Fisheries and Oceans Canada | Pêches et Océans Canada
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Canadian Science Advisory Secretariat (CSAS)

Research Document 2025/020

Maritimes Region

Framework Review for 4X5Y Haddock: Part 1 - Review of the Data Inputs

Barrett, T.J., and Barrett, M.A.

Fisheries and Oceans Canada
Saint Andrews Biological Station
125 Marine Science Drive
St. Andrews, New Brunswick, E5B 0E4

May 2025

Foreword

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

Published by:

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

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

ISSN 1919-5044
ISBN 978-0-660-76389-7 Cat. No. Fs70-5/2025-020E-PDF

Correct citation for this publication:

Barrett, T.J., and Barrett, M.A. 2025. Framework Review for 4X5Y Haddock: Part 1 - Review of the Data Inputs. DFO Can. Sci. Advis. Sec. Res. Doc. 2025/020. iv + 85 p.

Aussi disponible en français :

Barrett, T.J. et Barrett, M.A. 2025. Examen du cadre pour l'aiglefin des divisions 4X5Y : Partie1 – Examen des données d'entrée. Secr. can. des avis sci. du MPO. Doc. de rech. 2025/020. iv + 92 p.

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ABSTRACT

Haddock (*Melanogrammus aeglefinus*) are caught as part of a multi-species groundfish fishery concentrated on the western Scotian Shelf (SS) and in the Bay of Fundy (BoF) in the Northwest Atlantic Fisheries Organization (NAFO) Divisions 4X5Y. This document is a review of the data inputs for the modeling framework for the 4X5Y Haddock stock that is expected to be completed in 2024. Stock structure was reviewed and an evaluation of spatial differences in growth was conducted to identify appropriate boundaries for the separation of the data inputs for faster growing Haddock in the BoF and slower growing Haddock on the SS. Fleet structure and the spatial and temporal distribution of catches were reviewed. The method to estimate catch-at-age was revised and the catch history was estimated for two alternative catch scenarios that assume catches in the south of Fisheries and Oceans (DFO) statistical unit area (DFO unit area) 4Xp are from the 5Z Haddock stock. These catch scenarios can be used to capture uncertainty in stock mixing and to explore the potential causes of retrospective patterns in model fits. The DFO summer ecosystem survey biomass index for 4X5Y Haddock was estimated based on a weighted-mean biomass and a weighted-mean biomass assuming a delta-lognormal distribution. These two indices will be evaluated in sensitivity analyses when models are fit. The fishery and survey length-at-age, weight-at-age, age-length keys, and the survey maturity-at-age were estimated by region (BoF and SS) using methods to fill missing data. Stomach contents data and a number of ecosystem indicators from the DFO Atlantic Zonal Monitoring Program were identified to be considered for exploring ecosystem considerations for the stock.

INTRODUCTION

Haddock (*Melanogrammus aeglefinus*) occur in the northwestern Atlantic from southwest Greenland to Cape Hatteras. The species is a bottom dwelling member of the gadid family that occurs most commonly at depths of 30 to 350 m and at bottom temperatures above 2°C (Scott and Scott 1988). Their diet consists mainly of small invertebrates and fish. A major stock exists on the western Scotian Shelf (SS) and in the Bay of Fundy (BoF) in the North Atlantic Fisheries Organization (NAFO) divisions 4X5Y (Figure 1). Major spawning aggregations are found on Browns Bank (Figure 2) and peak spawning occurs from April to May, although spawning may occur as early as February if conditions are favorable (Head et al. 2005). The most recent analytical assessment of 4X5Y Haddock was based on a virtual population analysis (VPA) model (Wang et al. 2017). In 2018, projections from the VPA model showed large retrospective patterns and there was a mismatch between the model predicted biomass and the survey biomass (Finley et al. 2018). The VPA model has therefore not been used to provide catch advice or estimate stock status since 2018, and stock status updates have been provided qualitatively by examining temporal trends in the biomass index estimated from the Fisheries and Oceans Canada (DFO) Maritimes Summer Ecosystem Survey, hereafter the “DFO ecosystem survey”.

FRAMEWORK REVIEW AND OBJECTIVES

This document is Part 1 of the Framework Review for 4X5Y Haddock and represents the data inputs and considerations for the modelling framework that is expected to be completed in 2024. The specific objectives of this document are to:

- Review current stock structure and evaluate whether there is a scientific basis for any changes in stock structure or the management area for 4X5Y Haddock.
- Review the basis for separating the stock into regions (BoF and SS) based on growth rates and review how fishery fleets are defined.
- Review the commercial fishery data inputs: spatial and temporal distribution of the catch, fishery catch-at-age (CAA), age-length keys (ALK), and fishery weight-at-age (WAA).
- Review DFO ecosystem survey data inputs: biomass index, ALK, CAA, WAA, maturity, fish condition, relative annual fishing mortality (relF), and relative annual total mortality (relZ).
- Identify potential datasets that can be used to explore ecosystem considerations for the stock.

BACKGROUND

HISTORY OF THE 4X5Y FISHERY

A total allowable catch (TAC) for 4X5Y Haddock was first introduced in 1970 and a seasonal spawning closure was implemented on Browns Bank (February 1–June 15, Stone and Hansen 2015). The minimum mesh size used in fishing nets has varied throughout the fishery, but 130 mm square mesh was made mandatory in 1992. Limited entry licensing, first introduced for the large trawler fleet, was extended to all groundfish vessels in 1976. In 1977, Canada extended its jurisdiction from 12 nautical miles to 200 nautical miles from the coast, and foreign vessels could now only fish under a Canadian licence (DFO 2018). In the early 1990s, management measures were implemented for dockside monitoring, small fish protocols, and conservation harvesting plans (DFO 2018). For a more detailed review of the history of the 4X5Y Haddock fishery, see Stone and Hansen (2015).

Starting in the 2015–16 fishing season, a minimum size of 38 cm was established for a small fish protocol. Areas are closed when the number of undersized Haddock (<38 cm) exceed a percentage of the catch (25–40% depending on the year). At-sea observer coverage has been low in 4X5Y with a target of 5–20% for observed trips; however, the realized number of observed trips has been lower (<4.3%) in the last 5 years.

HISTORY OF THE 4X5Y ASSESSMENT

Over the past decade, two models were used for the 4X5Y Haddock assessment. The first was a Sequential Population Analysis (SPA) tuned to the DFO summer ecosystem survey and a joint industry and DFO led Individual Transferable Quota (ITQ) survey (1995–2012, Hurley et al. 2009). The second was a VPA model with varying natural mortality (M) at ages >10 for different time blocks (Stone and Hansen 2015, Wang et al. 2017). In both cases, a strong retrospective pattern in the model results (i.e., a tendency to systematically overestimate spawning biomass when additional years of data were added) and poor model fit to survey indices occurred within 5 years. Consequently, both the SPA and VPA model results were not considered reliable to produce meaningful projections and catch advice.

In 2010, the fishery was managed using a removal reference fishing mortality rate (F_{ref}=0.25). The limit reference point (LRP) was defined as 0.4 SSB_{MSY} (spawning stock biomass at maximum sustainable yield) and the upper stock reference point (USR) as 0.8 SSB_{MSY} based on biomass estimates from a Sissenwine-Sheppard stock production model (Mohn et al. 2010). During the 2016 framework, reference points were re-evaluated, and a fishing mortality limit reference (F_{lim}) of 0.25 was defined to be applied when the stock is in the healthy zone (i.e., SSB > USR), and a F_{ref} of 0.15 was defined to be applied when the stock is in the cautious zone (i.e., LRP < SSB < USR). The LRP was revised and defined based on B_{recover} (lowest biomass that produced recruitment that led to stock recovery) and the USR was changed to approximately twice the LRP (Wang et al. 2017). Since 2018, the VPA model has not been used to provide catch advice, and stock status updates have been provided qualitatively by comparing the annual survey biomass index to the long-term median biomass index (e.g., DFO 2020, DFO 2021a).

REVIEW OF STOCK STRUCTURE

The 4X Haddock assessments from 1974–1997 considered catches in 4Xs and the Canadian portion of 5Yb and survey strata 492–494 (Figure 3) as part of the Gulf of Maine (GoM) stock in 5Y (Hurley et al. 1998). The 4Xs and 5Yb areas were first combined with the 4X Haddock assessment in 1998 after a re-evaluation of stock definition (Hurley et al. 1998).

In the northwest Atlantic Ocean, there are likely to be partially discrete groups of Haddock on Georges Bank, northern GoM and BoF, western SS and Browns Bank, and the eastern SS (Grosslein 1962, Page and Frank 1989, Begg 1998) based on physical and oceanographic factors (e.g., Fundian Channel, Browns Bank gyre) that serve as semi-permeable barriers. Eggs and larvae of Haddock can episodically cross these barriers with changing environmental conditions (Campana et al.1989) and movement by juveniles and adults typically occurs seasonally (Schroeder 1942, Frank 1992, Begg and Weidman 2001, Brickman 2003, Fowler 2011).

The main Haddock spawning areas in the region are on Georges Bank and Browns Bank (Figure 2, Wise and Jensen 1960). The timing of spawning depends on temperature, with spawning occurring earlier in New England and on Georges Bank (February–March) compared to the SS (April–June, Lapolla and Buckley 2005, Begg 1998). Larvae that hatch earlier in the season are predicted to have higher survival due to lower predation (Lapolla and Buckley 2005). The spawning areas have strong gyres that retain fishes and their prey on the Banks (Campana et al. 1989). The gyre on Browns Bank releases larvae onto the SS where currents transport them inshore and towards the BoF (Campana et al. 1989, Hurley and Campana 1989). Biophysical modeling has suggested that ocean currents on Browns Bank may episodically export a significant amount of larvae to Georges Bank (Brickman 2003) and vice versa (Campana et al. 1989). When abundance is high, Haddock may move from high density areas to less suitable habitats with lower intraspecific competition (Brodziak et al. 2008, Stone and Hansen 2015).

Otolith stable isotope analyses have provided evidence that Haddock shift their distribution and home range throughout their life history (Begg and Weidman 2001). It is hypothesized that for large year classes, juvenile Haddock may move from the eastern SS (Western Bank) to the central and western SS, ultimately leading to mixed stocks (Frank 1992, Brickman 2003). Adults typically return to their natal origin to spawn, and larger, older Haddock migrate more than smaller Haddock (Needler 1930).

Early tagging studies of Haddock provided evidence of seasonal mixing of adults between the BoF, GoM, Great South Channel, and Georges Bank (Figure 2, Needler 1930, Schroeder 1942, McCracken 1960). Haddock tagged off Digby (BoF) were recaptured on Georges Bank, and in some years a small proportion of tagged individuals moved from Georges Bank to GoM (Brodziak and Col 2006), while in other years the tagging data suggested movement was minimal (Brodziak et al. 2008). Fowler (2011) proposed two remaining migratory populations of Haddock on the Scotian Shelf:

1. western SS which overwinter on Browns Bank and move inshore (4Xr) during the summer and;
2. eastern SS (4TVW) which overwinter in 4W offshore and move to the southern Gulf of St. Lawrence in the summer.

Genetic studies focused on the population structure of Haddock in the northwest Atlantic are limited. A study examining genetic variation of Georges Bank Haddock found significant differences between samples from 1975 and 1985, suggesting genetic heterogeneity and variation in the annual contributions of these genetic components (Purcell et al. 1996). Lage et al. (2001) found no significant genetic differences in four microsatellite loci among Haddock caught on Georges Bank, Browns Bank, and the SS; however, a study using single nucleotide polymorphisms (SNPs) found that samples from the western SS were significantly different from Georges Bank but not the GoM (Berg et al. 2021). Further research is needed to understand the potential genetic differentiation of Haddock populations.

REVIEW OF DIFFERENCES IN GROWTH BY DFO STATISTICAL UNIT AREA

Differences in growth rates between the BoF (DFO ecosystem survey strata 482–495) and western SS (DFO ecosystem survey strata 470–481) regions were reported by Hurley et al. (1998). These differences in growth rates formed the basis of the separation of the survey biomass index by region (BoF vs. SS) and estimation of the CAA using separate ALKs by region in the most recent assessment framework (Stone and Hansen 2015). However, spatial areas used to define the regions for the catch and survey did not align (see Figure 1 and Figure 32 in Stone and Hansen 2015), such that catches in 4Xp were grouped as SS and the portions of survey strata 482 to 485 in 4Xp (Figure 3) were grouped as BoF. An evaluation of growth rates was conducted by DFO statistical unit area (hereafter DFO unit area) to assess whether there is still support for the status quo preparation of data inputs by region and to determine the most appropriate spatial boundaries for the definition of regions (BoF vs. SS).

Von Bertalanffy (vonB) growth models were fit to the DFO ecosystem survey and National Marine Fisheries Service (NMFS) bottom trawl survey for GoM age and length data by cohort for DFO unit areas in 4X, GoM grouped as 5Y (NMFS survey strata 26–28 and 36–40; see Figure 4), the Canadian portion of 5Z (i.e., 5Zjm), and the western four DFO unit areas of 4W (i.e., 4Whjkl). There were insufficient NMFS survey data to fit vonB growth models at a finer geographic scale than 5Y. All available survey data were used (generally summer data for 4X, summer and winter for 5Z, and spring and fall for 5Y) and growth relationships were fit when there were at least 15 observations per area and cohort. There were insufficient data in the Canadian portion of 5Yb and in 4Xm to estimate growth relationships for these areas. Ages were adjusted to a fraction of the year to account for the month the fish was sampled (e.g., $a_{adj} = a + \frac{1}{12}$ for February and $a_{adj} = a + \frac{11}{12}$ for December where a is age as an integer in years). VonB growth models (modelling length as a function of age) were fit as:

$$L = L_{inf}\left(1 - e^{-k(a_{adj} - a_0)}\right) \qquad \text{Eqn 1}$$

using maximum likelihood estimation to minimize residuals where parameter L_{inf} represents the asymptotic length, parameter k represents the growth rate (a measure of how fast L_{inf} is reached), and parameter a_0 is the theoretical length-at-age (LAA) zero. The models were estimated with and without the a_0 parameter and the final selected models excluded a_0 due to the limited data available to reliably estimate a_0, and using the age adjustment, a length of zero at age zero was deemed a reasonable assumption.

The relationship between L_{inf} and k (Figure 5) and the changes in L_{inf} and k by cohort (Figure 6) showed differences among areas (e.g., slower growth in 4W and faster growth in 5Z). A loess smoother (span = 0.5) was used to smooth the interannual variability in the L_{inf} and k estimates and help identify differences among areas. Differences in L_{inf} among DFO unit areas can be described qualitatively as:

4Whjkl < 4Xnop < 4Xqrs ~ 5Y ~ 5Zjm

Although L_{inf} and k are correlated (Figure 5), the relationship is not 1:1 such that differences in k among DFO unit areas can be described qualitatively as:

4Whjkl > 5Zjm > 4Xqrs > 4Xnop and

5Y ~ 4Xqrs5Zjm

Ninety five percent confidence intervals were added to the loess smoothers for 4Xqrs and 4Xnop (Figures 7 and 8) to evaluate the *status quo* assumption that there are growth differences between BoF (4Xqrs) and western SS (4Xnop) regions. In general, there is support for this assumed difference in growth (e.g., non-overlapping confidence intervals in Figure 7), although L_{inf} in 4Xp is higher than 4Xno beginning in the mid-1980s and the relationship between L_{inf} and k for 4Xq deviates from 4Xrs.

To determine the appropriate spatial bounds for the separation of the BoF (faster growing) and SS (slower growing) regions, the vonB growth models were fit separately by survey strata in 4Xp (Figures 9 and 10). The growth parameters for survey strata 480 and 481 were more similar to 4Xno so these survey strata were included in the SS region and growth parameters for survey strata 482 and 483 were more similar to 4Xqr so these survey strata were included in the BoF region (Figure 1, Figure 9, Figure 10). This spatial definition also formed the basis for defining regions for the catch history and is supported by length frequency distributions and growth of Haddock from the fishery catch (data obtained from port samples).

FISHERY

Haddock in 4X5Y are caught as part of a multi-species groundfish fishery. The science advice and the management of the fishery is specific to each major harvested species (i.e., Haddock, Halibut, Cod, Pollock, Redfish, and Silver Hake). The Haddock fishery is limited by the incidental catch of Cod which has a TAC that is usually reached first among the TACs for the various groundfish species. Haddock are primarily caught using bottom trawls; however, fixed gears are also used (e.g., longline and handline). The directed Haddock fishery bottom trawls have used a 130 mm square mesh cod end net since 1992. Haddock are also landed in 4X5Y from the directed Redfish fishery (100–115 mm diamond mesh, DFO 2021b), Silver Hake fishery (55–60 mm, Stone et al. 2013), as well as the Sculpin (90–100 mm mesh) and Winter Flounder (155–165 mm mesh) fisheries (Andrushchenko et al. In press).

The 4X5Y Haddock fishing season is regulated by an annual TAC and runs from April 1 to March 31. Catch monitoring requirements for the fishery include logbooks,100% dockside monitoring, vessel monitoring systems (VMS), hail in and hail out requirements, and targeted observer coverage. A regulated spawning closure occurs on Browns Bank annually from February 1st to June 15th.

CATCH

The fishery catch was estimated by extracting landings data from the COMLAND database (1970–2001) and the MARFIS database (2002–2022). Catches were summarized by NAFO division, quarter (Q), region (BoF and SS), DFO unit area, and fleet (Tables 1–2, Figures 11–16). The COMLAND and MARFIS databases only include catch data for Canadian fleets. Foreign catches were reported from 1967 to 2002 (Table 1, Figure 11) and were included in the total fishery landings and CAA by using catch multipliers (ratio of the combined Canadian and foreign catch to the Canadian catch) that were applied to the individual Canadian catches. This assumption results in the foreign catches being assigned to fleets proportionally to the estimated Canadian catches by fleet.

Catches without coordinates but with an identified DFO unit area were assigned the average latitude and longitude for catches in that DFO unit area for the same year, month, and gear type. Catches assigned to 5Yu (u = unknown) or any other DFO unit area in 5Y were assigned to 5Yb. 4Xu catches (Figure 12) were assigned to a region (BoF or SS) based on past fishing behaviour, using the combinations of factors listed below. Regions were assigned based on combinations 1–3 if catches were from a single region; if not then the region for 4Xu catches were assigned proportional to the catch by region based on the factors in combination 4.

1. Year, Vessel, and Gear
2. Vessel and Gear
3. Year, Port, and Gear
4. Year, Month, and Gear

Fleets were initially defined based on two regions (BoF and SS) and four gear categories: i) fixed gear, ii) groundfish (GF) trawl: 120–150 mm mesh size, iii) Redfish (RF) trawl 101–120 mm mesh size, and iv) other (other mobile gears) (Figure 13). When mesh size was not reported for the trawl gear in COMLAND, the fleet was assigned as follows:

1. Based on the data column “MAIN_SPECIES_SOUGHT” for which Cod, Haddock, Pollock, and “unspecified groundfish” were assigned to GF and Redfish was assigned to RF
2. Based on the percentage of the catch as the specified species: >50% catch as Cod, Haddock, Pollock, and “unspecified groundfish” was assigned to GF and >50% catch as Redfish was assigned to RF

Although the catch history was initially generated for the 8 fleets (four gear categories defined above and two regions, Figure 13), the catches for the RF fleets and “other” fleets were relatively small and lacked sufficient port sampling data needed to estimate the CAA. The number of fleets was therefore reduced to two gear categories (Fixed and Mobile) and the two regions (BoF and SS) (Figure 14), consistent with the last framework for this stock (Stone and Hansen 2015).

SPATIAL AND TEMPORAL TRENDS OF THE CATCH

Landings of Haddock were highest in the late 1960s before the implementation of a TAC in 1970 (Table 1, Figure 11). Since the late 1980s, landings have generally been below 10,000 mt and have been consistent over the most recent time period. The landings by area varied over the historical catch time series, with a shift in contribution from 4Xo to 4Xp since the mid-1990s (Figure 12), in particular in survey strata 482 and 483 in the south of 4Xp in some years (Figure 16). This shift results in an increased proportion of the catch coming from the faster growing BoF region in more recent years (Figure 14, Figure 16).

In the last decade, the majority of landings were from mobile gear with a shift away from fixed gears (Figure 13, Figure 14, Table 2), and the proportion of annual landings in Q1 has increased (Figure 15). The Q1 landings were primarily from 4Xp and 4Xn (Figure 17 a–f) and the greatest landings were generally observed in February and March. This is consistent with the temporal shift in landings from 4Xo to 4Xp (Figure 12).

The spatial distribution of landings has been variable throughout the time series. In the early 2000s, higher landings were observed in the BoF (4Xs and 4Xr), spread throughout 4Xp, the southwestern portion of 4Xn, and in concentrated areas of 4Xq (Figure 17 a–f). Following a decline in 2010, catches increased from 2017–2020 in BoF and 4Xq; however, most catches in 2021–2022 were observed in 4Xp and 4Xn (Figure 12, Figure 17 a–f).

CATCH-AT-AGE (CAA)

The age composition of Haddock catches are estimated using otoliths collected by port sampling, where a random sub-sample of Haddock are selected and measured to estimate the length frequency distribution of the catch, and otoliths are taken for two fish per 2 cm length bin. The 4X5Y and 5Z Haddock ages were estimated by a new ager beginning in 2021, who replaced the ager that estimated ages from 2016 to 2020. During a quality control exchange with the US, as part of the assessment process for the transboundary 5Z Haddock stock in 2021, it was identified that there was low (59.8%) agreement between ages estimated in quarters 3 and 4 of 2020 by the DFO ager compared to the US ager. Upon inspection of the otoliths with discrepancies between agers, it was determined that the interpretation of otoliths differed between DFO and the US. According to the standard rules for age interpretation of DFO groundfish, a wide or narrow hyaline edge should not be counted as a year of growth in the months from August–January (Table 3). The hyaline rings were incorrectly counted on the edge, leading to the interpretation that two rings were aged as a 2 year old fish (as opposed to the correct age 1) for 5Z Haddock in quarters 3 and 4 in 2020. This finding triggered a re-aging in 2023 of all 4X5Y Haddock collected in August–January from 2016 to 2020.

A percent agreement between readers was estimated and the Evans and Hoenig (1998) test for symmetry was conducted between the old and revised ages following the re-aging. The annual percent agreement in 2018 was 86.8% with no significant bias ($p = 0.11$); however, the percent agreement ranged between 67.2 to 73.9% with significant ($p < 0.01$) bias for 2016–2017 and 2019–2020. This suggested a significant difference between readers and the revised ages for 2016–2020 were used in this document. A comparison between the present ager and the ager before 2016 was conducted to see whether there was a significant bias in quarters 3 and 4 using otoliths from 2014. The percent agreement between the initial ager and the new ager was 89.4% with no significant bias ($p = 0.08$), so no additional years were considered for re-aging.

The fishery CAA was estimated by first estimating the catch-at-length (CAL) using data on the length composition of catches from port samples and then estimating CAA by applying a forward ALK (i.e., distribution of age in each length bin). Length samples from the observer program were not used to estimate LF distributions. The fishery CAA has traditionally been estimated using DFO's CAA application (e.g., Stone and Hansen 2015). The CAA was previously calculated annually with some undocumented decisions to fill gaps in sampling (e.g., missing LF samples or missing ages in ALKs) making reproducibility of the CAA difficult. Here we apply a structured algorithm for estimating the CAA following a similar approach to that used for 3Pn4RS Atlantic Cod (Ouellette-Plante et al. 2022) with the objective of documenting the assumptions made for filling gaps in sampling and allowing for reproducibility of the calculations used to estimate the CAA. The algorithm is outlined below.

Catch at Length

The CAL was estimated by assigning a representative LF distribution to each individual reported catch. The CAL was generated using 2 cm length bins to be consistent with the length bins used for age sampling. At least five unique LF samples were used to represent an individual reported catch, with equal weight put on each LF sample. The estimated weights-at-length for each LF distribution were estimated using the DFO ecosystem survey weight-length relationships (Table 4, Figure 18). The representative LF samples were identified for each individual catch record by sequentially going through the following list of factors until at least five unique LF samples were identified:

1. Year, Quarter, Fleet, DFO unit area
2. Year, Quarter, Fleet, Region
3. Year, ± 1 Quarter, Fleet, DFO unit area
4. Year, ± 1 Quarter, Fleet, Region
5. ± 1 Year, Quarter, Fleet, DFO unit area
6. ± 1 Year, Quarter, Fleet, Region
7. ± 1 Year, ± 1 Quarter, Fleet, Region
8. Year, Quarter, Fleet
9. Year, ± 1 Quarter, Fleet
10. ± 1 Year, ± 1 Quarter, Fleet
11. Year, Fleet, Region
12. Year, Fleet
13. ± 1 Year, Fleet, Region

14. ± 1 Year, Fleet

This approach led to identifying at least five unique LF samples for each catch record, with the exception of some catches in 1970, for which only one unique LF sample was identified. The single LF sample was used for these catches in 1970. The 4Xp DFO unit area was divided into two areas (BoF and SS; see Figure 1). Coordinates were not available for some port samples in 4Xp (e.g., all years prior to 1991). All LF samples and landings in 4Xp in these years were assumed to be from the SS region for the estimation of the CAL. This is consistent with the assumption used in the last framework (Stone and Hansen 2015). The number of LF samples by DFO unit area and quarter is plotted in Figure 19. The CAL was over a broader size range in the 1970s and 1980s, with a declining and narrowing of length of the catch since the mid 1990s (Figure 20).

Age Length Key

Forward ALKs were generated using 2 cm groupings by year, quarter, and region (SS and BoF) that estimate the proportion of fish at age for a given length using ages collected from the port and observer sampling programs. Missing ages for length bins that were observed in the fishery (from port samples) were filled as follows:

1. ± 1 Length, Quarter, Year, Region
2. Length, ± 1 Quarter within a year, Year, Region
3. Length, Quarter, ± 1 Year, Region
4. ± 1 Length, Quarter, Year, Region [repeated after steps 1–3]
5. Length, Quarter, ± 2 Years, Region

When there were no ages for a year, quarter, and region to generate an ALK, an ALK from an adjacent quarter was used as a fill (consistent with number 2 above) and then an adjacent year was used as a fill (consistent with number 3 above) when required. The final steps in filling gaps in the ALK were assigning an age of 12+ to any length bin greater than or equal to 77 cm and manually filling 15 gaps for older fish (Age 12+) and younger fish (Ages 0–3) at the beginning and end of the length distributions.

Catch at Age

The CAA was estimated from the combination of the CAL and ALK (defined separately by region) (Figure 21, Figure 22, Table 5, Table 6). In general, the CAA estimated here was similar to that estimated for 1970–2013 by Stone and Hansen (2015) (Figure 23).

Catch Uncertainty in 4Xp

The CAA was estimated for three catch scenarios to be compared in sensitivity analyses when models are fit:

1. The *status quo* catch area: all catches in 4X5Y
2. Catches (as well as length frequency and age samples) in survey strata 483 and 5Z9 are excluded
3. Catches (as well as length frequency and age samples) in survey strata 482, 483, and 5Z9 are excluded

The spatial bounds for these catch scenarios were defined based on the similarity in growth (relative LAA) of Haddock and LF distributions of Haddock catches from port samples in strata 482, 483, and 5Z9 to Eastern Georges Bank (EGB).

Catches in the south of 4Xp were previously hypothesized to include Haddock from EGB (Stone and Hanson 2015). In the last assessment framework, an alternative catch scenario was examined in a sensitivity analysis that excluded catches within five nautical miles of the 4X5Z boundary line based on a hypothesis that when there were strong EGB Haddock year-classes (e.g., 2000 and 2003), EGB Haddock extend into the Fundian Channel (Stone and Hanson 2015). Data from the commercial fishery and the surveys were examined to evaluate this hypothesis by exploring four different data sources:

1. Spatial distribution of fishery catch vs. survey biomass
2. Fishery CAA vs. survey CAA (cohort strengths)
3. LF distributions
4. Growth (Length-at-age)

Spatial Distribution of Fishery Catch vs. Survey Biomass

There has been an increase in the proportion of total stock landings from 4Xp beginning around the year 2000, and this increase coincides with a decrease in the proportion of landings from 4Xo (Figure 12). The proportion of stock landings in survey strata 482 and 483 (including 5Z9) exceed 25% in the late 2000s (Figure 16) where significant landings were observed just north of the 4X and 5Z border (Figure 17 a–f). While relative catches in strata 482 and 483 were on average 25% in the 2000s, the mean proportion of survey biomass in these strata was only 7% in the 2000s (Figure 24).

Fishery CAA vs. Survey CAA

The largest cohorts contributing to the 4X5Y fishery CAA in the last two decades are the 1998, 2003, 2010, and 2013 cohorts (Figure 21). While the 2013 cohort is the largest in the survey CAA and the 1998 cohort is the second largest cohort in the last two decades, the 2003 and 2010 cohorts are approximately average in size (Figure 25). The 2003 and 2010 cohorts are ;however, large cohorts on EGB (Figure 26), suggesting that these cohorts may be contributing to the 4X5Y catch.

Classification based on size (LF) distribution of catch

Differences in growth have been identified between BoF, SS, and EGB (see Review of Differences in Growth by DFO Statistical Unit Area section). The southern portion of 4Xp is the spatial area where these three regions converge and was divided into smaller areas based on survey strata (strata 480–483, 5Z9). Cumulative LF distribution functions (CDFs) from port samples were used to estimate the probability of being drawn from each (statistical) population or group (BoF, SS, EGB), for each survey stratum. Given a single observed CDF from a survey stratum and a single CDF from each group, the predicted CDF for the survey stratum was estimated as the proportions ($\hat{p}_{BoF}$, $\hat{p}_{SS}$, $\hat{p}_{EGB}$) of each of the groups that minimize the differences in the squared cumulative proportions at length (nearest cm) between the observed and predicted CDFs. Predicted probabilities of belonging to each group were estimated by year, quarter, and fleet by averaging probabilities across 1,000 simulations, where a single simulation involved randomly selecting a single CDF for the survey stratum and each group (within the year, quarter, and fleet).

Probabilities were estimated for survey strata when at least one CDF was available. When a CDF was not available for each group for a given year, quarter, fleet, a set of CDFs was substituted as follows until at least one CDF was identified:

1. ± 1 Quarter
2. ± 1 Year (same Quarter)
3. ± 1 Quarter and ± 1 Year
4. Any Quarter within Year
5. Any Quarter ± 1 Year
6. Any Quarter ± 2 Year

Probabilities of belonging to each group were plotted by quarter and stratum, and a loess smoother (span = 0.75) was used to visualise the general patterns in the probability over time (Figure 27). Looking at trends from the loess smoothers, survey strata 480 and 481 generally had the highest probability of belonging to the SS group, with the exception of stratum 481 in quarter 3, where the predicted probabilities were similar among the three groups (Figure 27). Stratum 482 generally had low predicted probabilities of belonging to SS, and generally a higher probability for EGB at the beginning of the time series and then higher probability for BoF at the end of the time series (Figure 27). Survey strata 483 and 5Z9 generally had the highest probability of belonging to the EGB group (Figure 27).

Classification based on growth of catch using empirical LAA

The LAA from port and observer samples for each survey stratum (strata 480–483, 5Z9) were used to estimate the probability that the sample belongs to each (statistical) population or group (i.e., BoF, SS, or EGB) where the LAA "populations" for each group were defined based on LAA data from the DFO summer ecosystem survey (BoF and SS) and the DFO summer and winter ecosystem surveys (EGB). The BoF group was defined as survey strata 484 to 495, SS was strata 470 to 477, and EGB was strata 5Z1 and 5Z2. Only LAA data for ages 4 and older were used to estimate the probabilities to 1) reduce the bias in LAA due to fishery selectivity for younger fish and, 2) reduce the influence of growth within a year on the LAA for younger fish. Given a single LAA port or observer sample of fish (mean n = 20 fish per sample) from a trip (port) or set (observer), the predicted probability of each individual fish (i) belonging to each group (g) was estimated by calculating the likelihood that the sample was drawn from each population (group) distribution of LAA. The likelihood (L) that an individual fish with length (l_i) from sample j with age (a) in year (y) was drawn from group (g) was defined as:

$$L_{a,y,g,j,i}\left(l = l_i | N\left(\mu_{a,y,g}, \sigma^2_{a,y,g}\right)\right) \quad \text{Eqn 2}$$

where $N(\mu, \sigma^2)$ is a normal distribution with mean and variance defined as the mean and variance of the DFO ecosystem survey lengths-at-age a in year y for group g. The probability of each individual fish (i) belonging to each of the 3 groups ($\hat{p}_{i,j\in g}$) was defined as:

$$\hat{p}_{i,j\in g} = \frac{L_{a,y,g,j,i}\left(l=l_i|N\left(\mu_{a,y,g},\sigma^2_{a,y,g}\right)\right)}{\sum_g\left[L_{a,y,g,j,i}\left(l=l_i|N\left(\mu_{a,y,g},\sigma^2_{a,y,g}\right)\right)\right]} \quad \text{Eqn 3}$$

The overall probability of a sample (*j*) belonging to a group (g) was defined as the mean probability of each individual fish in the sample belonging to that group:

$$\hat{p}_{j\in g} = \frac{\sum_{i=1}^{n}\left(\hat{p}_{i,j\in g}\right)}{n} \quad \text{Eqn 4}$$

where n is the number of individual LAA observations (i) in sample j.

The results were displayed as the mean probability of belonging to each population by quarter (weighted by sample size n). A loess smoother (span = 0.75) was used to show the temporal trends in probability across groups for each stratum (Figure 28).

The variability in the predicted probabilities based on LAA (Figure 28) were much lower than for the LF distributions (Figure 27). Looking at trends from the loess smoothers, survey strata 480 and 481 generally had a high overlap of predicted probabilities across the time series (Figure 28). Stratum 482 generally had similar probabilities for BoF and EGB (higher than SS), except for quarter 4 in the 2000s where EGB had a higher probability that exceeded 50% in some years (Figure 28). Survey strata 483 and 5Z9 generally had similar trends over time with a higher probability of belonging to EGB at the beginning of the time period, similar probability for EGB and BoF after 2010, and lower probability for SS (but increasing over time) (Figure 28). The apparent decrease in the probability of belonging to the EGB group for 5Z9 (a stratum in EGB) appears to be caused by the similarity in growth between EGB and BoF in the later years (e.g., Figure 29) and not that Haddock in 5Z9 are believed to be from the BoF region.

Classification based on growth of catch using von Bertalanffy estimated LAA by cohort

The overall probability of a sample (*j*) of LAA belonging to a group (g) as described in 4a (above) was also estimated using a mean and variance for the populations (groups BoF, SS, and EBG) estimated from two parameter vonB growth models fit to length-at-adjusted age (see Review of Differences in Growth by DFO Statistical Unit Area section) by group and cohort. The mean and variance in Equation 2 were defined in this case to be the vonB model predicted mean length at the adjusted age of the individual fish and the variance of the residuals from the vonB model, respectively. The predicted probabilities based on predicted LAA using the vonB models (Figure 30) were very similar to those for LAA using the empirical mean LAA (Figure 28).

Catch-at-Age for the Alternative Catch Scenarios

Excluding catches and age composition data in survey strata 483 and 5Z9, in general had little influence on the CAA estimation, with the exception of a reduction of the strength of the 2000 and 2003 cohorts with the numbers-at-age 4 in 2007 being reduced the most (Figure 31). The strength of the 2000 and 2003 cohorts are further reduced in the CAA when the catches and data in stratum 482 are also excluded (Figure 32) where the size of the 2003 cohort became closer to an average sized cohort in the time series.

FISHERY LENGTH-AT-AGE (LAA)

A fishery LAA matrix was estimated by year and region using LAA data collected from port and observer samples. Lengths were adjusted to reflect a mid-year length to account for growth within the year. This was done by estimating the growth from the month the fish was caught to a month value of 6 (i.e., July) from a three-parameter vonB growth model fit by region and cohort (for cohorts 1966–2016) using an adjusted age that incorporated month (see Review of Differences in Growth by DFO Statistical Unit Area section). The vonB model from the nearest cohort was used to estimate the incremental growth for cohorts outside the range of 1966–2016. LAA was then estimated as the mean adjusted (July) LAA. Missing LAA values were filled as:

1. LAA-1 was filled when LAA-2 for that cohort was available using the mean rate of growth from age-1 to age-2 (i.e., LAA-2/LAA-1) from the cohorts above and below that cohort.
2. LAA-1 was filled when LAA-2 for that cohort was available using the mean rate of growth from age-1 to age-2 from the three cohorts above and below that cohort.

3. LAA was filled using the mean LAA from years above and below.
4. LAA was filled as a linear interpolation of log-transformed length over one age along a cohort.
5. LAA was filled as a linear interpolation of log-transformed length over two ages along a cohort (i.e., LAA[*i*,*j*] and LAA[*i*+1,*j*+1] are filled using LAA[*i*-1,*j*-1] and LAA[*i*+2,*j*+2] where *i* is year and *j* is age).
6. LAA-11 and LAA-12+ were filled using the maximum LAA in that cohort.

The average fishery LAA has declined for older ages of Haddock for both regions throughout the time series (Figure 33). A final LAA matrix for the stock (combined BoF and SS) was estimated as a mean LAA, weighted by the CAA for BoF and SS (Table 7).

FISHERY WEIGHT-AT-AGE (WAA)

A fishery WAA matrix was estimated by year and region by converting the mid-year LAA matrix to WAA using the weight-length relationship from the survey (Table 4). The average fishery WAA has declined for older ages of Haddock for both regions throughout the time series (Figure 33). A final WAA matrix for the stock (combined BoF and SS) was estimated as a mean WAA, weighted by the CAA for BoF and SS (Table 8).

SURVEYS

A mobile gear fixed station survey in NAFO division 4X was conducted by the ITQ mobile gear <65 ft fleet from 1996 to 2012. The survey covered a broader area (including nearshore areas) than the DFO summer ecosystem survey (see Stone and Hansen 2015) and was conducted in July using a standardized Balloon 300 trawl equipped with a cod end liner of the same mesh size as the DFO survey. The ITQ survey was discontinued in 2013 and the index was not estimated for 2011 and 2012 (Stone and Hansen 2015).

DFO has conducted a stratified random bottom trawl survey of the BoF and SS every summer since 1970 using seven research vessels: the *A.T. Cameron* from 1970–1981, the *Lady Hammond* in 1982, the *CCGS Alfred Needler* from 1983–2003, 2005–2006, 2009–2015, 2017, and 2019, the *CCGS Teleost* in 2004, 2007, 2016, 2018, 2020, and 2022, the CCGS *Templeman* in 2008, the *CCGS Cartier* in 2021, and the *CCGS Cabot* in 2022. Based on an analysis of comparative fishing experiments by Fanning (1985), a conversion factor of 1.2 for Haddock has been applied to the total abundance, total biomass and age-specific abundance series prior to 1982 (i.e., for 1970–1981) to account for the effect of vessel and gear changes (Yankee 36 to Western IIA bottom trawl) between the *A.T. Cameron* and the *Hammond/Needler* (Note: this is not a length-based conversion). A more recent analysis of comparative fishing experiments between the *Alfred Needler* and the *Teleost* showed that no conversion factor was required for 4X5Y Haddock (Fowler and Showell 2009). There are currently no conversion factors established for either the *Cartier* or *Cabot* between the *Needler/Teleost* so the data from these vessels are currently excluded from this document but will be integrated into the modelling framework when conversion factors become available in 2024. The average number of tows per year per strata for the DFO summer ecosystem survey over the last two decades has been 3.7 for the BoF strata and 4.0 for the SS strata (Figure 34).

INDIVIDUAL TRANSFERABLE QUOTA SURVEY

The ITQ survey biomass index and the estimated numbers-at-age for the survey from 1996–2010 is provided in Table 9 and Figure 35, and is unchanged from Stone and Hansen (2015). A comparison between the biomass index and the relative numbers-at-age estimated from the ITQ index and the DFO summer ecosystem survey are provided in Figures 36 and 37. The ITQ survey shows a larger decline in biomass after the year 2001 compared to the DFO survey and higher proportions of fish at age 1 and 2, suggesting the ITQ survey has higher selectivity of smaller fish.

DFO SURVEY INDEX

An index of stock biomass was estimated as the mean biomass per standardized tow, defined as a 1.75 nautical mile (nm) tow. Using a stratified random design, the annual mean biomass per tow was estimated as a weighted mean with weights (w) proportional to the strata area divided by the number of tows in that strata (n) and the weighted standard error of the mean was estimated as (Kish 1992):

$$SE = \sqrt{\frac{s^2}{n}\frac{(\sum w^2)/n}{(\sum w/n)^2}} \qquad \text{Eqn 5}$$

where s^2 is the unweighted sample variance. The mean biomass per standardized tow differed by region, with generally higher density of Haddock for SS compared to the BoF (Figure 38). The distribution of biomass per standardized tow was explored by plotting the residuals of a linear model with a response variable of biomass/tow and categorical factors *year* and *strata* (Figure 39a). The distribution appeared skewed to the right so the residuals from a model with ln-transformation of biomass (removing zeros) were plotted and appeared bell-shaped (Figure 39b). The index was therefore also estimated assuming a delta-lognormal distribution where the mean and SE were estimated following Pennington (1996). Although this method can provide less biased estimates of the mean when there are extreme observations (e.g., a large biomass estimate from a single tow), it is not robust to small departures from the assumed lognormal distribution of positive tows (Syrjala 2000). Small positive values (tows with biomass per standardized tow of less than 0.5 kg) were therefore replaced with zero following the suggestion of Pennington (1991). The two survey biomass indices were similar (Figure 40) with the main differences being the lower biomass in 1977 for the delta distribution (smaller influence of a single large tow in 1977), and more stable coefficient of variation over time (Figure 41).

The Gini index (Gini 1921) was calculated in each year as an indicator of the relative distribution of survey biomass among survey stations (Figure 42, index based on arithmetic mean only). The Gini index is commonly used as a summary of income inequality and is used here as a statistic to summarize the dispersion of biomass across tows. A value of zero reflects equal biomass at each survey station and a value of one reflects a single station with all the biomass. Over the last decade there has been a decline in the index from a time series maximum of 0.86 in 2009 to about 0.6 from 2016–2020. This could be related to the strength of the 2013 cohort which also has resulted in a low percentage (approximately 10%) of tows with zero biomass between 2014 and 2020 (Figure 43).

DFO SURVEY NUMBERS-AT-AGE AND LENGTH

The survey numbers-at-length (NAL) were estimated using the LF distribution for each tow using 2 cm length bins. When body weights were not available for a length bin, they were estimated using the survey weight-length relationships by region (BoF and SS) (Table 4). Forward ALKs were generated by year and region (BoF: survey strata 482 to 495 and SS: survey strata 470 to 471). Missing ages for lengths that were observed in the survey LF samples were filled as follows:

1. ± 1 Length bin, Year, Region

2. Fish <12 cm are age 0
3. ± 1 Year, Region

The final steps in filling gaps in the ALK were assigning an age of 12+ to older fish in length bins >77 cm and manually filling two gaps. The overall survey NAL were higher for SS compared to BoF and a truncation of the length distribution was observed over time for both regions (Figure 44). The survey numbers-at-age (NAA) were estimated by applying the ALKs to the NAL to obtain the NAA separate by region which was summed to obtain the stock NAA (Figure 25). Based on the survey NAA, only the 2013 cohort made a substantial contribution to the survey catch (Figure 25) with the largest estimated recruitment based on NAA-1 in 2014 (Figure 45).

