# Report of the data-review meeting in preparation for the assessment framework of 3Ps Cod stock in southern Newfoundland

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## Canadian Data Report of Fisheries and Aquatic Sciences 1381

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## Canadian Data Report of Fisheries and Aquatic Sciences

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## ABSTRACT

Varkey, D.A., Ings, D.W., Champagnat, J., Penney, H., Rogers, B., Robertson, G., Regular, P.M., Novaczek, E. 2024. Report of the data-review meeting in preparation for the assessment framework of 3Ps Cod stock in southern Newfoundland. Can. Data Rep. Fish. Aquat. Sci. 1381: x + 56 p.

In preparation for the assessment framework for Atlantic cod in NAFO Subdiv. 3Ps, a scoping meeting was held in October 2017. This meeting allowed discussion of various data types to be considered for the assessment model. Following the scoping meeting, a few projects were initiated where-in the different data streams were reviewed. Key items from this review were presented at the 'data-review meeting' held May 2-3, 2019. The objective of this meeting was to present the spatial and temporal coverage of the different data sets and discuss the appropriateness of the different data sets for inclusion in the new assessment model to be developed.

The survey time series examined at the data review included: the DFO- RV survey, the French (ERHAPS) RV survey, an industry-led survey, and the sentinel gillnet and line-trawl surveys. The spatial and temporal coverage of these surveys and biological information from these surveys were presented. Further, commercial data were also reviewed thoroughly.

The discussions led to several conclusions about the different data sets. These are presented in the section 'Summary of meeting conclusions'. Data questions that were resolved in the lead-up to the framework meeting in October 2019 are presented in the section 'Post data-review explorations'.

**RÉSUMÉ**

Varkey, D.A., Ings, D.W., Champagnat, J., Penney, H., Rogers, B., Robertson, G., Regular, P.M., Novaczek, E. 2024. Report of the data-review meeting in preparation for the assessment framework of 3Ps Cod stock in southern Newfoundland. Can. Data Rep. Fish. Aquat. Sci. 1381: x + 56 p.

En préparation du cadre d'évaluation du stock de morue de 3Ps, une réunion de cadrage a eu lieu en octobre 2017. Cette réunion a permis de discuter de divers types de données à considérer pour le modèle d'évaluation. À la suite de la réunion de cadrage, plusieurs projets ont été initiés et les différentes sources de données ont été examinées. Les éléments clés de cet examen ont été présentés lors de la « réunion d'examen des données » qui s'est tenue les 2 et 3 mai 2019. L'objectif de cette réunion était de présenter la couverture spatiale et temporelle des différents jeux de données et de discuter de leur pertinence pour inclusion dans le nouveau modèle d'évaluation à développer.

Les séries chronologiques de relevés examinées lors de l'examen des données comprenaient : le relevé par navire de recherche du MPO, le relevé par navire scientifique français (ERHAPS), le relevé de l'industrie et les relevés sentinelles au filet maillant et à la palangre. La couverture spatiale et temporelle ainsi que les informations biologiques provenant de ces relevés ont été présentées. De plus, les données commerciales ont également été examinées en profondeur.

Les discussions ont abouti à plusieurs conclusions sur les différents ensembles de données. Celles-ci sont présentées dans la section « Résumé des conclusions de la réunion ». Les questions relatives aux données qui ont été résolues avant la réunion-cadre d’octobre 2019 sont présentées dans la section « Explorations post-examen des données ».

## INTRODUCTION

In preparation for the assessment framework for Atlantic cod in NAFO Subdiv. 3Ps, a scoping meeting was held in October 2017. This meeting allowed discussion of various data types to be considered for the assessment model. Following the scoping meeting, several projects were initiated to understand and review the different data sources in detail and the results from these were presented at the ‘data-review meeting’ held from May 2-3, 2019. Following paragraphs provide a brief description of the different projects that were initiated.

The Atlantic cod stock within the NAFO sub-division 3Ps is jointly managed by Canada and France. The 3Ps boundaries include Canadian waters south of Newfoundland and waters around French overseas territory of St. Pierre et Miquelon. The development of the assessment framework involved collaboration between scientists at DFO and IFREMER (Institut Français de Recherche pour l'Exploitation de la Mer; French for 'French Research Institute for Exploitation of the Sea'). A scientific project was initiated in collaboration with IFREMER wherein a French scientist worked at the Northwest Atlantic Fisheries Centre, DFO St John’s and in collaboration with French institutes (IFREMER and the French Department of marine fisheries and aquaculture, DPMAX) to support the development of the new assessment model. This was to ensure that both Canadian and French researchers could contribute to the development of the assessment framework. The first step of this collaborative project was a review of the French (ERHAPS) survey and a comparison of cohort strengths from the DFO-RV and the French RV surveys (results presented under the section ‘French RV survey’).

The SURBA (Survey based assessment model) model adopted for the assessment of the stock from 2010 to the present framework process used only the Canadian DFO-RV survey data. Commercial data such as catch-at-age and landings information were not used in the model. The model time-span was 1983 and onwards. DFO-RV survey data were available from 1972 onwards, but coverage of the area varied and implications of changes in coverage for this framework were not well understood. Strata coverage for the full time series was presented and discussed at the data review meeting. Inshore strata were added to the survey in 1997. The trends from the survey indices, variability in the index, and consistency plots for the survey were presented. The spatial distribution of fish within the survey area was explored at the meeting. Trends in biological information available from the surveys were also presented, mainly length-at-age, weight-at-age, diets, and fish condition.

Another RV survey for the 3Ps cod stock is the Groundfish Enterprise Allocation Council (GEAC) surveys from 1997-2007. This survey was in the offshore area in late fall. Data from these surveys were presented at concurrent assessments (McClintock 2007), however information from this survey has not been presented at recent assessments. Inshore gillnet and line-trawl surveys have been conducted since 1995 through the sentinel program. The standardized catch-rates and biological information from these surveys have been presented at recent annual assessments (Mello *et al*. 2018, Mello *et al.* 2019). It has been noted previously (Cadigan 2010) that there are inconsistencies between the trends from DFO-RV offshore survey and the sentinel surveys. We present consistency plots from these surveys under the section ‘comparison of RV survey with Sentinel and GEAC surveys’.

Commercial landings and catch-at-age data have typically been presented at assessments, but these data have not been used in the SURBA assessment model. There have been some concerns about the quality of the landings and catch-at-age data, especially whether all Canadian and French landings data were accurately accounted for in all years and whether the methodology for calculations of catch-at-age were consistent across years. Catch at age data products were not available in electronic format except from 2011 onward, and historical data were only available aggregated across seasons, areas and gear types. A proposal was presented for the Cod rebuilding and catch monitoring funds to reconstruct the commercial catch-at-age data so that catch-at age data products and intermediate components were available in a consistent format for the entire stock time-series. A fisheries science collaborative program (FSCP) proposal was submitted with the goal to document the reliability of reported landings. The project conducted interviews of 3Ps cod fishers to identify key characteristics (from the perspective of catch reporting, discards etc.) of different time periods in the history of the fisheries. Information gathered from the interviews were presented at the data review meeting.

Tagging data are used very effectively to inform natural mortality levels for the Northern cod stock in NAFO divisions 2J3KL (Cadigan and Konrad, 2016; Cadigan 2016). The tagging program for the 3Ps cod stock was not well documented or understood in the context of this framework prior to this data review. A summary of the data from the tagging program for this stock was presented.

The discussions led to several conclusions about the different data sets. These are presented in the section ‘Summary of meeting conclusions’. Some data related questions (for example, regarding stock weights-at-age) could not be resolved at this meeting. In recent assessments, stock weights were obtained from commercial weight at age, which were adjusted to the beginning of the year (Rivard 1980). Stock weights in recent years show a declining trend and there is need to explore if these should be obtained from RV surveys or commercial sampling. Decision was postponed till further analysis could be done. These were resolved in the lead-up to the framework meeting in October 2019 and are briefly described in the section ‘Post data review updates’.

## CANADIAN RV SURVEY

**Summary**

| **Species** | **Atlantic Cod (*Gadus morhua*)** |
|---|---|
| Spatial resolution | North Atlantic Fisheries Organization (NAFO) Subdivision (Subdiv.) 3Ps |
| Temporal resolution | 1972-2018<br>Winter-Spring |
| Sampling methodology | Stratified-random surveys by Canadian research vessels |
| Types of structures collected | Otoliths |
| Types of data available | Index-at-age, numbers and biomass, length, weight, spatial distribution, diets |
| Contact person | Danny Ings (danny.ings@dfo-mpo.gc.ca); Bob Rogers (bob.rogers@dfo-mpo.gc.ca); Paul Regular (paul.regular@dfo-mpo.gc.ca)<br>Divya Varkey (divya.varkey@dfo-mpo.gc.ca) |

### Temporal coverage

Stratified-random surveys have been conducted in the offshore areas of Subdiv. 3Ps during the winter-spring period by Canada since 1972. Canadian surveys were conducted using the research vessels Canadian Coast Guard Ship (CCGS) A.T. Cameron (1972-82), CCGS Alfred Needler (1983-84; 2009-present), and CCGS Wilfred Templeman (1985-2008) (McCallum and Walsh 1997, Rideout and Ings 2021). From the limited amount of comparable fishing data available from sampling with the Engel and Yankee trawls, 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 CCGJ 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) during 2004, 2014 and 2016, and any potential vessel effect is unaccounted for.

The Canadian research vessel surveys employed a Yankee bottom trawl from 1972 to 1982 and an Engel 145 high-rise bottom trawl from 1983 to 1995.. The survey was conducted during winter up to 1993 when one surveys was conducted during the historical period and a second during spring. This shift in timing aimed to reduce the potential for the survey to sample Northern Gulf cod that were overwintering in 3Ps. In 1996, research surveys 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).

**Spatial coverage**

Index strata (Figure 1) are currently being used in the assessment of the stock, but two additional strata (709, 710) are included in the annual survey plan. Neither of these strata was sampled during 1980-82 (Yankee series) and was also missed during many of the subsequent years (Table 1).

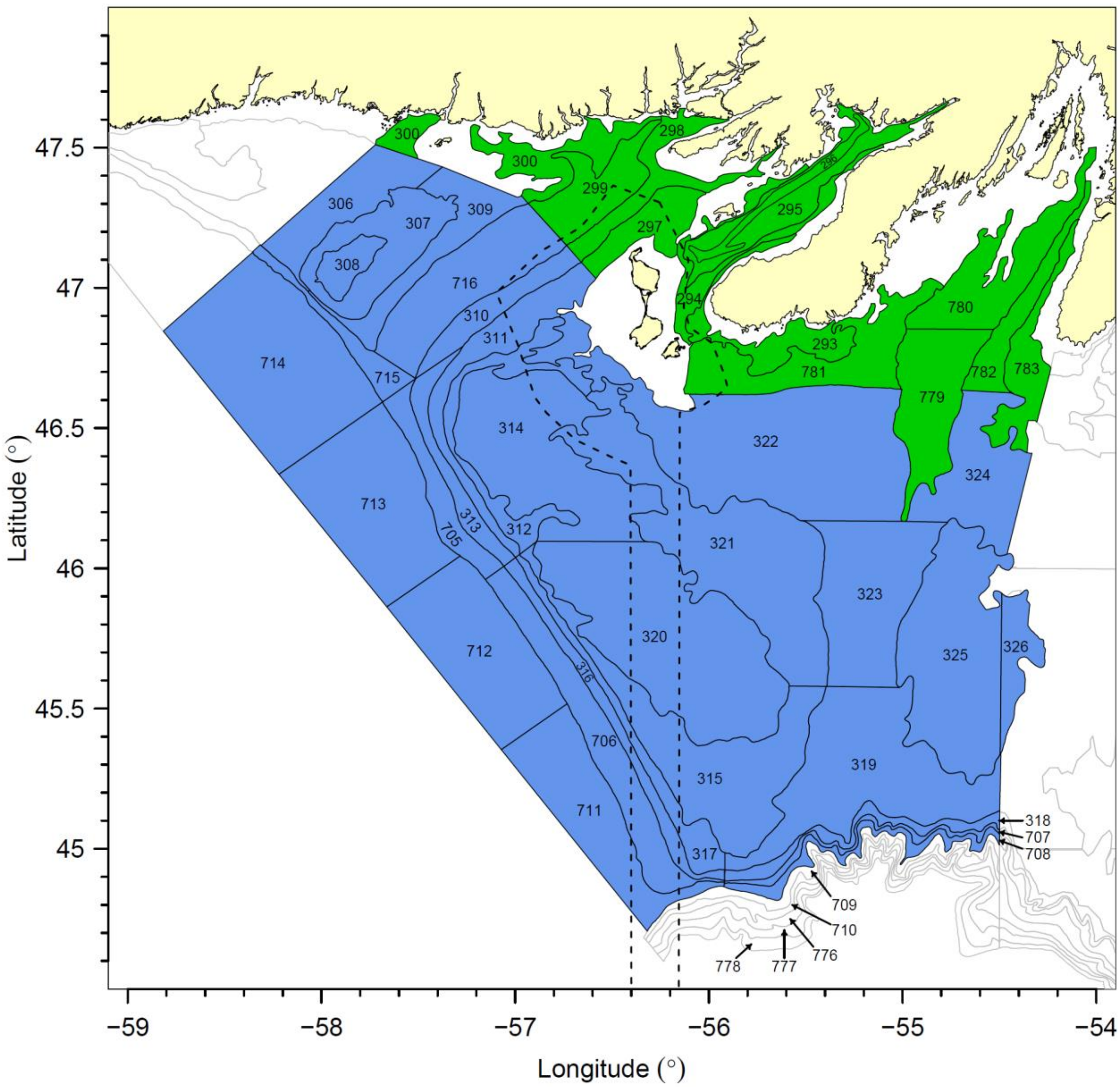


Figure 1: Stratum area boundaries and area surveyed during the DFO research vessel bottom-trawl survey of NAFO Subdiv. 3Ps. Offshore strata are shaded blue. Inshore strata were added in 1994 (strata 779 783) and 1997 (strata 293 300) and are shaded green.

During 1983 to1993 winter surveys, stratum 710 was often unsampled, and no cod were caught in that stratum when it was sampled. After 1992 spring, little biomass (< 1 % of annual total) was caught in stratum 710 annually. Only during 1993 was there substantial biomass (10.5% of annual winter total, 3% of spring total) sampled in 709. Note that during this year, most cod were found only in the deeper strata. With the low frequency of sampling and the typically low contribution of strata 709 and 710 to the annual biomass totals, there would be little value in adding these to the survey index. Strata deeper than 300 fathoms are not sampled in 3Ps.

Table 1 Years with no sampling in non-index strata.

| Stratum | Years without sampling |
|---|---|
| 709 | 1980-82, 1987, 1990, 1992, 1997, 2014 |
| 710 | 1980-82, 1987, 1989, 1990, 1992, 1995-1998, 2000-2018 |

During the years 1984, 1985, 1990, and 2006, one or more strata that may contribute considerably to the annual index were unsampled in 3Ps. During 2006, many of the index strata were not sampled and the survey was considered incomplete in this year. Index strata that were unsampled during a particular year are listed in
Table 7. Strata 708 and 709 are deeper strata that occur furthest from shore and are most frequently (5 and 7 years respectively) missed by the annual survey. Stratum 709 never contributed 2% or more of the annual biomass, but stratum 708 contributed about 16% of the biomass in 1983. Stratum 319 contributed a substantial (> 10%) percentage of the biomass in annual surveys during all three periods; it was unsampled only during 1990 (
Table 2-Table 3). Stratum 714 was relatively important (23% annual biomass) during 1983-93, but less so (3%) during the spring series (1993 onward). It was unsampled during 1984 and 1985.

Table 2: Years when index strata were not sampled in the annual survey.

| Stratum | Years without sampling |
|---|---|
| 295 (Inshore strata 1997 onward) | 2011 |
| 312 | 1980 |
| 316 | 1982, 1993 winter |
| 318 | 1981, 1985, 1990 |
| 319 | 1990 |
| 324 | 1981 |
| 326 | 1985 |
| 707 | 1981, 1982, 1985, 1990, 2018 |
| 708 | 1981, 1982, 1985, 1990, 2014, 2016, 2018 |

| | |
|---|---|
| 712 | 1984 |
| 713 | 1984 |
| 714 | 1984, 1985 |
| 715 | 1985, 2018 |

Table 3: Average contribution of index strata that were unsampled at least once, to total survey biomass for the three trawl time-series. Only strata that contributed at least 2% of the annual biomass during at least one of the time periods are shown.

| Strata | Percent of annual biomass during period | | | Years with no sampling |
|---|---|---|---|---|
| | 1980-82 | 1983-1993 | 1993-2018 | |
| 316 | 0.1 | 2.3 | 0.2 | 1982, 1993 winter |
| 318 | 1.7 | 4.6 | 5.4 | 1981, 1985, 1990 |
| 319 | 13.5 | 10.5 | 29.2 | 1990 |
| 708 | 16.8 | 6 | 3.1 | 1981, 1982, 1985, 1990, 2014, 2016, 2018 |
| 713 | 0.4 | 6 | 1 | 1984 |
| 714 | 0.1 | 23 | 3.2 | 1984, 1985 |
| 715 | 0.9 | 3.6 | 3 | 1985, 2018 |

Substantial numbers (> 5 % of annual total number) of most age-classes were caught in stratum 319 during all three time-series (Table 4). Various ages were also caught in relatively high numbers in stratum 318 during all three periods. Strata 708, 713 and 714 all contributed relatively high numbers of various age classes during the 1983 to1993 winter surveys, but the relative contribution of these strata is less important in the spring series (1993-2018).

Table 4: Index strata that were unsampled at least once during the time-series, with the years identified when >5% of the annual number of cod at age were observed there. in.

| Strata | Ages with >5% of annual total in stratum | | |
|---|---|---|---|
| | 1980-82 | 1983-93 winter | 1993 spring-2018 |
| 316 | none | none | none |
| 318 | 14 | 3, 9 & 10 | 5 to 8 |
| 319 | 1 to 9, 13 | 1 to 16 | 2 to 16 |
| 708 | none | 2 to 12, 14, 16 | none |
| 713 | 8 | 5 to 15 | none |
| 714 | none | 4 to 16 | none |
| 715 | none | none | none |

**Year effects**

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, degree of aggregation, etc.) 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, 1998 and 2013 surveys when compared to those from adjacent years. A clear sign of a year-effect is the fact that the 2013 RV survey (see Figure 2) 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.

