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Western Component Pollock Management Strategy Evaluation – Part 1: Data Inputs

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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.

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ABSTRACT

In 2011, Fisheries and Oceans Canada (DFO) resource managers and the fishing industry decided to manage western component (WC) Pollock using a risk-management approach and embarked on a Management Strategy Evaluation (MSE) process, with the help of government scientists and outside experts (DFO 2011). The MSE was intended to undergo review in 2016, but the inception of an acoustic index resulted in a deferral of that review until 2021. This document comprises the first step in the revision of the 2011 MSE, reviewing all available data sources as they pertain to WC Pollock and forming the basis of the subsequent population modeling work. In addition to revision of data inputs, this document presents a multi-species view of the groundfish fishery and proposes an improved method for estimating bycatch of Pollock-directed effort in the groundfish fishery.

INTRODUCTION

The Pollock stocks in the Maritimes Region are managed by Fisheries and Oceans Canada (DFO) under a two component structure. The eastern component (EC) currently has no analytical assessment, while the western component (WC) underwent a Management Strategy Evaluation (MSE) process in 2011, resulting in a harvest control rule (HCR) used to provide managers with annual total allowable catch (TAC) advice since then. The original MSE was intended to have a five year lifespan, with a revision scheduled for 2016. In addition, 2016 was the start of the development of an acoustic index for Pollock through a collaborative agreement with stakeholder groups, with the expectation that the acoustic index will be integrated into the revised MSE. Due to the need to collect at least five years of data for the new acoustic index, the revision of the 2011 MSE was deferred until 2021. This document represents the data inputs and considerations for the revision of the WC Pollock MSE and comprises the first portion of the MSE revision process.

STOCK STRUCTURE

The stock structure for Pollock in the Maritimes Region is currently comprised of the WC (DFO statistical areas 4Xopqrs and 5Yb and NAFO Sub/subdivision 5Zc) and EC (DFO statistical areas 4Xmn and NAFO Divisions 4VW) (Figure 1). This stock structure was initially defined during the 2004 framework (Neilson et al. 2003a), and built from the five principles used in assessing stock structure presented by Gulland (1983). Specifically, they examined (1) distribution and timing of commercial fisheries, (2) distribution of catches from DFO ecosystem bottom trawl surveys (formerly known as research vessel surveys), (3) ichthyoplankton data, (4) growth rates, (5) meristics and morphometrics, and (6) tagging studies (Neilson et al. 2003a).

Of the examined sources of information, the ichthyoplankton data and the tagging studies are limited to the 1970s and 1980s, with no new information available since then. Consequently, there is no benefit to revisiting those analyses at this time, but the conclusions of the analyses are summarized below.

New data describing the distribution of Pollock from the surveys have been updated to and including 2020, as has the growth analysis from the commercial and survey sampling. Although the distribution and timing of commercial fishery catches can also be updated with most recent data, changes in effort and distribution of a multi-species fishery can be driven by factors other than species abundance (i.e., balancing quota, directed effort, etc.). Consequently, Pollock distribution and abundance trends from the fishery are not considered indicative of the population trends, and are therefore excluded from the discussion of stock structure at this time. Distribution and timing across fisheries is examined in the subsequent Fishery section. Finally, a section incorporating a review of fishermen knowledge of spawning grounds is also included.

ICHTHYOPLANKTON AND TAGGING

In brief, data from ichthyoplankton surveys provided evidence of coordinated timing in reproduction for Pollock across all of 4VWX5Zc, with egg production peaking in January for both EC and WC, while retaining a discontinuity in egg distribution close to the 4X/4W line, supporting the split into EC and WC (Neilson et al. 2003a). In addition, the ichthyoplankton data from two different sources showed opposing results with respect to the continuity of egg distribution across the Fundian Channel, while also confounding the placement of the southernmost boundary along Georges Bank (Neilson et al. 2003a). The latter was later clarified by a notable disparity in the distribution of Pollock between United States of America (US) and Canadian waters as observed by the surveys, which in combination with pragmatic reasons led

to the decision to retain the International Boundary as the southernmost boundary of the stock complex (Neilson et al. 2003a).

The tagging information confirmed that the northern bounds of the EC with 4T and 3Ps remain appropriate, though some movement of strictly juvenile fish exists across the 3Ps boundary (Neilson et al. 2003a). Tagging data also supported the subdivision into the EC and WC within the Maritimes management unit, with limited movement noted between the two (Neilson et al. 2003a). As noted above, with no new data to contribute to the ichthyoplankton or tagging analyses, there is no benefit to revisiting them at this time, and their conclusions are still considered valid.

GROWTH

The inclusion of DFO statistical areas 4Xm and DFO Subdivision 4Xn with the EC was driven primarily by the difference in growth between the EC and WC, with fish in 4Xmn exhibiting slower growth characteristic of the east (Stephenson 2004). The original analysis was based on aged samples from the fishery between 1995 and 2002. The addition of two decades worth of aged samples expands that analysis to the most recent year (1995–2021), showing that 4Xmn continues to exhibit slower growth as compared to the rest of 4X5 (Figure 2). Interestingly, extending the analysis prior to 1995 shows that the divergence is a relatively recent effect, with data from the 1970s and 1980s showing no difference in growth between eastern and western areas (Figure 2). Similar growth across areas is also seen in the 1960s and early 1970s, but that time period is also subject to very low sample sizes (Table 1). The divisions of the time periods used in the figures may seem arbitrary, but are intended to match the divisions applied to the survey data (see Survey section below).

The same analysis was applied to all available summer RV survey data and also shows a divergence in growth starting in the 1985–1995 time period (Figure 3). Similar to the port sampling data, survey data from the 1970s show no difference between the east and the west, supporting the conclusion that the divergence in growth is relatively recent (Figure 3, Figure 4). Inclusion of the data distribution around the mean in Figure 4 shows that there is some overlap in fast and slow growth rates within the 4Xmn area, emphasizing the fact that the true biological division is not a stationary entity like a statistical area line, and may fluctuate slightly from year to year.

A point of note is the temporal trend in growth rates over time for the different areas (Figure 5). The EC fish in 4VW have shown a steady decline in growth rate over time, with mean length at most ages decreasing by 25% between the 1970s and the 2010s (Figure 5). In comparison, fish from the WC have comparable growth throughout the same time period, though a slight decrease in the most recent period (2011–2021) is also becoming apparent (Figure 5). The focus of the current process is strictly on WC, but the authors still felt that flagging the temporal change in the EC was important, especially as the stock is not assessed regularly.

DISTRIBUTION

The spatial distribution of catches from summer RV surveys does not show an evident break in Pollock distribution within 4X, with a uniform distribution stretching from the WC into 4W (Figure 6 through Figure 7). Although it does not directly support the division into EC and WC, it does show the lack of any physical barriers to Pollock along 4X and 4W. In addition, the most recent data which includes coverage of Eastern Georges Bank (EGB) demonstrates that the deep waters of the Fundian Channel do not constitute a natural boundary to the distribution of Pollock between 4X and EGB (Figure 7).

LOCAL KNOWLEDGE OF SPAWNING GROUNDS

There is one published report that addresses local knowledge of WC Pollock spawning grounds, and it focuses on the Bay of Fundy specifically (Graham et al. 2002). Graham et al. (2002) interviewed 37 fishermen and identified 28 areas associated with Pollock spawning, including Passamaquoddy Bay, a small segment between Deer Island and Campobello Island, the Wolves, Grand Manan Bank, Northeast Bank, Southwest Bank, Yankee Bank, the Quaco Ledges near St. Martins, and The Bluffs and Northwest Ledge near Long Island and Briar Island (Graham et al. 2002). Specific locations on Grand Manan Bank include Southern Head, Southern Reef, The Bulkhead, Old Proprietors Ledge, and Gannet Rock (Graham et al. 2002). At the time of publication, it was unclear if Passamaquoddy Bay, the Quaco Ledges, and Southern Head, Grand Manan were active spawning grounds, as there had been no Pollock fishery in those areas since the 1940s (Graham et al. 2002). In general, the fall months (September, October, and November) were most associated with Pollock spawning, but developing Pollock occurred in August and early September off the Bulkhead and Old Proprietors Ledge, at the mouth of Passamaquoddy Bay, and in the Yankee Bank area (Graham et al. 2002).

There are two studies that Graham et al. (2002) cite that are relevant but unavailable for this review. The first is an unpublished study by Benham and Trippel (unpubl.), which used interviews with fishermen to identify groundfish spawning and nursery areas in the Bay of Fundy, Gulf of Maine, and Eastern Scotian Shelf (Benham and Trippel, unpubl., as cited in Graham et al. 2002). The second is a published study by Coon (1999), who provided an overview of some Bay of Fundy fisheries (Coon 1999, as cited in Graham et al. 2002). Copies of neither report are locatable. However, Graham et al. (2002) state that Pollock spawning areas in the Bay of Fundy identified in Benham and Trippel (unpubl.) and Coon (1999) which differed from those identified in their own study include Trinity Ledge, Lurcher Shoal, Flaggs Bank, and Saint Mary's Bay.

In general, both published and anecdotal fishermen accounts are consistent with ichthyoplankton conclusions that describe spawning grounds distributed broadly across the Bay of Fundy and Southwest Nova Scotia regions, with spawning peaking in the late fall and early winter. Fishermen accounts have the added benefit of being able to pin-point spawning areas on a finer spatial scale than ichthyoplankton data, as well as providing a source of information sensitive to changes over time. Fishermen's knowledge can be used to help focus research and also acts as an early warning system for detecting changes in the ecosystem.

SUMMARY OF STOCK STRUCTURE AND OTHER CONSIDERATIONS

In general, there is continued support for a spatial separation of Pollock into WC and EC from a stock assessment perspective, driven primarily by the persistent growth difference between the two areas. Given that several other groundfish species are also experiencing poor growth along the eastern Scotian Shelf, it is currently unclear whether the difference in growth constitutes a delineation of two genetically diverse stock components, or if this is an environmentally driven effect. Genetic analysis of EC and WC Pollock could disentangle these two hypotheses, though a cost-benefit analysis of such a study would need to be considered first.

Given that the mismatch between the DFO Science (4Xopqrs+5Yb+5Zc) and the DFO Resource Management (4X5YbZc) spatial areas for WC Pollock is expected to persist into the future, some consideration needs to be given to the treatment of areas with slow growing fish (4Xmn) which fall under the WC management unit (4X5YbZc). Although the current scientific process is intended to deal with WC Pollock only, the perturbing trend seen in EC Pollock growth in recent years necessitates that fishery removals from 4Xmn should no longer be left as

an invariable addition to the WC TAC (4Xopqrs+5Yb+5Zc). It is currently unclear what impact continuing to roll over 700 mt of EC fish every year will have on the EC stock, and the impact has not been evaluated at this time.

FISHERY

Pollock are captured as part of a multi-species groundfish fishery operating in 4VWX5Y and 5Z (EGB). Despite the multi-species nature of this fishery, both the scientific assessment and the provision of TAC advice for each of the major harvested species (i.e., Haddock, Halibut, Cod, Pollock, Redfish, and Silver Hake) continue to occur independently of the others, with the fisheries often described as a species-specific entity (e.g., the Haddock fishery). Looking at a multi-species fishery through a single-fishery lens can misconstrue some of the trends and completely overlook others, adding to the already difficult task of implementing single-species advice in a multi-species management structure (e.g., Vinther et al. 2004, Link 2010). This disparity has been discussed and studied at length, with multiple attempts to bridge it made over the decades (e.g., Mercer 1982, Hollowed et al. 2000, Trijoulet et al. 2019); however, several substantial hurdles remain before a multi-species assessment can be proposed and operationalized for the Maritimes groundfish fishery. This document does not pretend to tackle those hurdles or take on the monumental task of proposing a multi-species assessment approach, but it does discuss the fishery trends specific to Pollock in the context of a multi-species groundfish fishery.

The scientific and management units of the major harvested groundfish stocks cover a range of geographical areas, from relatively small (e.g., statistical areas 5Zjm for EGB Cod) to very broad (e.g., NAFO 3NOPs4VWX5Zc for Halibut). The intent of this document is to discuss trends in the WC Pollock assessment unit (NAFO 4Xopqrs5YZ), with some consideration given to the additional areas included in the WC Pollock management unit (DFO statistical units 4Xmn). However, some discussion describes trends in the data across the larger Maritimes area (4VWX5YZ) where interesting or pertinent trends exist.

COMMERCIAL FISHERY MANAGEMENT STRUCTURE

The intricacies of the management structure of the Maritimes Region groundfish fishery are captured in detail in the Integrated Fisheries Management Plan (IFMP), with a very general overview of the points pertinent to this discussion summarized here (DFO 2018). In general, there is a directed fishery for Pollock in 4X5, and licence holders targeting other groundfish stocks (i.e., Redfish, Silver Hake, Haddock, and Halibut) must retain Pollock as bycatch. The fishery is subdivided into multiple fleets based on vessel size and gear type, with mobile (trawl) and fixed (handline, longline, gillnet) constituting the major gear types. Fishermen are able to target multiple species and modify gear configuration as needed, in order to maximize the species-specific quota allocations available to them at a given time. Retention of all major groundfish species captured in this mixed species fishery is mandatory, regardless of whether they were directed for or caught as incidental bycatch. In addition, there are various spatial and temporal closures that have been put in place over the years, both introduced by the department (mandatory) and introduced by stakeholder groups (voluntary). In addition to the introduction of various management measures, restructuring of large-scale operators in the groundfish fishery (i.e., National Sea Products Ltd.) may have both short and long term impacts on the way the fishery is carried out, reinforcing the need to expand the scope beyond single-species science when investigating trends in the groundfish fishery. Some of the major groundfish species (i.e., Haddock, Redfish, Silver Hake) are assessed through a traditional stock assessment process (DFO 2019a, DFO 2019b, DFO 2018b), with Pollock and Halibut assessed through an MSE process (DFO 2011, DFO 2024). This research document

summarizes the data revision component of the Pollock MSE review. The Pollock MSE was initiated in 2010 and implemented in 2011. The HCR coming out of the 2011 MSE process provided annual advice for the scientific assessment unit, however given the misalignment of the scientific assessment unit (4Xopqrs5) and the management unit (4X5), an additional 700 mt has been added annually to provide the total TAC for the management unit. Consequently, 4Xmn is treated as a separate area throughout this paper, to help facilitate the discussion about ways of dealing with the science and management unit mismatches in subsequent components of the MSE revision.

COMMERCIAL FISHERY INFORMATION

Multi-species Removals

The conglomeration of commercial landings data in the Maritimes into a single database (MARFIS) in the early 2000s, makes it relatively easy to look at the total species removals from 4VWX5YZ over the last two decades (Figure 8). Prior to 2002, however, total removals of major groundfish species from 4VWX5YZ are scattered through various databases, and included in assessments covering a range of spatial regions. Although the amalgamation of historic groundfish fishery removals across species, NAFO Divisions, and gear types is technically possible, the benefit of the work to the current document was considered too small given the amount of time it would involve. Consequently, although some Pollock trends are noted back to the 1980s, the multi-species discussion is limited to post 2002.

Figure 8 provides a wide-scale snapshot of groundfish catch species composition across the Maritimes region. Starting in the north and moving south along the shelf, NAFO Division 4V is dominated by Redfish catch, with Halibut becoming increasingly important in recent years. Groundfish removals from 4W are dominated by the Silver Hake fishery, coming mainly from the Emerald Basin, with some Halibut and Redfish removals increasing in prominence over the last decade. Unlike the other NAFO Divisions, removals of groundfish from 4X5Y (excluding 4Xmn) are very diverse, with Redfish, Cod, Haddock, and Pollock contributing equally to the catch throughout the 2000s. More recently, catches of Cod declined as TAC decreased, with the institution of Cod as a bycatch only species in 2018 resulting in very small amounts caught in recent years (DFO 2021a). The removals of Pollock from 4X5Y have also decreased in recent years, though not as drastically as Cod. Similar to other NAFO Divisions, the contribution of Halibut to the overall catch in 4X5Y has increased in recent years. The diversity of species catch in 4X5Y carries over into the 4Xmn statistical areas, also capturing the Silver Hake removals from LaHave Basin (DFO 2018b). The 5Z (EGB) groundfish catches are driven primarily by Haddock, Cod and Pollock, with some minor emergence of Redfish in recent years. It should also be noted that the overall trends described in Figure 8 are driven primarily by mobile gear, with fixed gear removals representing a small proportion in each NAFO Division (Figure 9). The fixed gear component, however, is the primary driver of the increase in Halibut removals across all NAFO Divisions, becoming a Halibut-dominated fishery across all NAFO Divisions except 5Z (Figure 10).

Within the WC Pollock assessment unit (4Xopqrs5YZ), the bulk of the recent groundfish catch using mobile gear comes from eastern Georges Bank (5Z), with 4Xpq making up the rest (Figure 11). Removals of Pollock tend to be associated with higher removals of Redfish and Haddock (4Xp, 4Xq), or only Haddock (5Z), indicating that in addition to directed Pollock effort, there could be substantial Pollock bycatch in Haddock and Redfish directed fishing. This effect is particularly evident in 4Xmn, which has had relatively low groundfish removals in recent years, but showed an unexpected increase in both Haddock and Pollock removals in 4Xn in 2020 (Figure 11) and 2021 (based on preliminary data). Given that the survey abundance has

remained relatively unchanged in 4Xmn over the past few years, this unexpected increase in Pollock catch is likely a consequence of increased Haddock-directed activity in the area.

Groundfish removals by fixed gear throughout the 2000s came primarily from NAFO Division 5Z (EGB); however, there was a marked decline in removals between 2011 and 2013, specifically in the removals of Haddock from EGB (Figure 12). In addition to an overall reduction in removals, the fixed gear species composition shows a very clear transition from a Cod/Haddock/Pollock combination to an almost exclusively Halibut catch across 4X (Figure 13). Directed Halibut fishing with fixed gear has very little Pollock bycatch, so removals of Pollock decreased across all of 4X, increasing the proportion of Pollock catch coming from 5Z (Figure 14). Participants of several recent Scotia Fundy Groundfish Advisory Committee (SFGAC) meetings have pointed to this trend when emphasizing the increasing importance of EGB as a Pollock fishing ground for fixed gear fleets. The other notable trend for fixed gear is the increasing proportion of Pollock records which are attributed to 4XU (unidentified area within 4X). Currently, records identified as 4XU are considered part of the WC assessment. In 2020, Pollock landings attributed to 4XU accounted for 121 mt, or 30% of the annual total for fixed gear landings (Figure 14). Although the inability to accurately split 4XU records into WC and EC is not expected to significantly impact the WC assessment, efforts should be made to address this issue moving forward.

Pollock Removals

Pollock catches from NAFO 4VWX5 were around 40,000 mt throughout the 1980s, with reported foreign catches making up a relatively small portion of that (Figure 15). Following the collapse of the Atlantic Cod stocks and imposition of the moratorium on 4VW Cod, strict TAC reductions resulted in a substantial decrease in Pollock catch, particularly from the EC (Figure 16). In recent years, removals from the EC account for 1–7% of the total Pollock catch from the Maritime Region (4VWX5). Since the mid 1990s, removals of Pollock from NAFO Divisions 4VWX by boats landing in other regions (i.e., Gulf, Quebec and Newfoundland) are generally limited to only NAFO Subdivisions 4Vn/4Vs, and are therefore not included in the WC assessment.

During the 2011 MSE, the Pollock commercial catch series was constructed beginning in 1982, citing poor sampling and inability to separate catches prior to the establishment of the Hague Line as the reason for the cut-off (Porter and Docherty 2011). During subsequent discussions of stock productivity, it was recommended that the catch time series be extended as far back as possible in hopes of providing a measure of stock productivity prior to 1982 (Porter and Docherty 2011). Although the sampling limitation could not be remedied, the total catch time series has been extended to 1960 in an attempt to address this question (Figure 15). Uncertainty with respect to Hague Line implementation is captured by showing catches from 1960-1979 as likely upper and lower bounds. Catches were retrieved from spatially aggregated ICNAF records with lower bound defined as catches reported as ‘Scotian Shelf’, while upper bound includes ‘Scotian Shelf’, ‘Georges Bank’ and ‘Gulf of Maine’ (Clark et al. 1980).

Trends in Pollock catches in NAFO 4X5 tend to be driven by mobile gear, with fixed gear only accounting for 15–25% of catches since 2000 (Figure 17). Although in the 1980s, removals of Pollock by all gears were broadly distributed across statistical areas, in recent years Pollock have been taken almost exclusively from statistical areas 4Xp, 4Xq and NAFO Division 5Z (Figure 18). This spatial shift in Pollock catches is consistent with total groundfish catch trends observed since 2000, and also coincides with focus on Haddock in 4Xpq. In addition, the shift in the distribution of Pollock catches is consistent with the population distribution shifts observed in the summer RV survey, with most of the population aggregating in the deeper waters around the mouth of the Bay of Fundy, along the Fundian Channel and EGB (Figure 7). The surprising

consistency between overall fishery and survey trends may provide one avenue for simulating the missing EGB survey biomass index for the earlier time period, although it would be subject to several major assumptions (see Survey section).

One important note about Pollock catches in 4X5 relates specifically to the removals from 4Xmn, which contain mostly slow-growing EC fish (see Stock Structure section). Pollock from 4Xmn used to constitute a large portion of the overall catches throughout the 1980s and early 1990s, but decreased substantially following the sweeping management changes in the mid 1990s (Figure 18). Removals throughout the 2000s continued to come predominantly from 4Xn, though at a substantially lower level. With the inception of the 2011 MSE, the fleets were permitted to catch 4Xmn TAC anywhere in the WC management unit, resulting in all fishing effort reallocated outside of 4Xmn by 2013 (Figure 18). This re-distribution of effort lowers the fishing pressure on the slow-growing EC fish in 4Xmn, but may inadvertently increase fishing pressure above the intended levels for WC Pollock if total catch approaches the TAC for the management unit, which has only happened once since 2013 (Figure 16). Note that the HCR advice for the WC Pollock assessment unit has been exceeded twice (DFO 2021b).

Finally, catches of Pollock are widely distributed across the entire WC assessment unit, with mobile gear being prevalent in the Bay of Fundy, Gulf of Maine basins, and Georges Bank. Fixed gear is most active in the Gulf of Maine basins and around the Scotian Shelf (Figure 19). Additional patterns emerge when the data are split into directed and bycatch Pollock effort, following the definition of directed effort outlined in the Bycatch section. Catches by mobile gear in the Bay of Fundy have become almost exclusively bycatch in recent years, with directed effort concentrated along the northern peak of Georges Bank and around Jordan, Crowell and Georges basins (Figure 19). Similarly, catches by fixed gear have become almost all bycatch along the Scotian Shelf in recent years, with all directed effort concentrated in the basins of the Gulf of Maine as well (Figure 19).

Fleet Composition

In the past, the size composition of the vessels within the groundfish fishery has been discussed, as it impacts fishery catch per unit effort (CPUE, Neilson et al. 2003b, Stephenson 2004). Although CPUE calculations are not recommended for use in Pollock due to several unsurmountable difficulties with identification of directed trips and standardization, some observations are recorded here for interest. Note that due to a low number of vessels in some tonnage classes (TC) in recent years, no figures or tables can be published in support of the discussion without written permission from the licence holders due to guidelines related to the *Privacy Act*. The breakdown to tonnage classes and associated tonnage is presented in Table 2.

In general, there appears to be two trends with regards to the vessel size composition of the groundfish fleet in 4X5 from 2001 until now: an increase in the uniformity of the vessel sizes for each gear type, as well as a directional trend in size for each gear type. For fixed gear, a growing proportion of the groundfish removals are made by TC1 vessels in recent years, accounting for 65% of removals in 2001 and almost 90% in 2020. The contribution of TC2 vessels has, in turn, decreased from approximately 25% of the catch prior to 2014, down to < 10% since then. For mobile gear, the bulk of the 4X5 groundfish catch (65–75%) has been landed by TC3 vessels throughout the examined time period, with TC1 boats making a noticeably smaller contribution to the catch in recent years. In addition, TC 5+ vessels were absent from the groundfish fishery for the bulk of the time series but are starting to fish again on Georges Bank.

Catch-, Length- and Weight-at-Age

The commercial catch-at-age (CAA) for WC Pollock currently begins in 1982, with sampling limitations generally precluding the use of the information prior to 1982. Given that generating the commercial CAA for a fishery requires sufficient spatial and temporal coverage of the catch, the Pollock removals appear to be covering all spatial and gear components of the fishery since then.

The bulk of the fishery catch has come from ages 4–6 throughout the time series, with age 7 fish becoming periodically more prominent as well (Figure 20). Although the abundance of older fish in the catch was higher prior to the mid 1990s, their prevalence in the catch since then has remained stable and even increased in recent years. The presence of fish above age 10 is intermittent, so a plus group in ages may be appropriate depending on the nature of the model applied. Finally, although the commercial CAA does not appear to track cohorts well, some general cohort progression trends can be seen that mirror the group cohort effect seen in the DFO survey CAA (see SURVEY – Ecosystem Survey – Catch at Age section).

The length-at-age (LAA) data for the commercial fishery is available from two data sources: port sampling and observers. Both of these data sets have already been presented in the Stock Structure section but have been restructured as a time series for this section. The LAA is calculated for each age, with fish aged 10 and older grouped together due to intermittent presence (Figure 21). When examined separately for 4Xopqrs5 and 5Z, the trends are generally consistent across ages (Figure 22). The trends in LAA tend to differ by age group, with younger fish (ages 4–5) experiencing a decline in growth in the mid 1990s, followed by a period of relatively stable growth throughout the 2000s. Older fish (ages 6+), on the other hand, have very similar growth between the two time periods. For all ages, the most recent time period shows a relatively drastic decrease in growth; a trend mirrored in the ecosystem surveys data.

Selectivity

Fishery selectivity was estimated across all available ages (1–15+). There is no empirical evidence which would justify a dome-shaped selectivity, so fishery selectivity is assumed to be flat topped. When calculated across years, the selectivity curve does not show any temporal shifts (Figure 23), with > 95% selectivity occurring at age 5 across many years, except for a few occurrences, particularly in recent years (Figure 24). This departure can be attributed to cohort effect, as discussed in the section on Survey Selectivity, and calculating selectivity across cohorts effectively eliminates the effect (Figure 25) and can be used to create a single selectivity curve for the time series (Figure 26).

Bycatch

The fundamental structure of the mixed species groundfish fishery described above makes it difficult to separate catch for a given species into directed effort and bycatch. Any attempt to do so requires an assumption of a percent weight cut-off, a spatial restriction, or certain gear configuration to identify directed trips in the commercial landings database. In addition, as the management of the fishery evolves over time, assumptions made to help identify directed effort in recent years may be invalid when applied to trips from ten years ago. In any proposed assessment model, all removals of Pollock in the groundfish fishery will be treated equally, but this section does attempt to quantify the dynamics between bycatch and directed removals of Pollock in the groundfish fishery, as well as quantify the bycatch of other species during Pollock-directed fishing effort.

Defining directed effort

Over the years, various methods have been developed for designating species-directed fishing in the groundfish fishery. For some species, gear configuration can be used to select out directed activity (e.g., Silver Hake directed mobile gear uses 55–65 mm mesh; Halibut directed longline fishing uses hook sizes 14, 15, and 16, N. denHeyer, pers. comm.; Unit III Redfish mobile gear uses 110–115 mm mesh, DFO 2021c). For others, such as Cod, Haddock, and Pollock, gear configuration is insufficient to isolate directed effort, and the predominance of the species in the catch has been used instead (e.g., > 50% Haddock in the catch indicates Haddock-directed effort). In the current document, gear configuration was used to identify sets with a valid gear configuration value. For Pollock-directed effort, sets in which the size of mesh specified is associated with targeting Sculpin, Redfish, Silver Hake, and Winter Flounder, or hook size associated with targeting Halibut (Table 3) were removed from the dataset; sets with invalid or missing entries for either mesh or hook size sets were retained. Within the remaining dataset, catch composition was used to further separate out Pollock-directed effort from Haddock-, Redfish-, and Cod-directed effort.

Species composition for the figures were calculated by dividing the weight of each species in a data parcel by the total weight of the major groundfish species in that data parcel. The main assumption going into these figures is that a higher proportion of a species in the catch is indicative of intent to direct for this species. Under this definition, incidents of high bycatch would be classified as directed effort as well, so the impact of this is mitigated by only considering the nine major groundfish species in the species catch composition calculation. The data were analyzed under the two broad gear categories of mobile and fixed, as further separation into specific gear types by statistical area do not meet confidentiality requirements for fixed gear.

Historically, attempts to identify directed fishing were done based on a trip-level aggregation of the data. Following suggestions by stakeholders from the 2004 Pollock framework (Stephenson 2004) and further consultation with SFGAC during the 2021 MSE Revision Process, the directed effort was estimated based on a set-level aggregation of the commercial data. The intent of this analysis is to tease out Pollock-directed effort on a set-level, particularly from trips that are otherwise identified as non-Pollock-directed and would have been excluded from the trip-level bycatch summaries. Figure 27 shows an example of such a trip (A), appearing as Haddock-directed in the trip-level dataset, but actually showing five Pollock-directed sets when disaggregated to set level (Figure 28). In addition, examining the bycatch information on set-level allows for the exclusion of non-Pollock-directed sets occurring during Pollock-directed trips (Figure 29, Figure 30), further increasing the accuracy of the bycatch summaries.

The set-aggregated species composition information is shown across the nine major species for a large spatial area (4VWX, Figure 31 and Figure 32), with a more in-depth spatial breakdown specific to the WC (4X5Y, Figure 33 and Figure 34). In both cases, the division between mobile and fixed gear groups is retained. The definition of a Pollock-directed set requires a cut-off for the proportion of set-level catch which constitutes Pollock. Given the absence of a clear cut-off in the set-level dataset (Figure 35, Figure 36), this analysis retains the previous assumption that Pollock-directed effort results in > 50% of the catch being Pollock. Given the relatively arbitrary nature of that value, a bycatch summary was also provided based on a cut-off of > 70% of the set-level catch being Pollock, showing the sensitivity of the analysis to this value (Figure 37, Figure 38).

As mentioned above, directed effort can be isolated based on gear configuration, species catch composition or, as in this case, a combination of both. Gear configuration refers to mesh size (mm) for mobile gear, mesh size (inches) for gillnet, and hook size for handline/longline gear. The accuracy of the gear-based method is dependent on the accuracy and completeness of the

effort data, as well as how distinct the species-specific gear combinations are between various target species. The effort data comes from fishing logs and is not subject to stringent auditing efforts, resulting in a varied proportion of null or invalid records since 2002, particularly early in the time series (Table 4). The effectiveness of the target assignment based on available gear configuration for mobile gear varies with species, being optimal for species with the most distinct configuration of the group (i.e., Silver Hake, Figure 39), and less definitive for species which overlap (i.e., Cod, Haddock and Pollock, Figure 39) or span a wide range of mesh sizes (i.e., Sculpin, Figure 39). Species-specific gear configuration for fixed gear was only detected for Halibut (i.e., sizes 14-16, Figure 40), with Cod, Haddock, Pollock and Redfish all overlapping in the smaller hook sizes (i.e., 12-13, Figure 40); gillnet showed no signals of species-specific gear configuration (Figure 41).

The consistency between applying the catch-based and gear-based methods separately to identify the directed species on a given set is summarized in Table 5 and Table 6, with various levels of success evident, depending on species. Mobile gear fishing Silver Hake, for example, shows a 99% agreement between the two methods, while Winter Flounder show a discouraging 52% agreement (Table 5). For comparison, a similar check was also carried out between the two methods and Mar.fleets, a recently developed tool for querying commercial and observer data in the Maritimes Region. Mar.fleets applies a combination of licence- and gear-based filters to commercial data (McMahon and Bowlby 2021). In general, the fishin_CHPs filter in Mar.fleets had good agreement with the gear-based method of identifying Cod/Haddock/Pollock-directed effort (> 98% for mobile gear, > 97% for fixed gear since 2004), suggesting that it is a reliable method of querying commercial data. Although Mar.fleets absolves the user of having a thorough understanding of data structure and linkages for the commercial and observer databases, the user must retain a good understanding of what is being queried and all associated caveats to avoid misuse of the data.

The current approach to estimating Pollock-directed effort in the groundfish fishery uses a blend of gear- and catch-based selections described above. The methods were combined due to the high overlap in gear configuration between Pollock and other species (Cod and Haddock for mobile gear; Cod, Haddock, and Redfish for fixed gear), as well as Pollock often being caught in the presence of other groundfish species (i.e., Redfish). In this case, records identified as targeting Redfish, Sculpin, Winter Flounder, and Silver Hake in mobile gear, and Halibut in fixed gear, were removed based on gear configuration, with the catch-based methods applied to the remaining dataset to identify Pollock-directed sets. The resulting dataset of Pollock-directed effort was used to provide subsequent bycatch summary tables and figures.

Bycatch of species during Pollock-directed effort

Using the set-level aggregated dataset, with the Pollock-directed set being defined as > 50% Pollock by weight, a summary of catch on Pollock-directed trips in 4X5 is shown in Table 7 and Table 8. As a point of comparison, bycatch information by gear group is also provided using a > 70% cut-off (Figure 37, Figure 38), though this is done as a demonstration of the sensitivity of the analysis to the cut-off assumption; the analysis using the > 50% cut-off is still considered the most appropriate method for estimating bycatch.

Switching from a trip-level to a set-level aggregation for estimating bycatch does not have a uni-directional impact on the summary, as evident by the 2020 trip-level summary provided in the terminal column of Table 7 and Table 8. These changes are driven by both the exclusion of non-Pollock-directed sets from Pollock-directed trips, and the inclusion of Pollock-directed sets from non-Pollock directed trips. Interestingly, the set-level analysis for mobile gear always increases the amount of Pollock caught with Pollock-directed effort, indicating that the set-level analysis tends to show a more selective mobile Pollock-directed fishery than trip-level analysis.

The trends in the summary bycatch tables and figures must be interpreted while remaining cognisant of the pertinent changes in the groundfish fishery over time (i.e., the decrease in the proportion of Pollock-directed sets, Figure 42, particularly for fixed gear). Currently, all of the bycatch tables provided apply to activity within the WC Pollock management unit (4X5). If the need arises, the information can also be separated out into the WC Pollock assessment unit (4Xopqrs5) and 4Xmn. Finally, future work building on the current bycatch analysis will focus on accounting for finer spatial parcels, as spatially discrete bycatch patterns for Pollock-directed effort are evident in the data and generally align with stakeholder comments on the topic (Figure 43). For a groundfish fishery operating within a portion of two NAFO Divisions, ignoring these finer spatial trends, characterizing bycatch for the whole unit based on a sub-area or making inference across gears and fisheries can lead to a gross mis-representation of the information.

General directing trends in the groundfish fishery

Mobile gear effort in 4VW appears to be primarily directed towards Redfish or Silver Hake (Figure 31), the latter of which is confirmed by the presence of the highly selective Silver Hake fishery in Emerald Basin in 4W (DFO 2018b). In 4X5Y, the directed effort for mobile gear is showing some temporal shifts that are best seen in a breakdown of 4X5Y into statistical areas (Figure 33). Haddock and Redfish show the most directed activity in recent years in many of the statistical areas, with Halibut appearing as a bycatch species across all of the areas (Figure 33). Sculpin-directed effort in 4Xr was pretty evident earlier in the time series, but has drastically decreased since 2015, with Winter Flounder taking over (Figure 33); this shift in species-directed effort is consistent with the reported decline of the Sculpin fishery in St. Mary's Bay (DFO 2021d). Both Cod and Pollock are characterized by having had directed effort in the earlier part of the time series, followed by a notable transition to primarily bycatch in recent years (Figure 33). Unlike Cod, which has moved to a bycatch only fishery 4X5Y, the groundfish fishery continues to conduct some Pollock-directed sets with mobile gear in 4Xpq (Figure 35). On Georges Bank, Pollock has also transitioned to a bycatch-only species in recent years, caught on Haddock-directed trips (Figure 33).

Across NAFO Divisions 4VW, fixed gear effort is directed primarily for Halibut, although earlier in the time series directing for Cod, Pollock, Haddock, Dogfish, and Sculpin is also evident (Figure 32). Within 4X5Y, the overwhelming trend is the movement away from directing for Cod, Haddock, Pollock, Dogfish, and Halibut to almost exclusively Halibut-directed activity, although some Pollock-directed activity persists in 4Xopq (Figure 34). Trends in fixed gear effort on Georges Bank show a surprising shift from Haddock-directed to Cod-directed in recent years (Figure 34), although this could be an artefact of the substantial decrease in overall fixed gear groundfish activity in 5Z in recent years (Figure 12). Within 4X5Y, in some areas Pollock appears to have shifted to primarily a bycatch species (i.e., 4Xmn), while remaining a directed species in others (i.e., 4Xpq; Figure 36).

Currently, the general directing trends in the groundfish fishery are derived based on catch-composition only. If the outputs of the analysis are deemed to have merit and relevance to the Pollock assessment, additional work to incorporate gear-based selectivity for all of the nine major groundfish species can be done.

Observer Information

Observer coverage targets in the groundfish fishery currently range from 5–10% across most 4X5Y groundfish fleets, and 25–100% in NAFO Division 5Z (DFO 2018). Although 5Z often achieves the desired target, coverage in 4X5Y often falls short, remaining at < 3% across most fleets in the area in recent years (pers. comm., SFGAC 2020). Given the spatial and temporal complexity of the groundfish fishery in 4X5Y, any attempts at extrapolating the observer data

from < 3% of the trips to fishery level will be biased and give a misleading impression of the bycatch profile; a shortcoming recognized by previous attempts to quantify discards in the 4X5Y groundfish fishery (Clark et al. 2015). Consequently, any bycatch and discard analyses for Pollock will continue to depend primarily on fishery information until observer coverage increases. Note that the level of observer coverage deemed sufficient for any analyses depends on the behaviour it is expected to detect (i.e., discarding, highgrading), as well as the species involved (i.e., rare or common). Although observer information is not being used in a stand-alone analysis of bycatch in this document, it was compared to the fishery-based analysis to identify shortcomings or bias in the current coverage.

Limitations

The commercial multi-species fishery analysis presented here is based on weight removals of the nine major groundfish species (i.e., Cod, Haddock, Pollock, Halibut, Silver Hake, Dogfish, Sculpin, Winter Flounder, and Redfish). The use of weight removals of nine major species in this analysis speaks to the total biomass removed by the fleet, but it completely overlooks the financial component of the groundfish catches, which is likely driving some of the trends observed here (e.g., low market price increasing the likelihood of Pollock being a bycatch species). In addition, this approach overlooks changes in TACs across all of the species considered, which are responsible for some of the trends observed (e.g., low Cod TAC likely restricting Haddock removals). Incorporating both of these missing components into this analysis would greatly improve the functionality of this multi-species description of the groundfish fishery.

In addition, the bycatch figures and tables are subject to a number of caveats, including creating some false trends due to the directed effort calculation using only the 'major' species. For example, a sample trip appears to be Pollock-directed, with a bycatch of Cod (Figure 44). When broken down by set-level, it becomes evident that some sets are truly Pollock-directed, while others are Cod-directed (Figure 45). Normally this is a testament to the benefit of the set-aggregated analysis, but knowing that this trip occurred in 4X5Y after 2018, this makes the apparent Cod-directing effort illegal. Expanding the dataset from only considering the nine major species to all species caught, however, shows that White Hake catches account for a substantial portion of the catch and eliminate the apparent Cod-directing effort (Figure 46). This analysis will also benefit from using an evolving list of the 'major' species, instead of a static one, which would account for both historic and future management changes to permitted directing effort.

Pollock is also known to interact with lobster gear, although exact levels are unknown. Available information is sparse and subject to gaps due to insufficient coverage or low sampling, invalidating any attempts to raise the bycatch to fishery level. Similarly, little to no data exists regarding the capture of Pollock in herring weirs.

Finally, bycatch reported via Species at Risk (SARA) logbooks is not included, as the data were not accessible at the time.

RECREATIONAL FISHERY

Recreational catches of Pollock in the Maritimes Region are permitted without a licence, and are subject to seasons and bag limits as described in the IFMP (DFO, 2018). Due to lack of reporting mechanisms for recreational fishing activity in tidal waters, it is not possible to determine the quantity or the size composition of the removals.

SURVEY

ECOSYSTEM SURVEY

The Maritimes Summer Ecosystem Research Vessel (summer RV survey) Survey has provided full coverage of 4Xopqrs5Y and 4Xmn in all years starting in 1970, though some vessel and gear modifications in 1983 preclude comparing catch data before and after this year. Survey coverage of 5Z is available for 1989–1990, and again from 2011 through 2021, although full representative coverage is only available for 2016–2017 and again from 2019 on. As both the WC Pollock assessment and management units include NAFO Division 5Z, the intent is to extend the 5Z survey indices required for the model(s) retroactively to 1984. Consequently, several factors are discussed in this section that may not normally be considered in a data inputs document.

The summer RV survey takes place primarily in July, though vessel problems and expanded coverage have resulted in sampling into August over the past decade (Figure 47). Given the history of the resource, management changes and availability of some data sources described in the Stock Structure section above, catches from the summer RV survey were aggregated into the following time periods:

- 1970–1977 (Figure 6): start of the time series.
- 1978–1983 (Figure 48): coincides with ichthyoplankton and mark-recapture studies, as well as survey gear and vessel changes in 1983.
- 1984–1994 (Figure 49): WC Pollock was considered healthy and some survey coverage of 5Z (EGB) in 1989–1990. This time period is also used for the 2011 MSE HCR survey index ratio.
- 1995–2010 (Figure 50): Period of decreased biomass as compared to the previous decade. Precedes the implementation of the MSE in 2011.
- 2011–2021 (Figure 7): MSE framework implemented. The summer RV survey begins coverage of 5Z (EGB).

The summer RV survey uses a random-stratified sampling design with bottom trawl gear, though more recent cruises have also employed acoustic gear. Due to the semi-pelagic nature of Pollock, the abundance and biomass information derived from the bottom-trawl survey catches are subject to greater variability than with a true demersal species. Although the acoustic index is expected to more accurately capture the presence of Pollock within the water column, the relatively recent application of the acoustic technology on the summer RV survey means that the survey bottom trawl data remains the best source of information of historic trends in population abundance for WC Pollock (Carruthers et al. 2003).

Spatial Distribution

Survey bottom trawl catches of Pollock have undergone a shift in the spatial distribution over the time period examined, with some contraction away from shallow waters. Between 1984 and 1994, a period of time when WC Pollock stock was considered to be the most productive, catches were distributed throughout most of 4WX5Y, with the exception of 4Wdefg (Canso, Middle and Sable Island banks), and most of 4Vs and 4Vn (Banquereau, Misaine, and Middle banks, Figure 49). Despite being mostly absent from the banks in 4V, large catches of Pollock were common along the edge of the Scotian Shelf and the Gully (Figure 49). During the subsequent time period (1995–2010), the large tows along the shelf edge in 4VW disappeared, as did the occurrence of large tows throughout all of 4W (Figure 50). In the most recent time

period (2011–2020), 4Xpq continues to show large aggregations of Pollock while 4Xrs (Bay of Fundy) has shown a notable reduction in catches (Figure 7), an observation supported by comments from fishermen (pers. comm., SFGAC). The additional coverage of 5Z (EGB) in the summer ecosystem survey since 2011 also shows high concentrations of Pollock along the northeastern edge of Georges Bank (Figure 7). With lack of coverage of EGB historically, it is difficult to say whether these aggregations are a recent development or have simply been overlooked in the absence of survey coverage, with comments from fishermen supporting the latter of these two options.

In addition to large decadal trends, design-weighted area of occupancy (DWAO) indices were calculated using the summer RV survey for a variety of spatial areas, as per the method outlined in Swain and Morin (1996) and applied more recently in Ricard (2022). The DWAO indices can be used to explore density-dependent changes in species distribution, with the geographic range defined as the area containing 95% of the species (D95) and the core area defined as the area containing 50% of the species (D50, Swain and Sinclair 1994). In the case of Pollock, as the number of strata contributing to a distribution index decreases, the likelihood of a single stratum dominating the catch increases, so the D50 becomes increasingly difficult to calculate (e.g., Figure 51). Given the similarity in trends between the D50 and D75, they were used interchangeable as a proxy for Pollock core area.

If the area surveyed remains invariable over time, trends in DWAO indices can convey changes in species distribution. In the case of Pollock, the addition of EGB coverage since 2012 and the reduced coverage in 2018 and 2021 due to research vessel breakdowns, violates the assumption of spatial invariability. To help mitigate the impact, the DWAO plots are all provided with and without the additional EGB coverage (i.e., NAFO Division 5Y versus NAFO subarea 5, Figure 52). The lack of data in 2018 and 2021 could not be mitigated, but the total area surveyed identifies years with a change to the spatial coverage of the data.

Looking across the Maritimes Region NAFO Divisions (4VWX5), both the geographical range and the core area of Pollock calculated using the survey information remained stable until the early 2000s, and then experienced a substantial decrease to a low around 2005–2006 (Figure 52). In subsequent years, both the geographical range (D95) and the core area (D50–D75) have shown improvement, but remain below pre-2000 levels. These improvements are evident even when the impact of increased EGB coverage is removed (Figure 52).

Splitting Pollock into EC and WC shows the same decrease in the mid-2000s, but the subsequent trends differ. Both the distribution and core area for WC Pollock exhibit an increase from the low levels and stabilize shortly after at approximately the same level as pre-2000 (Figure 51). EC Pollock, however, has not returned to pre-2000 levels in either the geographic range (D95) or the core area (D50–D75, Figure 53); the area containing 100% of the species (DWAO) does show a rebound in the early 2010 and then promptly declines again.

In combination with biomass trends, the distribution indices seem to behave in a manner generally consistent with density-dependent habitat selection theory. In this case, the population index declines through the 1990s, but the geographic distribution indices remains stable, presumably resulting in a decreasing density of fish within the core area (Figure 51, Figure 54). As the population reaches a low point around 2000, the low density appears to trigger contraction of the spatial distribution, with fish from the fringes moving in to occupy the newly available suitable habitat. Interestingly, the spatial contraction continues throughout the 2000s, even as the biomass index begins to trend upward, with the highest biomass accompanying some of the most contracted distributions between 2005 and 2009 (Figure 51). Presumably, the high biomass in the late 2000s caused a density-driven expansion of the distribution in the

2010s, though the subsequent decrease of biomass to low levels in the early 2010s did not trigger a contraction.

Another useful product of the area of occupancy analysis is identification of a period when both stocks exhibited the highest contraction in geographic distribution (2005–2008; Figure 51, Figure 53). Identifying survey strata with high Pollock catches (10+ kg/tow) during that time shows that Jordan Basin, Georges Basin, the north-east channel and some strata surrounding LaHave Basin recur as preferred Pollock habitat across multiple years (Figure 55). These areas remain important even at times of expanded population distribution in the 2010s (Figure 56), but differ from the core habitat observed earlier in the time series (Figure 57). Further work examining temporal shifts in core habitat for Pollock over time should be pursued as time and resources permit.

Although the DWAO approach has merit, it must be interpreted in light of its limitations and in combination with other metrics. If the DWAO relies solely on survey-based information, the absence of Pollock in a survey set is inferred as the absence of Pollock from that area; an assumption which is particularly problematic given set density within a stratum, and further compounded by the issue of surveying a semi-pelagic fish with a bottom trawl. One mitigation measure could be incorporation of both survey and fishery information into the distribution index, with fishery information converted to presence/absence to avoid confounding the effects of gear efficiency with population density. The fishery information would be used in concurrence with presence/absence information from the survey to build an initial layer representing the geographical distribution of the stock, while survey-based kg/tow can be used to overlay a second density layer used in delineating the core area of the stock.

Ecosystem Considerations

Given that the notable change in Pollock survey catches during the mid-1990s coincides with drastic shifts for most groundfish species in the area, large-scale trends in some environmental variables were also examined. Temperature data were obtained using the *azmpdata* package (Casault and Chrisolm 2021), with available areas summarized by major NAFO unit (Figure 58, Figure 59). It should be noted that the available data are annual summaries across large areas, and any analysis would greatly benefit from fine scale aggregation of the data by area and time. Given the semi-pelagic nature of Pollock, data for both the sea floor (approximately 5 m above bottom) and surface temperature were extracted, although the areas for which the information is available differs between the two (Figure 60, Figure 61).

The sea floor temperature does not indicate a major change between the two periods pre- and post-1995 (Figure 60), while sea surface temperature shows a sharp increase from 1993 to 1994, followed by a period of values that are higher than they were during the preceding decade (Figure 61). The link between Pollock abundance and temperature could be direct (e.g., temperature preference of fish, egg survival, etc.), indirect (e.g., temperature preference of prey or predators), a mixture of the two, or entirely coincidental. The preferred temperature range of Pollock varies by life stage and data source, but there appears to be a consistent upper limit of 11°C, particularly for adult Pollock (Collette and Klein-MacPhee 2002, Cargnelli et al. 1999). The annual trend in both bottom and surface temperature remained below that value across all regions throughout the 1990s, so any perceived impact on abundance at the time is unlikely to be a direct effect of temperature preference by Pollock, unless the annual average masks a seasonal increase above that threshold. More recently, a direct impact of temperature preference can be observed in Emerald Basin, with annual aggregated bottom temperatures approaching 11°C (Figure 60), accompanied by the apparent absence of large tows of Pollock in that area since 2015 (Figure 62). Interestingly, Carruthers et al. (2003) discussed the effect of bottom temperature on Pollock survey catches, but only found an effect of the lower thermal

limit ($< 4^{\circ}\text{C}$) in 4VW, noting that 4X never approached that lower limit. With the upward trend in temperatures across all areas since then, the upper thermal limit now likely plays a much more prominent role in affecting Pollock distribution than the lower limit.

Assessment of indirect impacts can include decreases in prey of various life stages of Pollock (e.g., copepods, krill, crustaceans, Northern Sandlance, Herring, hake, squid, etc.), as well as an increase in the predators (e.g., Monkfish, dogfish, Silver Hake, Redfish, Cod, Grey Seals and other Pollock). This list of Pollock prey and predator linkages is not exhaustive and constitutes a combination of information gleaned from the DFO Maritimes Food Habit Database (Figure 63, Figure 64), past frameworks (Stephenson 2004) and literature (Collette and Klein-MacPhee 2002, Cargnelli et al. 1999). Ideally, the impact of these trophic links would be examined on the specific life stage of Pollock they are thought to impact, but in the case of younger life stages (i.e., larvae, juveniles) there is a lack of a reliable index of abundance, so comparisons must be made to some measure of productivity, abundance, or distribution of the population as a whole.

Starting with prey for the earliest developmental stages of Pollock, dry weight of zooplankton were extracted from the azmpdata package (Casault and Chrisholm 2021). Collection of these data began in 1999, so it is not possible to check for large-scale changes in the mid-1990s. The data are available for a subset of stations across the survey area in the spring and summer, or as part of annual sampling of the three pre-defined lines (i.e., Browns Bank Line, Halifax Line and Louisbourg Line, as described in Casault et al. 2020). Given the narrow spatial nature of the lines, we focused on the survey station data collection, and considered both the spring and summer data to allow for full coverage of 4VWX5 (Figure 65). The only notable large-scale trend appears to be an increase in zooplankton dry weight in 5Z in recent years, driven entirely by the sampling conducted during Maritimes Winter Ecosystem Research Vessel Survey (winter RV survey), putting the zooplankton levels on the Bank on par with other areas (Figure 66). This upward trend coincides both with the increasing amount of Pollock survey biomass coming from EGB (DFO 2021b), as well as the gradual drift of the winter RV survey timing (Figure 47). Dividing the zooplankton data into finer spatial units within 4X5 begins to tread into low sample sizes, but indicates a gradual temporal decrease in zooplankton biomass around Browns Bank (statistical areas 4Xno), an increase in biomass across EGB (statistical areas 5Zjm) and Fundian Channel (statistical areas 4Xpqr), and a relatively stable trend in the Bay of Fundy (4Xs) over time (Figure 67). This description of recent zooplankton biomass distribution is relatively consistent with the spatial distribution of survey catches of Pollock across 4X5 in the most recent time period (Figure 7).

The list of prey items identified for both juvenile and adult Pollock available in literature is relatively extensive (Collette and Klein-MacPhee 2002, Cargnelli et al. 1999). For practical reasons, the original list has been cross-referenced with the DFO Maritimes Food Habit Database (Figure 68), and consequently narrowed down to Herring, Silver Hake, squid, shrimp and Northern Sandlance. When combined, these five species account for approximately 75% of the stomach contents of Pollock sampled in 4VWX5, also showing a notable shift from a piscivorous-dominated diet throughout the 2000s to an invertebrate-dominated one since 2010 (Figure 68).

The ability to adequately examine trends in other prey items of Pollock hinges on the availability of prey population index data, as well as the capacity to parcel out the available data to match the various Pollock areas involved. In the case of Northern Sandlance, for example, the behavior characteristic of the species makes it very difficult to survey a population using a bottom trawl survey, while the absence of a swim bladder negates the use of acoustic surveys for the task (DFO 1996). Consequently, sparse information are available on the abundance of a species which is considered to have a relatively high ecological importance in the ecosystem (Collette and Klein-MacPhee, 2002). The scant available information does indicate that the

species range appears to be constricted to 4Vs and eastern 4W (DFO 1996), which is consistent with their reduced importance as a prey item for WC Pollock, particularly since 2010 (Figure 64). Similarly, there is no reliable source of abundance or biomass available for krill or shrimp within 4X5, which appear to be staple items in the diet of Pollock (Figure 64). Shrimp abundance is only monitored along the eastern Scotian Shelf, which falls outside of the WC management unit (Cassista-Da Ros and Cosham 2020).

Squid populations are not formally assessed within the Maritimes Region either, despite being found ubiquitously across NAFO Divisions 4VWX (DFO 2021f). The only source of information on their abundance across the region is from annual trends in the summer RV survey, which provide a relative biomass index for Shortfin Squid for all of 4VWX (Figure 69). Although the difficulties of sampling a pelagic species by a bottom trawl outlined above apply here as well, it is currently the only available source of abundance information. The Shortfin Squid abundance index appears cyclical in nature, with peaks and troughs generally occurring concurrently with Pollock until the most recent few years, which show squid experiencing a relatively sharp increase while the Pollock index remains stable (Figure 69, Figure 54). In the recent time period, the contribution of squid to the diet of adult WC Pollock has increased, which is consistent with an increase in squid abundance (Figure 64).

Herring appear to make a significant contribution to adult WC Pollock diet in the earlier half of the time series (Figure 64) and also have a dedicated monitoring program in the Maritimes Region, with several acoustic surveys taking place in 4VWX5 (DFO 2020a). However, Herring data demonstrate a second issue often encountered when attempting to adequately examine trends across species: spatial compatibility. Although Herring are subject to several acoustic surveys, the surveys are limited to the spatial boxes where the majority of the spawning takes place (Figure 70). Consequently, Pollock abundance across NAFO Divisions 4VW can only be compared to Herring abundance in the two relatively small coastal fishing boxes which fall into those NAFO Divisions (Coastal Eastern Shore and Bras d'Or Lake & Glace Bay Fishing Boxes; Figure 70), with the assumption that all spawning Herring are surveyed, and then remain within 4VW post-spawning. The same concept applies within 4X, with the bulk of the surveyed Herring biomass coming from three fishing boxes, with eastern 4X (coastal southern shore fishing box) treated as a separate Herring component from western 4X (German Bank and Scots Bay fishing boxes, DFO 2020a).