DFO SURVEY LENGTH-AT-AGE AND WEIGHT-AT-AGE

The survey LAA was estimated by region as the mean LAA from all fish caught in the survey sampling. Missing LAA values were filled as follows:

1. LAA-0 and LAA-1 were filled by taking the mean LAA from years above and below.
2. LAA-0 at the beginning of the time series was filled using the mean LAA-0 from the first 5 years with data.
3. LAA was filled using model estimates from a three-parameter von Bertalanffy growth model of mean LAA by cohort for cohorts 1966 to 2016.
4. LAA was filled as a linear interpolation of log-transformed length over one age along a cohort.
5. LAA was filled using the rate of growth from the previous cohort (LAA[*i*-1,*j*]/LAA[*i*-2,*j*-1]) and multiplying by the LAA for the previous age in that cohort (i.e., LAA[*i*-1,*j*-1]) where *i* is year and *j* is age.
6. LAA-12 in 1970 for BoF was filled as the mean LAA-12 from the next 5 years.

The survey WAA was estimated by region as the mean WAA from all fish caught in the survey sampling. Missing WAA values were filled as follows:

1. WAA-0 and WAA-1 was filled by taking the mean WAA from years above and below.
2. WAA-0 at the beginning of the time series was filled using the mean WAA-0 from the first 5 years with data.
3. WAA was filled as a linear interpolation of log-transformed length over one age along a cohort.
4. WAA was filled as a linear interpolation of log-transformed length over two ages along a cohort (i.e., WAA[*i*,*j*] and WAA[*i*+1,*j*+1] are filled using WAA[*i*-1,*j*-1] and WAA[*i*+2,*j*+2] where *i* is year and *j* is age).
5. WAA was filled by taking the mean WAA from years above and below.
6. WAA was filled using the rate of growth from the previous cohort (WAA[*i*-1,*j*]/WAA[*i*-2,*j*-1]) and multiplying by the WAA for the previous age in that cohort (i.e., WAA[*i*-1,*j*-1]) where *i* is year and *j* is age.

The final survey LAA and WAA matrices for the stock (combined BoF and SS) were estimated as a mean, weighted by the survey NAA for BoF and SS (Table 10, Table 11). Both survey mean LAA and WAA show an overall decline in older ages (4+) throughout the time series, with minor improvements over the last 3 years in the Bay of Fundy (Figure 46). The LAA by cohort shows this decline with the length of Haddock much smaller in the 2000s compared to the

1960s–1990s (Figure 47). WAA matrices were estimated to represent January 1st stock WAA and SSB (April 1st) WAA by adjusting the survey WAA from month 7 to month 1 and 4, respectively using the Rivard (1982) method which uses a log-linear interpolation between a WAA a in year y and the WAA $a-1$ in year $y-1$.

DFO SURVEY MATURITY

Maturity data were only collected on the DFO summer ecosystem survey from 1970–1985 and then sporadically from the summer and winter surveys afterwards. Sufficient maturity data (n >20 observations by year and region) were available from the survey from 1970–1985 and 1988, 1993, 1994, 2016, 2019, and 2020 (Figure 48). Data from the NMFS surveys (Spring and Fall for strata 29, 30, 34, 35, 36) were explored as an additional data source for Haddock maturity; however, they were not incorporated based on similar gaps in the time series for the NMFS spring surveys and high variability in the estimation of maturity from the NMFS fall surveys likely due to survey timing. Maturity data were available from EGB (strata 5Z1, 5Z2, 5Z9) from 1987–2021 and were used to predict the length-at-maturity and age-at-maturity in years with no data in the stock area. The length and age at 50% and 90% maturity (L_{50}, L_{90}, A_{50}, A_{90}; hereafter, maturity statistics) were estimated by year and region using binomial logistic regression models (Figure 48a, Figure 48b). The values of these maturity statistics for BoF and SS for years with missing data were estimated from the predicted values from a linear model with the predictors *year* (categorical) and *region* (Figure 48c, Figure 48d). This effectively estimated the mean difference in each maturity statistic between regions in years when data were available, and this difference was used to predict the maturity statistics for BoF and SS from the EGB values. The maturity-at-age data will be used as a model input to estimate spawning stock biomass from total stock biomass. The focus for the data inputs is therefore on estimating a maturity-at-age matrix. Sharp changes with magnitude of approximately one year in the age-at-maturity in EGB from 2004–2005 and from 2009–2010 could be related to strong 2000 and 2003 cohorts observed on EGB (Figure 26), which were not observed to be as strong in 4X5Y. An alternative method to estimate age-at-maturity was also explored that was not dependent on EGB.

The A_{50} and A_{90} from 1986–present were filled as the mean values from 1986–present (Figure 48e) and these were used to generate the maturity-at-age matrices from the logistic regression equation:

$$P(x) = \frac{1}{1+e^{-(b_0+b_1x)}} \qquad \text{Eqn 6}$$

where the regression coefficients were defined from the predicted maturity statistics as:

$b_1 = \ln(9)\,/(A_{90} - A_{50})$ and $b_0 = \ln(9) - b_1\,A_{90}$. A final maturity-at-age matrix for the stock (combined BoF and SS) was estimated as a mean, weighted by the survey NAA for BoF and SS (Table 12).

DFO SURVEY DISTRIBUTION, CONDITION, SURVEY Z, AND RELATIVE F

The spatial distribution of survey catches has been consistent throughout the time series with large tows of Haddock more commonly observed on Browns Bank, Roseway Bank, Baccaro Bank, and areas of the BoF (Figure 49 a–d). Survey catches remain much lower in 4X5Y in the summer compared to winter catches on EGB.

Fulton's condition factor (K) was estimated for each region using a ratio of length (L) and weight (W) as K =100*W/L^3 from the DFO summer ecosystem survey data. In the BoF, mean annual condition of Haddock declined for both sexes until 2004, then fluctuated below the time series mean until a decline for females in 2010, and was followed by an increase in condition in recent years for both sexes (Figure 50). On the SS, mean annual condition of Haddock has fluctuated around the time series mean until 2010, and has remained below the mean in the most recent time period (Figure 50).

Relative total mortality (Z) was estimated using the DFO summer ecosystem survey NAA of fully recruited age groups (ages 3–8), and relative fishing mortality (relF) was estimated as the ratio of fishery catch to survey biomass to explore potential changes in natural mortality. For both BoF and SS, relative total mortality remained consistent over time, while relative fishing mortality declined (Figure 51, Figure 52). This decline was much more pronounced for the SS, suggesting a potential increase in natural mortality since 2000 (Figure 52).

ECOSYSTEM CONSIDERATIONS

Haddock adjust their depth distribution based on changing water temperatures throughout the year. They typically inhabit inshore waters but may overwinter in deeper waters and then move into shallower areas as temperatures rise in the summer months (Scott and Scott 1988, Rogers et al. 2016, Perry and Smith 1994). This behaviour may occur more readily in cooler waters associated with the SS and off Newfoundland compared to more temperate waters (Murawski and Finn 1988). Optimal water temperatures for adult Haddock range from 4–7 ˚C, with all life history stages of Haddock typically avoiding waters with temperatures above 10 ˚C (Bigelow and Schroeder 1953, Cargnelli et al. 1999).

Both the magnitude and the timing of algal blooms may impact the recruitment of Haddock (Friedland 2021, Platt et al. 2003). On Georges Bank, the fall phytoplankton bloom is hypothesized to provide energy to pre-spawning adult Haddock and years with higher algal blooms have been associated with recruitment of exceptional year classes (Friedland 2021). On the SS, the survival of Haddock larvae is dependent on the timing of the spring phytoplankton bloom, and when spawning time corresponds with algal blooms, higher survival may occur allowing for a more abundant food source (Platt et al. 2003). Thus a reduction in algal blooms may ultimately impact both reproductive success and recruitment.

DFO's Atlantic Zone Monitoring Program (AZMP) program was implemented in 1998 to collect and analyze biological, chemical and physical oceanographic field data. Data from this program are summarized and made available for use in tables from the azmpdata package in R (https://github.com/casaultb/azmpdata 2022). Sampling stations in the stock area include stations along a transect through Browns Bank and fixed stations in the BoF and near the 4X/4W border. Additional data are available in the azmpdata package and include the North Atlantic Oscillation (NAO) index, temperature, chlorophyll-a concentrations, and zooplankton abundance.

As larvae, Haddock consume plankton, and transition to a diet mostly of benthic invertebrates and fish as juveniles and adults (Kane 1984, Mahon and Neilson 1987, Brodziak 2005). Stomachs of commercially important fish species are collected annually on the DFO summer ecosystem survey. Haddock stomachs have been routinely sampled since 2007; however, stomach content analyses are currently available only up until 2017. From 1997–2017, 3,789 Haddock stomachs were analyzed, and the majority of the stomach contents contained crustaceans (e.g., shrimp, amphipods), echinoderms (e.g., brittle stars), marine worms (e.g., bristle worms) and bivalves (e.g., cockles, clams). The only abundant fish found in the stomachs of Haddock were sand lance (*Ammodytes dubius*). In general, adult Haddock are consuming more fish, crustaceans, and echinoderms than smaller sized (<38 cm) Haddock.

Stomachs that contained Haddock as a prey item occurred in the stomachs (*n*=30) of 11 species of fish from 1995–2020. Greater occurrences of Haddock in predator stomachs occurred earlier in the time series; however, this observation may be based on delayed processing of samples as opposed to a reduction in predation. Based on the limited data available, Pollock (*Pollachius virens*), followed by Atlantic Cod (*Gadus morhua*) had the highest occurrences of Haddock in their stomachs.

CONCLUSIONS

There is no evidence from the recent literature that would support a change in stock structure for 4X5Y Haddock. The basis for the separation of the fishery and survey data inputs by region (BoF: faster growing vs. SS: slower growing) was reviewed in this document. The vonB growth parameters estimated using data from the DFO summer ecosystem survey for strata 480 and 481 were more similar to 4Xno so these survey strata were included in the SS region and the vonB growth parameters for survey strata 482 and 483 were more similar to 4Xqr so these survey strata were included in the BoF region. This spatial definition also formed the basis for defining regions for the catch history (revised from the last framework which considered all catches in 4Xp as SS).

Landings have been consistent over the last 30 years; however, over the last two decades the majority of catches has been with mobile gear, temporally the fishery has shifted to relatively more landings in the winter months, and the spatial distribution of the catch has shifted from 4Xo to southern 4Xp which borders the EGB stock.

The methods to estimate fishery CAA for 4X5Y Haddock have been updated from the last assessment framework using a structured algorithm to allow for reproducibility of results. This resulted in only minor changes to the historical CAA. The stock origin of catches in the south of 4Xp remains a large uncertainty. Analyses were conducted in the document to evaluate the hypothesis that catches in the south of 4Xp are of EGB origin. Multiple lines of evidence are consistent with this hypothesis:

- Catches in survey strata 482 and 483 are large in some years (approximately 25% of the stock catch) but survey biomass estimates in these strata are low (approximately 7% of stock biomass).
- The 2003 and 2010 cohorts are strong in the 4X5Y fishery CAA and EGB survey NAA but not the survey NAA for 4X5Y.
- The LF distribution of the catches in survey strata 482 and 483 are generally more similar to EGB than BoF and SS, except for some recent years where there is overlap between BoF and EGB.
- The LAA of the catches in survey strata 482 and 483 are similar to EGB although not different from BoF in recent years.

The CAA was estimated by excluding landings and length/age composition data from a) survey strata 483 and 5Z9 and b) survey strata 482, 483, and 5Z9. The influence of removing these catches was a reduction of the strength of the 2000 and 2003 cohorts such that the 2003 cohort became closer to an average strength cohort for catch scenario that excluded survey strata 482, 483, and 5Z9. The three different catch scenarios will be considered in the modelling framework.

Fishery and survey WAA and LAA show an overall decline in older ages (4+) throughout the time series, with minor improvements observed from data over the last 3 years in BoF. Two methods for calculating the DFO summer ecosystem survey index were explored; 1) the *status quo* (annual mean biomass per tow as a weighted mean proportional to size of stratum and number of tows) and, 2) a weighted mean assuming a delta lognormal distribution. Although the indices estimated using the two different methods were similar, the delta lognormal index reduced the influence of extreme tows and had a more stable coefficient of variation over time. Both indices will be considered in the modelling framework. Estimates of relative fishing mortality indicate a decline on the SS since 2000 indicating a potential change in natural mortality.

Some environmental data sets have been identified from DFO's AZMP program and will be used in the modelling framework to explore relationships with model parameters such as recruitment and growth.

ACKNOWLEDGEMENTS

D. Frotten and D. D'Entremont of DFO and at-sea observers from Javitech Ltd. and Atlantic Catch Data provided the port and observer samples from the Canadian fishery. K. Kraska provided age estimates for the DFO ecosystem surveys and commercial fishery and S. Sutherland provided age estimates for the NMFS surveys. I. Andrushchenko, J. McIntyre, and E. Brunsdon provided background information, edits to the document, and code review. The section on the review of stock structure was supported by an unpublished literature review by G. Puncher. M. Cassista-Da Ros provided data from the DFO survey stomach collection database. Members of the Scotia-Fundy Groundfish Advisory Committee provided background on the fishery and contributed to the conceptualization of the 4Xp catch uncertainty analysis. Comments during the peer-review meeting by B. Hubley, C. Perretti, and members of the Scotia-Fundy Groundfish Advisory Committee improved the working paper.

REFERENCES CITED

Andrushchenko, I., Martin, R., Doherty, P., Debertin, A., McCurdy, Q., MacEachern, E., Clark, D., and Clark, C. In press. Western Component Pollock - Data Inputs. DFO Can. Sci. Advis. Sec. Res. Doc.

Begg, G.A. 1998. A review of stock identification of Haddock, *Melanogrammus aeglefinus*, in the northwest Atlantic Ocean. Mar. Fish. Rev. 60(4): 1–15.

Begg, G.A., and Weidman, C.R. 2001. Stable d13C and d18O isotopes in otoliths of Haddock *Melanogrammus aeglefinus* from the northwest Atlantic Ocean. Mar. Ecol. Prog. Ser. 216: 223–233.

Berg, P.R., Jorde, P.E., Glover, K.A., Dahle, G., Taggart, J.B., Korsbrekke, K., Dingsør, G.E., Skjæraasen, J.E., Wright, P.J., Cadrin, S.X., Knutsen, H., and Westgaard, J. 2021. Genetic structuring in Atlantic Haddock contrasts with current management regimes, ICES J. Mar. Sci. 78(1): 1–13.

Bigelow, H.B., and Schroeder, W.C. 1953. Fishes of the Gulf of Maine. U.S. Fish Wildl. Serv., Fish. Bull. 53: 577 p.

Brickman, D. 2003. Controls on the distribution of Browns Bank juvenile Haddock. Mar. Ecol. Prog. Ser. 263: 235–246.

Brodziak, J.K.T. 2005. Haddock, *Melanogrammus aeglefinus*, life history and habitat characteristics, Second Edition. NOAA Tech. Memo. NMFS-NE-196, 64 p.

Brodziak, J.K.T., and Col, L. 2006. Northeast Consortium Cooperative Haddock tagging project: summary of reported Haddock tag recaptures through November, 2006.

Brodziak, J.K.T., Col, L., Palmer, M., and Brooks, L. 2008. Northeast Consortium Cooperative Haddock tagging project: summary of reported Haddock tag recaptures through November, 2008.

Campana, S. E., Smith, S.J., and Hurley, P.C.F. 1989. A drift-retention dichotomy for larval Haddock (*Melanogrammus aeglefinus*) spawned on Browns Bank. Can. J. Fish. Aquat. Sci. 46: 93–102.

Cargnelli, L.M., Griesbach, S.J., Berrien, P.L., Morse, W.W., and Johnson, D.L. 1999. Haddock, (*Melanogrammus aeglefinus*) life history and habitat characteristics. NOAA Tech. Memo. NMFS-NE-128, 31 p.

DFO. 2018. 4VWX5 groundfish integrated fisheries management plan, Maritimes Region. Fisheries and Oceans Canada.

DFO. 2020. Stock Status Update of Haddock (*Melanogrammus aeglefinus*) in NAFO Divisions 4X5Y. DFO Can. Sci. Advis. Sec. Sci. Resp. 2020/021.

DFO. 2021a. Stock Status Update of Haddock (*Melanogrammus aeglefinus*) in NAFO Divisions 4X5Y for 2020. DFO Can. Sci. Advis. Sec. Sci. Resp. 2021/021.

DFO. 2021b. Stock Status Update of Unit 3 Redfish for 2020. DFO Can. Sci. Advis. Sec. Sci. Resp. 2021/026.

Evans, G.T., and Hoenig, J.M. 1998. Testing and viewing symmetry in contingency tables, with application to readers of fish ages. Biometrics. 54: 620–629.

Fanning, L.P. 1985. Intercalibration of Research Survey Results Obtained by Different Vessels. CAFSAC Res. Doc. 85/3. 43 p.

Finley, M., Wang, Y., and Stone, H.H. 2018. Assessment of 4X5Y Haddock (*Melanogrammus aeglefinus*) in 2016. DFO Can. Sci. Advis. Sec. Res. Doc. 2018/041. iv + 54 p.

Fowler, G.M. 2011. Old and older perceptions of the migrations and distribution of Haddock, *Melanogrammus aeglefinus*, in northwest Atlantic waters from tagging conducted in the Bay of Fundy, Georges Bank, Scotian Shelf, and the Southern Gulf of St Lawrence. J. Northw. Atl. Fish. Sci. 43: 137–157.

Fowler, G.M., and Showell, M.A. 2009. Calibration of bottom trawl survey vessels: Comparative fishing between the Alfred Needler and Teleost on the Scotian Shelf during the summer of 2005. Can. Tech. Rep. Fish. Aquat. Sci. 2824: iv +25 p.

Frank, K.T. 1992. Demographic consequences of age-specific dispersal in marine fish populations. Can. J. Fish. Aquat. Sci. 49: 2222–2231.

Friedland, K.D. 2021. A test of the provisioning hypothesis of recruitment control in Georges Bank Haddock. Can. J. Fish. Aquat. Sci. 78: 655–658.

Gini, C. 1921. Measurement of inequality of incomes. The Economic Journal. 31: 124–126.

Grosslein, M.D. 1962. Haddock stocks in the ICNAF convention area. ICNAF Redbook III: 124–131.

Head, E.J.H., Brickman, D., and Harris, L.R. 2005. An exceptional Haddock year class and unusual environmental conditions on the Scotian Shelf in 1999. J. Plank. Res. 27(6): 597–602.

Hurley, P. C. F., and Campana, S.E. 1989. Distribution and abundance of Haddock (*Melanogrammus aeglefinus*) and Atlantic cod (*Gadus morhua*) eggs and larvae in the waters off southwest Nova Scotia. Can. J. Fish. Aquat. Sci. 46: 103–112.

Hurley, P.C.F., Comeau, P., and Black, G.A.P. 1994. Assessment of 4X Haddock in 1993. DFO Atl. Fish. Res. Doc. 94/39. 42 p.

Hurley, P.C.F., Black, G.A.P., Mohn, R.K., and Comeau, P. 1997. Assessment of 4X Haddock in 1996 and the first half of 1997. DFO Can. Stock Assess. Sec. Res.Doc. 97/108. 101 p.

Hurley, P.C.F., Black, G.A.P., Comeau, P.A., Mohn, R.K., and Zwanenburg, K. 1998. Assessment of 4X Haddock in 1997 and the first half of 1998. DFO Can. Stock Assess. Sec. Res. Doc. 98/136. 96 p.

Hurley, P.C.F., Black, G.A.P., Simon, J.E., Mohn, R.K., and Comeau, P.A. 2002. Assessment of the Status of Div. 4X/5Y Haddock in 2002. DFO Can. Sci. Advis. Sec. Res. Doc. 2002/098. 77 p.

Hurley, P.C.F., Black, G.A.P., Young, G.A., Mohn, R.K., and Comeau, P.A. 2009. Assessment of the Status of Divisions 4X5Y Haddock in 2005. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/024. vi + 86 p.

Kane, J. 1984. The feeding habits of co-occurring Cod and Haddock larvae from Georges Bank. Mar. Ecol. Prog. Ser. 16(1): 9–20.

Kish, L. 1992. Weighting for unequal Pi. Journal of Official Statistics. 8: 183–200.

Lage, C., Purcell, M., Fogarty, M. and Kornfield, I. 2001. Microsatellite evaluation of Haddock (*Melanogrammus aeglefinus*) stocks in the northwest Atlantic Ocean. Can. J. Fish. Aquat. Sci. 58(5): 982–990.

Lapolla, A., and Buckley, L.J. 2005. Hatch date distributions of young-of-year Haddock *Melanogrammus aeglefinus* in the Gulf of Maine/Georges Bank region: implications for recruitment. Mar. Ecol. Prog. Ser. 290: 239–249.

Mahon, R. and Neilson, J.D. 1987. Diet changes in Scotian Shelf Haddock during the pelagic and demersal phases of the first year of life. Mar. Ecol. Prog. Ser. 37: 123–130.

McCracken, F.D. 1960. Studies of Haddock in the Passamaquoddy Bay Region. J. Fish. Res. Bd. Can. 17(2): 175–180.

Mohn, R.K., Trzcinski, M.K., Black, G.A.P., Armsworthy, S., Young, G.A., Comeau, P.A., and den Heyer, C.E. 2010. Assessment of the Status of Division 4X5Y Haddock in 2009. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/085. vi + 61 p.

Murawski, S. A., and Finn, J. T. 1988. Biological bases for mixed-species fisheries: species co-distribution in relation to environmental and biotic variables. Can. J. Fish. Aquat. Sci. 45: 1720–1735.

Northeast Fisheries Science Center. 2014. 59th Northeast Regional Stock Assessment Workshop (59th SAW) Assessment Report. US Dept. Commer. Northeast Fish. Sci. Cent. Ref. Doc. 14–09: 782 p.

Needler, A.W.H. 1930. The migrations of Haddock and the interrelationships of Haddock populations in North American waters. Contributions to Canadian Biology and Fisheries. 6(1): 243–313.

O'Boyle, R. 1981. An assessment of the 4X Haddock stock for the 1962-80 period. CAFSAC Res. Doc. 81/24. 54 p.

O'Boyle, R.N., Frank, K., and Simon, J. 1989. An evaluation of the population dynamics of 4X haddock during 1962-88 with yield projected to 1990. CAFSAC Res. Doc. 89/58. 59 p.

Ouellette-Plante, J., Van Beveren, E., Benoît, H.P. and Brassard, C. 2022. Details of catchR, an *R* package to estimate the age and length composition of fishery catches, with an application to 3Pn4RS Atlantic cod. DFO Can. Sci. Advis. Sec. Res. Doc. 2022/015. iv + 69 p.

Page, F.H., and Frank, K.T. 1989. Spawning time and egg stage duration in northwest Atlantic Haddock (*Melanogrammus aeglefinus*) stocks with emphasis on Georges and Browns Bank. Can. J. Fish. Aquat. Sci. 46: 68–81.

Pennington, M. 1991. On testing the robustness of lognormal based estimators. Biometrics. 47: 1623–1624.

Pennington, M. 1996. Estimating the mean and variance from highly skewed marine data. Fish. Bull. 94: 498–505.

Perry, R. I., and Smith, S. J. 1994. Identifying habitat associations of marine fishes using survey data: an application to the northwest Atlantic. Can. J. Fish. Aquat. Sci. 51: 589–602.

Platt, T., Fuentes-Yaco, C., Frank, K.T. 2003. Marine ecology: Spring algal bloom and larval fish survival. Nature. 423: 398–399.

Purcell, M.K., Kornfield, I., Fogarty, M., and Parker, A. 1996. Interdecadal heterogeneity in mitochondrial DNA of Atlantic Haddock (*Melanogrammus aeglefinus*) from Georges Bank. Molecular Marine Biology and Biotechnology. 5(3): 185–192.

Rivard, D. 1982. APL programs for stock assessment (revised). Can. Tech. Rep. Fish. Aquat. Sci. No. 1091.

Rogers, R., Rowe, S., and Morgan, J. 2016. Depth and temperature associations of Haddock *Melanogrammus aeglefinus* off southern Newfoundland. J. Fish Bio. 89(5): 2306–2325.

Schroeder, W.C. 1942. Results of Haddock tagging in the Gulf of Maine from 1923 to 1932. J. Mar. Res. 5(1): 1–19.

Scott, W.B., and Scott, M.G. 1988. Atlantic fishes of Canada. University of Toronto Press. Can. Bull. Fish. Aquat. Sci. 219: 731 p.

Syrjala, S.E. 2000. Critique on the use of the delta distribution for the analysis of trawl survey data. ICES J. Mar. Sci. 57(4): 831–842.

Stone, H.H., Themelis, D., Cook, A.M., Clark, D.S., Showell, M.A., Young, G., Gross, W.E., Comeau, P.A., and Allade, L.A. 2013. Silver Hake 2012 Framework Assessment: Data Inputs and Exploratory Modelling. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/008. v + 133 p.

Stone, H.H., and Hansen, S.C. 2015. 4X5Y Haddock 2014 Framework Assessment: Data Inputs and Exploratory Modelling. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/022. iv + 90 p.

Wang, Y., Stone, H.H., and Finley, M. 2017. 4X5Y Haddock 2016 Framework Assessment: Modelling and Reference Points. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/026. v + 69 p.

Wise, J.P. and Jensen, A.C. 1960. Stocks of the important commercial species of fish in the ICNAF Convention area. Int. Comm. NW Atl. Fish. Ann. Meet. Doc. 25, ser. No 743: 1–14.

TABLES

Table 1. Estimated total landings and total allowable catch (TAC) in metric tonnes by calendar year and region (SS = Scotian Shelf; BoF = Bay of Fundy) where the spatial definition of regions is defined in Figure 1. A dash (—) indicates no data or not applicable.

Year	Foreign Landings [a]	BoF (other)	BoF (strata 482)	BoF (strata 483 [b])	Total BoF	Total SS	Total 4X5Y Stock Area	Total Allowable Catch
1967	3,214 [c]	20,119	—	—	20,119	19,783	39,902	—
1968	3,345 [c]	11,787	—	—	11,787	20,521	32,308	—
1969	2,204 [c]	6,676	—	—	6,676	23,653	30,329	—
1970	2,022 [d]	4,329	—	—	4,329	13,743	18,072	18,000
1971	1,099 [d]	3,703	—	—	3,703	13,888	17,592	18,000
1972	890 [d]	3,411	—	—	3,411	10,072	13,483	9,000
1973	419 [d]	2,470	—	—	2,470	10,636	13,106	9,000
1974	792 [d]	5,183	—	—	5,183	8,195	13,378	0
1975	2,159 [d]	5,570	—	—	5,570	12,727	18,298	15,000
1976	1,072 [d]	4,000	—	—	4,000	13,497	17,498	15,000
1977	1,662 [d]	3,524	—	—	3,524	17,757	21,281	15,000
1978	1,164 [d]	5,562	—	—	5,562	21,647	27,209	21,500
1979	88 [d]	6,061	—	—	6,061	18,863	24,925	26,000
1980	332 [d]	8,052	—	—	8,052	21,087	29,139	28,000
1981	481 [d]	7,605	—	—	7,605	23,753	31,358	27,850
1982	858 [d]	8,749	—	—	8,749	16,952	25,701	32,000
1983	518 [d]	9,338	—	—	9,338	18,023	27,361	32,000
1984	206 [d]	7,120	—	—	7,120	14,013	21,133	32,000
1985	26 [d]	5,909	—	—	5,909	10,222	16,131	15,000
1986	50 [d]	5,316	—	—	5,316	10,257	15,573	15,000
1987	17 [d]	2,609	—	—	2,609	11,172	13,781	15,000
1988	55 [d]	2,057	—	—	2,057	9,231	11,288	12,400
1989	34 [e]	1,273	—	—	1,273	5,559	6,833	4,600
1990	52 [e]	1,565	20.7	1.38	1,587	5,966	7,553	4,600
1991	41 [e]	2,319	101	31.2	2,451	7,377	9,828	0
1992	17 [e]	2,218	89.9	14.1	2,322	8,203	10,525	0
1993	21 [e]	1,849	40.3	8.76	1,898	5,070	6,968	6,000
1994	1 [f]	1,598	14.3	6.37	1,619	2,787	4,406	4,500
1995	9 [f]	1,938	357	189	2,484	3,180	5,664	6,000
1996	8 [f]	2,556	318	170	3,044	3,200	6,244	6,500
1997	8 [f]	2,817	410	281	3,508	3,031	6,539	6,700
1998	1 [g]	2,620	659	296	3,576	4,303	7,878	8,100
1999	0 [g]	2,443	719	751	3,914	2,702	6,616	8,100
2000	0 [g]	2,052	631	421	3,105	3,852	6,956	8,100 [h]
2001	0 [g]	2,736	505	991	4,231	4,251	8,483	8,100 [h]
2002	0 [g]	3,235	741	698	4,674	3,329	8,003	8,100 [h]
2003	—	4,078	747	1,141	5,966	2,727	8,693	8,100 [h]
2004	—	2,529	432	1,039	3,999	2,511	6,510	10,000 [h]
2005	—	1,627	444	1,276	3,348	2,315	5,663	8,000 [h]
2006	—	1,343	405	585	2,333	2,399	4,732	7,000 [h]
2007	—	1,235	672	2,482	4,388	2,483	6,871	7,000 [h]
2008	—	1,000	1,147	837	2,984	2,377	5,361	7,000 [h]
2009	—	767	436	986	2,189	3,289	5,478	7,000 [h]
2010	—	613	419	957	1,989	3,662	5,651	6,000 [h]
2011	—	449	385	601	1,435	2,295	3,730	6,000 [h]
2012	—	761	296	188	1,244	2,883	4,127	5,100 [h]
2013	—	811	741	206	1,758	1,775	3,533	5,100 [h]
2014	—	895	158	395	1,448	1,276	2,724	5,100 [h]
2015	—	1,112	79.6	279	1,471	1,296	2,767	5,100 [h]
2016	—	1,752	206	346	2,304	1,105	3,409	5,100 [h]
2017	—	3,428	232	186	3,846	1,163	5,009	7,650 [h]
2018	—	3,358	365	145	3,868	945	4,813	7,650 [h]
2019	—	3,046	171	138	3,355	1,496	4,851	9,000 [h]
2020	—	2,007	281	309	2,597	3,294	5,891	6,877 [h]
2021	—	985	904	114	2,003	2,264	4,267	6,877 [h]
2022	—	767	700	97.5	1,564	2,552	4,116	6,198 [h]

Notes: [a] Foreign landings were proportionally assigned to SS and BoF in this table and therefore are included in the total 4X5Y stock area column. [b] The portion of survey strata 5Z9 in DFO unit area 4Xp is included with strata 483. [c] O'Boyle 1981, [d] O'Boyle et al. 1989, [e] Hurley and Comeau 1994, [f] Hurley et al. 1997, [g] Hurley et al. 2002, [h] TAC for fishing season (April 1–March 31 of following year).

Table 2. Estimated total landings in metric tonnes by fleet (SS = Scotian Shelf; BoF = Bay of Fundy; F = fixed gear; M = mobile gear) and calendar year.

Year	BoF (F)	BoF (M)	SS (F)	SS (M)	Total 4X5Y Stock Area
1967	1,825	18,294	0	19,783	39,902
1968	733	11,054	1,647	18,874	32,308
1968	802	5,874	1,908	21,745	30,329
1970	684	3,644	2,897	10,846	18,072
1971	530	3,173	3,087	10,802	17,592
1972	562	2,849	4,123	5,949	13,483
1973	452	2,017	5,920	4,716	13,106
1974	565	4,618	6,369	1,826	13,378
1975	600	4,971	5,199	7,528	18,298
1976	284	3,716	5,120	8,378	17,498
1977	211	3,313	4,405	13,352	21,281
1978	369	5,193	6,445	15,202	27,209
1979	250	5,811	4,402	14,461	24,925
1980	392	7,660	6,024	15,063	29,139
1981	265	7,340	7,422	16,332	31,358
1982	315	8,434	7,425	9,527	25,701
1983	348	8,990	8,233	9,791	27,361
1984	183	6,937	6,456	7,557	21,133
1985	137	5,772	4,077	6,145	16,131
1986	119	5,197	5,339	4,917	15,573
1987	166	2,444	4,917	6,255	13,781
1988	134	1,923	3,452	5,779	11,288
1989	121	1,152	2,746	2,814	6,833
1990	169	1,418	3,924	2,043	7,553
1991	278	2,173	5,129	2,248	9,828
1992	633	1,689	6,157	2,046	10,525
1993	464	1,434	3,741	1,329	6,968
1994	154	1,465	2,073	714	4,406
1995	415	2,069	2,073	1,107	5,664
1996	373	2,671	2,030	1,169	6,244
1997	390	3,118	1,841	1,190	6,539
1998	761	2,815	1,882	2,421	7,878
1999	696	3,218	1,325	1,377	6,616
2000	518	2,587	2,204	1,647	6,956
2001	367	3,864	1,891	2,361	8,483
2002	649	4,025	1,682	1,647	8,003
2003	666	5,300	1,374	1,353	8,693
2004	377	3,622	785	1,726	6,510
2005	401	2,947	560	1,755	5,663
2006	444	1,889	857	1,542	4,732
2007	547	3,841	1,031	1,452	6,871
2008	297	2,687	872	1,505	5,361
2009	383	1,806	532	2,758	5,478
2010	542	1,447	714	2,949	5,651
2011	338	1,097	565	1,730	3,730
2012	195	1,049	596	2,287	4,127
2013	38.4	1,720	378	1,397	3,533
2014	11.9	1,436	250	1,026	2,724
2015	10.6	1,460	101	1,196	2,767
2016	3.37	2,301	82.4	1,022	3,409
2017	2.85	3,843	49.0	1,114	5,009
2018	2.04	3,866	21.6	923	4,813
2019	1.49	3,354	16.7	1,479	4,851
2020	2.23	2,595	40.6	3,253	5,891
2021	2.45	2,001	44.6	2,219	4,267
2022	2.15	1,562	29.9	2,522	4,116

Table 3. Aging protocol by month and quarter (Q) for 4X5Y Haddock otoliths. Opaque sections indicate summer growth and hyaline (annuli) rings indicate slower winter growth. Based on the edge of the otolith and the month sampled, 1 year is added to the age (+1), 1 year is subtracted from the age (-1) or no changes are made (=).

Edge	**Q1 Jan**	**Q1 Feb**	**Q1 Mar**	**Q2 Apr**	**Q2 May**	**Q2 June**	**Q3 July**	**Q3 Aug**	**Q3 Sept**	**Q4 Oct**	**Q4 Nov**	**Q4 Dec**
wide opaque	=	+1	+1	+1	=	=	=	=	=	=	=	=
narrow opaque	=	=	=	=	=	=	=	=	=	=	=	=
wide hyaline	-1	=	=	=	=	=	=	-1	-1	-1	-1	-1
narrow hyaline	-1	=	=	=	=	=	=	-1	-1	-1	-1	-1

Table 4. Estimated regression coefficients (a = intercept and b = slope, n = sample size) from the regression of log_{10}(weight in kg) on log_{10}(length in cm) by year and region (BoF = Bay of Fundy; SS = Scotian Shelf) from Haddock at least 20 cm in length collected from the DFO summer ecosystem survey.

Year	BoF n	BoF a	BoF b	SS n	SS a	SS b
1970	192	-2.10539	3.084532	1,088	-2.44547	3.286905
1971	170	-2.07463	3.058974	867	-2.14671	3.093931
1972	162	-1.81137	2.923960	743	-2.23240	3.161174
1973	283	-2.05359	3.045901	565	-2.07990	3.066916
1974	324	-2.21714	3.145169	1,195	-2.12957	3.093631
1975	176	-2.00546	3.027663	550	-2.22950	3.153312
1976	419	-1.88172	2.938045	776	-2.13160	3.083517
1977	396	-2.06530	3.061609	759	-2.14581	3.103643
1978	365	-2.07951	3.081040	1,374	-2.27198	3.187906
1979	797	-2.21995	3.153333	1,242	-2.07712	3.063980
1980	880	-1.97929	3.005732	1,128	-2.01470	3.021643
1981	814	-1.91159	2.972035	1,219	-2.11162	3.082051
1982	456	-1.97447	3.010088	443	-2.12447	3.083612
1983	498	-1.88914	2.955086	893	-2.17436	3.100123
1984	412	-1.96667	2.998904	539	-2.17466	3.103408
1985	247	-1.88118	2.940965	572	-2.05412	3.030162
1986	212	-1.91085	2.967923	594	-2.10578	3.065523
1987	176	-1.97578	3.002859	503	-1.99127	3.005943
1988	200	-2.07309	3.062436	401	-2.28609	3.185882
1989	143	-1.97923	3.011611	441	-2.13304	3.085471
1990	210	-1.82158	2.922080	601	-1.97482	3.003685
1991	233	-1.93553	2.978873	559	-2.13663	3.082461
1992	144	-2.01079	3.021011	475	-1.94041	2.972012
1993	106	-1.74555	2.856694	412	-2.16575	3.096996
1994	164	-2.01753	3.021993	674	-2.12665	3.078891
1995	390	-2.08198	3.048451	638	-2.09047	3.047831
1996	357	-2.01853	3.015170	780	-2.06580	3.033495
1997	288	-1.91492	2.955286	764	-2.01672	3.011504
1998	260	-2.00805	3.012953	630	-2.11865	3.068482
1999	268	-2.00643	3.010496	787	-2.02224	3.017227
2000	443	-2.09292	3.056297	706	-2.20620	3.120640
2001	275	-1.91631	2.955476	907	-2.11672	3.069341
2002	445	-1.99233	2.990165	956	-2.04167	3.012269
2003	281	-1.85884	2.910944	730	-1.86694	2.911359
2004	239	-2.12751	3.061750	575	-2.29205	3.171636
2005	185	-1.99395	2.990214	907	-2.22288	3.135336
2006	265	-2.05702	3.036577	743	-2.11452	3.060106
2007	205	-1.91170	2.954522	717	-2.12756	3.078897
2008	158	-2.11512	3.066586	684	-2.21251	3.128347
2009	159	-2.03245	3.024403	559	-2.21013	3.139367
2010	189	-2.15173	3.081395	530	-2.28920	3.164332
2011	253	-2.06607	3.026162	633	-2.05209	3.020152
2012	215	-1.92561	2.948711	688	-1.97636	2.961146
2013	260	-1.98631	2.991648	648	-1.93290	2.946570
2014	385	-2.13575	3.081349	494	-1.99529	2.984684
2015	563	-2.02866	3.008123	828	-2.00063	2.985196
2016	762	-2.02121	2.993971	783	-1.99615	2.968785
2017	611	-1.99831	2.986591	660	-2.14259	3.077341
2018	373	-1.97576	2.981431	549	-2.19886	3.123689
2019	413	-2.09695	3.055958	681	-2.15529	3.098387
2020	327	-2.06140	3.033629	495	-2.27289	3.171666
2021	239	-2.00022	3.011811	325	-2.15442	3.097145
2022	320	-2.08845	3.059790	511	-2.15200	3.088947

Table 5. Estimated fishery numbers at age (000s) of Haddock from the Scotian Shelf.

Year	1	2	3	4	5	6	7	8	9	10	11	12+
1970	0	298	712	1,438	277	296	3,759	1,287	227	78.0	84.9	27.1
1971	0	136	2,080	935	1,160	460	42.6	2,922	1,000	172	108	172
1972	0.267	54.6	1,892	1,533	477	559	88.8	22.7	936	387	16.3	242
1973	0.640	170	462	2,650	892	397	588	349	279	385	68.8	24.0
1974	0	103	1,250	242	1,412	396	132	201	72.7	205	304	36.8
1975	0	149	1,646	3,561	595	1,095	279	173	54.8	43.0	102	171
1976	0	138	788	2,699	3,066	395	905	191	79.6	91.6	23.8	145
1977	0	765	2,166	1,642	3,254	2,559	324	378	43.4	72.4	30.9	63.3
1978	0	78.1	2,784	5,295	1,616	2,119	740	140	112	15.3	12.6	45.4
1979	0	61.0	828	5,351	3,127	817	952	228	40.7	34.6	10.9	18.9
1980	0	55.3	1,574	2,601	4,244	2,576	520	431	162	36.1	25.7	18.0
1981	0	55.9	597	4,244	3,316	3,024	1,234	381	342	110	21.9	44.5
1982	0	19.3	911	1,550	3,737	1,526	1,345	263	118	87.3	29.2	30.0
1983	0	9.61	851	3,686	3,351	1,919	797	357	160	98.1	50.4	34.0
1984	0	7.60	210	2,952	2,595	2,025	963	420	143	89.7	29.7	39.0
1985	0	23.0	520	985	2,965	1,293	515	464	406	252	99.0	78.6
1986	0	181	341	1,831	1,495	2,323	593	315	223	88.4	70.3	74.4
1987	0.501	20.6	252	674	2,513	1,030	2,170	566	215	205	53.6	80.4
1988	2.15	11.0	835	865	938	1,520	648	553	196	130	107	84.8
1989	0	64.5	317	467	775	318	607	355	389	118	45.3	84.6
1990	0	135	635	211	284	436	406	624	237	180	94.6	44.9
1991	0	2.98	368	1,634	463	261	316	188	326	272	124	315
1992	4.52	112	139	2,044	1,608	230	158	322	263	278	76.3	206
1993	0	12.0	391	317	1,532	771	138	68.5	73.4	29.4	65.3	77.9
1994	0	75.3	135	343	188	814	157	35.8	25.7	3.87	28.8	18.7
1995	0	31.1	351	388	402	115	326	373	111	20.2	10.3	37.9
1996	0	1.23	242	475	339	204	216	384	324	78.3	6.92	3.33
1997	0	0	242	1,057	390	247	110	57.0	72.2	76.8	29.2	2.19
1998	0	5.60	68.3	540	1,185	787	334	161	105	56.8	68.0	20.3
1999	0	21.4	106	218	558	488	301	89.2	35.8	21.2	16.8	15.7
2000	0	82.9	505	511	432	774	688	322	67.7	24.9	15.3	6.01
2001	0	30.5	573	533	444	384	912	565	211	41.9	25.0	38.5
2002	0.130	10.6	186	835	306	286	263	590	275	93.3	57.4	58.0
2003	0.029	0.873	45.5	730	942	328	193	61.0	96.3	128	34.6	4.94
2004	0	10.6	92.1	415	643	904	193	87.3	88.8	61.8	18.1	14.2
2005	0.154	8.20	36.3	318	943	483	303	386	26.2	44.2	17.7	4.34
2006	0	9.17	244	135	431	548	579	536	79.5	8.53	29.8	2.20
2007	0	12.6	114	971	157	389	381	330	341	64.3	35.3	13.5
2008	0	18.2	209	277	1,070	266	153	280	169	163	27.4	18.5
2009	0	10.5	299	353	360	1,053	214	140	217	173	67.4	34.9
2010	0	4.66	85.3	472	402	494	1,015	226	140	238	120	86.6
2011	3.16	34.7	58.9	140	1,071	376	209	483	36.6	25.7	3.77	59.8
2012	0	21.8	211	314	333	1,284	304	284	273	111	20.4	57.1
2013	0.922	49.1	653	303	240	105	289	339	77.9	69.7	31.9	9.63
2014	0.149	148	449	1,014	120	46.2	70.5	57.4	43.3	15.1	9.78	1.84
2015	0.547	139	667	604	556	37.2	10.6	13.4	57.1	2.55	0.589	5.75
2016	0	126	390	462	441	269	21.2	2.88	56.7	0.617	0.269	0.060
2017	0	4.09	176	713	402	132	62.9	5.66	8.65	0	0.310	0.066
2018	0	2.42	14.9	661	506	16.5	8.06	37.1	0.345	0.348	0	0
2019	0	6.96	139	86.2	533	1,305	30.0	12.6	2.81	0	0	0.003
2020	0.193	26.1	670	372	266	724	2,487	132	55.5	0.894	0	0.013
2021	6.47	103	695	858	825	180	177	959	81.1	9.04	0.397	0.010
2022	2.50	151	111	1,650	766	212	291	207	512	18.4	0	2.54

Table 6. Estimated fishery numbers at age (000s) of Haddock from the Bay of Fundy.

