Fisheries and Oceans Canada / Pêches et Océans Canada
Ecosystems and Oceans Science / Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat (CSAS)

Research Document 2026/012

Ontario and Prairies, Gulf, Maritimes, Newfoundland and Labrador, and Quebec Regions

Update of American Plaice (*Hippoglossoides platessoides*) in Atlantic Canada in a Species-at-Risk Context

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January 2026

Foreword

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

Published by:

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

http://www.dfo-mpo.gc.ca/csas-sccs/
DFO.CSAS-SCAS.MPO@dfo-mpo.gc.ca

ISSN 1919-5044
ISBN 978-0-660-97831-4 Cat. No. Fs70-5/2026-012E-PDF

Correct citation for this publication:

Wheeland, L., Atchison, S., Belanger, D., Collins, R., Cyr, F., Galbraith, P.S., Gauthier, J., Koen-Alonso, M., Morrissey, K., Morgan, M.J., Munro, H.J., Ouellette-Plante, J., Pretty, C., Ricard, D., Rogers, B., Simpson, M., Themelis, D., Walkusz, W., and Wells, N. 2026. Update of American Plaice (*Hippoglossoides platessoides*) in Atlantic Canada in a Species-at-Risk Context. DFO Can. Sci. Advis. Sec. Res. Doc. 2026/012. vi + 157 p.

Aussi disponible en français :

*Wheeland, L., Atchison, S., Belanger, D., Collins, R., Cyr, F., Galbraith, P.S., Gauthier, J., Koen-Alonso, M., Morrissey, K., Morgan, M.J., Munro, H.J., Ouellette-Plante, J., Pretty, C., Ricard, D., Rogers, B., Simpson, M., Themelis, D., Walkusz, W. et Wells, N. 2026. Mise à jour sur la plie canadienne (*Hippoglossoides platessoides*) au Canada atlantique dans le contexte des espèces en péril. Secr. can. des avis sci. du MPO. Doc. de rech. 2026/012. vi + 164 p.*

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ABSTRACT

The status of American Plaice (*Hippoglossoides platessoides*) in Canadian waters was reviewed by Fisheries and Oceans Canada (DFO) under a species at risk context for the Committee on the Status of Endangered Wildlife in Canada. This paper results from a zonal assessment process held October 22-23, 2019 and provides an update of information and indices for American Plaice produced previously by DFO (Busby et al. 2007) and COSEWIC (2009).

INTRODUCTION

The status of American Plaice (*Hippoglossoides platessoides*) in a species at risk context in Canadian waters was previously reviewed by Fisheries and Oceans Canada (DFO) under the terms of reference for the Committee on the Status of Endangered Wildlife in Canada (COSEWIC; Busby et al. 2007). Following that review, COSEWIC conducted an assessment and concluded that American Plaice in Canadian waters are composed of three Designatable Units (DUs; Figure 1): Newfoundland & Labrador (NL) and the Maritime DUs, both of which were designated as Threatened due to declines in abundance; and the Arctic DU, which was assessed as data deficient (COSEWIC 2009). This paper contributes new information and updates pre-existing information (e.g., Busby et al. 2007) and indices provided in earlier documents.

REVIEW OF DESIGNATABLE UNITS

Following the 2009 COSEWIC assessment, and based upon their criteria of discreteness and significance, COSEWIC established three DUs: NL, Maritime, and Arctic (Figure 1). The NL DU extends from Hudson Strait and Cape Chidley southeast to the Grand Bank and west to Cape Ray. The Maritime DU includes the Gulf of St. Lawrence (GSL), the Scotian Shelf, and Bay of Fundy. The Arctic DU includes the waters east of Baffin Island, extending from Hudson Strait to northern Baffin Bay.

However, Busby et al. (2007) had conducted a detailed review of the life history traits and geographic distribution of American Plaice and concluded that the population boundaries for American Plaice in Canadian waters generally follow the Northwest Atlantic Fisheries Organization (NAFO) management units (Figure 2). Given no new evidence to contest this conclusion, analyses here are presented by management unit–consistent with Busby et al (2007)—and/or geographic area. These areas are:

- Baffin Bay and Davis Strait (SA 0), Ungava Bay
- Labrador and Northeast Newfoundland (SA 2 + Division (Div). 3K)
- Newfoundland Grand Bank (Divs. 3LNO)
- Southern Newfoundland (Subdiv. 3Ps) and Subdiv. 3Pn
- Northern Gulf of St. Lawrence (Divs. 4RS)
- Southern Gulf of St. Lawrence (Div. 4T)
- Scotian Shelf & Bay of Fundy (Divs. 4VWX5Y)
- George's Bank (Div. 5Z)

BIOLOGICAL CHARACTERISTICS

There have been no changes or new information in regard to the taxonomic nomenclature, morphological description, or genetics of American Plaice since the publications by Busby et al. (2007) and COSEWIC (2009). In addition, there is no new research to allow for an update of American Plaice habitat requirements in Canadian waters (salinity, temperature, sediments, temperature, depth, oxygen), prey availability, or seasonality. Busby et al (2007) and COSEWIC (2009) provide a complete review of American Plaice biology and life history, information on life cycle and reproduction, natural mortality, generation time, spawning, feeding behaviour, physiology, migration and dispersal, and interspecific interactions. Updates to biological characteristics, where available, are presented below by DFO Atlantic Regions and/or management unit.

SPAWNING AREAS

No spawning grounds have yet been detected in the northern GSL (NGSL), but the presence of American Plaice eggs and larvae in different areas and across multiple years would indicate that this species does spawn there (Able 1978; Bui et al. 2010; Grégoire et al. 2006, 2009, and 2011).

Spawning areas in other regions are discussed in Busby et al. 2007.

CONCEPT OF RESIDENCE

Canada's *Species at Risk Act* defines "residence" as: "a dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating" (s.2[1]).

The DFO "Directive on the Application of *Species at Risk Act* Section 33 (Residence) to Aquatic Species at Risk" (January 2015) states that the following four conditions will be used to determine whether the concept of residence applies to an aquatic species at risk:

1. There is a discrete dwelling-place that has structural form and function similar to a den or nest or other similar area;
2. An individual of the species has made an investment in the creation and/or modification of the dwelling-place;
3. The dwelling-place has the functional capacity to support the successful performance of an essential life-cycle process such as spawning, breeding, nursing, and rearing; and
4. The dwelling-place is occupied by one or more individuals during one or more parts of their life cycle.

Based on the above criteria, the concept of residence does not apply to American Plaice.

HABITAT

An overview of known American Plaice habitat requirements and associations is provided in Busby et al. 2007. Updated information on oceanographic conditions throughout the Canadian range of American Plaice is provided here, and for habitat in the NGSL.

PHYSICAL OCEANOGRAPHY OF THE ATLANTIC REGION

The North Atlantic Oscillation (NAO) is calculated as the anomaly in the sea-level pressure (SLP) difference between the sub-tropical high (average location near the Azores) and the sub-polar low (average location near Iceland). The NAO is commonly used to study the variations in the North Atlantic climate. The winter NAO (here defined as the average over the months of December, January, and February) is also a good measure of the strength of the winter westerly and north westerly winds over the Northwest Atlantic. Except for some years for which the SLP patterns are spatially shifted (e.g., 1999, 2000, and 2018), positive winter NAO years favor strong northwest winds, heavy ice conditions, and cold air and sea temperatures in Atlantic Canada.

Except for a short period in the mid-1970s there is a clear predominance of negative NAO (warmer climate) before the 1980s (with the warm peak in the 1960s) (Figure 3) while the mid-1980s to the mid-1990s are characterized by a positive (cold) NAO phase that, as shown later, also corresponds to cold water conditions in the Northwest Atlantic. The cold phase reversed in the early-2010s (with 2010 being the most negative anomaly of the time series and one of the warmest winters on record). Since 2012, however, a succession of positive winter NAO indices (with 2015 the record-high of this 70-year time series) have caused a cooling of the water properties and an increase in the formation of cold Labrador Sea water that is similar to what was observed in the early-1990s (Yashayev and Loder 2017).

The air temperature for five sites around the Northwest Atlantic (Figure 4, Figure 5) generally follows the NAO index patterns described above, with colder periods in the mid-1970s and early-1990s, and a warm period from the mid-2000s to the mid-2010s. During recent years, 2010 stands as the warmest year on record for these sites and 2015 the coldest.

Sea surface temperature (SST) generally follows the air temperature. They are presented here as averages over NAFO Divs. (boxes are slightly modified from original NAFO boundaries, see Figure 5) and displayed as a scorecard picturing their annual standardized anomaly (i.e., departure expressed in standard deviation above or below the 1982–2010 climatological average). These regions are vertically organized from north to south for a better reading. The scorecards are summarized in Figure 6 where five of the regions studied in this report are presented (NGSL and southern GSL [SGSL] have been grouped together, while Baffin Bay and Davis Strait, as well as Georges Bank, are not considered). This figure shows the dominance of negative anomalies (cold SSTs) in the first half of the time series (before ~1994) followed by warmer anomalies, consistent with the NAO and air temperature presented above. Figure 6 and Figure 7 also show that in the recent years, the NL shelves have generally experienced colder than averaged sea surface conditions while the GSL, the Scotian Shelves and the Gulf of Maine have exhibited their warmest anomalies of the time series. This difference may highlight different environmental regimes between the regions on the north of the Grand Banks and the rest of the zone.

Sea bottom temperature will also respond to large-scale forcing (NAO, air temperature, etc.), but with a slower response time, especially in deeper areas. Figure 8 and Figure 9 present the bottom temperature anomalies derived from water column observations of various origin interpolated over a regular grid (see Cyr et al. 2019 for the methodology). Since the regions are organized vertically from north to south, it is sometimes possible to see the propagation of the cold signal from one year to the other (for example the predominance of cold anomalies in the northern areas in the late-1980s will translate to a predominance of cold anomalies in the south in the early-1990s). Again, these scorecards are summarized in a stacked bar plot for the same larger region studied in this report (Figure 9), and shows how bottom temperature condition varies on decadal time scales, with the early-1990s being coldest and the early-2010s being warmest.

BIOGEOCHEMICAL OCEANOGRAPHY OF THE ATLANTIC REGION

Since the last COSEWIC assessment in 2009, nitrate (Figure 10) and chlorophyll a (Figure 11) concentrations have remained mostly near or below the 1999–2015 climatological average across the Canadian Northwest Atlantic. In 2018, nitrate concentration was near normal on the Newfoundland Shelf, and below normal on the Grand bank, GSL, and Scotian Shelf, with second lowest levels for the time series in the latter two regions. Chlorophyll a concentration in the first 100 m of the water column recently increased to above normal levels on the Newfoundland Shelf and the Grand Bank but has remained mostly near or above normal in the GSL, and below normal on the Scotian shelf for the past ten years.

Zooplankton abundance (Figure 12) has remained mostly above normal on the Newfoundland Shelf and the Grand Bank since 2010 with particularly high levels since 2015–16. In the GSL and on the Scotian Shelf, high zooplankton abundances observed between 2014 and 2016 decreased to near or below normal levels in 2018. Zooplankton biomass (Figure 13) on the Newfoundland Shelf fluctuated above and below normal levels since the last assessment and reached a time series record high in 2018. On the Grand Bank, biomass constantly increased between 2014 and 2017 and remained above normal in 2018 with the second highest anomaly of the time series. In the GSL, biomass has remained mostly near or below normal over the past 10 years with particularly low levels in the Gulf since 2015. On the Scotian Shelf, biomass has remained near normal for all but three years (2013–15) since 2004.

Ungava Bay

Shrimp Fishing Area (SFA) 3 is comprised of two geographic areas; eastern Hudson Strait to the north and Ungava Bay to the south (Figure 7). Eastern Hudson Strait is a fairly deep channel ranging from 100–1,000 m with a deep trough (1,000 m) near the easternmost opening towards the Labrador Sea (Drinkwater 1986). Ungava Bay is a large shallow bay (less than 150 m deep) with a channel (200-450 m deep) running near Akpatok Island in the middle of the bay, east towards the opening to the Labrador Sea (Cobb 2011, Drinkwater 1986).

Surface current flow in eastern Hudson Strait is influenced by the strong Labrador Current that flows south along the coast of Baffin Island and then turns northwest and flows along the northern portion of the strait (Figure 14; Drinkwater 1986). There is also a current that flows southeast from the Hudson Bay complex, along the southern portion of the strait into the Labrador Sea (Drinkwater 1986). A portion of the current that flows southeast passes through Ungava Bay in an anticlockwise (cyclonic) pattern along the southernmost part of the bay before exiting into the Labrador Sea (Drinkwater 1986).

HABITAT IN THE NORTHERN GULF OF ST. LAWRENCE

Cumulative frequency curves of American Plaice catches ($kg \cdot tow^{-1}$) in terms of depth, temperature, dissolved oxygen, and salinity were created to compare the last five years (2014–18) with earlier data. The method outlined in Perry and Smith (1994) was used for these analyses.

The NGSL survey has covered an area with depths ranging from 38 to 525 m. For both periods considered (1984–2013 and 2014–18), the majority of American Plaice were caught between 100 m and 275 m (Figure 15A). Over these two periods there has been a warming of the deep waters of the GSL (Figure 15B). Hence American Plaice are caught at the same depths in the NGSL but in warmer waters. The survey data indicate that 50% of the sets were completed at temperatures of ~5°C and less for the period 1984–2013 whereas it reached ~5.5°C for the period 2014–18. This results in 50 % of cumulative catches being caught at ~3°C or less for 2014–18 compared to ~2°C for the period 1984–2013.

Salinity data are available for the period 1987–2018 with the exception of 1996. Catches are reported for stations with salinities ranging from 31 to nearly 35 PSU (Practical Salinity Unit). Salinity has increased in the survey area over two periods (Figure 15C), 50% of cumulative catch are reached below the ~34.4 PSU mark for the period 2014–18, compared to ~34.2 PSU for the period 1987–2013.

Catches are reported for stations with oxygen levels ranging from 51 to over 360 $\mu mol \cdot L^{-1}$ (Figure 15D). Although dissolved oxygen data are available only since 2004 for the NGSL surveys, a diminution for the period 2014–18 compared to 2004–13 is observed, which is consistent with the results of Blais et al. (2019). In fact, the survey data indicate that 50% of sets were done at oxygen levels of ~150 μmol·L^{-1} and less for the period 2004–13, whereas this 50% mark dropped to ~140 μmol·L^{-1} for the period 2014–18. In terms of catches, 50% of cumulative catch is reached below the ~190 μmol·L^{-1} mark for the period 2014–18, compared to ~225 μmol·L^{-1} for the period 2004–13.

In the early-2010s, Dutil et al. (2011) developed a sea-bottom classification system for the GSL. In short, their study took into account various geo-referenced physicochemical data (temperature, dissolved oxygen, slope, sediments, etc.) and interpolated this information over a grid made up of 100 km^2 cells. Using cluster analyses, cells were grouped into 13 different megahabitats. Additional work was subsequently carried out to link these megahabitats to the distribution of different species, including that of American Plaice (Dutil et al. 2013).

Although found over a very large part of NGSL, American Plaice are highly associated with a habitat characterized by shallow and cold coastal locations, with this area of the Gulf characterized by an average bathymetry of about 65 m and a temperature approaching 0.5°C ("megahabitat J", Dutil et al 2013). Although this type of habitat is present in the SGSL (31,400 km^2), its presence is non-negligible in the NGSL (4,809 km^2, Dutil et al. 2011). Good examples are the areas adjacent to the eastern tip of Anticosti Island and the west coast of Newfoundland. Given the fact that the NGSL is mainly characterized by deep megahabitats where American Plaice are less present, reduced areas of megahabitat J (<4 % of the NGSL) is of great importance for the species in this area.

GROWTH PARAMETERS

Newfoundland & Labrador (NAFO Divs. 2HJ3KLNOPs)

Updated length at maturity (L50) values are presented for stocks in NL (Figure 16, Figure 17). L50 was calculated from annual length-based maturity ogives for Subarea (SA) 2+ Div. 3K and Subdivision (Subdiv.) 3Ps, and from a cohort model in Divs. 3LNO. Males reach maturity at a significantly smaller size than females. L50 in 2+3K and 3Ps has been relatively stable through the time series following an initial decline observed in both stocks. However, decreases in L50 have been ongoing since 2012–13, with observed decreases in Divs. 2+3K from near 18 cm to 12.6 cm and 32–33 cm to 31 cm for males and females, respectively, and near 19 cm to 16 cm and 37–38 cm to 34 cm in 3Ps. In Divs. 3LNO, L50 declined for both sexes but recovered somewhat in recent cohorts. For males, the recent L50 of about 19 cm is 3–4 cm lower than the earliest cohorts estimated. The L50 of most recent cohorts for females is in the range of 33–35 cm, somewhat lower than the 39 cm of the earliest cohorts.

In 3LNO males, age at 50% maturity (A50) was fairly stable for cohorts of the 1960s to mid-1970s, with perhaps a slight increase over that time period. Male A50 then began a fairly steady decline to the 1991 cohort which had an A50 just over 3 years. Male A50 has increased somewhat but is still below values from the 1960s and 1970s, with an A50 of about 4 years compared to 6 years at the beginning of the time series (Figure 17). For females, estimates of A50 have shown a large, almost continuous decline, from the beginning of the time series to about 1990. For cohorts since then, females have had a fairly constant A50 of 7.5–8 years compared to 11 years for cohorts at the beginning of the time series. Recent aging data are not available for all stocks therefore updates on A50 are not provided for the stocks in SA 2 + 3K or Subdiv. 3Ps.

DIET

Newfoundland & Labrador (NAFO Divs. 2HJ3KLNOPs)

The diet of American Plaice across Ecosystem Production Units (EPUs) and time was assessed on the basis of stomach contents collected during DFO Research Vessel (RV) fall and spring surveys. These EPUs correspond to the management units associated with the Northeast NL Shelf (SA 2+ Div. 3K), Grand Bank (Divs. 3LNO), and St. Pierre Bank (Subdiv. 3Ps, Figure 18). Description of diets is based on stomach content analysis and integrates historical data with the information collected by the current DFO NL Ecosystem Research Program since 2008. Prior to 2008, stomach content collections were not carried out on a systematic and continuous basis, but sufficient years and regions were available to provide a contrast between pre-collapse (prior to the early-1990s) and more recent periods (Table 1).

Overall, the diet composition (considered here as proportion of stomach content by weight) of American Plaice has been generally dominated by forage fishes like Capelin (*Mallotus villosus*) and Sandlance (*Ammodytes spp.*), as well as ophiuroids (brittle/basket stars), and other echinoderms. However, there are some clear differences among EPUs and over time (Figure 19). Note that the following does not explicitly account for potential differences in consumption introduced by variation in fish size between areas or across years. However, data presented here are considered representative for broad scale comparisons.

While there are only two years of data available, the fall diet on the Newfoundland Shelf EPU (Divs. 2J3K) during the pre-collapse period shows Capelin and brittle/basket stars as dominant prey items. When the stomach content sampling was re-started in 2008, the diet was highly dominated by pandalid shrimp (*Pandalus* spp.), at a time where shellfish (with pandalid shrimps as main component) was a dominant functional group within the community (see CHANGES TO ECOSYSTEMS). The dominance of shrimp in the diet declined as shellfish declined in the ecosystem, with Capelin increasing in the diet between 2008 and 2013; this period also coincided with the build-up in large benthivore (including American Plaice) biomass. After 2013, pandalid shrimp and Capelin declined in the diet, with a diversity of other prey items (Arctic Cod [*Boreogadus saida*], blennies, polychaetes, amphipods, and other invertebrates) appearing as more even contributors to the diet (Figure 19). The diet of American Plaice in 2J3K showed, in comparison with the other EPUs, a higher dominance of invertebrates, especially in the late-2000s (Figure 19).

The Grand Bank (3LNO) is the only EPU where seasonal diets can be compared. Prey items are fairly consistent between seasons and over time (i.e., Capelin and sandlance as main forage fishes, brittle and basket stars, other echinoderms, and bivalves as main invertebrate prey categories); however, the fish component of the diet during the pre-collapse period appears more dominated by Capelin, while sandlance appears as more dominant in the more recent period (Figure 19). Further to its lesser overall dominance, there seems to be a slightly increasing trend of Capelin in the diet between the late-2000s and mid-2010s, and a decrease afterwards. This pattern in Capelin consumption between 2008 and 2019 is consistent with the signal observed in NAFO Divs. 2J3K. In terms of seasonal diet changes, the most obvious difference is that the dominance of fish prey items is higher in the spring, while there is a large fraction of invertebrates in the fall diet when brittle/basket stars and bivalves are the dominant prey categories (Figure 19).

For the Southern Newfoundland (3Ps) EPU the available data only covers spring diets during recent years. Here the diet of American Plaice has been highly dominated by sandlance, brittlestars, and basket stars; Capelin represents a very small fraction of the diet in 3Ps (Figure 19).

SURVEY EFFORT

BAFFIN BAY AND DAVIS STRAIT (SA 0), UNGAVA BAY

Data used to evaluate American Plaice in the Eastern Arctic (Baffin Bay and Davis Strait [SA 0], Ungava Bay) is taken from two separate surveys and have been compiled in this report to aid in assessing population sizes and trends. Note that depths and gear vary between these surveys (see below) and some may be more informative than others for American Plaice population size and trends in SA 0 and Ungava Bay. Note that there is no fishery for American Plaice in SA 0 or Ungava Bay and therefore no defined stocks for management purposes. Boundaries of NAFO SA 0 and SFAs 0–3 are shown in Figure 20.

SUBAREA 0 (BAFFIN BAY AND DAVIS STRAIT)

Since 1999, DFO has conducted multi-species, stratified random, bottom trawl surveys to assess stocks of Greenland Halibut (*Reinhardtius hippoglossoides*) in Subarea 0 (Divs. 0A and 0B; Figure 20; Table 2). Surveys were conducted at depths of 400 m to 1,500 m in the fall aboard the Greenland Institute of Natural Resources (GINR) RV *Pâmiut* using an Alfredo III trawl (mesh size of 140 mm with a 30 mm mesh-liner in the codend). Detailed descriptions of the survey methods can be found in Treble (2018).

Since 1999 changes in the overall survey area (e.g., due to closed areas) has resulted in changes to, or removal of, strata areas. In order to standardize the survey design across years changes in strata areas have been applied to previous years post-hoc and all strata and sets used for the biomass and abundance indices are standardized throughout the time series. However, successful sets that fall outside these indexed parameters may contain useful biological information and are used for non-indexed information (e.g., distribution).

Each Division has separate stratification schemes (Figure 8) and Division 0A has been further split into northern (N-0A, north of 72˚N) and southern (S-0A) portions. N-0A has been surveyed less frequently than S-0A and 0B. Surveys in N-0A took place in 2004, 2010, and 2012, while surveys in S-0A took place in 1999, 2001, every second year from 2004–14, and annually from 2015–17. Surveys in 0B took place in 2000, 2001, 2011, and annually from 2013 to 2016. The N-0A survey data is not used to develop a stock index; therefore, the survey stratification scheme is not presented for this area.

SFAS 0 TO 3 (BAFFIN BAY, DAVIS STRAIT, UNGAVA BAY)

Since 2005, multi-species, stratified random, bottom trawl surveys have been conducted by DFO to assess stocks of Northern and Striped Shrimp (*Pandalus borealis* and *P. montagui*) in Shrimp Fishing Areas (SFAs) 0 to 3 (Figure 20; Table 3). Detailed descriptions of the survey methods can be found in Siferd (2015) and DFO (2019a).

Figure 21 to Figure 23 show maps of scientific survey areas within SFAS 0 to 3 from which data were examined for American plaice. In SFAs 0 and 1 survey data were collected from the Greenland Institute of Natural Resources RV *Pâmiut* using a Cosmos 2000 shrimp trawl (20 mm codend mesh) from 100 m to 800 m depth. Surveys were conducted in SFA 0 in 2006 and 2008, and in SFA 1 every second year from 2006–12. The SFA 0 and 1 survey data is not used to develop a stock index, data are used only in the distribution plot; therefore, the survey stratification schemes are not presented.

Prior to 2014 surveys in SFA3 were conducted every second year (2007–13) from the GINR RV *Pâmiut*, using the Cosmos 2000 shrimp trawl (20 mm codend mesh). The 2007–13 surveys used the same stratification scheme used today (100–750 m, Figure 22) with an additional 750–

1,000 m strata. Data from the 750–1,000 m strata is not used for abundance and biomass calculations but is used for distribution.

In SFA 2 (2005 to 2018) and SFA 3 (2014–18), surveys have been conducted by the Northern Shrimp Research Foundation (NSRF), with survey plans developed by DFO Science (Figure 10). Surveys were conducted from 100 to 750 m depth using different vessel platforms: F/V *Cape Ballard* (2005–11), F/V *Kinguk* (2014), F/V *Katsheshuk II* (2015), and F/V *Aqviq* (2012, 2013, 2016–18). The impact of changes in vessel to gear catchability have not been investigated.

From 2005–07 a standard Campelen 1800 shrimp trawl (12.7 mm codend mesh) was used for the NSRF surveys. However, high incidences of trawl damage due to rough bottom led to modifications in trawl design, including increased footgear size and additional floatation on the fishing line and lower belly seams. Flume tank tests found that these modifications did not severely affect trawl geometry (Siferd and Legge 2014). The modified Campelen 1800 shrimp trawl has been used since 2008 in SFA 2 and 2014 in SFA 3.

Conversion factors between vessel and gear types have not been established. These data are not used to develop a stock index but are included in distribution plots (see DISTRIBUTION).

NEWFOUNDLAND & LABRADOR (NAFO DIVS. 2HJ3KLNOPS)

Annual multi-species, stratified random, bottom trawl surveys (Figure 24) are conducted by DFO in NAFO Divs. 2HJ3KLNO in the fall (September through December) and 3LNOPs in the spring (April to June). Detailed descriptions of the surveys can be found in Walsh et al. (2004), Brodie (2005) and Brodie and Stansbury (2007). The survey is stratified based on depth, and the allocation of sets proportional to stratum area within a Division, with a minimum of two sets in all strata. A description of the basic survey design and protocol can be found in Doubleday (1981).

Survey coverage in both the spring and fall has varied over the series, with coverage issues often resulting from mechanical issues with the survey vessels. Years with significant survey coverage reductions have been omitted from analyses herein. These include for spring: Divs. 3LNO in 2006, 2015, and 2017; Subdiv. 3Ps in 2006; and in the fall: Divs. 3LNO in 2004 and 2014. Specific coverage issues in each of these years, and impact on various indices, have been summarized elsewhere (Rideout et al. 2017; Rideout and Wheeland 2019). Coverage of the deep water (>730 m) strata in Div. 3L in the fall has been inconsistent; this area has only been fully sampled in four years since 2004 (2007, 2009, 2010, and 2014).

Fall surveys began in 1977 covering a portion of 2J3K and has since expanded to include the offshore portions of Div. SA2+Divs. 3KLNO. Coverage by Division and depth has varied over time. The deep water (>730 m) in Divs. 3NO was only surveyed in 2000–03, 2005, 2007, and 2009. Div. 2G was only surveyed from 1996 to 1999, while Div. 2H has been surveyed since 1996 with the exception of 2000, 2002, 2003, 2005, 2007, and 2009. Following a period of consistent coverage from 1996–2006 (1999 excluded), inshore strata in Divs. 2J3K have been largely incomplete each year to 2018, and are no longer allocated in the survey. The number of survey sets completed each year, by season and Division, is summarized in Table 4.

Four vessels, and three different trawls have been used through the survey time series. In the fall of 1995, the Canadian Coast Guard Ship (CCGS) *Gadus Atlantica* was replaced by the CCGS *Teleost*, and the Engel 145 trawls were replaced with a Campelen 1800 shrimp trawl. The CCGS *W. Templeman* operated until 1995 when it was replaced with the CCGS *Alfred Needler*. The Campelen trawl has been identified as having increased catch efficiency, particularly for smaller fish in some species (Warren et al. 1997; Power and Orr 2001). To address this, conversion factors have been derived for American Plaice from comparative fishing experiments to allow comparability between surveys completed with the Engel and Campelen trawls (Warren 1997; Warren et al. 1997; Morgan et al. 1998). Indices shown within this document for NL stocks are Campelen equivalent unless otherwise stated.

Stratified-random surveys have been conducted by DFO in Subdiv. 3Ps in the spring of each year from 1972 to 2018, with the exception of 2006. Coverage prior to 1980 was limited. Most of the surveys prior to 1993 were in February and March, while those since 1993 have typically been in April and May. There were two surveys in 1993, one in February and one in April. The data can be split into three time periods based on the trawl used in each period: 1971 to 1982 used a Yankee 36 trawl, 1983 to 1995 used an Engel 145 trawl, and since 1996 surveys have been completed with the Campelen 1800 trawl. There is a conversion factor between the Engel and Campelen gears (Morgan et al. 1998) but not the Yankee to Campelen , therefore survey points prior to 1983 are not comparable to current surveys.

Since 2013, the survey in Subdiv. 3Pn has not been completed.

The previous pre-COSEWIC assessment of this species used index strata for the NL Region. The deep-water strata (>730 m) where coverage has been inconsistent were excluded from analyses, as well as the inshore strata which are no longer allocated. For consistency with individual stock assessments, the most representative analyses of geographic distribution, and given the small difference in indices of abundance between index and all strata analyses (Busby et al. 2007), all completed survey strata have been included here.

CANADIAN JUVENILE GROUNDFISH SURVEYS (DIVS. 3LNO)

Annual juvenile groundfish surveys of the Grand Bank (Divs. 3LNO) were conducted from 1985 to 1994 to investigate the distribution of juvenile Yellowtail Flounder *Pleuronectes ferruginea* and American Plaice. The survey covered depths inside the 91 m depth contour from 1985 to 1988, were extended to 183 m from 1989 to 1991, and further to 273 m in the 1992 to 1994 surveys. These surveys aboard the RV *Wilfred Templeman*, a 50 m stern trawler (Morgan et al. 1997) used a stratified random sampling design similar to that used in the annual spring and fall multi-species surveys of the Grand Bank. The survey gear was a twobridle- Yankee 41 shrimp trawl with a mesh size of 38 mm throughout and included a 12 mm stretched mesh liner inside the codend (see McCallum and Walsh 1996 for details). The surveys were generally conducted from mid August to mid- September- in the 1985–86 and 1988–93 periods, early November in 1987, and September-October in 1994. After the gear change in the multi-species surveys (above) to Campelen in 1995 the juvenile surveys were discontinued because the new gear adequately sampled juvenile fish.

NORTHERN GULF OF ST. LAWRENCE (DIVS. 4RST)

DFO has conducted annual summer surveys of the NGSL since 1984. Survey protocols are described in Bourdages et al. (2019). These surveys are designated according to a stratified random sampling design (Doubleday and Rivard 1981), with strata (Figure 25) defined based on depth, NAFO Division, and bottom substrate.

The core objective is to assess the abundance and geographical distribution of the main commercial species (Bourdages and Ouellet 2011; Bourdages et al. 2019). This annual survey covers the NAFO Divs. 4RS, and the northernmost part of Div. 4T, which is mainly monitored by the Gulf Region. To prevent duplication of the data with those of the Gulf Region, deep strata (>200 m) in 4T that were covered by the southern Gulf survey were either removed when wholly overlapping (strata 401, 402, and 404) or reduced in area (strata 403, 405–408) in analyses.

For the period 1984–1990, the NGSL survey was completed by the *Lady Hammond* using a Western IIA trawl with a codend liner mesh size of 33/19 mm. From 1990 to 2005 the survey was conducted by the CCGS *Alfred Needler* equipped with a URI (University of Rhode Island) 81'/114' shrimp trawl and a codend liner mesh size of 19 mm. Since 2004, the survey has been carried out by the *CCGS Teleost* using a Campelen shrimp trawl with a codend liner of 12.7 mm (Nozères et al. 2015).

Comparative fishing experiments were conducted in 1990 between the *Lady Hammond*-Western IIA and *Alfred Needler*-URI (Gascon et al. 1991, Appendix A), and in 2004–05 between the *Alfred Needler*-URI and *Teleost*-Campelen (Bourdages et al. 2007). A multiplicative factor of 3.28 is applied to the catches of the *Alfred* Needler/URI to convert those into Lady *Hammond* / Western IIA equivalent, while a length-dependent conversion is used to convert *Alfred Needler* / URI and *Teleost* / Campelen (Bourdages et al. 2007). These conversions are used to produce the NGSL 1985–2018 summer survey series index of abundance in *Lady Hammond*–Western IIA equivalent units presented here. A single year, 1984, was excluded from analyses because of data issues (Figure 26). Only strata consistently covered over the time series were included in the index of abundance (Figure 25). Over the years, the minimum requirement of two successful tows was not reached in some strata. A multiplicative model has been applied to such year-stratum cells, providing a predicted value for year-stratum cells based on the data of the current year and neighboring years where these strata were sampled.

Indices of abundance were produced for total American Plaice population, as well as for mature and immature stages. Information used to differentiate immature and mature components of the total population is based on Gulf Region length at maturity data. Female of total length ≥26 cm and male of ≥19 cm were considered mature (DFO 2011). Indices for mature and immature components of the American Plaice population are available starting in 1987, since length data were not collected for the 1984–1986 period.

SOUTHERN GULF OF ST. LAWRENCE (DIV. 4T)

Surveys of the SGSL (Div. 4T) have been conducted every September since 1971. This survey has been administered by the DFO Gulf Region since 1982. Survey protocols are described by Hurlbut and Clay (1990). The southern Gulf survey area is divided into 24 strata (Figure 27). Three inshore strata were added in 1984, but these are not used in analyses of American Plaice.

Four research trawlers have been used in this survey: the *E.E. Prince* from 1971–85, the *Lady Hammond* from 1985–91, the *Alfred Needler* from 1991–2005, and the *Teleost* since 2004. Two changes have been made to the fishing gear: the Yankee 36 trawl was used until 1985, when it was replaced by the Western IIA trawl. Surveys conducted prior to 1985 operated during daylight hours only while later surveys have been conducted on a 24-hour a day fishing schedule. Comparative fishing experiments were conducted in 1985, 1992, and during 2004 and 2005 to establish the conversion factors required to maintain continuity in the time-series (Benoît and Swain 2003; Benoît 2006). Unlike other flatfish species in the southern Gulf, no diel variation in the catchability of American Plaice was detected.

The 2003 survey has been excluded from analyses of abundance and area of occupancy because an uncalibrated research trawler was used.

SCOTIAN SHELF, BAY OF FUNDY & GEORGE'S BANK ECOSYSTEM SURVEYS (DIVS. 4VW, 4X5Y, 5Z)

Data from three time series of annual stratified random bottom surveys are available for reviewing trends in American Plaice abundance and biomass in the DFO Maritimes Region (i.e., Scotian Shelf, Bay of Fundy, and Georges Bank).

The 4VWX summer RV survey has been conducted annually on the Scotian Shelf (Divs. 4VWX5Yb) since 1970, using a stratified random design (Figure 28). Forty five survey strata grouped into three categories based on depth (<92 m, 92–181 m, and >181 m) have been sampled during the series. Various vessels and trawl types (primarily Western IIA), with potentially different catchabilities, were used over the span of this survey (see Claytor et al. [2014] for details). Since 1982, the primary vessel has been the CCGS *Alfred Needler* deploying a Western IIA trawl with a 2 cm stretched mesh codend liner. At least two sets have been completed in every stratum since 1970 with the exception of 2018, when none of 4V (eastern Scotian Shelf) and most of 4W was not surveyed.

Between 1986 and 2010, the eastern Scotian Shelf was sampled by the 4VsW survey (Figure 29) during March using a Western IIA trawl. This survey did not include all of Divs. 4VW and used a stratification scheme differing from that of the 4VWX summer survey.

The February/March RV survey on Georges Bank (Div. 5Z) has occurred annually since 1987, using a Western IIA trawl and a stratified random design (Figure 30). This survey concentrates on the Canadian side of the bank with some additional sets in American waters just outside, and adjacent to Canada's Exclusive Economic Zone (EEZ) boundary (5Z 1–4). In recent years, (2012, 2014, 2016, 2018) sampling has extended north into the Bay of Fundy (4X5Y), following the sampling strata of the 4VWX summer research survey.

ADDITIONAL SURVEYS OUTSIDE CANADA'S EXCLUSIVE ECONOMIC ZONE (EEZ)

EU Survey - Div. 3L

The EU-Spain survey of Div. 3L NAFO Regulatory Area (NRA) was initiated in 2003. The survey has been conducted by the RV *Vizconde de Eza* equipped with a Campelen 1800 bottom trawl (see Román et al. 2019 for details).

EU Survey - Divs. 3NO

The EU-Spain survey of Divs. 3NO NRA was initiated in 1995. The survey began with the vessel C/V *Playa de Menduíña* equipped with a Pedreira bottom trawl until 2001, which was then replaced by the RV *Vizconde de Eza* with a Campelen bottom trawl (see González-Troncoso et al. 2019a for details).

EU Survey - Div. 3M

The EU-Spain Flemish Cap (Div. 3M) survey was initiated in 1988. The survey began with the vessel B/O Cornide de Saavedra (except in 1989–90) equipped with a Lofoten bottom trawl until 2005, which was then replaced by the RV *Vizconde de Eza* using a Lofoten bottom trawl (see Casas and González-Troncoso 2019a for details).

West Greenland - SA 1

The Greenland Institute of Natural Resources (GINR) survey of Divs. 1A-F covers depths 150 m to 600 m and has been sampling fish since 1992. The survey was conducted by the RV *Pâmiut* until 2017. A Skjervoy bottom trawl was used until 2005 when it was changed to a Cosmos shrimp trawl. Comparative trawling was conducted in 2004 and 2005 and a preliminary conversion factor developed for American Plaice but it was never adopted (Nygaard and Nogueira 2019). In 2018 the commercial vessel *Sjudarberg* was used with the Cosmos trawl (Nygaard and Nogueira 2019) Comparative trawling was not conducted between the vessels. However, in 2020 data from net sensors were compared and the vessel change was found to have minimal effect on gear performance, therefore, results in 2018 could be comparable to the *Pâmiut* data used in shrimp and fish assessments (Nogueira and Treble 2020).

DISTRIBUTION

American Plaice is a widespread arctic-boreal to temperate marine species occurring on the continental shelves of northern Europe and northeastern North America. American Plaice are found throughout the Canadian Atlantic (Figure 31), occurring from Baffin Bay (73°N), south through Davis Strait to the Bay of Fundy and the Gulf of Maine (Bigelow and Schroeder 1953; Scott and Scott 1988; Busby et al. 2007; Coad and Reist 2018).

While present, American Plaice are not widely distributed in the Canadian Arctic.

American Plaice are widely distributed across the banks off NL (Figure 32, Figure 33), and extend into the channels and along the shelf edge. In this area, American Plaice have been caught at depths from 35 to 1,440 m, but with 90% of occurrences across the survey time series being in depths of 275 m or less (Figure 34). Empirical Bayesian Krigging was used to create a surface distribution of American Plaice abundance and biomass across the surveyed area for five-year periods from 1980 to present based on multi-species survey trawl catches (Figure 32, Figure 33). Areas of greatest American Plaice abundance in the NL Region occur on the Grand Bank in Divs. 3LNO, particularly in Div. 3L, as well as on the tail of the bank (beyond 200 nautical miles in Divs. 3NO).

Surveys of the NGSL and SGSL indicate that American Plaice are widely distributed across the entire region including the lower Estuary (Figure 35, Figure 36, Figure 37, Dutil et al. 2013). In the NGSL concentrations of American Plaice are observed at the head of the Laurentian, Esquiman, and Anticosti Channels, and all along the west coast of Newfoundland. They are mostly found at depths ≤275 m and are present on both flanks of the Laurentian Channel but absent from the deeper center of the channel. The Laurentian Channel may contribute to a separation of northern and southern Gulf American Plaice, although there have been no studies to confirm this (Busby et al. 2007). Over the 1985–2018 period, spatial distribution of American Plaice abundance and biomass has not changed in the NGSL.

American Plaice is an omnipresent species in the SGSL, consistently occurring in around 90% of the research survey fishing locations since 1971 (Figure 37). While the dense aggregations observed in the Magdalen Shallows and east of Prince Edward Island in the 1970s, 1980s, and early-1990s have disappeared, the species distribution still covers the entire survey area. Across the survey time-series American Plaice catches occur 95% of the time at depths ≤120 m (Figure 38).

Catches of American Plaice in the Maritimes summer 4VWX survey from 1970–2019 (Figure 39) indicate that American Plaice are widely distributed on the Scotian Shelf. Historically, they are largely excluded from the Bay of Fundy, sparsely distributed on the southwestern Scotian Shelf (mainly Browns Bank) and concentrated on the northeastern shelf on Misaine and Banquereau Banks and on Sydney Bight Banks. American Plaice abundance and biomass distribution has declined from 1999–2004 to 2014–2019 (Figure 40), particularly in the east on Western Sable Island and Banquereau Banks. American Plaice are still widely but sparsely distributed on the western portion of the Scotian Shelf, but numbers and biomass have declined on Browns Bank.

AREA OCCUPIED

This section presents information on any changes in area occupied by American Plaice in Canadian waters. The data used are from stratified random surveys (Doubleday and Rivard 1981) and the indices calculated are based on this design.

For all Regions, the design weighted area occupied (DWAO) was calculated as:

$$A_t = \sum_{i=1}^{S} \sum_{j=1}^{n} \frac{a_i}{n_i}\ I \ where\ I = \begin{cases} 1\ if\ Y_j > 0 \\ 0\ otherwise \end{cases} \qquad \textbf{(eq 1)}$$

where A_t is the DWAO in year t, S is the number of strata, n_i is the number of sets in stratum i, a_i is the area of stratum i, and Y_j is the number of fish caught in set j, standardized for swept area. If a species were to be caught in every tow in a given year, the DWAO would be equal to the area surveyed. The DWAO measures the portion of the survey area where a species is encountered (presence/absence), without an indication of its abundance or biomass within the survey area.

Geographic range indicators that account for the distribution of individuals over an area surveyed are also presented for each area/management unit (except SA 0, as changes in survey area through the series preclude the calculation of a standard area occupied). Following methods described in Swain and Morin (1996), the area containing a given percentage of the population can be computed. To do this, catch-weighted cumulative distribution functions were first calculated for different density levels c:

$$F(c)_t = \sum_{j=1}^{n} w_j \frac{Y_j}{\overline{Y}} I \ where\ I = \begin{cases} 1\ if\ Y_j \le c \\ 0\ otherwise \end{cases} \qquad \textbf{(eq 2)}$$

where w_j is the proportion of the survey area in the stratum fished by tow j divided by the number of sets in that stratum, $\overline{Y}$ is the standardized stratified mean number per tow of American Plaice. $F(c)_t$ is an estimate of the number of fish that occur at a density of c or less in year t. F was evaluated at intervals of 0.01 and the density corresponding to $F=0.05$, calculated (c_{05}). This is the density at or below which the most sparsely distributed 5% of the fish are estimated to occur. The area containing this most sparsely distributed 5% of American Plaice was calculated as:

$$G(c_{05}) = \sum_{i=1}^{S} \sum_{j=1}^{n} \frac{a_i}{n_i} I \ where\ I = \begin{cases} 1\ if\ Y_j \le c_{05} \\ 0\ otherwise \end{cases} \qquad \textbf{(eq 3)}$$

The area containing 95% of American Plaice is:

$$D_{95} = SA_T - G_{(C_{05})} \qquad \textbf{(eq 4)}$$

where SA_T is the total survey area.

Similarly, the area containing 75% of the population (D_{75}) was calculated.

BAFFIN BAY AND DAVIS STRAIT (SA 0), AND UNGAVA BAY

Baffin Bay And Davis Strait (Subarea 0)

American Plaice in Baffin Bay and Davis Strait were found to occupy <8% of the area surveyed. There was no evident trend over time in DWAO (Table 5; Figure 41). Due to large differences in area surveyed each year, DWAO Figures are presented as bar graphs and comparisons across time should be made with caution.

Baffin Bay, Davis Strait and Ungava Bay (SFAs 0 to 3)

American Plaice are not widely distributed in Davis Strait or Ungava Bay and were found to occupy ≤10% of the area surveyed. There was no evident trend over time in DWAO (Table 6; Figure 42). Due to large differences in area surveyed each year, DWAO Figures are presented as bar graphs and comparisons across time should be made with caution.

LABRADOR AND THE NORTHEASTERN NEWFOUNDLAND SHELF (SUBAREA 2 + DIV. 3K)

Inconsistent survey coverage in Divs. 2GH does not allow consistent calculation of the DWAO or D_{95} for these divisions. In most years, greater than 80% of the surveyed area in Divs. 2J3K was occupied (Figure 43). D_{95} in Divs. 2J3K showed a general increase from the beginning of the time series until at least 2000 and has remained relatively stable since (Figure 44).

GRAND BANK (DIVS. 3LNO)

DWAO showed a large decline in the spring survey from 1990–95, with proportion of the survey area occupied by American Plaice decreasing by roughly 20% over this time. There was then a large increase in DWAO in 1996, coincident with the introduction of the Campelen trawl, then a decline to the early-2000s, remaining relatively stable since. More than 95% of the surveyed area was occupied in most years, though declining to below 80% during the low abundance period of the early-1990s. D_{95} is quite variable but has shown similar trends to that of DWAO (Figure 45).

The 3LNO fall survey shows the DWAO increasing from the start of the time series in 1990 to the late-1990s, and has been relatively stable, with a slight decrease since (Figure 46). The stock occupied more than 90% of the surveyed area in most years. The D_{95} increased to 1997 then declined since.

SUBDIV. 3PS

DWAO in Subdiv. 3Ps declined until 1995 (Figure 47). There was a large increase in 1996 with the introduction of Campelen trawl and a further increase to around 2000. DWAO remained stable until 2012, followed by a slight decrease to 2018. There was a general increase in D_{95} from the late-1980s to late-1990s, and a decrease since. In all years since the introduction of the Campelen trawl, >80% of the surveyed area contained American Plaice.

SUBDIV. 3PN

DWAO in Subdiv. 3Pn is updated here for 2004 to 2014 (Figure 48). Area occupied generally increased from 2004–13 followed by a decline to 2014. In all years, 75% or more of the survey area in Subdiv. 3Pn was occupied by American Plaice.

NORTHERN GULF OF ST. LAWRENCE (DIVS. 4RST)

Between 1985 and 2018, the area occupied by American Plaice in the NGSL represents on average 75,520 km^2 or nearly 70% of the surveyed area (109,412 km^2). There is a noticeable increase in DWAO starting in 2003, with American Plaice occupying more than 80% of the surveyed area between 2003 and 2018 (Figure 49). The D_{95} indicate a period of relative stability between 1985 and 2002 followed by an increase in 2003 and a second period of stability since (Figure 49).

SOUTHERN GULF OF ST. LAWRENCE (DIV. 4T)

American Plaice are widely distributed in the SGSL. American Plaice were found on average to occupy 86% of the area surveyed yearly since 1971. There was no evident trend over time in DWAO (Figure 50). D_{95} showed an increasing trend over the 1980s and 1990s but appears to have stabilized since 2000 (Figure 50). If habitat selection is density dependent, then foragers should occupy preferred habitats as their populations decline. This does not appear to be the case for Div. 4T American Plaice which appear to maintain or increase their area occupied as their population size declines.

SCOTIAN SHELF (DIVS. 4VWX)

DWAO for American Plaice in Divs. 4VWX was variable but relatively stable throughout the time period 1970–2008 (Figure 51), with plaice averaging 74% of the area surveyed (126,988 km^2). However, since 2008, the DWAO has declined steadily. In 2019, American Plaice occupied 46% of the surveyed area (79,339 km^2).

The D_{95} and D_{75} indices show a similar pattern of relative stability until 2008, followed by gradual decline (Figure 51).

POPULATION SIZES AND TRENDS

BAFFIN BAY AND DAVIS STRAIT (SA 0), UNGAVA BAY

Baffin Bay and Davis Strait (Subarea 0)

Northern 0A has only been surveyed three times from 1999–2017, with American Plaice caught only in the last year surveyed (2012). S-0A has been surveyed more frequently so is a better indicator of abundance for Div. 0A. The abundance index for S-0A varied without trend from 1999 to 2014 and then increased from 2014 to 2017. The biomass generally followed a similar pattern except in 2017 where abundance increased and biomass declined relative to 2016. However, it is noted that error values overlap in these years (Figure 52).

There is a gap in the Div. 0B survey from 2002 to 2010 that makes it difficult to interpret trends across the full time period. However, from 2011 to 2016 there has been a generally increasing trend in both abundance and biomass (Figure 53). The biomass index of Div. 0B generally followed a similar pattern as the abundance index.

American Plaice abundance is greater in Div. 0B than in S-0A with recent estimates of abundance indices at approximately 1.3 million and 520,000, respectively (Table 2). Note that these indices are not absolute estimates of population size.

Baffin Bay, Davis Strait and Ungava Bay (Shrimp Fishing Areas 0 to 3)

With only a few surveys in SFA 0 and SFA 1 between 2006 and 2012, these surveys are not considered informative of trends in American Plaice biomass and abundance in these areas of Baffin Bay (Table 3) (Figure 54). The abundance estimated for SFA 0 was approximately 0.6 million fish for both years surveyed (2006 and 2008). Abundance in SFA 1 was considerably greater and varied between 3.5 and 9.2 million fish from 2006 to 2012 (Table 3) and varied across the other three years surveyed, with large uncertainties around the indices in 2008 and 2010.

The depths and habitat included in the SFA 2 survey are considered most representative for American Plaice in Davis Strait. Abundance and biomass followed similar patterns, both varied without trend in the first part of the time series (2005–12), then following a period of increase in the mid-2010s they have been variable above the series mean since 2013 (Figure 56; Figure 55 and Table 3).

American Plaice are not as abundant in SFA 3 as in SFA 2. The abundance index increased gradually from 2007 to 2014 and then declined to just above the series mean (Figure 56). The biomass index was generally increasing throughout the time series (2007 to 2018), but was highly variable from 2015 to 2018.

Of all the survey areas, the abundance index was highest in SFA 2 ranging from approximately 12.5 million to a high of 40 million fish in 2015 (Table 3).

West Greenland (SA 1) – Outside Canada's EEZ

American Plaice is common throughout SA 1, off West Greenland. The abundance index has been generally increasing throughout the time series for both the old Skjervoy 3000/20 trawl (1992–2004) and the new Cosmos trawl (2005–18), with substantial fluctuations in recent years (Nygaard and Nogueira 2019).

NEWFOUNDLAND & LABRADOR

There are three stocks of American Plaice in the NL Region: Labrador and the Northeastern Newfoundland Shelf (SA 2 + Div. 3K), The Grand Bank (Divs. 3LNO), and Subdiv. 3Ps. American Plaice are also found in Subdiv. 3Pn, though this area is not managed as a stock. Information on stock size is available from RV survey indices for all stocks. For the Grand Bank and Subdiv. 3Ps, population models are used to assess these stocks (a virtual population analysis (VPA) and a surplus production model, respectively). Model outputs are considered the most complete source of information on population dynamics for these stocks and provide the longest available time series (since 1960) for which to examine trends in population size. The American Plaice stock in on the Grand Bank has historically been the largest of the NL stocks, though all stocks have experienced significant declines. An average of 89% of total spring survey abundance of American Plaice (Divs. 3LNOP), and 91 % of fall survey abundance (Divs. 2J3KLNO) has come from the Grand Bank (Divs. 3LNO, Figure 57). This comparison does not take into account potential differences in catchability between stocks/areas and should therefore be considered as an indicator of relative difference in stock abundance as opposed to absolute values.

Trends in survey indices across stocks have shown similar patterns over time, with decreases in population size to the early-1990s, remaining at a low level into the early-2000s. This has been followed by some recent increases, though remaining below levels observed at the start of each time series. Figure 58 presents normalized survey abundance indices for NL stocks, where abundance for each stock is normalized to the mean survey abundance across that stock's time series. Population size and trends for each stock are described below.

Labrador and the Northeastern Newfoundland Shelf (SA 2 + Div. 3K)

Abundance in this stock is primarily located in Divs. 2J and 3K (Busby et al. 2007), therefore overall trends in abundance are robust to variation in coverage of Divs. 2GH. Abundance of American Plaice in SA 2+3K declined from the beginning of the time series in 1978 to the early-1990s and remained very low to 2010. An increase in abundance was observed from 2010 to 2013, though remained well below early-1980s levels, followed by a slight decrease to 2018 (Figure 59). Biomass trends are similar to that of abundance, and are presented in Figure 60.

Grand Bank (Divs. 3LNO)

DFO (Canadian) Survey - Divs. 3LNO

Abundance in Divs. 3LNO spring surveys declined rapidly from the late-1980s to early-1990s. This was followed by a general increase from the mid-1900s to 2014 before declining to 2018 (Figure 61). Fall survey indices have shown a similar trend (Figure 61). The observed increase in abundance over 2012–15 was largely localized to Div. 3L. Biomass trends are presented in Figure 62. Recent increases in abundance indices have not translated into notable increases in biomass indices in subsequent years.

European Union (EU) Survey - Div. 3L, outside Canada's EEZ

In NAFO Div. 3L, the American Plaice abundance index has shown an increasing trend over 2005–09. However, in 2010, there was a decline in abundance below the 2006 value. From 2011–2015, the American Plaice index in the EU 3L survey increased but has declined slightly over 2016–18 (see Román et al. 2019 for details).

EU Survey - Divs. 3NO, outside Canada's EEZ

In NAFO Divs. 3NO, mean number per tow generally increased over 1997–2006, then fluctuated at a relatively high level to 2013. In 2014–15, the index declined to a moderate level and in 2016–18 the index showed a severe decline to the lowest levels observed since 1997 (see González-Troncoso et al. 2019a for details).

Virtual Population Assessment

A VPA model is used for the assessment of this stock (Wheeland et al. 2018). Results of this model are considered to be the best estimate of stock size and population dynamics in this area (Figure 62). Model formulation is outlined in Wheeland et al. (2018) and references therein, with the model including commercial catch at age (1960–2017) (ages 5–15+), Canadian spring RV survey (1985–2016) (no 2006 or 2015 value) (ages 5–14), Canadian autumn RV survey (1990–2017) (no 2004 or 2014 value) (ages 5–14); and EU-Spanish Div. 3NO survey (1998–2017) (ages 5–14). The VPA analyses showed that population abundance and biomass declined fairly steadily from the mid-1970s to early-1900s (Figure 61, Figure 62). Spawning Stock Biomass (SSB) declined to the lowest estimated level in 1994 and 1995, and then increased slightly to 2001, though remaining well below historic levels (Wheeland et al. 2018). SSB has varied at a low level since this time; the stock remains low compared to historic levels and is still estimated to be below B_{LIM}.

Division 3P (Subdivs. 3Ps, 3Pn)

Survey abundance in Subdiv. 3Ps declined from the mid-1980s to 1990, and has increased slightly since that time, remaining below the levels at the start of the time series (Figure 63). Survey biomass trends are similar to that of abundance.

A surplus production model is used for the assessment of Subdiv. 3Ps American Plaice (DFO 2020, Morgan et al. 2020). Results of this model are considered to be the best estimate of stock size and population dynamics in this area (Figure 64: Biomass (B), and B/Bmsy from 3Ps Surplus Production Model. Shaded areas indicate 95% credible intervals. Dashed line is at B/BMSY=1). Stock size estimated from the surplus production model decreased fairly steadily from the late-1960s to a low in 1994. Biomass increased slowly from 1994 to 2008. The stock has shown little or no growth since 2008 and is in the Critical Zone (DFO 2020).

Although American Plaice in Subdiv. 3Pn are not assessed as a stock, data are available from RV surveys from the NL and Quebec Regions. However, updated information is only available from the NL Region (until 2013), since the Quebec Region ceased surveying this region in 2003. The updated Subdiv. 3Pn abundance and biomass indices are presented in Figure 65. Earlier information can be found in Busby et al. (2007).

Flemish Cap (Div. 3M) - EU Survey, Outside Canada's EEZ

The abundance of American Plaice on the Flemish Cap (Div. 3M) declined significantly from 1988–2000 and was followed by a stable period at very low levels from 2001–09. Since 2010, the abundance index has been generally increasing. In 2017–18, the abundance index was approximately 32% of the 1988 estimate (the beginning of the time series, see González et al. 2019b for details).

NORTHERN GULF OF ST. LAWRENCE (DIVS. 4RST)

The index of population abundance for NGSL American Plaice fluctuated over the 1985–2018 period with a general increasing trend (Figure 66a). A similar increasing trend is observed for biomass (Figure 66b).

Estimated minimum trawlable abundance of American Plaice is over 163 million individuals in 2018, of which more than 107 million individuals (66 %) are estimated to be mature. The total biomass is estimated at around 26,000 t.

SOUTHERN GULF OF ST. LAWRENCE (DIV. 4T)

The index of population abundance for Div. 4T American Plaice peaked in the late-1970s with the appearance of strong recruiting year-classes from the early 1970s (Figure 67). The stock declined sharply in the early-1980s, levelled off during the late 1980s, and then decline thereafter. Since 2006, annual abundance has been variable and predominately at or below the time series mean.

SCOTIAN SHELF (DIVS. 4VWX)

Abundance and biomass of American Plaice on the Scotian Shelf–based on the 4VWX summer RV survey index–declined gradually from the mid-1970s through the early-1990s and was variable in the late-1990s and early-2000s (Figure 68). Abundance has declined every year since 2005 with the exception of 2012 and the last five years have been the lowest in the survey series. In 2014, the index was the lowest in the time series with the minimum trawlable abundance at 28 million fish. The index has remained low over 2015–17 at an average of 35 million.

Length frequencies by sex from 2000–19 show that a broad range of lengths in both males and females has persisted in the last 19 years, however with a large decline in abundance at all lengths starting around 2007 (Figure 69).

In contrast, the Georges Bank survey in Div. 5Z demonstrated an increase in minimum trawlable abundance and biomass from 1987–97 followed by a decline over 1998–2004. During 2005–07 the stock was slightly higher (Figure 70). However, in 2011 the stock declined to 27% of its 2008 level, the lowest level the stock has reached since the start of the 5Z survey. Since 2012, the stock has remained relatively stable at a low level.

FLUCTUATIONS AND TRENDS IN THE MATURE COMPONENT OF THE STOCK

BAFFIN BAY AND DAVIS STRAIT (SA 0), UNGAVA BAY

Baffin Bay and Davis Strait (Subarea 0)

Maturity information is not collected for American Plaice on DFO surveys in SA 0, therefore the mature component of the stock cannot be quantified.

Davis Strait and Ungava Bay (SFAs 0 to 3)

Maturity information is not collected on DFO or NSRF surveys of SFAs 0-3, therefore the mature component of the stock cannot be quantified.

NEWFOUNDLAND & LABRADOR REGION (DIVS. 2J3K, 3LNO, SUBDIV. 3PS)

The number of mature individuals in Divs. 2J3K, Divs. 3LNO spring, Divs. 3LNO fall, and Subdiv. 3Ps were calculated by applying male and female maturity ogives by length to the males and females, respectively, by stock. These numbers were added together to produce the number of mature individuals. Additionally, for Divs. 3LNO, population numbers from the VPA were applied to a female sex ratio, and then a maturity ogive was applied to get the proportion of mature females; the males were derived from the total stock estimate minus the females and a male maturity ogive was applied to produce the proportion of males mature for each year. Again, these numbers were added to produce the number of mature individuals.

The percentage of mature individuals remaining was calculated as the percentage of the average abundance of mature individuals over the last three years surveyed relative to the average of the first three years of the time series (Figure 71). In Divs. 2J3K, the number of mature individuals showed a steady decline during the 1980s-2000s, reaching the lowest levels in 2002. Since 2002, the number of mature individuals has generally increased (Figure 71). Of the mature individuals present at the beginning of the time series for Divs. 2J3K, 3Ps and 3LNO, only 29.1%, 34.0%, and 30.7%, remain at the end, respectively (Busby et al. 2007); whereas for Divs. 3LNO fall, this value was 60.8% (Table 8). The number of mature individuals from the Divs. 3LNO VPA population estimates reveals two periods of decline; the first from the late-1960s to mid-1970s and the second in the late-1980s to early-1990s, from which there has been no increase (Figure 72). The number of mature individuals remaining in recent years based on the 3LNO VPA is 6.3% of that from the beginning of the time series.

Rate of decline was estimated from the slope of the linear regression of the natural logarithm of abundance of mature individuals (N_t) versus time (t, in years). The resulting regression equation is:

$$Ln(N_t) = \alpha + \beta \cdot t \qquad \textbf{(eq 5)}$$

The percentage decline over t years (number of years in time series) can be calculated as:

$$(1 - \exp(\beta \cdot t)) \cdot 100 \qquad \textbf{(eq 6)}$$

The decline across the available time series is considered here for stocks examined based on RV survey data because in each case there were fewer than three times the generation time recommended by COSEWIC (3*16=48 years). For Divs. 3LNO; however, VPA model results extend from 1960 to 2017, providing 58 years of data, therefore decline across the time series and across the last 48 years (three times the generation time) are examined (Figure 72).

For Divs. 2J3K the percentage decline over a 36-year period (1983–2018) was 74.4%, 23.9% for Subdiv. 3Ps across 1984–2018, and 34.0% and 60.1% for fall and spring surveys in Divs. 3LNO across 1985–2018, respectively. The R^2 values ranged from 0.02 to 0.24 indicating a poor fit of the data to the models (Table 8); the sharp declines in these survey indices were largely associated with a protracted period in the late-1980s to early-1990s, with stocks remaining at a low level, or showing an increase since the late 1990s-early 2000s (Figure 58), therefore a linear model employed here (consistent with that from Busby et al. 2007) is not a good representation of the population dynamics across the series.

Additional regressions were run to examine trends in numbers mature across portions of the time series: from the maximum number mature to the minimum for each stock, from the minimum abundance to current (2018) levels, and since the previous pre-COSEWIC assessment (2007, Figure 71). In all cases, abundance of mature individuals declined from the start of the time series, reaching a minimum value between the mid-1990s and early-2000s, before increasing to present values. Since the previous pre-COSEWIC Assessment (Busby et al. 2007), there has been an increase in the mature survey abundance in Divs. 2+3K, and no significant change in 3LNO or 3Ps (Table 8).

VPA numbers mature for Divs. 3LNO indicate a 98.0% decline over the time series (R^2=0.89, and 96.9% decline over 3 generations (48 years; since 1969; R^2=0.87), though neither regression appropriately captures the dynamics of the stock whereby the declines are largely associated with the first half of the time series.

NORTHERN GULF OF ST. LAWRENCE (DIVS. 4RST)

The trend in abundance for NGSL American Plaice was estimated by regression of the log-transformed annual survey abundance indices (Figure 73) for the mature component of the population. Regressions were done over the entire series (1987–2018) and three distinct periods corresponding to each of the vessel/trawl combinations used in the NGSL surveys over the time series. The regression using the entire survey dataset was statistically significant ($p<0.05$) with a positive slope, indicating an increase in the adult population over time. However, the R^2 was 0.26, indicating a poor fit of the linear model to the data. The regressions over each survey series, although not significant, all show positive slopes which are indicative of an increasing trend.

SOUTHERN GULF OF ST. LAWRENCE (DIV. 4T)

Figure 74 shows the abundance indices for mature American Plaice in the Div. 4T survey. Over the 1971–2006 period, the adult stock declined by 86 %. From its peak in 1976–83, an eight-year time span, the adult stock declined by 69 %; over the longer period, from 1990–2002, the stock declined by 76%. The stock reached lows in 2002 and 2004, but surveys since 2006 indicated a return to stock levels that were recorded at the beginning of the decade, in 2000 and 2001. However, since 2015, this index has decreased annually, and in 2018 was the lowest in the time series.

SCOTIAN SHELF (NAFO DIVS. 4VWX)

Maturity data were only available for plaice in Divs. 4VWX for 1970–85, so Busby et al. (2007) used a minimum fork length of 31 cm as an indicator of mature individuals. DFO (2011) observed a decline in age and size at maturity for females, and a size at maturity for males from 1985–2009, but advised these trends should be interpreted cautiously as they were based on data from a single year of sampling undertaken in 2010. In the absence of further sampling and confirmation of a declining size at maturity since DFO (2011), a minimum fork length of 31 cm as an indicator of maturity is used here for consistency with Busby et al. (2007). The abundance of mature American Plaice in Divs. 4VWX has declined by 85% since the start of the time series (1969–2018) (Figure 75).

CAUSES OF DECLINE

There have been drastic declines in abundance of many of the American Plaice stocks in Canadian waters. The causes of these declines are not well defined or understood, especially with the complexities of the many stocks involved. Some discussion of likely contributing factors follows.

