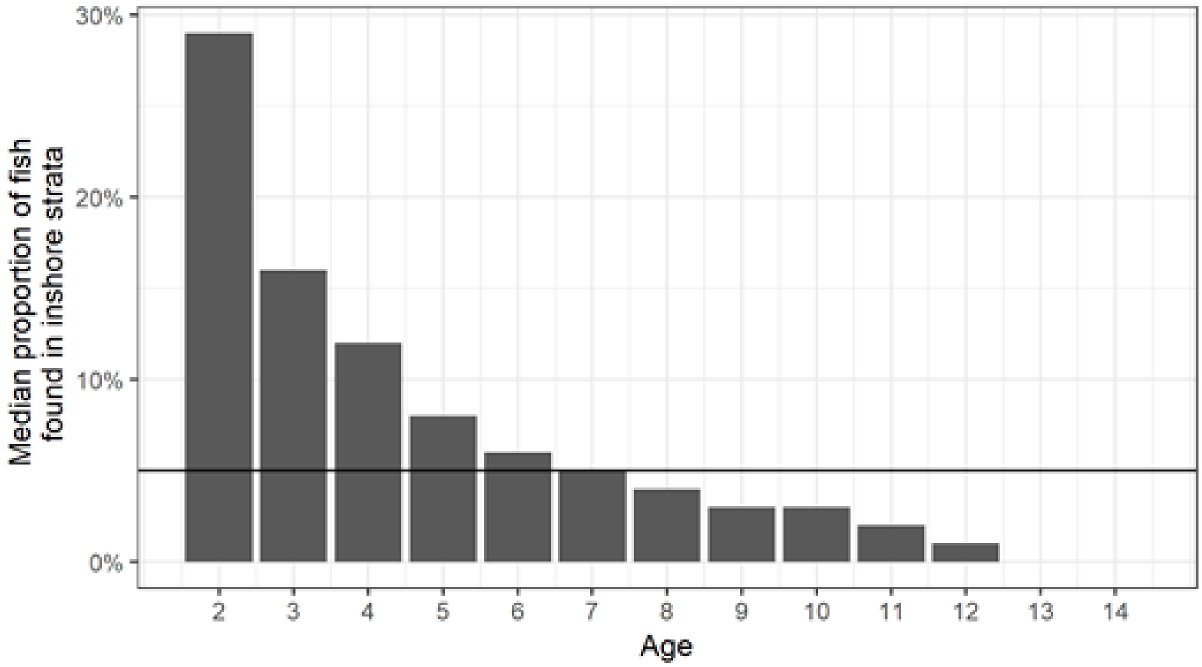


Figure 23. Proportion of fish by age in the inshore versus combined inshore-offshore area in the Canadian-RV surveys from 1997–2018. The offset for q was applied to ages 8 and older. The horizontal line indicates 5% which was used as a cut-off for ages to apply the offset.

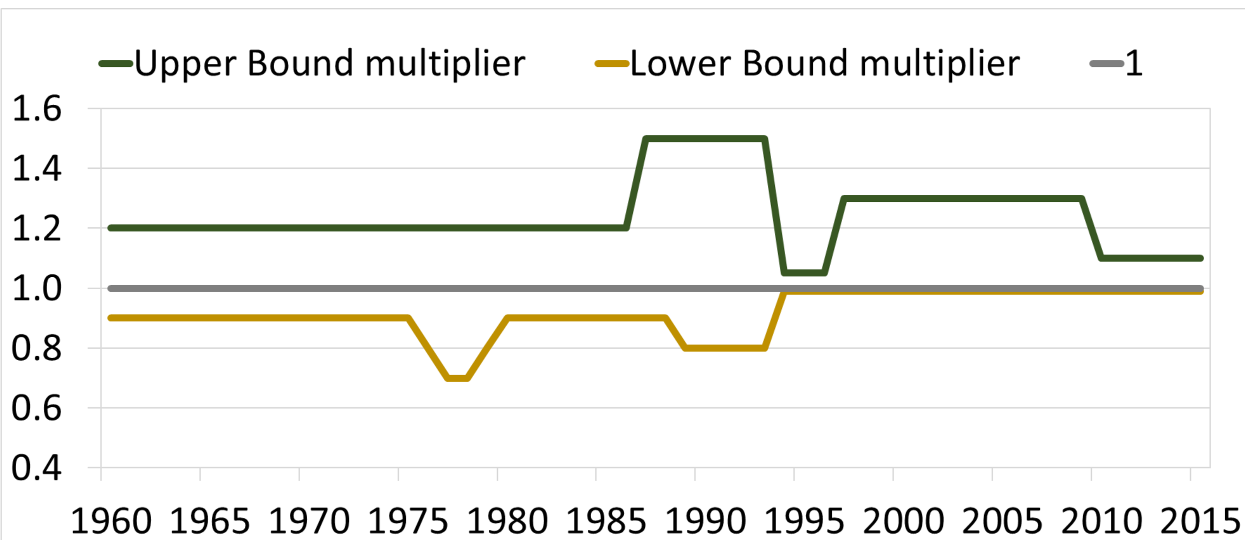


Figure 24. Landings bounds agreed upon at the Framework meeting for 3Ps cod in October 2019.

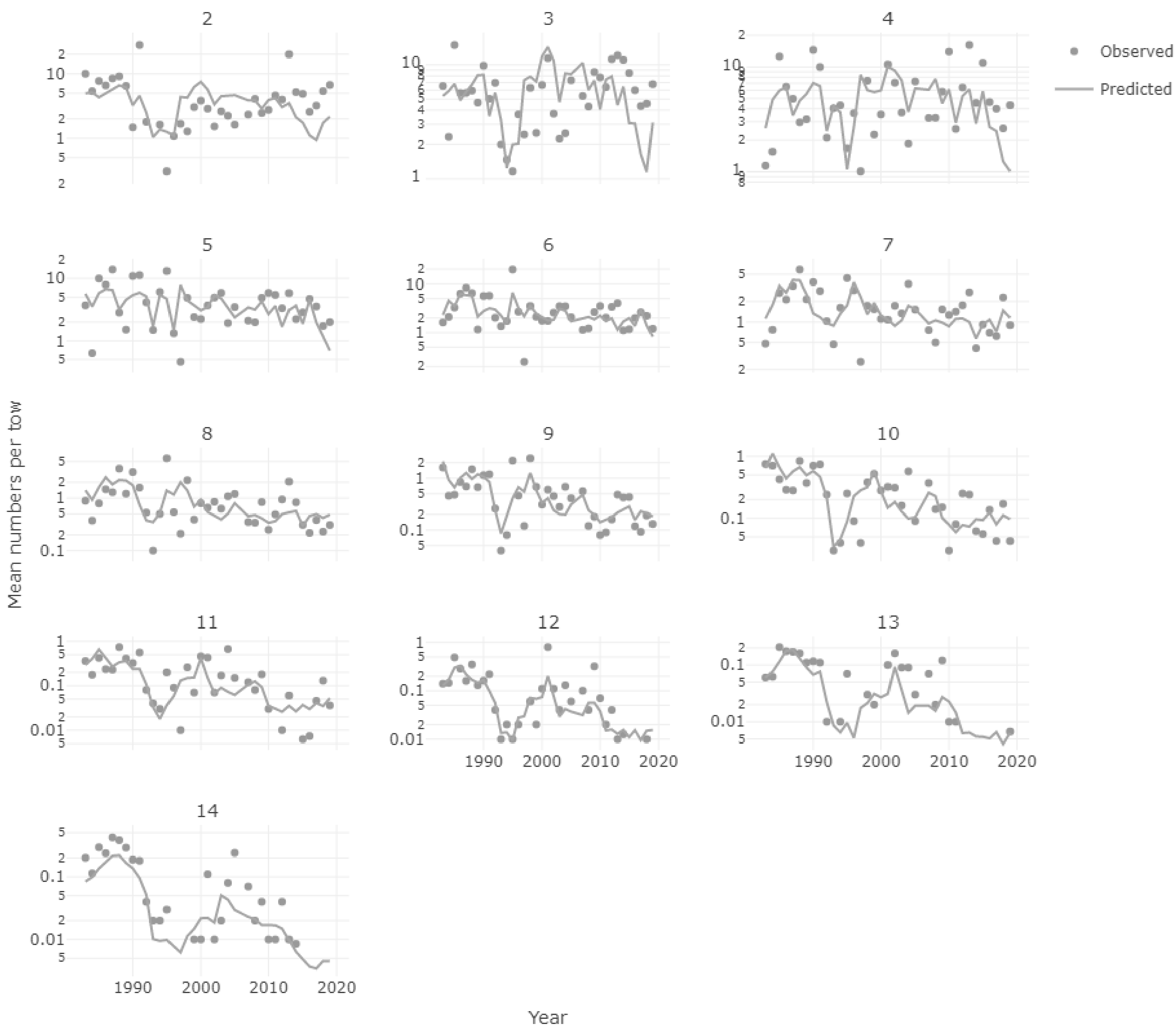


Figure 25. Model fits to DFO RV survey.

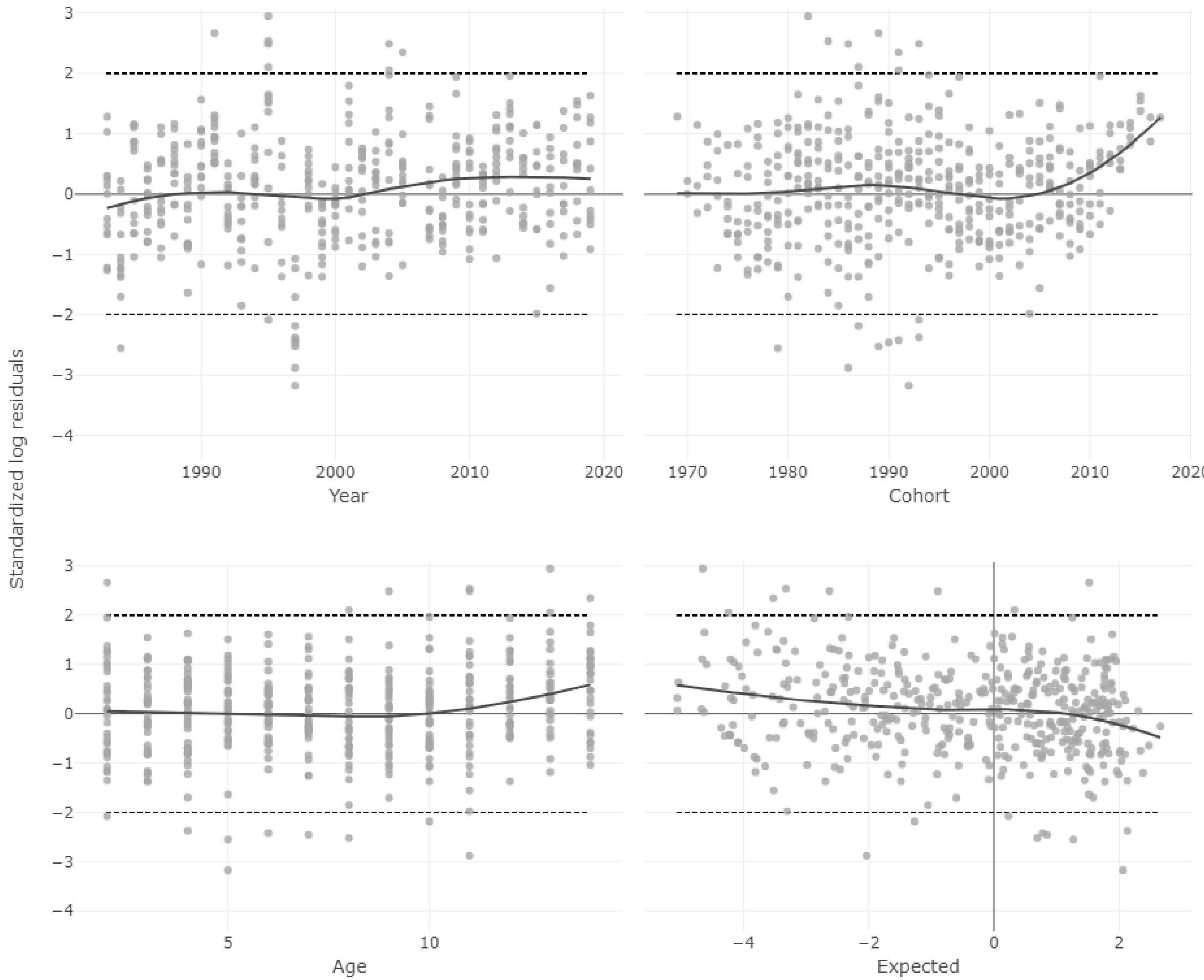


Figure 26. Residuals of model fit to the RV survey.

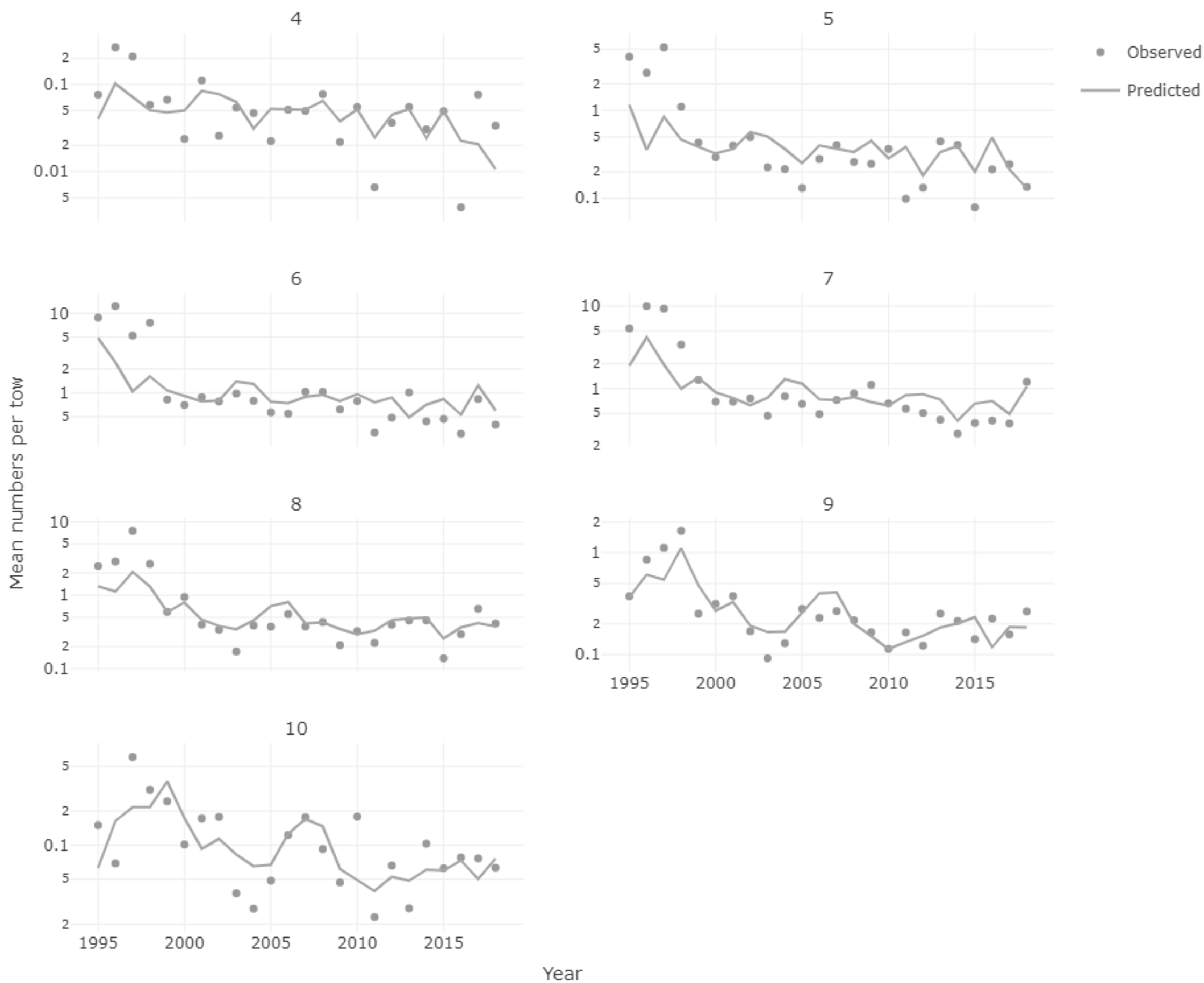


Figure 27. Model fits to sentinel gillnet survey.