Year	1	2	3	4	5	6	7	8	9	10	11	12+
1970	6.07	459	147	119	77.1	142	898	238	33.5	13.8	39.7	25.6
1971	0.250	445	403	148	151	8.15	7.88	593	140	15.2	4.65	200
1972	8.62	305	1,432	206	72.9	64.0	13.2	37.5	236	121	0.788	52.9
1973	61.9	2,162	68.4	414	79.5	29.0	75.6	10.9	42.3	109	9.07	2.29
1974	38.6	771	3,476	147	388	92.7	24.5	46.2	27.6	36.7	107	1.50
1975	0.683	1,689	2,212	1,441	50.7	102	34.9	5.80	1.84	1.70	8.27	34.0
1976	1.11	1,204	1,699	871	355	11.5	73.6	0	0	0	0	16.0
1977	12.8	1,091	768	305	279	211	35.8	23.1	21.6	0.153	0	5.74
1978	0.003	11.0	1,116	1,287	321	518	139	11.5	19.0	6.38	0	31.7
1979	6.67	25.3	325	599	695	786	182	121	69.7	35.3	2.16	37.9
1980	1.19	294	1,070	984	1,411	828	120	225	60.1	12.0	3.37	0.419
1981	0.408	647	1,106	1,632	715	553	154	77.5	54.5	18.7	1.75	1.63
1982	0	940	2,135	1,093	1,013	385	345	50.8	68.7	21.3	6.23	1.29
1983	0	116	3,115	2,111	764	672	157	61.9	71.2	41.5	35.6	25.7
1984	2.72	1,083	1,323	2,240	780	397	148	41.0	22.7	15.5	13.8	1.38
1985	7.31	740	2,481	462	710	289	207	83.6	48.3	64.9	17.9	14.7
1986	0	349	703	2,251	311	467	77.8	47.9	25.4	37.8	4.55	16.5
1987	0	120	495	361	623	188	94.1	45.0	17.8	17.7	11.4	12.8
1988	2.24	67.0	179	150	167	287	109	90.3	45.5	34.6	18.8	20.3
1989	0.068	111	265	107	115	18.6	45.1	25.5	19.4	14.6	28.0	8.03
1990	0	159	437	97.0	59.2	53.0	41.0	63.9	38.2	23.4	8.89	2.69
1991	2.31	20.5	596	542	131	37.0	38.6	27.0	33.0	33.5	14.5	24.2
1992	0.598	83.8	66.9	497	415	27.5	29.6	47.6	19.6	25.7	2.05	27.9
1993	0.577	98.6	264	70.4	306	258	43.8	12.8	14.9	12.1	11.1	9.64
1994	2.46	56.1	207	193	41.8	249	90.0	5.79	1.43	11.1	2.48	9.05
1995	0.282	45.6	381	426	222	90.2	128	112	60.6	4.57	5.95	12.8
1996	0	17.8	658	656	254	145	63.9	109	125	37.7	9.95	7.91
1997	0	2.47	290	1,024	567	281	90.3	40.7	34.4	17.7	14.5	2.35
1998	0	43.2	82.3	592	754	431	180	116	29.0	25.7	38.7	16.3
1999	0	10.2	222	295	556	472	304	158	11.5	16.0	53.3	14.0
2000	0	72.2	176	293	239	454	274	211	110	54.0	8.05	20.7
2001	0	43.6	828	721	391	144	269	312	167	72.3	29.5	8.42
2002	0.486	32.9	271	1,461	612	286	216	205	170	96.9	60.6	6.28
2003	0	19.0	860	822	1,824	383	111	162	45.0	39.3	24.7	22.8
2004	0	1.27	112	734	414	871	483	188	45.1	62.6	54.6	26.4
2005	0	8.01	16.3	142	1,086	477	399	126	40.6	21.4	14.4	7.48
2006	0	21.9	473	147	287	510	299	132	33.5	3.51	1.25	15.2
2007	0.180	50.5	184	3,015	124	115	338	183	72.4	32.2	13.9	4.96
2008	0	39.4	166	316	1,654	106	95.4	158	104	44.1	3.80	3.24
2009	0.578	17.3	74.8	202	316	789	320	55.4	31.0	15.1	4.05	6.12
2010	0	6.14	4.65	74.0	101	287	878	190	18.8	28.1	32.5	8.30
2011	0.166	20.8	39.3	34.2	170	154	170	443	138	19.6	11.5	4.83
2012	2.62	122	84.1	68.5	58.4	156	134	116	263	87.3	4.54	24.2
2013	17.2	92.6	969	215	82.5	29.2	70.3	60.9	56.8	185	86.9	7.10
2014	5.78	143	310	765	148	52.1	26.0	44.1	27.5	4.11	22.2	14.9
2015	0	156	329	396	650	39.0	12.5	20.2	10.5	7.35	2.94	10.1
2016	1.63	281	1,448	381	544	446	36.1	8.66	8.09	4.63	0.426	6.49
2017	1.83	18.8	540	4,283	300	260	181	5.96	0	3.55	0.535	0
2018	1.48	108	164	729	3,897	193	29.9	81.3	0.921	0	0	0
2019	1.63	93.7	188	249	501	3,167	83.5	16.4	3.07	3.28	0	0
2020	6.52	60.5	195	456	265	305	1,670	49.0	21.7	8.48	1.21	0
2021	24.3	104	461	216	355	109	107	473	193	5.75	1.12	0
2022	76.9	436	304	200	344	217	83.8	185	177	5.16	0	0

Table 7. Fishery length-at-age (LAA) in cm, estimated as the weighted mean LAA from Bay of Fundy (BoF) and Scotian Shelf (SS), weighted by the catch-at-age for BoF and SS, and adjusted for growth to the month of August.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12+
1970	12.7	25.4	36.0	42.7	47.2	49.5	56.5	57.1	61.9	65.6	67.5	67.0	74.5
1971	12.4	24.8	35.0	43.0	49.5	52.0	54.0	54.6	60.1	63.9	66.8	67.6	69.1
1972	12.9	25.8	34.8	43.6	51.7	54.5	58.9	59.8	63.3	62.8	64.8	68.6	68.1
1973	12.7	25.4	35.2	40.2	48.7	56.3	60.4	61.4	64.3	64.2	70.1	69.0	75.4
1974	13.5	27.0	34.1	43.2	49.0	56.5	61.6	64.9	64.5	66.1	67.3	69.6	74.2
1975	12.5	25.0	36.6	42.6	50.2	57.7	61.1	65.3	67.1	68.2	67.9	68.8	71.8
1976	14.0	28.0	35.7	42.4	49.0	56.1	61.7	64.6	66.5	66.7	69.1	69.6	71.8
1977	14.5	29.0	36.1	44.3	49.5	54.4	60.4	65.7	67.3	68.5	70.1	71.0	72.5
1978	14.5	29.0	35.4	43.6	51.1	57.3	61.4	65.9	69.3	71.5	73.6	72.4	72.8
1979	11.4	22.7	35.1	42.4	49.8	56.9	61.3	65.5	68.9	72.6	72.5	74.6	73.1
1980	12.0	24.0	35.3	42.1	49.1	55.2	62.1	65.2	68.8	70.7	74.0	74.2	78.6
1981	15.0	30.0	37.1	43.2	49.3	55.4	60.7	64.0	67.0	70.1	71.2	74.3	76.1
1982	13.9	27.7	35.2	42.9	50.1	54.6	60.1	64.4	67.8	70.4	72.8	73.7	76.9
1983	13.9	27.8	32.5	40.9	48.5	56.2	61.4	66.1	67.9	69.1	71.0	72.1	73.5
1984	13.5	27.0	35.2	40.9	45.9	52.3	58.7	62.4	65.5	68.2	70.6	71.9	74.9
1985	14.8	29.7	36.7	43.1	46.3	50.0	55.1	59.7	61.6	62.7	64.6	66.8	69.4
1986	15.2	30.4	35.2	42.7	46.8	49.7	53.4	58.2	61.5	64.1	65.7	67.3	70.1
1987	15.5	25.6	37.2	41.3	46.4	49.1	53.5	56.0	59.5	61.3	63.9	67.9	69.1
1988	15.6	31.1	38.8	43.8	46.5	52.7	53.7	56.7	58.7	62.6	65.2	65.1	68.1
1989	14.5	29.1	40.2	47.1	50.4	53.1	56.6	59.6	60.5	60.4	60.4	65.5	67.9
1990	16.0	31.9	42.3	47.1	50.6	57.4	59.7	61.3	62.5	63.3	63.5	67.3	70.8
1991	16.4	32.7	41.4	45.0	52.1	57.8	60.8	63.9	64.9	65.3	65.1	65.2	66.6
1992	17.0	29.1	38.7	44.8	49.6	56.9	60.4	62.1	62.6	63.1	65.8	65.6	63.8
1993	17.4	34.7	39.6	44.1	46.8	52.6	58.6	61.7	64.9	62.3	69.4	64.5	64.1
1994	16.9	33.8	42.0	46.7	50.3	54.2	57.7	62.4	64.1	60.2	67.1	63.9	68.4
1995	11.5	23.0	39.6	46.6	51.8	55.4	58.7	60.7	62.7	67.6	66.1	67.3	68.5
1996	12.6	25.2	40.0	44.7	49.1	53.6	57.8	56.4	59.9	61.7	62.8	67.1	68.2
1997	10.9	21.8	43.7	44.4	49.0	54.1	59.8	63.0	62.6	65.5	66.8	69.0	68.7
1998	10.8	21.6	37.9	45.0	45.0	51.5	55.8	60.4	63.6	63.9	66.4	65.7	68.8
1999	11.5	23.0	40.8	46.6	50.6	51.6	56.7	61.6	65.6	64.6	64.7	68.8	68.2
2000	12.3	24.7	37.8	42.1	48.8	49.0	52.4	56.7	59.5	63.9	65.7	64.4	69.6
2001	13.0	25.9	41.6	44.3	48.5	53.7	52.1	55.5	58.7	62.1	65.3	64.2	70.6
2002	14.5	28.2	38.4	44.4	49.1	52.4	55.9	55.0	54.7	62.2	64.0	65.3	69.8
2003	13.3	25.7	40.8	45.2	46.6	53.6	55.4	56.2	61.1	58.8	61.8	62.1	65.1
2004	12.7	25.3	39.4	41.7	45.6	46.3	53.0	57.2	59.3	58.8	61.6	65.4	66.6
2005	14.7	24.0	33.0	34.5	40.6	46.9	50.2	55.2	54.9	60.7	60.2	61.1	66.1
2006	13.5	27.1	41.6	39.4	42.8	45.9	51.2	50.1	52.5	55.4	53.4	54.7	60.6
2007	12.5	25.0	38.1	38.7	43.4	44.8	48.7	54.1	51.9	52.1	55.5	53.0	57.8
2008	13.2	26.3	36.4	40.3	44.3	48.0	45.5	50.2	54.8	52.7	53.3	53.6	54.2
2009	16.6	33.1	34.7	39.1	43.7	48.0	50.8	51.6	54.2	54.7	54.1	56.6	58.4
2010	15.5	31.1	38.3	41.6	43.1	46.7	50.3	53.0	54.8	57.1	57.8	55.9	60.3
2011	15.0	22.1	35.5	39.2	41.7	44.9	48.3	52.6	53.3	54.2	55.0	59.0	56.2
2012	15.2	30.4	35.5	39.7	41.0	45.7	48.6	52.3	53.0	53.8	53.6	57.4	54.9
2013	14.5	28.9	33.7	40.7	44.7	46.6	45.3	51.1	50.8	53.6	54.2	55.8	56.7
2014	15.6	31.1	34.5	39.6	46.3	50.2	51.3	49.8	54.8	53.3	51.1	56.2	58.0
2015	16.1	23.0	34.0	38.5	44.5	50.3	53.7	52.8	52.0	54.2	55.3	57.4	56.5
2016	12.8	25.5	35.4	37.5	42.4	49.2	51.6	53.9	53.6	55.7	53.9	56.2	57.7
2017	13.5	27.0	30.1	38.7	41.2	48.3	52.6	54.1	58.1	56.3	62.9	51.7	55.0
2018	15.0	30.0	32.3	34.0	41.3	45.3	52.5	55.0	52.3	53.2	52.0	62.9	54.7
2019	15.4	30.8	32.5	35.0	38.4	42.8	46.0	54.0	52.9	56.5	50.9	62.9	55.9
2020	11.1	33.7	32.6	35.2	38.5	41.9	44.8	47.5	48.8	55.7	51.6	52.0	56.3
2021	12.8	30.4	33.6	35.8	38.0	41.0	43.3	49.7	48.7	50.9	52.5	54.6	60.0
2022	14.7	29.2	35.3	39.4	38.5	43.1	50.0	45.1	47.5	53.5	52.9	57.4	46.0

Table 8. Fishery weight-at-age (WAA) in kg, estimated as the weighted mean WAA from Bay of Fundy (BoF) and Scotian Shelf (SS), weighted by the catch-at-age for BoF and SS.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12+
1970	0.020	0.169	0.485	0.826	1.14	1.33	2.03	2.11	2.75	3.33	3.66	3.51	4.88
1971	0.019	0.156	0.443	0.816	1.26	1.46	1.63	1.77	2.28	2.76	3.16	3.30	3.53
1972	0.027	0.206	0.490	0.921	1.53	1.81	2.31	2.43	2.87	2.82	3.11	3.74	3.62
1973	0.020	0.168	0.457	0.693	1.25	1.95	2.41	2.53	2.92	2.90	3.79	3.62	4.75
1974	0.022	0.193	0.402	0.848	1.26	1.96	2.56	3.02	2.95	3.18	3.37	3.74	4.54
1975	0.021	0.169	0.532	0.834	1.37	2.11	2.53	3.11	3.39	3.57	3.52	3.67	4.19
1976	0.031	0.234	0.477	0.784	1.21	1.83	2.44	2.82	3.08	3.12	3.48	3.55	3.89
1977	0.031	0.258	0.503	0.934	1.30	1.75	2.41	3.13	3.37	3.58	3.82	3.99	4.26
1978	0.032	0.267	0.469	0.914	1.50	2.16	2.68	3.35	3.94	4.35	4.76	4.54	4.60
1979	0.013	0.114	0.457	0.817	1.33	2.01	2.56	3.09	3.67	4.37	4.32	4.63	4.47
1980	0.018	0.148	0.468	0.788	1.26	1.79	2.54	2.95	3.47	3.77	4.32	4.37	5.16
1981	0.038	0.301	0.566	0.876	1.29	1.84	2.42	2.85	3.28	3.77	3.95	4.52	4.85
1982	0.029	0.234	0.478	0.857	1.35	1.73	2.32	2.87	3.35	3.78	4.17	4.33	4.92
1983	0.031	0.238	0.374	0.728	1.17	1.80	2.38	2.96	3.21	3.43	3.71	3.91	4.16
1984	0.026	0.212	0.467	0.730	1.01	1.47	2.08	2.51	2.90	3.31	3.67	3.91	4.39
1985	0.037	0.281	0.525	0.837	1.01	1.26	1.68	2.15	2.35	2.48	2.71	3.00	3.37
1986	0.040	0.311	0.465	0.827	1.08	1.27	1.57	2.03	2.41	2.72	2.97	3.16	3.59
1987	0.040	0.174	0.549	0.749	1.05	1.24	1.61	1.84	2.20	2.41	2.73	3.29	3.46
1988	0.038	0.306	0.622	0.882	1.06	1.58	1.69	2.00	2.23	2.72	3.10	3.09	3.56
1989	0.033	0.268	0.694	1.12	1.33	1.57	1.89	2.22	2.32	2.32	2.33	3.00	3.32
1990	0.049	0.374	0.858	1.14	1.42	2.05	2.30	2.49	2.64	2.73	2.77	3.28	3.82
1991	0.048	0.377	0.755	0.959	1.46	1.99	2.31	2.69	2.82	2.88	2.85	2.87	3.06
1992	0.051	0.261	0.610	0.946	1.27	1.90	2.27	2.47	2.52	2.58	2.93	2.88	2.69
1993	0.063	0.453	0.654	0.879	1.03	1.46	2.04	2.38	2.79	2.46	3.38	2.73	2.68
1994	0.049	0.401	0.755	1.06	1.33	1.64	1.99	2.54	2.74	2.26	3.18	2.72	3.36
1995	0.014	0.117	0.610	1.00	1.38	1.71	2.03	2.24	2.47	3.09	2.90	3.06	3.23
1996	0.020	0.162	0.648	0.904	1.20	1.54	1.93	1.79	2.15	2.35	2.49	3.06	3.22
1997	0.014	0.110	0.855	0.891	1.20	1.60	2.16	2.53	2.48	2.83	3.01	3.32	3.28
1998	0.013	0.103	0.555	0.933	0.926	1.38	1.76	2.24	2.64	2.69	3.01	2.90	3.36
1999	0.015	0.124	0.699	1.03	1.34	1.41	1.87	2.40	2.90	2.77	2.82	3.40	3.33
2000	0.017	0.145	0.533	0.735	1.16	1.19	1.44	1.85	2.15	2.69	2.94	2.79	3.47
2001	0.024	0.183	0.730	0.883	1.16	1.57	1.45	1.73	2.05	2.44	2.82	2.69	3.60
2002	0.030	0.221	0.573	0.846	1.15	1.40	1.69	1.63	1.60	2.33	2.54	2.69	3.26
2003	0.026	0.172	0.681	0.909	0.991	1.49	1.64	1.70	2.18	1.97	2.25	2.34	2.65
2004	0.018	0.147	0.584	0.704	0.910	0.964	1.46	1.82	2.04	2.06	2.33	2.77	2.93
2005	0.031	0.132	0.360	0.407	0.669	1.04	1.27	1.69	1.69	2.25	2.26	2.33	2.88
2006	0.024	0.197	0.716	0.610	0.774	0.956	1.35	1.26	1.44	1.71	1.58	1.61	2.26
2007	0.021	0.165	0.585	0.601	0.844	0.932	1.18	1.62	1.43	1.45	1.76	1.53	1.99
2008	0.021	0.174	0.474	0.646	0.863	1.11	0.946	1.27	1.67	1.48	1.55	1.57	1.64
2009	0.045	0.367	0.425	0.613	0.862	1.15	1.37	1.44	1.70	1.75	1.69	1.96	2.15
2010	0.033	0.279	0.530	0.685	0.763	0.985	1.24	1.47	1.63	1.85	1.93	1.73	2.21
2011	0.031	0.103	0.424	0.575	0.693	0.867	1.08	1.39	1.45	1.53	1.61	1.97	1.71
2012	0.036	0.280	0.439	0.587	0.640	0.878	1.05	1.33	1.38	1.46	1.45	1.74	1.54
2013	0.031	0.243	0.379	0.665	0.871	0.977	0.913	1.28	1.25	1.50	1.57	1.72	1.76
2014	0.035	0.290	0.398	0.606	0.968	1.24	1.34	1.21	1.61	1.49	1.31	1.81	1.99
2015	0.040	0.116	0.375	0.545	0.841	1.22	1.49	1.41	1.35	1.50	1.62	1.82	1.73
2016	0.019	0.155	0.409	0.491	0.699	1.09	1.27	1.43	1.42	1.54	1.45	1.65	1.79
2017	0.024	0.189	0.261	0.555	0.668	1.09	1.40	1.52	1.91	1.76	2.36	1.33	1.63
2018	0.034	0.268	0.335	0.388	0.702	0.918	1.43	1.66	1.43	1.51	1.45	2.43	1.61
2019	0.034	0.284	0.334	0.420	0.560	0.784	0.975	1.59	1.53	1.93	1.31	2.50	1.81
2020	0.011	0.377	0.342	0.428	0.570	0.737	0.914	1.09	1.19	1.80	1.36	1.39	1.90
2021	0.019	0.296	0.401	0.482	0.554	0.720	0.842	1.27	1.20	1.37	1.52	1.73	2.25
2022	0.030	0.249	0.445	0.651	0.566	0.799	1.27	0.945	1.10	1.55	1.50	1.96	0.964

Table 9. Mean biomass per tow in kg and coefficient of variation (COV), and mean numbers per tow by age and year for 4X5Y Haddock from the Individual Transferable Quota (ITQ) Survey, 1996–2011. Age composition data were not available in 2011 (—).

Year	Biomass/ tow (kg)	COV (%)	1	2	3	4	5	6	7	8	9	10	11	12+
1996	44.26	10.3	6.9	41.3	25.1	9.0	3.5	0.9	0.7	0.8	0.2	0.2	0	0
1997	43.39	15.0	14.7	9.5	33.1	19.4	5.0	1.6	0.6	0.2	0.3	0.2	0	0
1998	38.90	15.1	14.9	29.3	8.3	21.5	8.0	1.2	0.8	0.4	0.2	0.2	0.1	0
1999	51.04	14.7	98.8	39.7	18.2	7.1	11.1	4.6	2.1	0.6	0.5	0.1	0.1	0.1
2000	62.06	10.1	75.6	75.1	11.7	7.5	7.0	7.6	2.4	0.9	0.3	0.1	0	0
2001	74.80	13.0	58.9	54.5	56.5	13.5	5.0	2.1	5.3	1.9	1.0	0.7	0.1	0
2002	53.23	9.8	17.3	29.3	30.4	29.9	6.5	3.0	2.2	3.0	1.6	0.9	0.8	0
2003	55.14	16.6	6.2	17.1	30.6	26.3	13.9	2.4	2.4	1.2	2.0	0.8	0.3	0
2004	37.96	11.8	38.6	12.8	12.3	16.1	10	6.9	2.2	1.3	0.6	0.6	0.3	0.2
2005	36.38	13.2	7.2	35.9	4.1	4.7	7.7	6.9	3.6	1.8	0.6	0.5	0.2	0.1
2006	34.88	9.9	20.3	8.7	23.7	7.2	3.5	6.4	3.8	4.8	0.8	0.7	0.4	0.1
2007	36.84	12.8	48.8	47.1	14.3	34.8	4.0	4.0	7.6	4.47	2.84	0.67	0	0
2008	46.14	15.3	2.5	43.8	18.3	7.3	15.9	1.3	1.5	3.26	2.46	1.4	0	0
2009	33.00	22.5	2.4	3.4	16.6	6.5	3.1	5.4	1.6	1.4	2.5	2.1	0	0
2010	34.09	20.8	25.9	8.5	2.3	11.2	4.6	3.6	4.3	2.5	1.1	0.8	0	0
2011	39.26	18.2	—	—	—	—	—	—	—	—	—	—	—	—

Table 10. Survey length-at-age (LAA) in cm, estimated as the weighted mean LAA from Bay of Fundy (BoF) and Scotian Shelf (SS), weighted by the survey numbers-at-age for BoF and SS. The 2021 survey LAA was not calculated (—).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12+
1970	12.2	20.7	33.5	41.3	45.9	50.0	52.1	56.5	59.4	60.1	64.8	68.2	60.0
1971	12.2	18.9	29.2	41.3	46.7	50.9	53.3	54.9	59.7	63.1	71.1	68.0	72.3
1972	12.2	19.4	27.7	39.5	48.9	53.1	56.0	56.2	60.3	63.6	69.8	69.0	78.1
1973	12.2	20.6	30.4	38.1	49.6	55.2	59.3	60.1	61.0	62.7	64.6	71.0	70.0
1974	12.2	20.3	30.6	40.9	46.0	54.2	59.0	60.9	62.8	62.8	63.3	68.8	73.0
1975	12.2	21.9	32.9	41.1	48.5	54.3	59.6	63.4	64.7	65.8	66.2	67.5	68.4
1976	12.2	21.4	32.0	39.9	48.3	53.0	58.5	63.2	61.4	65.9	66.2	69.6	68.2
1977	8.0	21.3	33.0	42.0	48.8	54.7	58.3	64.2	66.2	70.4	65.5	67.0	71.6
1978	8.0	19.0	33.8	42.3	50.3	54.8	58.0	61.7	66.0	66.4	69.5	63.0	71.7
1979	11.4	22.3	31.6	42.5	50.1	55.4	60.6	63.9	66.9	70.6	69.5	70.3	73.5
1980	11.0	21.5	33.7	40.9	49.6	55.7	59.9	62.6	65.0	68.2	69.3	70.2	74.1
1981	11.2	22.5	34.6	43.4	48.1	55.5	59.7	63.1	64.8	68.0	70.6	72.9	74.7
1982	11.5	18.0	28.0	40.2	49.8	54.6	61.8	64.5	67.9	69.6	76.0	75.4	74.0
1983	12.4	18.9	27.4	38.1	47.6	54.8	58.7	61.8	63.2	64.4	67.1	69.6	71.9
1984	11.2	19.4	30.6	36.6	44.0	51.9	57.3	59.7	62.4	66.2	69.3	70.0	69.5
1985	15.8	19.0	30.0	36.8	41.0	46.7	52.4	57.7	58.5	58.7	63.7	63.0	67.8
1986	6.9	19.8	28.8	37.4	40.8	46.6	49.9	52.9	55.4	60.9	60.7	67.3	66.2
1987	6.7	21.0	31.3	35.8	45.8	49.4	50.0	53.8	55.6	57.9	58.2	61.4	69.8
1988	7.0	20.3	34.7	39.6	44.7	49.6	50.4	53.4	55.2	58.2	55.7	60.6	64.8
1989	10.0	20.0	32.1	41.6	44.6	49.3	52.6	52.9	53.7	54.1	56.7	62.0	56.2
1990	9.0	21.2	32.4	41.9	49.8	54.1	55.6	58.9	59.1	61.6	59.1	61.2	63.4
1991	9.0	21.0	33.6	41.2	50.5	53.4	59.9	60.9	60.2	59.5	55.8	66.9	64.4
1992	8.6	20.0	31.1	38.1	46.2	54.4	59.4	60.6	57.0	60.1	64.3	64.8	65.5
1993	8.7	22.1	32.7	41.3	47.3	51.2	57.6	57.6	56.6	52.8	58.0	59.2	60.6
1994	8.5	24.1	34.6	42.6	48.6	50.2	54.1	56.5	61.5	54.0	55.6	59.0	56.3
1995	7.8	19.0	32.7	43.3	49.3	53.0	54.2	57.5	60.1	64.8	60.8	77.6	54.0
1996	8.7	17.7	27.3	39.8	49.0	52.9	55.3	59.1	59.6	64.3	63.7	58.1	69.7
1997	8.2	21.7	27.0	33.9	43.2	49.8	51.8	56.1	57.8	58.0	55.3	61.0	59.1
1998	8.8	18.7	28.7	33.8	39.4	47.2	52.1	55.6	59.1	59.6	55.2	60.9	55.0
1999	9.7	21.3	27.2	36.3	38.2	43.2	47.2	50.2	51.6	52.6	56.0	56.4	57.7
2000	9.5	21.4	34.3	39.1	45.6	43.9	48.9	52.6	55.7	59.6	63.0	57.0	63.0
2001	9.4	19.8	28.2	37.5	41.6	47.4	46.9	48.8	51.3	54.1	49.6	54.3	64.0
2002	7.0	19.6	26.6	33.5	40.6	42.2	47.4	50.2	49.1	51.9	53.6	50.3	61.2
2003	8.1	18.7	26.6	31.6	39.2	45.7	47.9	49.3	49.2	52.4	53.2	55.9	67.0
2004	8.2	21.5	27.0	35.0	38.3	41.5	45.1	47.1	47.0	48.2	49.9	53.1	60.3
2005	5.5	20.0	28.7	34.2	38.8	39.8	42.5	46.3	47.0	50.2	49.1	49.5	52.0
2006	8.4	21.1	25.9	34.3	36.2	40.1	44.2	46.2	46.8	50.8	49.9	51.9	51.7
2007	7.0	19.6	26.7	33.4	40.2	42.8	45.5	46.2	49.1	50.3	53.1	50.4	57.4
2008	8.5	21.9	31.3	36.7	40.2	42.7	45.6	48.9	46.8	49.0	48.8	48.5	52.8
2009	8.8	22.3	29.5	34.9	39.6	42.0	47.1	47.9	47.1	47.9	47.9	49.9	50.1
2010	9.2	24.5	31.5	36.9	40.4	43.7	46.9	49.9	49.5	47.9	49.7	52.6	53.4
2011	8.2	23.1	31.7	39.9	40.9	43.4	46.4	47.3	50.1	50.7	48.0	49.6	52.1
2012	9.6	22.7	31.9	37.1	42.1	43.5	45.8	47.3	47.5	51.1	51.0	51.5	50.8
2013	9.2	23.7	30.9	37.1	40.8	45.2	45.5	45.2	46.4	49.8	51.6	50.2	54.5
2014	9.9	21.4	30.7	36.3	41.1	44.0	45.7	47.6	46.1	47.7	50.0	52.3	52.4
2015	9.1	19.1	29.5	36.4	40.3	43.3	45.8	45.3	44.3	47.1	48.6	46.3	53.4
2016	9.5	18.5	24.8	34.2	41.5	44.1	47.7	48.1	49.8	53.5	51.6	57.3	54.5
2017	9.0	19.8	26.3	31.4	38.5	45.4	46.9	46.8	47.5	52.0	55.2	54.0	52.0
2018	9.8	20.1	27.4	32.0	37.2	41.0	45.0	46.0	46.8	48.0	53.5	55.7	54.3
2019	8.3	17.4	26.7	32.8	35.8	40.4	44.5	51.6	49.0	47.8	50.9	53.7	56.0
2020	10.1	19.1	26.4	33.2	36.7	40.7	43.3	45.0	47.8	48.1	48.5	54.5	53.9
2021	—	—	—	—	—	—	—	—	—	—	—	—	—
2022	9.3	22.8	30.2	36.5	37.2	40.5	43.7	44.6	45.7	47.4	50.5	48.0	52.0

Table 11. Survey weight-at-age (WAA) in kg, estimated as the weighted mean WAA from Bay of Fundy (BoF) and Scotian Shelf (SS), weighted by the survey numbers-at-age for BoF and SS. The 2021 survey WAA was not calculated (—).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12+
1970	0.006	0.078	0.385	0.783	1.102	1.423	1.620	2.072	2.351	2.365	2.908	3.659	2.225
1971	0.006	0.075	0.248	0.746	1.084	1.402	1.631	1.734	2.296	2.582	3.997	3.475	4.641
1972	0.006	0.074	0.223	0.673	1.301	1.654	1.998	2.067	2.508	2.954	4.104	3.700	5.742
1973	0.006	0.092	0.304	0.614	1.352	1.837	2.376	2.411	2.469	2.685	2.949	3.600	4.000
1974	0.006	0.100	0.299	0.763	1.052	1.713	2.210	2.490	2.692	2.726	2.797	3.537	4.000
1975	0.006	0.106	0.380	0.742	1.271	1.810	2.352	2.857	3.015	3.230	3.106	3.395	3.612
1976	0.007	0.097	0.358	0.697	1.156	1.513	1.963	2.475	2.372	2.711	2.671	3.427	3.137
1977	0.007	0.099	0.395	0.821	1.296	1.824	2.144	2.955	3.088	4.075	2.994	3.500	3.883
1978	0.007	0.082	0.409	0.860	1.486	1.952	2.278	2.717	3.316	3.166	3.150	2.600	4.082
1979	0.007	0.086	0.322	0.846	1.373	1.803	2.379	2.774	3.368	3.905	3.361	3.150	4.547
1980	0.007	0.090	0.431	0.786	1.310	1.787	2.208	2.542	2.786	3.422	3.317	3.400	3.303
1981	0.007	0.105	0.411	0.962	1.230	1.875	2.302	2.727	3.107	3.426	3.650	3.873	4.009
1982	0.007	0.077	0.227	0.748	1.293	1.662	2.326	2.854	3.188	3.733	4.510	4.521	4.000
1983	0.007	0.066	0.210	0.603	1.173	1.595	1.980	2.331	2.617	2.802	3.245	3.513	3.967
1984	0.007	0.076	0.317	0.519	0.853	1.385	1.871	2.080	2.411	2.815	3.700	2.350	2.900
1985	0.006	0.077	0.302	0.566	0.725	1.071	1.513	2.029	1.985	2.005	2.532	2.600	3.094
1986	0.007	0.076	0.252	0.573	0.765	1.109	1.292	1.539	1.764	2.285	2.301	3.267	2.881
1987	0.006	0.111	0.344	0.510	1.122	1.354	1.308	1.654	1.825	2.092	1.934	2.347	3.919
1988	0.007	0.088	0.512	0.687	1.022	1.348	1.486	1.822	1.853	2.324	1.918	2.305	3.082
1989	0.007	0.088	0.353	0.797	0.970	1.319	1.553	1.629	1.803	1.724	1.860	2.487	1.659
1990	0.006	0.108	0.402	0.831	1.407	1.718	1.950	2.336	2.343	2.730	2.288	2.496	3.135
1991	0.006	0.097	0.411	0.762	1.400	1.603	2.241	2.334	2.344	2.366	1.857	3.574	2.903
1992	0.006	0.092	0.316	0.568	1.084	1.759	2.259	2.322	1.978	2.495	2.993	2.847	3.130
1993	0.007	0.103	0.363	0.746	1.118	1.376	1.929	1.966	1.846	1.491	2.197	2.274	2.385
1994	0.007	0.147	0.445	0.851	1.211	1.360	1.710	1.939	2.416	1.575	1.801	2.195	1.877
1995	0.006	0.071	0.357	0.858	1.199	1.484	1.601	1.877	2.207	2.609	2.216	3.892	1.510
1996	0.008	0.052	0.211	0.676	1.231	1.534	1.807	2.116	2.106	2.699	2.704	2.237	3.742
1997	0.005	0.110	0.203	0.421	0.861	1.275	1.513	1.827	1.913	2.004	1.656	2.070	1.896
1998	0.008	0.070	0.245	0.401	0.647	1.097	1.487	1.887	2.207	2.454	1.633	2.228	1.465
1999	0.010	0.101	0.217	0.512	0.590	0.859	1.095	1.354	1.433	1.559	1.946	1.914	1.878
2000	0.010	0.097	0.425	0.630	1.002	0.867	1.249	1.525	1.868	2.287	2.662	1.858	2.200
2001	0.008	0.080	0.226	0.557	0.749	1.106	1.021	1.185	1.366	1.639	1.307	1.690	2.630
2002	0.003	0.075	0.192	0.386	0.680	0.763	1.023	1.246	1.136	1.381	1.478	1.371	2.295
2003	0.005	0.067	0.198	0.335	0.623	0.986	1.099	1.190	1.172	1.451	1.505	1.652	2.802
2004	0.005	0.090	0.191	0.428	0.571	0.724	0.928	1.025	1.032	1.086	1.226	1.465	1.971
2005	0.002	0.077	0.243	0.424	0.598	0.660	0.815	1.014	1.067	1.262	1.234	1.283	1.461
2006	0.005	0.092	0.170	0.420	0.472	0.637	0.876	1.002	1.032	1.333	1.236	1.341	1.277
2007	0.003	0.076	0.200	0.388	0.699	0.833	0.986	1.021	1.261	1.323	1.481	1.292	1.967
2008	0.005	0.107	0.322	0.502	0.682	0.816	0.975	1.184	1.040	1.232	1.192	1.164	1.531
2009	0.006	0.113	0.267	0.443	0.653	0.810	1.130	1.159	1.162	1.210	1.212	1.263	1.359
2010	0.007	0.136	0.298	0.533	0.659	0.823	1.032	1.237	1.207	1.096	1.263	1.473	1.542
2011	0.005	0.121	0.313	0.639	0.663	0.811	0.987	1.012	1.262	1.296	1.099	1.240	1.365
2012	0.009	0.116	0.342	0.497	0.733	0.803	0.917	0.994	1.055	1.266	1.316	1.151	1.157
2013	0.007	0.135	0.300	0.520	0.688	0.909	0.899	0.897	0.985	1.187	1.367	1.263	1.497
2014	0.010	0.101	0.294	0.482	0.696	0.849	0.944	1.040	0.940	1.079	1.250	1.473	1.418
2015	0.007	0.070	0.271	0.484	0.638	0.802	0.931	0.854	0.787	0.958	1.099	0.977	1.380
2016	0.009	0.065	0.160	0.411	0.684	0.756	0.996	0.997	1.008	1.214	1.210	1.423	2.446
2017	0.008	0.081	0.188	0.333	0.576	0.917	0.988	1.026	0.999	1.456	1.982	1.840	1.300
2018	0.011	0.075	0.202	0.330	0.520	0.713	0.892	0.925	1.012	1.069	1.857	1.982	2.434
2019	0.006	0.063	0.204	0.347	0.393	0.620	0.784	1.173	1.111	1.001	1.488	1.857	1.680
2020	0.010	0.085	0.212	0.357	0.475	0.705	0.827	0.914	1.113	1.049	1.132	1.528	2.456
2021	—	—	—	—	—	—	—	—	—	—	—	—	—
2022	0.008	0.129	0.284	0.486	0.529	0.692	0.873	0.907	0.937	1.093	1.190	1.092	2.021

Table 12. Proportion mature-at-age (MAA) for 4X5Y Haddock, estimated as the weighted mean MAA from Bay of Fundy and Scotian Shelf, weighted by the survey numbers-at-age in each year. The 2021 survey proportion mature was not calculated (—).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12+
1970	0.020	0.013	0.076	0.351	0.770	0.946	0.988	0.997	0.999	1.000	1.000	1.000	1.000
1971	0.001	0.005	0.057	0.392	0.880	0.987	0.998	1.000	1.000	1.000	1.000	1.000	1.000
1972	0.007	0.002	0.031	0.433	0.937	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1973	0.000	0.001	0.025	0.539	0.982	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1974	0.000	0.001	0.017	0.282	0.838	0.988	0.999	1.000	1.000	1.000	1.000	1.000	1.000
1975	0.001	0.001	0.067	0.416	0.942	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1976	0.000	0.000	0.017	0.204	0.834	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1977	0.000	0.005	0.049	0.318	0.831	0.981	0.998	1.000	1.000	1.000	1.000	1.000	1.000
1978	0.000	0.022	0.512	0.978	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1979	0.000	0.003	0.091	0.713	0.966	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1980	0.001	0.014	0.280	0.682	0.947	0.994	0.999	1.000	1.000	1.000	1.000	1.000	1.000
1981	0.001	0.020	0.211	0.672	0.919	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000
1982	0.000	0.004	0.064	0.601	0.955	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1983	0.000	0.002	0.028	0.322	0.882	0.990	0.999	1.000	1.000	1.000	1.000	1.000	1.000
1984	0.000	0.005	0.119	0.489	0.873	0.991	0.999	1.000	1.000	1.000	1.000	1.000	1.000
1985	0.051	0.035	0.234	0.612	0.874	0.979	0.997	0.999	1.000	1.000	1.000	1.000	1.000
1986	0.012	0.036	0.210	0.665	0.923	0.987	0.998	1.000	1.000	1.000	1.000	1.000	1.000
1987	0.009	0.057	0.354	0.748	0.970	0.996	0.999	1.000	1.000	1.000	1.000	1.000	1.000
1988	0.006	0.060	0.405	0.767	0.968	0.996	0.999	1.000	1.000	1.000	1.000	1.000	1.000
1989	0.006	0.047	0.326	0.825	0.961	0.996	0.999	1.000	1.000	1.000	1.000	1.000	1.000
1990	0.009	0.043	0.357	0.786	0.972	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1991	0.009	0.046	0.336	0.798	0.972	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1992	0.008	0.049	0.294	0.738	0.965	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1993	0.006	0.044	0.301	0.799	0.964	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1994	0.007	0.068	0.355	0.813	0.968	0.994	0.999	1.000	1.000	1.000	1.000	1.000	1.000
1995	0.009	0.053	0.387	0.844	0.973	0.996	0.999	1.000	1.000	1.000	1.000	1.000	1.000
1996	0.006	0.044	0.325	0.846	0.980	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1997	0.007	0.070	0.291	0.777	0.967	0.996	0.999	1.000	1.000	1.000	1.000	1.000	1.000
1998	0.008	0.044	0.324	0.747	0.963	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1999	0.006	0.049	0.270	0.772	0.959	0.995	0.999	1.000	1.000	1.000	1.000	1.000	1.000
2000	0.006	0.049	0.400	0.815	0.976	0.995	0.999	1.000	1.000	1.000	1.000	1.000	1.000
2001	0.006	0.046	0.283	0.777	0.962	0.996	0.999	1.000	1.000	1.000	1.000	1.000	1.000
2002	0.006	0.055	0.322	0.775	0.966	0.995	0.999	1.000	1.000	1.000	1.000	1.000	1.000
2003	0.008	0.045	0.310	0.744	0.966	0.997	0.999	1.000	1.000	1.000	1.000	1.000	1.000
2004	0.007	0.061	0.352	0.777	0.961	0.995	0.999	1.000	1.000	1.000	1.000	1.000	1.000
2005	0.006	0.046	0.315	0.765	0.964	0.995	0.999	1.000	1.000	1.000	1.000	1.000	1.000
2006	0.006	0.070	0.285	0.777	0.963	0.995	0.999	1.000	1.000	1.000	1.000	1.000	1.000
2007	0.008	0.044	0.275	0.755	0.970	0.995	0.999	1.000	1.000	1.000	1.000	1.000	1.000
2008	0.009	0.066	0.402	0.805	0.971	0.995	0.999	1.000	1.000	1.000	1.000	1.000	1.000
2009	0.006	0.052	0.343	0.758	0.962	0.994	0.999	1.000	1.000	1.000	1.000	1.000	1.000
2010	0.008	0.063	0.324	0.796	0.964	0.996	0.999	1.000	1.000	1.000	1.000	1.000	1.000
2011	0.006	0.062	0.315	0.817	0.960	0.995	0.999	1.000	1.000	1.000	1.000	1.000	1.000
2012	0.008	0.060	0.396	0.789	0.975	0.996	0.999	1.000	1.000	1.000	1.000	1.000	1.000
2013	0.007	0.052	0.331	0.804	0.963	0.995	0.999	1.000	1.000	1.000	1.000	1.000	1.000
2014	0.007	0.057	0.352	0.767	0.968	0.996	0.999	1.000	1.000	1.000	1.000	1.000	1.000
2015	0.006	0.071	0.397	0.775	0.966	0.996	0.999	1.000	1.000	1.000	1.000	1.000	1.000
2016	0.006	0.064	0.368	0.834	0.974	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2017	0.007	0.053	0.362	0.796	0.974	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2018	0.006	0.054	0.330	0.819	0.973	0.996	0.999	1.000	1.000	1.000	1.000	1.000	1.000
2019	0.007	0.048	0.334	0.788	0.973	0.996	0.999	1.000	1.000	1.000	1.000	1.000	1.000
2020	0.007	0.063	0.301	0.775	0.966	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2021	—	—	—	—	—	—	—	—	—	—	—	—	—
2022	0.006	0.072	0.322	0.803	0.957	0.995	0.999	1.000	1.000	1.000	1.000	1.000	1.000

FIGURES

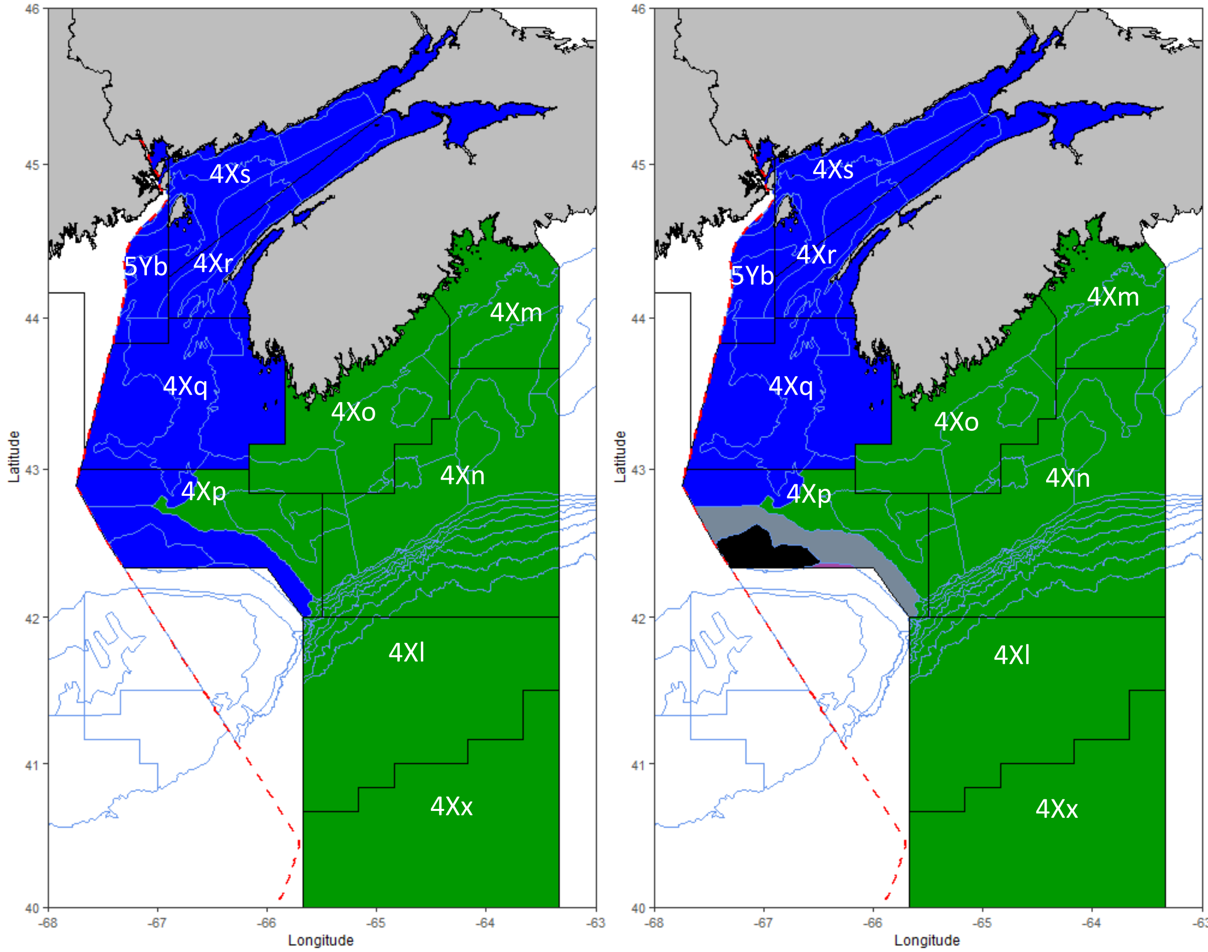


Figure 1. 4X5Y Haddock stock area showing spatial boundaries for the Bay of Fundy (blue) and Scotian Shelf (green) regions (left panel) and showing survey strata 482 (grey), 483 (black), and 5Z9 (purple) in DFO unit area 4Xp (right panel). Notes: black lines = DFO unit area boundaries, light blue lines = survey strata boundaries, dashed red line = international border.

