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2018 4X5Y Atlantic Cod Framework Data Inputs

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Foreword

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

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ABSTRACT

In 2018, the Maritimes Region of Fisheries and Oceans Canada will be undertaking a framework assessment of 4X5Y Atlantic Cod (*Gadus morhua*). Such assessments are intended to be a comprehensive review of the biology, stock structure, the fishery, abundance indices, current assessment methodology and approaches for determining acceptable harvest limits. This document explores a variety of data sources available for 4X5Y Cod, including tagging projects (1980s–2000s), commercial fishery information (1980–2017) and departmental research surveys (1983–2017). The results of stock structure analyses, spatial and temporal patterns in distribution, bycatch, biological attributes (length and weight at age, condition factor, growth and maturity) and updates to data inputs for stock assessment (fishery catch at age, survey indices of abundance, relative fishing mortality, total mortality) are also described here, as well as any persistent data gaps. Finally, a preliminary review of ecosystem indicators and accompanying data considered relevant to the 4X5Y Cod assessment is summarized.

INTRODUCTION

Atlantic Cod (*Gadus morhua*) have a broad distribution in the western Atlantic, ranging from Cape Hatteras to the coast of Greenland. Cod on the Southern Scotian Shelf and Bay of Fundy in Northwest Atlantic Fisheries Organization (NAFO) Divisions 4X and Canadian portion of 5Yb have been managed as a single unit since 1985 and are jointly referred to as 4X5Y Cod. The last full assessment for this management unit was conducted in 2008 (Clark and Emberley 2009), followed by a Recovery Potential Assessment (RPA) in 2011, which concluded that this stock was in the critical zone (Clark et al. 2015). This research document is intended to provide an update on several biological and fishery attributes and constitutes the first part of a 4X5Y Cod Framework Review scheduled for 2018–2019.

FRAMEWORK REVIEW AND OBJECTIVES

The objectives for the Framework Review meeting are to review the data inputs for 4X5Y Cod, as well as the model(s) used to determine stock status, reference points, risk analysis and the inter-framework assessment strategy. There will be two parts to this process:

Part 1 - Review of Fishery Data Inputs and Indices of Abundance (March 2018):

- Review definition of the 4X5Y Cod management unit (growth, morphometrics, movement).
- Review 4X5Y Cod fishery distribution, landings, age composition, timing and bycatch.
- Review Research Vessel survey age-specific indices of abundance, weight/length at age, condition, spatial distribution, age composition, recruitment, survey Z and maturity.
- Examine sources of ecosystem information (environmental factors, diet information, unaccounted for sources of mortality, etc.).

Part 2 - Assessment of Model(s) to determine stock status, reference points, risk analysis and the inter-framework assessment strategy (October 2018)

BACKGROUND

STOCK STRUCTURE IN 4X5Y

Atlantic Cod (*Gadus morhua*) have a broad distribution in the western Atlantic, ranging from Cape Hatteras to the coast of Greenland. It is found in several concentrations along the Canadian Atlantic coast, including the Southern Scotian Shelf and the Bay of Fundy in Northwest Atlantic Fisheries Organization (NAFO) Divisions 4X and the Canadian portion of 5Yb (Figure 1). Cod in these two areas have been managed as a single unit since 1985 and are henceforth jointly referred to as 4X5Y Cod.

Spawning of Cod is distributed geographically throughout the 4X5Y area. In the spring, spawning occurs primarily on Browns Bank, with some fishermen reporting spawning fish in the waters off Digby Neck and Grand Manan (Behnam and Trippel 1998). Egg and larval studies support these findings, with eggs found in high concentrations on Browns Bank and more generally distributed throughout the Bay of Fundy in the spring (Neilson and Perley 1996). The fall spawning event takes place between October and December, and is generally restricted to the inshore waters of Nova Scotia (Neilson and Perley 1996). Although detailed historic accounts of spawning fish around Halifax Harbour, Sambro Head and St. Margaret's Bay exist (McKenzie 1940), recent reports of spawning fish in the area are sparse (Clark and Emberley 2009). Lack of recent, detailed information on the fall spawning event represents a major data gap for interpreting the stock structure of Cod within the 4X5Y management unit.

Although assessed together, Cod in the Bay of Fundy (NAFO areas 4Xqrs5Yb) and Scotian Shelf (NAFO areas 4Xmno) areas of the management unit exhibit distinctly different growth rates (Figure 2). Cod from the Bay of Fundy region (henceforth referred to as western fish) have a higher growth rate, reaching an average length of 77cm by age 5, while those from the Scotian Shelf (henceforth referred to as eastern fish) attain an average length of 65cm at age 5 (Figure 2). Instantaneous rates of growth at age (length/age) from the summer RV survey data show the transition in distribution of fast growing fish found throughout the Bay of Fundy region, to the slower growth seen along the Scotian Shelf (Figure 3). Some movement between these areas is bound to occur, but only fish caught in NAFO area 4Xp consistently exhibit characteristics of both growth curves throughout the time series (Figure 4). Although the exact extent of mixing within 4Xp has not been quantified, it is considered a mixing area for eastern and western Cod within the 4X5Y management unit.

The degree to which fish mix within the whole 4X5Y management area varies seasonally and is not uniform across the region. Tagging studies generally showed that fish tagged in the Bay of Fundy were predominantly recaptured within the bay during the fall, whereas those recaptured in the spring moved southward towards the Gulf of Maine, Georges Bank (5Z) and Browns Bank (4Xp) (Clark and Emberley 2009). Cod tagged on the Scotian Shelf (Roseway, LaHave and Baccaro banks, 4Xmno) were recaptured in much closer proximity to the release locations, with few recaptured west of Browns Bank (4Xp). While Cod tagged in the Bay of Fundy and those tagged on the Scotian Shelf exhibit little intermixing, Cod tagged on Browns Bank (4Xp) were recovered broadly in both areas (Campana and Simon 1985, Hunt et al. 1999, Clark and Emberley 2009). Results from these tagging studies are consistent with having two stock components within 4X5Y, along with a mixing area in 4Xp (Browns Bank), but do not provide insight into the actual rates of mixing within 4X5Y (Figure 5).

Tagging studies also found some movement occurring from 4X5Y into adjacent areas. Cod tagged on Browns Bank moved south onto Georges Bank while Cod released on the north-eastern portion of Georges Bank (5Zej) exhibited a reciprocal movement into the Bay of Fundy and Georges Basin; Cod tagged on the south-eastern portion remained on Georges Bank or moved south towards Cape Cod (Hunt et al. 1999, Clark and Emberley 2009, O'Brien and Worcester 2009). Although conventional tagging studies can identify possible linkages between adjacent management areas, the extent of mixing is difficult to quantify, as results are often influenced by fishing effort distribution, tag release location and timing of release/recapture (O'Brien and Worcester 2009). In addition, the rate of mixing between the areas seems to vary with time, as the growth relationship for Cod on eastern Georges Bank (5Zjm) used to resemble that of Bay of Fundy fish prior to 1994, but has shifted closer to that of Scotian Shelf fish since then (Figure 6).

In general, a two stock component structure within 4X5Y seems to persist, with a mixing area in 4Xp and some movement taking place between adjacent management areas. Additional work, particularly in the field of genetics, would be highly beneficial in improving the understanding of the Cod population structure in this area. Finally, given this two-stock component structure within the 4X5Y Cod management unit and assuming no broad mixing between the two stock components, a concentration of fishing effort in one area could lead to overexploitation of a single component, while leaving the other unharmed. Management of the fishery should be conducted in a fashion which aims to avoid over-exploitation in any part of the 4X5Y stock area (Clark et al. 1998).

HISTORY OF THE 4X5Y FISHERY

Prior to 1962, Cod in NAFO area 4X were caught as part of an inshore fishery prosecuted primarily by small Canadian vessels using handline and longline gears (Figure 7). In 1962, both

Canadian and foreign otter trawlers began fishing heavily on Browns and LaHave banks, quickly increasing Cod landings from < 15,000 t per year to 35,500 t per year (Figure 8). Although no quota was set for Cod at this time, Haddock quota was imposed on the mixed groundfish fishery around 1970 which led to a reduction in fishing effort and a steep decrease in Cod landings followed in subsequent years (Figure 8). This decrease was further emphasized by the closure of Browns Bank to fishing in March and April of 1970.

Total Allowable Catch (TAC) for Cod in 4X was first set in 1975, but only applied to the offshore portion of 4X, as Browns and LaHave banks were thought to be a discrete stock. However, the impact of this offshore TAC on 4X Cod landings was limited, due to misreporting of catches as adjacent 4X inshore areas which did not have a TAC (Gagne et al. 1983). Following a rapid increase of 4X Cod landings from 1976 to 1981, a TAC of 30,000 t was imposed on the whole 4X management area. This resulted in a spike in misreporting of 4X catches as 5Y in subsequent years (Figure 9). The TAC on 4X Cod was held constant until 1985, when 4X5Y Cod was first assessed as a single stock (Figure 8). Following this assessment, 4X5Y Cod quotas quickly became more stringent, leading to both underreporting of landings and misreporting of landed Cod as other species, particularly in 1987 and 1988 (Campana and Simon 1987, Campana and Hamel 1990). In response, enforcement efforts increased, mandatory weigh-outs were established (1990) and data accuracy improved (Campana and Hamel 1992, Gavaris 1993).

The 1990s were a period of drastic quota changes, increasing to a maximum of 26,000 t in 1991, dropping to 9,000 t by 1995, and decreasing even further after 1997 (Figure 8). Although total fishing effort in 4X5Y declined accordingly across all gear sectors, the decline was concentrated on the Scotian Shelf portion of 4X5Y, with gillnet and otter trawl effort in the Bay of Fundy remaining stable throughout the 1990s (Clark et al. 1998). This redistribution of fishing effort into the Bay of Fundy was attributed to a combination of changing management measures (e.g., area-time closures), the industry's need to balance quotas and an apparent shift in resource distribution (Clark et al. 1998).