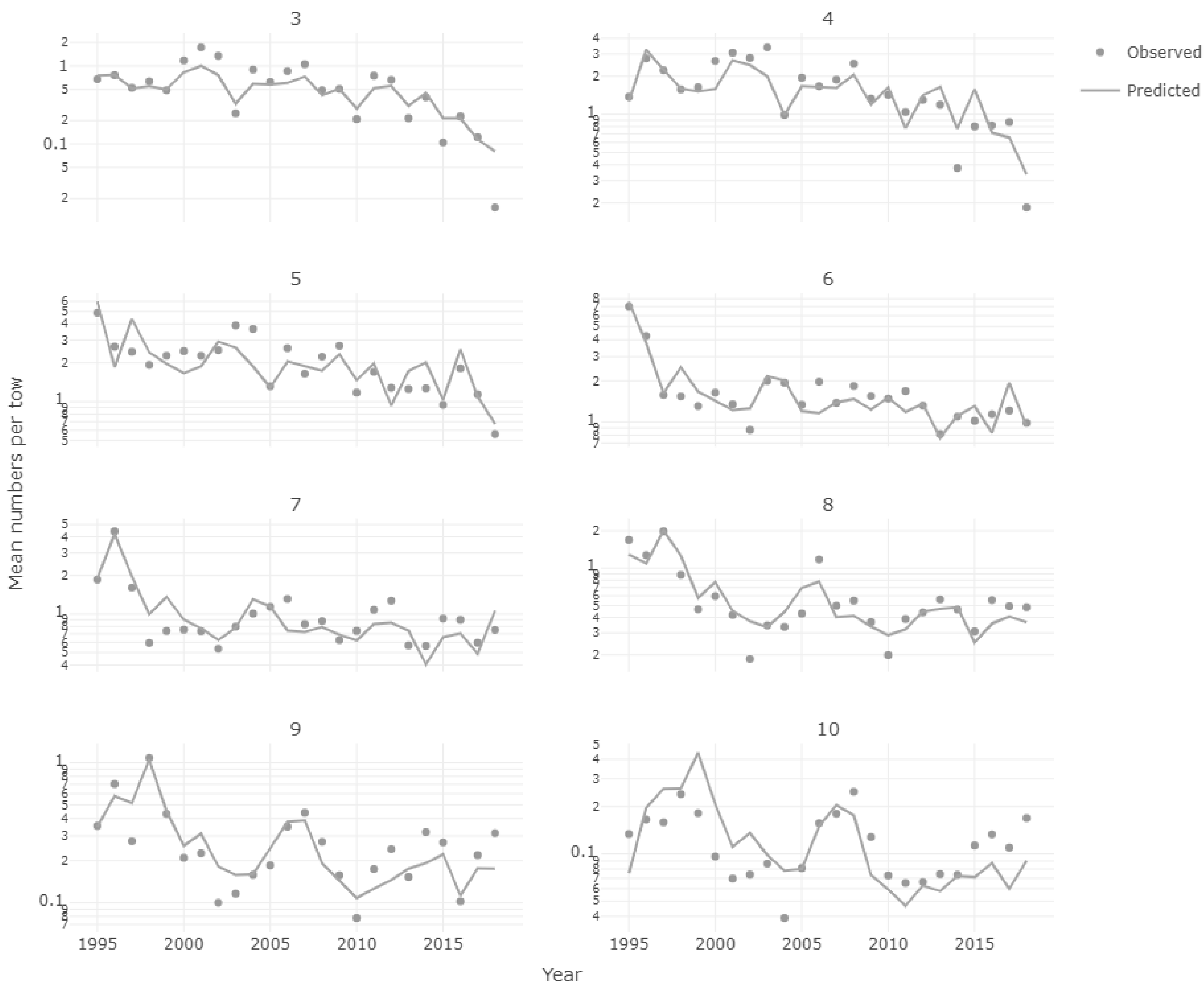


Figure 28. Model fits to sentinel line-trawl survey.

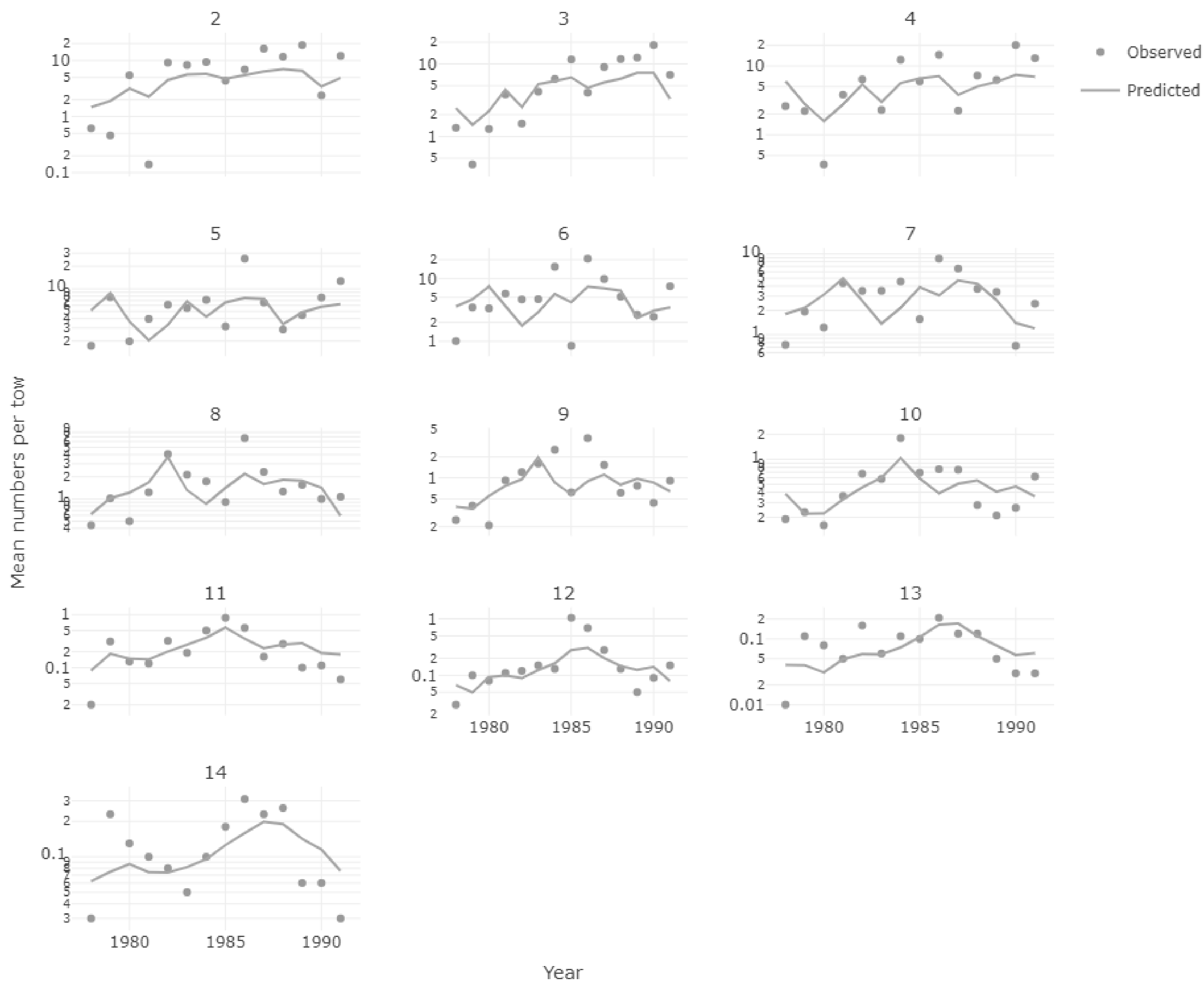


Figure 29. Model fits to IFREMER ERHAPS survey.

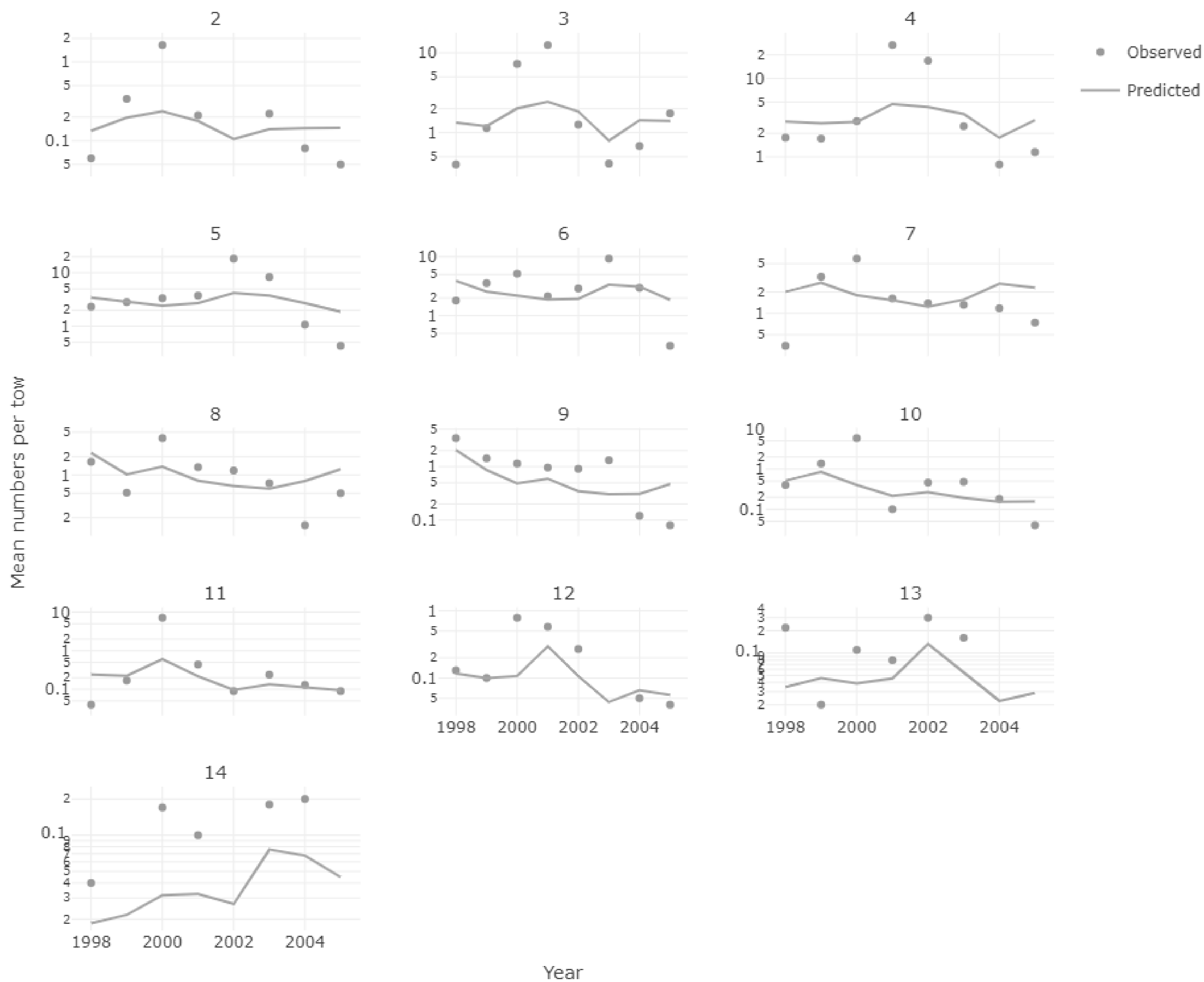


Figure 30. Model fits to GEAC survey.

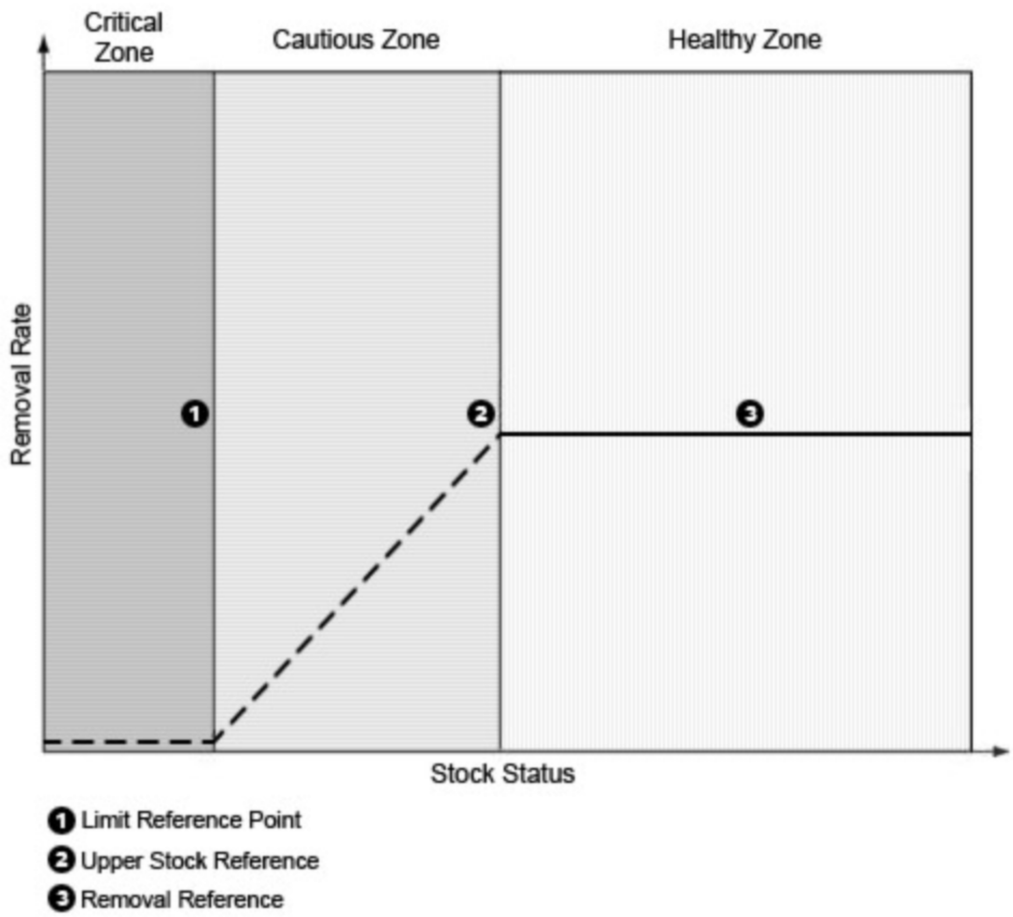


Figure 31. Guidelines from Canadian PA framework.

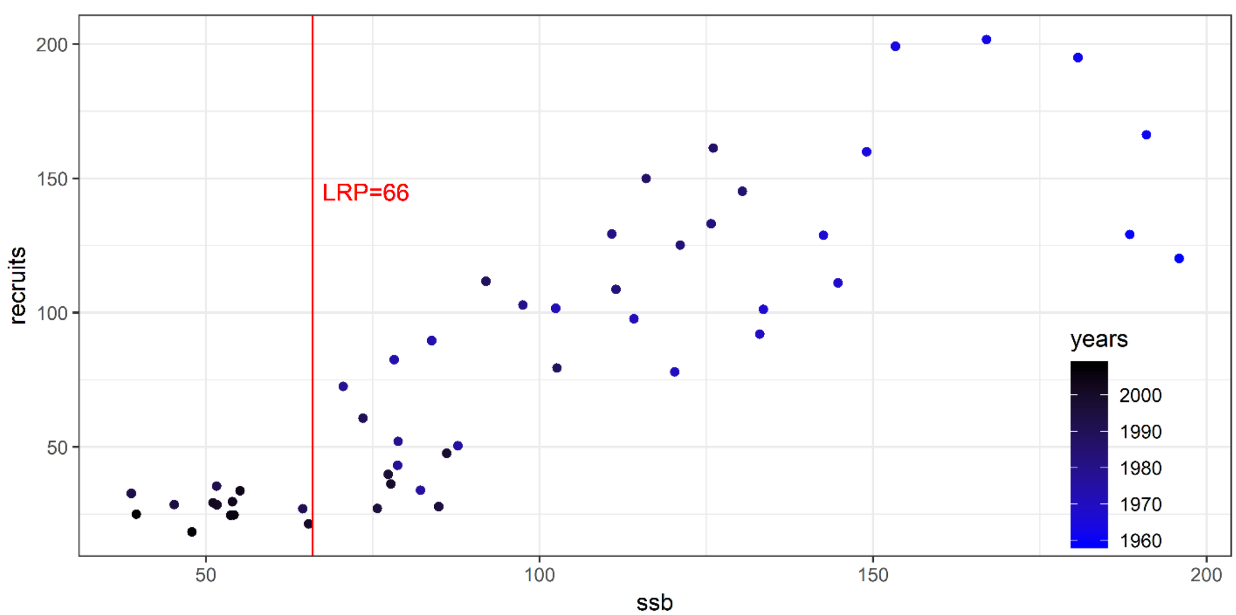


Figure 32. Breakpoints detected in stock-recruit scatter.

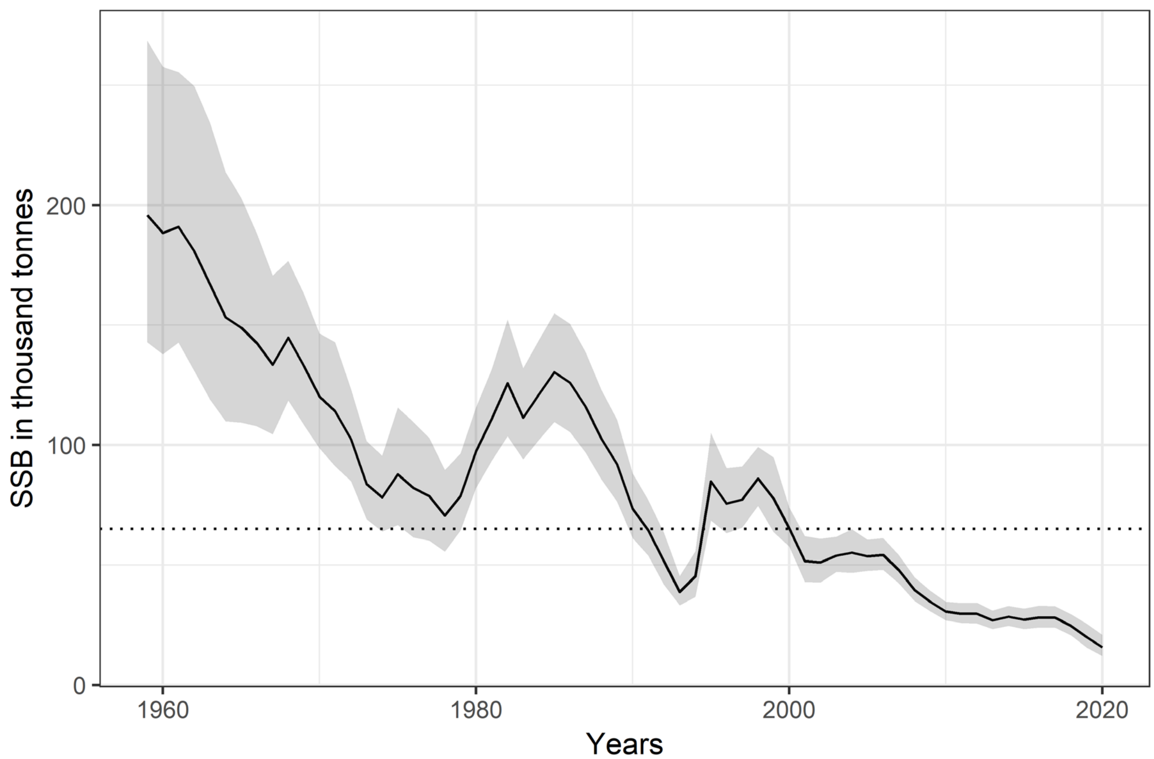


Figure 33. Cohort analysis estimates of SSB (median estimate with 95% confidence interval) for the period 1959 to 2020, dotted line indicates B_{lim} value. This reference point represents the boundary between the critical and cautious zones of DFO's precautionary approach framework.