OVERFISHING

It is generally agreed that overfishing contributed to the declines of American Plaice. On the Grand Bank (Divs. 3LNO) fishing mortality, as measured by commercial catch divided by survey biomass, doubled from the mid-1980s to the early-1990s (Morgan et al. 1997). In contrast, overfishing has not been able to account for the declines observed off Labrador and northeastern Newfoundland where increased total mortality occurred under decreasing fishing effort (Bowering et al. 1997; Morgan et al. 2000). It is obvious that all NL stocks showed a steep decline over the late-1980s to early-1990s. Since fishing pressure was not consistent over all areas, this suggests factors other than overfishing as possible contributors to the declines.

Information from research surveys conducted in the NGSL since 1985 have shown no decline in the abundance of the American Plaice population in this region. The data show rather a stability with a small increasing trend for the period 1985–2018 (Figure 66). This region has not experienced a large American Plaice directed fishery.

CHANGES TO ECOSYSTEMS

In the western North Atlantic, major displacements in the fisheries and changes to ecosystems occurred over a relatively short time period during the 1990s. During this time, major groundfish stocks, American Plaice included, collapsed and have been closed to commercial exploitation since. Concurrently, the physical environment of the Northwest Atlantic was characterized by prolonged below-normal sea temperatures (Colbourne 2004). It has proved difficult to disentangle the role of fishing and environmental factors on the ecosystems affected (Lilly et al. 1999). The collapse of populations of Atlantic Cod, *Gadus morhua* and other groundfish stocks, and subsequent failure to recover after collapse in the western North Atlantic suggest that induced changes to the ecosystem may be preventing recovery (Frank et al. 2005).

Newfoundland & Labrador

The ecosystem structure of the NL bioregion can be described in terms of four EPUs: the Labrador Shelf (2GH), the Newfoundland Shelf (2J3K), the Grand Bank (3LNO), and southern Newfoundland (3Ps). Given the more limited information about trends in the fish community for the Labrador Shelf EPU, this section will focus on the remaining three EPUs (Figure 18).

Trends in the fish community are described on the basis of DFO RV fall and spring multi-species surveys. RV biomass trends were summarized using standard swept area estimates from ecosystem core strata (set of strata that have been consistently sampled over time; they do not include inshore and deep-water strata). Overall biomass trends in the fish community are described by fish functional groups, which are defined in terms of general fish size and feeding habits: small, medium, and large benthivores, piscivores, plank-piscivores, planktivores, and shellfish (only commercial species, recorded since 1995). Since American Plaice is a dominant species within large benthivores; the trajectory and structure of this specific fish functional group is presented in more detail.

DFO changed the gear used in its RV surveys in 1995–96, switching from an Engel to a Campelen trawl. While there are no conversion factors for all species, coarse scaling factors, applied at the fish functional group level, have been used to scale the Engel series and allow for general comparisons (i.e., on the scale of order of magnitude) between the two gears. The utilization of these scaling factors was limited to the 2J3K and 3LNO EPUs, until their adequacy for 3Ps can be evaluated.

The ecosystem units in the NL bioregion were historically dominated by groundfishes, most typically Atlantic Cod, which were also the main target of their fisheries (Dempsey et al. 2017). Fishing pressure on these ecosystems was very high during the 1960s and early-1970s, with overall fishing catches above the capacity of these ecosystems to sustain. Even though catches were lower in the 1980s, many stocks had not recovered from the previous decade of exploitation, and some continued to be overfished at a time when environmental conditions were becoming less favorable for demersal fish production.

In the late-1980s and early-1990s, the entire bioregion underwent an abrupt shift in community structure (Koen-Alonso and Cuff 2018). Changes were observed earlier and were more dramatic in the north than in the south but were evident all around. These changes involved major declines in groundfish and pelagic fishes and involved both commercial and non-commercial species alike. Capelin, a key forage species, collapsed in 1991, and has yet to rebuild to its pre-1991 levels. During this period, the cold environmental conditions together with the reduced predation pressure from groundfishes allowed the build-up of shellfish species like Northern Shrimp and Snow Crab (*Chionoecetes opilio*). Even though changing environmental conditions were important drivers of this abrupt ecosystem change, the overfishing experienced by many important fish stocks is believed to have weakened the ability of these ecosystems to tolerate environmental perturbations. In the mid to late-2000s, some signals of groundfish rebuilding started to be observed. These positive trends were associated with modest improvements in Capelin and warming conditions. Groundfish biomass doubled from 2005 to 2010, while shellfish species like Northern Shrimp and Snow Crab declined. While these groundfish build-ups were important, the total biomass was still significantly below pre-collapse levels. Total biomass remained fairly stable during the early-mid 2010s, but saw important declines after 2014–2015, especially in the Grand Bank EPU (3LNO).

At the EPU level, the Newfoundland Shelf (2J3K) fish community was highly dominated by piscivores prior to the collapse, with large benthivore biomass representing coarsely half of the piscivore biomass (Figure 76A). In this EPU, piscivores appear to collapse rapidly in the early-1990s, but large benthivores were already showing clear signals of decline since the early to mid-1980s (Figure 76A-B). American Plaice was the dominant species among large benthivores, with roughly half of the functional group total biomass (Figure 76C). While during the early years of the decline period (1985–89) the structure of the functional group remained fairly stable, between 1990 and 1995 the dominance of American Plaice and Wolffishes (*Anarhichas spp*.) declined, while Thorny Skate (*Amblyraja radiata*) increased its relative contribution to the large benthivore biomass (Figure 76C). The decade of 1995–2005 saw very little change in the total biomass of large benthivores, but the structure of the functional group showed some additional changes including an increase in relative dominance of Roughhead Grenadier *Macrourus berglax*, and the decline of wolffishes (Figure 76C). Between 2005 and 2011–12, total large benthivore biomass increased, but the structure of the functional group remained fairly stable, with American Plaice representing around 20–30% of the biomass. This build-up plateaued in the early-2010s. The current structure of the functional group still has American Plaice as a dominant species, but less so than prior to the collapse.

The Grand Bank (3LNO) fish community shows a similar collapse pattern as the Newfoundland Shelf (2J3K) EPU, with piscivores collapsing more suddenly in 1991, and large benthivores showing a more gradual and earlier decline (Figure 77A). The differences between 2J3K and 3LNO EPUs are in timing, with the decline in large benthivores only becoming clear in the late-1980s; in magnitude, with the collapse being comparatively less drastic than in 2J3K; and in community structure. In the Grand Bank (3LNO) EPU, large benthivores were as dominant as piscivores in the pre-collapse period (Figure 77A). Also, the increase in shellfish after the collapse does not lead to high shellfish dominance as observed in the Newfoundland Shelf (2J3K, Figure 76). After the collapse, medium benthivores–which include Yellowtail Flounder–seem to have increased faster than large benthivores. On the Grand Bank, the groundfish build-up from the low levels of the mid-1990s appear more modest than those observed in 2J3K. After 2014, a clear decline in total biomass was observed and appears, to a greater or lesser extent, across all fish functional groups (Figure 77A).

Among large benthivores in the Grand Bank EPU, American Plaice and Thorny Skate overwhelmingly dominate the total biomass of this functional group (Figure 77B-C). The dominance of American Plaice is larger than observed in the Newfoundland Shelf EPU, with around 60–70% of the functional group biomass during the mid-1980s. During the collapse, American Plaice dominance within large benthivores also declined, falling to around 40% of the functional group biomass by 1994–95. The build-ups of large benthivores in the Grand Bank after the collapse appear somewhat more gradual than overall fish biomass in this EPU, but both are characterized by a series of ups and downs (akin to a cyclic pattern) from 1996 to 2014 (Figure 77A-B). During this period, the biomass structure of the large benthivores functional group remained fairly stable, with American Plaice representing 50–60% of the functional group biomass. After 2014, there is a clear decline in large benthivore biomass; this decline appears relatively more severe for American Plaice, which shows a clear decline in dominance within the functional group.

Unlike other EPUs, the Grand Bank is surveyed twice a year, allowing for seasonal comparisons in the observed trends. While the summary provided above is based on the spring survey because it has a longer time series, the fall survey (Figure 78) provides a very similar picture.

While still important, the overall magnitude of the declines in the Southern Newfoundland EPU are less drastic than in the Newfoundland Shelf (2J3K) and the Grand Bank (3LNO) EPUs. Here, overall fish biomass declined by around 50% during the collapse period (Figure 79). Like in the other EPUs, the declines involved all fish functional groups. Unlike 2J3K and 3LNO, build-ups of groundfish biomass after the collapse are less evident in the Southern Newfoundland EPU. There was some modest initial rebuilding in the late-1990s and early-2000s; however, total fish biomass has been fairly stationary since the early-2000s, and with some sporadic high biomass signals driven by plank-piscivores (overwhelmingly dominated by Redfish [*Sebastes spp.*]). Within this variability, total biomass after 2014 also showed a reduced level in comparison with earlier years, but biomass levels improved in 2018–19 beyond the high spike of plank-piscivores observed in 2019 (Figure 79A); this is in contrast to other EPUs which showed declines in 2018–19. Despite the relative stability in total biomass, the structure and composition of this fish community has been changing. For example, Atlantic Cod used to be the dominant species among piscivores, but in the 2010s Silver Hake (*Merluccious bilinearis*), a warm water species, started to increase in biomass, and it has currently reached biomass levels comparable to Atlantic Cod. Also, the improvement in piscivore biomass observed in 2019 is actually driven by Spiny Dogfish (*Squalis acanthias*), another warm water species, with Atlantic Cod and Silver Hake remaining at the levels observed after 2014.

These kind of ecosystem changes are also evident among large benthivores. The decline of this functional group during the collapse period appears more severe than what is observed for the overall fish biomass, with American Plaice experiencing the brunt of the decline (Figure 79A-B). After the collapse there was some build-up of large benthivore biomass between the late-1990s and early-2000s, remaining fairly stable since. While American Plaice showed some improvement, most of this post-collapse rebuilding was driven by Thorny Skate. American Plaice represented more than 50% of the large benthivore biomass in the early to mid-1980s, but the collapse led to a rapid loss of American Plaice dominance within this functional group, with Thorny Skate becoming the most dominant species among large benthivores (Figure 79C). This new structure in the biomass composition of the functional group, with American Plaice representing 20–30% of the large benthivore biomass, has persisted since the mid-1990s.

When considering the changes in all EPUs, it becomes abundantly clear that the collapse in the late-1980s and early-1990s impacted the entire groundfish community. While some improvements have been observed since the mid to late-2000s, the declines observed in the late-2010s indicate that rebuilding of these communities is unlikely to be a steady and secure process. While conditions for fish production clearly improved in the mid to late-2000s, likely associated with warmer ocean conditions and modest improvements observed in forage fishes like Capelin, overall fish productivity seems to remain somewhat hindered. The lack of clear and steady recovery of American Plaice needs to be understood within the context of a larger fish community where productivity continues to be impaired. Furthermore, the dominance of American Plaice among large benthivores declined during the collapse in all three EPUs and has yet to regain those former levels of dominance. In most cases, Thorny Skate has been the species that has clearly increased its dominance among large benthivores; the implications of these changes in community and functional group structure for American Plaice rebuilding remain poorly understood.

PREY AVAILABILITY

Newfoundland & Labrador

In addition to diet composition (see *Life History Characteristics* section above), the general availability of food is an important factor for understanding changes in productivity of the fish community in general and of American Plaice in particular. To explore this dimension, the average stomach content weight as a function of fish size for three blocks of time were compared (Figure 80). These blocks were selected to represent the pre-collapse period, a post-collapse period where groundfish biomass was increasing, and the more recent years where groundfish declines have been observed.

The fall stomach content weights during the pre-collapse years are consistently lower than the weights of post-collapse stomach contents, in both 2J3K and 3LNO (Figure 80). The beginning of the decline of American Plaice in the 1980s suggests that reduced availability of food (and its potential impact on survival and productivity) may have been a contributing factor to the stocks declines. In contrast, the pre- and post-collapse stomach weights during the spring for 3LNO do not show that pattern, indicating that food limitation would be expected to have a seasonal component.

The comparison of more recent years associated with increases and declines in groundfish biomass do not show differences as clear as between pre- and post-collapse periods. In recent periods, spring diets in 3LNO and 3Ps do not show a difference; however, fall diets in 2J3K and 3LNO hint towards lower average stomach content weights for the years with declines in groundfishes, especially in 2J3K (Figure 80). While these differences are more subtle than the pre- and post-collapse comparison, the fact they are observed over the same season, and consistent with the general observations of build-ups and declines in groundfish biomass, they suggest that food availability could be playing a role in recent declines and/or stalling of rebuilding processes. These observations are also consistent with analyses of other key groundfish stocks, like Northern Cod, where food availability (e.g., Capelin) has been identified as an important driver of that stock, and more general observations that fish productivity in the NL bioregion appears to be regulated from the bottom-up.

POPULATION FORECAST

For stocks where there is a quantitative stock assessment model, the current models were updated where possible using new data. Each model was forecast forward based on various scenarios of fishing mortality.

SUBDIV. 3PS

Stock status of American Plaice in Subdiv. 3Ps is assessed using a Bayesian surplus production model (Morgan et al. 2020 and references therein). Projections of stock size (Figure 81) were conducted to the beginning of 2023 under conditions of zero catch, current F, current F plus 15%, and current F minus 15%. Although the stock is projected to grow under all scenarios, at the end of the projection period there is a high probability(>0.88) of being below Blim in all cases (DFO 2020, Morgan et al. 2020).

GRAND BANK (DIVS. 3LNO)

American Plaice in Divs. 3LNO is assessed using a virtual population assessment (VPA) model in an ADAPTive framework tuned to the Canadian 3LNO spring, Canadian 3LNO fall and the EU-Spain Divs. 3NO surveys (Wheeland et al. 2018). Simulations were carried out to examine the trajectory of the stock under two scenarios of F: F=0 and $F=F_{2015\text{-}2017}$ (0.08). The SSB was projected to have a probability of >99 % of being less than B_{lim} by the start of 2022 under both F scenarios. Under the F=0 scenario, there is a 99 % probability that SSB in 2022 will be greater than in 2018: however this is reduced to 47 % probability under F status-quo (Figure 82). These analyses illustrate that even very low levels of F are inhibiting growth of the stock.

SOUTHERN GULF OF ST. LAWRENCE (DIV. 4T)

American Plaice in SGSL is assessed using a VPA that estimates time-varying natural mortality. The SSB of the stock was estimated to be 55,023 t at the beginning of 2015, which is 40% of the limit reference point of 139,134 t and a marginal increase since the previous assessment in 2012 (Ricard et al. 2016). Despite very low levels of directed and bycatch fishing mortality experienced by the stock, rebuilding prospects are low due to the high level of natural mortality. SSB of American Plaice in Div. 4T is expected to remain in the critical zone (with >95% chance of being below B_{lim}) during 2016–21 even with no fishing related mortality (Figure 83).

SCOTIAN SHELF (DIVS. 4VWX)

A Bayesian two stage state-space model was used to assess American Plaice during the Recovery Potential Assessment conducted by DFO in 2011 (DFO 2011). Two variations were considered: a) length and age at maturity remained constant over the time series and b) length and age at maturity declined over time. An updated version of the model was used to develop reference points for 4VWX American Plaice (Fowler 2012). A Limit Reference Point of 40 % of female-only SSB_{MSY} (maximum sustainable yield) (12,952 t) and an Upper Stock Reference of 80% female-only SSB_{MSY} (25,905 t) were proposed as reference points for 4VWX American Plaice based on this model (DFO 2012). The model has not been updated here because model outcomes differed depending on assumptions about the degree of change in length and age at maturity. These are population characters that have not been assessed since 1985.

HABITAT PROTECTION

In recent years significant areas within the range of American Plaice in Atlantic waters have been protected from bottom contact gears which can capture American Plaice (Figure 84, Table 9). These areas comprise a combination of Marine Protected Areas (MPAs) and Marine Refuges. These area closures are considered effective measures to help protect important species and their habitats. While currently it is unknown if area closures are a successful conservation tool for the recovery of American Plaice, these measures are intended to be in place for the long-term. In many cases these conservation areas are established to help protect species such as unique and significant aggregations of corals and sponges; however, the restriction of bottom contact gears which catch groundfish may create beneficial refugia for American Plaice stocks. Areas under protection range in size from very small areas such as Les Demoiselles nursery (Plaisance Bay), Magdalen Islands Closure which is only 0.3 km^2, to very large areas such as the Northeast Newfoundland Slope Closure which is 55,353 km^2. In total, there is greater than 210,000 km^2 of area closures protected from bottom contact gear within the range of American Plaice in the Northwest Atlantic which could potentially make a contribution to American Plaice conservation. However, in NL Region none of these area closures overlap with the areas of highest abundance of American Plaice (Figure 85, Figure 86).

It is noted that in NL, survey areas do not extend into inshore areas or to depths >730 m in Divs. 3NO or >1,500 m in Divs. 2HJ3KL or 3Ps, therefore, the full extent of overlap between American Plaice and some closed areas cannot be quantified. However, based on typical distribution and depth range observed for this species, analyses here are considered representative.

In the Maritimes region, only the St. Ann’s Bank MPA and Jordan Basin Conservation Area overlap with important habitat for 4VW and 4X American Plaice, respectively (see Horsman and Shackell 2009).

THREATS

CHANGES TO ECOSYSTEMS

Fish distribution is strongly influenced by temperature, given its significant impact on metabolic processes. As a result, fish are predicted to respond to ongoing changes in ocean climate by altering their distribution to maintain preferred temperatures (e.g., Frank et al. 1996; Brander et al. 2003), which may result in species shifting or expanding to more northern and/or deeper waters (e.g., Perry et al. 2005; Dulvy et al. 2008; Nye et al. 2009). For fishes, climate change may strongly influence distribution and abundance through changes in growth, survival, reproduction, or responses to changes at other trophic levels; however, the specific impacts on the biology of American Plaice are currently poorly understood. Species-specific responses are likely to vary according to rates of population turnover. Species with longer life histories, which are already more vulnerable to overexploitation, may also be less able to compensate for warming through rapid demographic responses (Perry et al. 2005, and references therein). In addition to the direct effects on the fish, ocean temperatures are also a good indicator of more profound changes in the environment (changes in main currents, stratifications, etc.) that might also affect the nutrient supply, oxygen concentration, primary and secondary productions, etc.

Following a cold period from the mid-1980s to the mid-1990s, the Northwest Atlantic has experienced a warm phase that peaked in the early 2010s (see PHYSICAL OCEANOGRAPHY OF THE ATLANTIC REGION). Current oceanographic and ecosystem conditions suggest that the northern regions have experienced a recent cooling, especially north of Divs. 3LNO. While most of the regions have experienced a relative period of low -productivity over the last decade (characterized by a decline in nutrient availability and phytoplankton across the Atlantic Regions and overall decrease in zooplankton biomass), the region north of Divs. 3LNO seems to be less affected. This difference in physical -biogeochemical conditions between the northern portion of the zone and the rest is intriguing and worth investigating.

Direct impacts of these changes on the biology, distribution, and abundance of American Plaice are currently not well understood. Across species, timing of plankton blooms relative to larval hatching can have a significant impact on survival of early life stages (Cushing 1974; Mullowney et al. 2016). With a shift in the spring bloom timing and magnitude, changes in zooplankton availability, community composition, and shift to higher abundance of zooplankton in the fall, it may be expected that American Plaice larval feeding, growth, and mortality may be impacted. However, these effects and resulting impacts on the American Plaice population are not currently quantified or understood, and previous studies on match-mismatch in relation to recruitment in Yellowtail Flounder, a flatfish species with similar life history and which occupies a similar ecological niche, have been inconclusive (Johnson 2000).

The ecosystem of the GSL has also undergone significant changes in recent decades (Galbraith et al. 2019, Blais et al. 2019). Deep waters have become warmer and dissolved oxygen levels have decreased. In 2018, the water temperature at 150, 200, and 300 m remained above normal. New temperature records of ~6.38°C were reached at 250 m and 300 m, almost 1°C higher than the average temperature for the period 1981–2010. The level of dissolved oxygen in bottom waters has decreased significantly in the GSL estuary and deep channels. The lowest levels are found in the deep waters of the St. Lawrence Lower Estuary, a location where American Plaice are present. The current levels are the lowest observed over the last 90 years and correspond to values of less than 18% saturation. Unpublished studies on the tolerance of American Plaice to hypoxia indicate that the species is more tolerant than Atlantic Cod but less then Greenland Halibut (Denis Chabot, pers. comm.). The main nursery for the GSL Greenland Halibut is located in the Lower Estuary and this location still produces good recruitment, however, those recruits have shown a mark reduction in growth in some years (DFO 2019b). So far, the low level of oxygen has not caused a detectable effect on American Plaice in the Lower Estuary. In 2018, American Plaice had the highest occurrence of any fish species captured in the 2018 NGSL survey, being present in 81% of fishing sets (Bourdages et al. 2019).

PREDATORS

The ecosystem mass balance models developed for the NGSL provide a good summary of what has been understood so far about predation on American Plaice (Morissette et al. 2003; Savenkoff et al. 2009; Savenkoff et al. 2005; Savenkoff et al. 2004; Savenkoff & Rioual unpubl.) in this area. In the NGSL, large Atlantic Cod (>35 cm) and Harp Seals (*Pagophilus groenlandicus*) are the main predators of American Plaice, averaging ~70% of predation according to the period investigated (Table 10). American Plaice would have between 11 and 17 predators depending on the periods investigated. The mean annual consumption by predators across period is estimated at 0.17 t km^{-2} and is by far the main cause of mortality for this species in the NGSL.

Although no invertebrates are mentioned in Table 10, it has been shown that shrimp and crab could be significant sources of mortality on young-of-the-year American Plaice and closely related flatfishes. For example, Albaina et al. (2012) showed European Plaice *Pleuronectes platessa* as being a prey of Brown Shrimp (*Crangon crangon*) and Green Crab (*Carcinus maenas*) on the Scottish west coast. In the northwest Atlantic, Sand Shrimp (*Crangon septemspinosa*) have been demonstrated to prey on newly settled Winter Flounder *Pseudopleuronectes americanus* (Taylor 2005).

Consumption by Harp Seals *Pagophilus groenlandicus* on American Plaice in Divs. 2J3KL is not considered to be a significant source of mortality. Diet composition data indicate American Plaice accounted for 0.15–3.38% of Harp Seal diet in this area (Stenson 2013). Finfish or invertebrate predation on American Plaice in NL waters has not been quantified.

FISHING MORTALITY

American Plaice have been commercially harvested in Canadian waters since at least the 1940s. In 1978, the extension of Canada's EEZ to 200 miles resulted in a fishery that was almost exclusively Canadian, with the exception of foreign fishing outside the 200 nautical mile limit along the nose and tail of the Grand Bank (Divs. 3LNO). Most of the American Plaice fisheries in Canada are under moratoria, such that bycatch is the largest source of fishing mortality since the mid-1990s. The history of directed fisheries and ongoing commercial fishing (directed and bycatch) are summarized below, by stock.

Baffin Bay and Davis Strait (SA 0), Ungava Bay

There is no directed fishery for American Plaice in Subarea 0 or Ungava Bay. Mortality is due to bycatch in Greenland Halibut trawl and gillnet fisheries in Subarea 0 and Northern and Striped Shrimp fisheries in SFAs 0 to 3. Since 1997 the shrimp fishery has been required to use Nordmore exclusion grates (28 mm spacing) which helps to minimize groundfish bycatch (DFO 2018). American Plaice bycatch was available for 2002 to 2018 and is based on logbook data from commercial trawling vessels provided by DFO statistics, Ontario & Prairie Region, and has been combined across fisheries and area to ensure privacy guidelines, requiring more than five license holders or vessels, were met (Figure 87). Note that numbers are provisional.

From 2002–18 an average of 2,829 kg y^{-1} of American Plaice was reported as bycatch with a minimum of 106 kg in 2014 and max of 6,586 kg in 2006. On average, the shrimp fishery reported 653 kg of American Plaice bycatch per year with the greatest quantity of annual bycatch occurring in SFA 1, while the Greenland Halibut fishery reported an average of 122 kg or American Plaice bycatch per year with the greatest quantity of annual bycatch occurring in Div. 0A.

Labrador and the Northeastern Newfoundland Shelf (SA 2+ Div. 3K)

The first total allowable catch (TAC) for this stock (10,000 t) was established by the International Commission for the Northwest Atlantic Fisheries (ICNAF) in 1974, though commercial landings data are available for 1960 onwards (ICNAF 1974). Landings for this stock peaked in 1970 at almost 13,000 t according to the NAFO STATLANT-21 A database. Subsequent annual TAC reductions occurred in 1975 (8,000 t) and 1978 (6,000 t) before returning to 10,000 t in 1982. From 1978–81, landings averaged 4,800 t. At this point, removals were almost entirely attributable to Canadian fleets, given the establishment of the 200-mile limit in 1978. Severe reductions in stock size as a consequence of high levels of exploitation occurred through the

1980s and early-1990s (Morgan et al. 2012). The TAC of 10,000 t was maintained until 1992, despite the fact that reported landings for this period did not exceed 4,300 t in any given year. In 1993, the TAC was reduced to 5,000 t. In 1994, a moratorium was declared on the stock, and there has been no directed fishing since. A bycatch limit of 500 t was introduced at the same time and was reduced to 100 t for 1995–97. In 1998 to 2003, the bycatch limit was not referenced and the TAC was set at 0. The reported bycatches from 1994 to 1999 were in effect less than 30 t per year, mostly as bycatch in gillnet fisheries. The low bycatch was due to a drastic reduction in the TAC in 1994 and the moratorium and limited fisheries for Northern Cod (Divs. 2J3KL) which, after 1992, essentially eliminated a major source of American Plaice bycatch (Dwyer et al. 2003). An increase in the catch of American Plaice in 2000 to 2002 was observed mainly as a result of the increased effort directed toward Greenland Halibut in Div. 3K (Brodie and Power 2003). It is of some concern that bycatch sampled in 2001 and 2002 from the Greenland Halibut fishery consisted of 97 to 98% females. In most years the bycatches came from Div. 3K; catches from Divs. 2GH have been negligible (zero reported since 1990). Catch in SA 2+ Div. 3K is a small proportion of American Plaice catch in Newfoundland and Labrador (Figure 88).

From 1994–2018, reported landings have averaged 29 t, and since 2000, the vast majority (>90% in most years) of American Plaice bycatch has come from the Greenland Halibut fishery, primarily using otter trawl and gillnets (Figure 89).

Bycatch of this stock is currently considered to be low, however fishing mortality cannot be quantified, and impact of current removal on stock growth cannot be determined.

Grand Bank (Divs. 3LNO)

Considered the major stock of this species in the Northwest Atlantic, American Plaice in 3LNO have been exploited consistently since the early 1950s. This stock once supported the largest flatfish fishery in the world, which at times approached 10% of the entire Canadian Atlantic groundfish fishery, in terms of both landings and value (Pitt 1989; COSEWIC 2009).

This stock has been under TAC regulation since 1973 when a TAC of 60,000 t was established. From 1973–87, the TAC varied from 47,000 t to 60,000 t but was lowered to 33,585 t in 1988. Further reductions followed, bringing the TAC to 10,500 t in 1993. In 1994, a TAC of 4,800 t was implemented, but the NAFO Fisheries Commission stated that no directed fisheries were to take place on this stock. The TAC has been set at 0 t since that time.

Highest recorded catches for this stock took place in the late-1960s (Figure 90); the largest nominal catch (94,000 t) occurred in 1967. Landings in the 1960s-1970s were relatively stable, averaging about 50,000 t (Wheeland et al. 2018). From 1988–92 catch averaged 28,000 t, with 7,900 t in 1993, and 560 t in 1994. Fishing mortality in Divs. 3LNO was high through the 1980s until the moratorium in the mid-1990s (Dwyer et al. 2007). The stock was placed under moratorium in 1995.

Fishing mortality continues to occur as a consequence of bycatch in fisheries directing for other species, notably Yellowtail Flounder, Redfish, Thorny Skate and Greenland Halibut fisheries. This represents a significant threat to the recovery of this stock (Shelton and Morgan 2005; Morgan et al. 2011). Catches decreased following the moratorium for a few years; however, the opening of the Yellowtail Flounder fishery in 2000 in Divs. 3LNO saw an increase in American Plaice bycatch. In 2005, the total Canadian catch of American Plaice in Divs. 3LNO was 1,464 t, 97% of which came from the directed fishery for Yellowtail Flounder in 3LNO. In 2006, there was virtually no fishery for Yellowtail Flounder, and bycatch was relatively small at only 92 t, coming from the Div. 3O Redfish fishery (Dwyer et al. 2007). Canadian bycatch of American

Plaice in Divs. 3LNO has come primarily from the Yellowtail Flounder fishery, which operates using otter trawls (Figure 91).

Reported landings for this stock averaged about 1,400 t from 1995–99, and 1,900 t from 2000–18. The VPA analyses showed average F for ages 9 to 14 increasing from about 1965 to 1985. There was a large unexplained peak in F in 1993. F increased from 1995 to 2001 and has since declined (Figure 92).

Projections for this stock indicate that even low levels of F are inhibiting stock growth (Wheeland et al. 2018).

Div. 3P (Subdivs. 3Ps, 3Pn)

Subdiv. 3Pn has never been under quota/TAC management, but is subject to a small directed fishery for American Plaice. Since the extension of Canada's EEZ in 1978, NAFO STATLANT 21-A landings have exceeded 100 t only four times, all prior to 1985. Landings averaged 23 t from 1985–2018, and have been 0 in the last three years (2016–18).

Commercial exploitation of the resource in Subdiv. 3Ps was taking place by the 1950s, and possibly earlier. STATLANT 21-A data are available from 1960 onward, and these data indicate that the directed fishery has been dominated by Canadian fleets. Highest landings (14,800 t) occurred in 1973. The first TAC (11,000 t) was established by ICNAF in 1974, and was reduced to 8,000 t in 1976, and 6,000 t in 1977. Landings during the period averaged 5,200 t.

The establishment of the 200-mile limit restricted the resource to exploitation by Canadian and French fleets from 1978 onward. With this establishment of Canada's EEZ, the TAC was further reduced to 4,000 t for 1978–79, but was increased to 5,000 t for 1980–89. The TAC was reached only twice during this ten-year period, while landings averaged 3,600 t. In 1990, the TAC was again reduced to 4,000 t and in September of 1993, a moratorium on directed fishing was declared. Bycatch continues to occur in 3Ps fisheries directing for Atlantic Cod and Witch Flounder *Glyptocephalus cynoglossus*, and is believed to be a significant threat to the recovery of the stock (Morgan et al. 2011). Reported annual landings from STATLANT-21A for 1993–2018 averaged 460 t. Catches of American Plaice in Subdiv. 3Ps come from a combination of gillnets, trawls, and to a lesser degree longlines and Danish seines, with the majority from fisheries targeting Atlantic Cod and Witch Flounder (Figure 93).

Fishing mortality reached a peak in 1991 after which it declined for several years (Figure 94). Fishing mortality increased again to above F_{MSY} in the late-1990s when landings started to increase. It has been below F_{MSY} since 2011 with current median fishing mortality estimated to be 24% of F_{lim}. (DFO 2020).

Northern Gulf of St. Lawrence (NAFO Divs. 4RS)

Landings of American Plaice for NAFO Divs. 4RS were extracted from the NAFO STATLANT 21-B files for the period 1960–1984 and from Zonal Interchange File Format (ZIFF) files for the period 1985–2018. The 2017 and 2018 data are provisional.

There has never been a notable fishery directing for American Plaice in Divs. 4RS and this fishery has never been managed by quota. Most of the American Plaice reported landings are from bycatch in fisheries targeting other species. Over 65 % of the landings originated from Div. 4R (Figure 95, Figure 96A), with >60% of landings occurring in the months of May to August (Figure 96B). American Plaice directed fisheries in Divs. 4RS generally occur between July and September with the bulk of catches in July and August. Considerable variation over the years is found with the fishing gear type used to land American Plaice as well as the different fisheries contributing to the landings (Figure 96C-D).

From 1960 to 1995, annual landings averaged 1,778 t, with bycatch generally accounting for ~90% of these records (Figure 97). During that period, incidental catches of American Plaice were mainly associated with Atlantic Cod, unspecified flatfish/groundfish, and Witch Flounder directed fisheries, with respectively 49%, 11% and 6% of the reported incidental landings (Figure 96D).

There was a marked reduction in American Plaice landings in the 1996–2010 period, averaging ~190 t per year (Figure 95). In those years, bycatch accounted for >60% of landings and came mainly from the fisheries targeting Witch Flounder (41%), Atlantic Cod (23%), and Greenland Halibut (15%, Figure 96). The remaining 20% was from landings without a specified targeted species (15%) or fisheries targeting other commercial species. It has been noted that since the late-1990s, fewer fisheries directed at species other than American Plaice have incidentally caught American Plaice. Also, the proportion of landings from Div. 4R directed fisheries increased in the late-1990s, resulting from an increase in the number of active fishers in Div. 4R. For the first time since 2008, no fisheries were directed to American Plaice in 2017 and 2018.

Since 2010, landings have continued to decline with close to 30 t annually between 2014–18 (Figure 95). Although provisional, this figure shows actual landings that are 40 and 90 times smaller than the annual means of the 1960s (1,145 t) and 1970s (2,600 t), respectively. Most bycatch landings from the last five years are from commercial fisheries targeting Greenland Halibut (70%) and Witch Flounder (20%). Since 2010, 89% of the directed fishery landings are from unit area 4Rd.

Several types of fishing gear have been used to catch American Plaice (Figure 96, Figure 97). Prior to 1998, the directed American Plaice fishery was conducted with a range of gear including bottom trawls, longline, and gillnet. Following the moratorium on Atlantic Cod and Redfish, mobile gear is no longer permitted in 4RS with the exception of an index fishery for Redfish with a TAC of 2,000 t (Senay et al. 2019), and shrimp fishers. As a result, the directed American Plaice fishery has been almost exclusively conducted with gillnets since the introduction of the fishing gear legislation. Following these changes, the large proportion of American Plaice bycatch landings reported from other fisheries is due to three gear types in decreasing importance of landings: Danish seine, gillnet, and longline.

No quota exists for American Plaice in Divs. 4RS where, up until recently, a small, directed fishery was still active; however, mitigation measures exist in other directed fisheries to reduce negative impacts on species such as American Plaice. These measures include: a maximum percentage of incidental catches in other groundfish fisheries at 10% of the directed species, a dockside monitoring program where catch data is collected, and an At-Sea Observers (ASO) program.

Data from the ASO Program have been available for the NGSL since 1999, providing an overview of the discards at sea in the various commercial fisheries (Tables 11–15). In the case of American Plaice from Divs. 4RS, it appears that since 1999, 28.71 t have been discarded at sea in the presence of observers, of which almost 100% is attributable to fisheries targeting five species: Northern Shrimp (63.4%), Greenland Halibut (14.8%), Witch Flounder (13.3%), Atlantic Cod (5.2%), and American Plaice (2.8%, Tables 11–15), with American Plaice catches occurring in 59% of the monitored fishing activities for these five targeted species. The intended percentage of fishing trips carrying an at-sea observer is generally 5% in fisheries targeting these five species. The mean annual occurrence of American Plaice in catches of fisheries targeting for Atlantic Cod, Northern Shrimp, Greenland Halibut, American Plaice, and Witch Flounder are 47.1%, 55.9%, 65.9%, 93.3%, and 96.8%, respectively.

Since the ASO program informs on the quantity of American Plaice discarded at sea in relation to the amount of landed catches of the targeted species, it is then possible to extrapolate the at-sea discards of American Plaice from the landing data obtained in the ZIFF files. The use of both sources of data enable a rough scaling of ASO data to the fishery. Thus, it has been estimated that for the period 1999–2018, a period for which ASO data are available, a total of 609 t of American Plaice was discarded at sea in fisheries directed to one of the five species reported in Tables 11–15.

The Northern Shrimp directed fishery accounted for 64% of these at-sea discards. Since 1999, it is estimated that 30 t of American Plaice are annually discarded at sea by the directed fisheries aimed at the five species investigated here. We note that extrapolating trends observed during observer trips to all commercial fisheries for the species investigated introduces uncertainty into estimations (e.g., based on timing of sampling, distribution of fisheries). However, we consider that the >15,000 different fishing activities where catches of American Plaice have been reported for these five species are sufficient to represent conditions in the NGSL.

Moreover, the ASO program protocol includes length frequency measurements of the different species caught in monitored fishing activities. These data make possible the determination of the American Plaice size distribution caught according to the target species. Thus, 43,175 American Plaice have been measured in monitored fisheries since 1999 (Figure 98). For fisheries directing for Greenland Halibut, American Plaice, and Atlantic Cod, less than 5% of American Plaice bycatch was under the legal size of 30 cm. The Northern Shrimp and Witch Flounder directed fisheries had respectively 96% and 30% of American Plaice bycatch under 30 cm. Regarding the Northern Shrimp fishery, this situation is explained by the introduction in 1993 of the mandatory use of the Nordmore grid, a separating device, which allows larger individuals (>30 cm) to leave the trawl while small individuals passing through the grid find themselves in the catch. A study by Bourdages and Marquis (2014) determined that this bycatch of American Plaice is low and represents less than 1% of the estimates of minimum trawlable biomass for American Plaice less than 30 cm in the NGSL RV survey.

Recently, there has been a massive increase in Redfish abundance and biomass within the NGSL. Three strong cohorts (2011, 2012, and 2013) of Deepwater Redfish (*Sebastes mentella*) have strongly contributed to this increase, accounting for >80% of the catches (all fishes and invertebrates combined) in the 2018 NGSL August survey (Bourdages et al. 2019). The Redfish fishery has been under moratorium since 1995 in the Gulf with a small index fishery of 2,000 t. American Plaice was ranked 13th in occurrence for species caught as bycatch in the Redfish index fishery activities monitored by the ASO program (1,633 sets from 1999 to 2016, Senay et al. 2019). A reopening of the Redfish commercial fishery in the near future has the potential to negatively affect American Plaice.

Southern Gulf of St. Lawrence (Div. 4T)

American Plaice in the SGSL (Div. 4T) were exploited primarily by longlines during the 1930s. Otter trawls were introduced during the 1940s and, by the 1950s or 1960s, seines and otter trawls were responsible for most catches (Morin et al. 2001; DFO 2001; DFO 2004). An unusually high amount of discarding of undersize American Plaice characterized the mobile gear fishery during this early period (Jean 1963; Chouinard and Metuzals 1985). Landings from 1960–76 averaged 8,600 t. Quota management was first introduced in 1977, with an annual TAC of 10,000 t. Stock declines occurred throughout the 1980s, and it was evident by 1988 that the resource could not sustain the established quota/TAC; however, concerns that a decreased quota would exacerbate discards at sea resulted in a delay in reducing the limit until 1992 (Tallman and Sinclair 1989; Morin et al. 2001). During 1977–92, the 10,000 t annual TAC was not taken in full in any given year and reported landings averaged 7,500 t. In 1993, the Div. 4T cod fishery was closed, and new management measures (i.e., quota reduction to 5,000 t, increased mesh size in gear to minimize capture of American Plaice <30 cm, and mandatory landing of all American Plaice) were introduced to both limit the redirection of fishing effort to American Plaice, and to minimize catches of cod, which were now subject to a bycatch limit (Morin et al 2001). Landings declined sharply afterward. The TAC/quota was further reduced to 2,000 t in 1996, but was subsequently increased to 2,500 t in 1997, before being reduced to 1,500 t in 1998, and then increased to 2,000 t for 1999–2001. From 1993–2001, reported landings averaged 1,700 t. In 2002, the TAC was reduced to 1,000 t. In 2003, it was further reduced to 750 t. A third TAC reduction, to 500 t, was implemented in 2008. Reported landings from 2002–18 averaged 193 t and have been less than 8 t for the last three years.

In Div. 4T, American Plaice landings ranged between 6,000 t and 12,000 t during the 1960s to the late-1980s (Figure 99). Starting in 1993, with the introduction of new management measures (quota reduction and increased mesh size for mobile gear), the fishing effort on American Plaice and landings were greatly reduced. As well, from 1993 to 1998 the fishery for Atlantic Cod was closed which also reduced the fishing effort on other species including American Plaice. Overall, American Plaice landings have steadily declined since 1993 and in recent years have been at historically low levels. Current landings of American Plaice are mainly as bycatch in the mobile gear Witch Flounder fishery and in the Greenland Halibut gill net fishery (Figure 100).

Scotian Shelf (Divs. 4VWX, 5Y)

Commercial fishing of American Plaice on the Scotian Shelf has been taking place since at least 1960. American Plaice in addition to Yellowtail and Witch flounders were managed as a single flatfish stock complex and subject to quota management/TACs in Divs. 4VWX starting in 1973, with an initial TAC of 32,000 t; this was reduced to 28,000 t in 1976. Foreign fishing was eliminated with the expansion of Canada's EEZ in 1977, followed by a reduction in the TAC to 14,000 t in 1978. A further reduction to 10,000 t was implemented in 1994.

NAFO STATLANT 21-A landings from 1973–93 averaged 6,200 t, with the highest values occurring in the earliest part of the time series (average from 1973–76 was 18,000 t, and did not exceed 8,000 t thereafter); the lowest values were associated with the early-1990s (averaging 1,200 t from 1990–93). Reported landings for 1993 were only 122 t.

The Scotian Shelf management area was divided in 1994 into two units: eastern (Divs. 4VW) and western (Div. 4X). American Plaice continued to be managed as part of a stock complex along with Witch Flounder and Yellowtail Flounder in Divs. 4VW. In Div. 4X, American Plaice was grouped with Witch Flounder, Yellowtail Flounder, and Winter Flounder. From 1994 to 2002, the TAC for these flounder species was decreased from 5,500 to 1,000 t in Divs. 4VW, and from 4,500 to 2,000 t in Div. 4X. From 1994–99, reported landings of American Plaice averaged 725 t for Divs. 4VW, and 89 t for Div. 4X. Reported landings for 2000–10 averaged 160 t in 4VW and 90 t in 4X (Fowler 2012).

Recent changes have been made to the management of flounders. Beginning in the 2015 fishing year, all flounders must be identified and separated by species. In 4VW, the 1,000 t quota was maintained for flounders, of which no more than 500 t could be American Plaice. In 4X5, the TAC was reduced to a 1,600 t for Winter Flounder, of which 10% could be American Plaice. American Plaice must be landed in all groundfish fisheries, whether as a directed fishery (mixed flounders in 4VW) or as a bycatch in other groundfish fisheries (Silver Hake, Redfish). There is no directed fishing for American Plaice in 4X5.

Landings of American Plaice recorded in the database MARFIS (2002-present) declined from a high of 384 t in 2003 to an average of 20 t per year during 2014–18 (Figure 101). Most landings are from 4Vs (Eastern Scotian Shelf/Banquereau Bank) using mobile gear.

At-sea observer data indicates that American Plaice were mainly observed when targeting for groundfish (gadids, Redfish, Silver Hake, and flatfish). They are also observed in other fisheries using mobile gear such as shrimp, scallop and sea cucumber, but seldom in fixed gear such as traps and longline.

Past allowance for labelling flatfish catches as “Unspecified Flounder” has proven a major problem for assessing the status of the various flatfish populations on the Scotian Shelf and in the Bay of Fundy, and has resulted in uncertainty in catches for other Divisions. However, more recent regulations require the reporting of catches by species on an ongoing basis.

INCIDENTAL MORTALITY

Incidental mortality can be divided into two components, fatal damage to uncaught fish and discarded bycatch. There is insufficient quantitative data on post-selection and ghost-fishing mortality to provide estimates of these sources of incidental mortality to American Plaice.

Discard mortality, on the other hand, is a major consideration for American Plaice. It is thought to be a primary source of unusual and/or unpredictable changes associated with population trends, especially prior to the rash of fishery collapses in the 1990s. The GSL population has proven extremely vulnerable to this type of mortality due to discarding of smaller fish in the catch, and the fishery has been closed in the past due to differences in apparent length compositions between observed fishing trips and commercial landings of unobserved fishing trips (Morin et al. 2001). The allocation of mixed-species flatfish TACs for Scotian Shelf stocks also increases the potential for discarding of less valuable flatfish species (i.e. high-grading to more valuable species).

OIL AND GAS DEVELOPMENT

Offshore petroleum activities occur within the range of distribution of American Plaice (see: Canada - Newfoundland & Labrador Offshore Petroleum Board website). It is unknown how ongoing oil and gas exploration and development in their habitat areas impact American Plaice. Concern exists for disruption of spawning behavior. Primary areas for spawning in NL are largely inshore in Div. 3L, and on the tail of the Grand Bank in Divs. 3NO (Ollerhead et al. 2004). However, spawning areas for American Plaice are thought to be dynamic; locations of primary spawning areas have changed through time. While current known spawning areas do not overlap with areas where offshore licenses have been granted, this does not preclude future conflicts.

The impact of seismic exploration on American Plaice is currently unknown, with potential effects on marine fishes typically poorly understood (Payne 2004; Elliott et al. 2019). Seismic survey operations have been shown to lead to significant mortality in zooplankton (McCauley et al. 2017), which may have broader impacts on ecosystem productivity and structure.

AQUACULTURE

In the Northwest Atlantic, aquaculture activities are largely limited to inshore areas (bays, inlets), outside the main areas of distribution of American Plaice. While not quantified at this time, aquaculture is not currently considered to be a significant threat to American Plaice in Canadian waters.

INSHORE ANTHROPOGENIC DISTURBANCES

The vast majority of American Plaice are distributed in offshore areas. While inshore disturbances have the potential for localized impacts, they are not anticipated to have population-level consequences for this species in Canadian waters. However, it is noted that disturbances may expect to be of greater consequence when they occur in spawning areas (e.g., inshore 3L, Ollerhead et al. 2004).

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

In Canada, American Plaice are protected by the *Fisheries Act* and the *Oceans Act*. American Plaice are not listed in the Canadian Species at Risk Act. As of this meeting, American Plaice have not been assessed by the International Union for Conservation of Nature (IUCN) in either the Northwest or Northeast Atlantic.

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TABLES

Table 1: Sample size of American Plaice stomachs collected during DFO RV fall and spring surveys in the Newfoundland Shelf (2J3K), Grand Bank (3LNO), and southern Newfoundland (3Ps) ecosystem production units (EPUs).

Year	Ecosystem Production Unit (EPU) and season			
	2J3K Fall	3LNO Fall	3LNO Spring	3Ps Spring
1977	141	-	190	-
1978	216	-	473	-
1981	-	2,356	2,319	-
1982	-	1,615	1,695	-
1983	-	1,614	-	-
1984	-	3,391	1,540	-
1985	-	3,502	3,670	-
1986	-	-	9	-
1987	-	2,556	-	-
2008	216	631	-	-
2009	492	559	-	-
2010	458	1,006	-	-
2011	484	686	-	-
2012	467	687	-	-
2013	545	752	701	321
2014	100	2	742	254
2015	548	802	528	396
2016	588	762	902	343
2017	550	807	396	428
2018	448	699	674	361
2019	-	-	724	342

Table 2: Summary of effort data for Fisheries and Oceans Canada multi-species surveys in Subarea 0. Area surveyed, abundance index, and standard error are rounded to the nearest whole number.

Year	Area	Area Surveyed (km2)	Number sets from indexed strata	Number of indexed sets with American Plaice	Abundance Index (ind.)	Standard Error (Abundance index)	Density (Mean Abundance /km2)	Standard Error (Mean Abundance /km2)	Biomass Index (t)	Standard Error (biomass index)
1999	S-0A	31,685	44	8	124,122	76,533	3.9	2.4	26.5	17.1
2000	0B	39,401	34	9	356,881	116,225	9.1	2.9	92.9	34.7
2001	0B	39,401	23	6	639,890	155,595	16.2	3.9	153.8	51.1
2001	S-0A	23,602	29	4	126,681	72,365	5.4	3.1	30.5	17.7
2004	N-0A	55,072	35	0	0	0	0.0	0	0.0	0.0
2004	S-0A	28,155	44	8	105,522	33,112	3.7	1.2	24.9	8.5
2006	S-0A	24,901	40	8	185,588	83,989	7.5	3.4	22.2	8.5
2008	S-0A	37,221	64	8	115,311	52,465	3.1	1.4	42.4	19.5
2010	N-0A	62,819	31	0	0	0	0.0	0	0.0	0.0
2010	S-0A	41,307	71	16	322,386	87,548	7.8	2.1	100.0	27.1
2011	0B	39,401	44	17	846,538	194,969	21.5	4.9	234.5	62.2
2012	N-0A	64,079	79	3	57,711	46,592	0.8	0.5	28.1	22.0
2012	S-0A	40,538	71	14	244,088	69,597	6.0	1.7	79.2	22.8

Year	Area	Area Surveyed (km2)	Number sets from indexed strata	Number of indexed sets with American Plaice	Abundance Index (ind.)	Standard Error (Abundance index)	Density (Mean Abundance /km2)	Standard Error (Mean Abundance /km2)	Biomass Index (t)	Standard Error (biomass index)
2013	0B	39,401	45	21	969,596	219,664	24.6	5.6	317.1	80.3
2014	0B	39,401	39	12	1,332,445	563,886	33.8	14.3	441.9	175.4
2014	S-0A	42,121	76	11	140,871	41,980	3.3	1.0	57.9	19.6
2015	0B	39,401	41	20	1,034,977	295,369	26.3	7.5	387.4	115.8
2015	S-0A	37,888	64	12	220,524	65,920	5.8	1.7	77.2	24.2
2016	0B	40,111	46	21	1,296,054	295,201	32.3	7.4	452.3	123.4
2016	S-0A	38,922	66	16	373,164	136,198	9.6	3.5	148.5	65.8
2017	S-0A	34,819	65	20	520,179	262,510	14.9	7.5	74.0	20.0

Table 3: Summary of effort data for Fisheries and Oceans Canada surveys in SFAs 0 and 1 and Northern Shrimp Research Foundation surveys in SFAs 2 and 3. Area surveyed, abundance index, standard error, and density are rounded to nearest whole number.

Area	Year	Area Surveyed (km^2)	Number of Sets	Number of Sets with American Plaice	Abundance Index (ind.)	Standard Error (Abundance Index)	Density (fish km^2)	Biomass Index (t)	Standard Error (Biomass Index)
SFA0	2006	46,877	75	18	588,785	285,429	13	141	70
SFA0	2008	45,707	53	15	673,997	267,909	15	227	103
SFA1	2006	7,627	14	3	50,333	27,643	7	8	4
SFA1	2008	12,411	22	14	5,401,224	2,685,193	435	349	187
SFA1	2010	12,411	22	15	9,232,863	2,625,906	744	607	283
SFA1	2012	12,411	13	9	3,475,944	538,025	280	212	63
SFA2	2005	113,528	133	56	16,555,551	6,444,586	146	1,734	639
SFA2	2006	112,934	127	38	14,037,449	5,140,598	124	927	290
SFA2	2007	112,202	159	73	13,856,209	4,824,320	123	1,370	412
SFA2	2008	108,477	131	82	28,162,866	8,449,060	260	2,360	670
SFA2	2009	107,228	141	61	12,389,174	3,974,346	116	1,036	340
SFA2	2010	110,833	146	57	33,412,620	18,883,467	301	2,174	675
SFA2	2011	110,833	145	47	14,399,651	6,065,994	130	1,085	337
SFA2	2012	110,833	147	70	14,078,164	3,711,094	127	1,689	448

Area	Year	Area Surveyed (km^2)	Number of Sets	Number of Sets with American Plaice	Abundance Index (ind.)	Standard Error (Abundance Index)	Density (fish km^2)	Biomass Index (t)	Standard Error (Biomass Index)
SFA2	2013	110,833	146	79	30,416,375	8,223,535	274	2,798	663
SFA2	2014	105,998	140	84	34,395,624	7,787,560	324	2,924	638
SFA2	2015	110,833	146	86	39,392,970	8,475,854	355	4,165	997
SFA2	2016	108,573	145	80	30,753,735	8,194,825	283	3,644	930
SFA2	2017	111,634	148	68	24,111,941	5,082,233	216	2,746	747
SFA2	2018	97,611	147	98	28,760,430	6,854,696	295	3,894	1,102
SFA3	2007	68,296	89	19	1,481,496	704,991	22	116	70
SFA3	2009	66,216	87	23	2,816,060	2,003,010	43	184	116
SFA3	2011	66,216	93	16	2,712,370	1,639,090	41	172	92
SFA3	2013	66,216	91	19	2,311,819	1,045,600	35	251	134
SFA3	2014	63,016	74	12	7,004,538	3,830,182	111	220	134
SFA3	2015	64,768	88	12	2,334,053	1,282,848	36	203	119
SFA3	2016	64,768	87	12	5,455,556	3,356,193	84	445	274
SFA3	2017	64,768	90	9	2,967,785	1,972,861	46	111	77
SFA3	2018	64,768	90	14	2,596,234	1,202,814	40	346	158

Table 4: Survey effort (successful sets per NAFO Division) from Newfoundland & Labrador RV Surveys.

Year	Fall							Spring				Winter
	2G	2H	2J	3K	3L	3N	3O	3L	3N	3O	3P	3P
1978	-	-	55	70	-	-	-	-	-	-	-	-
1979	-	-	55	69	-	-	-	-	-	-	-	-
1980	-	-	56	78	-	-	-	-	-	-	-	-
1981	-	-	103	121	-	-	-	-	-	-	-	-
1982	-	-	157	146	-	-	-	-	-	-	-	-
1983	-	-	130	126	-	-	-	-	-	-	-	171
1984	-	-	99	163	-	-	-	-	-	-	-	-
1985	-	-	131	195	232	-	-	221	85	93	-	112
1986	-	-	109	106	142	-	-	211	101	102	-	145
1987	-	-	129	159	165	-	-	181	91	100	-	135
1988	-	-	110	129	189	-	-	160	77	84	-	152
1989	-	-	125	151	174	-	-	205	94	101	-	157
1990	-	-	108	135	161	80	91	156	85	93	-	109
1991	-	-	132	181	219	67	84	143	93	116	-	164
1992	-	-	139	180	215	34	54	178	94	91	-	147
1993	-	-	105	158	153	70	75	181	85	81	138	141
1994	-	-	103	152	200	73	75	160	76	81	172	-
1995	-	-	84	140	182	90	81	151	89	85	164	-
1996	47	77	117	175	211	67	58	188	82	86	148	-
1997	69	71	117	175	205	74	73	158	71	81	158	-
1998	34	83	118	171	204	90	87	163	88	93	177	-
1999	69	81	115	154	169	68	75	177	82	86	175	-
2000	-	-	117	159	176	94	100	134	81	83	171	-

Year	Fall							Spring				Winter
	2G	2H	2J	3K	3L	3N	3O	3L	3N	3O	3P	3P
2001	-	57	120	165	205	94	97	154	79	79	173	-
2002	-	-	117	175	206	94	99	146	79	79	177	-
2003	-	-	116	168	205	70	83	156	79	79	176	-
2004	-	87	115	151	147	69	76	151	79	79	177	-
2005	-	-	117	167	184	86	99	133	78	79	178	-
2006	-	81	117	154	185	70	74	141	22	32	48	-
2007	-	-	115	129	168	94	99	137	79	79	178	-
2008	-	69	99	108	126	64	66	122	71	80	169	-
2009	-	-	108	143	160	75	100	142	78	79	175	-
2010	-	70	113	173	196	72	75	130	78	80	177	-
2011	-	79	99	125	116	70	75	144	79	78	174	-
2012	-	84	115	141	142	70	75	132	78	79	177	-
2013	-	83	116	147	148	70	75	134	79	79	179	-
2014	-	66	110	154	170	3	-	135	60	59	156	-
2015	-	53	114	151	142	69	75	56	72	74	175	-
2016	-	77	115	143	138	70	74	140	78	75	157	-
2017	-	68	114	153	143	70	73	32	68	71	179	-
2018	-	83	106	111	141	70	75	111	79	79	170	-

Table 5: Design Weighted Area Occupied (DWAO; km^2) and proportion of area occupied for the multi-species survey of Baffin Bay and Davis Strait (SA 0, Divs. 0AB).

Year	Surveyed Area(s)	DWAO (km^2)	Proportion Occupied (%)
1999	S-0A	6,156.3	4.2
2000	0B	21,761.8	4.6
2001	S-0A & 0B	27,228.5	6.9

Year	Surveyed Area(s)	DWAO (km²)	Proportion Occupied (%)
2004	N-0A & S-0A	9,539.5	7.2
2006	S-0A	9,505.3	6.5
2008	S-0A	12,707.3	7.3
2010	N-0A & S-0A	13,341.4	7.4
2011	0B	25,926.6	2.7
2012	N-0A & S-0A	13,019.4	7.4
2013	0B	30,459.0	3.1
2014	S-0A & 0B	39,253.0	6.1
2015	S-0A & 0B	41,796.4	4.3
2016	S-0A & 0B	50,496.4	4.4
2017	S-0A	12,293.6	7.7

Table 6: Design Weighted Area Occupied (DWAO; km²) and proportion of area occupied for surveys of Davis Strait and Ungava Bay (Shrimp Fishing Areas 0 to 3).

Year	Surveyed Shrimp Fishing Area(s)	DWAO (km²)	Proportion Occupied (%)
2005	2 & 3	48,053.8	7.4
2006	0, 1, 2, & 3	44,500.7	4.9
2007	2 & 3	59,589.8	5
2008	0, 1, 2, & 3	81,361.1	10.1
2009	2 & 3	59,791.0	5.4
2010	1, 2 & 3	46,176.5	6.5
2011	2 & 3	43,360.1	3.5
2012	1, 2 & 3	51,447.2	7.6
2013	2 & 3	63,054.0	5.2
2014	2 & 3	66,853.5	6

Year	Surveyed Shrimp Fishing Area(s)	DWAO (km^2)	Proportion Occupied (%)
2015	2 & 3	67,994.0	5.4
2016	2 & 3	64,350.1	5.1
2017	2 & 3	53,074.9	4.1
2018	2 & 3	67,359.1	5.6

Table 7: Percent mature individuals remaining (as an average of the last three years of the time period compared to the first three years) and rate of decline for each index.

Division	Percent mature individuals remaining (%)	Rate of decline (%)	No. years in time series
Divs. 2J3K	29.1	74.4	36
Divs. 3LNO Fall	60.8	34.0	34
Divs. 3LNO Spring	30.7	60.1	34
Divs. 3LNO (from VPA)	6.3	98.0	58
Subdiv. 3Ps	34.0	23.9	36
Div. 4T	31.6	79	49
Divs. 4VWX	14.9	91	50
Divs. 4RS	299.0	-	32

Table 8: Rates of decline in survey abundance of mature individuals for Newfoundland & Labrador stocks. Linear regressions were computed for four periods for each stock to examine direction, significance, and rates of change across: the full time series, from maximum abundance to minimum abundance, from minimum abundance to 2018, and since the previous COSEWIC assessment (2007).

Time Series	Stock	Season	Intercept (α)	Slope (β)	R^2	p-value	Rate of decline (%)
Full series	2+3K	fall	94.15	-0.04	0.24	0.00	74.4
max (1986) to min (2002)	2+3K	fall	317.79	-0.15	0.94	0.00	92.2

Time Series	Stock	Season	Intercept (α)	Slope (β)	R^2	p-value	Rate of decline (%)
min to 2018	2+3K	fall	-199.36	0.11	0.85	0.00	-529.1
Since 2007	2+3K	fall	-155.32	0.09	0.65	0.00	-181.7
full series	3LNO	fall	44.84	-0.01	0.09	0.09	34.0
max (1990) to min (1994)	3LNO	fall	700.70	-0.34	0.89	0.02	81.9
min to 2018	3LNO	fall	-42.61	0.03	0.70	0.00	-118.7
Since 2007	3LNO	fall	-10.31	0.02	0.10	0.34	-20.1
full series	3LNO	spring	73.97	-0.03	0.18	0.02	60.1
max (1985) to min (1995)	3LNO	spring	750.20	-0.37	0.96	0.00	98.2
min to 2018	3LNO	spring	-34.43	0.03	0.27	0.02	-91.1
Since 2007	3LNO	spring	66.38	-0.02	0.07	0.44	24.2
full series	3P	spring	33.27	-0.01	0.02	0.46	24.5
max (1983) to min (1997)	3P	spring	369.52	-0.18	0.79	0.00	92.9
min to 2018	3P	spring	-69.48	0.04	0.56	0.00	-159.5
Since 2007	3P	spring	-23.23	0.02	0.07	0.42	-27.7

Table 9: Conservation areas, marine protected areas, and closures within the Canadian range of American Plaice.

Name	Description	Establishment Mechanism
Hatton Basin Conservation Area	Conservation objective: To conserve sensitive benthic areas. Prohibited Activities: All bottom-contact fishing activities.	Variation Order and/or Condition of License
Hopedale Saddle Closure	Conservation objective: Protect corals and sponges and contribute to the long-term conservation of biodiversity. Prohibited Activities: All bottom-contact fishing activities.	Variation Order and/or Condition of License

Name	Description	Establishment Mechanism
Hawke Channel Closure	Conservation objective: Conserve benthic habitat and Atlantic cod Prohibited Activities: Bottom trawl, gillnet, and longline.	Variation Order and/or Condition of License
Northeast Newfoundland Slope Closure	Conservation objective: Protect corals and sponges and contribute to the long term conservation of biodiversity. Prohibited Activities: All bottom contact fishing activities.	Variation Order and/or Condition of License
Funk Island Deep Closure	Conservation objective: Conserve benthic habitat and Atlantic cod Prohibited Activities: Bottom trawl, gillnet, and longline.	Variation Order and/or Condition of License
Laurentian Channel MPA	Conservation objectives: Protect corals, particularly significant concentrations of sea pens, from harm due to human activities (e.g., fishing, oil and gas exploratory drilling, submarine cable installation and anchoring) in the Laurentian Channel. Protect Black Dogfish from human induced mortality (e.g., bycatch in the commercial fishery) in the Laurentian Channel. Protect Smooth Skate from human induced mortality (e.g., bycatch in the commercial fishery) in the Laurentian Channel. Protect Porbeagle sharks from human induced mortality (e.g., bycatch in the commercial fishery, seismic activities) in the Laurentian Channel. Promote the survival and recovery of Northern Wolffish by minimizing risk of harm from human activities (e.g., bycatch in the commercial fishery) in the Laurentian Channel. Promote the survival and recovery of Leatherback Sea Turtles by minimizing risk of harm from human activities (e.g., entanglement in commercial fishing gear, seismic activities) in the Laurentian Channel. Prohibitions: Laurentian Channel MPA Regulations prohibit activities that disturb, damage, destroy or remove from this Area, living marine organisms or any part of their habitat or that is likely to do so, unless listed as exceptions in the Regulations or approved by the Minister. Recreational and commercial fishing, and oil and gas exploration and exploitation are prohibited in all zones of the MPA. The Core	Oceans Act

Name	Description	Establishment Mechanism
	Protection Zone provides additional protection by prohibiting anchoring and laying of submarine cables.	
Div. 3O Coral Closure	Conservation objective: To protect coral and sponges. Prohibited Activities: Prohibits all bottom fishing activities.	License Condition
Eastern Gulf of St. Lawrence Coral Conservation Area	Conservation objective: Protect cold-water corals, notably *Pennatula grandis* and *Anthoptilum grandiflorum* sea pens. Prohibited Activities: All fishing that uses bottom-contacting gear.	Variation Order and/or Condition of License
Slope of Magdalen Shallows Coral Conservation Area	Conservation objective: Protect cold-water corals, notably *P. grandis* and *A. grandiflorum* sea pens. Prohibited Activities: All fishing that uses bottom-contacting gear.	Variation Order and/or Condition of License
Central Gulf of St. Lawrence Coral Conservation Area	Conservation objective: Protect cold-water corals, notably A. grandiflorum sea pen. Prohibited Activities: All fishing that uses bottom-contacting gear.	Variation Order and/or Condition of License
South-East of Anticosti Island Sponge Conservation Area	Conservation objective: Protect cold-water sponges. Prohibited Activities: All fishing that uses bottom-contacting gear.	Variation Order and/or Condition of License
East of Anticosti Island Sponge Conservation Area	Conservation objective: Protect cold-water sponges. Prohibited Activities: All fishing that uses bottom-contacting gear.	Variation Order and/or Condition of License
Beaugé Bank Sponge Conservation Area	Conservation objective: Protect cold-water sponges. Prohibited Activities: All fishing that uses bottom-contacting gear.	Variation Order and/or Condition of License
North of Bennett Bank Coral Conservation Area	Conservation objective: Protect cold-water corals, notably A. grandiflorum sea pen and the three other species of sea pen : Pennatula aculeata, Pennatula grandis and Halipteris finmarchica. Prohibited Activities: All fishing that uses bottom-contacting gear.	Variation Order and/or Condition of License

Name	Description	Establishment Mechanism
Eastern Honguedo Strait Coral and Sponge Conservation Area	Conservation objective: Protect cold-water sponges and corals, notably Halipteris finmarchica, Anthoptilum grandiflorum, Pennatula grandis and Pennatula aculeata. Prohibited activities: All fishing that uses bottom-contacting gear.	Variation Order and/or Condition of Licence
Western Honguedo Strait Coral Conservation Area	Conservation objective: Protect cold-water corals, notably P. aculeata, P. grandis and A. grandiflorum. Prohibited Activities: All fishing that uses bottom-contacting gear.	Variation Order and/or Condition of License
Parent Bank Sponge Conservation Area	Conservation objective: Protect cold-water sponges. Prohibited activities: All fishing that uses bottom-contacting gear.	Variation Order and/or Condition of License
Jacques-Cartier Strait Sponge Conservation Area	Conservation objective: Protect cold-water sponges. Prohibited Activities: All fishing that uses bottom-contacting gear.	Variation Order and/or Condition of License
St Anns MPA	Conservation Objective: protect all major benthic, demersal and pelagic habitats.	Oceans Act
The Gully MPA	Conservation objective: Protect cold-water corals, dolphins and whales. Prohibited Activities: All activities that disturb, damage or remove any living marine organism or any part of its habitat in Zone 1. Hook-and line fishing allowed in Zones 2 and 3	Oceans Act
Corsair and Georges Canyons Conservation Area	Conservation objective: To protect cold-water corals Prohibited Activities: Prohibits all commercial bottom-contact fishing gear.	Condition of License
Lophelia Coral Conservation Area	Conservation objective: To protect the only known living Lophelia pertusa coral reef in Canada's Atlantic waters. Prohibited Activities: Prohibits all commercial bottom-contact fishing gear.	Variation Order and/or Condition of License

Name	Description	Establishment Mechanism
Jordan Basin Conservation Area	Conservation objective: To protect cold water corals. Prohibited Activities: Prohibits all commercial bottom-contact fishing gear.	Condition of License
Emerald Basin and Sambro Bank Sponge Conservation Areas	Conservation objective: To protect globally unique concentration of Vazella pourtalesi, a structure-forming species of glass sponge. Prohibited Activities: Prohibits all commercial bottom-contact fishing gear.	Variation Order and/or Condition of License
Western/ Emerald Banks Conservation Area (restricted fisheries zone) (Haddock Box)	Conservation objective: Support productivity objectives for groundfish species of Aboriginal, commercial, and/or recreational importance, particularly NAFO Division 4VW haddock. Prohibited Activities: Prohibits all commercial and recreational fisheries using bottom-contact gear and/or gear known to interact with groundfish.	Condition of License

Table 10: Predators of American Plaice in the northern Gulf of St. Lawrence. The values presented are the average percentage values that American Plaice represents in each predator's diet. These data are the estimates calculated with the different inverse models used for each period. Blank cells mean that a predator has not been evaluated for that period of time, whereas "0" indicates that American Plaice was found in very small amounts. The causes of total mortality are also provided.