Working within these limitations, the Herring biomass trends in the area overlapping with WC Pollock are available since 1999, and show a decrease in western 4X in 2005, followed by a stable period until 2016, and finally a drastic decrease in the most recent years (Figure 71). In contrast, eastern 4X shows a relatively flat trend up until 2010, followed by a steady increase to the highest levels in the series (Figure 72). It should also be noted that during the deceptively stable period in western 4X (2005–2017), the two boxes within the area showed opposing trends, with the German Bank fishing box showing a decline, while the inshore Scots Bay fishing box shows an increase (Figure 72). Overall, there appears to be an increase in surveyed acoustic Herring biomass in the inshore areas of 4X, with the only fishing box in deeper waters showing a steady decline.

With two opposing trend signals from the 4X acoustic Herring surveys, the lower summer RV survey biomass of Pollock in 4Xopqrs5Y in recent years (see Biomass section) corresponds to an increase in Herring inshore and a decrease of Herring in deeper water. Interestingly, the industry acoustic survey of NAFO Divisions 4VW, which is based on two inshore fishing boxes (Figure 70), appears to have the same correlation with the summer RV survey biomass index for EC Pollock (NAFO Divisions 4VW), with peaks in acoustic Herring biomass coinciding with lows in the summer RV survey Pollock biomass (Figure 72, Figure 73). This coincides with comments made by stakeholders during the 2004 Framework, that summer Pollock tend to

follow Herring (Stephenson 2004). However, situation is further complicated by the apparent shift in diet of Pollock from piscivorous to invertebrate-based species during the period when abundance of Herring in deeper water has decreased.

The population trends for Silver Hake are based on a population model spanning all of 4VWX, so population trends for areas spanning just the WC are not available. In general, the 4VWX Silver Hake population remained at relatively low levels throughout the 2000s, then increased and remained high throughout most of the 2010s, and is now starting to exhibit a downward trend (Figure 74, DFO 2020b). Surprisingly, the period of low Silver Hake abundance coincides with a period of their prominence in Pollock stomachs (Figure 64), with very few Silver Hake found in Pollock stomachs since 2010, despite their abundance along the Scotian Shelf. Silver Hake is also considered a predator of Pollock, indicating that predator pressure would have been high throughout the 2010s and is currently starting to decrease. In addition, fishermen have noted that Silver Hake moving into an area is often accompanied by Pollock leaving (pers. comm., SFGAC), implying competitive pressure exerted on adult Pollock as well, which should alleviate if Silver Hake density decreases.

Other Pollock predators include Cod, Redfish, monkfish, dogfish, and Grey Seals. The Cod stocks spanning 4X5 experienced the ubiquitous groundfish crash in the 1990s and have shown no signs of recovery since then (DFO 2021a), indicating that any predation pressure exerted on juvenile Pollock by Cod remains low. Unit 3 Redfish includes NAFO Division 4X and has shown a rebound in mature biomass around 2010, following a relatively long period of low biomass (Figure 75, DFO 2021c). This is expected to coincide with additional predation pressure on juvenile Pollock, as well as increased competition with adult Pollock, as Pollock and Redfish are often found occupying similar habitats.

Although no official assessments exist for monkfish or dogfish exist, the summer RV survey does provide a biomass index spanning 4X for both species (Figure 76, Figure 77, DFO 2021f). In general, monkfish biomass has remained high throughout the time series, with the exception of a low time period from the late 2000s to the early 2010s (Figure 76). Since then, the biomass has increased back to the highs observed throughout the 1990s. Similarly, relative biomass of dogfish remained high throughout the 1990s and 2000s, experienced a brief low around 2010, and has shown some improvements again since then (Figure 77). In both cases, predation pressure on Pollock is expected to be alleviated around 2010, with higher levels before and after that time period. Finally, Grey Seal colonies along the Scotian Shelf have experienced unprecedented growth over the last decade (DFO 2017), likely increasing predation pressure on a suite of groundfish species, including Pollock.

In summary, Pollock have experienced a shift from a piscivorous to an invertebrate-based diet, indicating that squid and shrimp are becoming more instrumental in the diet of WC Pollock, replacing fish species that were more integral in the past. High temperatures may be starting to play an increasingly important role in Pollock distribution, particularly in hot spots when temperature approaches the 11°C limit. Spawning of Pollock is known to have a very defined temperature aspect, starting when waters cool in late fall (8–10°C) and peaking in early winter (5–6°C, McGlade et al. 1993), so any drastic changes may impact spawning timing and locations. Data limitations continue to plague attempts to investigate some of the most basic trophic links impacting Pollock, particularly for prey interactions. Finally, various trends in predator species may result in shifts in predation pressures on juvenile and adult Pollock, with likely implications on the stationarity of natural mortality for this species over time.

Biomass

The Pollock survey biomass index for 4Xopqrs5Y shows a productive period during the late 1980s, followed by a drastic decrease throughout the 1990s (Figure 54, top panel). This was followed by a second increase and subsequent decrease between 2005–2010, with the biomass index remaining at a relatively low level since then (Figure 54). Note that given lack of coverage of NAFO Division 5Z prior to 2011, the combined index currently excludes 5Z altogether. Given the increasing contribution of 5Z to commercial catch (see Fishery section), the intent is to try and model the 5Z biomass index retroactively, allowing it to be included in the total survey biomass estimation for WC Pollock from 1984 onward. This will constitute a departure from the original 2011 MSE approach, which assumed that the survey biomass per tow (kg/tow) in NAFO Divisions 4X5Y was also representative of 5Z. If successful, modeling the 5Z survey catches would also eliminate the dependence on a kg/tow index currently in place, and allow for the use of a total biomass index for the assessment unit (4Xopqrs5).

Currently, full summer coverage of EGB is only available in 2016–2017, and 2019–2020. Generating a combined biomass index using the available years makes a marginal difference across three of the four years impacted, with only the 2016 value increasing substantially (Figure 54, bottom panel).

Catch at Age

The survey CAA for WC Pollock shows very strong year effects, which is a consequence of the high variability in bottom-trawl catches of Pollock (Figure 78). In general, there is indication of at least three strong year classes throughout the time series, but the year effects might hide multiple strong cohorts if they occurred within 3–4 years of each other. The first strong year class likely occurred in the late 1980s, the second one in the late 1990s and the third in the early 2010s, with the most recent one appearing to be the weakest of the three. Although there is an overall decrease in the abundance-at-age with time, the survey continues to catch a broad range of ages in recent years.

Converting the abundance-at-age to proportions of total abundance in each year removes year effects and confirms the presence of at least three strong year class events throughout the time series (Figure 79). The persistence of apparent multiple strong year classes within each event in Figure 79 could indicate age smearing, particularly if the effect appeared/disappeared during changes in primary agers or if Pollock was considered a difficult species to age. As the occurrence of multiple subsequent year classes carries throughout the entire time series and across five changes in primary agers, the more likely scenario is that this population of Pollock is subject to multi-year batches of strong and weak recruitment events.

Due to the mismatch between area surveyed (i.e., lack of coverage in 5Z) and the area assessed (i.e., includes 5Z), the WC survey CAA previously consisted of area-weighted mean number per tow at age for ages 3–8 (Porter and Docherty 2011). The current data review has retained the original survey CAA, extended it to include the most recent information, and also calculated the total abundance index for the survey area consistently covered throughout the time series (4Xopqrs5Y, Figure 80). If the work retroactively simulating the survey index for NAFO Division 5Z successfully produces a survey catch-at-age for 5Z back to the 1980s, it can be added to the total abundance indices at age in 4Xopqrs5Y to produce total abundance-at-age indices for the whole WC assessment area (4Xopqrs5). The inclusion of 5Z in the abundance indices would allow the assessment to accurately account for divergence of trends between 5Z and the rest of the WC area, if such a situation arises.

Length- and Weight-at-Age

The LAA and weight-at-age (WAA) from the summer RV survey were examined for ages 1 through 10, with 10 being a plus group due to the intermittent presence of older fish in the survey catch (Figure 81, Figure 82). Given that the coverage of EGB started in 2011, both LAA and WAA are identified separately for the 4Xopqrs5Y and the 5Z portions of the WC assessment unit.

In general, ages 2+ show a high mean LAA and WAA throughout the 1970s and 1980s, remaining above the series mean (Figure 81, Figure 82). In the mid-1990s, the mean WAA and LAA of ages 4+ decreased further to reach the series mean and stabilized at that level until the 2010s. Since then, a further decline has become evident in both LAA and WAA, reaching series lows in the most recent years. The most recent decline in growth appears to start with the 2010 year class and applies to all subsequent cohorts (Figure 83, Figure 84). This latest shift is tied to a year class and does not align with a change in the primary ager (Figure 85), although cross-validation tests are currently being carried out just in case.

The trend in LAA and WAA weight for ages 2 and 3 appears to oscillate around the series mean over time, while age 1 shows a slowly increasing trend in both LAA and WAA over time (Figure 81, Figure 82). Including the available survey data from Georges Bank does not drastically impact the trends in 4Xopqrs5Y, as the range of LAA and WAA are consistent between the two areas.

Given the shifts in both LAA and WAA over time, some additional discussion is warranted about any likely causes and how either one is expected to trend in the future. The decreased rate of growth for 2010+ year classes in 4Xopqrs5 is accompanied by a period of higher temperatures (Figure 60, Figure 61) and a shift from piscivorous to an invertebrate-dominated diet (Figure 64), although mechanistic relationships for either one have not been identified at this time.

Age and Length at Maturity

The summer RV survey does not collect maturity information. The winter RV survey does collect maturity data, but that survey prioritizes the 5Z and southern NAFO Divisions, so several gaps exist in the time series when the 4X5Y portion of the WC unit was not covered. Consequently, data were divided into 'older' (1979–1987) and 'recent' (2008–2020) time periods based on the availability of summer RV survey data in 4X. In addition, the recent time period also has data available from EGB, so both length and weight at maturity for the recent time period was calculated for 4X5Y only, as well as 4X5YZ (Figure 86, Figure 87). Winter RV survey coverage of EGB is not available for the early time period.

The age at 50% maturity (A50) for Pollock in the Western Component of 4X5Y has increased slightly from 3.22 to 3.37 over the decades, with the inclusion of fish from 5Z making very little difference to the calculation (3.37, Figure 86). Although the A50 shows very little change over time, the steepness of the curve does seem to decrease, with > 95% of the fish mature at age 4 in the early time period, but only about 75% of them being mature at age 4 in the later time period. For the 2011 MSE, maturity at a given age was assumed to be zero up until, and including, age 3, and assumed to be one at age 4 (Rademeyer and Butterworth 2011).

The length at 50% maturity for Pollock in the WC of 4X5Y decreased from 45.1 cm in the early time period to 41.2 cm in the recent time period (Figure 87). Similarly to the A50, including EGB Pollock in the recent time period only has a minor effect on the length at 50% maturity (40.8 cm, Figure 87).

Condition and Length-Weight

Condition was evaluated by calculating Fulton's condition factor separately for male and female Pollock on the winter and summer RV surveys (Figure 88). The summer RV survey provides the dataset that spans the majority of the WC assessment area in most years, with the exception of EGB prior to 2011. The winter RV survey has several gaps in coverage of the 4X portion of WC, but has consistently covered Georges Bank since 1987. Following a period of very good condition for both genders in the 1980s, condition decreased in the early 1990s and has fluctuated around the same level since then (Figure 88). Note that in 1995 the summer RV survey changed from using spring scales to electronic scales when measuring individual fish at sea; a change which may confound a trend in fish condition. This change in precision is quite evident when looking at the a and b parameters of the annual length-weight relationship, with a notable constriction in the range of the values in the mid-1990s (Figure 89). The shift in Pollock diet from piscivorous to invertebrate-based noted above does not seem to impact the condition of the fish.

Relative Fishing Mortality

Commercial landings and summer RV survey biomass indices can be used to provide an estimate of relative fishing mortality for WC Pollock. Given the spatial areas described throughout this document, relative fishing mortality was calculated for the whole WC management area (4Xopqrs5YZ), the 4Xopqrs5Y portion (i.e., without 5Z), and for distinct sub-regions within the WC (4Xopq = South Nova Scotia, 4Xrs5Y = Bay of Fundy region, and 5Zc = Georges Bank). It is important to note the disparity in the data used with respect to EGB, with commercial landings including NAFO Division 5Zc throughout the time series, while the summer RV survey biomass index excludes the area until 2011. Even after 2011, full coverage of the EGB area is only available in 2016–2017, and from 2019 on. Consequently, the relative F estimates leading up to 2016, as well as in 2018, is an over-estimation of the true value for the affected area, which can be seen when both the survey biomass and the commercial landings exclude 5Z (Figure 90). With an increasing proportion of the commercial catch coming from 5Z (Figure 91), the disparity is expected to increase, emphasizing the need for full survey coverage of EGB in the summer moving forward.

The trend in relative F is subject to a lot of inter-annual variation, but in general relative F tended to be higher in the earlier part of the time series, and lower since the mid-2000s (Figure 90). Breaking down the dataset by sub-regions within 4X5 amplifies the noise but seems to show the temporal decrease along the Bay of Fundy areas, with the southern Scotian Shelf showing periods of high F in the late 1990s and early 2000s, followed by relatively low levels since then (Figure 90). The relative F specific to the EGB (NAFO Division 5Zc) region shows very high variation, which is attributed to the incomplete coverage of the area from 2011 to 2015.

With consideration given to the spatial mismatch between the WC Pollock assessment and management areas, relative F was also calculated specifically for 4Xmn (Figure 92). The trend follows a very clear pattern of higher mortality earlier in the time series, with relatively low levels since 2008. The most recent years are starting to show an increase, which is consistent with the increase in Pollock bycatch catch activity in 4Xn, while directing for Haddock (see Commercial Fishery – Multi-species Removals section).

Total Mortality

Mortality for WC Pollock was calculated using both catch-curve and Sinclair Z methods (fishR, Sinclair 2001). Ages 2–4 are not fully susceptible to the survey gear, resulting in mostly negative values in both cases (Figure 93, Figure 94). Ages 5 through 7 also show consistent results

using both methods, with total mortality rising in the early 1990s, peaking around 1997, and subsequently declining to very low levels in 2005 (Figure 93, Figure 94). Since then, total mortality increased and since 2010 appears to have stabilized at a relatively high level (Figure 93, Figure 94). These trends are consistent with the rises and falls in survey biomass for WC Pollock (Figure 54).

Selectivity

Survey selectivity can be estimated outside of a model for all available ages (1–16+). Presence of age 10+ fish can be intermittent over the years and there is no empirical evidence of older fish existing while becoming unavailable to the survey, so survey selectivity is assumed to be flat-topped.

Initially, selectivity was calculated across ages in a given year and shows that in most years selectivity is around 95% at age 5 (Figure 95). Variations from this occur in blocks of years where the selectivity curve shifts to the right, with < 95% of fish fully selected at age 5 (Figure 96). These blocks of years are not random and appear to line up with the progression of stronger year classes through the survey CAA, pulling the curve towards the older ages (Figure 79). This effectively creates two logistic selectivity curves, one for years with large year classes contributing to the spawning stock biomass (SSB) and one without (Figure 97). This is further confirmed when selectivity is calculated for ages within each cohort, stabilizing the trend around 95% selectivity at age 5 across the entire time series, aside from a few year effects (Figure 98). Calculation of selectivity across cohorts yields a relatively unchanged selectivity curve across the time series with no directional impact of strong cohorts (Figure 99).

Survey selectivity can also be explored based on population model outputs once they become available, as was the case in 2011 (Rademeyer and Butterworth 2011).

Diel Effect on Survey Catches

Given the semi-pelagic nature of Pollock, some investigation of a diel effect was made into the survey data. Mean catch per tow, standardized for tow length, was calculated for hourly periods thought to best resemble day (6:00–20:59) and night (21:00–05:59) times during July and August (Figure 100). Note that these values were not standardized to stratum area and therefore differ from the summer RV survey biomass indices for Pollock discussed in the Biomass Section. In general, the catches were comparable between night and day, but in years where a substantial difference exists, catches were always greater during the day. This is not supported by comments by fishermen (as documented in Stephenson 2004), so further investigation might be required, either via finer spatial disaggregation of the survey data into strata or via acoustic information from the summer RV survey.

Other Considerations

One interesting thing of note are the trends of the WC and EC Pollock biomass indices. Both indices follow a remarkably similar trend, although the nodes are slightly offset from one another (Figure 73, Figure 54). Substantial discussion was devoted at the 2004 Pollock assessment framework to the separation of the two units (Stephenson 2004), but similar biomass trends indicate that some connectivity may persist. If connectivity hypotheses are to be pursued, resources would need to be devoted to generating an EC survey CAA, to see if cohorts or certain age groups reallocate from EC to WC, or vice versa.

ACOUSTIC SURVEY

The population status of WC Pollock is currently assessed using bottom-trawl data collected from annual trawl surveys. While bottom-trawl-based indices are considered unbiased for demersal fish species, these indices may underestimate biomass for pelagic and semi-pelagic fish species because bottom-trawling may not capture fish higher in the water column (Neilson et al. 2003a). Pollock is a semi-pelagic species, and biomass indices generated from bottom-trawl sampling may be biased and imprecise, causing misguided stock assessment advice (Perley and Neilson 2007). Internationally, hydroacoustic indices are generally used for the monitoring trends in Pollock biomass (e.g., Nedreaas 1997).

An acoustic-based biomass estimate for WC Pollock was developed from acoustic data that was recorded during summer RV surveys using a Kongsberg EK60 echosounder (Debertin 2020). The acoustic data captures acoustic backscatter throughout the water column, which may be better suited to estimating semi-pelagic species, such as Pollock. Rather than attempting to assign echo-integrals to a particular acoustic target, a mixed-species approach was applied which assigned acoustic backscatter based on known backscattering cross-sections of fishes, and cluster analyses which assigned homogeneous regions based on species composition. WC Pollock acoustic-based index of biomass was considered as appropriate as bottom-trawl index for fisheries management advice because the bias and variance were similar between the indices when analyzed using repeated K-fold cross-validation. Therefore, the acoustic-based index of WC Pollock biomass could be used towards stock assessment advice. Currently, the acoustic-based WC Pollock biomass exists for 2012, 2016–2020 as acoustic data was only available for those years of the time-series (Table 9). Acoustic data using a EK80 echosounder system was collected on the CCGS Jacques Cartier during the 2021 summer RV survey but will need to be processed to be added to the time-series. Age-based acoustic indices of abundance and biomass could be developed for this time series using existing age-length-keys. The extent to which to compare to historical trends is limited with this time series. However, the acoustic-based index could be used to link bottom-trawl based indices which experienced gear and vessel changes but have yet to have vessel comparisons undertaken.

OTHER SOURCES OF SURVEY INFORMATION

ITQ

The ITQ Industry survey was first conducted in the summer of 1995, with the objective of collecting information on Cod, Haddock, and Winter Flounder in NAFO Division 4X (Claytor et al. 2013). It had a fixed station design and took place in the first two weeks of July, providing good overlap with the summer RV survey. The ITQ survey was originally designed to cover a similar area to the summer RV survey, though the ITQ survey tended to sample further inshore and missed some of the deeper strata compared to the summer RV survey. Inconsistencies in station selection within each block and adherence to fishing all blocks over the years biased the information, but coverage of inshore areas from Cape Sable Island to St. Mary's Bay is considered very good (Claytor et al. 2013). Gear configuration of the ITQ survey is described in detail in Claytor et al. (2013) and Clark and Emberley (2009), but in general is expected to have a higher catchability for bottom species.

The design and useability of the ITQ survey for assessments of Pollock have been evaluated on several occasions, with the evaluation coming to various conclusions (Carruthers et al. 2003, Stephenson 2004, Claytor et al. 2013). The final review by Claytor et al. (2013) determined that although it provided a good source of biological information (i.e., length at age), the trends in biomass/abundance for Pollock were accompanied by many substantial caveats and could not

be used. An assessment of impact deemed that dropping the ITQ survey had no impact on the analytical assessments of Pollock to date, and the survey was subsequently terminated, resulting in the last year for the data series being 2012 (Claytor et al. 2013). Given the conclusions of previous assessments, this document avoids Pollock population trends from the ITQ survey and instead focuses on the biological information, as well as some presence/absence data.

The catch distribution of Pollock on the ITQ survey shows some very clear spatial gaps around Browns Bank and Fundian Channel, where sets were carried out but no Pollock was caught (Figure 101). This generally aligns with the lack of Pollock catches in that area by the summer RV survey over the same time period (Figure 50). The shallow areas south of Yarmouth covered by the ITQ, but missed by the summer RV survey, show very few sets with Pollock, especially in the latter part of the time series (Figure 101).

Given that Pollock are known to aggregate by size, with younger ages in closer proximity to shore, the mean and mode length of the sampled fish in each available tow was examined with respect to the location of the tow. The aggregate lengths were further binned to following the 4Xopqrs5 growth curve over the same time period (Figure 4), as to represent approximate age groups. The use of mean versus mode simply shows the difference in assumption trade-offs, with mean length not always representing the predominant length of the catch, while modal length not accurately representing the catch in sets where an equal number of fish at multiple lengths was caught. In both cases, there is support for age- and size-based aggregation of Pollock, with age 1 fish being found in coastal waters of 4X, and older fish found in deeper water. Both analyses identify a consistent aggregation of age 4–6 Pollock around Jordan and Crowell basins (Figure 102, Figure 103).

National Marine Fisheries Service Surveys

The National Marine Fisheries Service (NMFS) in the US carries out bottom trawl groundfish surveys that cover part of the WC management unit and includes EGB. Unlike the DFO summer RV survey, the NMFS surveys occur in the spring and fall. These surveys also use a bottom trawl and therefore are also subject to high inter-annual variability in Pollock abundance. In addition to a seasonal difference, the US surveys don't always extend into Canadian waters past NAFO Division 5Z, limiting the amount of overlap to only five years of summer data in 5Z. Finally, the number of sets carried out each year on the Canadian portion of EGB is relatively low in the seven US strata spanning the area, with stratum 1160 covering 66% of the area and thus having the highest number of sets almost every year (Figure 104, Table 10). Since the set allocation occurs per stratum and the Hague Line bisects stratum 1160, the set-level coverage of the Canadian portion of stratum 1160 can range from zero to 12 sets per year (Figure 105).

Gear and vessel changes

The NMFS spring and fall surveys have undergone a number of gear and vessel changes over the length of the time series, namely a trawl door change in 1985, the intermittent use of the Delaware vessel instead of the Albatross IV, and finally the replacement of the Albatross IV with the Henry B. Bigelow in 2009 (NEFSC 2010). Of these, the door trawl change in 1985 yielded an accepted ratio conversion coefficient, the periodic Delaware substitute showed no significant difference in catchability, and the Henry B. Bigelow change did not yield an accepted ratio conversion factor due to low sample sizes (NEFSC 2010, Miller et al. 2010). In subsequent attempts, Miller (2013) calculated length-based number per tow conversions for Pollock during the Henry B. Bigelow – Albatross IV change, although Pollock remained the most poorly sampled species of all those considered. Currently, the US assessment of Pollock assumes a

ratio conversion of one between the Henry B. Bigelow and the Albatross IV, maintaining a single time series throughout the switch (NEFSC 2010, NEFSC 2017).

Looking across species, the suite of conversion factors calculated for the Bigelow-Albatross change, to date, indicate that the new vessel and gear combination has a higher catchability across almost all species for both ratio- and length-based conversions (Miller et al. 2010, Brooks et al. 2010, Miller 2013). There was no accepted ratio-based conversion factor calculated for Pollock, but ratios of other semi-pelagic species ranged from 1.19 (Acadian Redfish) to 4.59 (Silver Hake, Table 11). Length-based conversion factors were calculated for Pollock by Miller (2013), but had the lowest sample size of all species considered and was the only species with a conversion of 1 at most length sizes; the other semi-pelagic species considered all had conversion factors ranging from 2 to 8 at median lengths (i.e., hakes and Redfish in Figure 106). Consequently, a Pollock-specific Bigelow-Albatross conversion factor of 1 was not thought to be appropriate here, as it is likely higher than 1.

In the absence of a useable conversion factor for biomass and abundance, the US spring and fall time series will be split into independent indices. Alternatively, an approximation of a biomass ratio conversion factor can be made by simply averaging the conversion factors for the other semi-pelagic species (i.e., hakes and Redfish), though this calculation can only be done on ratio-based conversions for biomass (3.16 for biomass per tow), the application of which can introduce bias into an index (Alade and Traver 2018, Brooks et al. 2010). The impact of this decision can be evaluated as a sensitivity run in the MSE.

Biomass Index

Given the US survey coverage rarely extends past 5Z, it cannot be used as a relative index of abundance for 4Xopqrs5 Pollock (Figure 105). However, in combination with the DFO winter RV survey, it can be one of the tools used to simulate an index of Pollock abundance for the Canadian portion of 5Z, which can be added to the existing 4Xopqrs index to generate an index spanning the whole assessment area. The few years of available summer RV survey data spanning the Canadian portion of EGB can be used to further ground-truth the simulated index. This approach is not ideal and comes with a number of assumptions pertaining to timing, small sample sizes and free movement of fish across the Hague Line. However, given the relatively recent shift of Pollock fishing activity into 5Z and the expanded coverage of 5Z by the summer RV survey moving forward, it was the best available solution.

The use of a survey index spanning the entire assessment unit does require that the summer RV survey continues to provide coverage of the Canadian portion of EGB.

As mentioned previously, the WC Pollock assessment unit stops at the Hague Line. This division is imposed for management purposes and poses no biological barrier to Pollock movement. Consequently, trends in abundance for the Canadian portion of EGB can be a construct of fish moving into US waters. Expanding the southern boundary into US waters may avoid depicting phantom trends due to minor spatial fish movement, but poses a larger problem with respect to managing the fishery.

Other biological Information

Biological information from the US surveys can also be compared to the DFO summer RV survey data, as long as spatial coverage and seasonal differences are kept in mind. Condition trends, for example, seem very consistent between the DFO summer, DFO winter, and US spring surveys (Figure 88); US fall appears to be at odds with the other three, showing good condition in recent years while the other three show below average condition.

Comparison of other biological indicators between US and DFO surveys can be made as the need arises, although the differences in timing and spatial coverage cannot be ignored.

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REFERENCES CITED

- Alade LA and Traver ML. 2018. 2017 northern and southern silver hake and red hake stock assessment update report. Northeast Fish Sci Cent Ref Doc. 18-02; 77 p.
- Brooks, E.N., T.J. Miller, C.M. Legault, L. O'Brien, K.C. Clark, S. Gavaris and L. Van Eeckhaute. 2010. Determining length-based calibration factors for cod, haddock and yellowtail flounder. Transboundary Resource Assessment Committee Reference Document 2010-08.
- Cargnelli, L., S. Griesbach, D. Packer, P. Berrien, D. Johnson, W. Morse. 1999. Pollock, *Pollachius virens*, life history and habitat characteristics. NOAA Technical Memorandum, NMFS-NE-131: 1-30.
- Carruthers, E.H., Neilson, J.D., Perley, P., Clark, D., and S. Smith. 2003. [Evaluation of research vessel and ITQ survey data as abundance indices for Pollock](#). CSAS Res. Doc. 2003/110.
- Casault, B. and Chrisholm, E. 2021 [azmpdata R package](#).
- Casault, B., C. Johnson, E. Devred, E. Head, A. Cogswell, and J. Spry. 2020. [Optimal, Chemical, and biological oceanographic conditions on the Scotian Shelf and in the eastern Gulf of Maine during 2019](#). CSAS Res Doc 2020/071.
- Cassista-Da Ros, M. and Cosham, J. 2020. [Eastern Scotian Shelf Shrimp \(*Pandalus borealis*\): 2018–2019](#). DFO Can. Sci. Advis. Sec. Res. Doc. 2020/045. v + 47 p.
- Clark, D.S. and J. Emberley. 2009. [Assessment of Cod in Division 4X in 2008](#). DFO Can. Sci. Advis. Sec. Res. Doc. 2009/018.
- Clark, K.J., Hansen. S.C., and J. Gale. 2015. [Overview of discards from Canadian Commercial Groundfish Fisheries in Northwest Atlantic Fisheries Organization \(NAFO\) Divisions 4X5Yb for 2007-2011](#). DFO Can. Sci. Advis. Sec. Res. Doc. 2015/054.
- Clark, S. H., Burns, T.S., and R. J. Essig. 1980. Scotian Shelf, Gulf of Maine, and Georges Bank Pollock Assessment Update. NMFS Laboratory Reference 79-59.
- Clayton, R., D. Clark, T. McIntyre, H. Stone, A. Cook, L. Harris, J. Simon, P. Emery, and P. Hurley. 2013. Review of Surveys Contributing to Groundfish Assessments with Recommendations for an Ecosystem Survey Program in the Maritimes region. Canadian technical Report of Fisheries and Aquatic Sciences 3083.
- Collette, B., G. Klein-MacPhee. 2002. Pollock, *Pollachius virens*. Pp. 247-252 in B Collette, G Klein-MacPhee, eds. Bigelow and Schroeder's fishes of the Gulf of Maine. Third Edition. Washington, D.C.: Smithsonian Institution Press.

-
- Debertin, A. 2020. Estimating the biomass of a mixed species complex using hydroacoustics and catch data from the Bay of Fundy and Scotian Shelf summer ecosystem survey. *CJFAS* 77: 1101-1116.
- DFO. 1996. [Scotian Shelf Sand Lance](#). DFO Atlantic Fisheries Stock Status Report 96/77E.
- DFO. 2011. [Western Component \(4Xopqrs5\) Pollock Management Strategy Evaluation](#). DFO Can Sci. Advis. Rep. 2011/054.
- DFO. 2017. [Stock assessment of Canadian Northwest Atlantic Grey Seals \(*Halichoerus grypus*\)](#). DFO Can. Sci. Advis. Rep. 2017/045.
- DFO. 2018a. [4VWX5 Groundfish Integrated Fisheries Management Plan](#).
- DFO. 2018b. [Stock Status Update of Scotian Shelf Silver Hake \(*Merluccius bilinearis*\) in NAFO Divisions 4VWX](#). DFO Can. Sci. Resp. 2018/031.
- DFO. 2019a. [Stock status update of Haddock \(*Melanogrammus aeglefinus*\) in NAFO divisions 4X5Y](#). DFO Can Sci. Resp. 2019/016.
- DFO. 2019b. [Stock status update of unit 3 Redfish](#). DFO Can Sci. Resp. 2019/014.
- DFO. 2020a. [Stock Status Update of 4VWX Herring for the 2019/2020 Fishing Season](#). DFO Can. Sci. Advis. Sec. Sci. Resp. 2020/050.
- DFO. 2020b. [Stock Status Update of Scotian Shelf Silver Hake \(*Merluccius bilinearis*\) in NAFO divisions 4VWX](#). DFO Can. Sci. Advis. Sec. Sci. Resp. 2020/023.
- DFO. 2021a. [Stock Status Update of Atlantic Cod \(*Gadus morhua*\) in NAFO Divisions 4X5Yb for 2020](#). DFO Can. Sci. Advis. Sec. Sci. Resp. 2021/023
- DFO. 2021b. [Harvest Control Rule Update for Western Component Pollock \(*Pollachius virens*\) in NAFO Divisions 4Xopqrs5 for 2020](#). DFO Can. Sci. Advis. Sec. Sci. Resp. 2021/025.
- DFO. 2021c. [Stock Status Update of Unit 3 Redfish for 2020](#). DFO Can. Sci. Advis. Sec. Sci. Resp. 2021/026.
- DFO. 2021d. [Proceedings of the Regional Peer Review of the Stock Assessment of St. Mary's Bay Longhorn Sculpin \(*Myoxocephalus octodecemspinosus*\) Fishery](#). DFO Can. Sci. Advis. Sec. Proceedings 2021/004.
- DFO. 2021f. [Maritime Research Vessel Survey Trends on the Scotian Shelf and Bay of Fundy for 2020](#). DFO Can. Sci. Advis. Sec. Sci. Resp. 2021/022.
- DFO. 2024. [2022 Assessment of Atlantic Halibut on the Scotian Shelf and Southern Grand Banks \(NAFO Divisions 3NOPS4VWX5Zc\)](#). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2024/009.
- Graham, J., Engle, S., Recchia, M. 2002. Local Knowledge and Local Stocks: An Atlas of Groundfish Spawning in the Bay of Fundy. The Centre for Community-Based Management. Antigonish, NS: St. Francis Xavier University.
- Gulland, J.A. 1983. Fish Stock Assessment. FAO/Wiley Series on Food and Agriculture. John Wiley and Sons, Chichester, 223p.
- Hendrickson, L., P. Nitschke, and B. Linton. 2015. [2014 Operational stock assessments for Georges Bank winter flounder, Gulf of Maine winter flounder, and pollock](#). Northeast Fisheries Science Center Reference Document 15-01.

-
- Hollowed A.B., Bax N., Beamish R., Collie J., Fogarty M., Livingston P., Pope J., and Rice J.C. 2000. Are multispecies models an improvement on single-species models for measuring fishing impacts on marine ecosystems? *ICES J. Mar. Sci.* 57(3): 707–719.
- Link, J.S. 2010. *Ecosystem-based fisheries management: confronting tradeoffs*. Cambridge University Press, Cambridge.
- McGlade, J.M., D, Beanlands and M. Oberle. 1993. *Pollock*.
- McMahon, M and Bowlby, H. 2021. *Mar.fleets: an R package for integrating commercial catch and at-sea observer data from Maritimes Region*. *Can. Tech. Rep. Fish. Aquat. Sci.* 3450: V + 28 p.
- Mercer, M.C. 1982. Multispecies approaches to fisheries management advice. *Can. Sci. Publ. Fish. Aquat. Sci.* 59: 169p.
- Miller, T.J. 2013. A comparison of hierarchical models for relative catch efficiency based on paired-gear data for US Northwest Atlantic fish stocks. *Can. J. Fish. Aquat. Sci.* 70:1306–1316.
- Miller, T.J., Das, C., Politis, P.J., Miller, A.S., Lucey, S.M., Legault, C.M., Brown, R.W., and P.J Rago. 2010. Estimation of Albatross IV to Henry B. Bigelow calibration factors. U.S. Department of Commerce, Northeast Fisheries Science Center Ref. Dog. 10-05; 233p.
- Nedreaas, K.H. 1997. Evaluation of the north-east Arctic saithe (*Polloachius virens*) acoustic survey. *ICES CM* 1997/Y:20.
- Neilson, J.D., Perley, P., Carruthers, E.H., Stobo, W., and C. Clark. 2003a. [Stock Structure of Pollock in NAFO Divs. 4VWX5Zc](#). CSAS Research Document 2003/045.
- Neilson, J.D. Perley, P., Fowler, M., and Clark, D. 2003b. [An evaluation of Commercial Fishery Catch Rates as an Index of Abundance for Pollock in Divs 4X5](#). CSAS Research Document 2003/109.
- Northeast Fisheries Science Center. 2010. 50th Northeast Regional Stock Assessment Workshop (50th SAW) assessment report. 10-17; 844 p.
- Northeast Fisheries Science Center. 2012. Assessment or data updates of 13 Northeast groundfish stocks through 2010. *Northeast Fish Sci Cent Ref Doc.* 12-06; 789 p.
- Northeast Fisheries Science Center. 2013a. 55th Northeast Regional Stock Assessment Workshop (55th SAW) assessment report. *Northeast Fish Sci Cent Ref Doc.* 13-11; 845 p.
- Northeast Fisheries Science Center. 2013b. 56th Northeast Regional Stock Assessment Workshop (56th SAW) assessment report. *Northeast Fish Sci Cent Ref Doc.* 13-10; 868 p.
- Northeast Fisheries Science Center. 2014. 59th Northeast Regional Stock Assessment Workshop (59th SAW) assessment report. *Northeast Fish Sci Cent Ref Doc.* 14-09; 782 p.
- Northeast Fisheries Science Center. 2017. Operational Assessment of 19 Northeast Groundfish Stocks Updated Through 2016. Reference Document 17-17; 264 p.
- Northeast Fisheries Science Center. 2018a. 65th Northeast Regional Stock Assessment Workshop (65th SAW) assessment report. *Northeast Fish Sci Cent Ref Doc.* 18-11; 659 p.
- Northeast Fisheries Science Center. 2018b. 64th Northeast Regional Stock Assessment Workshop (64th SAW) assessment report. *Northeast Fish Sci Cent Ref Doc.* 18-06; 529 p.
- Perley, P., and Neilson, J.D. 2007. Summary of pollock hydroacoustic surveys on the Scotian Shelf. *Can. Tech. Rep. Fish. Aquat. Sci.* 2725.

-
- Politis, J.P. Galbraith, J.K., Kostovick, P., and R. W. Brown. 2014. Northeast Fisheries Science Center Bottom Trawl Survey Protocols for the NOAA Ship Henry B. Bigelow. Northeast Fisheries Science Center Reference Document 14-06.
- Porter, J.M., and Docherty, V., Chairpersons. 2011. Proceedings of 4X5 Pollock Management Strategy Evaluation Workshop – 2010. Can. Manuscr. Rep. Fish. Aquat. Sci. 2945: iv + 158 p.
- Rademeyer, R.A., and D.S. Butterworth. 2011. [Technical Details Underlying the Management Strategy Evaluation Process Leading to Selection of a Management Procedure for Western Component \(4Xopqrs5\) Pollock](#). DFO Can. Sci. Advis. Sec. Res. Doc. 2011/090: vi + 33 p.
- Sinclair, A.F. 2001. Natural mortality of cod (*Gadus morhua*) in the southern Gulf of St. Lawrence. ICES J. Mar. Sci. 58: 1–10.
- Stephenson, R.L., Chairperson. 2004. [Proceedings of the Pollock Framework Assessment: 1 May 2003; 16-18 June 2003; and 6-8 April 2004](#). DFO Can. Advis. Sec. Proceed. Ser. 2004/030.
- Swain, D., and R. Morin. 1996. Relationships between geographic distribution and abundance of American plaice (*Hippoglossoides platessoides*) in the southern Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci. 53:1.
- Swain, D.P. and A.F. Sinclair. 1994. Fish distribution and catchability: what is the appropriate measure of distribution? Can. J. Fish. Aquat. Sci. 51(5): 1046-1054.
- Trijoulet, V., Fay, G., K.L. Curti, B. Smith and T.J. Miller. 2019. Performance of multispecies assessment models: insights on the influence of diet data. ICES J. Mar. Sci., 76: 1464-1476
- Vinther, M., Reeves, A.S. and K.R. Patterson. 2004. From single-species advice to mixed-species management: taking the next step. ICES J. Mar. Sci. 61:8.

TABLES

Table 1. Number of aged Pollock samples available by major area, year, and data source.

Source	Port Samples				Survey Samples			
	4VW	4Xmn	4Xopqrs5Y	5Z	4VW	4Xmn	4Xopqrs5Y	5Z
1962	349	0	131	0	0	0	0	0
1965	46	0	0	0	0	0	0	0
1970	55	0	123	0	7	167	78	0
1971	0	0	297	34	86	64	17	0
1972	0	0	208	0	3	6	168	0
1973	276	30	247	0	14	62	127	0
1974	170	83	344	59	90	13	60	0
1975	154	197	359	264	79	24	18	0
1976	306	0	638	148	33	87	108	0
1977	872	161	617	161	38	55	199	0
1978	534	407	506	202	151	78	48	0
1979	1,038	158	275	93	228	96	303	0
1980	914	377	339	311	311	219	194	69
1981	499	142	929	191	321	69	249	1
1982	753	307	1,344	340	397	175	300	0
1983	1,313	501	1,662	203	561	223	352	0
1984	1,384	240	968	41	504	108	248	57
1985	1,401	152	1,033	52	220	150	118	0
1986	1,562	344	1,536	171	174	152	460	0
1987	1,353	696	1,638	224	267	167	197	102
1988	1,244	360	1,158	157	158	133	194	0
1989	877	522	797	63	194	60	141	232
1990	949	133	903	234	232	58	179	136
1991	866	172	1,426	239	421	117	227	192
1992	808	270	1,045	388	301	140	164	0
1993	307	582	1,068	587	371	185	204	0
1994	384	348	880	562	245	118	158	31
1995	418	209	1,019	161	259	115	127	0
1996	182	214	833	141	166	79	130	0
1997	168	121	905	297	166	141	128	0
1998	305	84	1,316	344	84	30	68	0
1999	430	170	1,058	428	97	80	104	0
2000	215	140	1,579	351	85	57	172	0
2001	29	137	1,403	928	137	97	182	0
2002	87	84	1,078	450	115	136	123	0
2003	0	0	1,067	413	85	47	158	0

Source	Port Samples				Survey Samples			
Year	4VW	4Xmn	4Xopqrs5Y	5Z	4VW	4Xmn	4Xopqrs5Y	5Z
2004	49	74	1,219	401	39	32	127	0
2005	0	0	884	368	22	80	110	0
2006	46	0	678	419	46	16	183	0
2007	145	115	1,087	302	32	63	102	0
2008	160	151	972	282	26	94	96	0
2009	186	241	943	384	102	77	113	0
2010	342	149	949	442	73	137	57	2
2011	140	233	591	162	167	88	144	82
2012	190	240	498	300	145	141	163	122
2013	24	207	572	286	130	60	212	85
2014	0	0	556	411	173	101	209	66
2015	0	0	649	256	107	71	103	123
2016	0	0	680	276	82	76	377	210
2017	0	149	761	257	91	41	288	210
2018	30	57	578	435	19	41	165	111
2019	0	31	614	406	69	69	253	106
2020	0	156	546	444	150	25	331	140

Table 2. Tonnage class grouping for commercial vessels.

Tonnage Class	Weight (T)
1	1–24.9
2	25–49.9
3	50–149.9
4	150–499.9
5	500–999.9
6	1,000–1,999
7	2,000+

Table 3. Summary of gear-based definition of directed sets for mobile and handline/longline gears in NAFO Divisions 4X5YZ.

Gear Type	Type Size	NAFO	Year	Target
Mobile	50-70 mm mesh	4Xmn	All	Silver Hake
Mobile	90-100 mm mesh	4X5Y	All	Sculpin
Mobile	110-120 mm mesh	4X5Y	All	Redfish
Mobile	130-150 mm mesh	4X5Y	Pre-2019	Cod/Haddock/Pollock
Mobile	130-150 mm mesh	4X5Y	2019	Haddock/Pollock
Mobile	125-150 mm mesh	5Z	All	Cod/Haddock/Pollock
Mobile	155-165 mm mesh	4X5Y	All	Winter Flounder
Handline/Longline	12-13 Hook Size	4X5Y	Pre-2019	Cod/Haddock/Pollock/Redfish
Handline/Longline	12-13 Hook Size	4X5Y	2019	Haddock/Pollock/Redfish
Handline/Longline	12-13 Hook Size	5Z	All	Cod/Haddock/Pollock Redfish
Handline/Longline	14–16 Hook Size	4X5	All	Halibut

Table 4. Summary of valid, set-level gear configuration information across the major gear groups.

Year	Mobile	Fixed
2002	72%	0%
2003	81%	12%
2004	96%	58%
2005	96%	60%
2006	95%	72%
2007	96%	76%
2008	95%	79%
2009	97%	80%
2010	98%	78%
2011	97%	78%
2012	97%	82%
2013	98%	85%
2014	97%	84%
2015	99%	81%
2016	97%	78%
2017	97%	76%
2018	94%	85%
2019	96%	87%
2020	97%	91%

Table 5. Comparison of agreement (PropAgreement) between the catch-composition-based and gear-configuration-based methods of determining a directed species for mobile gear sets. Blue cells identify number of set records in agreement. Catch-directed species is determined based on > 50% composition by weight. Dashes indicate cells where a comparison is nonsensical. CHP-Cod, Pollock, Haddock, HP-Haddock, Pollock, RED-Redfish, SCU-Sculpin, SLH-Silver Hake, WIN-Winter Flounder.

Mobile Gear	Gear Direct							Prop Agreement
CATCH_DIRECT	CHP	HP	RED	SCU	SLH	WIN	Invalid Data	Prop Agreement
Cod/ Haddock/ Pollock	572,584	0	13,168	365	280	5,121	89,374	97%
Haddock/ Pollock	0	34,303	2,367	15	0	519	1,460	92%
Redfish	18,874	1,942	124,017	306	41	63	26,146	85%
Sculpin	2,791	43	4	10,597	13	1,558	2,534	71%
Silver Hake	26	12	13	0	8,648	21	3,825	99%
Winter Flounder	32,655	682	42	163	277	36,482	12,349	52%
Dogfish	218	8	387	0	0	18	59	-
Halibut	1,002	89	161	8	41	231	246	-
No Dominant Species	65,281	3,421	10,496	94	86	4,289	20,539	-
PropAgreement	83%	85%	82%	92%	92%	76%	-	-

Table 6. Comparison of agreement (PropAgreement) between the catch-composition-based and gear-configuration-based methods of determining a directed species for fixed gear sets. Blue cells identify number of set records in agreement. Catch-directed species is determined based on > 50% composition by weight. Dashes indicate cells where a comparison is nonsensical. CHP-Cod, Pollock, Haddock, HPR-Haddock, Pollock, Redfish, HAL-Halibut.

FIXED GEAR	GEAR DIRECT				
CATCH_DIRECT	CHPR	HPR	HAL	Invalid Data	PropAgreement
Cod/Haddock/Pollock/Redfish	72,079	0	13,019	76,718	85%
Haddock/Pollock/Redfish	0	204	73	798	74%
Halibut	6,761	554	62,381	6,117	90%
Dogfish	3,626	0	943	6,662	-
Sculpin	7	0	18	4,146	-
Silver Hake	5	0	2	71	-
Winter Flounder	1	0	1	2,272	-
No Dominant Species	9,677	130	2,870	5,150	-
PropAgreement	78%	23%	79%	-	-

Table 7. Summary of the total weight (kg) of all species caught on Pollock-directed mobile gear sets in NAFO Divisions 4X5. Final column shows the 2020 bycatch summary if aggregated by trip instead of set, and is included for example purposes only. Dashes indicate no catch; 0s indicate a catch of < 0.5kg.

Species Grouped	2002-2005	2006-2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Trip_Level 2020
POLLOCK	16,923,518	8,831,196	1,965,045	2,748,342	2,488,444	1,979,096	1,122,864	1,766,532	1,322,417	910,571	1,574,196	1,172,742	1,442,654	1,118,315
HADDOCK	1,278,095	527,524	95,098	221,492	228,609	207,318	187,244	286,753	296,373	208,574	226,674	144,720	256,165	291,075
COD	959,994	496,986	119,904	61,137	46,464	101,610	62,490	46,068	44,365	34,998	21,592	16,457	27,884	29,819
REDFISH	354,650	105,890	23,716	37,590	32,960	46,111	33,044	25,071	22,295	32,240	81,270	34,528	49,463	43,136
WHITE HAKE	289,223	142,901	64,706	60,839	36,564	27,004	27,880	22,255	21,547	24,701	31,115	17,589	29,059	23,763
MONKFISH	311,502	68,780	3,429	3,762	3,216	5,283	2,335	1,791	2,684	2,219	3,863	4,153	5,046	4,757
GREYSOLE/WITCH	106,513	53,409	6,220	3,443	3,263	9,729	3,148	4,451	1,634	1,107	1,837	1,471	3,415	3,534
HALIBUT	8,697	5,683	1,183	1,822	1,723	4,858	2,575	2,847	2,479	1,638	4,500	2,571	3,716	2,916
WINTER FLOUNDER	15,275	7,440	2,106	1,377	2,247	3,456	1,331	1,292	519	439	174	216	88	112
FLOUNDER, UNSPECIFIED	13,336	9,645	1,214	1,626	847	142	11	-	-	-	1	-	-	-
AMERICAN PLAICE	16,238	6,154	546	1,369	345	644	30	80	71	23	-	31	42	-
SILVER HAKE	512	3	-	-	-	93	13	63	3,980	145	4,119	7,113	242	223
RED HAKE	-	10,853	-	8	-	-	-	74	-	-	632	-	3,258	-
SCULPIN	2,619	4,435	1,718	1,413	556	112	969	29	334	102	85	1,064	66	226
CATFISH	11,515	1,361	-	-	-	-	-	-	-	-	-	-	-	-
CUSK	5,183	2,697	457	342	671	1,470	193	295	204	141	354	98	138	122
YELLOWTAIL	9,792	927	192	69	368	125	9	36	51	13	10	-	69	-
SKATE	1,128	6,004	-	739	898	-	32	11	-	-	-	-	2,545	994
OTHER	2,044	166	-	216	563	3	1	-	-	-	-	-	8	-
WOLFFISH, STRIPED	-	753	85	348	48	80	16	9	20	2	9	3	9	-
HERRING/ALEWIFE/SHAD	106	155	-	-	-	4	203	35	14	-	-	-	33	17
DOGFISH	-	69	-	-	-	-	-	77	-	1	-	22	31	29
TILEFISH	17	11	7	19	8	-	-	-	-	-	6	-	-	-
SUMMER FLOUNDER	7	52	-	-	-	-	-	-	-	-	0	-	-	-
WOLFFISH, UNSPECIFIED	-	-	44	-	-	-	-	-	-	-	-	-	-	2
MACKEREL	9	-	-	1	-	-	-	-	-	-	-	-	30	-
LUMPFISH	3	-	-	-	-	-	-	-	-	-	-	-	-	-
WOLFFISH, SPOTTED	-	-	-	-	-	-	-	-	-	-	-	-	1	-
WOLFFISH, NORTHERN	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 8. Summary of the total weight (kg) of all species caught on Pollock-directed fixed gear sets in NAFO Divisions 4X5. Final column shows the 2020 bycatch summary if aggregated by trip instead of set, and is included for example purposes only. Dashes indicate no catch; 0s indicate a catch of < 0.5kg.

Species	2002-2005	2006-2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Trip_Level_2020
POLLOCK	6,635,936	4,537,161	1,230,535	1,068,303	936,757	638,223	633,530	869,955	787,940	681,202	387,478	384,146	353,106	350,852
WHITE HAKE	2,001,031	938,479	364,463	369,825	258,744	136,457	128,970	110,390	102,446	171,813	115,201	67,523	36,354	36,505
COD	1,476,665	578,180	141,494	105,087	73,229	97,597	157,554	124,307	112,329	147,307	38,888	50,013	27,196	25,853
MONKFISH	61,753	22,476	4,436	3,207	2,213	3,531	2,116	3,114	5,953	11,582	4,603	10,886	8,089	8,019
CUSK	33,970	27,006	14,044	11,847	13,144	10,407	5,164	5,832	3,950	3,935	4,169	2,567	3,365	3,360
OTHER	48,214	32,748	17,541	7,220	2,600	1,033	1,251	442	594	398	232	202	44	44
HADDOCK	48,569	13,999	3,380	3,470	2,607	2,470	1,664	1,374	1,820	1,813	540	1,546	1,440	1,115
REDFISH	11,568	5,931	2,381	3,842	2,933	1,277	384	1,329	428	317	613	486	213	224
DOGFISH	9,552	19,732	-	-	-	50	3	-	-	-	12	-	84	84
HERRING/ALEWIFE/SHAD	20,464	3,273	62	470	-	264	-	-	9	-	-	-	-	-
HALIBUT	1,863	4,084	559	416	998	699	1,090	2,546	1,659	606	1,917	1,337	840	891
SILVER HAKE	4,495	2,018	-	-	-	10	1	-	-	-	-	-	-	-
SKATE	38	67	-	62	348	622	23	15	3	9	21	7	9	9
TILEFISH	680	280	-	-	-	-	-	-	-	-	-	-	-	-
RED HAKE	0	398	22	-	-	-	-	-	-	-	-	-	10	10
MACKEREL	-	25	-	-	-	-	-	-	-	-	1	-	-	-
WOLFFISH, STRIPED	0	12	27	2	16	-	-	-	100	203	17	-	-	-
CATFISH	172	18	-	-	-	-	-	-	-	-	-	-	-	-
FLOUNDER, UNSPECIFIED	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WINTER FLOUNDER	19	-	-	-	-	-	-	-	-	2	-	-	-	-
GREYSOLE/WITCH	1	4	-	-	-	-	-	-	-	-	-	-	-	-
AMERICAN PLAICE	1	-	-	-	-	-	-	-	-	-	-	-	-	-
SCULPIN	-	-	-	-	-	-	1	-	-	-	-	-	-	-
LUMPFISH	1	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 9. Acoustic Index for WC Pollock, with confidence intervals (CI). NA – Not Applicable.

Year	Acoustic	lowCI	HiCI
2011	NA	NA	NA
2012	11,578	11,511	11,636
2013	NA	NA	NA
2014	NA	NA	NA
2015	NA	NA	NA
2016	36,969	36,758	37,162
2017	16,431	16,355	16,504
2018	16,317	16,271	16,362
2019	9,341	9,298	9,382
2020	38,408	37,501	39,286

Table 10. Stratum information for the US National Marine Fisheries Service survey strata spanning eastern Georges Bank. Note that partial strata areas were calculated using an Albers Equal Area projection (C. Foley, pers. com.), which may differ from the projection used to calculate the full stratum area (Politis et al. 2014).

Stratum	Full Stratum Area (NM ²)	Stratum Area in Canadian Waters (NM ²)
1190	2,454	1.0
1200	1,221	0.3
1160	2,980	1,518.9
1170	360	272.8
1180	172	148.0
1210	424	230.0
1220	454	127.9

Table 11. Available estimates of the biomass-based ratio calibration factors for the US Albatross-Bigelow vessel switch (Miller et al. 2010). Application of various conversion factors in assessments and the relevant source documents are identified for non-flatfish species only, with flatfish showing as dashes.