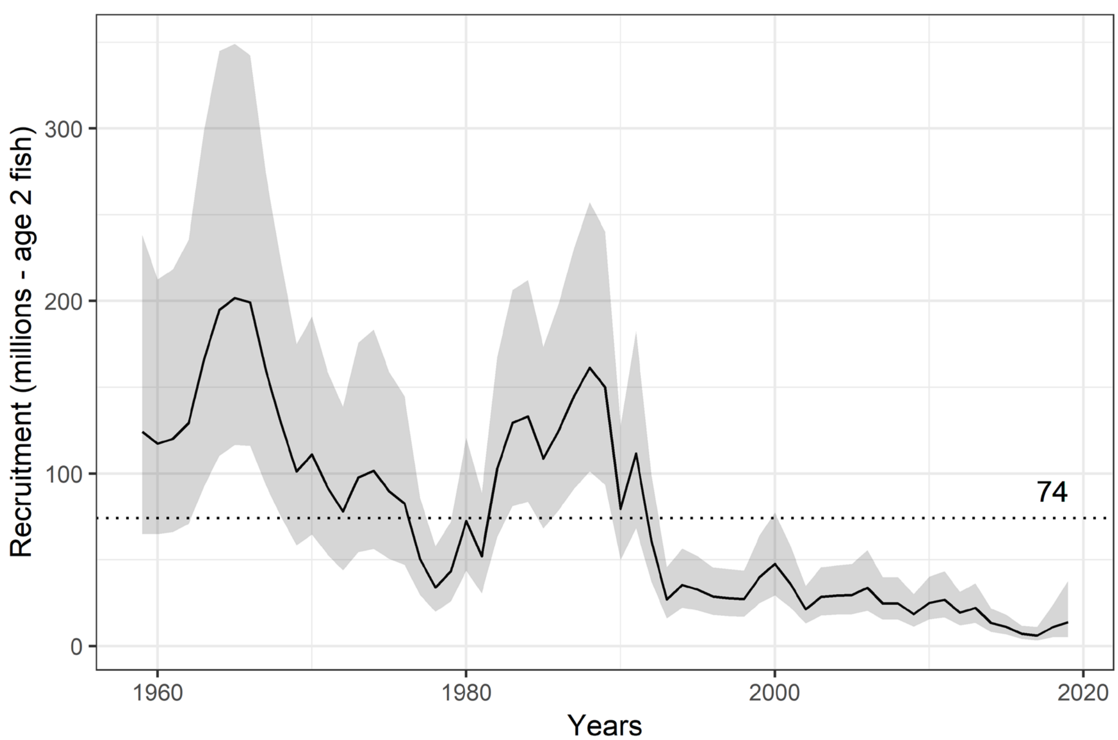


Figure 34. Recruitment (age 2) estimates for 3Ps cod between 1959 and 2019.

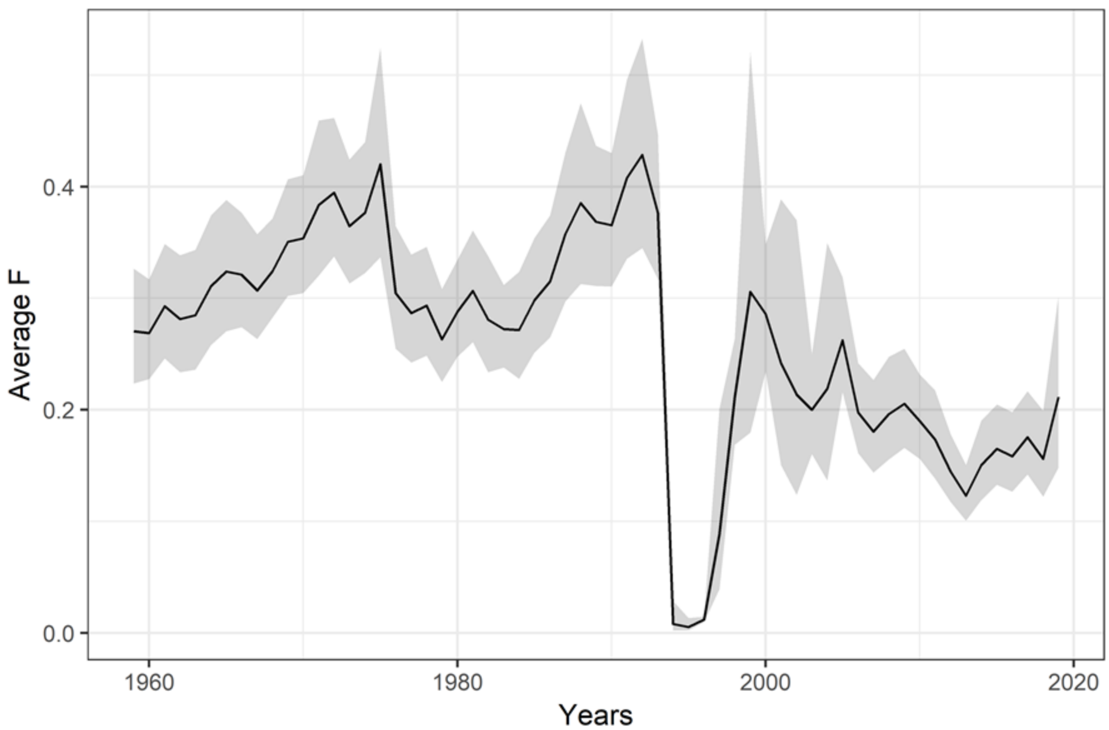


Figure 35. Average F (ages 5 to 8) estimates for 3Ps cod between 1959 and 2019.

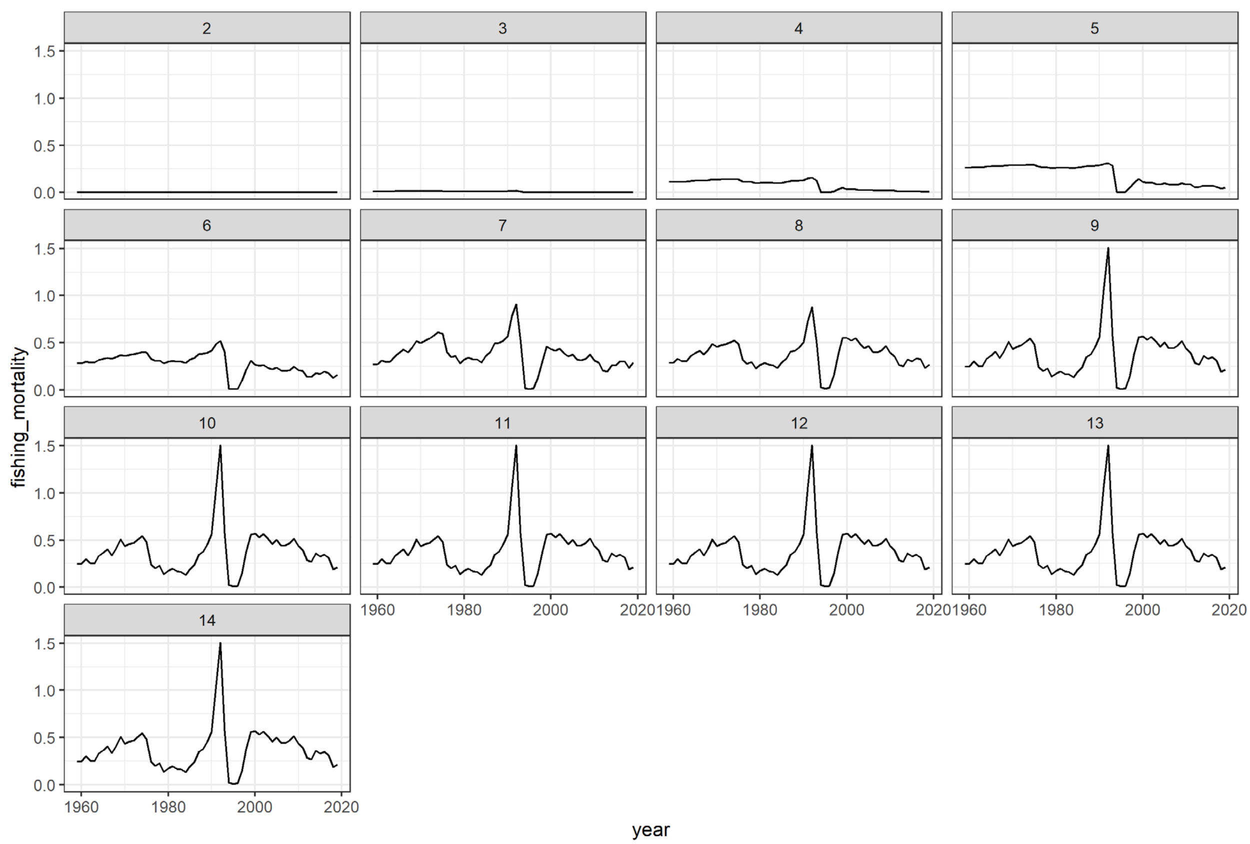


Figure 36. Estimated fishing mortality-at-age.

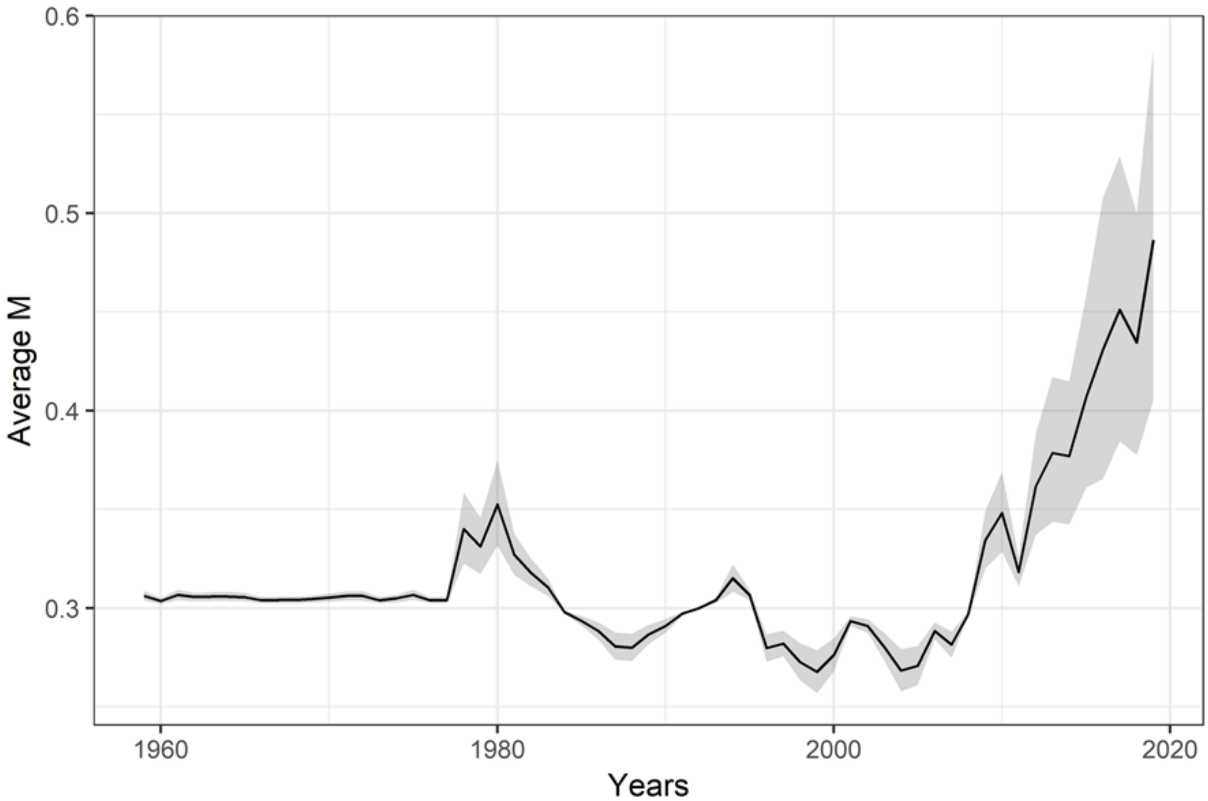


Figure 37. Natural mortality of 3Ps cod between 1959 and 2019 based on fish condition.

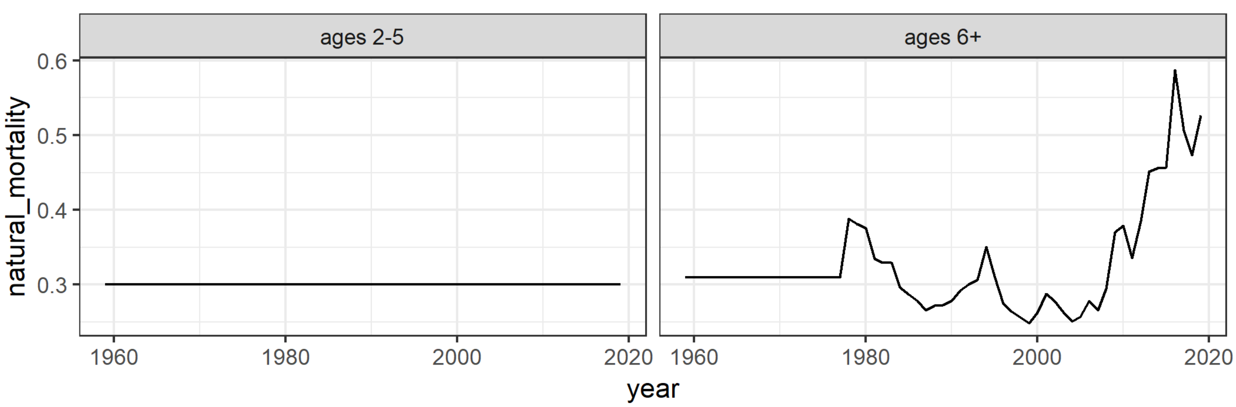


Figure 38. Estimated natural mortality-at-age.

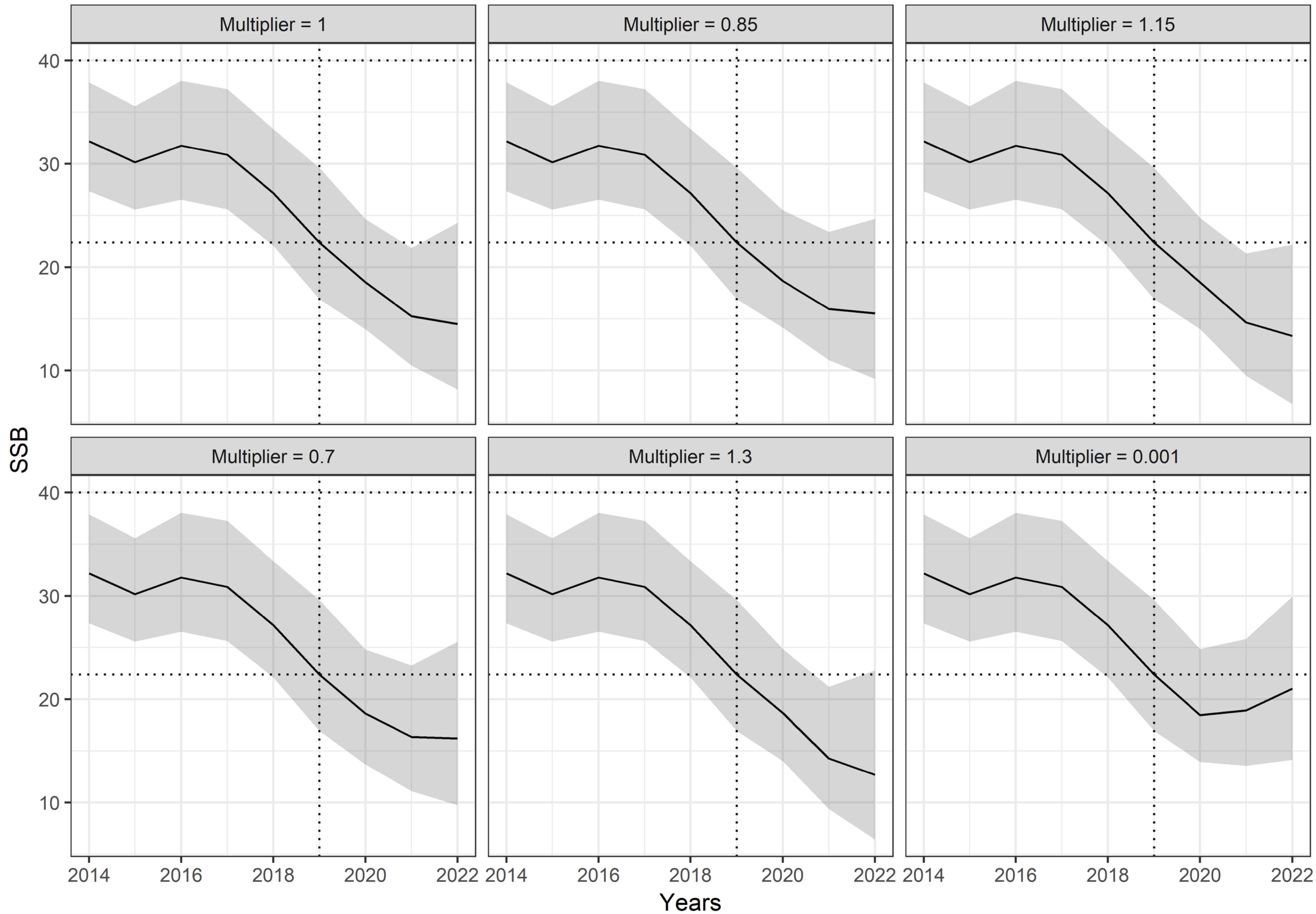


Figure 39. Projected spawning stock biomass estimates. The dotted lines indicate the 2019 assessment.