Predator	Mid-1980[1]	Mid-1990[2]	2000–2002[3]	2003–2005[4]	2006–2010[5]
Cetaceans	0	0	0	0	-
Dolphins	-	-	0	0	0
Harp Seal	17	31	24	80	40
Grey Seal	-	-	-	1	9
Hooded Seal	3	10	20	1	3
Total marine mammals	20	41	44	82	52
Seabirds	0	1	0	0	0
Large Atlantic Cod (>35 cm)	64	6	47	9	43
Small Atlantic Cod (≤35 cm)	0	0	0	0	-
Large Greenland Halibut (>40 cm)	0	0	0	0	-

Predator	Mid-1980[1]	Mid-1990[2]	2000–2002[3]	2003–2005[4]	2006–2010[5]
Small Greenland Halibut (≤40 cm)	-	-	-	1	-
American Plaice	10	5	0	0	0
Skates	0	0	0	0	-
Large demersal feeders	6	1	2	4	0
Small demersal feeders	-	45	6	2	2
Large pelagic feeders	0	0	0	2	1
Piscivorous small pelagic feeders	-	-	0	0	-
Planktivorous small pelagic feeders	-	-	0	0	-
White Hake	-	-	-	-	1
Wolffish	-	-	-	-	0
Herring	-	-	-	-	0
Mackerel	-	-	-	-	0
Total fish	80	57	55	18	47
$t \cdot km^{-2} \cdot yr^{-1}$	0.23	0.18	0.20	0.12	0.10
Causes of total mortality					
Predation	75	88	94	92	93
Fishing	7	1	1	1	2
Other causes	18	11	5	7	5

[1] Morissette et al. 2003
[2] Savenkoff et al. 2004
[3] Savenkoff et al. 2005
[4] Savenkoff et al. 2009
[5] Savenkoff & Rioual 2013, unpublished document

Table 11: Annual estimation of American Plaice (AP) at-sea discards in fisheries targeting American Plaice (TS) for the 1999–2018 period in Divs. 4RS. APC=AP capture, ASO=At-Sea Observer Program, ZIFF=Zonal Interchange File Format, N_{AP}=Number of monitored fishing activity where AP was caught; N_{tot}=Number of monitored fishing activity where the target species is TS, Occ=occurrence of AP, ASD=at-sea discard, L=landed; TSC=target species capture, EAPD=estimated AP at-sea discards in the whole fisheries, TS = target species.

Year	ASO data							Landings data (ZIFF)	EAPD (t)
	Occurrence			APC (kg)			TSC (t)	TSC (t)	
	N_{AP}	N_{tot}	Occ (%)	ASD	L	% ASD	L	L	
1999	33	33	100	28	5,336	0.5	5	178	0.9
2000	31	31	100	418	7,994	5	8	208	10.9
2001	41	41	100	182	4,743	3.7	5	100	3.8
2002	12	12	100	38	1,473	2.5	1	62	1.6
2003	7	7	100	0	637	0	1	113	0
2004	20	20	100	45	1,742	2.5	2	35	0.9
2005	-	-	-	-	-	-	-	61	-
2006	11	11	100	9	1,639	0.5	2	16	<0.1
2007	4	4	100	10	4,453	0.2	4	31	<0.1
2008	0	1	0	0	0	-	0	0	-
2009	3	3	100	6	955	0.6	1	43	0.3
2010	-	-	-	-	-	-	-	29	-
2011	6	6	100	28	1,629	1.7	2	49	0.8
2012	3	3	100	15	1,207	1.2	1	47	0.6
2013	2	2	100	15	1,088	1.4	1	25	0.4
2014	-	-	-	-	-	-	-	17	-
2015	3	3	100	0	0	-	0	22	-
2016	5	5	100	18	607	2.9	1	7	0.2
2017*	-	-	-	-	-	-	-	0	-

Year	ASO data							Landings data (ZIFF)	EAPD (t)
	Occurrence			APC (kg)			TSC (t)	TSC (t)	
	N_{AP}	N_{tot}	Occ (%)	ASD	L	% ASD	L	L	
2018*	-	-	-	-	-	-	-	0	-
Total	**181**	**182**	**-**	**812**	**33,503**	**-**	**34**	**1,046**	**20.6**
Mean	**12**	**12**	**93.3**	**54**	**2,234**	**1.8**	**2**	**52**	**1.6**

Table 12: Annual estimation of American Plaice at-sea discards in fisheries targeting Atlantic Cod for the 1999–2018 period in Divs. 4RS. See Table 11 for column header descriptions.

Year	ASO data							ZIFF data	EAPD (t)
	Occurrence			APC (kg)			TSC (t)	TSC (t)	
	N_{AP}	N_{tot}	Occ (%)	ASD	L	% ASD	L	L	
1999	66	129	51.2	109	367	22.9	61	5,032	9
2000	104	299	34.8	34	1,299	2.6	46	4,769	3.6
2001	94	260	36.2	10	380	2.6	119	4,776	0.4
2002	57	184	31	44	235	15.8	56	4,417	3.4
2003	-	-	-	-	-	-	-	60	-
2004	45	137	32.8	12	310	3.7	41	2,113	0.6
2005	131	209	62.7	140	755	15.6	144	3,180	3.1
2006	137	231	59.3	100	1,283	7.2	144	3,988	2.8
2007	207	408	50.7	104	1,133	8.4	304	4,781	1.6
2008	288	564	51.1	301	1,888	13.8	338	4,696	4.2
2009	157	257	61.1	170	402	29.7	120	3,207	4.5
2010	154	319	48.3	192	385	33.3	114	2,733	4.6
2011	60	143	42	175	208	45.7	35	1,297	6.5
2012	28	77	36.4	3	68	4.2	35	1,007	<0.1
2013	30	109	27.5	8	133	5.7	26	970	0.3
2014	46	93	49.5	15	335	4.3	40	1,050	0.4
2015	6	14	42.9	4	0	-	1	1,021	4.3
2016	20	25	80	25	16	61	13	1,076	2.1
2017*	33	76	43.4	10	87	10.3	27	2,217	0.8
2018*	43	79	54.4	45	117	27.8	26	2,128	3.7
Total	**1,706**	**3,613**	**-**	**1,501**	**9,401**	**-**	**1,689**	**54,517**	**56.1**
Mean	**90**	**190**	**47.1**	**79**	**495**	**17.5**	**89**	**2,726**	**3**

*Provisional data

Table 13: Annual estimation of American Plaice at-sea discards in fisheries targeting Greenland Halibut for the 1999–2018 period in Divs. 4RS. See Table 11 for column header descriptions.

Year	ASO data							ZIFF data	EAPD (t)
	Occurrence			APC (kg)			TSC (t)	TSC (t)	
	N_{AP}	N_{tot}	Occ (%)	ASD	L	% ASD	L	L	
1999	120	163	73.6	23	1,359	1.7	58	1,293	0.5
2000	113	194	58.2	11	361	3	60	906	0.2
2001	14	54	25.9	0	41	0	8	582	0
2002	20	50	40	20	35	36.4	14	773	1.1
2003	174	286	60.8	52	356	12.7	99	1,825	1
2004	137	223	61.4	3	268	1.1	53	2,065	0.1
2005	156	198	78.8	153	495	23.6	86	2,316	4.1
2006	160	242	66.1	904	911	49.8	104	2,611	22.6
2007	184	253	72.7	276	899	23.5	112	2,908	7.2
2008	238	337	70.6	406	1,830	18.2	144	2,389	6.7
2009	143	228	62.7	18	332	5.1	107	3,195	0.5
2010	290	379	76.5	147	952	13.4	157	3,107	2.9
2011	258	319	80.9	132	934	12.4	163	3,317	2.7
2012	460	582	79	654	2,205	22.9	279	2,811	6.6
2013	470	559	84.1	439	852	34	118	1,999	7.4
2014	371	555	66.8	198	685	22.4	180	2,125	2.3
2015	284	482	58.9	96	469	17	195	2,247	1.1
2016	197	285	69.1	215	279	43.5	131	1,971	3.2
2017*	205	338	60.7	149	498	23	68	1,018	2.2
2018*	163	227	71.8	352	970	26.6	65	1,107	6
Total	**4,157**	**5,954**	**-**	**4,248**	**14,731**	**-**	**2,201**	**40,565**	**78.6**
Mean	**208**	**298**	**65.9**	**212**	**737**	**19.5**	**110**	**2,028**	**3.9**

*Provisional data

Table 14: Annual estimation of American Plaice at-sea discards in fisheries targeting Northern shrimp for the 1999–2018 period in Divs. 4RS. See Table 11 for column header descriptions.

Year	ASO data							ZIFF data	EAPD (t)
	Occurence			APC (kg)			TSC (t)	TSC (t)	
	N_{AP}	N_{tot}	Occ (%)	ASD	L	% ASD	L	L	
1999	584	1,172	49.8	534	314	63	1,126	22,071	10.5
2000	414	1,006	41.2	444	154	74.2	1,014	20,341	8.9
2001	291	859	33.9	359	178	66.9	864	21,171	8.8
2002	392	979	40	524	118	81.6	1,054	26,956	13.4
2003	641	1,019	62.9	866	257	77.1	1,278	19,592	13.3
2004	685	1,105	62	2,458	81	96.8	1,568	31,785	49.8
2005	512	796	64.3	832	34	96.1	1,139	28,215	20.6
2006	541	882	61.3	771	91	89.4	1,200	30,289	19.5
2007	436	955	45.7	763	21	97.3	1,365	33,256	18.6
2008	581	916	63.4	974	25	97.5	1,383	32,679	23
2009	476	941	50.6	631	1	99.8	1,518	33,322	13.9
2010	761	1,151	66.1	984	15	98.5	1,566	33,833	21.3
2011	637	1,039	61.3	971	0	-	1,629	30,887	18.4
2012	671	906	74.1	2,372	0	-	1,323	27,981	50.2
2013	473	872	54.2	795	3	99.6	1,332	28,024	16.7
2014	499	789	63.2	785	0	-	1,120	28,043	19.7
2015	431	955	45.1	507	10	98.1	1,386	28,284	10.3
2016	674	1,136	59.3	1,018	7	99.3	1,383	27,004	19.9
2017*	784	1,155	67.9	1,106	4	99.6	972	20,893	23.8
2018*	412	786	52.4	495	1	99.8	804	16,942	10.4
Total	**10,895**	**19,419**	**-**	**18,189**	**1,314**	**-**	**25,025**	**541,568**	**390.8**
Mean	**545**	**971**	**55.9**	**909**	**66**	**90.3**	**1,251**	**27,078**	**19.5**

*Provisional data

Table 15: Annual estimation of American Plaice at-sea discards in fisheries targeting Witch Flounder for the 1999–2018 period in Divs. 4RS. See Table 11 for column header descriptions.

Year	ASO data							ZIFF data	EAPD (t)
	Occurence			APC (kg)			TSC (t)	TSC (t)	
	N_{AP}	N_{tot}	Occ (%)	ASD	L	% ASD	L	L	
1999	87	87	100	0	12,665	0	25	339	0
2000	84	98	85.7	0	6,491	0	50	436	0
2001	59	65	90.8	0	2,182	0	22	435	0
2002	-	-	-	-	-	-	-	440	-
2003	-	-	-	-	-	-	-	273	-
2004	-	-	-	-	-	-	-	401	-
2005	-	-	-	-	-	-	-	470	-
2006	-	-	-	-	-	-	-	412	-
2007	73	74	98.6	2,388	2,132	52.8	28	427	36.3
2008	7	7	100	159	140	53.2	4	301	12.7
2009	-	-	-	-	-	-	-	244	-
2010	-	-	-	-	-	-	-	118	-
2011	2	2	100	20	56	26.3	11	318	0.6
2012	26	27	96.3	1,012	5,050	16.7	20	222	11.3
2013	1	1	100	5	0	-	<0.1	132	-
2014	-	-	-	-	-	-	-	145	-
2015	-	-	-	-	-	-	-	127	-
2016	24	24	100	238	320	42.7	16	131	2
2017*	-	-	-	-	-	-	-	215	-
2018*	-	-	-	-	-	-	-	217	-
Total	**363**	**385**	**-**	**3,822**	**29,036**	**-**	**175**	**5,802**	**62.9**
Mean	**40**	**43**	**96.8**	**425**	**3,226**	**24**	**19**	**290**	**7.9**

*Provisional data

FIGURES

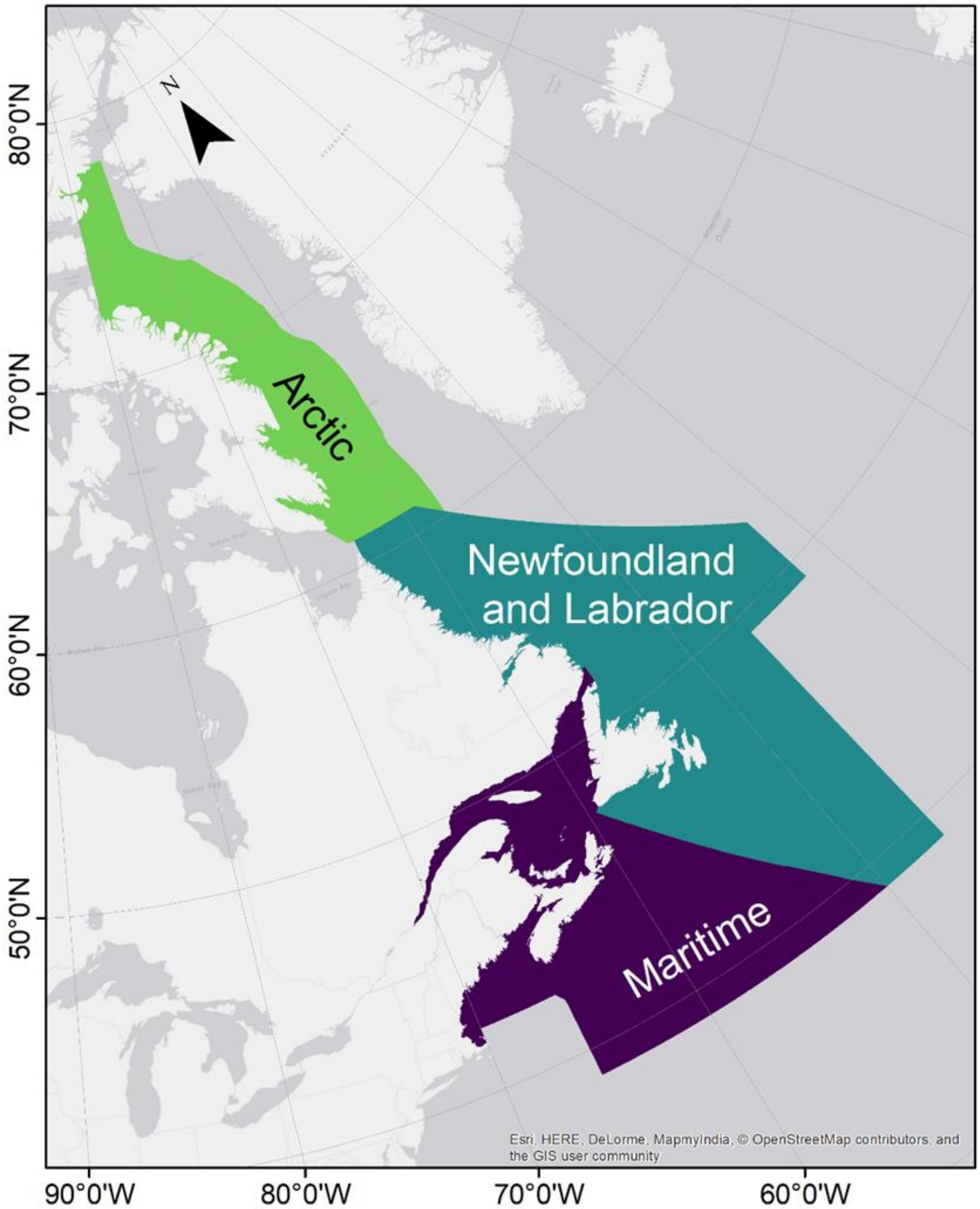


Figure 1: Three Designatable Units for American Plaice defined by COSEWIC in 2009.

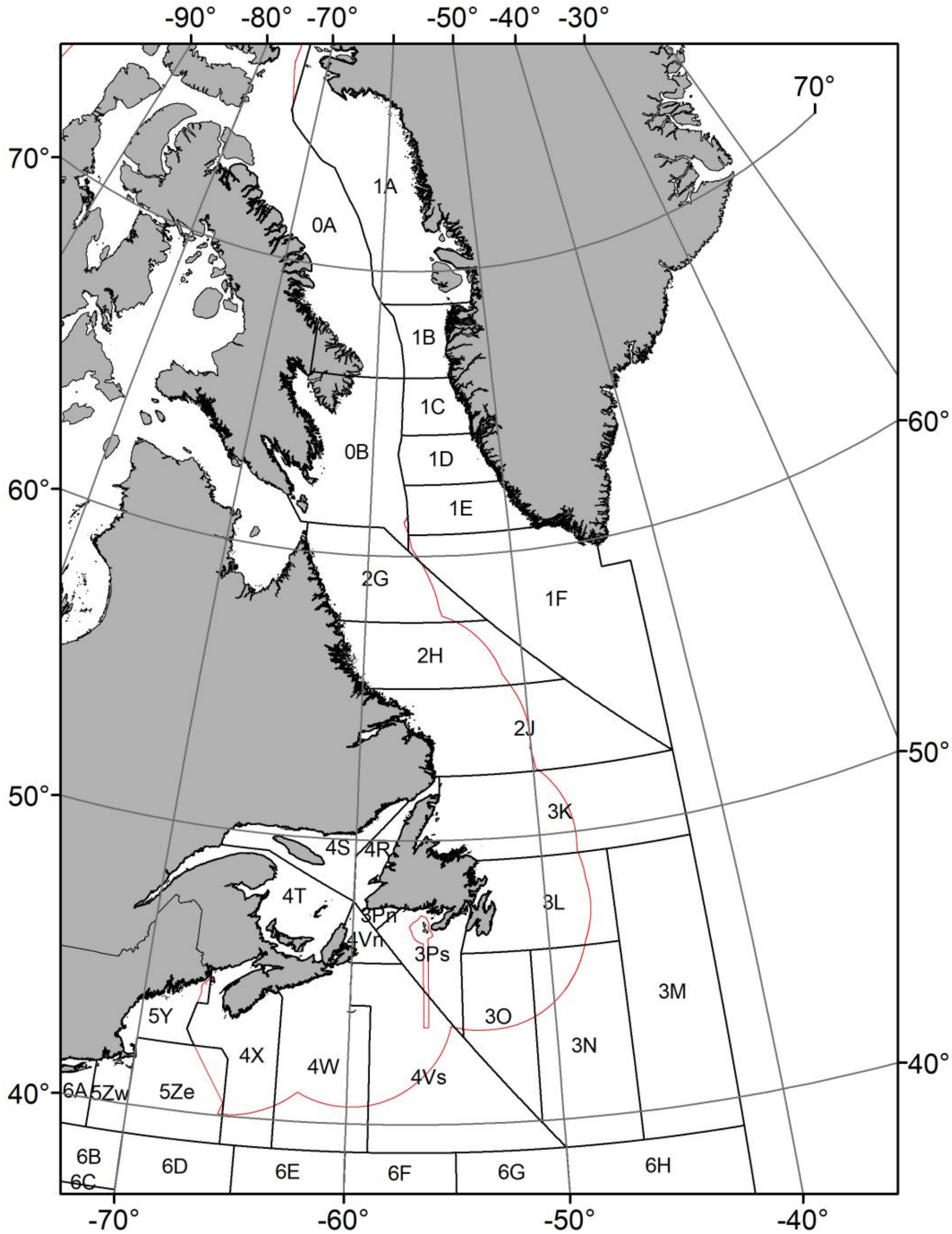


Figure 2: NAFO Divisional boundaries (black lines) and Canadian Exclusive Economic Zone (red line).

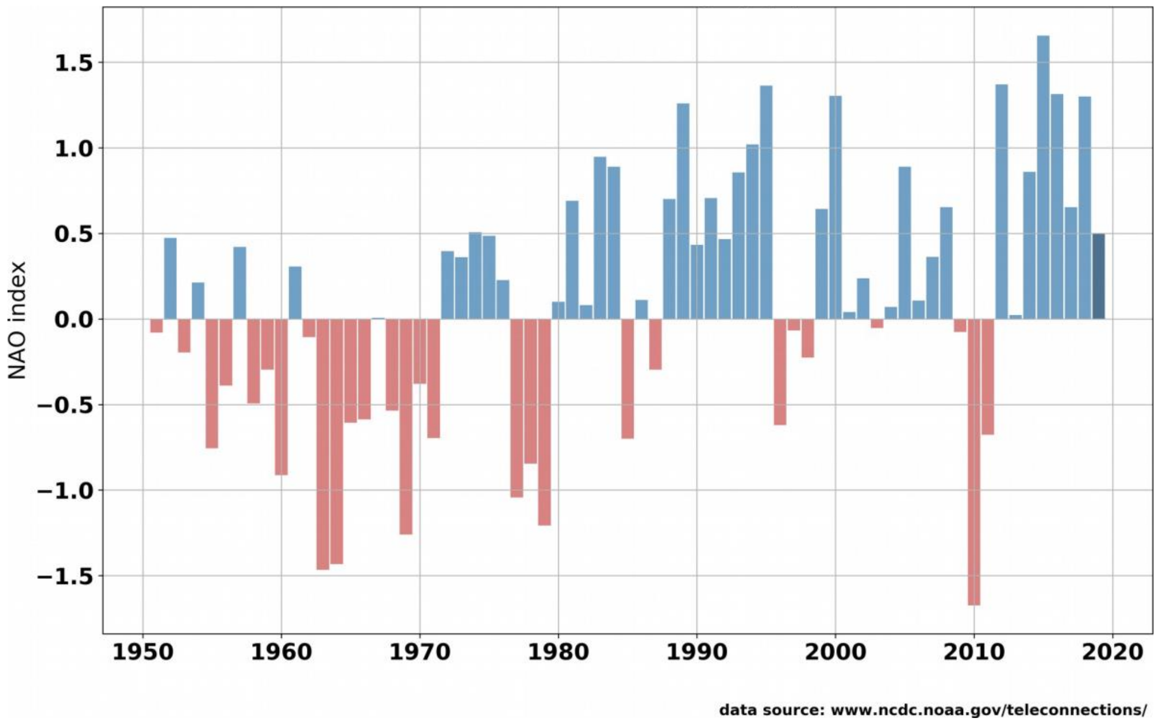


Figure 3: Winter North Atlantic Oscillation (NAO) index (average of December, January, and February) between 1950 and 2019.

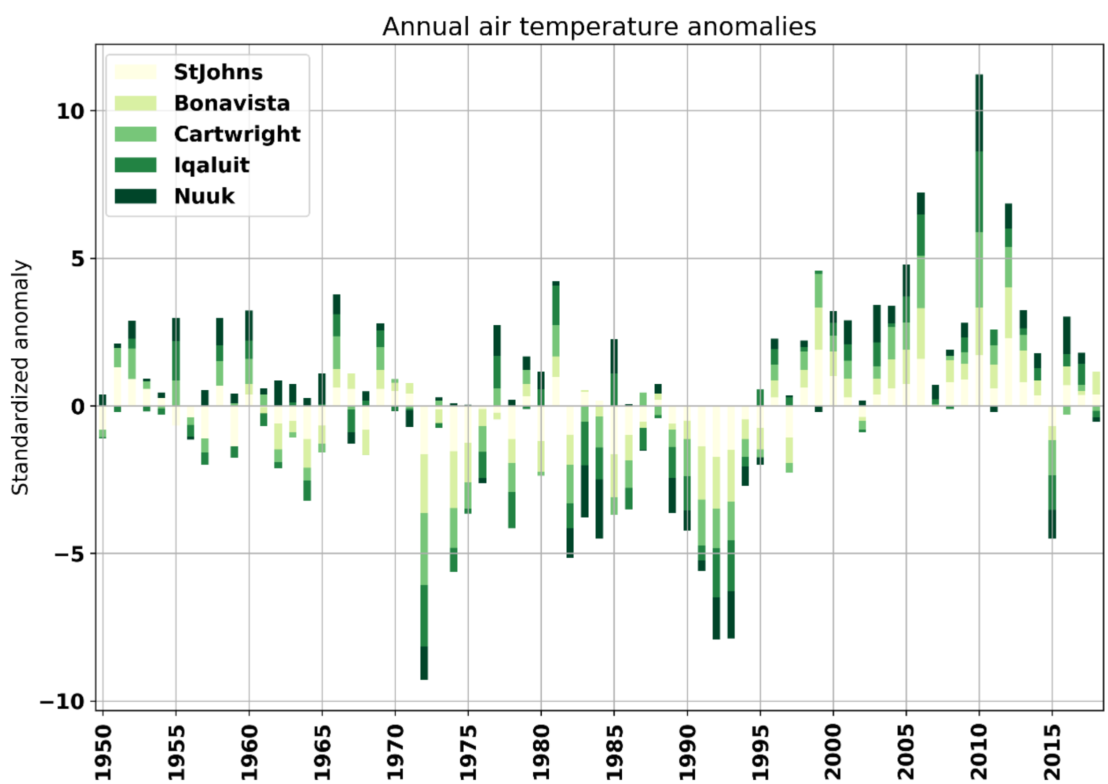


Figure 4: Standardized anomaly of the annual mean temperature for five sites around the Northwest Atlantic displayed in a stacked bar plot. St. John's and Bonavista are located on the island of Newfoundland, Cartwright in Labrador, Iqaluit on Baffin Island, and Nuuk in Western Greenland.

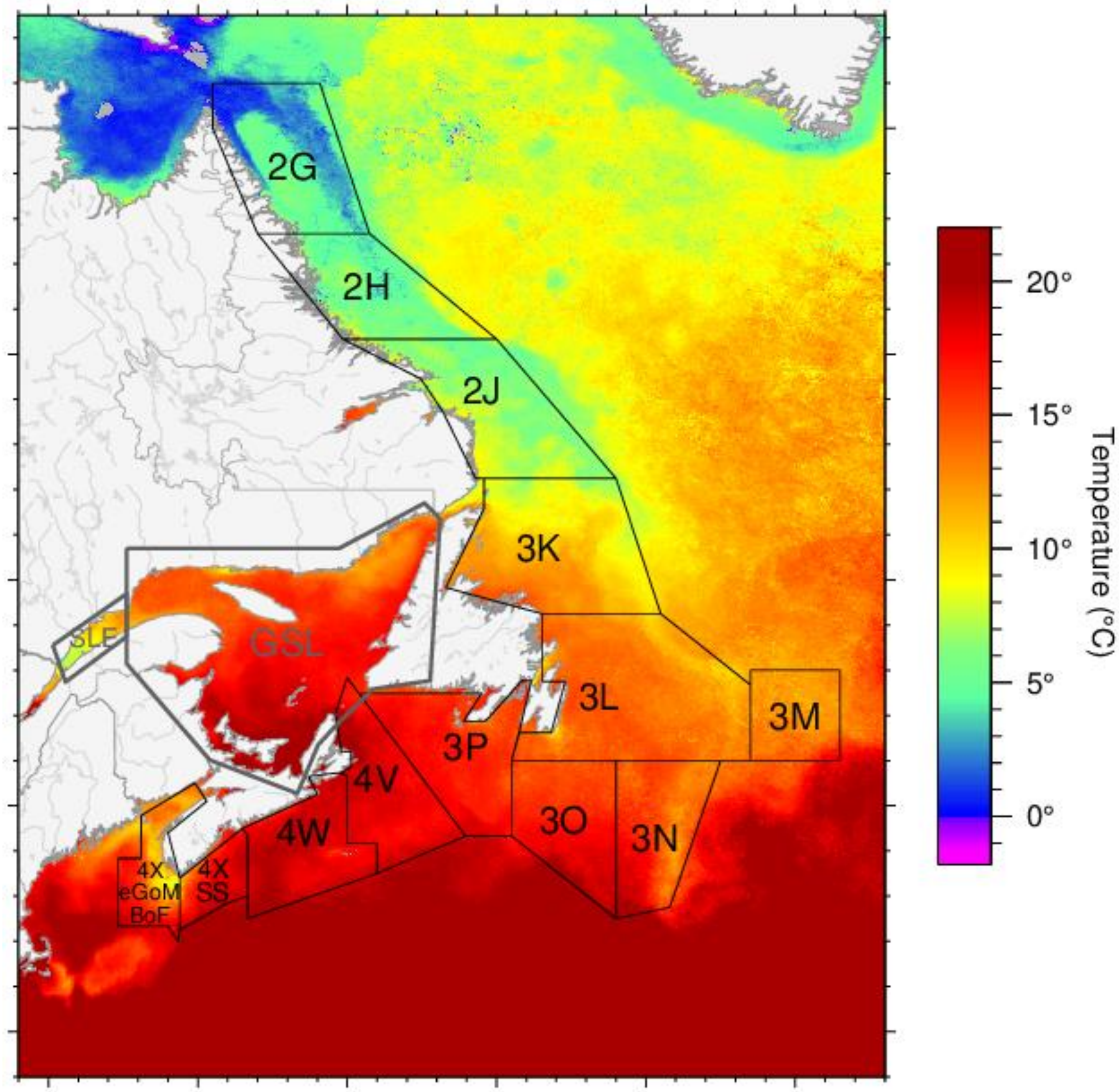


Figure 5: Map of the modified NAFO Division boxes used to calculate sea surface temperature (SST). The color background of the map is the climatological SST.

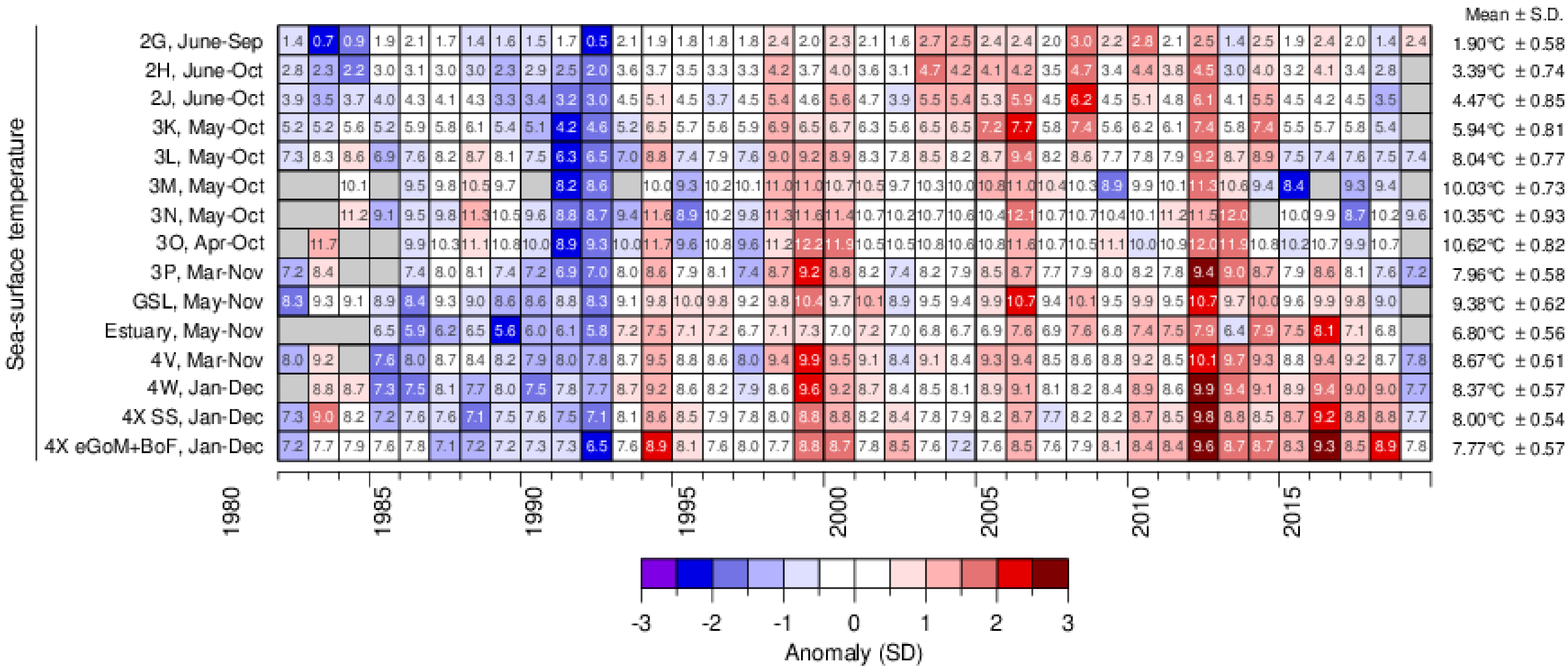


Figure 6: Scorecards presenting standardized SST anomalies for NAFO Divs. presented in Figure 5 during ice-free months (see first column for months identification). The reference climatological period used for anomaly calculations is 1982–2010 (climatological average and standard deviations are reported in the last column of the figure).

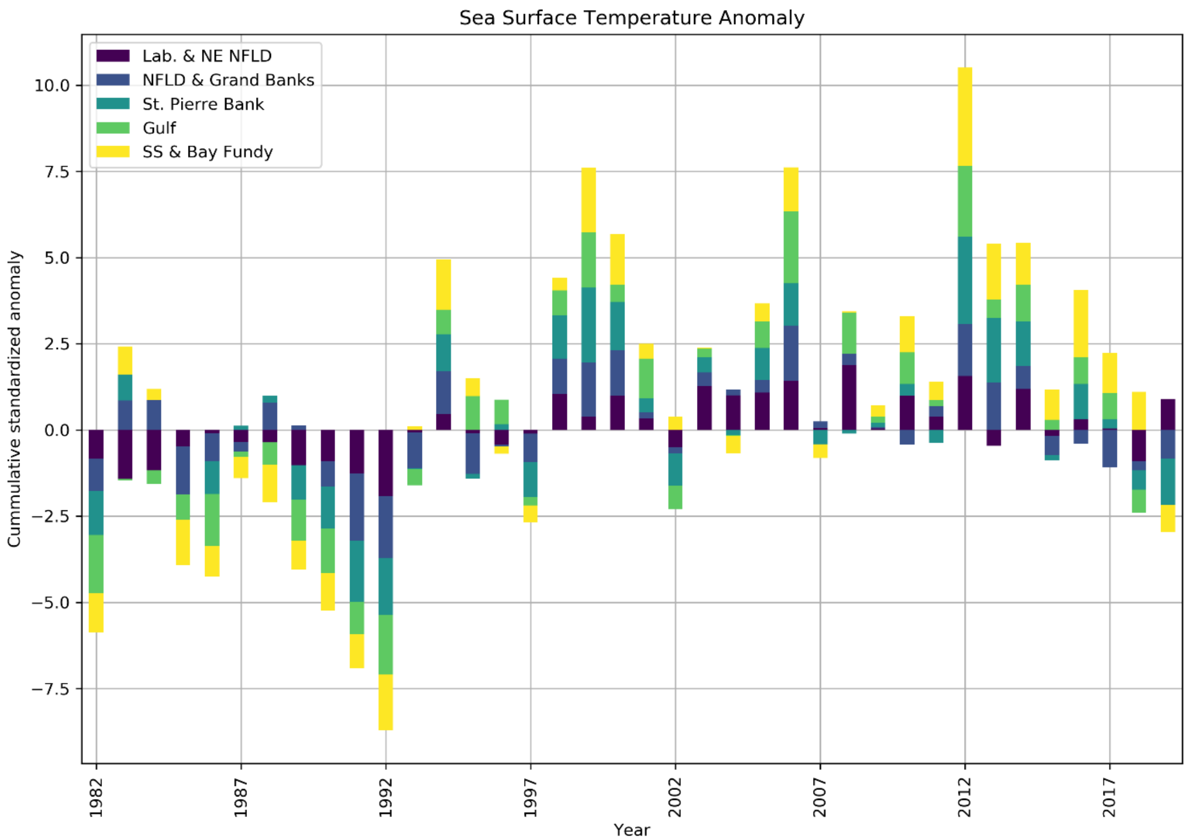


Figure 7: Stacked bar plot of standardized SST anomalies for five studied Regions. The anomaly per Region is made by averaging anomalies presented in Figure 6 as follows: Labrador and Northeast Newfoundland shelf (purple) corresponds to NAFO Divs. 2GHJ3K; Newfoundland and Grand Bank (blue) corresponds to 3LNO; St. Pierre Banks (turquoise) correspond to 3P; the Gulf of St. Lawrence (green) correspond to GSL; and the Scotian Shelf and the Bay of Fundy (yellow) corresponds to 4X-SS and 4X-GoM-BoF on Figure 5 and Figure 6.

	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	x̄	sd
-- NAFO division 2GH (Summer) --																																									
T_{bot}	0.0	0.5	-0.7		-0.3	-1.7	1.3	-0.4	0.2	-2.7	-0.6	-1.0		0.2			0.8		0.5	0.4	-0.8	0.1	-0.3	-0.2		1.4	0.1	1.1	1.7	-0.6	0.9	2.0	0.0	-0.7	-0.4	1.0	0.1	-1.0	1.1	1.0	0.5
$T_{bot<100m}$	0.6	0.2	-0.4		-0.6	-0.9	0.5	-0.5	-0.2		-1.1			-0.9			2.6			0.0	-0.1	-0.2	-0.7	0.3			2.3			-0.5	0.1	0.4	0.0	-0.7	-0.9	0.0		2.2	0.2	-0.9	0.7
-- NAFO division 2J (fall) --																																									
T_{bot}	-0.2	0.3	-1.1	-0.9	-1.9	-1.5	0.3	-1.2	0.1	-0.4	-1.1	-0.7	-1.5	-1.4	-0.8	0.0	0.7	0.4	0.4	0.7	0.1	0.9	0.6	1.0	1.3	1.4	0.1	1.5	0.4	0.5	1.8	1.8	0.4	0.4	-0.1	-0.1	0.6	0.2	1.1	2.0	0.6
$T_{bot<100m}$	1.1	1.4	-0.1	0.5	-0.7	-0.4	-1.5	-0.6	0.4	-0.7	-0.5	-0.2	-0.4	-0.2	-0.5	-2.2	-0.2	1.6	1.1	0.3	0.3	-0.5	-2.1	-0.8	2.0	0.4	1.0	0.8	0.7	-0.3	1.2	1.2	2.4	0.5	2.0	1.6	0.6	1.1	-0.8	1.5	0.7
-- NAFO division 3K (fall) --																																									
T_{bot}	0.1	0.1	-0.2	-0.5	-1.1	-2.0	-0.1	-0.9	-0.3	-0.2	-1.6	-0.7	-1.6	-1.6	-1.1	-0.6	0.0	0.7	0.6	1.0	0.6	0.3	0.8	1.0	1.6	1.1	0.4	1.2	0.9	0.5	1.7	2.3	0.5	0.7	0.0	0.2	0.0	-0.3	0.9	2.4	0.5
$T_{bot<100m}$	0.2	0.0	-2.1	-1.5	-0.7	0.1	-0.1	-0.9	-1.1	-1.3	-1.2	-1.6	0.3	-0.6	-0.7	0.0	1.5	0.6	0.3	0.4	0.1	0.7	0.1	0.7	1.4	1.5	0.9	0.3	1.7	-0.1	1.3	2.2	1.4	0.6	1.2	1.3	0.3	0.5	0.9	0.9	0.7
-- NAFO division 3LNO (fall) --																																									
T_{bot}	0.5	0.0	1.3	0.3	-0.3	-1.1	0.2	-0.7	-1.1	0.3	-1.0	-1.4	-1.4	-2.2	-1.4	-0.2	0.2	0.1	1.0	2.2	-0.2	0.3	0.2	-0.1	1.2	0.5	0.9	0.1	-0.3	0.8	1.8	3.1	0.7	0.9	0.5	0.1	0.7	-1.0	0.4	1.1	0.4
$T_{bot<100m}$	0.4	-0.9	2.2	0.3	-0.8	-0.6	0.3	-0.5	-0.6	0.7	0.1	-1.0	-1.2	-1.8	-1.3	0.2	0.5	-0.5	0.9	2.6	-0.5	0.0	-0.3	-0.4	0.4	0.1	0.6	-0.4	-0.6	0.8	1.8	2.2	0.7	0.9	0.8	0.0	0.8	-0.7	0.1	1.1	0.6
-- NAFO division 3Ps (spring) --																																									
T_{bot}	0.7	2.8	0.0	0.5	0.5	-1.3	-0.3	-1.8	0.3	-0.8	-1.8	-1.6	-0.2	-0.5	-0.6	-0.2	0.3	-0.5	0.2	1.0	1.3	-0.4	0.1	-1.0	0.3	1.0	1.0	-0.6	0.3	0.8	0.9	1.5	1.3	1.1	0.9	1.1	1.9	0.7	1.4	2.1	0.6
$T_{bot<100m}$	0.3	2.7	0.2	0.7	0.8	-1.4	0.2	-1.1	0.6	-0.7	-1.3	-0.9	1.4	-1.4	-0.9	-0.9	0.2	-1.0	0.4	1.2	1.3	-0.5	-0.3	-1.4	0.3	1.0	0.6	-0.6	0.2	0.3	0.4	1.3	0.7	0.8	0.1	0.0	1.0	-0.1	1.4	0.5	0.8
-- NAFO division 4RST (summer) --																																									
T_{bot}	1.8	3.7	0.4	1.0	-1.4	0.1	0.6	-0.4	-0.4	-0.7	-0.9	0.2	-2.0	-0.1	-0.5	-1.0	-0.1	-0.8	-0.9	0.4	0.7	-0.2	0.5	0.1	0.1	0.1	-0.1	0.9	-0.6	0.8	0.7	1.0	0.6	-0.1	0.3	0.4	-0.3	0.2		3.3	0.7
$T_{bot<100m}$	1.8	3.6	0.4	1.0	-1.4	0.1	0.6	-0.4	-0.5	-0.7	-0.8	0.2	-2.2	-0.2	-0.4	-0.9	-0.1	-0.8	-0.9	0.3	0.7	-0.2	0.5	0.1	0.1	0.1	-0.1	0.9	-0.5	0.8	0.7	0.9	0.6	-0.1	0.3	0.4	-0.4	0.2		3.2	0.7
-- NAFO division 4VWX (summer) --																																									
T_{bot}	0.4	0.8	-0.3	0.0	1.5	1.2	1.1	-0.7	-0.2	0.1	-0.7	-1.5	-0.3	-0.2	0.4	-0.1	-0.6	0.3	-1.6	0.3	1.0	-2.2	0.5	-0.4	-1.7	0.9	0.9	-0.9	-0.3	2.2	0.6	0.4	2.2	1.0	1.7	1.1	2.1	2.0		6.4	0.8
$T_{bot<100m}$	0.2	1.0	-0.3	-0.3	1.7	1.1	0.8	-0.4	-0.1	0.2	-0.9	-1.4	-0.4	-0.5	-0.3	-0.3	-0.7	0.2	-1.2	0.5	1.2	-1.6	0.4	-0.9	-1.9	1.5	0.9	-0.9	0.5	2.1	0.2	0.0	2.3	0.4	1.1	0.7	1.6	1.3		5.5	0.9
-- NAFO division 5Y (summer) --																																									
T_{bot}	-0.5	-0.8	-0.2	-0.3	-0.6	0.0	0.1	-0.5	-1.4	-1.7	-0.7	-0.7	-1.1	-1.1	0.8	0.6	0.1	0.0	-1.2	0.3	1.2		1.6	-0.5	0.6	0.8	0.7	-1.0	1.3	1.3	2.4	2.4	3.2	1.4		0.9	1.1	1.9		7.4	0.8
$T_{bot<100m}$	0.3	0.3	0.4	-0.1	-1.3	0.5	0.4	-0.7	-2.1	-2.0	-0.3	-0.5	-1.3	-0.9	1.0	0.7	0.2	-0.1	-1.2	-0.3	1.5		1.1	-0.4	0.6	0.2	0.2	-0.4	1.3	1.0	2.0	1.7	2.5	0.7		0.5	0.7	1.2		8.0	1.1

Figure 8: Scorecards presenting standardized bottom temperature anomalies for several NAFO Divisions (both the average over the entire area and the mean of bottom shallower than 100 m are presented). The reference climatological period used for anomaly calculations is 1981–2010 (climatological average and standard deviations are reported in the last column of the figure). The greyed cells correspond to absence of data.

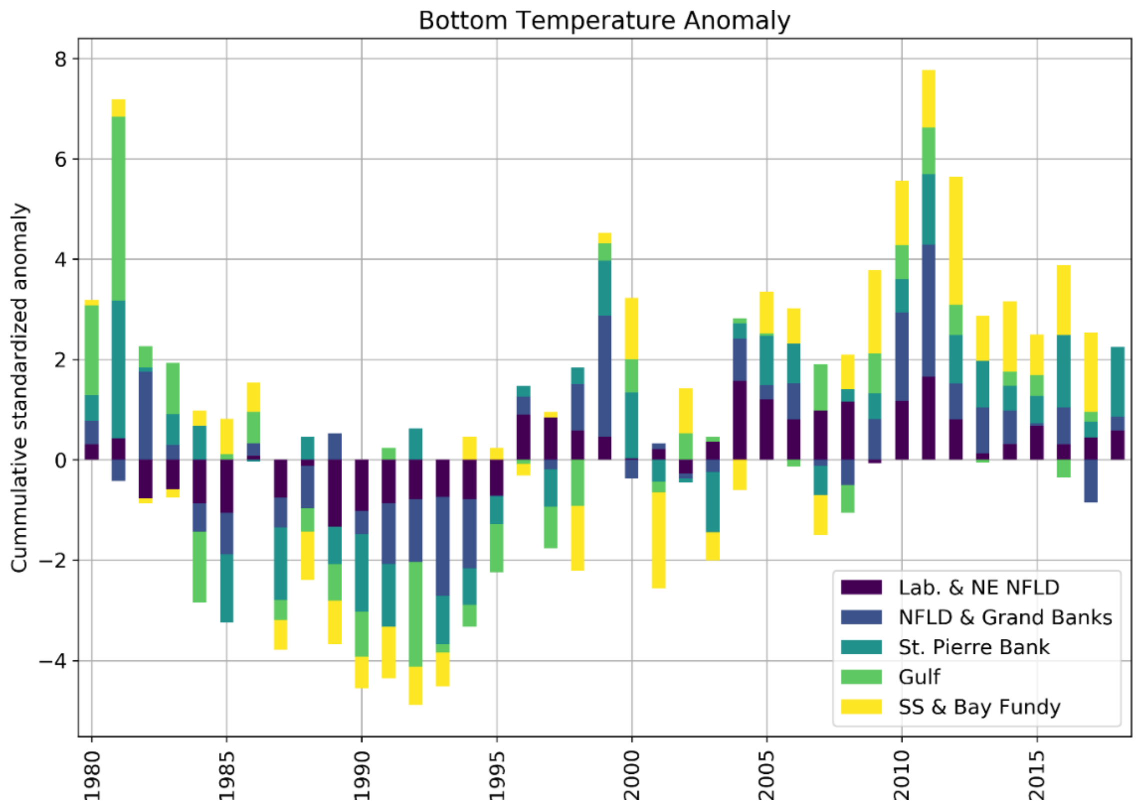


Figure 9: Stacked bar plot of standardized bottom temperature anomalies for five Regions studied here. The anomaly per Region is made by averaging anomalies presented in Figure 8 as follows: Labrador and Northeast Newfoundland shelf (purple) corresponds to Divs. 2GHJ3K Newfoundland and Grand Bank (blue) corresponds to 3LNO; St. Pierre Banks (turquoise) correspond to 3Ps; the Gulf of St. Lawrence (green) correspond to 4RST; and the Scotian Shelf and the Bay of Fundy (yellow) corresponds to 4VWX5Y on Figure 8.

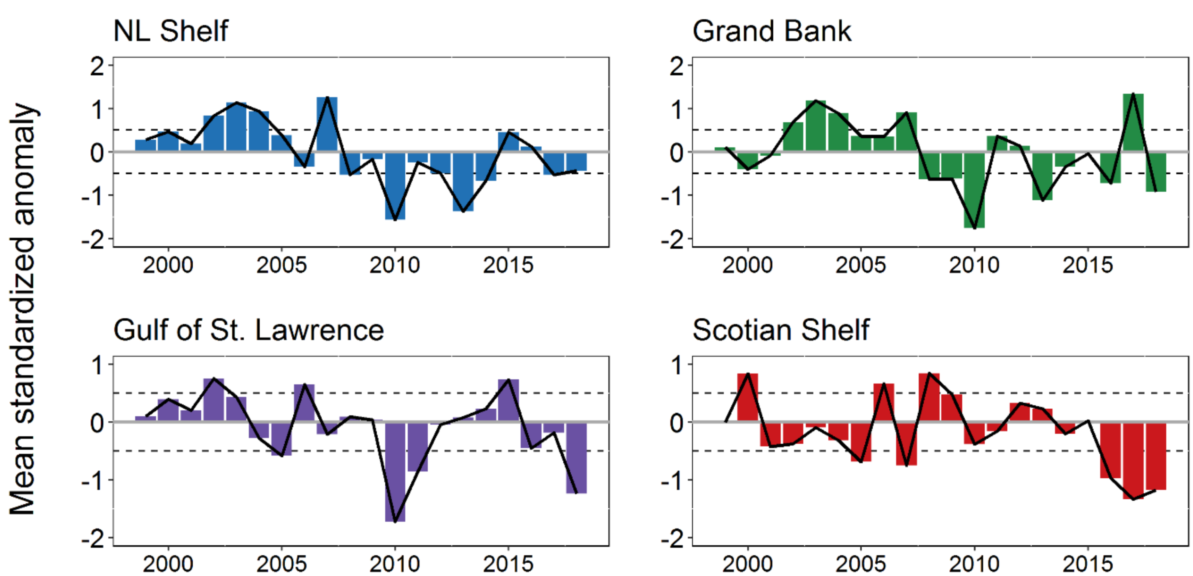


Figure 10: Mean annual anomalies of integrated (0–150 m) nitrate concentration for the period 1999–2018. Anomalies within ± 0.5 standard deviation of the mean (dashed lines) for the 1999–2015 climatology are considered normal conditions.

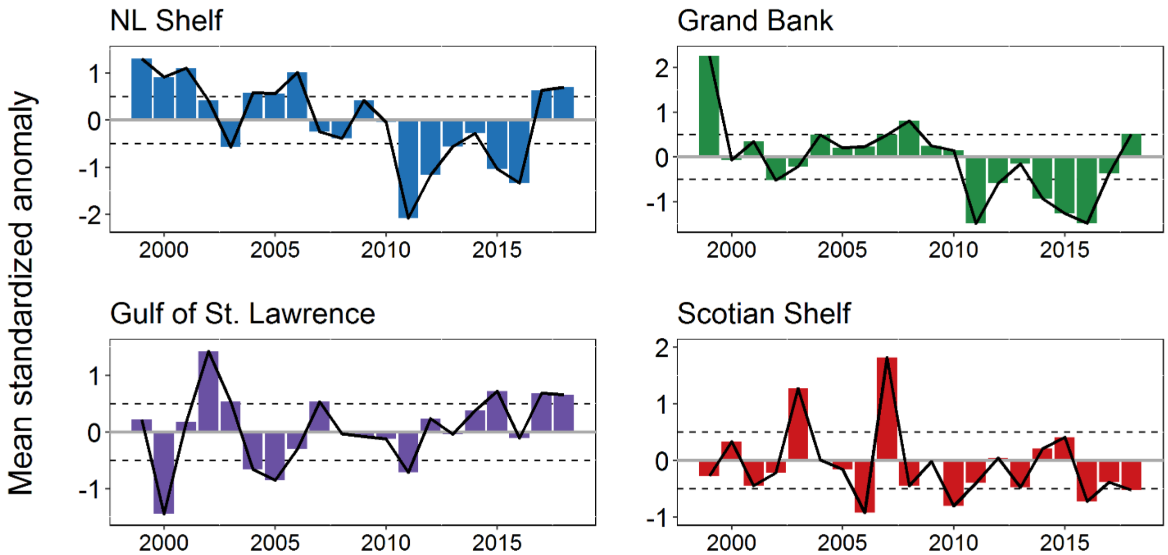


Figure 11: Mean annual anomalies of integrated (0–100 m) chlorophyll a concentration for the period 1999–2018. Anomalies within ± 0.5 standard deviation of the mean (dashed lines) for the 1999–2015 climatology are considered normal conditions.

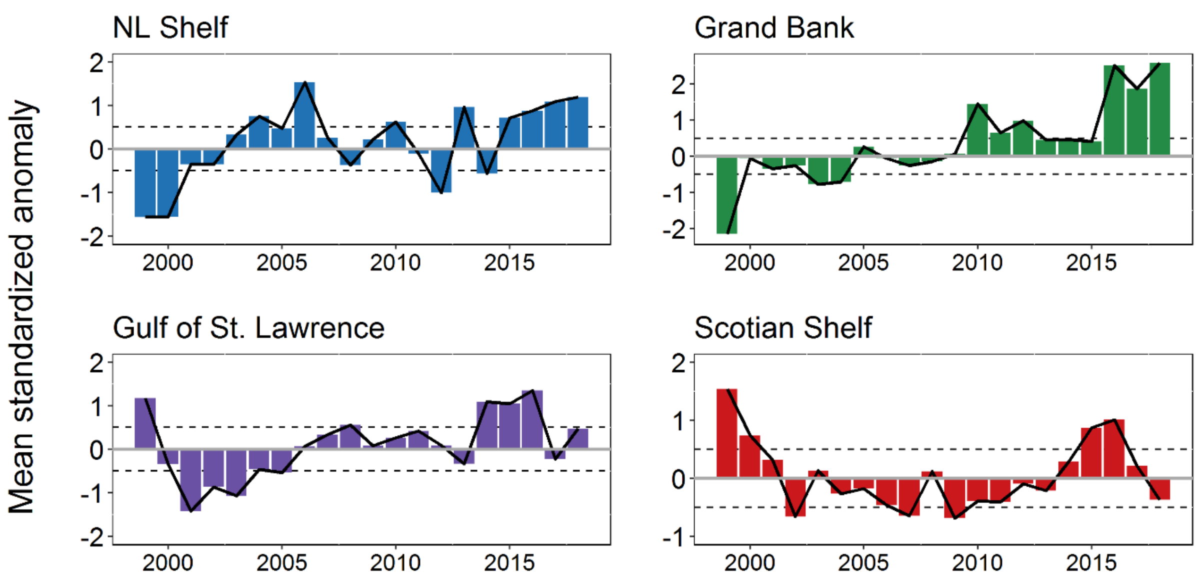


Figure 12: Mean annual anomalies of zooplankton abundance for the period 1999–2018. Anomalies within ± 0.5 standard deviation of the mean (dashed lines) for the 1999–2015 climatology are considered normal conditions.

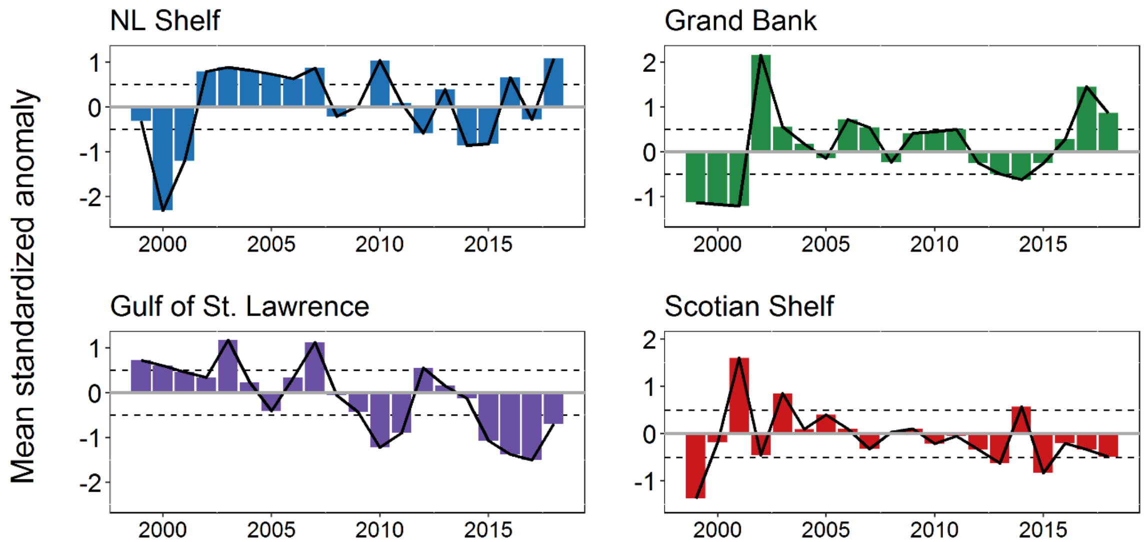


Figure 13: Mean annual anomalies of zooplankton biomass for the period 1999–2018. Anomalies within ± 0.5 standard deviation of the mean (dashed lines) for the 1999–2015 climatology are considered normal conditions

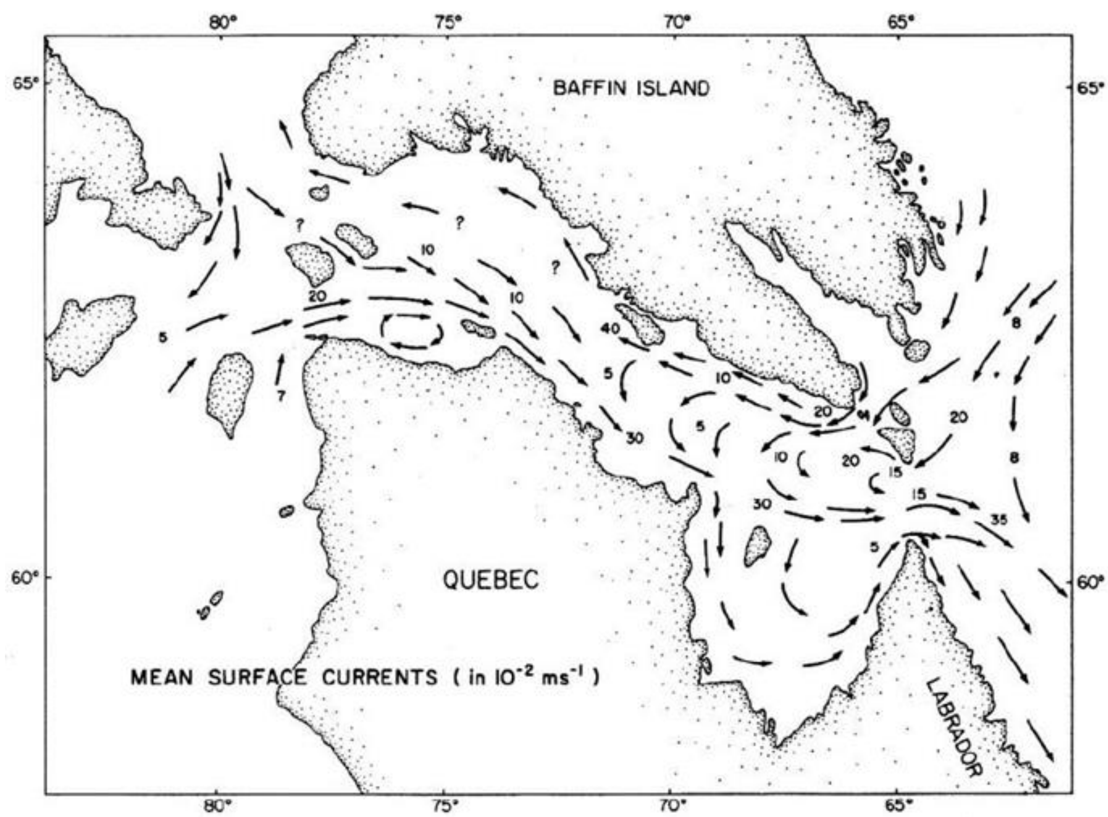


Figure 14: Surface circulation in Ungava Bay (Drinkwater 1986).