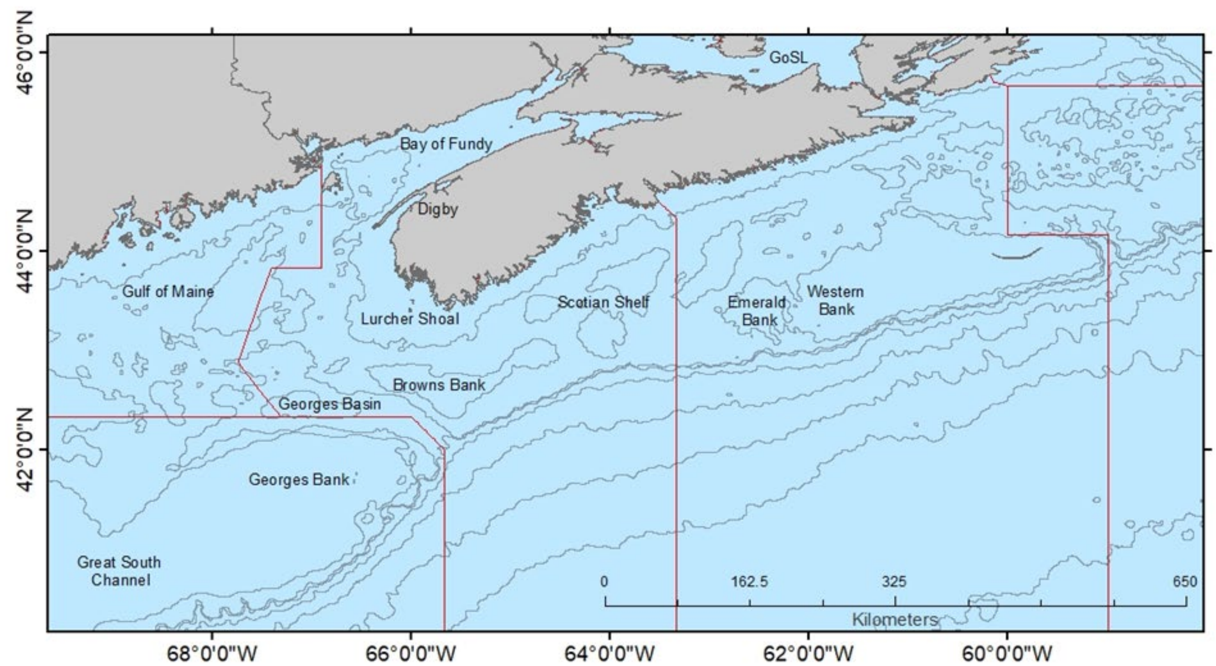


Figure 2. Map of the Scotian Shelf, Bay of Fundy, Gulf of Maine and Georges Bank showing the location of the major areas identified in tagging studies of Haddock. The red lines indicate the NAFO division boundaries, and the grey lines are depth contours.

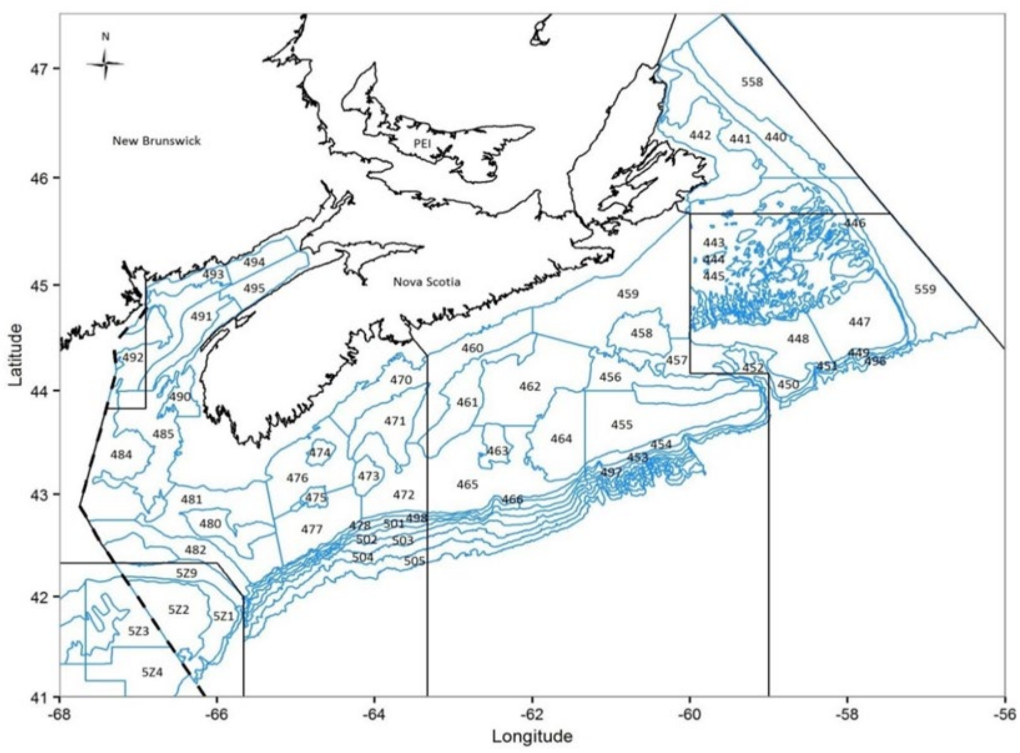


Figure 3. Fisheries and Oceans Canada (DFO) ecosystem survey strata (indicated by the number and blue lines as boundaries). The black lines indicate the NAFO division boundaries, and the dashed line is the international border. The 4X5Y stock area includes portions of survey strata (470–495).

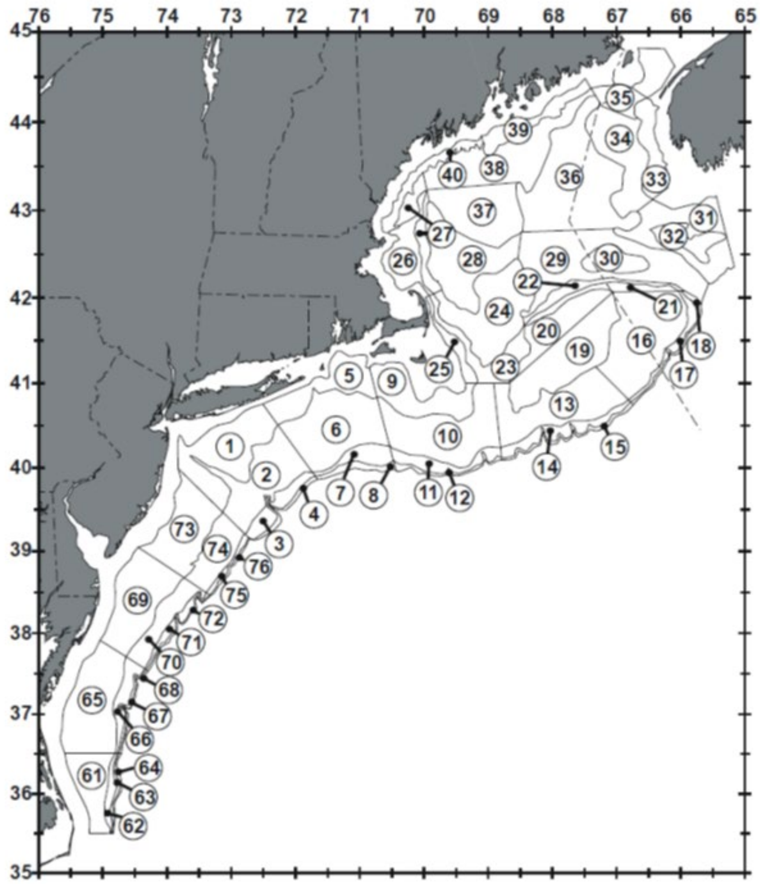


Figure 4. National Marine Fisheries Service (NMFS) bottom trawl survey strata (figure adapted from Northeast Fisheries Science Center 2014). The Gulf of Maine region is defined by strata 26–28 and 36–40.

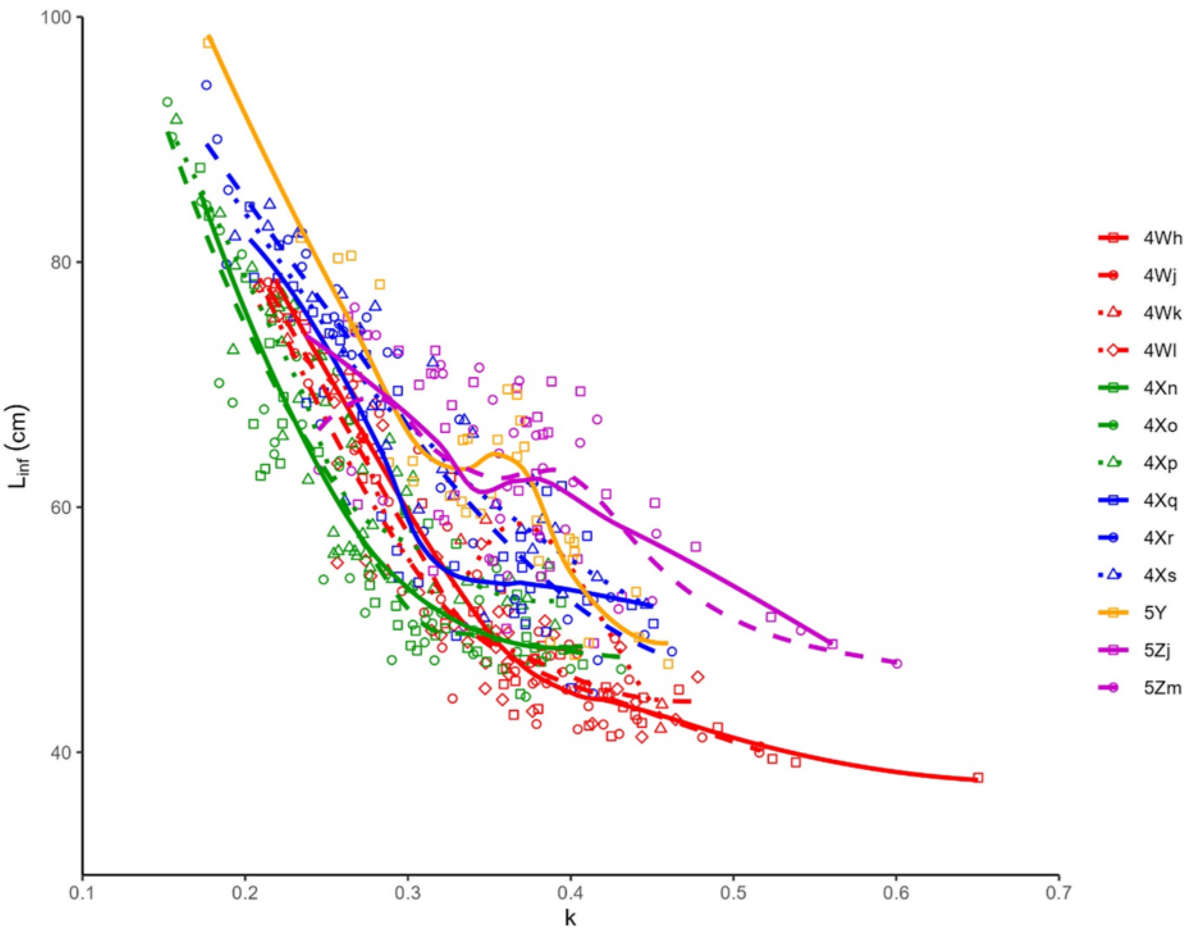


Figure 5. Scatterplot of Von Bertalanffy growth parameter estimates for asymptotic length (L_{inf}) versus growth rate (k) for Haddock, by DFO unit area with a loess smoother (span = 0.5).

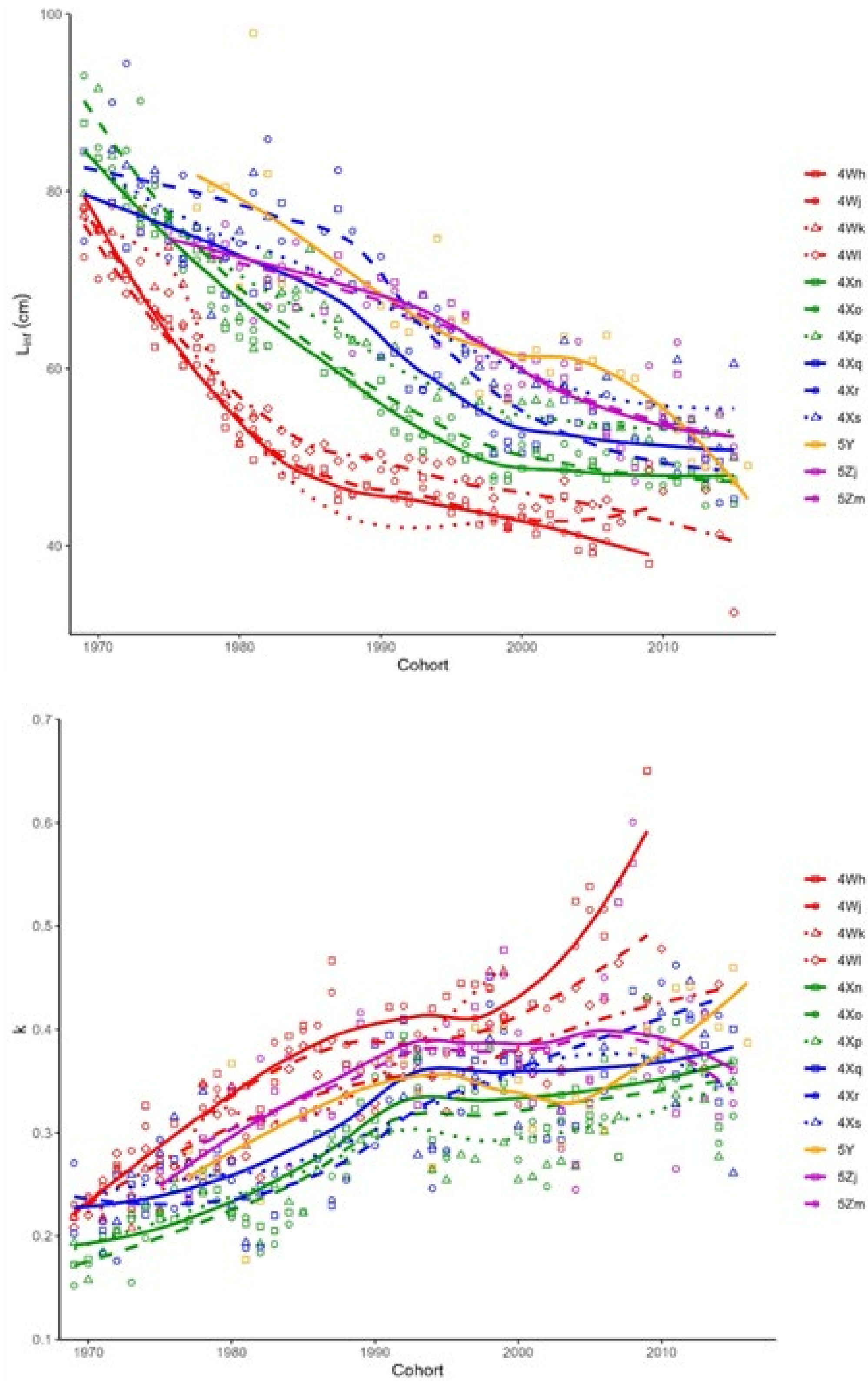


Figure 6. Scatterplot of Von Bertalanffy growth parameter estimates for asymptotic length (L_{inf}) versus cohort and growth rate (k) versus cohort for Haddock by DFO unit area with a loess smoother (span = 0.5).

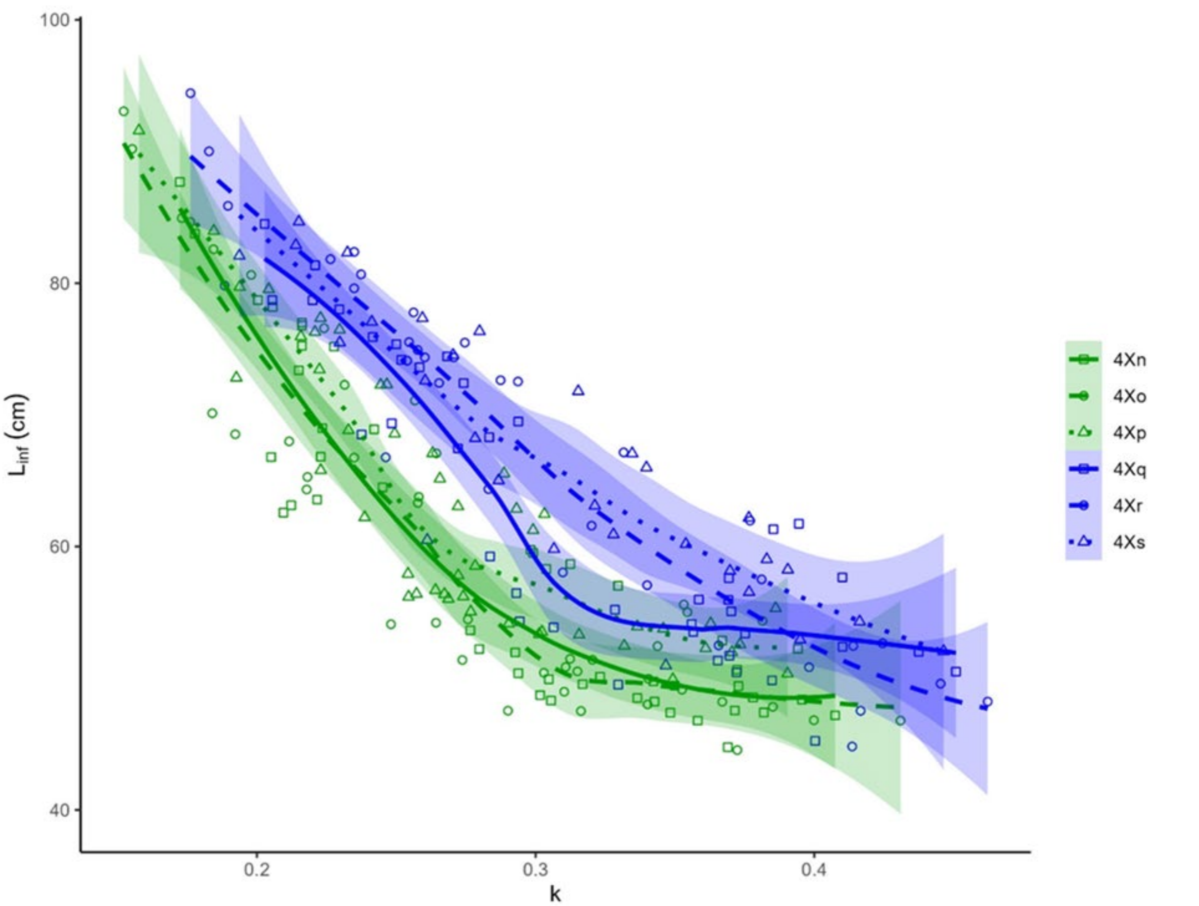


Figure 7. Scatterplot of Von Bertalanffy growth parameter estimates for asymptotic length (L_{inf}) versus growth rate (k), by DFO unit area in the Bay of Fundy (DFO unit areas in blue) and Scotian Shelf (DFO unit areas in green) regions with a loess smoother (span = 0.5) with 95% confidence limits (shading).

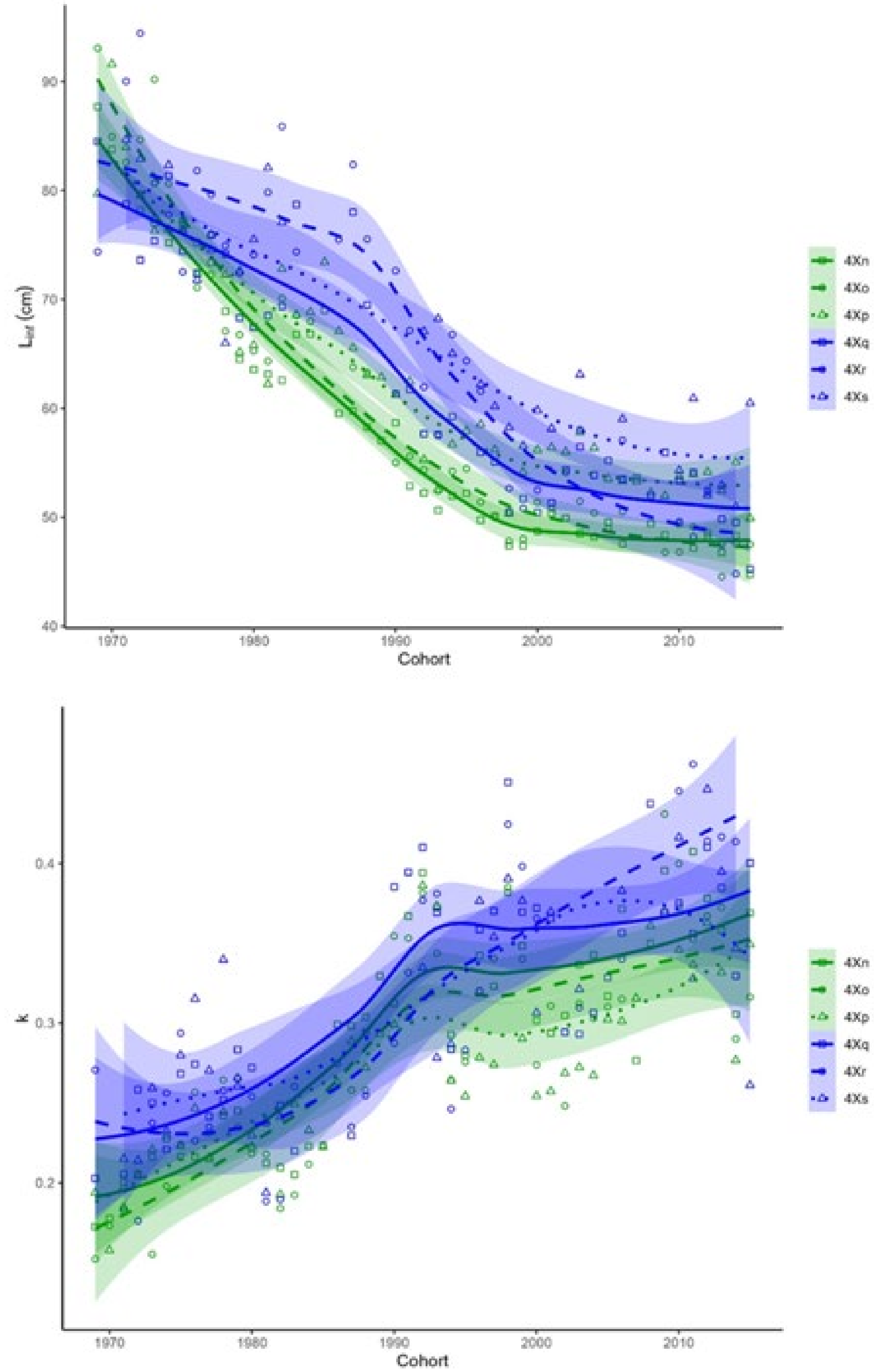


Figure 8. Scatterplot of Von Bertalanffy growth parameter estimates for asymptotic length (L_{inf}) versus cohort and growth rate (k) versus cohort by DFO unit area in the Bay of Fundy (DFO unit areas in blue) and Scotian Shelf (DFO unit areas in green) regions with a loess smoother (span = 0.5) with 95% confidence limits (shading).

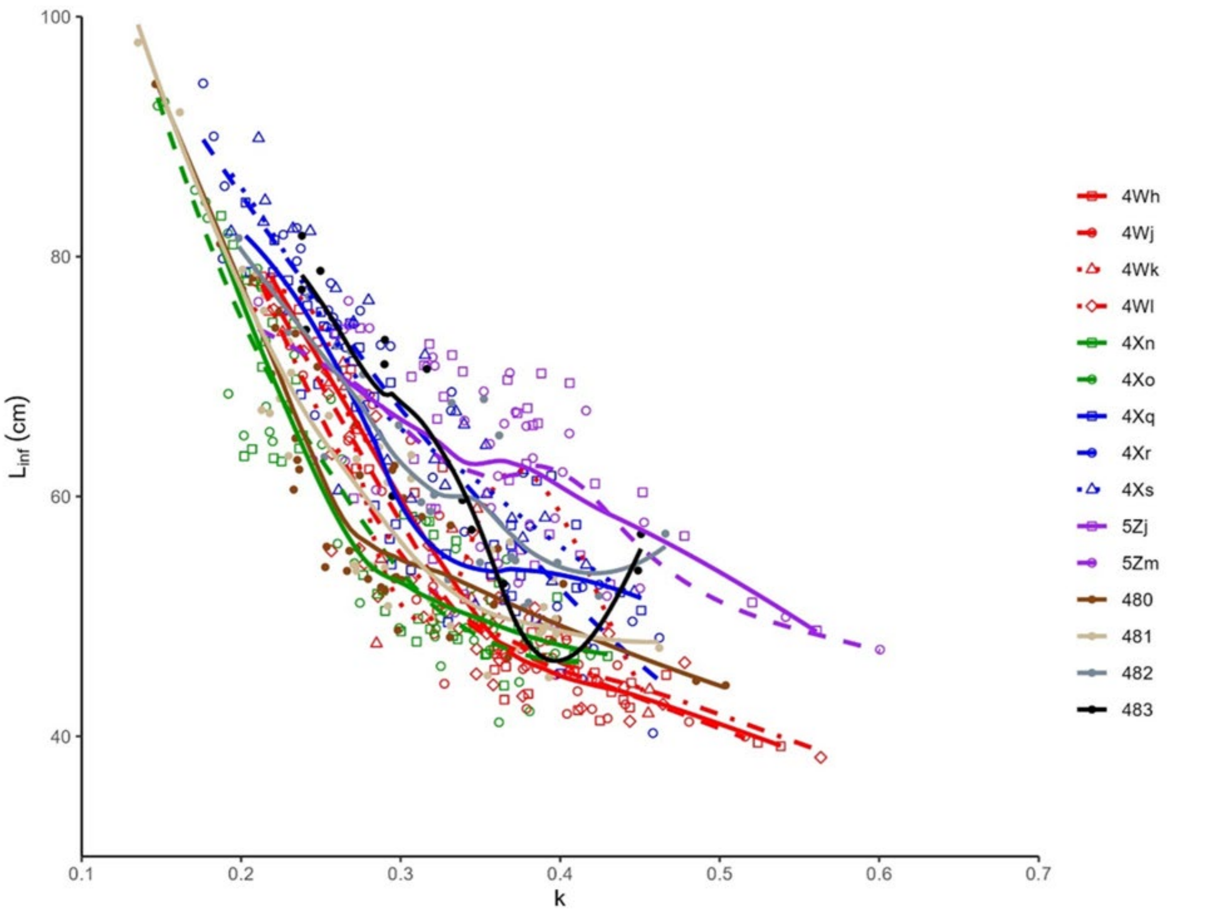


Figure 9. Scatterplot of Von Bertalanffy growth parameter estimates for asymptotic length (L_{inf}) versus growth rate (k), by DFO unit area with data for DFO unit area 4Xp separated by survey strata (480–483) with loess smoothers (span = 0.5).

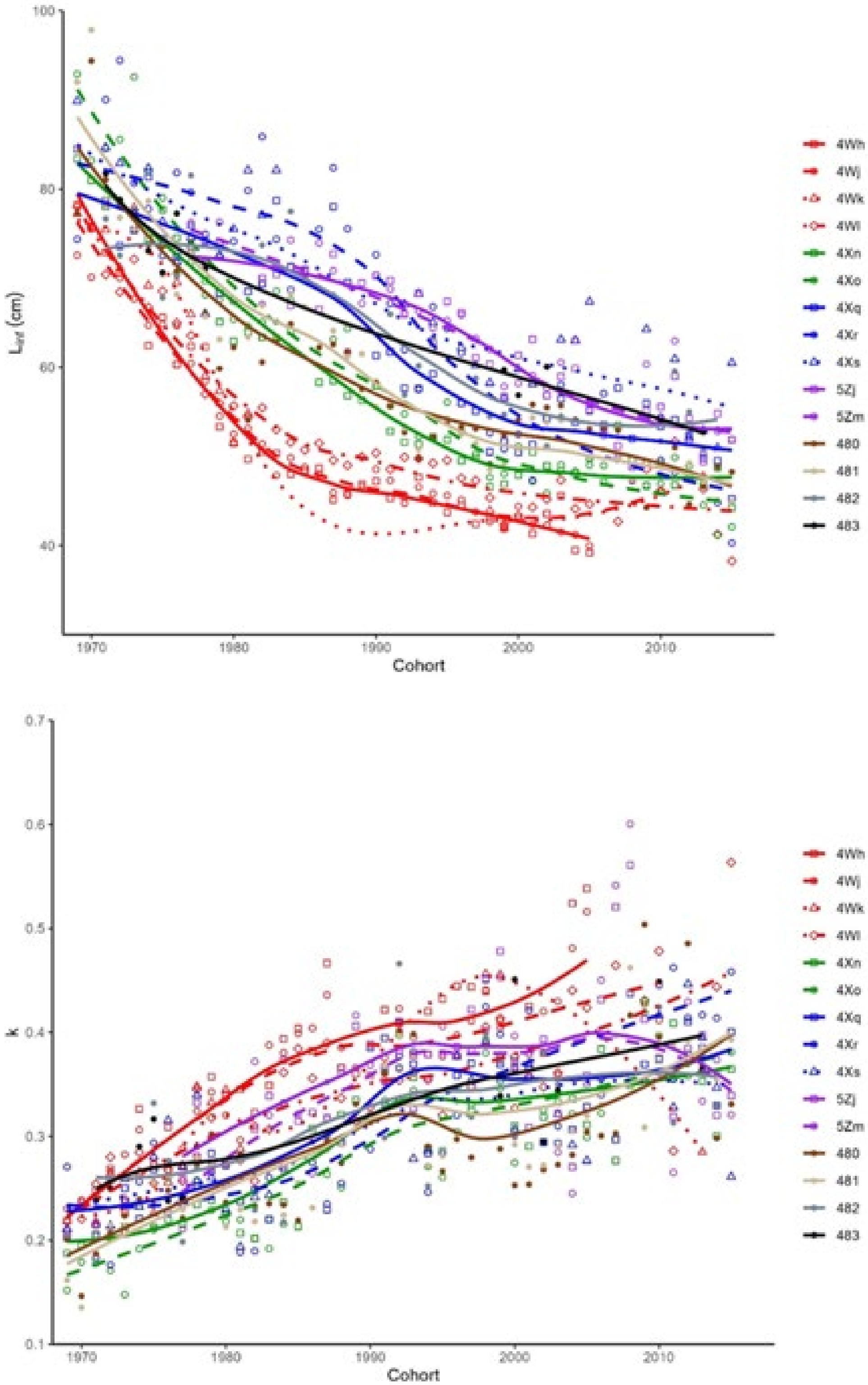


Figure 10. Scatterplot of Von Bertalanffy growth parameter estimates for asymptotic length (L_{inf}) versus cohort and growth rate (k) versus cohort by DFO unit area with data for DFO unit area 4Xp separated by survey strata (480–483) with loess smoothers (span = 0.5).

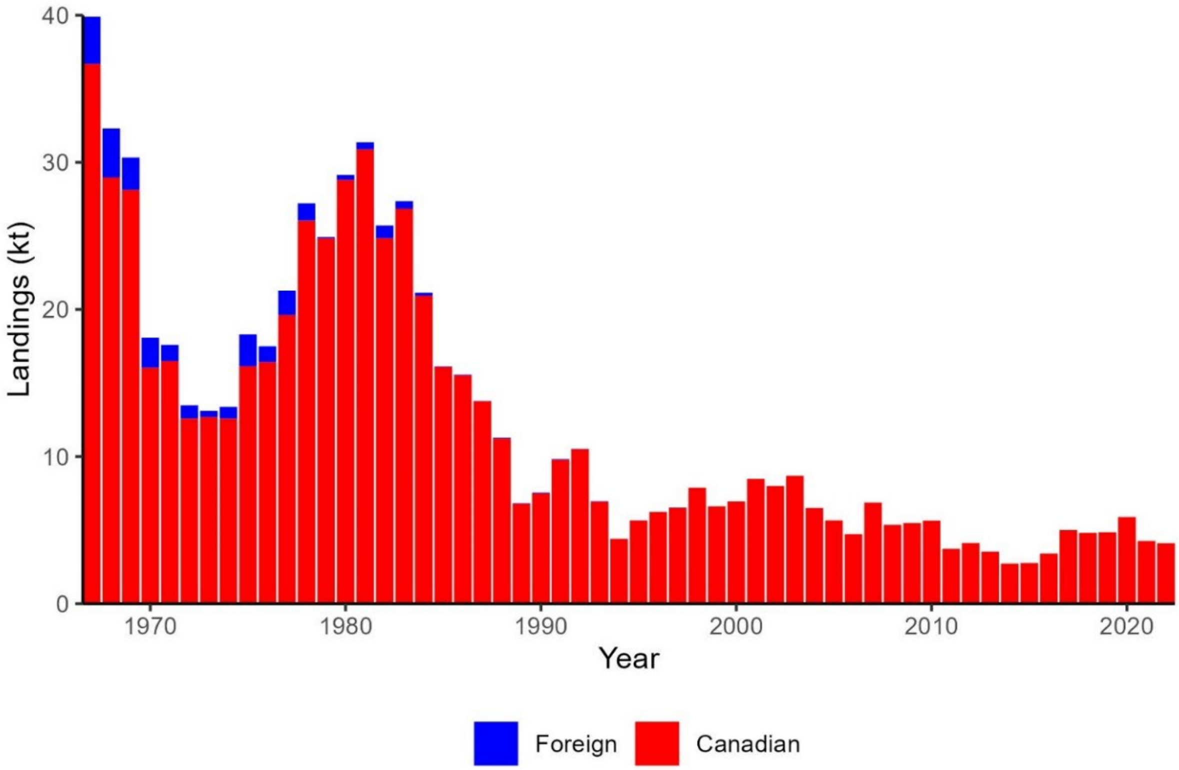


Figure 11. Total annual (calendar year) Haddock landings for the 4X5Y stock area by fleet (Foreign and Canadian).

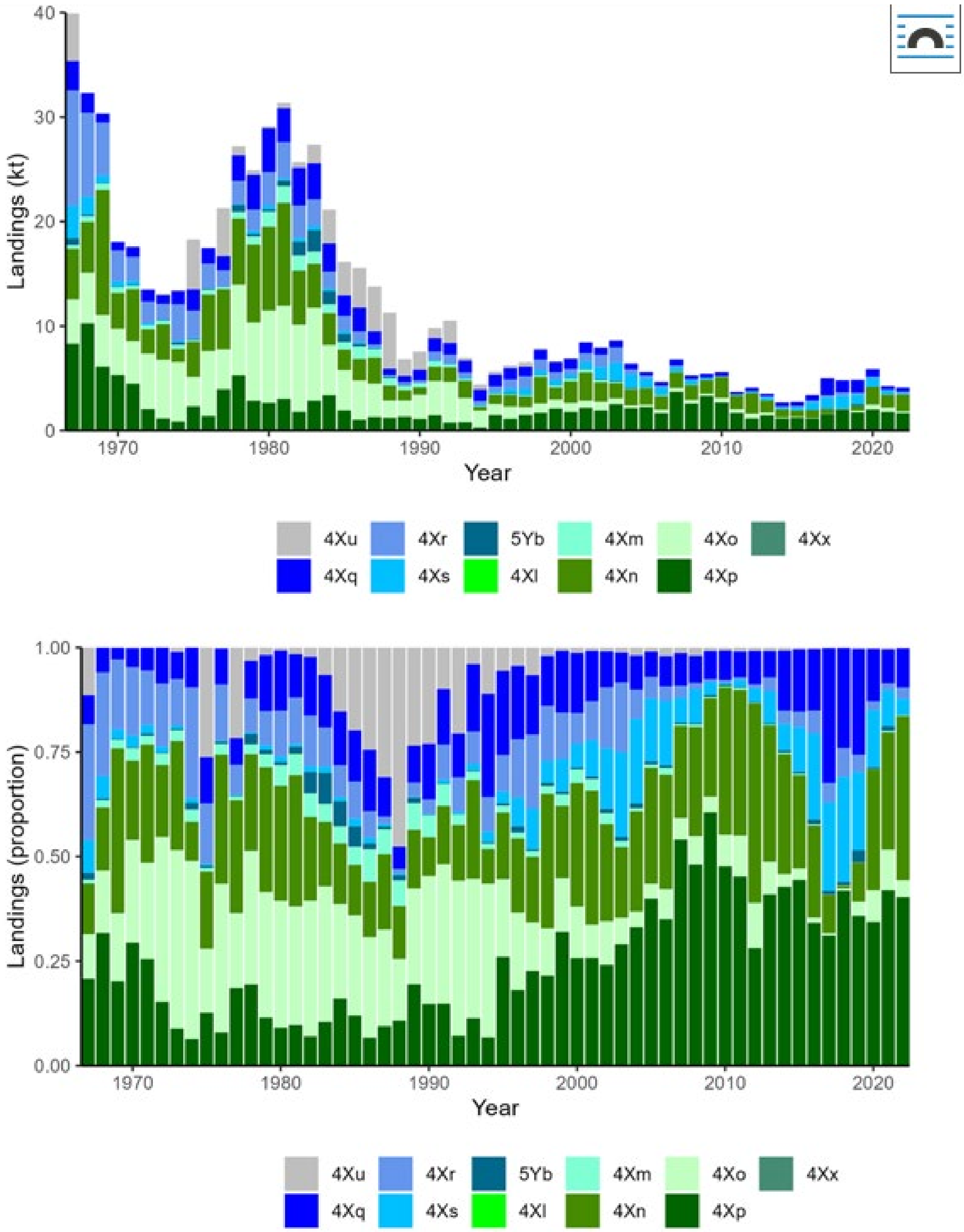
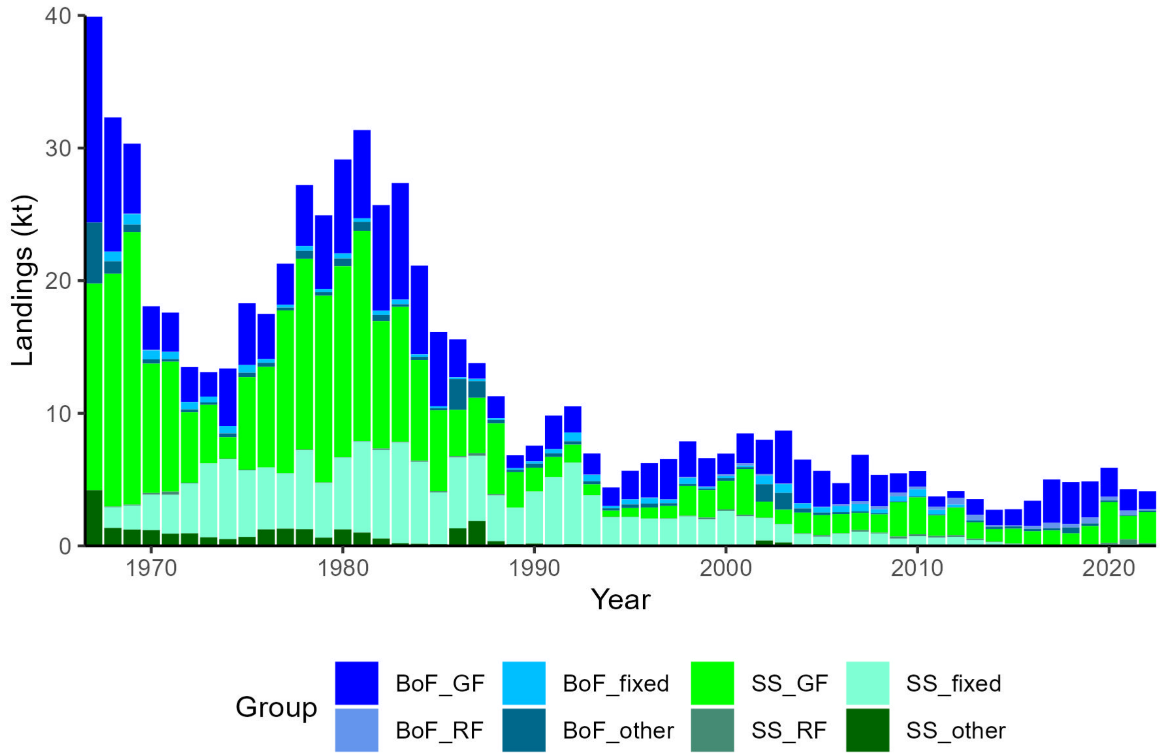


Figure 12. Total annual (calendar year) Haddock landings for the 4X5Y stock area by DFO unit area in kt (top) and as a proportion (bottom).