Species	Type	Season	Conversion	UsedInAssessment	Source
American Plaice	flat fish	Spring	2.092	-	-
American Plaice	flat fish	Fall	1.692	-	-
Barndoor Skate	flat fish	SpringFall	3.661	-	-
Little Skate	flat fish	Spring	2.786	-	-
Little Skate	flat fish	Fall	8.814	-	-
Smooth Skate	flat fish	SpringFall	4.45	-	-
Summer Flounder	flat fish	Spring	3.066	-	-
Summer Flounder	flat fish	Fall	2.141	-	-
Thorny Skate	flat fish	SpringFall	3.626	-	-
Windowpane	flat fish	Spring	3.069	-	-
Winter Flounder	flat fish	SpringFall	2.086	-	-
Winter Skate	flat fish	Spring	3.718	-	-
Winter Skate	flat fish	Fall	2.174	-	-
Witch Flounder	flat fish	SpringFall	3.257	-	-
Yellowtail Flounder	flat fish	Spring	2.244	-	-
Yellowtail Flounder	flat fish	Fall	2.402	-	-
Atlantic Cod	bottom	SpringFall	1.58	Used ratio-based (EGB, GB) or length-based (GOM,GB)	TRAC, NEFSC 2013a
Haddock	bottom	Spring	0.878	Used ratio-based (EGB, GB) and length-based (GB)	TRAC, NEFSC 2014
Haddock	bottom	Fall	1.489	Used ratio-based (EGB, GB) and length-based (GB)	TRAC, NEFSC 2014
Acadian Redfish	semi-pelagic	SpringFall	1.191	Used ratio-based	NEFSC 2012
Red Hake	semi-pelagic	Spring	3.712	Used length-based	Alade and Traver 2018
Red Hake	semi-pelagic	Fall	3	Used length-based	Alade and Traver 2018
Silver Hake	semi-pelagic	Fall	4.349	Used length-based	Alade and Traver 2018
Silver Hake	semi-pelagic	Spring	4.591	Used length-based	Alade and Traver 2018
White Hake	semi-pelagic	SpringFall	2.088	Used ratio-based	NEFSC 2013b
Alewife	pelagic	SpringFall	1.1	Not assessed	-
Atlantic Herring	pelagic	Spring	5.394	Series Break	NEFSC 2018a
Atlantic Herring	pelagic	Fall	1.95	Series Break	NEFSC 2018a
Atlantic Mackerel	pelagic	SpringFall	0.868	Series Break	NEFSC 2018b

FIGURES

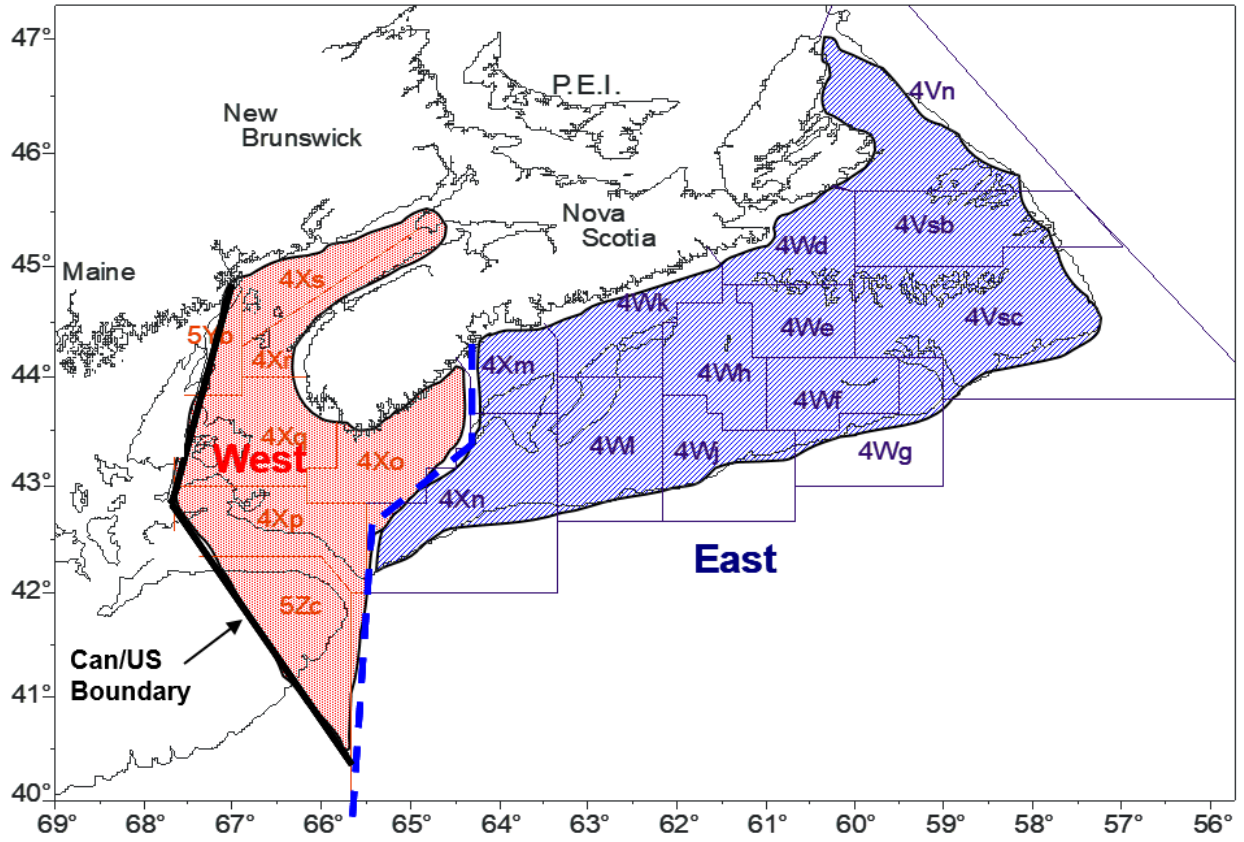


Figure 1. Stock structure components of Pollock in the Maritimes Region.

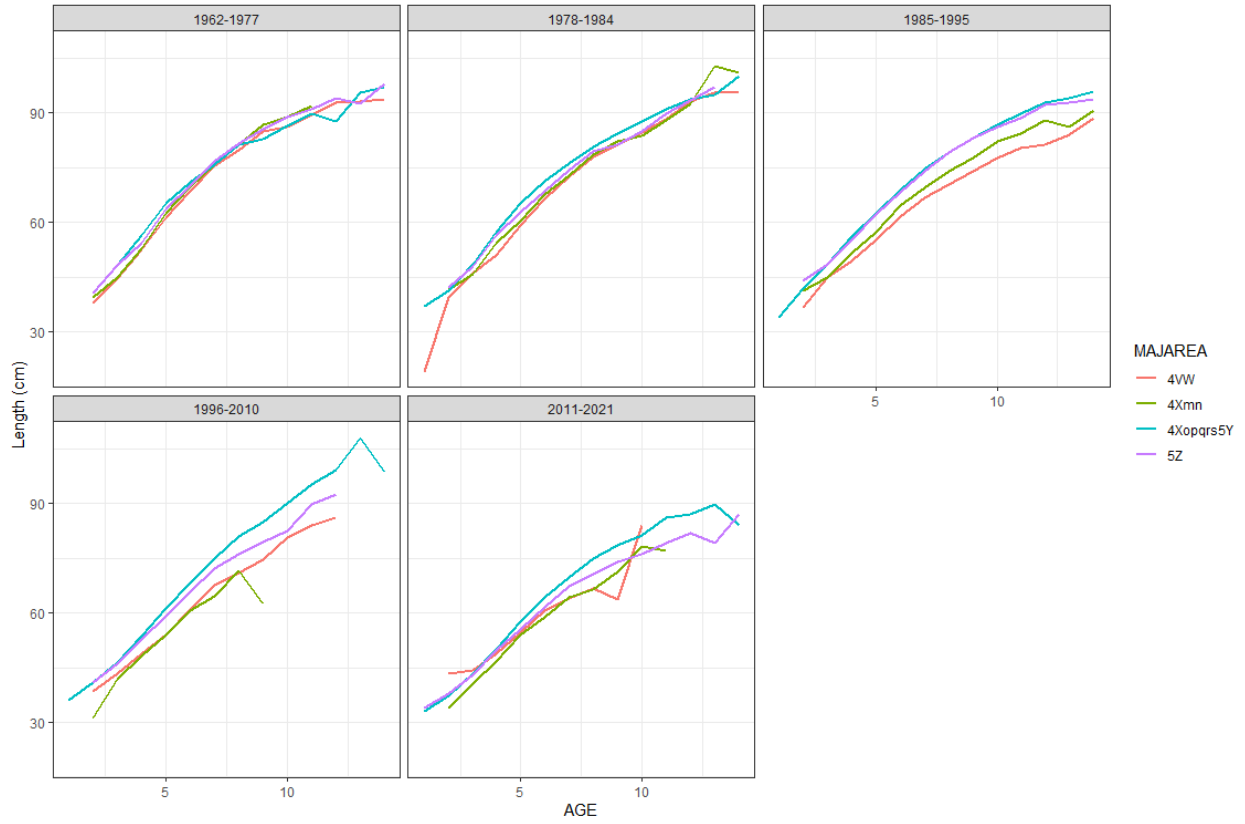


Figure 2. Mean length-at-age for Pollock by unit area (denoted by colours) and time periods (denoted by facets) from the port sampling program.

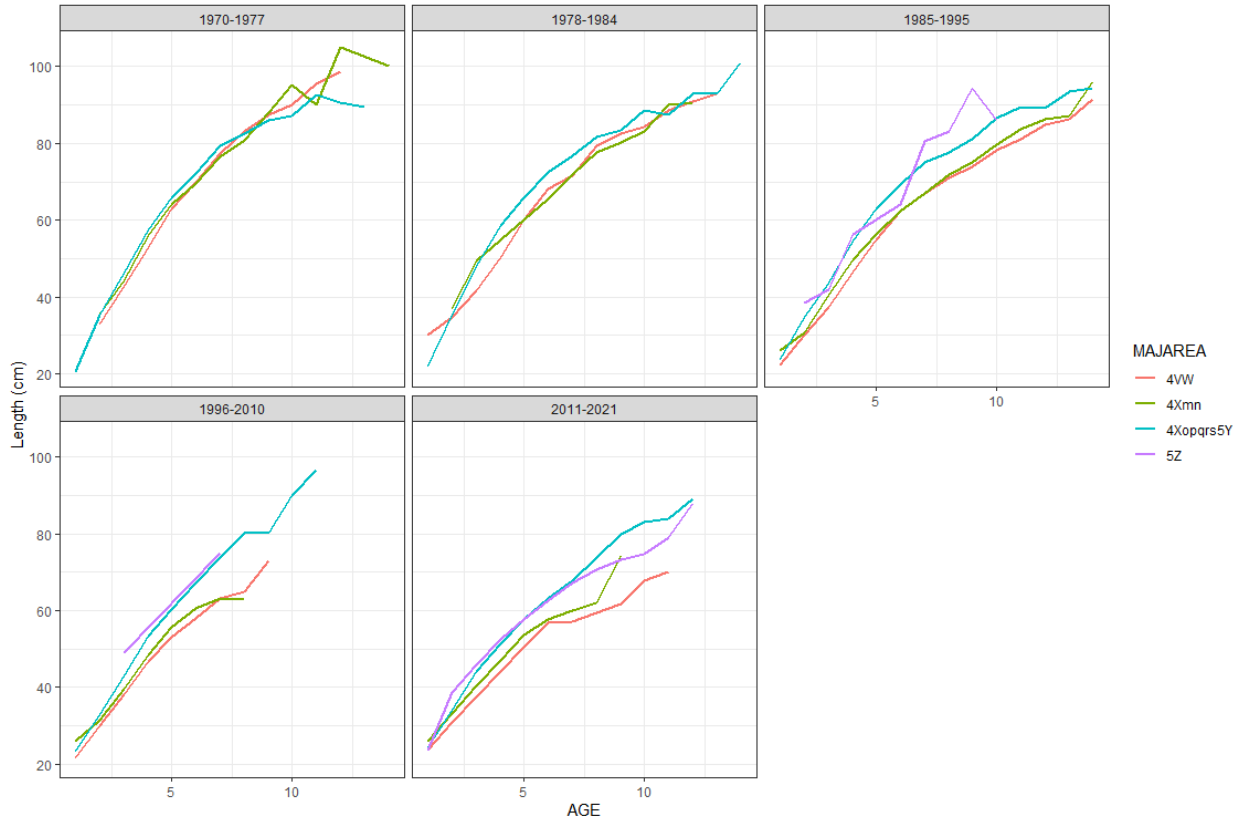


Figure 3. Mean length-at-age for Pollock by unit area (denoted by colours) and time periods (denoted by facets) from the DFO summer RV survey.

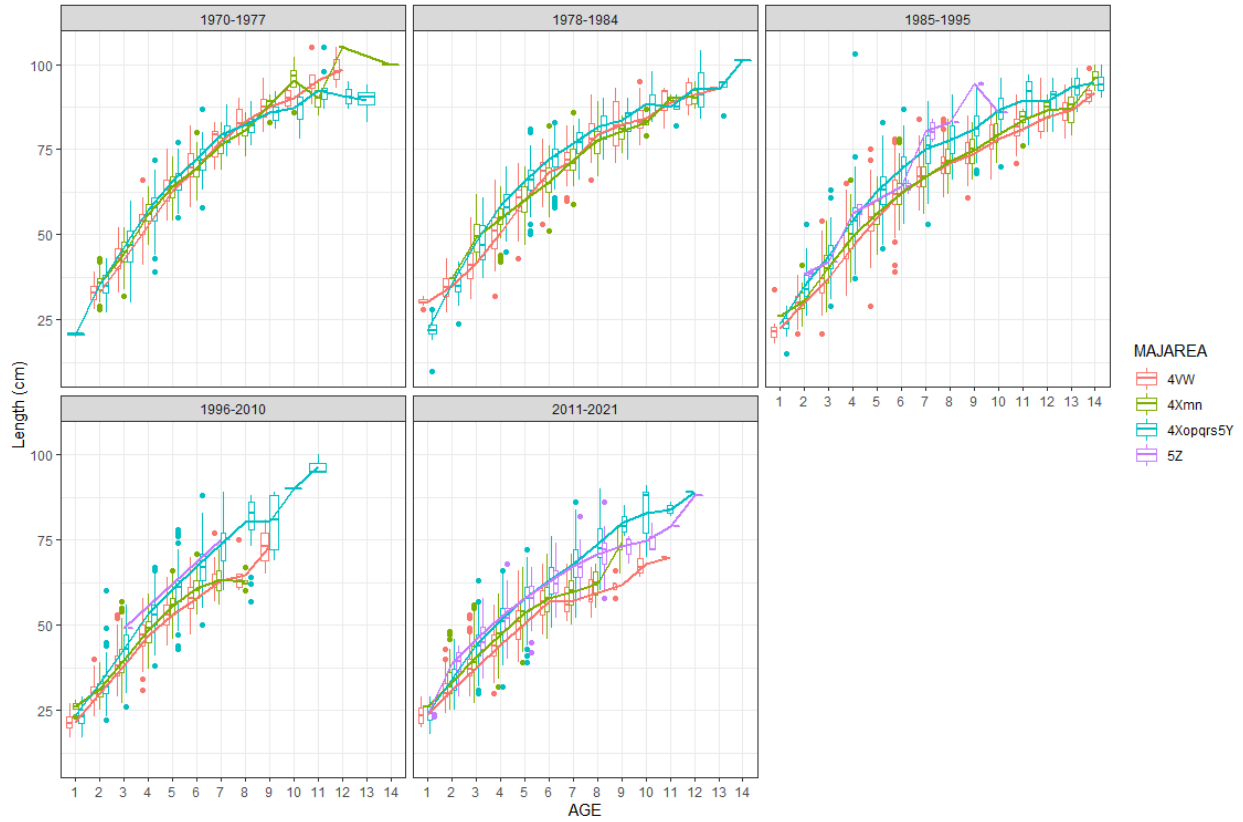


Figure 4. Length-at-age for Pollock by unit area (denoted by colours) and time periods (denoted by facets) from the DFO summer RV survey. Lines denote the mean value. Boxplots show the data distribution around the mean.

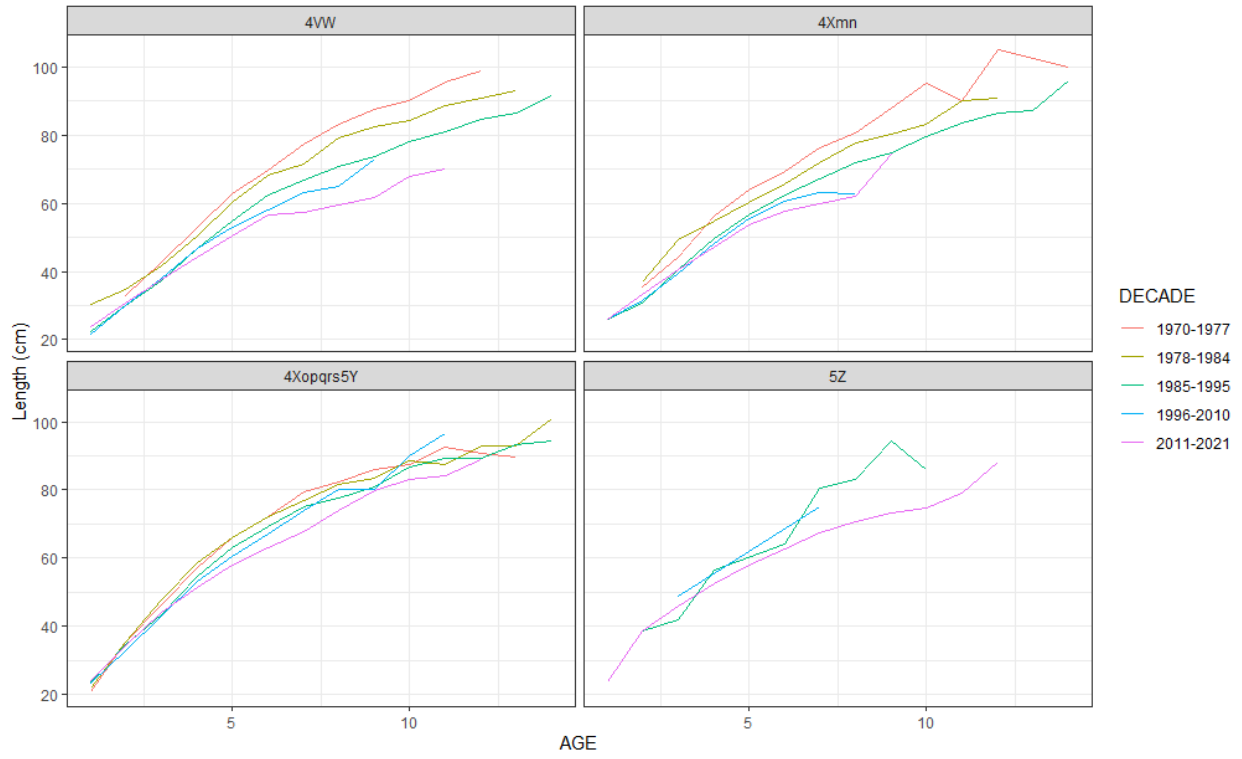


Figure 5. Mean length-at-age for Pollock by unit area (facet) and time periods (colours) from the DFO summer RV survey.

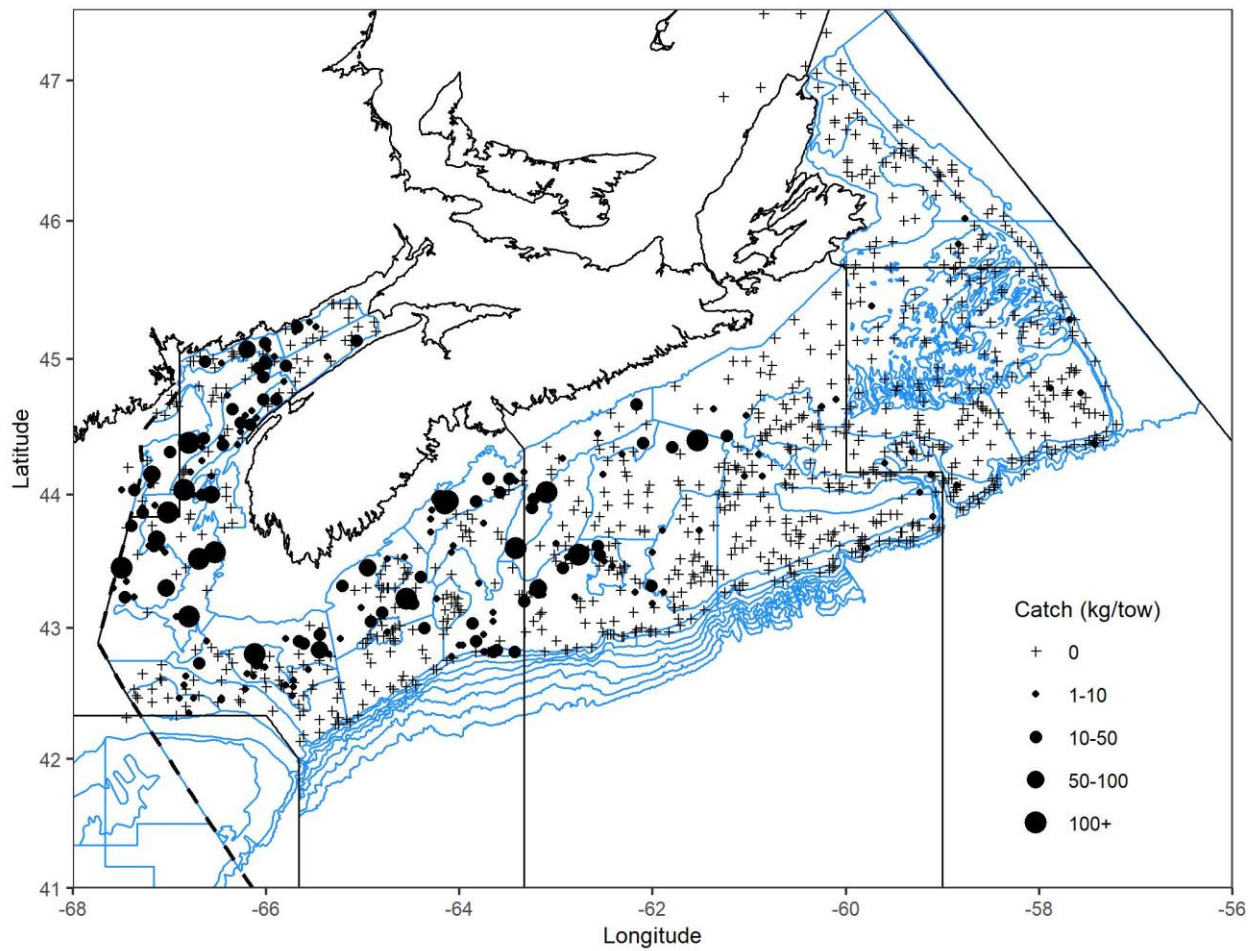


Figure 6. Catches of Pollock (kg/tow) from the DFO summer RV survey from 1970 through 1977. Plus signs indicate null catch. The size of the circle is proportional to the size of the catch. Blue lines indicate approximate depth contours and associated survey strata.

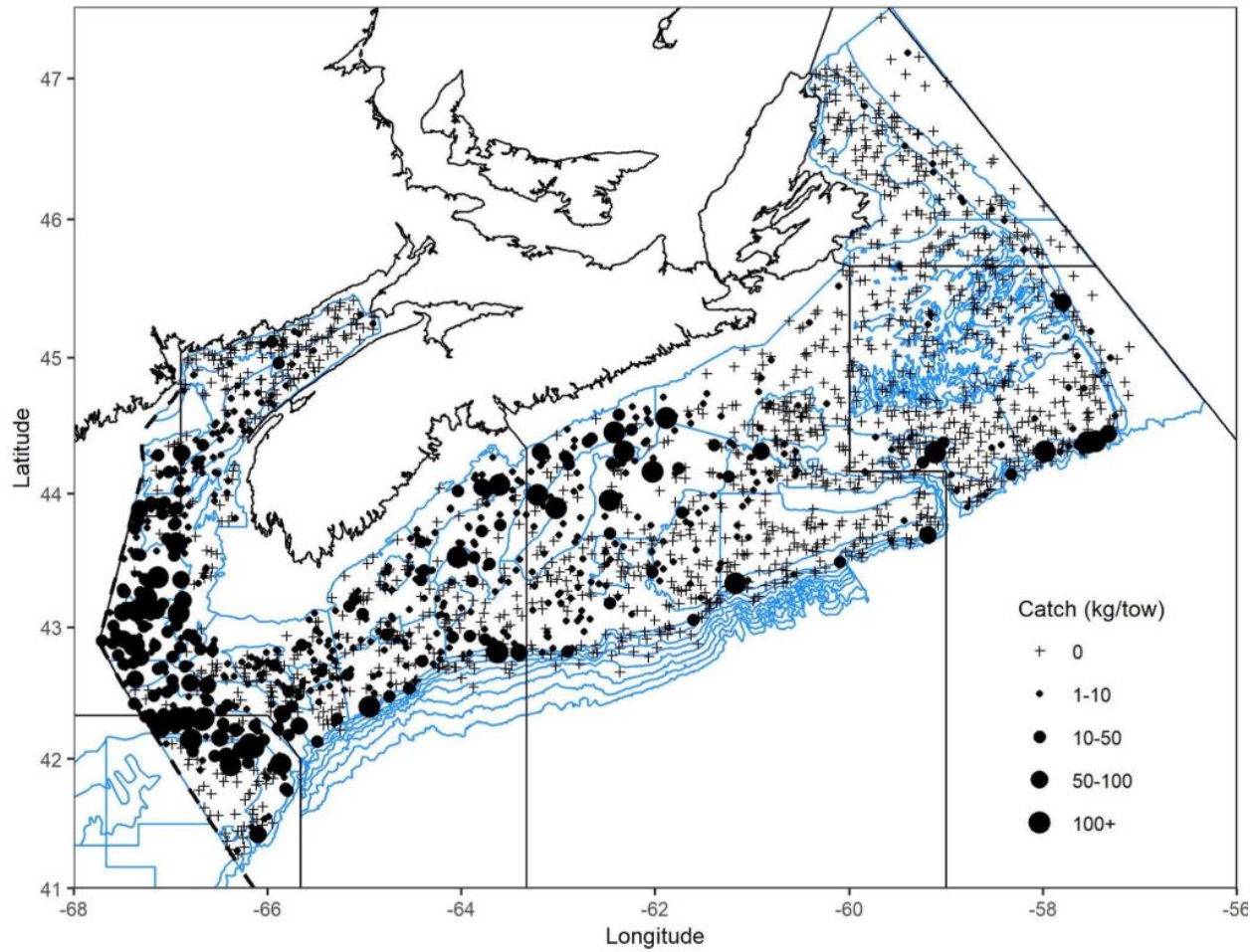


Figure 7. Catches of Pollock (kg/tow) from the DFO summer RV survey from 2011 through 2021. Plus signs indicate null catch. The size of the circle is proportional to the size of the catch. Blue lines indicate approximate depth contours and associated survey strata.

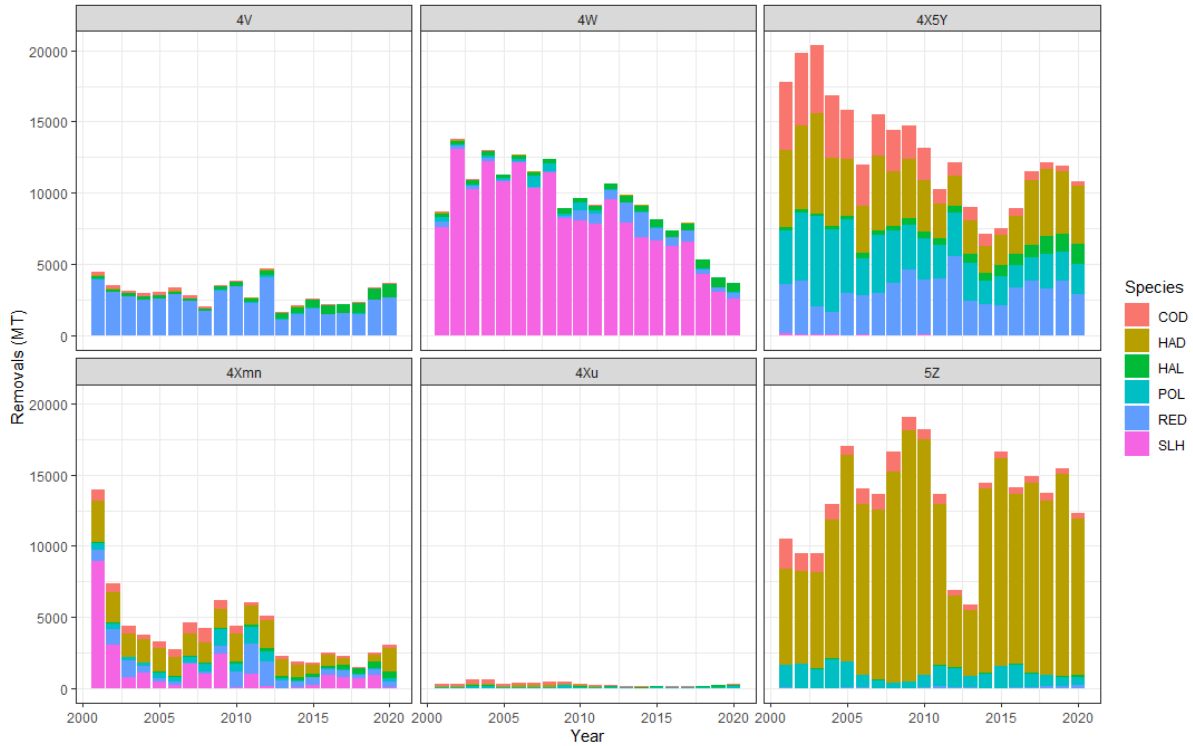


Figure 8. Removals of major groundfish species (colours) in tonnes (MT) across NAFO Divisions and DFO statistical areas (facets). Note that the 4X5Y facet excludes catches from 4Xmn. HAD-Haddock, HAL-Halibut, POL-Pollock, RED-Redfish, SLH-Silver Hake.



Figure 9. Combined removals in tonnes (MT) of major groundfish species (Cod, Haddock, Pollock, Redfish, Halibut, Silver Hake) by the groundfish fishery by gear type (colours) and NAFO division and DFO statistical areas (facet). Note that the 4X5Y facet excludes catches from 4Xmn. HL/LL-Handline/longline, MISC-miscellaneous, OT-Otter trawl.

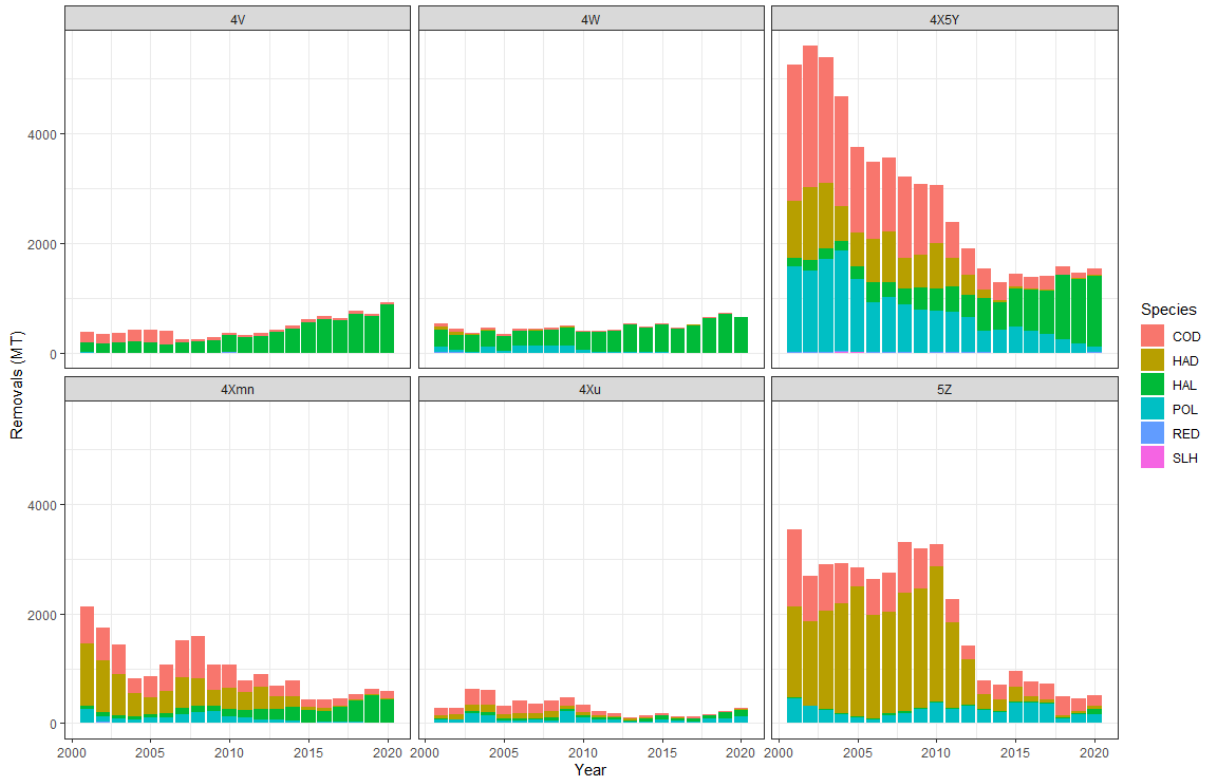


Figure 10. Removals of major groundfish species (colours) in tonnes (MT) across NAFO Divisions and DFO statistical areas (facets) by fixed gear (handline, longline and gillnet). Note that the NAFO Divisions 4X5Y facet excludes catches from 4Xmn. HAD-Haddock, HAL-Halibut, POL-Pollock, RED-Redfish, SLH-Silver Hake.

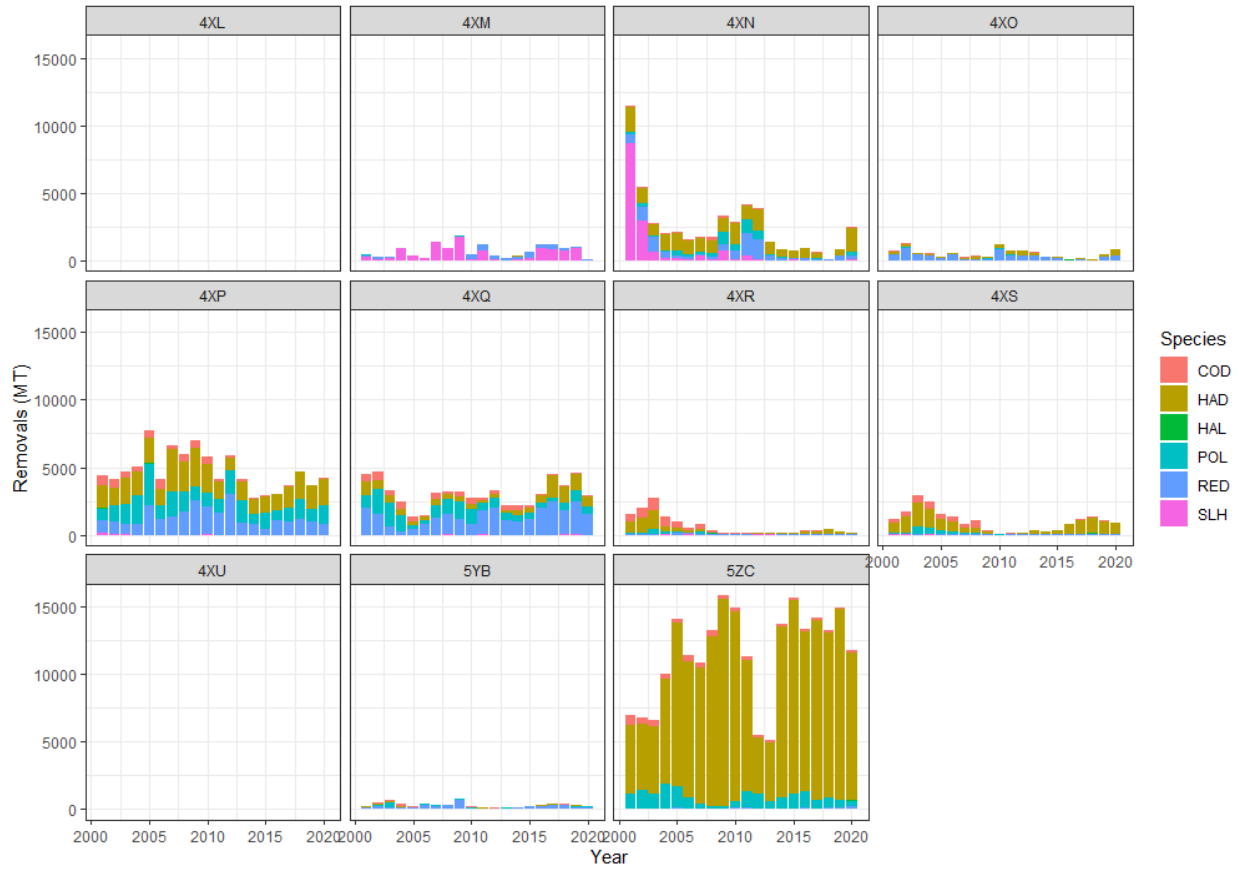


Figure 11. Catches (MT) of major groundfish species in NAFO Divisions 4X5 using mobile (otter trawl) gear. Species are differentiated by colours. Facets represent DFO statistical areas, with the same y axis across all facets. HAD-Haddock, HAL-Halibut, POL-Pollock, RED-Redfish, SLH-Silver Hake.



Figure 12. Catches (mt) of major groundfish species in NAFO Divisions 4X5 using fixed (gillnet, handline and longline) gear. Species are differentiated by colours. Facets represent DFO statistical areas, with the same y axis across all facets. HAD-Haddock, HAL-Halibut, POL-Pollock, RED-Redfish, SLH-Silver Hake.

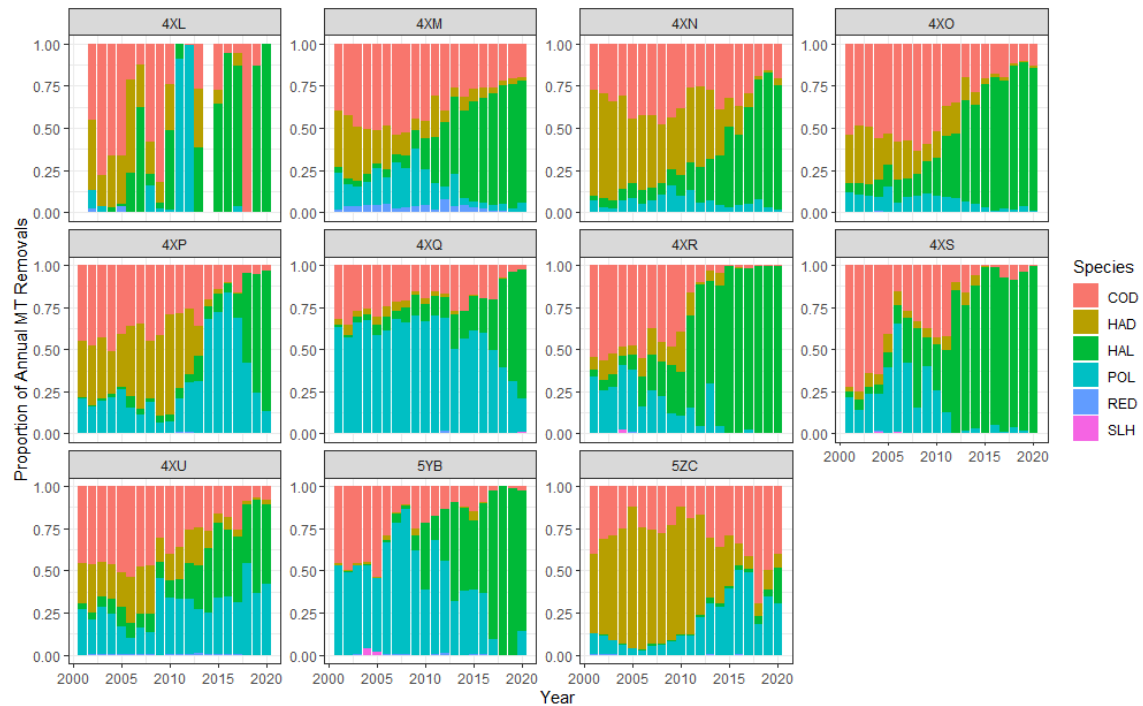


Figure 13. Proportion of total catches of major groundfish species in NAFO Divisions 4X5 using fixed (gillnet, handline and longline) gear. Species are differentiated by colours. Facets represent DFO statistical areas. HAD-Haddock, HAL-Halibut, POL-Pollock, RED-Redfish, SLH-Silver Hake.

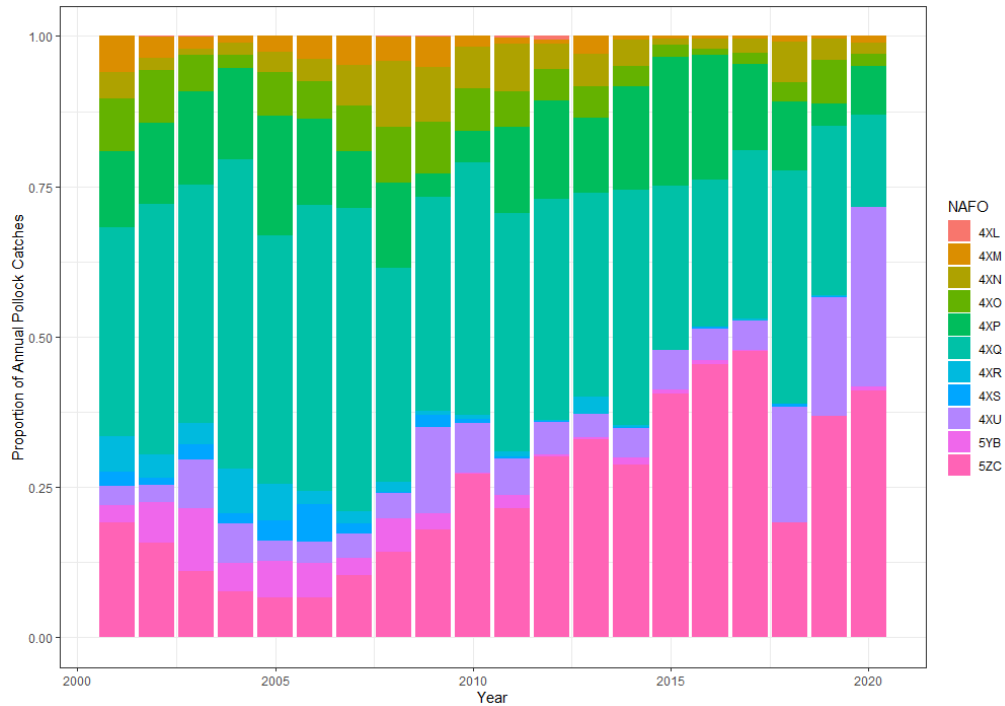


Figure 14. Proportion of annual Pollock removals by fixed gear (handline, longline and gillnet) across DFO statistical areas in NAFO Divisions 4X5.

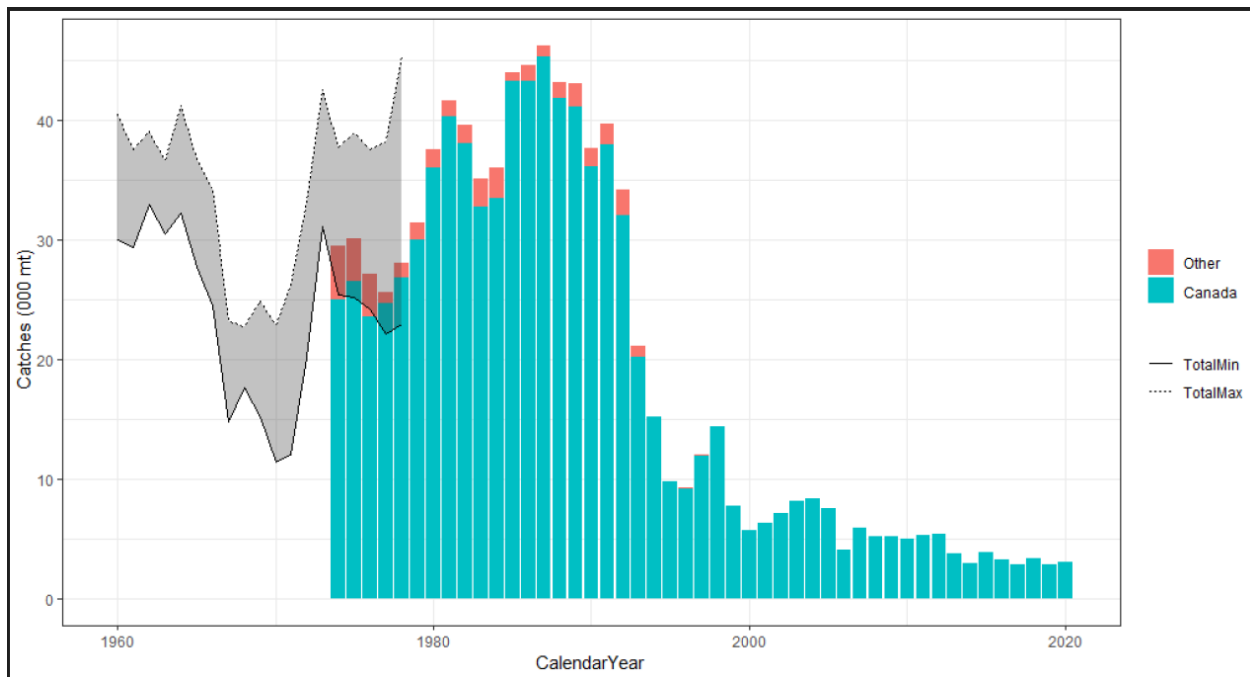


Figure 15. Catches of 4VWX5 Pollock in Canadian waters by Canadian and foreign (colour) entities since 1974 (bars). Catches are reported here by calendar year (Jan 1st – Dec 31st). Data prior to 1974 is subject to a lot of uncertainty, due to the difficulty of distinguishing Canadian and US landings prior to the implementation of the Hague Line, so plausible minimum and maximum bounds of total removals from 4VWX5 are provided. The bounds approach is extended until 1979 for comparative purposes.

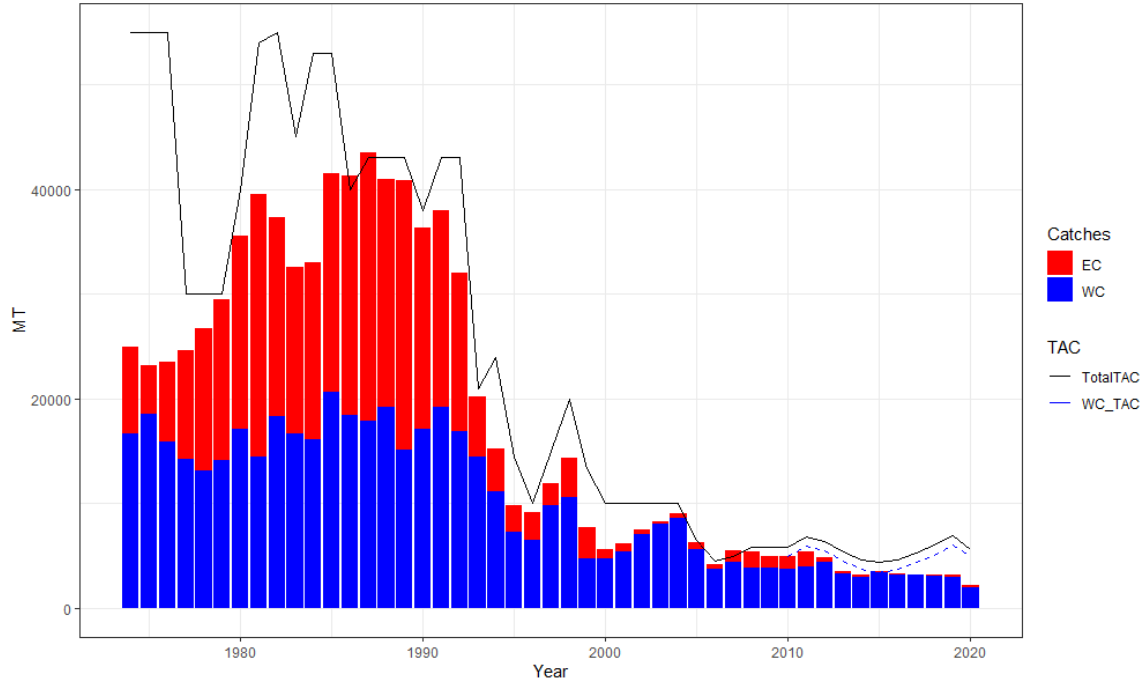


Figure 16. Canadian catches (mt) of Pollock from eastern (EC, red bars) and western (WC, blue bars) components for fishing year (Apr 1 – March 31). Black line indicates combined quota (TotalTAC) for both components. Dashed blue line indicates the quota for just the Western Component (WC_TAC) Management Unit, starting in the 2010 fishing year (April 1, 2010 – March 31, 2011).

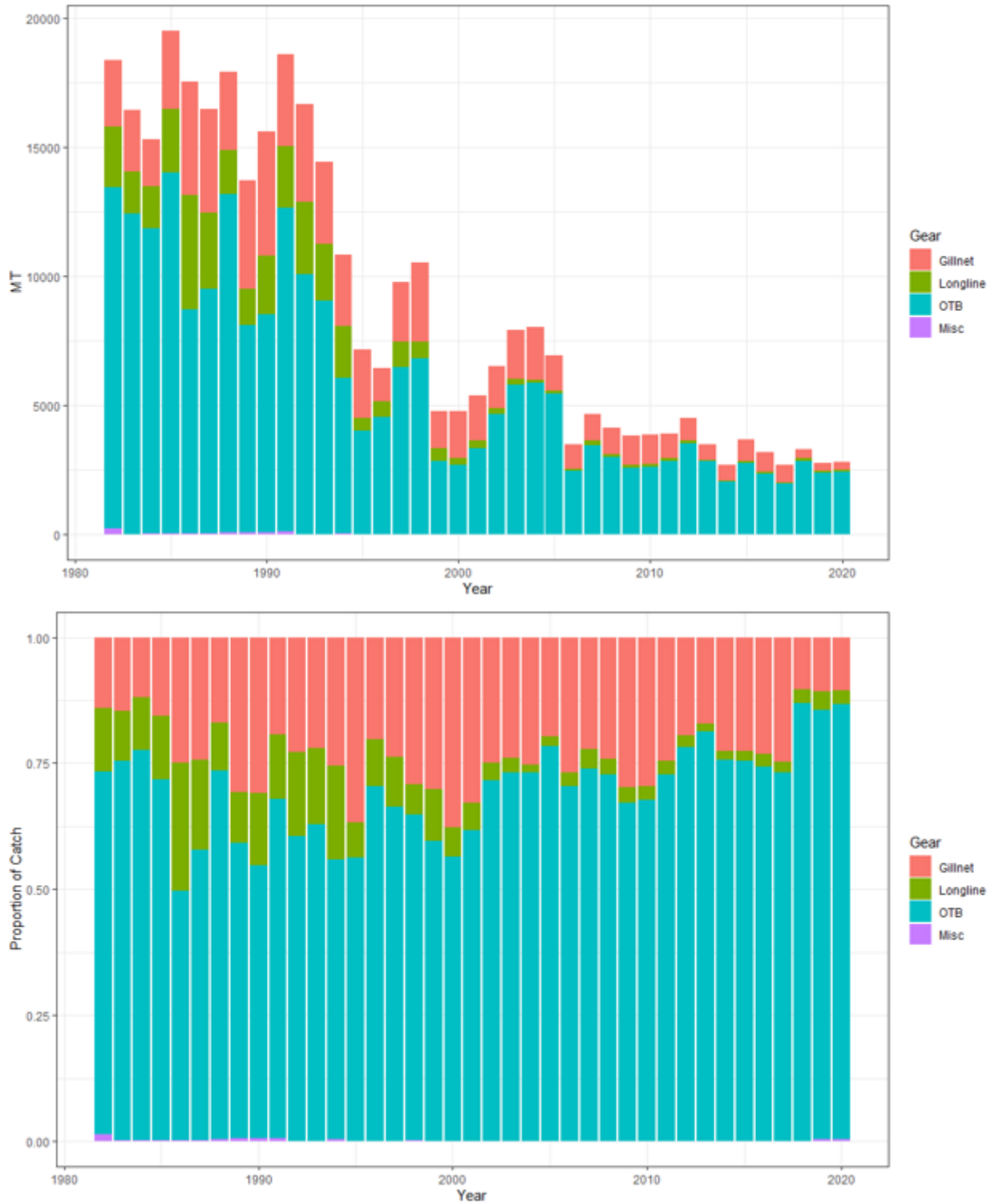


Figure 17. Catches of Pollock in NAFO Divisions 4X5 by gear type in metric tonnes (mt, upper panel) and as proportion of total annual catch (bottom panel).

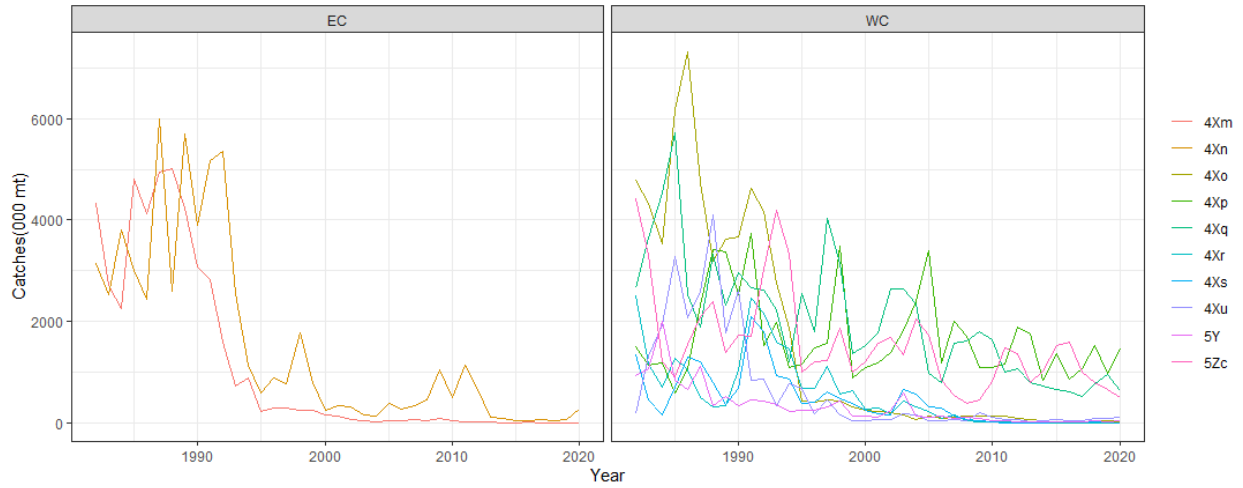


Figure 18. Commercial Canadian catches of Pollock in NAFO Divisions 4X5 broken down by DFO statistical area (colours) and eastern (left panel) and western (right panel) components.