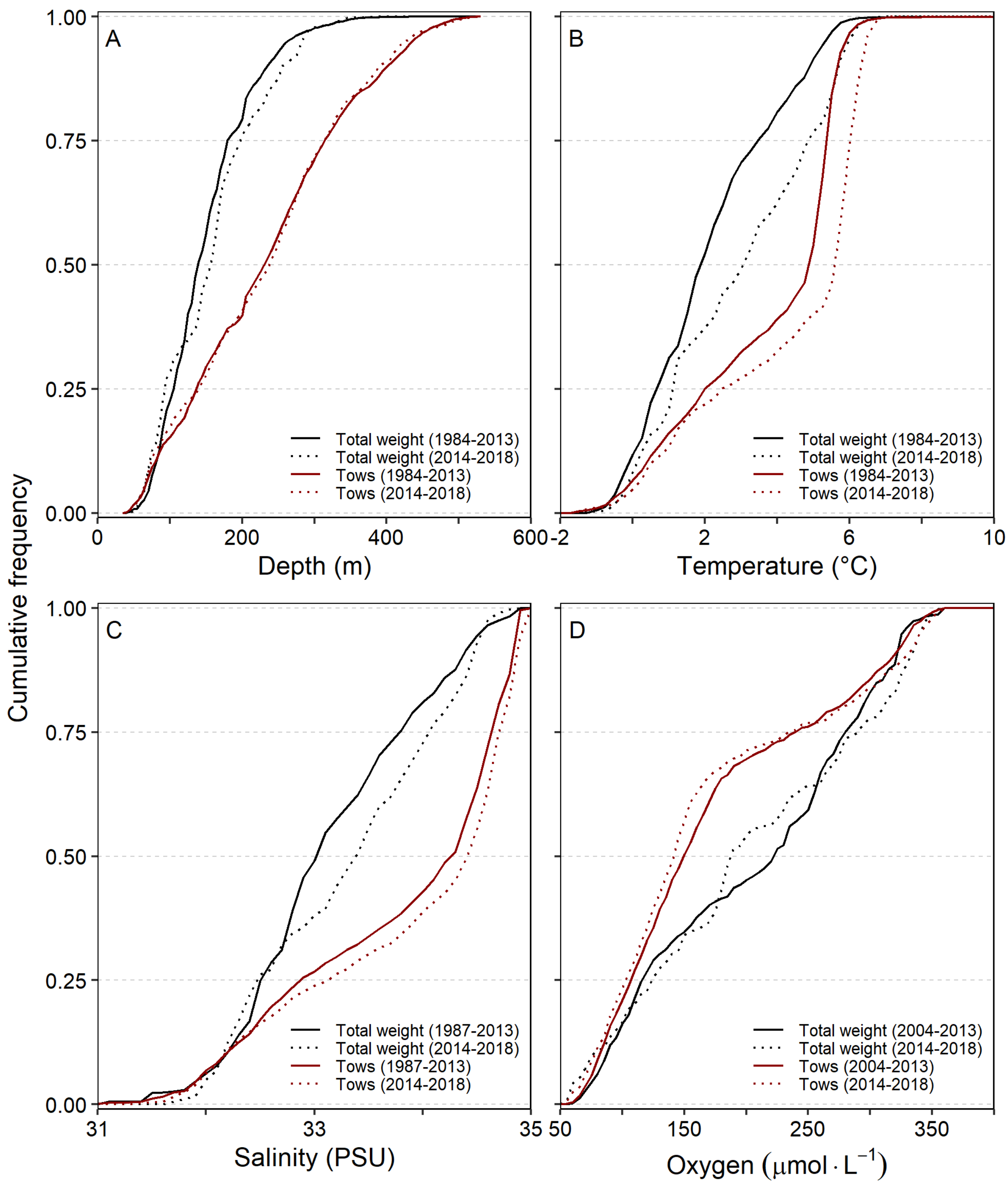


Figure 15: Cumulative frequency of American Plaice catches (kg tow^{-1}, black curves) by A) depth, B) temperature, C) salinity and D) dissolved oxygen for the last five years (dotted line) and earlier years (solid line) of the northern Gulf of St. Lawrence August scientific surveys. The data are corrected in Lady Hammond-Western IIA equivalent. The red curves represent all the sets done during each period.

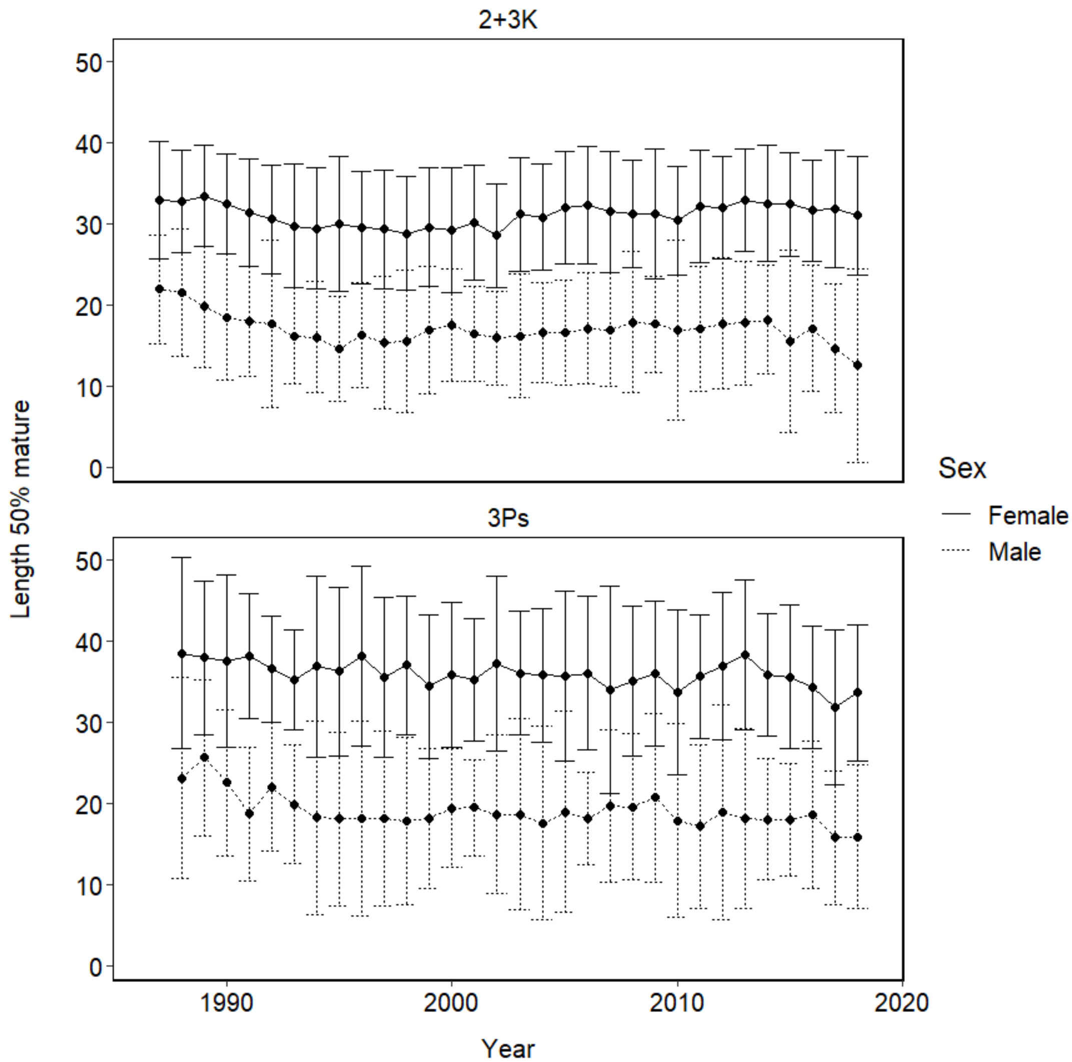


Figure 16: Length (cm) at 50% maturity (± 95% Confidence interval) by year for male and female American Plaice in NAFO SA2 + Div. 3K (top) and Subdiv. 3Ps (bottom).

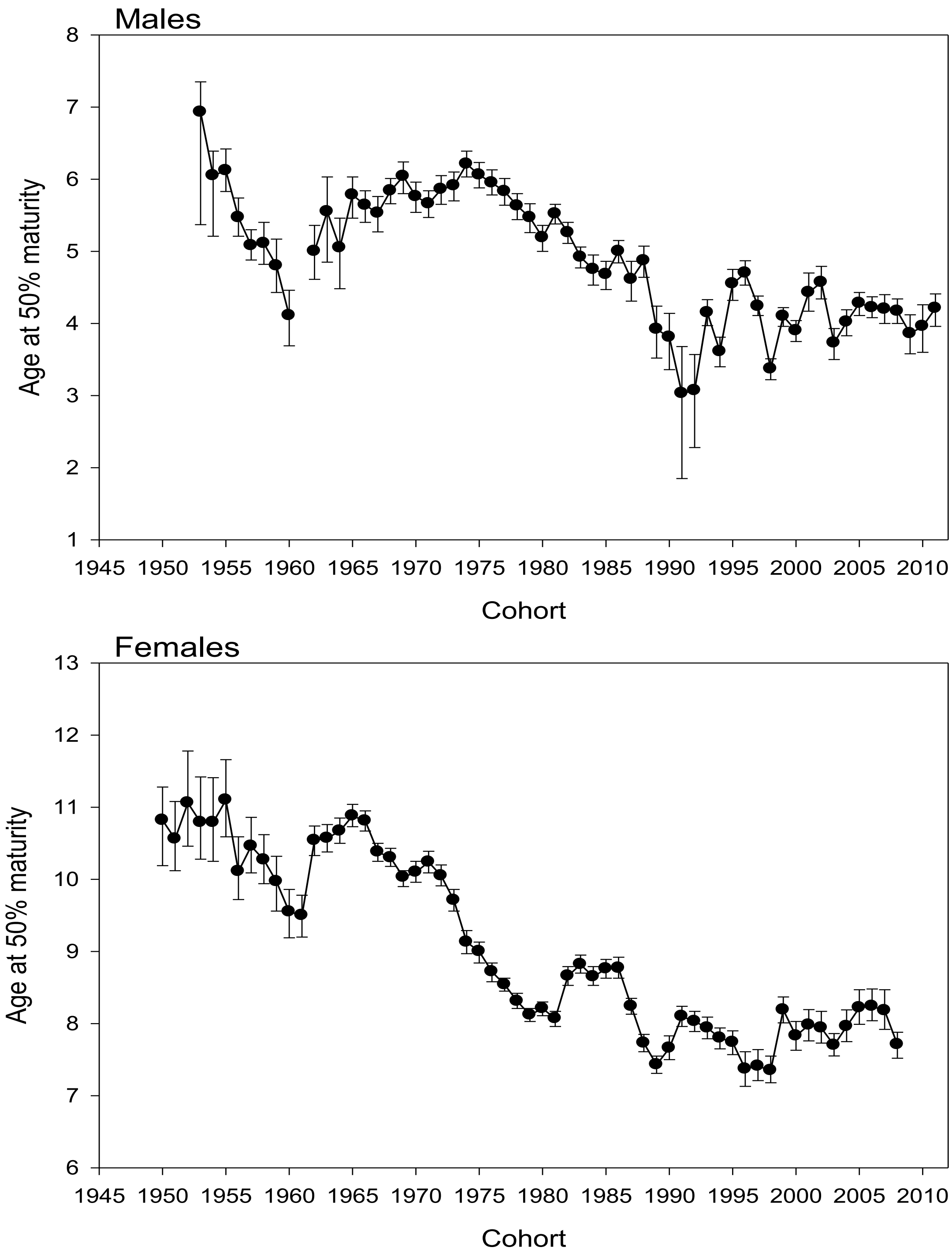
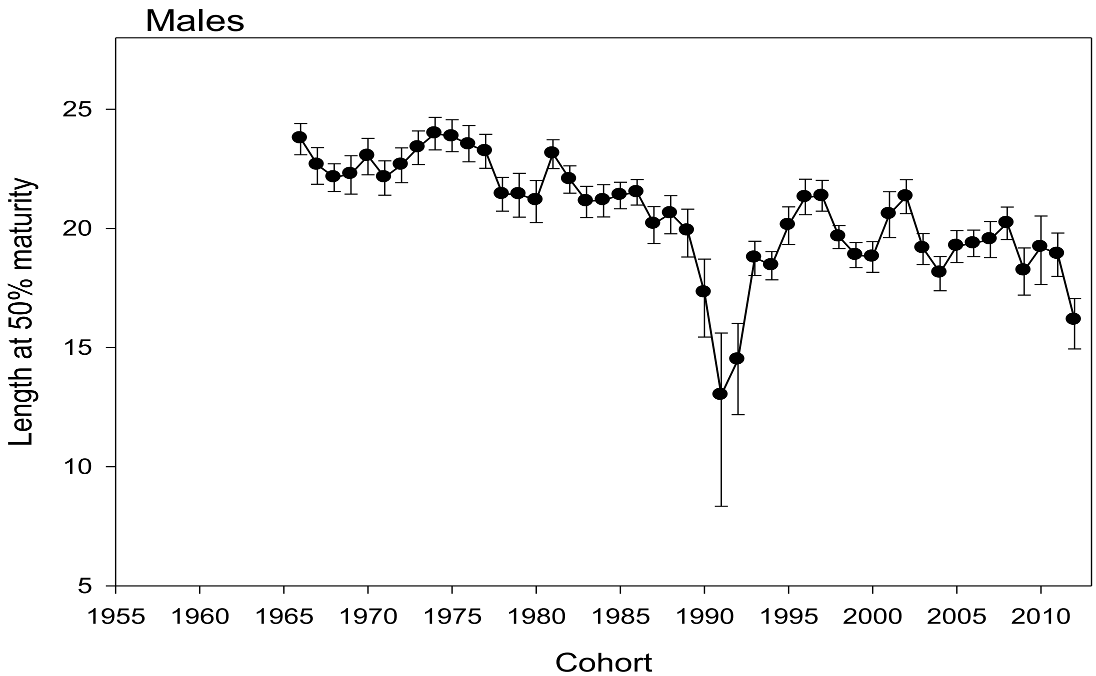


Figure 16 continued.



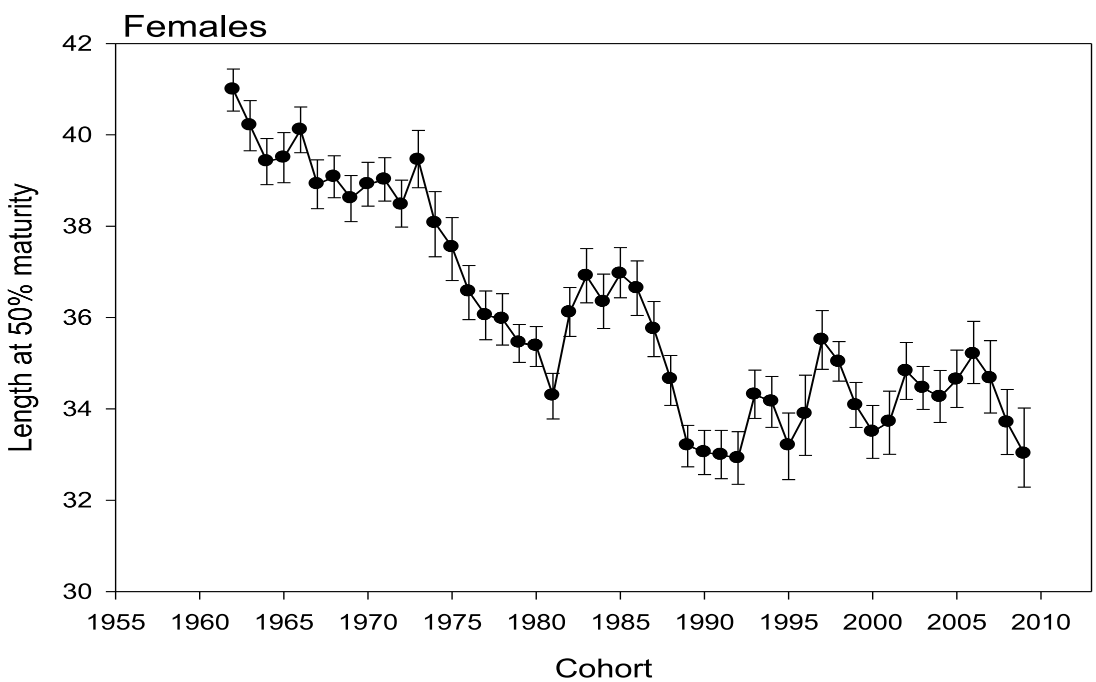


Figure 17: Age (left) and length in centimeters (right) at 50% maturity (± 95% fiducial limits) by cohort for male and female American Plaice in NAFO Divs. 3LNO.

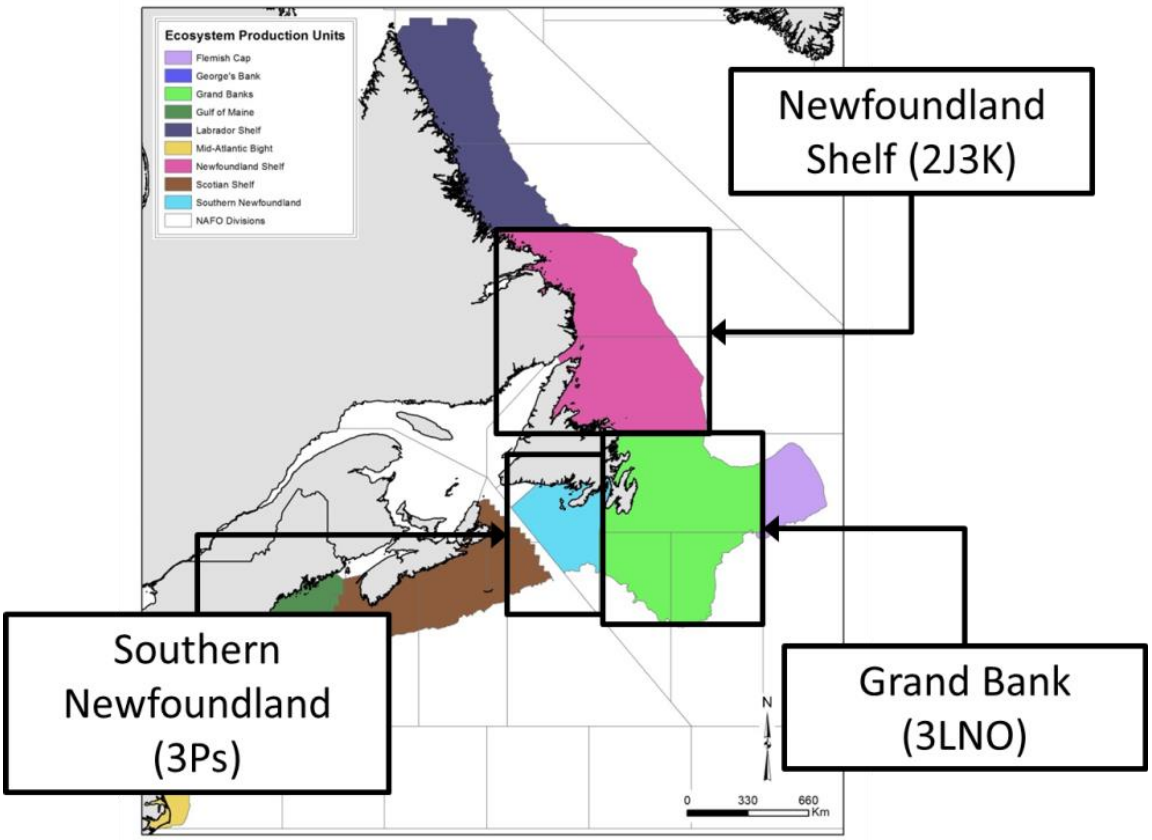


Figure 18: Ecosystem Production Units (EPUs) in the Newfoundland & Labrador (NL) Bioregion: the Newfoundland Shelf (2J3K), the Grand Bank (3LNO), and southern Newfoundland (3Ps).

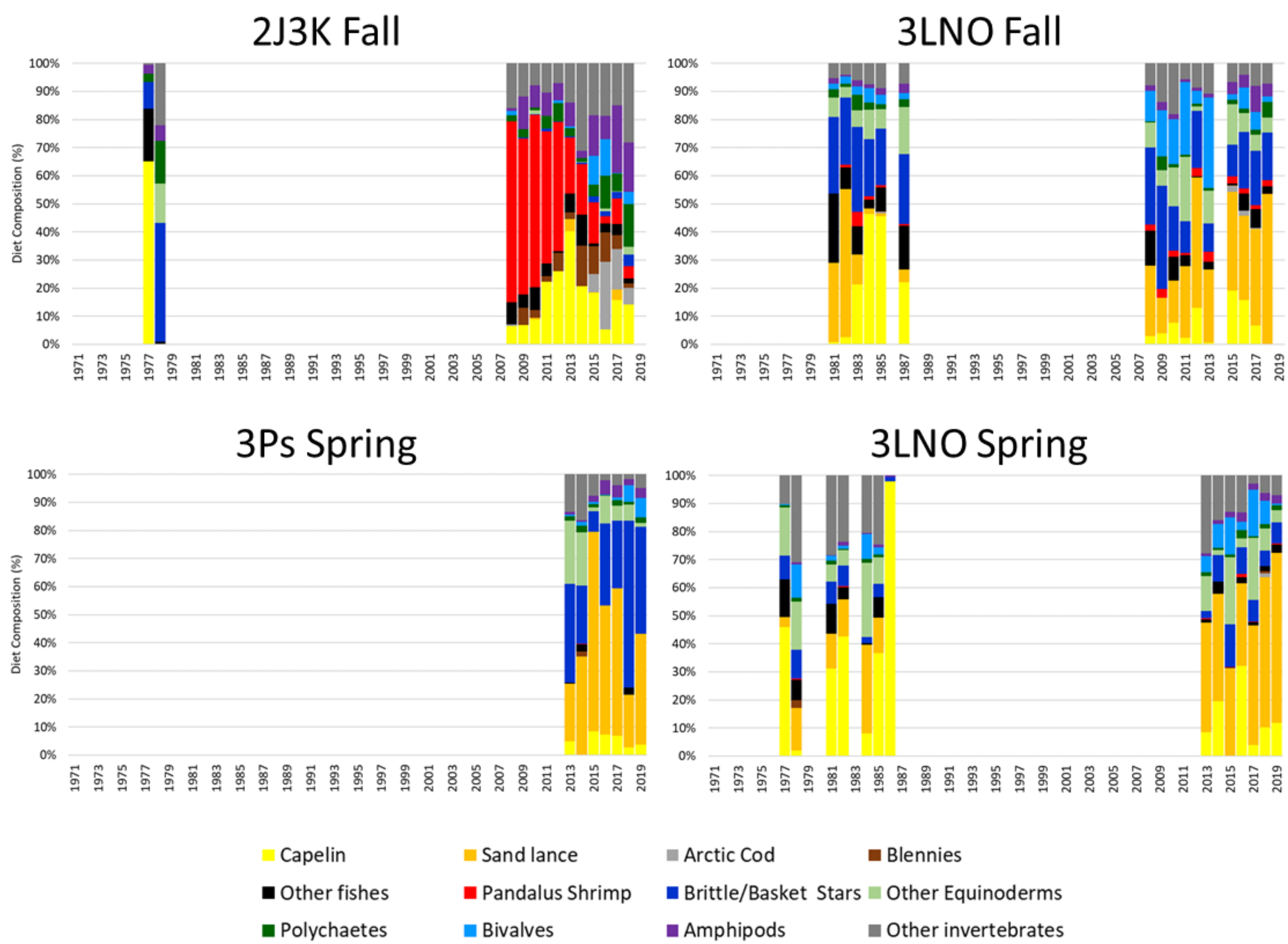


Figure 19: American Plaice diet composition, % by weight, over time by Ecosystem Production Unit and Season from samples collected during DFO RV surveys. Effect of fish size on diet is not considered here. Note: the high fraction of Capelin for 1986 in the 3LNO spring series is likely an artifact of the small sample size during that year (9 stomachs collected, see Table 1).

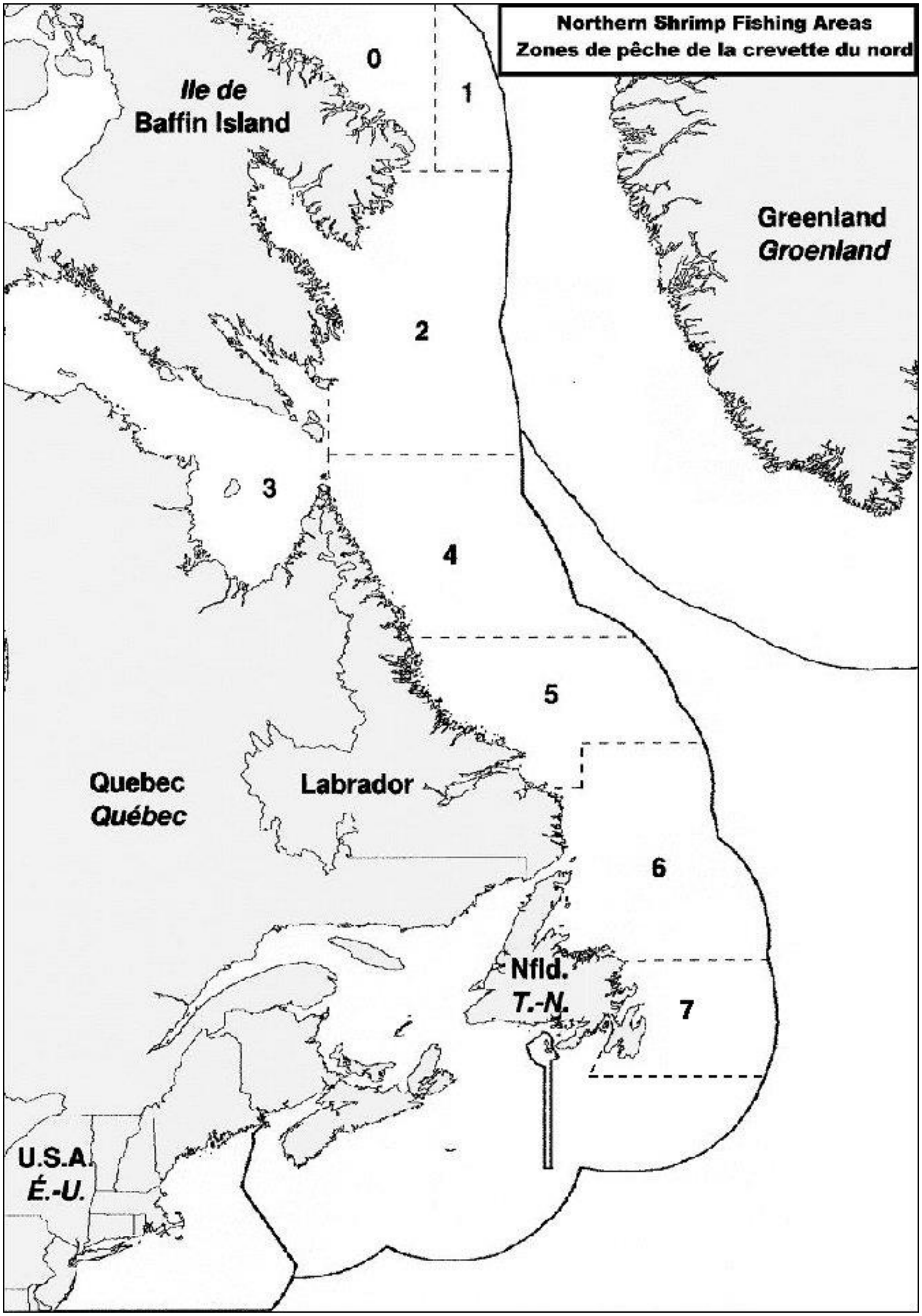


Figure 20: Northern Shrimp Fishing Areas (SFAs) 0 and 1 (Baffin Bay), 2 (Davis Strait) and 3 (Ungava Bay), [DFO 2018](#).

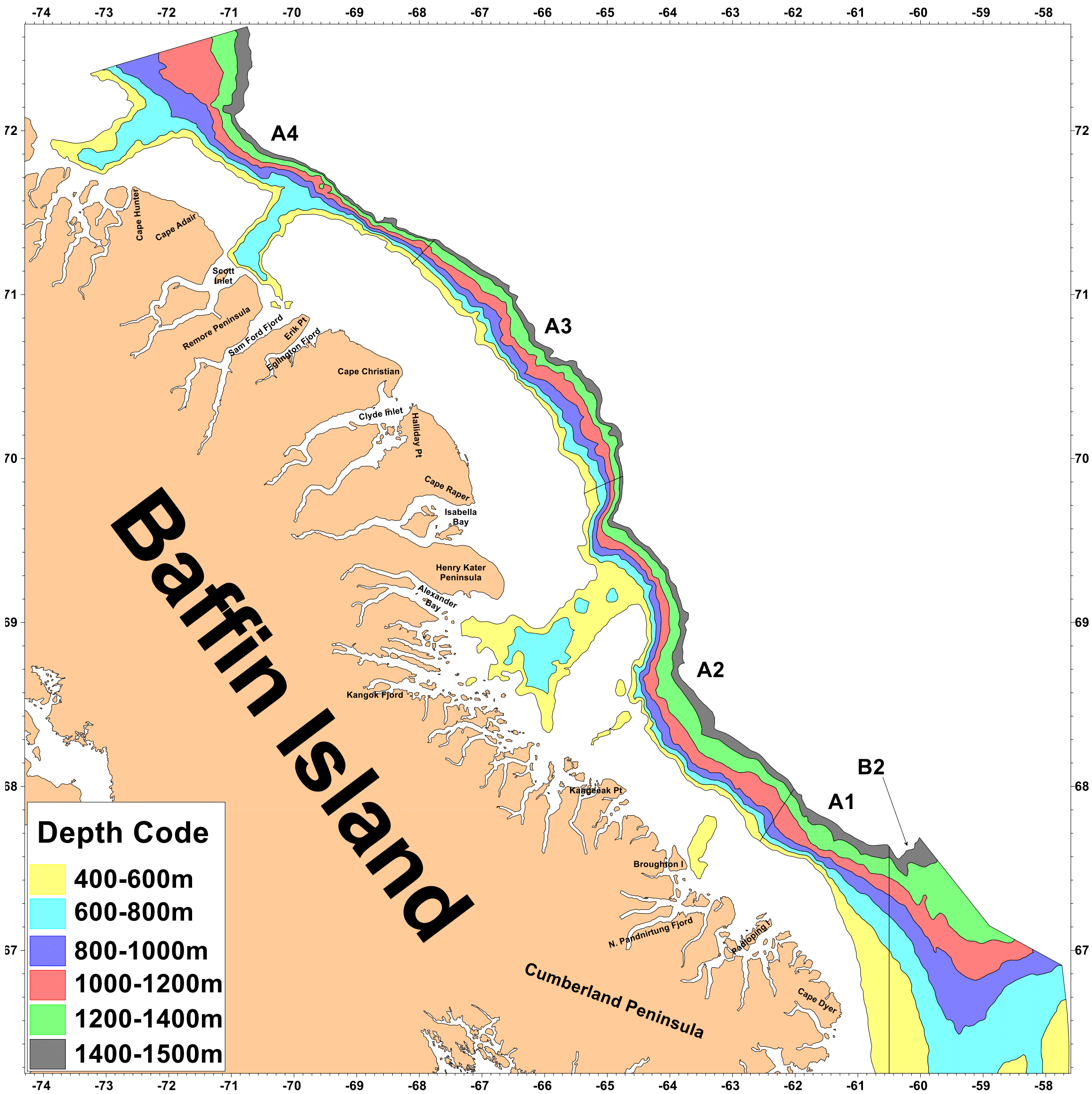


Figure 20 continued.

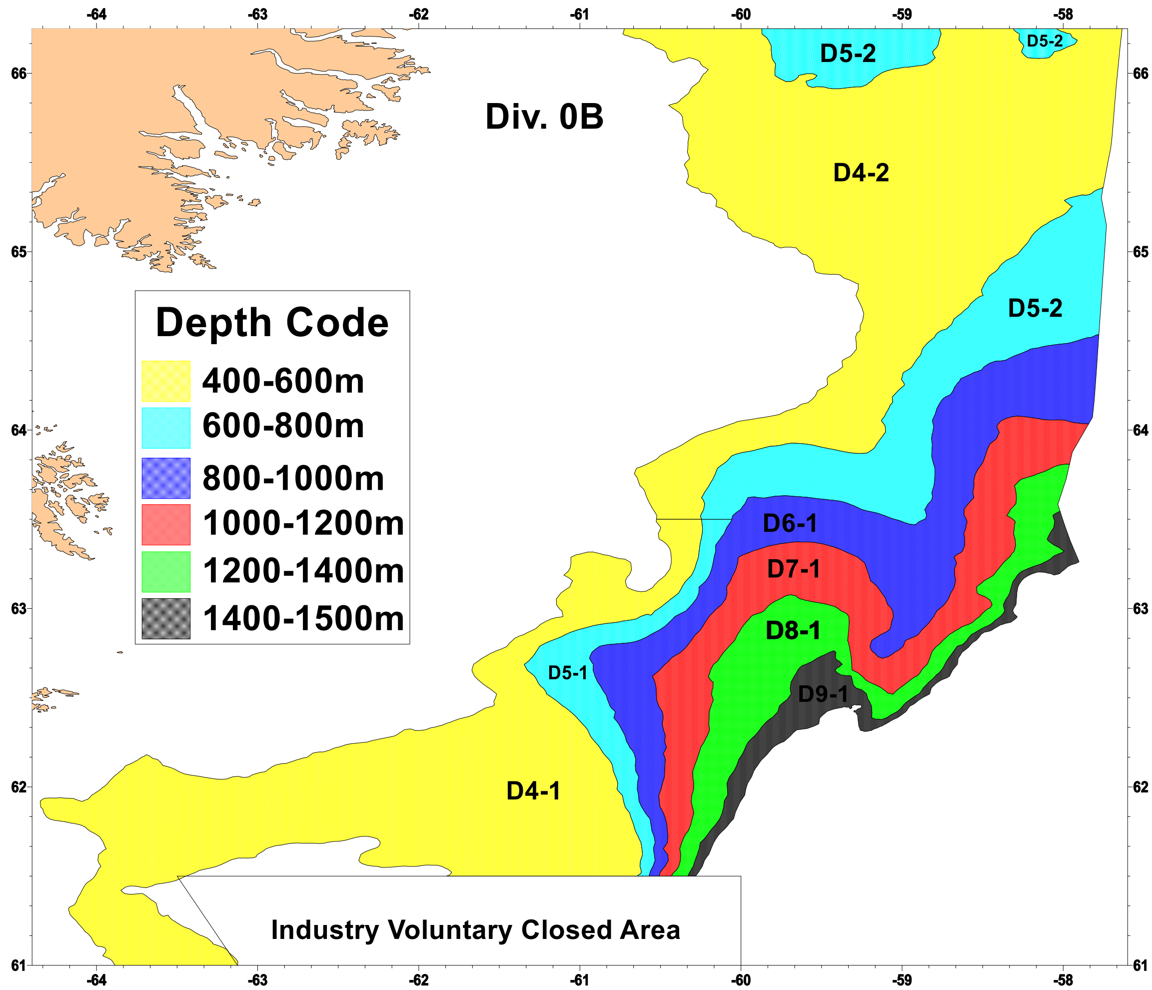


Figure 21: Stratification scheme for DFO surveys conducted in NAFO Divisions 0A (top) and 0B (bottom).

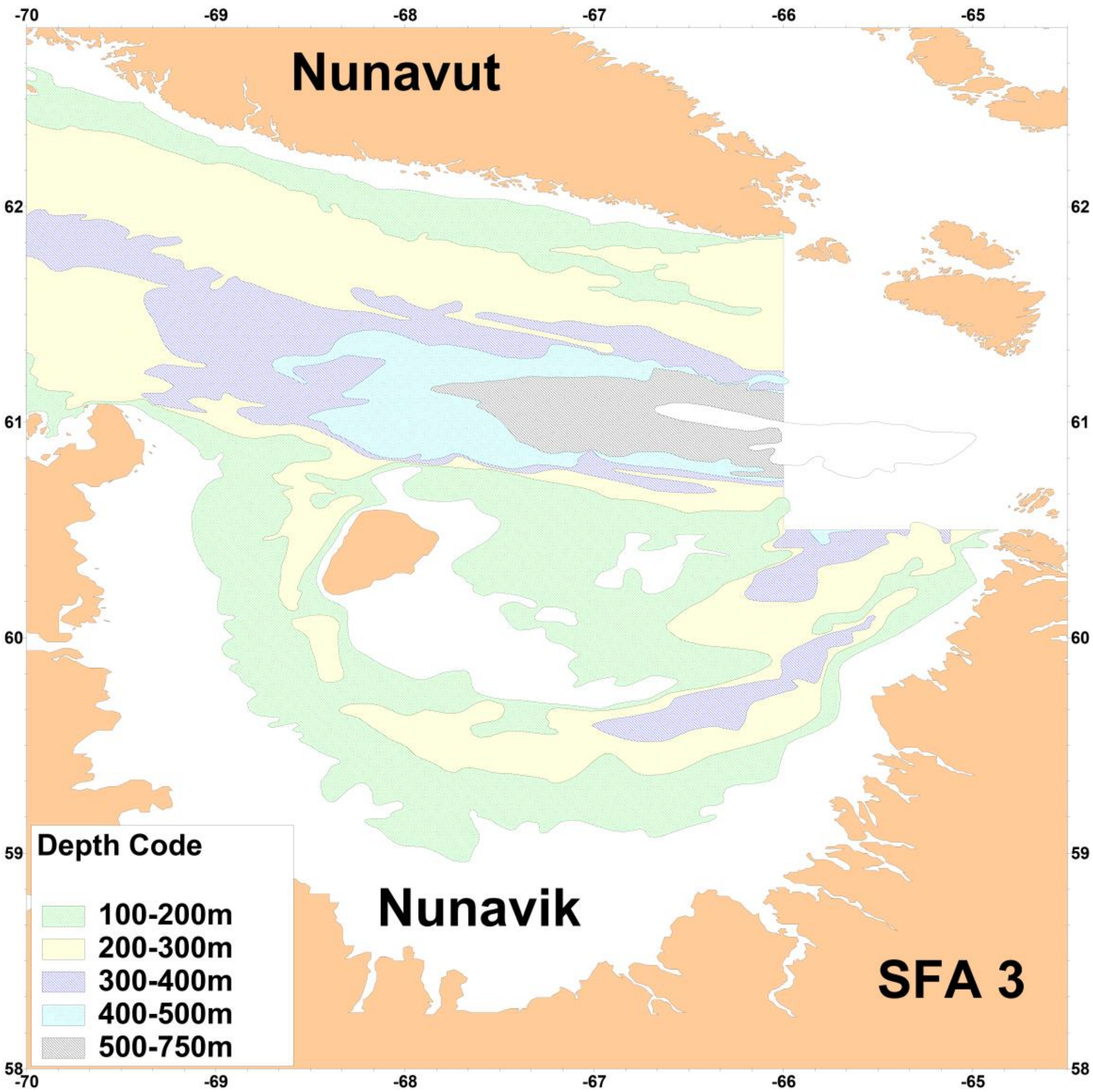


Figure 22: Stratification scheme for NSRF/DFO surveys in SFA 3.

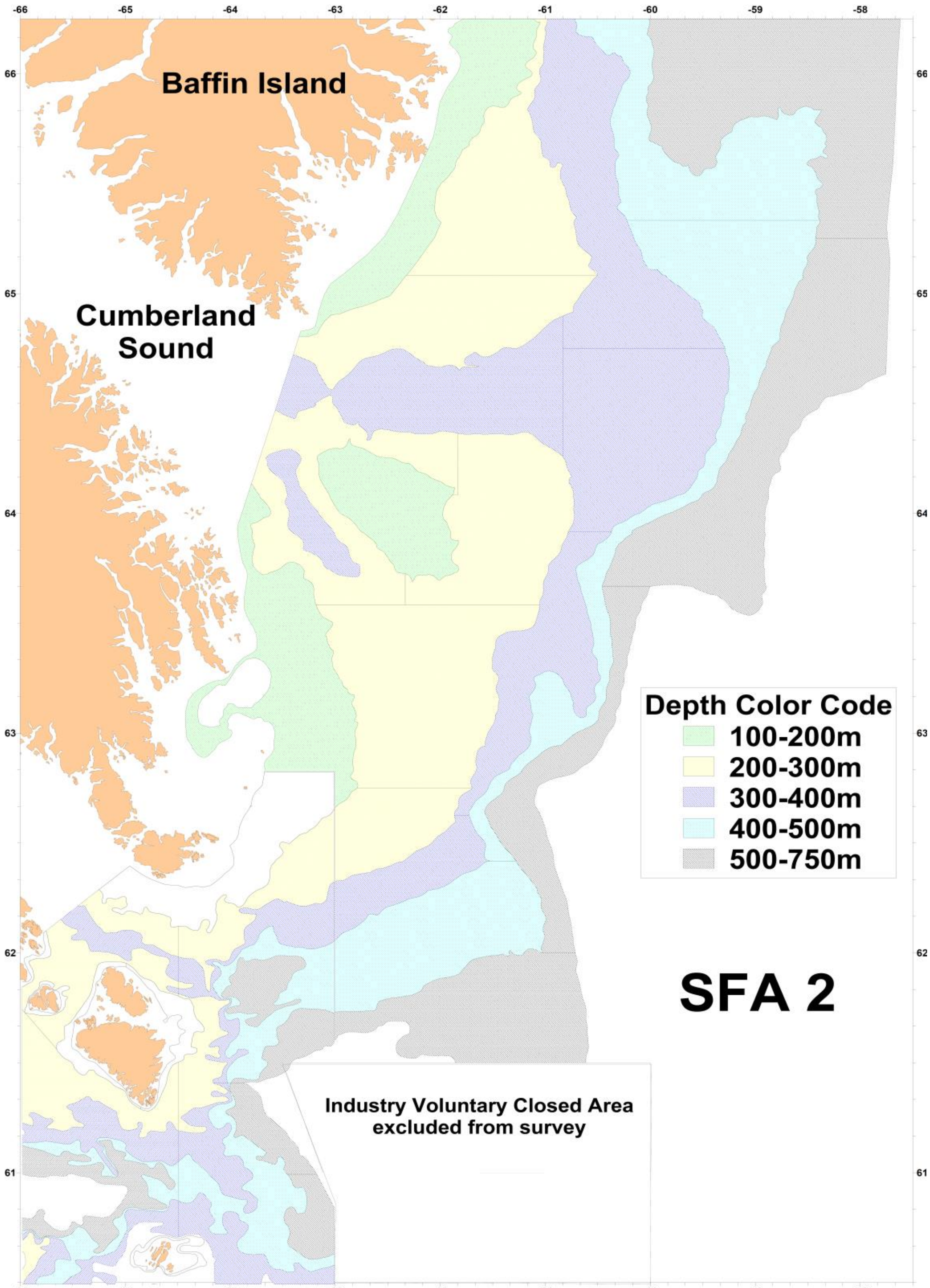


Figure 23: Stratification scheme for NSRF/DFO surveys in SFA 2.

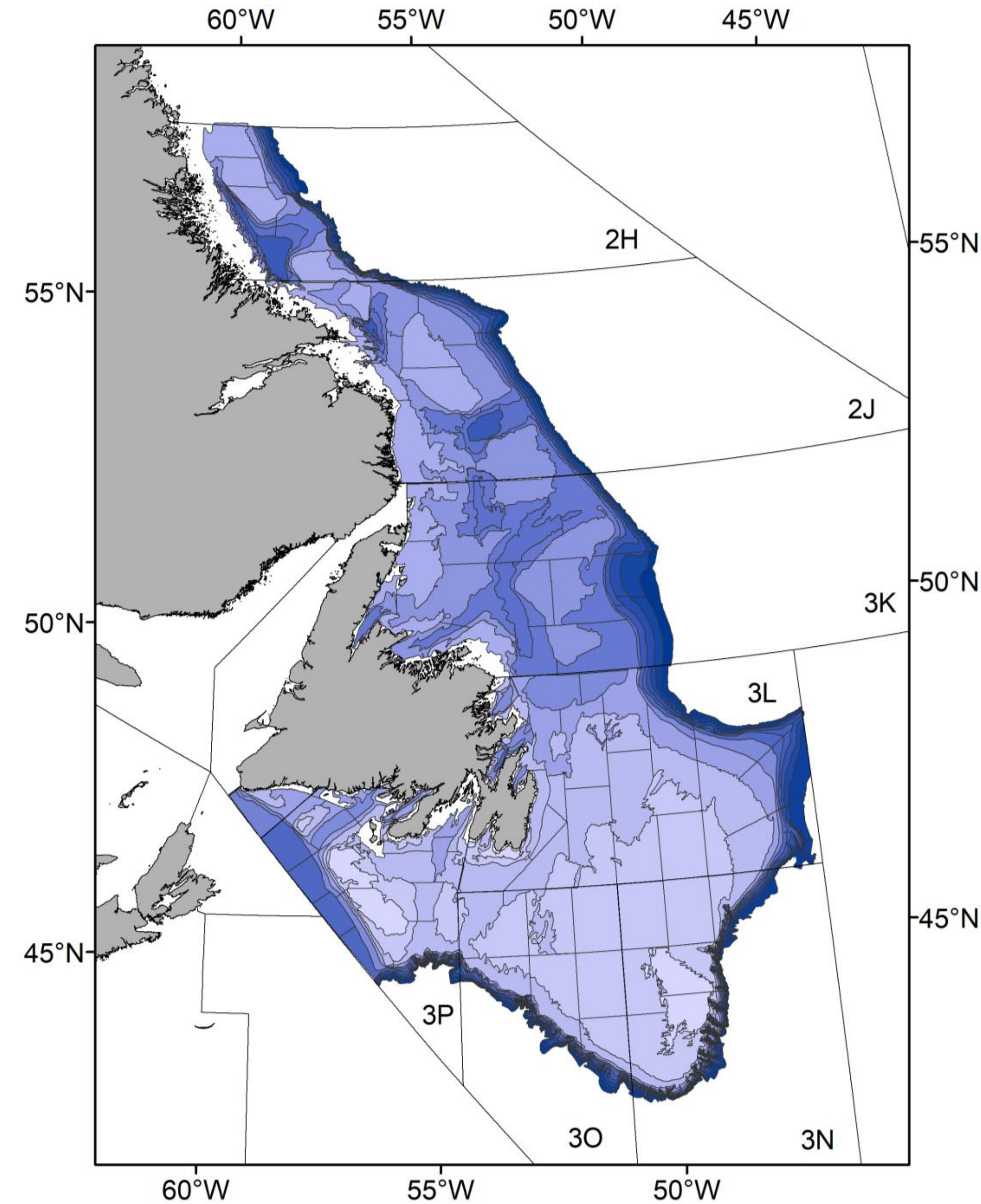


Figure 24: Current survey strata for DFO-Newfoundland & Labrador stratified-random trawl surveys in Divs. 2HJ3KLNO (fall) and 3LNOP (spring). Darker blue indicates deeper waters.

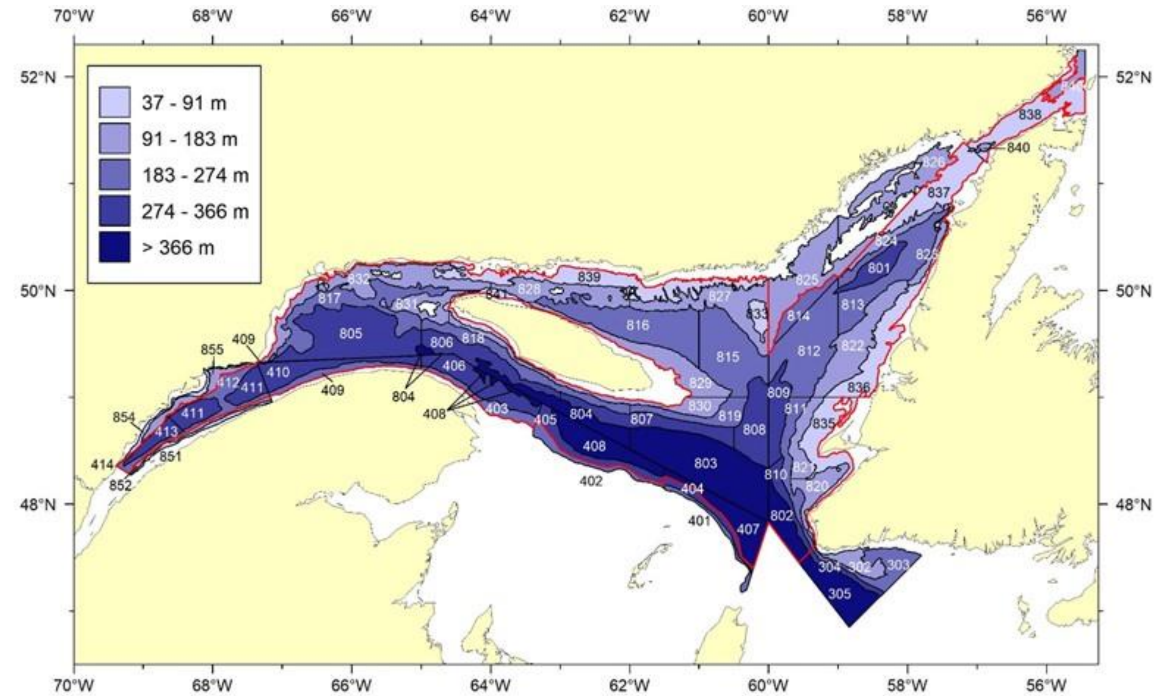


Figure 25: Stratification scheme used for the bottom trawl research survey performed in the northern Gulf of St. Lawrence. The red contour delimits the strata consistently surveyed which were included in the present study. See Figure 26 for details on strata sampling history.

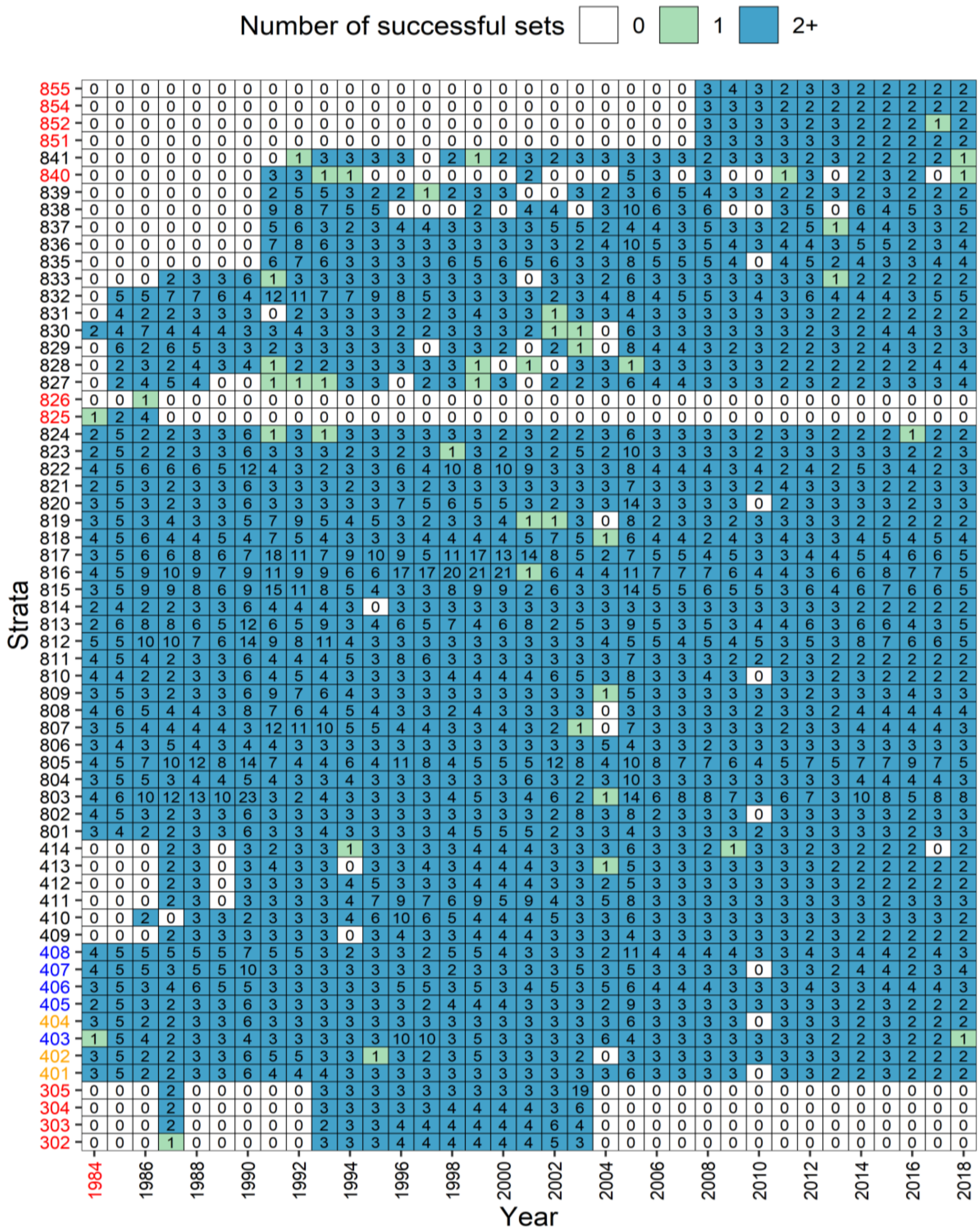


Figure 26: Strata sampled during the bottom trawl research survey performed in the northern Gulf of St. Lawrence since 1984. Year 1984 was not included in analyses because of issues with the data. Strata in red were removed from analyses because of inconstant sampling over the time series. Additional strata were either removed (orange) or had their area modified (blue) because of partial overlapping with strata from the Gulf region September survey.

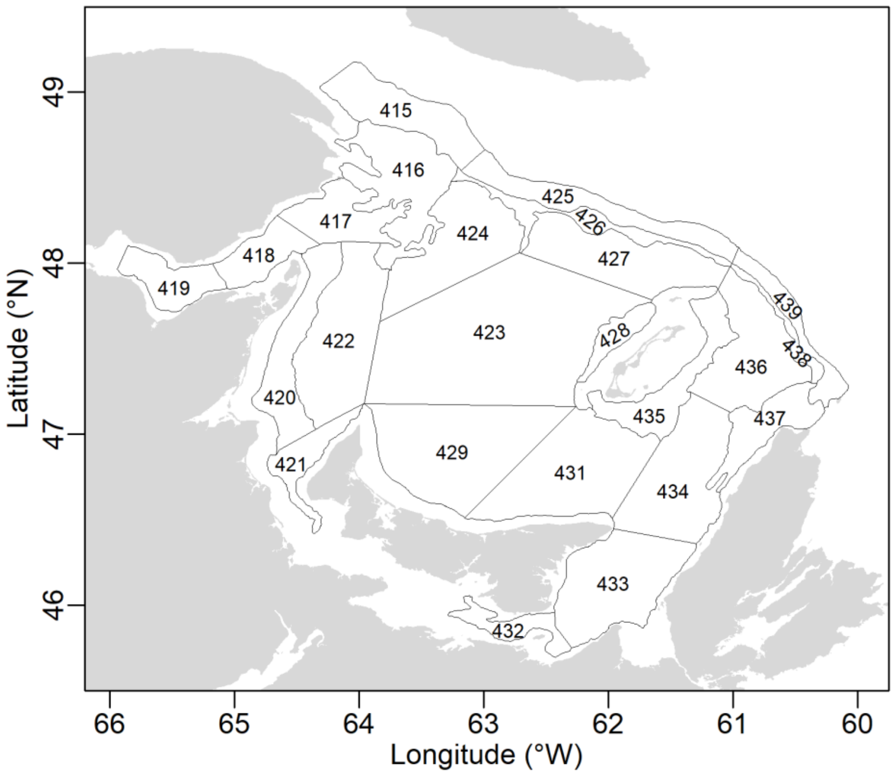


Figure 27: Stratification scheme for the southern Gulf of St. Lawrence September trawl survey. Strata depths are as follows: <50 fathoms: 417 to 424, 427 to 436; 51 to 100 fathoms: 416, 426, 437 and 438; >100 fathoms: 415, 425, 439.

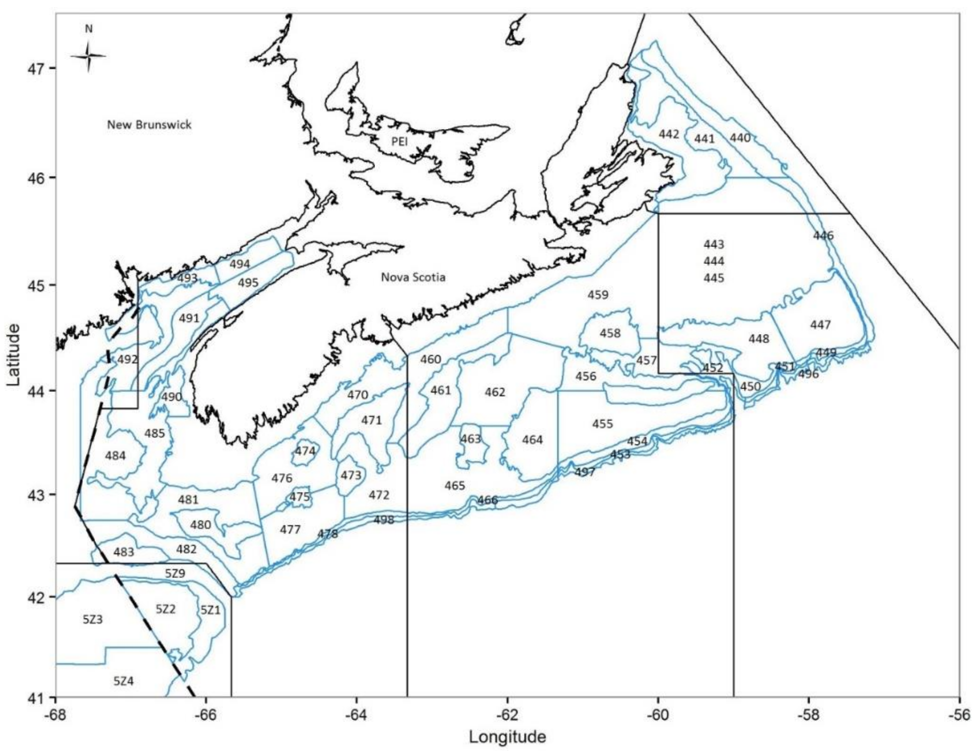


Figure 28: Stratification scheme used for the DFO Maritimes Region 4VWX summer RV survey.

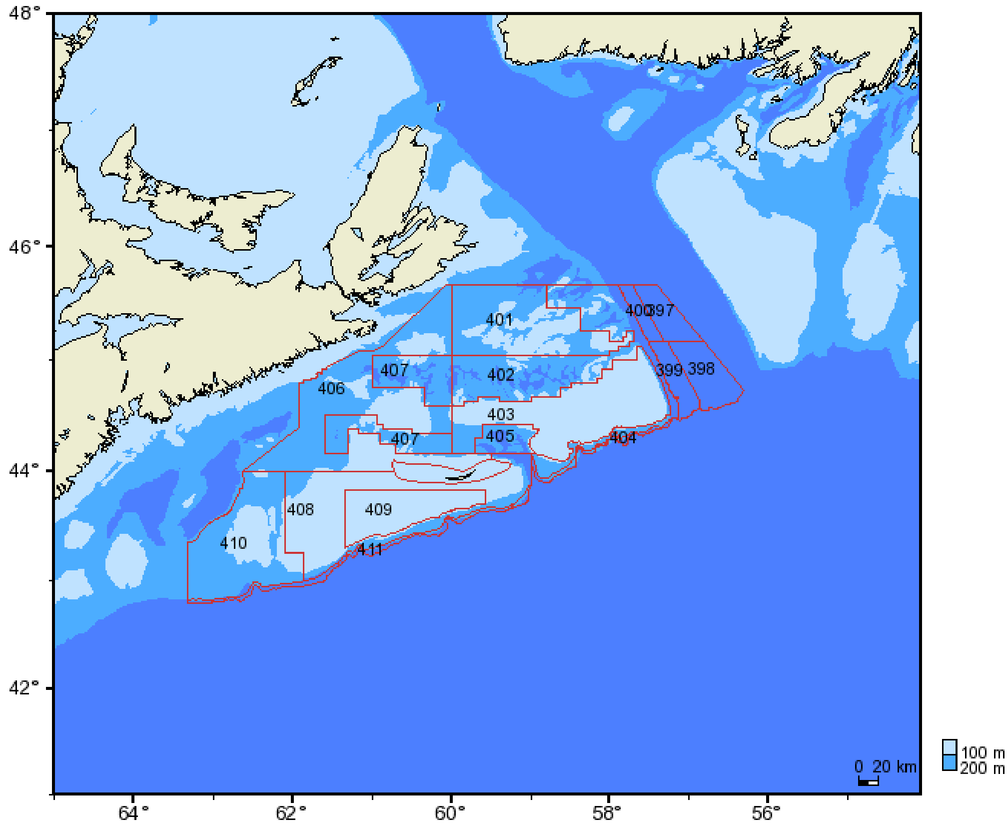


Figure 29: Stratification scheme used for the DFO Maritimes Region 4VsW winter survey.

Figure 30: Stratification scheme used for the Fisheries and Oceans Canada Georges Bank winter survey.

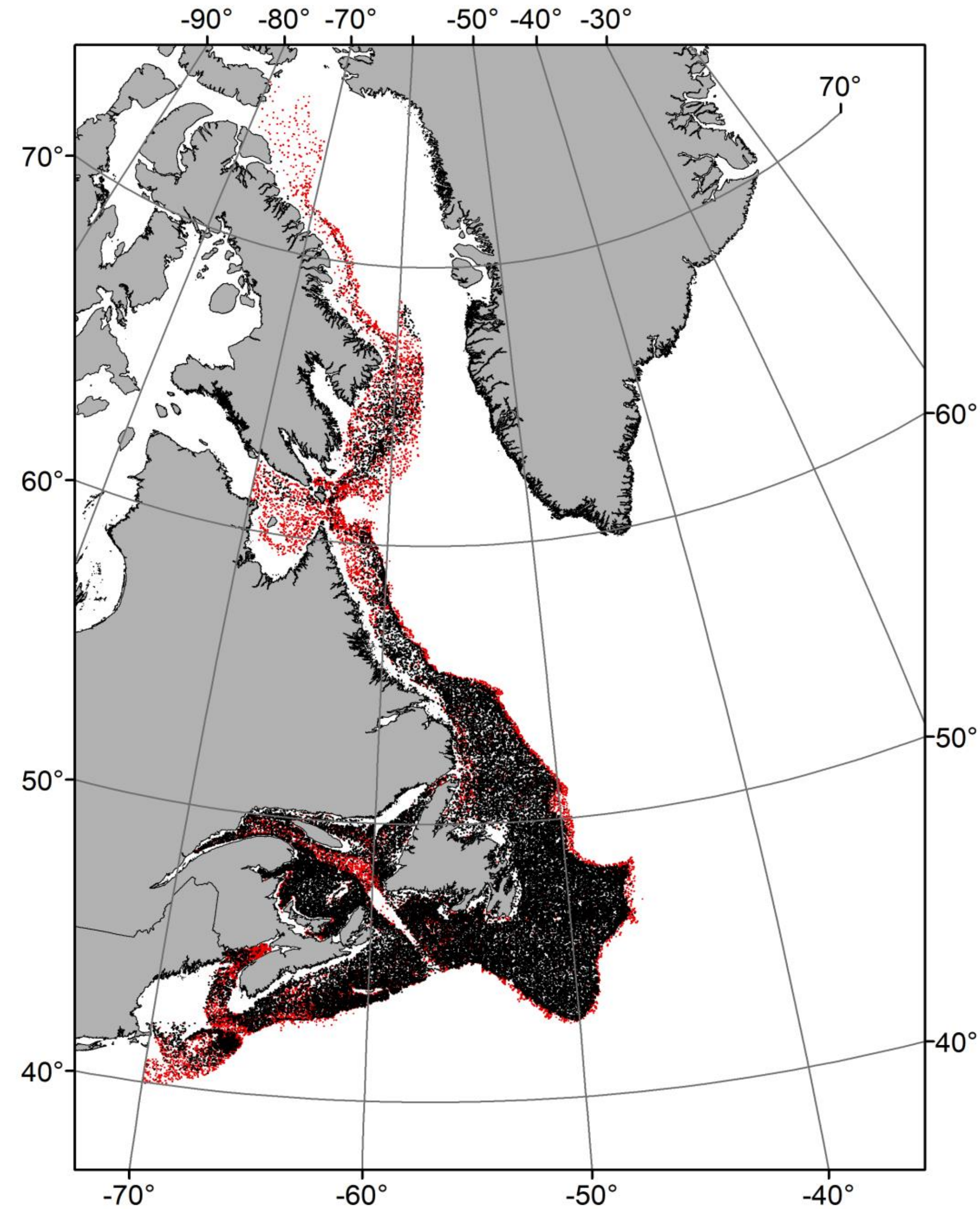


Figure 31: Presence (black) and absence (red) of American Plaice from survey trawls in Canadian waters. Points include surveys by DFO in the following regions: Maritimes (1970–2019), Gulf (1971–2018), Quebec (1985–2018), NL (1978–2018), Arctic (1999–2018), and by the Northern Shrimp Research Foundation (2005–18) in Shrimp Fishing Areas 2 and 3.