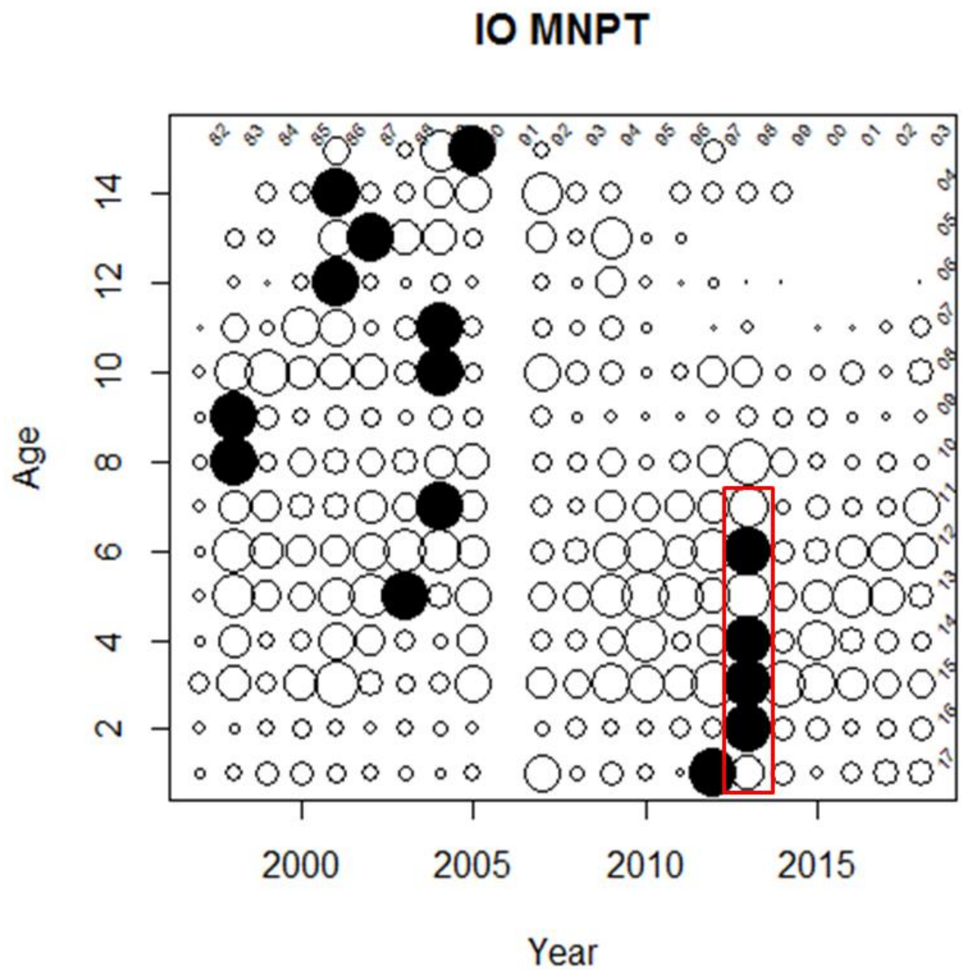


Figure 2. Age - Standardized catch rates from the spring bottom trawl survey of Subdiv. 3Ps. Catch rates (mean numbers per tow) were converted to proportions within each age. Values were standardized by subtracting the mean proportion and dividing by the standard deviation of the proportions computed across ages.

## SPAY plots and consistency plots

SPAY (Standardized Proportion at Age per Year) plots for the entire series (1983-2018) and for the inshore-offshore combined index (1997-2018) show cohorts tracking through time (Figure 3). Recently, stronger cohorts were observed in in 2006 and 2011. Consistency plots are here used to explore how well the survey tracks cohorts. These show the correlation between different ages from the same cohorts based on numbers observed in the survey time series. Consistency plot of log-index from RV survey shows that cohorts track fairly well from age 1 to age 5 (Figure 4). Moderate correlations are also observed among the high age groups from ages 10 to 12 and 13 to 15. Sub-setting the data to post 1997 (Figure 5) when the survey was extended to inshore strata shows an increase in correlation between the younger ages.

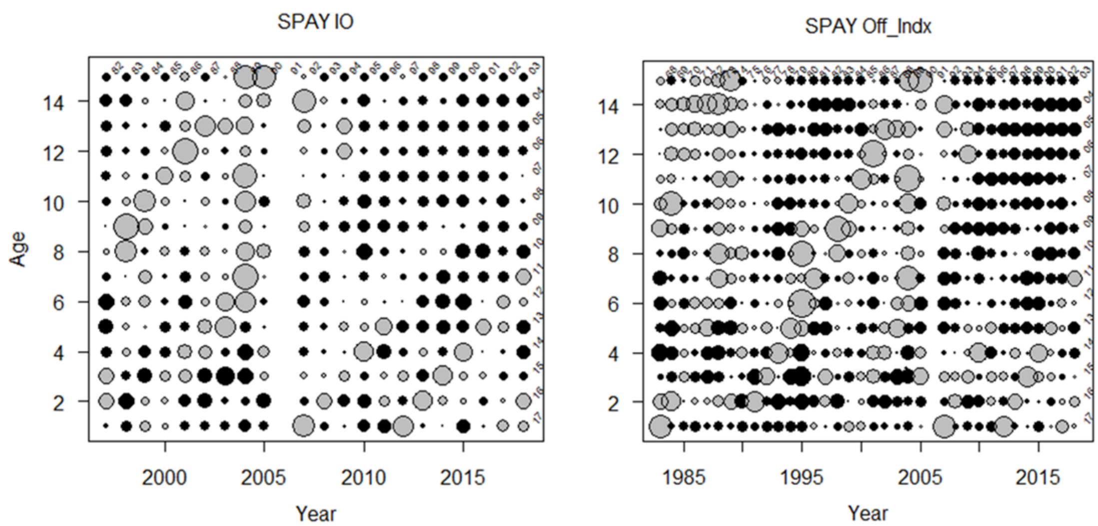


Figure 3: Standardized age-disaggregated catch rates from the spring bottom trawl survey of Subdiv. 3Ps

Catch rates (mean numbers 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 (1983-2018).

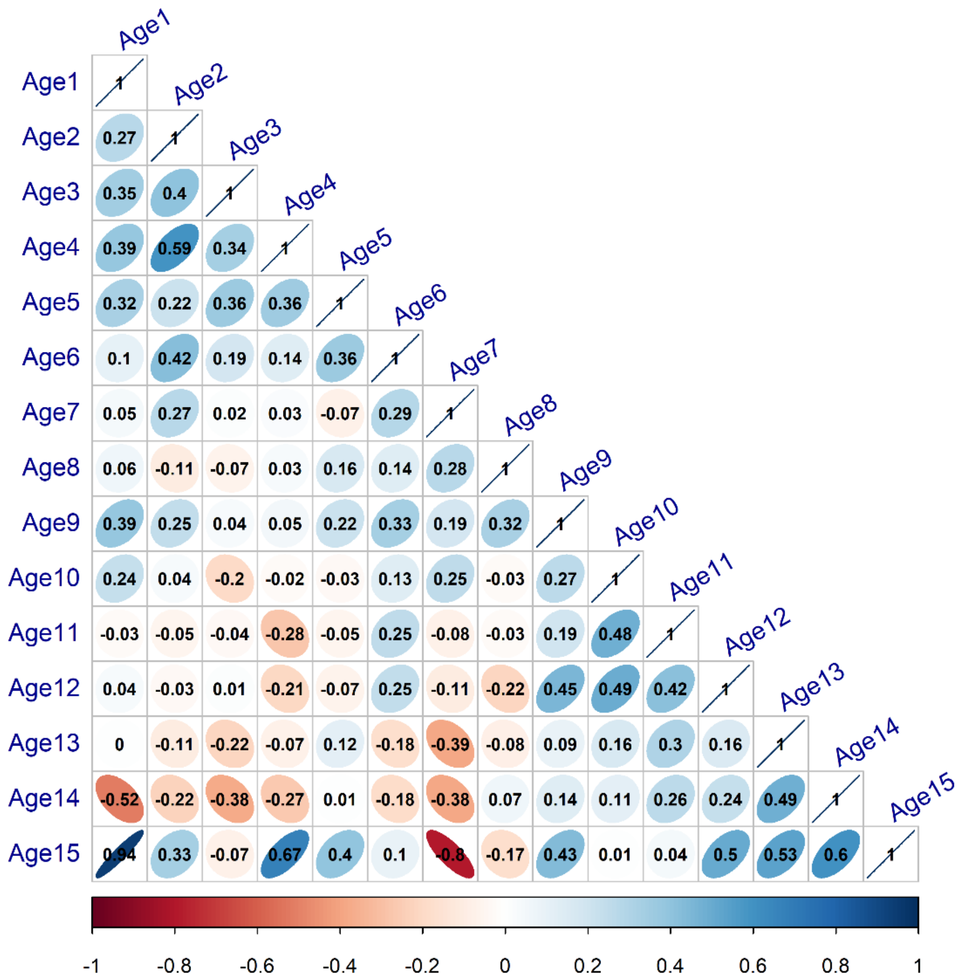


Figure 4: Consistency plot for RV survey 1983-2018. Blue indicates positive correlation and red indicates negative correlation with the darker shades indicating stronger correlations. The numbers are the estimate for the correlation coefficient.

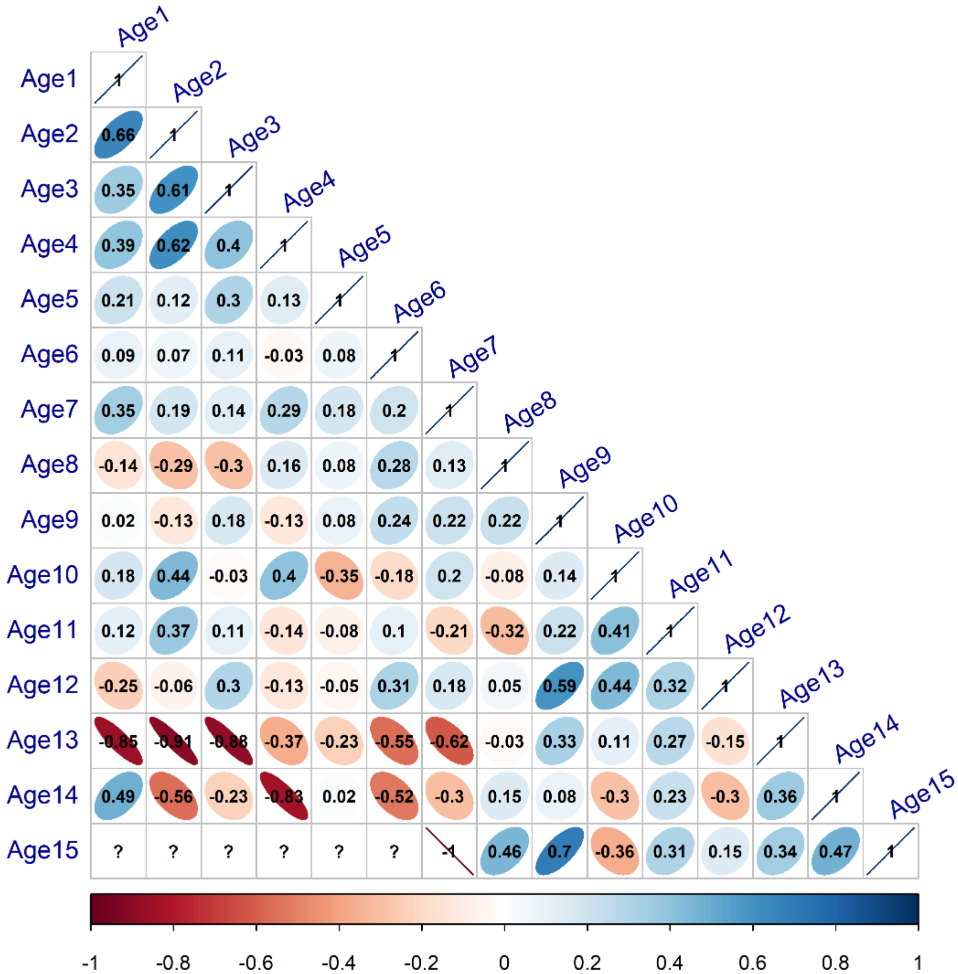


Figure 5: Consistency plot for RV survey 1997-2018. Blue indicates positive correlation and red indicates negative correlation with the darker shades indicating stronger correlations. The numbers are the estimate for the correlation coefficient.

### Sampling summary

The current sampling design for cod in Subdiv. 3Ps requires that an attempt be made to obtain otoliths from two fish per centimeter length class from each of the following locations: Northwest St. Pierre Bank (strata 294-298, 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) (Figure 6). The overall goal is thus to collect 10 fish per centimeter group from all of 3Ps. This spatial stratification ensures sampling is distributed over the surveyed area. Sampling has been consistent over the time period of the survey (Figure 7).

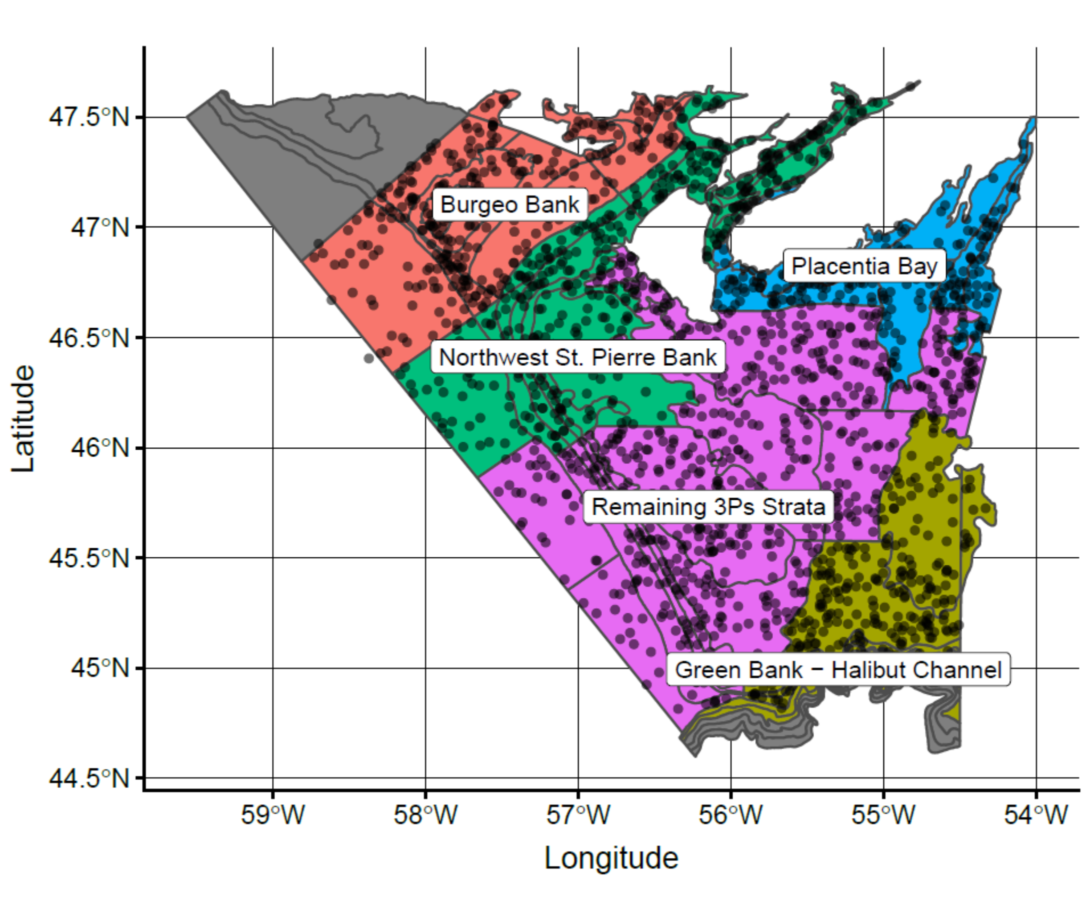


Figure 6: Sampling locations in 3Ps

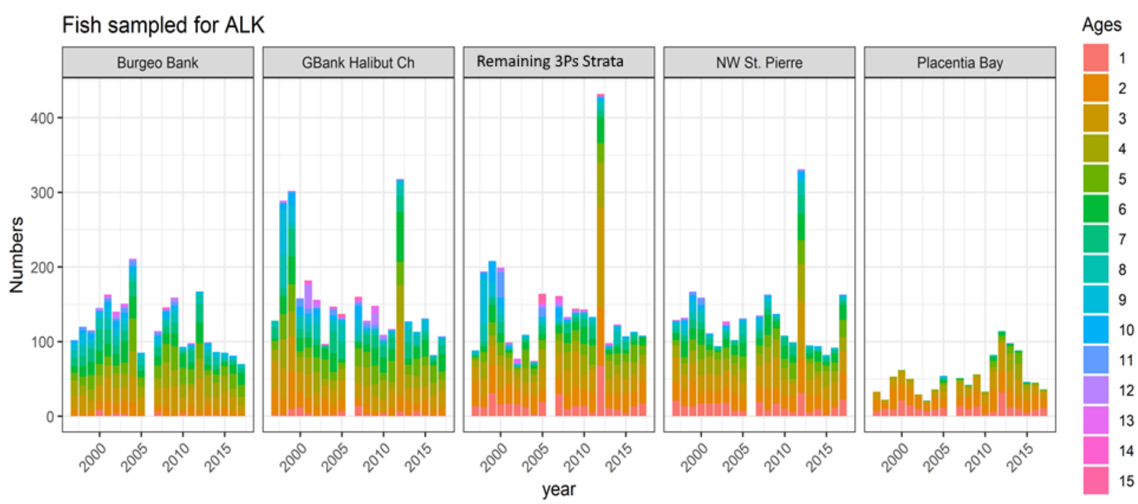


Figure 7: Numbers of fish sampled for generating Age-length keys (ALK) and distribution of ages recorded in the respective ALKs

### 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. As mentioned previously, otoliths are collected from five sampling regions. The otoliths are then combined into a single ALK and applied to the survey data. At the scoping meeting in October 2017, it was noted that the impact of using only ALKs aggregated across the stock (global ALKs combined from all five sampling regions) versus spatial ALKs (applying ALK to survey data collected by the five sampling regions), on index estimates should be explored. We did a comparison of log-index-at-age developed using a global ALK and log-index-at-age developed using regional (5) ALKs. We found that using regional ALKs resulted in a greater percentage of fish to which ages could not be assigned. When global ALKs were used, fish were distributed into more ages, especially in the inshore strata: when the regional ALK allocated fish into ages 1 to 3, the global ALK allocated fish into ages 1 to 5. Consistency plot showed slightly improved correlations, but it is to be considered that larger numbers of fish had unassigned ages. See Figure 8, Figure 9, and Table 5 for differences in indices obtained.

Table 5: Comparison of Log-Index for 2017 developed based on global and regional ALK

| Age | Log_index - Global ALK | Log_index - Regional ALK |
|---|---|---|
| 1 | 6.669 | 6.672 |
| 2 | 6.938 | 6.925 |
| 3 | 7.067 | 7.035 |
| 4 | 7.031 | 7.030 |
| 5 | 6.982 | 6.978 |
| 6 | 6.848 | 6.880 |
| 7 | 6.223 | 6.343 |
| 8 | 6.012 | 6.041 |
| 9 | 5.395 | 5.364 |
| 10 | 5.063 | 5.082 |
| 11 | 5.090 | 5.161 |


Figure 8: Log-index by strata for year 2013. Year 2013 is presented as an example. The red bars were generated by the global ALK and the blue bars were generated by the regional ALKs.


Figure 9: Log-index by strata for year 2013.
The red bars were generated by the global ALK and the blue bars were generated by the regional ALKs.

**Comparison of RV survey with SENTINEL and GEAC surveys**

SENTINAL SURVEY

Sentinel surveys operated in the inshore waters from 1995 to 2018, and ongoing. Survey gears operational were gillnets and line trawls. Details on the coverage of the sentinel surveys and methodology used for standardization of survey catch rates are available from Mello et al., 2018. Consistency plot for the sentinel gillnet survey shows good correlation between ages 5 to 8. The sentinel line trawls show good correlation between ages 3 to 5 and between ages 6 to 9 (Figure 10 and Figure 11).