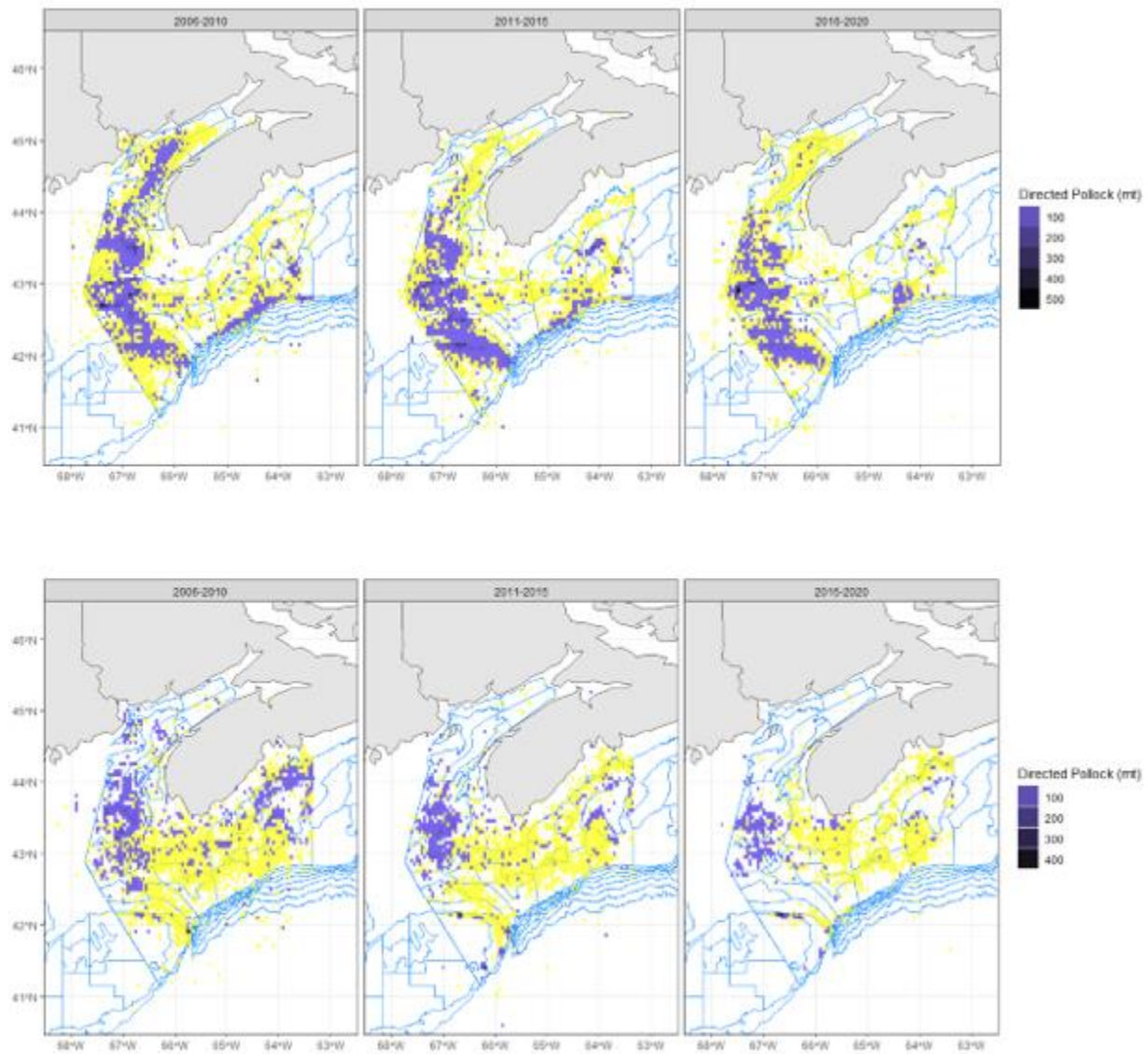


Figure 19. Set-level catches of Pollock aggregated into three minute spatial blocks and five year time blocks. Purple tiles identify Pollock-directed effort, as defined in the Bycatch section, while yellow records identify Pollock catch on non-Pollock-directed sets. Top row shows catches by mobile gear, and bottom row shows catches by fixed gear.

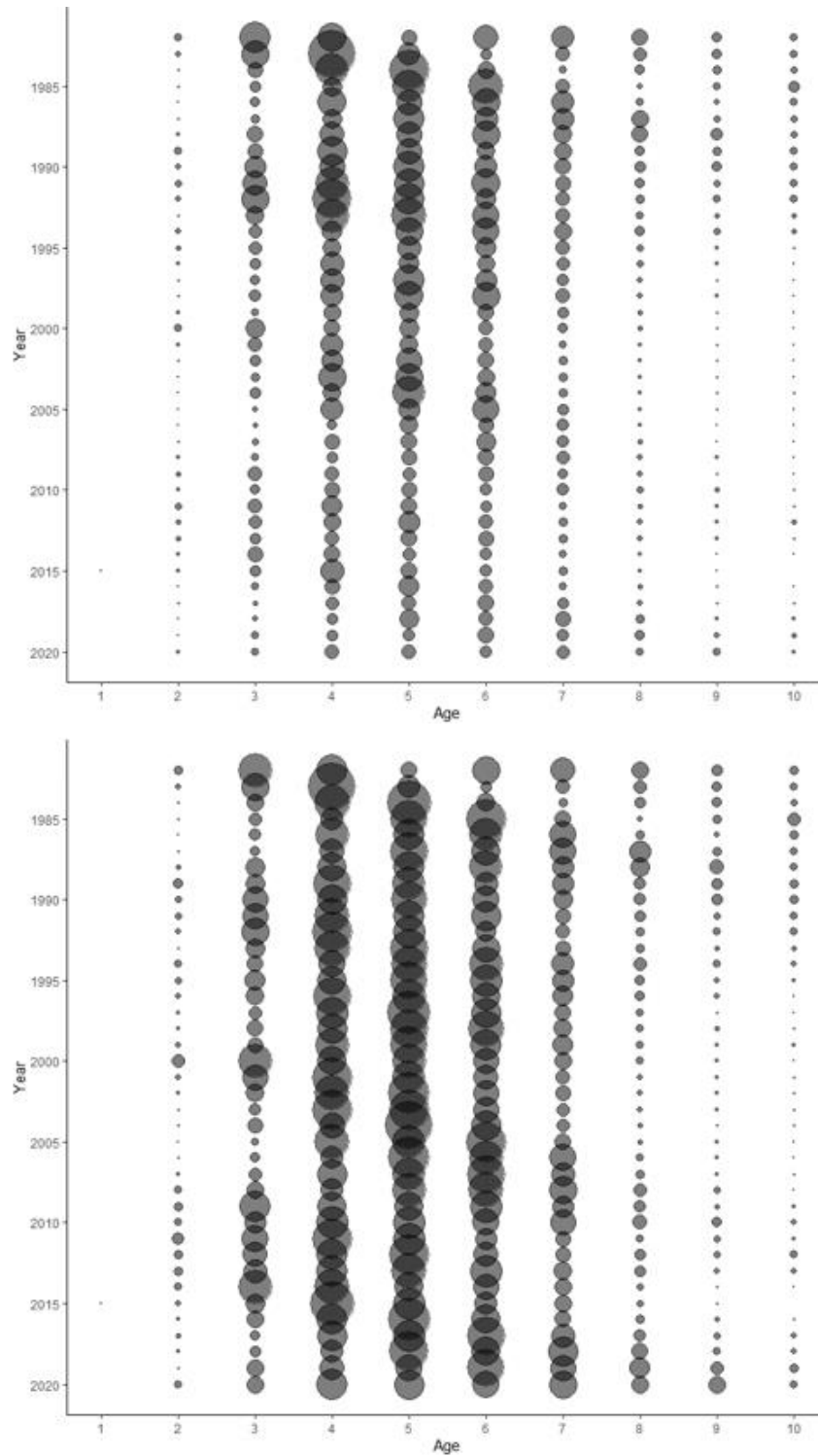


Figure 20. Commercial catch age for the western component Pollock (4Xopqrs5YZ) fishery. Top panel: size of the bubble represents abundance at age. Bottom panel: size of the bubble represents proportion at age.

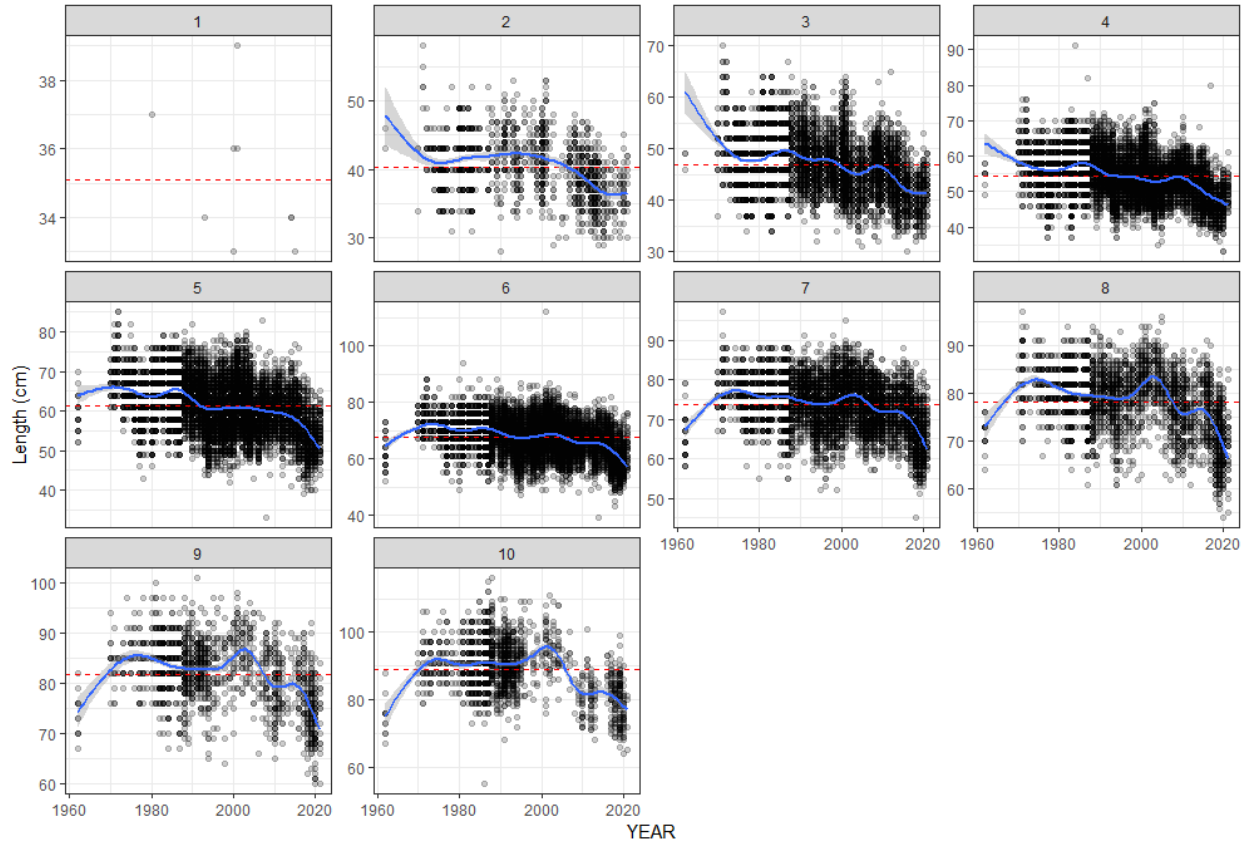


Figure 21. Length-at-age for western component Pollock port samples (4Xopqrs5). Dashed lines indicate the series mean for each age (facet) and blue line is a smoother. Facet for Age 10 represents the plus group (Ages 10+).



Figure 22. Length-at-age for Pollock port samples in the WC in NAFO subareas 4Xopqrs5 (red) and division 5Z (black). Dashed lines indicates the 95% CIs, and horizontal line is the series mean for each age (facet).

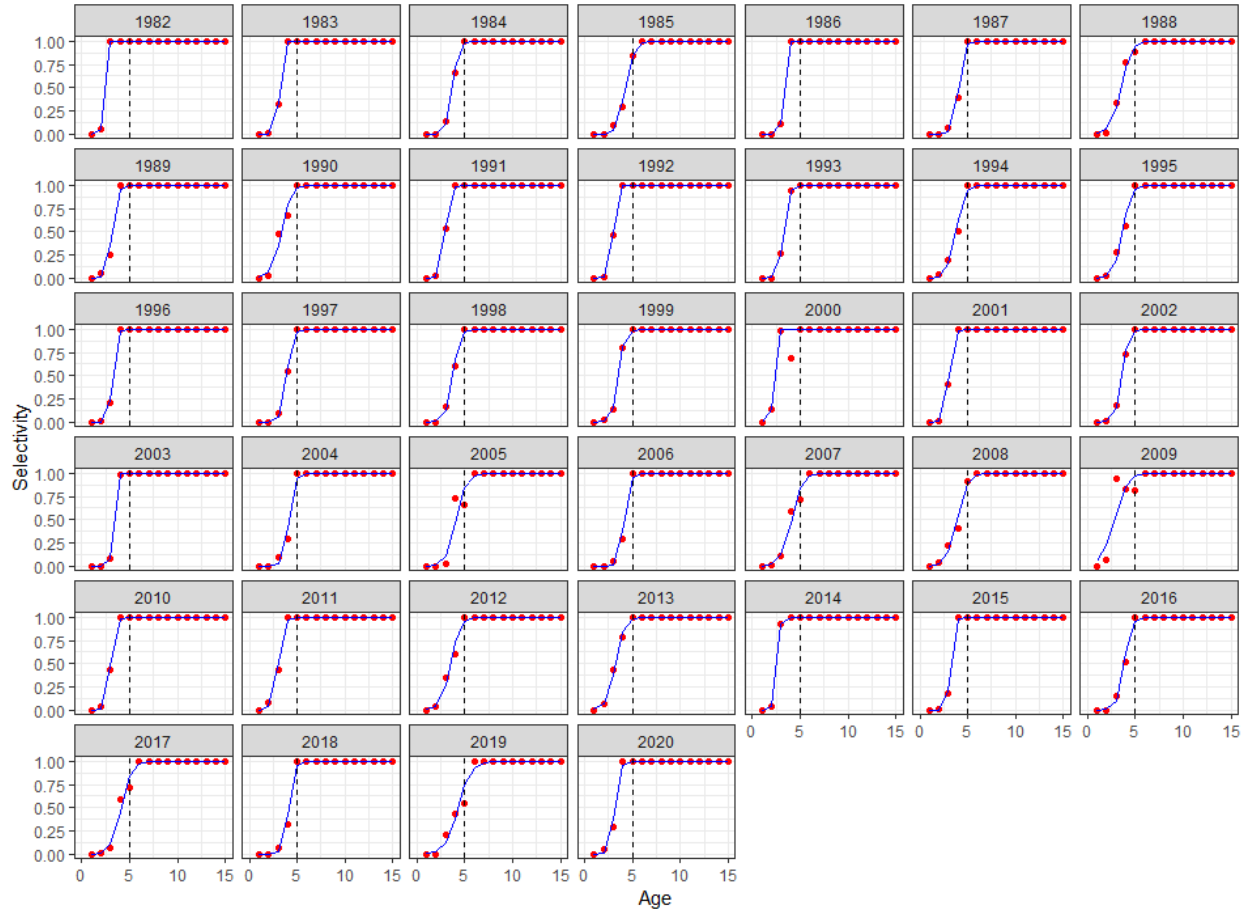


Figure 23. Selectivity-at-age calculated for the WC Pollock commercial fishery catch at age. Red points indicate raw data with a flat top imposed after the first age at which 95% selectivity is reached. Blue line shows a logistic curve fit to the data. A vertical line is arbitrarily drawn at age 5 to help interpret the plots.

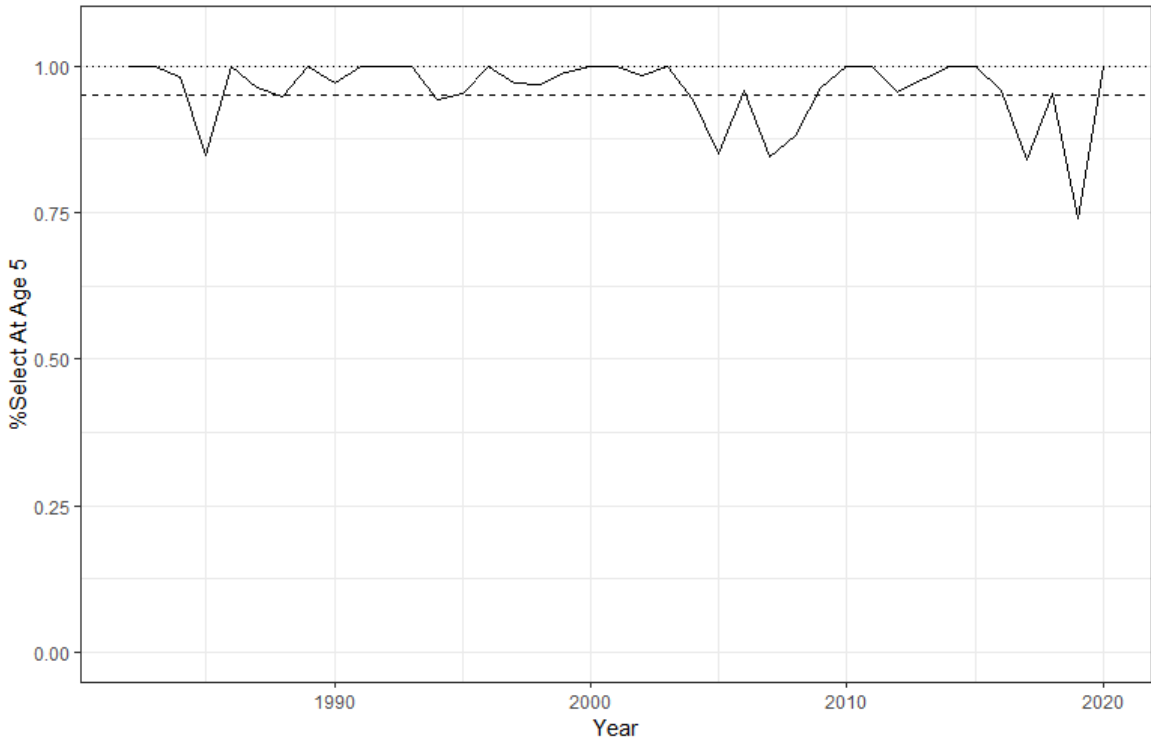


Figure 24. Percent selectivity for age 5 Pollock within each year. Horizontal lines depict 1 (fine dashed) and 0.95 (coarse dashed) for reference.

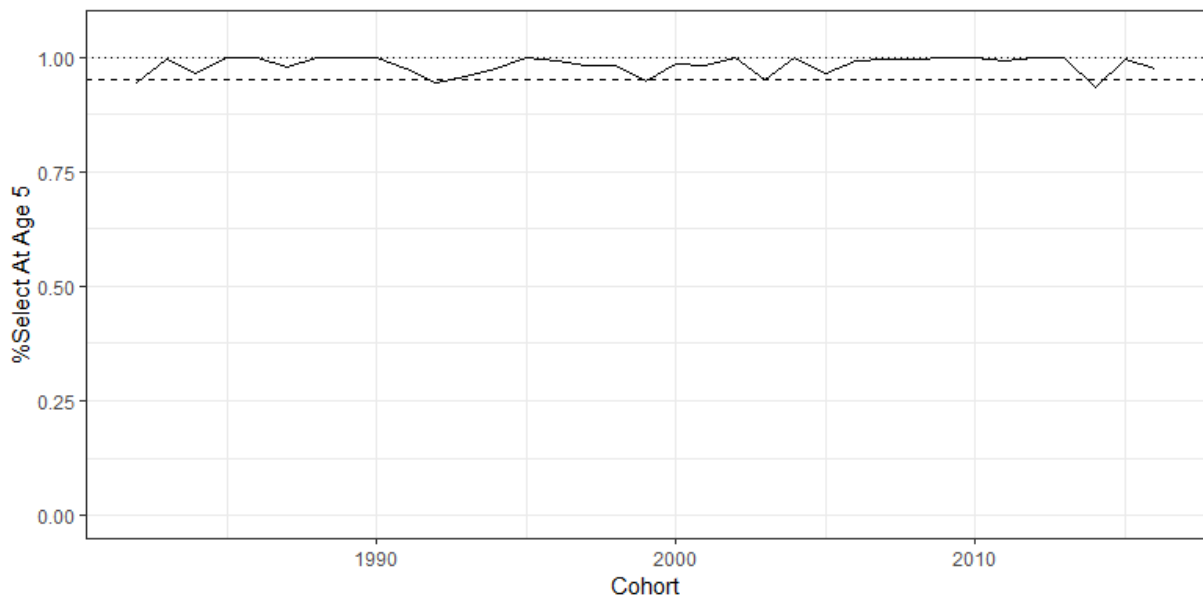


Figure 25. Percent selectivity for age 5 Pollock within each cohort. Horizontal lines depict 1 (fine dashed) and 0.95 (coarse dashed) for reference.

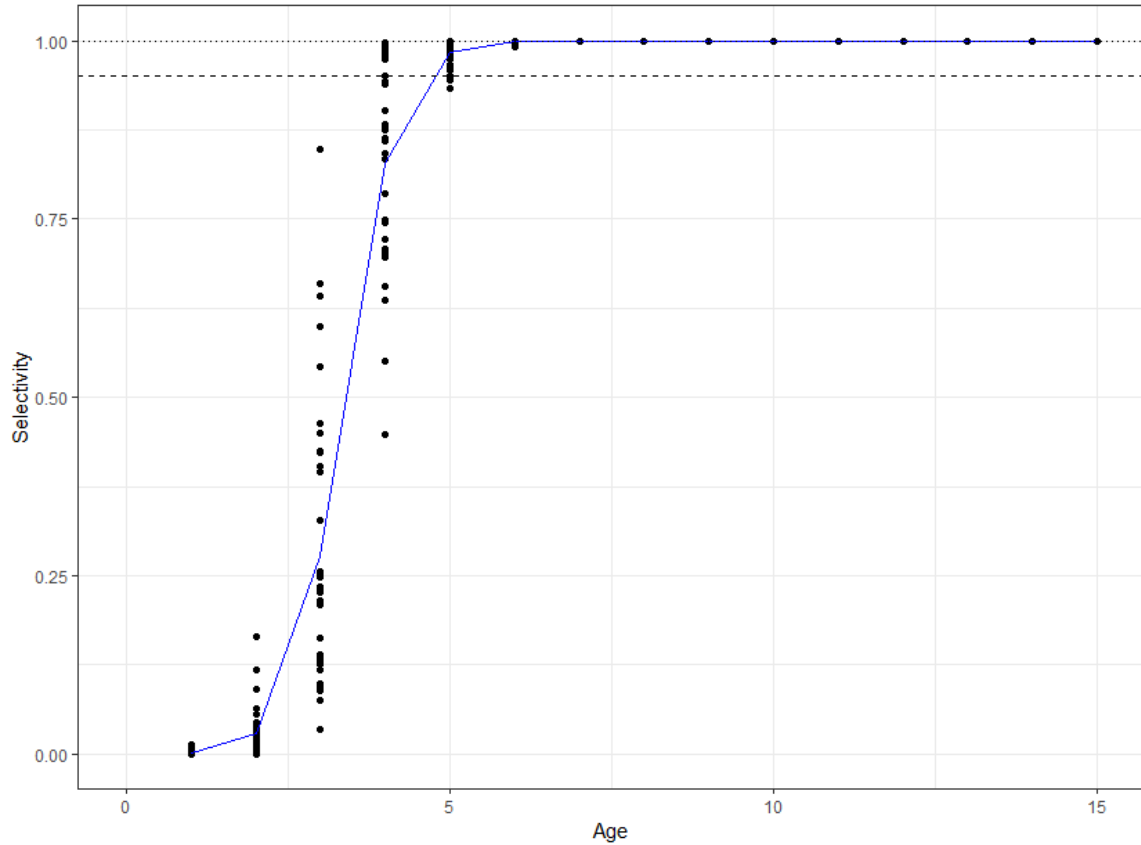


Figure 26. Selectivity curve calculated across Pollock cohorts since 1985. Horizontal lines depict 1 (fine dashed) and 0.95 (coarse dashed) for reference.

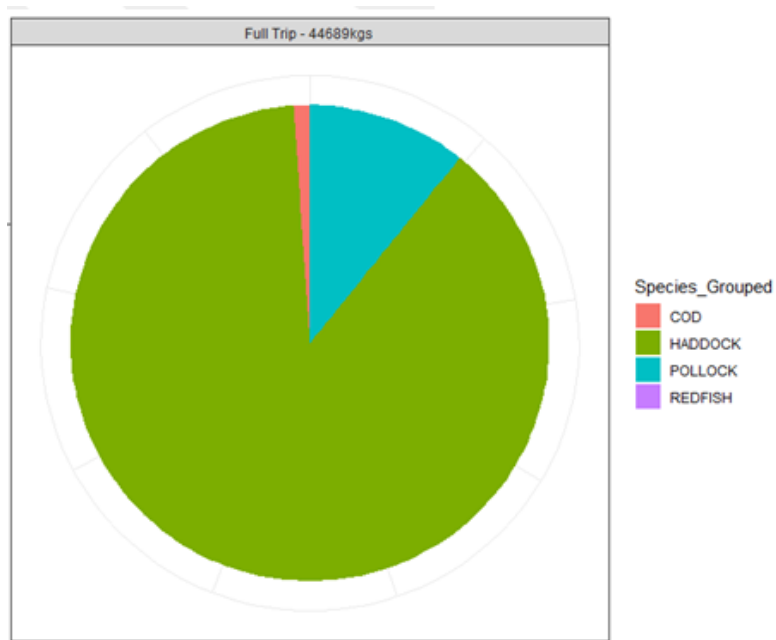


Figure 27. Total catch composition of an example trip A based on the weight of nine major groundfish species examined. The value in the header shows the total weight of all major groundfish species on this trip.

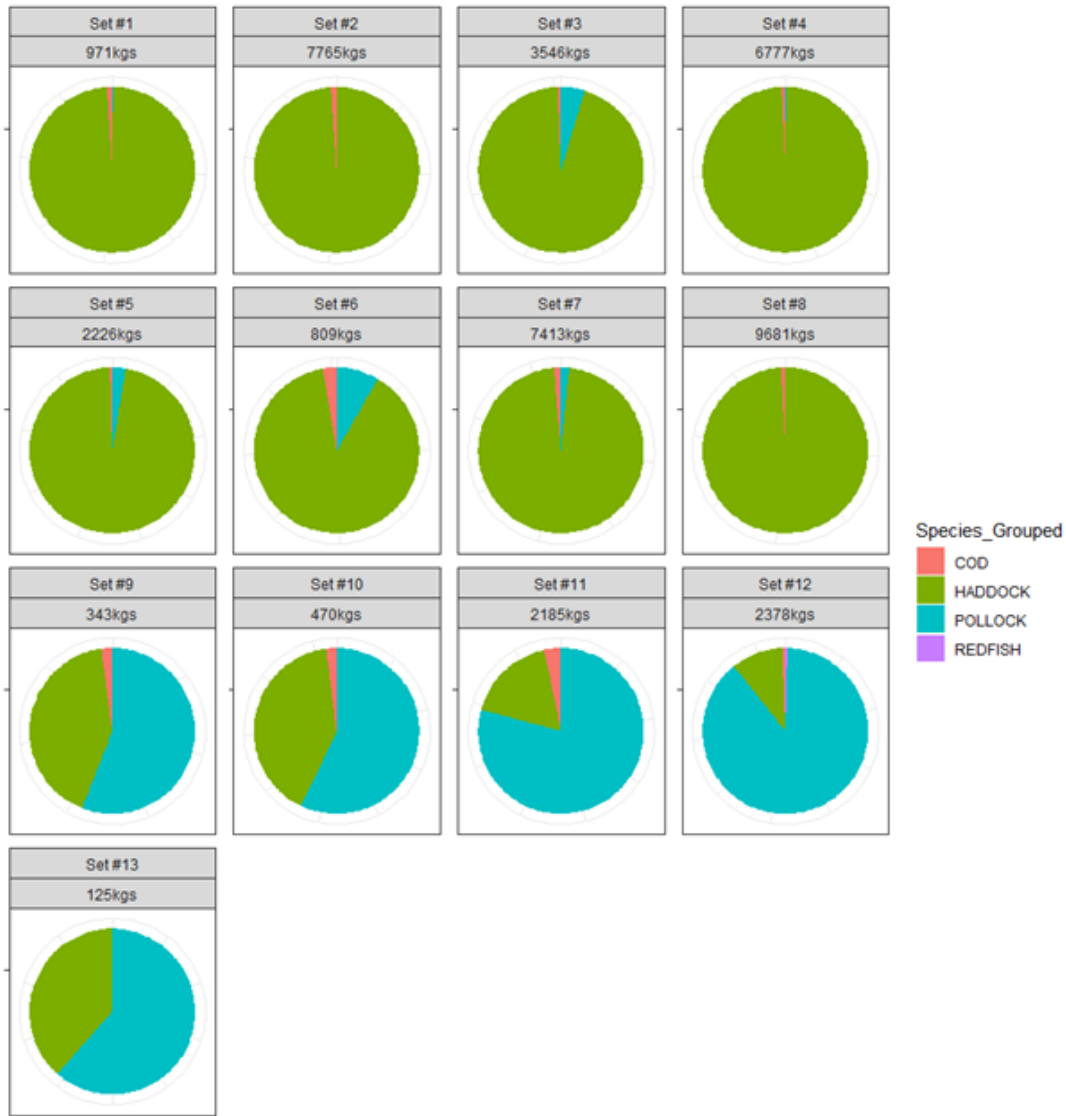


Figure 28. Set-level catch composition of an example trip A based on the weight of nine major groundfish species examined. The value in each header shows the total weight of all major groundfish species on that set.

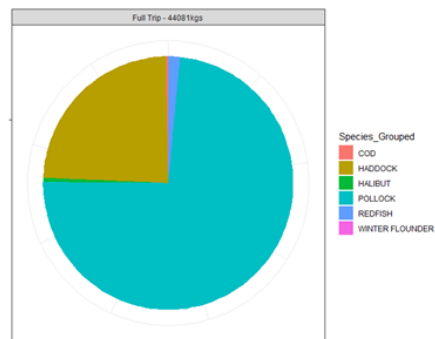


Figure 29. Total catch composition of an example trip B based on the weight of nine major groundfish species examined. The value in the header shows the total weight of all major groundfish species on this trip.

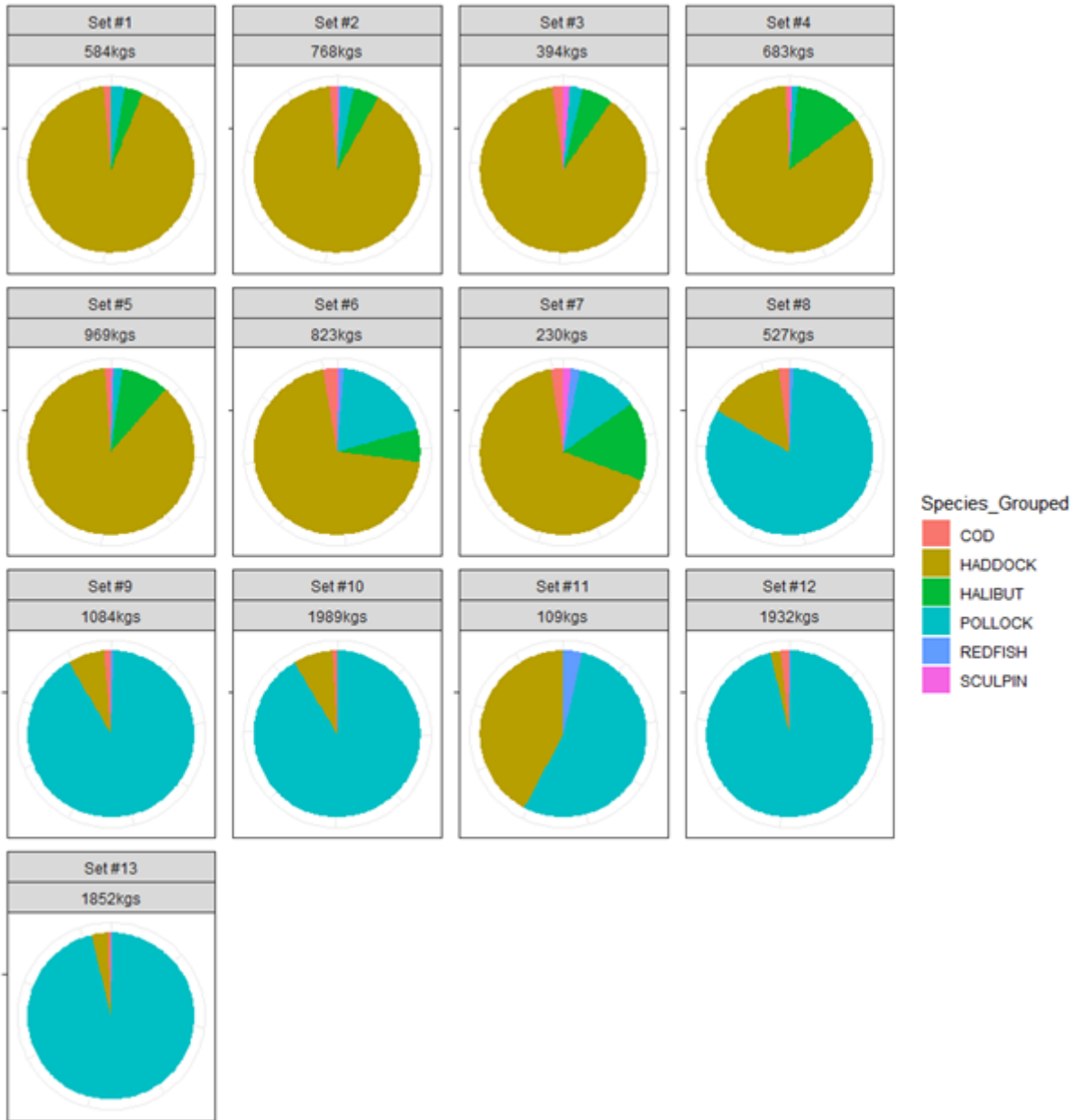


Figure 30. Set-level catch composition of an example trip A based on the weight of nine major groundfish species examined. The value in each header shows the total weight of all major groundfish species on that set.

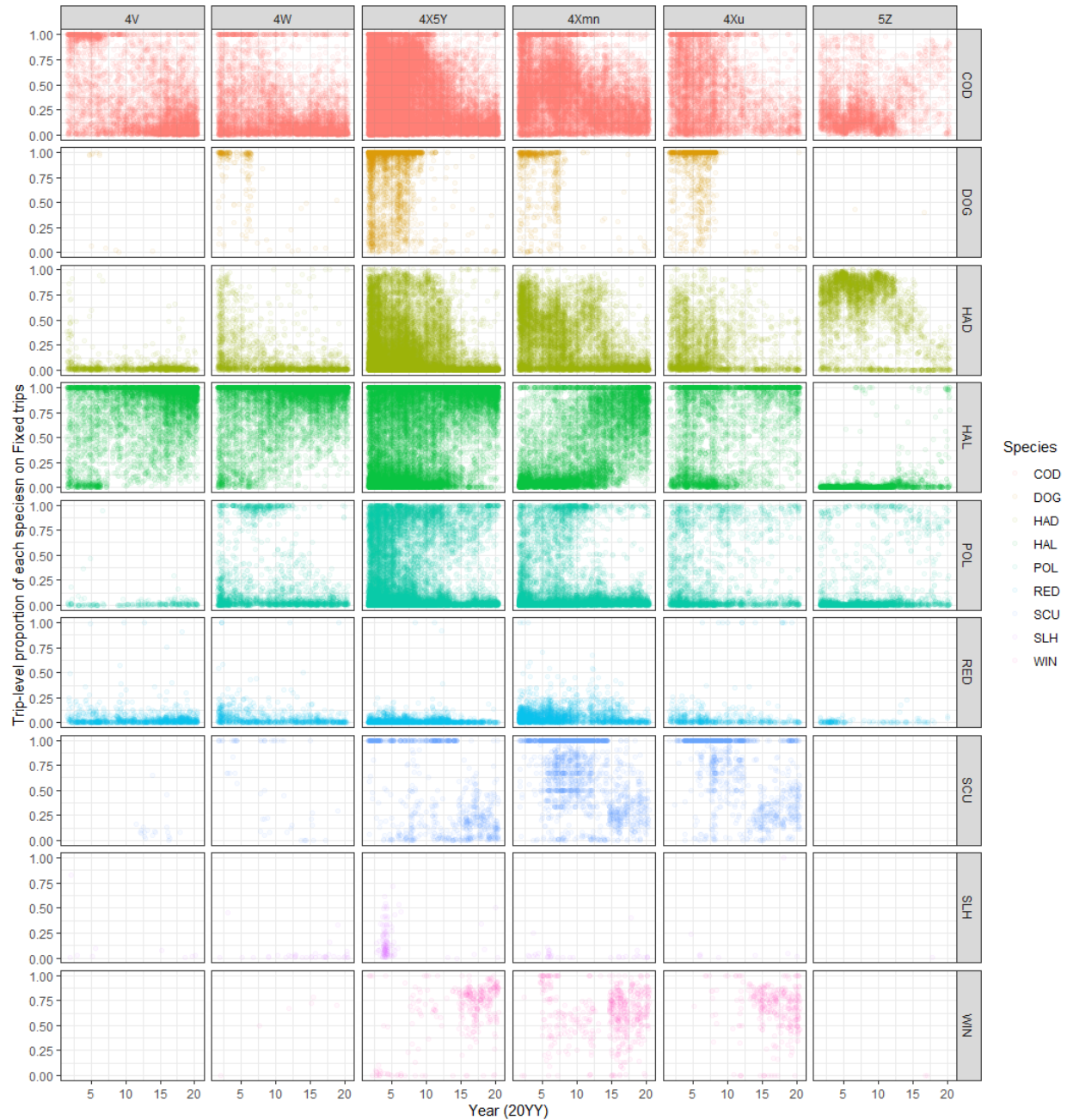


Figure 32. Set-level proportion of each major groundfish species of total groundfish catch on that set (rows), by NAFO Divisions and DFO statistical area (columns) for fixed gear. The red line denotes the 50% mark. Note that NAFO Divisions 4X5Y excludes 4Xmn. HAD-Haddock, HAL-Halibut, POL-Pollock, RED-Redfish, SLH-Silver Hake.

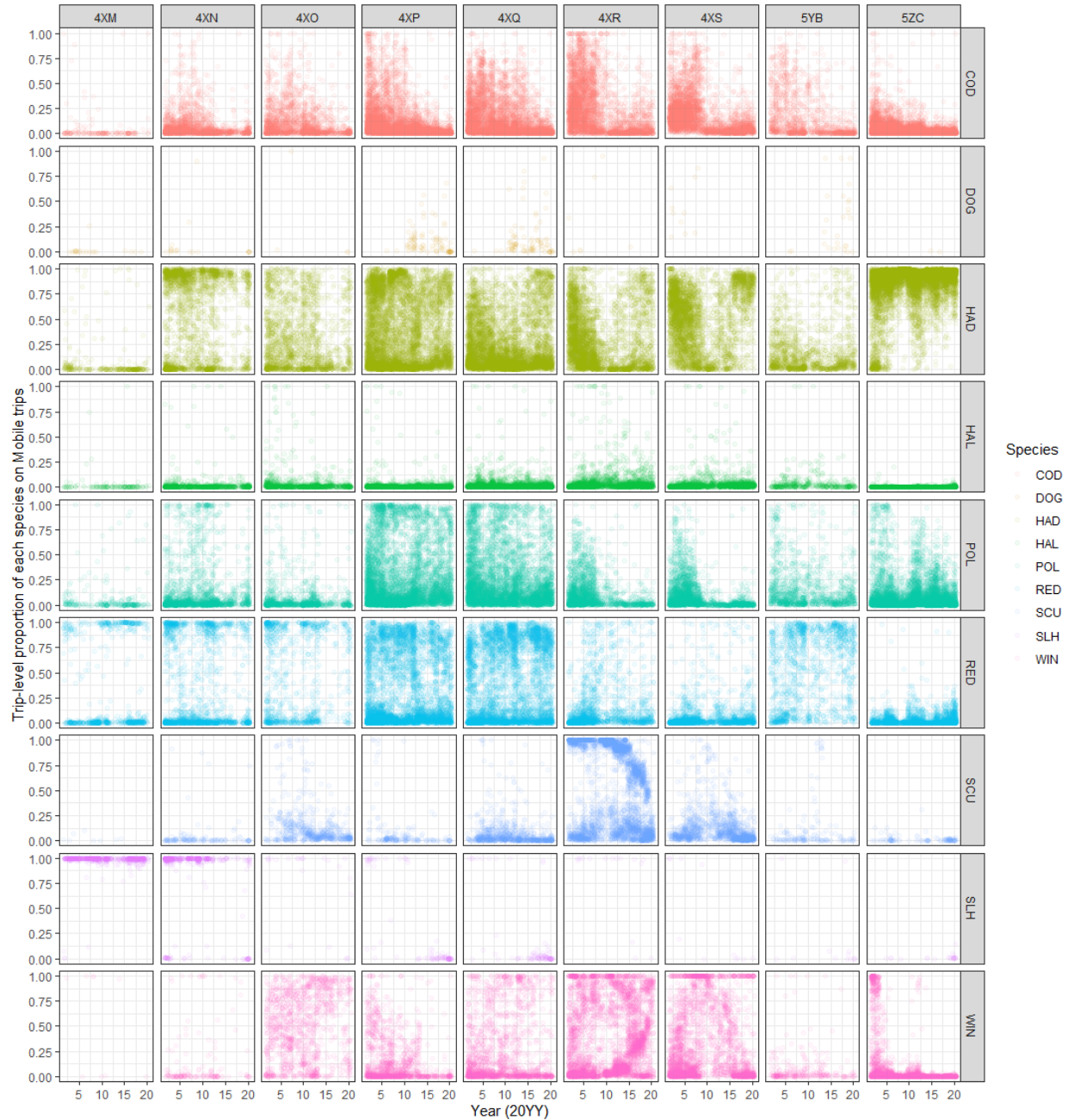


Figure 33. Set-level proportion of each major groundfish species of total groundfish catch on that set (rows), by DFO statistical area (columns) within NAFO Divisions 4X5Y for mobile gear. DOG-Dogfish, HAD-Haddock, HAL-Halibut, POL-Pollock, RED-Redfish, SCU-Sculpin, SLH-Silver Hake, WIN-Winter Flounder.

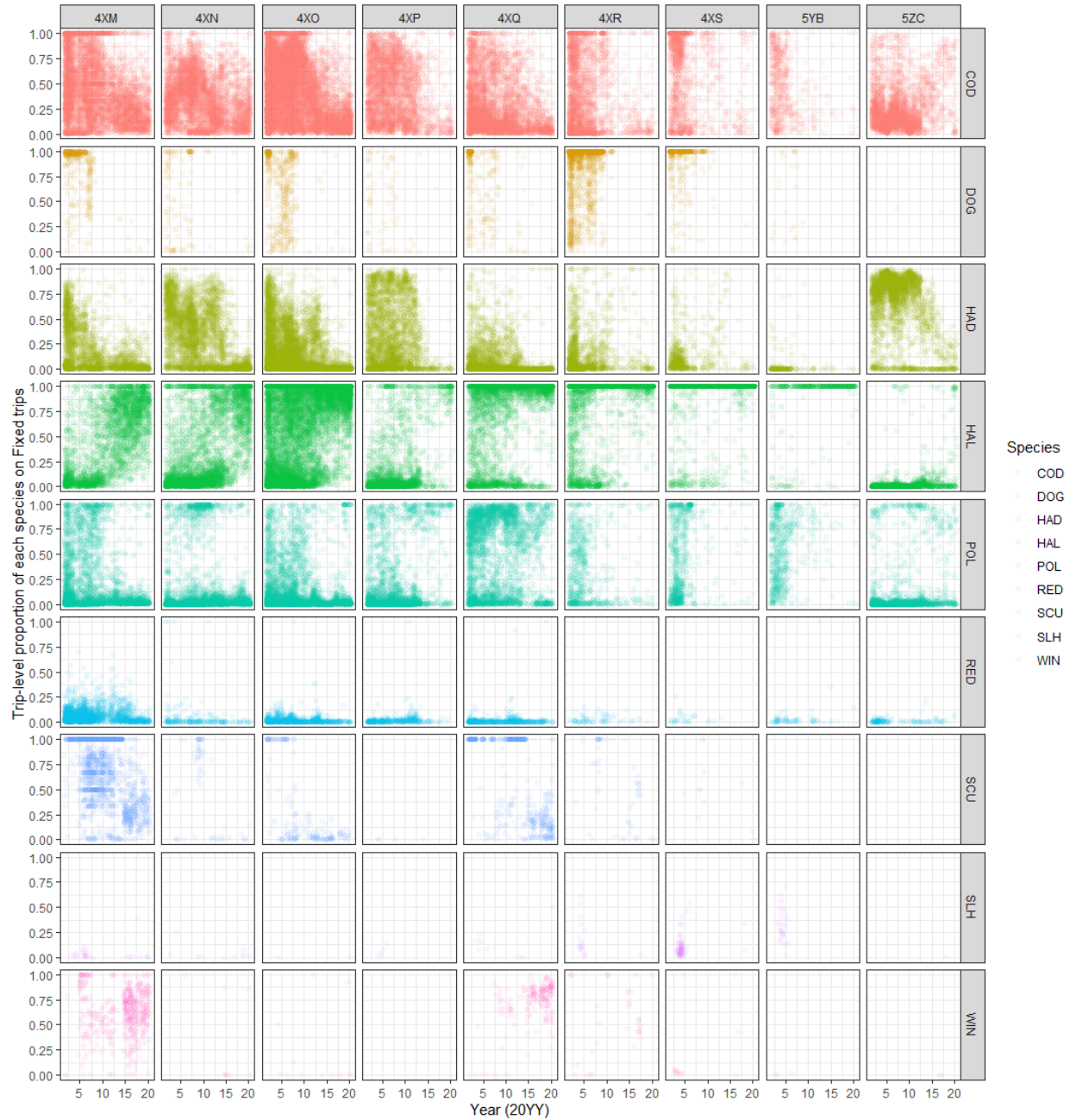


Figure 34. Set-level proportion of each major groundfish species of total groundfish catch on that set (rows), by DFO statistical areas (columns) within 4X5Y for fixed gear. DOG-Dogfish, HAD-Haddock, HAL-Halibut, POL-Pollock, RED-Redfish, SCU-Sculpin, SLH-Silver Hake, WIN-Winter Flounder.

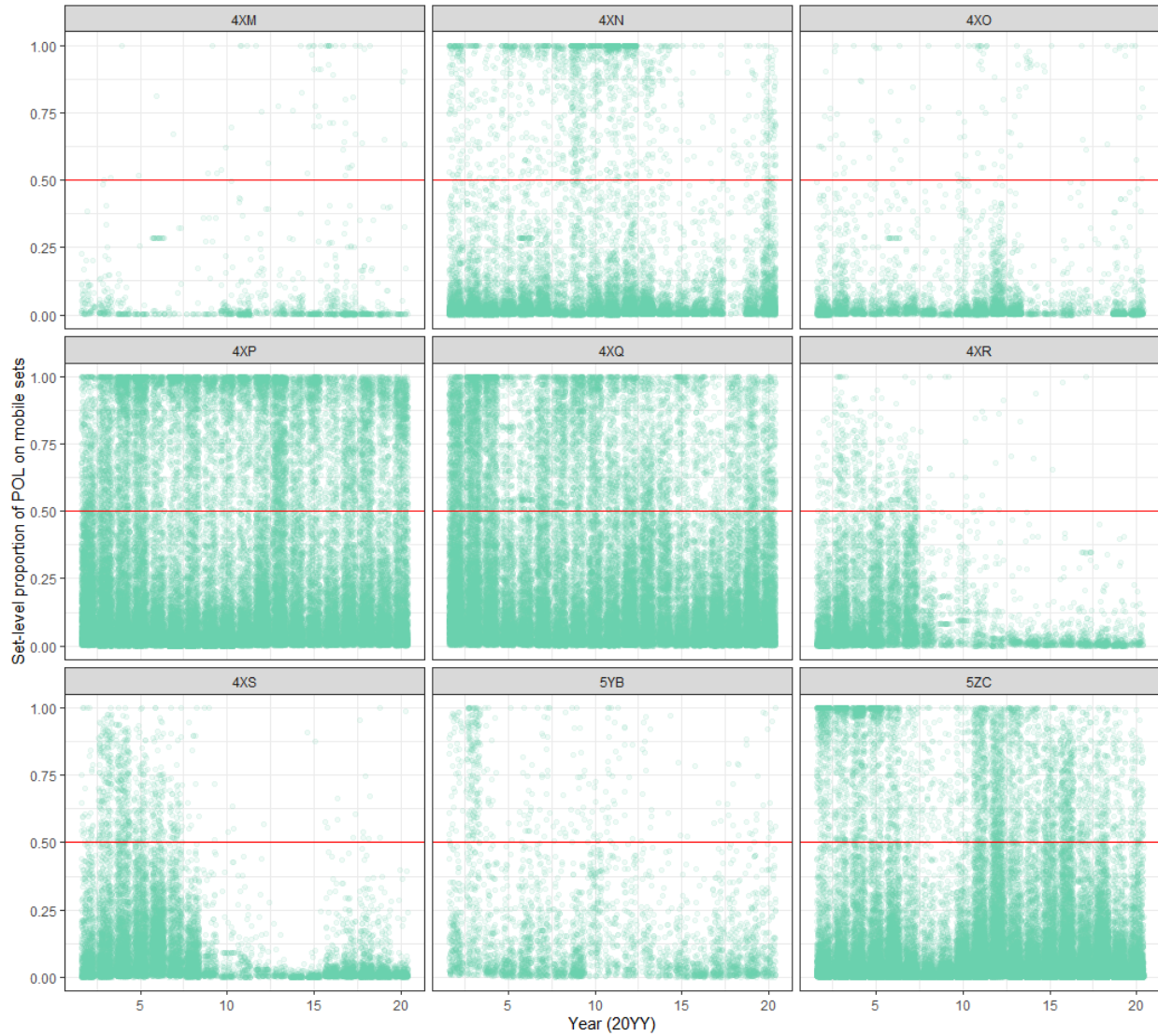


Figure 35. Set-level proportion of Pollock out of the total major groundfish species catch on that trip, by NAFO Divisions and DFO statistical areas (columns) within 4X5 for mobile gear. The red line denotes the 50% mark.



Figure 36. Set-level proportion of Pollock out of the total major groundfish species catch on that trip, by DFO statistical areas (columns) within 4X5 for fixed gear. The red line denotes the 50% mark.

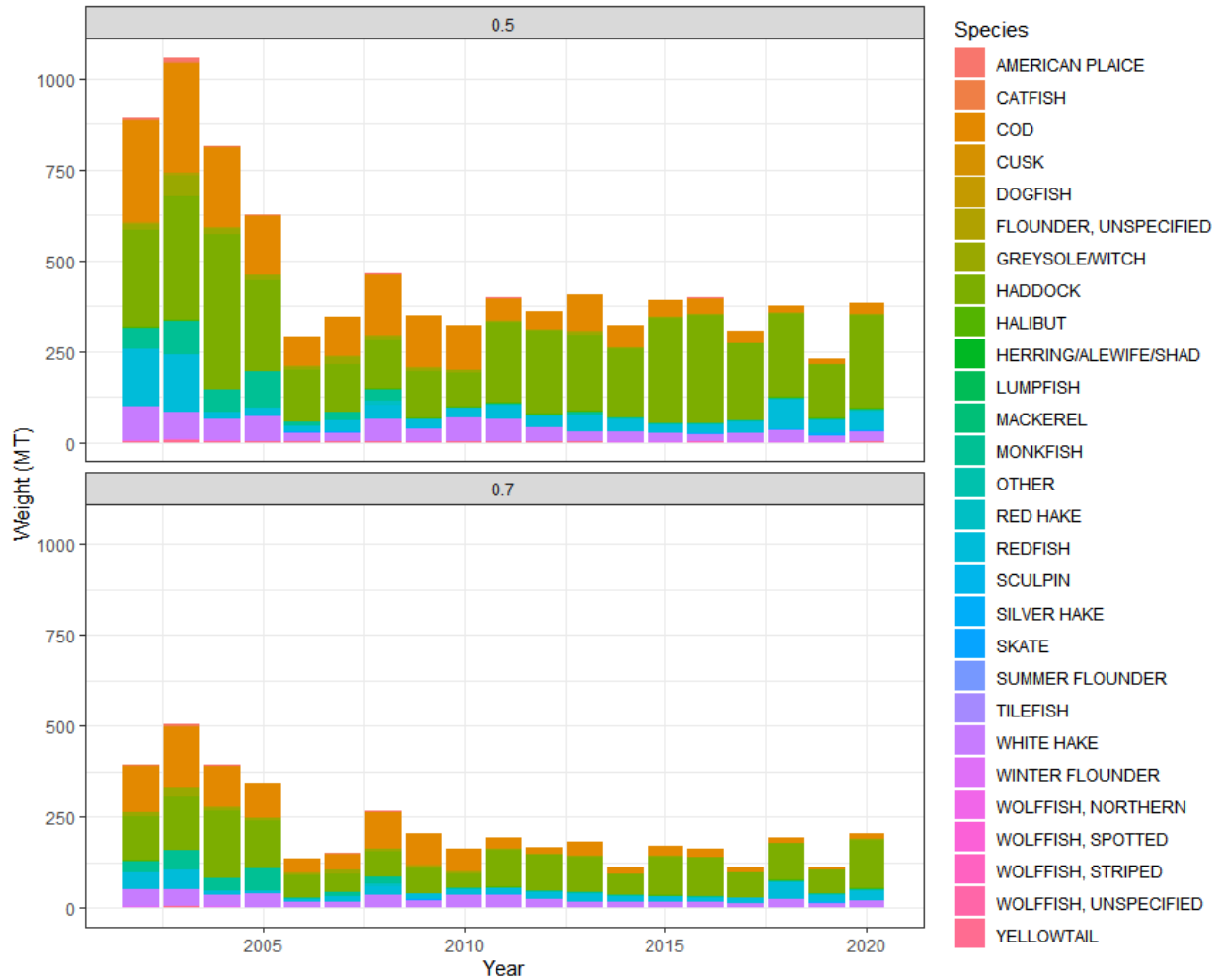


Figure 37. Bycatch of species (colour) by weight caught on Pollock-directed sets by mobile gear in 4X5. Facets represent a > 50% cut-off and a > 70% cut-off for definition of a Pollock-directed set.