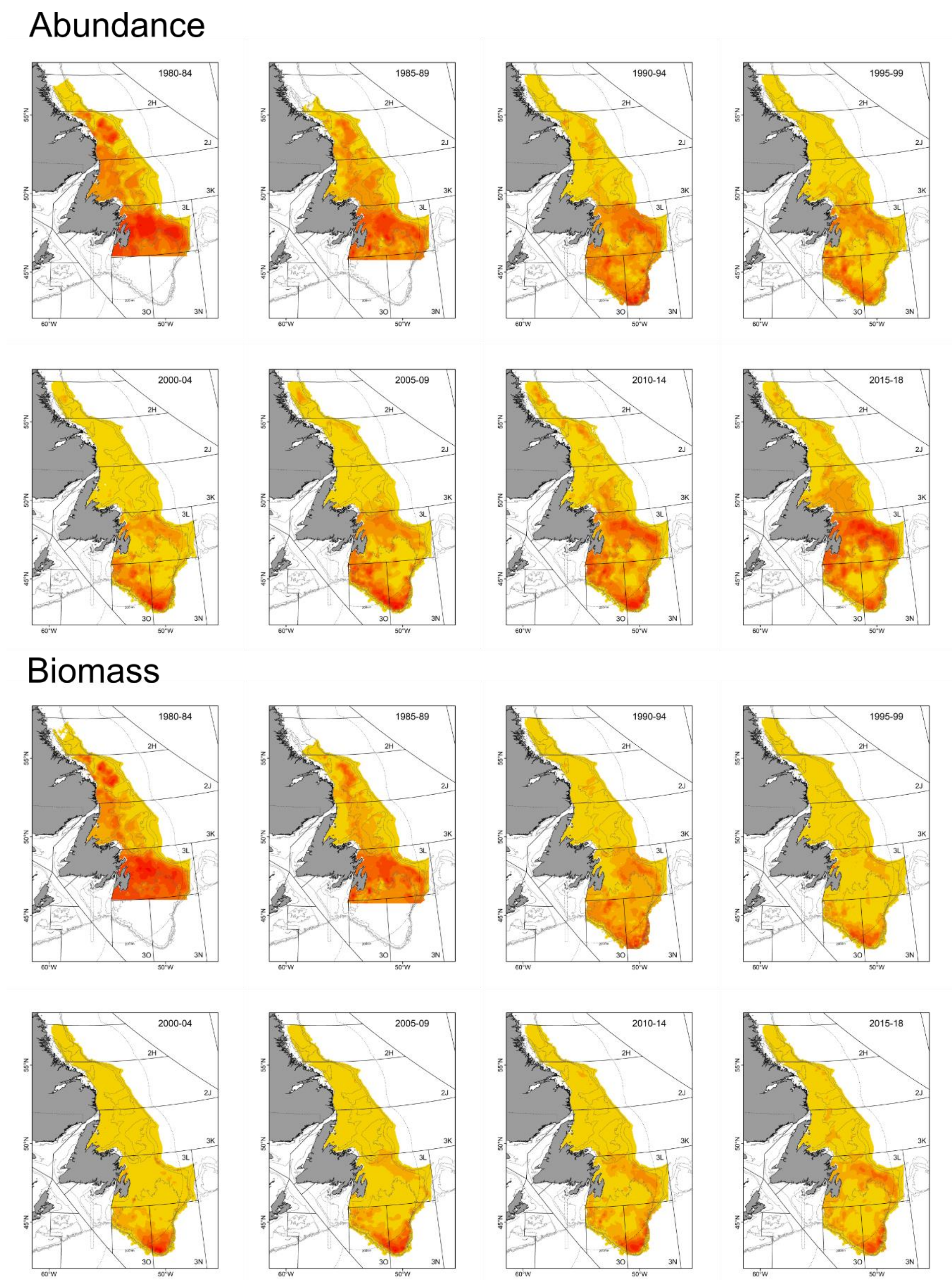


Figure 32: Distribution of American Plaice abundance (top) and biomass (bottom) from fall research vessel surveys in Newfoundland & Labrador, 1980–2018, where yellow is low and red high.

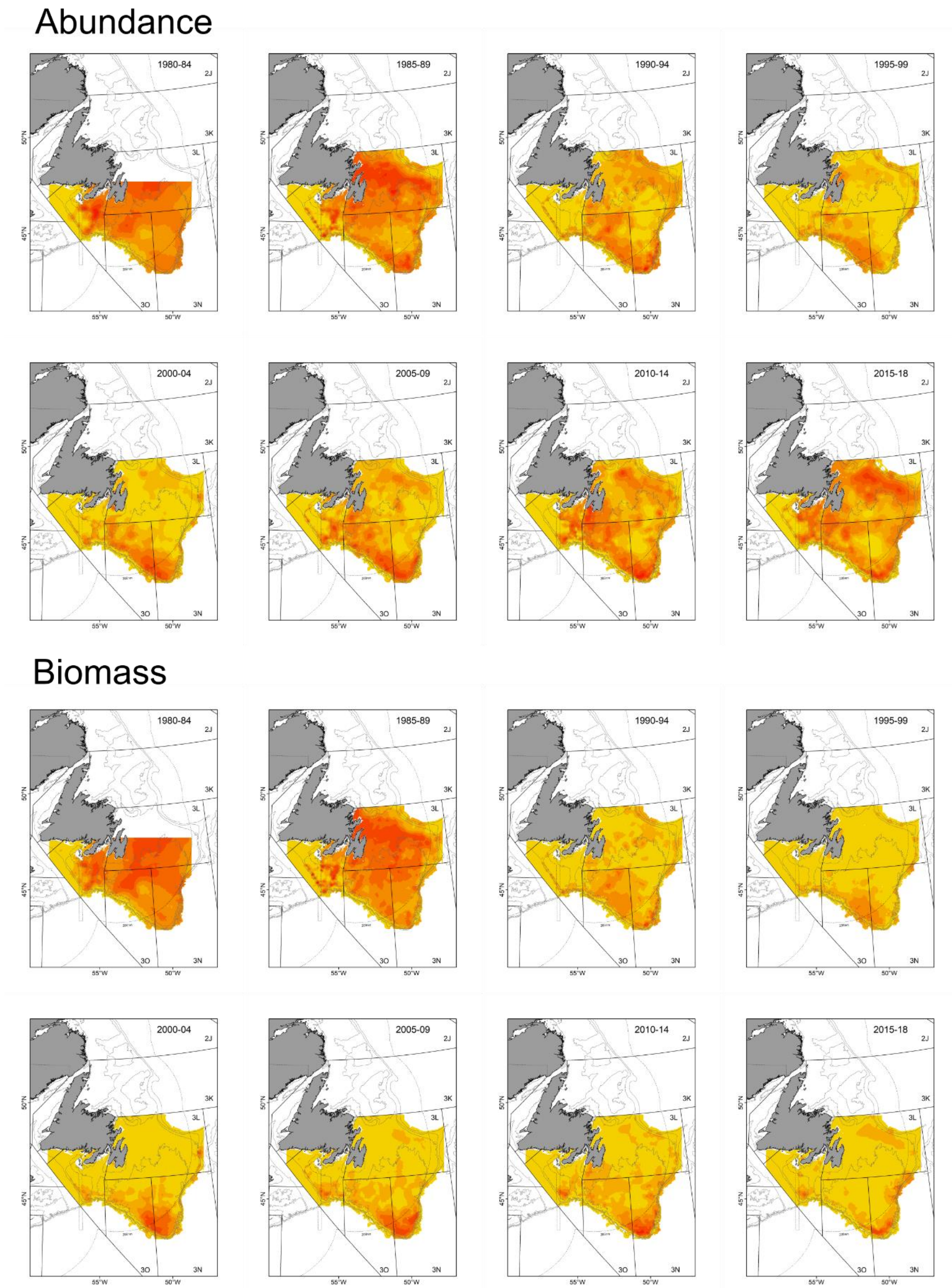


Figure 33: Distribution of American Plaice abundance (top) and biomass (bottom) from spring research vessel surveys in Newfoundland & Labrador, 1980–2018, where yellow is low and red high.

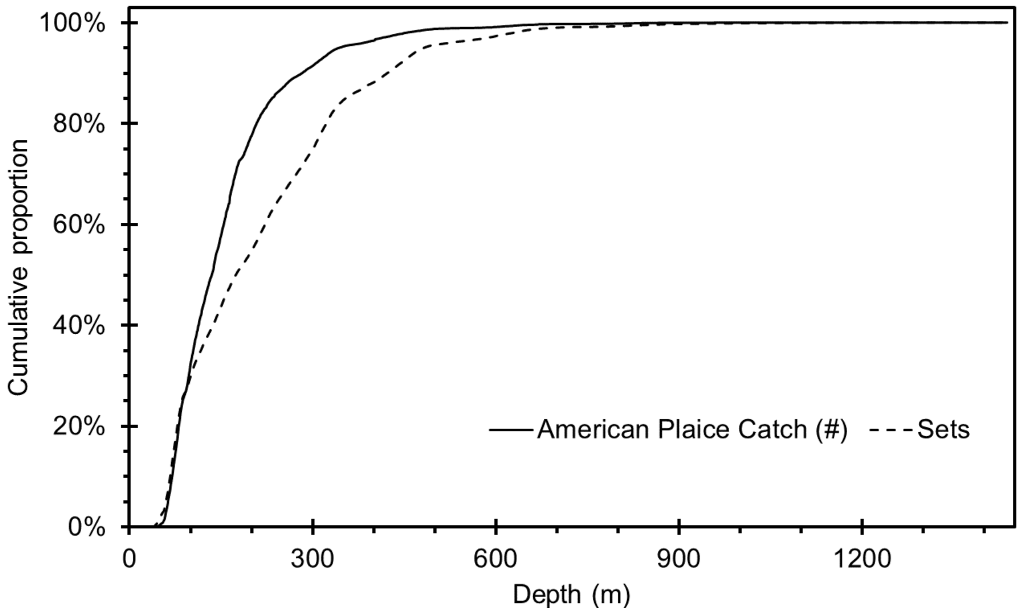


Figure 34: Cumulative depth distribution of American Plaice catches within Newfoundland & Labrador surveys (1978–2018).

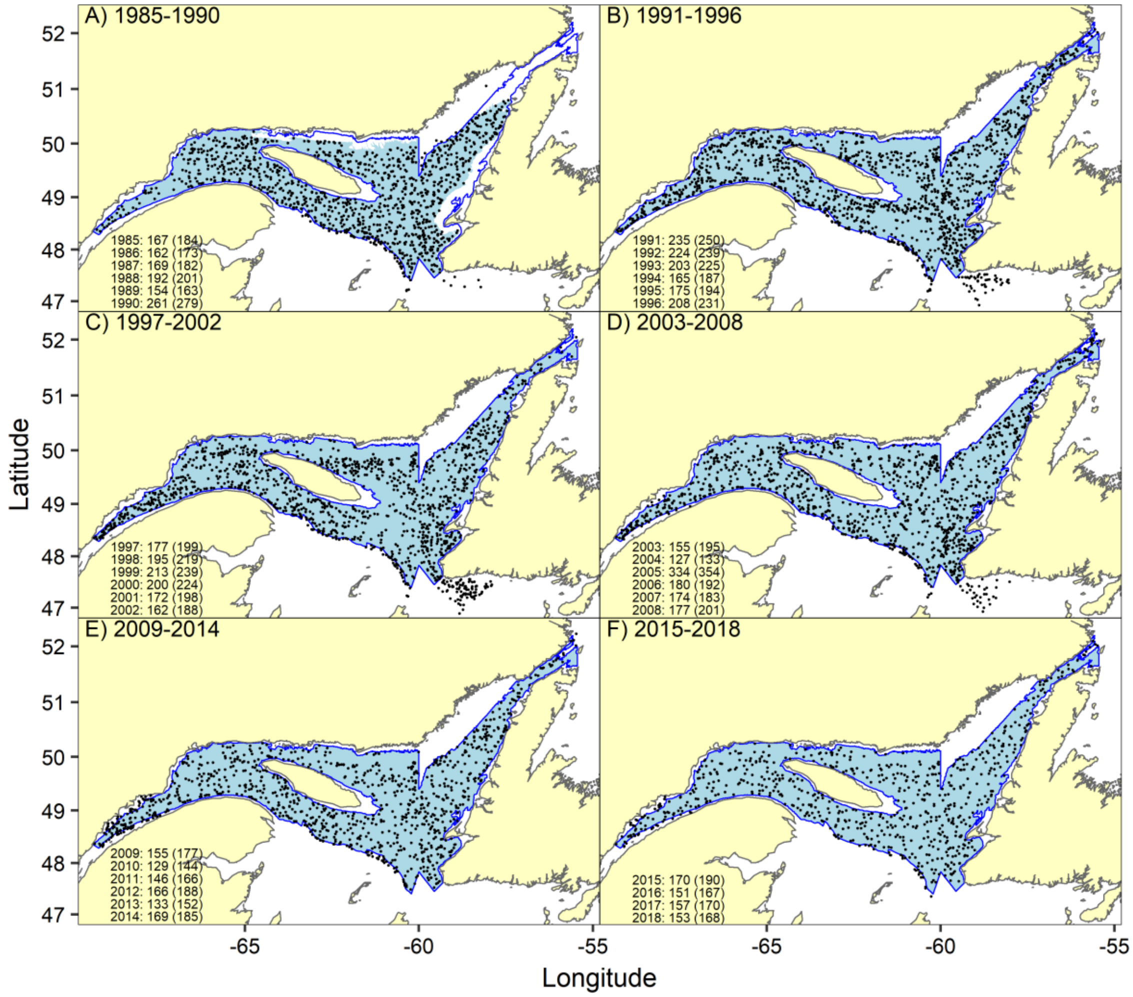


Figure 35: Black dots indicate the position of all sets performed during the northern Gulf of St. Lawrence annual August surveys over the different year blocks. Light blue areas are the combination of strata sampled in each period. The darker blue contour delimits strata that are included in the analysis for American Plaice. For each year, the number of successful random sets kept for the analysis is indicated with, in brackets, the total number of tows.

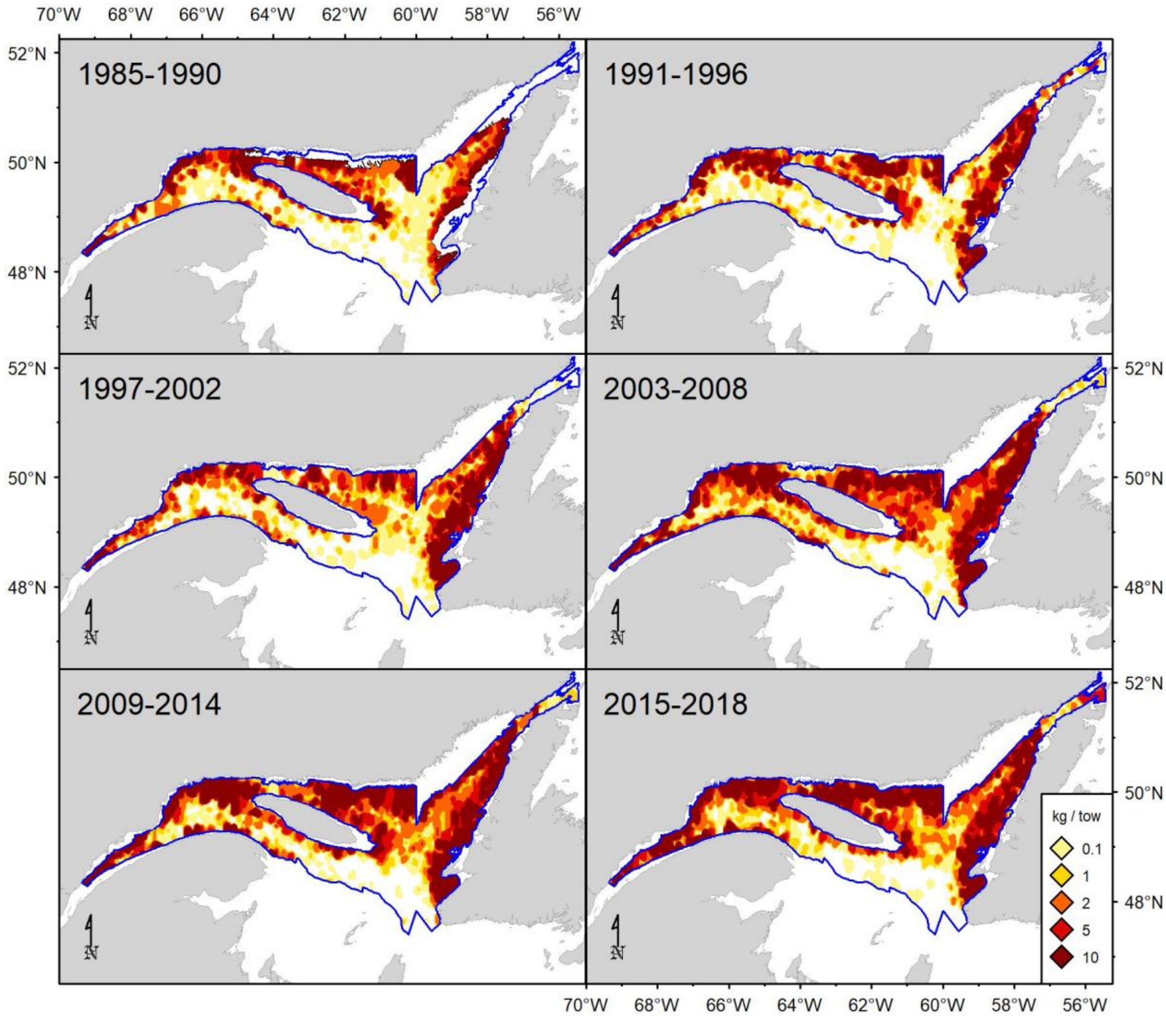


Figure 36: Distribution of American Plaice (kg/tow) in the northern Gulf of St. Lawrence derived from the annual August research surveys, 1985–2018. The blue line delimits the area surveyed.

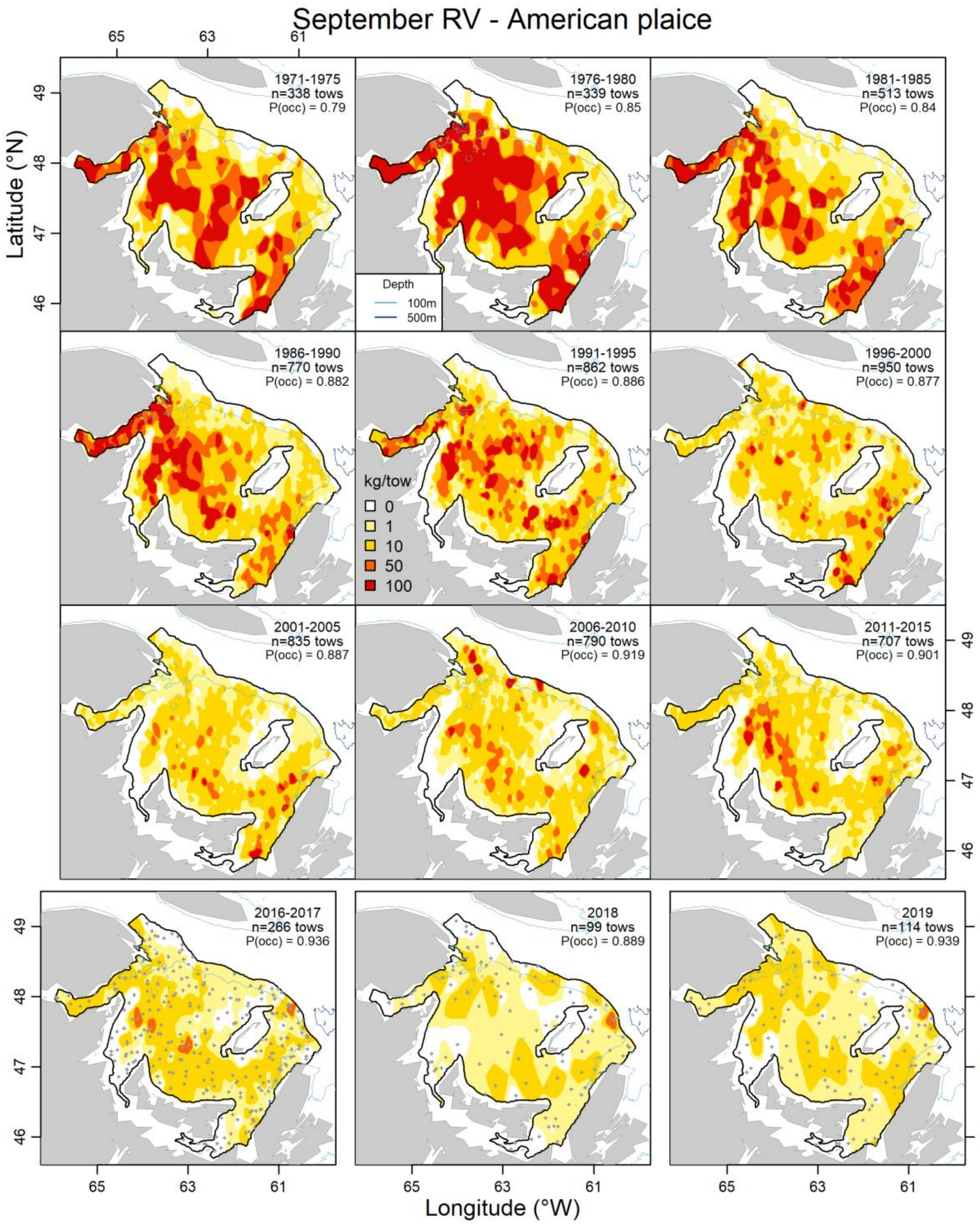


Figure 37: Distribution of American Plaice derived from the annual southern Gulf of St. Lawrence September trawl survey, 1971 to 2019. Catch per tow has been corrected for trawled distance, vessel/gear effects. The data used to compute the stratified random mean are equivalent to a Teleost day tow with a Western IIA trawl.

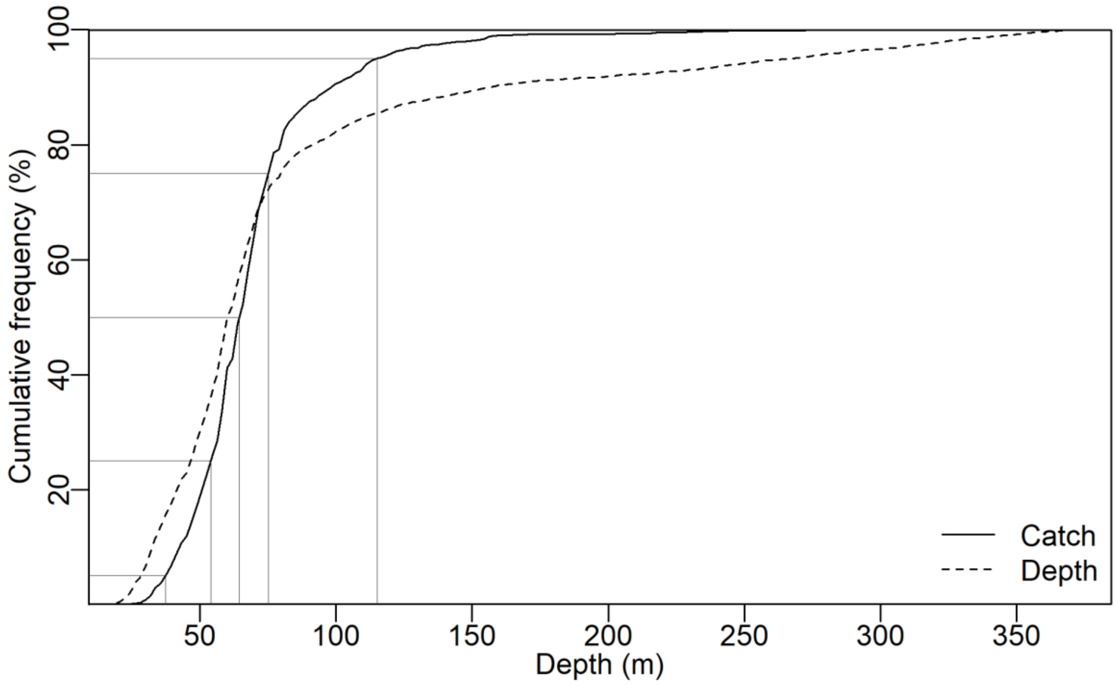


Figure 38: Cumulative depth distribution of survey tows in the southern Gulf of St. Lawrence (dashed line) and American Plaice catches (solid line) for 1971 to 2018. The vertical lines indicate the depths associated with 5, 25, 50, 75 and 95 percent of total catch biomass.

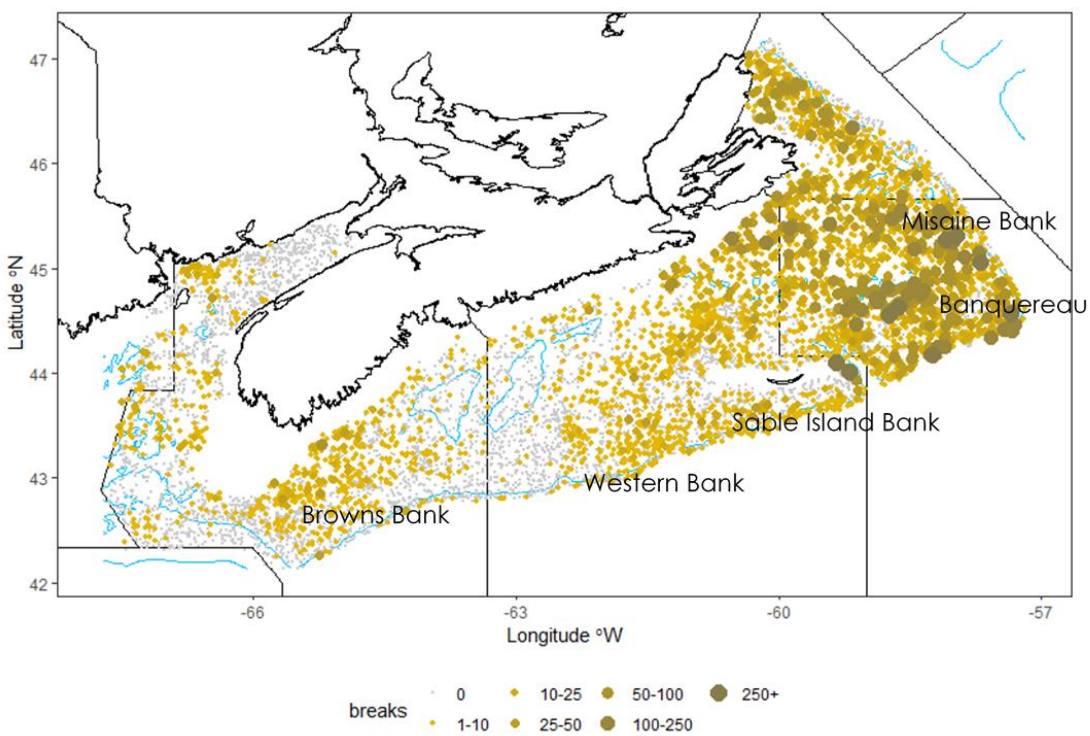


Figure 39: Distribution of American Plaice (kg/tow) on the Scotian Shelf (4VWX) in the summer 4VWX RV survey (1970–2019).

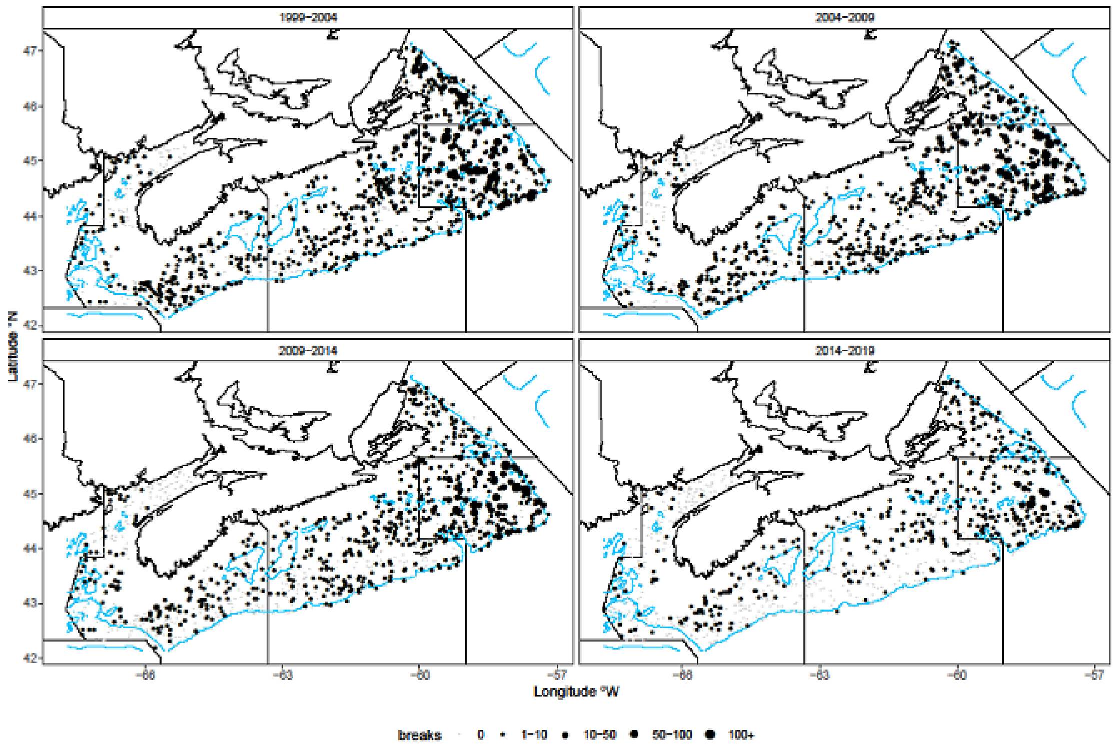


Figure 40: Trends in the distribution of American Plaice (kg/tow) on the Scotian Shelf (4VWX) in the summer 4VWX RV survey (1999–2019).

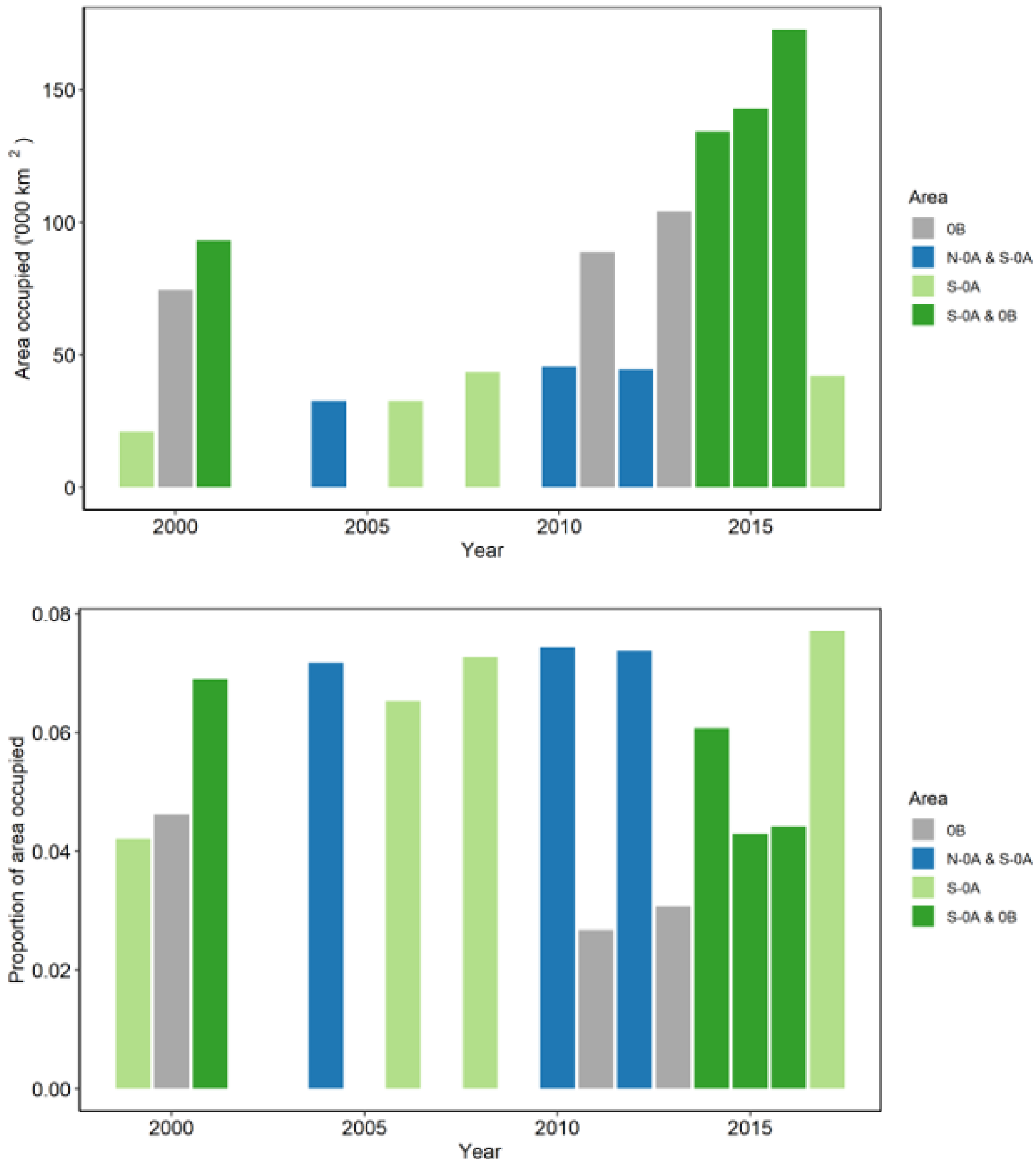
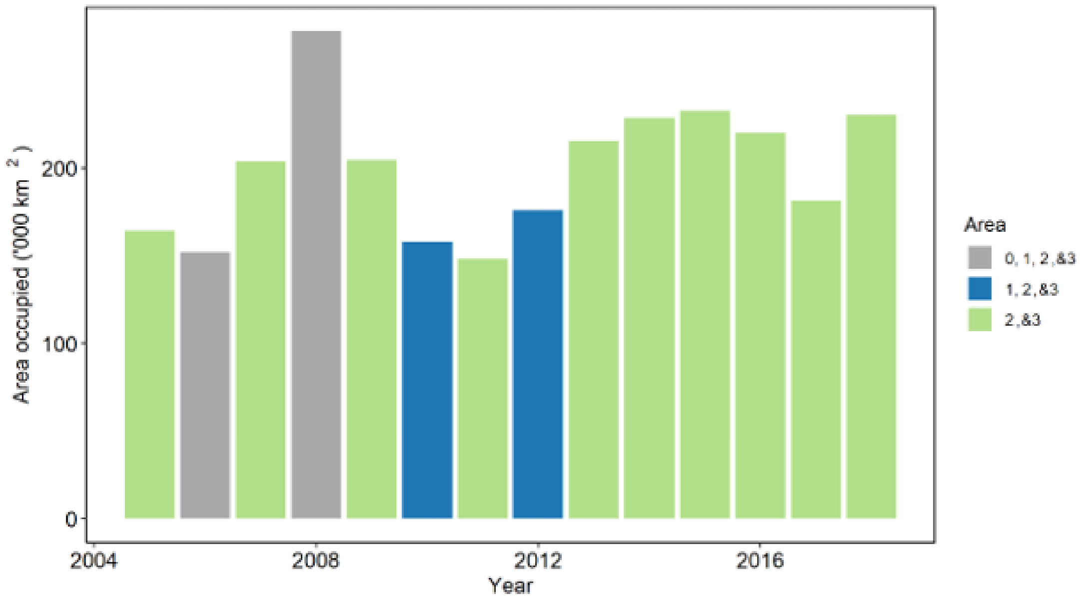


Figure 41: Design Weighted Area Occupied (DWAO; top) and proportion of area occupied (bottom) for American Plaice in SA 0. The combinations of area surveyed each year are represented by different colours.



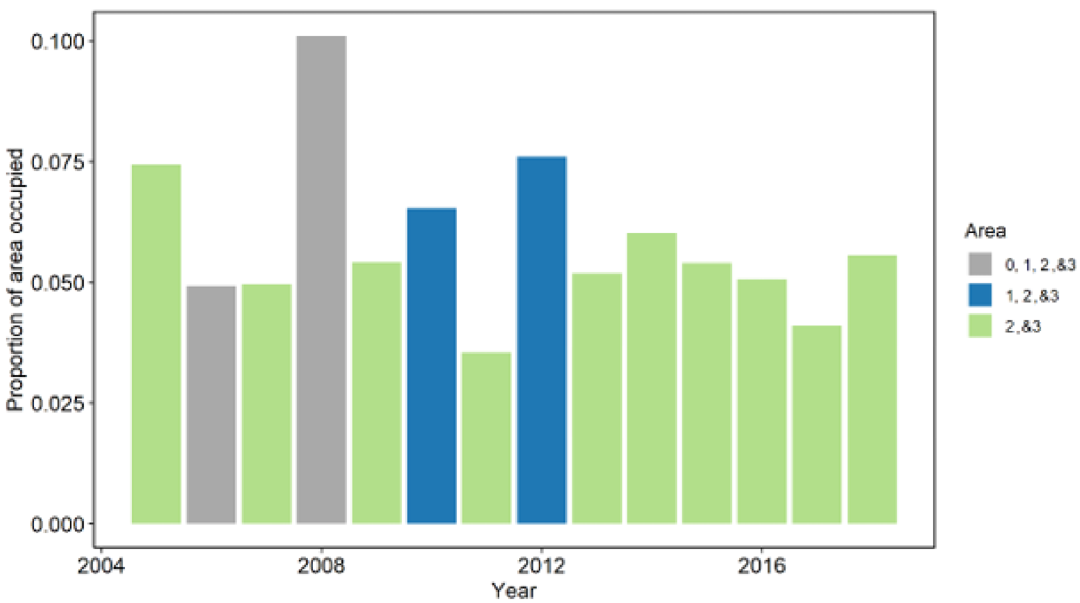


Figure 42: Design Weighted Area Occupied (DWAO; top) and proportion of area occupied (bottom) for American Plaice in Shrimp Fishing Areas 0–3. The combinations of SFAs surveyed each year are represented by different colours.

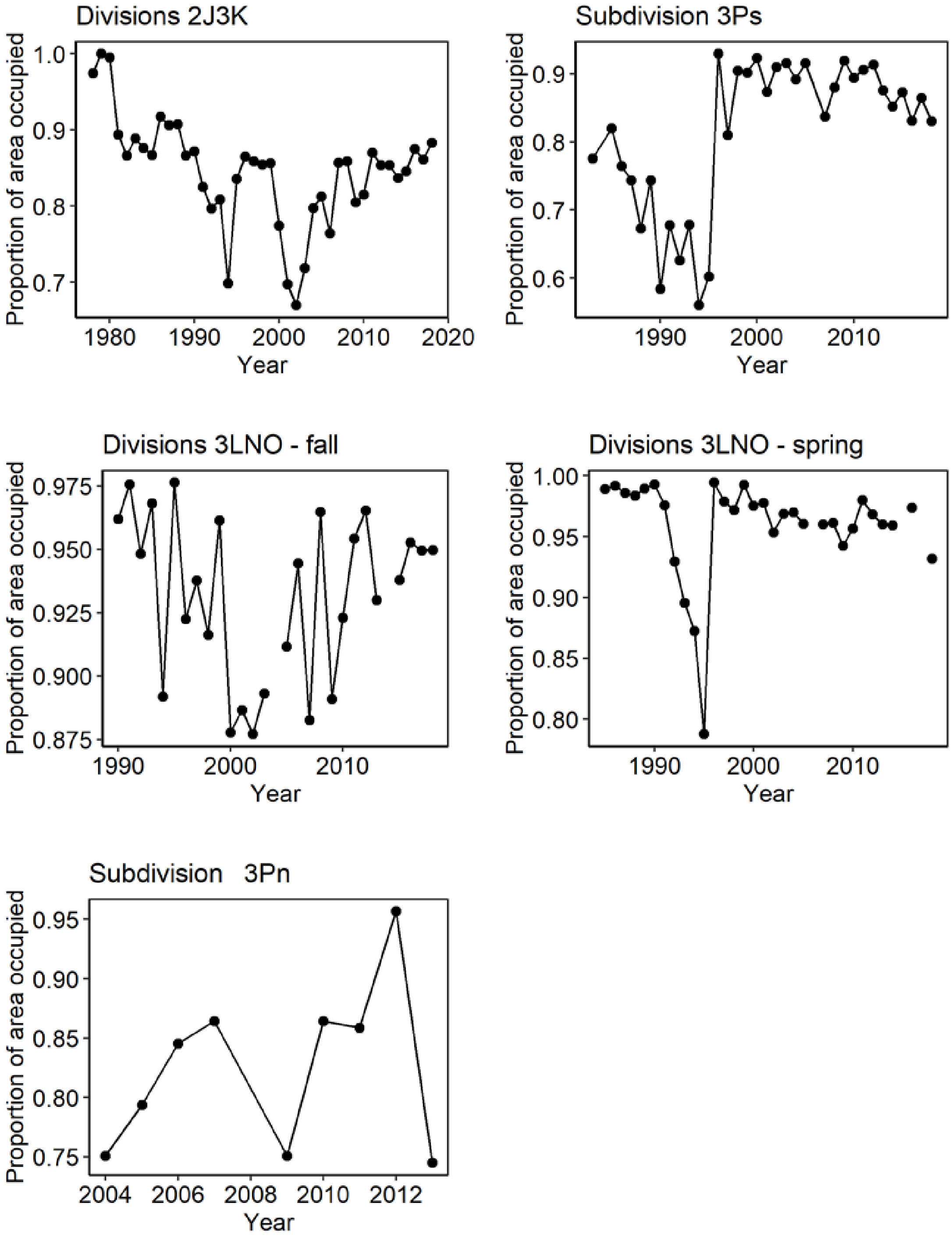


Figure 43: Proportion of survey area occupied by American Plaice in Newfoundland & Labrador Region surveys of Divs. 2JK3LNOP. Abrupt changes in proportion of area occupied in 3Ps and 3LNO in the spring from 1995 to 1996, and in the fall in Divs. 2J3K and 3LNO from 1994 to 1995 coincide with the introduction of the Campelen trawl.

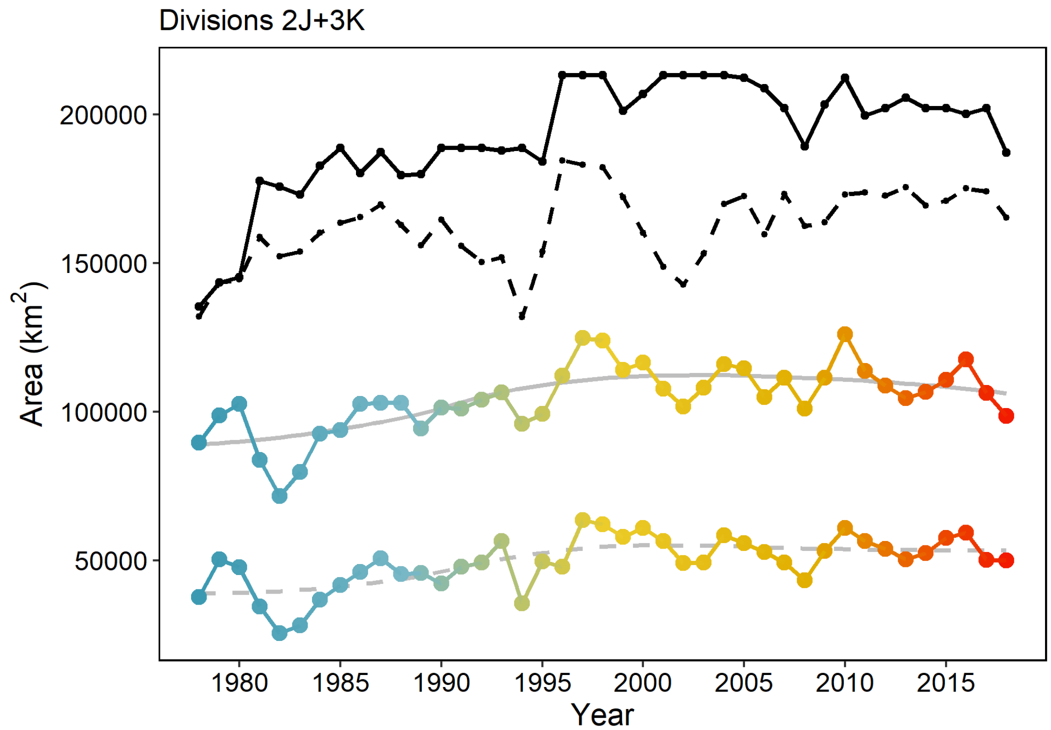


Figure 44: Indices of area occupied by American Plaice in Divs. 2J3K. Solid black line indicates surveyed area, dashed black line is Design Weight Area Occupied (DWAO). Grey lines indicate lowess smoothers through 95% DWAO (solid) and 75% DWAO (dashed).

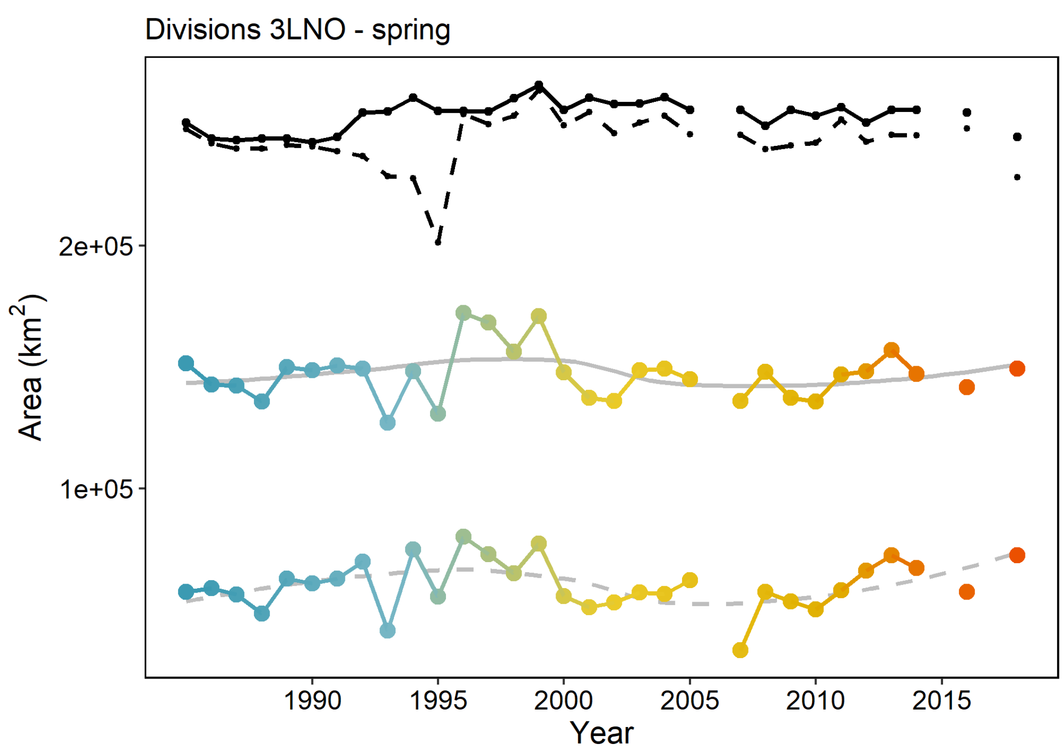


Figure 45: Indices of area occupied by American Plaice in Divs. 3LNO from the spring survey. Solid black line indicates surveyed area, dashed black line is Design Weight Area Occupied (DWAO). Grey lines indicate lowess smoothers through 95% DWAO (solid) and 75% DWAO (dashed).

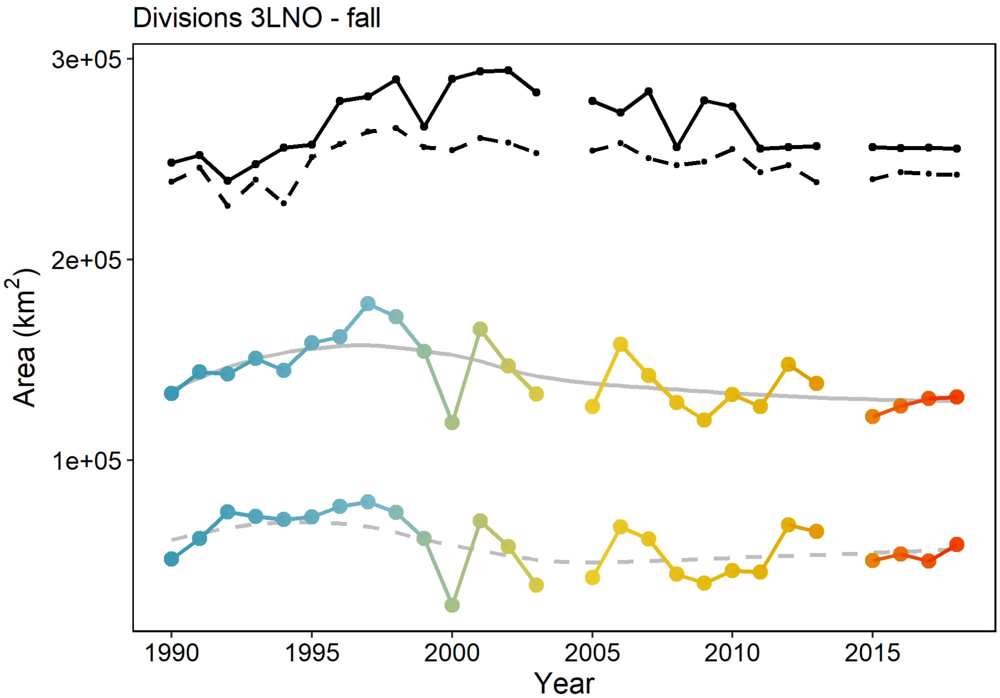


Figure 46: Indices of area occupied by American Plaice in Divs. 3LNO from the fall survey. Solid black line indicates surveyed area, dashed black line is Design Weight Area Occupied (DWAO). Grey lines indicate lowess smoothers through 95% DWAO (solid) and 75% DWAO (dashed).

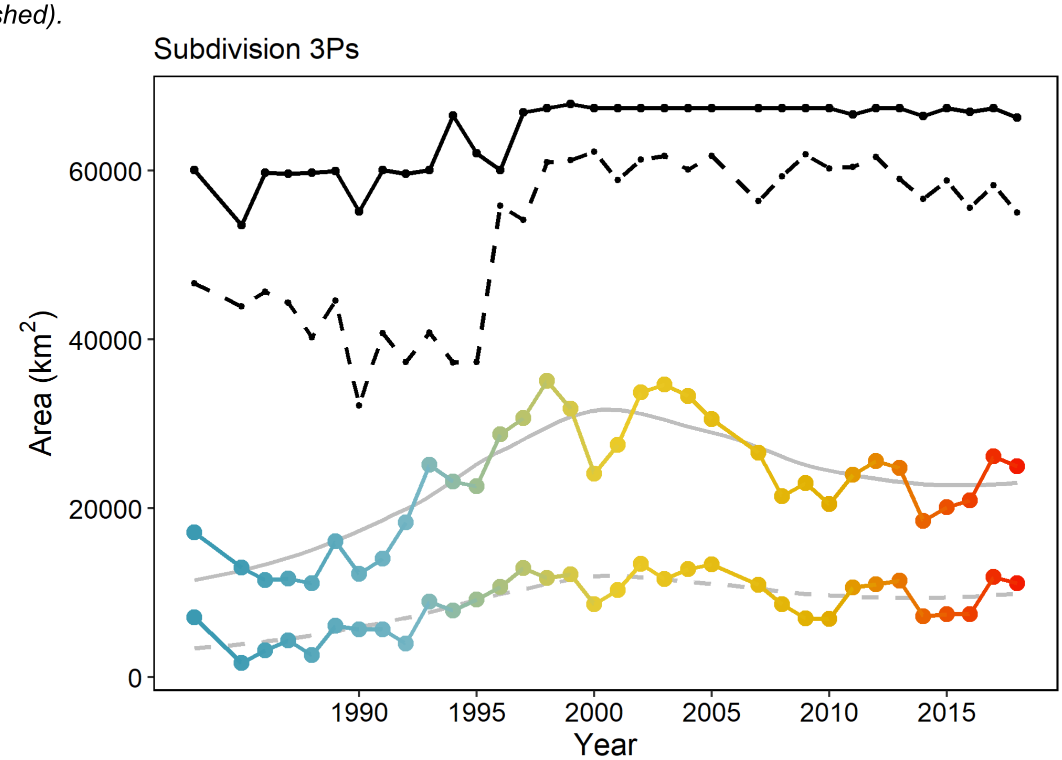


Figure 47: Indices of area occupied by American Plaice in Subdiv. 3Ps. Solid black line indicates surveyed area, dashed black line is Design Weight Area Occupied (DWAO). Grey lines indicate lowess smoothers through 95% DWAO (solid) and 75% DWAO (dashed).

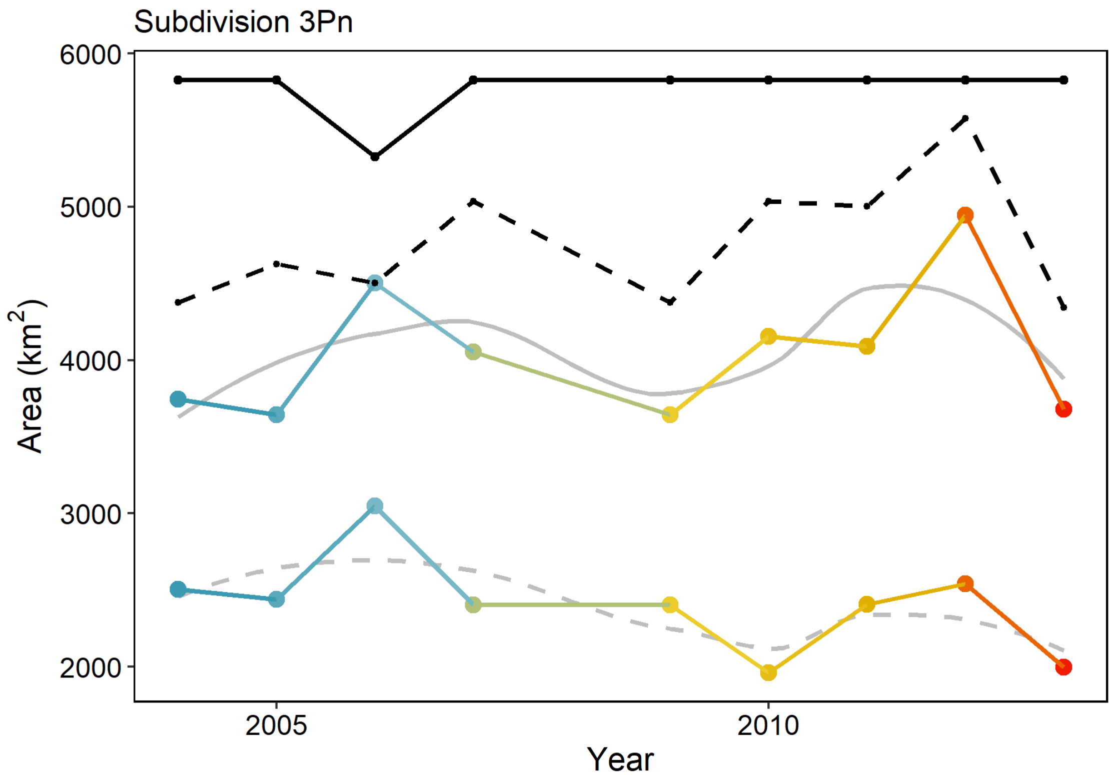


Figure 48: Indices of area occupied by American Plaice in Subdiv. 3Pn. Solid black line indicates surveyed area, dashed black line is Design Weight Area Occupied (DWAO). Grey lines indicate lowess smoothers through 95% DWAO (solid) and 75% DWAO (dashed).

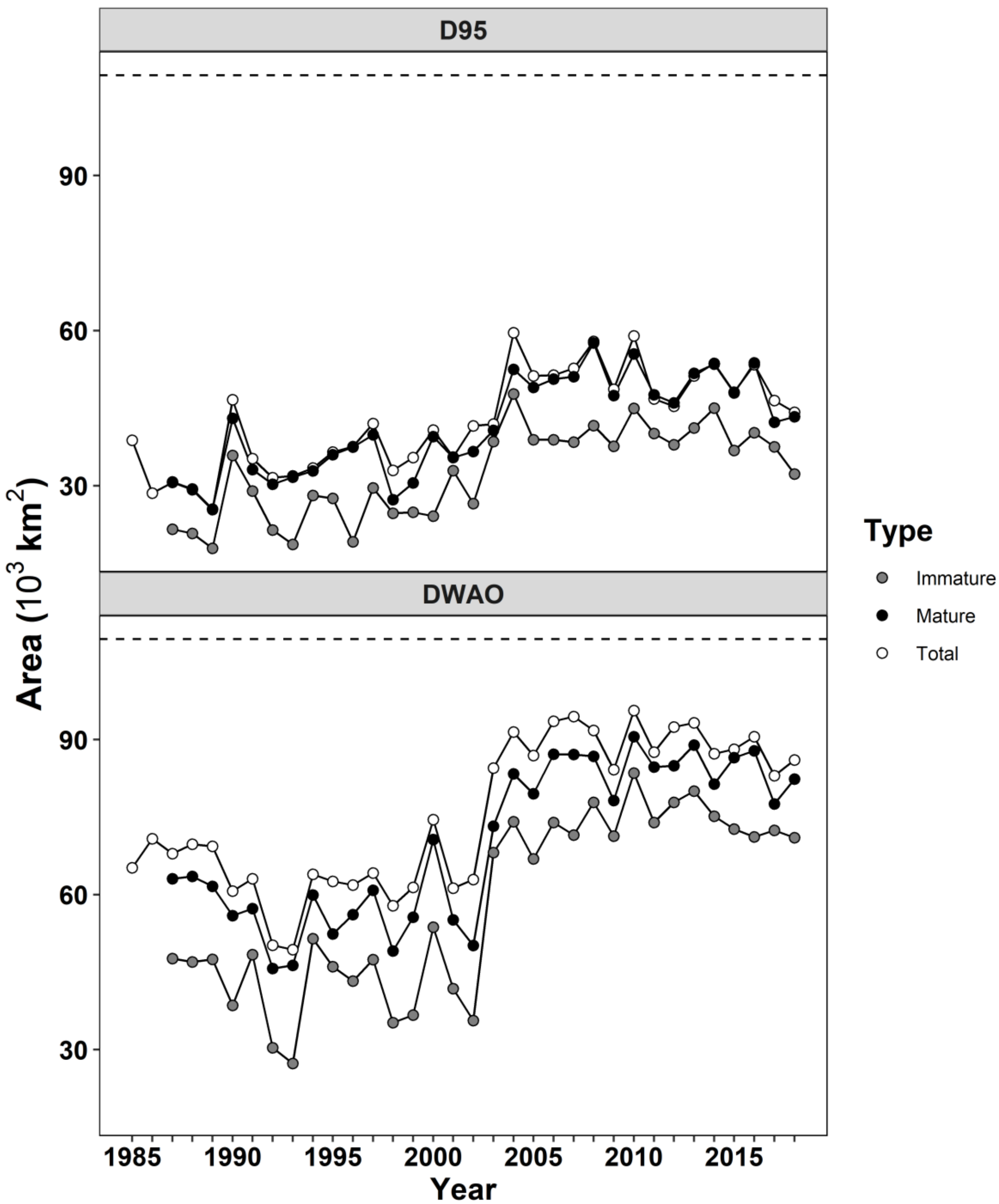


Figure 49: D_{95} and Design Weighted Area Occupied (DWAO) for American Plaice captured during the August annual northern Gulf of St. Lawrence scientific surveys for the period 1985–2018. The data presented is in Lady Hammond-Western IIA equivalents. The dashed horizontal lines represent the total area surveyed (i.e., 109,412 km^2).

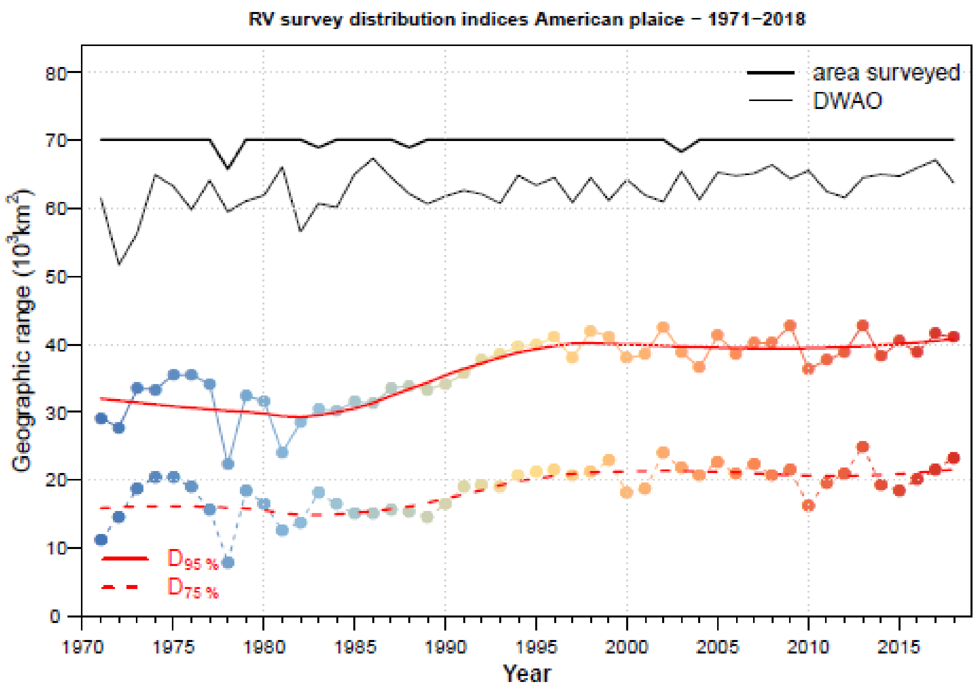


Figure 50: Indices of area occupied by American Plaice derived from the annual southern Gulf of St. Lawrence September trawl survey, 1971 to 2018. Catch per tow has been corrected for trawled distance, vessel/gear effects. The data used to compute the stratified random mean are equivalent to a Teleost day tow with a Western IIA trawl.

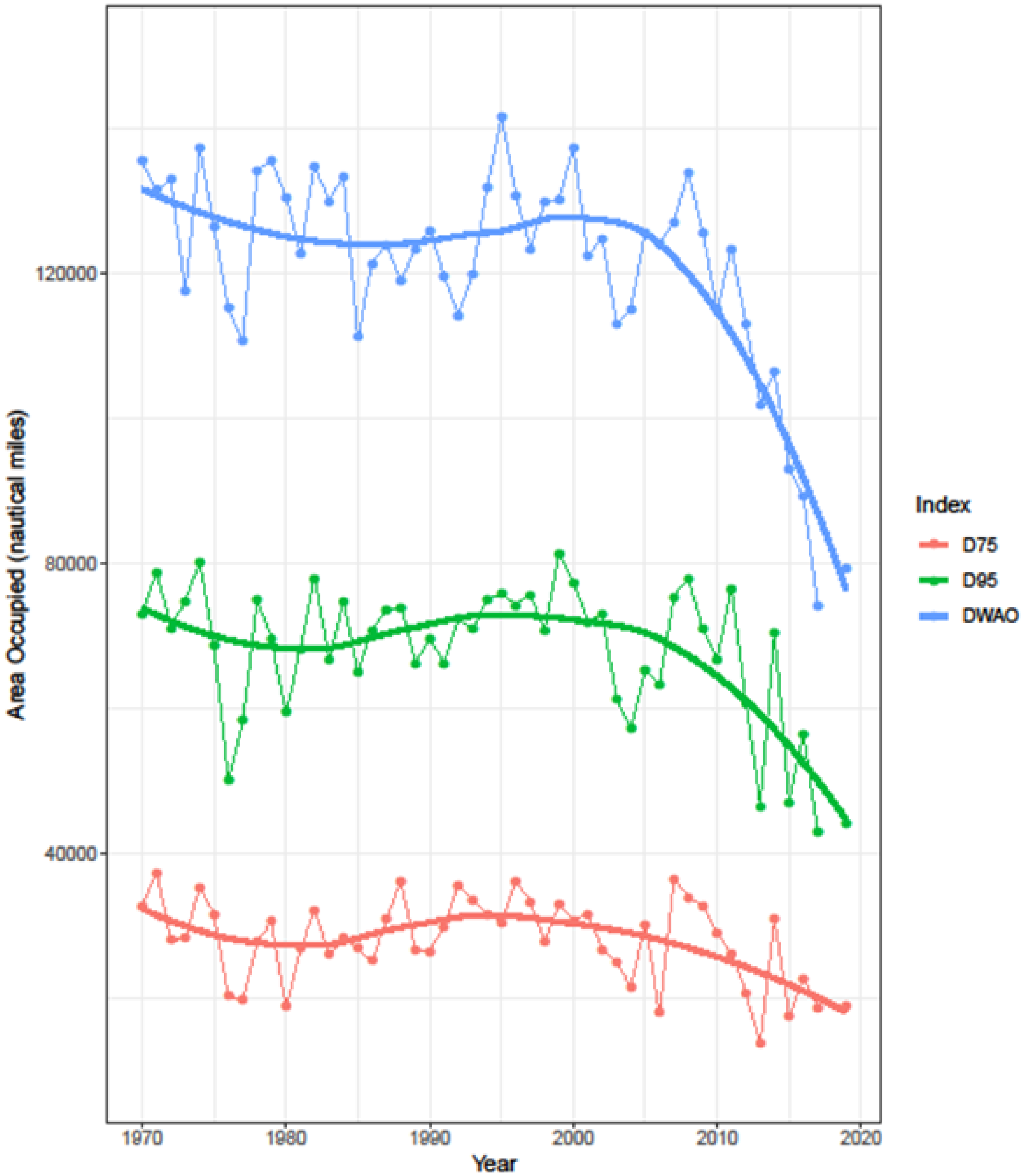


Figure 51: Trends in density indices for American Plaice in Divs. 4VWX, as measured by the Design Weight Area Occupied (DWAO), the proportion of area containing 95% (D_{95}) and area containing 75% of abundance. Thick lines represent loess smoothers through indices.