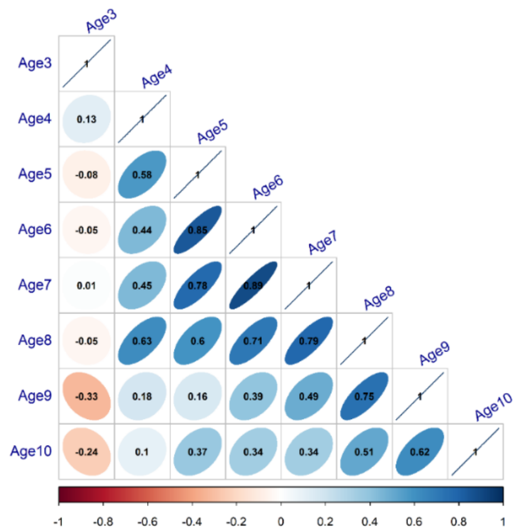


Figure 10: Sentinel gillnet

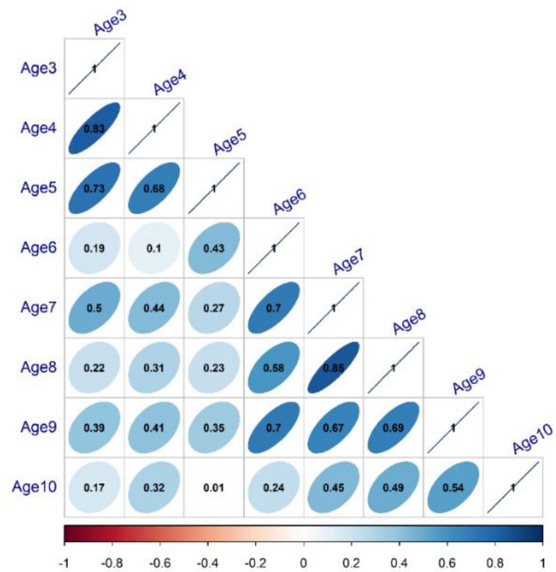


Figure 11: Sentinel line trawl

GEAC Survey

Groundfish Enterprise Allocation Council (GEAC) surveys extended from 1997-2007. There were vessel and coverage issues in 1997 and in 2007, therefore these years are not included in the assessment. The spatial coverage of the survey was in the offshore region, similar to the Canadian RV survey (Figure 12) and the timing of the survey was annually in the fall. Similar to the DFO surveys in spring, this survey also recorded occasional sets with large catch. A consistency plot for the GEAC survey data from 1998 to 2005 (Figure 13) does not show correlation between ages 1 and 2, but shows correlation between ages 2 to 5 and between some higher ages. Because of the short duration of the survey, it is not possible to explore correlations between fish ages more than five years apart.

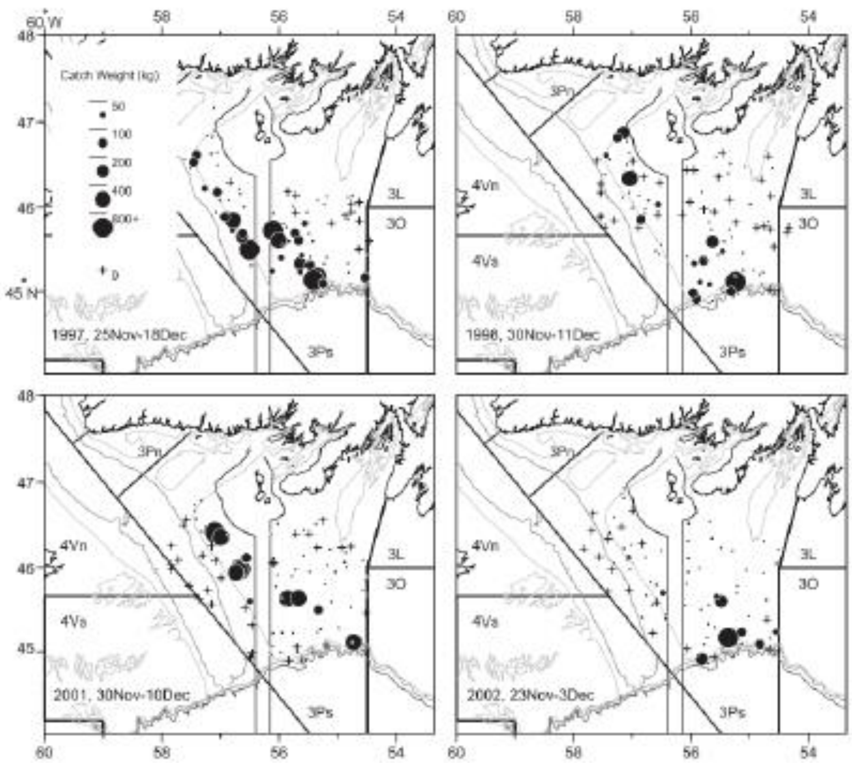


Figure 12: GEAC survey coverage

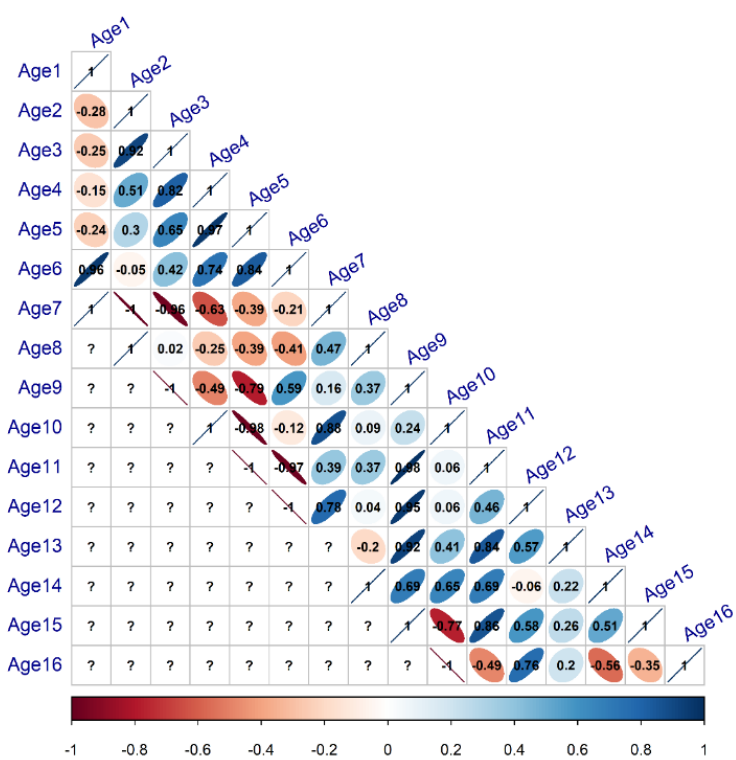

Figure 13: GEAC Survey consistency plot

**Spatial distribution of 3Ps cod in the DFO-RV survey**

Atlantic cod in 3Ps display a shift in distribution as they grow. Data collected from the DFO-NL annual multispecies survey in NAFO Subdivision 3Ps from 1983-2018 show that age 1 (Figure 14a) cod generally occupy inshore strata and shallower banks at depths less than 100m with very few fish being observed in deeper strata and along the bank slopes (>200 m). By age 2 (Figure 14b), some cod begin displaying movement into deeper waters along the shelf slope (150-200 m) but are not generally found in water >200 m. Older fish (ages 8 and 9; Figure 14c-d) tend to be distributed farther offshore and occupy waters of 300-400 m in depth and being infrequently encountered in waters <200 m or in inshore strata during the survey.

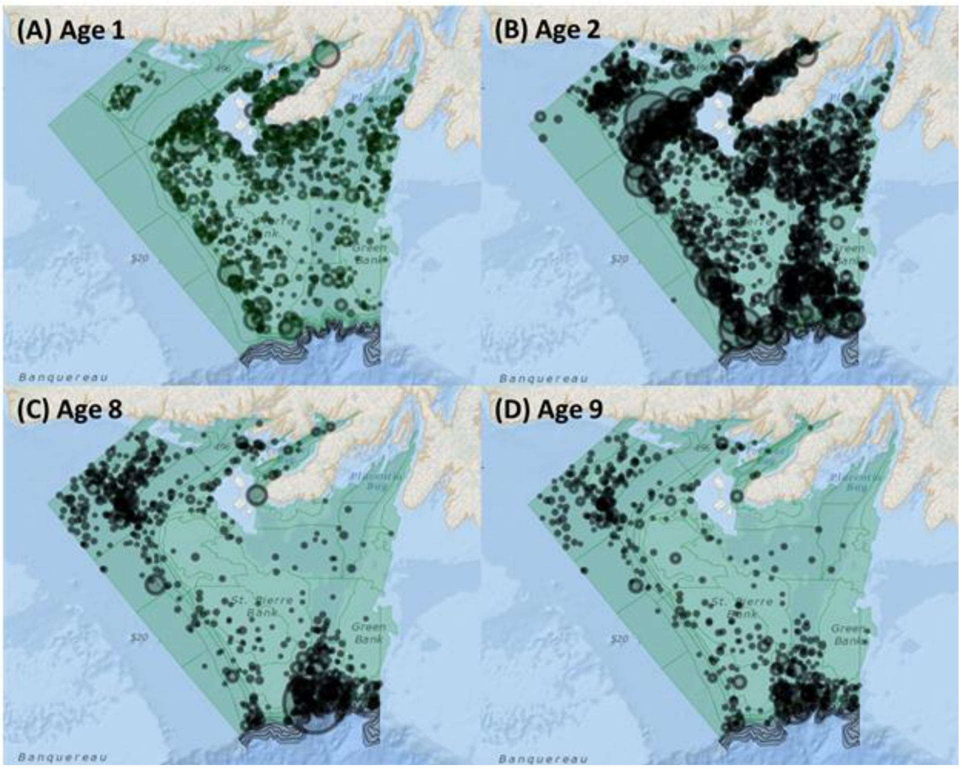


Figure 14. Distribution of Atlantic cod during the DFO-NL annual winter-spring multispecies survey in NAFO Subdivision 3Ps from 1983-2018. Displayed are ages 1 (A), 2 (B), 8 (C), and 9 (D). Note the survey was changed from a “winter” survey to a “spring” survey in 1993 and inshore strata were added in 1997.

Analysis of thermal and depth associations for Atlantic cod in NAFO Subdivision 3Ps were investigated using methodology developed by Perry and Smith (1994). Using these habitat associations, we can examine annual trends in habitat preference and disentangle the spatial distribution of cod across the stock area. Generally, cod selected for temperatures higher (~4.5°C) than the median available temperatures (~2°C), although the preferred temperature occupied shifted considerably in the late-1990s and early-2000s (Figure 15). In ~1998, the median temperature occupied decreased from ~5°C to ~2°C. This shift occurred nearly simultaneously with a shift in survey design to cover more inshore areas as well as a change in the size-structure of the stock towards smaller fish. Further research is required to disentangle whether the change in median occupied temperatures was driven by a change in survey design, a change in water temperatures, a change in the size structure of the stock, or a combination of the three. Cod also avoided shallower areas (such as St. Pierre Bank and Green Bank, Figure 16 & Figure 17) and were more readily found in the channels and on the slopes of 3Ps, with fewer fish found in the deeper waters of the Laurentian Channel. As temperature and depth are tightly linked, bivariate investigations were also undertaken to determine which hydrographic variable was driving the habitat associations of 3Ps Atlantic cod. Results indicated that temperature is a stronger driver of cod distribution than depth and that cod will occupy a wide range of depths in order to maintain thermal habitat preferences. Analysis of the thermal habitat available over time (i.e. the bottom area covered by varying range of temperature) showed warming across all areas in recent years. Prior to 1998, cod seemed to prefer temperature ~3.25-4.75°C (yellow band, Figure 18) whereas after 1998, cod seemed to prefer ~1.5-3.25°C (green band, Figure 18).

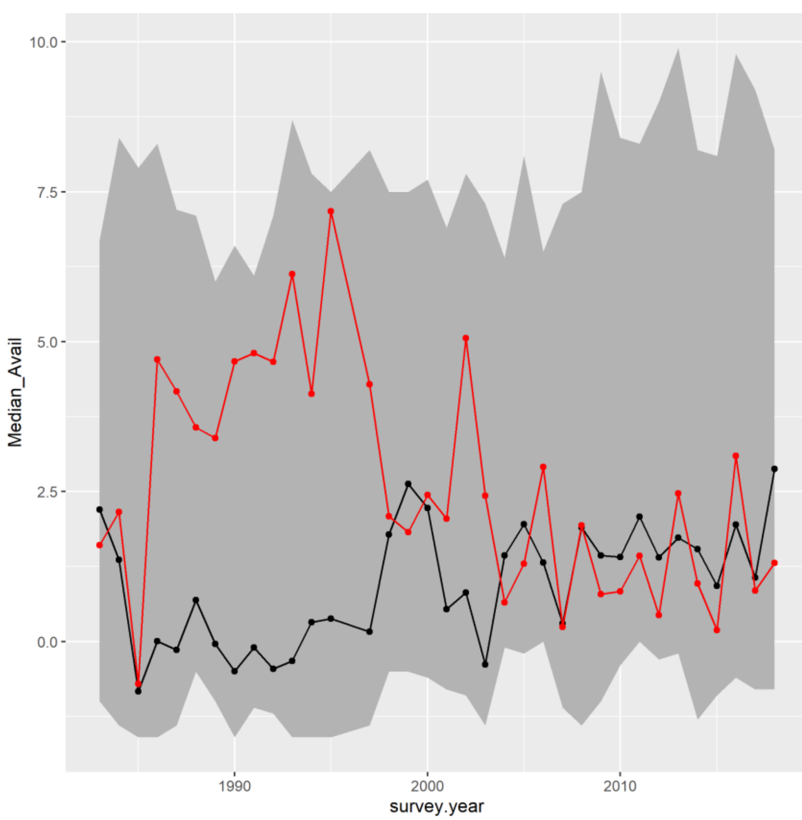


Figure 15. Median temperatures occupied (red line) by Atlantic cod in 3Ps. Black line represents the median available temperature and the grey polygon represents the minimum and maximum bottom temperature recorded annually on the DFO multispecies survey.

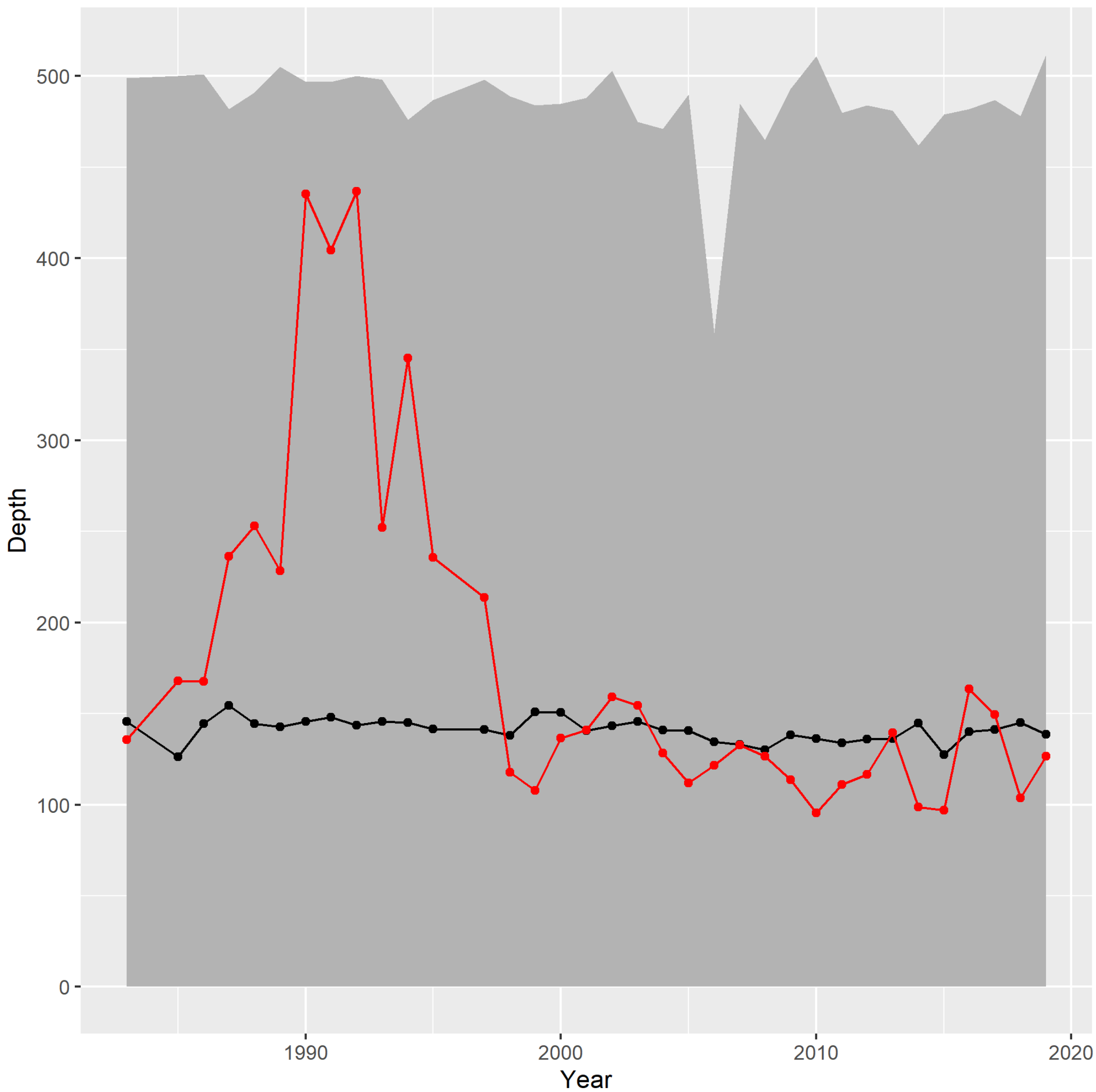


Figure 16. Median depths occupied (red line) by Atlantic cod in 3Ps. Black line represents the median available depth and the grey polygon represents the minimum and maximum depth fished annually on the DFO multispecies survey.