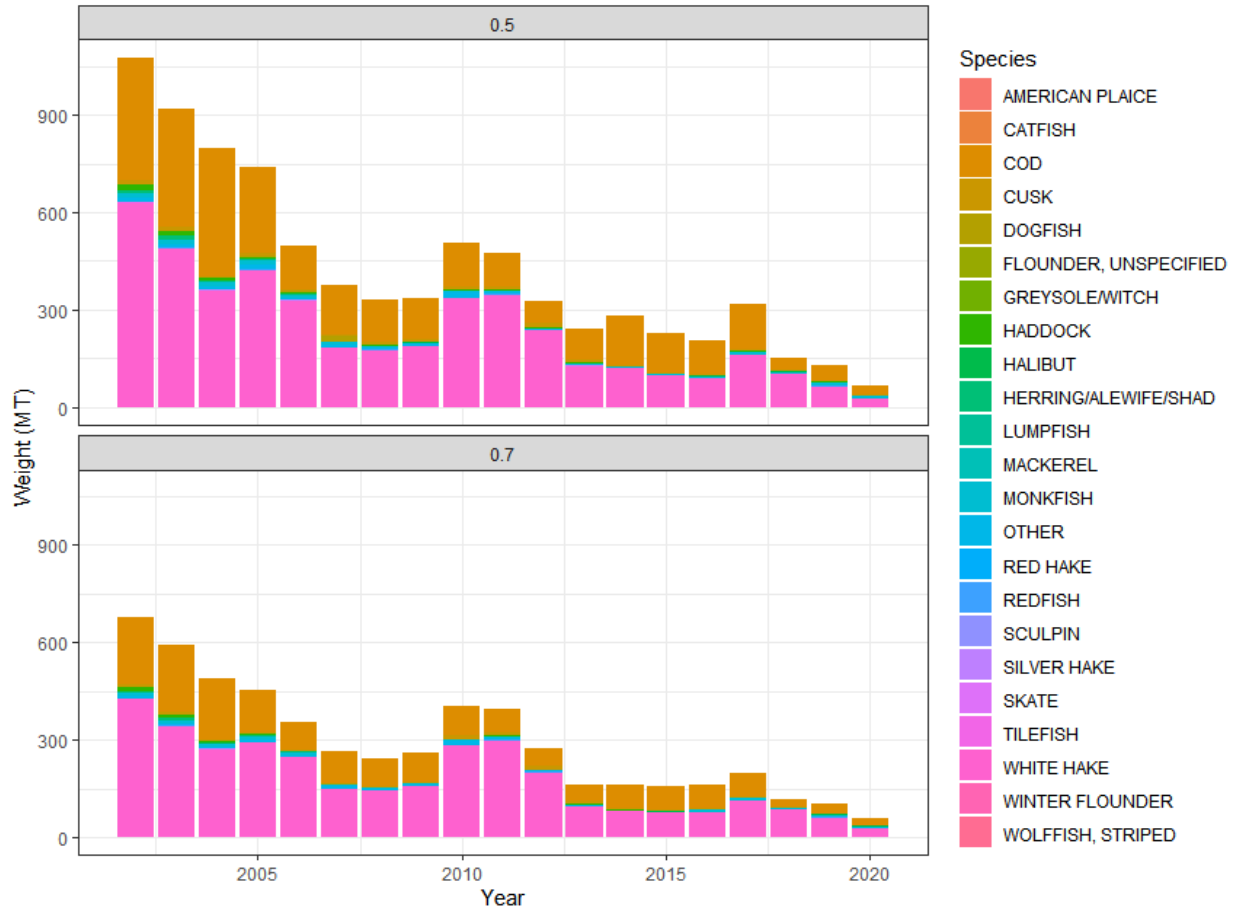


Figure 38. Bycatch of species (colour) by weight caught on Pollock-directed sets by fixed gear in NAFO division 4X5. Facets represent a > 50% cut-off and a > 70% cut-off for definition of a Pollock-directed set.

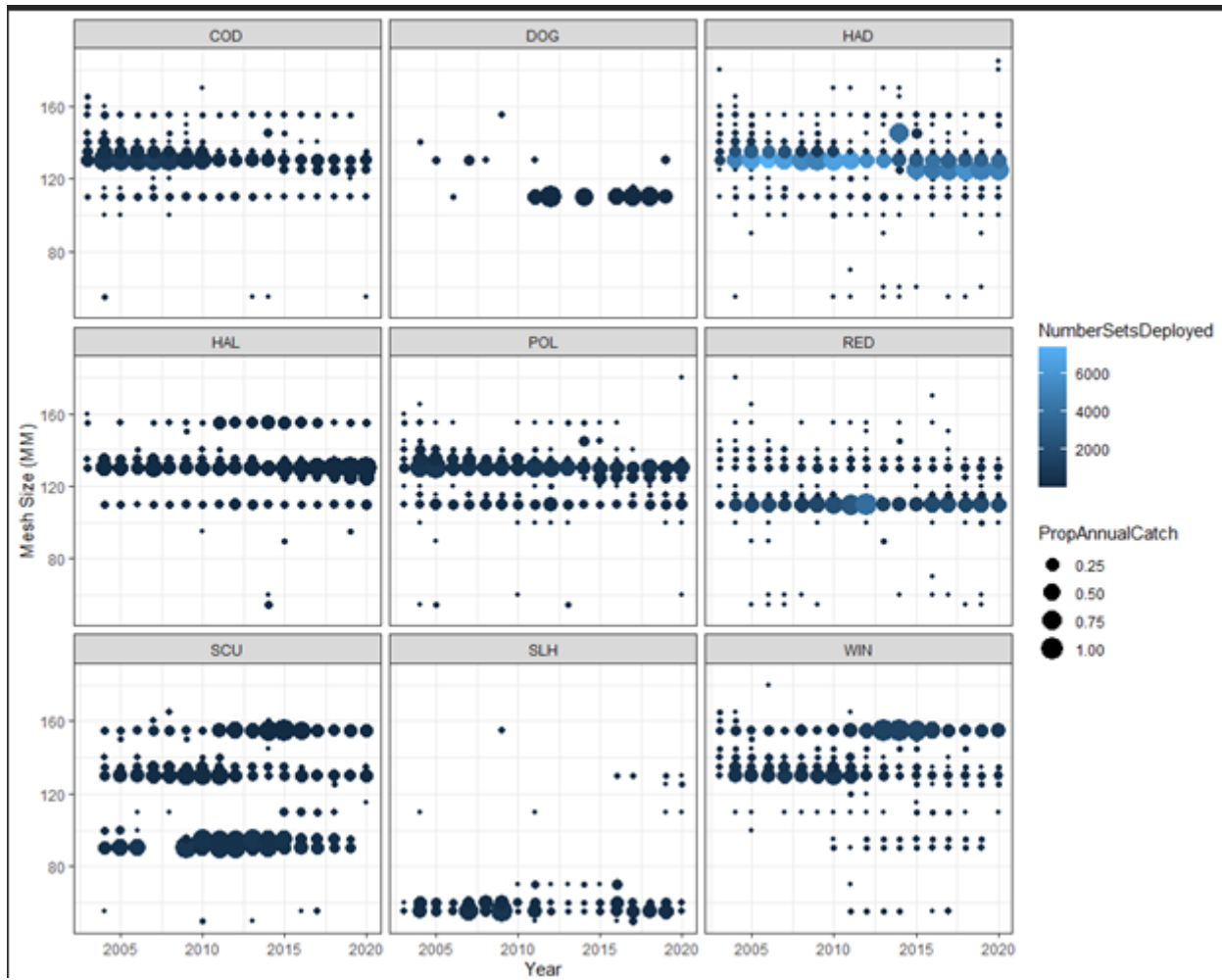


Figure 39. Relative annual catch of species (facets) by mesh size (mm) and year for mobile gear. Colour of dots is indicative of the number of sets deployed with that gear configuration.

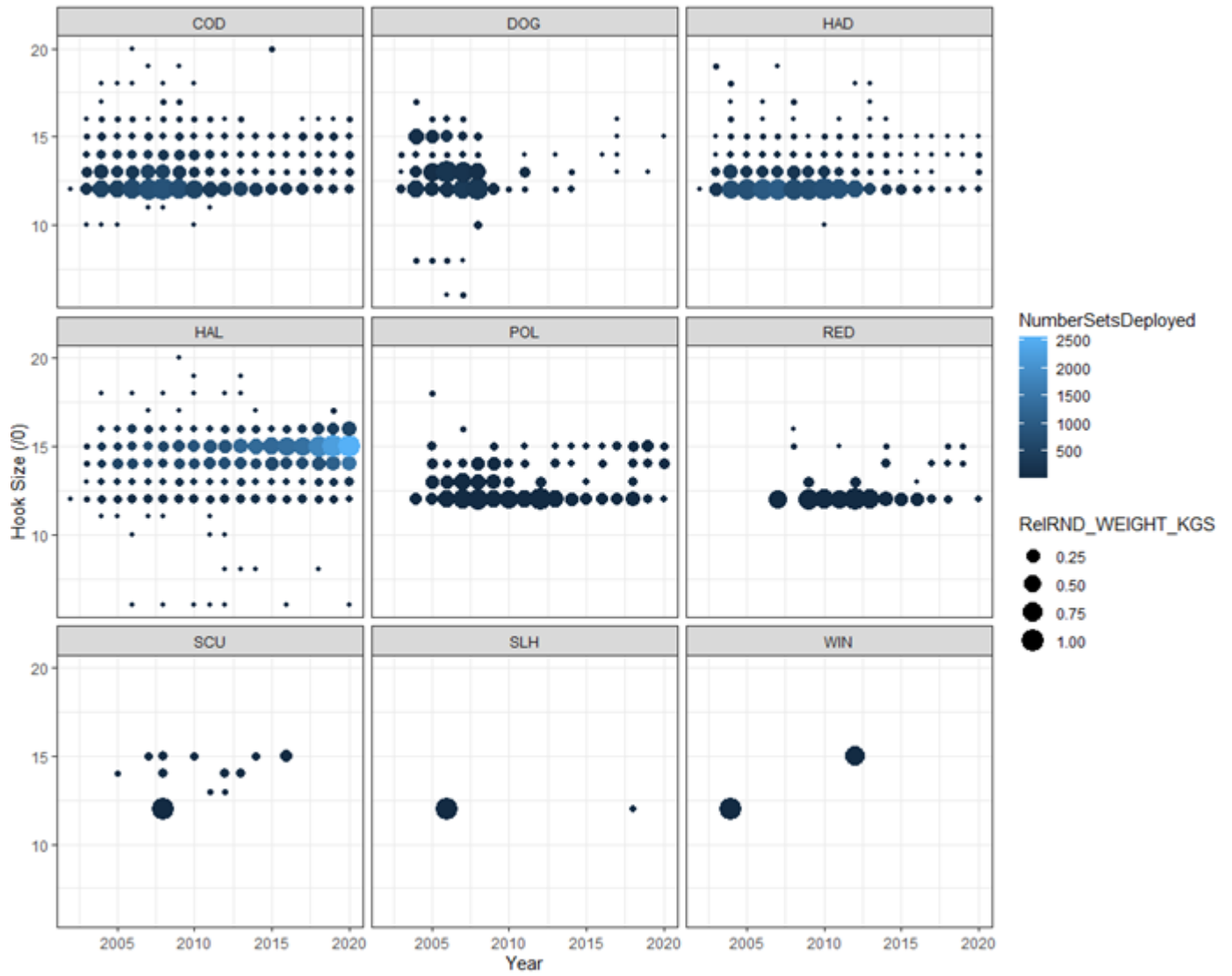


Figure 40. Relative annual catch of species (facets) by hook size (mm) and year for handline/longline gear. Colour of dots is indicative of the number of sets deployed with that gear configuration.

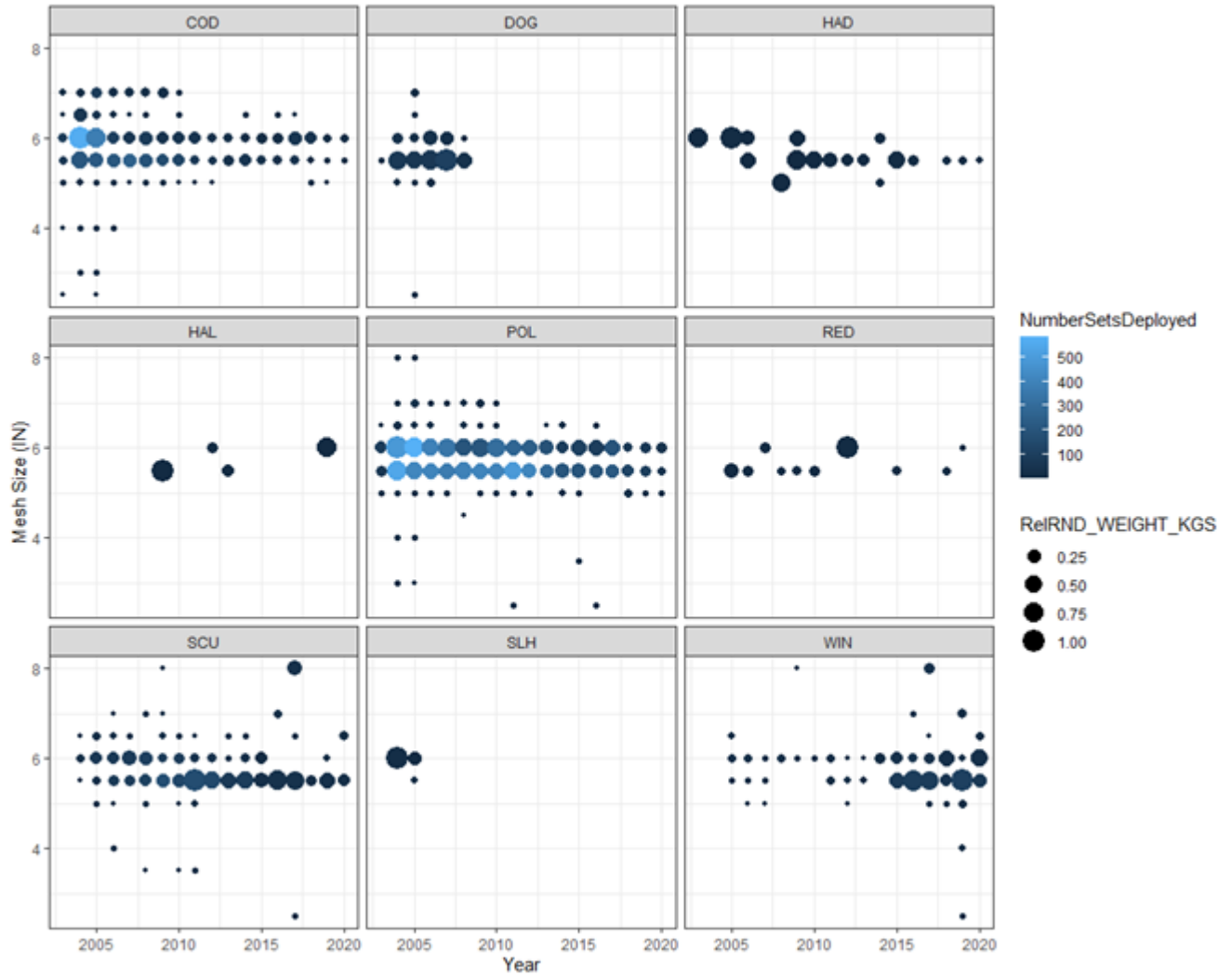


Figure 41. Relative annual catch of species (facets) by mesh size (IN) and year for gillnet. Colour of dots is indicative of the number of sets deployed with that gear configuration.

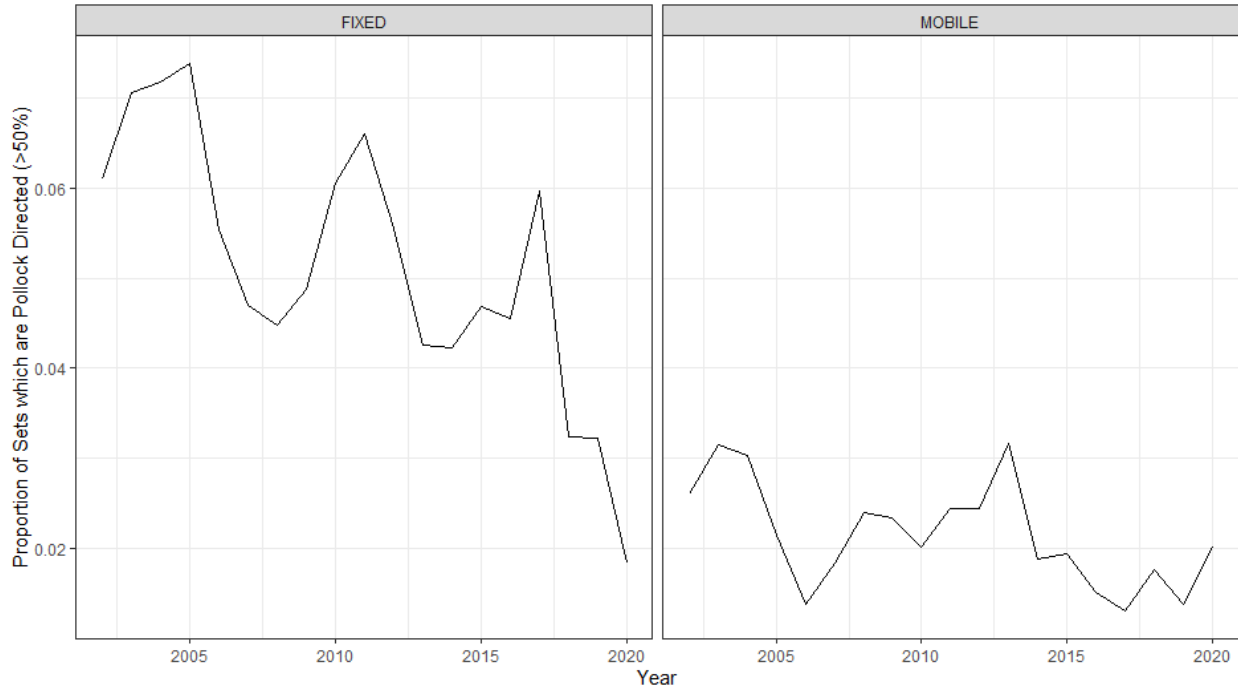


Figure 42. Proportion of Pollock-directed sets from all groundfish trips taken in NAFO division 4X5 by fixed (handline, longline and gillnet) and mobile (otter trawl) gear. A trip is considered Pollock-directed when > 50% of the catch of nine major groundfish species constitutes Pollock.

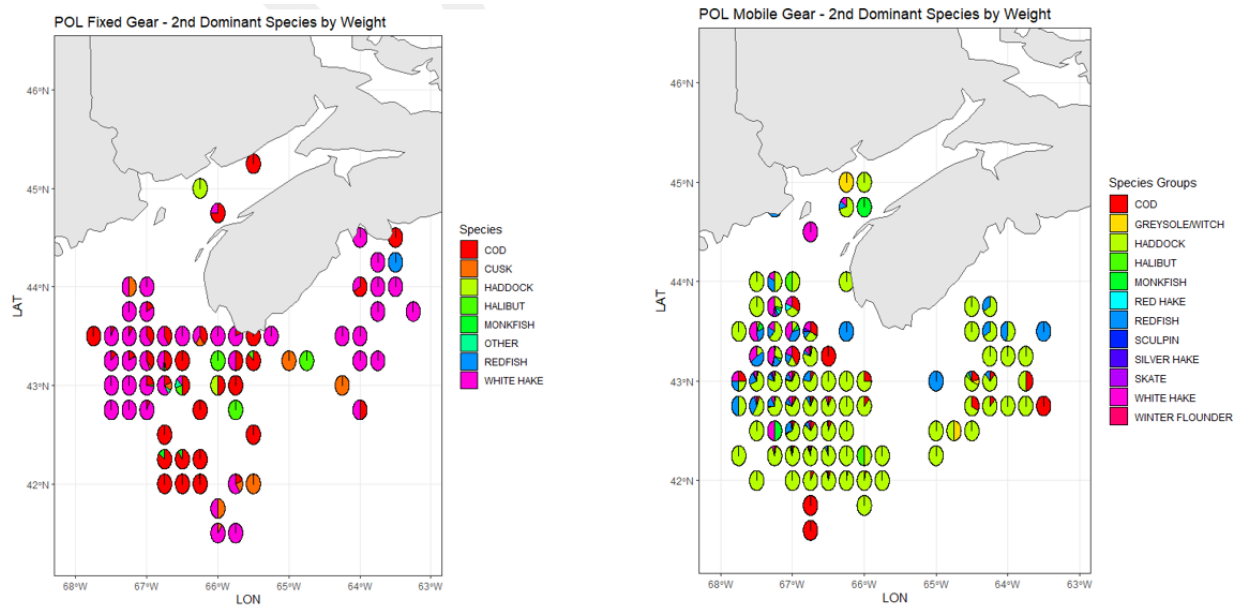


Figure 43. Occurrence of the second most abundant species (by weight) on Pollock-directed sets for fixed (left panel) and mobile (right panel) gears between 2017 and 2020. Each set is given equal weighting and pie charts show aggregate set data in 15 minute squares over the three year time period. Species colours are consistent between the two panels. Figure code courtesy of M. McMahon.

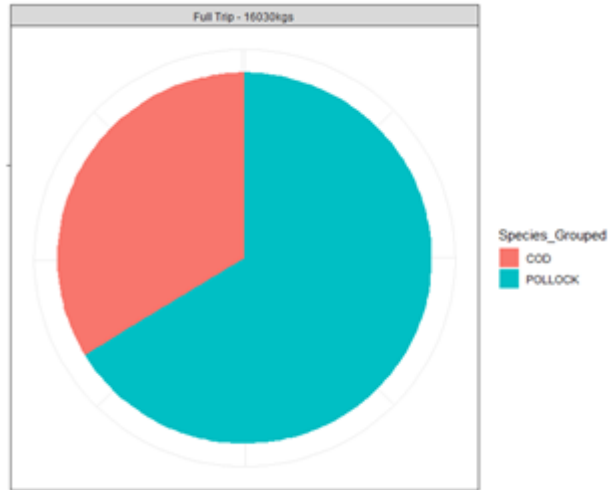


Figure 44. Total catch composition of an example trip based on the weight of nine major groundfish species examined.



Figure 45. Set-level catch composition of an example trip based on the weight of nine major groundfish species examined.

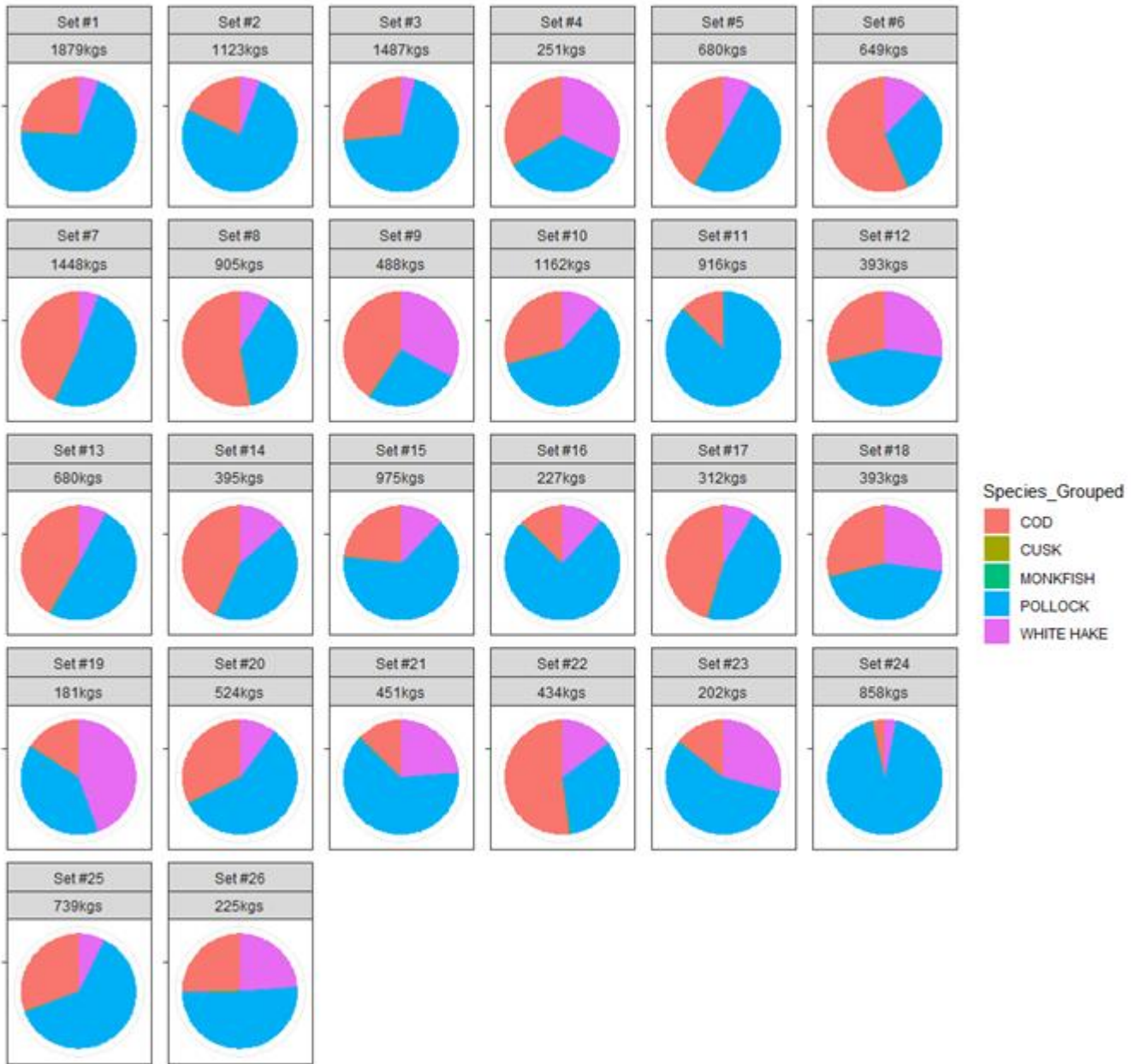


Figure 46. Set-level catch composition of an example trip based on the weight of nine major groundfish species examined.



Figure 47. Timing of the DFO summer and winter RV surveys over the years. Lower panel shows the spring surveys and the upper panel shows the summer. Each point represents a valid tow, coloured by month.

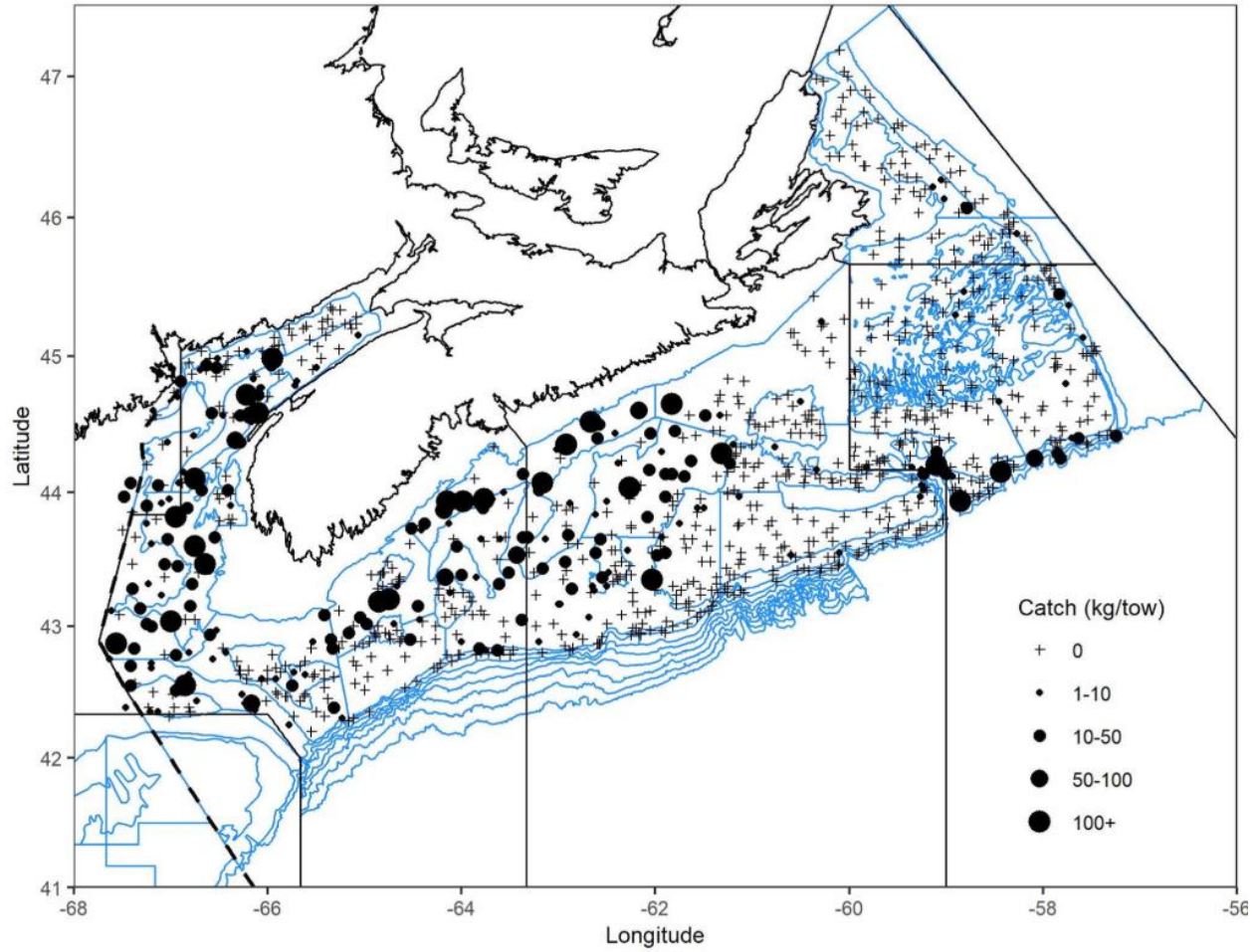


Figure 48. Catches of Pollock (kg/tow) from the DFO summer RV survey from 1978 through 1983. Plus signs indicate null catch. The size of the circle is proportional to the size of the catch. Blue lines indicate approximate depth contours and associated survey strata.

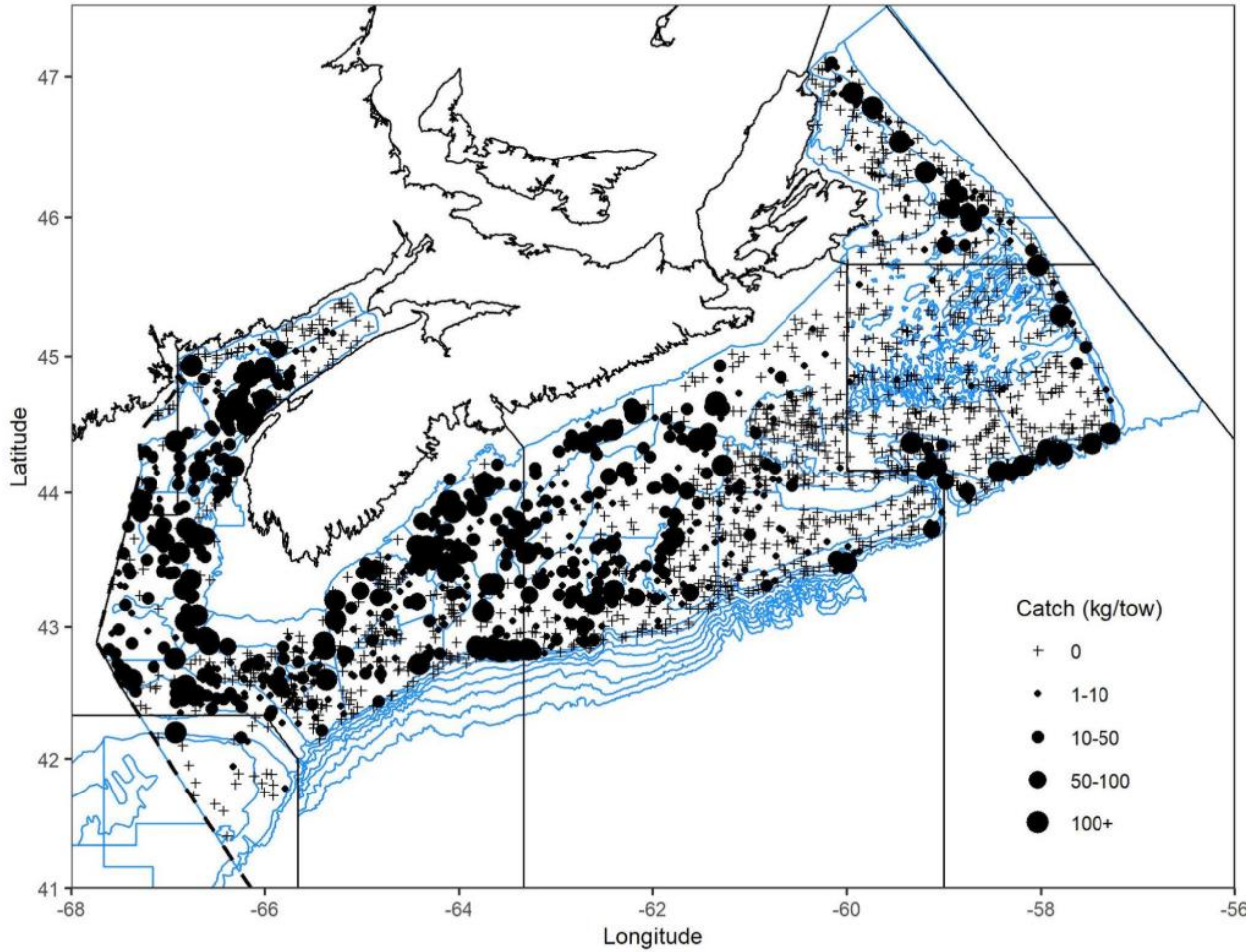


Figure 49. Catches of Pollock (kg/tow) from the DFO summer RV survey from 1984 through 1994. Plus signs indicate null catch. The size of the circle is proportional to the size of the catch. Blue lines indicate approximate depth contours and associated survey strata.

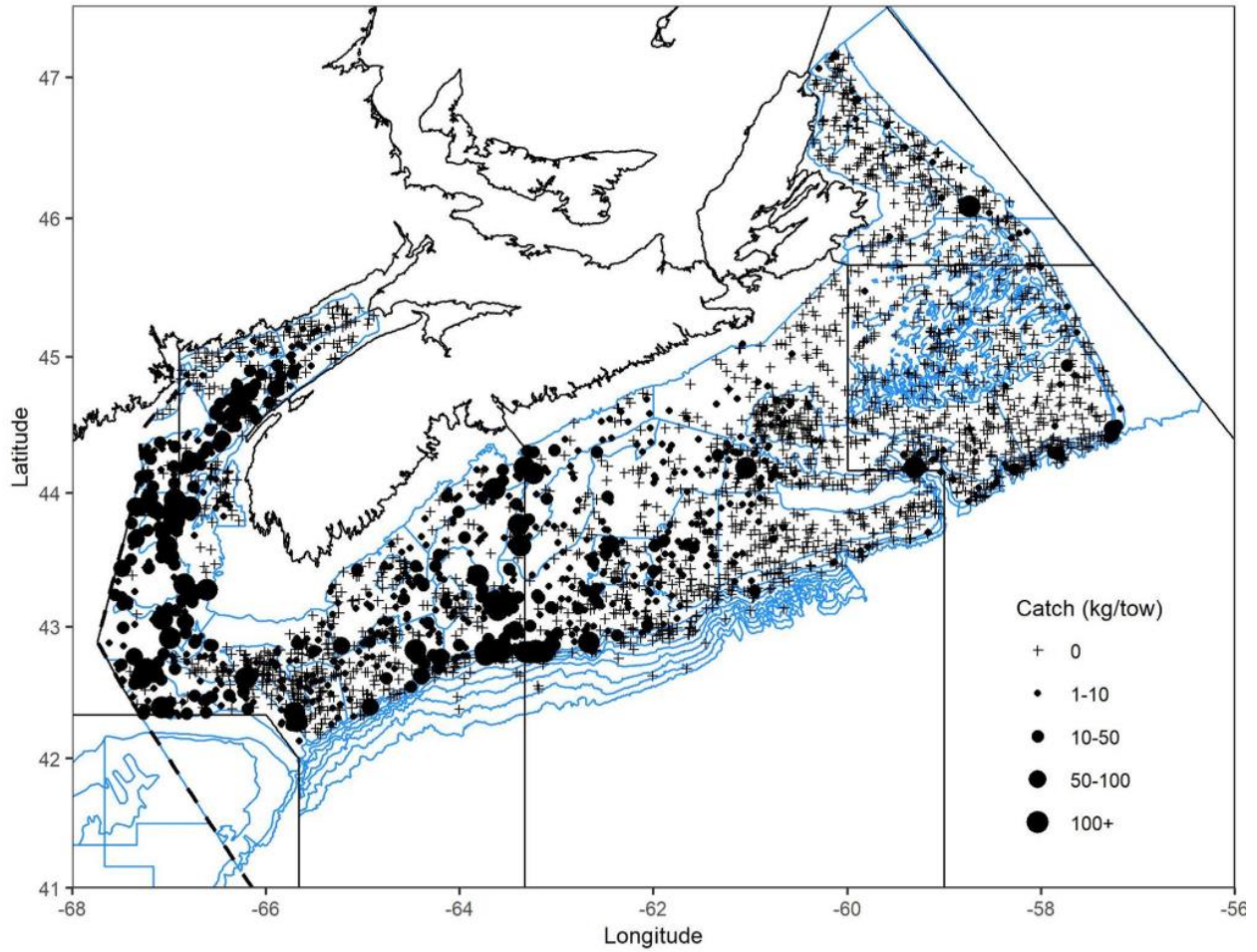


Figure 50. Catches of Pollock (kg/tow) from the DFO summer RV survey from 1995 through 2010. Plus signs indicate null catch. The size of the circle is proportional to the size of the catch. Blue lines indicate approximate depth contours and associated survey strata.

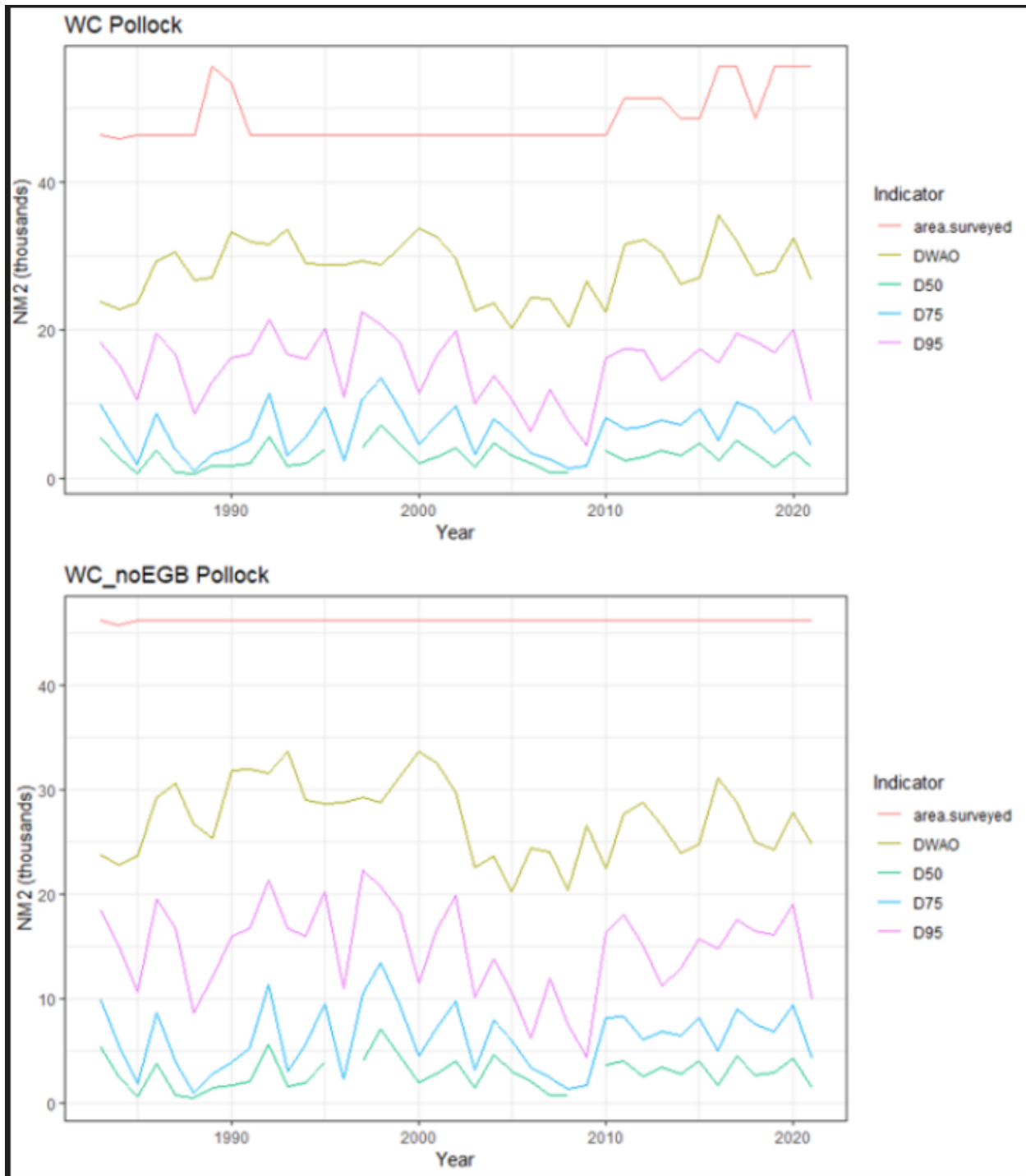


Figure 51. Design-weighted area of occupancy indices for WC Pollock statistical areas 4Xopqrst5 (top panel, includes EGB) and 4Xopqrs5Y (bottom panel, excludes EGB). Area surveyed indicates the total area in square nautical miles (NM2) covered by the summer RV survey that year. D95, D75 and D50 are indicative of area containing 95%, 75% and 50% of the species; DWAO is the area containing 100% of the species.

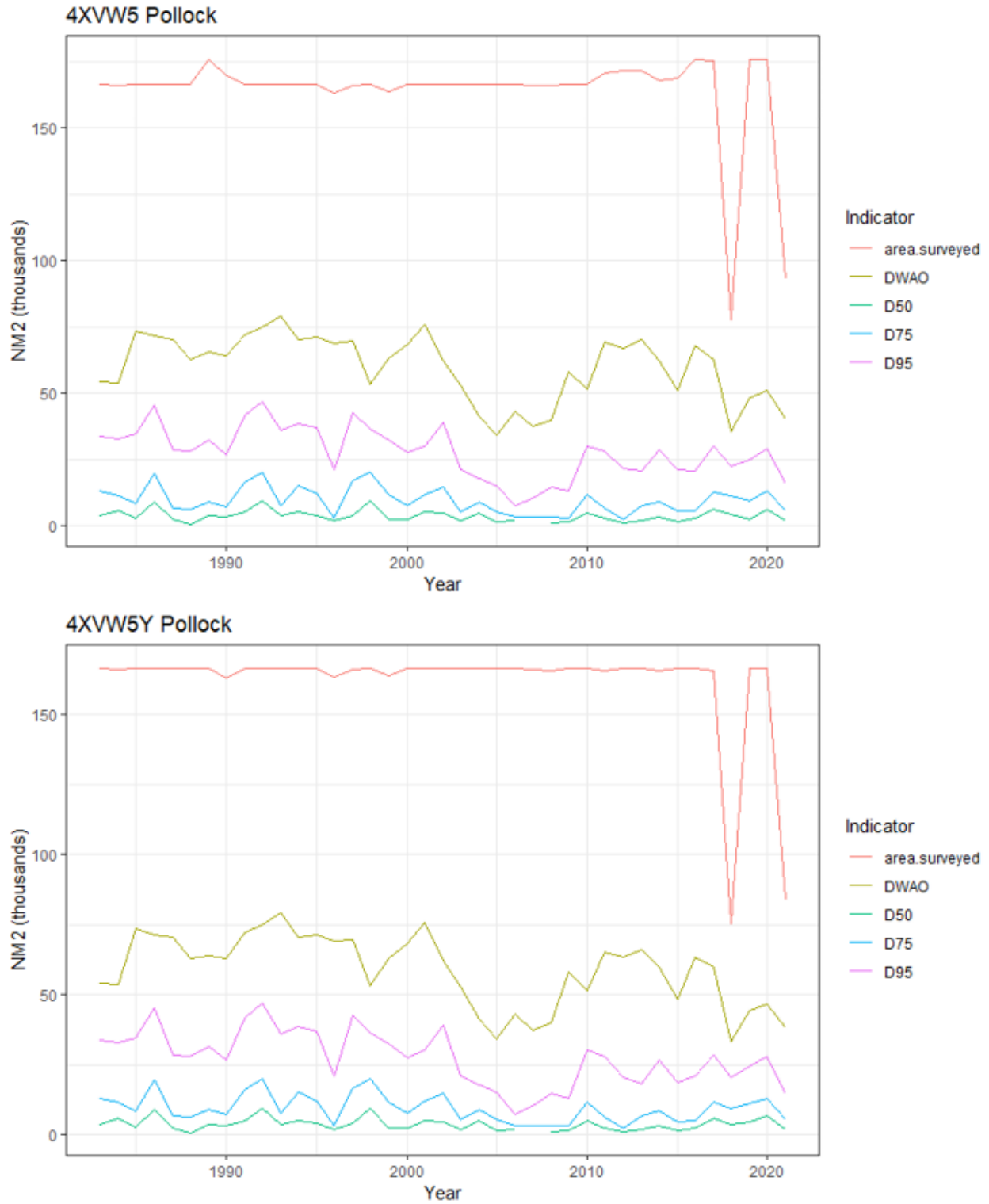


Figure 52. Design-weighted area of occupancy indices for Pollock in NAFO Divisions 4XVW5 (top panel, includes EGB) and NAFO Divisions 4XVW5Y (bottom panel, excludes EGB). Area surveyed indicates the total area in square nautical miles (NM2) covered by the summer RV survey that year. D95, D75 and D50 are indicative of area containing 95%, 75% and 50% of the species; DWAO is the area containing 100% of the species.

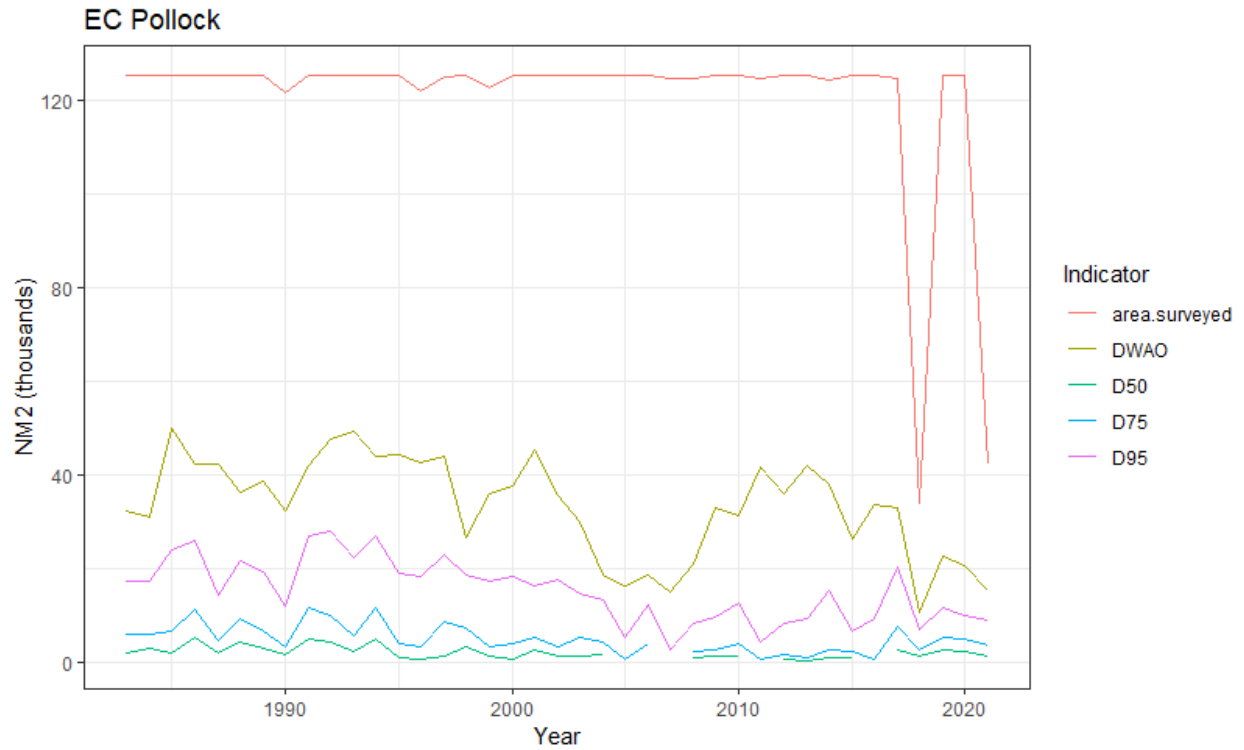


Figure 53. Design-weighted area of occupancy indices for EC Pollock in NAFO Divisions and DFO statistical areas 4XmnoVW. Area surveyed indicates the total area in square nautical miles (NM2) covered by the summer RV survey that year. D95, D75 and D50 are indicative of area containing 95%, 75% and 50% of the species; DWA0 is the area containing 100% of the species (NM2 is square nautical miles).

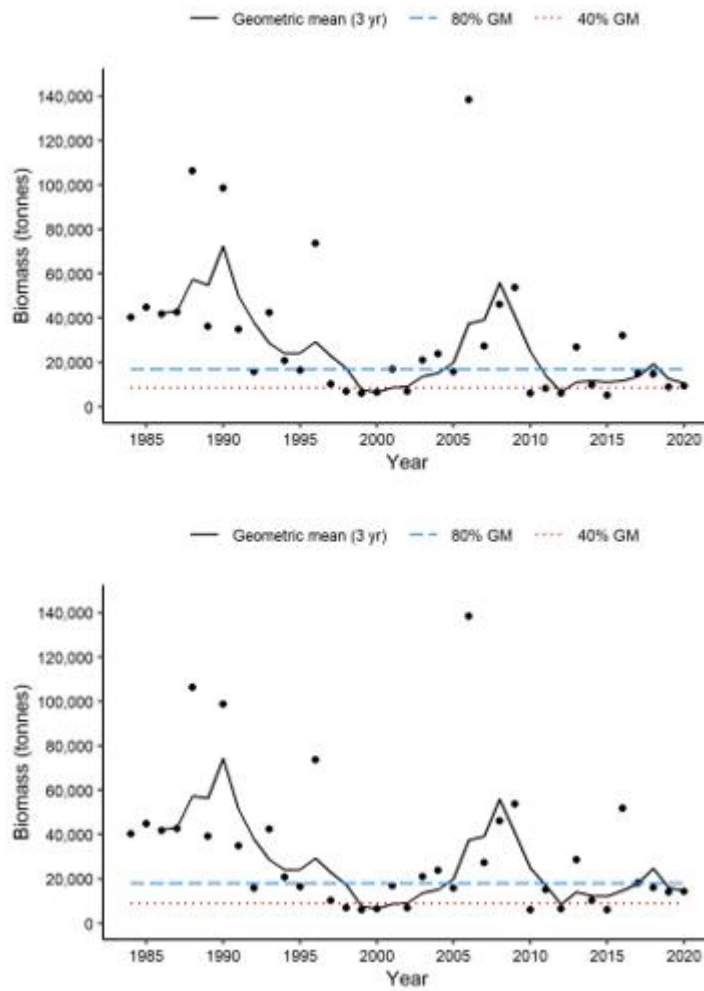


Figure 54. The Pollock biomass survey trend for NAFO Divisions and DFO statistical areas 4Xopqrs5Y (top) and 4Xopqrs5 (bottom) from the DFO summer RV survey. Points represent raw data and black line is the three-year geometric mean. The horizontal lines represent the 40% and 80% of the series mean; lines often included in the annual reports on survey trends.

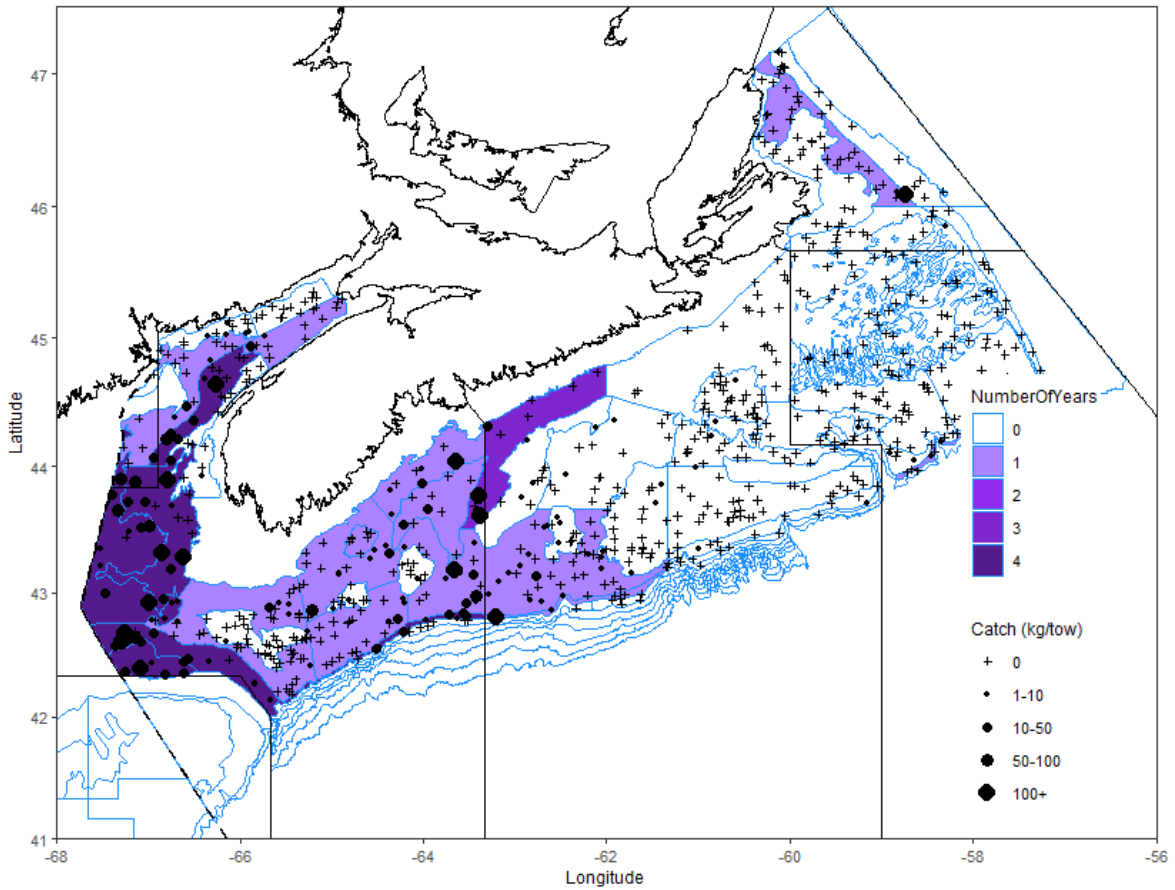


Figure 55. DFO summer RV survey catches of Pollock from 2005 through 2008. Blue lines delineate survey strata and fill indicates how many of the four years did the stratum have a Pollock catch exceeding 10 kg/tow.