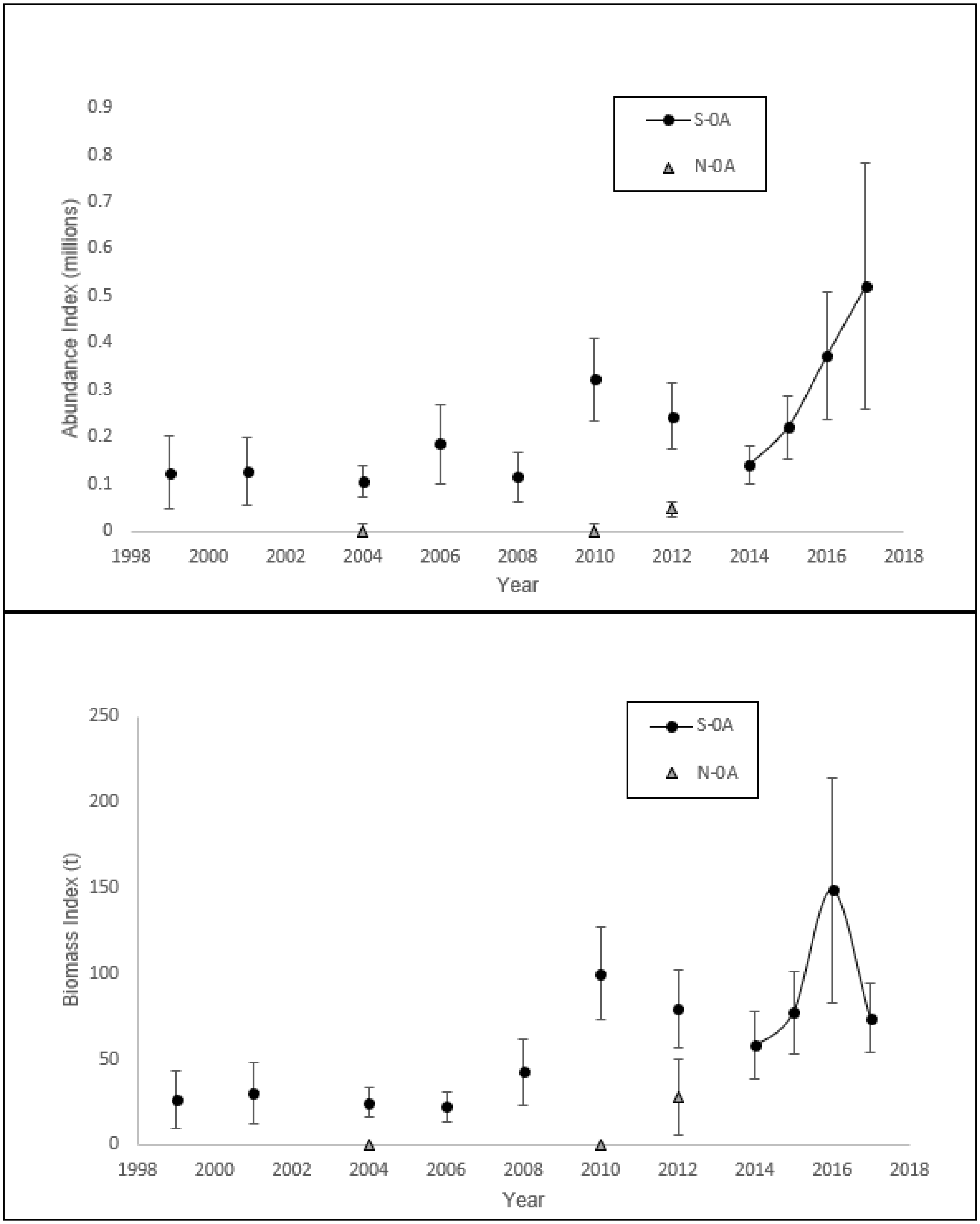


Figure 52: Abundance (top) and biomass (bottom) indices for Fisheries and Oceans Canada surveys in Div. 0A (north N-OA and south S-OA). Error bars represent ± 1 standard error.

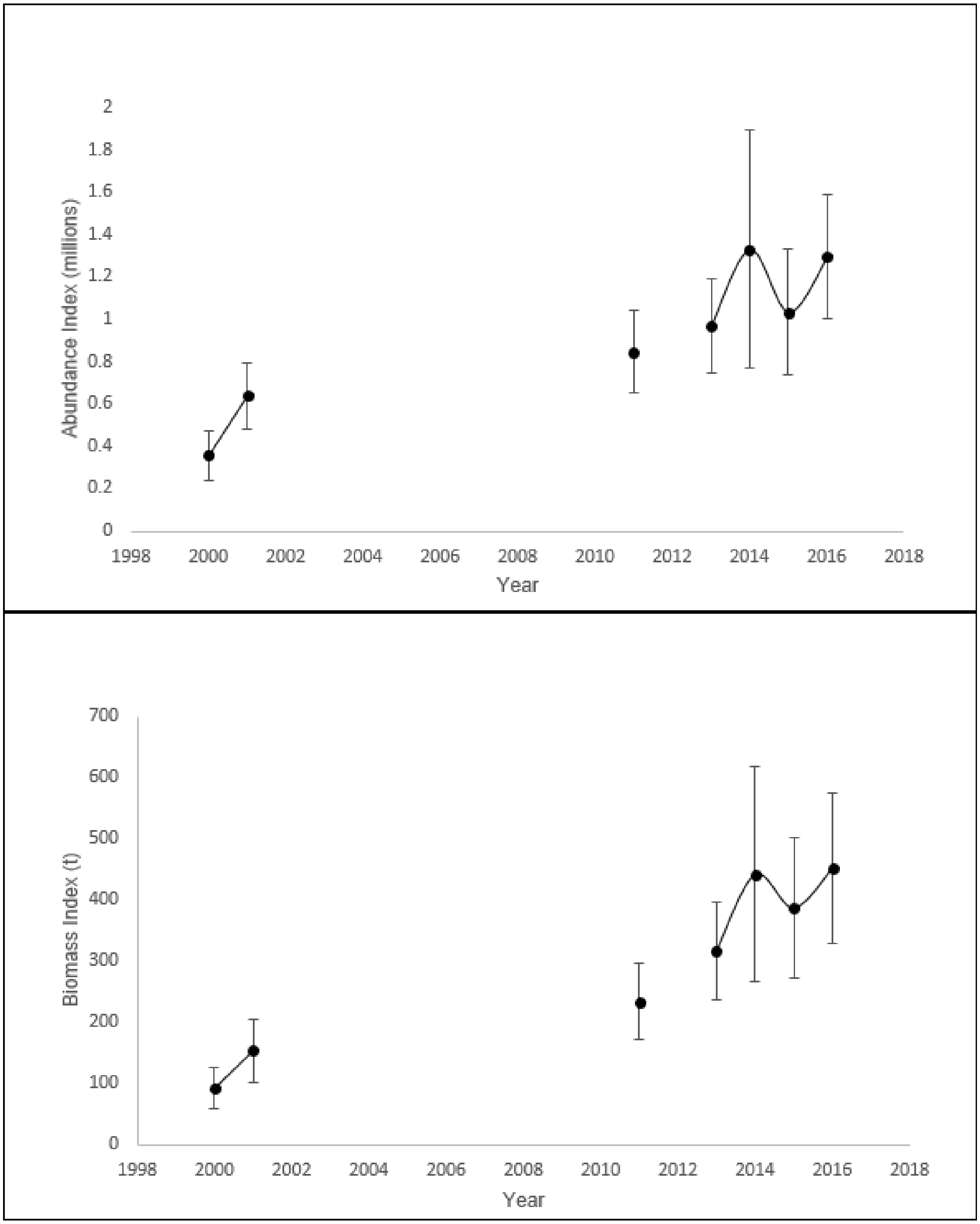


Figure 53: Abundance (top) and biomass (bottom) indices for Fisheries and Oceans Canada surveys in Div. 0B. Error bars represent ± 1 standard error.

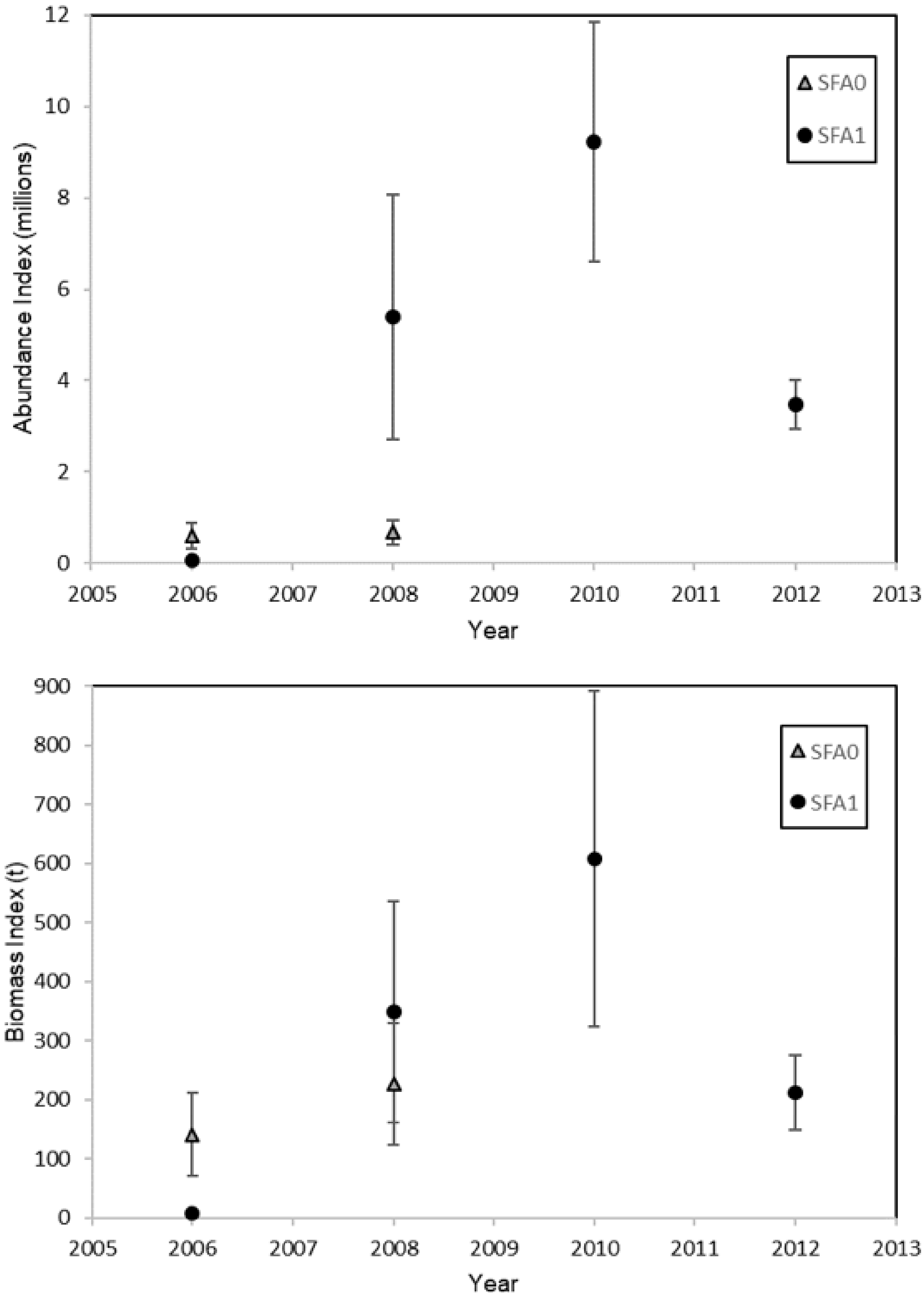


Figure 54: Abundance (top) and biomass (bottom) indices for Fisheries and Oceans Canada surveys in SFAs 0 and 1. Error bars represent ± 1 standard error.

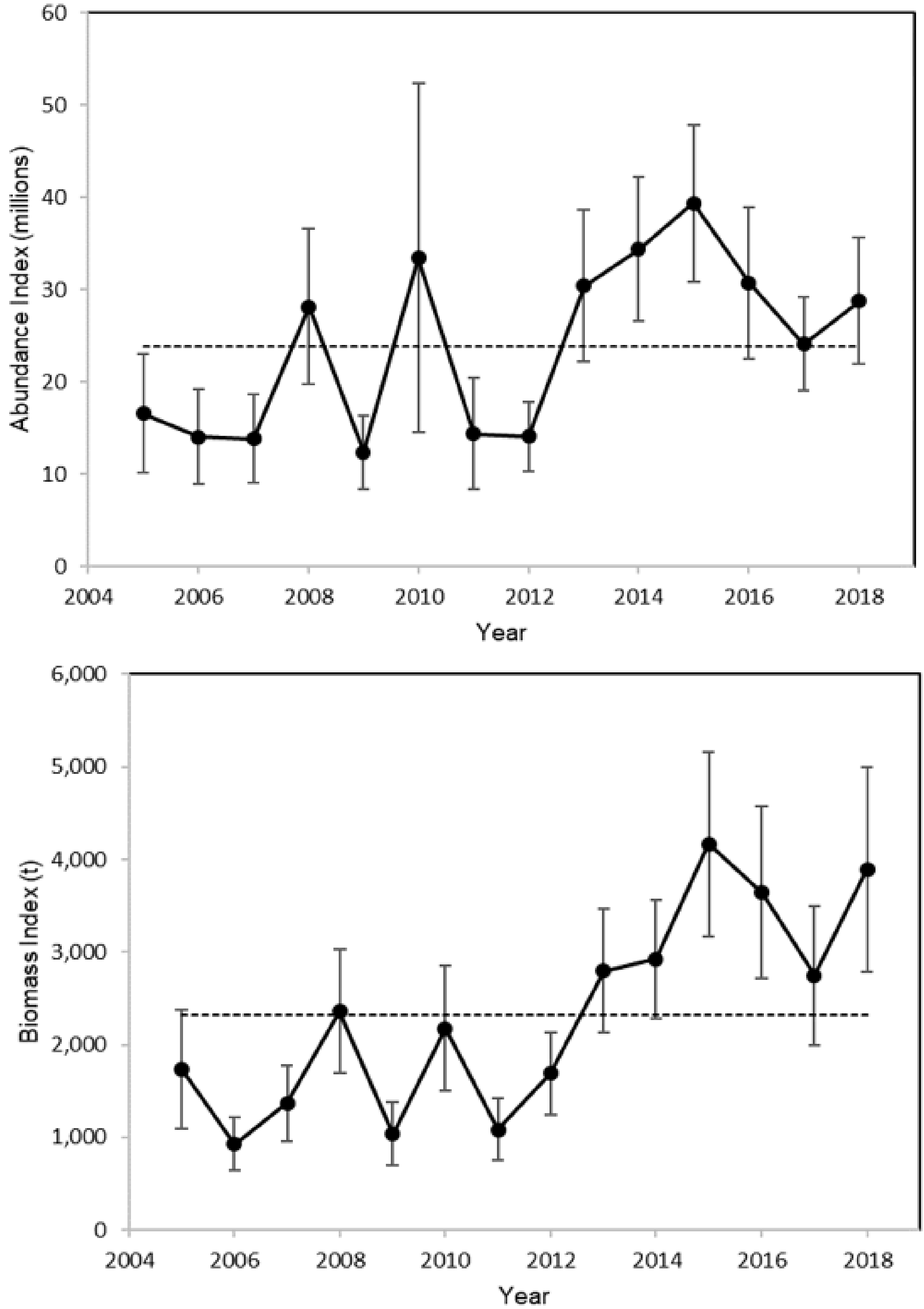


Figure 55: Abundance (top) and biomass (bottom) indices for Northern Shrimp Research Foundation surveys in SFA2. The dashed line represents the index mean. Error bars represent ± 1 standard error.

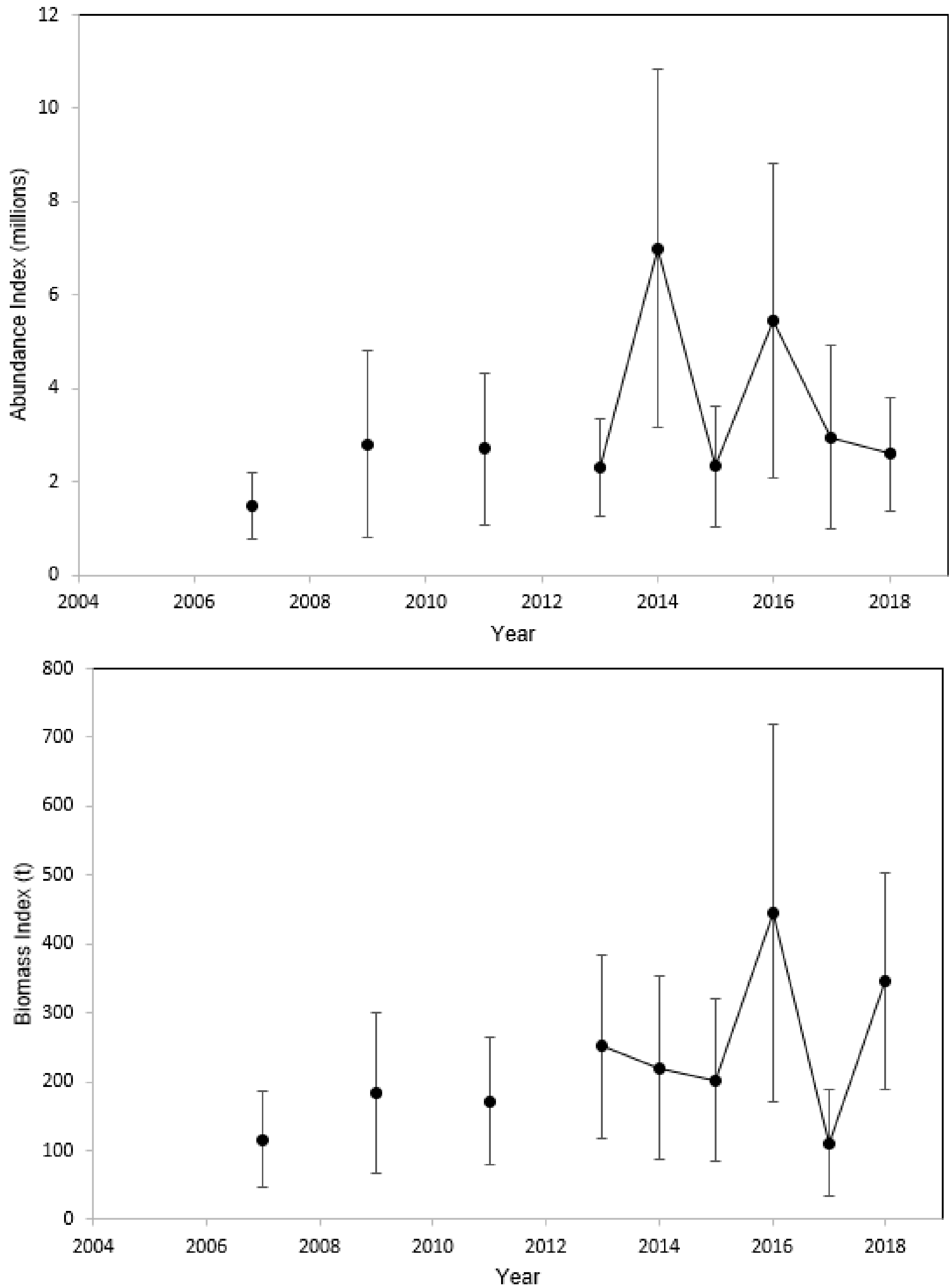
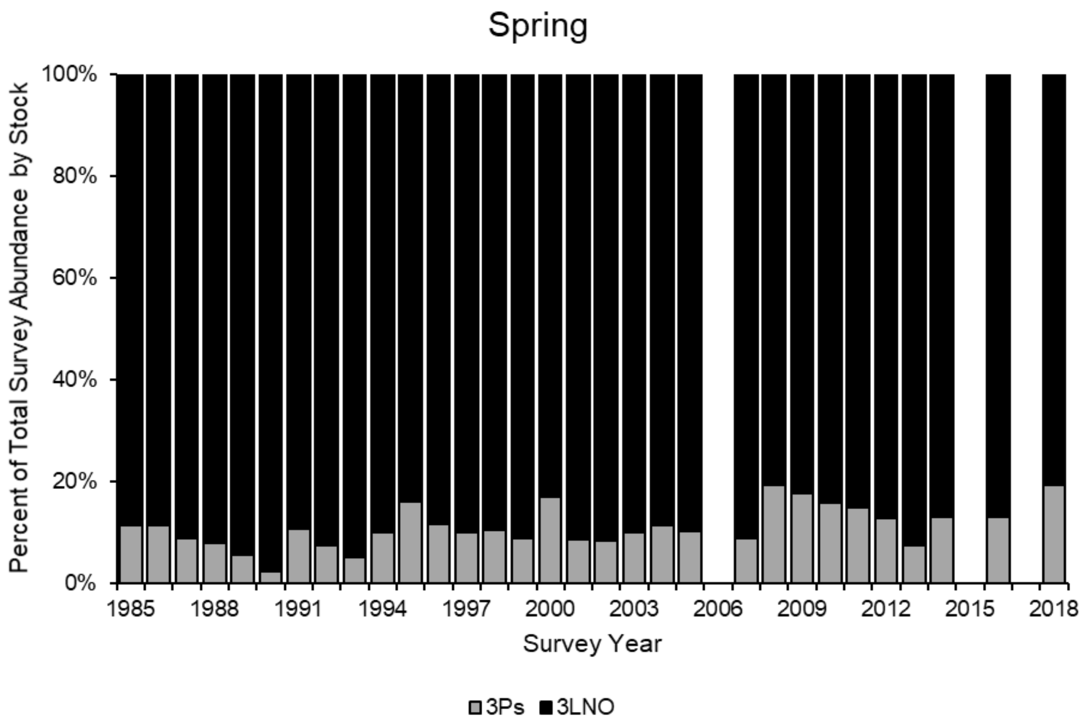


Figure 56: Abundance (top) and biomass (bottom) indices for Northern Shrimp Research Foundation surveys in SFA 3. Error bars represent ± 1 standard error.



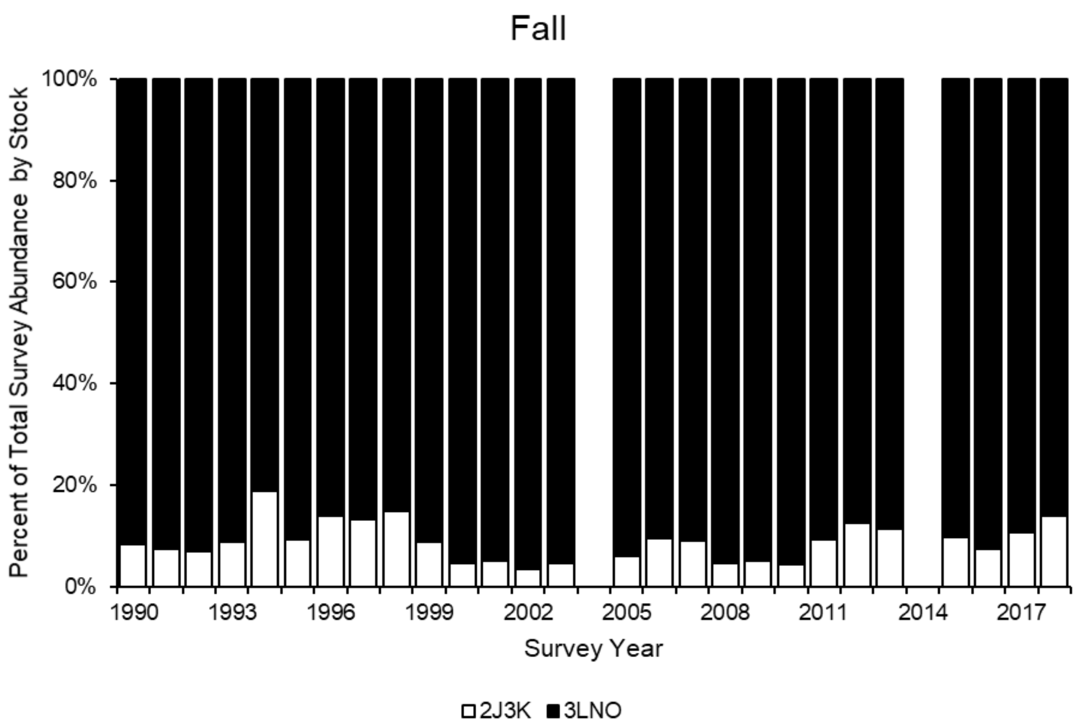


Figure 57: Percent of spring (top) and fall (bottom) survey abundance of American Plaice by stock (Subdiv. 3Ps, Divs. 3LNO, Divs. 2J3K). As potential differences in catchability between areas are not accounted for here, these should be considered as indicators of relative differences in stock abundance rather than absolute values.

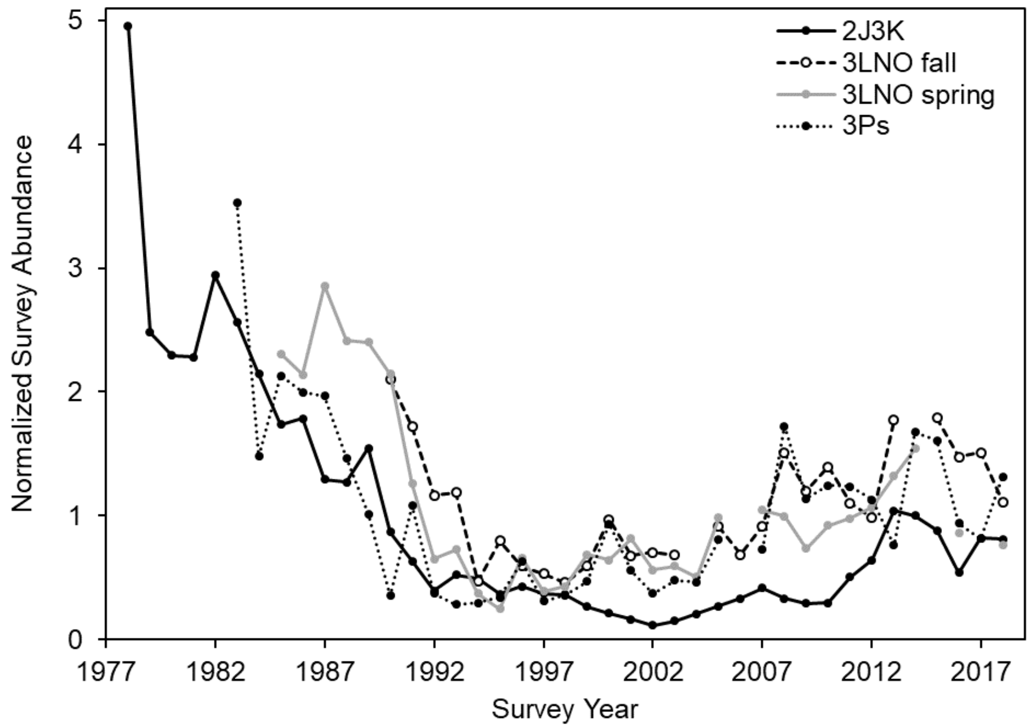


Figure 58: Normalized survey abundance for each Newfoundland & Labrador stock (each year's abundance was divided by its time series' mean abundance). All stocks have shown similar trends, with decreases from the start of the survey time series to the early to mid-1990s, remaining at a low level with some recent increases.

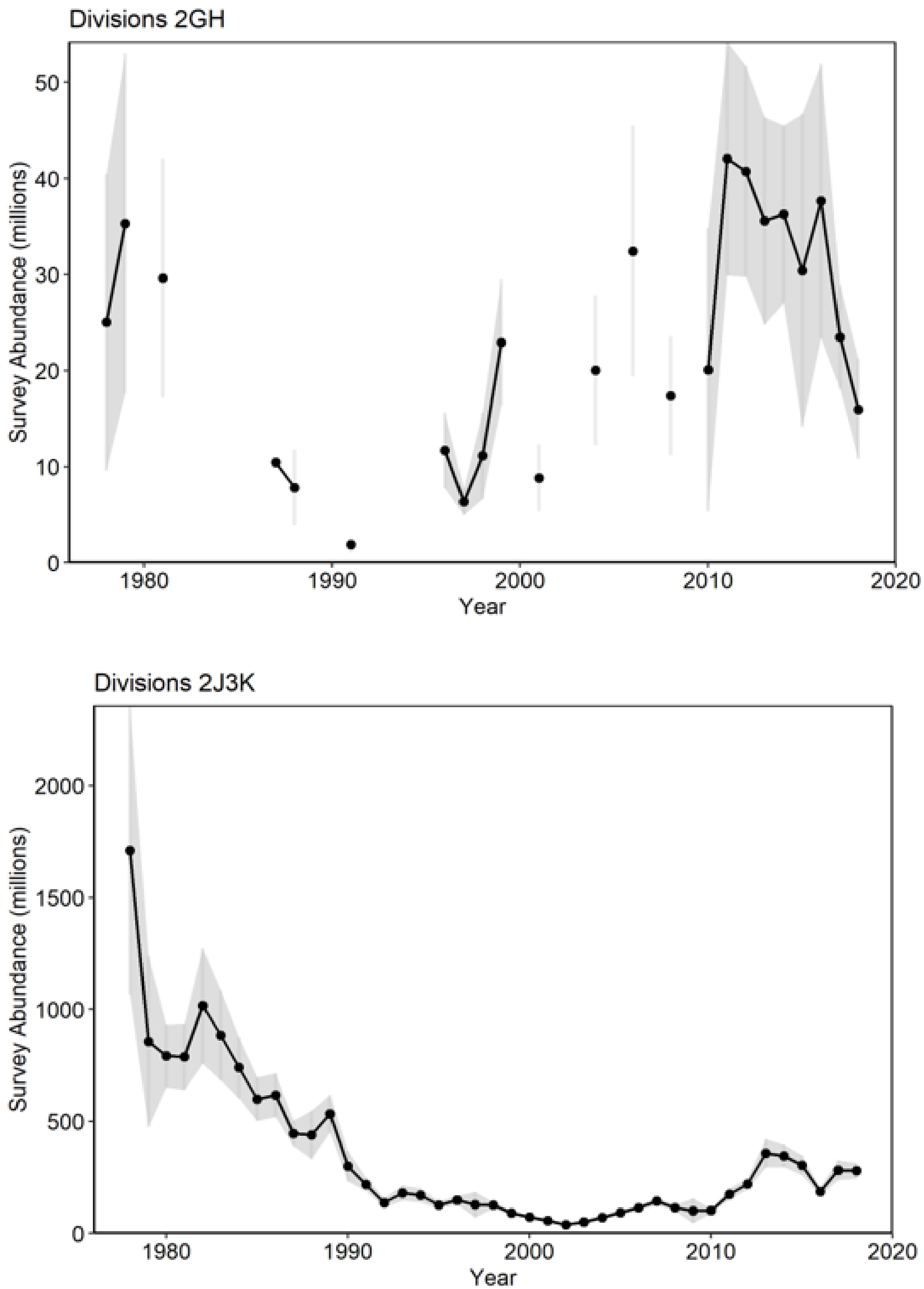


Figure 59: Survey abundance of American Plaice for SA 2 + Div. 3K over the time series 1978–2006. Top panel shows Divs. 2GH, showing non-converted data prior to 1996, and Campelen data units from 1996–2018. Bottom panel shows Divs. 2J3K in Campelen data units. Shaded areas indicate 95% confidence intervals.

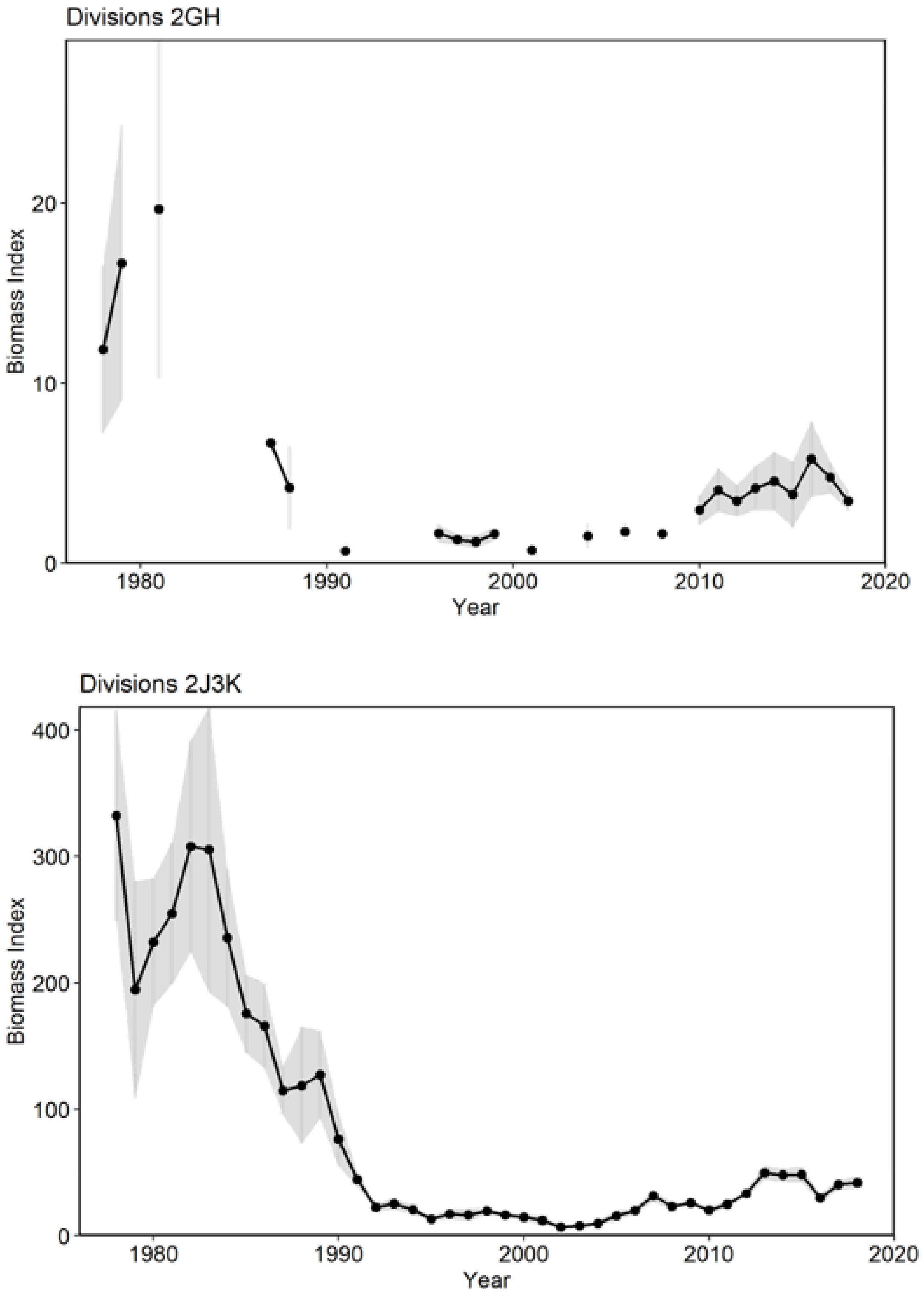


Figure 60: Survey biomass of American Plaice for SA 2 + Div. 3K over the time series 1978–2006. Top panel shows Divs. 2GH, showing non-converted data prior to 1996, and Campelen data units from 1996–2018. Bottom panel shows Divs. 2J3K in Campelen data units. Shaded areas indicate 95% confidence intervals.

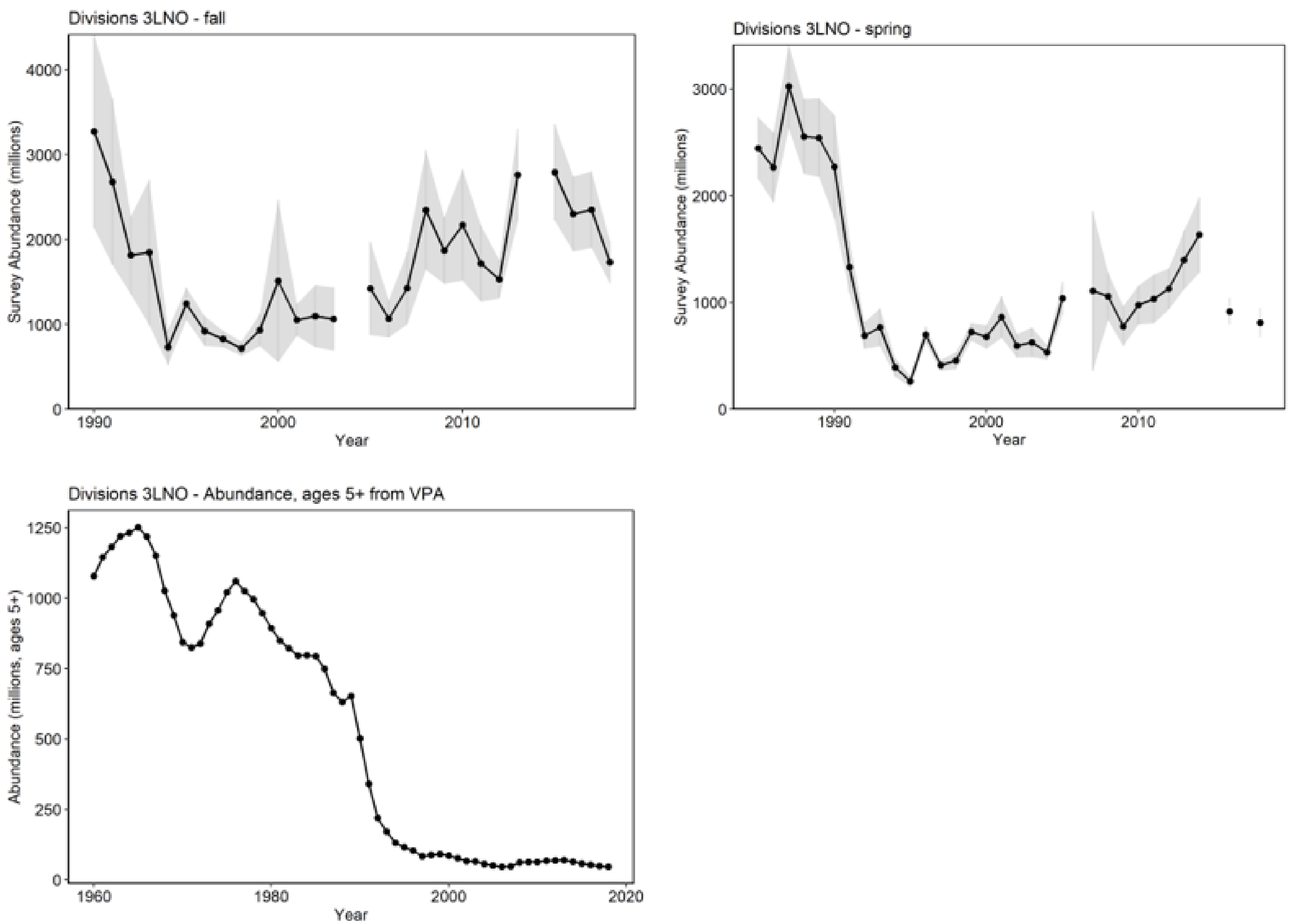


Figure 61: Abundance of American Plaice for Divs. 3LNO over the time series. Top panels show Divs. 3LNO survey abundance from the fall RV surveys from 1990–2018 (left), and spring RV surveys from 1985–2018 (right). Shaded areas indicate 95% confidence intervals. The bottom panel shows the total population numbers (ages 5+) estimated from a Virtual Population Analysis (VPA) from 1960–2018.

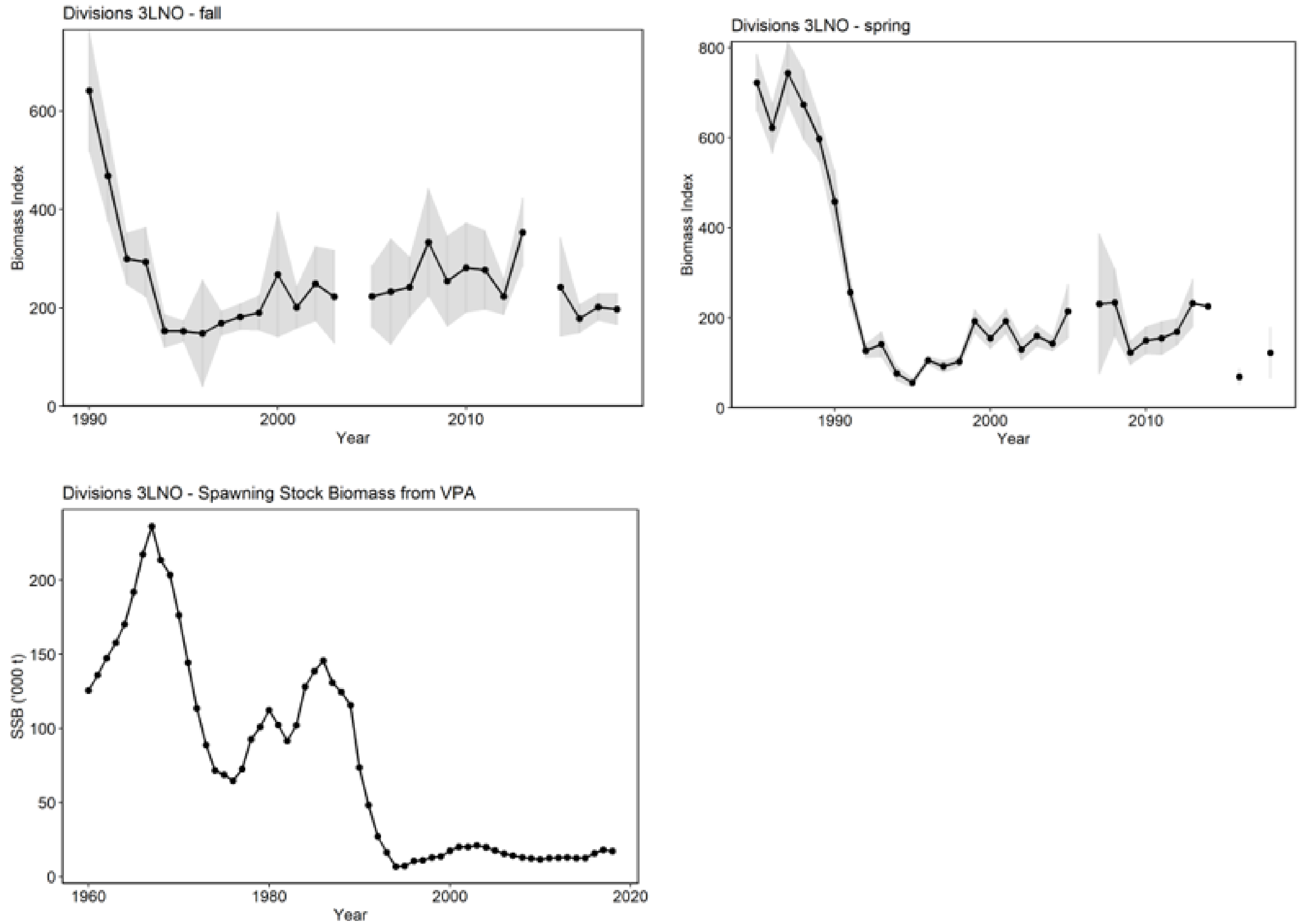
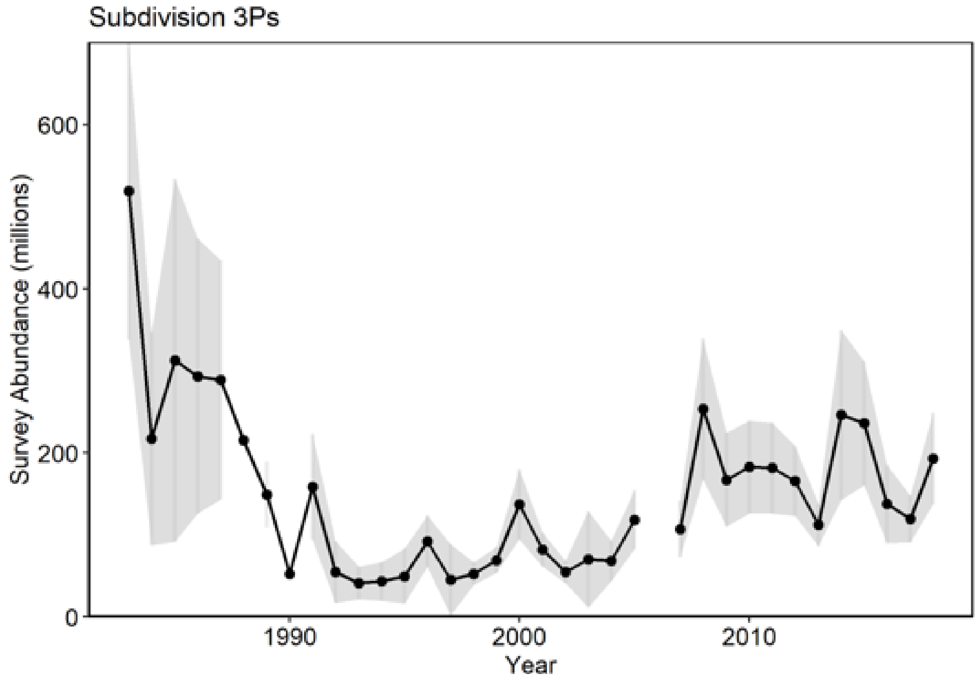


Figure 62: Biomass of American Plaice for Divs. 3LNO over the time series. Top panels show survey biomass from the fall RV surveys from 1990–2018 (left), and spring RV surveys from 1985–2018 (right). Shaded areas indicate 95% confidence intervals. The bottom panel shows the Spawning Stock Biomass (SSB) estimated from a Virtual Population Analysis (VPA) from 1960–2018.



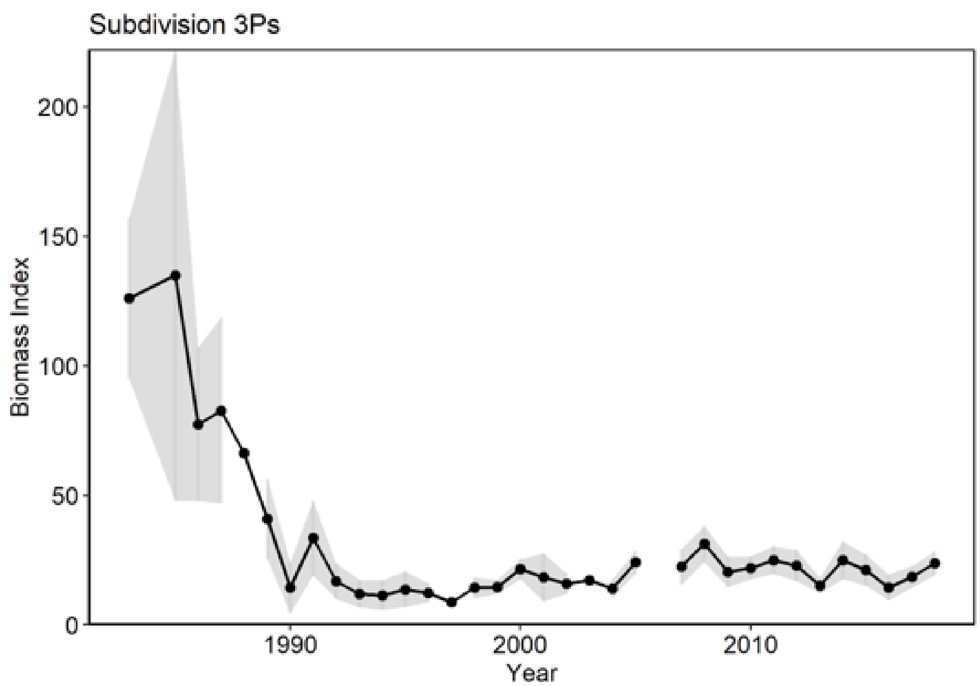


Figure 63: Survey abundance (top) and biomass (bottom) of American Plaice for Subdiv. 3Ps over the time period 1983–2018. Shaded areas indicate 95% confidence intervals.

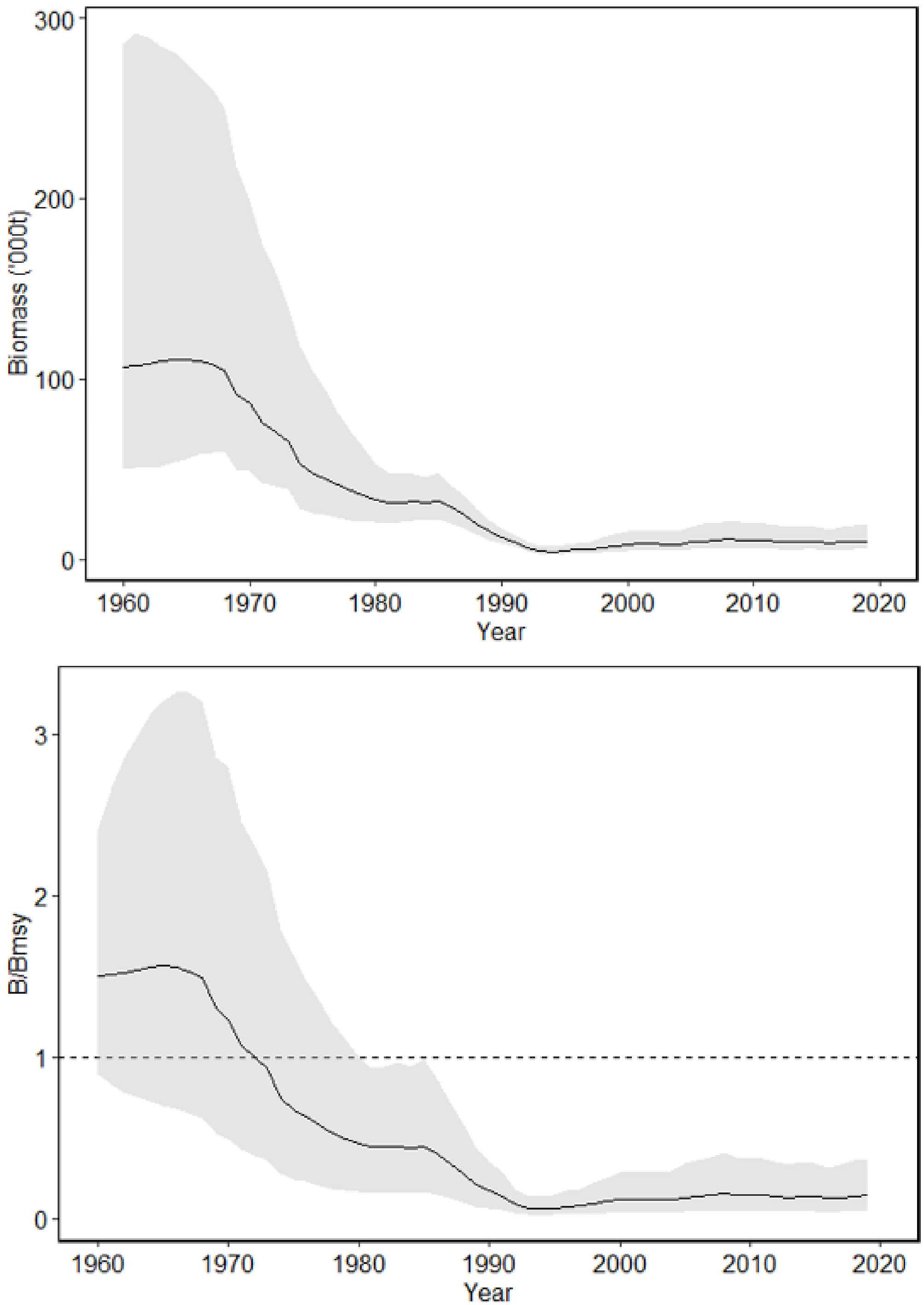
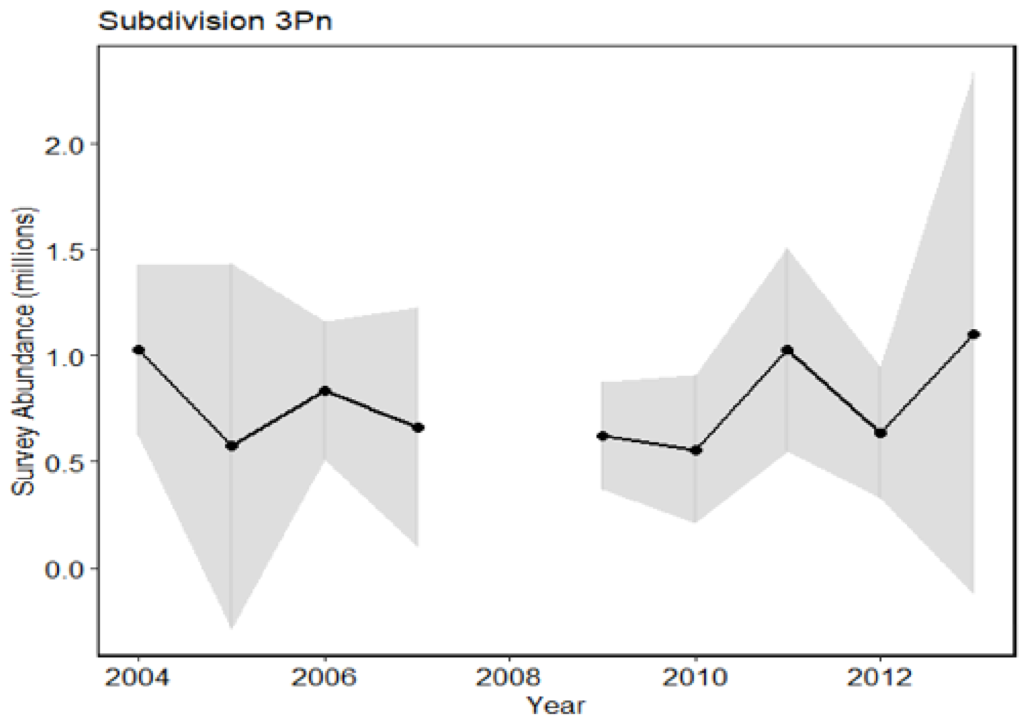


Figure 64: Biomass (B), and B/B_{msy} from 3Ps Surplus Production Model. Shaded areas indicate 95% credible intervals. Dashed line is at B/B_{MSY}=1 (Morgan et al. 2020).



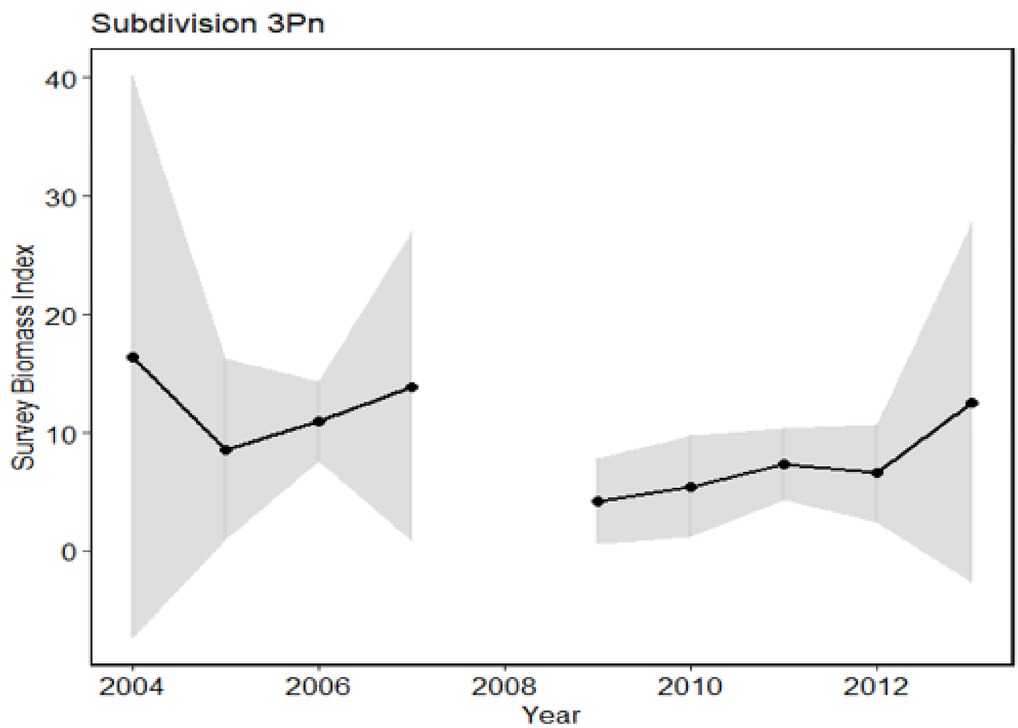


Figure 65: Survey abundance (top) and biomass (bottom) of American Plaice for subDiv. 3Pn from 2004 to 2013. Shaded areas indicate 95% confidence intervals. Earlier series are shown in [Busby et al. (2007)](#).

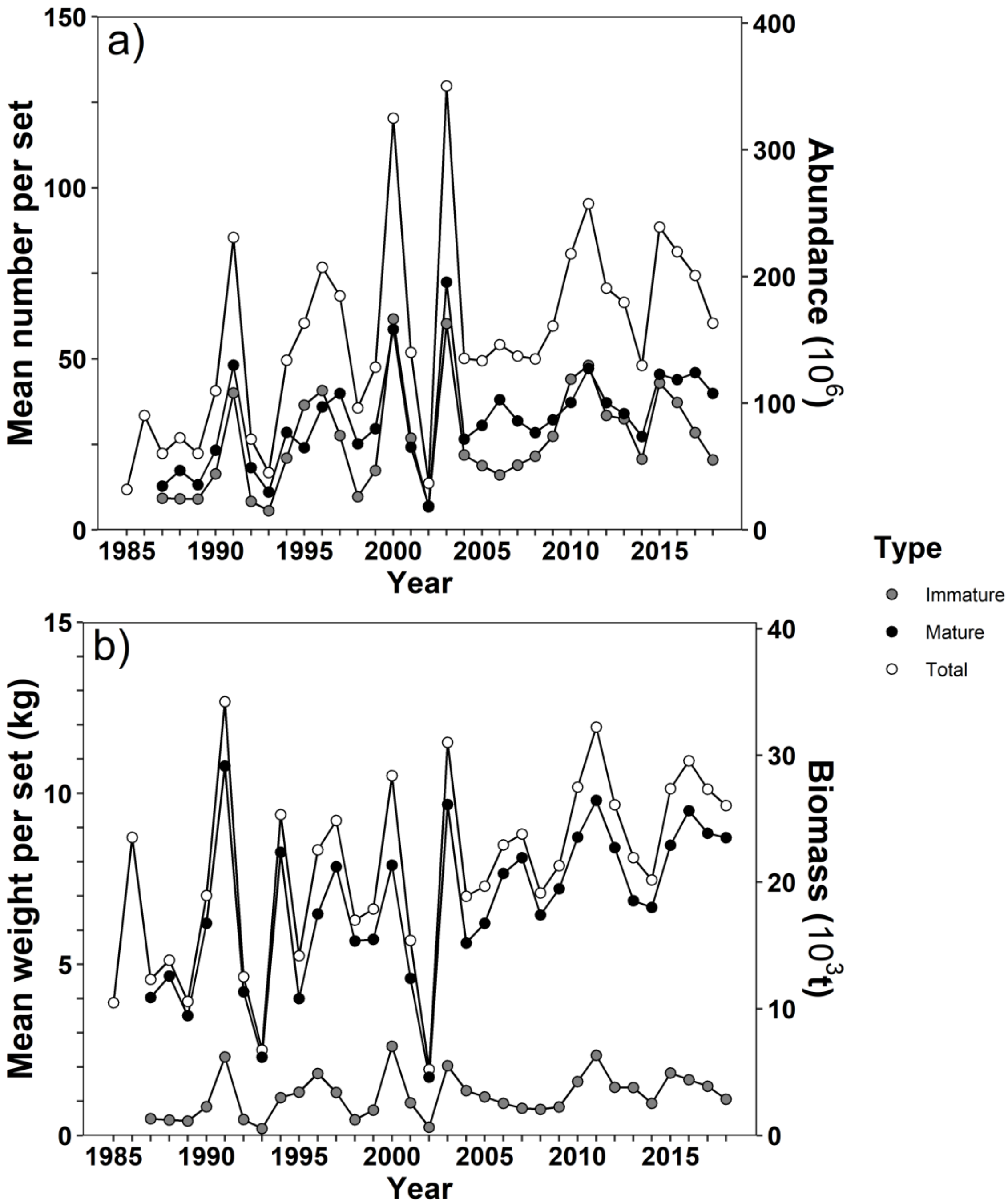


Figure 66: Mean number per set (a) and mean weight (kg) per set (b) of American Plaice captured during the August northern Gulf of St. Lawrence surveys for the period 1985–2018. Information is presented for total, immature and mature populations in Lady Hammond-Western IIA equivalents. The corresponding abundances and biomasses are also provided.

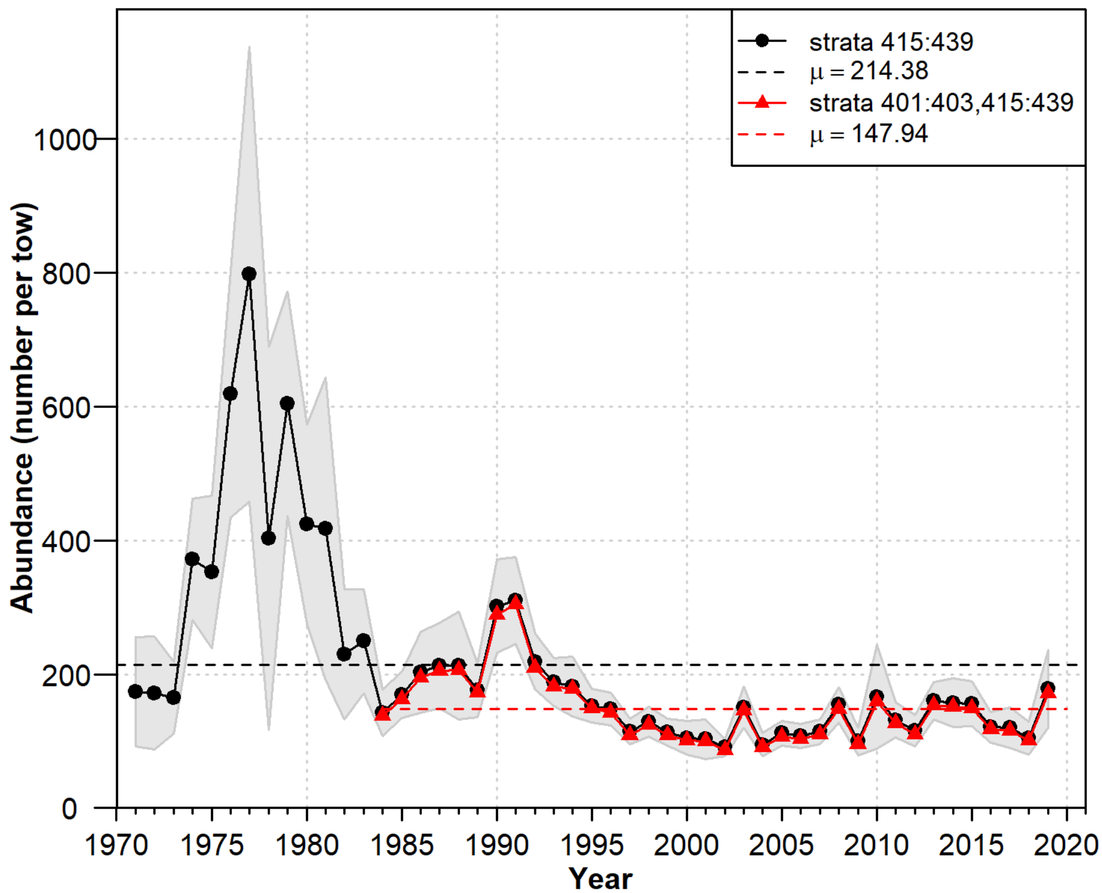


Figure 67: Abundance index for American Plaice (all lengths) derived from the annual southern Gulf of St. Lawrence (Div. 4T) September trawl survey, 1971–2019. Catch per tow has been corrected for trawl distance and for vessel/gear effects. The data used to compute the stratified random mean are equivalent to a Teleost day tow with a Western IIA trawl.