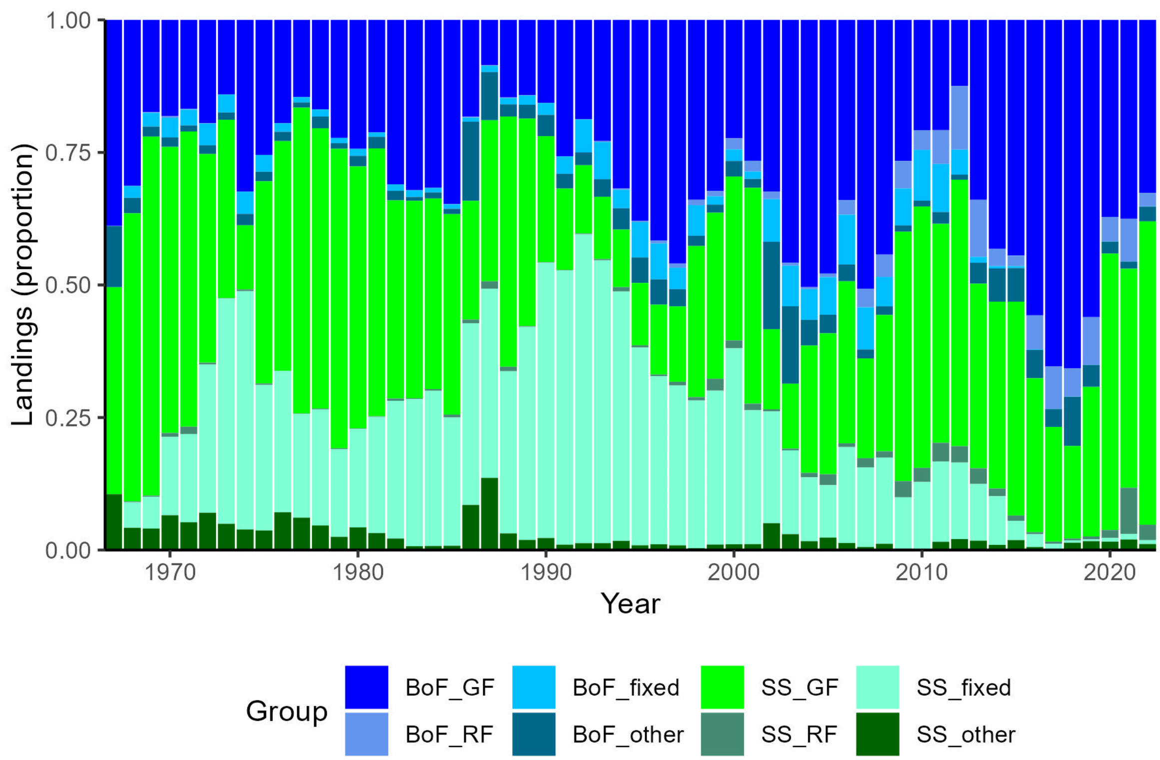


Figure 13. Total annual (calendar year) Haddock landings for the 4X5Y stock area by initial fleets (four gear types and two regions) in kt (top) and as a proportion (bottom). GF = groundfish fleet, RF = redfish fleet, fixed = fixed gear, other = other (or unknown) mobile gear. BoF = Bay of Fundy, SS = Scotian Shelf (regions as defined in Figure 1).

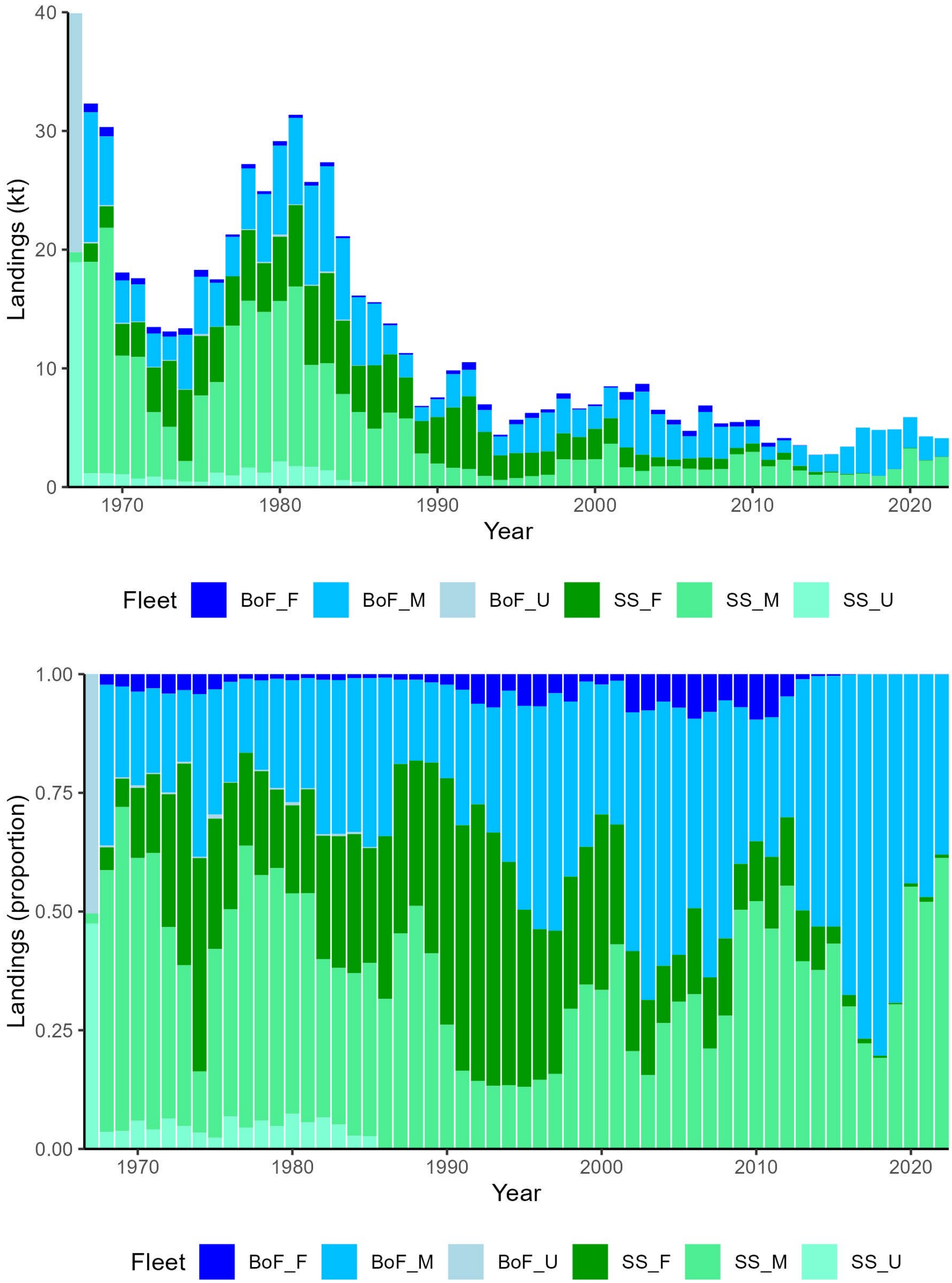
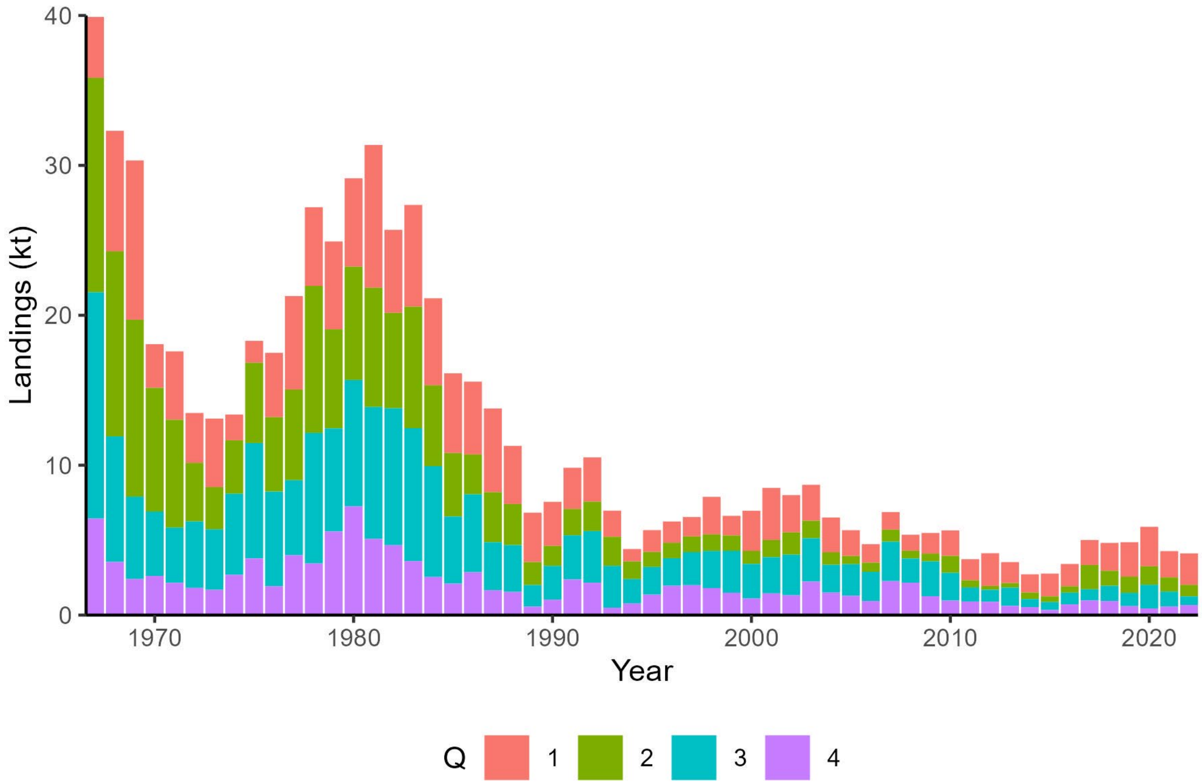


Figure 14. Total annual (calendar year) Haddock landings for the 4X5Y stock area by fleet (two gear types and two regions) in kt (top) and as a proportion (bottom). F = fixed gear, M = mobile gear, unknown = unknown gear type which was assigned proportionally to F and M in the final summary of landings. BoF = Bay of Fundy, SS = Scotian Shelf (regions as defined in Figure 1).



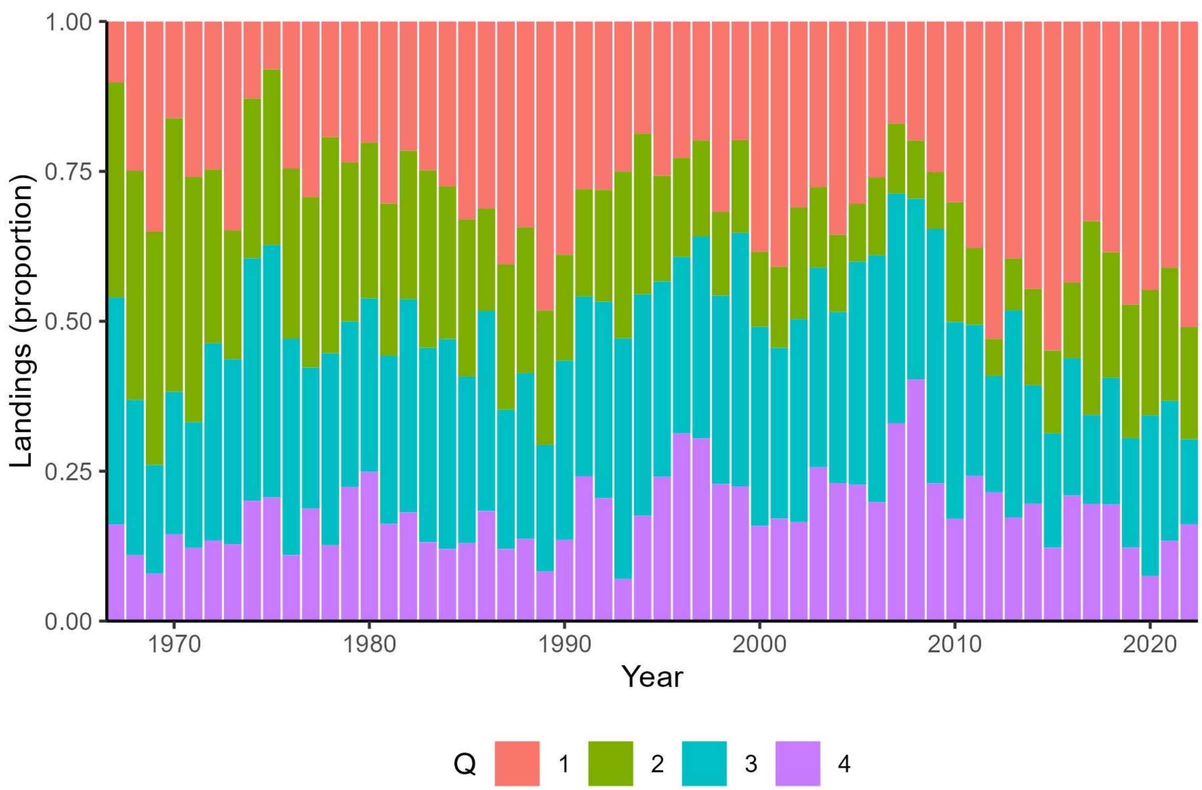


Figure 15. Total annual (calendar year) Haddock landings for the 4X5Y stock area by quarter in kt (top) and as a proportion (bottom).

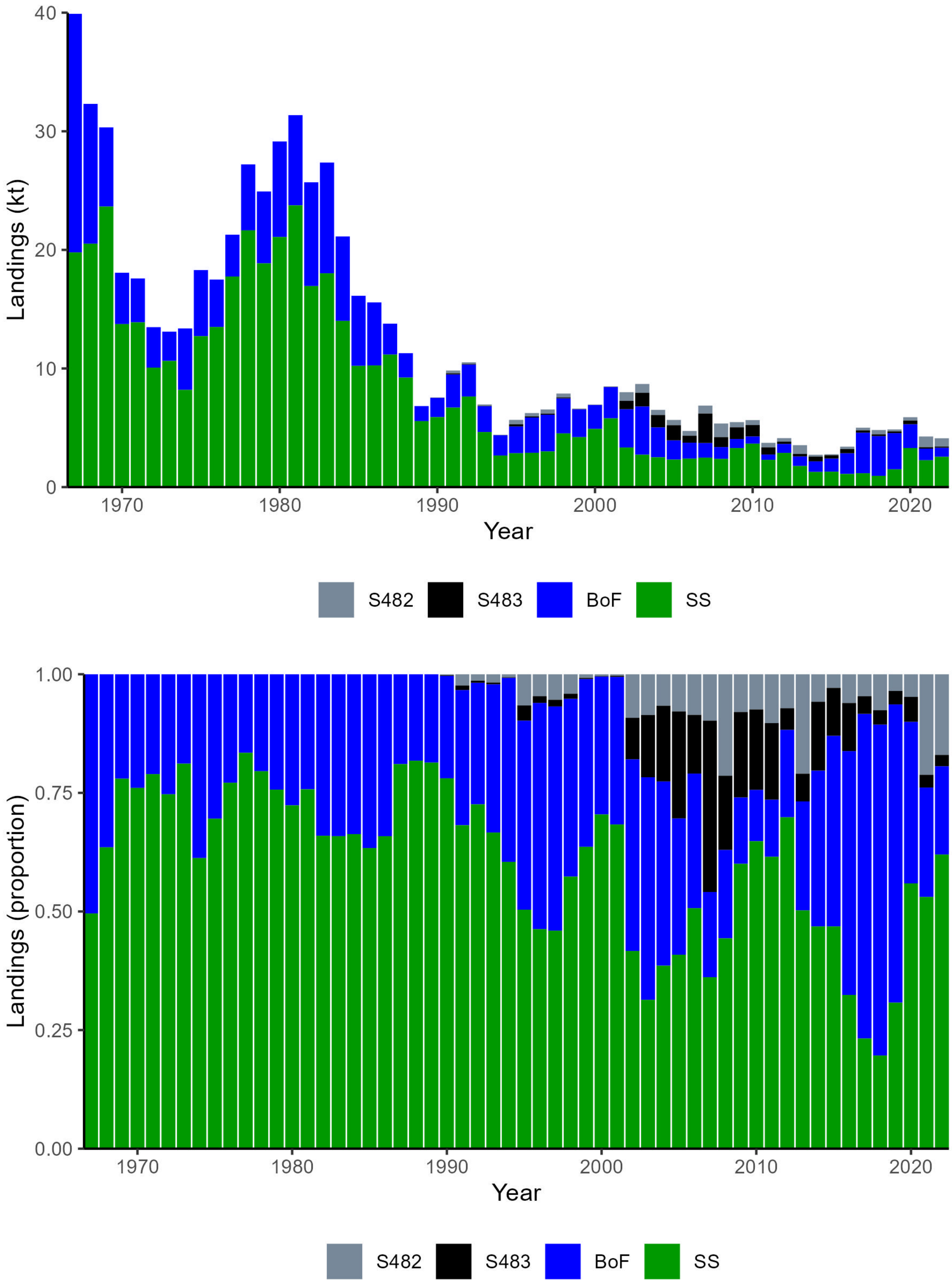


Figure 16. Total annual (calendar year) Haddock landings for the 4X5Y stock area in kt (top) and as a proportion (bottom) by region where landings from survey strata 482 and 483 are plotted separately. BoF = Bay of Fundy, SS = Scotian Shelf (regions as defined in Figure 1). Note that landings from the portion of survey strata 5Z9 in 4Xp are included with survey strata 483 (see Figure 1) and the coordinates for the landings data prior to 1988 were not reported to allow the disaggregation of catches to the survey strata level. All landings with unknown coordinates in 4Xp are grouped with SS, consistent with Stone and Hansen (2015).

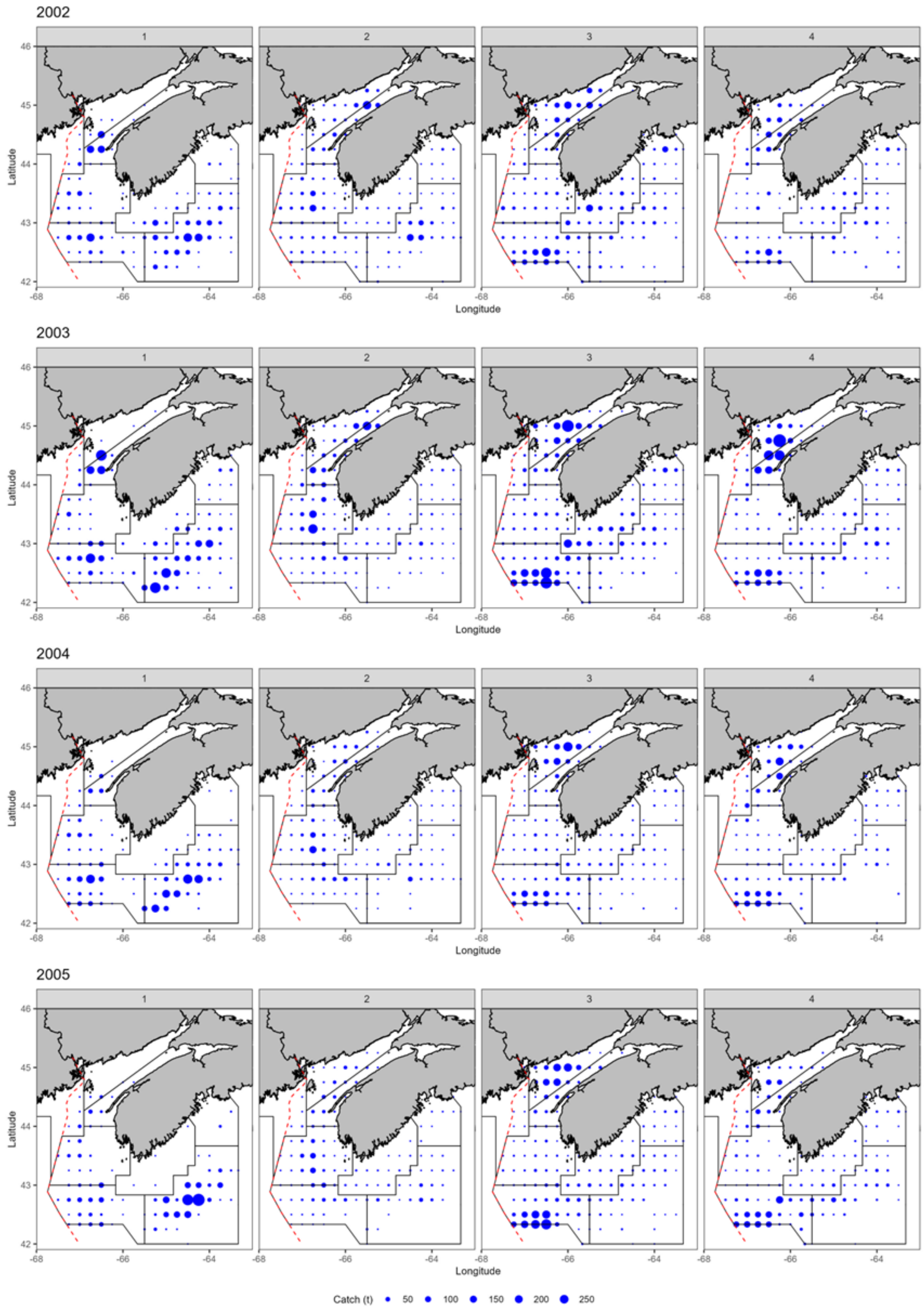


Figure 17a. Spatial distribution of catch from the 4X5Y Haddock fishery from 2002–2022 (2002–2005 shown above). The area of the bubble is proportional to catch. The DFO unit area boundaries are indicated by black lines and the red line identifies the international border.

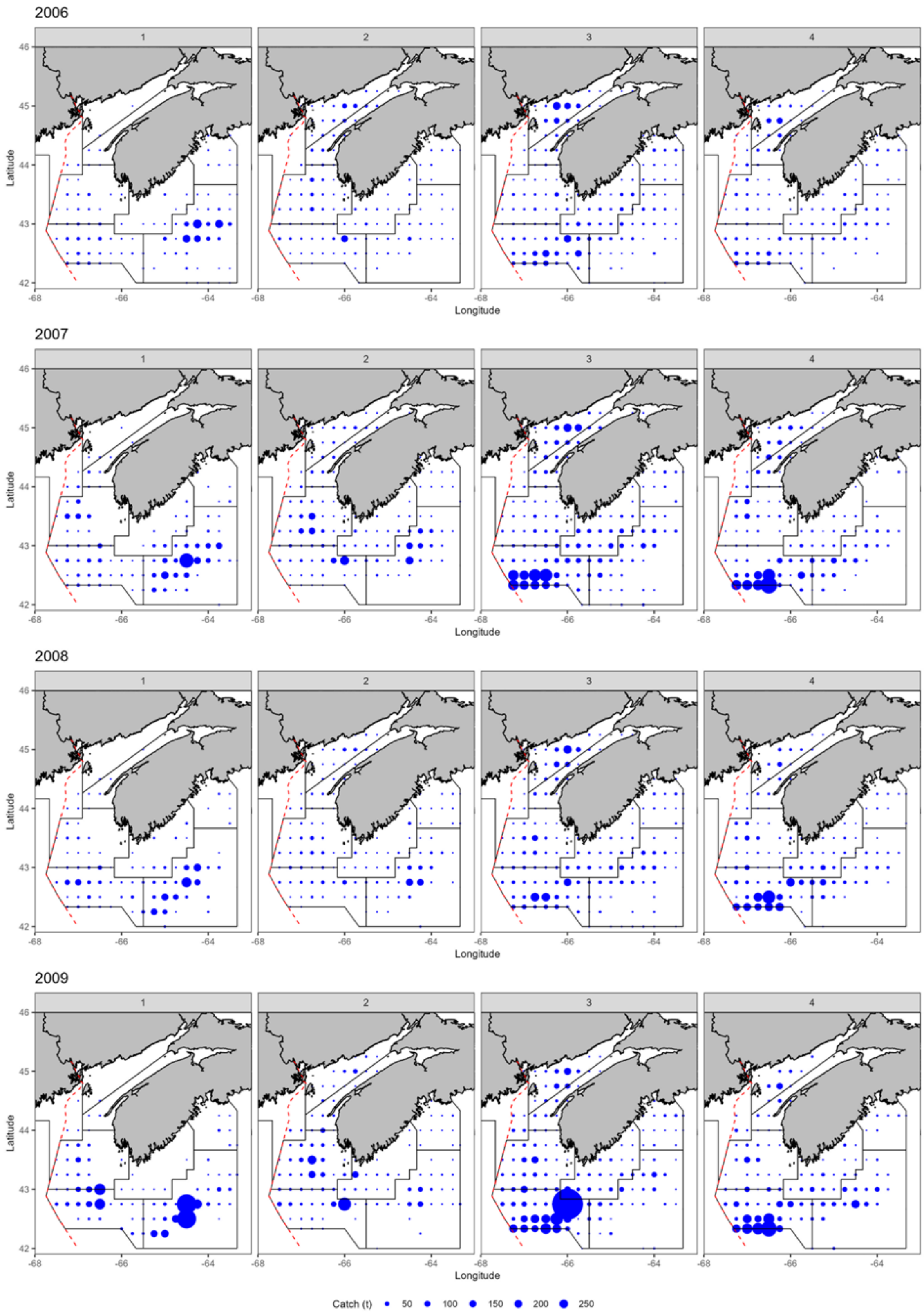


Figure 17b. Spatial distribution of catch from the 4X5Y Haddock fishery from 2002–2022 (2006–2009 shown above). The area of the bubble is proportional to catch. The DFO unit area boundaries are indicated by black lines and the red line identifies the international border.

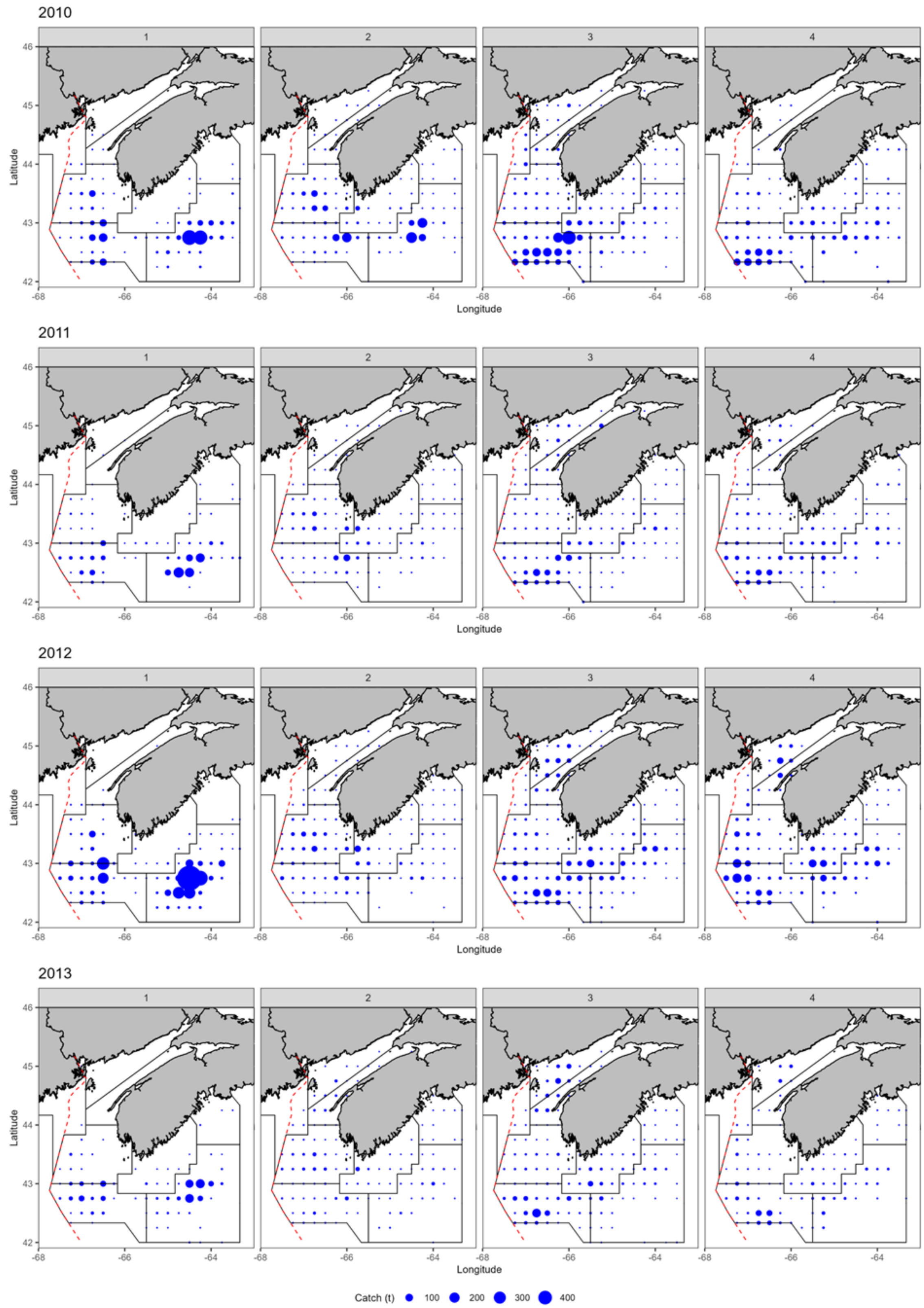


Figure 17c. Spatial distribution of catch from the 4X5Y Haddock fishery from 2002–2022 (2010–2013 shown above). The area of the bubble is proportional to catch. The DFO unit area boundaries are indicated by black lines and the red line identifies the international border.

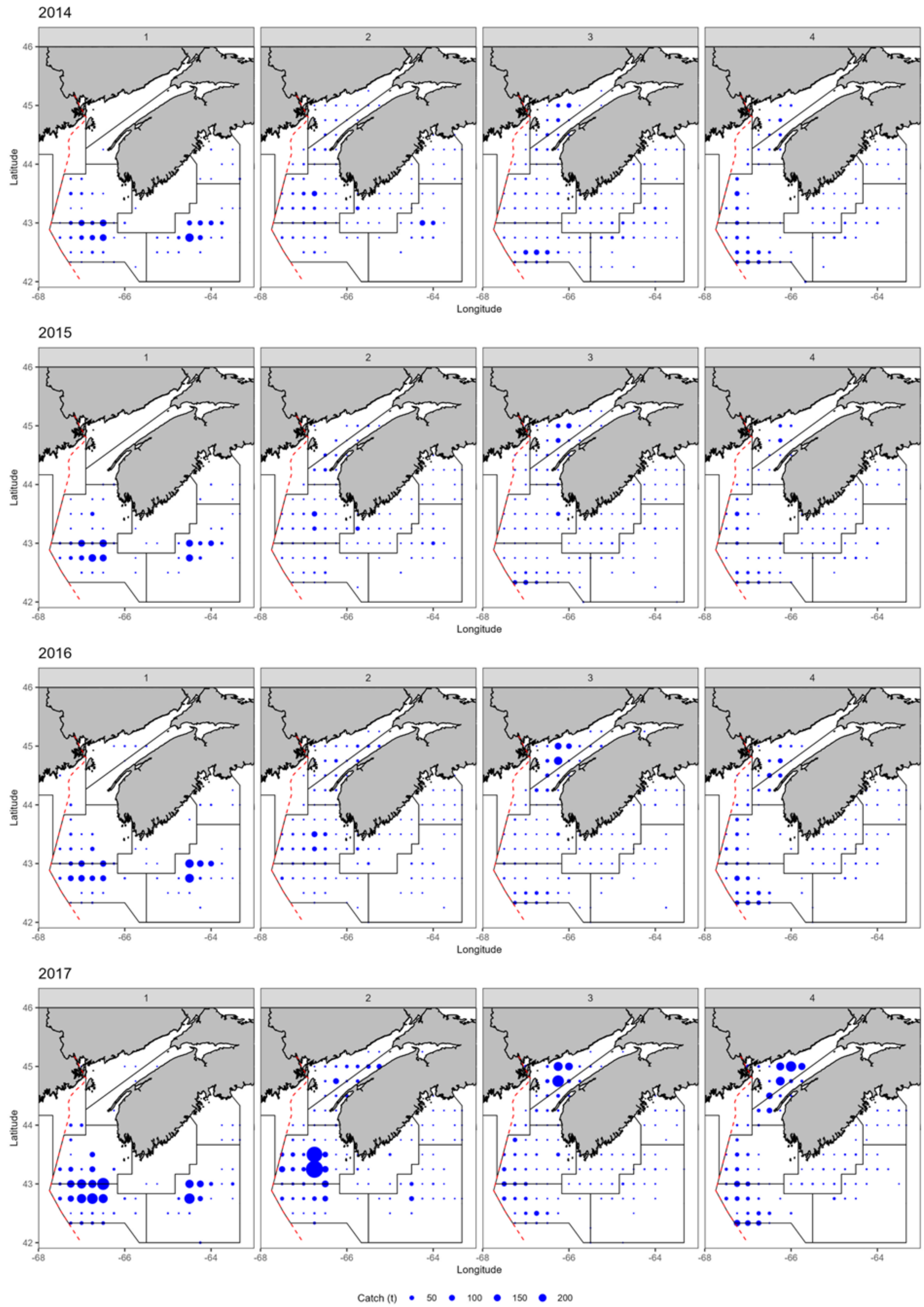


Figure 17d. Spatial distribution of catch from the 4X5Y Haddock fishery from 2002–2022 (2014–2017 shown above). The area of the bubble is proportional to catch. The DFO unit area boundaries are indicated by black lines and the red line identifies the international border.

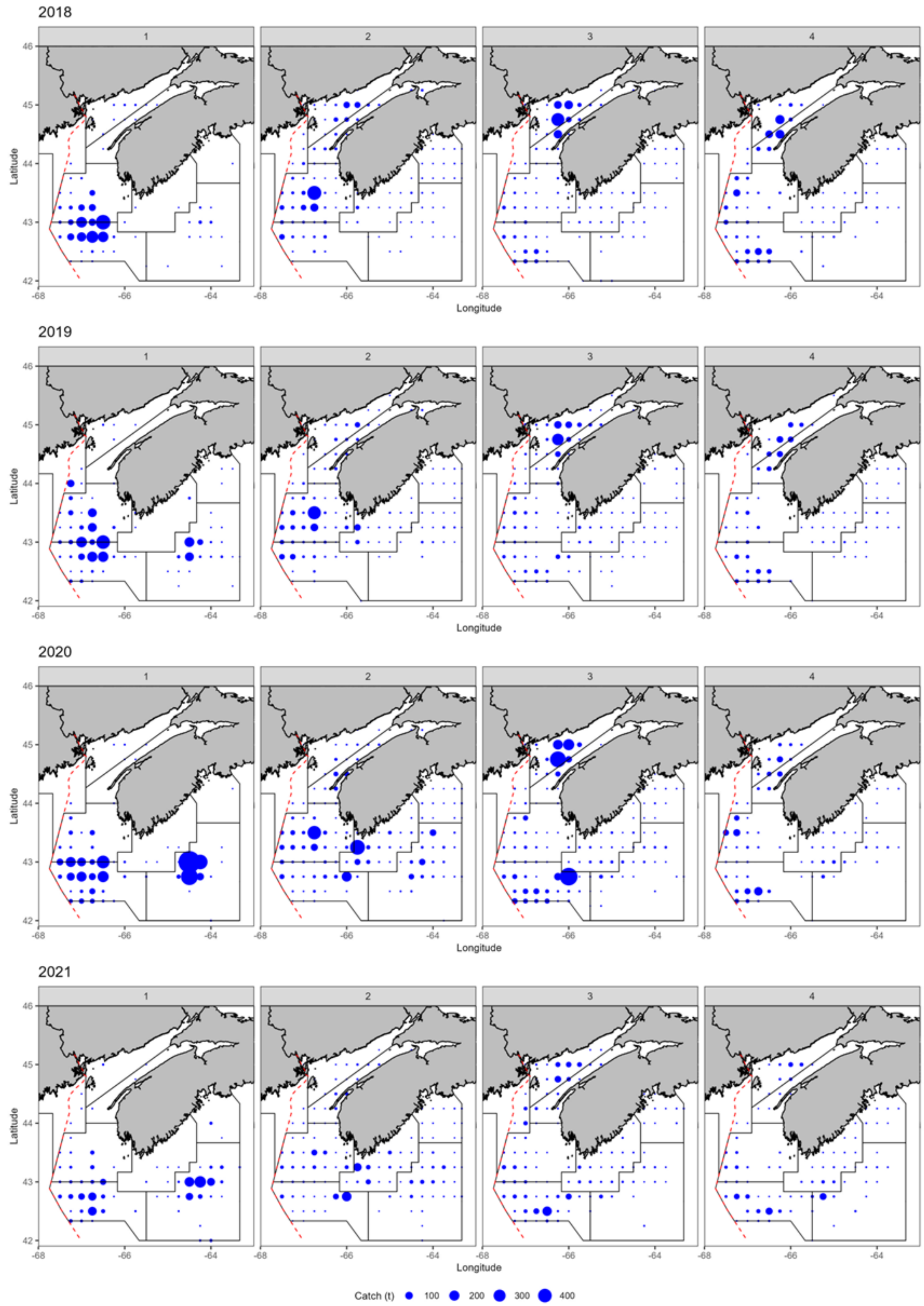


Figure 17e. Spatial distribution of catch from the 4X5Y Haddock fishery from 2002–2022 (2018–2021 shown above). The area of the bubble is proportional to catch. The DFO unit area boundaries are indicated by black lines and the red line identifies the international border.

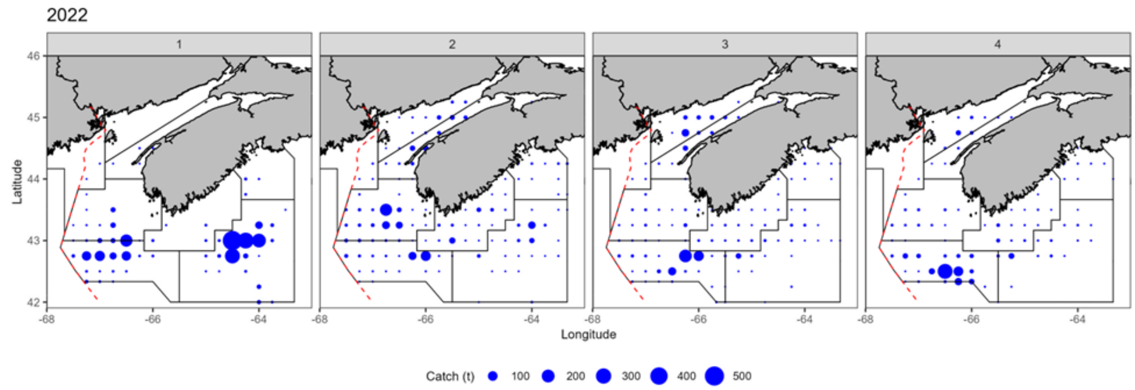


Figure 17f. Spatial distribution of catch from the 4X5Y Haddock fishery from 2002–2022 (2022 shown above). The area of the bubble is proportional to catch. The DFO unit area boundaries are indicated by black lines and the red line identifies the international border.