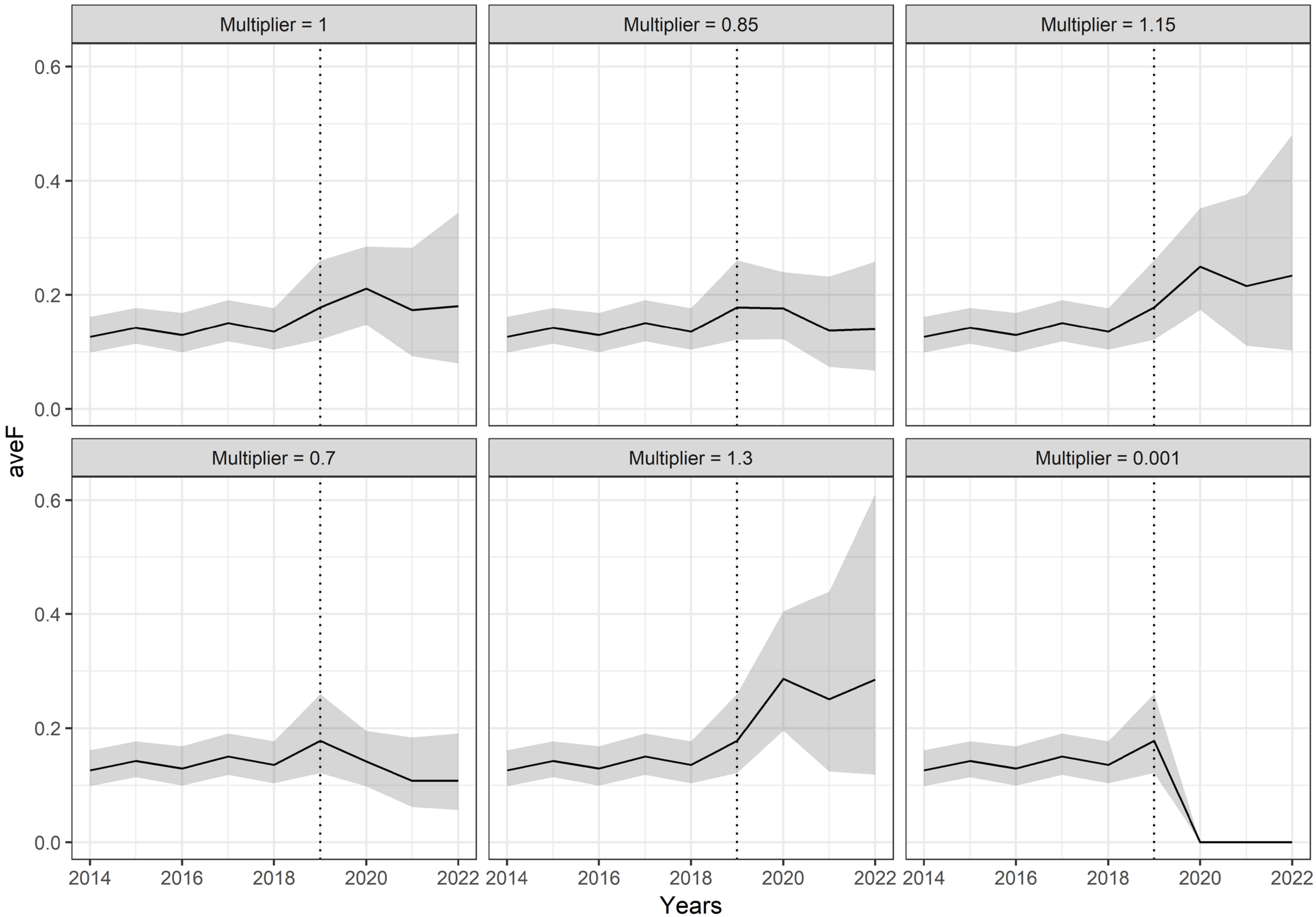


Figure 40. Projected average F estimates.

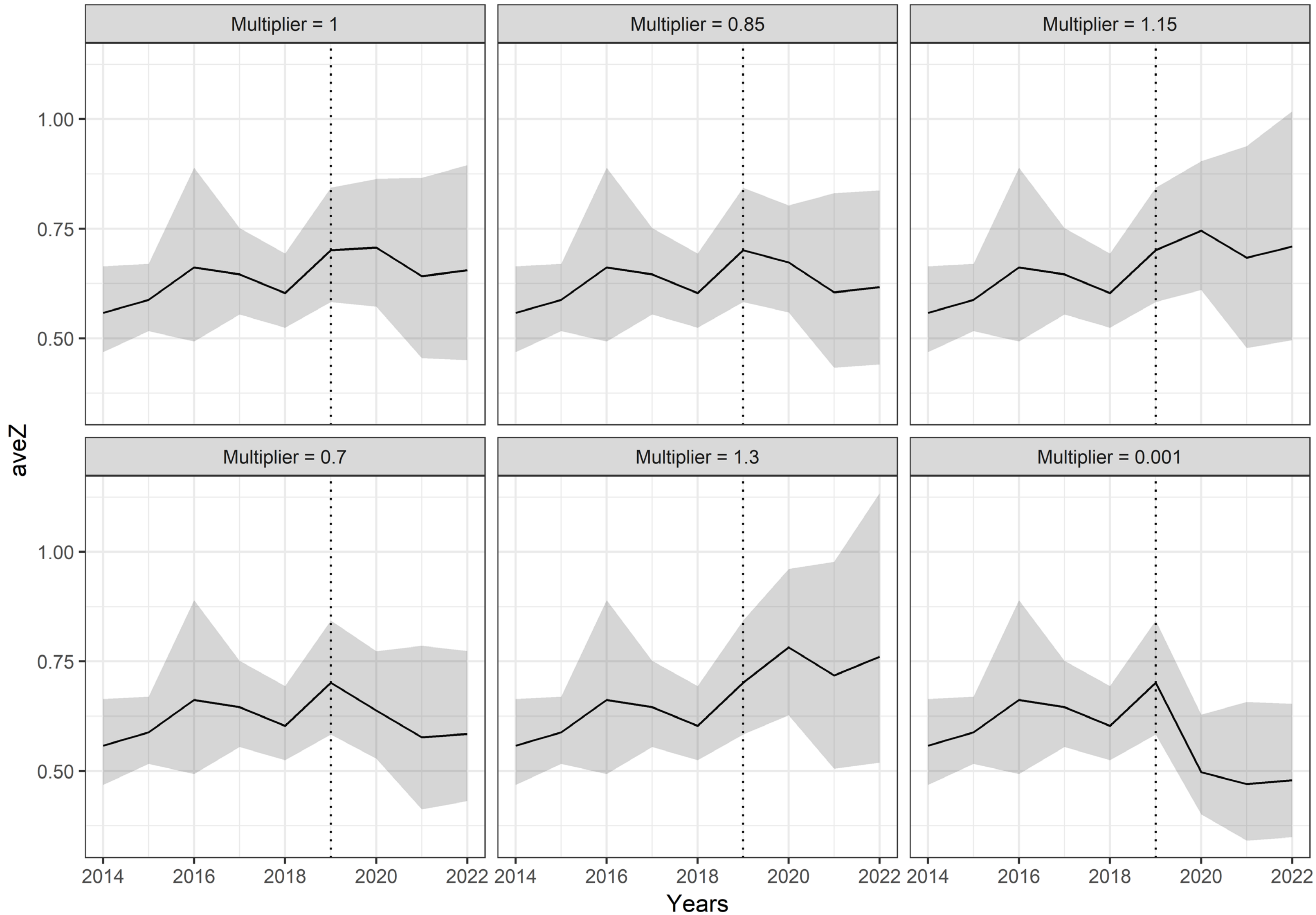


Figure 41. Projected average Z estimates.

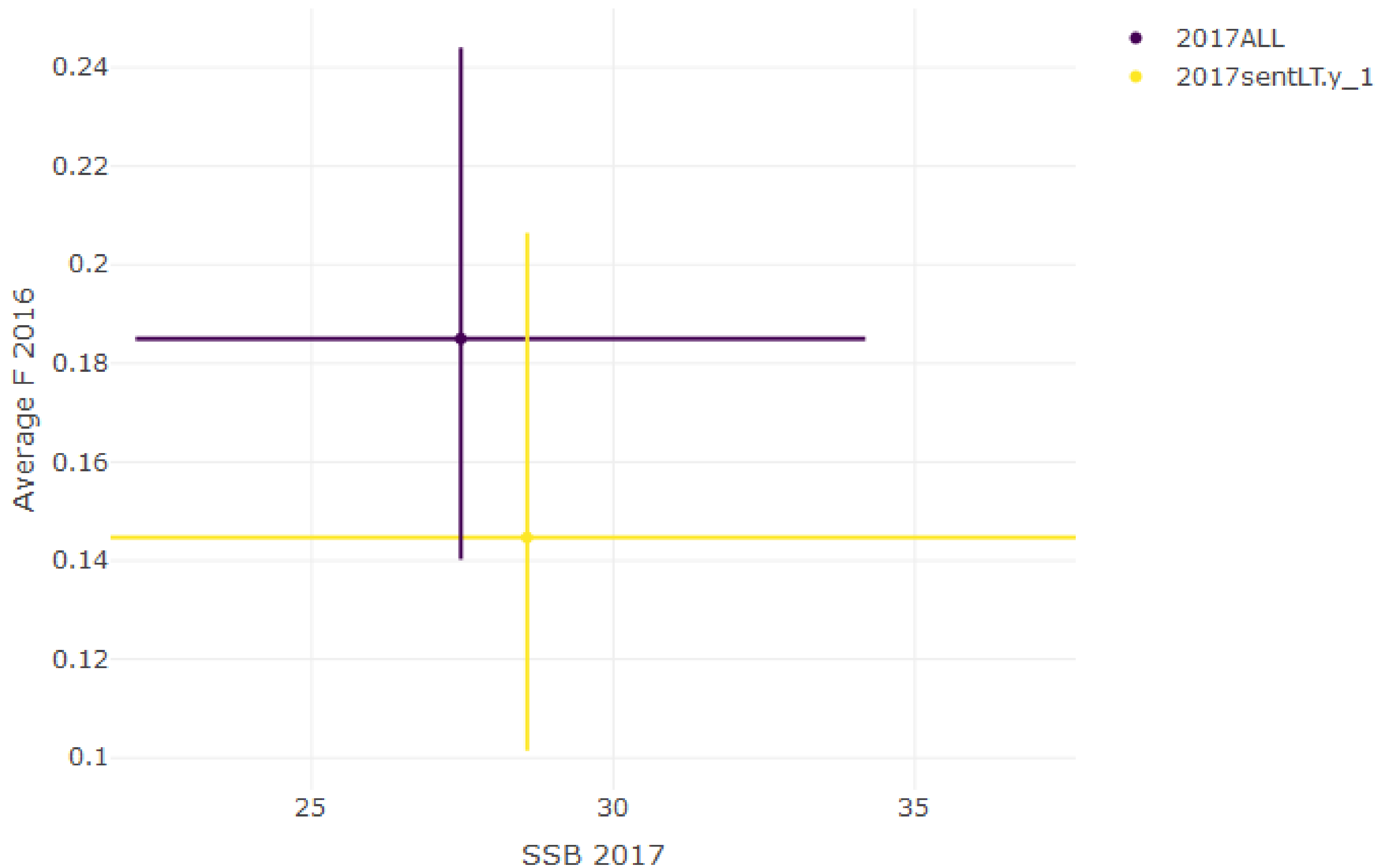


Figure 42. Estimates and confidence intervals of average fishing mortality in 2016 over SSB in 2017 from SAM current run (2017ALL) and one year less inputs for sentinel line trawl data (2017sentLT.y-1).

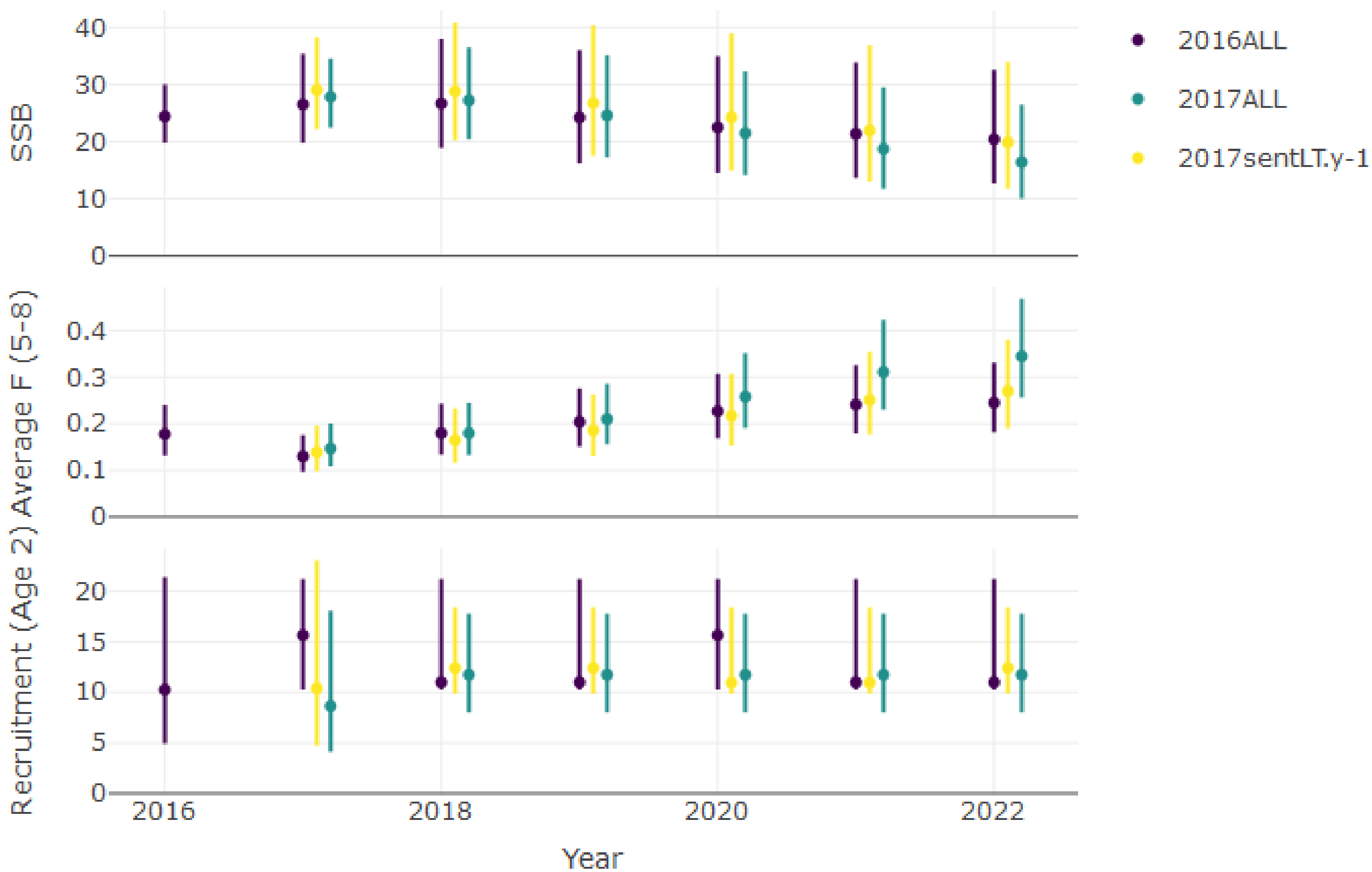


Figure 43. Estimates and confidence intervals of SSB, average fishing mortality and recruitment from SAM projection performed on current run (2017ALL), one year less inputs for sentinel line trawl data (2017sentLT.y-1), and one year behind run (2016ALL).

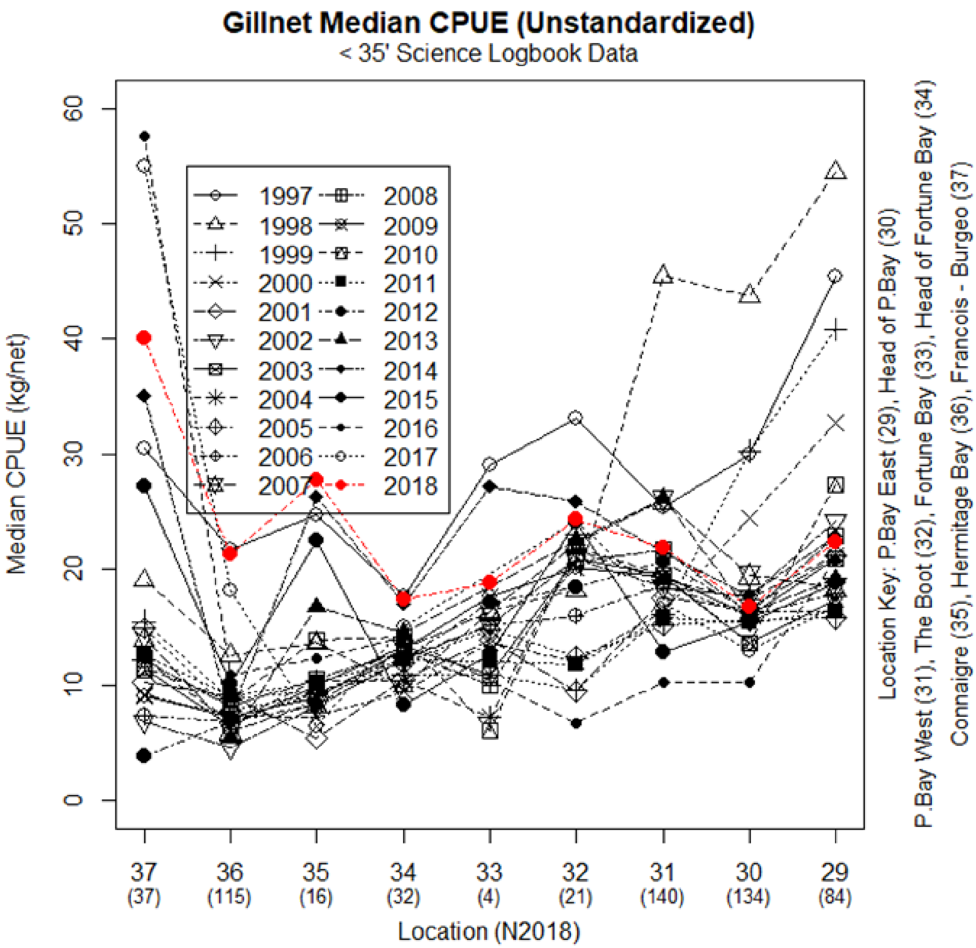


Figure 44. Unstandardized catch rates in gillnets based on data reported in logbooks for vessels <35 feet.