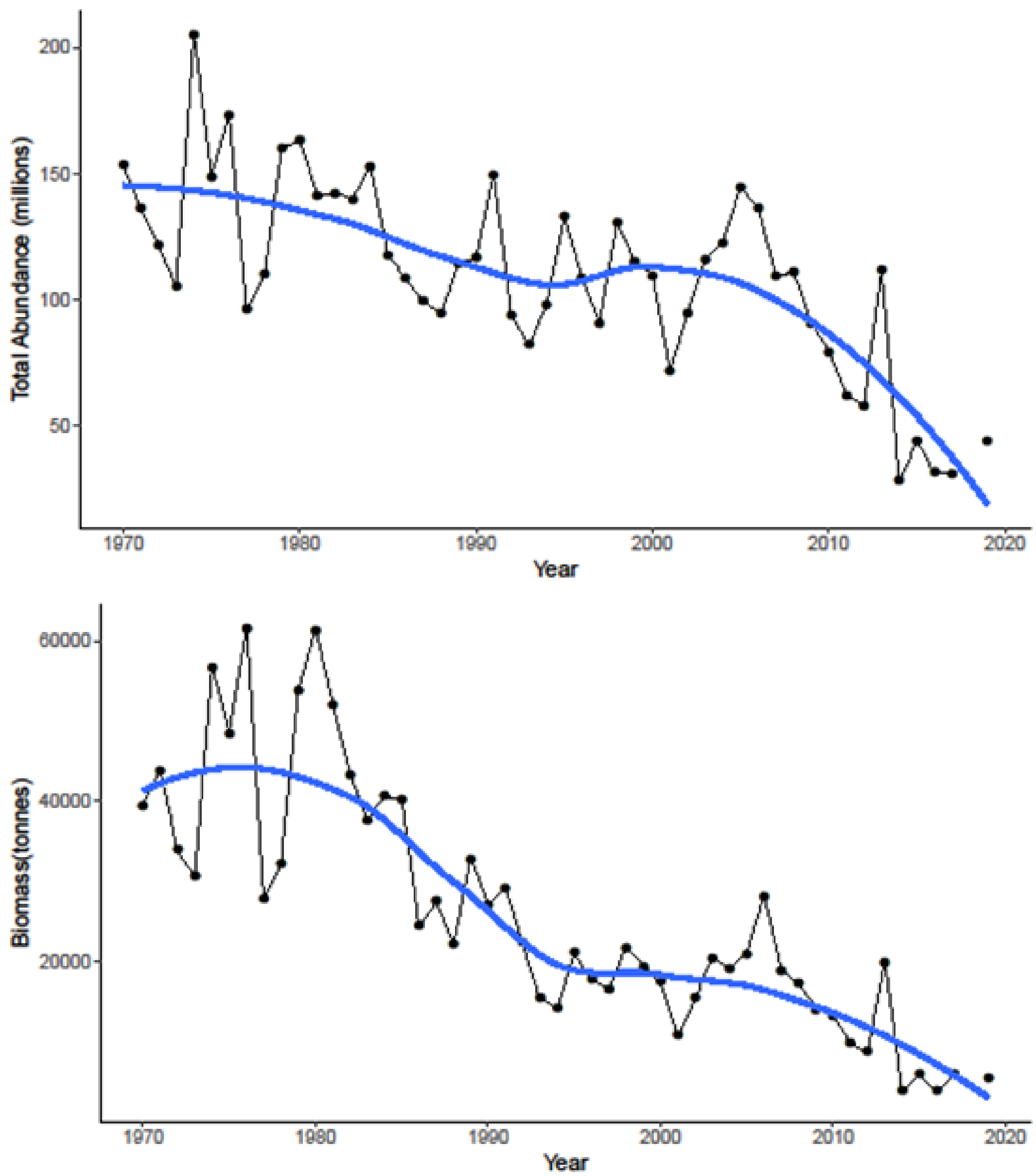


Figure 68: Trends in minimum trawlable abundance (millions, upper panel) of all American Plaice and biomass (tonnes, lower panel) in the 4VWX summer RV survey. Thick lines are lowess smoothers through indices.

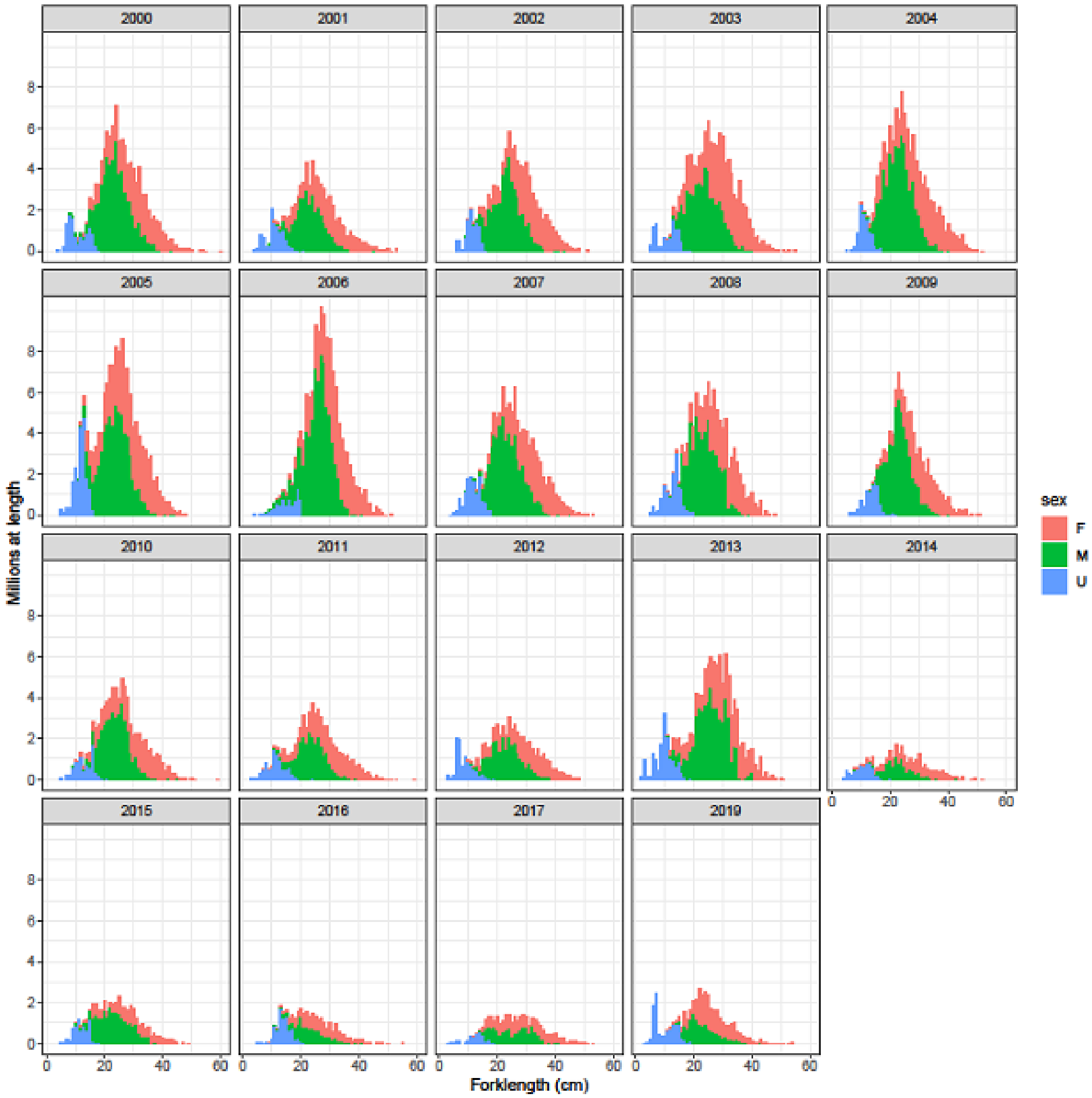


Figure 69: Numbers at length (cm) for American Plaice in the 4VWX summer RV survey (only years 2000–19). (F: females; M: males, U: not sexed are depicted).

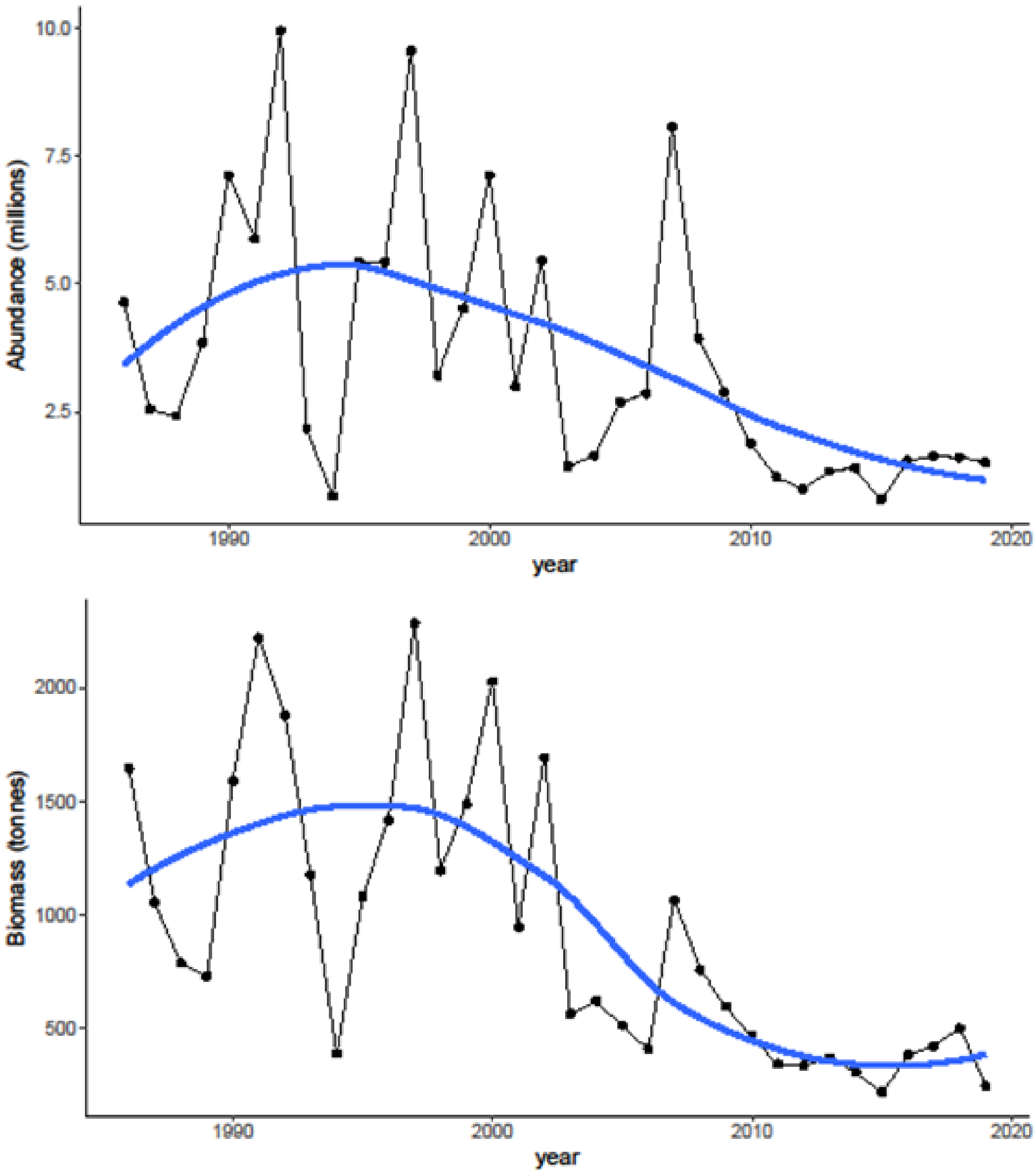


Figure 70: Trends in minimum trawlable abundance (millions, upper panel) of all American Plaice and biomass (tonnes, lower panel) in the 5Z winter RV survey. Thick lines represent lowess smoothers.

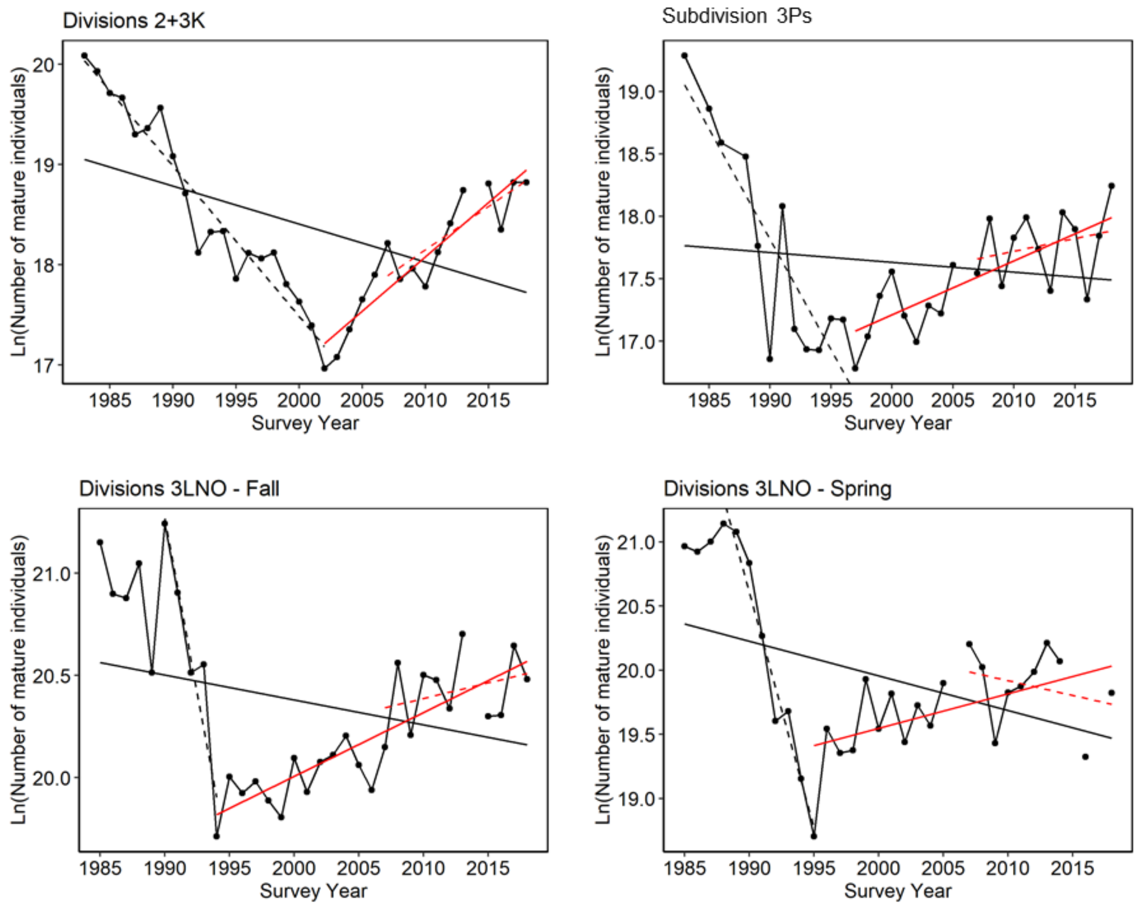


Figure 71: Number of mature individuals (thousands of fish) for SA2+Div 3K, Subdiv. 3Ps, Divs. 3LNO fall and spring. Lines indicate linear regressions for the full time series (black solid), maximum to minimum (black dashed), minimum to 2018 (red solid), and since 2007 (red dashed). Regression coefficients can be found in Table 8.

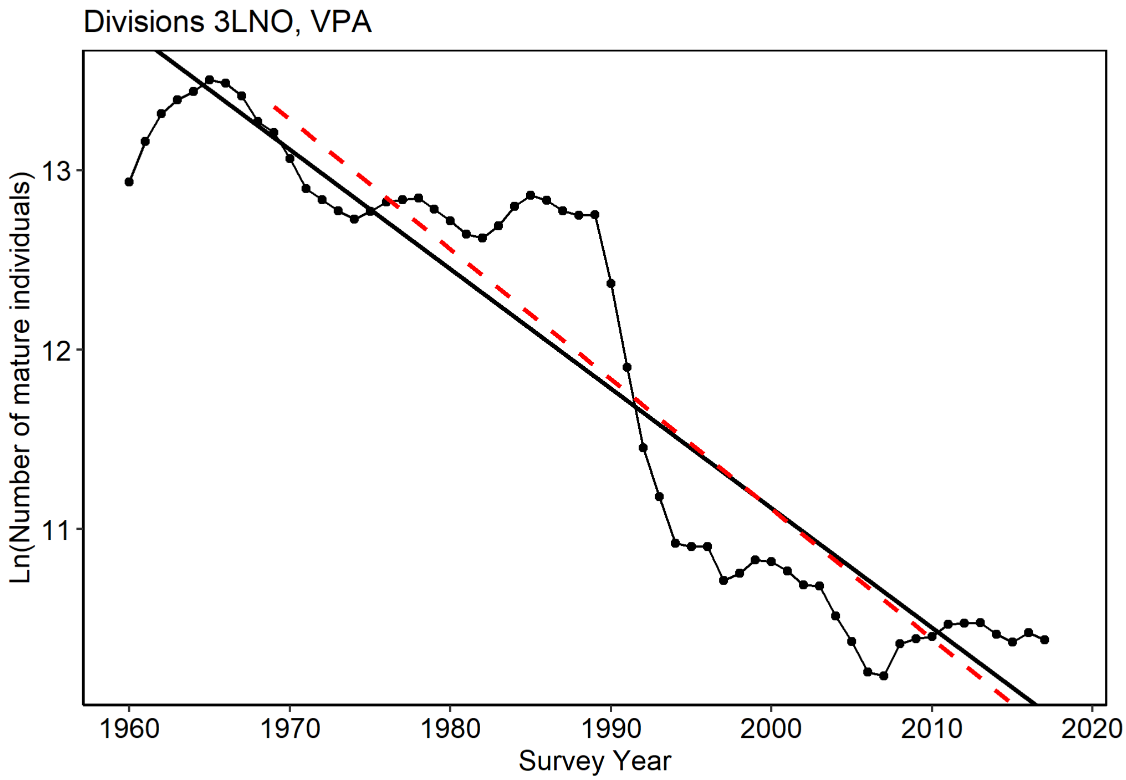


Figure 72: Number of mature individuals based on Divs. 3LNO VPA estimates with associated regression equations across the time series (black dashed) and for three generations (48 years, red dashed).

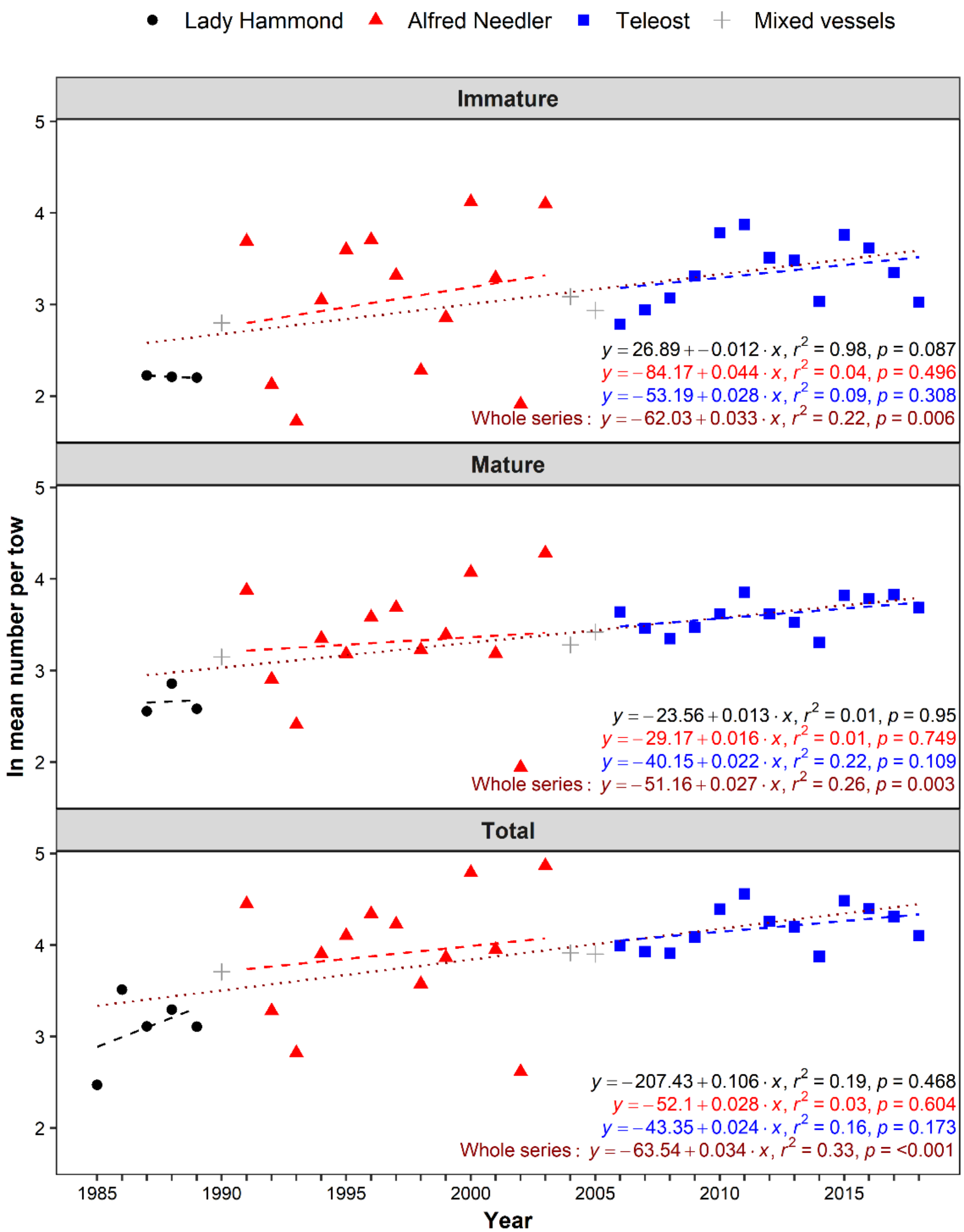


Figure 73: Trends in abundance for immature, mature and total populations of American Plaice captured in the northern Gulf of St. Lawrence August surveys. Data presented are converted to Lady Hammond Western IIA equivalent. Each line represents the regression of the natural log of abundance versus year for each series survey series listed above the figure.

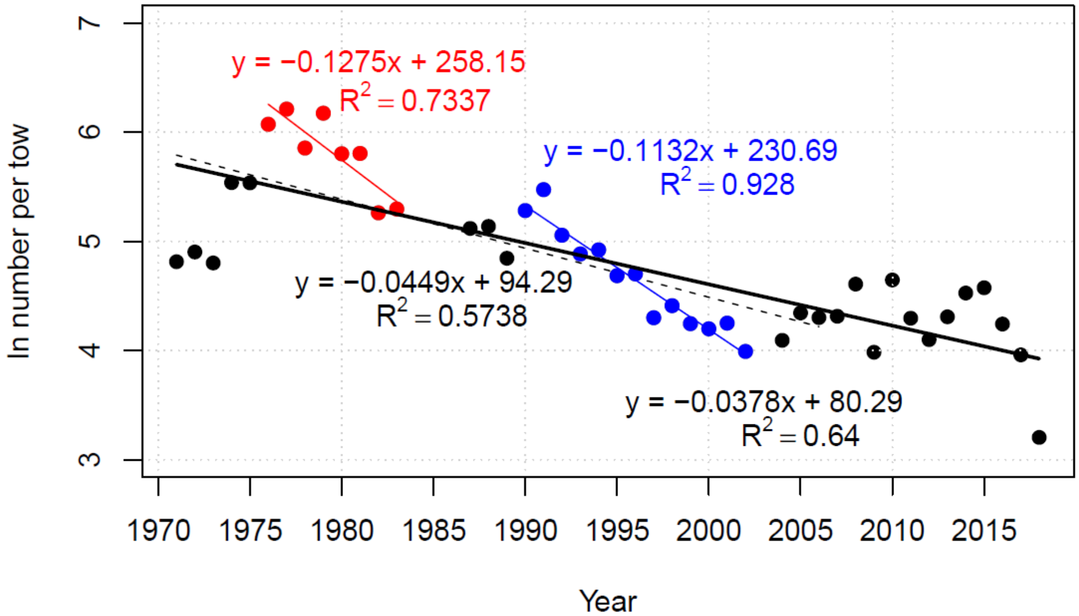


Figure 74: Trends in the mature (mature number per tow) component of the American Plaice stock in the southern Gulf of St. Lawrence (Div. 4T).

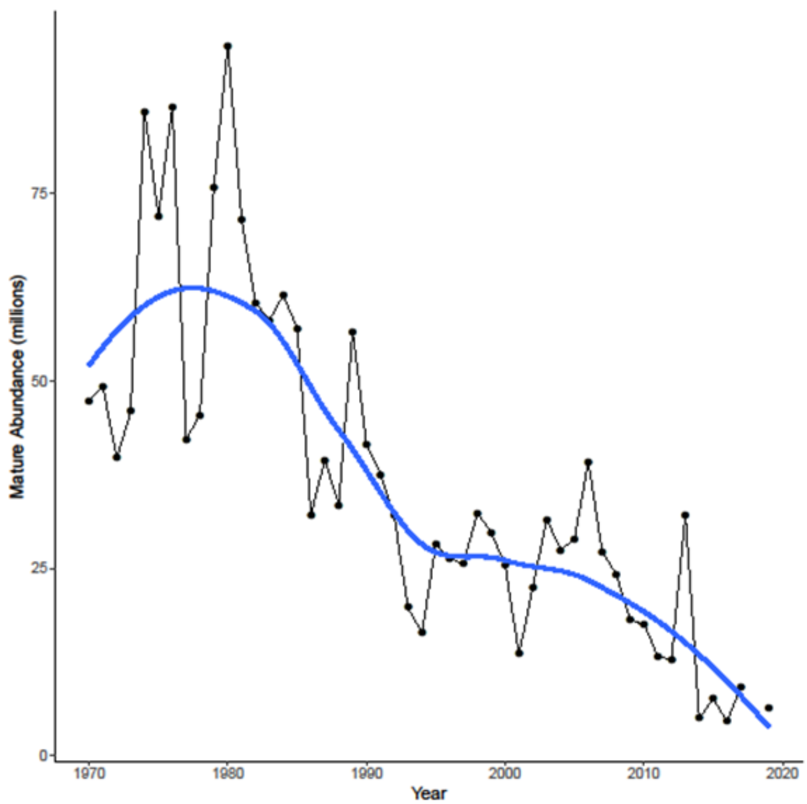


Figure 75: Trends in minimum trawlable abundance (millions) of American Plaice with a minimum length of >31 cm in the 4VWX summer RV survey. Thick blue line is a loess smoother.

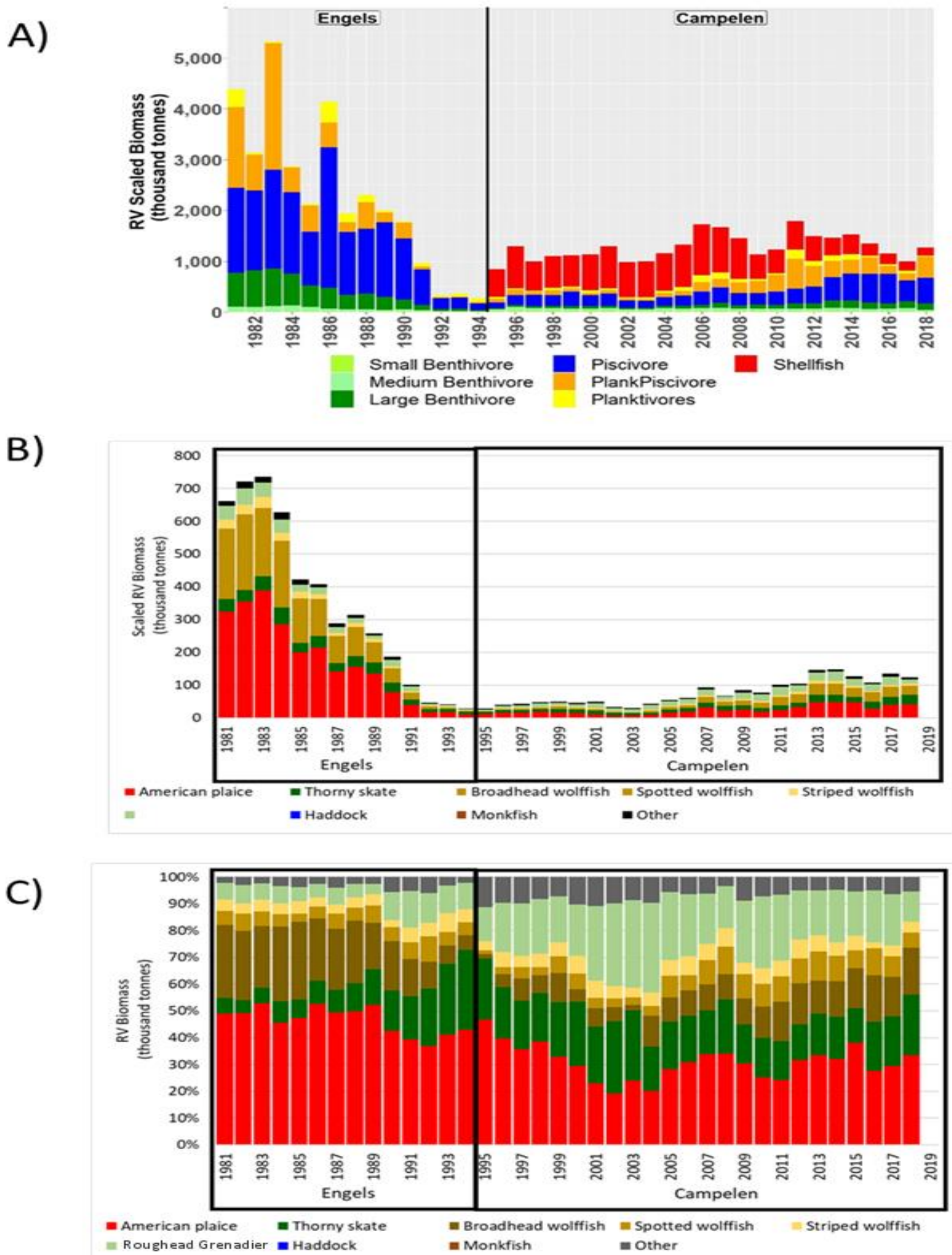


Figure 76: Trends in the fish community of the Newfoundland Shelf (2J3K) EPU from DFO RV Fall survey. A) RV Biomass trends for all fish functional groups; fish biomass for the Engels period has been scaled to allow for a coarse comparison between Engels and Campelen periods. Shellfish data is not available for the Engels series. B) Trends of RV biomass for large benthivores, with indication of the major species within this fish functional group; fish biomass for the Engels period has been scaled to allow for a coarse comparison between Engels and Campelen periods. C) Relative composition of large benthivores RV Biomass, showing the changes in the structure of this functional group over time.

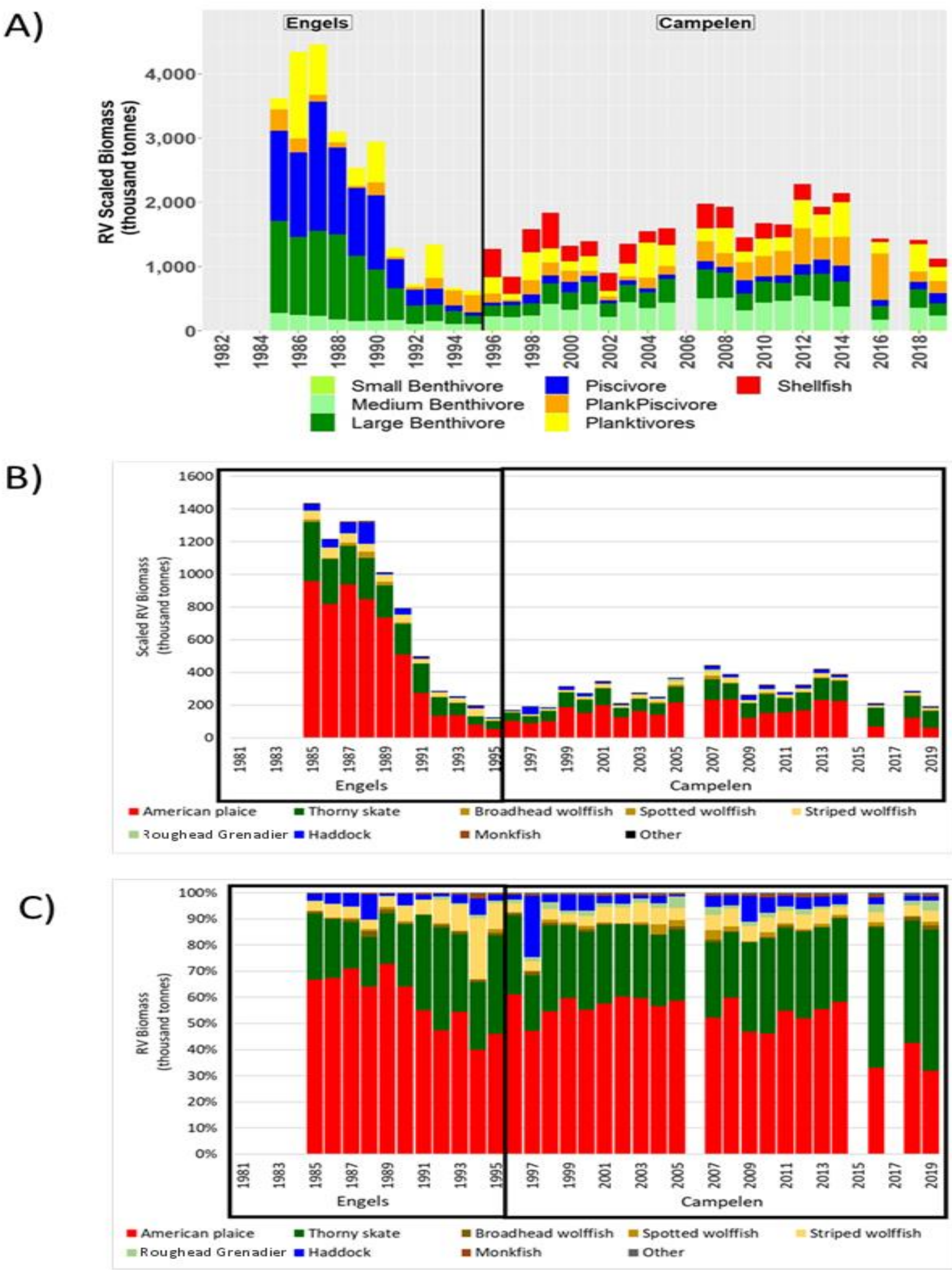


Figure 77: Trends in the fish community of the Grand Bank (Divs. 3LNO) EPU from DFO RV spring survey. A) RV Biomass trends for all fish functional groups; fish biomass for the Engels period has been scaled to allow for a coarse comparison between Engels and Campelen periods. Shellfish data is not available for the Engels series. B) Trends of RV biomass for large benthivores, with indication of the major species within this fish functional group; fish biomass for the Engels period has been scaled to allow for a coarse comparison between Engels and Campelen periods. C) Relative composition of large benthivores RV Biomass, showing the changes in the structure of this functional group over time.

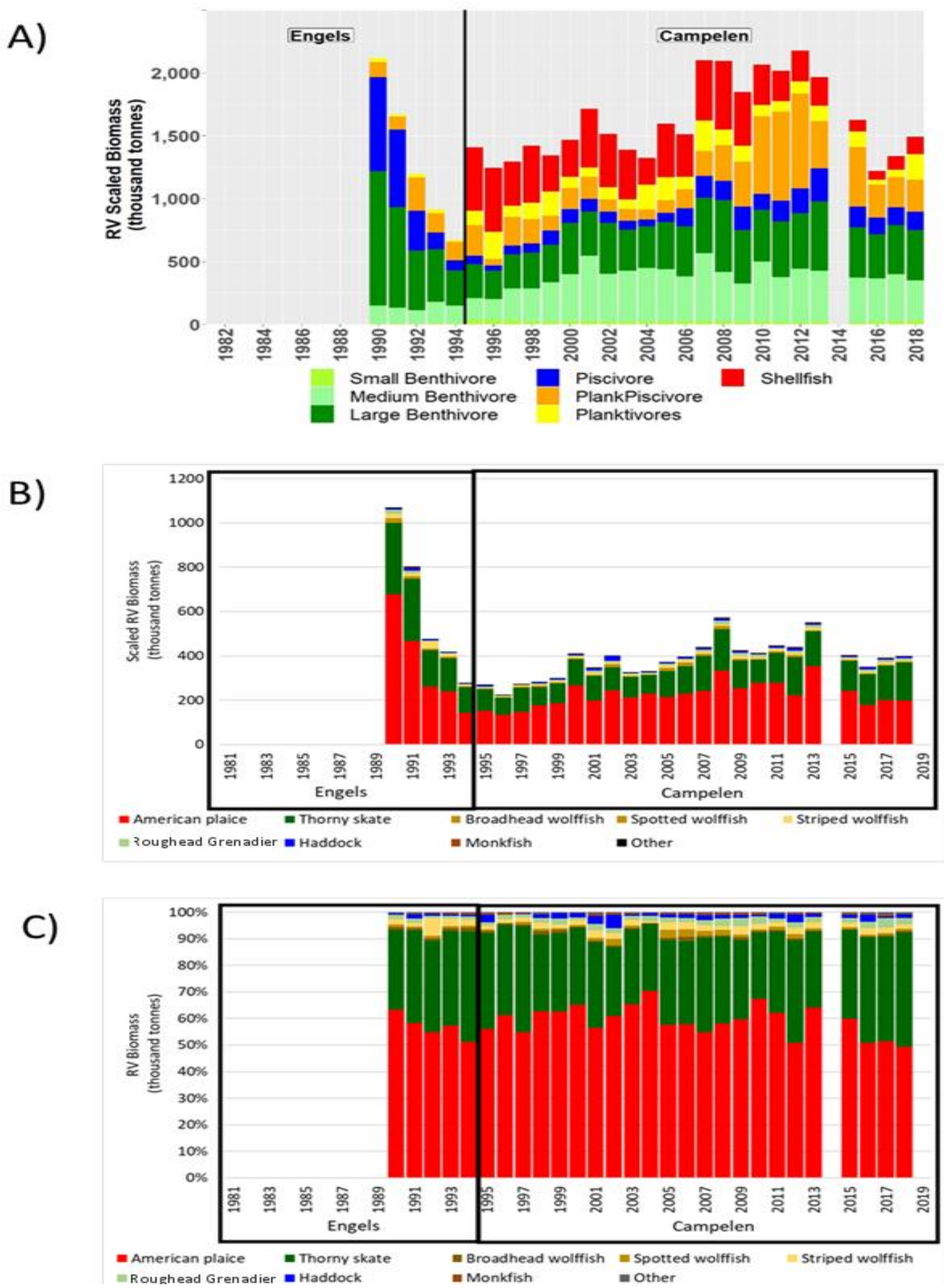


Figure 78: Trends in the fish community of the Grand Bank (Divs. 3LNO) EPU from DFO RV fall survey. A) RV Biomass trends for all fish functional groups; fish biomass for the Engels period has been scaled to allow for a coarse comparison between Engels and Campelen periods. Shellfish data is not available for the Engels series. B) Trends of RV biomass for large benthivores, with indication of the major species within this fish functional group; fish biomass for the Engels period has been scaled to allow for a coarse comparison between Engels and Campelen periods. C) Relative composition of large benthivores RV Biomass, showing the changes in the structure of this functional group over time.

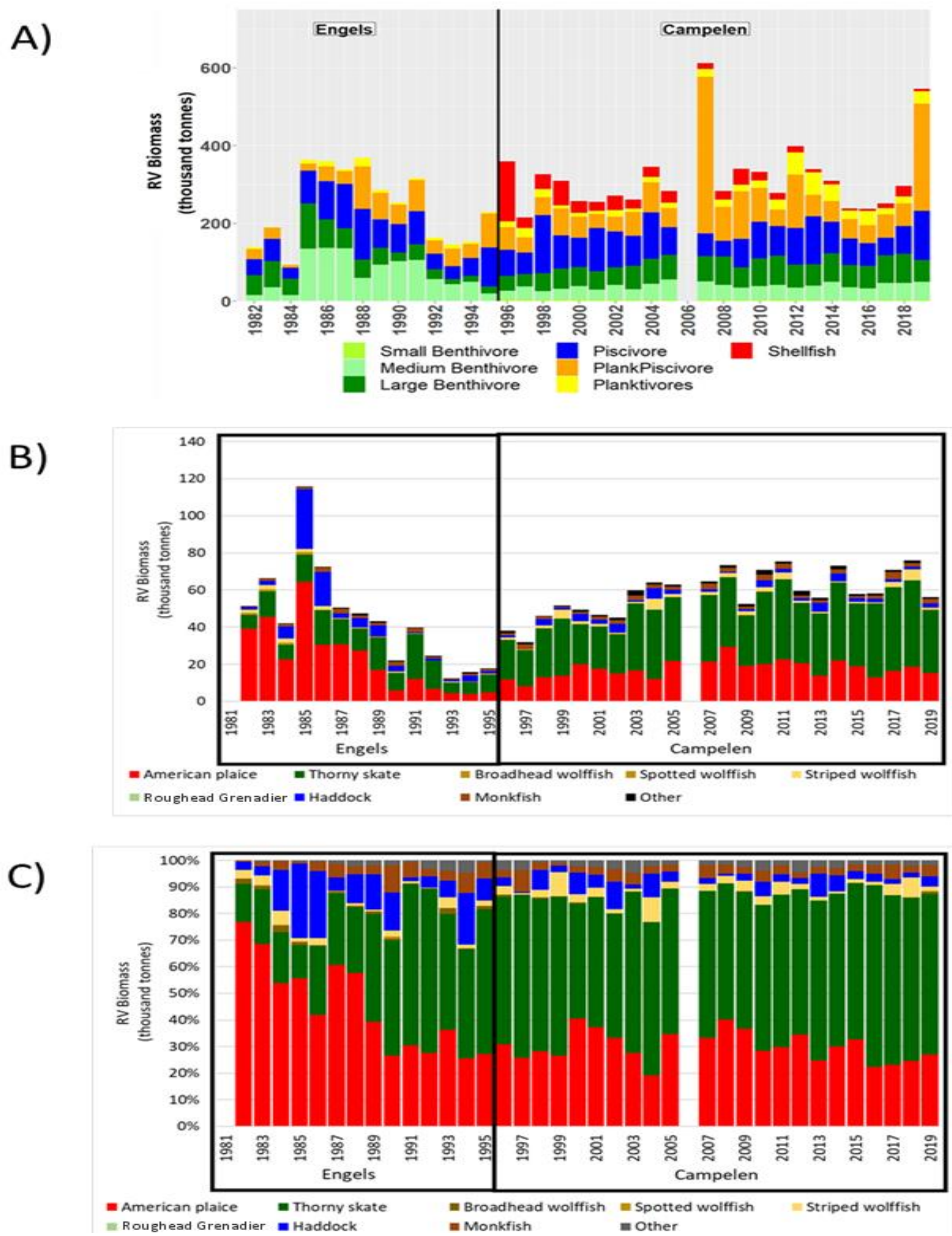


Figure 79: Trends in the fish community of the Southern Newfoundland (Subdiv. 3Ps) EPU from DFO RV spring survey. There was no survey in 2006. A) RV Biomass trends for all fish functional groups; fish biomass for the Engels period has not been scaled; only relative comparisons between Engels and Campelen periods are possible. Shellfish data is not available for the Engels series. B) Trends of RV biomass for large benthivores, with indication of the major species within this fish functional group; only relative comparisons between Engels and Campelen periods are possible. C) Relative composition of large benthivores RV Biomass, showing the changes in the structure of this functional group over time.

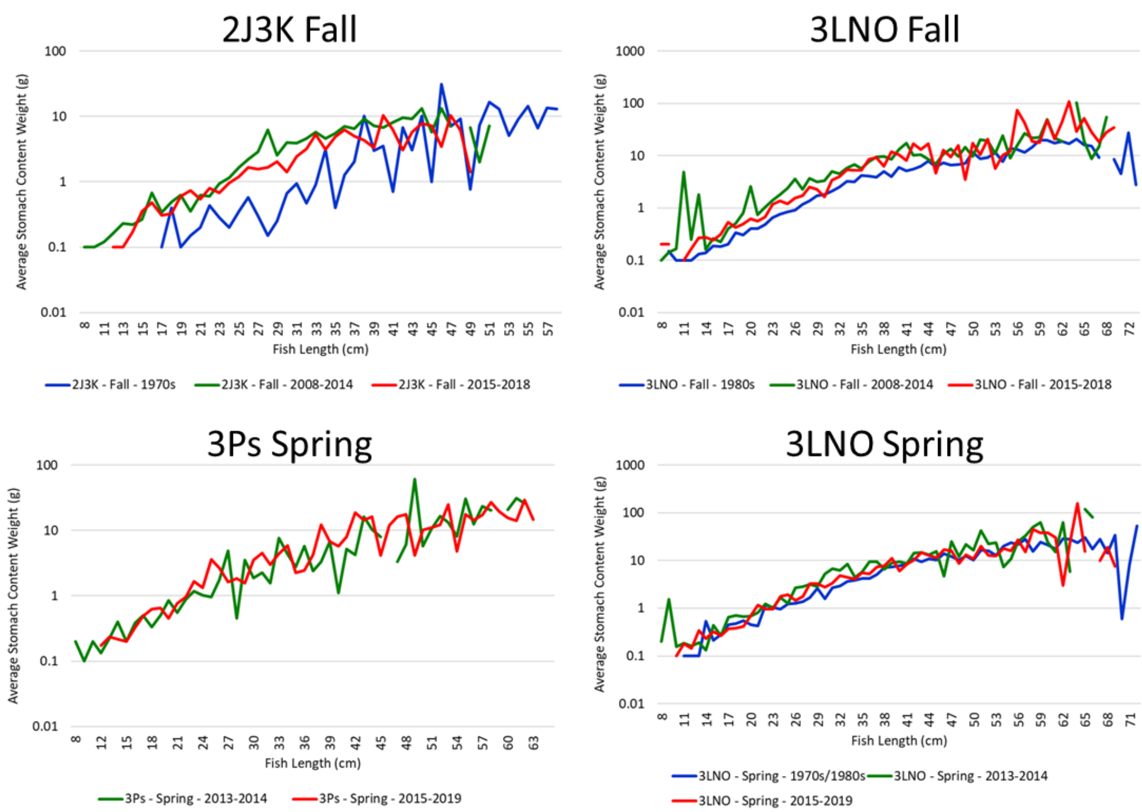


Figure 80: Average weight of American Plaice stomach contents as a function of fish size by Ecosystem Production Unit and Season for three general blocks of time, pre-collapse (blue line), recent years during a period with observed build-ups of groundfish biomass (green line), and recent years during a period of observed declines of groundfish biomass (red line). Empty stomachs were excluded from these analyses.

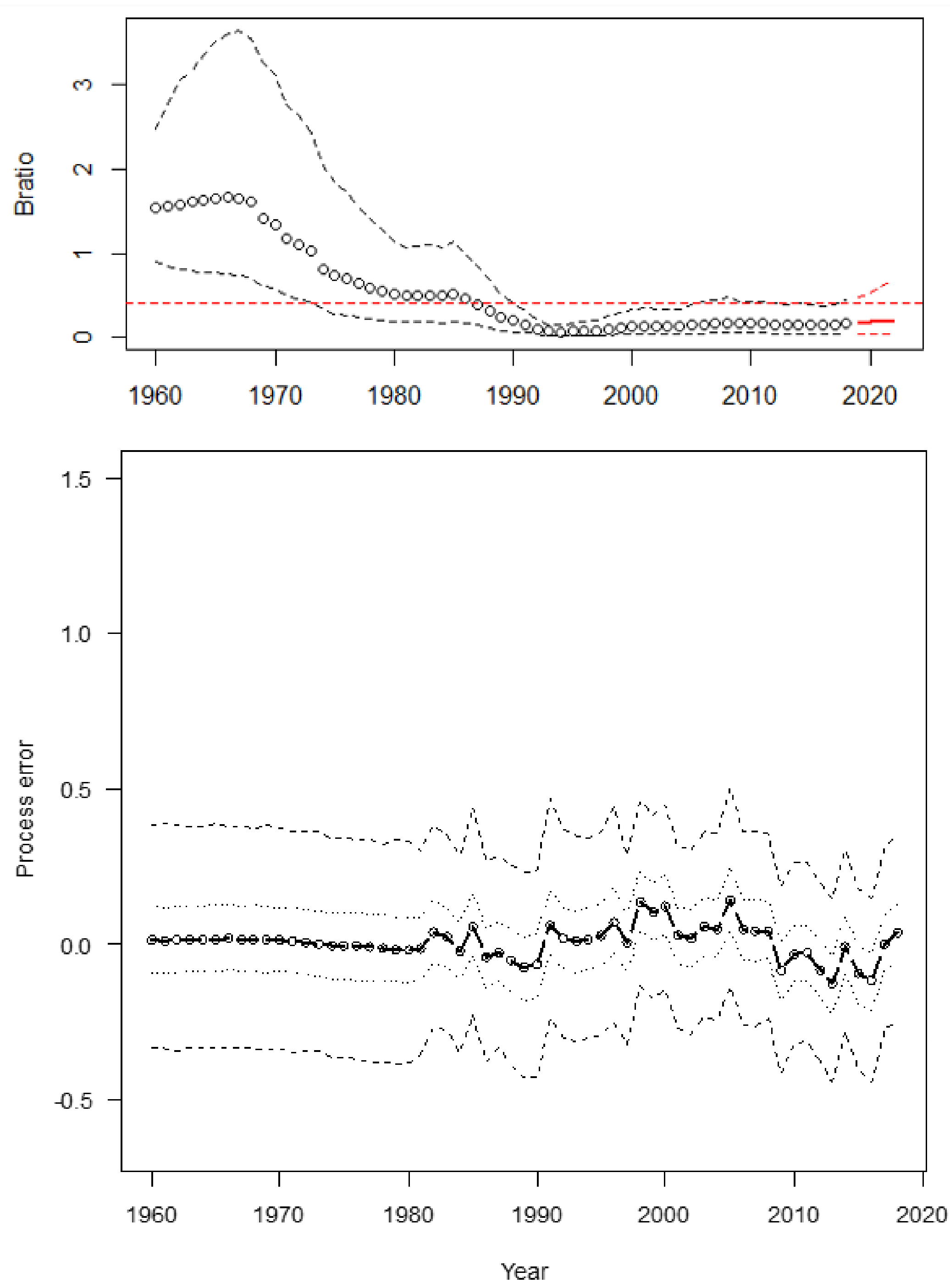


Figure 81: Projections of Bratio (B/B_{lim}, top), from the 3Ps Surplus Production model run at the 2020 assessment (DFO 2020). The red horizontal line is Blim (i.e. 40% of BMSY). Process error (bottom) from the model is also shown with median, 50% and 95% credible intervals shown.

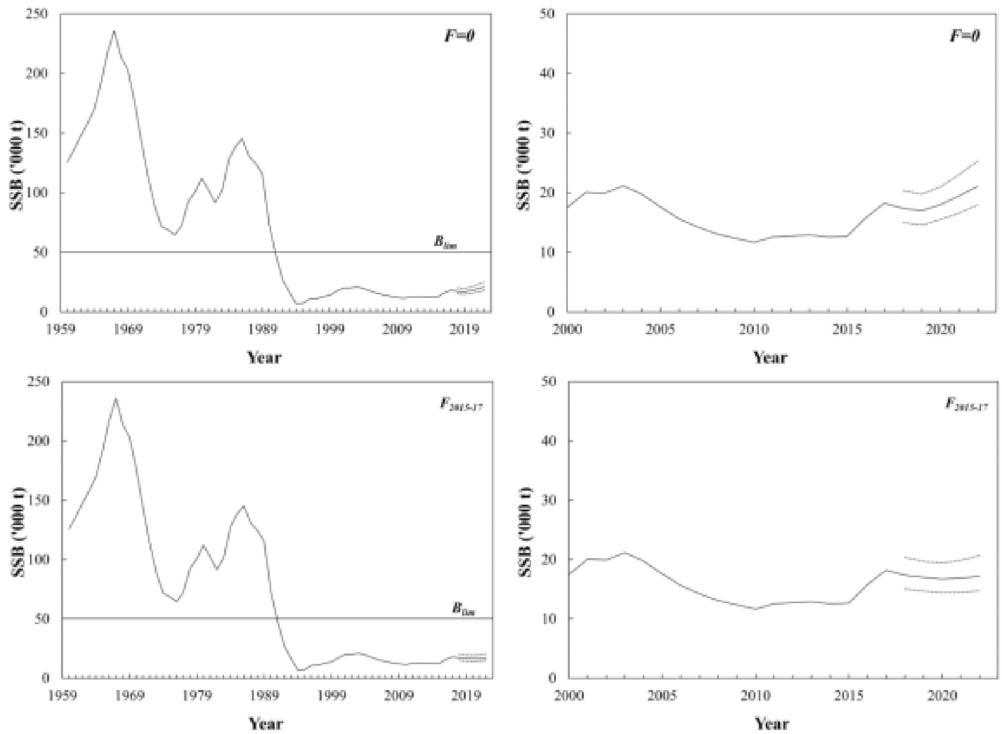


Figure 82: American Plaice in Divs. 3LNO: SSB from projections along with 10th and 90th percentiles (dotted lines) for F=0 (upper) and $F_{2015\text{-}2017}$ (bottom). Panels on the right show an enlarged portion of the time series starting in 2000 ([Wheeland et al. 2018](#)).

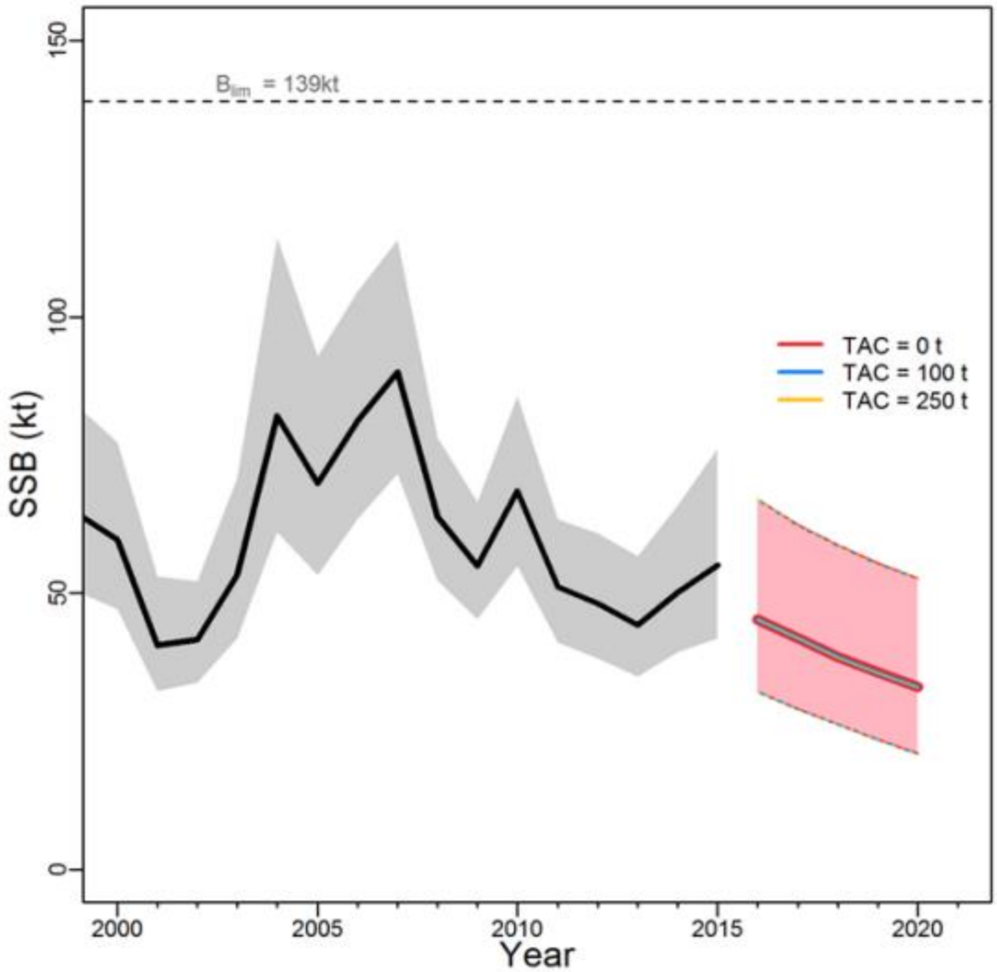


Figure 83: Five-year stock projections of southern Gulf of St. Lawrence American Plaice SSB under a TAC of 0 t, 100 t and 250 t under current levels of natural mortality in Div. 4T (Ricard et al 2016).

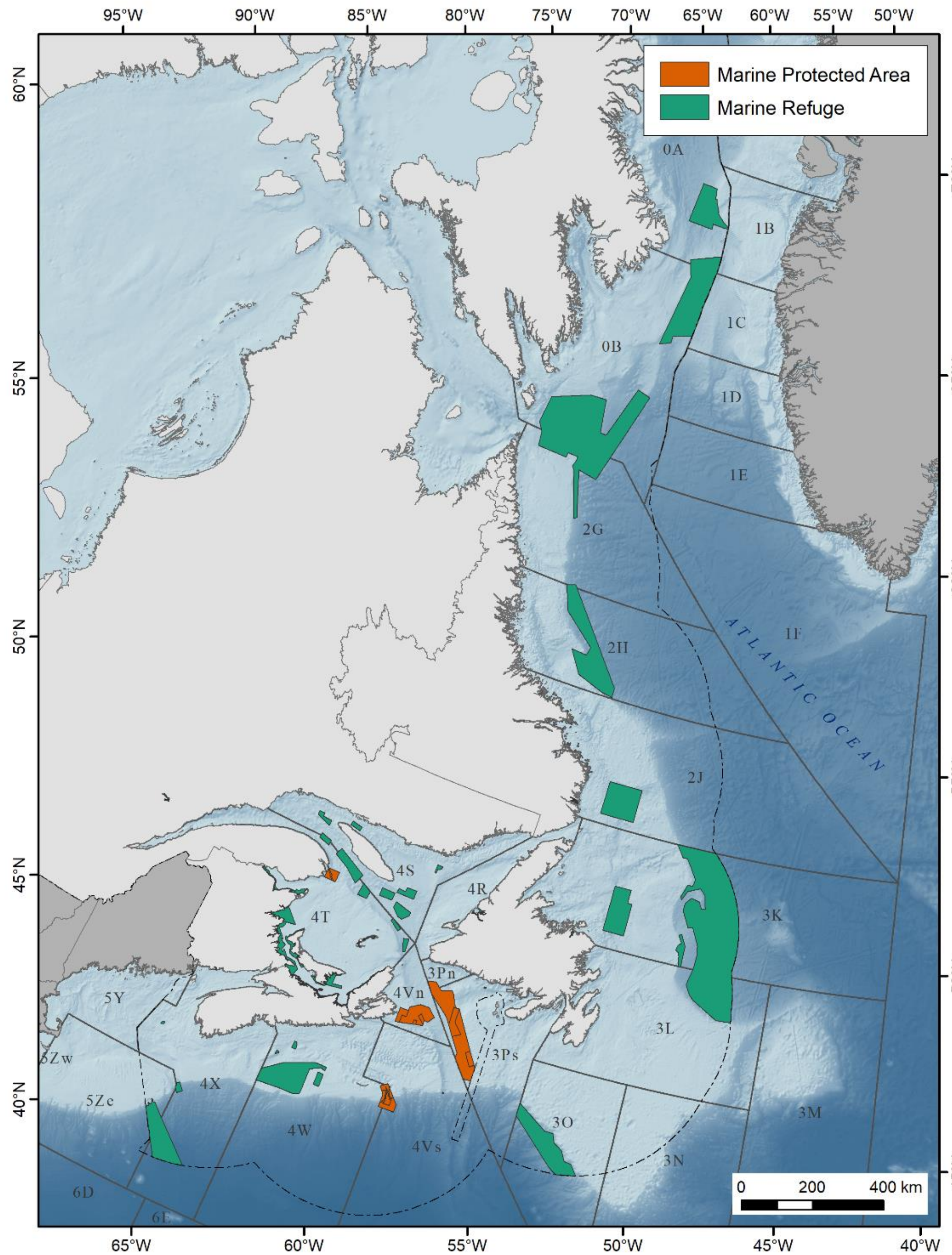


Figure 84: Location of Marine Protected Areas (MPAs, orange) and Marine Refuges (green) in the Canadian distribution of American Plaice.

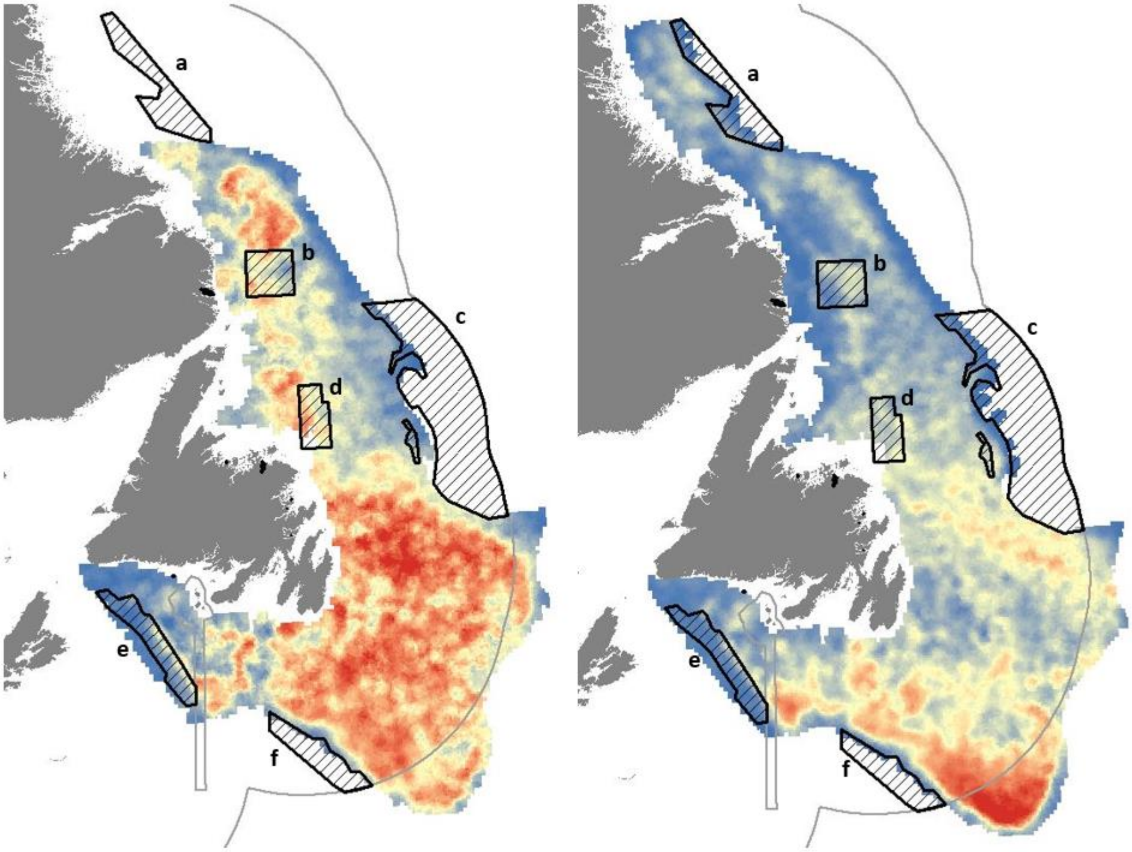


Figure 85: American Plaice spring/fall average relative density based on RV survey data from 1981–95 (left; Engel years) and 1995–2017 (right; Campelen years). Black hatched areas are conservation areas closed under the Fisheries Act and Oceans Act. a=Hopedale Saddle Closure, b=Hawke Channel Closure, c=Northeast Newfoundland Slope Closure, d=Funk Island Deep Closure, e=Laurentian Channel MPA, f=Div. 3O Coral Closure. Survey data used for these analyses do not extend to inshore waters or to depths >1,500 m.