A rebuilding strategy was adopted for 4X5Y Cod in 2000, and quota was maintained at 6,000 t for four years (Table 1). Groundfish directed effort (Cod, Haddock and Pollock) for the mobile fleet remained focused on the Bay of Fundy throughout the early 2000s, but shifted almost entirely to Haddock directed trips (Clark and Hinze 2003). Inshore catch rates began to decline in 2003, forcing inshore fixed gear fishermen further offshore, but most other groups continued to catch their quota (Clark and Hinze 2003). Between 2004 and 2008, Cod landings fell well below quota, with many participants targeting other species and reserving Cod quota as bycatch (Clark and Emberley 2009). As quota continued to decrease into the 2010s, the proportion of Cod directed trips (> 50% of landed weight is Cod) in the mixed groundfish fishery decreased across all gear types and Cod became primarily a bycatch species (Figure 10; Table 2). The most recent quota decrease took place in 2014, with TAC reduced by 50% to a total of 1,650 t over two years (2015–2016 and 2016–2017) and this arrangement was renewed for the 2017–2018 and 2018–2019 quota years (Table 1).

HISTORY OF THE 4X5Y ASSESSMENT

The treatment of inshore and offshore Cod stock components in 4X5Y as a single unit for assessment purposes commenced in 1985 (Campana and Simon 1985). The increasing range capability of the fleet made the apportioning of landings to inshore or offshore, on the basis of tonnage class, unreliable. Furthermore, the results from tagging of Cod on Browns Bank in spring suggested substantial mixing between inshore and offshore components, as well as among inshore spawning groups. Consequently, it was felt that separate assessments of

inshore and offshore components of 4X5Y were no longer appropriate (Campana and Simon 1986).

Growth differences between eastern (Scotian Shelf) and western (Bay of Fundy) fish were first incorporated into the 4X5Y stock assessment in 1994 (Clark et al. 1995). Shortly after, a variety of model formulations for the 4X5Y Cod stock were explored, including changes in survey catchability (q), natural mortality (M), and separate assessments for Bay of Fundy and Scotian Shelf stocks, but none seemed to adequately capture the variability in the data (Clark 1997, Clark and Paul 1999). The attempt at modeling two stocks separately showed no significant difference from modeling them together, suggesting that recruitment patterns were very similar in the two areas (Clark 1997). These results may, however, have been confounded by the degree of mixing of Cod between these areas.

Eventually, a single model formulation was accepted (Clark et al. 2000) but displayed a strong retrospective pattern and was rejected in 2003, leaving the 4X5Y stock without a formal assessment model until 2008. Several models investigating a change in survey catchability, change in natural mortality and exclusion of the Individual Transferable Quota (ITQ) survey were again examined during the 2008 assessment (Clark and Emberley 2009). The accepted model assumed no change in survey catchability, estimated an increase in M from 0.2 to 0.76 on older Cod (ages 4+) since 1996, and excluded the ITQ survey from the assessment (Clark and Emberley 2009). Since then, multiple stock status updates have been provided, summarizing DFO Summer Research Vessel and fishery landing data to date (DFO 2016, DFO 2017).

A Recovery Potential Assessment (RPA) for 4X5Y Cod was carried out in 2011 to provide the information and scientific advice required to meet requirements under the Species at Risk Act (SARA). This process used data from the 2008 assessment (1980–2008) and concluded that the 4X5Y stock was in the critical zone (Clark et al. 2015).

FISHERY

Atlantic Cod are captured as part of a multi-species groundfish fishery in NAFO areas 4X and Canadian portion of 5Yb. A recreational fishery for Cod also exists within this management area, but catches are not currently recorded.

DATA QUALITY

As with many fisheries, data quality is a crucial part of the assessment process, and efforts to improve the collection, verification and processing of data are constantly ongoing. Use of pre-1980 catch data is limited to total amounts, as catch sampling prior to 1980 excluded the Bay of Fundy region, rendering any age or size stratification of the catch within the 4X5Y area inaccurate prior to 1980. The institution of Cod quotas in 1982 led to misreporting of catches into NAFO area 5Y, as well as a decrease in the voluntary reporting of landings in a specific region of 4X, causing a spike in landings in 4Xunspecified (4Xu; Figure 9). In general, landings by NAFO sub-area are considered reliable since the institution of mandatory weigh-outs in 1990 (Campana and Simon 1987, Campana and Hamel 1990, Gavaris 1993). The issue of misreporting throughout the 1980s necessitates the assessment of 4X5Y Cod as a single unit; assessing Bay of Fundy and Scotian Shelf Cod separately would require additional work to address misreporting throughout the 1980s, or a time series starting post 1990. Since then, data quality has continuously improved, though anecdotal reports of misreporting of Cod catches were noted throughout 2000 and 2001 (Clark et al. 2002, Clark and Hinze 2003). The extent of the unreported catches was unknown, but they were thought to be considerably less than the reported landings at the time.

FISHERY SAMPLES

The annual age-length key applied to the 4X5Y catch at length has been based on 750+ aged otoliths every year (Table 5). The collected otolith samples are selected for ageing based on having a broad length distribution, timing (quarter) and gear type. The otoliths for 4X5Y Cod have been aged by the same ager since 1988, with ager validation completed annually. The most recent evaluation (2017; 215 otoliths aged) resulted in a 90.7% agreement, with a CV of 2.37% and no indication of bias (Figure 11). The aged samples are aggregated by area and quarter; quarters 1 and 2 (Q1, Q2) do not exhibit distinct differences in age at length and are combined into half 1 (H1; Table 5).

Dockside monitors also sample groundfish trips for length composition of the catch. Length samples are grouped in the same manner as the otolith samples (area, gear and quarter), with small samples (< 50 fish measured) excluded from the analysis. Although efforts are made to achieve representative sampling for all groupings every year, in reality the catch sampling program is not set up for random sampling, so representativeness can be undermined by port sampler availability, proximity to port or even processing plant.

Separation of length and age samples by area is intended to account for growth differences between western (4Xqrs5Yb) and eastern (4Xmno) fish. Cod in 4Xp are considered a mixture of the two stock components and catches, have been historically separated based on a line which roughly follows the 90 fathom depth contour and loosely mirrors the strata used for each area in the RV survey (Figure 1). Fish from shallow water in the eastern part of 4Xp are grouped with the Scotian Shelf landings, while those from deeper waters of 4Xp are grouped with landings from the Bay of Fundy. If currently ongoing genetic studies improve understanding of stock delineation within 4X5Y, the method of splitting catches within 4Xp would need to be revisited.

Separation of length samples by gear is intended to account for differences in size catchability for different gear types (Table 6). In recent years, sampling of the gear types has become more unbalanced, with longline sampling intensity being half that of otter trawl, despite roughly equal proportion of annual landings by each (Table 3). Although efforts to balance port sampling effort by gear type in accordance with relative catches are made, gradual downsizing of the sampling program (e.g., decrease from six full time port samplers to one) make this goal logistically difficult to achieve.

The seasonal length-weight parameters used in deriving catch numbers at age were calculated by Campana and Hamel (1992) from seasonal survey data between 1978 and 1985 (Table 13). These parameters have been used since 1985 and continue to be appropriate, as there is no long-term trend in condition for 4X5Y Cod (Figure 32).

LANDINGS AND CATCH DISTRIBUTION

Historically, Cod have been caught in 4X5Y as part of a multi-species fishery by a variety of fleets using mobile gear (e.g., otter trawl) and fixed gear (e.g., handline, longline and gillnet) (Table 3). Reported bycatch of other species on Cod-directed (> 50% Cod catch by weight) trips was summarized by species, year and major gear type (Table 7, Table 8). For mobile gear, Haddock, Pollock and Winter Flounder have been the prevalent species, with a drastic decrease in Cod directed trips evident in recent years (Table 2, Table 7). For fixed gear, the decrease in Cod directed trips is more gradual, with Haddock, Cusk and Halibut making up the majority of bycatch species (Table 2, Table 8).

Currently, Cod in 4X5Y are landed primarily by the Fixed Gear < 45’ and the Mobile Gear < 65’ fleets, with smaller contributions by the Fixed Gear 45’–65’ (Table 9). Landings by vessels from the other fleets (Fixed Gear > 65’, Mobile > 65’, First Nations and Offshore) do not meet the

Confidentiality Guidelines for Fisheries and Oceans Canada and therefore cannot be reported here individually.

Fixed gear fishing activity takes place mostly between June and December, and has generally been distributed throughout NAFO areas 4Xmnopq (Figure 13). Since 2014, catches of Cod by fixed gear have shifted out of 4Xp, but remain distributed throughout 4Xmnoq (Figure 14). Longline catches take place primarily in shallow waters off the south-western coast of Nova Scotia early in the season, and then expand outward on to the Scotian Shelf as the season progresses (Figure 13). The Pollock-directed gillnet fishery is responsible for the majority of fixed gear Cod catches in 4Xq, occurring mostly in the eastern portion of Jordan Basin throughout July and August (Figure 13). Handline catches have decreased throughout 2000s (Table 3), and currently only occur sporadically throughout the management unit.

Catches of Cod from mobile gear occur year round and are generally constrained to the western portion of the management unit (Georges Basin, Crowell Basin, Jordan Basin and the Bay of Fundy) (Figure 15, Figure 21). Similar to fixed gear, catches of Cod by mobile gear on Browns Bank (eastern portion of 4Xp) have all but disappeared since 2014 (Figure 16).