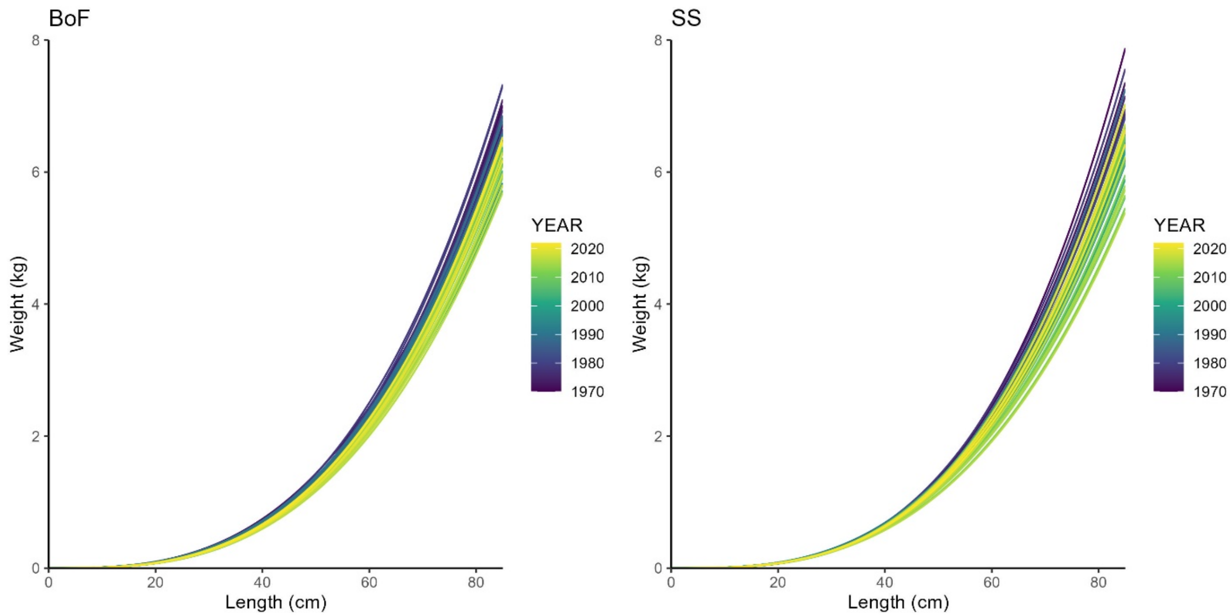


Figure 18. Regression model predicted weight-length relationships of Haddock by year and region (BoF = Bay of Fundy and SS = Scotian Shelf) using the regression parameter estimates in Table 4.

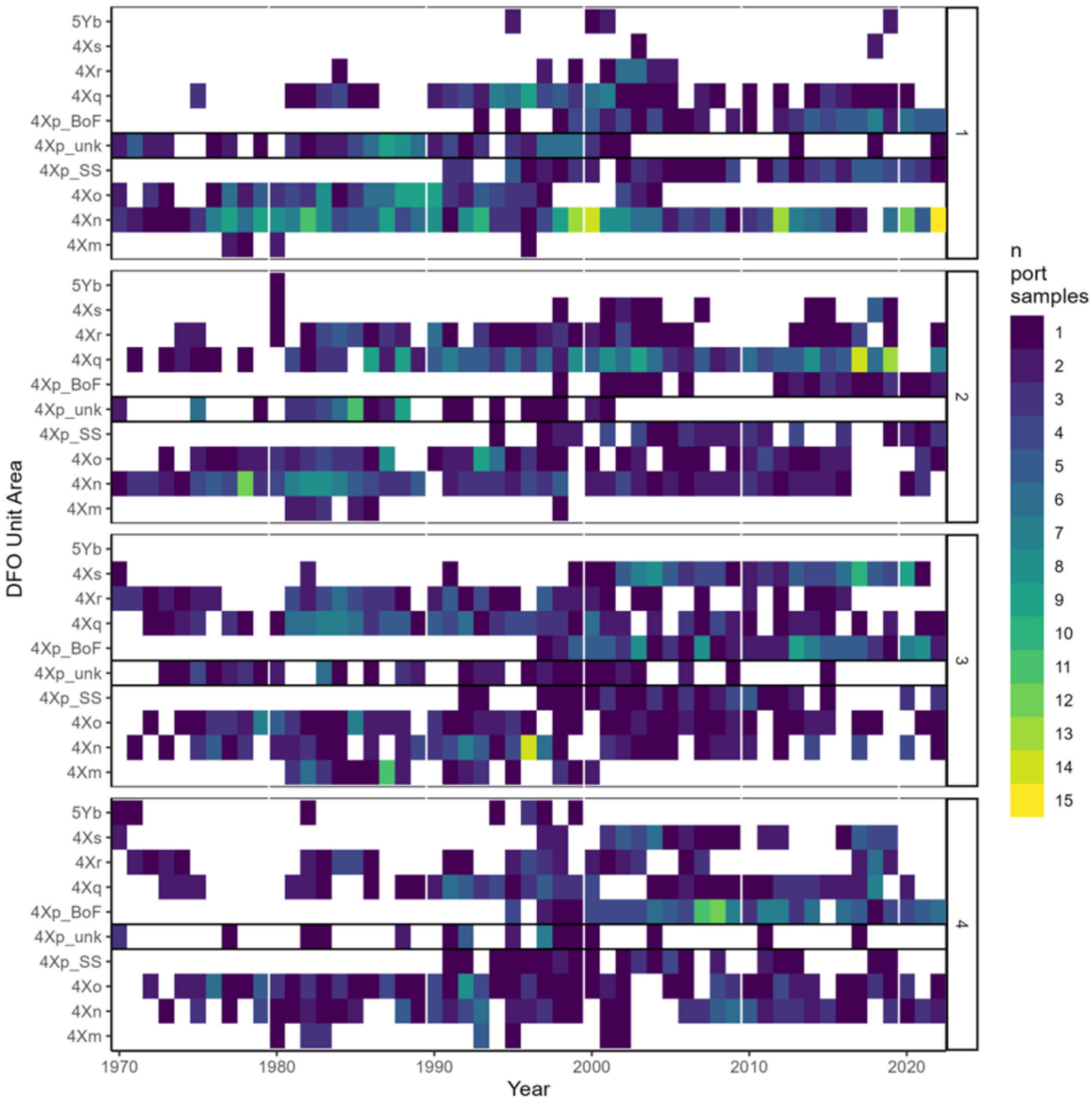


Figure 19. Number of length-frequency samples of Haddock by DFO unit area and quarter (panels 1 to 4 representing quarters 1 to 4). DFO unit area 4Xp is separated by region (BoF = Bay of Fundy; SS = Scotian Shelf; unknown = unk).

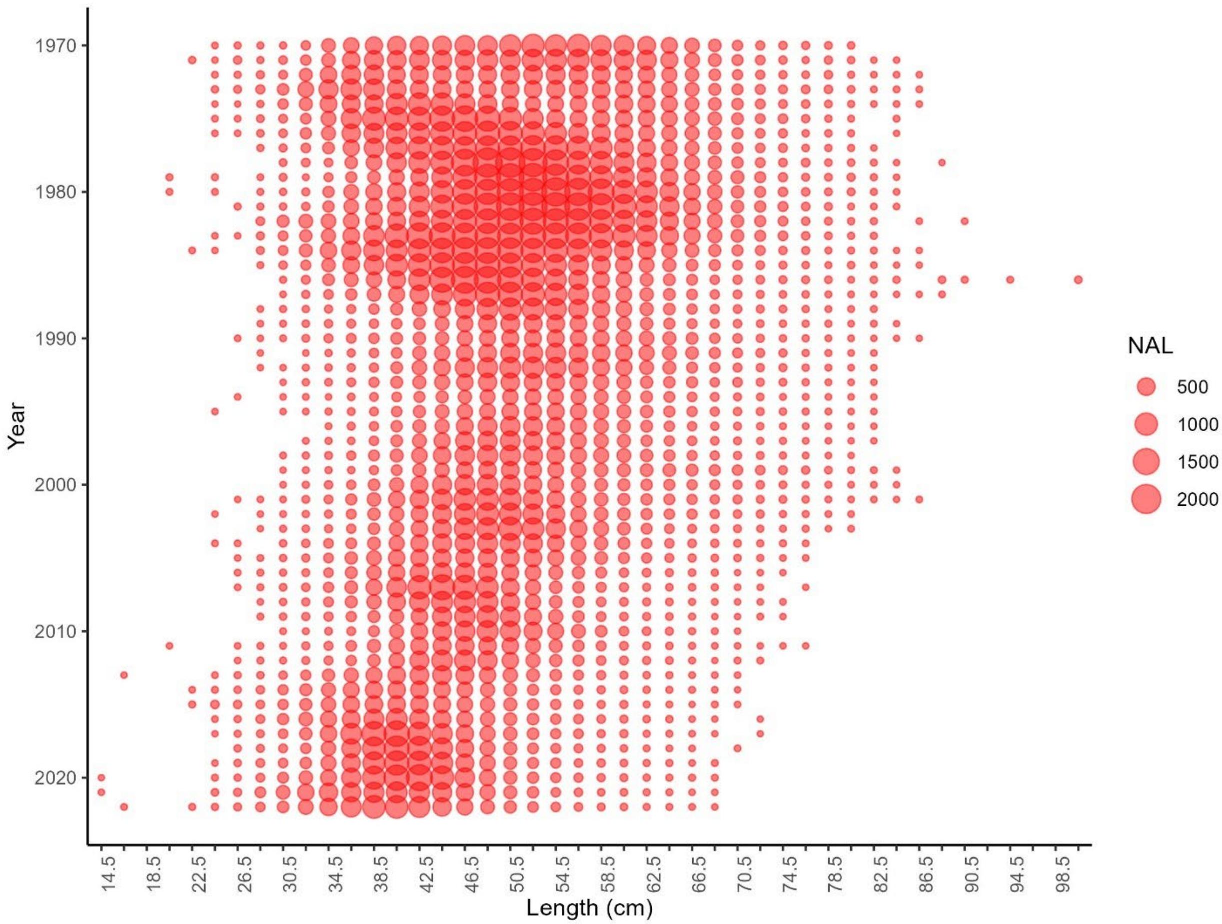


Figure 20. Fishery catch-at-length for the 4X5Y Haddock stock (combined by fleet). The area of the bubble is proportional to catch. NAL = numbers-at-length in thousands.

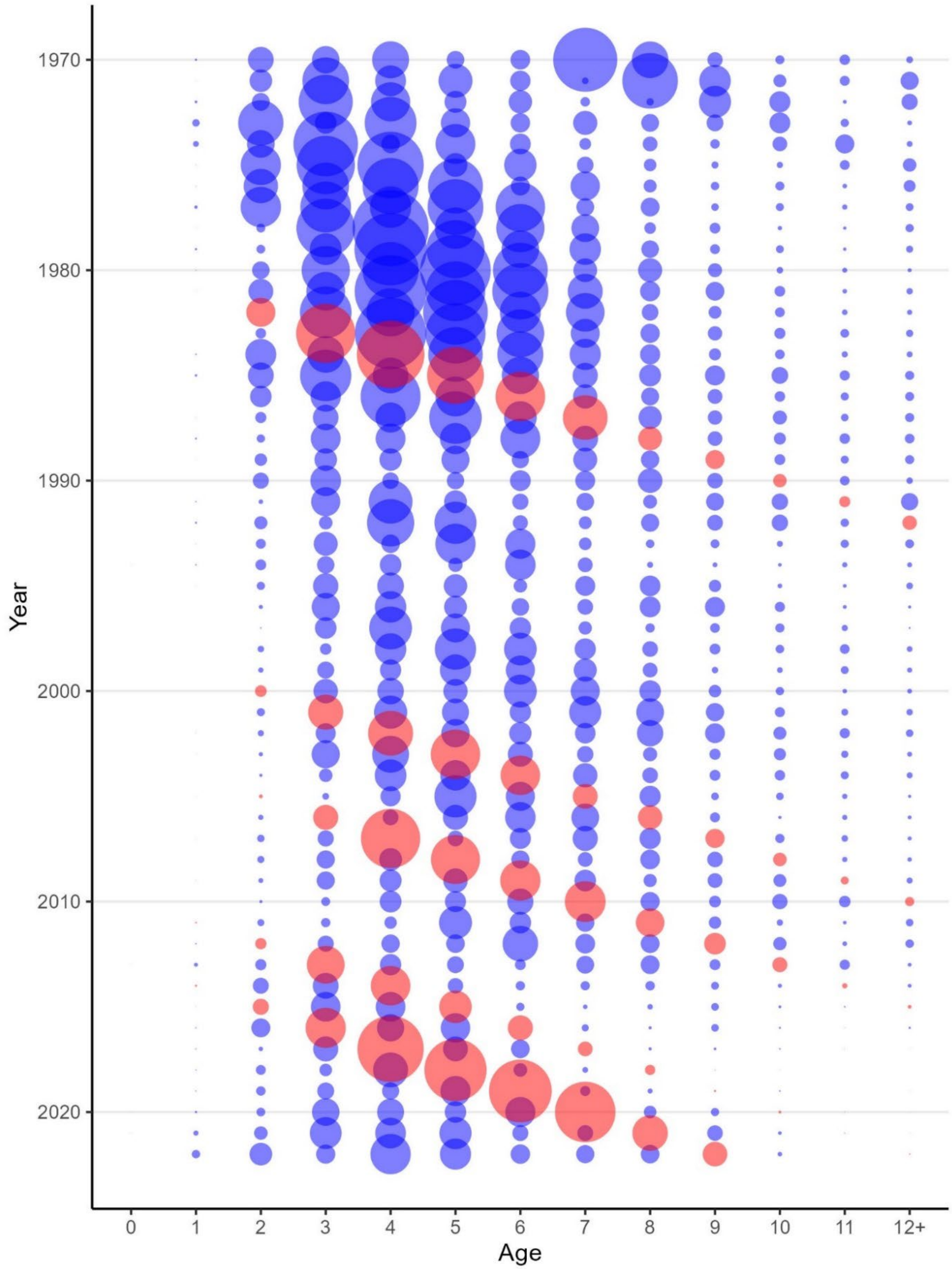


Figure 21. Fishery catch-at-age for the 4X5Y Haddock stock (combined by fleet). The 1980, 1998, 2003, 2010, and 2013 cohorts are plotted in red. The area of the bubble is proportional to the number-at-age.

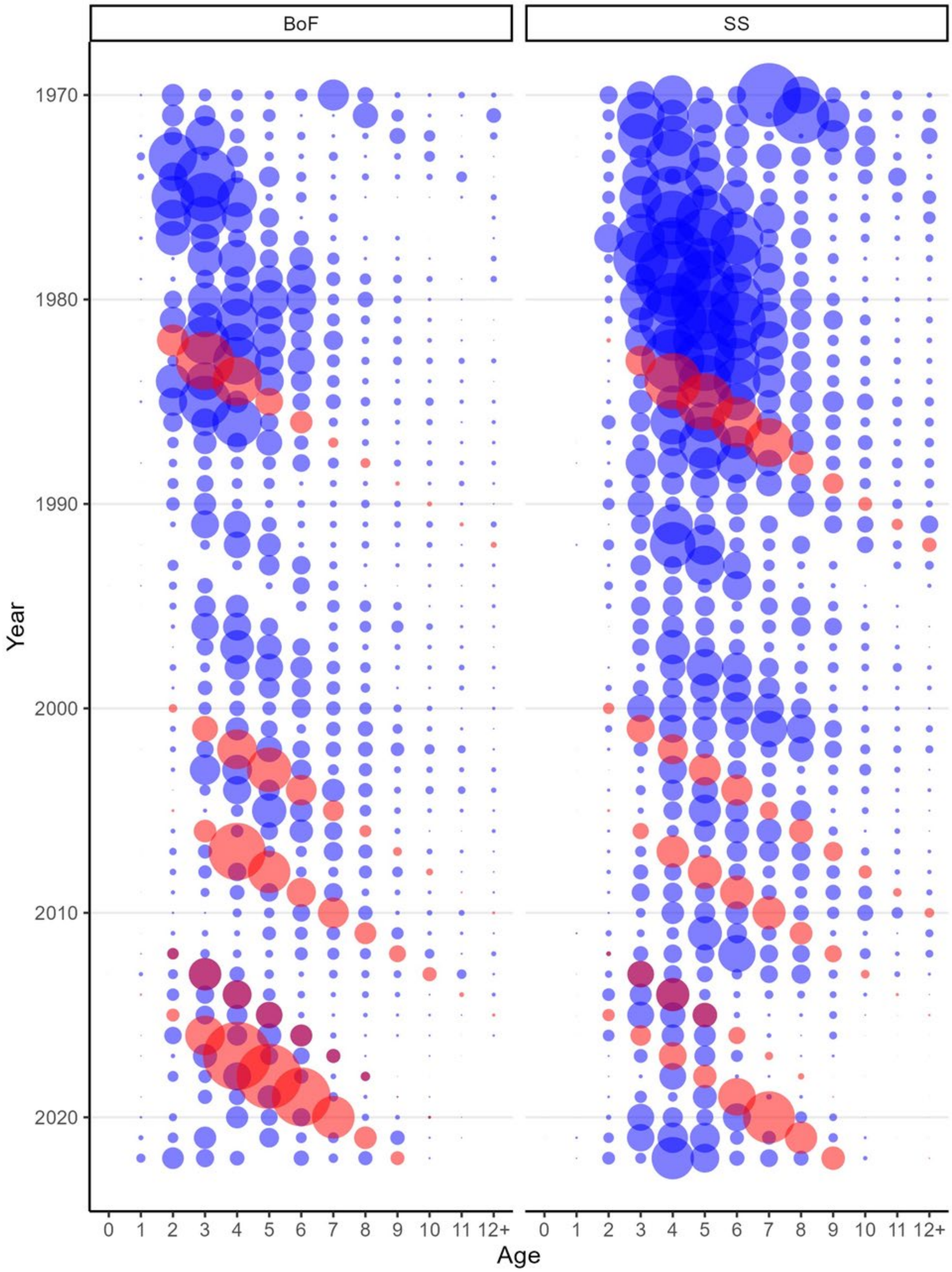


Figure 22. Fishery catch-at-age for 4X5Y Haddock by region (BoF = Bay of Fundy and SS = Scotian Shelf). The 1980, 1998, 2003, 2010, and 2013 cohorts are plotted in red. The area of the bubble is proportional to the number-at-age.

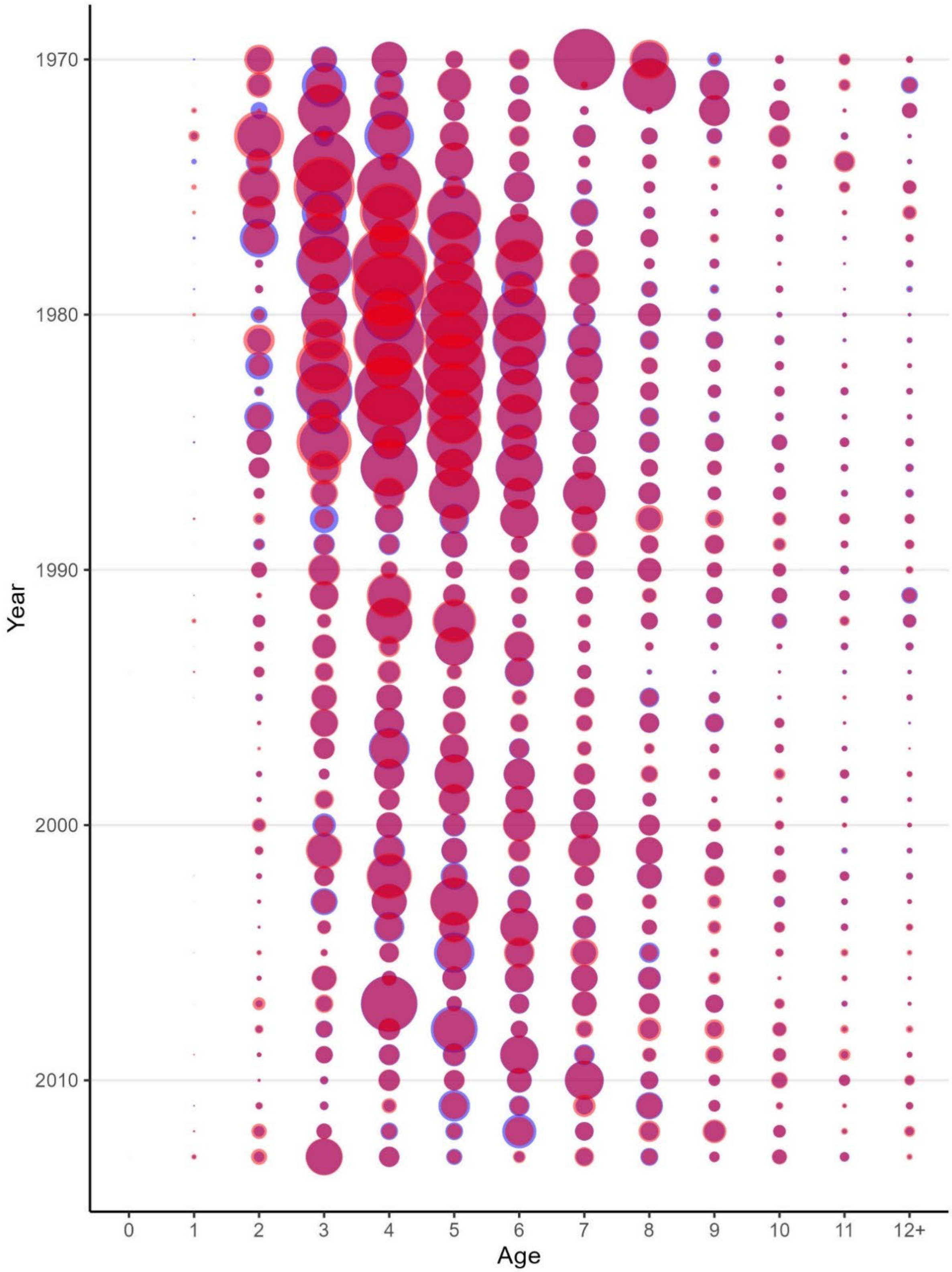


Figure 23. Fishery catch-at-age (1970–2013) for the 4X5Y Haddock stock estimated using the methods in this document (red) and reported in Stone and Hansen (2015; blue). The area of the bubble is proportional to the number-at-age.

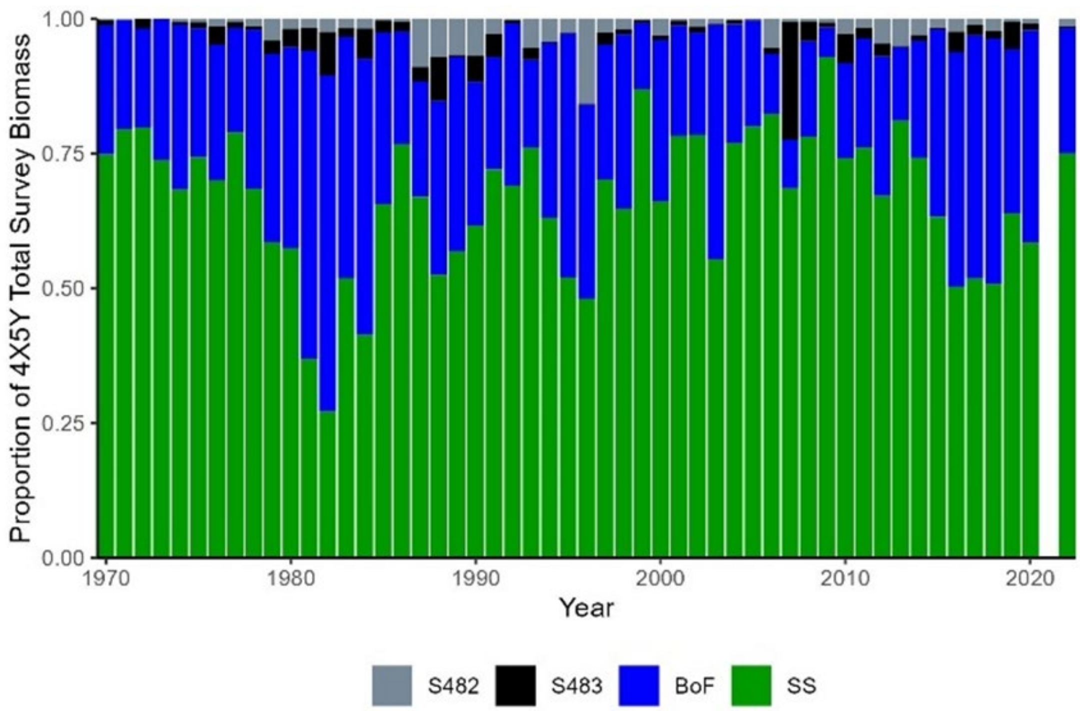


Figure 24. Relative distribution of survey biomass of Haddock by year and region (BoF = Bay of Fundy and SS = Scotian Shelf) with survey strata 482 and 483 (plotted separately). The 2021 survey biomass was collected using a new vessel and currently there are no calibration factors to compare to the time series (white bar).

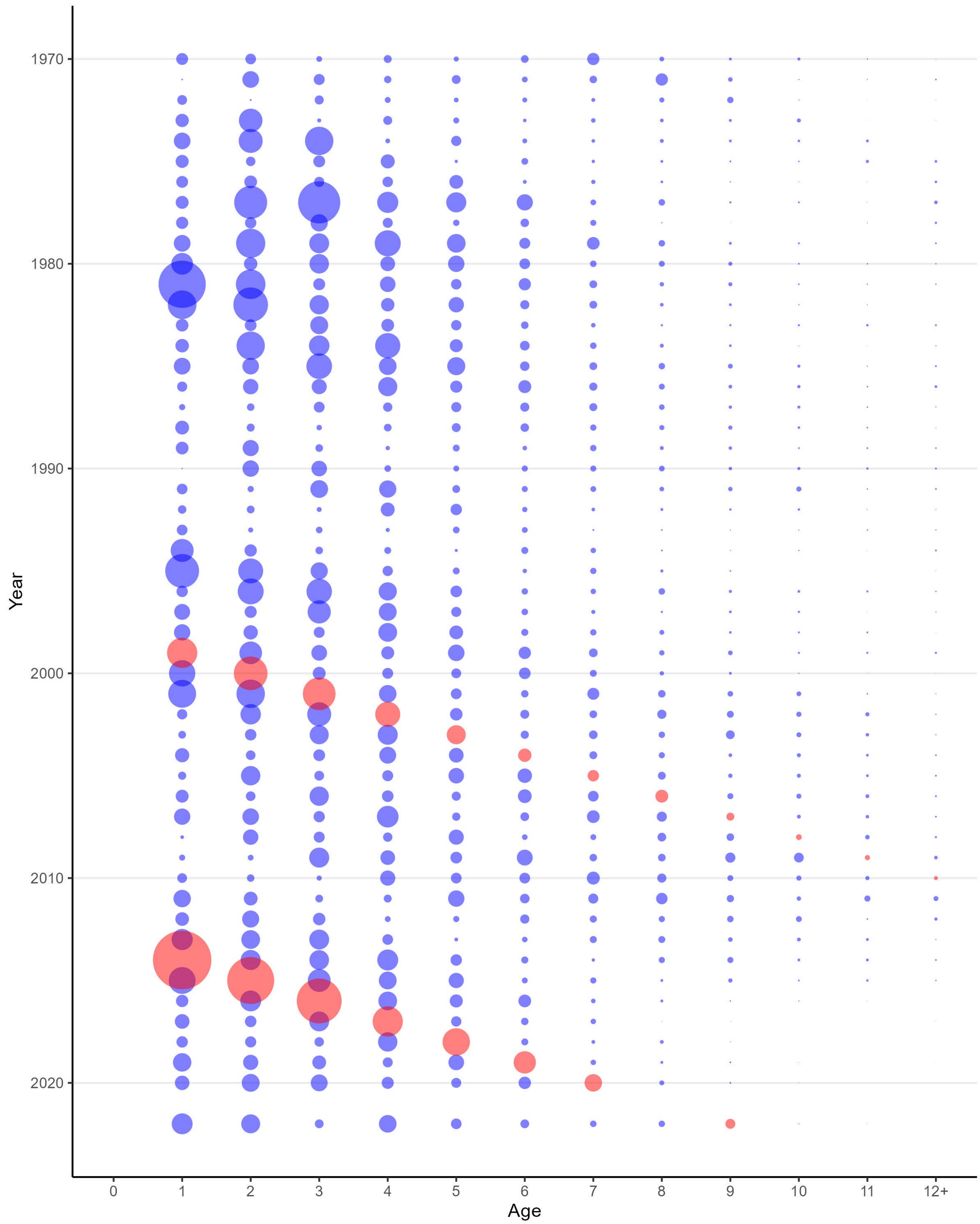


Figure 25. Numbers-at-age for the 4X5Y Haddock stock estimated from the DFO summer ecosystem survey. The 1998 and 2013 cohorts are plotted in red. The area of the bubble is proportional to the number-at-age. The 2021 survey was conducted using a new vessel and currently there are no calibration factors to compare to the time series.

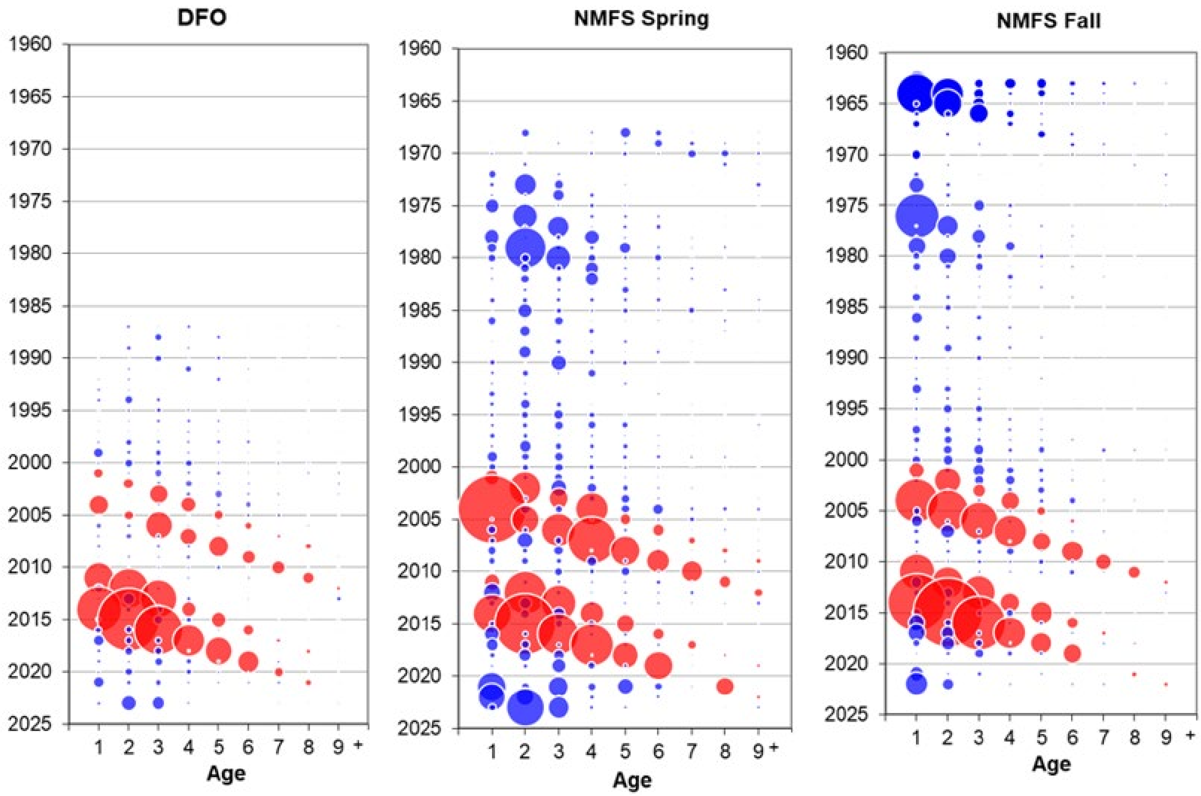


Figure 26. Survey numbers-at-age for Eastern Georges Bank (5Z) Haddock for the Winter DFO ecosystem survey, and the National Marine Fisheries Service (NMFS) Spring and Fall surveys. The 2000, 2003, 2010, and 2013 cohorts are plotted in red.

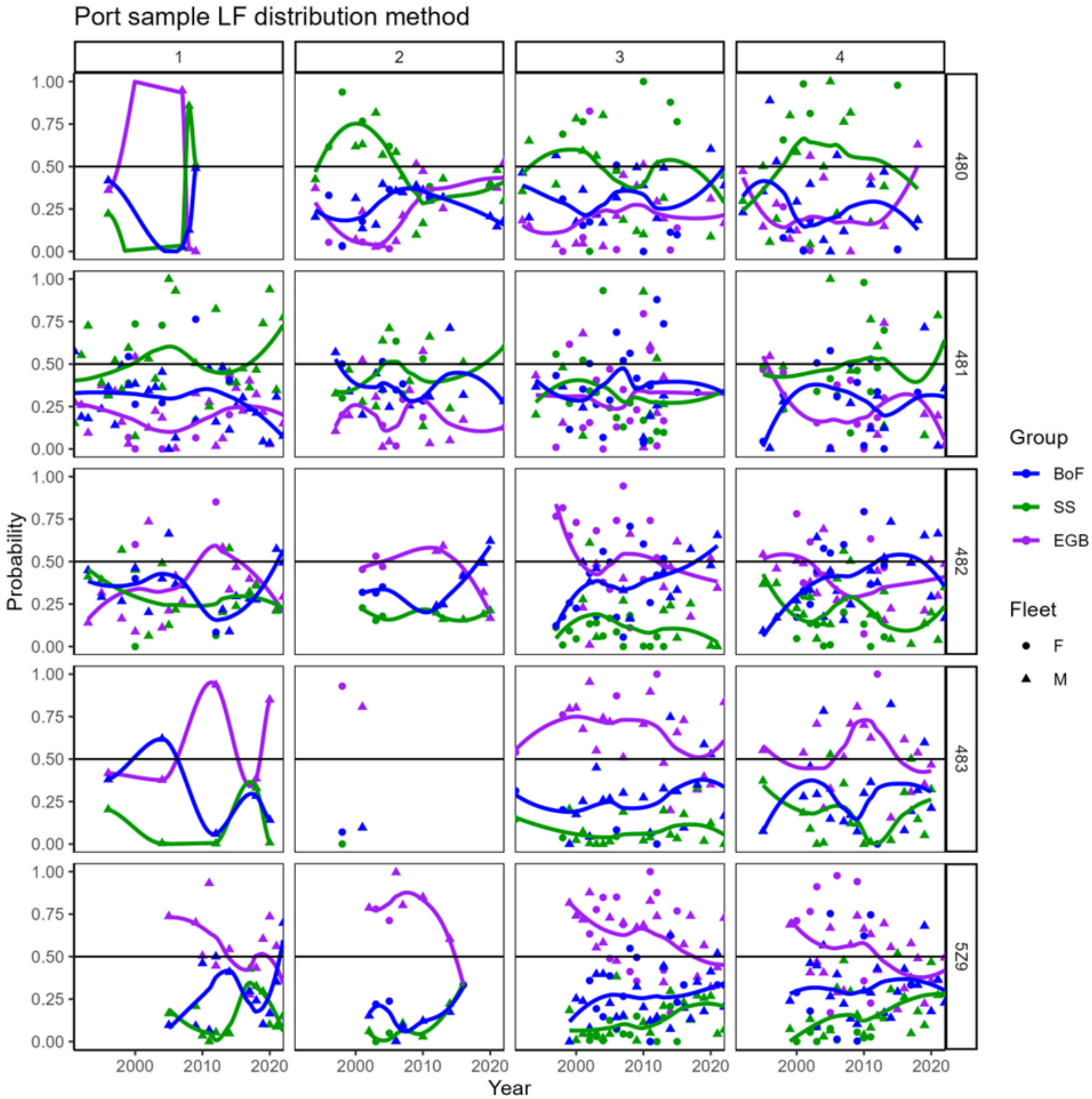


Figure 27. Predicted probabilities by fleet (F = fixed gear; M = mobile gear) of samples from survey strata (480, 481, 482, 483, 5Z9) belonging to the “groups”: Bay of Fundy (BoF), Scotian Shelf (SS), and Eastern Georges Bank (EGB) by quarter (1–4) based on cumulative length frequency distributions from port samples. Loess smoothers (fleets combined) plotted by group with a span of 0.75.

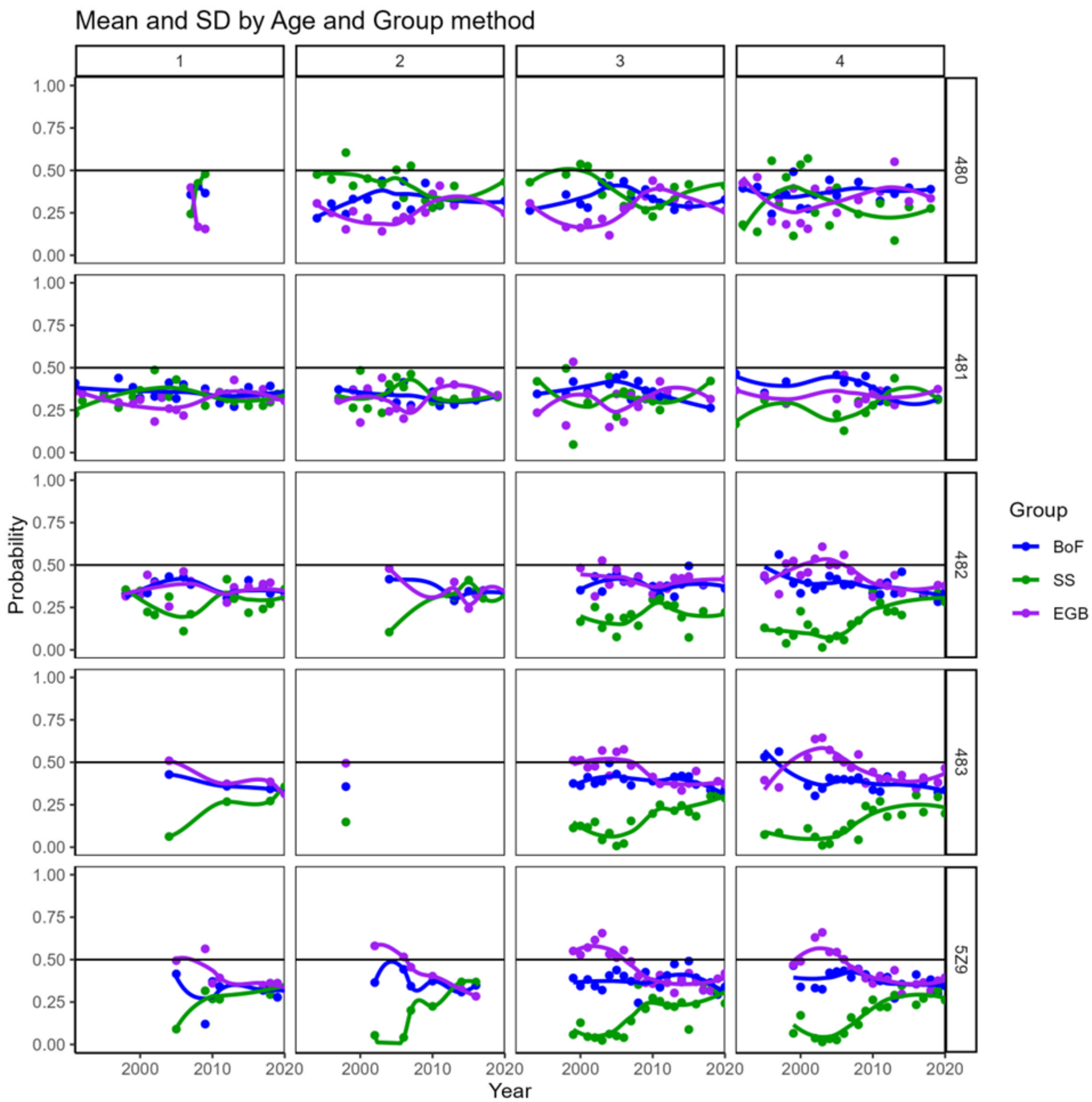


Figure 28. Predicted probabilities by fleet of samples from survey strata (480, 481, 482, 483, 5Z9) belonging to the "groups": Bay of Fundy (BoF), Scotian Shelf (SS), and Eastern Georges Bank (EGB) by quarter (1–4) based on lengths-at-age from port and observer samples compared to the group empirical mean length-at-age from survey samples. Loess smoothers (weighted by sample size) plotted by group with a span of 0.75.

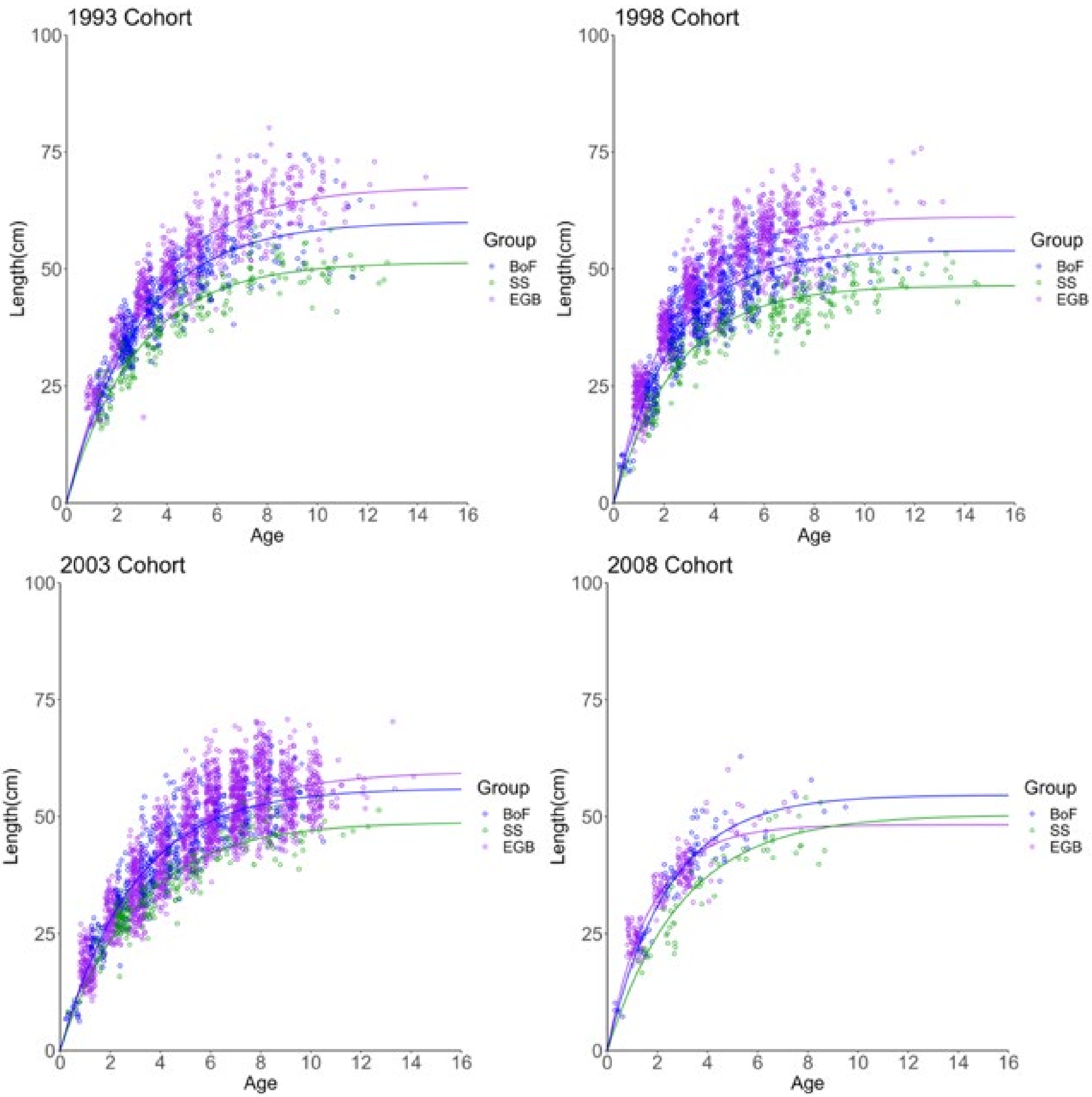


Figure 29. Two-parameter von Bertalanffy growth curves fit to survey length-at-age data for the 1993, 1998, 2003, and 2008 cohorts belonging to the "groups": Bay of Fundy (BoF), Scotian Shelf (SS), and Eastern Georges Bank (EGB).