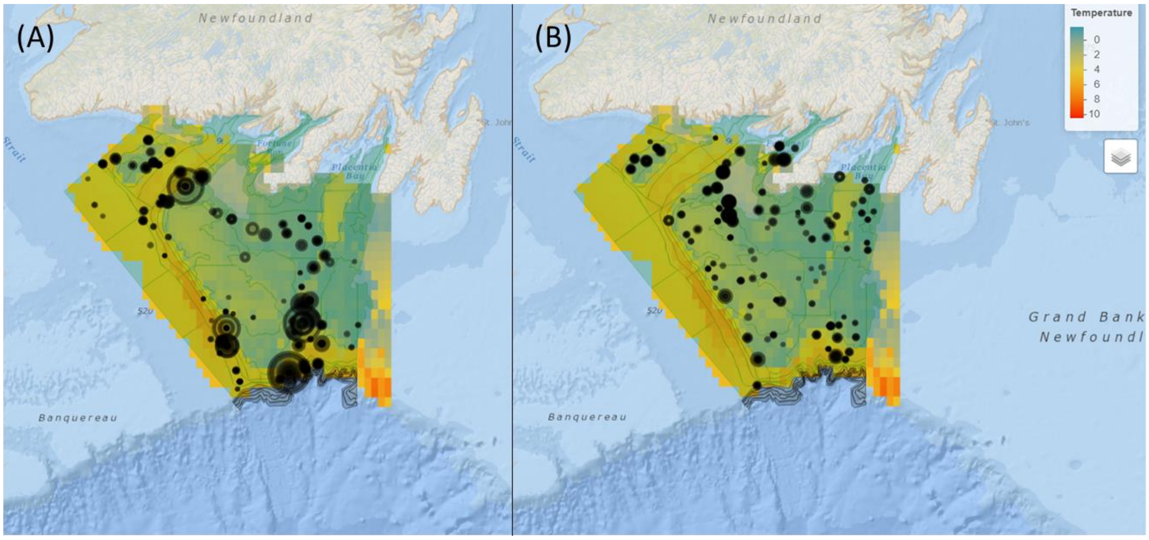


Figure 17. Comparison of cod distribution in 1987 (A) and 2018 (B). In 2018, cod are distributed into shallower areas (St. Pierre Bank) but are still associated with preferred temperatures. In 1987, cod are found in larger numbers in the channels and along the slopes of banks, following preferred temperature availability. The radius of the point is proportional to the number of cod caught in each set. Multiple ages of cod are plotted here, resulting in some overlap of points.

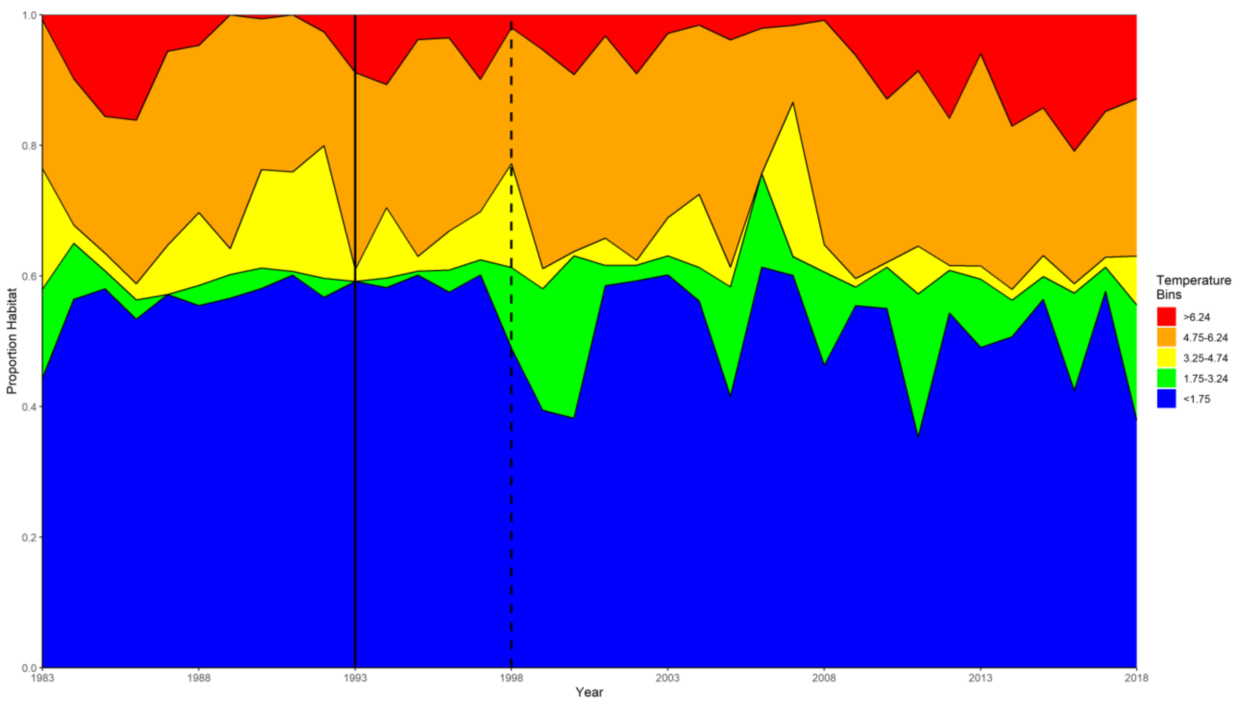


Figure 18. Survey area covered by various water temperatures based on bottom temperature measured as part of annual winter–spring bottom trawl surveys of 3Ps during 1983–2018. Percent coverage was calculated using design-weighted area of occupancy for various thermal ranges. Solid black line represents the shift from winter-based survey to a spring-based survey. Dashed line indicates the addition of inshore shallow strata to survey.

**Trends in diet and fish condition from RV survey sampling**

Key prey items were evaluated using the "called" stomach data from the spring RV survey of 3Ps and the sentinel survey. "Called" stomachs are visually assessed at-sea during sampling to determine primary prey content. These data provide a course view of trends in the diet of cod as a portion of the fish caught in these surveys are sub-sampled . Across the whole time series, sandlance, capelin, redfish, cod, and plaice were the most common fish prey, and amphipods, crab, shrimp, brittlestars, and euphasiids were the most common invertebrate prey. Empty stomach were also common as were other categories (e.g. unknown fish, digested). Amphipods and other invertebrates were more common in the diet of younger cod (ages 2-4), and diets tended to shift towards fish as cod aged (5+; Figure 19).

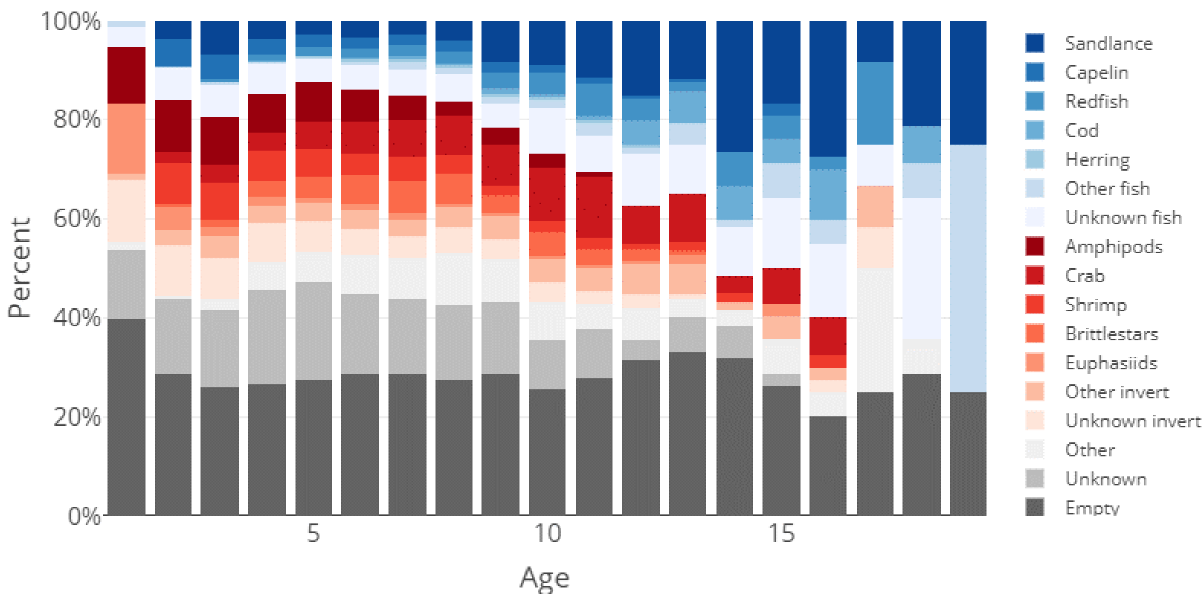


Figure 19. Dietary composition of Atlantic cod sampled in NAFO sub-division 3Ps based on primary prey content 'called' in the RV and sentinel surveys.

To explore potential links between body condition and natural mortality, Fulton's K was calculated using the RV and Sentinel survey data. Fulton's K was based on gutted weight, for a less variable assessment of condition (Dutil and Lambert 2000), and the proportion of cod with a $K < 0.65$ was considered an index of starvation mortality (Dutil and Lambert 2000, Casini et al. 2016). As expected, the greatest proportions of starving cod were observed through the critical spring period. The proportion of cod in poor condition was much lower during the fall (Figure 20). Overall, the results indicate that the condition of cod has been deteriorating in recent years and rates of starvation are potentially increasing.

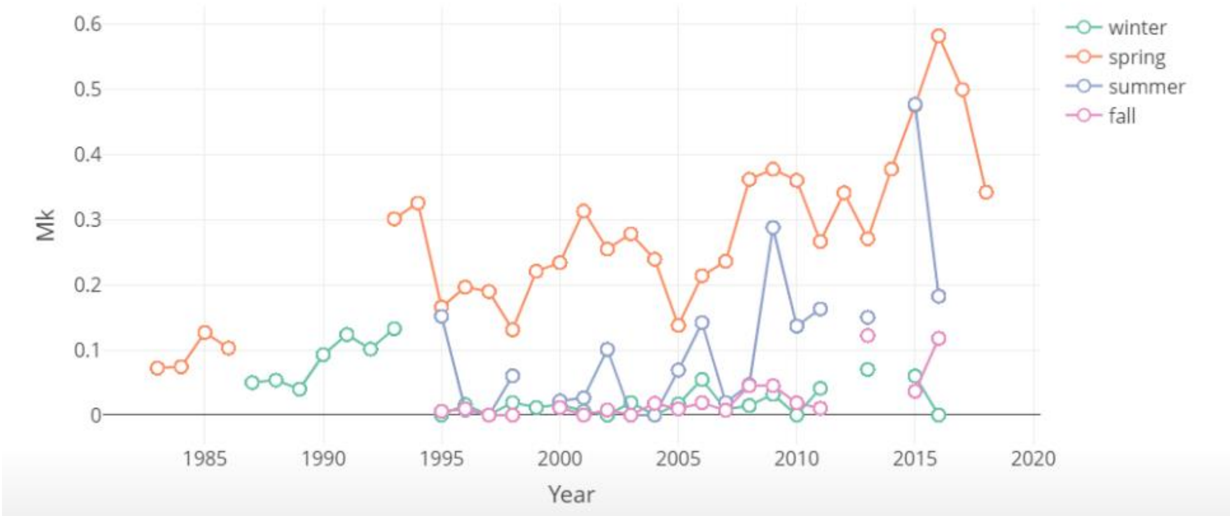


Figure 20. Trends in the starvation-induced mortality index (Mk) derived from the proportion of Atlantic cod in poor condition (K < 0.65) in NAFO Subdivision 3Ps based on samples collected in the RV and sentinel surveys across winter, spring, summer, and fall.

## FRENCH RV SURVEY

**Summary**

| **Species** | **Atlantic Cod (*Gadus morhua*)** |
|---|---|
| **Spatial resolution** | North Atlantic Fisheries Organization (NAFO) Subdivision (Subdiv.) 3Ps |
| **Temporal resolution** | 1978-1992<br>Winter |
| **Sampling methodology** | Stratified-random surveys by French research vessels |
| **Types of structures collected** | Otoliths |
| **Types of data available** | Index-at-age, numbers and biomass per tow |
| **Contact person** | Joel Vigneau (Joel.Vigneau@ifremer.fr)<br>Juliette Champagnat<br>(juliette.champagnat@agrocampus-ouest.fr) |

### Temporal coverage

Stratified-random surveys were conducted in the offshore areas of Subdiv. 3Ps during the winter period (February-March) by France between 1978 and 1992 (Spatial coverage

The stratification scheme of the survey uses the same stratum than Canada offshore RV survey (see Figure 1 strata in blue in the section on Canadian RV Survey). However, the deepest strata (200-300 fathoms) have only been covered in 1981,1983, 1990, 1991 and 1992. To account for this incomplete coverage for certain years, estimates of biomass and abundance for non-sampled strata were obtained using a multiplicative model. The sampling method is also consistent with the Canadian one, except that the trawling was done only during daylight. The spatial coverage within year is presented in Figure 21 and
Table 7.

### Sampling summary

Biological (length frequencies, maturity stage at length, otoliths) and physical (temperature, depth) data were collected. Data available are the abundance and biomass per tow, length distribution, and indices at age. Mean number at age per tow is used as an index of the population. As described above, a multiplicative model has been used to account for un-sampled deep strata, so two series of indices are available. Uncertainty in the index-data were not estimated. Survey age-composition data are currently unavailable.

Table 6). The fishing gear used is a Lofoten trawl (21.2 m headline and 17.7 m footrope) with a small mesh at the cod end (50mm). The swept area is assumed to be constant and equal to 0.015 square nautical mile i.e., tow distance = 2 nautical miles * distance from wing to wing 13.50m).

The French surveys were conducted using the research vessels Cryos (1978-1991) and Thalassa (1992). Comparable fishing data between those two vessels is not available although the same fishing gear and survey design have been used (Bishop and Murphy, 1992). It has been previously noted that the results from the two surveys might not be comparable. Further information about this survey is available in Champagnat and Vigneau (*in press*[1]).

**Spatial coverage**

The stratification scheme of the survey uses the same stratum than Canada offshore RV survey (see Figure 1 strata in blue in the section on Canadian RV Survey). However, the deepest strata (200-300 fathoms) have only been covered in 1981,1983, 1990, 1991 and 1992. To account for this incomplete coverage for certain years, estimates of biomass and abundance for non-sampled strata were obtained using a multiplicative model. The sampling method is also consistent with the Canadian one, except that the trawling was done only during daylight. The spatial coverage within year is presented in Figure 21 and
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Biological (length frequencies, maturity stage at length, otoliths) and physical (temperature, depth) data were collected. Data available are the abundance and biomass per tow, length distribution, and indices at age. Mean number at age per tow is used as an index of the population. As described above, a multiplicative model has been used to account for un-sampled deep strata, so two series of indices are available. Uncertainty in the index-data were not estimated. Survey age-composition data are currently unavailable.

Table 6: French survey timing and details

| Year | Start.date | End.date | Number of days | Number of set |
|---|---|---|---|---|
| 1978 | 21/02/1978 | 23/03/1978 | 30 | 70 |
| 1979 | 21/02/1979 | 19/03/1979 | 26 | 66 |
| 1980 | 04/03/1980 | 11/03/1980 | 7 | 40 |
| 1981 | 24/02/1981 | 31/03/1981 | 35 | 109 |

[1] Champagnat, J., and J. Vigneau. In press. ERHAPS: a French survey for cod in 3Ps (NAFO subdiv) IFREMER REPORT

| | | | | |
|---|---|---|---|---|
| 1982 | 05/03/1982 | 02/04/1982 | 28 | 81 |
| 1983 | 10/02/1983 | 14/03/1983 | 32 | 108 |
| 1984 | 15/02/1984 | 18/03/1984 | 32 | 87 |
| 1985 | 10/02/1985 | 10/03/1985 | 28 | 100 |
| 1986 | 05/02/1986 | 11/03/1986 | 34 | 94 |
| 1987 | 04/02/1987 | 06/03/1987 | 30 | 82 |
| 1988 | 09/02/1988 | 10/03/1988 | 30 | 83 |
| 1989 | 16/02/1989 | 17/03/1989 | 29 | 112 |
| 1990 | 28/02/1990 | 27/03/1990 | 27 | 122 |
| 1991 | 20/02/1991 | 25/03/1991 | 33 | 114 |
| 1992 | 17/02/1992 | 10/03/1992 | 22 | 76 |

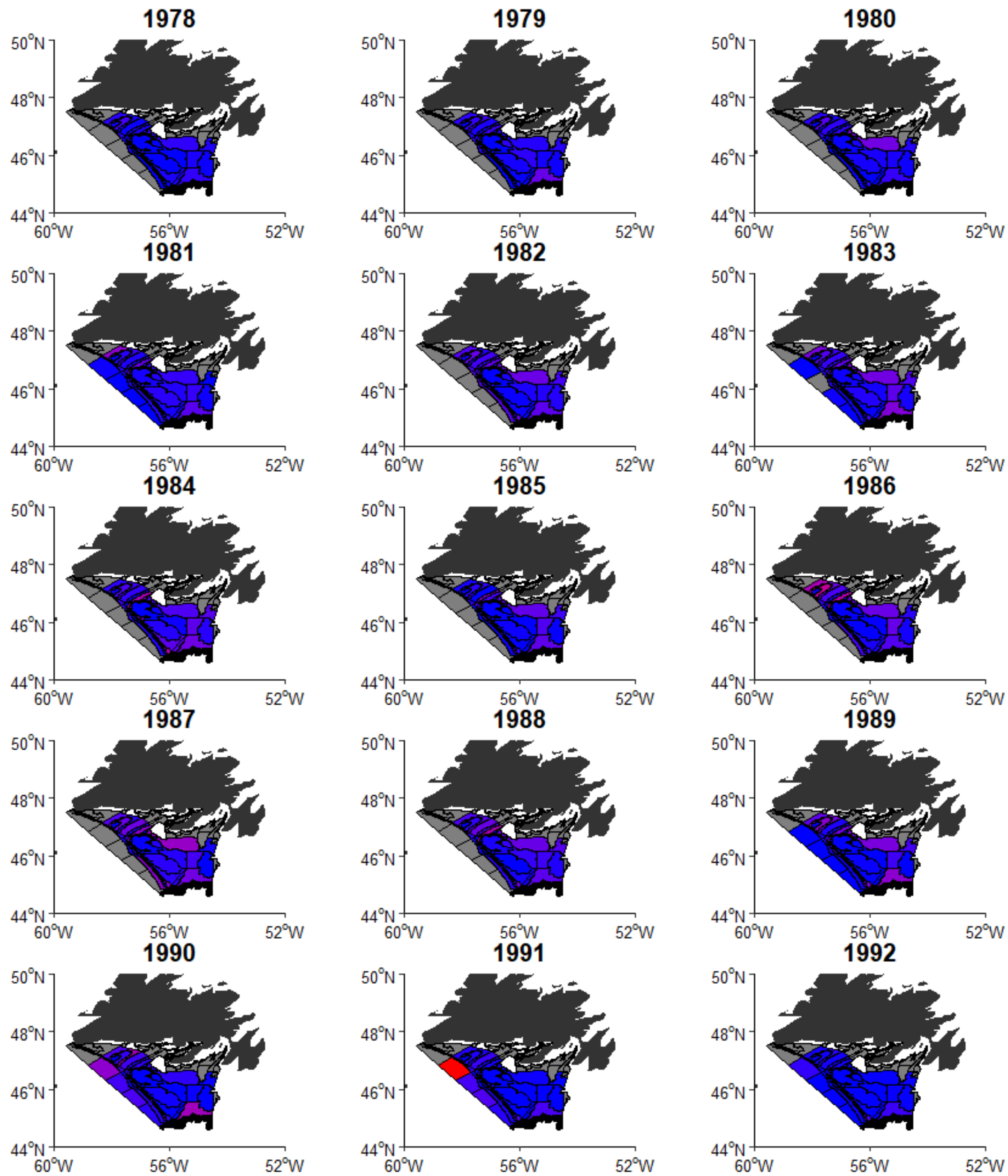


Figure 21: Annual spatial coverage of the French survey: total abundance of cod in the strata from low (blue) to high (red). Missed strata in grey. Note that 3Pn (also in grey at the western boundary of the stock) is not part of the survey design.