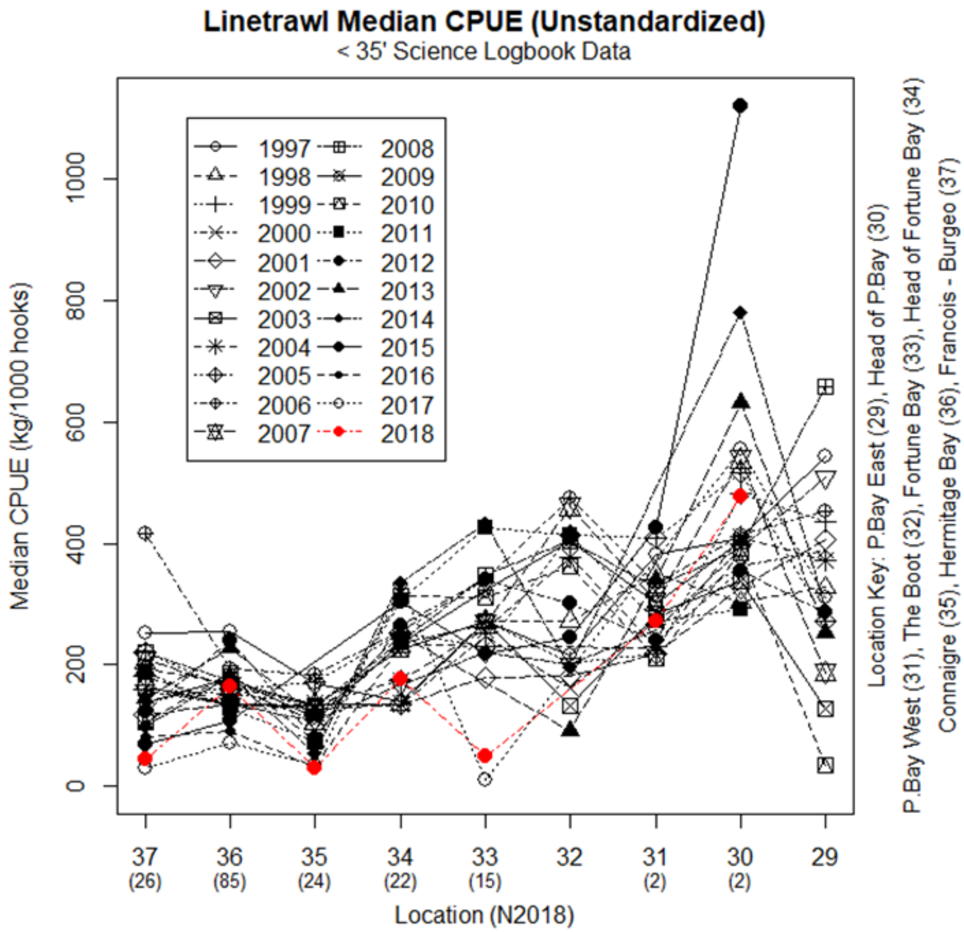


Figure 45. Unstandardized catch rates in linetrawls based on data reported in logbooks for vessels <35 feet.

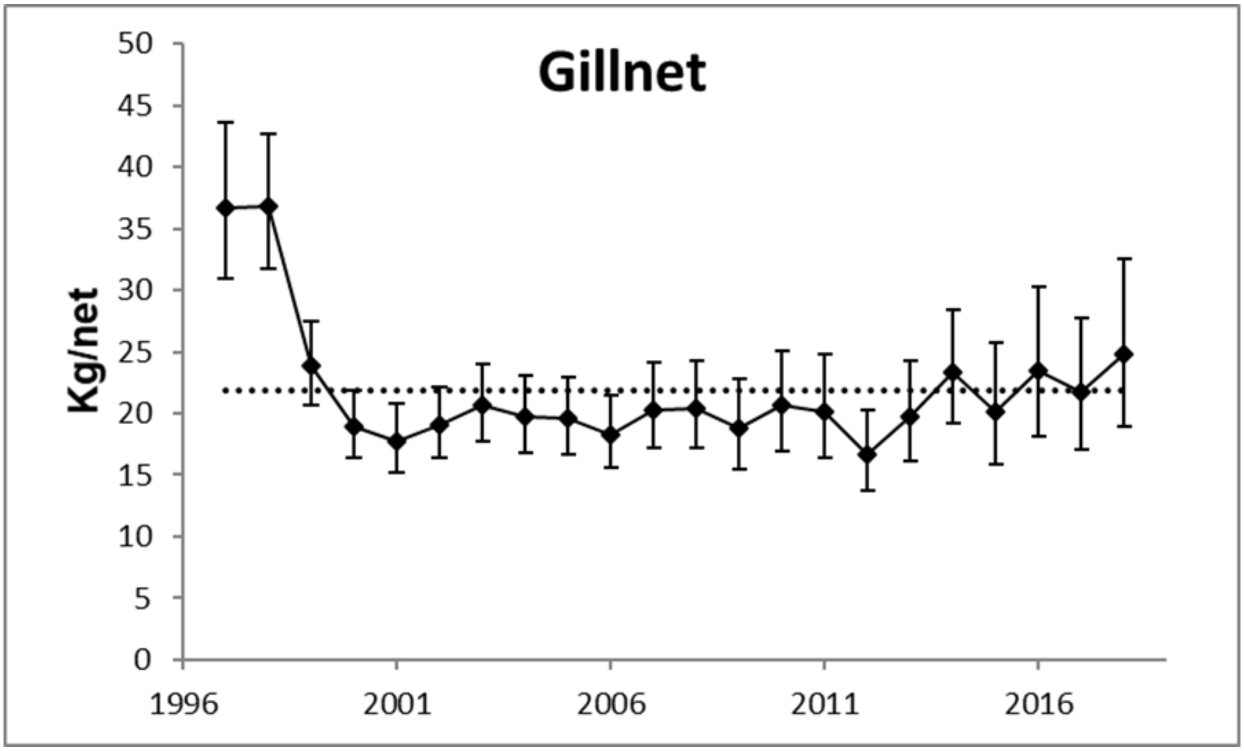


Figure 46. Standardized catch rates plus 95% confidence intervals for gillnets based on data reported in logbooks for vessels less than 35 feet. Horizontal line represents the time-series average.

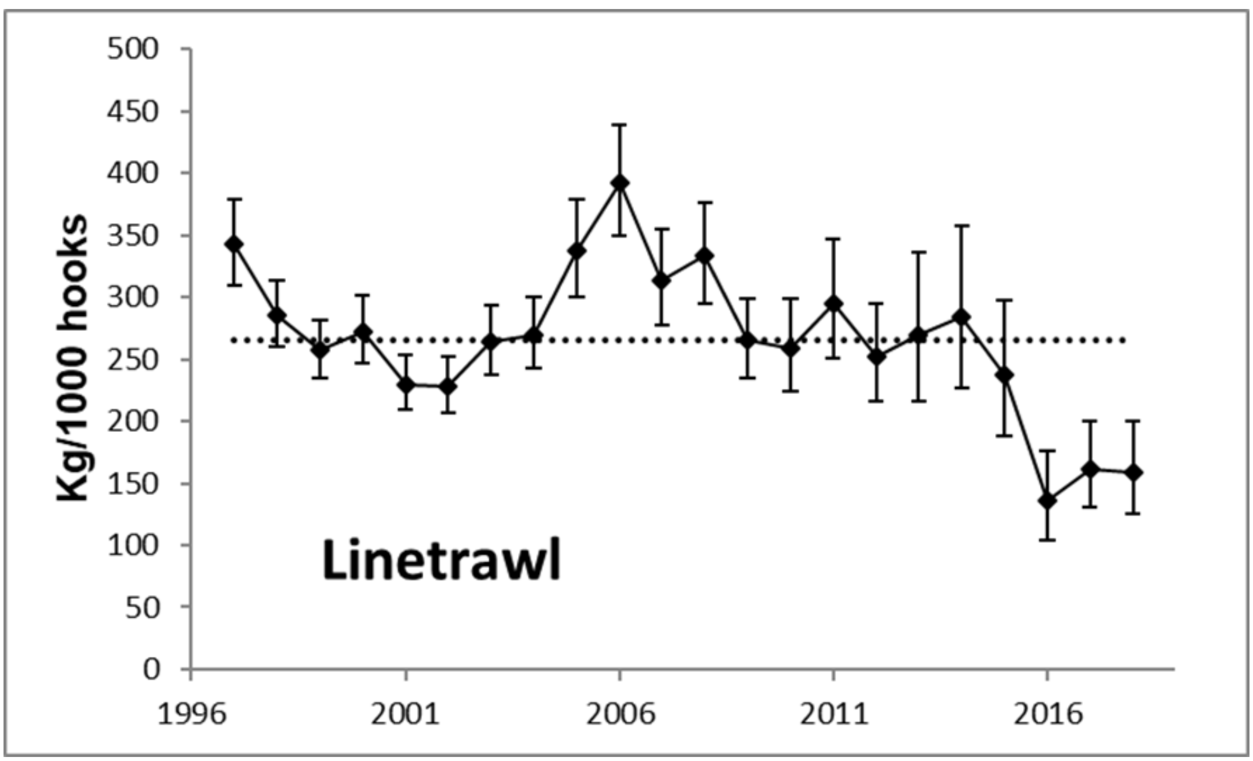


Figure 47. Standardized catch rates plus 95% confidence intervals for linetrawls as reported in logbooks for vessels less than 35 feet. Horizontal line represents the time-series average.

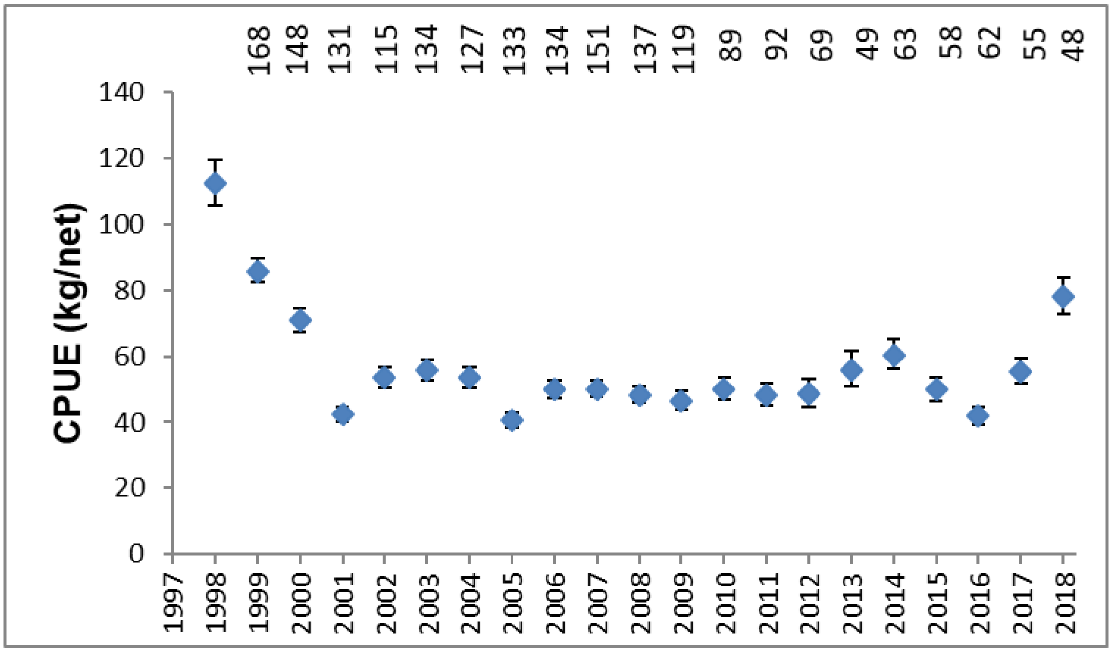
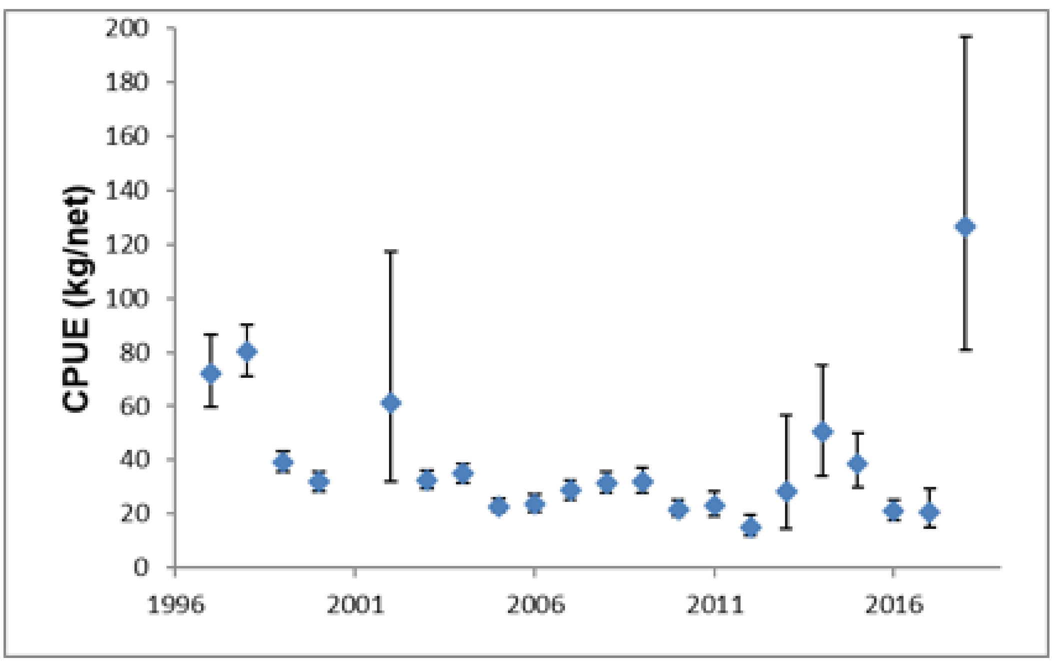


Figure 48. Standardized catch rates with 95% confidence intervals for gillnets based on data from logbooks from vessels greater than 35 feet. Number of sets annually shown at top of graph.



Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Trips	19	22	32	20	0	3	40	34	23	23	19	30	13	10	9	5	1	3	8	7	6	5
Sets	111	350	425	395	0	8	432	457	363	217	285	304	179	212	94	49	7	21	53	110	28	17

Figure 49. Standardized catch rates for gillnets plus 95% confidence intervals based on at sea sampling by observers during 1996 to 2016. Number of sets annually shown below graph.