Historically the proportion of Cod landings from the Scotian Shelf has been greater than those from the Bay of Fundy, but the proportions switched with the redistribution of fishery effort in the late 1990s and early 2000s. More recently, the contributions from the two areas have become equivalent (Table 4; Figure 12). The contribution of landings from 4Xp was relatively low (approximately 10%) during the 1970s and 1980s, but increased steadily to account for 30% of the 4X5Y Cod landings in the late 2000s (Figure 12).

Longline and otter trawl gears tend to catch Cod of similar size, with length frequencies peaking between 50 and 60 cm for both gears across all areas of the 4X5Y management unit (Figure 17). In contrast, gillnet tends to catch larger Cod, reflecting the selectivity of the 5.5” mesh size, with size frequencies peaking between 65 and 70 cm (Figure 17).

CATCH AT AGE

Catch at age for 4X5Y Cod is calculated by applying the seasonal length-weight relationships to port and observer measured length (3cm bin) frequency samples to obtain an estimated weight for each sample. The estimated sample weights are raised to the total commercial landed weight within gear, quarter and area, giving an estimated length frequency for the commercial catch within those groupings. Seasonal age-length keys are then applied to the length frequencies to obtain an age composition for the commercial catch.

Cod landings reported from 4Xu (unspecified area) were split between Scotian Shelf and Bay of Fundy components according to gear type, quarter, year and homeport. Landings reported in NAFO area 4Xp were divided into Scotian Shelf and Bay of Fundy components using their reported location. Historically, the line depicted in Figure 1 has been used to split 4Xp catches, but recent redistribution of fishery catches is increasing the influence of this line. If single stock models are to be applied, alternative methods for delineating the two stocks should be investigated (e.g., genetics). Conversely, a multi-stock model which allows for mixing between the eastern and western fish can be used, assuming the extent of mixing in 4Xp is investigated.

Fishery catch at age (CAA) for Cod in 4X5Y has been undergoing a consistent truncation in age structure since the 1990s, until 2014 when age 6 Cod were barely detectable and ages 8+ were completely absent (Table 14; Figure 18). There has been some reappearance of these older fish in the 2016 CAA, with both the Bay of Fundy and Scotian Shelf fisheries seeing a number of age 6 and 7 fish, but the number of older fish remains very low. The adjacent Cod stock on

Eastern Georges Bank (5Zjm) has experienced a similar trend in fishery CAA (Martin et al. 2017).

Throughout the 2000s, fishery catch was predominantly composed of Cod aged 3 through 5, with small contributions of Age 2 and 6 fish (Table 14; Figure 18). In 2016, however, contributions of Age 2 and 3 fish have decreased substantially on the Scotian Shelf (Figure 19). This drastic disappearance of young fish from the commercial CAA is unusual, as they are still being caught in the Research Vessel (RV) summer survey (Figure 37). Contradictory trends in the commercial and survey CAA can result from a change in the way the fishery is being prosecuted. A geographical redistribution of fishing effort, such as a recent shift out of 4Xp, could avoid grounds with younger fish and reduce their susceptibility to fishing activity. However, this shift occurred in 2014; two years before the disappearance of small fish from the Scotian Shelf CAA. Changes in management measures could also be responsible for diverging trends in commercial and survey CAA, but the most recent reduction in quota (DFO 2017c) were implemented in 2015, not 2016. Finally, a lack of small fish in the fishery CAA could be indicative of discarding and this possibility is examined in the Observer Data section below.

WEIGHT AT AGE

Weights at age (WAA) for commercial landings in 4X5Y have shown divergent trends for different ages. Younger fish (ages 2 and 3) have experienced a steady increase in weights at age throughout the entire time series (Table 15; Figure 20). Given the declining presence of older fish in recent years, commercial fishery weights for fish ages 7 and above were not considered reliable.

Commercial weights at age for ages 4 through 6 decreased between 2003 and 2007, particularly in the Bay of Fundy, and the difference in weight at age between the two regions became notably smaller thereafter (Figure 20). This apparent convergence of weights at age between eastern and western fish becomes more pronounced with age and more closely resembles that of the eastern fish. Although this effect could be caused by a variety of factors (e.g., redistribution of fishery effort, influx of eastern fish into the Bay of Fundy, etc.), the actual cause is likely fishery-dependent, as survey weights at age do not exhibit the same convergence.

OBSERVER DATA

Annual observer coverage for 4X5Y Cod can be calculated based on landings (observed landed weight of Cod / total landed weight of Cod) or trip (number of observed trips landing Cod / total trips landing Cod) for the three observed gear types (i.e., mobile, longline and gillnet) and a total estimate across these gears. Although observed trips can be further subdivided by target species (e.g., Redfish, Cod/Haddock/Pollock, Halibut, etc.), the commercial database does not record this information, limiting the observer coverage estimate for trips catching Cod to broad gear groups. The only exceptions are Redfish and silver hake directed trips, which can be isolated based on a combination of gear type (otter trawl) and mesh size (≤ 60mm for Silver Hake and 65–130 mm for Redfish). Consequently, observer coverage was estimated for all trips within 4X5Y which landed Cod since 2003, and then further split into the following gear categories:

- Mobile gear ≤ 65 mm mesh size; includes Silver Hake directed trips.
- Mobile gear 65–130 mm mesh size; includes Redfish directed trips.
- Mobile gear ≥ 130 mm mesh size; includes Cod/Haddock/Pollock and flatfish directed trips.
- Fixed gear (longline); includes Halibut, White Hake and Cod/Haddock/Pollock directed trips.

- Fixed gear (gillnet); includes White Hake and Cod/Haddock/Pollock directed trips.

Observer coverage for the groundfish fishery remained below 2.5% until 2009, when a three-year Species at Risk Coordination Espèces en Péril (SARCEP) bycatch project enhanced it to 5–7% (Table 10, Table 11). Although coverage across the groundfish fishery returned to low levels immediately following the completion of the SARCEP project, it has steadily increased since then and is currently estimated at 5–7% (Table 10, Table 11). The coverage has been disproportionally higher for the mobile fleet, often doubling that of longline gear for both landings and trips (Table 10, Table 11). Observer coverage of the gillnet fishery remains at 0% in 4X5Y, as priority for coverage within the gillnet fishery is given to the 5Zjm management unit (H. Stone, Observer Program, pers. communication).

The recent disagreement of survey and commercial CAA on abundance of young fish (age 2 and 3), coupled with restrictive Cod quotas, could be indicative of discarding. However, comparison of length frequencies from observed and unobserved trips shows no indication of discarding of small fish since 2012 (Figure 22). A more in-depth analysis investigating the occurrence of discarding in the groundfish fishery would require higher and more representative observer coverage.

DISCARDS

Discarding of Cod from the groundfish fishery is not permitted, and no discard estimate is routinely calculated or reported. Clark et al. (2015) estimated discards for a variety of species caught in the groundfish, Redfish and Sculpin fisheries, but these estimates were intended for broad comparisons across fisheries and years, and not as conclusive discard values. In addition, apparent reporting of Cod discards on observed trips in a fishery, where discarding of Cod is illegal, points to possible inconsistencies in what constitutes a discard. Low and often unrepresentative observer coverage, coupled with decreasing Cod abundance, continue to be the main hurdle for assessing the occurrence of discards in the 4X5Y groundfish fishery (Gavaris et al. 2010, Clark et al. 2015).

Cod are a demersal species, and would therefore be expected to interact with most fisheries using bottom gear in 4X5Y. However, observer coverage for these fisheries is either absent, too low or not representative, rendering discard estimates unreliable (Gavaris et al. 2010). Attempts to augment observer coverage for three principal 4X5Y fisheries (groundfish, inshore Scallop and Lobster) through a SARCEP program took place between 2008 and 2011. For the inshore Scallop fishery this resulted in observer coverage in Scallop Fishing Area (SFA) 28 for the first time, and a slight increase in existing coverage in SFA 29W (Figure 23), though the combined coverage for these areas was still relatively low (3.7% and 4.2% in 2008 and 2009, respectively; Sameoto and Glass 2012). For the Lobster fishery, the augmented observer coverage under the SARCEP program amounted to 0.2% of landings observed in Lobster Fishing Areas (LFA) 33 and 34 over two years, with substantial concerns raised about the quality of the data being collected (Figure 24; DFO 2011, DFO 2017, Pezzack et al. 2014). Cod discards have also been recently estimated for the 4X portion of LFA 41, which covers the shelf edge portion of 4Xn and 4Xp, but concerns regarding the bias of the observer coverage remain (Cook et al. 2017). Cod discard estimates from the principal 4X5Y fisheries above are summarized in Table 12, but use of these values for anything but broad comparisons across fisheries is not advised.

Despite several attempts to bridge knowledge gaps identified by Gavaris et al. (2010), insufficient levels of observer coverage and lack of systematic, unbiased sampling continue to be the major impediments to quantifying the magnitude of Cod bycatch in non-groundfish fisheries. Substantial, unaccounted-for removals from a population would be problematic for

most assessment models, so model-based ways of accounting for unreported sources of fishing mortality will be explored during the 4X5Y Cod modeling framework (Fall 2018).

SURVEY

The annual bottom trawl Research Vessel (RV) survey has been conducted since 1970 and covers a substantial portion of the 4X5Y Cod management unit. Survey coverage is restricted to depths of > 15 fathoms in Bay of Fundy and > 50 fathoms off southern Nova Scotia, except for an area north of Browns Bank, which is not surveyed due to un-trawlable bottom. The survey is based on a stratified random sampling design, with 244 stations allocated to 57 strata. The survey uses a bottom trawl with a 19mm Cod end liner and samples both fish and invertebrates for distribution, abundance, biological condition and stomach contents within the 4VWX5 area. Sampling is generally conducted during the summer season (June–August), but periodical spring sampling (February–March) has taken place in 4X5Y as well. Additional detail on survey coverage and sampling is available in DFO 2016.