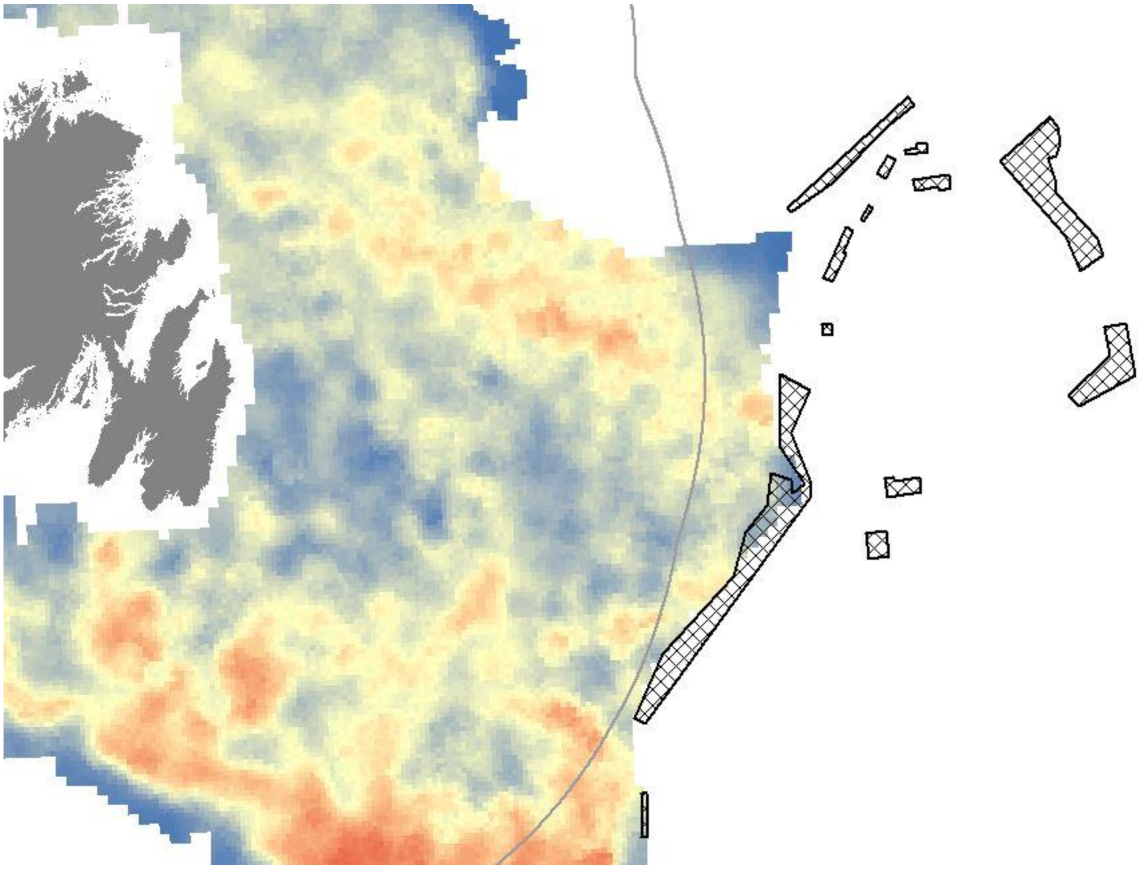


Figure 86: American Plaice spring/fall average relative density based on RV survey data from 1995–2017 (Campelen years). Black hatched areas are NAFO's Vulnerable Marine Ecosystem closures. Survey data used for these analyses do not extend to inshore waters or to depths >1,500 m.

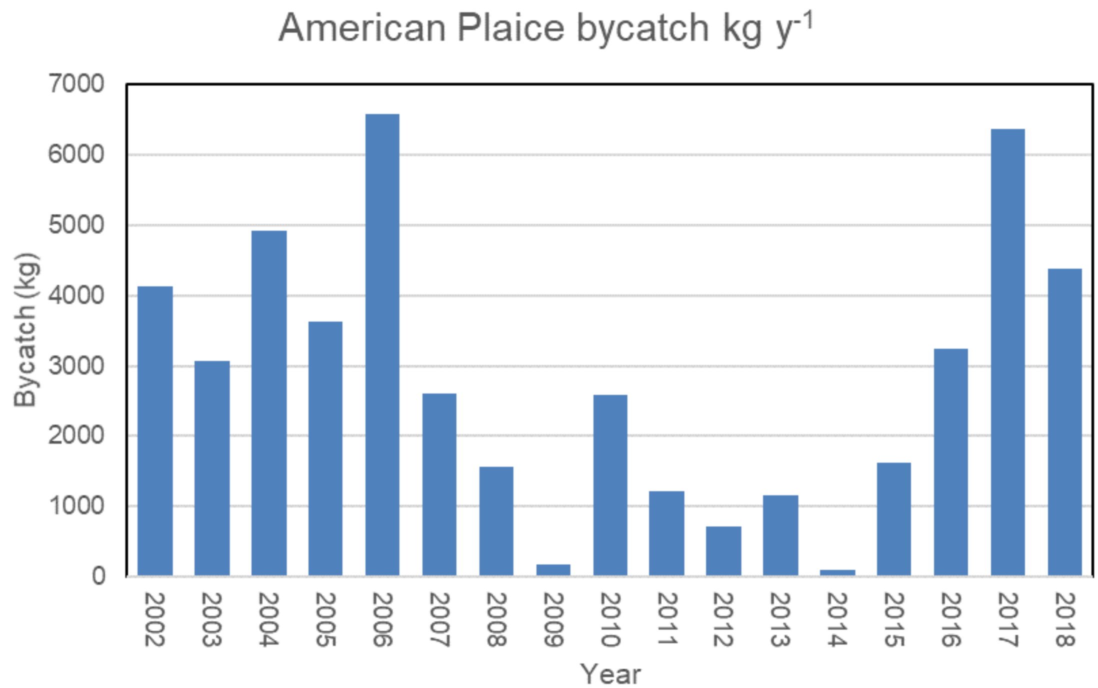


Figure 87: Bycatch (kg) per year of American Plaice reported in Greenland Halibut and Northern and Striped Shrimp fisheries in SA 0, and Shrimp Fishing Areas 0 to 3. Fisheries and areas have been combined to meet privacy guidelines, numbers are provisional for all years.

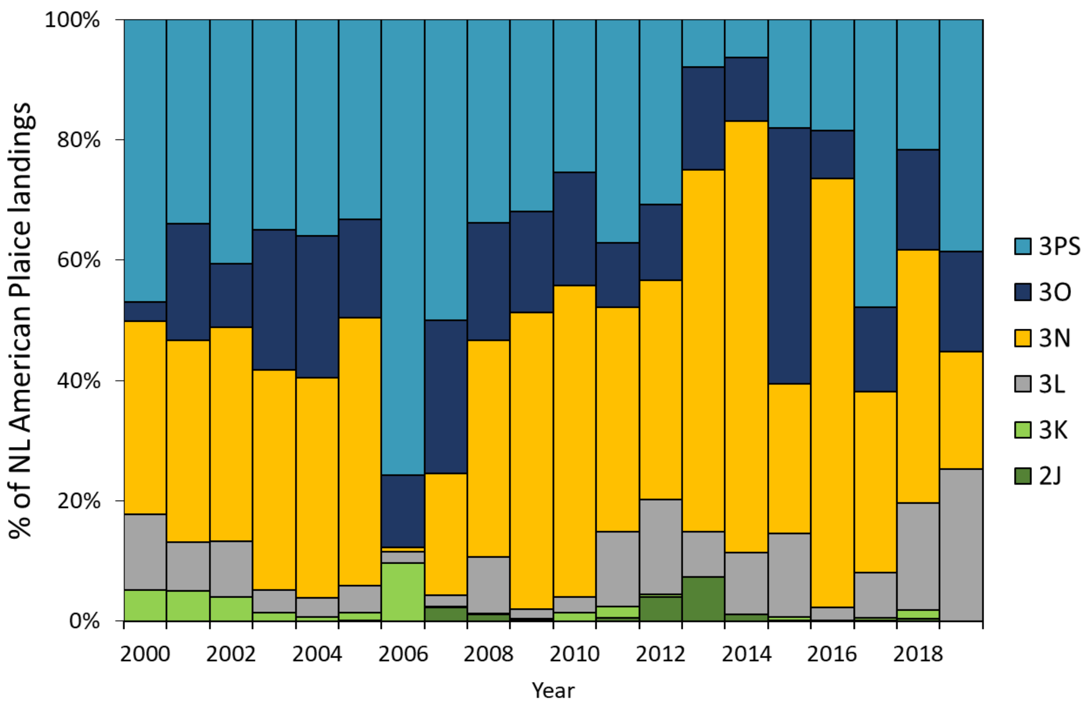
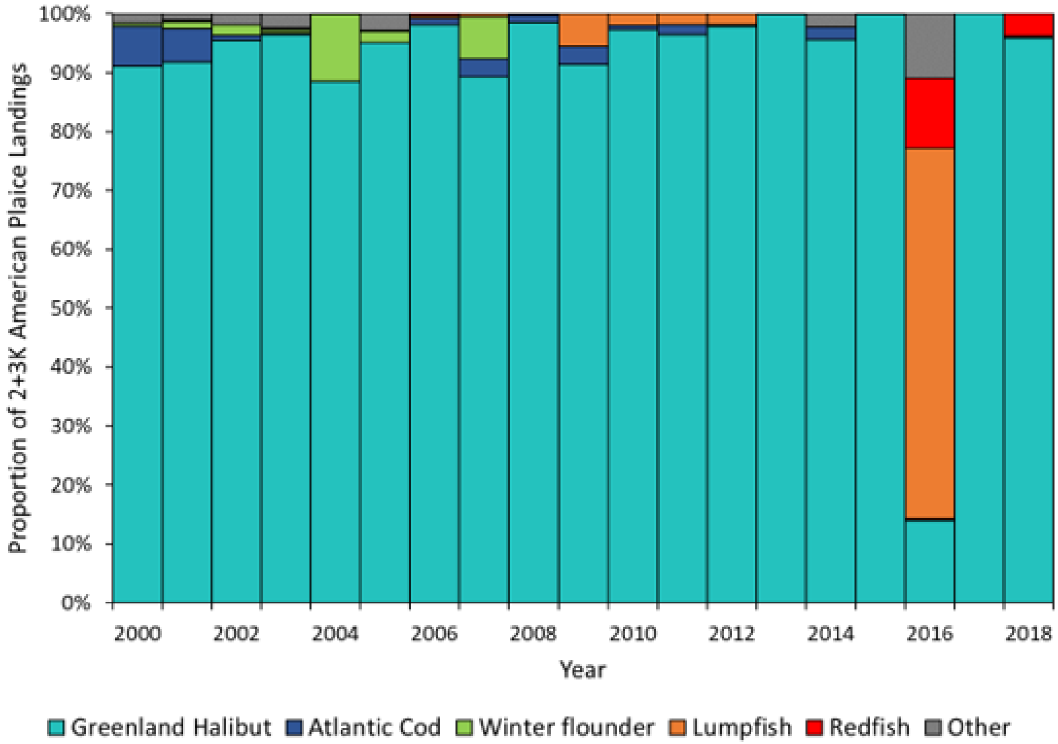


Figure 88: Proportion of Canadian landings of American Plaice in the Newfoundland & Labrador Region by NAFO Division, 2016 to 2019 values are provisional.



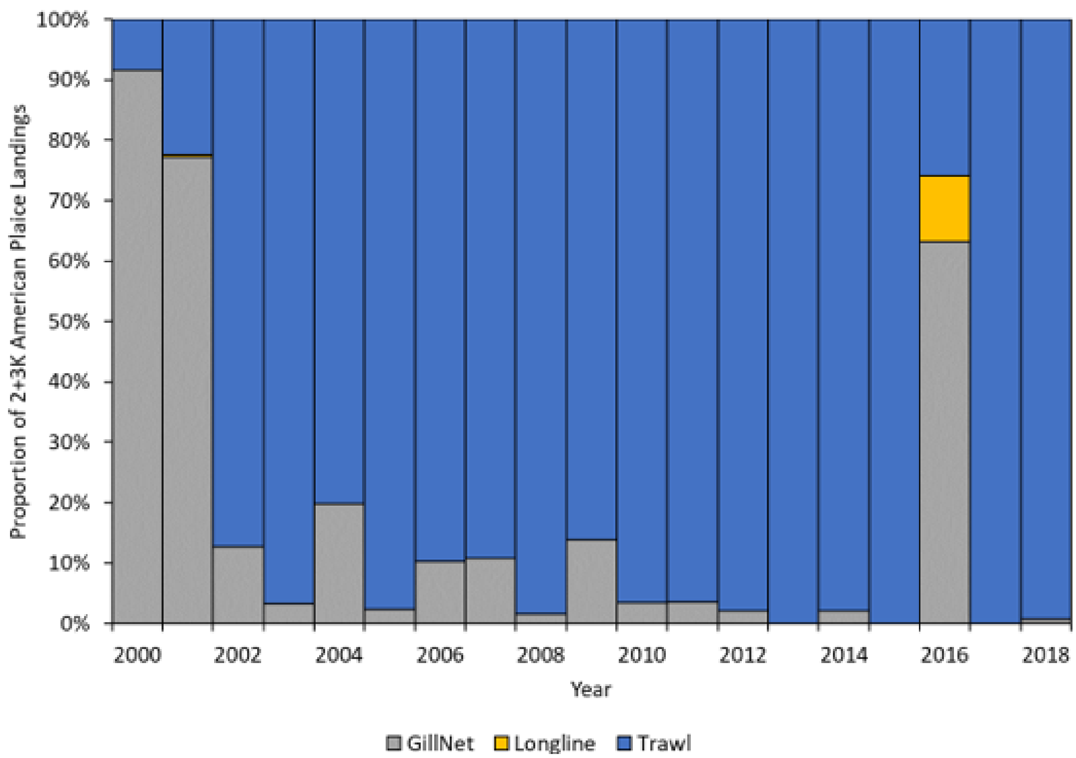


Figure 89: Proportion of American Plaice landings in NAFO SA 2+ Div. 3K by target species (top) and gear (bottom), 2016–18 values are provisional.

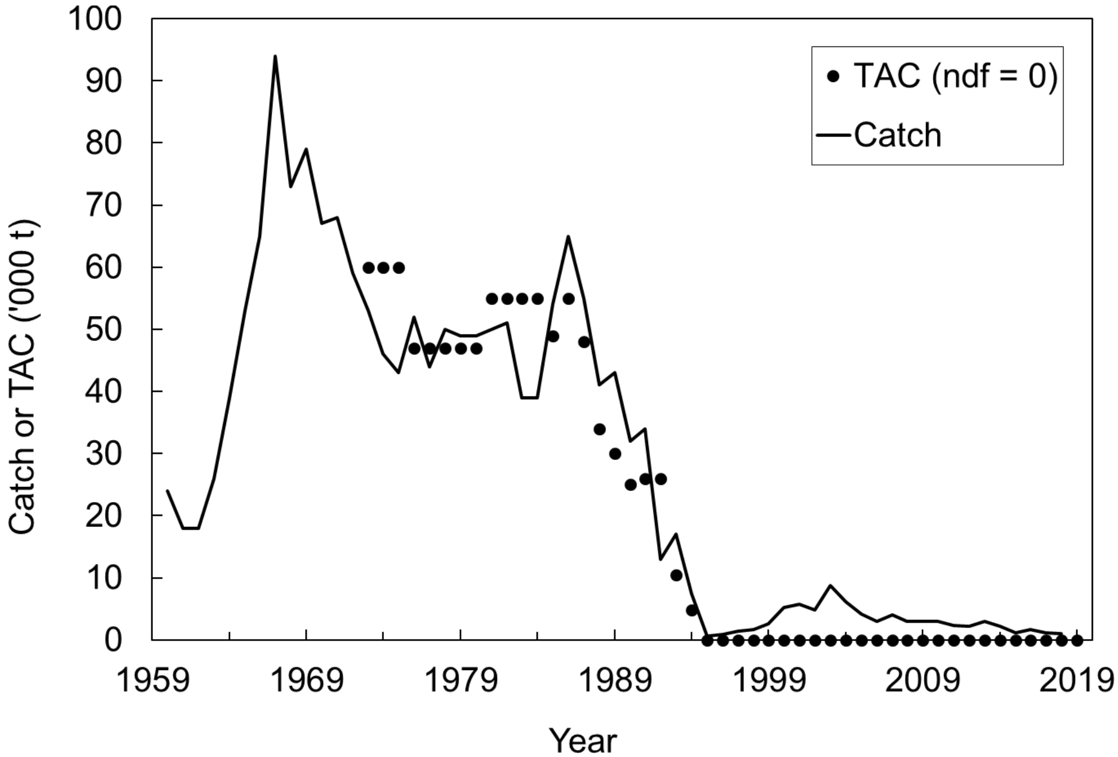
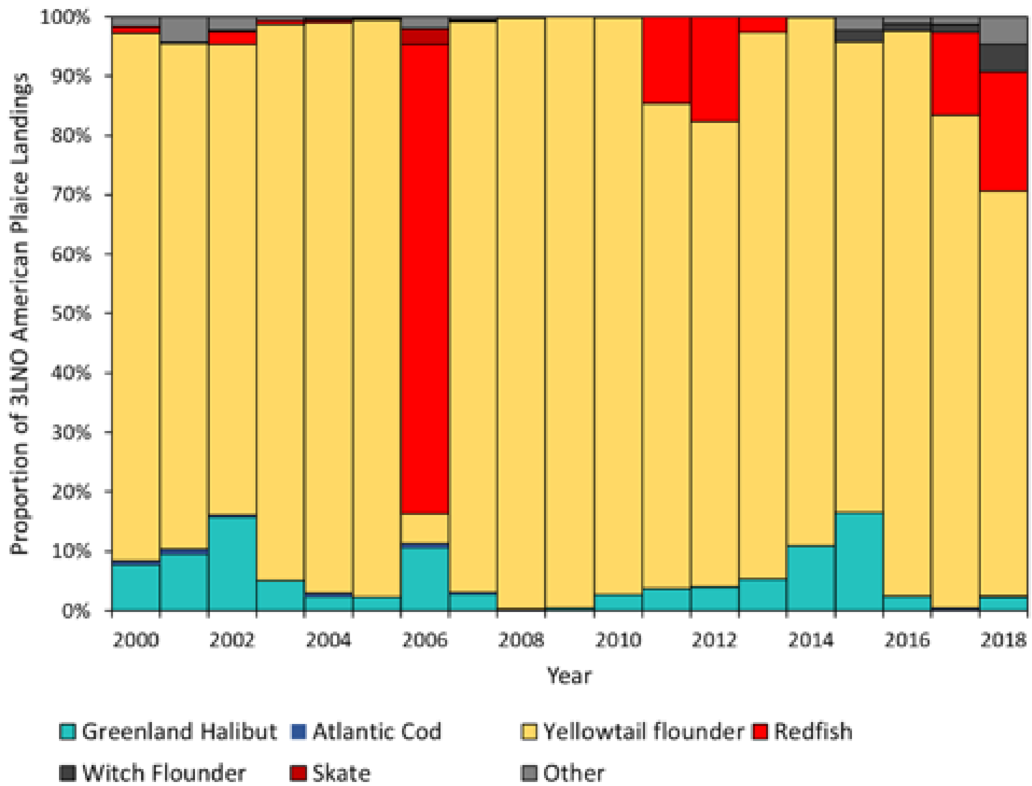


Figure 90: Catch and TAC for Divs. 3LNO. Ndf = no directed fishing.



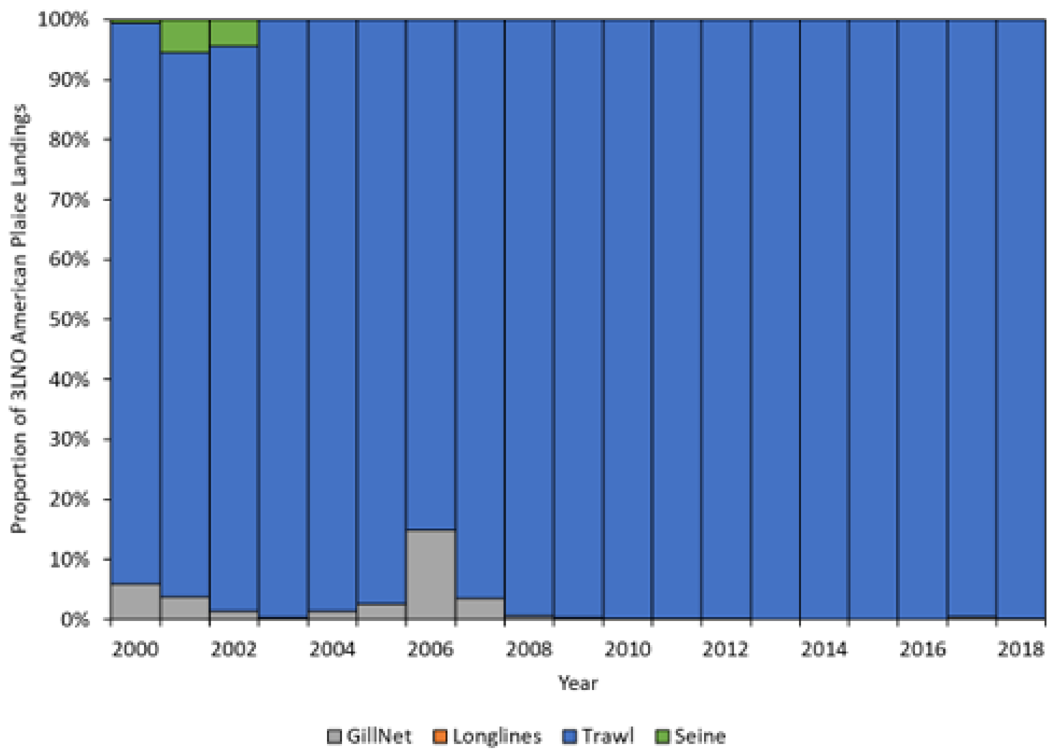


Figure 91: Proportion of Canadian American Plaice landings in NAFO Divs. 3LNO by target species (top) and gear (bottom), 2016–18 values are provisional.

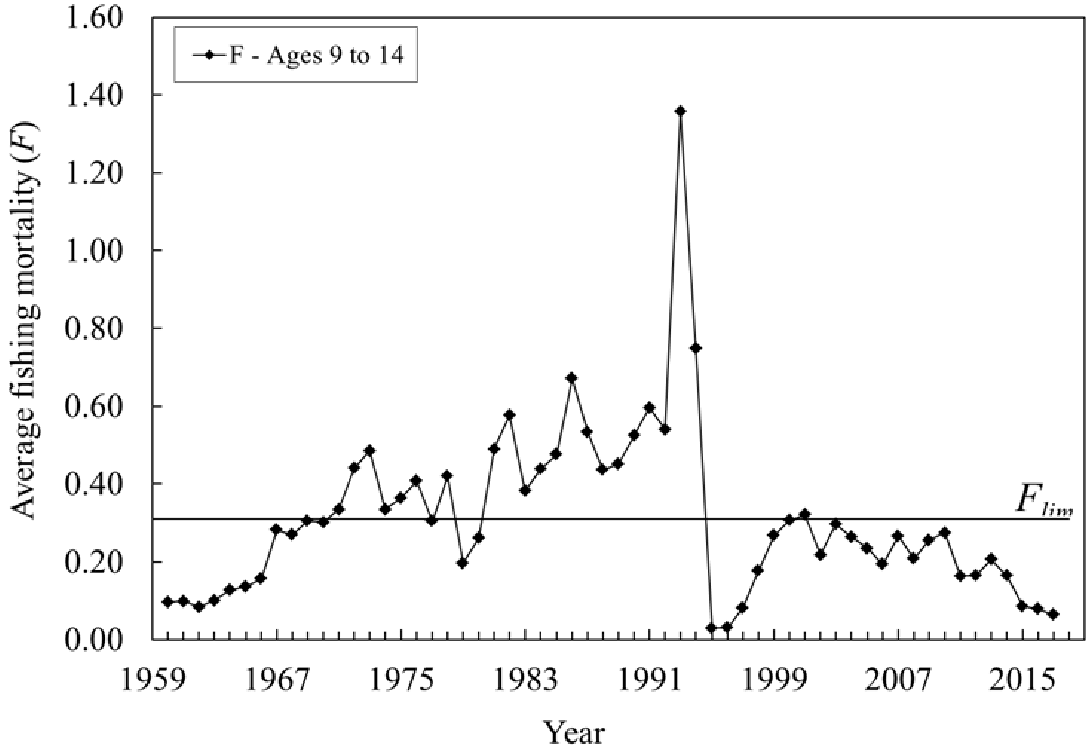


Figure 92: Average fishing mortality (ages 9–14) from the VPA for American Plaice in Divs. 3LNO.

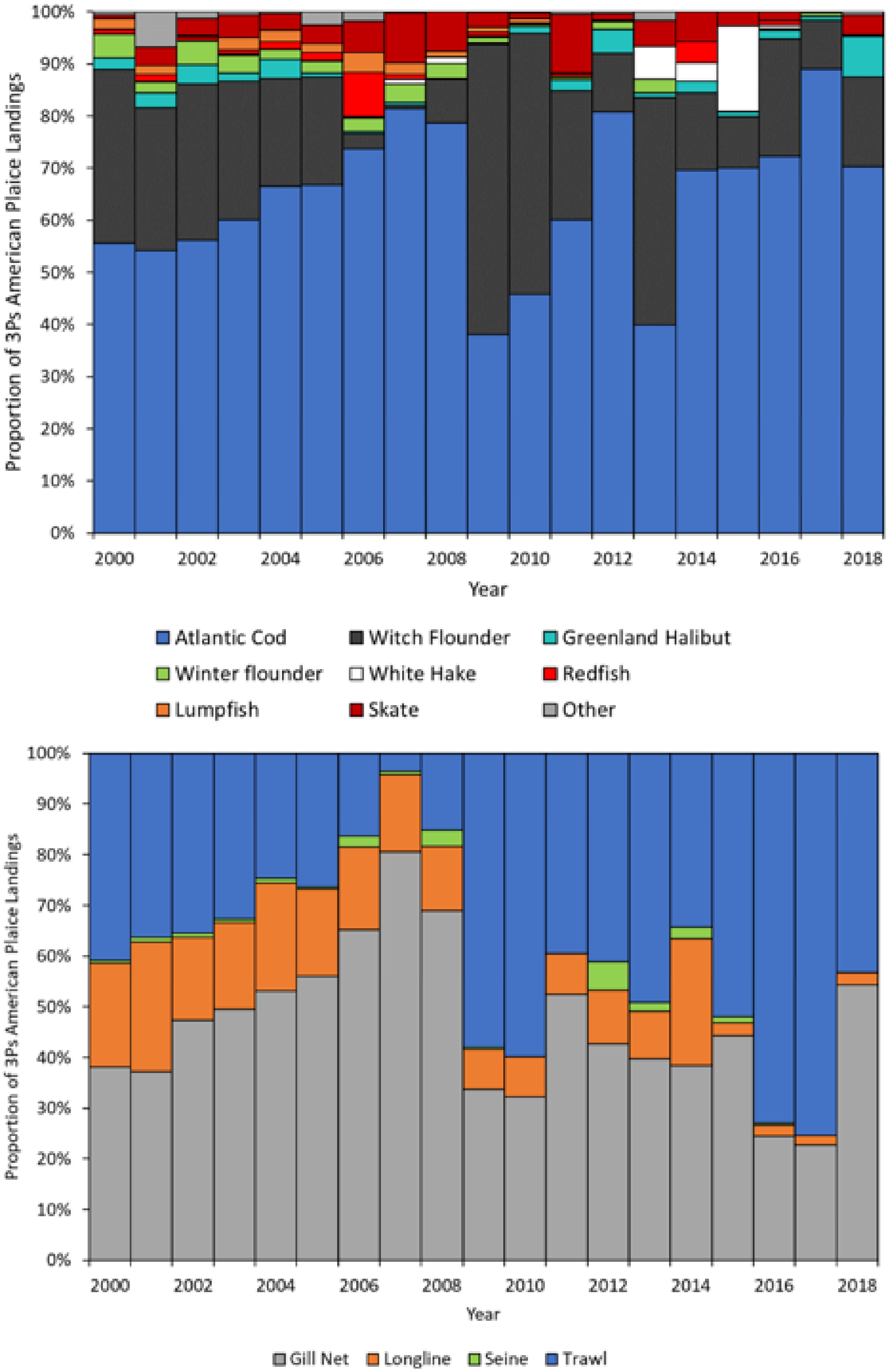


Figure 93: Proportion of Canadian American Plaice landings in Subdiv. 3Ps by target species (top) and gear (bottom), 2016–18 values are provisional.

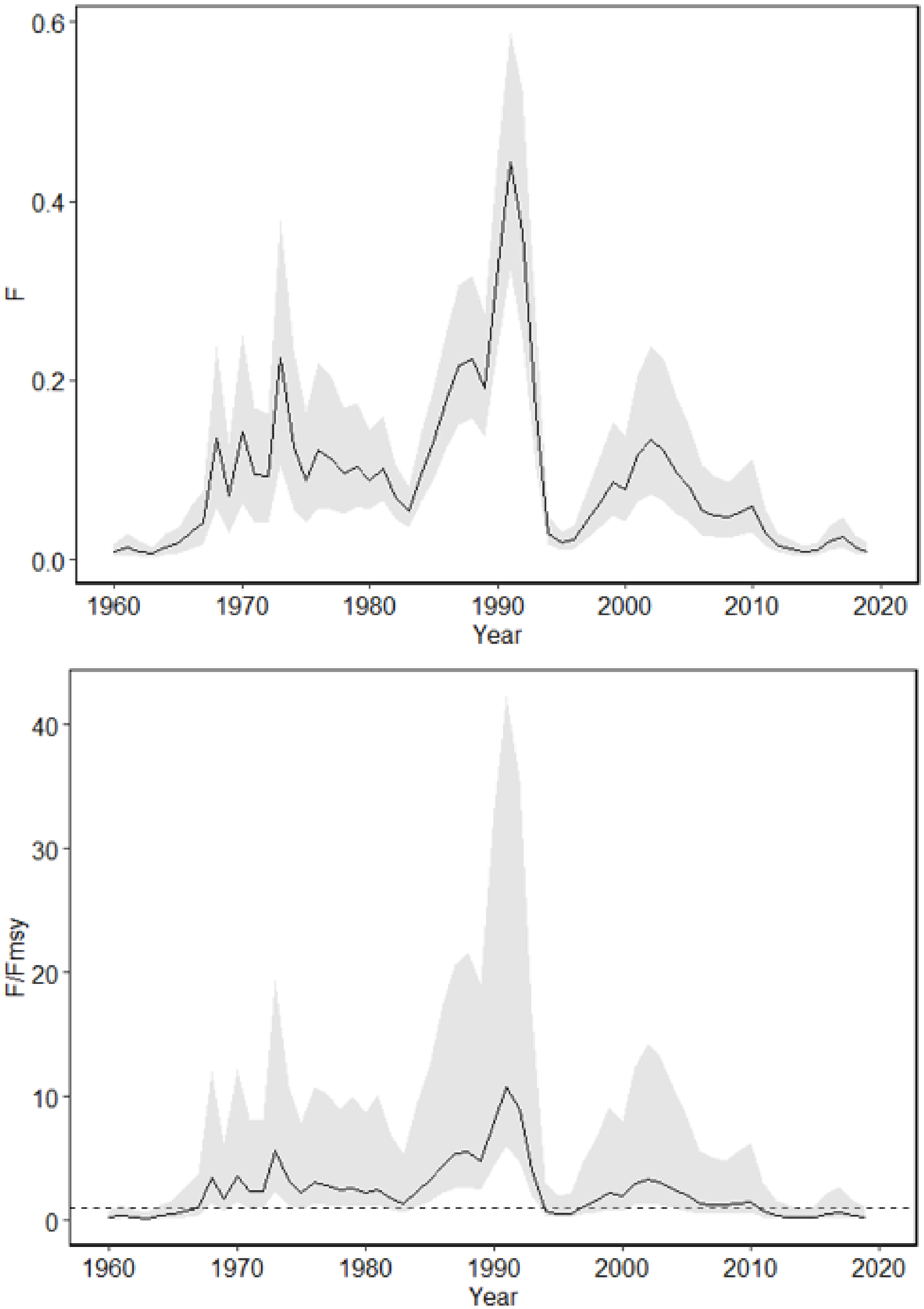


Figure 94: Fishing mortality (F) and F/F_{msy} from 3Ps American Plaice Surplus Production Model. Dashed line indicate F/F_{msy}=1. Shaded areas indicate 95% credible intervals.

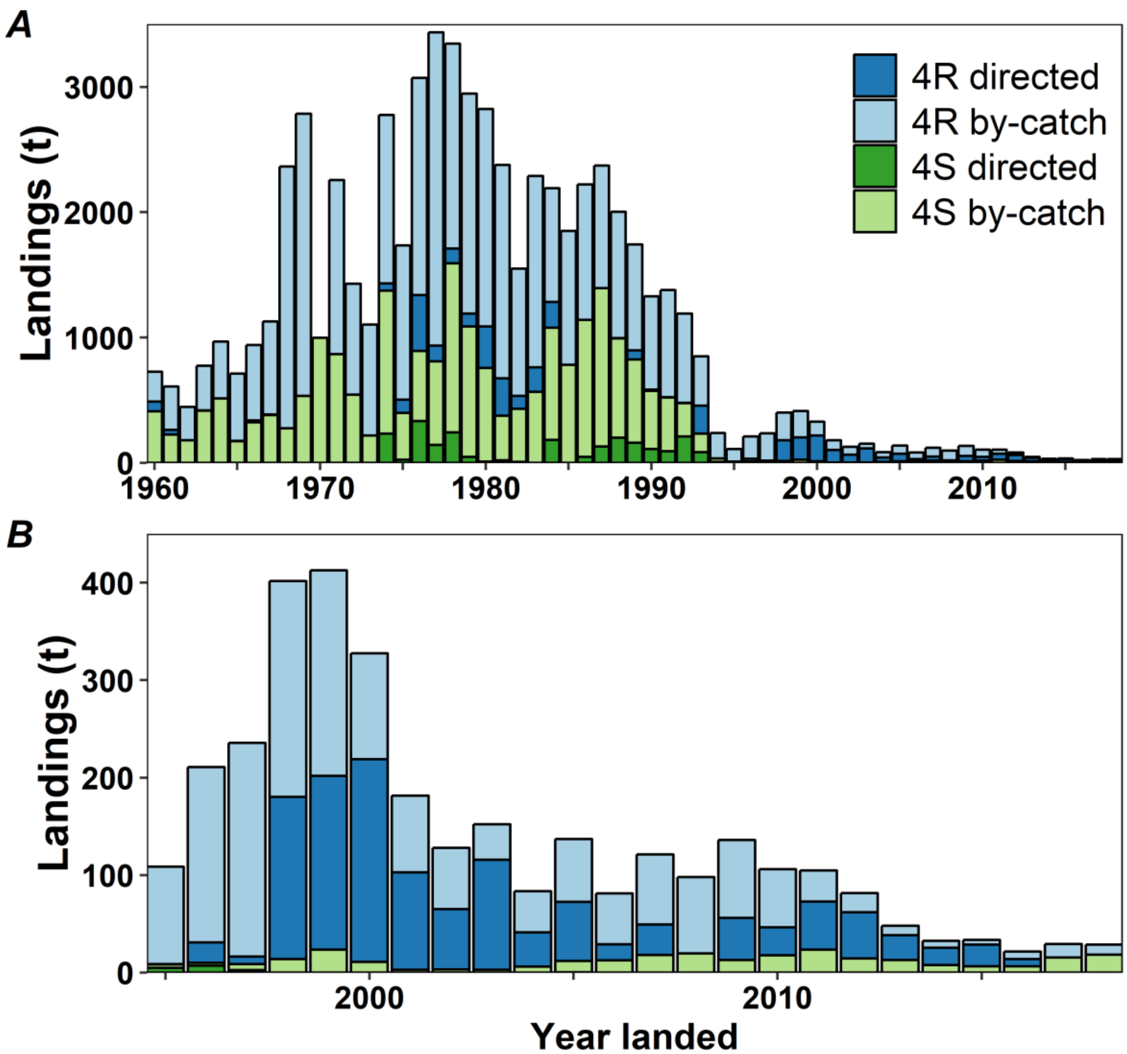


Figure 95: A) Annual reported landings of American Plaice in Divs. 4RS American Plaice directed fishery and as bycatch in other fisheries for the period 1960–2018. The 1995–2018 period is enlarged in B). The 2017 and 2018 data are provisional.

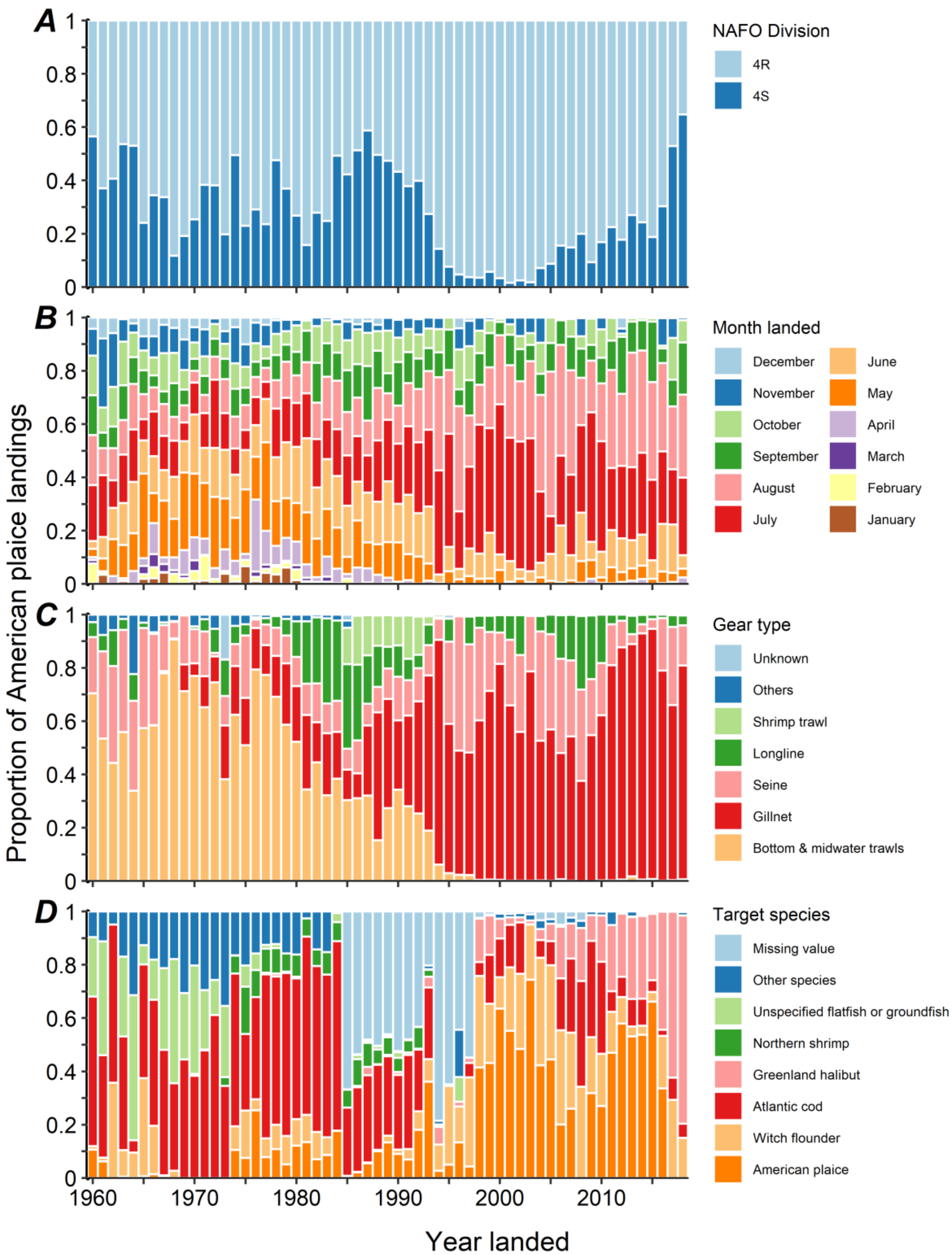


Figure 96: Proportion of annual reported American Plaice landings in Divs. 4RS by A) NAFO Division, B) month, C) type of fishing gear, and D) target species for the period 1960–2018. The 2017 and 2018 data are provisional.

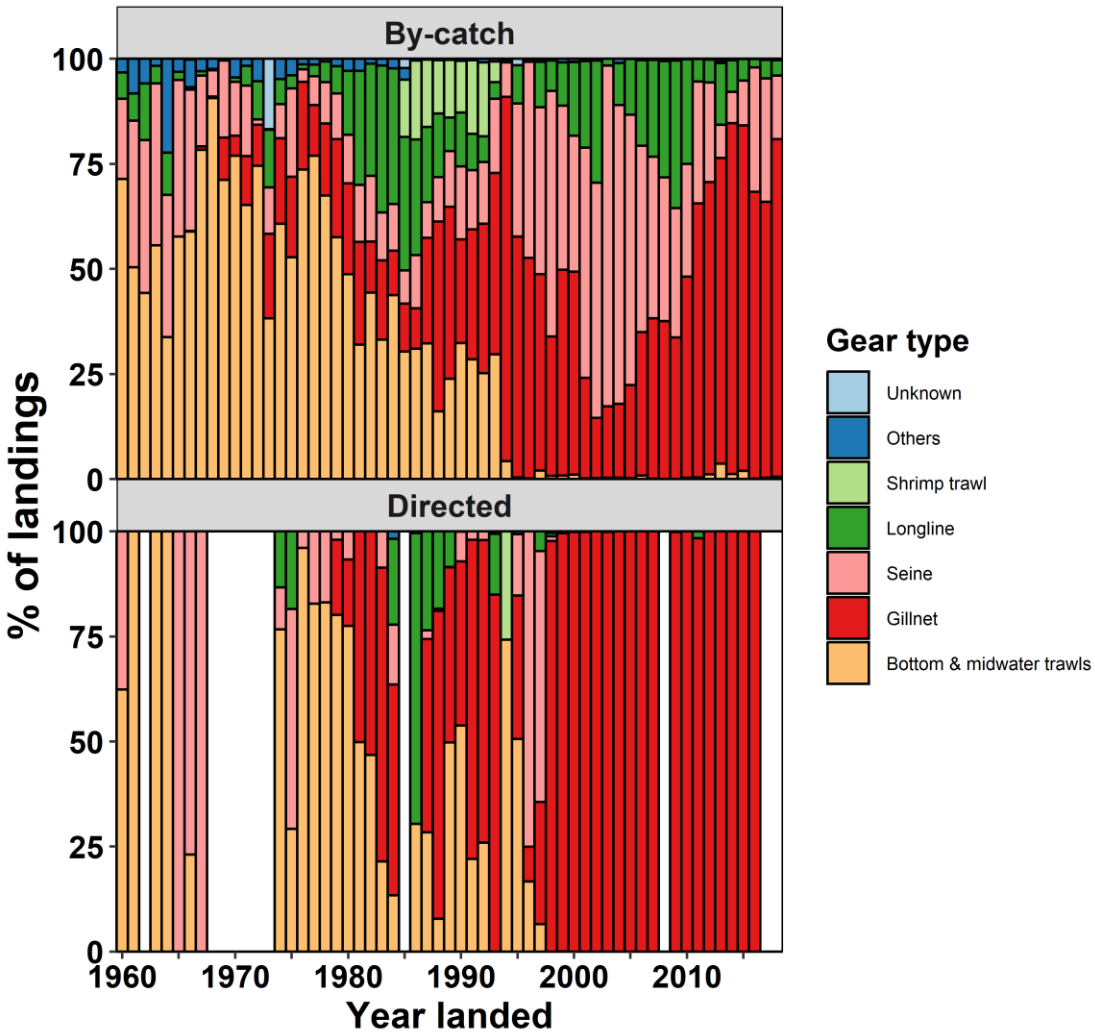


Figure 97: Fishing gear involved in the catch of American Plaice in directed and incidental (bycatch) fisheries in Divs. 4RS for the period 1960–2018. The 2017 and 2018 data are provisional.

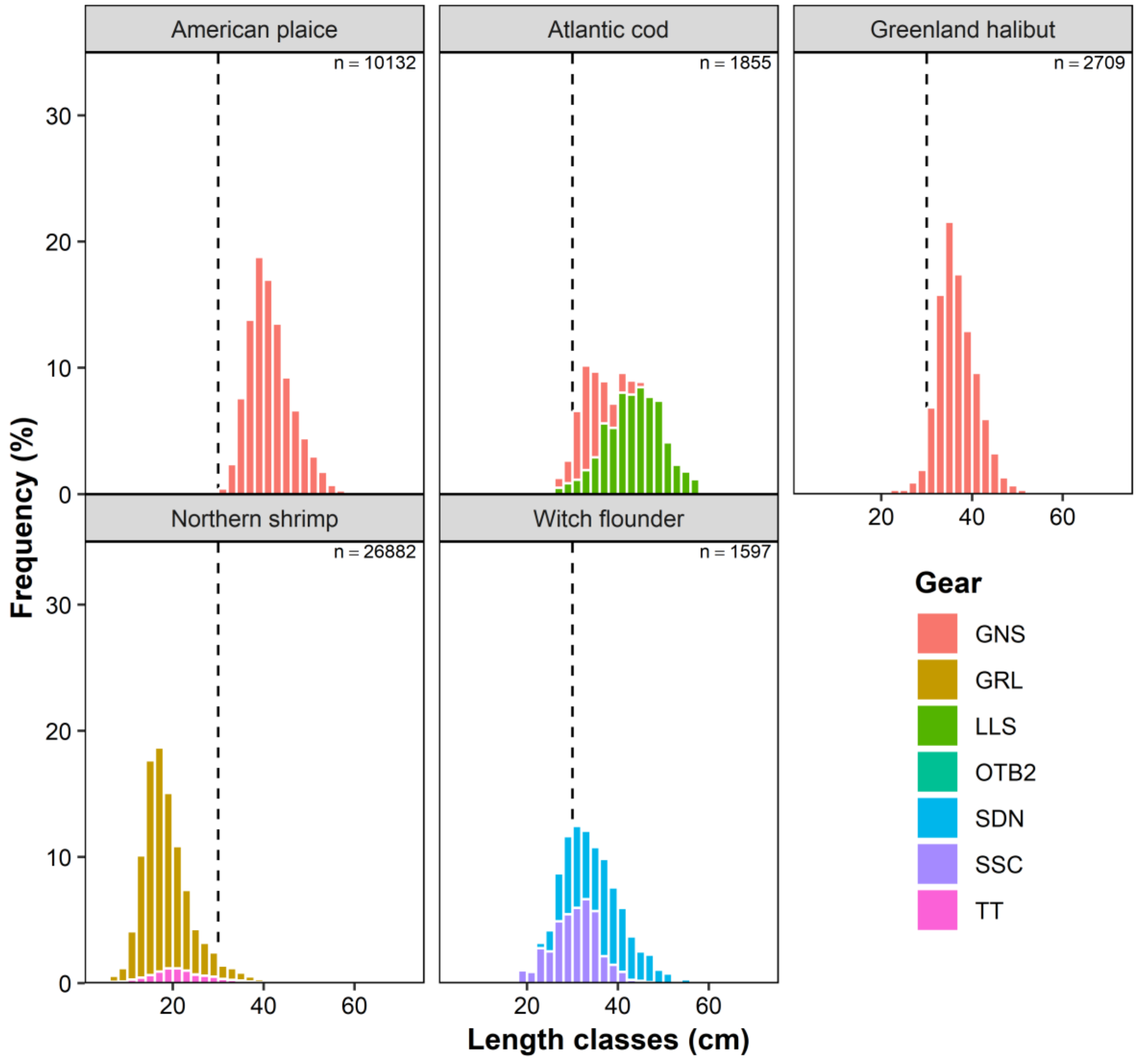


Figure 98: Length frequency distribution of American Plaice measured since 1999 by the 4RS At-Sea Observer program, by targeted species and fishing gear used. The vertical dotted line represents the 30 cm minimum regulatory size for American Plaice. The n value represents the number of American Plaice measured. Gear codes: GNS=gillnets, GRL=shrimp trawl, LLS=longlines, OTB2=bottom trawl (rear panel), SDN=Danish seine, SSC=Scottish seine, TT=twin trawl.

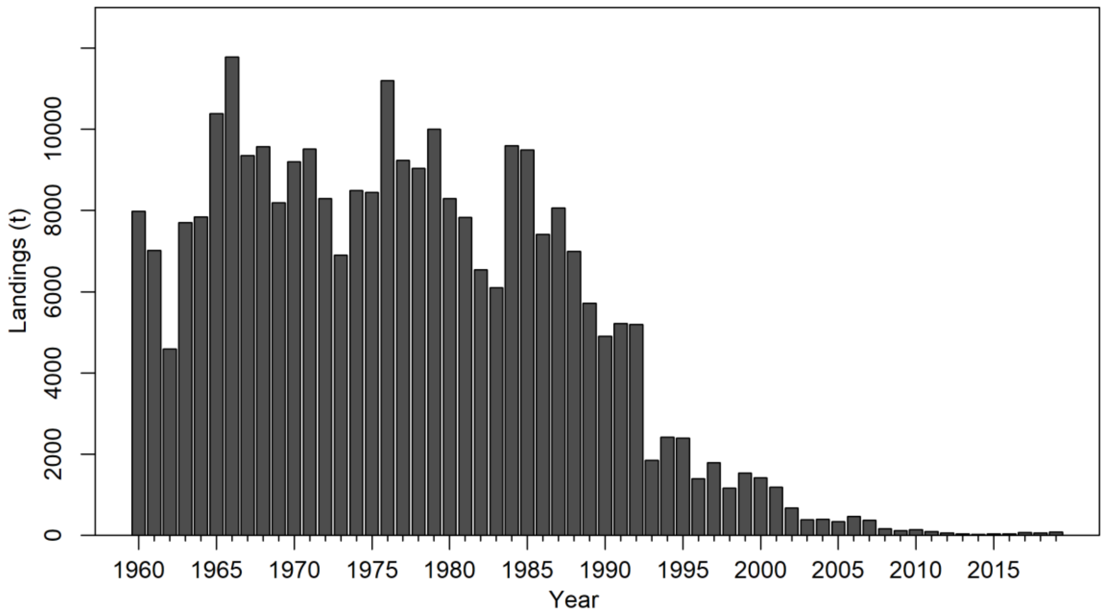


Figure 99: Reported annual landings of 4T American Plaice 1960 to 2019.

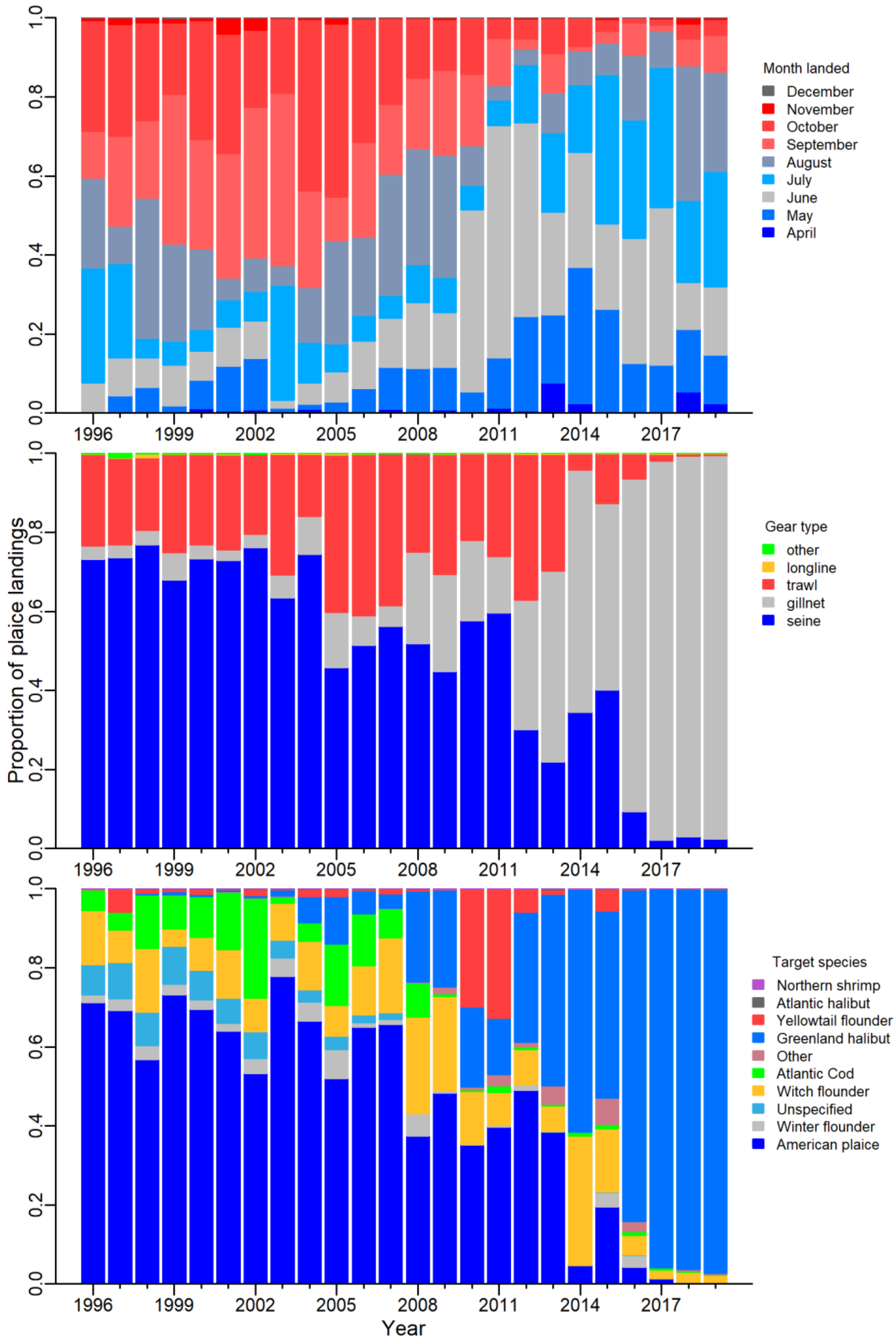


Figure 100: Proportion of annual American Plaice landings by month (first panel), by type of fishing gear (second panel) and by target species (lower panel) from 1996 to 2019.

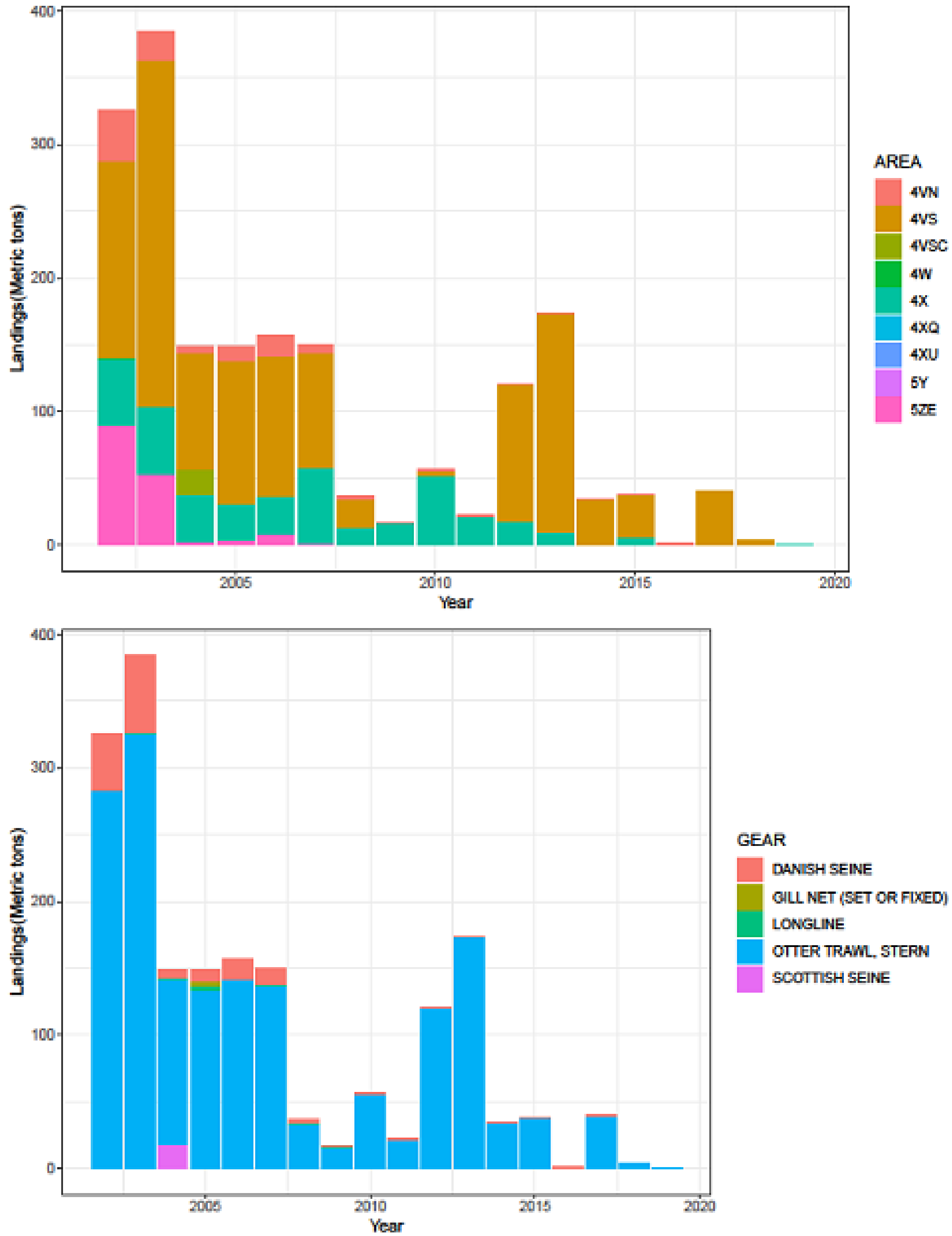
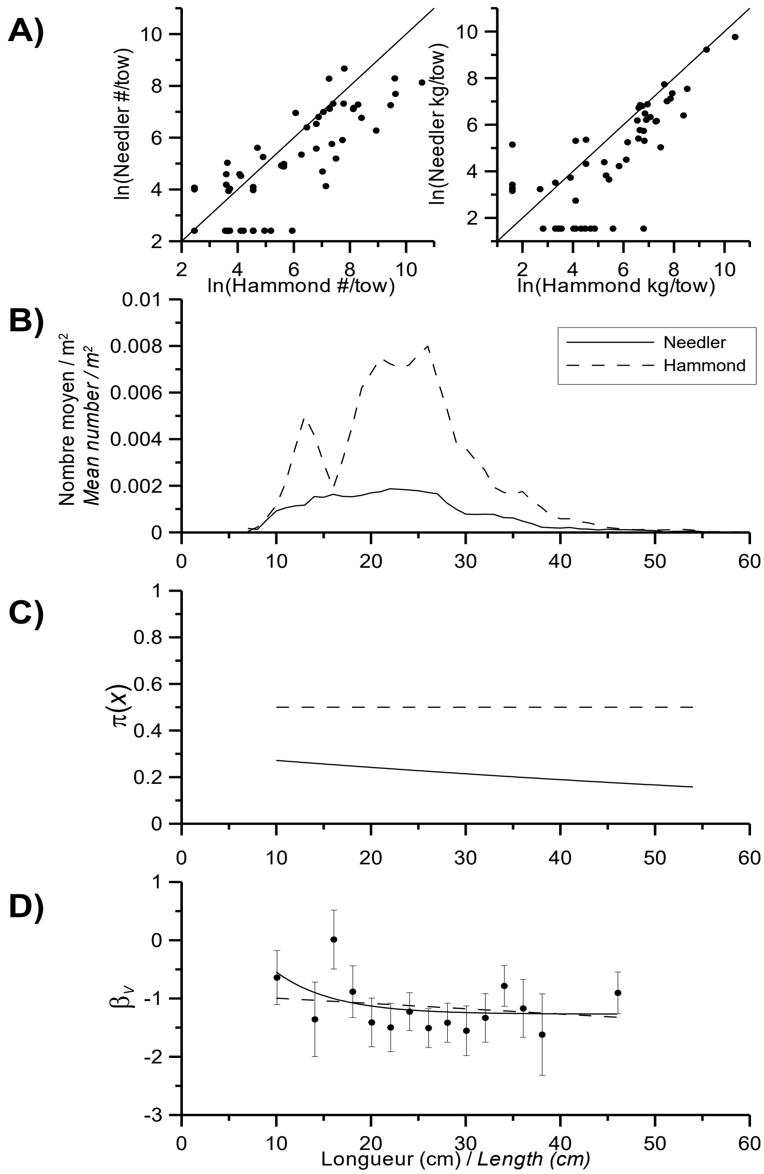


Figure 101: Reported American Plaice landings from 2002–18 in Divs. 4VWX. Upper panel shows landings by NAFO Div./Subdiv. and lower panel shows associated fishing gear.

APPENDIX A. COMPARATIVE FISHING EXPERIMENT CONDUCTED IN 1990 BETWEEN THE LADY HAMMOND-WESTERN IIA AND ALFRED NEEDLER-URI VESSEL TRAWL TANDEM IN THE NORTHERN GULF OF ST. LAWRENCE



Appendix A. Figure 1: A) Catches from the CCGS Alfred Needler in relation to catches from Lady Hammond for a same pair of comparative tows. Catches are expressed on a log_e scale; a constant equals to half of the smallest catch different from zero was added to the catches. Left panel: catch expressed in number per standard tow; Right panel: catch expressed in kg per standard tow. B) Mean number of individuals caught by the CCGS Alfred Needler (full line) and by the Lady Hammond (dotted line) per size class for the comparative tows in total. C) Logistic curve describing the difference in catchability (π) between the CCGS Alfred Needler and the Lady Hammond by size class. The dotted line at π=0.5 means that the catchability is equal between both tandems. D) Difference in catchability between the CCGS Alfred Needler and the Lady Hammond expressed by the vessel term of the logistic model (β_v) with its standard error, per size class. The dotted line represents the linear regression and the full line represents the exponential curve that were used to model the data.

Results of the analyses testing the catchability difference between the Lady Hammond and the CCGS Alfred Needler catches in numbers.

N :Total number of paired tows

β_v : Vessel term in the logit model with its standard error (S.E.)

P : Significance of the probability

b_v : Relative capturability

N	β_v	S.E.	*P*	b_v
59	-1.18705	0.522	0.003	3.28

Results of the analyses testing the effect of the size of the individuals on the difference in catchability between the Lady Hammond and the CCGS Alfred Needler.

N : Total number of paired tows

β_v : Vessel term in the logit model

B_{length} : *Size term with its standard error (S.E.);*

P : Significance of the probability

N	β_v	β_{length}	S.E.	*P*
58	-0.82941	-0.0156	0.0067	0.093