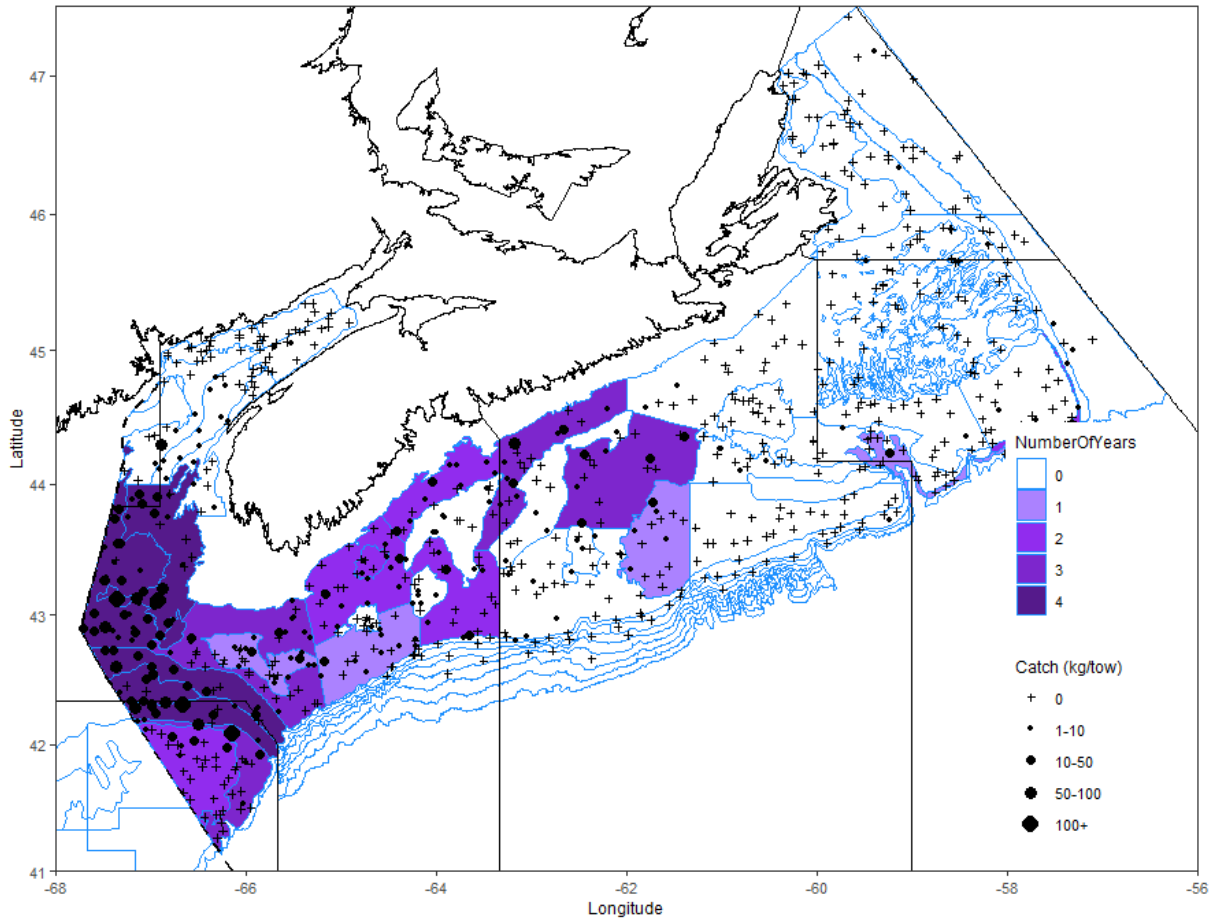


Figure 56. DFO summer RV survey catches of Pollock from 2017 through 2020. Blue lines delineate survey strata and fill indicates how many of the four years did the stratum have a Pollock catch exceeding 10 kg/tow.

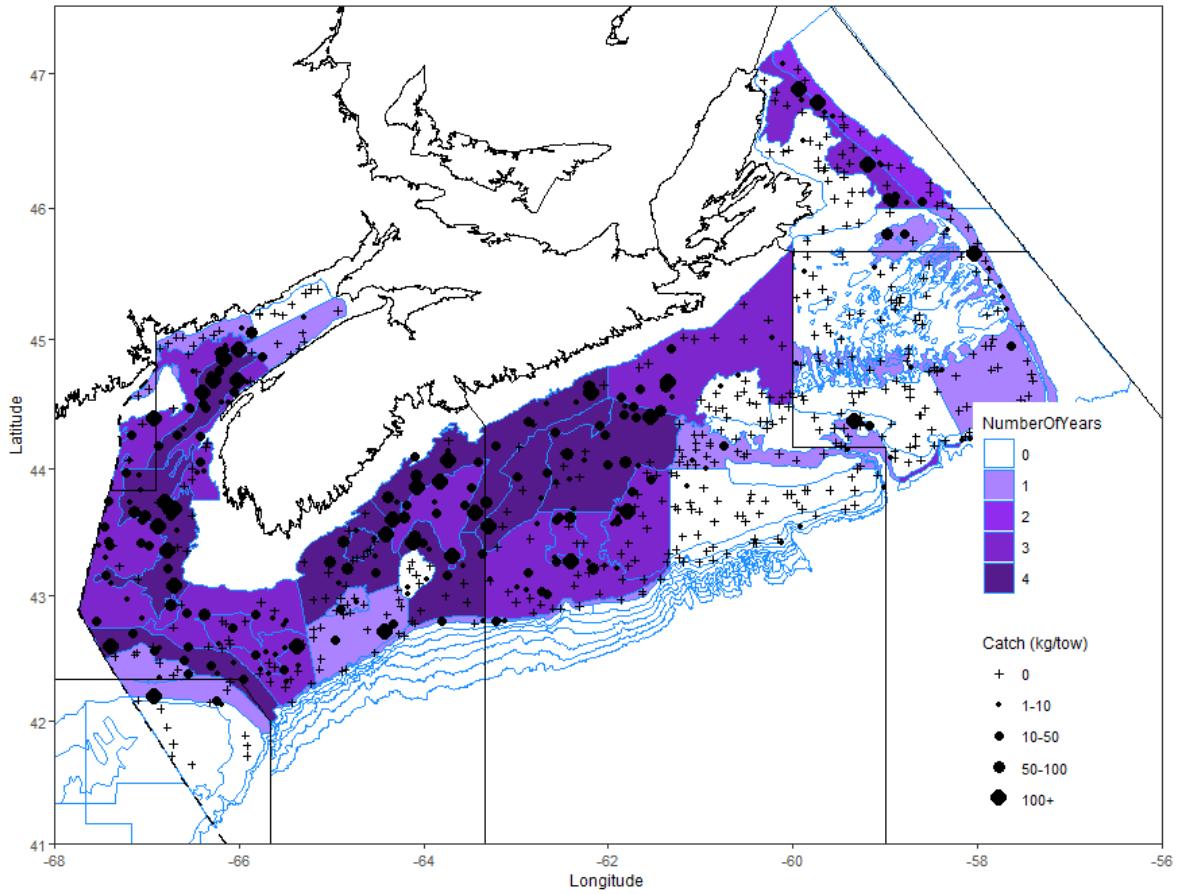


Figure 57. DFO summer RV survey catches of Pollock from 1986 through 1989. Blue lines delineate survey strata and fill indicates how many of the four years did the stratum have a Pollock catch exceeding 10 kg/tow.

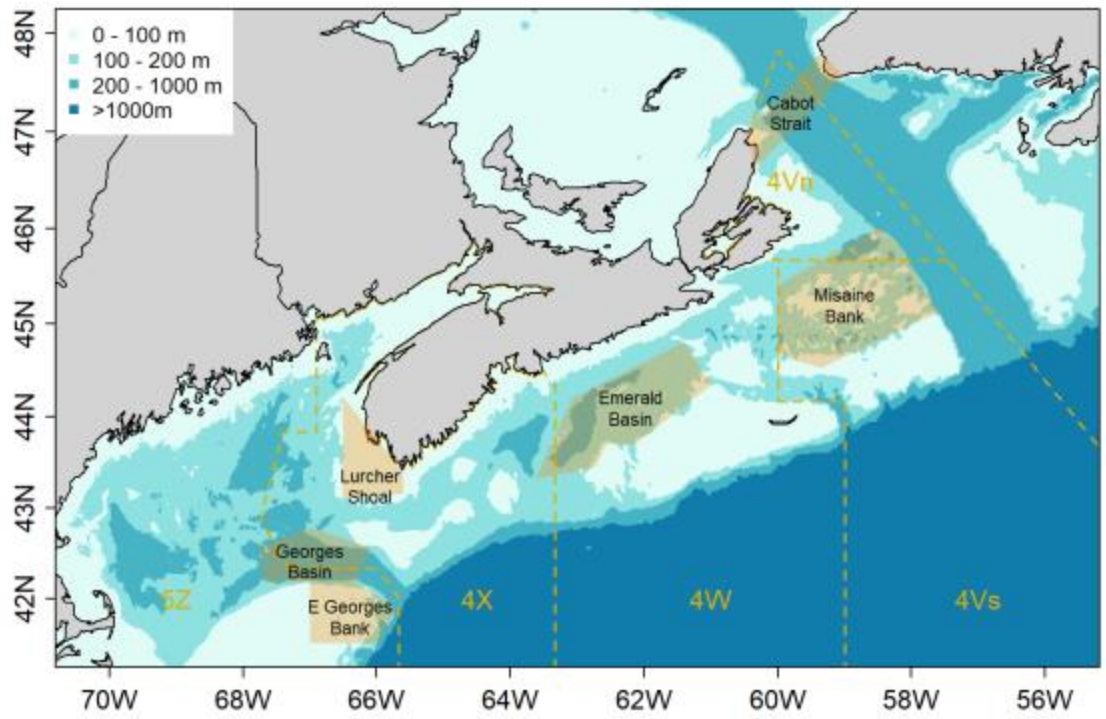


Figure 58. Areas depicting different water masses used in estimating sea floor temperature. Figure originally from Hebert et al. 2021.

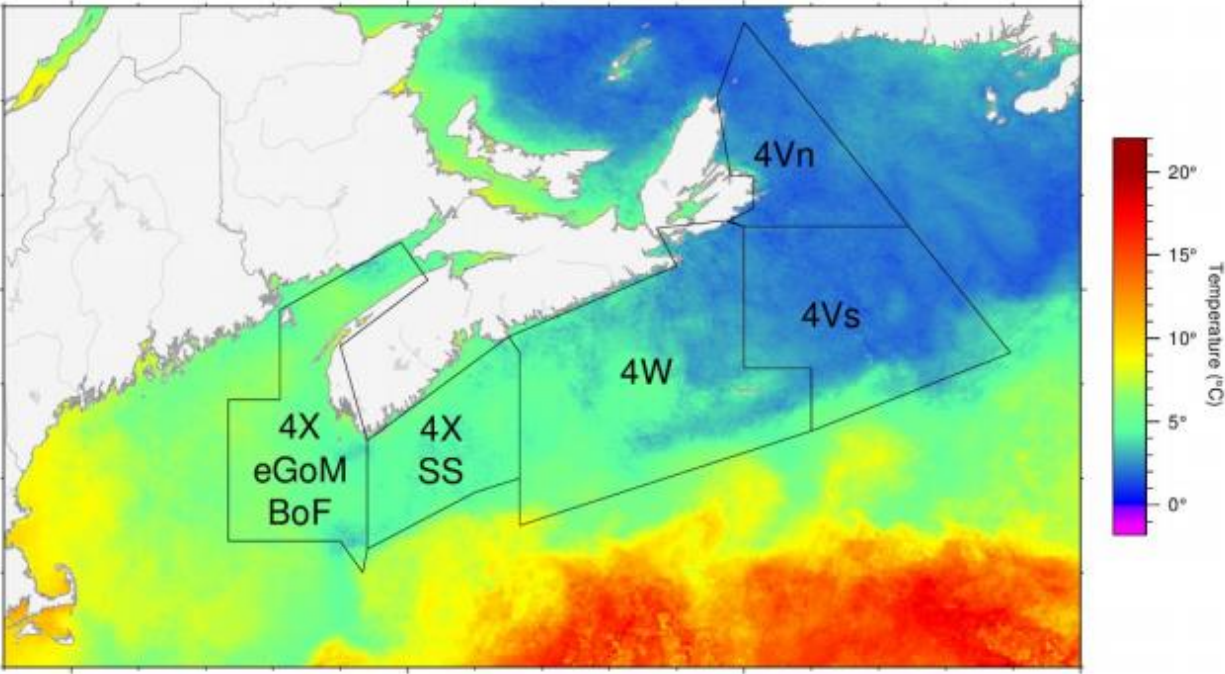


Figure 59. Areas used for extraction of sea surface temperature. Figure originally from Hebert et al. 2021/040.



Figure 60. Available annual sea temperature at sea floor for various areas (colours) falling within the four NAFO Divisions (facets). Dashed lines indicate the time periods used to aggregate DFO summer RV survey data for Pollock. Horizontal red line indicates 11°C.



Figure 61. Available annual sea surface temperature for various areas (colours) falling within the four NAFO Divisions (facets). Dashed lines indicate the time periods used to aggregate DFO summer RV survey data for Pollock.

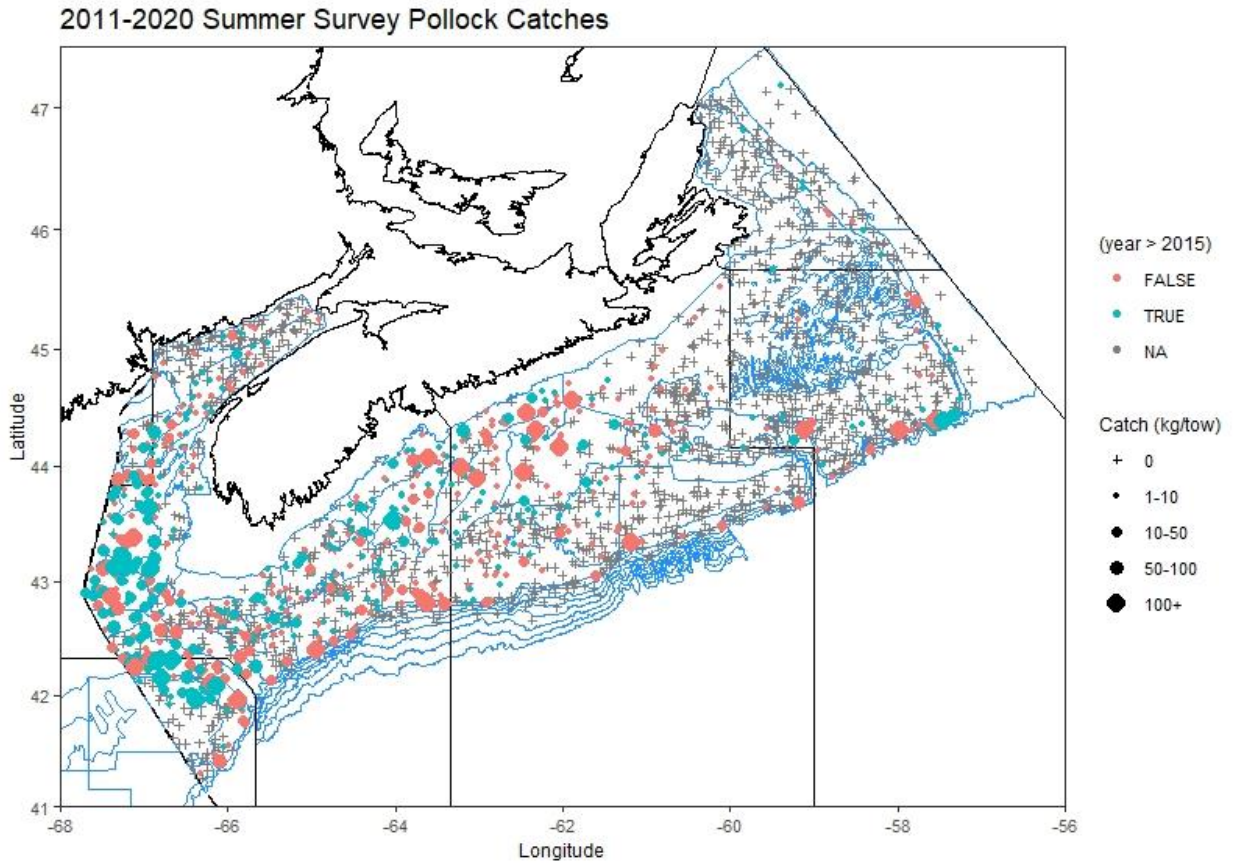


Figure 62. Catches of Pollock (kg/tow) from the DFO summer RV survey from 2011 through 2021. Plus signs indicate null catch. The size of the circle is proportional to the size of the catch. The colour of the circle indicates whether the tow was made after 2015. Blue lines indicate approximate depth contours.

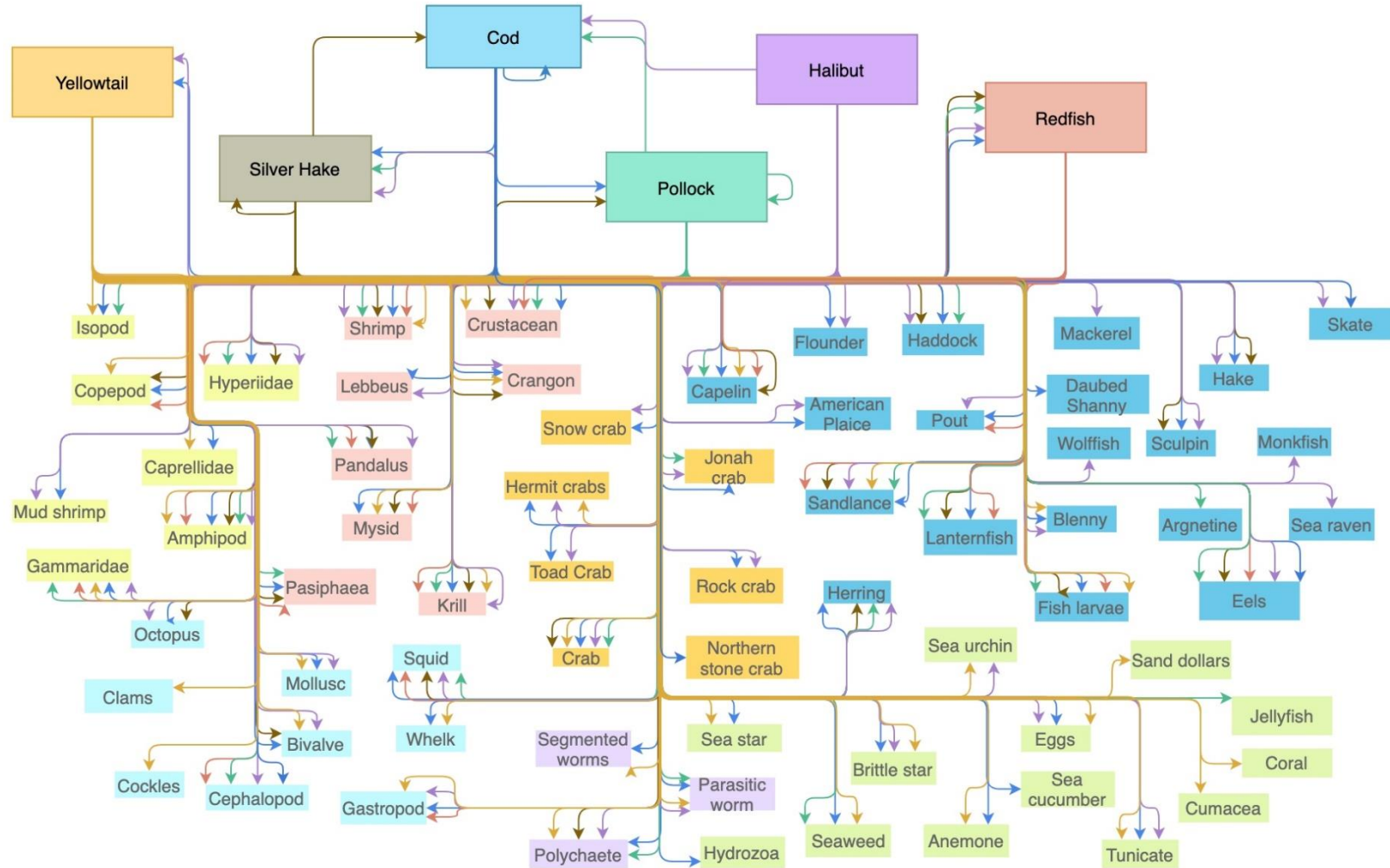


Figure 63. Trophic linkages of predator-prey interactions for some groundfish species, as recorded in the MAR stomach contents database (*mfd_stomach* schema). The colour of the arrow-head indicates the predator, in whose stomach the given prey item was found. The prey item boxes are loosely coloured by major groups (e.g., copepods, fish, etc.).

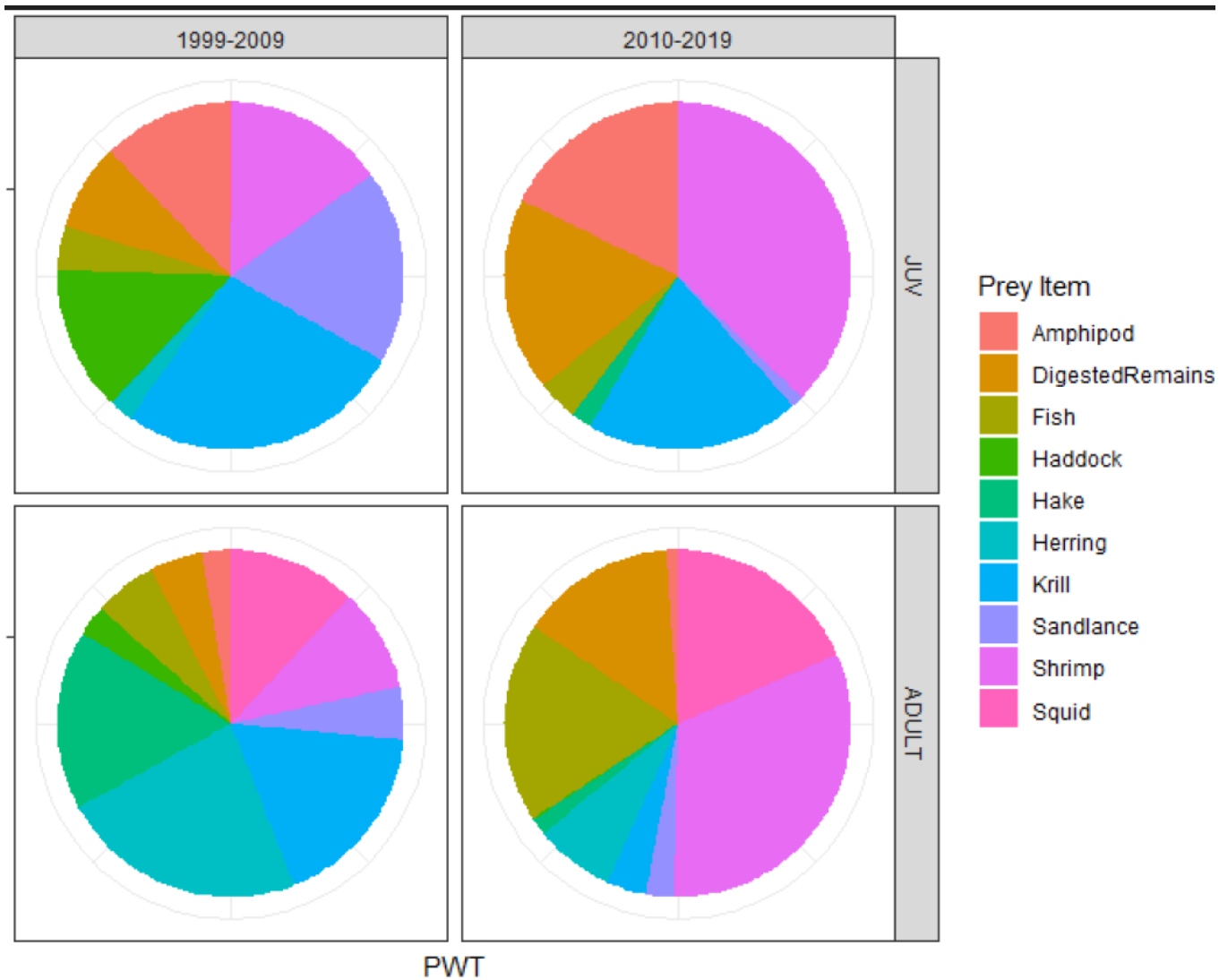


Figure 64. Diet composition (percent by weight, PWT) of juvenile (upper) and adult (lower) Pollock in NAFO Divisions 4X5, as identified in the MAR stomach sampling database (mfd_stomach) from the DFO summer RV survey. Left panels are based on samples collected between 1999 and 2011, while right panels are based on samples collected between 2010 and 2019.

Maritimes Region Zooplankton Sampling Locations

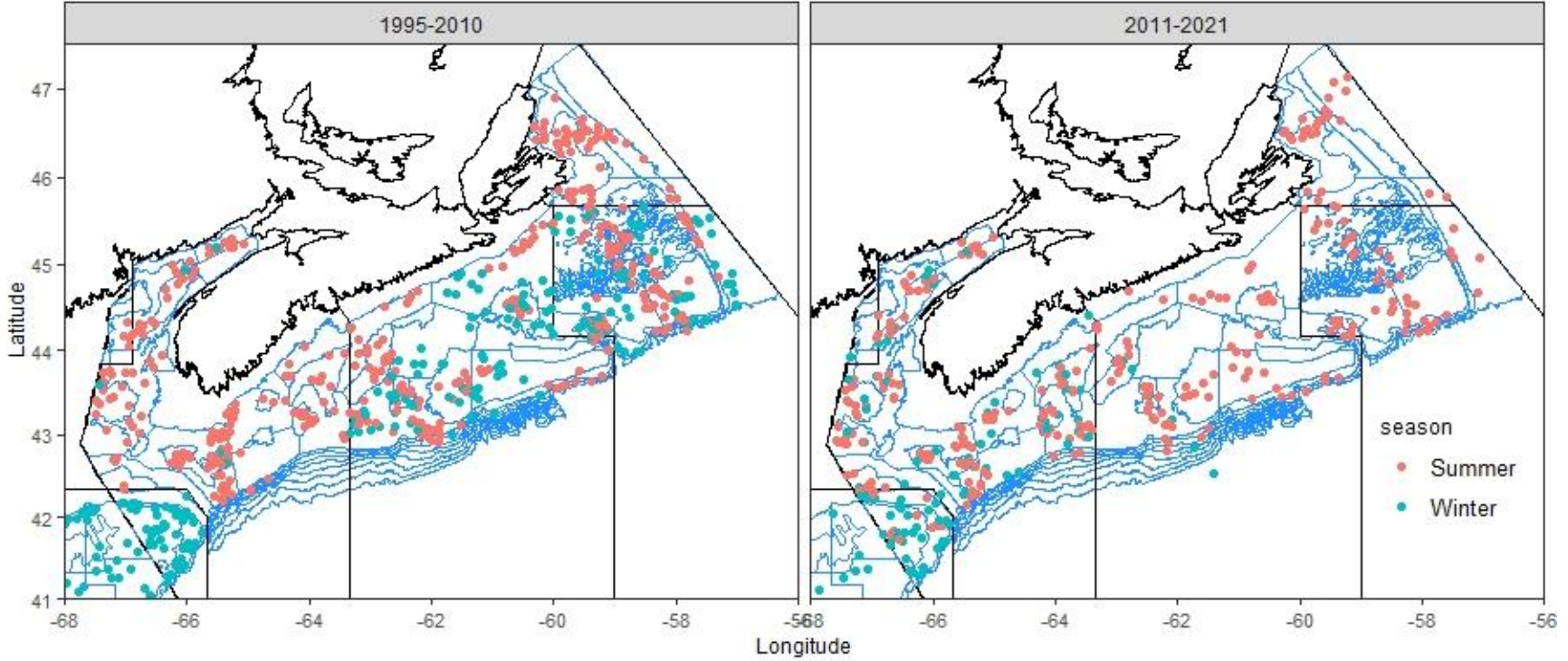


Figure 65. Location of available zooplankton sampling accompanying survey sets. Colour indicates the seasonal timing of the sampling.

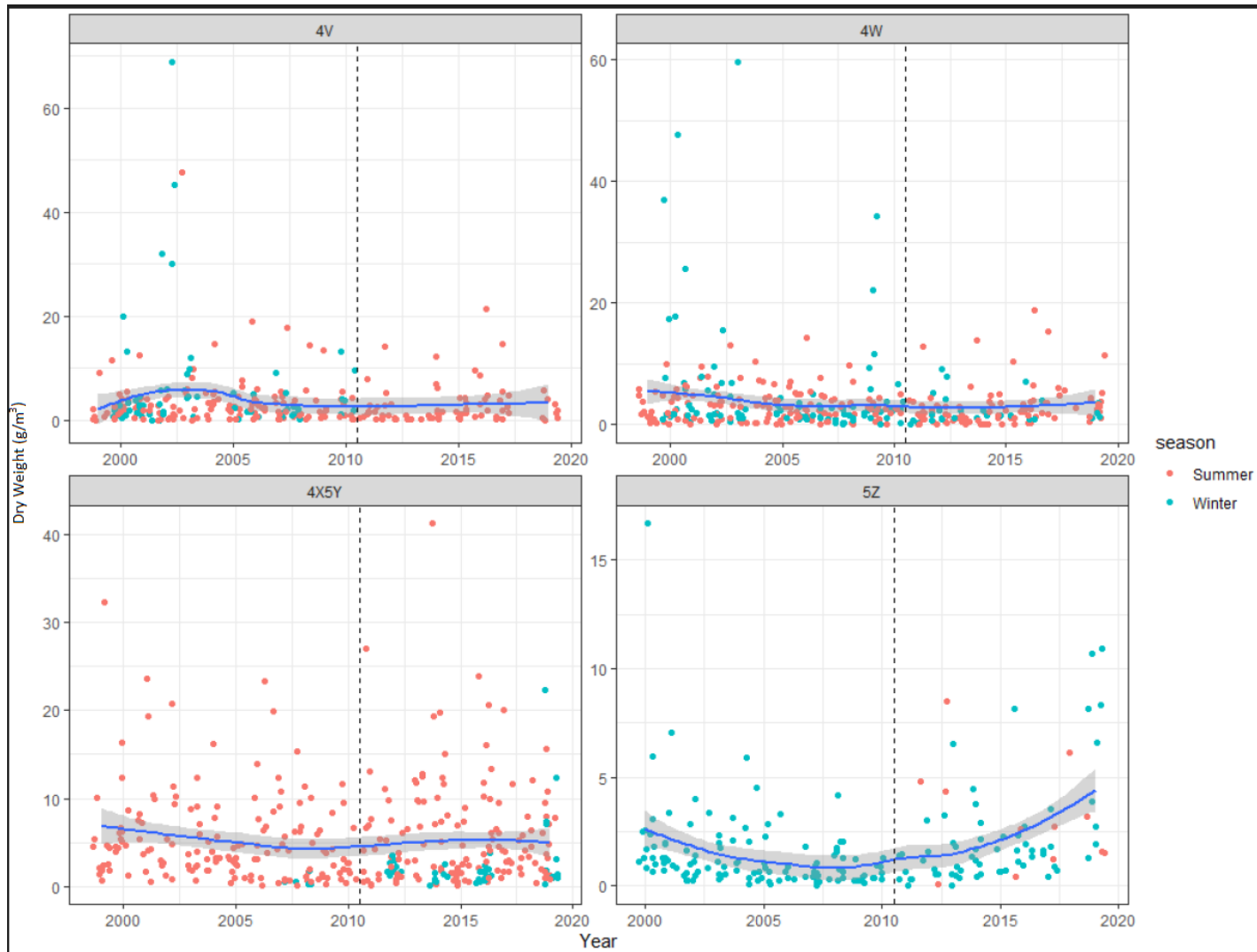


Figure 66. Zooplankton dry weight data series available through the azmpdata package. Each point indicates a set, with colour distinguishing the time of year the sample was collected. The line shows a loess smooth fit. Individual samples were obtained in concurrence with selected DFO summer RV survey tows. Dashed vertical lines indicate the time periods used to aggregate Pollock survey data.

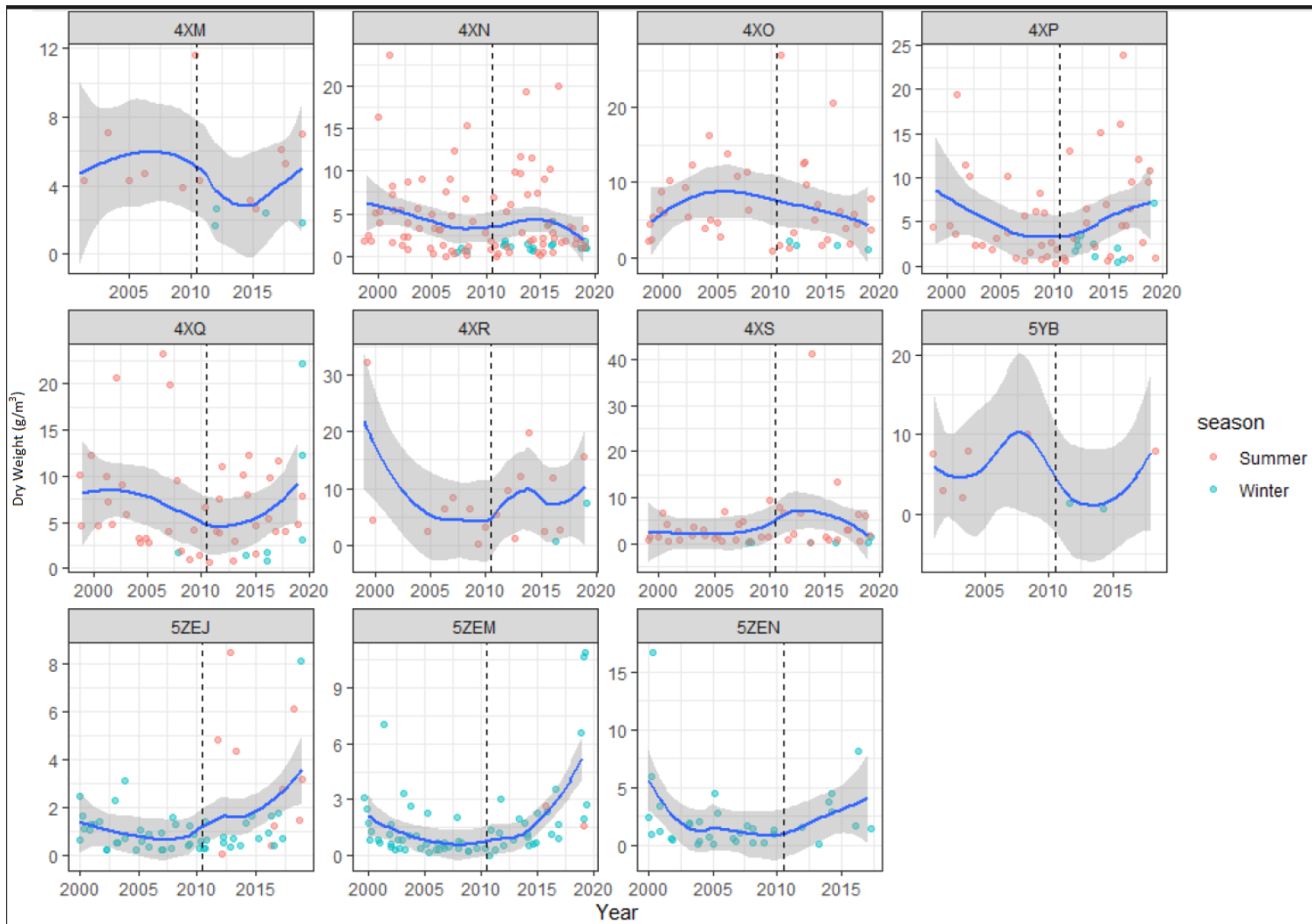


Figure 67. Zooplankton dry weight data series available through the azmpdata package, divided into NAFO sub-units (facets). Each point indicates a set, with colour distinguishing the time of year the sample was collected. The line shows a loess smooth fit. Individual samples were obtained in concurrence with selected DFO summer RV survey tows. Dashed vertical lines indicate the time periods used to aggregate Pollock survey data.

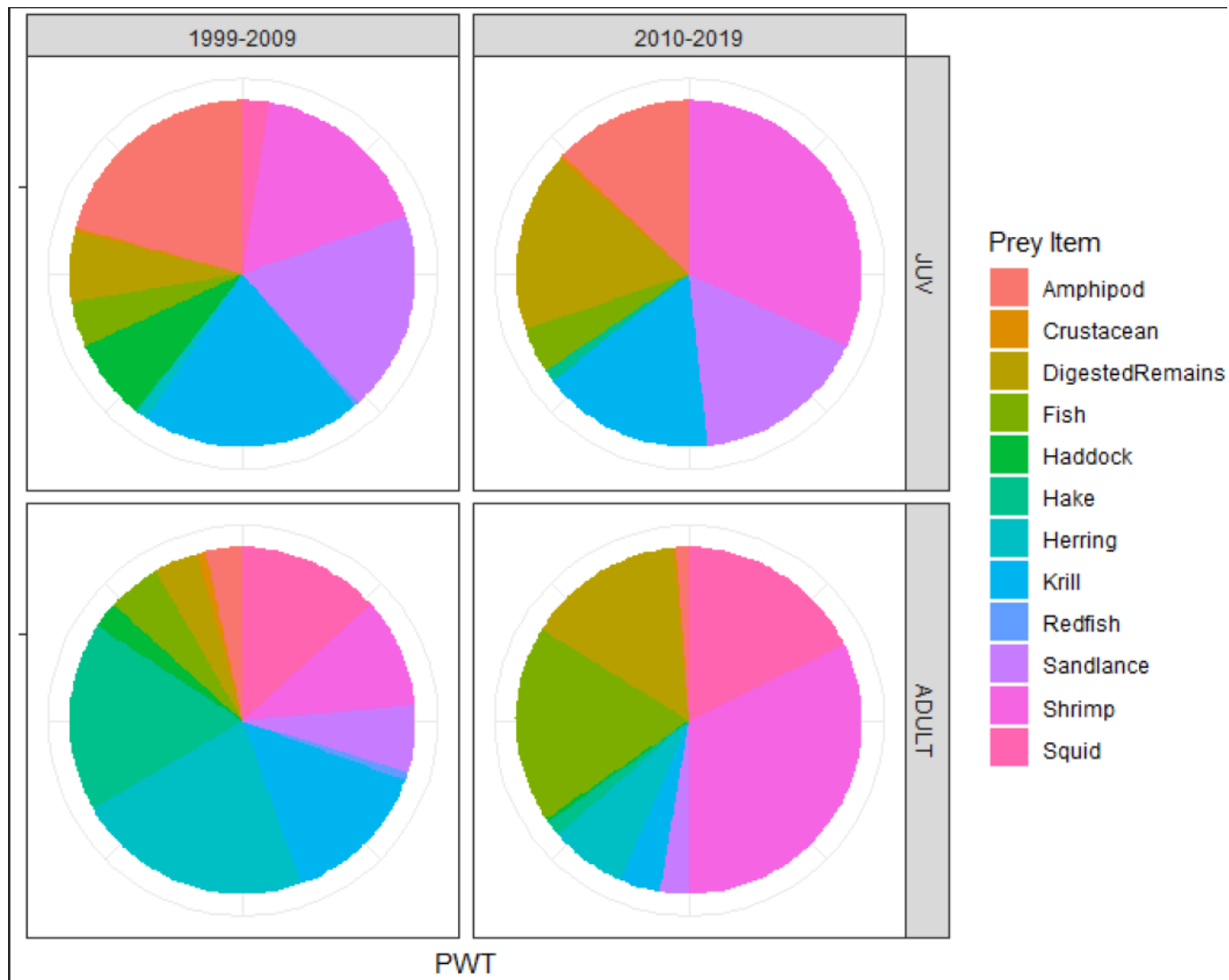


Figure 68. Diet composition (percent weight, PWT) of juvenile (upper) and adult (lower) Pollock in NAFO Divisions 4VWX5, as identified in the MAR stomach sampling database (mfd_stomach) from the DFO summer RV survey. Left panels are based on samples collected between 1999 and 2011, while right panels are based on samples collected between 2010 and 2019.

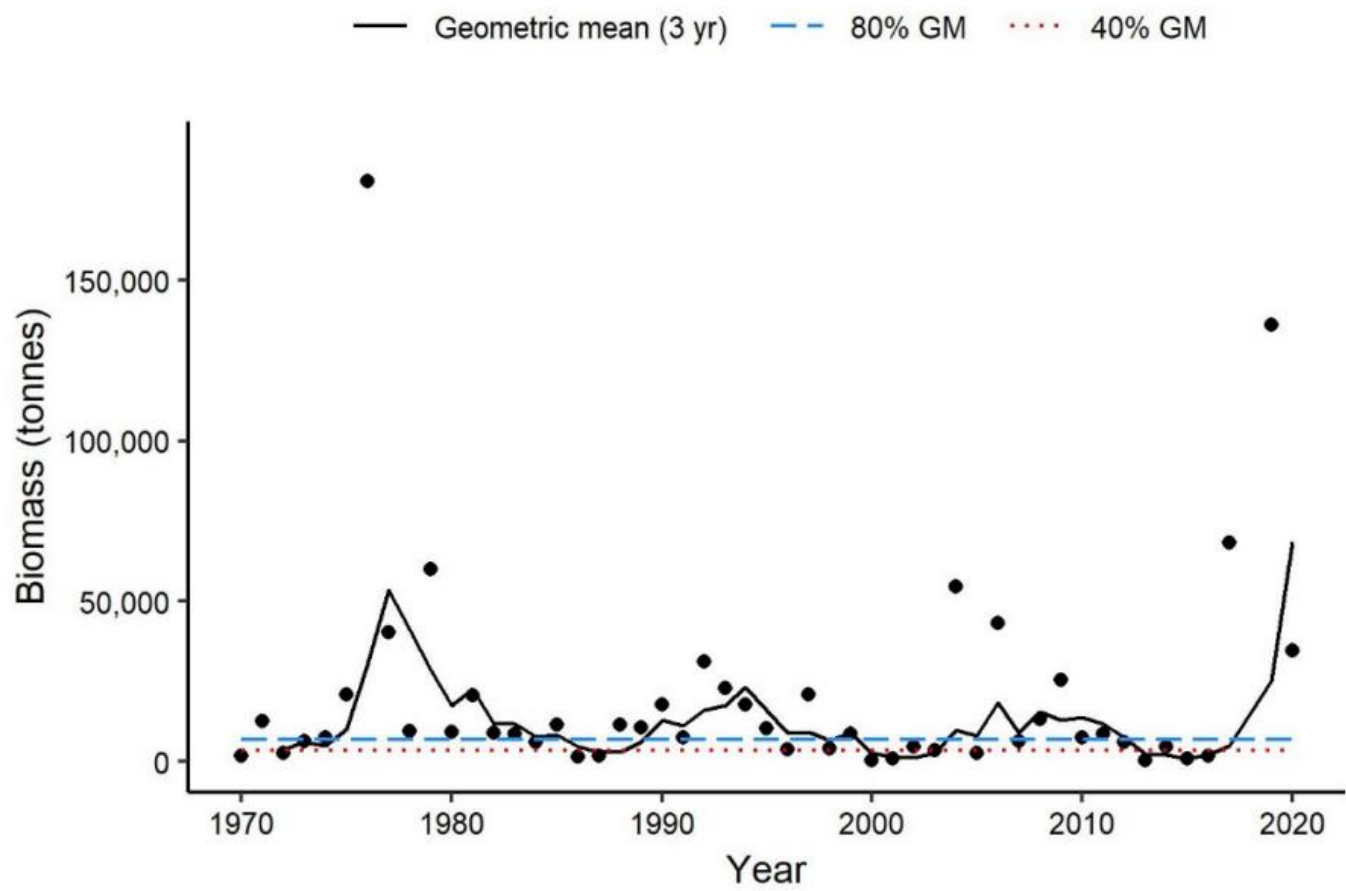


Figure 69. Biomass index for Shortfin Squid in 4VWX from the DFO summer RV survey. Original figure from DFO 2021f.

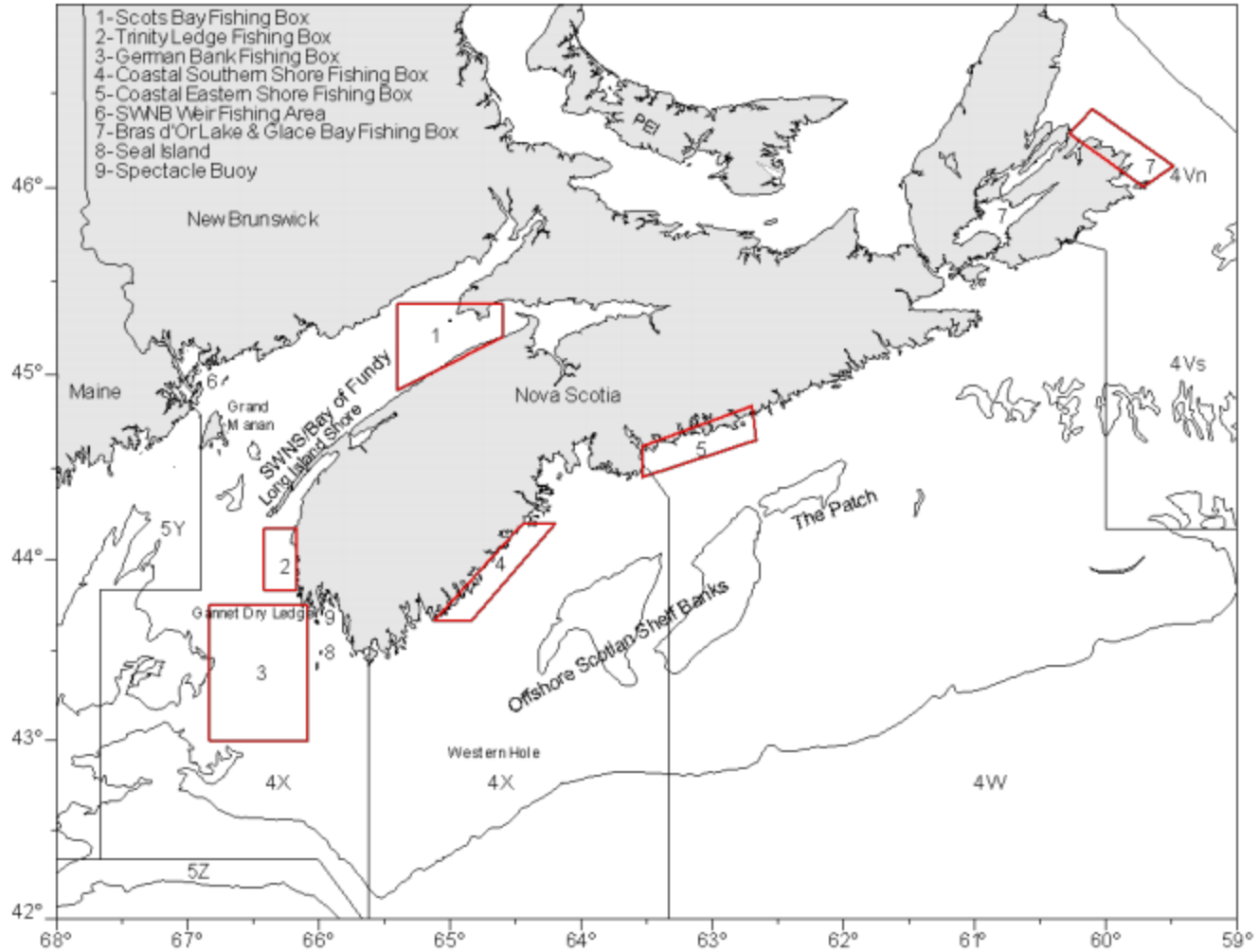


Figure 70. Place names and fishing locations for Southwest Nova Scotia/Bay of Fundy, coastal Nova Scotia (South Shore, Eastern Shore, Cape Breton), Offshore Scotian Shelf, and Southwest New Brunswick weirs. Figure from DFO 2020a.

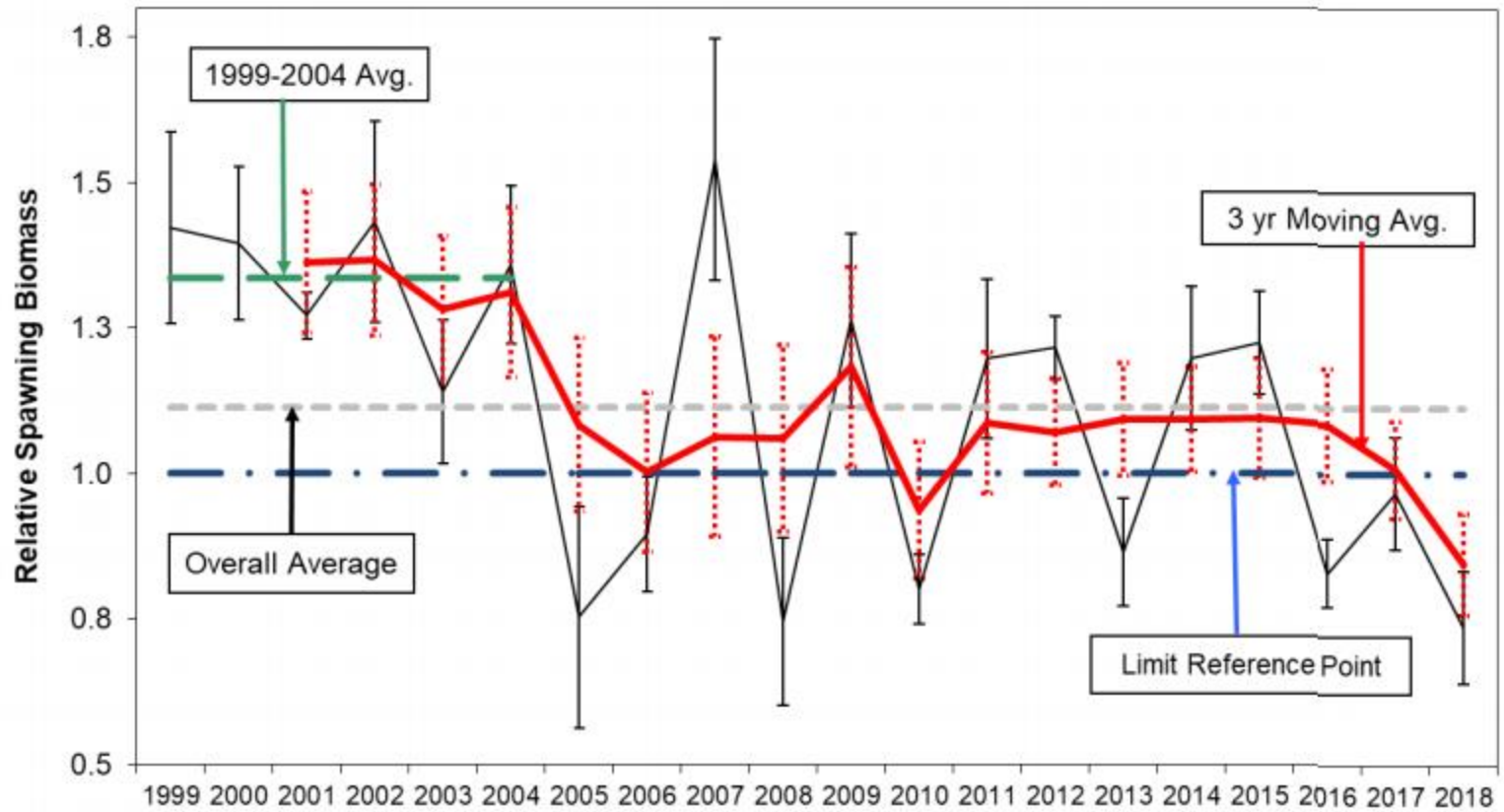


Figure 71. Relative spawning stock biomass of herring (with 95% CI), the calculated 3-year moving average, the overall average since 1999, the 1999-2004 average, and the LRP for the Southwest Nova Scotia/Bay of Fundy spawning component (German Bank and Scots Bay). Figure from DFO 2020a.

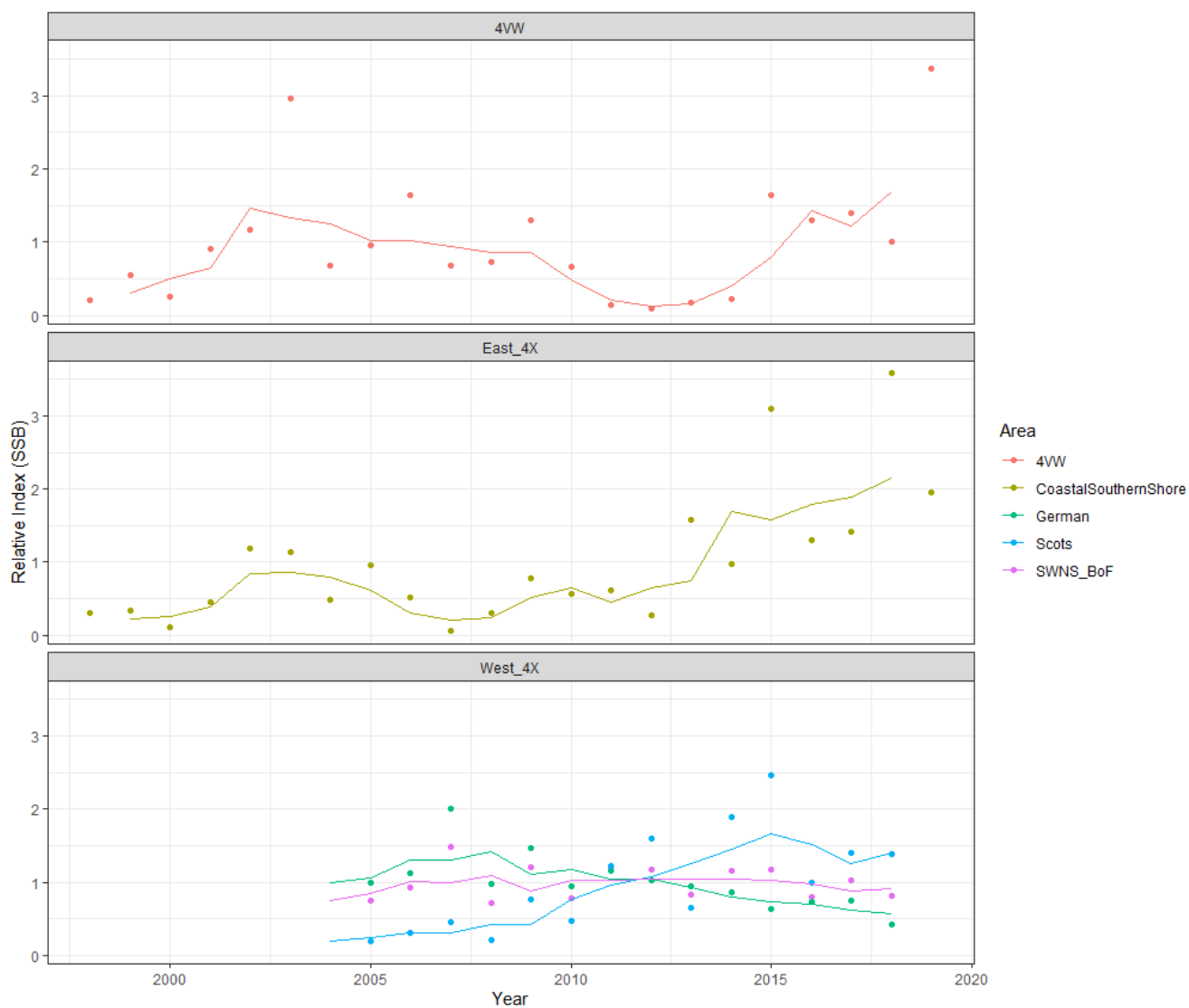


Figure 72. Relative indices of abundance for herring for select areas (facets) and the fishing boxes within those areas (colours). Points show the raw acoustic biomass values (DFO 2020a, Herring Group) and lines show a geometric 3-year mean of the raw values.