The RV survey has undergone several vessel and gear changes throughout the time series, but problems during comparative fishing between RV Lady Hammond to the RV Alfred Needler in 1983 and uncertainties about the relative fishing power of the two vessels resulted in unreliable Cod conversion factors (Clark and Brown 1996, Mohn 1999). Without reliable conversion factors, abundance and biomass trends prior to 1983 are not comparable to subsequent years and have therefore been excluded from population models of 4X5Y Cod. Fish biology data (e.g., condition, maturity, etc.) are independent of vessel effects and can continue to be reliably compared throughout the survey time series (1970+).

The Individual Transferable Quota (ITQ) Survey conducted by Industry vessels took place between 1996 and 2011, and consisted of a fixed station design (Claytor et al. 2014). In general, the ITQ survey had higher coverage of inshore areas along the coast of Nova Scotia, but less coverage along the New Brunswick coastline or within deeper waters along the Scotian Shelf. Following several in-depth evaluations of the ITQ survey data, it was concluded that data from this survey did not improve model fit or change the current perception of stock dynamics, so it continues to be excluded from 4X5Y stock assessments (Clark and Emberley 2009, Claytor et al. 2014).

DISTRIBUTION OF CATCHES

Prior to 1994, catches of Cod from the RV summer survey were distributed throughout the Bay of Fundy, across the southern portion of the Scotian Shelf and along the Shelf edge (Figure 25). This spatial distribution persisted into the 2000’s, though a general decrease in weight per tow of Cod was seen in all areas (Figure 26).

Since 2005, some notable shifts in summer distribution have become evident. Cod in the Bay of Fundy, previously distributed throughout the entire Bay area, have receded away from the coast and are now found primarily in deeper waters at the mouth of the bay, between Grand Manan and Digby Neck (Figure 27). Cod along the Scotian Shelf have all but disappeared from the Shelf edge, and are now concentrated almost exclusively on the banks (e.g., Browns, Lahave, Roseway, Baccaro, etc.) (Figure 27).

LENGTH FREQUENCIES

Since the 2008 assessment, catches at length of Cod from the RV survey have generally been below the long-term mean for all years and areas, except for fish below 20 cm which were at or above the long term mean (Figure 28, Figure 29). The abundance of small fish (< 10 cm) was particularly notable in 2013, with both the Bay of Fundy and Scotian Shelf components showing signs of a strong incoming year class. Interestingly, similar trends were noted for the 4X5Y Haddock stock, with the 2013 year class moving on to become the strongest on record for that stock (DFO 2017g). Unlike Haddock, however, the initial signs of strong recruitment for Cod did not materialize as high abundances of larger fish in subsequent years (Figure 28, Figure 29).

Another notable occurrence since the last assessment was an unusually high abundance at most lengths of eastern fish in 2009 (Figure 29). As this high abundance did not persist in subsequent years and no biological or environmental explanation could be found, it was attributed to a survey year effect.

WEIGHT AT AGE, SIZE AT AGE AND CONDITION

Weights at age (WAA) of Cod from the RV summer survey highlight the known divergence in growth rates between the two areas (Figure 30). Younger fish (ages 1 through 4) continue to exhibit the divergence in weight at age by region, with western fish experiencing a steady increase in weight at ages 1, 2 and 3 throughout the 2000s (Figure 30). A similar trend in the commercial weights at age indicates that the two population components continue to exist with relatively little mixing of younger fish between the regions (Figure 20). In contrast to the commercial catch, weights at age for four year old fish caught on the survey do not converge throughout the 2000s, indicating that rates of mixing have not changed substantially between the two components (Figure 20, Figure 30). The intermittent presence of ages 5+ in the survey catch, particularly for the Bay of Fundy region, makes it difficult to discern trends on older fish.

Lengths at age for 4X5Y Cod from the RV summer survey are stable for both regions, with increased inter-annual variability on older fish in recent years, due to their decreasing abundance (Figure 31). Lack of discernible trend in lengths at age over the whole time series also underlines the consistency of ager performance for this stock since 1970.

Average Fulton's K, a measure of fish condition calculated as weight over length cubed, has generally been higher for western fish than for those from the Scotian Shelf (Figure 32). Throughout the time series, this measure of condition seems to fluctuate without trend within both stock components (Figure 32). Since trends in Fulton's K throughout the time series could be obscured by significant changes in age structure within each stock component, an alternative measure of condition was also calculated by dividing the average weight at length for a given year by the average weight at length for all years (Figure 33). No obvious changes in condition at size were evident throughout the time series.

MATURITY

Maturity data for 4X5Y Cod come exclusively from the RV spring survey, as Cod are not sampled for maturity during the summer cruises for logistical reasons. In addition, the spatial coverage of the spring survey was limited to NAFO area 5Z (Georges Bank) in the late 1980s, effectively excluding 4X5Y from the spring survey altogether. Although coverage expanded again in 2008 to include areas outside of 5Z, coverage of NAFO 4X5Y has been sporadic as Georges Bank remains the area of priority for the spring cruise. Consequently, the maturity data for 4X5Y Cod is intermittent, and had to be grouped into two broad time periods (pre and post 2000) to obtain a sufficient sample size for analyses (Table 18).

Length at 50% maturity has decreased slightly within the 4X5Y management area, dropping from 43 cm to 37–39 cm for both stock components (Figure 34). Age at 50% maturity shows a slight decrease as well, dropping from 2.5 to 2.2 years in the Bay of Fundy and from 3 to 2.8 years on the Scotian Shelf (Figure 35). In both cases, the age at 50% maturity remains between 2 and 3 years of age, so use of ages 3 and older as spawning stock biomass remains appropriate for this stock.

INDICES OF ABUNDANCE AND BIOMASS

The total biomass index for 4X5Y Cod has been steadily declining since the 1990s, but appears to have stabilized at a low level since 2010 (Figure 36). This trend is seen in both areas of the management unit, though the Bay of Fundy has experienced a steeper rate of decline than the Scotian Shelf (Figure 36).

Similar to commercial CAA, survey catch at age in 4X5Y shows a progressive truncation of the age structure, beginning in the mid-1990s and reaching a low in 2013 and 2014 (Table 17, Figure 37). In these two years, the oldest fish caught on the survey were 5 years old on the Scotian Shelf and 4 years old in the Bay of Fundy (Table 16; Figure 38). Since then, Cod aged 6 through 9 have begun reappearing in the survey catch on the Scotian Shelf, while the Bay of Fundy continues to only see fish aged 1 through 5.

The survey catch at age has tracked periodical large year classes throughout the time series, though the signals appear stronger in the Bay of Fundy catch at age (Figure 38). The frequency of large year classes has decreased substantially in the latter half of the time series, with only one (2001) detected since 1995 (Figure 38). Indices at all other ages show large inter-annual variation and have all decreased in the latter half of the time series (Figure 39, Figure 40). Abundances of age 2 Cod in the recent survey CAA is at historical lows (Table 16).

The stock-recruitment relationship for 4X5Y Cod is not particularly strong (Figure 41), implying that additional factors (e.g., prey abundance, temperature, etc.) may play a role in determining recruitment. The stock-recruitment relationship for 4X5Y Cod should be derived in concurrence with factors identified in the ecosystems consideration analyses (see Ecosystem Considerations).

ESTIMATES OF RELATIVE AND TOTAL MORTALITY

The relative fishing mortality (catch biomass / RV summer survey biomass) for 4X5Y Cod decreased along with the steep quota reductions implemented throughout the 1990s (Figure 42). Since then, it has remained relatively stable across the management unit, aside from a brief increase in the mid-2000s. Changes in relative fishing mortality within 4X5Y are driven almost entirely by changes within the Scotian Shelf area, as relative fishing mortality in the Bay of Fundy has remained stable until the most recent three years (Figure 42). The latest round of quota reductions in 2015 has resulted in some of the lowest relative fishing mortalities on record (Figure 42).

Estimating total mortality (Z) on groups of ages for 4X5Y Cod is complicated by the persistent truncation in age structure. Given the intermittent presence of age 6+ fish in the survey catch since 2010 and high inter-annual variability, total mortality was calculated across ages 2, 3 and 4 as a running five-year average for each region (Figure 43). Total mortality on ages 2–4 increased throughout the early 2000s, and has remained at a high level since then; an increase more prominent in the Bay of Fundy than on the Scotian Shelf (Figure 43). Total mortality on older fish (ages 5+) is high across the management unit, as evident by their persistent absence and low abundance in the survey catch.

A high level of total mortality accompanied by unchanging or low relative mortality, as is the case in the Bay of Fundy, indicates that something other than reported landings is causing the disappearance of fish from the western component of 4X5Y. Similarly, recent changes in relative fishing mortality without complementary changes in total mortality, as is the case for the Scotian Shelf, indicates that reported landings are not the only driving force in current population dynamics, including the recent reappearance of older fish. In both cases, factors other than reported landings which could influence the disappearance and reappearance of fish from NAFO areas 4X5Y must be investigated (e.g., changes in catchability, unaccounted for fishing mortality, increases in natural mortality, etc.).

ECOSYSTEM CONSIDERATIONS

Past assessments of 4X5Y Cod have attempted to account for changes in population trends by examining biology, abundance and distribution of Cod. However, Cod are part of a complex ecosystem and changes to their population structure are inevitably linked to bottom-up or top-down ecosystem processes (e.g., predator abundance, food availability, temperature, etc.). Identifying which of these processes are correlating with dynamics of Cod populations, and deriving associated indicators, are an important step towards implementing an Ecosystem Approach (EA) to fisheries management (Bundy et al. 2017).