Table 7: Total abundance of cod per stratum each year. NA is used for non-sampled strata. Cells are shaded with a color gradient according to the contribution value divided in classes: [0,5], [5,10], [10,20] and [20,35]. A very high value is shaded in orange.

| STRATE | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **306** | 7.83 | 5.40 | 4.12 | 33.13 | 6.23 | 14.54 | 1.38 | 0.76 | 16.51 | 4.40 | 4.57 | 6.39 | 4.33 | 0.77 | 2.15 |
| **307** | 19.93 | 7.16 | 18.18 | 2.19 | 10.23 | 6.79 | 3.81 | 2.14 | 24.08 | 6.99 | 2.01 | 14.37 | 1.80 | 0.61 | 1.49 |
| **308** | 1.93 | 0.07 | 0.21 | 0.12 | 0.35 | 0.11 | 0.23 | 0.14 | 0.15 | 0.05 | 0.07 | 0.11 | 0.00 | 0.02 | 0.18 |
| **309** | 3.63 | 10.19 | 1.56 | 4.97 | 1.31 | 3.44 | 2.31 | 2.38 | 5.56 | 1.24 | 5.05 | 9.50 | 21.36 | 0.69 | 6.39 |
| **310** | 4.05 | 1.15 | 0.09 | 1.67 | 2.40 | 2.15 | 0.15 | 25.96 | 0.20 | 0.57 | 4.02 | 0.24 | 0.87 | 0.40 | 2.39 |
| **311** | 4.11 | 10.10 | 6.83 | 14.90 | 8.76 | 9.52 | 22.04 | 5.33 | 20.45 | 14.14 | 28.67 | 9.70 | 1.63 | 0.38 | 2.17 |
| **312** | 6.19 | 0.61 | 0.17 | 2.31 | 1.00 | 0.23 | 9.94 | 0.42 | 0.34 | 0.00 | 0.13 | 0.09 | 0.01 | 0.52 | 0.00 |
| **313** | 1.33 | 2.04 | 0.06 | 2.94 | 1.79 | 1.56 | 0.12 | 6.44 | 0.16 | 2.13 | 0.04 | 2.66 | 1.56 | 0.44 | 0.22 |
| **314** | 0.34 | 0.00 | 0.43 | 0.91 | 0.05 | 0.31 | 0.00 | 0.09 | 0.04 | 0.10 | 0.63 | 0.05 | 0.00 | 0.00 | 0.00 |
| **315** | 3.77 | 0.35 | 0.00 | 0.92 | 0.25 | 0.20 | 5.23 | 0.08 | 0.36 | 1.29 | 0.47 | 0.05 | 0.04 | 0.00 | 0.22 |
| **316** | 0.67 | 0.59 | 0.23 | 0.56 | 0.93 | 0.07 | 0.25 | 11.16 | 0.94 | 0.32 | 1.18 | 7.91 | 9.79 | 2.11 | 21.07 |
| **317** | 0.00 | 0.74 | 4.11 | 2.48 | 10.84 | 3.89 | 23.89 | 2.70 | 1.34 | 12.59 | 9.56 | 12.96 | 1.35 | 3.27 | 18.47 |
| **318** | 0.21 | 0.05 | 1.13 | 0.84 | 0.07 | 2.71 | 0.88 | 1.57 | 6.59 | 0.15 | 4.92 | 1.78 | 3.04 | 2.45 | 1.31 |
| **319** | 10.76 | 28.44 | 6.76 | 11.15 | 7.71 | 17.61 | 7.95 | 10.67 | 3.27 | 8.48 | 6.43 | 15.28 | 20.91 | 3.16 | 11.25 |
| **320** | 0.37 | 1.50 | 1.51 | 2.68 | 0.20 | 1.31 | 0.92 | 0.37 | 0.05 | 1.17 | 0.00 | 0.15 | 0.28 | 0.00 | 0.35 |
| **321** | 0.20 | 5.56 | 1.92 | 1.72 | 0.85 | 0.51 | 0.21 | 0.04 | 0.06 | 0.93 | 2.16 | 0.00 | 0.00 | 0.00 | 0.00 |
| **322** | 9.61 | 3.83 | 33.85 | 3.93 | 10.78 | 13.14 | 3.78 | 11.57 | 5.54 | 16.77 | 8.44 | 10.93 | 1.43 | 0.19 | 0.43 |
| **323** | 3.57 | 1.40 | 1.87 | 3.95 | 1.25 | 8.43 | 5.35 | 7.29 | 5.19 | 2.84 | 2.95 | 2.63 | 0.15 | 0.03 | 0.57 |
| **324** | 4.90 | 3.79 | 3.36 | 0.00 | 4.05 | 5.98 | 4.57 | 4.39 | 0.82 | 0.35 | 5.59 | 3.05 | 0.13 | 0.05 | 0.93 |
| **325** | 1.11 | 0.94 | 0.81 | 0.44 | 1.24 | 0.63 | 0.94 | 0.18 | 0.26 | 0.00 | 0.86 | 0.00 | 0.00 | 0.00 | 0.51 |
| **705** | 2.60 | 6.09 | 0.16 | 1.45 | 7.21 | 1.54 | 1.32 | 0.19 | 0.25 | 0.33 | 0.48 | 0.43 | 0.14 | 0.11 | 0.00 |
| **706** | 0.23 | 0.00 | 0.58 | 2.30 | 6.70 | 0.41 | 0.77 | 0.44 | 2.25 | 13.36 | 1.40 | 0.25 | 1.13 | 0.55 | 0.77 |
| **707** | 1.43 | 3.64 | 0.98 | 0.04 | 5.71 | 0.42 | 0.03 | 2.26 | 1.33 | 0.12 | 0.14 | 0.08 | 0.11 | 0.15 | 15.29 |
| **708** | 0.53 | 0.42 | 0.37 | 0.15 | 0.77 | 0.02 | 0.01 | 0.86 | 0.43 | 2.30 | 0.16 | 0.28 | 0.47 | 3.57 | 2.81 |
| **711** | NA | NA | NA | 0.00 | NA | 0.08 | NA | NA | NA | NA | NA | 0.00 | 1.29 | 1.02 | 0.17 |
| **712** | NA | NA | NA | 0.00 | NA | 0.31 | NA | NA | NA | NA | NA | 0.00 | 3.87 | 3.86 | 0.27 |
| **713** | NA | NA | NA | 0.07 | NA | NA | NA | NA | NA | NA | NA | 0.00 | 2.91 | 2.92 | 0.17 |
| **714** | NA | NA | NA | 0.47 | NA | 0.00 | NA | NA | NA | NA | NA | 0.00 | 15.50 | 68.92 | 8.31 |
| **715** | 9.44 | 3.70 | 5.28 | 2.15 | 5.43 | 1.35 | 2.38 | 2.50 | 1.28 | 1.43 | 1.56 | 0.45 | 3.21 | 1.90 | 0.35 |
| **716** | 1.26 | 2.22 | 5.44 | 1.56 | 3.89 | 2.75 | 1.54 | 0.07 | 2.56 | 7.97 | 8.54 | 0.66 | 2.68 | 1.92 | 1.75 |

## Internal consistency

The internal consistency of indices has been explored using a correlation test of Kendal (Figure 22). Each age is correlated to the next age within the same cohort. The consistency plot for the ERHAPS survey data (Figure 22) shows good correlations between the younger ages (2 to 5) and between the older ages (9 to 14). However, there is no correlation between ages 5 to 7.

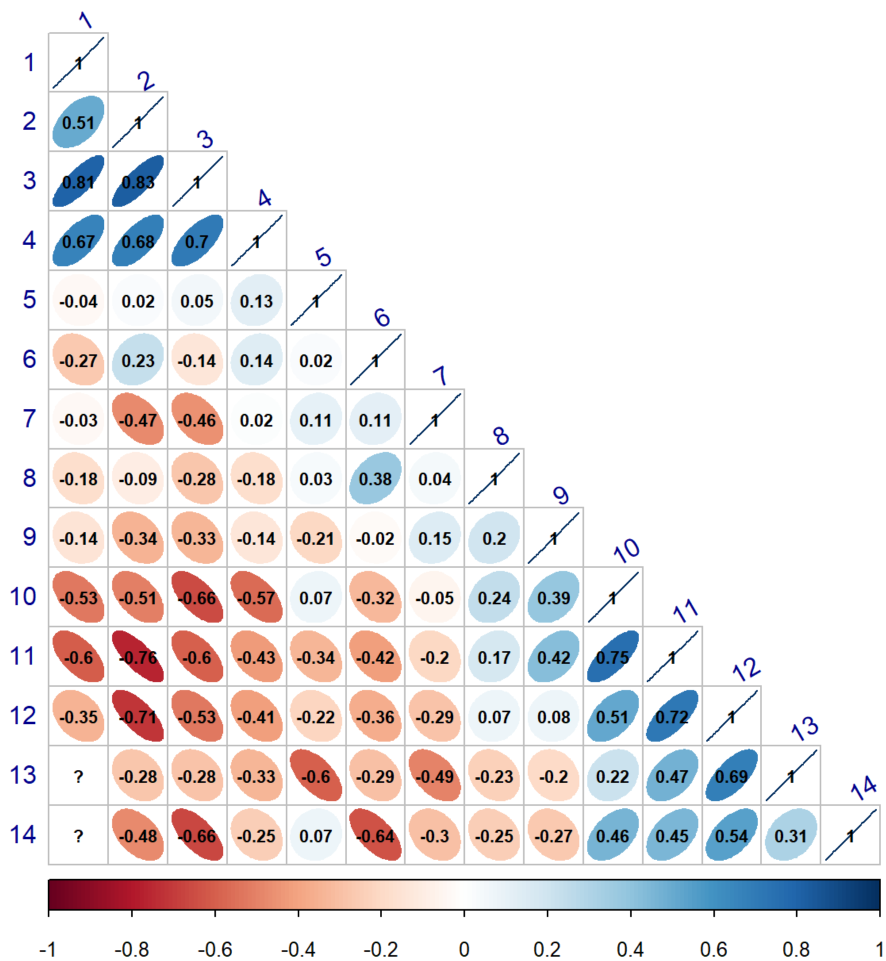


Figure 22: Internal consistency of French indices. Blue indicates positive correlation and red indicates negative correlation with the darker shades indicating stronger correlations. The numbers are the estimate for the correlation coefficient.

**Cohort strength modelling**

A cohort strength analysis has been used to compare French indices with the Canadian RV survey. A multiplicative model was used to estimate the relative year class strength of the stock using indices. This model is applied only on pre-exploitation age only, here age 1 to 4.

$\log(I_{a,y}) = \mu + Q_a + Y_{y-a} + \tau_y + \varepsilon_{a,y}$

where μ = overall mean
*I* = Index (mean numbers per tow)
*Y* = year class (eg cohort) effect
*Q* = Age effect,
*τ* = year random effect
ε = error term,
And a and y = age and year subscript

A random effect multiplicative model has been chosen because of the year effect in the residual pattern, it improves the residual analysis and AIC. The cohort strength model was applied to the two French series of indices and the Canadian indices series to check their consistency (Figure 23). Both series displayed a good cohort tracking and mostly the estimate are similar. The 1984, 1985, 1988 and 1989 are particularly strong.

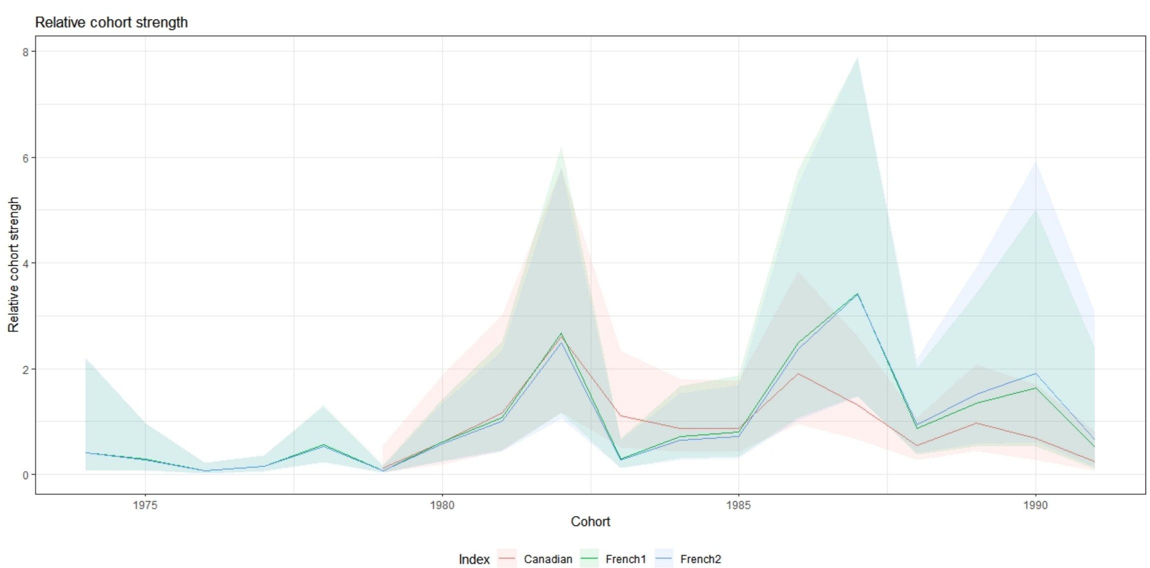


Figure 23: Relative cohort strength estimated for the two French indices series and Canadian indices series (French1: raw indices, French2: multiplicative model used for unsampled deep strata).

## COMMERCIAL LANDINGS DATA

### Summary

| Species | Atlantic Cod (*Gadus morhua*) |
|---|---|
| **Spatial resolution** | North Atlantic Fisheries Organization (NAFO) Subdivision (Subdiv.) 3Ps, unit areas a through h. |
| **Temporal resolution** | Year: 1959 to 2017, |
| **Sampling methodology** | Various approaches |
| **Types of structures collected** | NA |
| **Types of data available** | Landings and upper and lower bounds for uncertainty |
| **Contact person** | Danny Ings<br>Danny.Ings@dfo-mpo.gc.ca |

Prior to the moratorium, Canadian landings for vessels < 35 ft (Figure 24) 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 24). 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 25), with remaining catch taken mainly by the mobile gear sector fishing the offshore, i.e., unit areas 3Psd, 3Pse, 3Psf, 3Psg, and 3Psh.

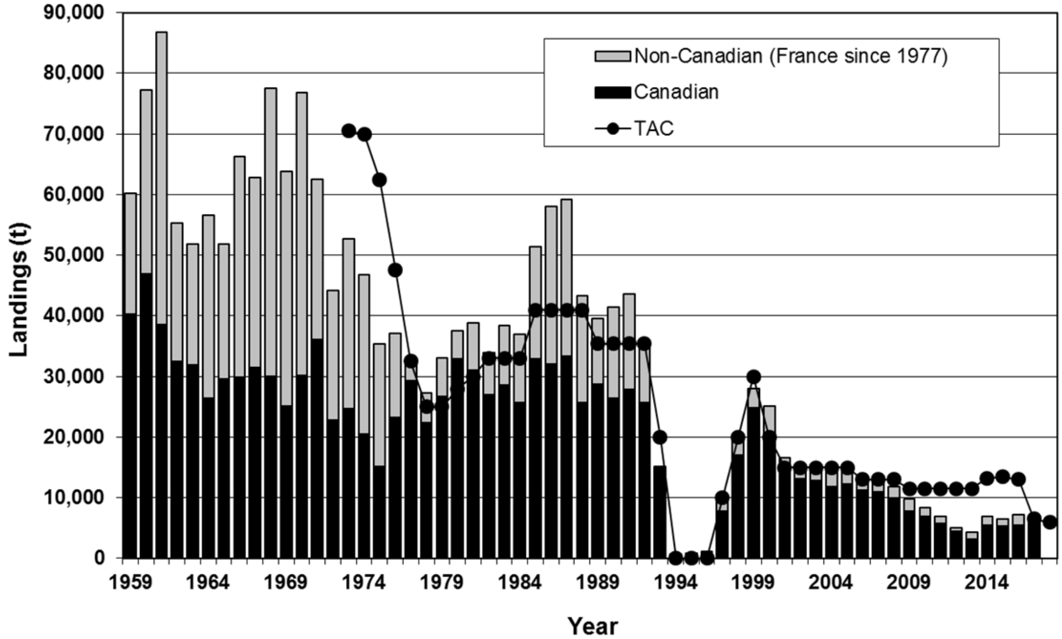


Figure 24. Reported landings of cod by Canadian and non-Canadian vessels in NAFO Subdiv. 3Ps.

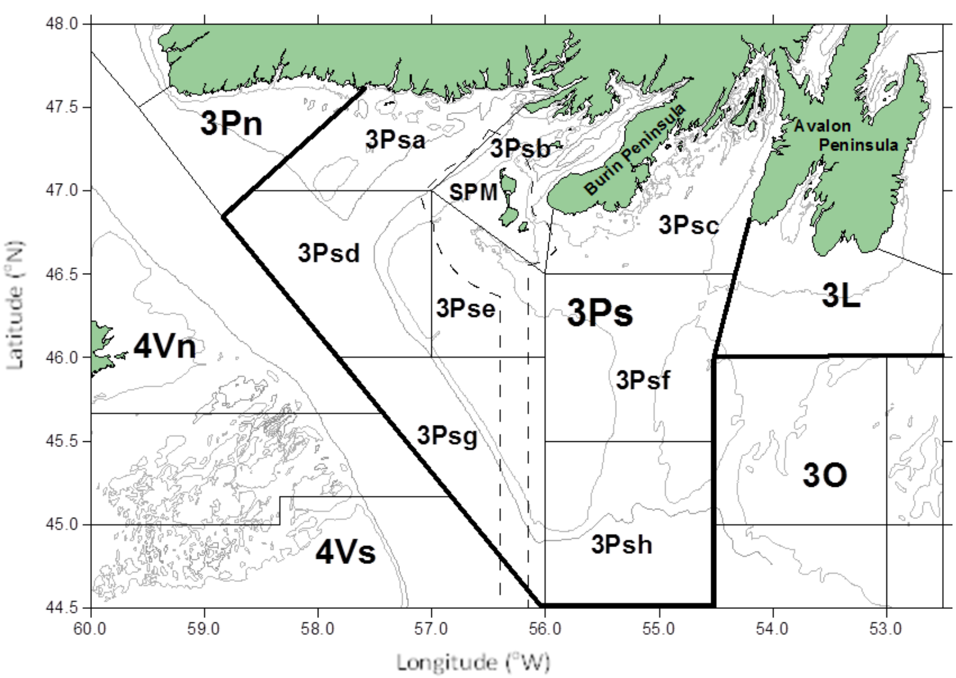


Figure 25 NAFO Subdiv. 3Ps management zone showing the economic zone around the French islands of St. Pierre et Miquelon (SPM, dashed line), the 100 m and 250 m depth contours (grey lines) and the boundaries of the statistical unit areas (solid lines).