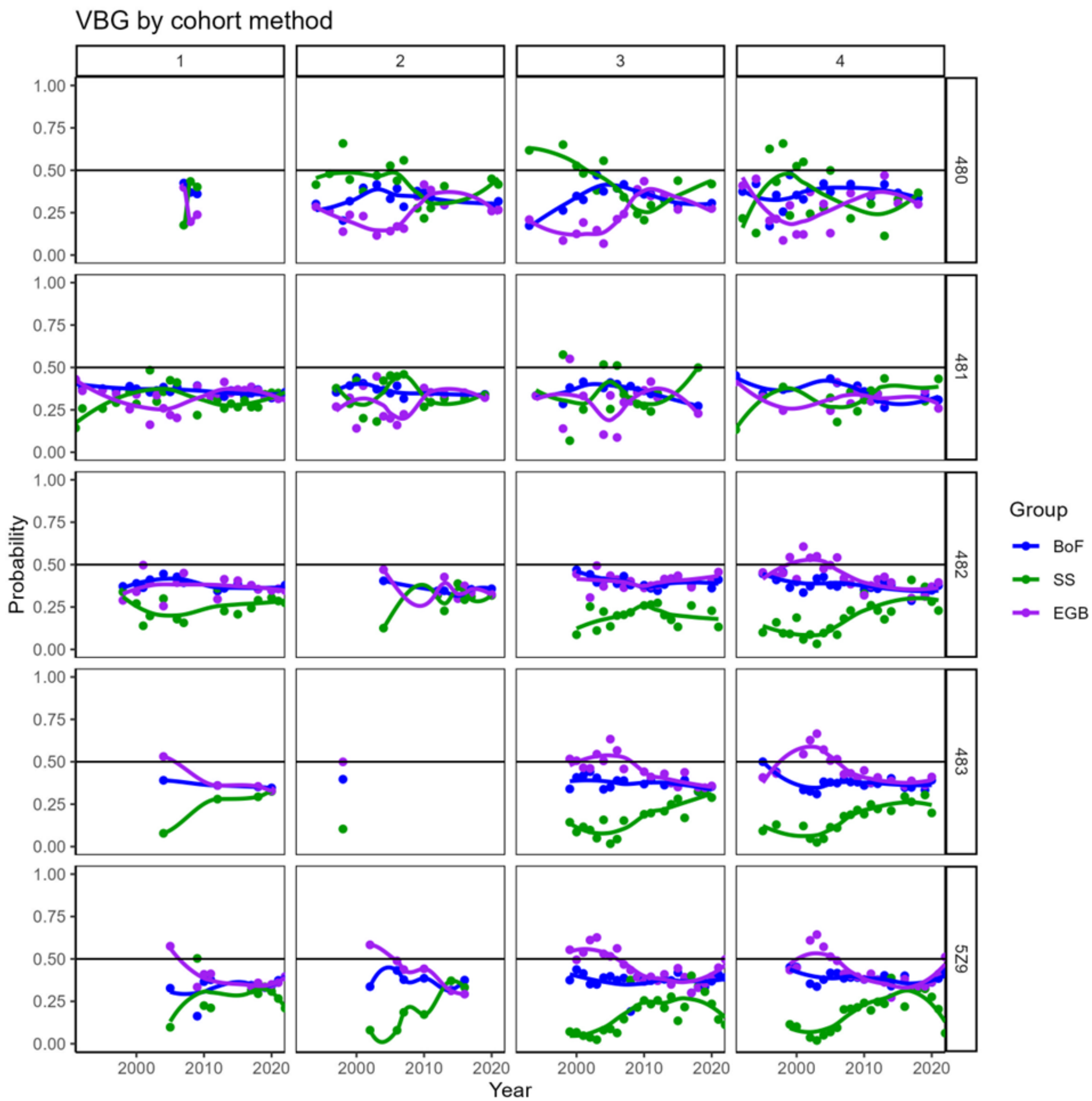


Figure 30. Predicted probabilities by fleet of samples from survey strata (480, 481, 482, 483, 5Z9) belonging to the "groups": Bay of Fundy (BoF), Scotian Shelf (SS), and Eastern Georges Bank (EGB) by quarter based on lengths-at-age from port and observer samples compared to the group predicted length-at-age from a von Bertalanffy growth model by cohort based on survey samples. Loess smoothers (weighted by sample size) plotted by group with a span of 0.75.

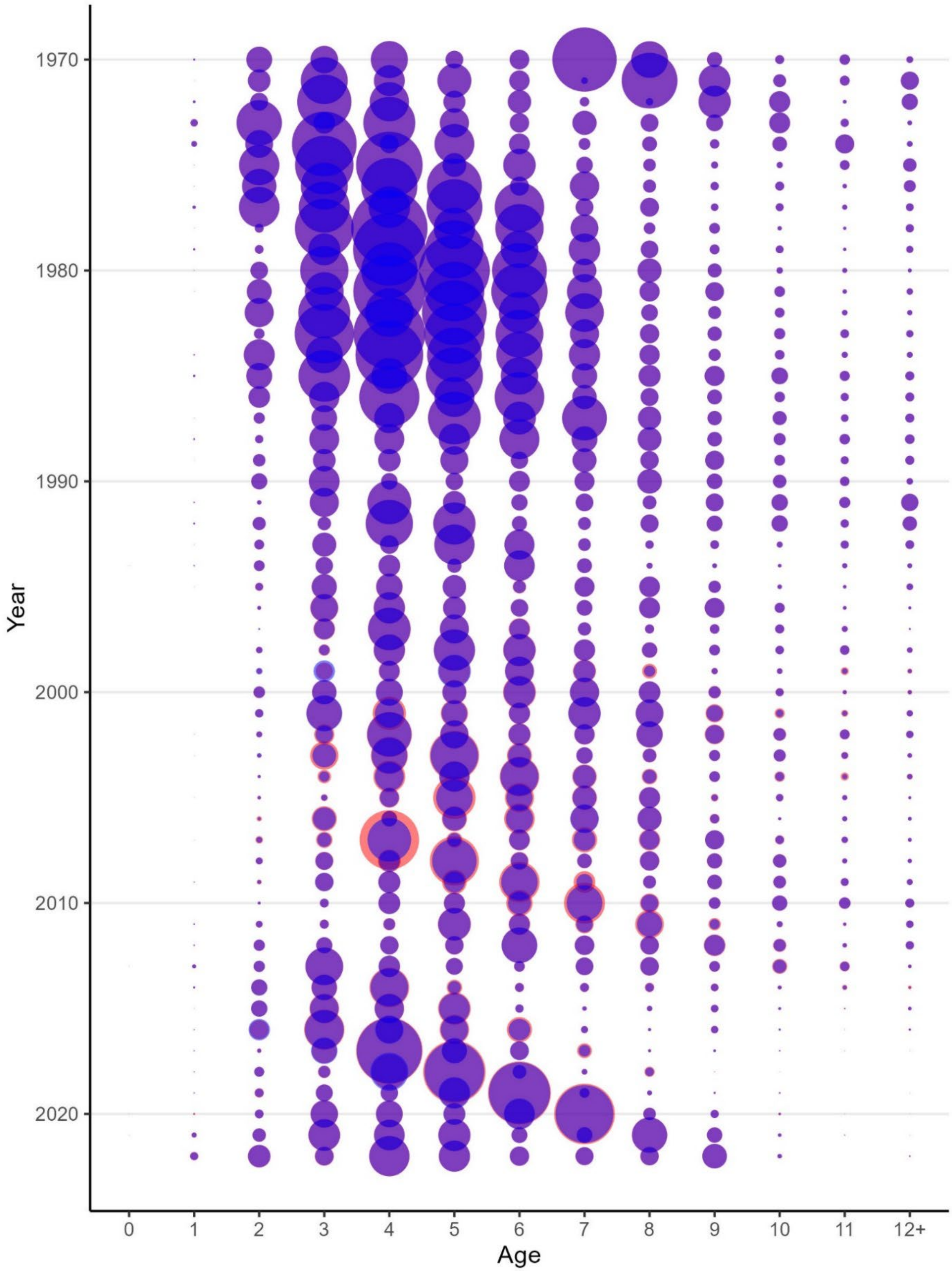


Figure 31. Fishery catch-at-age for the entire 4X5Y Haddock stock area (red) and after removing catches from survey strata 483 and 5Z9 (blue). The area of the bubble is proportional to the number-at-age.

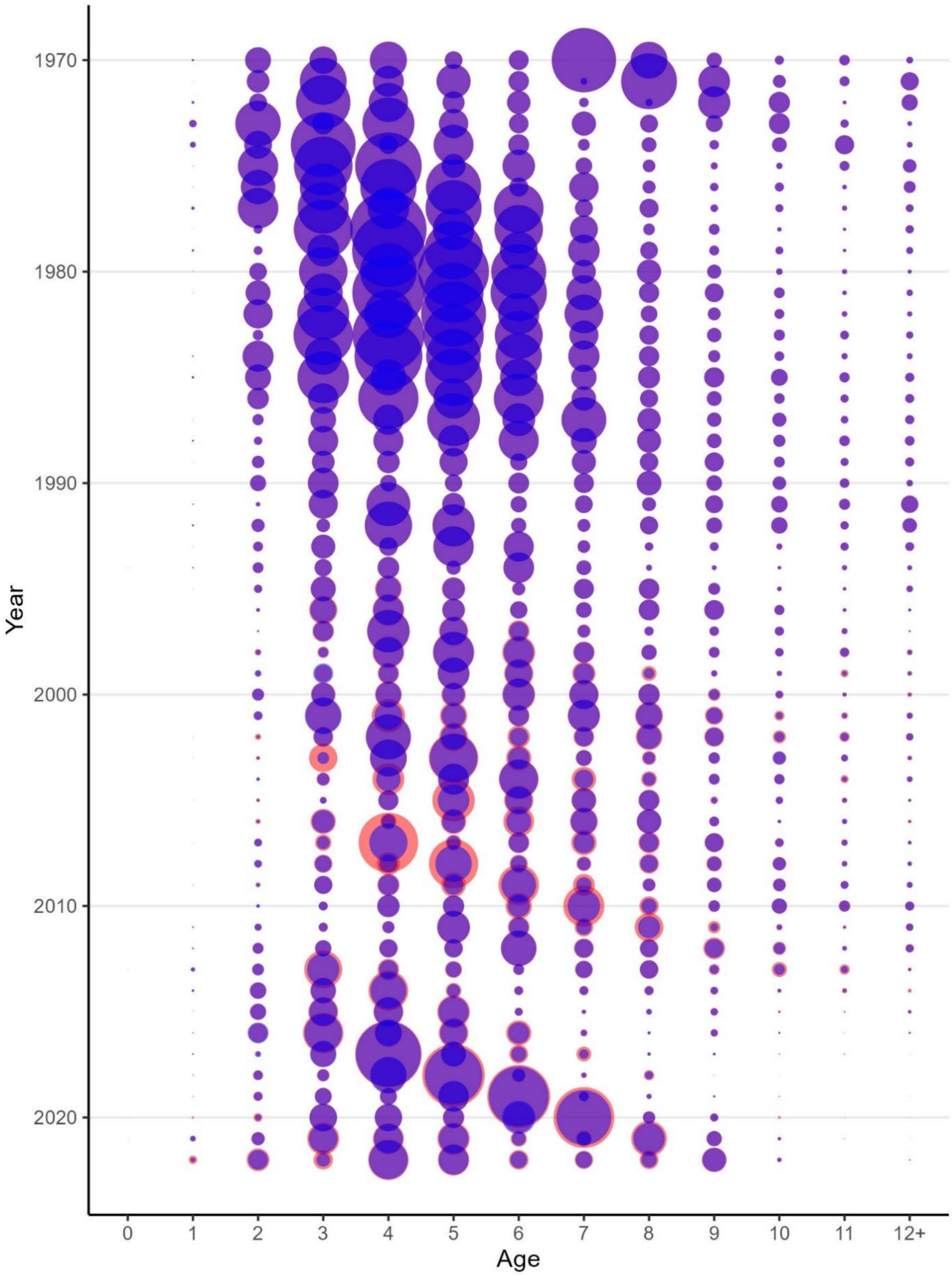


Figure 32. Fishery catch-at-age for the entire 4X5Y Haddock stock area (red) and after removing catches from survey strata 482, 483, and 5Z9 (blue). The area of the bubble is proportional to the number-at-age.

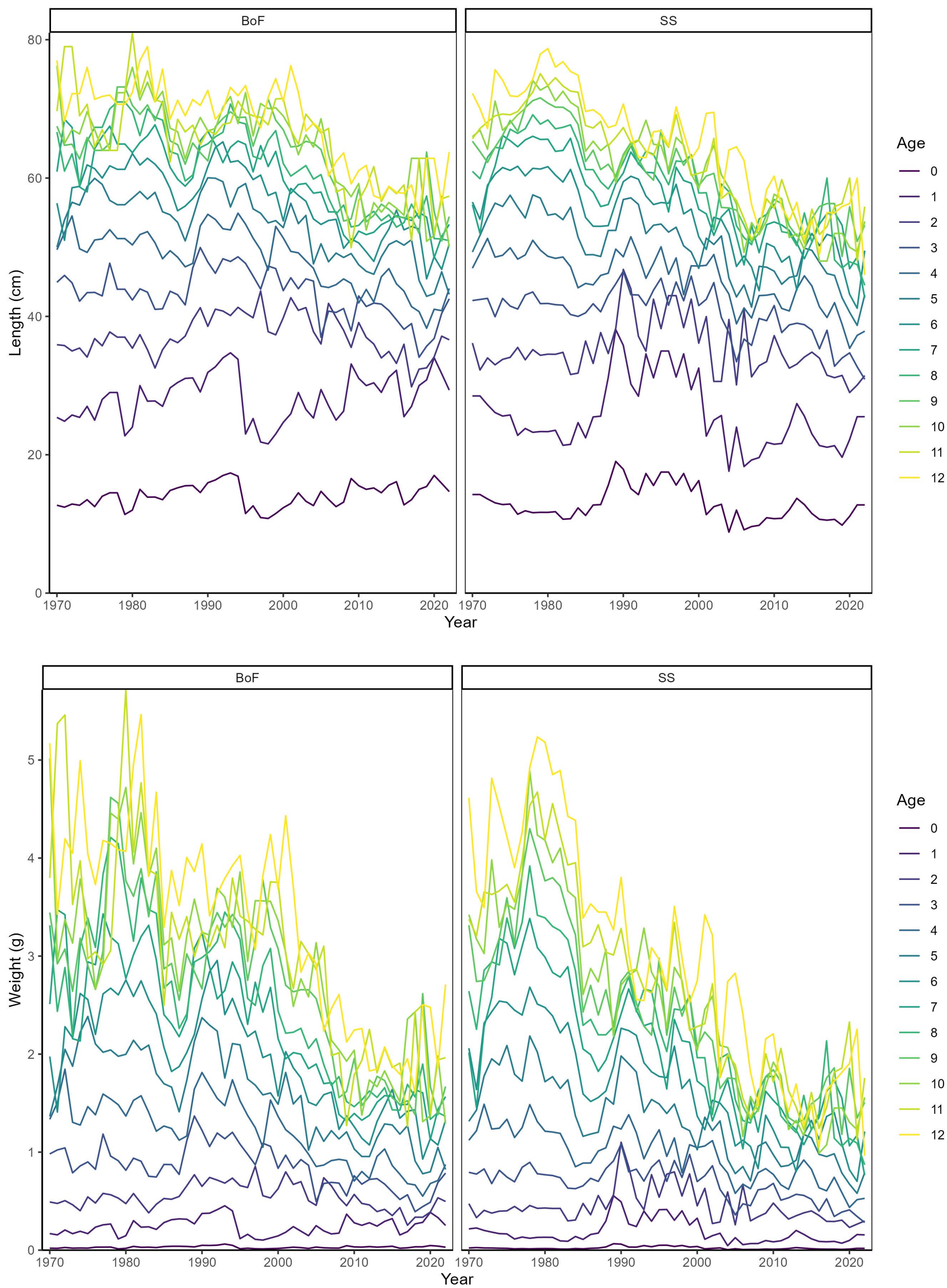


Figure 33. Mean empirical length- (top) and weight- (bottom) -at-age of Haddock for the Bay of Fundy (BoF) and the Scotian Shelf (SS) estimated from samples in the 4X5Y Haddock fishery catch.

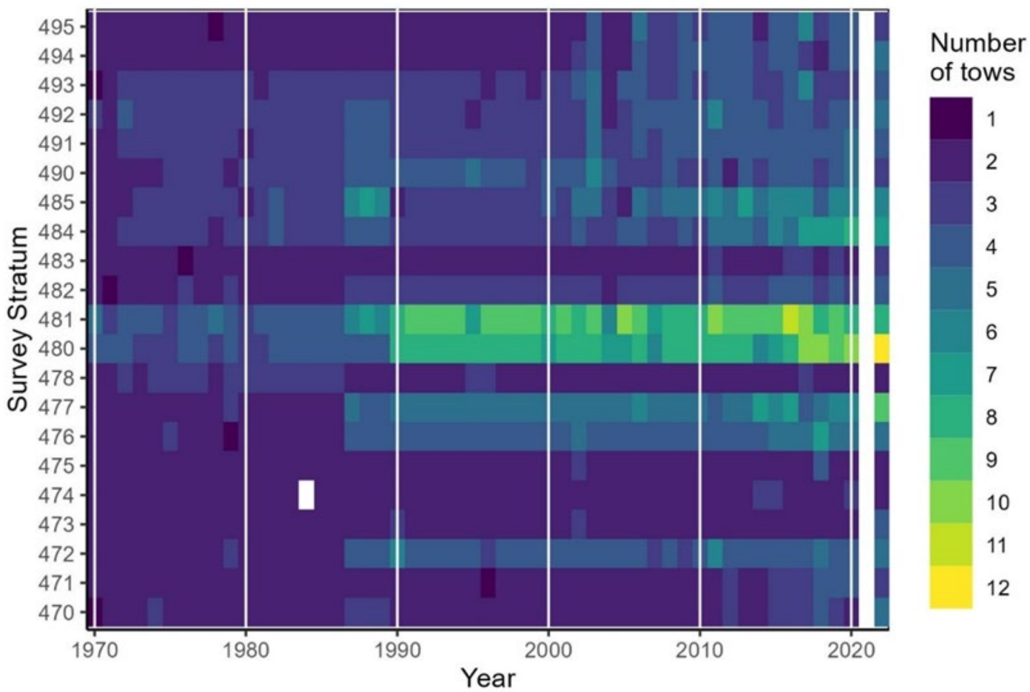


Figure 34. Number of tows by survey stratum for the DFO summer ecosystem survey. The 2021 sample sizes are not plotted because the survey was conducted using a new vessel and there currently are no calibration factors to compare to the time series (white bar).

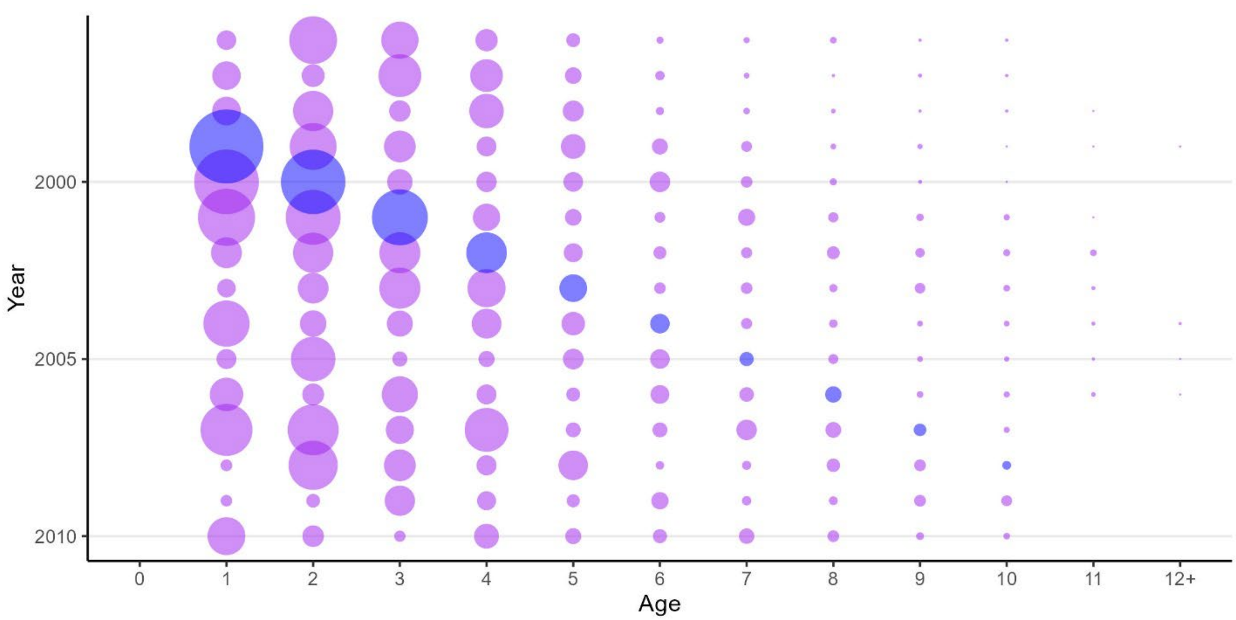


Figure 35. Survey number-at-age from the ITQ (Individual Transfer Quota) survey (1996–2011). The 1998 cohort is plotted in blue. The area of the bubble is proportional to the number-at-age.

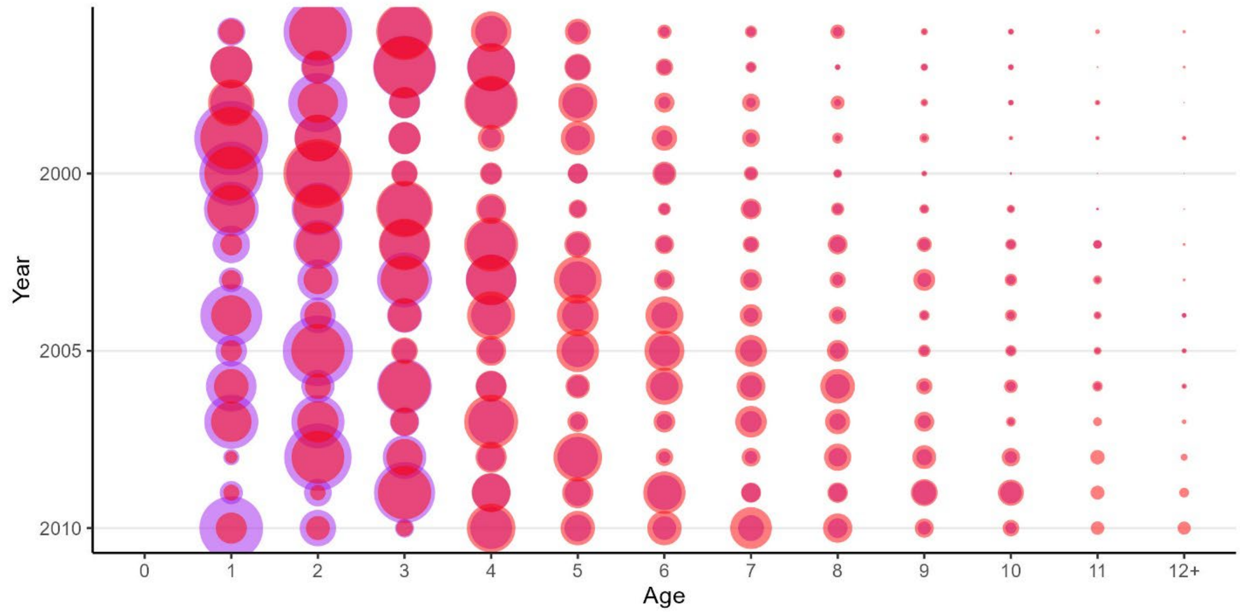


Figure 36. Survey annual proportions of number-at-age from the ITQ (Individual Transfer Quota) survey (purple) and DFO summer ecosystem survey (red) (1996–2011). The area of the bubble is proportional to the annual proportion of the number-at-age.

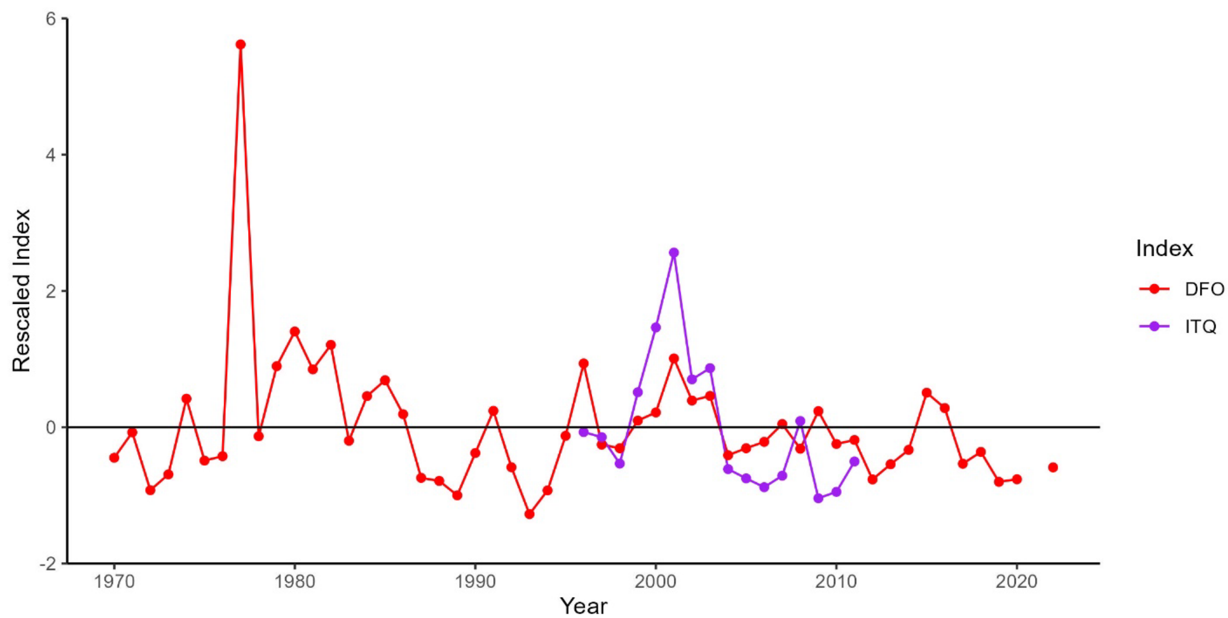


Figure 37. Comparison of the DFO ecosystem survey (red; 1970–2022) and the ITQ (Individual Transfer Quota) survey (purple; 1996–2011) biomass indices. The 2021 survey was conducted using a new vessel and currently there are no calibration factors to compare to the time series.

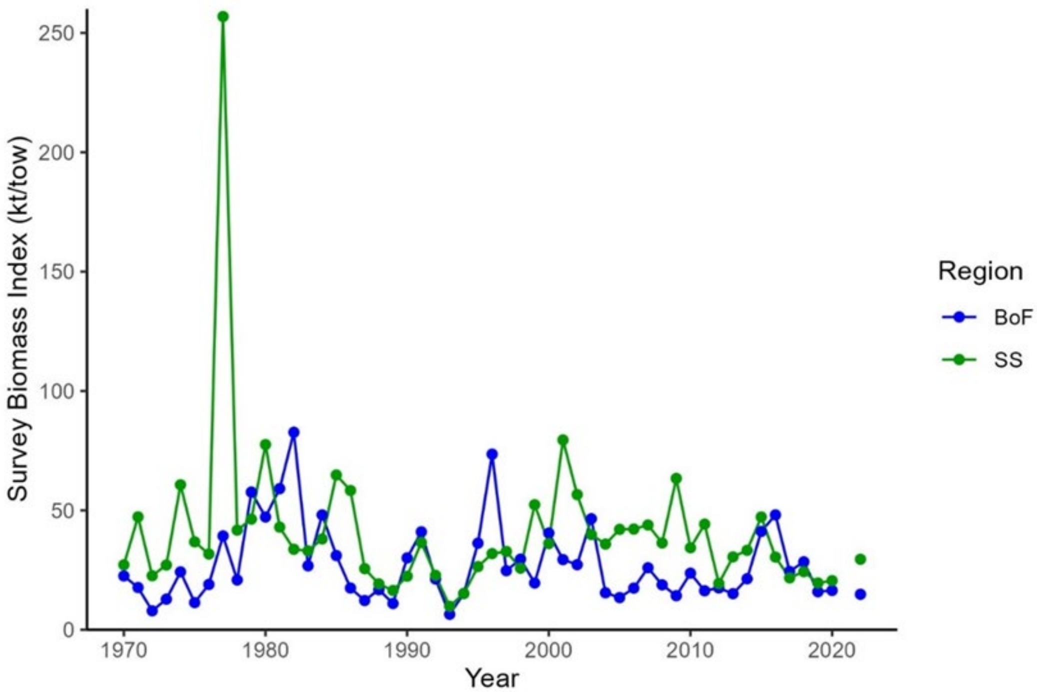


Figure 38. Survey biomass indices for Haddock for the Bay of Fundy (BoF; blue) and Scotian Shelf (SS; green) regions from the DFO summer ecosystem survey. The 2021 survey biomass was collected using a new vessel and currently there are no calibration factors to compare to the time series.

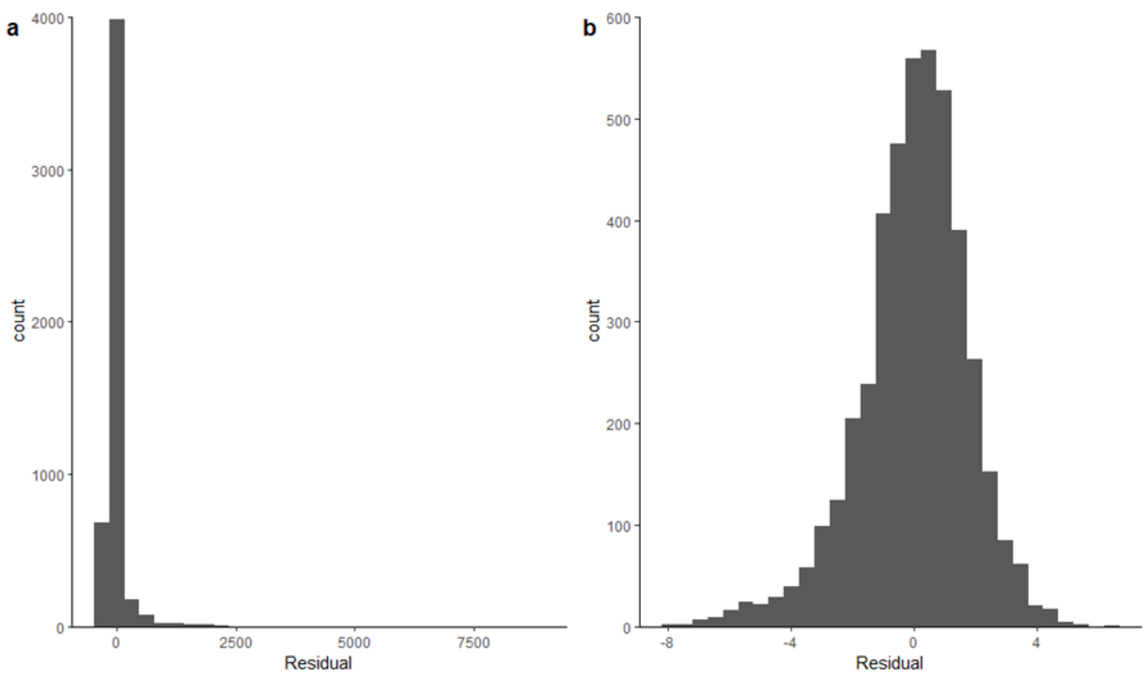


Figure 39. Histograms of the residuals of a linear model with a response variable of biomass per tow and categorical factors year and strata for untransformed biomass (a) and log-transformed biomass (b) with zero tows removed.

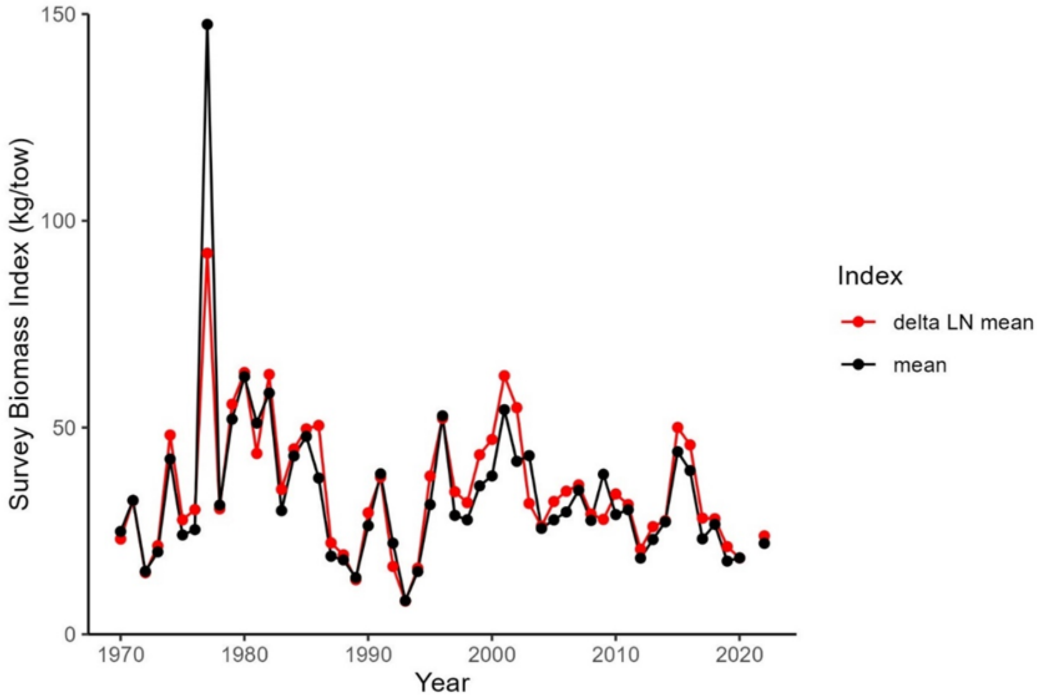


Figure 40. Survey biomass indices for 4X5Y Haddock from the DFO summer ecosystem survey estimated using an arithmetic mean and the mean based on a delta lognormal (LN) distribution. The 2021 survey biomass was collected using a new vessel and currently there are no calibration factors to compare to the time series.

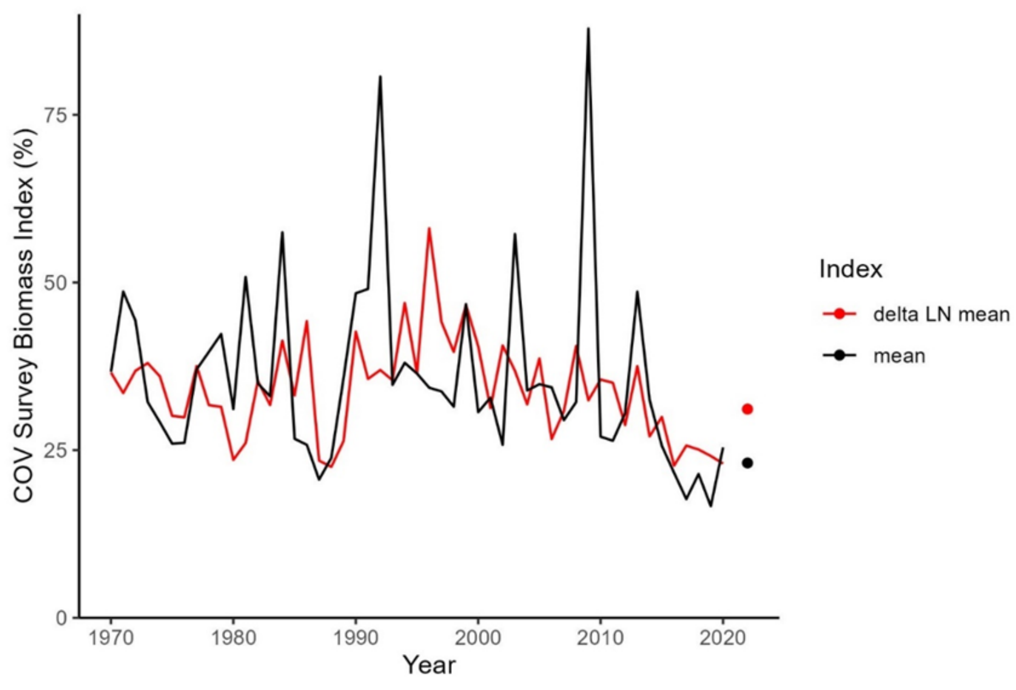


Figure 41. Coefficient of variation (COV) for the survey biomass indices for 4X5Y Haddock from the DFO summer ecosystem survey estimated using an arithmetic mean and the mean based on a delta lognormal (LN) distribution. The 2021 survey biomass was collected using a new vessel and currently there are no calibration factors to compare to the time series.

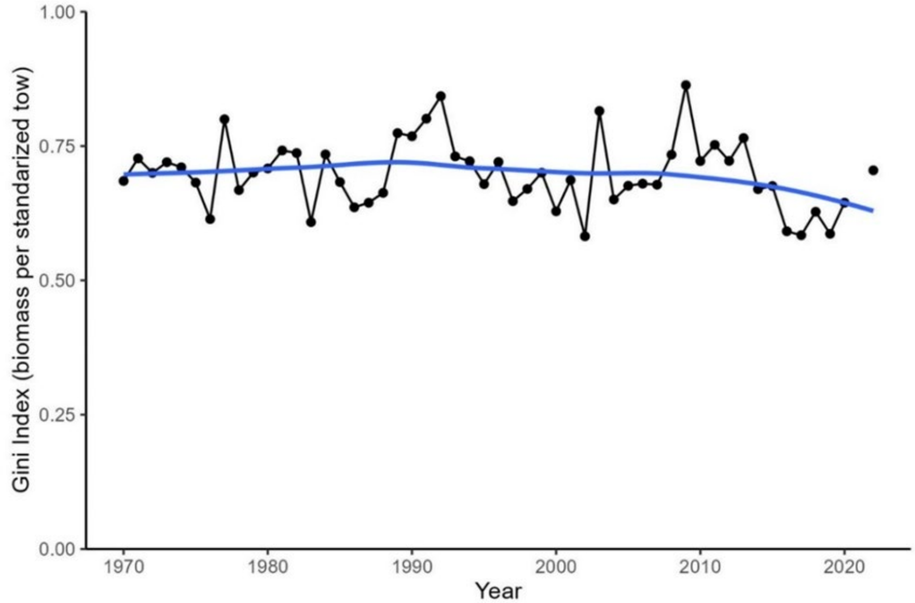


Figure 42. Gini index for the biomass per standardized tow for 4X5Y Haddock from the DFO summer ecosystem survey. Blue line is a loess smoother with span = 0.75. The 2021 survey was conducted using a new vessel and currently there are no calibration factors to compare to the time series.

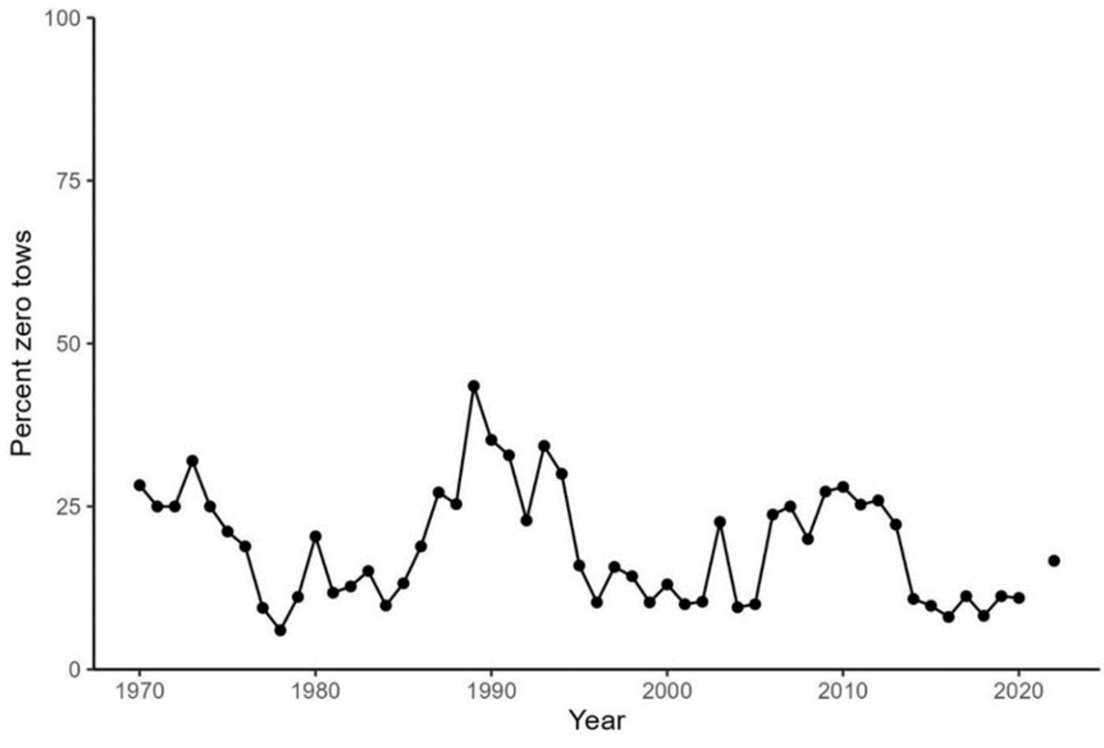


Figure 43. Percent of tows with zero biomass by year for 4X5Y Haddock from the DFO summer ecosystem survey. The 2021 survey was conducted using a new vessel and currently, there are no calibration factors to compare to the time series.