For the purposes of this document, a suite of indicators falling into three basic groups were identified: Cod prey, Cod predator and environmental factors. Although many other trophic linkages exist within an ecosystem context, these were the only ones considered at this time. The selected indicators can be correlated with a number of Cod population trends, including abundance of juveniles, spawning stock biomass and condition of Cod in 4X5Y following the method presented by Gomez and Bundy (2017). The relevant ecosystem factors and availability of their respective indices are summarized below.

COD PREY

Cod are generalist feeders and prey preferences vary by life stage and prey availability (Kohler and Fitzgerald 1969, Daan 1973, Waiwood et al. 1980, Langton and Bowman 1980, Rose and Leggett 1989, McLaren and Avendano 1995, Methven 1999, Link and Garrison 2002, Savenkoff et al. 2006). Larval Cod are known to feed on zooplankton, with several species of copepods (*Pseudocalanus* and *Paracalanus* sp) identified as primary prey along the western portion of Scotian Shelf (McLaren and Avendano 1995, McLaren et al. 1997). Johnson et al. (2017) provide abundance indices for copepod nauplii and *Pseudocalanus* sp along the western Scotian Shelf (Figure 44).

Major prey species for juvenile (< 37cm) and adult (≥ 37cm) Cod in 4X5Y were identified by summarizing stomach data collected on the RV summer survey between 1999 and 2016 (Table 19). The size division (37cm) was based on the most recent (post-2000) length at maturity for Scotian Shelf, as it is the lower of the two area-specific values within 4X5Y (Figure 34). Diet of juvenile Cod consisted primarily of krill (Euphausiidae), sand lance (Ammodytidae) and decapods (shrimp and crab). Although some preliminary work has been done to describe relative distributions of krill and sand lance in 4X5Y, no reliable index of abundance exists (DFO 1996, DFO 1996b, Plourde et al. 2016). Similarly, none of the identified shrimp and crab species have a reliable index of abundance for the Bay of Fundy and western Scotian Shelf areas (Table 19).

Prey preferences of adult Cod collected on the RV summer survey comprised of Herring (*Clupea harengus*), Crabs (Cancer sp.) and Silver Hake (*Merlucciidae bilinearis*) (Table 19). The 4VWX Herring assessment contains acoustic indices of SSB for several spawning components

within the Bay of Fundy and along the eastern Scotian Shelf (i.e., Scots Bay, German Bank, Trinity Ledge and Little Hope/Port Mouton, Figure 45; DFO 2017b). Juvenile migratory Herring are caught as part of an inshore weir fishery at the mouth of the Bay of Fundy, but no biomass estimate exists and landings are not considered indicative of abundance due to confounding changes in effort (DFO 2015). Silver Hake is assessed across 4VWX using a biomass index from the RV Survey, so an index of abundance can be generated exclusively for 4X. Similar to juvenile prey, no reliable index of abundance exists for the identified crab species (Table 19).

COD PREDATORS

Cod are preyed upon by a wide variety of marine species, ranging from invertebrates and fish (including larger Cod), to Seals, Whales and seabirds (Palsson 1994, Link et al. 2009, Savenkoff et al. 2006). An examination of stomach content data (1999–2016) from the RV survey found only 38 samples contained identifiable Cod remains, with Atlantic Cod, Halibut, Sea Raven and Monkfish as the main predators. Several attempts to quantify the contribution of Grey seals to natural mortality in Cod on the Scotian Shelf have come up with contradicting conclusions, depending on the method applied (Mohn and Bowen 1996, Fu et al. 2001, Bundy and Fanning 2005, Trzcinski et al. 2006, O'Boyle and Sinclair 2012). For the purposes of this analysis, indicators of predator abundance for juvenile Cod were limited to adult Cod, Halibut and Monkfish (Figure 46; DFO 2017e, DFO 2017h), while those of adult Cod included Halibut, Monkfish and Grey Seals (Figure 47; DFO 2017g, DFO2017e, Hamill et al. 2017). In both cases, the list of predators can be expanded as the work investigating trophic linkages relevant to Atlantic Cod in 4X5Y continues.

ENVIRONMENTAL INDICATORS

The Atlantic Zone 4 Monitoring Program (AZMP) provides a variety of environmental indicators across the Scotian Shelf and Gulf of Maine (Johnson et al. 2017, DFO 2017f, DFO 2018). The following indicators were chosen for preliminary analysis based on literature review (Planque and Fredou 1999, Clark et al. 2003, Beaugrand and Kirby 2010, Olsen et al. 2011). The authors acknowledge that this list is limited and additional indicators can be added as the work progresses:

- Bottom temperature – Mean anomaly in bottom temperature across NAFO unit 4X, between 100m and 1000m depths (Figure 48; DFO 2018)
- Mean surface temperature – Mean annual anomaly for 4X Scotian Shelf and 4X eastern Gulf of Maine/Bay of Fundy (Figure 49; DFO 2017f)
- Chlorophyll and Bloom parameters: Initiation, Duration (days), Amplitude and Magnitude (Figure 50; DFO 2017f, DFO 2018)

OTHER CONSIDERATIONS

Notable trends in abundance of other demersal and forage fish along the Scotian Shelf and the Bay of Fundy can be considered as well. For example, despite no apparent recovery in Cod stocks, biomass of Haddock, Halibut, Silver Hake and Redfish along the Scotian Shelf are at record levels (DFO 2015, DFO 2016, DFO 2017e, DFO 2017g).

Cod are part of a complex ecosystem and a wide range of indicators can be considered within the scope of this stock assessment. The current work aims to identify changes in the ecosystem indicators relevant to 4X5Y Cod, working towards implementing an ecosystem approach to management of groundfish fisheries in the Maritime Region. Although this work is still in progress, substantial data gaps have already been identified for some elementary ecosystem

components (i.e., lack of information on Seal and Cod diet, no reliable indicators for Sandlance, Crabs and larval Cod), and these gaps will need to be addressed before an effective ecosystem approach can be implemented.

CONCLUSIONS

STOCK STRUCTURE, HISTORY OF FISHERY AND ASSESSMENT

- Although assessed together, Cod in the Bay of Fundy (NAFO areas 4Xqrs5Yb) and Scotian Shelf (NAFO areas 4Xmno) areas of the management unit exhibit distinctly different growth rates, with western fish (Bay of Fundy) growing faster than those from the east (Scotian Shelf). Fish caught in NAFO area 4Xp consistently exhibit growth characteristics of both regions and the area is considered a mixing zone within 4X5Y.
- Spawning is distributed geographically throughout the 4X5Y area and occurs in the spring and in the fall. Lack of recent, detailed information on spawning events, particularly in the fall, represents a major data gap for interpreting the stock structure of Cod within the 4X5Y management unit.
- In general, a two stock component structure within 4X5Y seems to persist, with a mixing area in 4Xp and some movement taking place between adjacent management areas. Additional work, particularly in the field of genetics, would be highly beneficial in improving understanding of the Cod population structure in this area.
- A concentration of fishing effort in one area of 4X5Y could lead to overexploitation of a single spawning component, while leaving the other unharmed. Management of the fishery should be conducted in a fashion which aims to avoid over-exploitation in any part of the 4X5Y stock area.

COMMERICIAL FISHERY

- Use of pre-1980 catch data is limited to total amounts, as catch sampling prior to 1980 excluded the Bay of Fundy region, rendering any age or size stratification of the catch within the 4X5Y area inaccurate prior to 1980.
- The issue of misreporting of catches between sub-units of 4X and 5Y throughout the 1980s necessitates the assessment of 4X5Y as a single unit; assessing Bay of Fundy and Scotian Shelf Cod separately would require additional work to address misreporting throughout the 1980s, or a time series starting post 1990.
- Fishery catch at age (CAA) for Cod in 4X5Y has been undergoing a consistent truncation in age structure since the 1990s, until 2014 when age 6 Cod were barely detectable and ages 8+ were completely absent. There has been some reappearance of these older fish in the 2016 CAA, but the number of older fish remains very low.
- Commercial weights at age have shown varying trends throughout the time series, but these changes are likely fishery-dependent, as survey weights at age do not exhibit the same trends.

OBSERVER COVERAGE AND BYCATCH

- Observer coverage of the groundfish fishery has steadily increased since 2013 and is currently estimated at 5–7%.

- Despite several attempts to bridge knowledge gaps identified by Gavaris et al. (2010), insufficient levels of observer coverage and lack of systematic, unbiased sampling continue to be the major impediments to quantifying the magnitude of Cod bycatch in non-groundfish fisheries.

RESEARCH VESSEL SURVEY

- Cod in the Bay of Fundy, previously distributed throughout the entire Bay area, have receded away from the coast and are now found primarily in deeper waters at the mouth of the bay, between Grand Manan and Digby Neck. Cod along the Scotian Shelf have all but disappeared from the Shelf edge, and are now concentrated almost exclusively on the banks (e.g., Browns, Lahave, Roseway, Baccaro, etc.).
- Trends in weight at age (WAA) indicate that the two population components continue to exist with relatively little mixing of younger fish between the regions. Lengths at age and condition for 4X5Y Cod from the RV summer survey are stable for both regions.
- Age at 50% maturity has decreased slightly within the 4X5Y management area, but remains between 2 and 3 years of age, so use of ages 3 and older as spawning stock biomass remains appropriate for this stock.
- The total biomass index for 4X5Y Cod has been steadily declining since the 1990s, but appears to have stabilized at a low level since 2010. This trend is seen in both areas of the management unit, though the Bay of Fundy has experienced a steeper rate of decline than the Scotian Shelf.
- Survey catch at age in 4X5Y shows a progressive truncation of the age structure, reaching an all-time low in 2013 and 2014. Since then, older Cod have begun reappearing in the survey catch on the Scotian Shelf, while the Bay of Fundy continues to only see fish aged 1 through 5.
- Changes in relative fishing mortality within 4X5Y are driven almost entirely by changes within the Scotian Shelf area, as relative fishing mortality in the Bay of Fundy has remained stable until the most recent three years. The latest round of quota reductions in 2015 has resulted in some of the lowest relative fishing mortalities on record.
- Total mortality on ages 2–4 increased throughout the early 2000s, and has remained at a high level since then; an increase more prominent in the Bay of Fundy than on the Scotian Shelf. Total mortality on older fish (ages 5+) is high across the management unit, as evident by their persistent absence from the survey catch.