## Uncertainty in commercial landings

A fisheries science collaborative project conducted jointly with the FFAW is ongoing. As part of the project, inshore harvesters were interviewed to determine uncertainty in commercial landings time series over the history of the fishery. An overview of the methodology including study design (fishing sectors and interview questions and format), and current progress with the project was presented at the meeting. The project was designed with the expectation that fisher interviews will help highlight weaknesses in the current protocols that have caused low reliability in certain situations. The project will provide an opportunity to bring fisher perspectives into the problems related to catch monitoring and reliability. This project will help the adoption of methodologies in fisheries stock assessment which aim to include uncertainty in catch history instead of assuming that the data provided to the model are 100% accurate. Conclusions based on the findings were presented at the assessment framework meeting held a few months after this data-review meeting (DFO *in press*). The findings from the project were used to develop upper and lower bounds for the commercial fishery (Varkey et al., 2022).

## COMMERCIAL CATCH-AT-AGE

### Summary

| Species | Atlantic Cod (*Gadus morhua*) |
|---|---|
| **Spatial resolution** | North Atlantic Fisheries Organization (NAFO) Subdivision (Subdiv.) 3Ps, unit areas a through h (Figure 25). |
| **Temporal resolution** | Year: 1988 to 2010, except 1993<br>Season: all, but most of the data is from June to October |
| **Sampling methodology** | Cluster sampling of the catch* |
| **Types of structures collected** | Otoliths |
| **Types of data available** | Catch at age<br>Weight at age<br>Lengths and weights from fishery |
| **Contact person** | Bob Rogers (Bob.Rogers@dfo-mpo.gc.a) |

**Sampling methodology**

Fish length measurements and otoliths are collected by at-sea observers onboard fishing vessels or by DFO Science Branch personnel through the port sampling program. All measurements for cod are unsexed. The sampling design for port sampling is based on “cells” composed of quarter, gear type, and unit area (see Figure 25), whereby which a certain number of fish are meant to be sampled per cell. This sampling methodology may help reduce biases in the collection of cod measurements and otoliths.

For Newfoundland  data, there are length frequencies (LF) and age-length keys (ALK) from gill nets, longlines, hand line, and otter trawls from most years. In some years there are also have details from midwater trawls, Danish seines, and cod traps . Additionally, from 1997 onward there are LFs and ALKs from the sentinel fishery which has both long line and gill net components.

Table 8: Summary of commercial sampling – number of fish measured and aged

| Year | Fish measured | Fish aged | Year | Fish measured | Fish aged |
|---|---|---|---|---|---|
| 1970 | 13815 | 1322 | 1993 | 7743 | 1092 |
| 1971 | 8664 | 642 | 1995 | 115342 | 374 |
| 1972 | 10688 | 1294 | 1996 | 112296 | 2668 |
| 1973 | 14413 | 1449 | 1997 | 159820 | 8257 |
| 1974 | 13305 | 1467 | 1998 | 119922 | 12404 |
| 1975 | 8622 | 1084 | 1999 | 99304 | 9965 |
| 1976 | 12484 | 1598 | 2000 | 89564 | 8005 |
| 1977 | 12175 | 2244 | 2001 | 81196 | 7347 |
| 1978 | 24271 | 3045 | 2002 | 82026 | 8023 |
| 1979 | 22325 | 2838 | 2003 | 80797 | 9032 |
| 1980 | 29272 | 3716 | 2004 | 80131 | 7943 |
| 1981 | 30004 | 4638 | 2005 | 60503 | 7986 |
| 1982 | 41589 | 4010 | 2006 | 75812 | 8969 |
| 1983 | 71920 | 4589 | 2007 | 76456 | 7147 |
| 1984 | 56978 | 3499 | 2008 | 50132 | 7187 |
| 1985 | 47240 | 3155 | 2009 | 52336 | 5513 |
| 1986 | 33416 | 3091 | 2010 | 69873 | 5924 |
| 1987 | 49851 | 4001 | 2011 | 29903 | 5143 |
| 1988 | 50111 | 3309 | 2012 | 35008 | 4018 |
| 1989 | 52417 | 3123 | 2013 | 29774 | 3851 |
| 1990 | 52946 | 3460 | 2014 | 45802 | 3679 |
| 1991 | 29637 | 2560 | 2015 | 27971 | 2661 |
| 1992 | 42978 | 3334 | 2016 | 31611 | 2389 |

**Length Frequency – Age-Length Key (LF – ALK) matching**
Commercial length frequencies from different months, NAFO unit areas, and gear types are matched to a corresponding ALK (ALK are organized by gear, NAFO unit area, and quarter).

Commercial length frequencies from France (St. Pierre and Miquelon) are sometimes unavailable. If unavailable, French landings can be matched to Canadian LF using the following:

- Inshore French catch – Inshore Canadian gillnet (GN) and handline (HJ)
- Offshore French catch – Offshore Canadian Otter trawl (OT) LF.

The LF are then matched to a corresponding ALK based on gear, quarter, and NAFO subdivision. Once the best match available is selected, it is assigned a catch value (obtained from the either French colleagues or the regional catch database), this produces an age frequency (AF), and the quality of the match is determined by looking at the sums of products (SOP), where an SOP=1 indicates an exact match. SOPs less than 0.85 and greater than 1.05 are generally considered to be less acceptable matches and different ALKs are applied to the LF (following the process below) until the best match is found. The acceptable range is greater on the lower end than on the higher end likely to make sure numbers-at-age are not overestimated (which would happen if the SOP was high).

When a perfect match is not available, or the SOP are unacceptable, the next best biologically relevant ALK is used. A decision tree used to determine the next best ALK is as follows:

1) Same gear, same quarter, closest unit area
    a. 3Pa 3Pb and 3Pc for inshore
    b. 3Pd to 3Ph for offshore
2) Same gear, same Unit area, different quarter
    a. 1 to 2, and 3 to 4 preferably because of growing season
3) Same unit area, same quarter, different gear
    a. Only used as a last resort due to selectivity differences
    b. HJ→ line trawl/longline (LT); GN←→LT, Canadian GN ← → Sentinel GN

**Catch Assignment and bump up**
After the matches are made and catch is assigned, different combinations of AFs are used to look at catch at age (CAA) by Gear type, overall Commercial catch, overall sentinel catch, and total catch values. The AF combinations can also be used for future projects and investigations, such as examining CAA by quarter.

**Purpose behind reconstruction**
The matching between LFs and ALKs can be subjective. Decisions can be different person to person or even one person over time. Before 2011 CAA was calculated in a different program. In 2011, the DFO-NL had a CAA program made that makes groundfish CAA easier to examine both within years and between years, and easier to modify if catch values change.

The decision was made at the 3Ps cod meeting in October 2018 that CAA would be recreated starting in 2010 and working backwards. This would provide updated CAA for historical landings and provide a consistent methodology and analysis among years and would also allow the examination of CAA results spatially and by gear type.

Table 9. Summary of reconstruction of commercial catch-at-age

| Year Range | Status | Issue(s) |
|---|---|---|
| 1959-1970 | Extracted from ICNAF documents to add 14 + | Original methods |
| 1971-1973 | Could not reconstruct | Data documentation not available |
| 1974-1978 | Completed | Recheck the amount of foreign catch added prior to compiling the final estimates for CAA. |
| 1979-1992 | Completed | none |
| 1993 | Could not reconstruct | Missing data |
| 1994-2017 | Completed | None |

**Results:**
Catch at age was recreated for 1988 to 2010 (except 1993 due to missing length frequencies). The overall SOP of the entire CAA range from 0.91 to 1.02, well within the accepted criteria (SOP between 0.85 and 1.05). There are two years 1995 and 1996 during the commercial fishing moratorium which have a low sum of products and should be investigated further in the future. Data existed to recreate CAA as far back as 1970.

**Uncertainty and bias**
*Statement about uncertainty:* A standard error and coefficient of variation (CV) is provided for each age class and a sum of products is calculated. Currently, standard error and CV are not used in any meaningful way when examining CAA or incorporating CAA into a model framework.

*Statement about biases:* Given that commercial sampling data is a small sub-sample of the total landings, there is a potential for bias (over or underestimation of numbers in a certain age group) in the calculation of catch-at-age for the total fishery from the annual commercial sampling. For the 3Ps cod calculation of CAA, the potential for bias is minimised by collecting large number of samples by 1. gear types operating in the region, 2. time period when the fishery is active (quarter) and 3. spatial area of operation: unit area (Figure 25) and applying age-length-keys at finer resolution of the sample rather than at aggregate levels. Despite best efforts, logistical constraints may prevent the collection of representative samples for all combinations of gears, areas and seasons. In these situations, sampling from other areas or gears are applied, which may contribute to bias.

**Issues to date:**
There are missing length frequencies and age length keys from both Nova Scotia and St. Pierre and Miquelon in some years. To account for these missing data, it is assumed that Newfoundland length frequencies and age length keys are representative of these catches. During the moratorium fewer samples were collected as most of the catch was bycatch. Therefore, there were greater challenges associated with determining a CAA for these years.

## Length-weight relationship

The process of catch assignment and aggregation to total landings requires the calculation of fish weights based on the length-frequency. For this step, a ‘reference’ length-weight relationship is used. We were unable to locate the source for the ‘reference’ length-weight relationship used previously for catch at age analyses for this stock. We calculated the LW relationships using data from the RV survey data and the sentinel survey data and these relationships indicated lower weights at a given length (Figure 26; Table 10). However, the meeting decided to continue using the reference relationship because the reference relationship had a better SOP for a few random years where the catch-at-age was reconstructed using different LW relationships. Analysis exploring change in LW relationship over time did not result in any evidence to support the same.

Another analysis explored potential changes in LW relationship over time by fitting a time varying model to commercial sampling of length and weight. Several model formulations were attempted with year effects on both alpha and beta parameters (some random-walk (RW) or autoregressive (AR1) smoothing along time was also tested). Although some differences in parameter estimation along time were detected, clear trends could not be identified. In addition, some concerns were raised concerning low numbers of samples in some particular years. Finally, these relationships did not result in better SOP so this work was not carried on further.

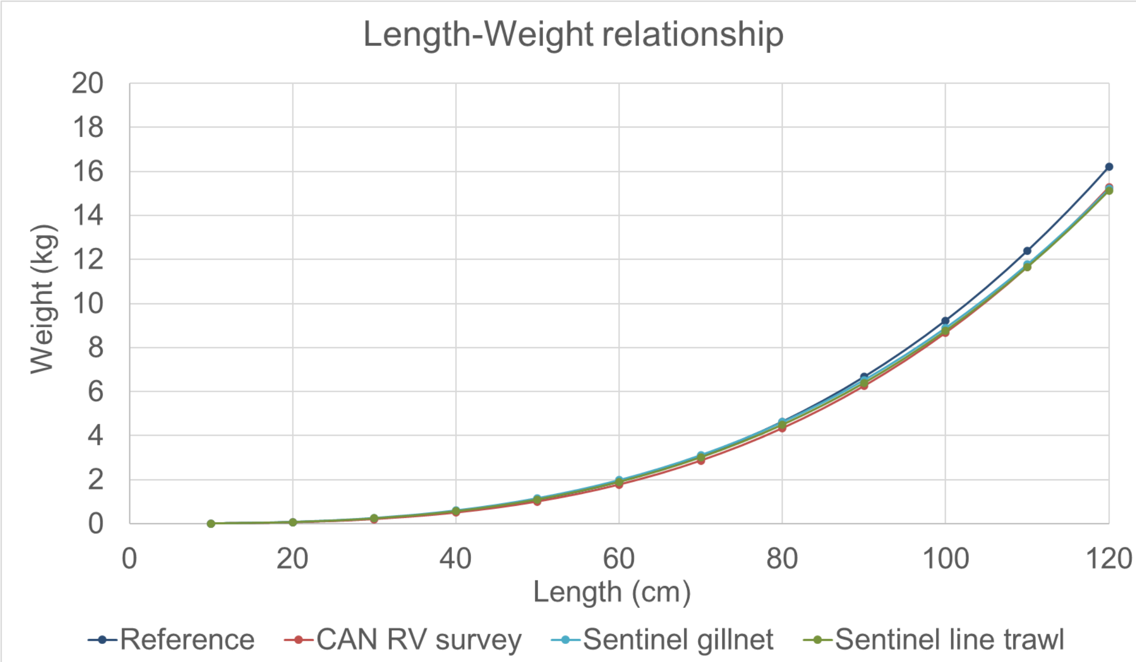


Figure 26 Length weight relationship of cod

Table 10. Parameters of Length-weight relationships for cod

| LW relationships | log10(alpha) | beta |
|---|---|---|
| Reference | -5.2106 | 3.0879 |
| CAN RV survey | -5.27116 | 3.10466 |
| Sentinel gillnet | -4.9343 | 2.94166 |
| Sentinel line trawl | -5.041 | 2.99189 |

## Stock-weights

**Numbers and weight-at-age from commercial sampling**

Stock weights for the assessment (Ings et al. 2019) have been calculated from commercial weight-at-age. These weights are known to differ from survey weight-at-age. Stock-weights used in the previous assessment indicated decreasing weight-at-age. We present weight-at-age across gears to explore whether the pattern is consistent across all gears. For most gears, there is a declining trend in older ages over time, however there seem to be differences between different gear types. It was decided to further investigate the trends in fish weights from different gears and unit areas.

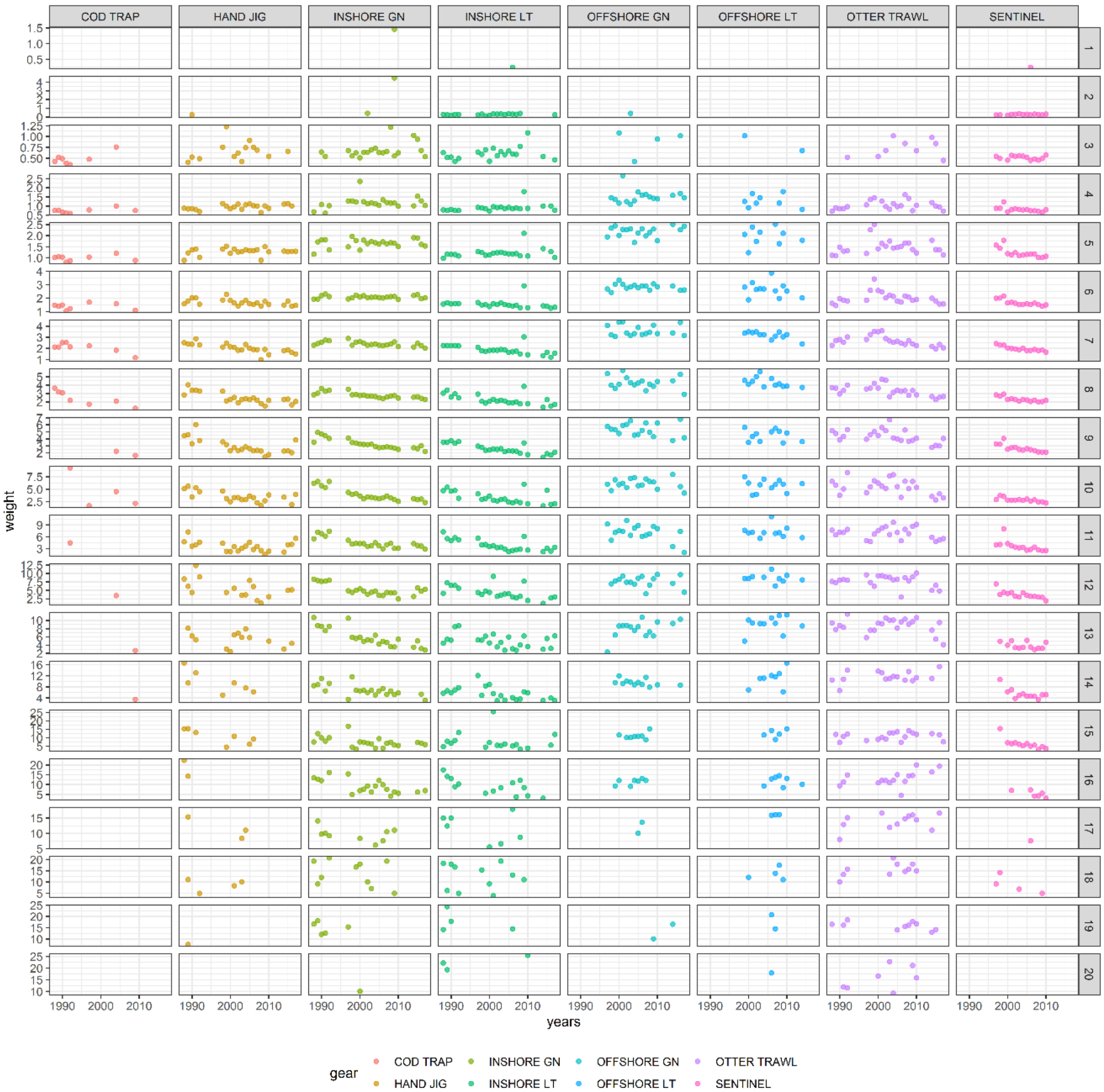


Figure 27. Weight-at-age in commercial samples. Different ages shown in the vertical panels and different ages in the horizontal panels.

## COD TAGGING PROGRAM

**Summary**

| **Species** | **Atlantic Cod (*Gadus morhua*)** |
|---|---|
| Spatial resolution | North Atlantic Fisheries Organization (NAFO) Subdivision (Subdiv.) 3Ps<br>Most effort inshore in 3Psb and 3Psc, sporadic tagging in 3Psa and offshore (3Psd-3Psh) |
| Temporal resolution | Sporadic 1954-1996 (9 different years)<br>Annually since 1997 (except 2006)<br>1954-1996<br>Offshore: January - May<br>Inshore: February - November<br>Since 1997-<br>Offshore: December and April<br>Inshore: January - November |
| Sampling methodology | Various tags pre-1997 (disc, external and internal).<br>Since 1997, t-bar floy tags with low and high rewards<br>1997-: Only fish > 45 cm. |
| Types of structures collected | None |
| Types of data available | Tag release and recovery dates and locations. Length at tagging for all fish, rarely fish length and/or weight at recovery. |
| Contact person | Emilie Novaczek (emilie.novaczek@dfo-mpo.gc.ca); |

The Newfoundland Cod tagging program started in 1954 using various methods and tag types (Taggart et al. 1995). The modern program, with t-bar Floy tags and high ($100) and low ($10) reward tags started in 1997 (Brattey et al 2002; Cadigan and Brattey 2003). Tag and recovery data is entered into a single data base by a dedicated technician, and follow-up with tag returners is conducted when information is unclear or missing. Data quality assurance/ quality control (QA/QC) occurs at the data entry stage, and also during data summaries for annual assessment, where unlikely recovery locations or times are identified (e.g. returns of fish from positions on land).

Data quality for deployments of tags generally excellent and very few errors, data quality for tag returns highly variable and depends on fisher returning the tag.

Recovery year (and sometimes month) are key inputs into any recovery analysis, and not every tag will have that information. Recovery location is also important, although not essential for a simple recovery analysis. Tagged fish cannot be aged, so tagging age is inferred based on length at tagging and an appropriate age-length key (Cadigan and Konrad 2016).