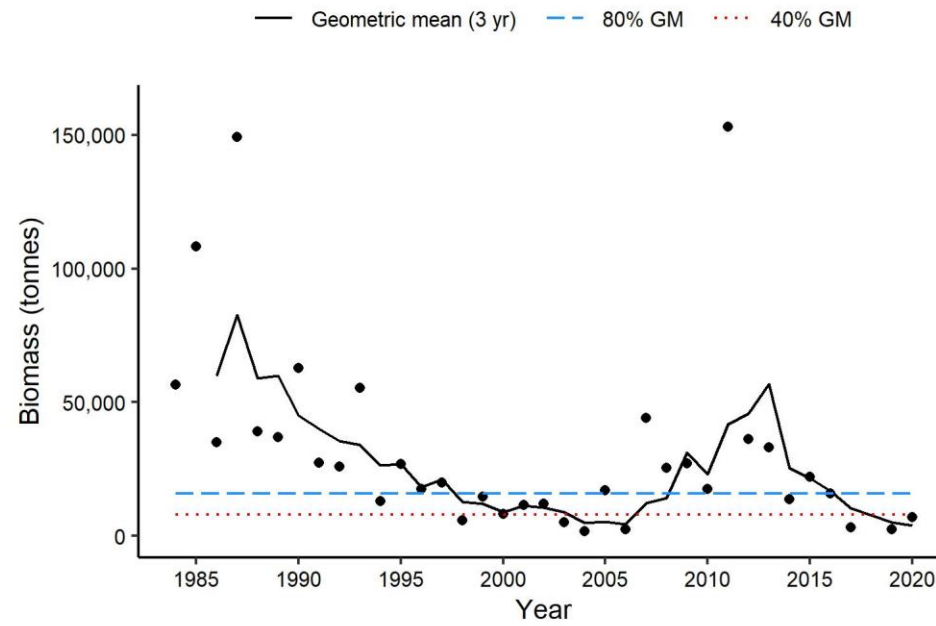


Figure 73. Survey biomass Index for Eastern Component Pollock from the DFO summer RV survey.

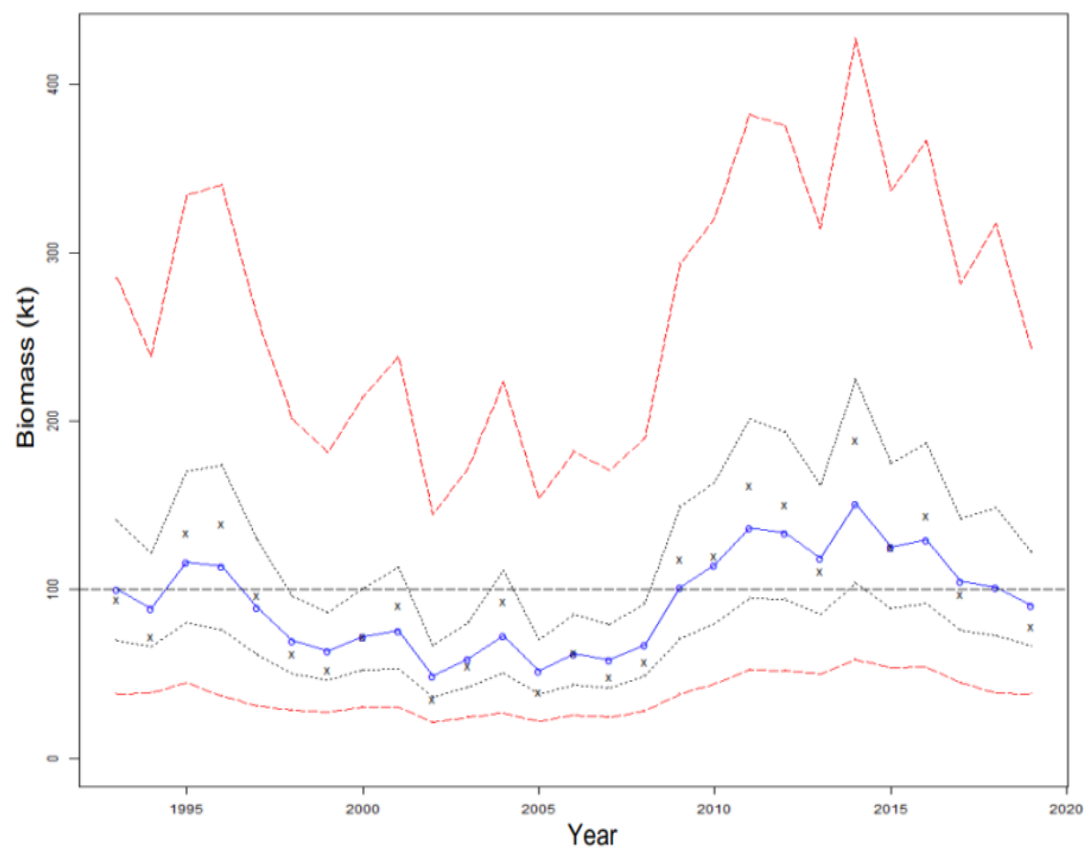


Figure 74. q-Correct survey biomass index for Silver Hake since 1993. Figure from DFO 2020b.

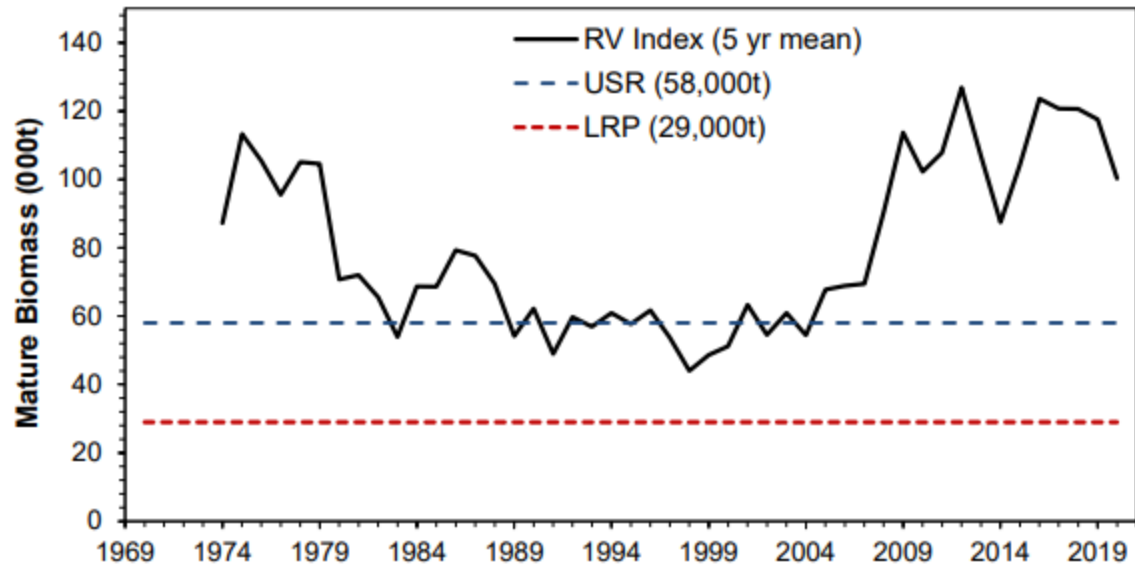


Figure 75. Mature biomass index (5-year smoothed moving average) calculated for Unit 3 Redfish strata (456, 458–495; 1970–2020). Figure from DFO 2021c.

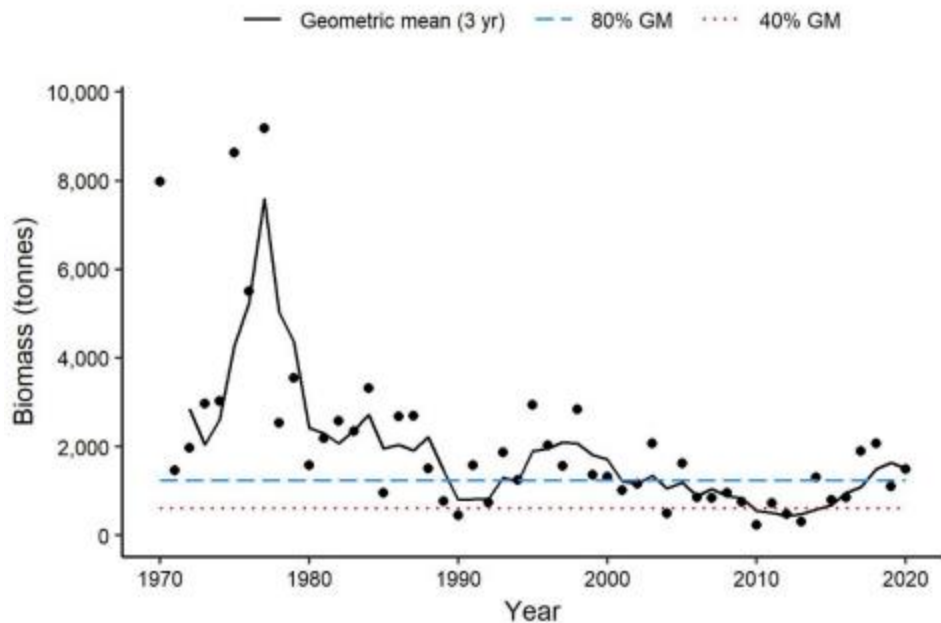


Figure 76. Biomass index for Monkfish in NAFO division 4X from the DFO summer RV survey. The three-year geometric mean biomass index is represented by the solid black line. The black dots represent the biomass index for that year. Figure from DFO 2021f.

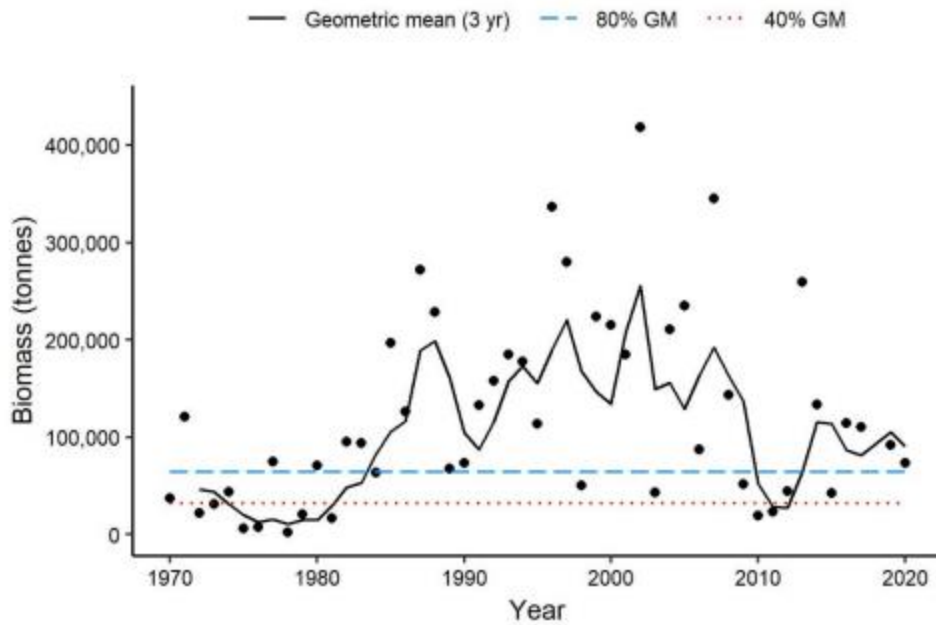


Figure 77. Biomass index for Spiny Dogfish in NAFO Divisions 4VWX from the DFO summer RV survey. The three-year geometric mean biomass index is represented by the solid black line. The black dots represent the biomass index for that year. Figure from DFO 2021f.

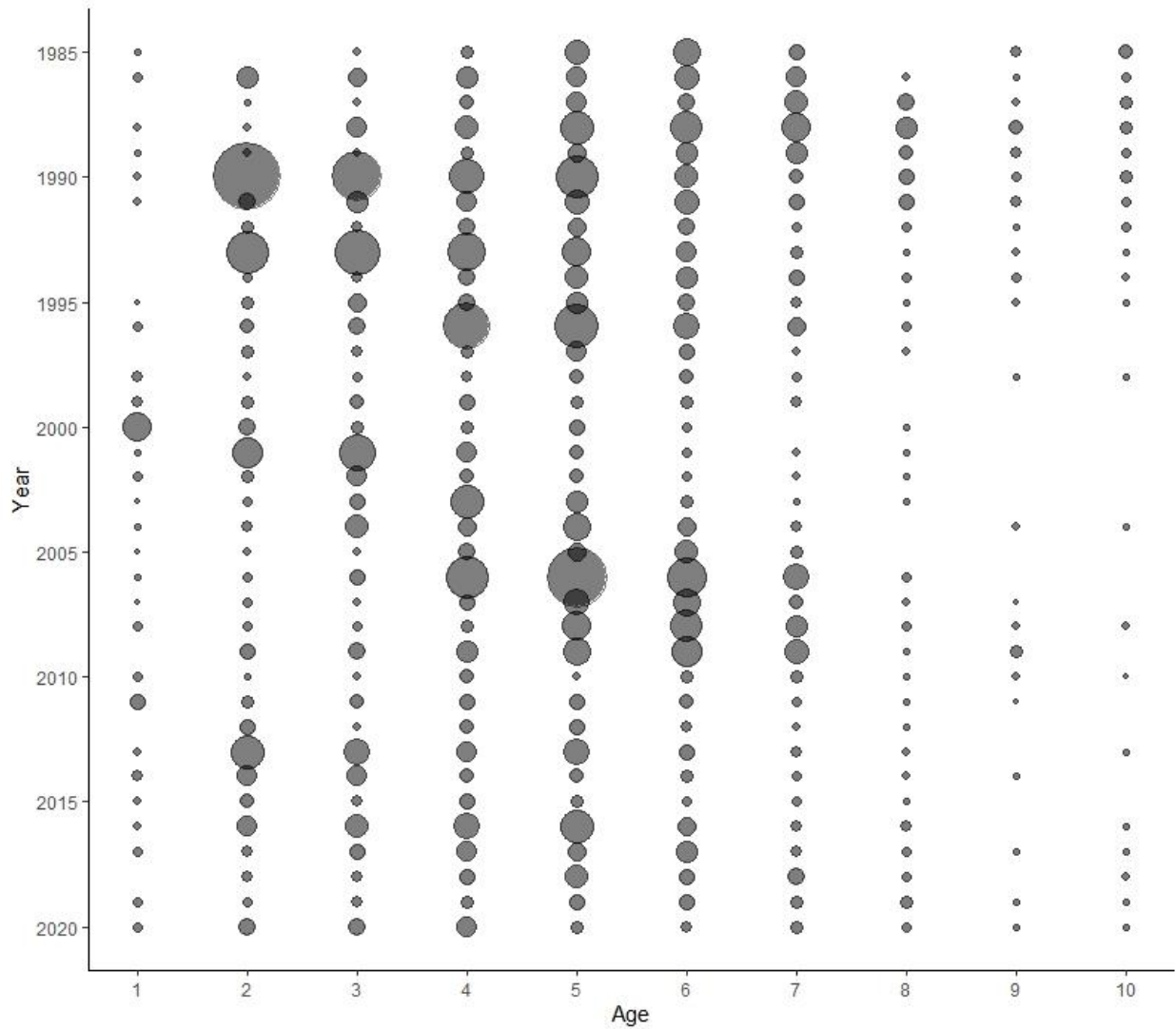


Figure 78. Survey catch-at-age for western component Pollock 4Xopqrs5Y). Size of the bubbles is indicative of the mean number per tow in each year and age.

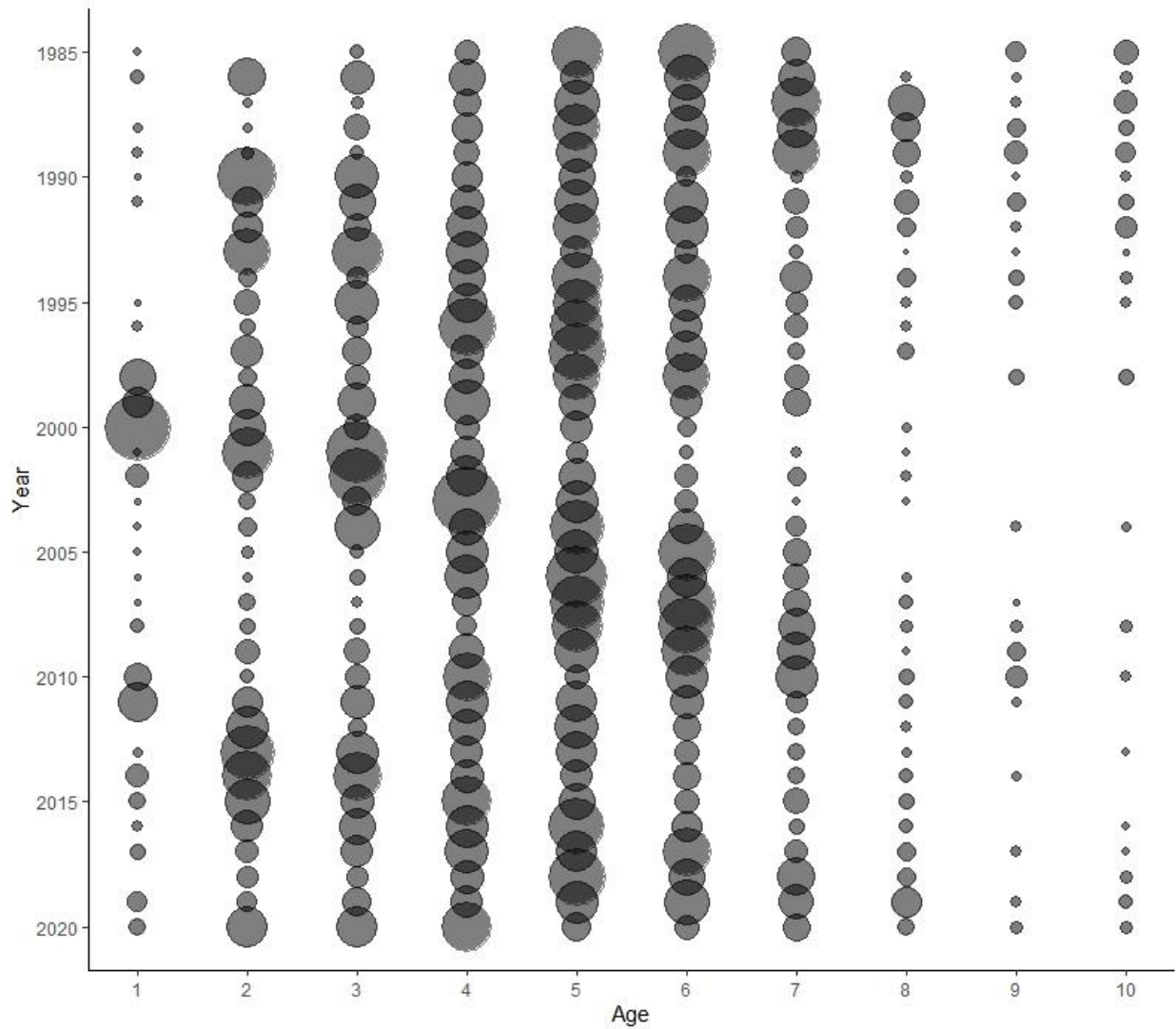


Figure 79. Survey catch-at-age for western component Pollock (4Xopqrs5Y). Size of the bubbles is indicative of the proportional mean number per tow at age within each year.

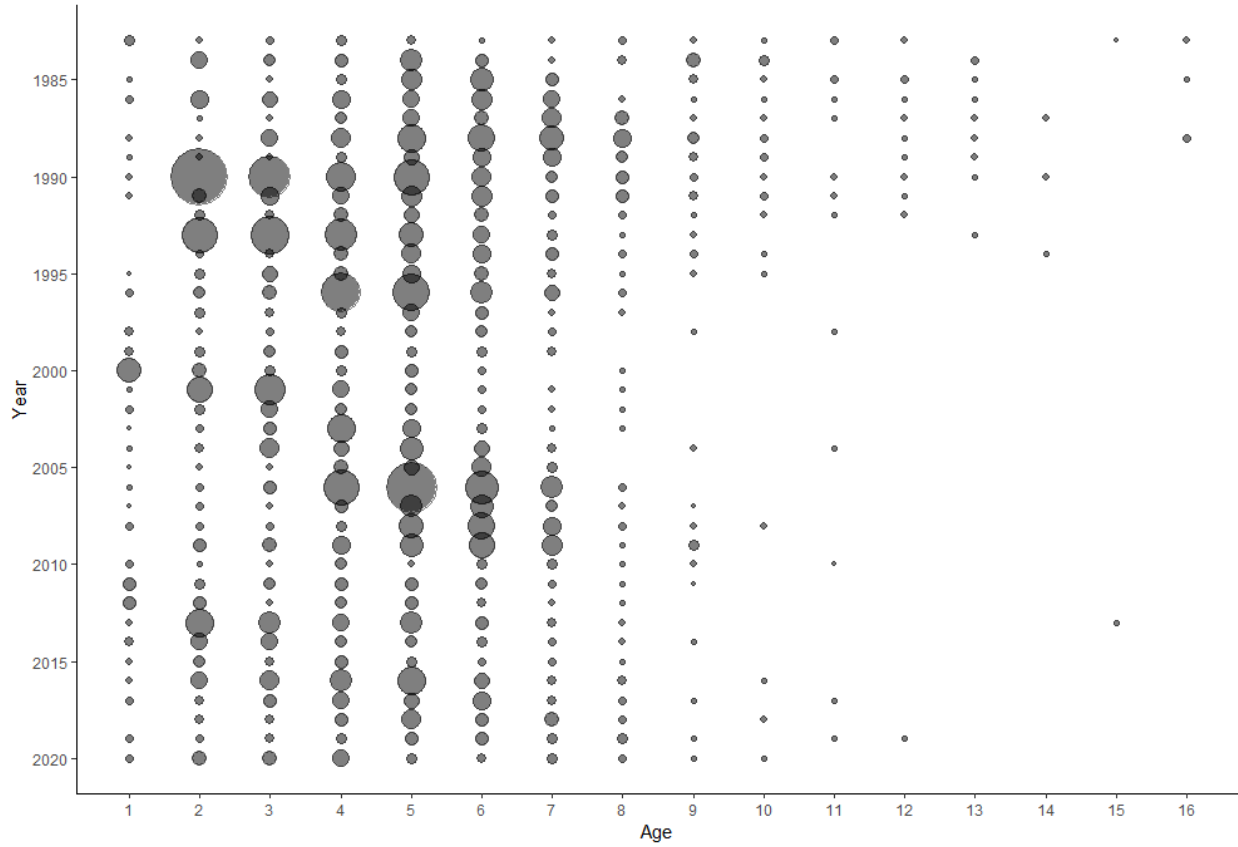


Figure 80. Survey catch-at-age for western component Pollock (4Xopqrs5Y). Size of the bubbles is indicative of the total abundance in each year and age.

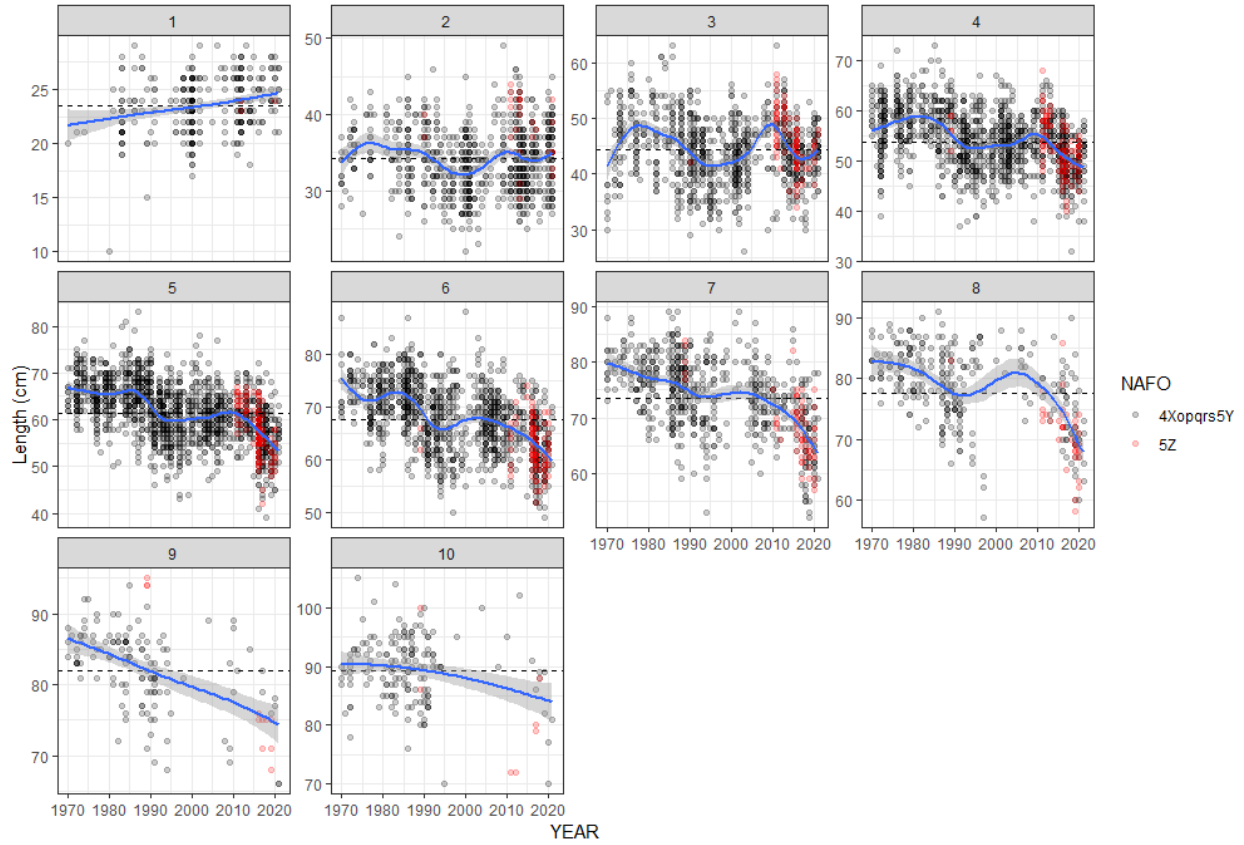


Figure 81. Length (points) -at-age (facets) by year for Pollock caught on the DFO summer RV survey in NAFO Divisions and DFO statistical areas 4Xopqrs5Y (black) and area 5Z (red). Horizontal dashed line shows the series mean at age. Blue line is a geom_smooth.

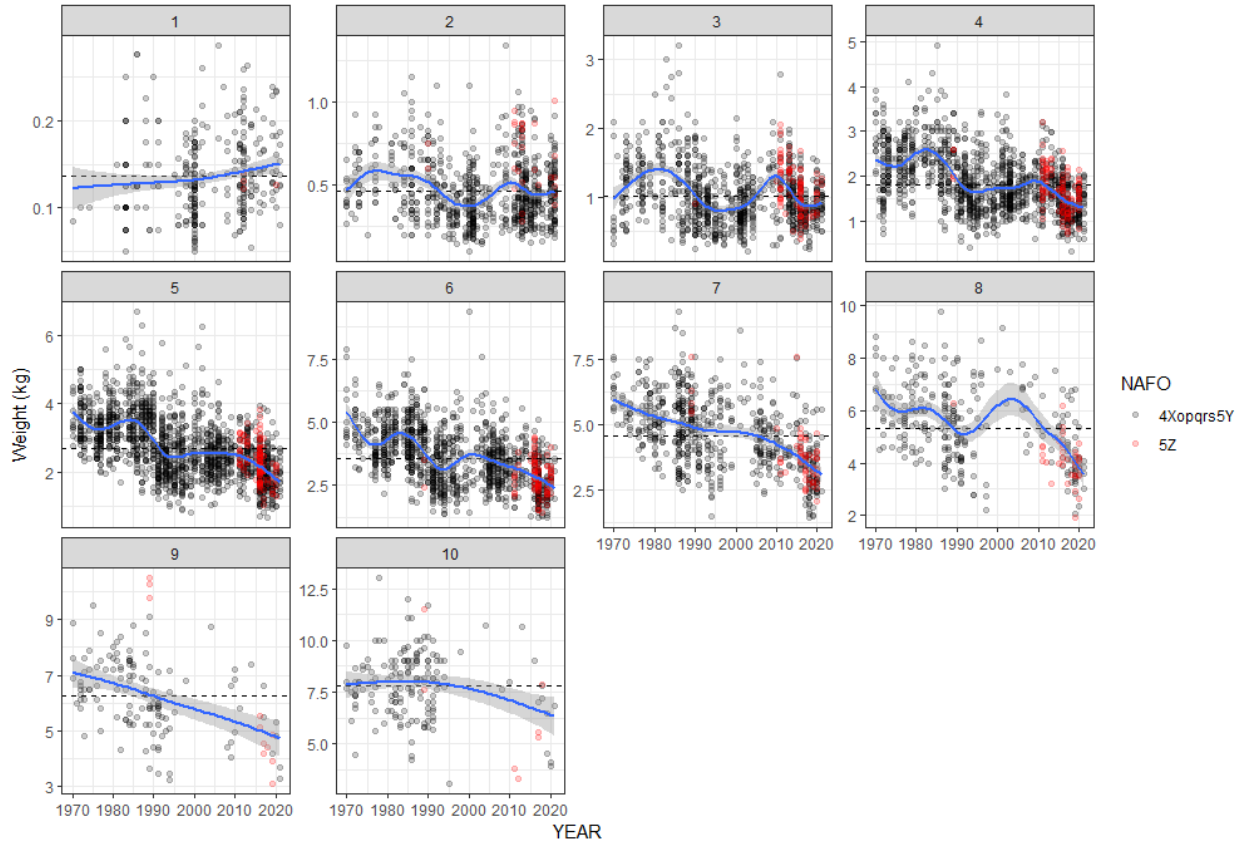


Figure 82. Weights (points)-at-age (facets) by year for Pollock caught on the DFO summer RV survey in NAFO Divisions and statistical areas 4Xopqrs5Y (black) and area 4Xopqrs5 (WC; red). Horizontal dashed line shows the series mean at age. Blue line is a geom_smooth.

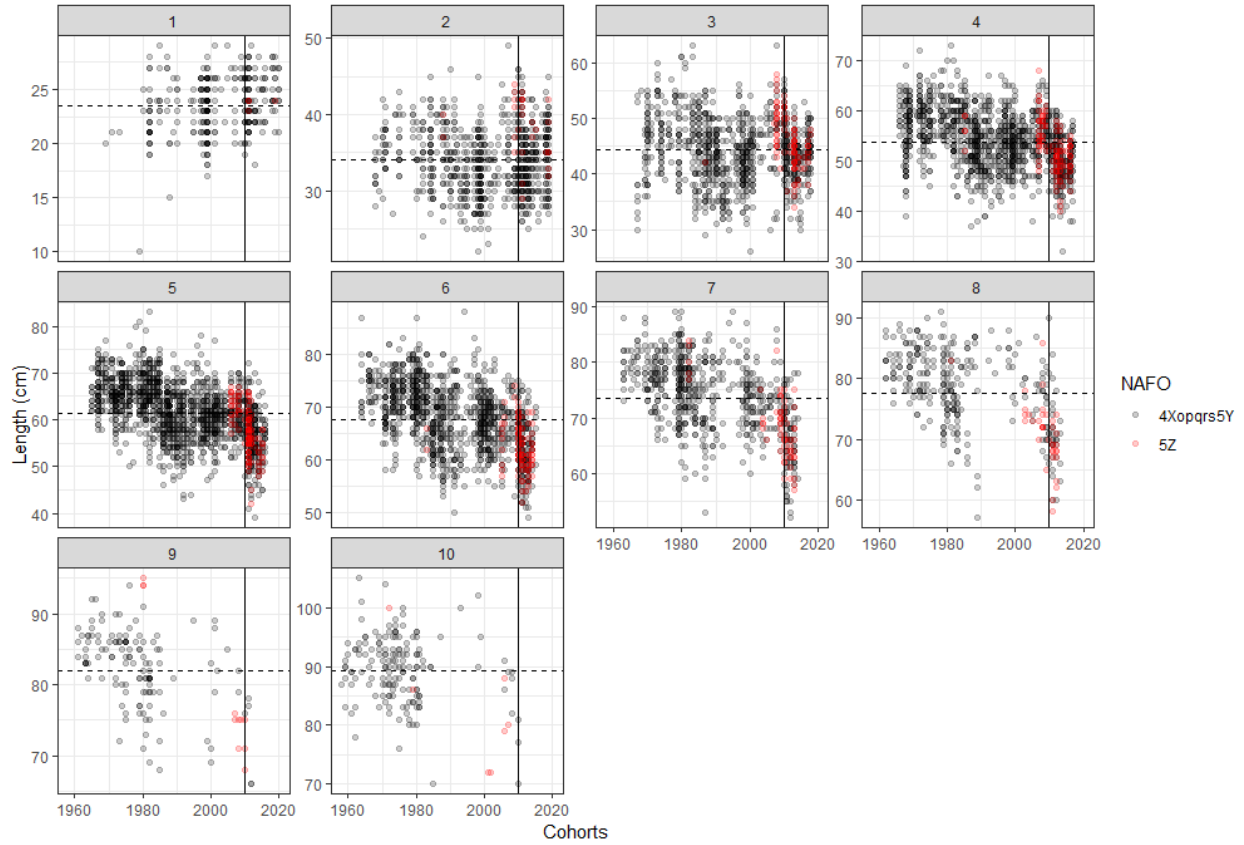


Figure 83. Length (points) -at-age (facets) by cohort for Pollock caught on the DFO summer RV survey in NAFO Divisions and DFO statistical areas 4Xopqrs5Y (black) and 4Xopqrs5 (WC; red). Horizontal dashed line shows the series mean at age. Vertical line identifies the 2010 cohort.

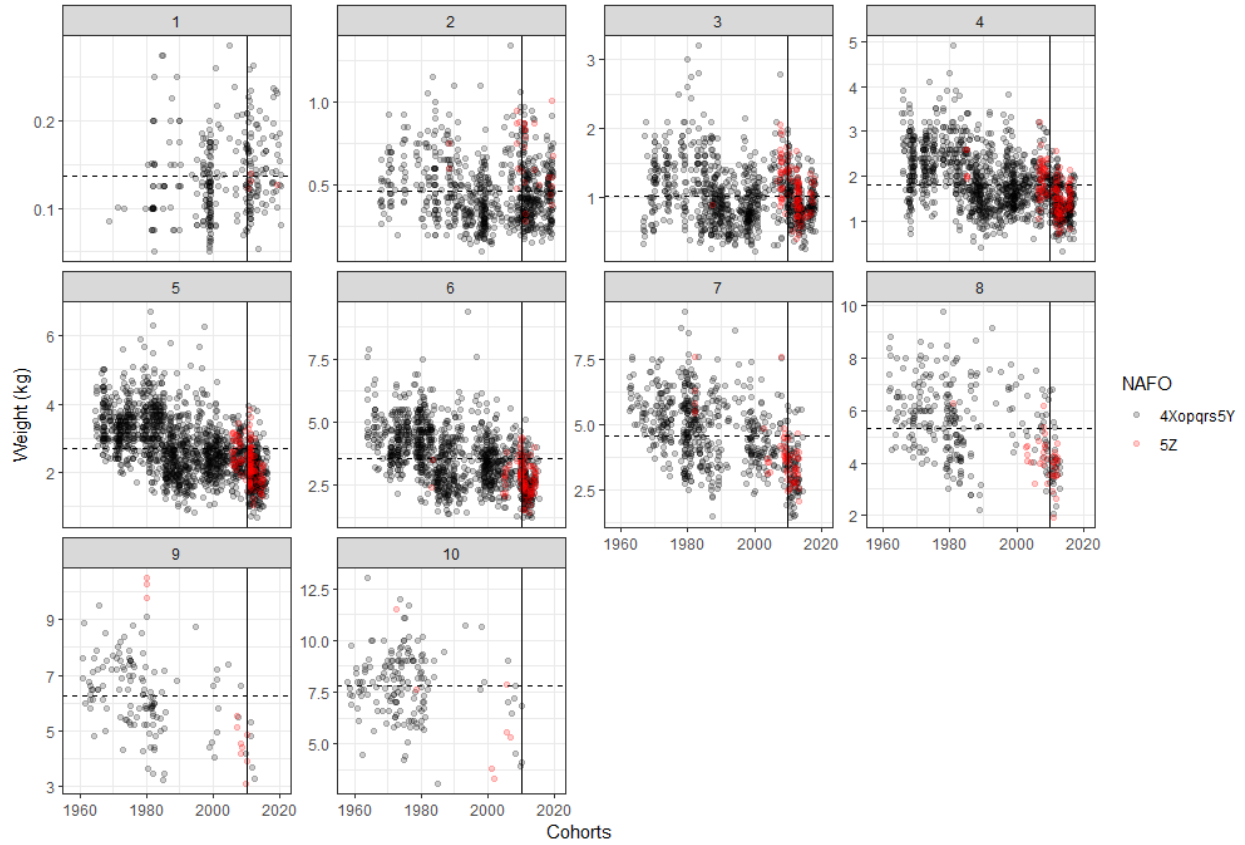


Figure 84. Weights (points) -at-age (facets) by cohort for Pollock caught on the DFO summer RV survey in NAFO Divisions and DFO statistical areas 4Xopqrs5Y (black) and 4Xopqrs5 (WC; red). Horizontal dashed line shows the series mean at age. Vertical line identifies the 2010 cohort.

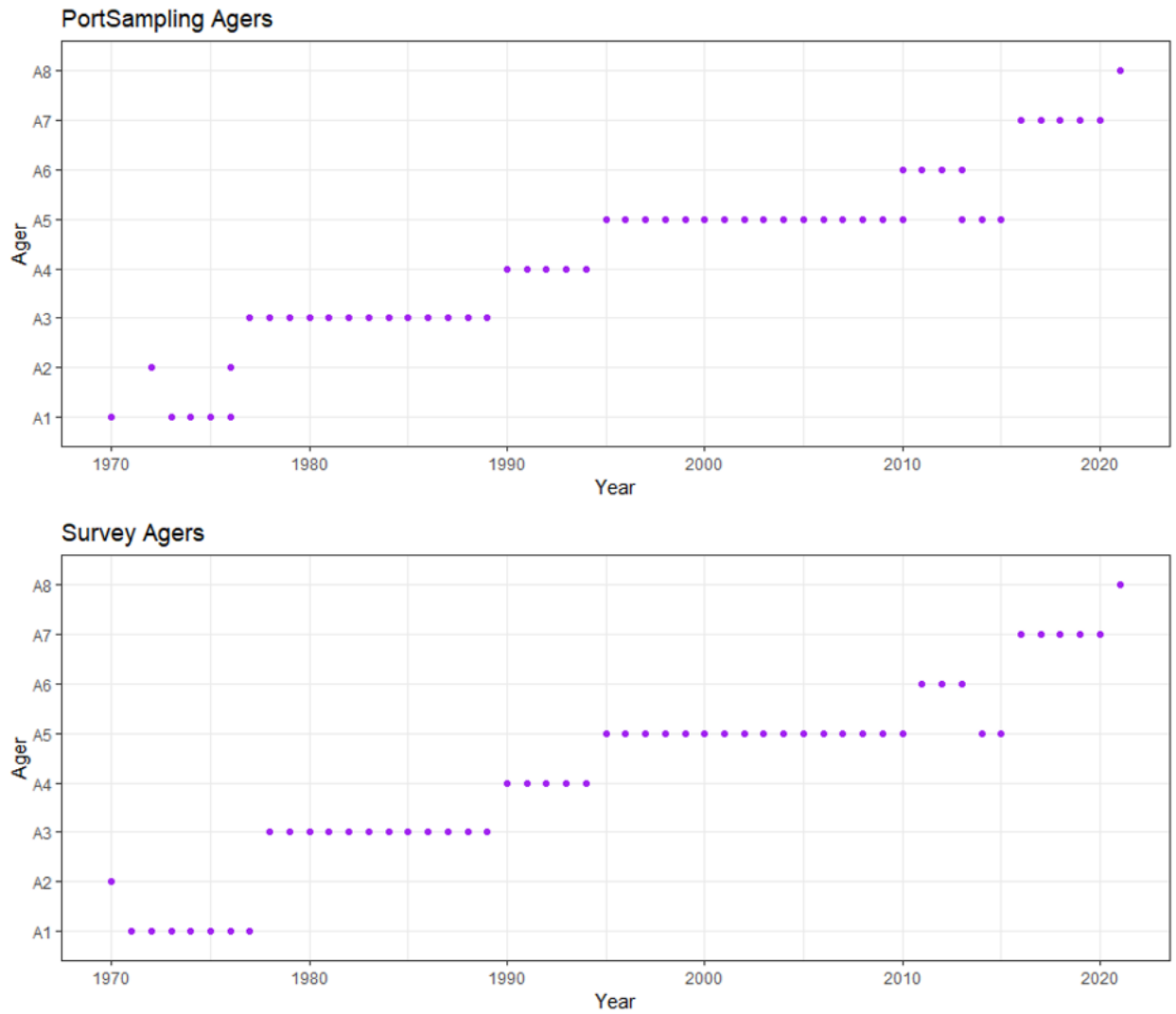


Figure 85. Ager activity for western component Pollock samples collected through port sampling (upper panel) and the DFO summer RV survey (lower panel). Purple points represent years in which a given ager is active.

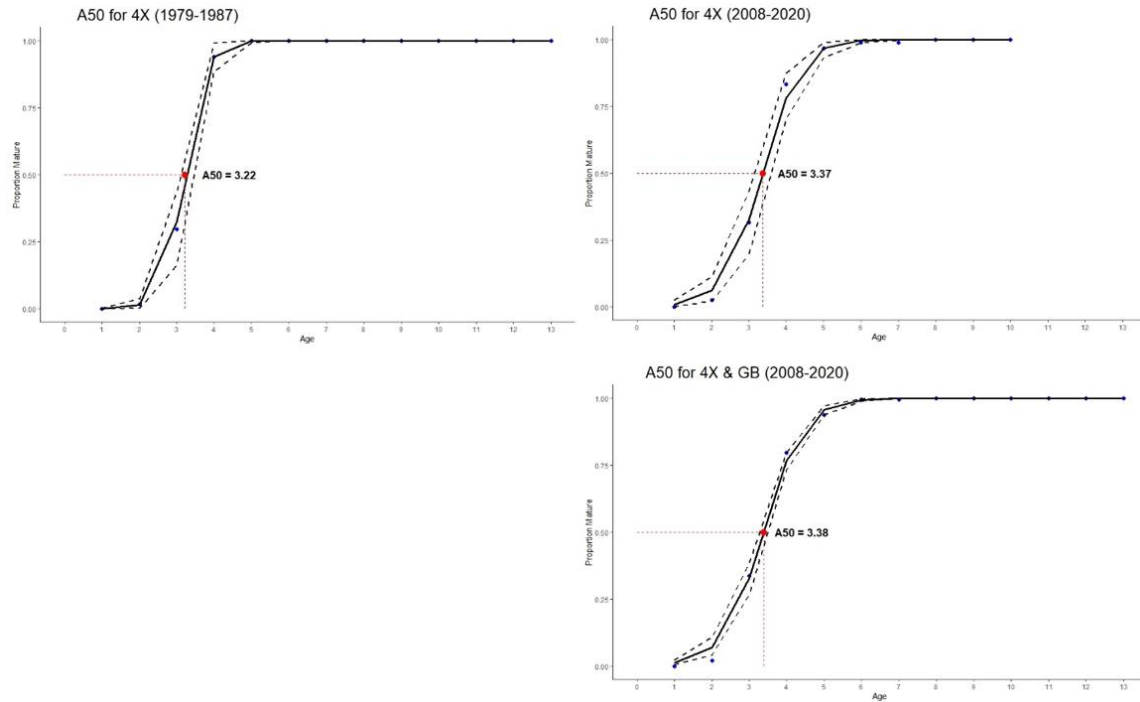


Figure 86. Age at 50% maturity for Pollock caught on the DFO winter RV survey. Top row is only for NAFO divisions 4X5Y, for the early (left) and late (right) time periods. Second row is for NAFO Divisions 4X5YZ for the late time period only.

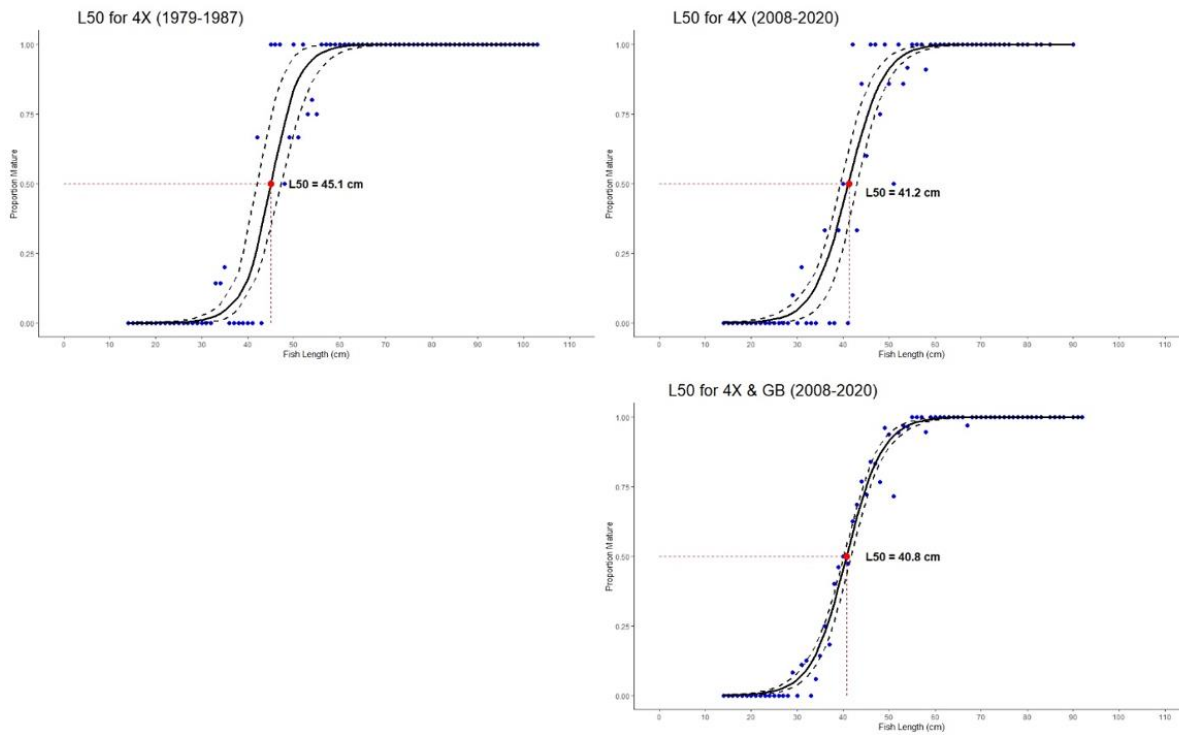


Figure 87. Length at 50% maturity of Pollock caught on the DFO winter survey. Top row is only for NAFO Divisions 4X5Y, for the early (left) and late (right) time periods. Second row is for NAFO Divisions 4X5YZ for the late time period only.

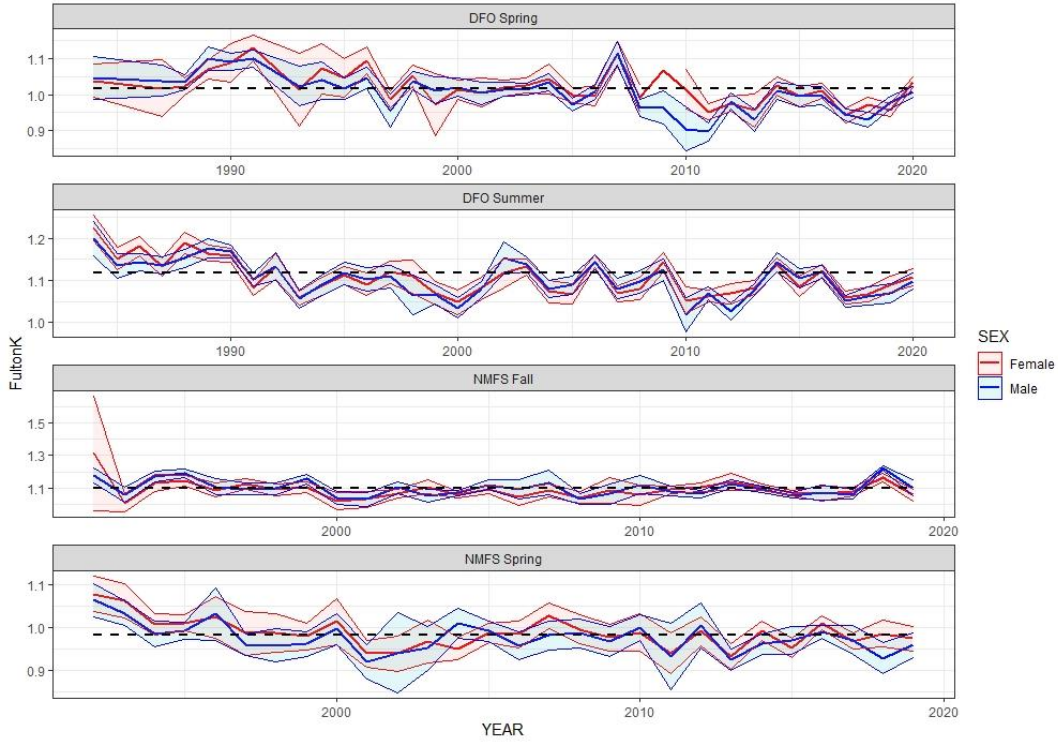


Figure 88. Fulton's condition factor for Pollock from a variety of data sources (facets) by gender (colour). Note that the temporal and spatial coverage of each survey varies, so comparisons between them must be made with caution.

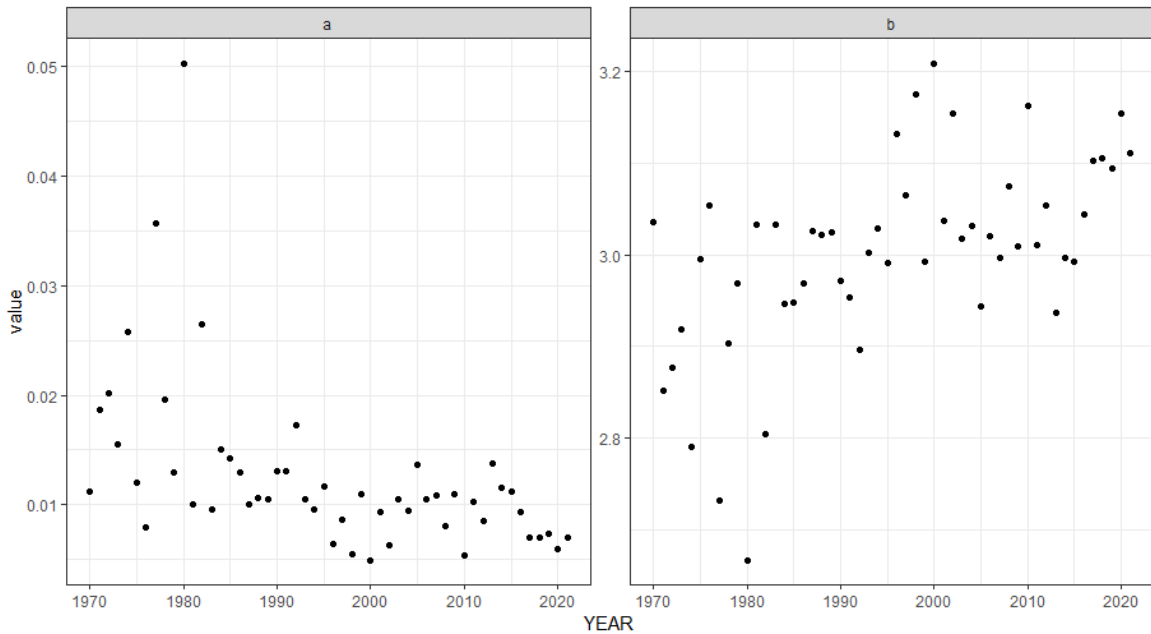


Figure 89. A and b parameters for annual length-weight relationships calculated using the DFO summer RV survey data.