ECOSYSTEM CONSIDERATIONS

- Cod are part of a complex ecosystem and a wide range of indicators can be considered within the scope of this stock assessment. The current work aims to identify changes in the ecosystem indicators relevant to 4X5Y Cod, working towards implementing an ecosystem approach to management of groundfish fisheries in the Maritime Region. Although this work is still in progress, substantial data gaps have already been identified for some elementary ecosystem components (i.e., lack of reliable indicators for Sandlance, Crabs and larval Cod), and these gaps will need to be addressed before an effective ecosystem approach can be implemented.

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TABLES

Table 1. Monthly landings for NAFO Division 4X5Y Cod. Zeroes indicate < 0.5t landings; dashes indicate no landings.

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Unknown	Calendar year	Fishing year	TAC
1960	119	428	235	388	1,565	1,329	2,924	1,365	1,703	934	662	417	-	12,069	-	-
1961	225	298	246	597	964	2,324	2,527	1,397	1,250	1,299	880	416	-	12,423	-	-
1962	63	108	363	904	1,181	1,984	3,473	1,846	1,988	1,157	926	556	-	14,549	-	-
1963	309	122	309	577	1,564	2,896	2,570	2,660	1,933	1,714	777	359	-	15,790	-	-
1964	474	320	832	1,690	1,727	3,182	3,592	2,856	2,417	2,362	899	367	349	21,067	-	-
1965	392	367	1,229	1,881	2,603	3,724	4,694	2,634	2,708	2,377	927	685	-	24,221	-	-
1966	911	755	838	2,061	2,034	3,419	4,299	3,323	2,555	2,470	910	588	-	24,163	-	-
1967	874	823	820	1,462	2,304	5,155	4,210	4,052	3,334	2,962	1,304	513	-	27,813	-	-
1968	871	1,107	1,406	2,377	3,121	5,009	4,952	4,116	2,742	3,037	1,328	774	-	30,840	-	-
1969	1,876	1,694	1,071	1,845	2,160	4,176	3,722	2,797	1,943	1,483	827	518	-	24,112	-	-
1970	805	500	617	970	2,024	2,745	2,775	2,279	1,969	1,874	921	541	-	18,020	-	-
1971	526	848	584	814	1,725	3,939	3,328	2,483	2,487	1,902	1,110	555	-	20,301	-	-
1972	862	633	473	744	1,258	3,832	3,982	2871	2038	2663	925	250	-	20,531	-	-
1973	1,009	925	514	1,056	1,381	3,919	2,937	2,623	2,264	1,544	818	1,001	-	19,991	-	-
1974	771	397	399	695	1,335	3,583	3,150	2,538	1,968	1,765	877	1,464	-	18,942	-	-
1975	648	169	394	712	3,223	3,250	3,355	2,647	1,796	1,457	668	1,267	-	19,586	-	-
1976	363	555	376	581	1,220	2,824	2,869	2,064	1,968	1,399	782	1,140	-	16,141	-	-
1977	580	940	861	1,580	2,232	3,782	3,366	2,444	1,740	2,048	1,443	973	-	21,989	-	-
1978	862	2,042	911	1,371	1,987	3,411	3,379	2,920	2,454	1,473	1,085	1,828	-	23,723	-	-
1979	889	752	1,973	1,400	1,846	4,276	3,638	3,555	3,218	2,233	2,992	1,935	-	28,707	-	-
1980	706	2,188	1,704	2,485	3,317	5,316	3,433	3,346	2,603	2,876	1,547	1,756	-	31,277	-	-
1981	1,649	2,451	2,529	1,533	2,881	4,093	3,845	4,067	2,253	3,119	1,728	1,373	-	31,521	-	-
1982	757	2,390	2,569	1,491	3,415	5,109	4,734	3,258	3,540	2,890	1,244	1,737	-	33,134	-	30,000
1983	1,713	1,654	1,648	1,888	2,743	5,713	4,554	2,832	3,183	1,787	1,037	719	-	29,471	-	30,000
1984	1,798	2,021	752	817	1,796	3,471	3,688	4,567	2,773	1,668	1,201	976	-	25,528	-	30,000
1985	779	1,699	956	1,268	1,974	2,586	3,199	2,650	2,737	1,801	787	1,063	-	21,499	-	30,000
1986	904	1,633	1,775	1,450	1,437	1,939	2,739	1,995	2,576	1,714	771	1,107	-	20,040	-	20,000
1987	1,208	1,837	1,242	1,059	1,870	2,778	2,663	1,821	1,679	1,403	910	535	-	19,005	-	18,000
1988	2,104	1,531	535	939	1,620	2,931	3,104	2,122	2,524	1,441	636	1,050	-	20,537	-	16,000
1989	2,150	2,347	1,362	1,707	1,292	3,562	1,830	1,772	1,535	1,278	637	413	-	19,885	-	13,000
1990	2,619	2,027	707	778	1,560	3,104	3,751	3,123	2,598	1,689	1,158	790	-	23,904	-	22,000
1991	2,023	2,651	993	1,666	2,322	3,167	3,963	2,881	2,967	2,208	1,650	1,258	-	27,749	-	26,000
1992	2,088	1,740	1,297	1,502	1,685	3,622	3,366	2,803	2,625	2,353	1,478	1,521	-	26,080	-	26,000
1993	657	903	994	996	1,617	2,312	2,834	2,221	1,804	1,048	562	78	-	16,026	-	16,000

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Unknown	Calendar year	Fishing year	TAC
1994	734	972	547	847	824	1,771	2,246	1,503	1,267	1,154	726	454	-	13,045	-	14,000
1995	610	229	317	827	574	1,236	1,771	774	1,071	521	276	561	-	8,767	-	9,000
1996	503	331	446	531	819	1,755	1,805	1,317	880	887	679	619	-	10,572	-	11,000
1997	98	362	378	806	644	1,440	1,779	1,382	1,548	1,424	710	668	--	11,239	-	13,000
1998	285	348	402	313	512	955	1,290	978	1,150	793	528	729	-	8,283	-	9,300
1999[1]	186	105	124	331	416	1,056	1,296	868	872	479	333	239	-	6,304	7,330	7,910
2000	215	255	556	113	368	906	1,104	755	545	507	324	107	-	5,755	5,834	6,000
2001	361	103	641	315	449	745	870	672	594	470	318	169	-	5,707	5,908	6,000
2002	376	278	561	624	493	677	841	744	567	360	230	141	-	5,893	5,817	6,000
2003	296	160	685	289	475	442	565	776	800	569	401	209	-	5,668	5,399	6,000
2004	118	224	529	451	513	432	641	569	593	424	245	271	-	5,010	4,857	6,000
2005	194	289	235	351	281	245	457	583	445	437	315	289	-	4,121	3,850	5,500
2006	229	68	150	68	118	357	658	626	647	364	335	79	-	3,700	3,712	5,000
2007	77	100	282	140	196	372	593	661	526	394	259	190	-	3,790	3,937	5,000
2008	146	210	250	279	150	269	488	548	641	736	319	96	-	4,132	4,064	5,000
2009	119	182	238	92	220	211	446	480	560	420	186	30	-	3,183	2,947	3,000
2010	66	81	155	162	251	333	447	572	413	283	131	70	-	2,964	2,864	3,000
2011	58	67	78	47	75	158	198	187	224	209	119	29	-	1,448	1,423	1,650
2012	45	71	61	46	93	88	186	205	183	156	120	60	-	1,315	1,202	1,650
2013	30	14	21	39	48	212	239	206	143	140	67	22	-	1,181	1,212	1,650
2014	25	33	37	55	164	140	123	194	219	112	55	21	-	1,177	1,207	1,650
2015	11	39	76	53	76	49	82	97	89	80	42	13	-	705	675	825[2]
2016	25	30	41	33	110	60	43	94	106	70	82	23	-	716	736	825[2]
2017	20	42	53	49	81	61	48	111	129	121	66	8	-	790	675[3]	825[2]

[1]Switch from Calendar Year to Fishing Year. 1999 Fishing Year landings are from January 1, 1999 to April 1, 2000.
[2]Quota is 1650 mt over two years.
[3]Preliminary number as Fishing Year is not complete. Data pulled December 2017.

Table 2. Number of all groundfish trips, Cod-directed trips and percent Cod-directed of total groundfish trips by gear and year. Groundfish trips were identified based on using a groundfish licence (licence_species 199). A trip is considered Cod-directed if Cod makes up > 50% of the landings by weight.