**Spatial and Temporal coverage**

Tagging experiments have been conducted annually in 3Ps since 1996, except during 2006 (Tables 11 and 12). Prior to 1996, tagging experiments were conducted there only infrequently, with gaps of many years between some tag releases. With the low frequency of tagging releases prior to 1997, when the fishery was reopened, it was decided to focus attention on the utility of tagging data only from the post moratorium period. Tagged cod have been most consistently released in inshore areas, particularly in Placentia Bay (3Psc). However, there was no tagging there during 2004 to 2006 or in 2016. Tagging was conducted in Fortune Bay from 1998 to 2003, in 2007 and from 2012 to 2018. There was infrequent tagging in the inshore, west of Fortune Bay. In offshore areas, cod were tagged in the Halibut Channel (3Psh) annually during the period 1998 to 2005, and tagging was conducted annually in 3Psd during 1998 to 2003. Tagged cod were released in 3Psg only during 2003.

Exploitation rates were routinely calculated for Placentia Bay during the 2000s and 2010s and presented at annual assessments (e.g. Healey *et al*. 2012). Estimates of exploitation rates available for offshore and western areas of 3Ps were found to be lower than those in Placentia Bay although there were substantial landings reported for all areas, leading Cadigan and Brattey (2003) to conclude that exploitation rates from these areas may be less reliable than those from Placentia Bay. They attributed the less reliable estimates with infrequent releases of tagged cod outside of Placentia Bay and unknown survivability of cod caught in deep water and subsequently tagged. Temporal issues with tagging cod in 3Ps have also been documented. Brattey *et al*. (2007) noted that due to the lapse in tagging during 2004 to 2006, any estimates of exploitation rates in 2006 could only be considered partial estimates. The meeting concluded that it is likely not possible to integrate tagging data into the assessment model but could be explored to understand spatial tag recovery patterns and possibility provide some information on natural mortality.

**Stock components**

Tagging studies conducted in 3Ps following the moratorium provided strong evidence for resident stock components in Placentia Bay and Fortune Bay with seasonal movements between these bays and into southern 3L (Brattey *et al.* 2002). In addition, a portion of the offshore cod in the Halibut Channel migrate shoreward during late spring and summer into Placentia Bay and the southern Avalon, but are rarely found west of the Burin Peninsula in inshore waters. Despite no directed fishing for cod in 3NO, a few tag recoveries have were reported in 3NO during many years indicating movement from cod in the Halibut

Channel to the southern Grand Bank. Tagging on Burgeo Bank during spring, has indicated that mixing with 3Pn-4Rs cod can extend into April during some years, especially in 1998.

Table 11: Summary of tagging experiments in 3Ps, 1997-2018

| Year | Experiment # | Subdivision | Month | Tags deployed | Recoveries (up to 2018) |
|---|---|---|---|---|---|
| 1997 | 199701 | 3PSc | April | 996 | 282 |
| 1997 | 199702 | 3PSc | April | 966 | 237 |
| 1997 | 199704 | 3PSc | May | 817 | 300 |
| 1997 | 199705 | 3PSc | May | 709 | 220 |
| 1997 | 199706 | 3PSc | June | 963 | 144 |
| 1997 | 199708 | 3PSc | June | 794 | 197 |
| 1997 | 199715 | 3PSc | November | 784 | 181 |
| 1998 | 199801 | 3PSh | April | 1799 | 81 |
| 1998 | 199802 | 3PSd | April | 1352 | 131 |
| 1998 | 199803 | 3PSc | April | 2073 | 657 |
| 1998 | 199804 | 3PSc | April | 1211 | 497 |
| 1998 | 199805 | 3PSc | May | 1037 | 443 |
| 1998 | 199806 | 3PSb | May | 939 | 268 |
| 1998 | 199808 | 3PSc | October | 511 | 162 |
| 1998 | 199809 | 3PSc | October | 883 | 301 |
| 1998 | 199810 | 3PSc | October | 92 | 27 |
| 1999 | 199901 | 3PSh | April | 1808 | 134 |
| 1999 | 199902 | 3PSd | April | 464 | 52 |
| 1999 | 199903 | 3PSb | April | 1293 | 201 |
| 1999 | 199904 | 3PSc | April | 2422 | 884 |
| 1999 | 199905 | 3PSc | May | 175 | 66 |
| 1999 | 199939 | 3PSc | November | 2152 | 667 |
| 1999 | 199940 | 3PSc | November | 79 | 20 |
| 1999 | 199943 | 3PSa | November | 57 | 12 |
| 2000 | 200001 | 3PSh | April | 1044 | 23 |
| 2000 | 200003 | 3PSd | April | 5 | 0 |
| 2000 | 200004 | 3PSb | April | 1665 | 233 |
| 2000 | 200006 | 3PSb | April | 752 | 195 |
| 2000 | 200007 | 3PSc | May | 2494 | 797 |
| 2000 | 200008 | 3PSc | May | 528 | 165 |
| 2000 | 200009 | 3PSc | April | 100 | 29 |
| 2000 | 200010 | 3PSc | May | 46 | 4 |
| 2000 | 200033 | 3PSc | November | 1165 | 276 |
| 2000 | 200034 | 3PSc | November | 792 | 210 |
| 2000 | 200035 | 3PSc | November | 1212 | 277 |

| Year | Experiment # | Subdivision | Month | Tags deployed | Recoveries (up to 2018) |
|---|---|---|---|---|---|
| 2001 | 200101 | 3PSb | January | 200 | 53 |
| 2001 | 200102 | 3PSb | January | 388 | 102 |
| 2001 | 200103 | 3PSh | April | 1145 | 43 |
| 2001 | 200104 | 3PSh | April | 47 | 0 |
| 2001 | 200105 | 3PSh | April | 49 | 0 |
| 2001 | 200106 | 3PSa | April | 999 | 121 |
| 2001 | 200107 | 3PSd | April | 666 | 46 |
| 2001 | 200108 | 3PSb | April | 477 | 45 |
| 2001 | 200109 | 3PSb | April | 60 | 13 |
| 2001 | 200110 | 3PSc | April | 1704 | 562 |
| 2001 | 200111 | 3PSc | May | 2273 | 663 |
| 2001 | 200125 | 3PSa | August | 7 | 1 |
| 2001 | 200127 | 3PSc | November | 350 | 90 |
| 2002 | 200201 | 3PSb | January | 408 | 99 |
| 2002 | 200202 | 3PSb | January | 222 | 60 |
| 2002 | 200203 | 3PSh | April | 1509 | 47 |
| 2002 | 200204 | 3PSb | April | 1792 | 131 |
| 2002 | 200206 | 3PSd | April | 963 | 34 |
| 2002 | 200207 | 3PSc | April | 1832 | 549 |
| 2002 | 200208 | 3PSc | April | 1399 | 494 |
| 2002 | 200212 | 3PSb | June | 138 | 25 |
| 2002 | 200224 | 3PSc | November | 1676 | 459 |
| 2003 | 200302 | 3PSh | April | 133 | 4 |
| 2003 | 200303 | 3PSb | April | 1481 | 219 |
| 2003 | 200304 | 3PSd | April | 878 | 33 |
| 2003 | 200305 | 3PSc | May | 3427 | 1103 |
| 2003 | 200306 | 3PSb | June | 1384 | 281 |
| 2003 | 200307 | 3PSb | June | 630 | 84 |
| 2003 | 200308 | 3PSc | November | 1645 | 358 |
| 2003 | 200309 | 3PSc | November | 634 | 122 |
| 2003 | 200310 | 3PSh | December | 488 | 24 |
| 2003 | 200311 | 3PSg | December | 511 | 23 |
| 2004 | 200402 | 3PSh | December | 1748 | 106 |
| 2004 | 200405 | 3PSa | May | 3 | 0 |
| 2005 | 200510 | 3PSh | December | 1490 | 99 |
| 2007 | 200704 | 3PSb | June | 881 | 111 |
| 2007 | 200705 | 3PSc | June | 740 | 121 |
| 2007 | 200707 | 3PSc | July | 179 | 28 |
| 2007 | 200708 | 3PSb | July | 138 | 45 |
| 2007 | 200710 | 3PSa | July | 316 | 67 |
| 2007 | 200711 | 3PSa | July | 524 | 186 |

| Year | Experiment # | Subdivision | Month | Tags deployed | Recoveries (up to 2018) |
|---|---|---|---|---|---|
| 2007 | 200713 | 3PSc | October | 448 | 44 |
| 2007 | 200714 | 3PSc | October | 359 | 51 |
| 2007 | 200718 | 3PSc | November | 305 | 41 |
| 2008 | 200806 | 3PSc | June | 395 | 60 |
| 2009 | 200903 | 3PSc | June | 2510 | 467 |
| 2010 | 201001 | 3PSc | May | 1022 | 243 |
| 2011 | 201101 | 3PSc | May | 811 | 186 |
| 2011 | 201102 | 3PSc | May | 152 | 31 |
| 2012 | 201201 | 3PSc | May | 963 | 135 |
| 2012 | 201204 | 3PSc | July | 634 | 76 |
| 2012 | 201205 | 3PSb | November | 743 | 92 |
| 2013 | 201301 | 3PSc | May | 1005 | 155 |
| 2013 | 201302 | 3PSa | May | 120 | 15 |
| 2013 | 201305 | 3PSb | June | 554 | 75 |
| 2013 | 201306 | 3PSc | June | 1503 | 148 |
| 2013 | 201312 | 3PSb | June | 437 | 60 |
| 2013 | 201313 | 3PSc | November | 332 | 50 |
| 2014 | 201412 | 3PSb | August | 91 | 7 |
| 2014 | 201415 | 3PSc | November | 573 | 65 |
| 2014 | 201417 | 3PSb | November | 308 | 36 |
| 2014 | 201418 | 3PSb | November | 18 | 0 |
| 2015 | 201509 | 3PSb | July | 33 | 2 |
| 2015 | 201515 | 3PSc | September | 602 | 33 |
| 2015 | 201516 | 3PSb | September | 476 | 65 |
| 2015 | 201521 | 3PSb | September | 5 | 0 |
| 2015 | 201522 | 3PSc | September | 134 | 19 |
| 2016 | 201608 | 3PSb | August | 250 | 29 |
| 2016 | 201617 | 3PSb | August | 123 | 8 |
| 2016 | 201619 | 3PSb | October | 129 | 21 |
| 2017 | 201702 | 3PSb | June | 62 | 7 |
| 2017 | 201703 | 3PSb | June | 8 | 1 |
| 2017 | 201704 | 3PSa | June | 130 | 27 |
| 2017 | 201705 | 3PSb | June | 165 | 22 |
| 2017 | 201706 | 3PSb | June | 169 | 16 |
| 2017 | 201707 | 3PSb | June | 212 | 18 |
| 2017 | 201708 | 3PSb | June | 80 | 3 |
| 2017 | 201710 | 3PSc | May | 144 | 15 |
| 2017 | 201711 | 3PSc | June | 224 | 25 |
| 2017 | 201712 | 3PSc | June | 206 | 18 |
| 2017 | 201713 | 3PSb | June | 109 | 5 |
| 2017 | 201714 | 3PSb | June | 117 | 6 |

| Year | Experiment # | Subdivision | Month | Tags deployed | Recoveries (up to 2018) |
|---|---|---|---|---|---|
| 2017 | 201715 | 3PSb | June | 109 | 12 |
| 2017 | 201716 | 3PSb | June | 105 | 9 |
| 2018 | 201804 | 3PSb | July | 359 | 2 |

Table 12: Summary of tagging experiments in 3Ps, 1954-1996

| Year | Experiment number | Subdivision | Month | Tags deployed | Recoveries (up to 2018) |
|---|---|---|---|---|---|
| 1954 | 5401 | 3PSa | April | 1361 | 423 |
| | 5402 | 3PSe | May | 1362 | 370 |
| 1963 | 6301 | 3PSh | January | 736 | 150 |
| | 6303 | 3PSa | April | 1152 | 572 |
| | 6305 | 3PSa | April | 1152 | 523 |
| | 6306 | 3PSe | May | 1152 | 366 |
| 1965 | 6503 | 3PSc | September | 384 | 208 |
| | 6504 | 3PSb | October | 384 | 173 |
| 1978 | 7805 | 3PSc | October | 105 | 0 |
| 1980 | 8001 | 3PSb | February | 2173 | 212 |
| 1986 | 8601 | 3PSa | March | 3190 | 407 |
| | 8602 | 3PSh | March | 1923 | 96 |
| | 8603 | 3PSh | March | 176 | 11 |
| | 8609 | 3PSc | September | 160 | 41 |
| 1988 | 8809 | 3PSb | August | 698 | 167 |
| | 8810 | 3PSb | August | 421 | 98 |
| | 8811 | 3PSb | August | 122 | 13 |
| 1989 | 8907 | 3PSb | August | 917 | 177 |
| 1996 | 9604 | 3Psc | June | 990 | 267 |
| | 9615 | 3Psc | July | 31 | 4 |
| | 9628 | 3Psb | October | 188 | 35 |
| | 9630 | 3Psc | September | 84 | 26 |
| | 9632 | 3Psb | September | 55 | 3 |
| | 9641 | 3Psb | November | 139 | 19 |
| | 9642 | 3Psb | October | 36 | 5 |
| | 9643 | 3Psb | November | 147 | 22 |

## SUMMARY OF MEETING CONCLUSIONS/SUGGESTIONS

From the data review, the following conclusions were made about the data types.

### French RV Survey data

It was decided that the French RV survey conducted by IFREMER will be used in the modelling exercise.

***Comments and discussion:*** *Since this survey series extends back to 1978 (compared to 1983 for the Canadian RV survey used in the SURBA model), there is the advantage of adding five additional years to the beginning of the time series. However, considering the change in the vessel used in 1992, and the absence of conversion factors between vessels, restricting the time series to 1991 is advised (Bishop et al. 1994).*

*As discussed, deep strata sampling was restricted to 1981, 1983 and 1990-1992, so corrections were made by French scientists to adjust for the missing strata over a large area. A multiplicative model based on Canadian survey catch data was used to infer what could have been caught in those deep strata. However, the computation is not clearly documented, so there is no detail about how the deep strata are incorporated into the index. Nevertheless, it was advised to use the time series of indices based on the multiplicative model (Bishop et al., 1994).*

*Meeting participants expressed interest in reanalyzing cohort strength without the 1991 outlier. It was suggested that this reanalysis may yield better agreement with the DFO results. However, it was also pointed out that random year effects are already included and the results may not change significantly due to the removal of a single outlying year. For 1991, the DFO RV data indicates a shift of cod into deeper strata. This period is notable as the time when Atlantic cod were recorded in some of these deep strata. For example, the highest DFO RV cod catches in strata 714, occurred in 1991-93. These inconsistencies may be due, in part, to differences in the gear used by the French and the DFO-RV surveys. Consideration of gear differences introduces some uncertainty into any comparison because the foot gear, the length and the sweep-lines impact catchability.*

*Historically, there have been some issues with aging differences between DFO and French RV survey data (Danny Ings personal communication). Further, age-length keys from the French survey are not available, so it is not possible to try to recreate the index calculations.*

*The consistency plots show that the juveniles are correlated across ages and the adults are correlated across ages; but the juveniles are not correlated with the adults. Meeting participants noted it may be worthwhile to check if the same pattern is seen in other surveys.*

*The  meeting concluded that the French RV survey data should be included in modelling attempts. Throughout the modelling process, we will be able to assess how the datasets are being incorporated and impacting model results. It was suggested by that incorporation of different indices will guard against the biases of the other datasets.*

**Canadian RV Survey data**

1. Given the spatial coverage of the survey before 1983 and the gear change from Yankee to Engel without conversion, it was decided not to use the indices before 1983.
2. Habitat associations – Presentation of habitat associations of cod in 3Ps resulted in further interest in exploring Colbourne and Murphy, (2008) research work on temperatures in 3Ps and it was decided to continue work on habitat associations presented at the meeting.

***Comments and discussion:*** *The Canadian RV survey was well known to all meeting participants, and discussion of this data source focussed on the issue of stratification. It was suggested by one participant that the survey may be over stratified (i.e. there are many small strata, few samples per strata, and many missing strata year to year due to weather and other issues). It was agreed that the stratification makes sense as a sampling strategy, however, it would be useful to explore re-stratification post-survey. An index based on larger strata may provide more robust results from year to year. It was also suggested that the DFO RV survey index may benefit from a smoothing factor over space and bathymetry, however participants agreed that a simple post-survey re-stratification was a more pragmatic approach. Previously analyses have found no benefits from spatial and depth smoothing because the strata include a lot of information (due to spatial autocorrelation and covariation of environmental data) that may influence fish (N Cadigan personal communication).*

*The consistency plots showed strong year to year correlations for juveniles, and within adults; but correlations between juveniles and adults were weak.*

*The inclusion of non-index strata was also considered by the meeting. There are two deep-water strata that are occasionally sampled outside the index (709 and 710). These deep strata last held significant biomass in 1993, suggesting that they are important areas during cold periods. Although sampling of the deep areas is inconsistent, strata 709 has only been missed once since 1997. Participants suggested that the inclusion of two additional strata would not be a significant analytical burden, and may be quite important to understanding variability in the stock.*

**GEAC and Sentinel surveys**
It was decided to include them in the modelling exercise

***Comments and discussion:*** *Due to the short time series available, it is difficult to assess the utility of the GEAC survey at this time. However, the meeting agreed that the data should be considered during model development.*

*The Sentinel Survey provides a time series for the inshore, however cohort tracking in the Sentinel data yields very different results than the DFO RV Survey. There were concerns if the sentinel and RV surveys were targeting surveying different parts of the stock. The meeting agreed that despite some discrepancies, the Sentinel data should be considered as a candidate tuning index. The information provided by the Sentinel survey would be particularly useful in a spatially explicit model where spatial indices could be incorporated.*

**Catch at Age**
Although catch is sampled fairly extensively over the year, there are months when there is no sampling or when an appropriate age-length key is not available for the length samples. The methodology for calculating the catch numbers at age relies on borrowing from other samples in the year. Some questions were raised at the data-review meeting with regards to whether the borrowing of age-length keys from commercial sampling should be done from nearby samples (i.e. adjoining month or quarter for the same year, gear, and unit area or the annual average for the year-gear-unit area). This needs to be investigated immediately by in-depth evaluation of our sampling coverage. Current catch at age numbers were created by using the annual average for the year-gear-unit area. If the evaluation suggests that the methodology should be changed, catch at age will be redone with the new method. Regardless of any changes in sampling coverage, decisions made for bumping up the catch will be the same throughout the time series.

**Landings**
Efforts will continue on creating the bounds for the aggregate series of catch landings. There were questions about possibility to develop upper and lower bounds separately for the inshore and offshore gears and combined bounds for the aggregate series. However, that depends on the feasibility of using the findings from the inshore fisher interviews to create bounds for the inshore fisheries and the availability of separate bounds from the offshore fisheries. The possibility to do additional interviews of the offshore fishermen to develop bounds will be considered.

**Tagging data**
Analysis of tagging data will not be included within the modelling framework.

***Comments and discussion:*** *There might be possibility to inform M in the assessment model. There is a small possibility that tagging analysis could be* *integrated into the assessment model. An alternate series for M exploration will be based on condition index. The tagging mortality estimate and the index of starvation mortality appear to be tracking similar patterns.*

## POST DATA REVIEW UPDATES

### Catch-at-age

Catch-at-age reconstruction was repeated. When commercial sampling was not sufficient to inform the length frequency within the same gear and same month, the protocol followed was to borrow data for the same gear from within the same quarter of the year. This reconstructed catch-at-age was used for the assessment model development.