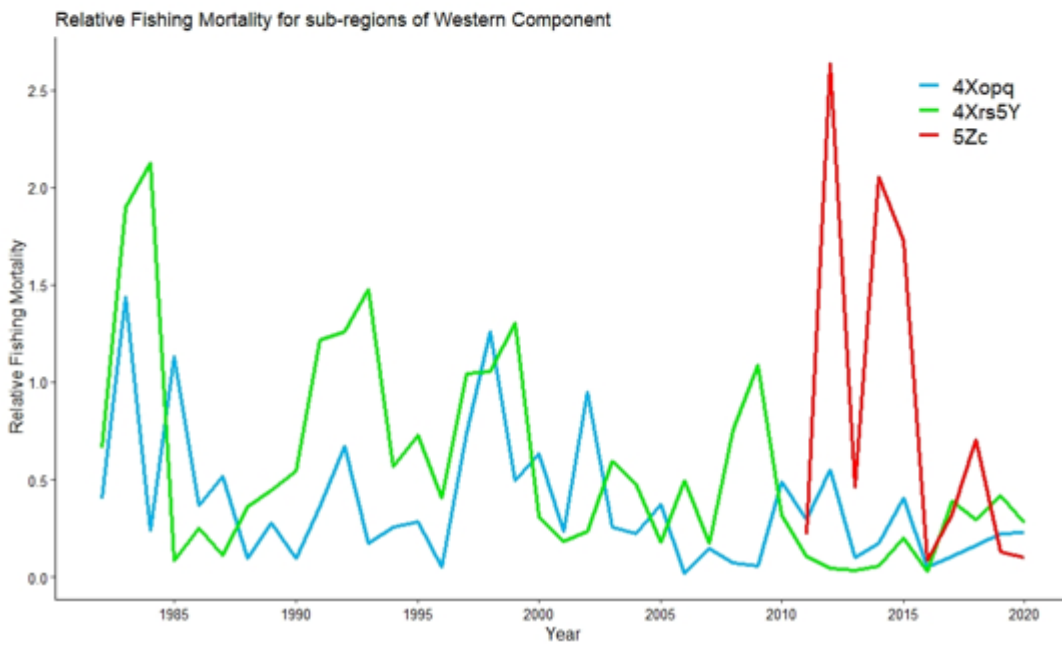
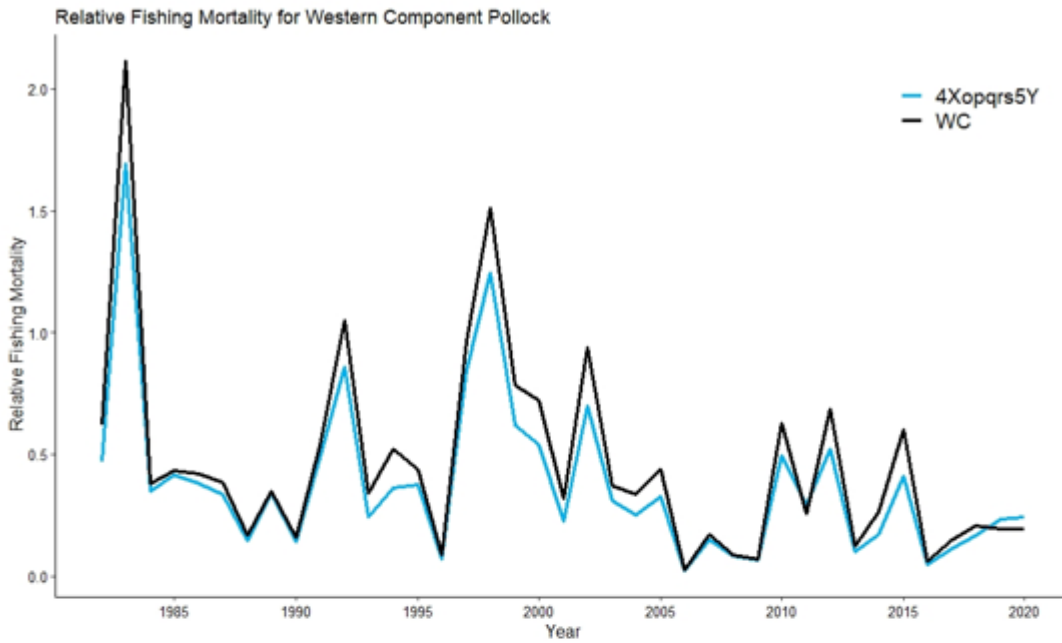


Figure 90. Relative Fishing mortality (total landings / total biomass) for different spatial units of Pollock, denoted by various colours. WC refers to NAFO Divisions and DFO statistical areas 4Xopqrs5ZY.

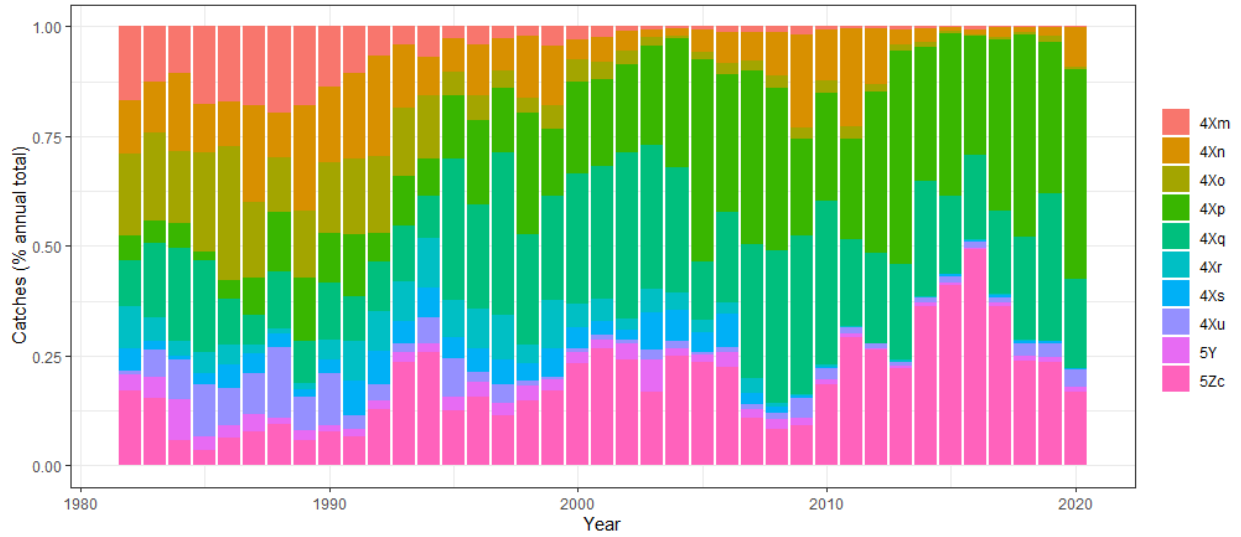


Figure 91. Commercial catches of Pollock in NAFO Divisions 4X5, proportioned out by DFO statistical areas.

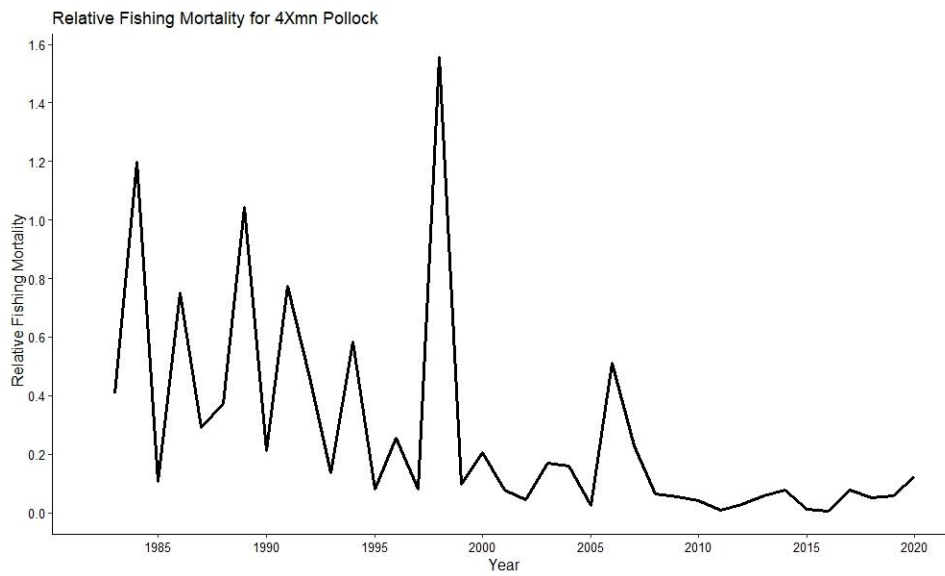


Figure 92. Relative fishing mortality (total landings / total biomass) for Pollock caught in DFO statistical area 4Xmn.



Figure 93. Total mortality (Z) for Pollock calculated by various age groups, as depicted by both facets and colours. Points represent raw values and lines represent a loess smooth.

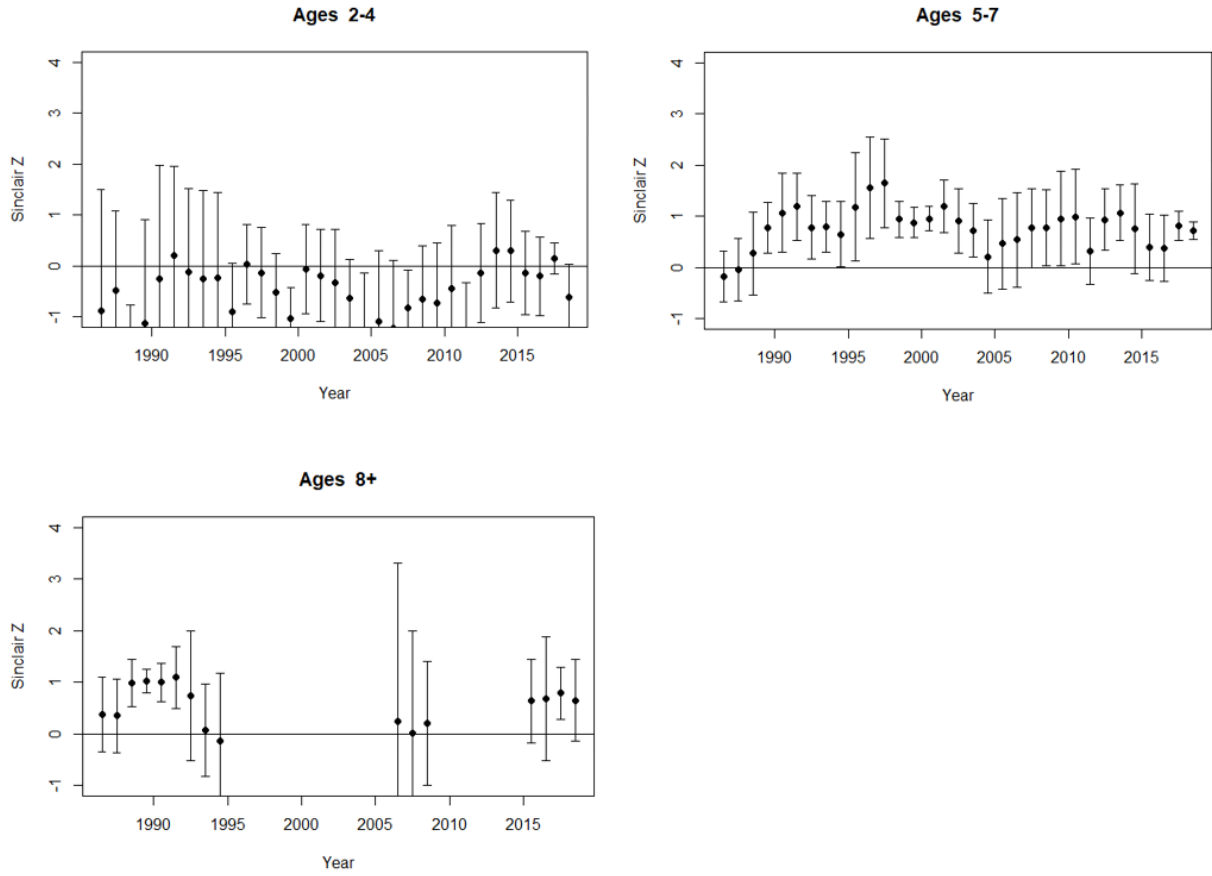


Figure 94. Sinclair Z estimate of mortality for Pollock calculated by various age groups, as depicted by facets.

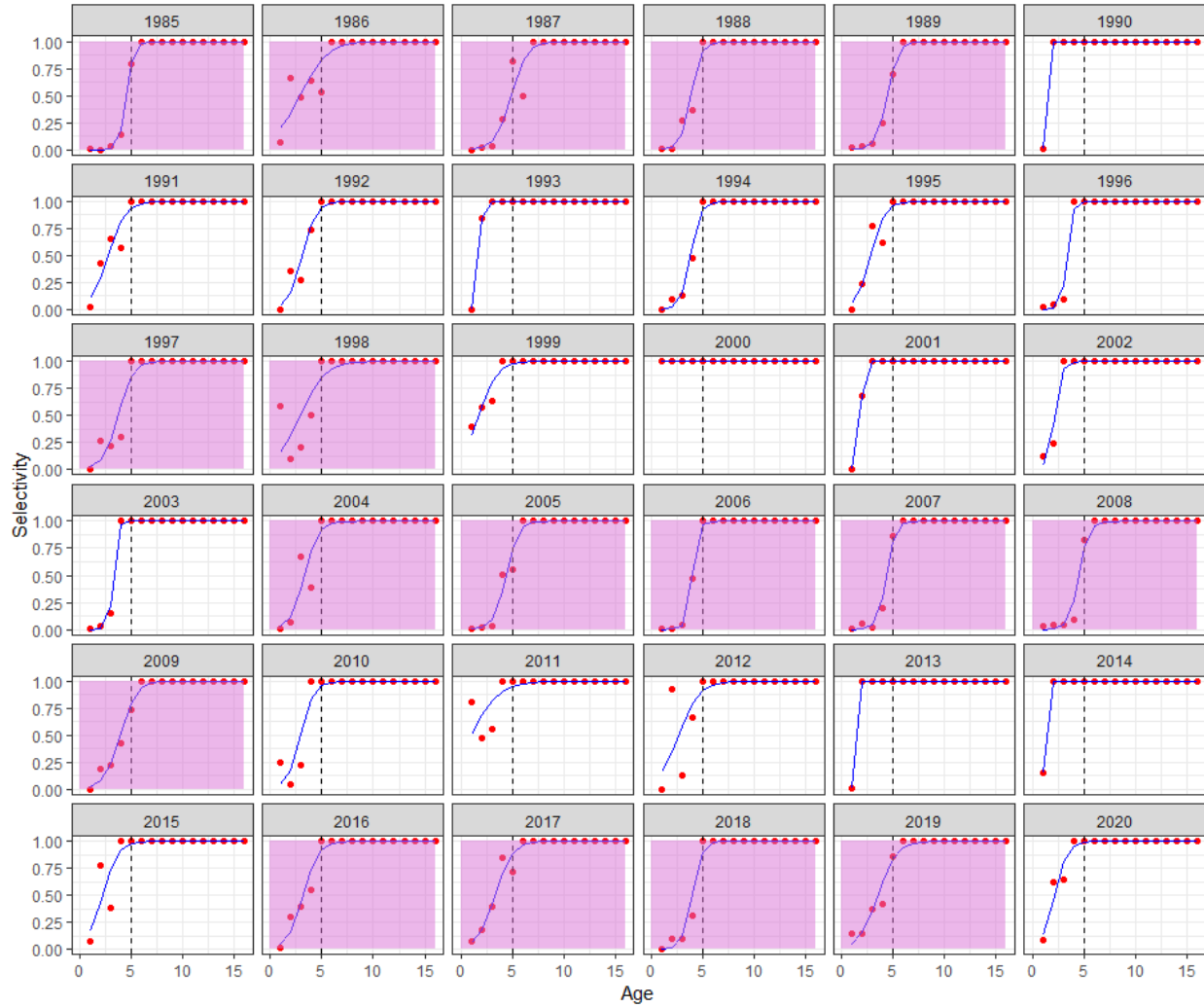


Figure 95. Selectivity-at-age calculated across years from the DFO summer RV survey catch-at-age for western component Pollock. Red points indicate raw data with a flat top imposed after the first age at which 95% selectivity is reached. Blue line shows a logistic curve fit to the data. A vertical line is arbitrarily drawn at age 5 to help interpret the plots. Pink identifies years where selectivity at age 5 falls below 95%.

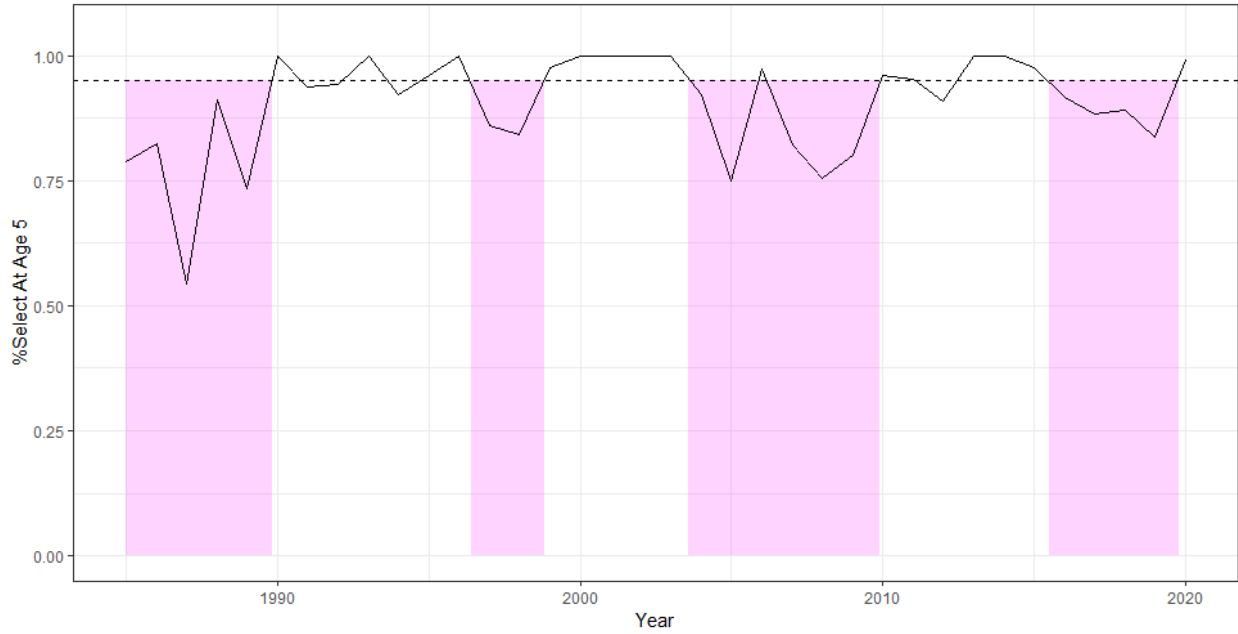


Figure 96. Percent selectivity for Pollock at age 5 within each year. Pink periods identify blocks of years where selectivity at age 5 drops below 95%. Horizontal lines depict 1 (fine dashed) and 0.95 (coarse dashed) for reference.

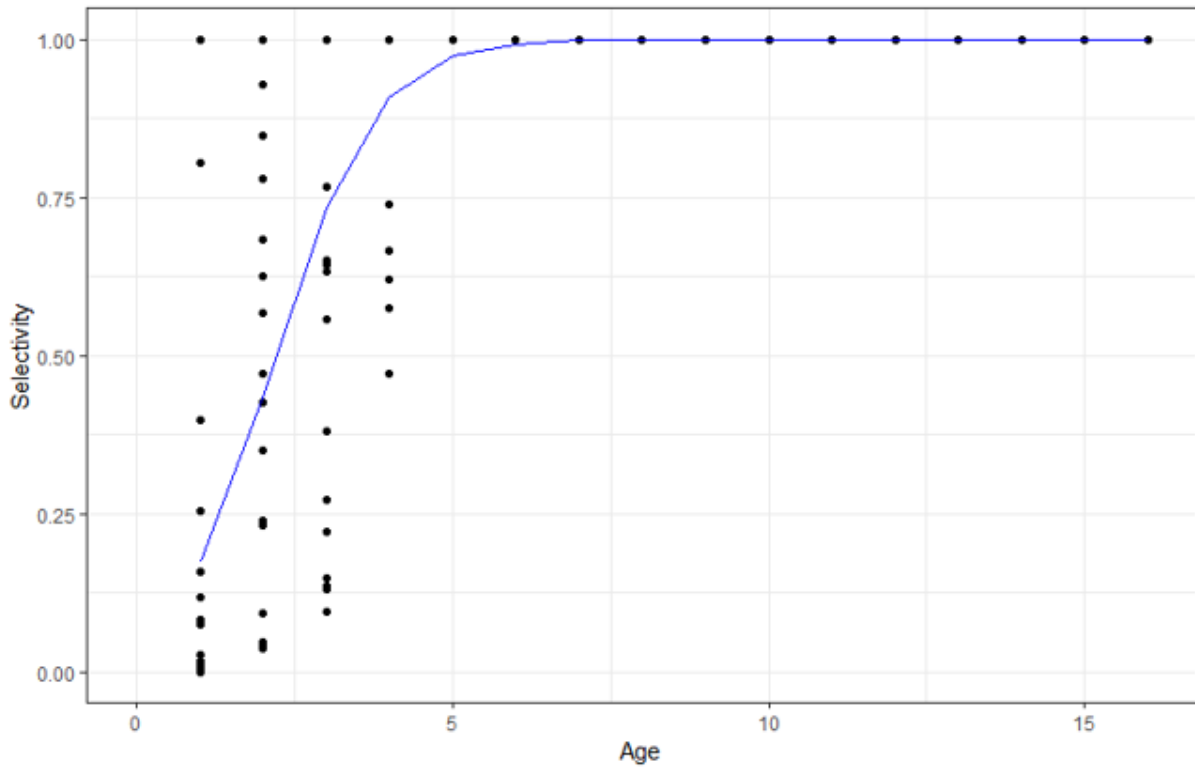
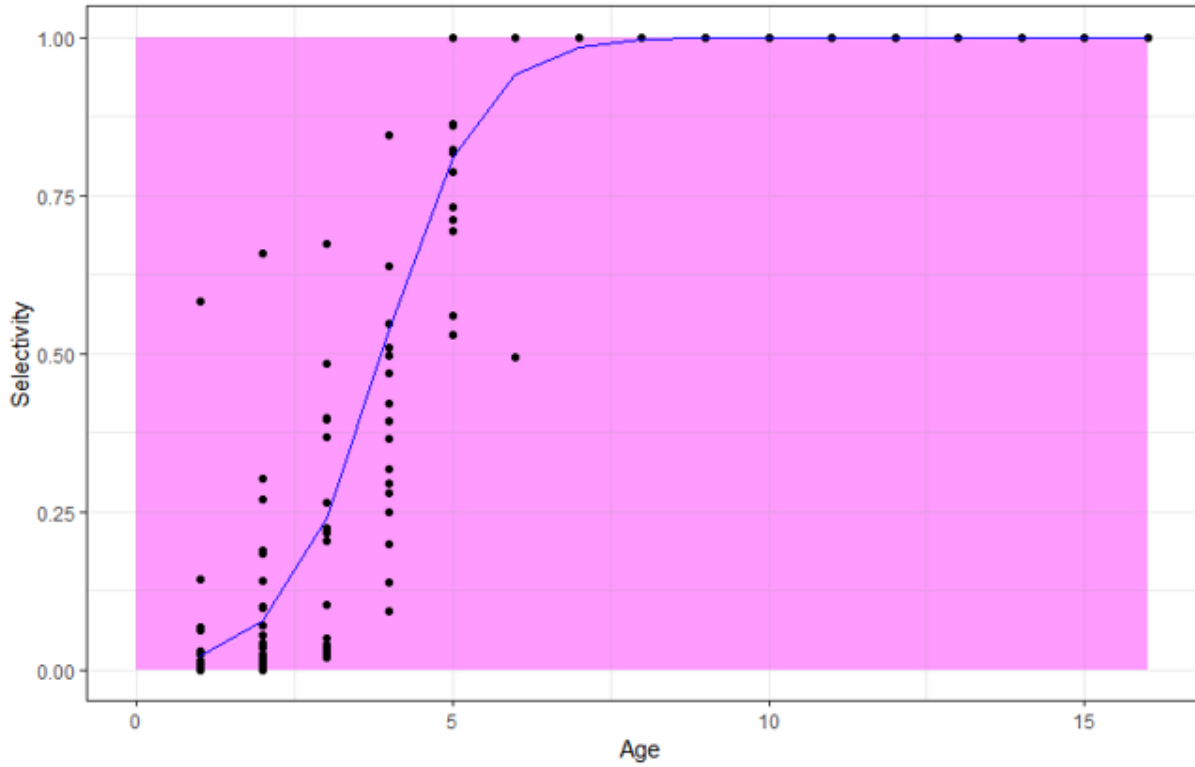


Figure 97. Flat-top selectivity curves for Pollock calculated across years, for years with (top plot, pink) and without (bottom plot, white) strong year classes contributing to the SSB.

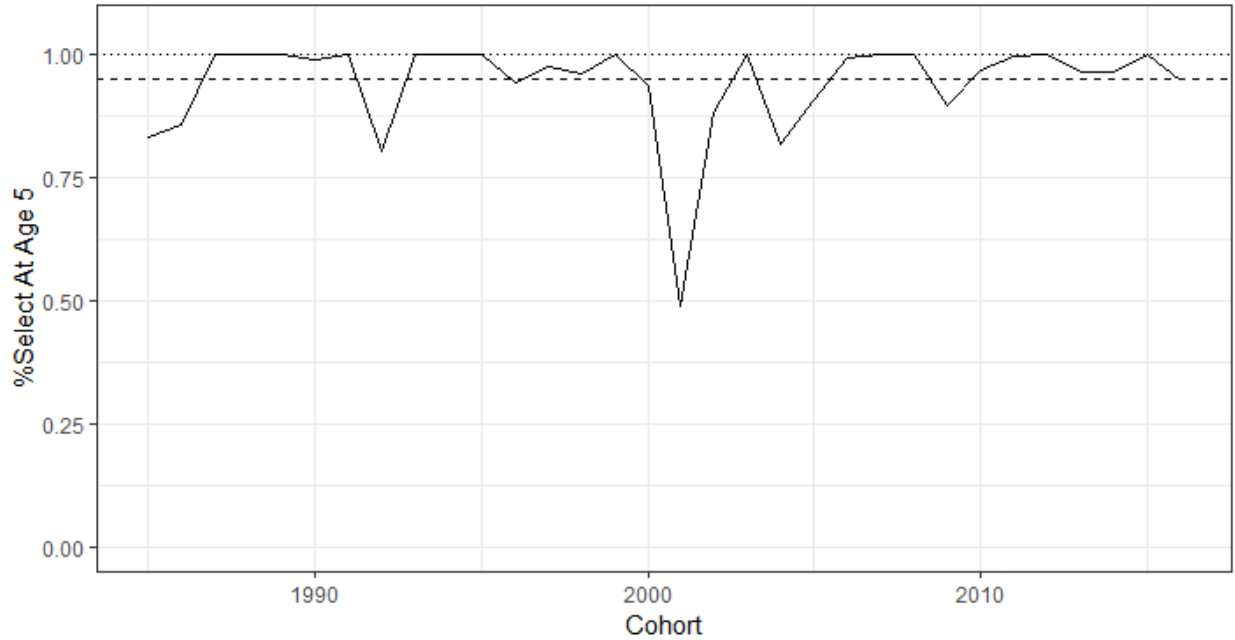


Figure 98. Percent selectivity for Pollock at age 5 within each cohort. Horizontal lines depict 1 (fine dashed) and 0.95 (coarse dashed) for reference.

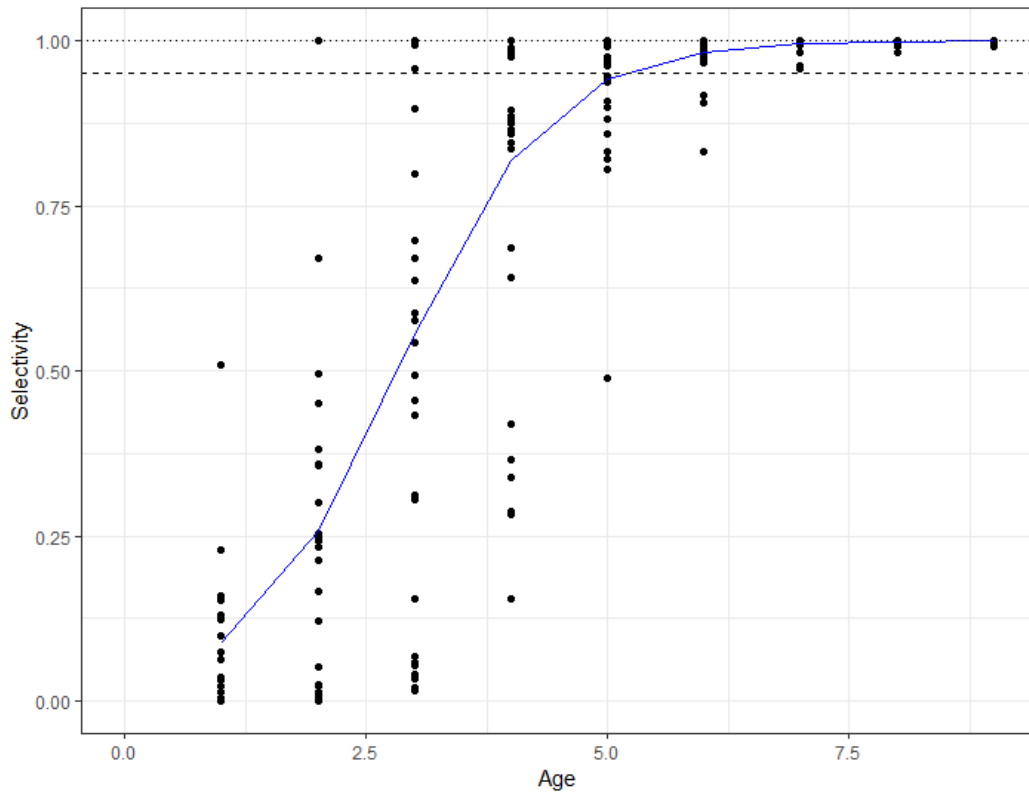


Figure 99. Selectivity curve for Pollock calculated across cohorts since 1985. Horizontal lines depict 1 (fine dashed) and 0.95 (coarse dashed) for reference.

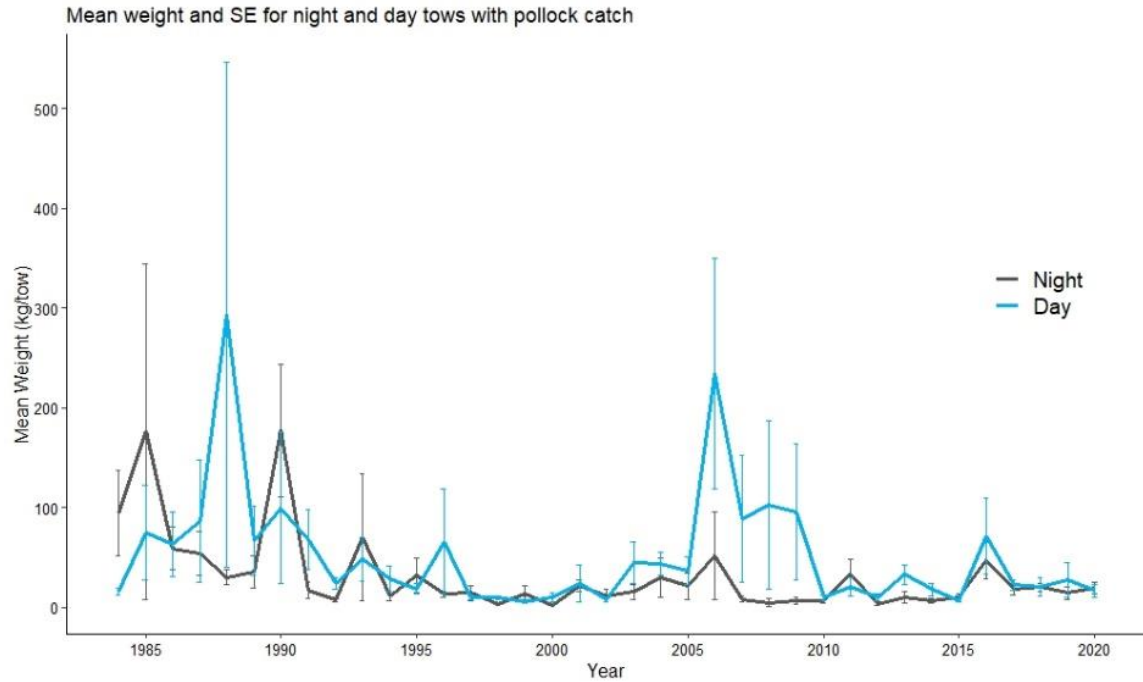


Figure 100. Mean Pollock weight (kg/tow) from the DFO summer RV survey, with accompanying standard error. Colour is indicative of night (21:00-05:59) and day (6:00-20:59) catches.

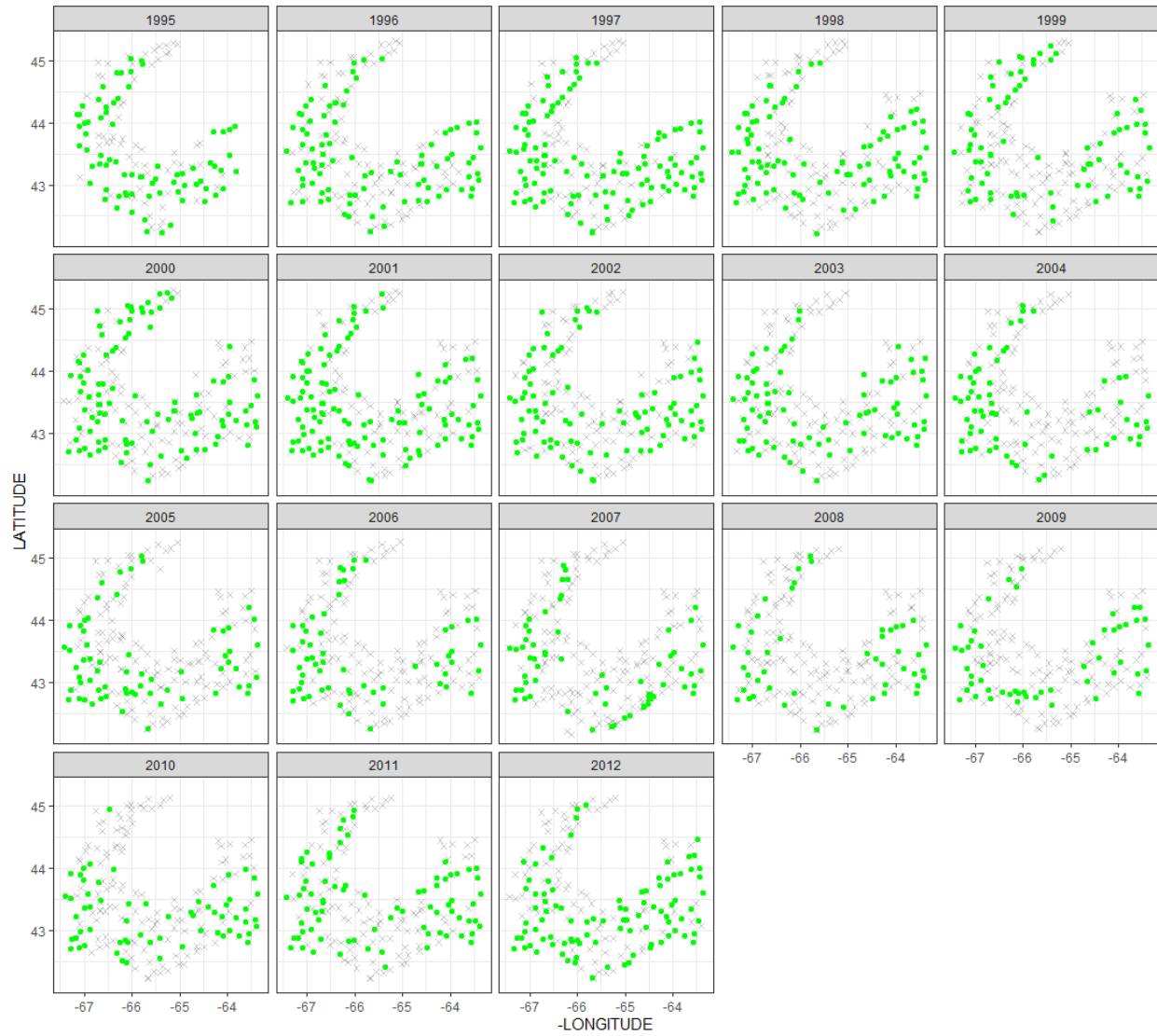


Figure 101. Distribution of Pollock catches (green points) in the ITQ survey time series. Plusses indicate sets which caught no Pollock.

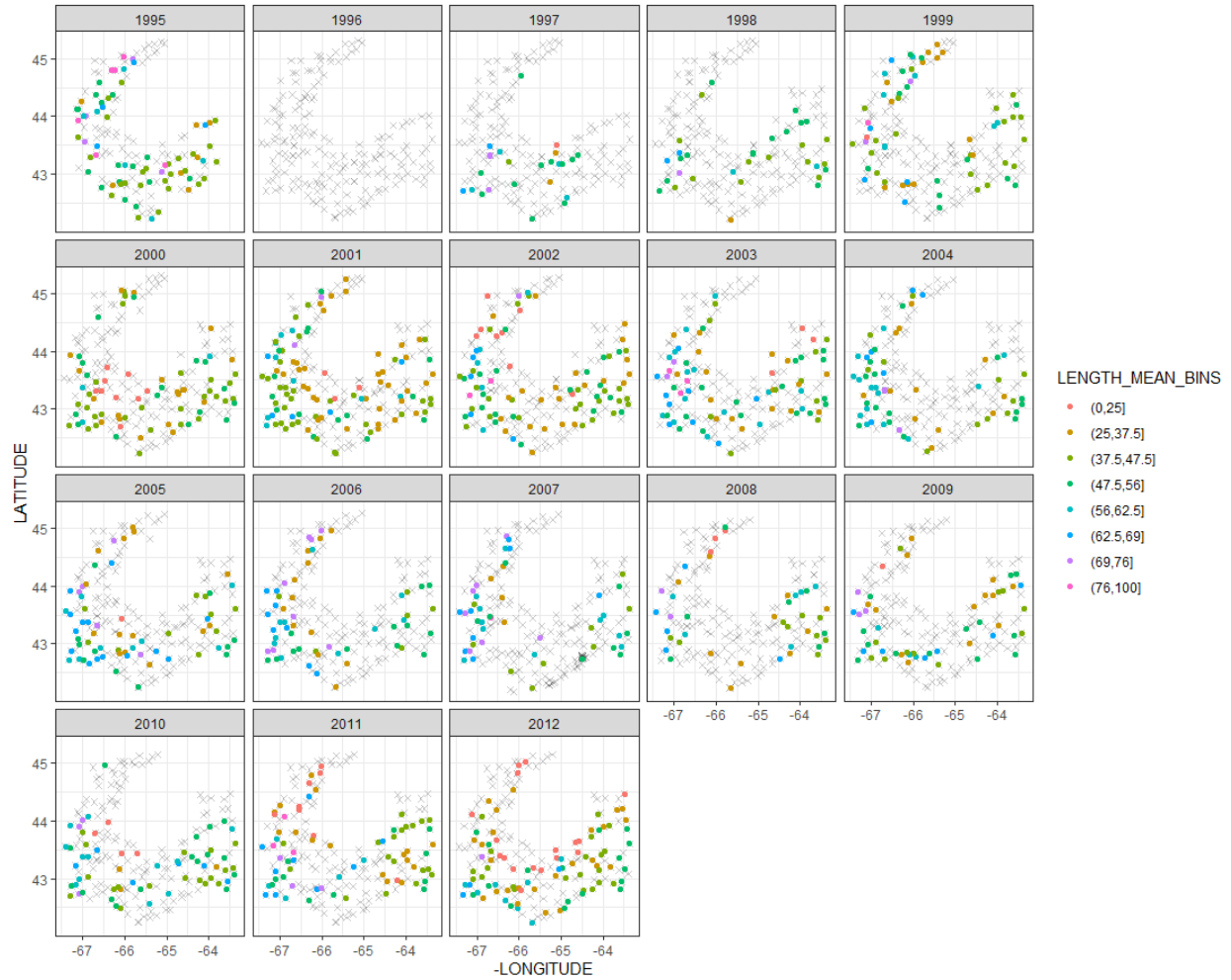


Figure 102. Distribution of sets from the ITQ survey where Pollock catch was sampled for length. Colour is indicative of the mean age of the catch, based on the mean length and the DFO summer RV survey growth curve at the time. Plus signs are indicative of sets where no Pollock were caught or the catch of Pollock was not sampled for length.



Figure 103. Distribution of sets from the ITQ survey where Pollock catch was sampled for length. Colour is indicative of the mean age of the catch, based on the mean mode and the DFO summer RV survey growth curve at the time. Plus signs are indicative of sets where no Pollock were caught or the catch of Pollock was not sampled for length.

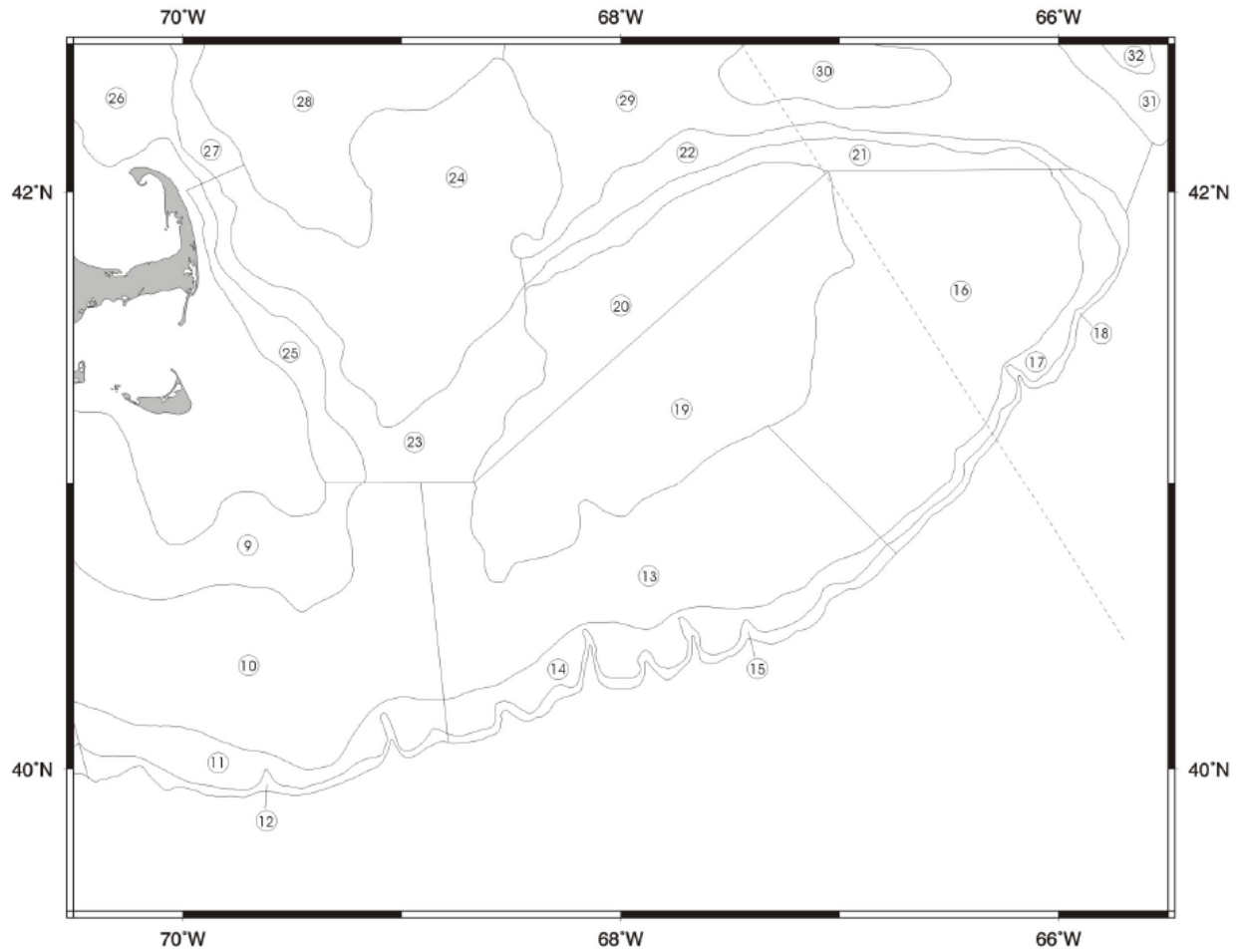


Figure 104. NEFSC Standard Bottom Trawl Survey strata spanning Georges Bank. Dashed line represents the Hague Line. Numbers represent a stratum numbers which make up the full stratum ID (1XX0; e.g., 16 = Stratum 1160). Figure from Politis et al. 2014.

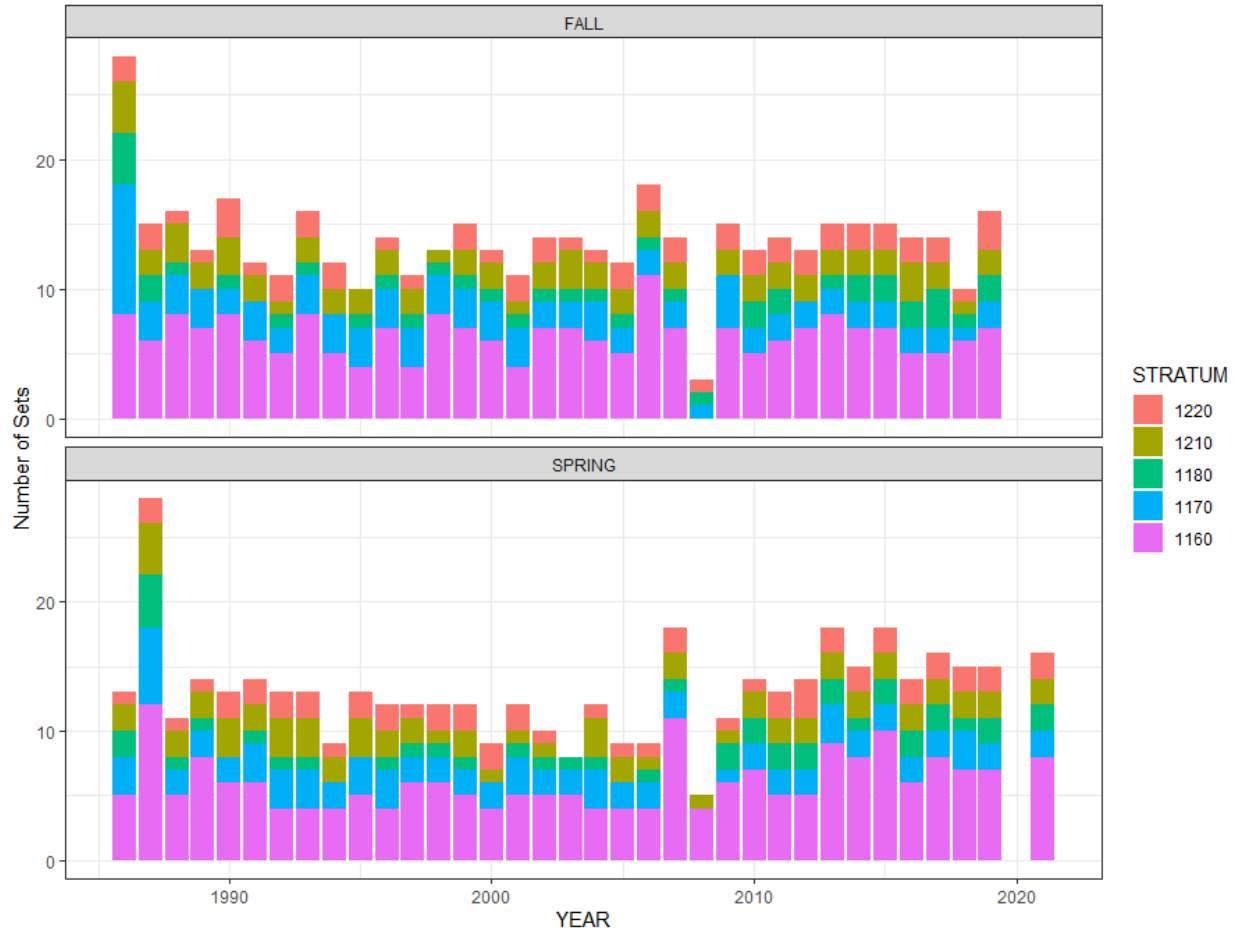


Figure 105. Number of sets carried out on the NMFS bottom trawl surveys in the Canadian portion of eastern Georges Bank during spring and fall cruises.

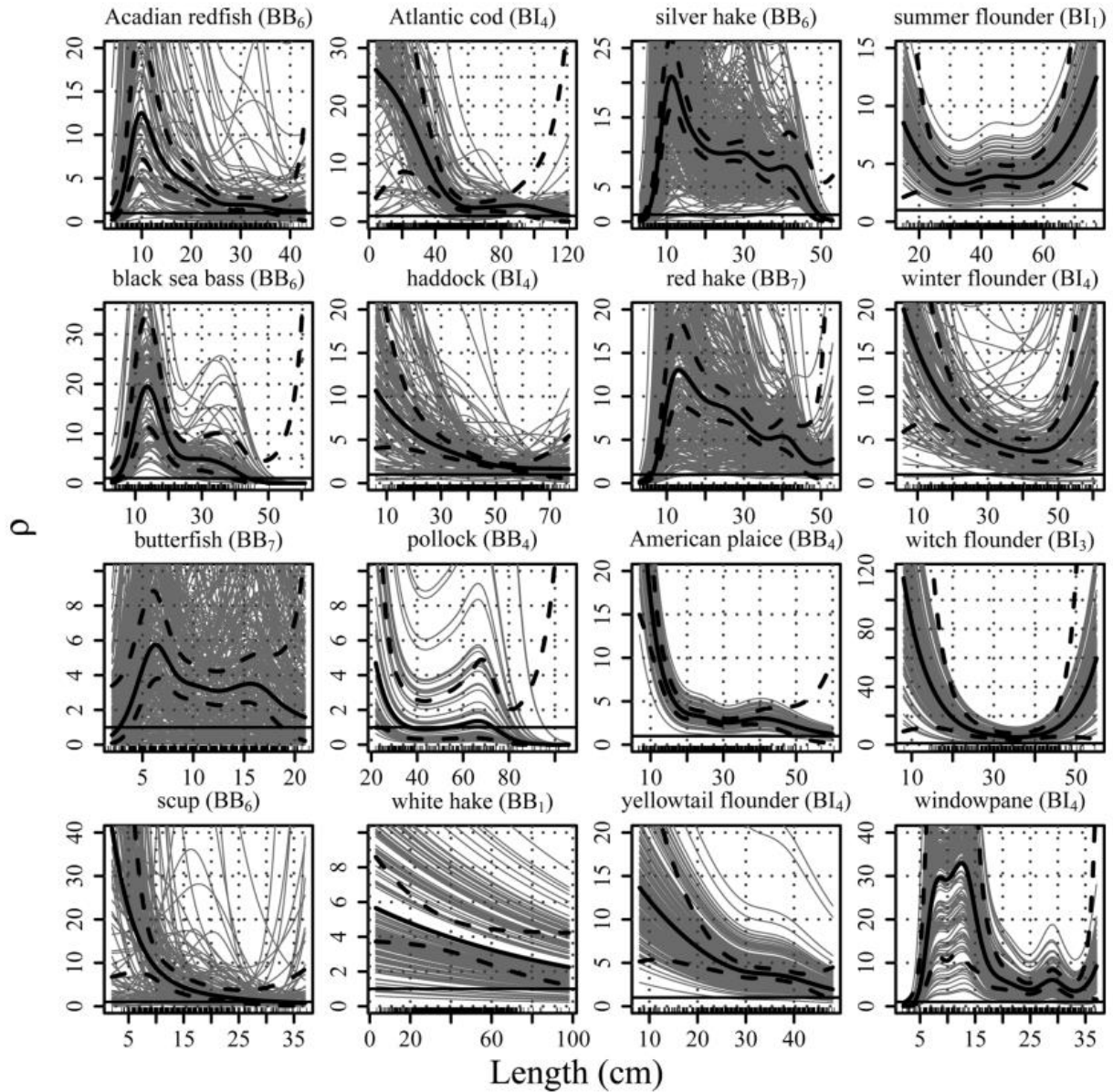


Figure 106. Estimated mean relative catch efficiency (solid black line) and associated 95% CI (dashed black lines) at size for a range of species from best performing models, as evaluated by Miller 2013. The relative catch efficiency is comparing the Albatross IV and Henry B. Bigelow, with values above 1 indicating that the Henry B. Bigelow was more efficient. Figure is originally from Miller 2013.

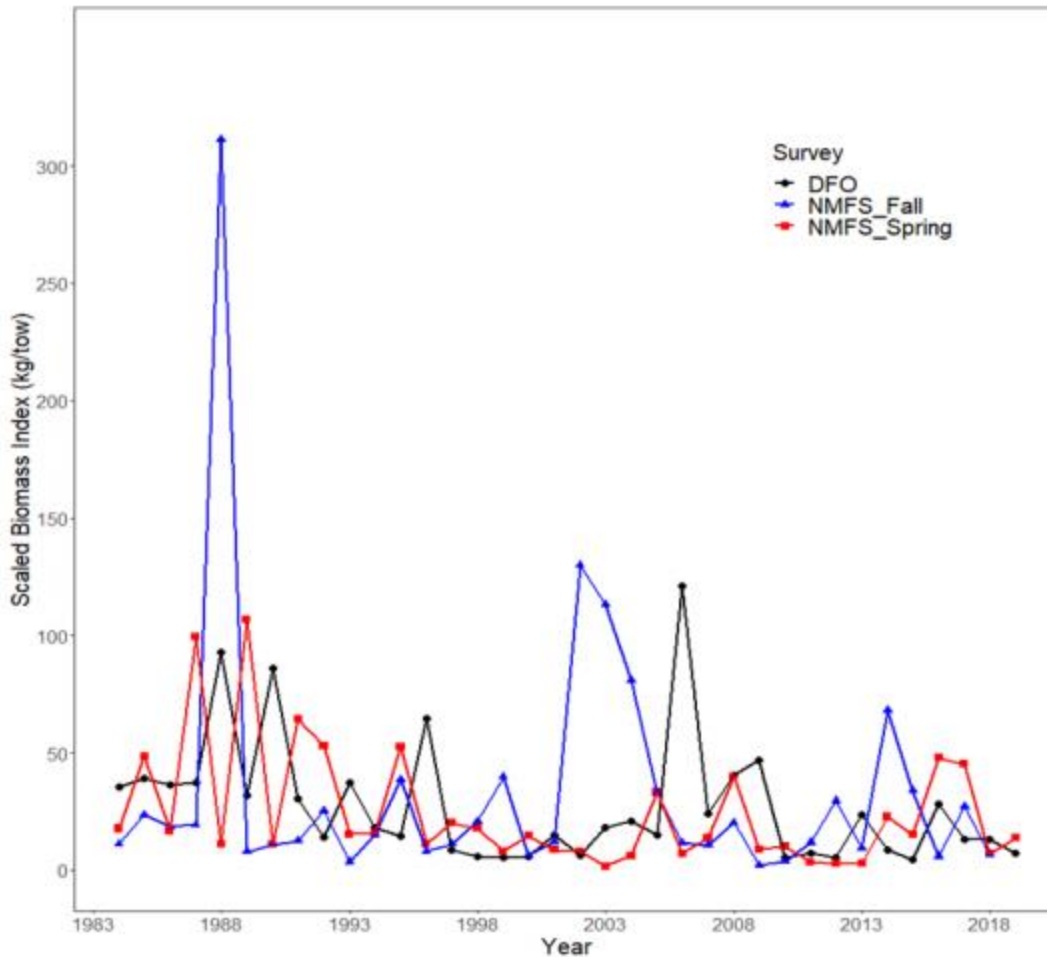


Figure 107. Western component Pollock biomass indices, scaled to the DFO summer RV survey mean (1984-1994) for the DFO summer (black), NMFS spring (red) and NMFS fall (blue) surveys from 1984-2019. Figure from DFO 2021b. Note that US survey does not extend into NAFO division 4X, while the DFO summer RV survey only recently extends into NAFO division 5Z.