Calendar Year	Otter Trawl			Longline			Gillnet			Handline		
	Total Trips	Cod Directed Trips	%	Total Trips	Cod Directed Trips	%	Total Trips	Cod Directed Trips	%	Total Trips	Cod Directed Trips	%
2002	2175	105	4.8%	4146	812	19.6%	1374	367	26.7%	1463	887	60.6%
2003	2119	67	3.2%	3607	846	23.5%	1392	491	35.3%	748	386	51.6%
2004	1874	123	6.6%	3452	650	18.8%	1280	362	28.3%	681	319	46.8%
2005	1715	126	7.3%	3285	568	17.3%	1192	185	15.5%	423	175	41.4%
2006	1428	75	5.3%	3875	723	18.7%	1269	170	13.4%	275	60	21.8%
2007	1557	88	5.7%	3877	664	17.1%	1161	173	14.9%	111	44	39.6%
2008	1118	68	6.1%	3215	768	23.9%	1123	152	13.5%	90	54	60.0%
2009	1271	23	1.8%	2126	543	25.5%	915	67	7.3%	70	47	67.1%
2010	1069	40	3.7%	1692	343	20.3%	854	56	6.6%	91	62	68.1%
2011	1069	7	0.7%	1504	173	11.5%	641	22	3.4%	52	22	42.3%
2012	1095	6	0.5%	1597	76	4.8%	558	3	0.5%	34	8	23.5%
2013	926	18	1.9%	1636	61	3.7%	252	2	0.8%	24	5	20.8%
2014	674	13	1.9%	1455	122	8.4%	259	4	1.5%	31	13	41.9%
2015	618	1	0.2%	1410	67	4.8%	236	1	0.4%	29	5	17.2%
2016	761	1	0.1%	1370	49	3.6%	265	1	0.4%	42	4	9.5%
2017	757	2	0.3%	1508	64	4.2%	232	0	0.0%	17	2	11.8%

Table 3. Canadian landings of Cod in NAFO Division 4X (and the Canadian portion of 5Yb) by gear and tonnage class. Zeroes indicate < 0.5t landings; dashes indicate no landings.

Year	Otter Trawl						Gillnet			Long Line				Hand Line	Misc.	Total
	0&1	2	3	4	5+	Total	0&1	2&3	Total	0&1	2	3+	Total	Total		
1953	27	87	53	3	-	170	-	-	-	-	-	-	-	-	12,884	13,054
1954	34	113	17	7	-	171	-	-	-	-	-	321	321	-	13,914	14,406
1955	51	121	6	10	-	188	-	-	-	-	-	271	271	-	12,973	13,432
1956	118	104	42	4	-	268	-	-	-	-	376	414	790	-	13,791	14,849
1957	240	173	143	-	-	556	-	-	-	-	1,777	370	2,147	-	10,916	13,619
1958	240	314	127	52	-	733	-	-	-	1	1,197	591	1,789	-	8,581	11,103
1959	552	565	234	-	-	1,351	-	-	-	-	1,182	608	1,790	-	9,725	12,866
1960	578	426	229	10	-	1,243	1	-	1	2,740	1,007	497	4,244	4,802	1,833	12,123
1961	505	735	390	12	-	1,642	520	-	520	2,269	1,502	597	4,368	4,661	1,232	12,423
1962	565	1,007	971	410	-	2,953	645	-	645	2,883	1,337	456	4,676	4,571	1,811	14,656
1963	258	877	1,159	1,414	-	3,708	748	-	748	2,839	1,021	398	4,258	5,417	1,660	15,791
1964	457	1,384	1,510	4,063	-	7,414	750	-	750	2,672	1,151	677	4,500	5,403	2,700	20,767
1965	466	1,758	2,320	7,857	-	12,401	765	-	765	3,502	885	564	4,951	-	6,104	24,221
1966	284	2,023	3,064	7,222	72	12,665	851	-	851	3,733	513	702	4,948	-	5,700	24,164
1967	269	2,359	3,376	7,281	1,483	14,768	1,847	-	1,847	3,027	373	940	4,340	5,205	1,653	27,813
1968	253	2,245	3,684	7,596	3,111	16,889	1,856	0	1,856	3,482	479	806	4,767	5,766	1,562	30,840
1969	207	1,385	2,448	4,298	3,721	12,059	926	0	926	3,554	513	681	4,748	4,446	1,933	24,112
1970	158	1,151	1,529	1,960	1,259	6,057	653	0	653	4,171	515	768	5,454	3,444	2,410	18,018
1971	81	1,097	1,611	1,799	1,220	5,808	546	4	550	5,472	691	1,575	7,738	4,421	1,783	20,300
1972	121	1,235	1,635	2,246	1,371	6,608	1,187	0	1,187	6,119	668	1,174	7,961	3,128	1,646	20,530
1973	100	1,214	1,232	1,350	553	4,449	669	0	669	7,407	1,048	1,641	10,096	3,672	1,105	19,991
1974	128	1,433	1,310	575	577	4,023	1,851	0	1,851	6,834	1,400	1,096	9,330	3,247	490	18,941
1975	129	2,666	1,298	460	601	5,154	1,482	27	1,509	6,013	1,600	781	8,394	2,526	2,001	19,584
1976	82	1,025	1,263	436	896	3,702	2,403	167	2,570	4,828	1,067	760	6,655	2,690	525	16,142
1977	298	1,972	2,909	527	1,065	6,771	2,052	79	2,131	6,151	1,831	907	8,889	2,943	1,254	21,988
1978	615	1,805	2,573	745	1,731	7,469	2,562	96	2,658	6,904	2,216	1,149	10,269	2,059	1,264	23,719
1979	663	1,749	2,744	1,139	1,405	7,700	3,527	116	3,643	7,517	2,051	862	10,430	4,140	2,770	28,683
1980	1,322	2,769	4,284	1,042	2,037	11,454	2,683	61	2,744	8,356	2,360	898	11,614	4,198	1,267	31,277
1981	1,165	3,086	2,989	416	1,131	8,787	2,871	114	2,985	10,302	2,555	1,235	14,092	5,174	483	31,521
1982	879	3,159	4,493	563	2,217	11,311	3,154	214	3,368	9,120	3,465	1,087	13,672	4,299	484	33,134
1983	638	4,735	6,306	518	1,118	13,315	2,180	235	2,415	5,747	2,757	883	9,387	3,750	604	29,471

Year	Otter Trawl						Gillnet			Long Line				Hand Line	Misc.	Total
	0&1	2	3	4	5+	Total	0&1	2&3	Total	0&1	2	3+	Total	Total		
1984	964	4,198	5,904	302	1,513	12,881	1,248	220	1,468	3,916	2,825	980	7,721	3,005	453	25,528
1985	523	3,954	5,562	90	1,185	11,314	1,837	161	1,998	2,617	1,740	635	4,992	2,755	440	21,499
1986	573	3,663	5,123	224	974	10,557	1,453	196	1,649	2,479	1,918	576	4,973	2,490	371	20,040
1987	312	2,645	3,504	531	929	7,921	1,968	241	2,209	3,075	2,175	499	5,749	2,670	456	19,005
1988	454	3,966	3,542	160	467	8,589	903	444	1,347	3,528	3,149	672	7,349	3,081	171	20,537
1989	409	3,933	4,184	67	713	9,306	1,254	475	1,729	2,915	2,167	623	5,705	2,937	208	19,885
1990	505	3,668	3,577	268	170	8,188	1,933	692	2,625	4,201	2,967	849	8,017	4,871	203	23,904
1991	355	4,598	5,805	298	751	11,807	2,225	619	2,844	4,712	3,679	842	9,233	3,737	128	27,749
1992	238	4,494	5,711	143	726	11,312	1,811	586	2,397	4,455	3,574	719	8,748	3,517	106	26,080
1993	176	2,778	3,598	68	241	6,861	1,387	523	1,910	2,768	1,693	310	4,771	2,439	45	16,026
1994	132	2,022	2,343	138	82	4,717	993	421	1,414	2,837	1,412	231	4,480	2,367	67	13,045
1995	100	1,387	1,619	112	75	3,293	470	507	977	1,632	959	182	2,773	1,706	18	8,767
1996	92	1,552	2,314	157	103	4,218	611	442	1,053	1,774	1,306	201	3,281	1,914	106	10,572
1997	79	2,094	2,430	136	35	4,774	694	471	1,165	2,013	1,255	231	3,499	1,794	6	11,238
1998	99	1,404	1,892	166	22	3,583	437	376	813	1,717	1,016	244	2,977	910	0	8,283
1999	86	779	1,253	63	11	2,192	501	408	908	1,551	771	120	2,442	762	0	6,304
2000	113	851	1,268	78	9	2,319	358	356	714	1,420	533	106	2,059	662	1	5,755
2001	120	975	1,292	29	9	2,425	383	390	773	1,532	423	72	2,027	409	0	5,634
2002	181	873	1,484	0	51	2,589	524	535	1,059	1,559	338	55	1,953	292	0	5,893
2003	299	704	1,518	8	5	2,534	610	435	1,045	1518	350	60	1,927	154	7	5,667
2004	269	667	1,513	-	-	2,448	590	591	1,181	1,048	187	20	1,255	125	1	5,010
2005	209	660	1,103	21	-	1,993	433	392	825	1,038	208	12	1,258	42	0	4,117
2006	245	561	735	69	-	1,609	259	71	330	1,376	322	37	1,735	27	0	3,700
2007	265	471	861	10	-	1,607	252	42	294	1,389	432	44	1,865	24	-	3,790
2008	266	452	982	0	-	1,699	236	72	307	1,667	432	8	2,107	18	-	4,132
2009	173	370	749	0	-	1,292	210	37	248	1,305	300	4	1,609	17	-	3,166
2010	198	312	803	21	-	1,334	189	31	220	1081	299	13	1,393	17	-	2,964
2011	50	95	356	10	-	511	103	22	125	649	147	8	804	8	-	1,448
2012	64	142	324	8	-	538	67	14	81	529	165	-	694	1	-	1,314
2013	62	171	352	12	-	597	74	30	104	354	125	-	479	2	-	1,182
2014	55	125	344	2	-	526	115	29	144	405	101	0	506	1	-	1,177
2015	40	63	188	-	-	291	69	17	86	274	46	5	325	2	-	704
2016	54	102	172	-	-	328	60	14	74	276	32	-	308	6	-	716
2017	42	111	229	0	-	382	81	10	91	279	36	1	316	1	-	790

Table 4. Nominal catches of NAFO Division 4X5Y Cod by unit area. Zeroes indicate < 0.5t landings; dashes indicate no landings.