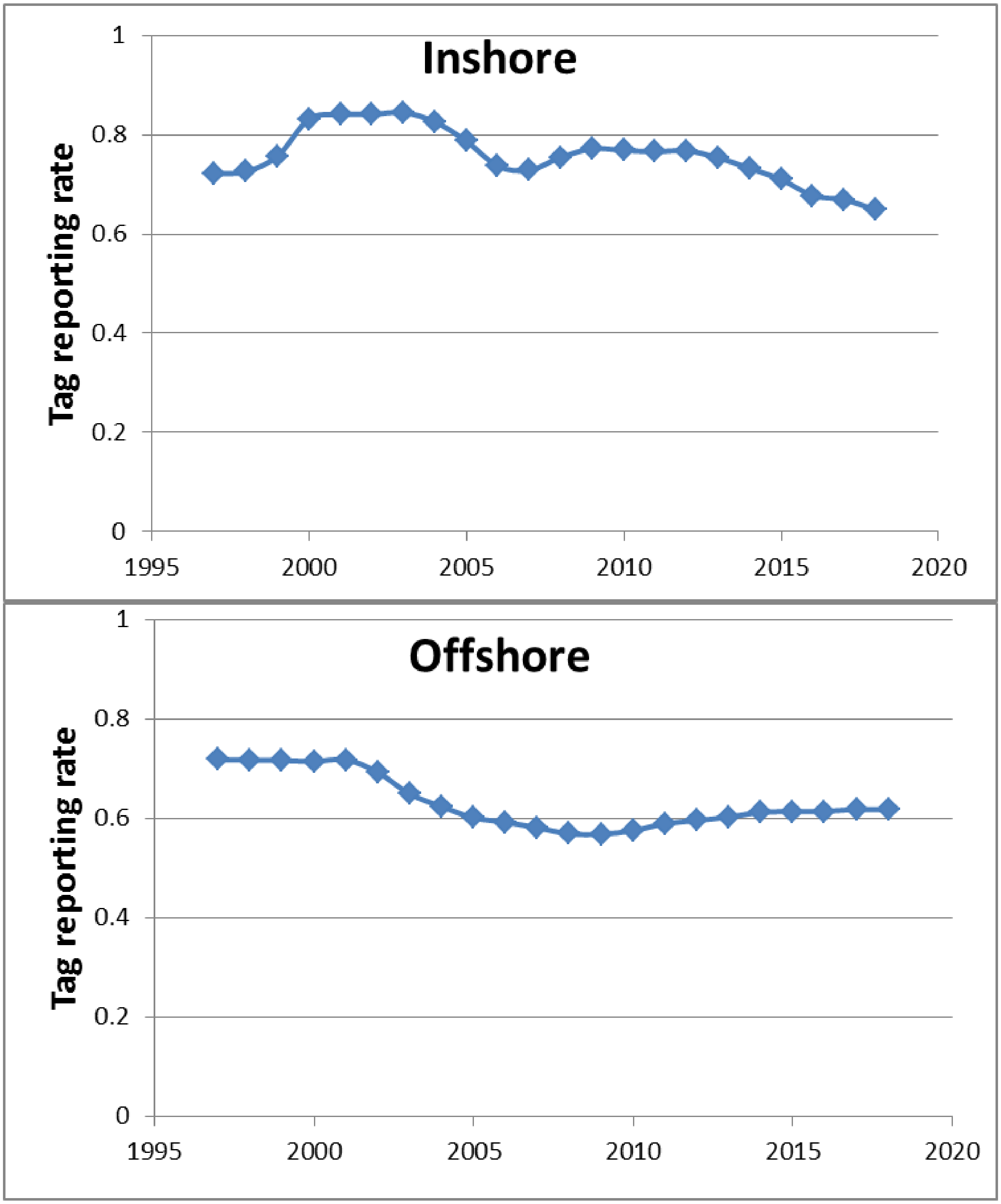


Figure 50. Trends in annual tag reporting rates for low reward ($10) tags based on a mixed effects logistic regression model.

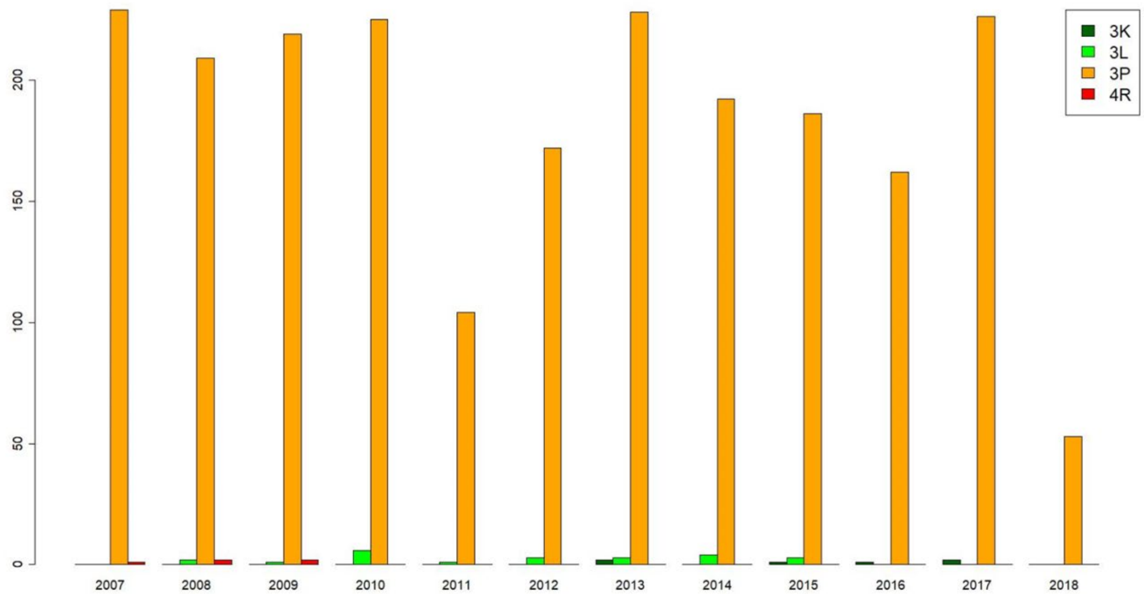


Figure 51. NAFO divisions where tags were recovered during 2007 to 2018, from cod tagged in 3Ps.

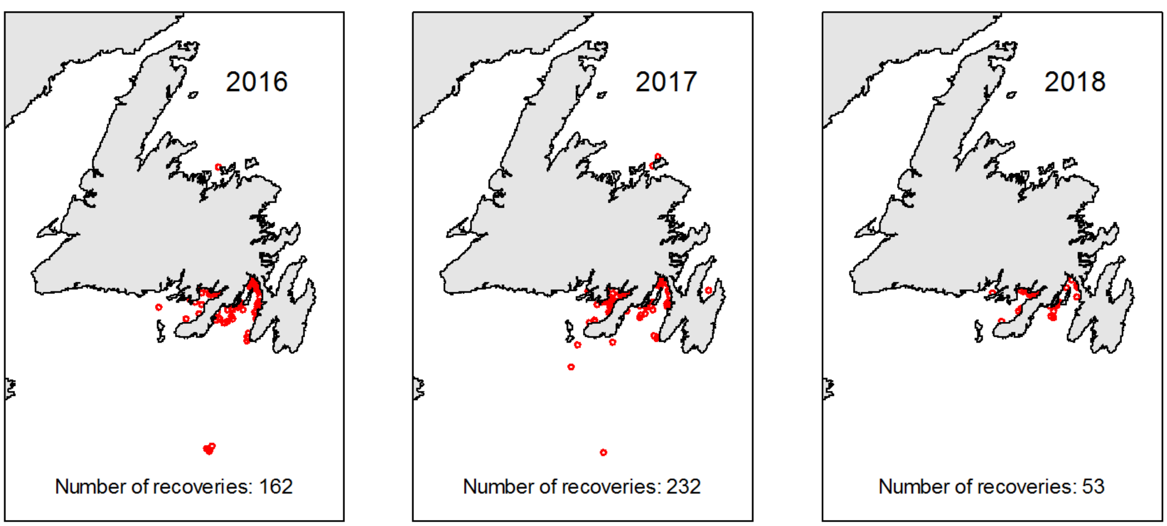


Figure 52. Locations within 3Ps where tags were recovered during 2016 to 2018 from cod tagged in 3Ps.

APPENDIX A – SAM MODEL UPDATE 2019

SAM MODEL DESCRIPTION

The SAM model for 3Ps cod stock was developed with the stock assessment package (from Nielsen and Berg 2014 and Berg and Nielsen 2016), and has been described extensively in Champagnat et al. (in prep[4]). The model formulation follows Champagnat et al. (in prep[4]) description of 'sentinel run' (run 143).

Sentinel Line Trawl Influence

Sentinel line trawl index has a very low standard deviation estimate (Table A1), which points that the model is fitting substantially to this index. To assess the influence of that series, leave out fleet runs were performed (e.g., running the same model but with one survey out). In the recent period the run without sentinel line trawl index is the one displaying more differences (Figure A1). Those differences are underlined in Figure A2, where stock status (SSB and F) is displayed. The run without sentinel line trawl indices has a higher SSB value and lower F estimate than the normal run (e.g., all data in, denoted as 'current' in the plot). In addition, normal run confidence intervals don't overlap w.o sentinel line trawl estimate. Finally, the w.o sentinel line trawl run also shows more uncertainty (wider confidence intervals).

Impact of Having No 2019 Data for Sentinel

At the assessment time (November 2019), sentinel fishery is still running and consequently sentinel indices for 2019 are not available. Considering the important impact of sentinel line trawl series on the assessment results, some analysis has been performed to evaluate the bias induced. In this purpose two runs of models going up to 2017 (data available at the time the study was undertaken) are compared:

1. one with all data going until 2017, and
2. one with all data going until 2017 except the sentinel indices going until 2016.

First the impact on stock status perception is assess (Figure 42): the two runs displayed some differences in both SSB and F but those are small, and the confidence intervals overlap.

Then the impact on projection was estimated (Figure 43) comparing the estimates and confidence intervals from the two runs cited above and one starting in 2016, with all the data going into 2016. This illustrates roughly our situation before the assessment: having a complete input model up to 2018, or a model going until 2019 but with sentinel indices one year behind. The projection displays some differences in the estimates for the three runs, but confidence intervals mostly overlap. For SSB and average fishing mortality the differences are small (Table 18). On the contrary recruitment exhibits more important differences between projection starting in 2016 or 2017, the inclusion of last year data (especially the RV recruitment index) impacts the recruitment estimation. This leads us to prefer running assessment and projection from a 2019 model even with sentinel data one year behind.

Stock Recruitment Relation and Associated BRP

From SAM run output, diverse stock- recruitment relation have been fitted (for details see Champagnat et al. in prep[4]), including some time varying parameter ones. None of them evidenced the existence of a 'plateau' in the stock recruit. Consequently, none of the usual BRP can be used here. A breakpoint analysis was performed to track discontinuities in the recruitment over SSB (Figure A3). Breakpoint values are 34, 59 and 113 thousand tonnes.

Updated RUN

It has been updated until 2019 with the more recent data presented above, the natural mortality input has been set to 0.3.

The stock spawning biomass displays a declining trend since 2004, beginning with a sharp decrease (-43% between 2006 and 2009) and more gradually in the most recent period (3% decrease in average since 2010). The 2019 estimate is 20 thousand tonnes, it is the lowest value of all time series and comprised at 50% of age 7 and 8 (2011 and 2012 strong year classes) (Figure A4; Table A2).

Population weighted fishing mortality has overall decreased since 2000 and 2019 estimate is 0.14. 2018 estimate is the lowest value of the series (apart from moratorium years) (Figure A5; Table A2).

Recruitment estimates (abundance of age 2 fishes) are low since 2002. After 2011 and 2012 strong year classes, it has been decreased and reaching the lowest values of the series. In 2018 and 2019 DFO RV spring survey has been tracking few more young fishes resulting in slight increase of recruitment estimates (Figure A6).

Model diagnostics are similar to results discussed at the framework meeting. There are evidences of year-effect in the survey fit and some conflict between DFO RV survey and sentinel line trawl indices. The retrospective analysis shows directional pattern in the revision of SSB; F and R which is a concern for the evaluation. This pattern is thought to be link with an increase of natural mortality evidenced by a condition analysis.

Projection with SAM

Projection of the stock to 2022 was conducted assuming catch removal will be within ±30% of current value (2019 landings). Recruitment was assumed to be the mean of the age 2 estimates over 2017–19, weights at age, mortality at age and fishing selectivity were assumed to equal the average of those over 2015–17. The proportions mature at age were projected forward from the cohort-specific model estimates. Six projection scenarios were conducted, using multipliers of 0.7, 0.85 1.0, 1.15, and 1.3 on current landings, with a constant value assumed for each year projected. All projections with assumed landings show SSB in 2022 to be lower than SSB in 2019 and fishing mortality to be higher (Tables A3–A5). Where catch is increasing, fishing mortality is multiplied by two (15% increase scenario) or three (30% increase scenario).

Tables

Table A1. Standard deviation parameters estimated for SAM sentinel run.

Standard deviation parameters	Standard run + sentinels (143)
Recruitment	0.35
Survival/population	0.22
Age2 F	0.68
Age3-4 F	0.97
Age5+ F	0.65
Age2 catch	1.62
Age3-4 catch	0.64
Age5+ catch	0.26
OFF	0.74
IO	0.81

Standard deviation parameters	Standard run + sentinels (143)
GEAC	0.98
ERHAPS	0.75
Sentinel LT	2.74
Sentinel GN	0.38

Table A2. Estimates, upper and lower bounds of SSB F and R from SAM.

Variable	Year	Estimate	Lower – Upper bound
SSB	2017	22.814	18.53–28.1
	2018	22.052	17.5–27.8
	2019	20.078	15.1–26.7
F	2017	0.207	0.16–0.28
	2018	0.139	0.1–0.19
	2019	0.143	0.1–0.2
Recruitment	2017	5.940	3.2–10.97
	2018	9.880	4.9–20.08
	2019	11.593	4.7–28.67

Table A3. Estimates, upper and lower bound of SSB and fishing mortality in 2020 from SAM projection.

Variable	Catch scenario	Estimate	Lower bound	Upper bound
SSB	Statut.quo	20.441	14.465	28.457
	15%	20.474	14.539	29.547
	-15%	20.874	14.371	28.874
	30%	20.563	14.678	29.872
	-30%	20.536	14.229	29.54
	0	20.893	14.63	29.33
F	Statut.quo	0.202	0.144	0.286
	15%	0.237	0.164	0.341
	-15%	0.168	0.12	0.236
	30%	0.271	0.186	0.389
	-30%	0.135	0.095	0.197
	0	0	0	0

Table A4. Estimates, upper and lower bound of SSB and fishing mortality in 2021 from SAM projection.

Variable	Catch scenario	SAM Estimate	SAM Lower bound	SAM Upper bound
SSB	Statut.quo	18.483	12.31	27.963
	15%	18.174	11.76	28.212
	-15%	19.65	13.01	29.318
	30%	17.722	11.23	28.092
	-30%	19.933	13.12	29.989
	0	23.3	16.16	35.328
F	Statut.quo	0.251	0.18	0.356
	15%	0.306	0.211	0.44
	-15%	0.202	0.144	0.283
	30%	0.365	0.25	0.523
	-30%	0.159	0.111	0.231
	0	0	0	0

Table A5. Comparative estimates, upper and lower bound of SSB and fishing mortality in 2022 from SAM projection.

Variable	Catch scenario	Estimate	Lower bound	Upper bound
SSB	Statut.quo	17.274	11.136	28
	15%	16.228	9.498	27.976
	-15%	18.73	11.377	30.464
	30%	15.189	8.942	25.444
	-30%	19.959	12.4	31.941
	0	26.702	17.789	39.976
F	Statut.quo	0.274	0.196	0.387
	15%	0.342	0.236	0.493
	-15%	0.213	0.152	0.299
	30%	0.423	0.29	0.607
	-30%	0.163	0.114	0.237
	0	0	0	0

Figures

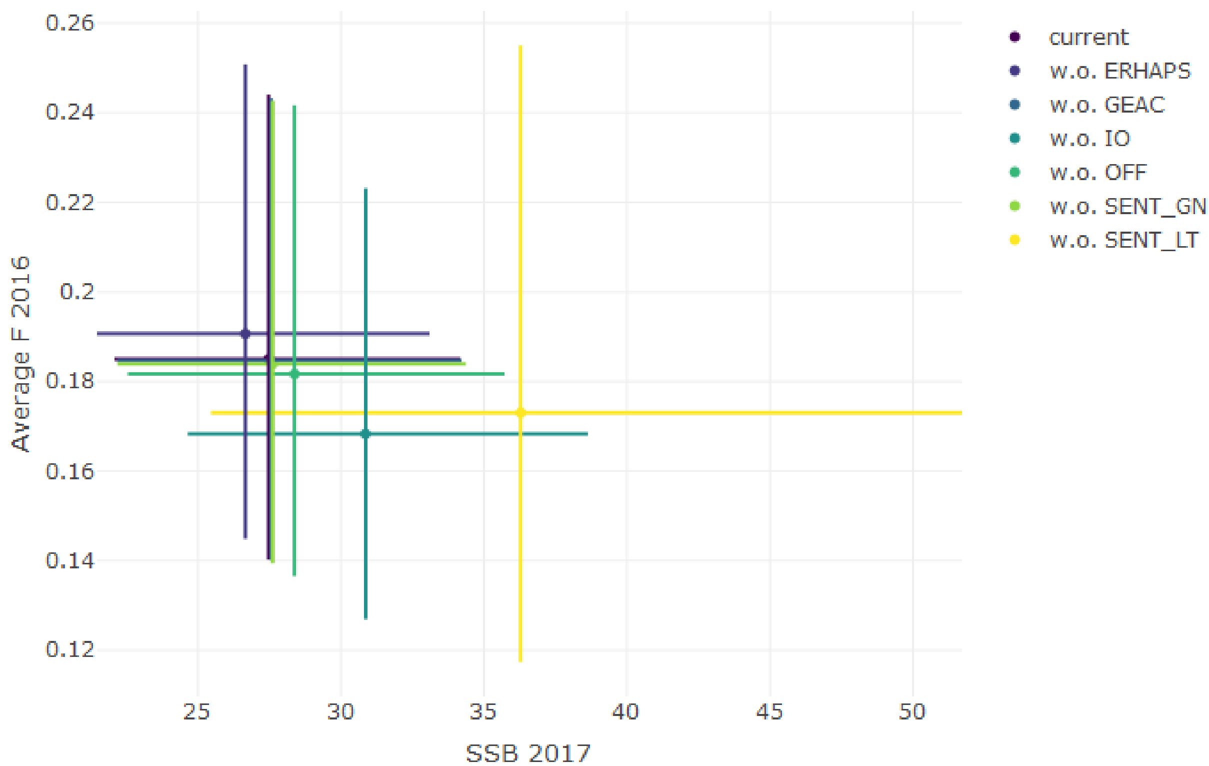


Figure A1. Estimates and confidence intervals of average fishing mortality in 2016 over SSB in 2017 from SAM current run and leave out fleet runs for data from 1959–2017.