### Stock weights

Up to the 2018 assessment, beginning of year adjusted commercial weights (Rivard 1980) were used as stock weights. The commercial weights-at-age were presented by gears fished for each spatial region (3Ps a-h Figure 25 **Error! Reference source not found.**). It was noted that the commercial weights were influenced by gear selectivity (see plot for 3Ps-A Figure 28-31); Weights obtained from gillnets for a given age showed different trends compared to other gears. It was decided to use stock weights based on fish weights-at-age from the RV survey (Cadigan 2023) for the assessment model.

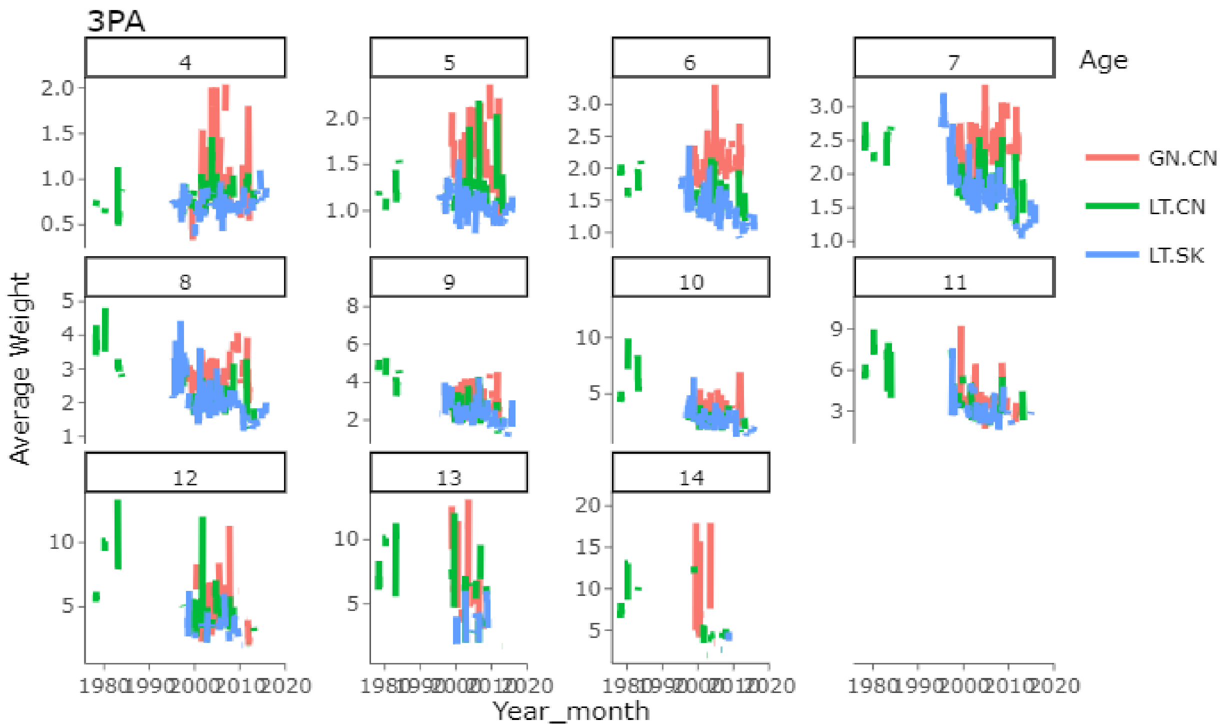


Figure 28. Average weights from commercial sampling in unit area 3PsA. GN denotes gillnet and LT denotes line trawls.

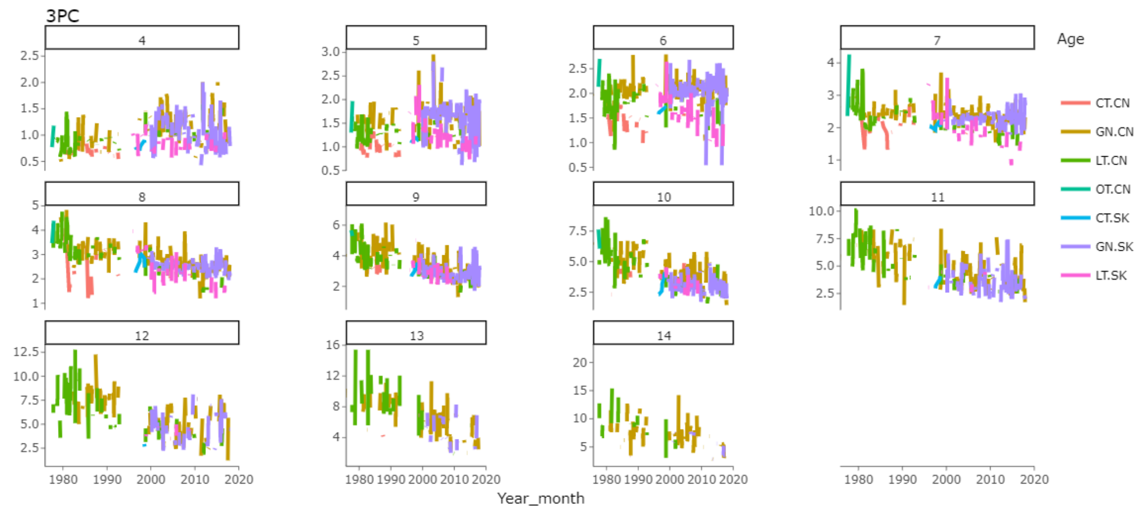


Figure 29. Average weights from commercial sampling in unit area 3PsC. GN denotes gillnet and LT denotes line trawls.

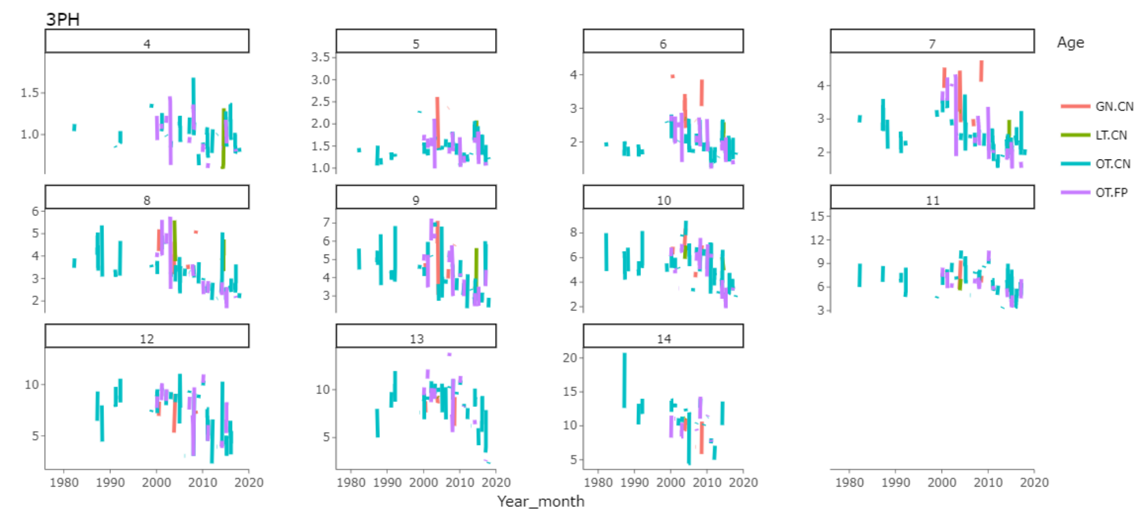


Figure 30. Average weights from commercial sampling in unit area 3PsH GN denotes gillnet, LT denotes line trawls, and OT denotes otter trawls.

**Post stratification**

One of the suggestions was to explore post-stratification of the survey indices in order to reduce the inter-annual variability in the data and to allow a balanced contribution of the different strata to the survey index. Several clustering approaches for the post-stratification were explored (Champagnat *et al.* in prep.). The results showed that post-stratification methods reduced uncertainty in the index, but did not improve the internal consistency of the index. Therefore, post stratification analyses were not pursued further.

**Spatial analyses**

Interest in spatial explorations for the stock led to further work on spatial age-length keys. A project on spatial age-length keys, supported through funds from IGS (International Governance Strategy) was initiated. We found that using the spatial age-length key reduced errors in simulations but there were not many differences between the abundance index for 3Ps cod generated from the traditional versus spatial approach (readers are directed to Babyn *et al.* 2021).

## REFERENCES

Babyn, J., Varkey, D., Regular, P., Ings, D., & Flemming, J. M. (2021). A gaussian field approach to generating spatial age length keys. Fisheries Research, 240, 105956.

Bishop, C.A., Murphy, E.F., and M.B. Davis. 1994. An assessment of the cod stock in NAFO Subdivision 3Ps. DFO Atl. Fish. Res. Doc. 1994/033, 33p.

Brattey, J., and Cadigan, N. G. 2004. Estimation of short-term tagging mortality of adult Atlantic cod (*Gadus morhua*). Fisheries Research 66: 223–233.

Brattey, J., Cadigan, N.G., Healey, B.P., Murphy, E.F., and Mahé, J. C. 2007. Assessment of the cod (Gadus morhua) stock in NAFO Subdiv. 3Ps in October 2006. DFO Can. Sci. Advis. Sec. Res. Doc. 2007/053.

Brattey, J., D. R. Porter and C. W. George. 2002. Exploitation rates and movements of Atlantic cod (*Gadus morhua*) in NAFO Subdiv. 3Ps based on tagging experiments conducted in 1997-2021. DFO Can. Sci. Advis. Sec. Res. Doc. 2002/003.

Cadigan, N. 2016. Updates to a Northern Cod (*Gadus morhua*) State-Space Integrated Assessment Model. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/022. v + 58 p.

Cadigan, N. 2023. A simple mixed-effects model to smooth and extrapolate weights-at-age for 3Ps cod. DFO Can. Sci. Advis. Sec. Res. Doc. 2023/024. iv + 49 p.

Cadigan, N. and Konrad, C. 2016. A cohort time-series Von Bertalanffy growth model for Northern cod (*Gadus morhua*), and estimation of the age of tagged cod. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/017. v+37 p.

Cadigan, N. G. 2015. A state-space stock assessment model for Northern cod, including under-reported catches and variable natural mortality rates. Can. J. Fish. Aquat. Sci. 92: 1-13.

Cadigan, N. G., and Brattey, J. 2003. Analyses of stock and fishery dynamics for cod in 3Ps and 3KL based on tagging studies in 1997 to 2002. . DFO Can. Sci. Advis. Sec. Res. Doc. 2003/037. v + 76 p.

Cadigan, N. G., and Brattey, J. 2006. Reporting and shedding rate estimates from tag-recovery experiments in Atlantic cod (*Gadus morhua*) in coastal Newfoundland. Can. J. Fish. Aquat. Sci. 63: 1944-1958.

Casini, M., Eero, M., Carlshamre, S., and Lövgren, J. 2016. Using alternative biological information in stock assessment: Condition-corrected natural mortality of Eastern Baltic cod. ICES Journal of Marine Science 73(10): 2625–2631. Oxford University Press.

Colbourne, E. B., & Murphy, E. F. (2008). Physical oceanographic conditions in NAFO Division 3P during 2007-potential influences on the distribution and abundance of Atlantic cod (Gadus morhua). Fisheries and Oceans Canada, Science.

Dutil, J.-D., and Lambert, Y. 2000. Natural mortality from poor condition in Atlantic cod (Gadus morhua). Canadian Journal of Fisheries and Aquatic Sciences 57(4): 826–836. NRC Research Press.

Healey, B. P, E.F. Murphy, J. Brattey, M. J. Morgan, D. Maddock Parsons, and J. Vigneau. 2012. Assessing the status of the cod (*Gadus morhua*) stock in NAFO Subdivision 3Ps in 2012. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/087. v + 84 p.

Konrad, C., Brattey, J. and Cadigan, N.G. 2016. Modelling temporal and spatial variability in tag reporting-rates for Newfoundland cod (*Gadus morhua*). Environ. Ecol. Stat. 23: 387.

McCallum, B. R., and S. J. Walsh 1997. Groundfish survey trawls used at the Northwest Atlantic Fisheries Centre, 1971 to Present. NAFO Sci. Coun. Studies 29: 93-104.

McClintock, J. 2007. Year Nine of the NAFO Subdivision 3Ps Fall GEAC Surveys: Catch Results for Atlantic Cod (*Gadus morhua*), American Plaice (*Hippoglossoides platessoides F.*), Witch Flounder (*Glyptocephalus cynoglossus L.),* and Haddock (*Melanogrammus aeglefinus*). DFO Can. Sci. Advis. Sec. Res. Doc. 2007/055.

Mello, L.G.S., Miri, C.M., Maddock-Parsons, D., Rockwood, H., and Simpson, M.R. 2018. Sentinel Surveys 1995-2016 – Catch rates and biological information on Atlantic Cod (Gadus morhua) in NAFO Subdivision 3Ps. DFO Can. Sci. Advis. Sec. Res. Doc. 2018/033. iv + 25 p.

Mello, L.G.S., Miri, C.M., Maddock-Parsons, D., Rockwood, H., and Simpson, M.R. 2018. Sentinel Surveys 1995-2016 – Catch rates and biological information on Atlantic Cod (Gadus morhua) in NAFO Subdivision 3Ps. DFO Can. Sci. Advis. Sec. Res. Doc. 2018/033. iv + 25 p.

Myers, R.A., Barrowman, N. J., and Hutchings, J. A. 1997. Inshore exploitation of Newfoundland Atlantic cod (*Gadus morhua*) since 1948 as estimated from mark-recapture data. Can. J. Fish. Aquat. Sci. 54(1): 224-235.

Myers, R.A., Barrowman, N.J., Hoenig, J.M., and Qu, Z. 1996. The collapse of cod in Eastern Canada: the evidence from tagging data. ICES J. Mar. Sci. 53(3): 629–640.

Rideout, R. M. and D. W. Ings. 2021. Research Vessel Bottom Trawl Survey Report (NL Region): A stock-by-stock summary of survey information up to and including the 2019 spring and autumn surveys. Can. Tech. Rep. Fish. Aquat. Sci. 3425: vii + 52 p.

Rivard, D. 1980. Back-calculating production from cohort analysis, with discussion on surplus production for two redfish stocks. CAFSAC Research Document, 80/23.

Taggart, C.T., Penney, P., Barrowman, N. and C. George. The 1954-1993 Newfoundland cod-tagging database: statistical summaries and spatial-temporal distributions. Canadian Technical Report of Fisheries and Aquatic Sciences 2042: 468p.

Warren, W. G. 1996. Report on the Comparative Fishing Trial Between the Gadus Atlantica and Teleost. NAFO SCR DOC. 96/28.

Warren, W., W. Brodie, D. Stansbury, S. Walsh, J. Morgan, and D. Orr. 1997. Analysis of the 1996 Comparative Fishing Trial between the Alfred Needier with the Engel 145 trawl and the Wilfred Templeman , with the Campelen 1800 trawl. NAFO SCR Doc. 97/68.

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| Geoff Evans | DFO Science (NL) |
| Hannah Murphy | DFO Science (NL) (Chair) |
| Heather Penney | DFO Science (NL) |
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## APPENDIX A: TERMS OF REFERENCE FOR DATA REVIEW MEETING

Background

The 3Ps stock of Atlantic cod off southern Newfoundland extends from Cape St. Mary's to just west of Burgeo Bank, and over St. Pierre Bank and most of Green Bank. Previous scientific assessments of the stock have documented (DFO 2012; DFO 2017a) the need to improve current assessment methods to provide advice on stock and fisheries status. In the past several years, there was a "strong directional retrospective pattern" in the estimates of spawning stock biomass and stock status (Rideout et al. 2017). The Survey-based modelling approach that is currently used for providing advice on the stock does not incorporate fisheries data. The assessment framework is expected to provide improved methodology to assess the cod stock.

Objectives

The objectives for the data review meeting are to document and review

1. Document and Review
    a. Survey data
        i. Canadian RV survey
        ii. French RV survey
        iii. Sentinel Survey
        iv. Industry survey
    b. Fisheries data
        i. Landings
        ii. Catch-at-age
    c. Tagging data
    d. Ecosystem influences – diet data
    e. Environmental data
2. Discuss utility of data sources for inclusion in stock assessment.

Expected Publication

1. Canadian Data Report of Fisheries and Aquatic Sciences

Expected Participation

1. Fisheries and Oceans Canada (Science, Fisheries Management)
2. IFREMER (Institut français de recherche pour l'exploitation de la mer)
3. Academics
4. NL-DFFA (Newfoundland Department of Fisheries, Forestry and Agrifoods)
5. Industry participants representing GEAC (Groundfish Enterprise Allocation Council) and FFAW (Fish, Food and Allied Workers Union).

## APPENDIX B: AGENDA FOR DATA REVIEW MEETING

Assessment Framework for 3Ps cod: Data Review
Chairperson: Hannah Murphy, DFO Science
May 2-3, 2019
Memorial Room - Northwest Atlantic Fisheries Centre 80 East White Hills Road, St. John’s

Thursday, May 2

| Time | Topic | Presenter |
|---|---|---|
| 09:00 | Opening remarks<br>Terms of Reference<br>Agenda | |
| | **Introduction to Data Review** | Divya Varkey |
| | **French ERHAPS Survey** | |
| | • Time series of survey index data | Juliette Champagnat |
| | • Index strata and spatial coverage | Juliette Champagnat |
| | • Biological data | Juliette Champagnat |
| | • Internal consistency | Juliette Champagnat |
| | • Cohort Strength Analysis | Juliette Champagnat |
| | **Canadian RV Survey** | |
| | • Time series of survey index data | Danny Ings |
| | • Index strata and spatial coverage | Danny Ings |
| | • Sampling coverage and aging | Divya Varkey |
| | • Spatial age length keys | Jonathan Babyn |
| | • Spatial distribution of cod in 3Ps | Bob Rogers |
| | • Biological data – weight/length-at-age, condition, maturity | Joanne Morgan |
| | • Biological data – ecosystem influences – diet data | Paul Regular |
| | | |
| | **Sentinel survey** | |
| | • Time series of survey index data | Luiz Mello |
| | • Spatial coverage | Luiz Mello |
| | • Index standardization | Luiz Mello |
| | **GEAC survey** | |
| | • Temporal and Spatial coverage | Divya Varkey |
| | **Survey comparisons** | Divya Varkey |

Friday, May 3

| Time | Topic | Presenter |
|---|---|---|
| 09:00 | Opening remarks<br>Agenda | |
| | **Fisheries Landings** | |
| | • Time series | Danny Ings |
| | • Accuracy of time series | Erin Carruthers and Danny Ings |
| | **Fisheries Catch-at-Age** | |
| | • Sampling | Divya Varkey |
| | • Biological data – weight/length-at-age, condition | Divya Varkey |
| | • Methodology for calculating age-composition | Heather Penney |
| | • Temporal and Spatial Coverage | Heather Penney |
| | • Stock weights | Divya Varkey |
| | **Tagging** | |
| | • Temporal and Spatial Coverage | Greg Robertson |
| | **Discussion of modelling approaches** | All |