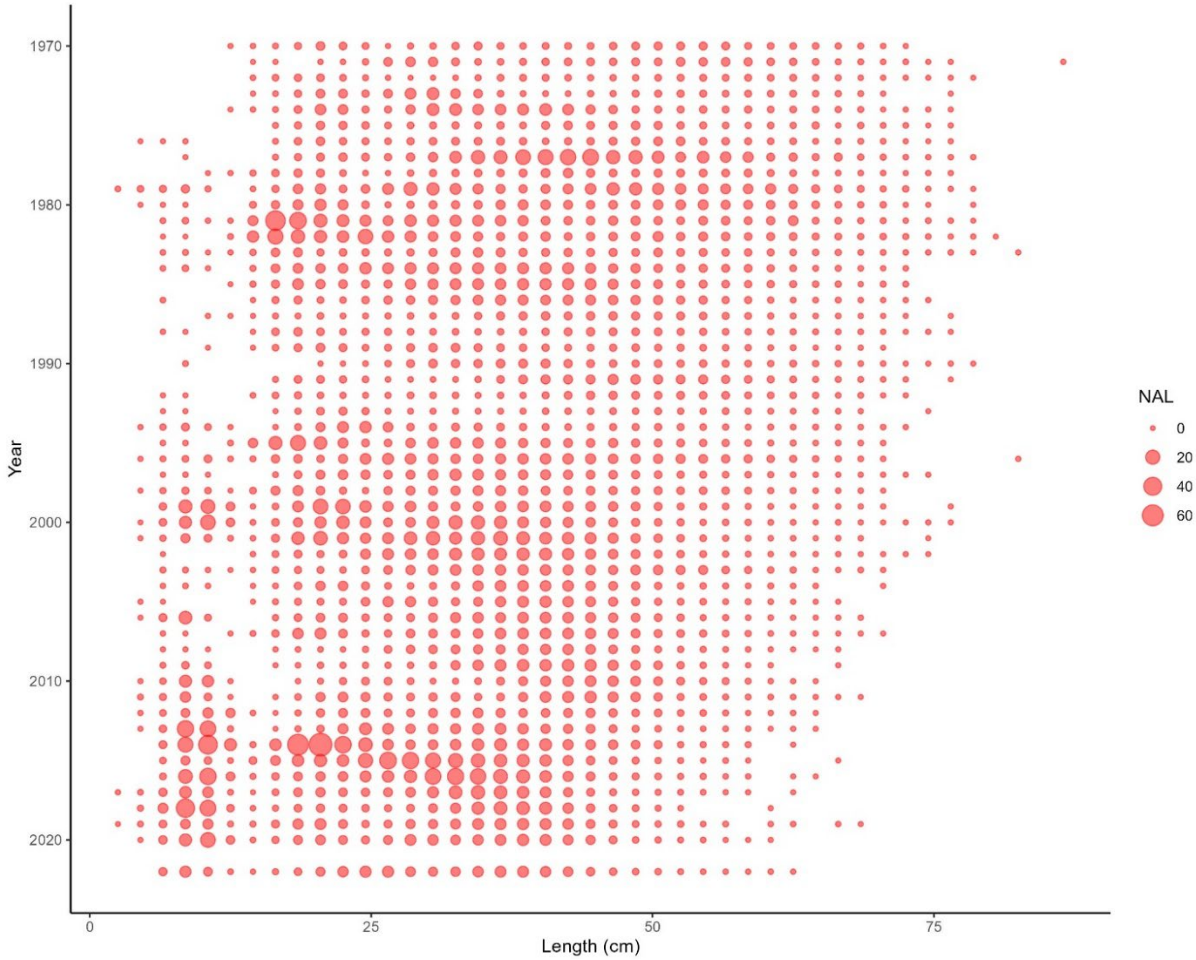


Figure 44. Numbers-at-length (NAL) in millions of 4X5Y Haddock from the DFO summer ecosystem survey using 2 cm length bins. The area of the bubble is proportional to the number-at-length.

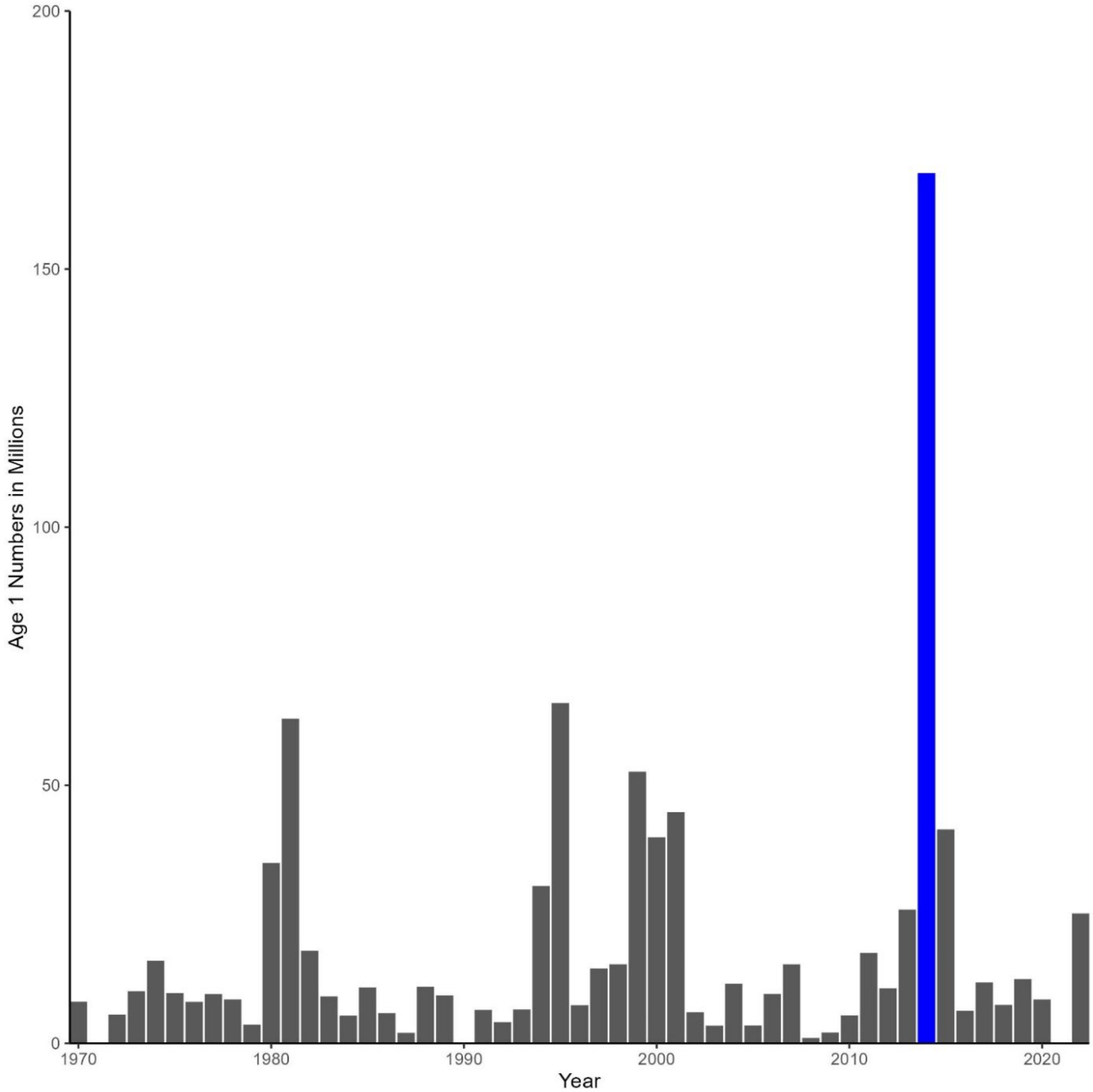


Figure 45. Numbers of age-1 4X5Y Haddock in millions estimated from the DFO summer ecosystem survey. The 2013 cohort at age 1 is highlighted in blue. The 2021 survey was conducted using a new vessel and currently there are no calibration factors to compare to the time series.

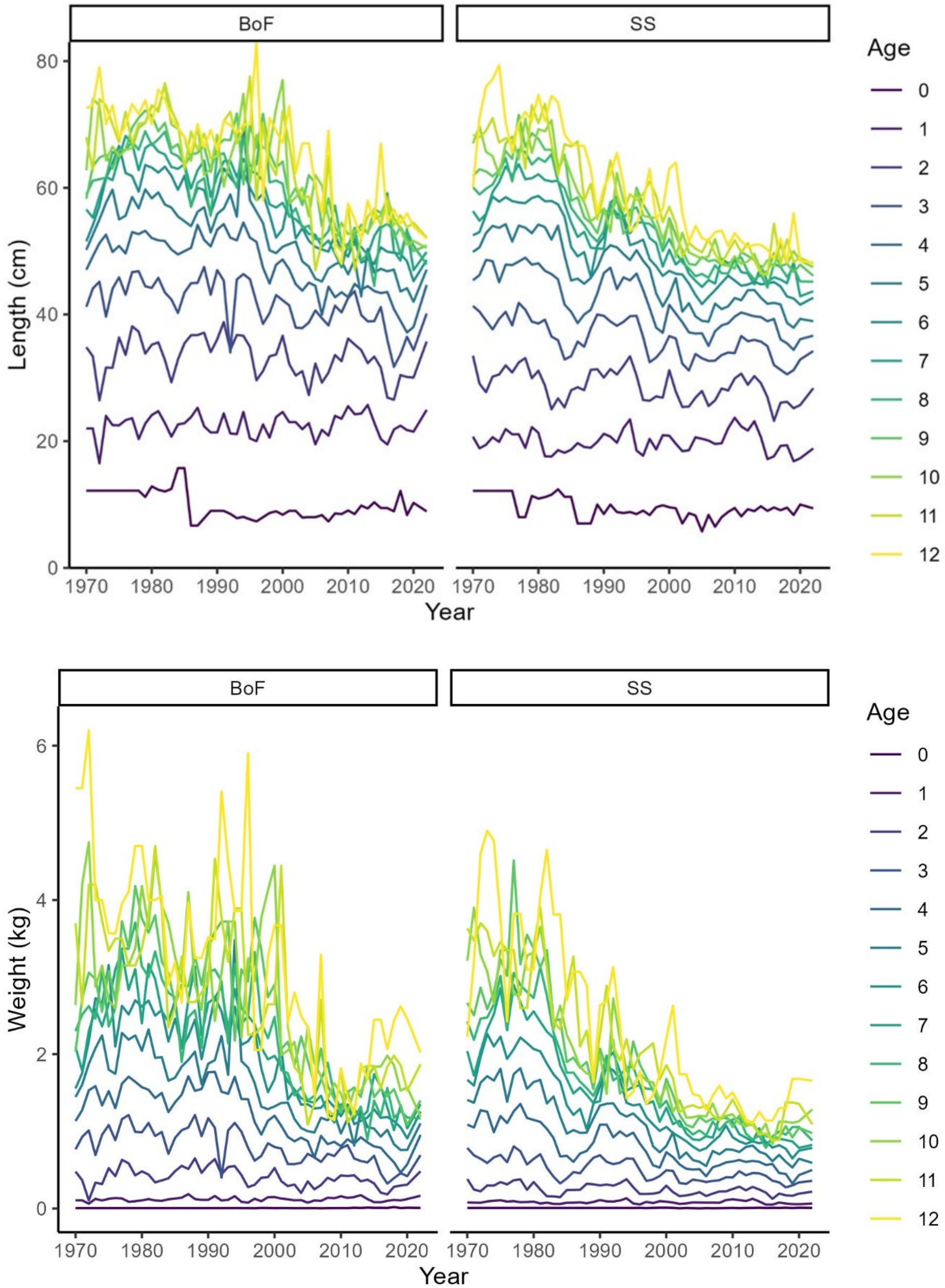


Figure 46. Mean empirical length- (top) and weight- (bottom) -at-age of Haddock for the Bay of Fundy (BoF) and the Scotian Shelf (SS) from the DFO summer ecosystem survey.

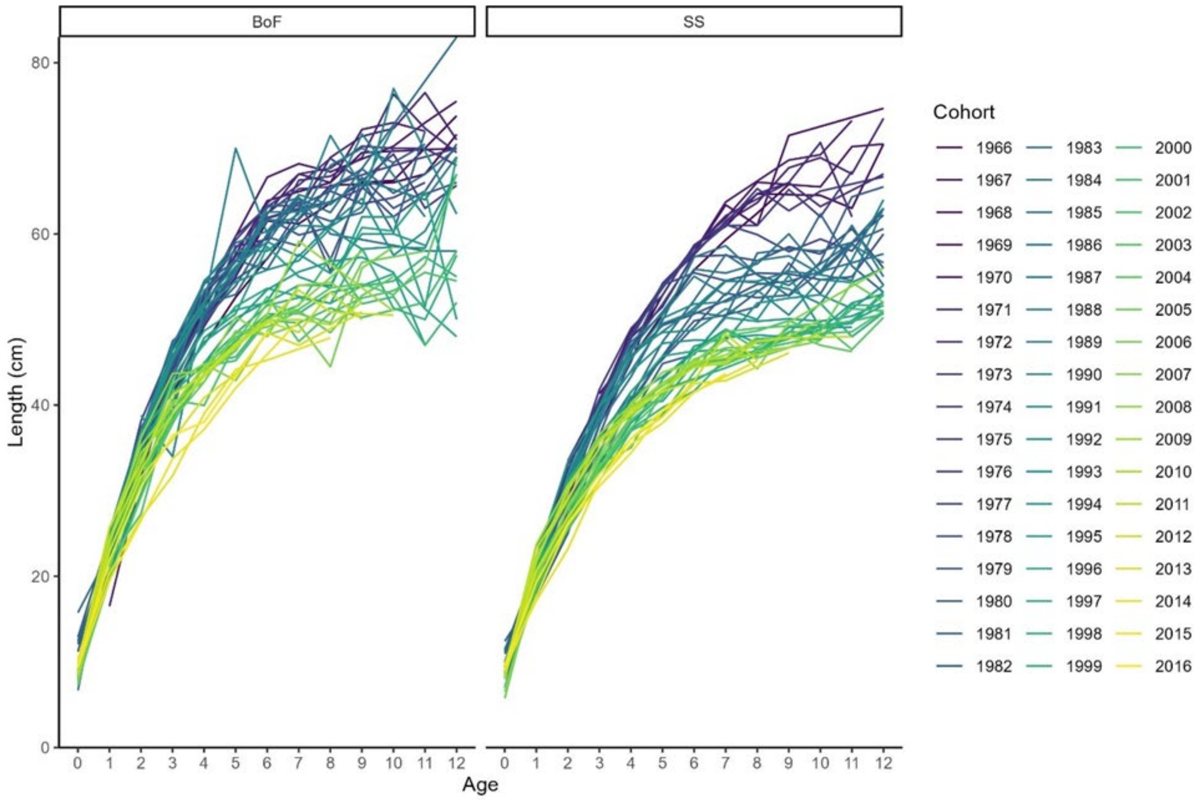


Figure 47. Empirical mean length-at-age of Haddock by cohort for the Bay of Fundy (BoF) and the Scotian Shelf (SS) from the DFO summer ecosystem survey.

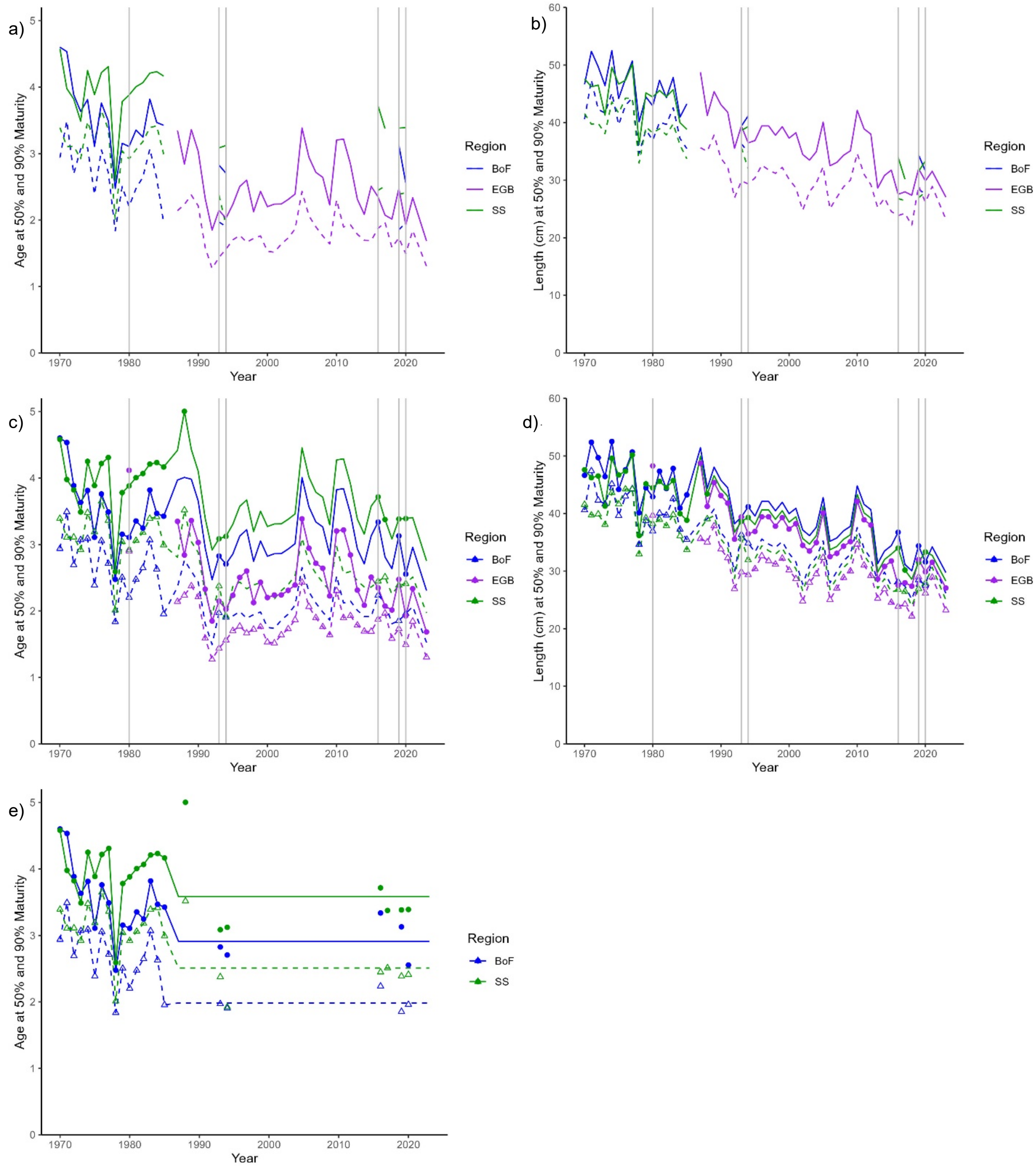


Figure 48. Age (a) and length (b) at 50% (dashed line) and 90% (solid line) maturity estimated from binomial logistic regression models by year from the DFO ecosystem surveys by region (BoF = Bay of Fundy; EGB = Eastern Georges Bank; SS = Scotian Shelf). Observed age (c) and length (d) at 50% (triangle) and 90% (circle) maturity by year and missing values filled (lines with no points) with predicted values from a linear model with factors year and region. Age (e) at 50% and 90% maturity with 1986–present filled with the mean values over that period. Vertical reference lines show years when data are available from all three regions.

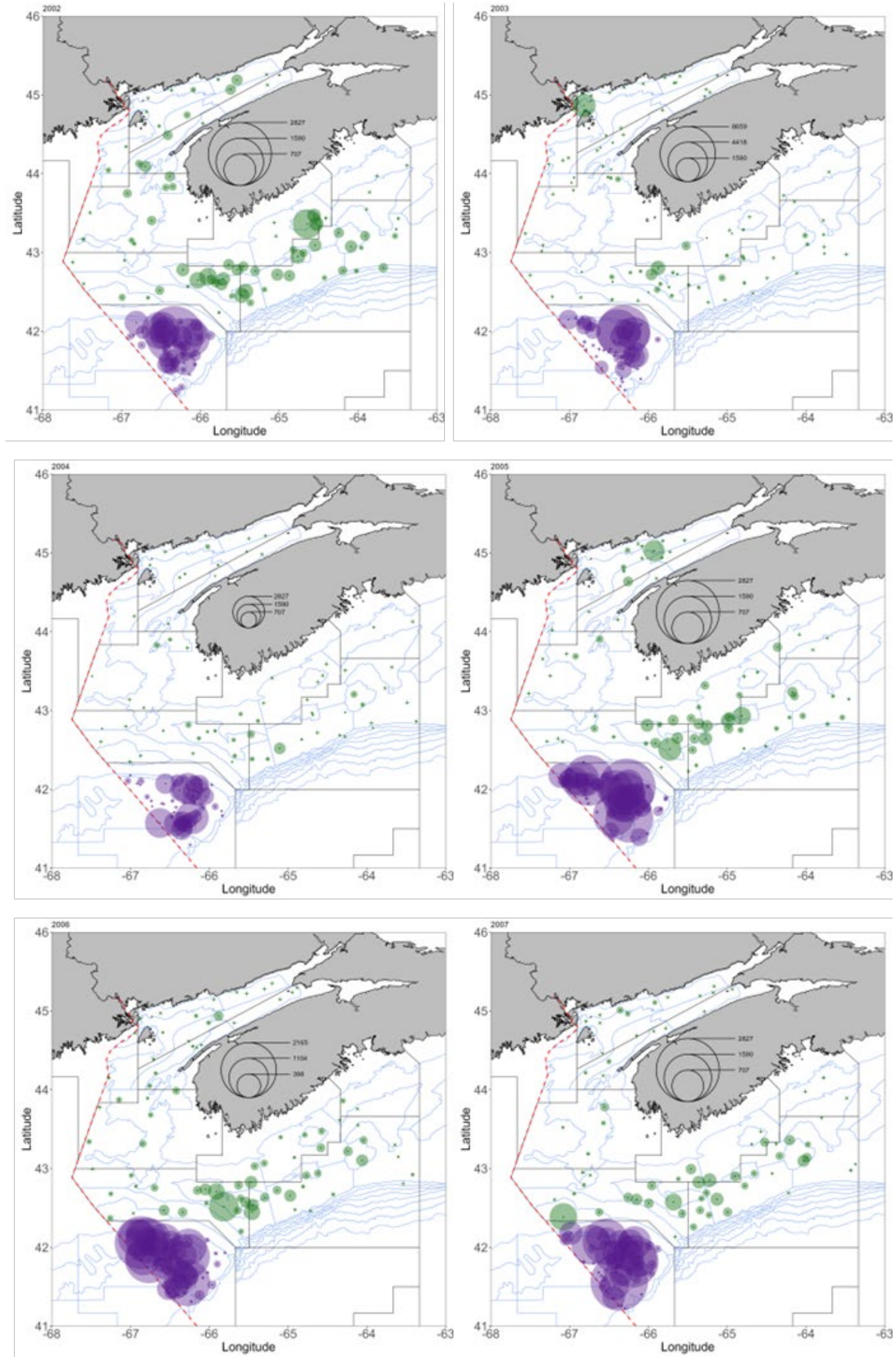


Figure 49a. Spatial distribution of survey biomass from the DFO winter (purple: on Eastern Georges Bank) and summer (green: in the 4X5Y Haddock stock area) ecosystem surveys from 2002–2022 (2002–2007 shown above). The area of the bubble is proportional to catch. The DFO unit area boundaries are indicated by black lines and the red line separates the international border. The 2021 summer survey was conducted using a new vessel and calibration factors are currently unavailable, so these data were excluded. For 2022, only the summer survey (green) is shown as calibration factors are not yet available for the winter survey data. Tows with zero biomass are plotted as × and tows with small but positive biomass are plotted as +.

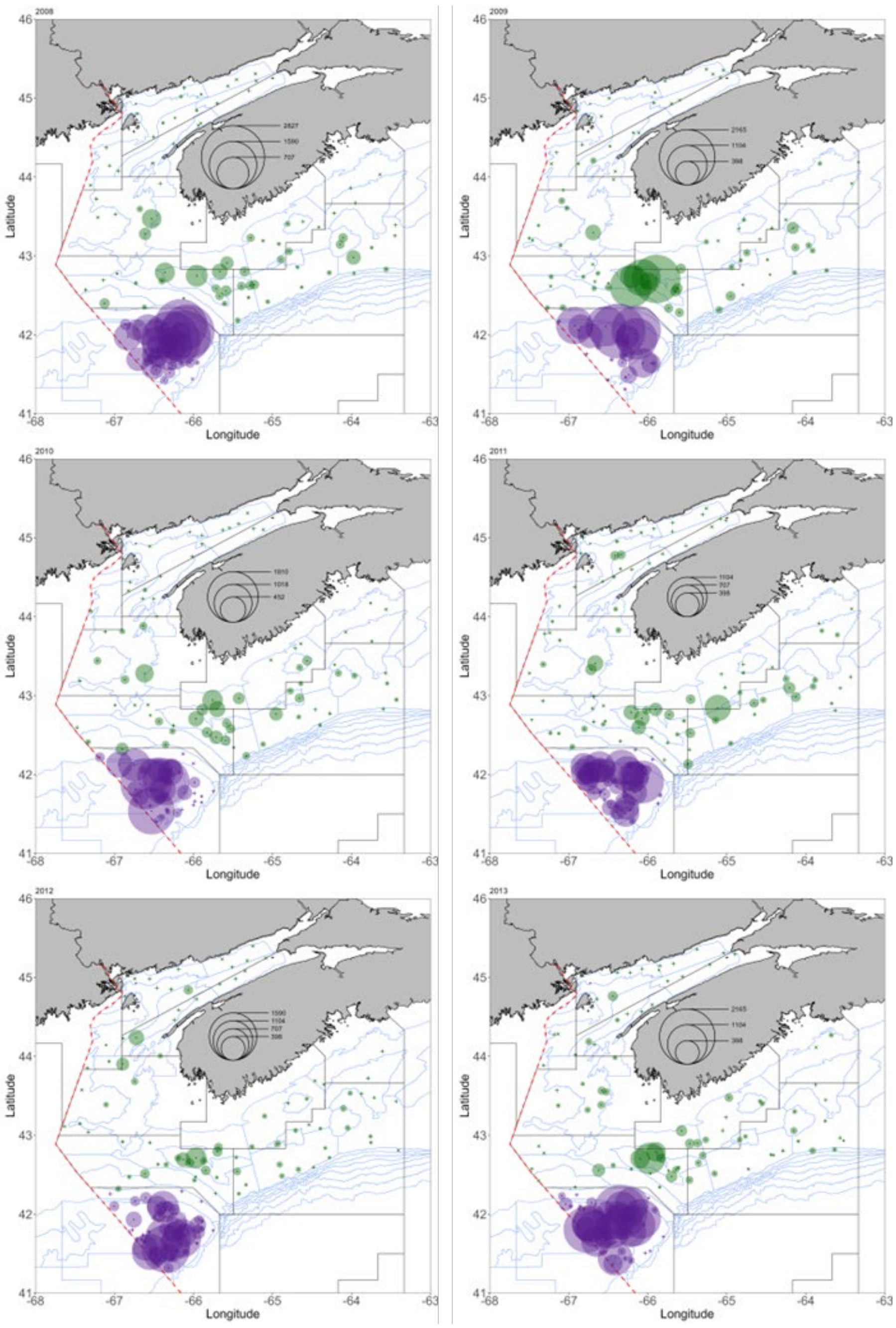


Figure 49b. Spatial distribution of survey biomass from the DFO winter (purple: on Eastern Georges Bank) and summer (green: in the 4X5Y Haddock stock area) ecosystem surveys from 2002–2022 (2008–2013 shown above). The area of the bubble is proportional to catch. The NAFO area boundaries are indicated by black lines and the red line separates the international border. The 2021 summer survey was conducted using a new vessel and calibration factors are currently unavailable, so these data were excluded. For 2022, only the summer survey (green) is shown as calibration factors are not yet available for the winter survey data. Tows with zero biomass are plotted as × and tows with small but positive biomass are plotted as +.

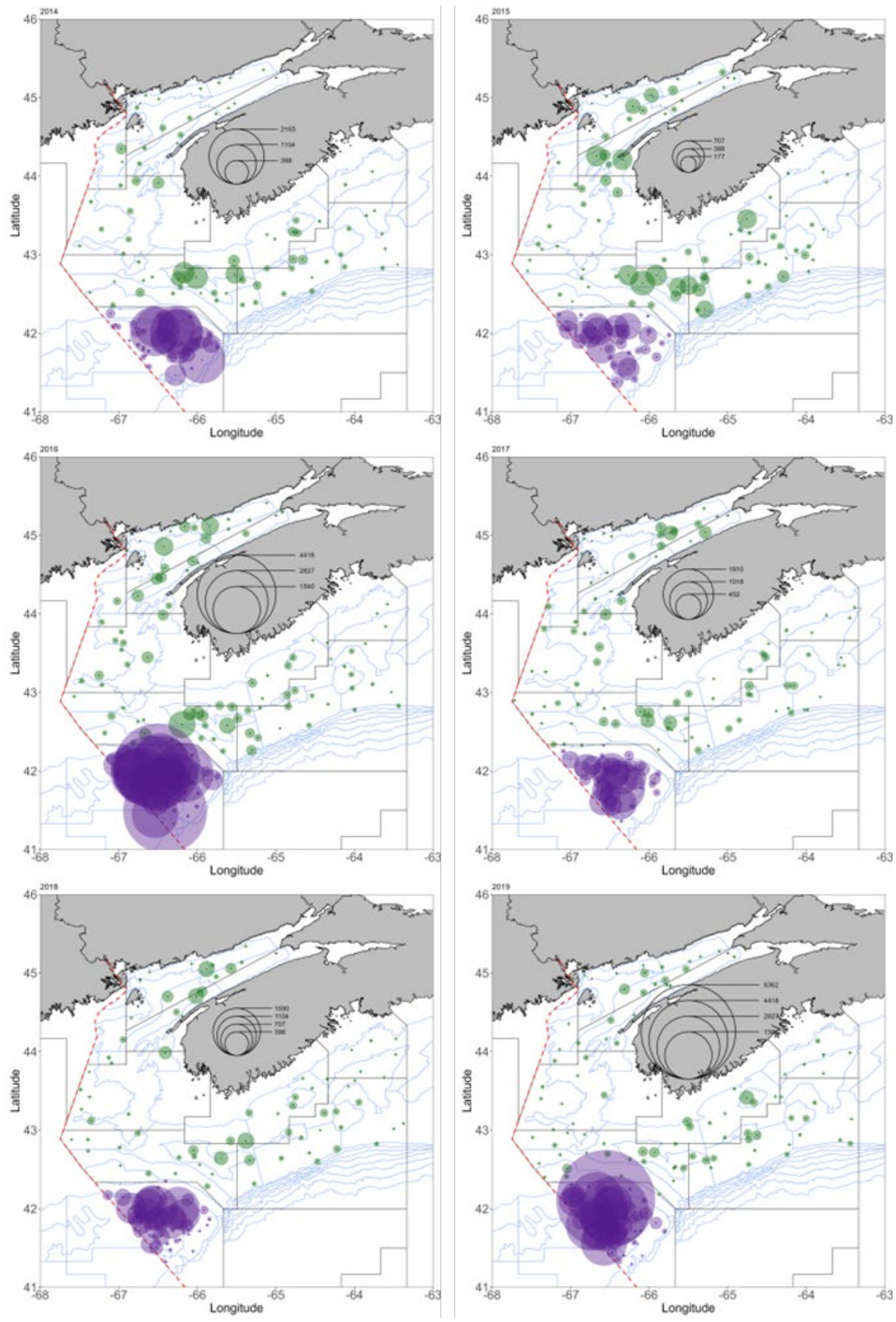


Figure 49c. Spatial distribution of survey biomass from the DFO winter (purple: on Eastern Georges Bank) and summer (green: in the 4X5Y Haddock stock area) ecosystem surveys from 2002–2022 (2014–2019 shown above). The area of the bubble is proportional to catch. The NAFO area boundaries are indicated by black lines and the red line separates the international border. The 2021 summer survey was conducted using a new vessel and calibration factors are currently unavailable, so these data were excluded. For 2022, only the summer survey (green) is shown as calibration factors are not yet available for the winter survey data. Tows with zero biomass are plotted as × and tows with small but positive biomass are plotted as +.

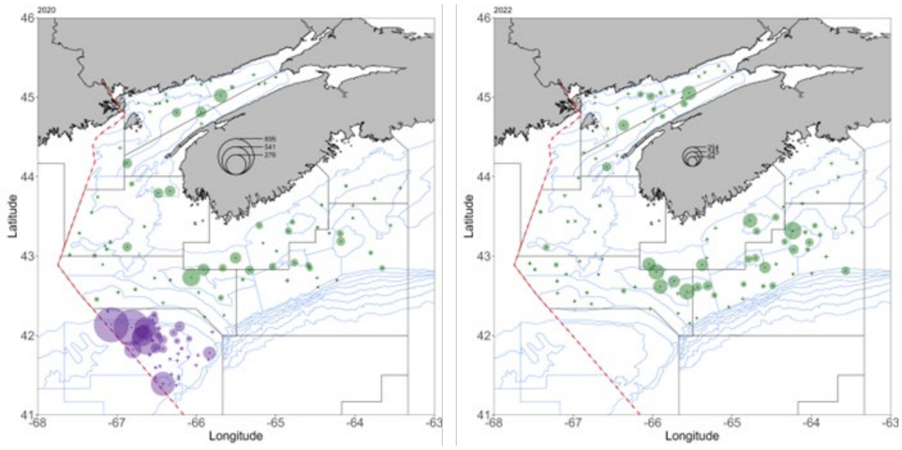


Figure 49d. Spatial distribution of survey biomass from the DFO winter (purple: on Eastern Georges Bank) and summer (green: in the 4X5Y Haddock stock area) ecosystem surveys from 2002–2022 (2020 and 2022 shown above). The area of the bubble is proportional to catch. The NAFO area boundaries are indicated by black lines and the red line separates the international border. The 2021 summer survey was conducted using a new vessel and calibration factors are currently unavailable, so these data were excluded. For 2022, only the summer survey (green) is shown as calibration factors are not yet available for the winter survey data. Tows with zero biomass are plotted as × and tows with small but positive biomass are plotted as +.

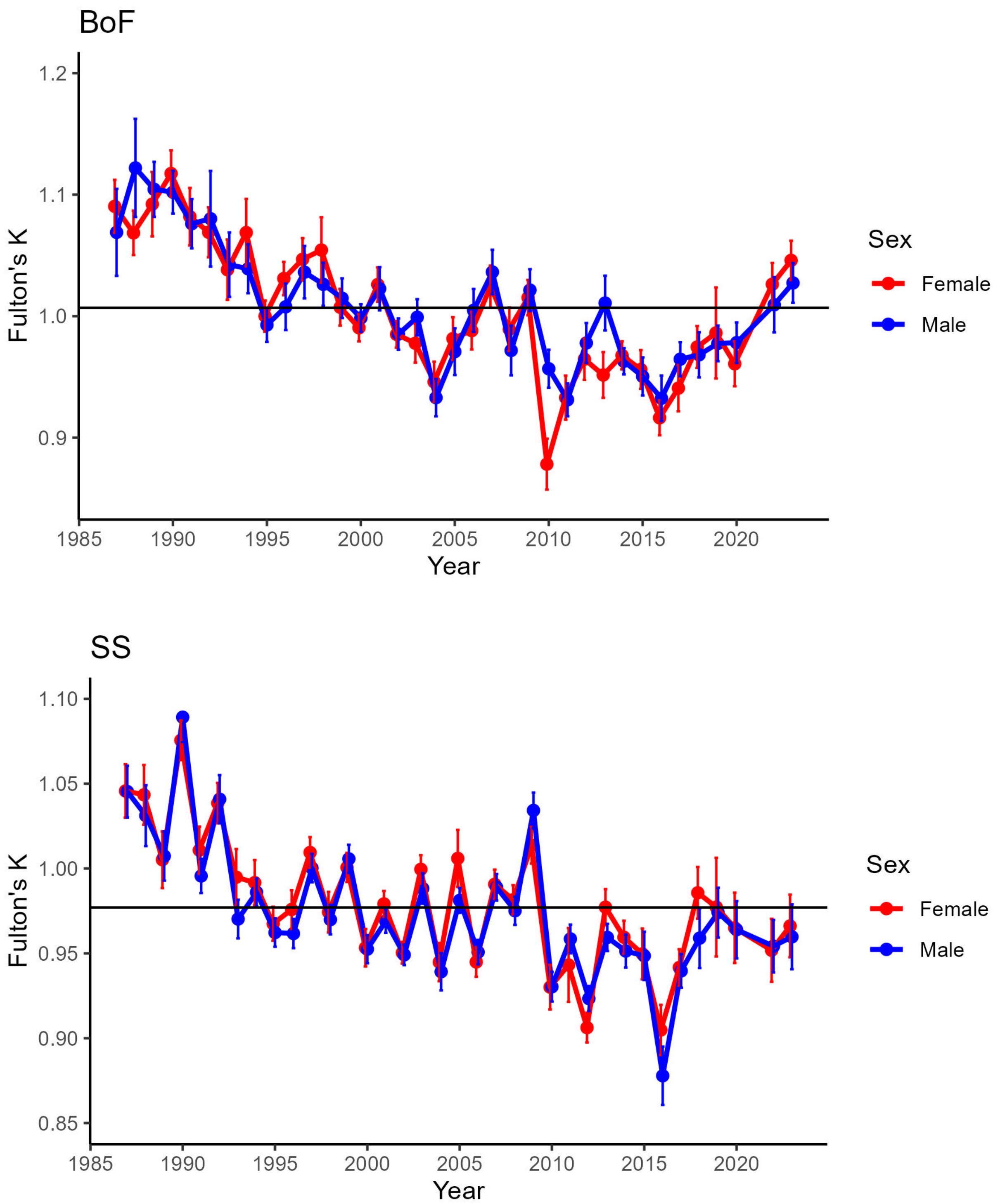


Figure 50. Mean annual condition factor of 4X5Y Haddock (Fulton's K) for the Bay of Fundy (BoF) and Scotian Shelf (SS) using data from the DFO summer ecosystem survey. The black solid line is the time series mean (1987–2022) and the error bars are 95% confidence intervals.

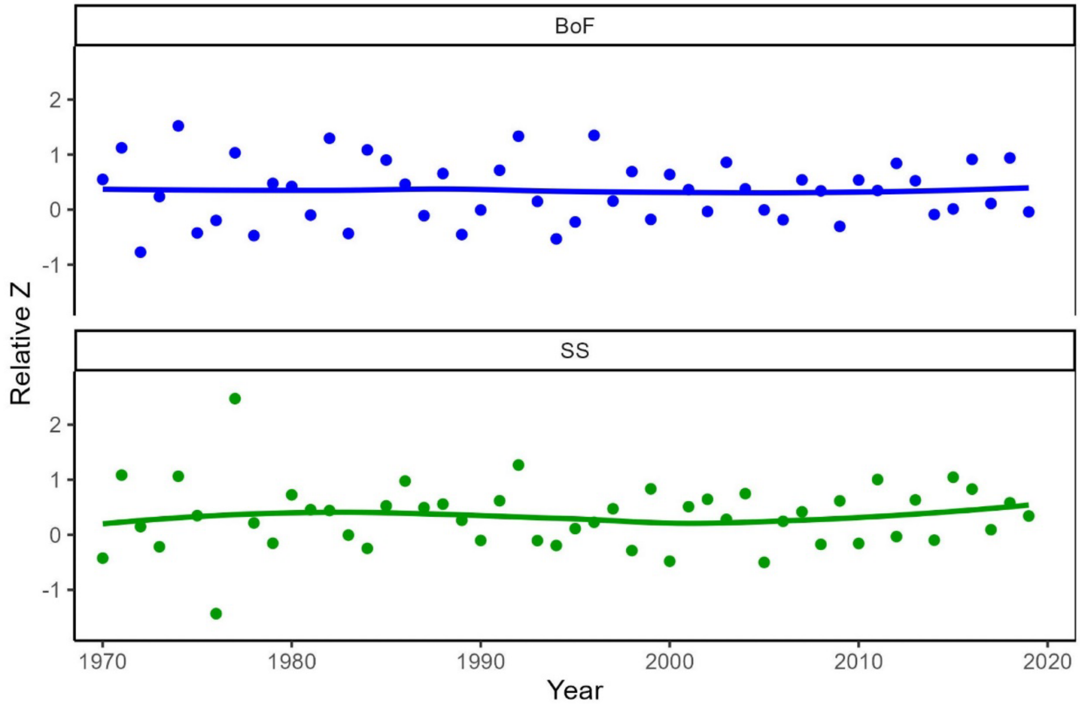


Figure 51. Relative total mortality (Z) of 4X5Y Haddock aged 3–8 for the Bay of Fundy (BoF) and Scotian Shelf (SS) estimated using the DFO summer ecosystem survey numbers-at-age. The solid line is a loess smoother with span = 0.75. The 2021 survey was conducted using a new vessel and currently there are no calibration factors to compare to the time series.

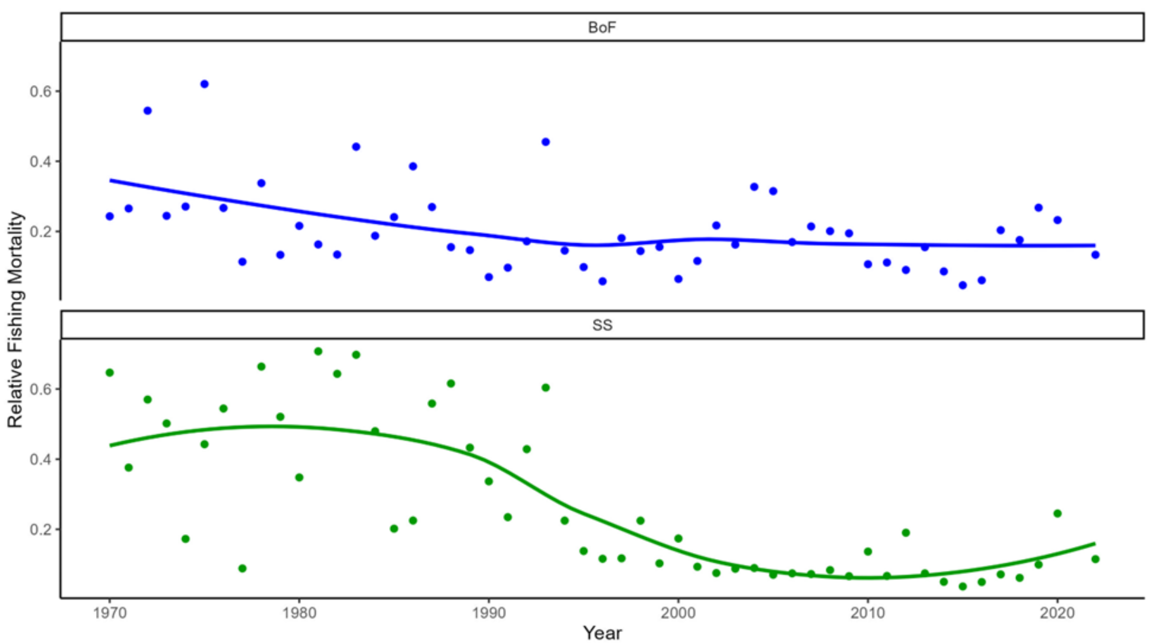


Figure 52. Relative fishing mortality (ratio of catch/survey biomass) of 4X5Y Haddock for the Bay of Fundy (BoF) and Scotian Shelf (SS). The solid line is a loess smoother with span = 0.75. The 2021 survey was conducted using a new vessel and currently there are no calibration factors to compare to the time series.