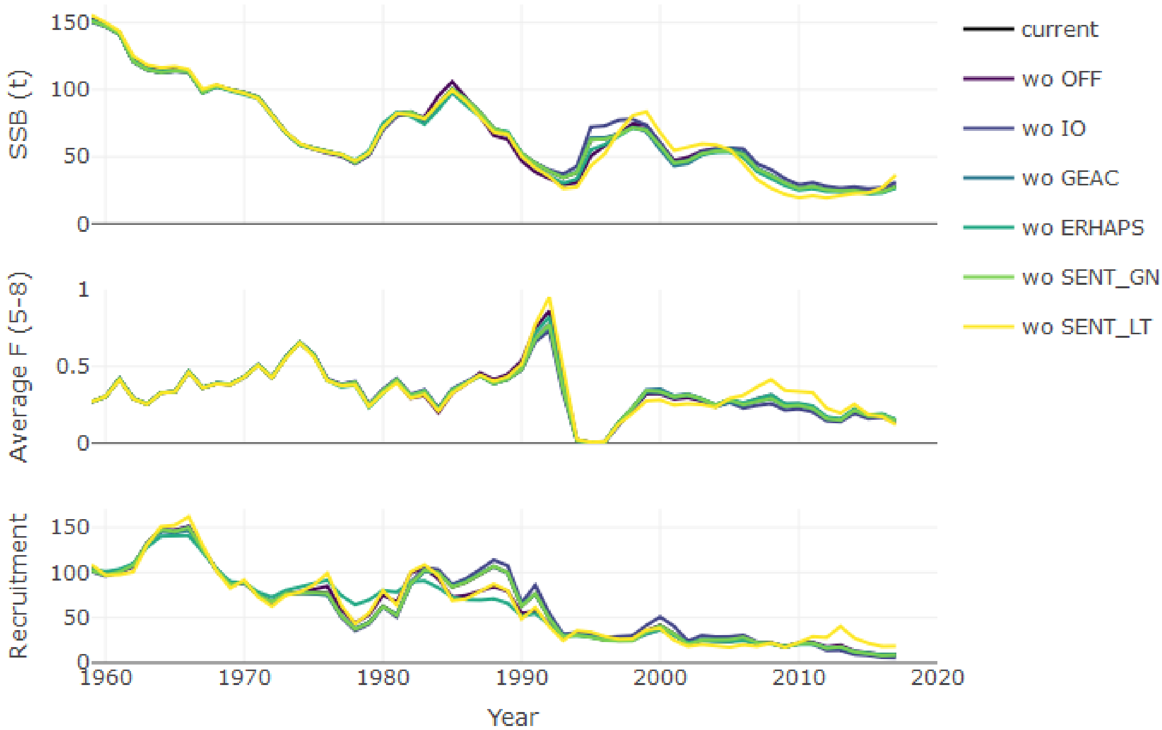


Figure A2. Trends in SSB, average fishing mortality and recruitment (age 2) estimated by SAM for current run and leave out fleet runs.

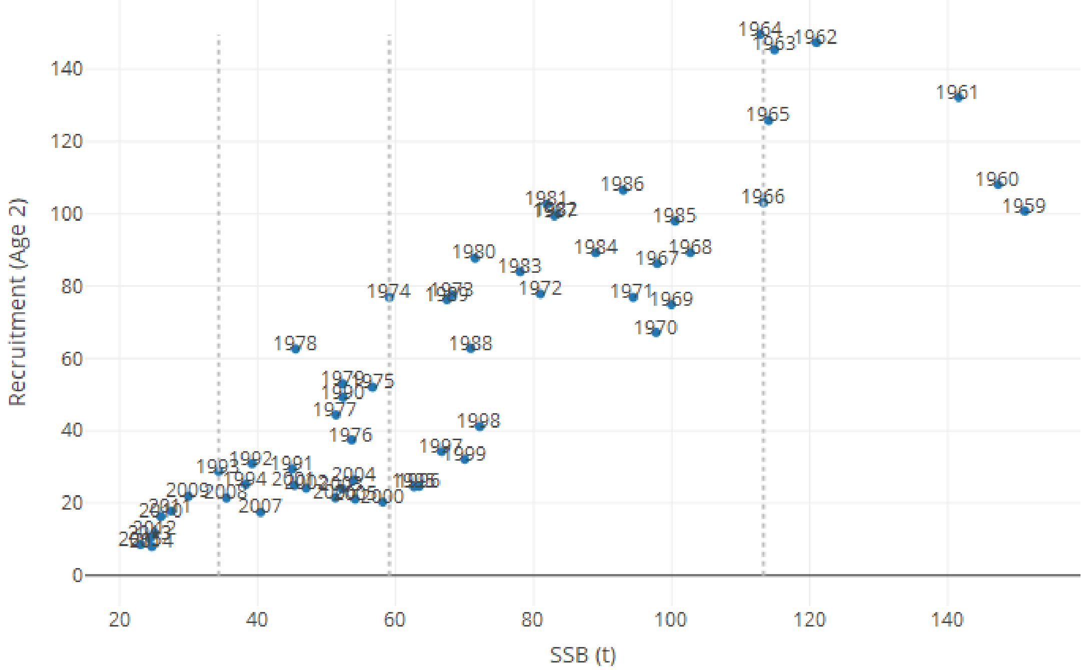


Figure A3. Estimates of recruitment (age 2) over SSB from SAM run. Grey lines are the three breakpoints happening at values of SSB of 34, 59, 113 thousand of tonnes.

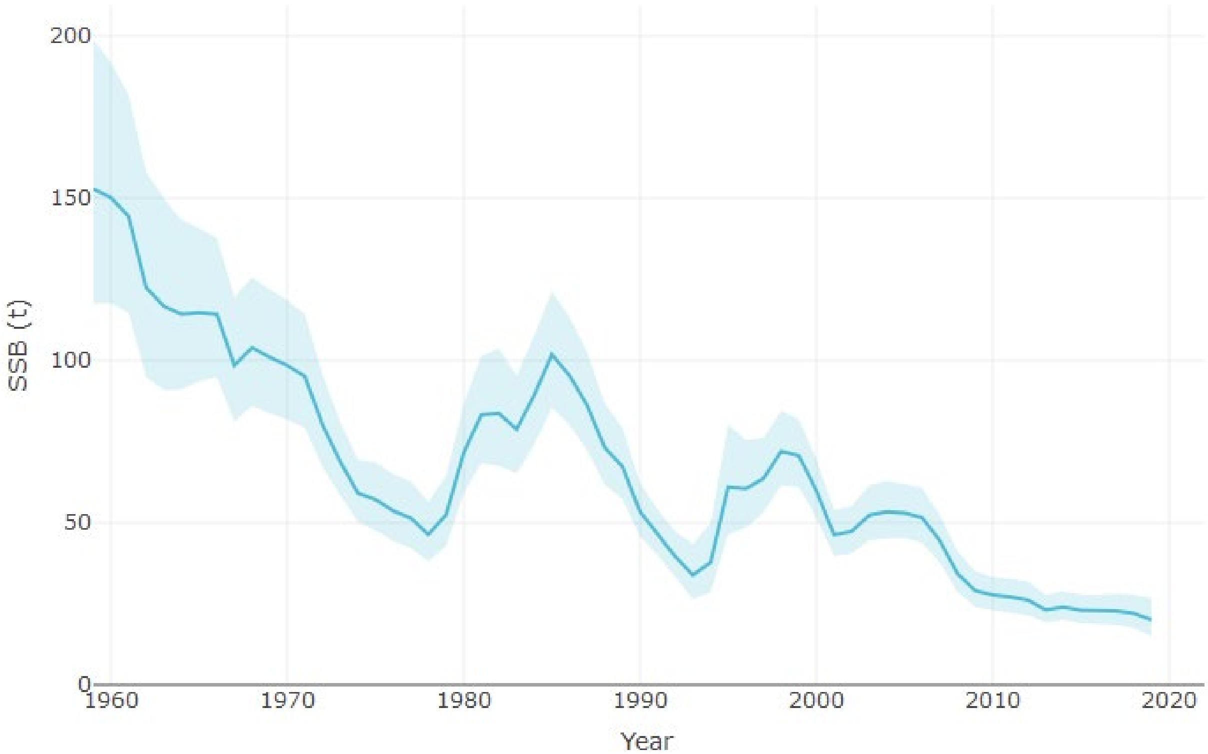


Figure A4. Estimates and confidence intervals for SSB from SAM run.

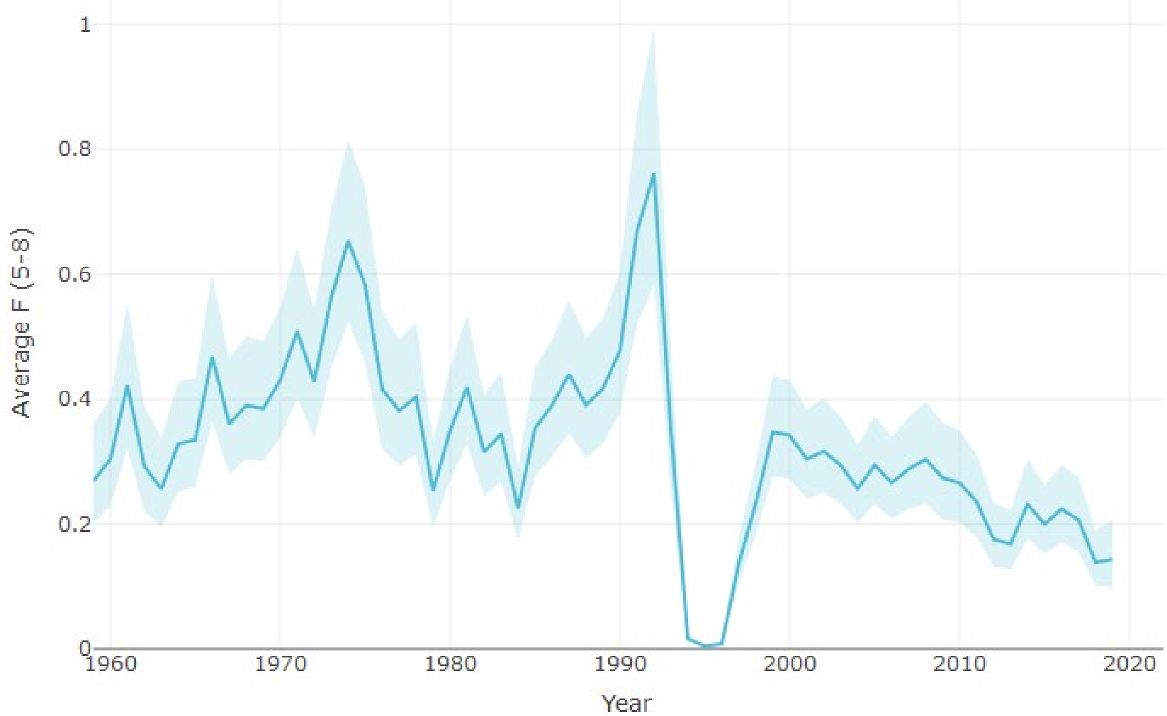


Figure A5. Estimates and confidence intervals of average fishing mortality from SAM run.

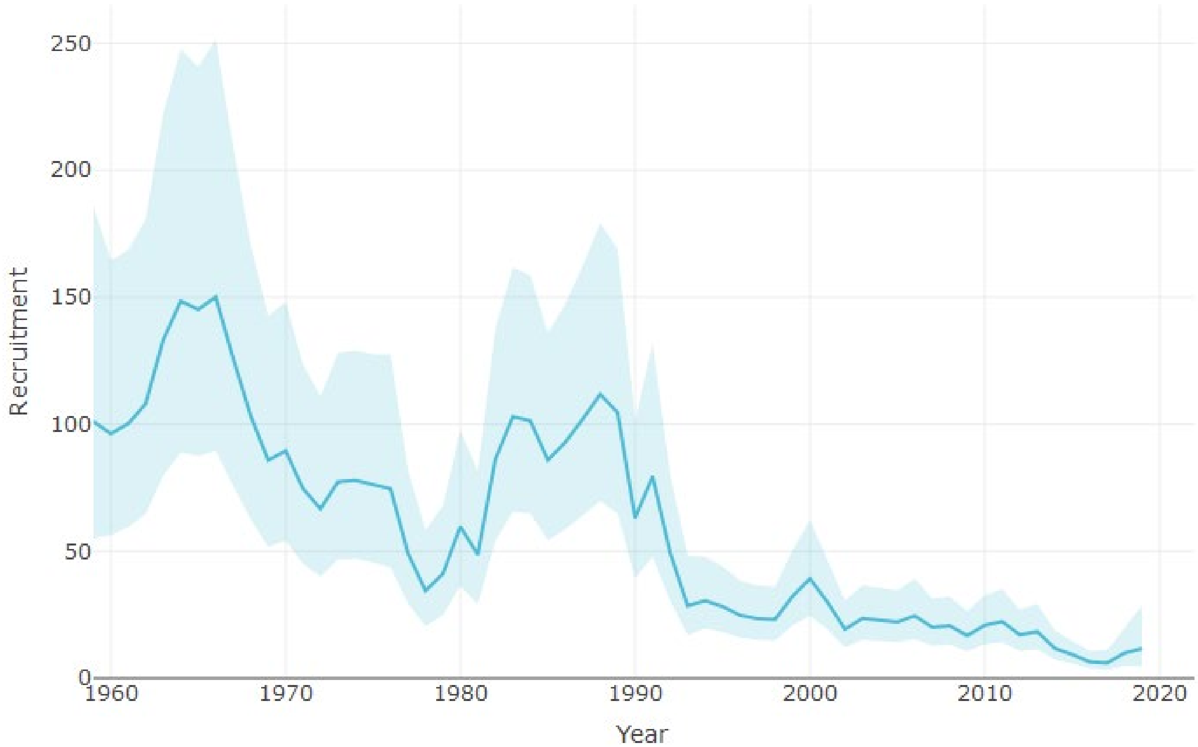


Figure A6. Estimates and confidence intervals of recruitment (age 2) from SAM run.

APPENDIX B – DESCRIPTION OF MODEL PROJECTION SET-UP

This appendix describes the equations for the projections from the Hybrid model.

Ten thousand threads of model projections are simulated within the TMB code for the model. The projections begin from the abundance estimates of the terminal year (2019).

$$N_{2019,a} = N_{2019,a} e^{\sigma P} \tag{11}$$

The age 2 recruits are sampled from a log-normal distribution where the mean is the average of respective values from the last three years and standard deviation σR estimated in the model. For ages 3 and above, the abundance is simulated using the standard cohort model.

$$log\ N_{2,y} = log\ \mu_R + \eta_{2,y};\ \eta_{2,y} \sim N(0, \sigma R) \tag{12}$$

$$log\ N_{a,y} = log\ N_{a-1,y-1} - F_{a-1,y-1} - M_{a-1,y-1} + \eta_{a,y}; 3 \leq a < A - 1;\ \eta_{3:A-1,y} \sim N(0, \sigma P) \tag{13}$$

$$log\ N_{A,y} = log \begin{pmatrix} N_{A,y-1} * \exp(-F_{A,y-1} - M_{A,y-1}) + \\ N_{A-1,y-1} * \exp(-F_{A-1,y-1} - M_{A-1,y-1}) \end{pmatrix} + \eta_{A,y};\ A = 14+ \tag{14}$$

For calculation of abundance in 2020, the terminal (2019) estimates of F and M are used. For years 2021 and 2022 of the stock to 2022 was conducted assuming fishery removals to be within ±30% of current values, assuming a catch of 4,453 t for 2019, and with no catch (Figure 39). In the projection years 2021 and 2022, as mentioned previously, selectivity and catch weights-at-age are three-year averages.

F is calculated using an iterative function (solveF), that we obtained from the code for the Northern cod assessment model; we had to slightly modify the function because in our model the catch weights are different from the stock weights. A description of this function is provided at the end of this document. This function minimises the difference between the projected catch and the expected yield from the model. In the following function, projC is the projected catch, Finit is an initial value for F, and Cw is catch weights. We found that within 7 iterations of the function, the F which provides an Yield (Y) close to the projected catch is obtained. Catch and yield are estimated based on the F value thus calculated.

$$C_{a,y} = N_{a,y}(1 - \exp(-Z_{a,y})) \, {}^{F_{a,y}}\!/_{Z_{a,y}} \tag{15}$$

$$Y_y = \sum_{a=2}^{A} C_{a,y} * Cw \tag{16}$$

In addition to simulating process error and error in recruitment, error is also simulated in F and M. To simulate error in F, a MVN sample is drawn from the covariance matrix of the MVN random walk of F, and this is applied to the three-year average of F used in the projections.

$F_{average,y} = F_{average,2017:2019} + e_{2:A,y};\ e_{2:A,y} \sim MVN_{2:A}(0, \Sigma)$	**17**

In the solveF function, selectivity S is the $F_{average,y}$ thus calculated.

Uncertainty in M was simulated based on the variance in the estimate of the $mpar_a$ (see equation 8), where σ_{mpar} is the standard deviation of the estimated $mpar_a$ parameter.

$mpar_{a,y} = mpar_a + e_{2:A,y};\ e_{2:A,y} \sim N\left(0, \sigma_{mpar,a}\right)$	**18**

$\log M_{a,y} = \log(0.3) + mpar_a * X_t;$	**19**

In equation 28, X_t is the average condition-based index of M for years 2017 to 2019, the last three years of the model.

Description of the solveF function.

```
solveF <- function(projC, Finit, A, S, M, N, Cw)
{
niter = 7
F = Finit
for(i in 1:niter){
 Z = F * S + M;
 eZ = exp((-1.0) * Z);
 Mort = 1.0 - eZ;
 Y = F * ((N * Mort * S * Cw/Z) %>% sum());
 derY = (N * S * Cw * (Mort * M/Z + eZ * F * S)/Z) %>% sum();
 F = F + ((projC - Y)/derY);
}
return(F)
}
```

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APPENDIX C – MODEL OUTPUTS

This appendix presents key outputs from the assessment.

Table C1. Estimated SSB (in thousand tonnes).

Year	SSB	Low	High
1959	196	143	269
1960	188	138	258
1961	191	143	256
1962	181	131	250
1963	167	119	234
1964	153	110	214
1965	149	109	203
1966	143	108	188
1967	134	104	171
1968	145	119	177
1969	133	109	163
1970	120	99	147
1971	114	91	143
1972	102	85	123
1973	84	69	102
1974	78	64	96
1975	88	67	116
1976	82	62	110
1977	79	60	103
1978	71	56	90
1979	79	64	96
1980	98	82	116
1981	111	93	131
1982	126	104	152
1983	111	94	132
1984	121	102	144
1985	130	110	155
1986	126	105	151
1987	116	97	139
1988	103	86	123
1989	92	76	111
1990	74	61	88
1991	64	54	77
1992	52	42	64
1993	39	33	45
1994	45	37	56
1995	85	69	105
1996	76	63	90

Year	SSB	Low	High
1997	77	66	91
1998	86	75	99
1999	78	64	95
2000	65	58	74
2001	52	43	62
2002	51	43	61
2003	54	47	62
2004	55	47	65
2005	54	48	61
2006	54	48	61
2007	48	42	54
2008	40	35	45
2009	35	31	39
2010	31	27	35
2011	30	26	34
2012	30	26	34
2013	27	23	31
2014	28	25	33
2015	27	23	32
2016	28	24	33
2017	28	24	33
2018	25	21	30
2019	20	16	26
2020	16	12	21

Table C2. Estimated Recruits (in million).

Year	Recruits	Low	High
1959	124	65	238
1960	117	65	212
1961	120	66	219
1962	129	71	235
1963	166	92	299
1964	195	110	345
1965	202	117	349
1966	199	116	342
1967	160	93	274
1968	129	75	222
1969	101	59	175
1970	111	65	191
1971	92	53	159
1972	78	44	139
1973	98	54	176

Year	Recruits	Low	High
1974	102	56	183
1975	90	51	159
1976	83	47	145
1977	50	30	86
1978	34	20	58
1979	43	26	72
1980	73	44	121
1981	52	31	89
1982	103	63	168
1983	129	81	206
1984	133	84	212
1985	109	68	173
1986	125	79	199
1987	145	91	231
1988	161	101	257
1989	150	94	240
1990	79	50	127
1991	112	68	183
1992	61	37	99
1993	27	16	46
1994	35	22	56
1995	33	21	52
1996	29	18	45
1997	28	17	45
1998	27	17	44
1999	40	25	64
2000	48	29	77
2001	36	22	58
2002	21	13	35
2003	28	18	46
2004	29	18	47
2005	30	18	48
2006	34	20	56
2007	25	15	40
2008	25	15	40
2009	18	11	30
2010	25	15	40
2011	27	17	43
2012	19	12	31
2013	22	13	36
2014	13	8	22
2015	11	7	18

Year	Recruits	Low	High
2016	7	4	12
2017	6	3	11
2018	11	5	24
2019	14	5	38

Table C3. Estimated Average fishing mortality (ages 5 to 9).

Year	Average F	Low	High
1959	0.27	0.22	0.33
1960	0.27	0.23	0.32
1961	0.29	0.25	0.35
1962	0.28	0.23	0.34
1963	0.28	0.24	0.34
1964	0.31	0.26	0.37
1965	0.32	0.27	0.39
1966	0.32	0.27	0.38
1967	0.31	0.26	0.36
1968	0.32	0.28	0.37
1969	0.35	0.30	0.41
1970	0.35	0.30	0.41
1971	0.38	0.32	0.46
1972	0.39	0.34	0.46
1973	0.36	0.31	0.42
1974	0.38	0.32	0.44
1975	0.42	0.34	0.52
1976	0.30	0.25	0.36
1977	0.29	0.24	0.34
1978	0.29	0.25	0.35
1979	0.26	0.22	0.31
1980	0.29	0.25	0.33
1981	0.31	0.26	0.36
1982	0.28	0.23	0.34
1983	0.27	0.24	0.31
1984	0.27	0.23	0.32
1985	0.30	0.25	0.35
1986	0.31	0.26	0.37
1987	0.36	0.30	0.43
1988	0.39	0.31	0.47
1989	0.37	0.31	0.44
1990	0.37	0.31	0.43
1991	0.41	0.34	0.50
1992	0.43	0.34	0.53
1993	0.38	0.32	0.45

Year	Average F	Low	High
1994	0.01	0.00	0.03
1995	0.01	0.00	0.01
1996	0.01	0.01	0.01
1997	0.09	0.04	0.20
1998	0.21	0.17	0.26
1999	0.31	0.18	0.52
2000	0.29	0.23	0.35
2001	0.24	0.15	0.39
2002	0.21	0.12	0.37
2003	0.20	0.16	0.25
2004	0.22	0.14	0.35
2005	0.26	0.22	0.32
2006	0.20	0.16	0.24
2007	0.18	0.14	0.23
2008	0.20	0.16	0.25
2009	0.21	0.17	0.25
2010	0.19	0.16	0.23
2011	0.17	0.14	0.22
2012	0.14	0.12	0.18
2013	0.12	0.10	0.15
2014	0.15	0.12	0.19
2015	0.16	0.13	0.20
2016	0.16	0.13	0.20
2017	0.18	0.14	0.22
2018	0.16	0.12	0.20
2019	0.21	0.15	0.30

Table C4. Estimated Average natural mortality (ages 5 to 9).

Year	Average M	Low	High
1959	0.31	0.30	0.31
1960	0.30	0.30	0.31
1961	0.31	0.30	0.31
1962	0.31	0.30	0.31
1963	0.31	0.30	0.31
1964	0.31	0.30	0.31
1965	0.31	0.30	0.31
1966	0.30	0.30	0.31
1967	0.30	0.30	0.31
1968	0.30	0.30	0.31
1969	0.30	0.30	0.31
1970	0.31	0.30	0.31
1971	0.31	0.30	0.31

Year	Average M	Low	High
1972	0.31	0.30	0.31
1973	0.30	0.30	0.31
1974	0.30	0.30	0.31
1975	0.31	0.30	0.31
1976	0.30	0.30	0.31
1977	0.30	0.30	0.31
1978	0.34	0.32	0.36
1979	0.33	0.32	0.35
1980	0.35	0.33	0.37
1981	0.33	0.32	0.34
1982	0.32	0.31	0.33
1983	0.31	0.31	0.31
1984	0.30	0.30	0.30
1985	0.29	0.29	0.30
1986	0.29	0.28	0.29
1987	0.28	0.27	0.29
1988	0.28	0.27	0.29
1989	0.29	0.28	0.29
1990	0.29	0.29	0.29
1991	0.30	0.30	0.30
1992	0.30	0.30	0.30
1993	0.30	0.30	0.31
1994	0.32	0.31	0.32
1995	0.31	0.30	0.31
1996	0.28	0.27	0.29
1997	0.28	0.28	0.29
1998	0.27	0.26	0.28
1999	0.27	0.26	0.28
2000	0.28	0.27	0.28
2001	0.29	0.29	0.30
2002	0.29	0.29	0.29
2003	0.28	0.27	0.29
2004	0.27	0.26	0.28
2005	0.27	0.26	0.28
2006	0.29	0.28	0.29
2007	0.28	0.27	0.29
2008	0.30	0.30	0.30
2009	0.33	0.32	0.35
2010	0.35	0.33	0.37
2011	0.32	0.31	0.33
2012	0.36	0.34	0.39
2013	0.38	0.34	0.42

Year	Average M	Low	High
2014	0.38	0.34	0.41
2015	0.41	0.36	0.46
2016	0.43	0.37	0.51
2017	0.45	0.38	0.53
2018	0.43	0.38	0.50
2019	0.49	0.41	0.58

Table C5. Estimated Average total mortality (ages 5 to 9).

Year	Average Z	Low	High
1959	0.58	0.53	0.63
1960	0.57	0.53	0.62
1961	0.60	0.55	0.65
1962	0.59	0.54	0.64
1963	0.59	0.54	0.65
1964	0.62	0.56	0.68
1965	0.63	0.57	0.69
1966	0.63	0.58	0.68
1967	0.61	0.57	0.66
1968	0.63	0.59	0.67
1969	0.66	0.61	0.71
1970	0.66	0.61	0.71
1971	0.69	0.62	0.76
1972	0.70	0.64	0.77
1973	0.67	0.62	0.73
1974	0.68	0.63	0.74
1975	0.73	0.64	0.83
1976	0.61	0.56	0.67
1977	0.59	0.54	0.64
1978	0.63	0.59	0.69
1979	0.59	0.55	0.64
1980	0.64	0.60	0.69
1981	0.63	0.59	0.69
1982	0.60	0.55	0.65
1983	0.58	0.55	0.62
1984	0.57	0.52	0.62
1985	0.59	0.54	0.65
1986	0.60	0.55	0.66
1987	0.64	0.58	0.71
1988	0.67	0.59	0.75
1989	0.66	0.60	0.72
1990	0.66	0.60	0.72
1991	0.30	0.30	0.30

Year	Average Z	Low	High
1992	0.30	0.30	0.30
1993	0.30	0.30	0.31
1994	0.32	0.31	0.32
1995	0.31	0.30	0.31
1996	0.28	0.27	0.29
1997	0.28	0.28	0.29
1998	0.27	0.26	0.28
1999	0.27	0.26	0.28
2000	0.28	0.27	0.28
2001	0.29	0.29	0.30
2002	0.29	0.29	0.29
2003	0.28	0.27	0.29
2004	0.27	0.26	0.28
2005	0.27	0.26	0.28
2006	0.29	0.28	0.29
2007	0.28	0.27	0.29
2008	0.30	0.30	0.30
2009	0.33	0.32	0.35
2010	0.35	0.33	0.37
2011	0.32	0.31	0.33
2012	0.36	0.34	0.39
2013	0.38	0.34	0.42
2014	0.38	0.34	0.41
2015	0.41	0.36	0.46
2016	0.43	0.37	0.51
2017	0.45	0.38	0.53
2018	0.43	0.38	0.50
2019	0.49	0.41	0.58

Table C6. Estimated Numbers-at-age (in millions).

Year	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14+
1959	124.29	100.82	173.21	45.60	38.65	27.81	5.59	7.62	5.84	5.70	3.15	0.49	0.01
1960	117.31	94.24	71.73	117.77	29.48	19.66	15.79	3.75	4.20	3.03	3.51	1.59	0.32
1961	120.19	85.05	74.70	46.87	65.08	14.64	14.28	7.82	2.43	2.25	1.65	2.41	0.98
1962	129.17	88.28	67.10	54.48	27.12	33.94	8.48	6.09	3.93	1.26	1.18	0.90	2.07
1963	166.30	90.86	59.48	46.30	31.16	15.52	18.04	5.61	2.92	2.10	0.69	0.68	1.77
1964	195.03	128.29	60.32	36.00	27.20	15.60	9.14	8.99	3.98	1.52	1.30	0.38	1.39
1965	201.76	152.78	91.27	35.19	20.67	13.69	9.01	5.14	3.94	2.61	0.70	0.69	0.94
1966	199.24	144.19	111.89	57.62	18.23	14.20	5.43	4.68	2.86	1.57	1.82	0.35	0.78
1967	160.02	161.25	111.91	69.64	31.40	10.35	6.56	2.62	2.14	1.40	0.55	1.18	0.59
1968	128.88	120.74	119.14	77.71	33.22	15.46	5.62	3.47	1.36	1.13	0.67	0.20	1.54
1969	101.20	90.23	90.76	74.96	38.85	17.79	6.87	2.68	1.91	0.62	0.57	0.32	0.89
1970	111.16	68.17	63.14	60.29	41.24	20.42	8.40	2.98	1.07	0.82	0.29	0.26	0.50
1971	92.07	91.78	45.99	37.51	28.52	22.33	9.04	3.66	1.53	0.50	0.41	0.15	0.31
1972	77.94	68.83	66.78	27.06	18.16	15.39	10.01	3.77	1.59	0.75	0.25	0.19	0.21
1973	97.72	51.49	50.24	44.54	13.74	9.94	6.08	4.55	1.69	0.68	0.36	0.11	0.19
1974	101.60	78.56	32.33	33.62	20.93	6.76	4.63	2.64	1.82	0.72	0.28	0.16	0.16
1975	89.65	74.93	54.94	16.20	17.86	13.51	2.74	1.90	1.05	0.74	0.29	0.12	0.14
1976	82.56	66.93	55.57	36.09	11.41	7.63	4.32	1.17	0.78	0.47	0.33	0.13	0.14
1977	50.46	71.56	51.79	37.80	19.73	5.12	2.40	2.59	0.67	0.45	0.29	0.20	0.17
1978	33.92	37.14	63.52	33.30	17.15	7.78	2.64	1.62	1.61	0.37	0.28	0.17	0.26
1979	43.23	21.92	29.73	56.28	21.99	9.11	4.28	1.49	0.90	0.75	0.20	0.16	0.31
1980	72.59	33.81	16.66	23.65	35.47	13.37	5.13	2.26	0.92	0.61	0.38	0.13	0.36
1981	52.08	66.93	29.38	13.23	17.06	21.11	7.01	3.17	1.35	0.59	0.41	0.20	0.30
1982	102.86	38.51	57.10	21.38	8.36	11.15	15.49	3.90	1.87	0.82	0.36	0.24	0.30
1983	129.35	79.70	31.81	43.88	13.64	5.79	5.48	8.00	2.45	1.10	0.51	0.24	0.33
1984	133.14	88.15	59.56	27.35	26.44	9.00	3.53	3.44	4.16	1.47	0.66	0.30	0.38
1985	108.73	98.80	70.03	42.60	19.56	16.30	5.89	2.37	2.39	2.31	1.14	0.43	0.51
1986	125.22	70.80	75.59	49.07	34.85	13.09	9.18	3.66	1.60	1.44	1.25	0.68	0.65
1987	145.24	84.24	40.59	47.77	32.91	20.35	6.79	4.65	2.12	0.98	0.84	0.72	0.83
1988	161.37	94.46	53.68	21.95	30.25	18.60	7.76	3.36	2.34	1.15	0.61	0.47	0.80

Year	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14+
1989	149.96	114.36	62.63	31.46	11.21	11.69	7.57	4.16	1.74	1.24	0.54	0.33	0.61
1990	79.43	114.95	79.48	37.39	14.61	6.16	6.19	3.78	2.06	0.83	0.62	0.25	0.51
1991	111.70	49.95	74.46	40.93	16.84	5.55	2.70	3.15	1.76	0.88	0.39	0.30	0.37
1992	60.78	80.18	27.65	35.81	15.96	4.60	1.38	0.94	0.85	0.41	0.23	0.09	0.21
1993	27.04	48.98	51.98	13.28	13.60	4.81	1.45	0.36	0.15	0.14	0.06	0.04	0.05
1994	35.46	18.45	43.77	39.15	8.49	6.25	1.90	0.67	0.17	0.06	0.05	0.02	0.04
1995	32.75	29.67	12.42	33.65	35.79	8.16	5.00	1.46	0.32	0.13	0.04	0.04	0.04
1996	28.59	30.22	31.59	10.45	17.29	17.69	4.15	2.36	0.81	0.20	0.10	0.02	0.03
1997	27.81	20.29	22.25	25.54	7.88	8.92	8.46	2.32	1.19	0.55	0.13	0.07	0.03
1998	27.13	21.76	15.97	14.72	13.26	5.21	6.31	5.68	1.43	0.67	0.32	0.10	0.05
1999	39.77	19.77	15.37	12.44	9.46	7.99	3.26	2.79	2.76	0.72	0.32	0.15	0.07
2000	47.62	32.80	15.87	10.26	7.92	5.25	4.43	1.61	1.32	2.01	0.35	0.13	0.10
2001	36.20	39.59	26.68	11.49	6.83	4.51	2.59	1.95	0.71	0.72	0.97	0.15	0.11
2002	21.37	30.03	24.52	17.90	7.04	3.70	2.16	1.16	0.88	0.32	0.36	0.44	0.09
2003	28.50	13.00	19.78	15.81	11.68	4.37	1.83	0.95	0.60	0.42	0.14	0.17	0.24
2004	29.23	23.27	9.85	11.35	10.64	7.05	2.32	0.91	0.45	0.33	0.19	0.07	0.20
2005	29.62	22.93	16.60	7.86	6.46	6.35	3.70	1.46	0.48	0.29	0.17	0.09	0.14
2006	33.72	23.92	16.23	12.37	6.21	3.99	4.04	2.18	0.88	0.27	0.16	0.09	0.11
2007	24.62	28.74	16.05	11.30	7.33	3.85	2.05	2.21	1.19	0.49	0.15	0.09	0.11
2008	24.68	16.66	20.33	10.44	7.99	4.34	2.19	1.13	1.06	0.59	0.26	0.07	0.10
2009	18.35	20.18	11.90	14.18	7.33	4.17	1.98	0.95	0.49	0.45	0.28	0.13	0.08
2010	24.94	11.24	16.19	8.87	8.72	3.61	1.59	0.67	0.38	0.17	0.18	0.11	0.08
2011	26.75	20.55	7.76	11.95	6.61	4.59	1.67	0.73	0.28	0.14	0.07	0.07	0.08
2012	19.39	21.91	13.89	5.50	7.49	4.57	2.24	0.81	0.35	0.12	0.07	0.03	0.07
2013	22.13	12.24	16.15	10.20	4.45	4.13	2.47	1.01	0.34	0.16	0.06	0.03	0.05
2014	13.46	17.81	7.61	12.07	6.68	2.41	2.69	1.19	0.46	0.13	0.07	0.03	0.03
2015	11.11	8.48	15.50	6.14	7.81	3.89	1.39	1.35	0.44	0.17	0.05	0.03	0.02
2016	7.06	8.44	7.04	15.14	5.65	4.80	2.24	0.77	0.61	0.15	0.08	0.03	0.02
2017	5.98	4.51	6.43	6.45	12.13	3.13	2.37	1.10	0.38	0.19	0.05	0.03	0.02
2018	11.02	3.18	3.29	3.90	5.48	6.20	1.93	0.96	0.51	0.16	0.07	0.02	0.02
2019	13.76	8.60	2.66	2.27	3.30	5.01	2.29	0.84	0.45	0.24	0.07	0.03	0.02