Year	4Xm	4Xn	4Xo	4Xp	4Xq	4Xr	4Xs	4Xu	5Yb	Shelf	Fundy	Foreign	Total
1956	1,981	1,043	5,909	-	756	2,648	817	1,695	-	10,204	4,645	1,663	14,849
1957	1,929	1,447	6,369	-	934	2,041	616	283	-	9,957	3,662	1,083	13,619
1958	1,480	1,130	5,056	-	651	1,859	774	153	-	7,781	3,322	1,110	11,103
1959	2,212	937	5,302	-	1,123	2,339	957	-	-	8,451	4,419	862	12,870
1960	1,654	963	5,164	-	885	2,373	828	256	-	7,973	4,150	1,605	12,123
1961	1,630	1,279	5,275	24	892	2,449	905	-	-	8,208	4,246	1,272	12,454
1962	1,520	1,031	6,250	651	768	2,946	1,327	163	-	9,574	5,082	1,280	14,656
1963	1,862	829	6,861	1,443	767	2,419	1,579	-	-	10,995	4,765	1,995	15,760
1964	2,099	2,178	7,174	3,334	1,093	3,572	1,317	-	-	14,785	5,982	4,688	20,767
1965	1,665	2,088	6,526	7,733	962	4,091	1,215	-	-	18,012	6,268	2,693	24,280
1966	2,201	1,521	5,444	7,254	1,099	4,607	2,032	-	-	16,420	7,738	6,746	24,158
1967	2,384	1,400	7,120	8,041	1,276	5,425	2,051	-	-	18,945	8,752	4,651	27,697
1968	3,251	2,059	8,159	9,341	1,327	4,785	1,849	4	65	22,813	8,027	4,776	30,840
1969	2,413	2,923	7,355	5,523	947	3,686	1,120	59	60	18,258	5,828	8,704	24,086
1970	2,851	1,300	6,966	2,310	1,077	2,621	847	23	26	13,444	4,577	4,308	18,021
1971	2,750	1,728	9,029	2,157	1,395	2,355	754	13	119	15,674	4,626	3,197	20,300
1972	3,124	1,585	8,908	1,421	1,938	2,818	977	7	52	15,044	5,786	1,902	20,830
1973	2,130	1,478	10,180	1,228	1,742	2,186	802	179	67	15,159	4,833	2,222	19,992
1974	2,243	1,122	9,369	955	1,526	2,839	768	1	120	13,690	5,253	2,166	18,943
1975	81	1,374	967	1,033	864	2,867	133	12,180	86	13,199	6,386	1,598	19,585
1976	1,973	1,408	8,267	743	1,061	2,034	601	40	16	12,423	3,720	519	16,143
1977	184	1,706	1,229	1,487	907	2,686	122	13,562	105	15,456	6,532	378	21,988
1978	2,812	2,864	8,522	3,591	2,286	2,246	676	341	382	18,062	5,658	301	23,720
1979	6,565	2,750	10,495	1,748	2,325	2,550	1,646	229	379	21,741	6,946	78	28,687
1980	5,205	3,325	9,899	1,561	3,571	4,684	2,278	47	166	20,023	10,712	541	31,276
1981	4,767	2,114	12,097	1,830	2,413	5,072	2,031	419	599	21,051	10,290	179	31,520
1982	5,255	2,922	10,451	2,079	3,715	4,571	2,009	538	1,349	20,956	11,933	245	33,134
1983	3,437	1,690	8,537	2,497	3,160	3,787	1,674	1,826	2,543	16,891	12,258	320	29,469
1984	2,255	2,251	6,192	1,655	2,244	2,959	1,414	3,583	2,698	14,110	11,141	277	25,528
1985	3,006	1,199	5,438	1,026	1,999	2,301	1,511	3,608	1,364	12,236	9,216	47	21,499
1986	2,914	1,762	4,670	544	1,754	1,802	1,500	4,469	557	11,748	8,224	68	20,040
1987	2,676	1,611	4,777	1,131	1,240	858	1,207	5,116	360	12,783	6,179	29	18,991

Year	4Xm	4Xn	4Xo	4Xp	4Xq	4Xr	4Xs	4Xu	5Yb	Shelf	Fundy	Foreign	Total
1988	1,502	1,086	5,458	1,271	1,124	850	1,103	7,990	142	14,814	5,711	11	20,536
1989	1,370	1,019	5,506	2,820	1,360	1,112	915	5,267	478	13,855	5,994	38	19,887
1990	1,846	764	7,915	1,746	2,238	1,721	1,722	5,404	326	15,551	8,119	222	23,892
1991	2,552	1,584	8,963	2,440	2,763	4,243	2,560	2,246	307	17,275	10,383	91	27,749
1992	1,523	1,818	10,347	1,455	2,919	3,352	1,503	2,876	278	17,556	8,515	9	26,080
1993	1,364	1,646	4,845	1,436	1,959	2,428	1,399	760	189	9,406	6,620	-	16,026
1994	828	561	4,414	1,128	1,662	1,883	892	1,540	137	7,942	5,166	-	13,108
1995	293	696	1,737	1,586	1,306	1,032	510	1,528	79	3,349	5,500	-	8,849
1996	466	813	2,787	1,484	1,608	1,659	930	654	171	4,885	5,755	-	10,640
1997	453	837	2,213	1,327	1,793	2,240	1,070	1,303	183	4,490	7,058	-	11,548
1998	478	907	1,657	1,800	993	1,288	615	394	152	3,369	4,916	-	8,283
1999	401	593	1,591	1,296	964	784	415	140	121	2,748	3,553	-	6,304
2000	291	395	1,433	1,198	1,071	680	413	151	124	2,222	3,535	-	5,756
2001	257	535	1,049	1,395	985	814	441	125	106	2,289	3,418	-	5,707
2002	231	422	901	1,485	1,152	867	487	132	216	1,663	4,219	-	5,893
2003	186	421	700	1,276	723	1,112	695	280	274	1,808	3,853	-	5,668
2004	88	245	360	1,211	926	928	709	289	254	1,081	3,922	-	5,010
2005	99	403	444	1,085	726	584	409	166	201	1,453	2,664	-	4,117
2006	130	420	721	1124	352	293	382	223	54	2,122	1,578	-	3,700
2007	129	626	761	693	678	415	279	172	38	2,043	1,747	-	3,790
2008	123	884	866	1053	347	157	481	199	23	2,476	1,656	-	4,132
2009	99	537	754	894	471	86	156	141	46	2,090	1,093	-	3,183
2010	54	476	620	898	567	91	49	133	76	1,890	1,075	-	2,964
2011	25	267	342	428	227	27	40	79	12	951	497	-	1,448
2012	29	262	299	314	311	19	22	46	11	751	564	-	1,315
2013	28	170	161	262	465	24	34	27	10	474	707	-	1,181
2014	35	269	176	122	485	25	20	37	9	542	636	-	1,177
2015	29	116	152	165	169	14	22	30	7	397	308	-	705
2016	30	131	148	106	182	56	38	23	3	364	353	-	717
2017	22	137	135	146	206	45	63	30	5	353	436	-	790

Table 5. Sampling intensity (number of fish aged) for 4X5Y Cod by season (half or quarter of calendar year), area and year.

Area	Bay of Fundy			Scotian Shelf		
Season	H1	Q3	Q4	H1	Q3	Q4
2010	330	288	118	245	188	297
2011	92	253	164	392	231	193
2012	262	165	252	262	133	246
2013	262	248	202	163	198	92
2014	225	179	115	205	208	166
2015	150	213	96	223	132	85
2016	248	193	130	212	179	133

Table 6. Sampling intensity (number of fish measured) for 4X5Y Cod by gear and year.

Gear	HL	LL	GN	OT
2010	0	5,917	1,945	6,251
2011	0	4,902	781	4,764
2012	0	5,173	1,693	6,884
2013	0	4,102	1,439	5,301
2014	0	3,553	1,936	5,253
2015	0	2,039	951	5,296
2016	132	3,032	1,686	4,857

Table 7. Landings (kgs) of other species on Cod-directed trips in 4X5Y from commercial logs for mobile gear. Cod-directed trip is defined as having > 50% catch of Cod by weight. Zeroes indicate < 0.5 values; dashes indicate no value.

Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
COD	313,832	686,488	635,231	448,430	382,875	553,239	126,599	390,107	54,637	22,447	122,737	85,616	12,645	1,358	179
HADDOCK	99,307	134,928	169,341	165,971	84,427	91,205	32,064	124,043	23,760	2,607	8,962	17,858	3,206	413	3
POLLOCK	46,629	37,694	38,238	34,467	72,586	82,791	9,699	24,228	2,748	6,744	49,396	26,247	5,557	120	26
WINTER FLOUNDER	9,741	18,373	5,817	20,938	19,588	5,050	8,517	9,365	4,587	3,436	2,027	2,273	-	-	72
WHITE HAKE	2,444	14,640	13,685	8,435	15,288	23,429	2,712	6,422	1,590	753	5,795	4,543	496	5	-
REDFISH	5,601	15,151	11,425	5,131	12,498	16,019	1,372	488	276	61	5,331	1,809	168	21	-
GREYSOLE /WITCH	8,441	15,739	15,645	3,924	10,532	8,620	1,051	880	2,747	173	3,065	2,544	345	59	13
MONKFISH	16,356	19,266	7,820	7,264	6,613	13,435	667	407	383	44	618	666	73	-	6
HALIBUT	188	12,036	5,511	2,270	12,445	9,839	5,615	5,194	3,873	281	1,394	1,105	-	37	-
SCULPIN	1,270	6,192	4,518	1,282	430	2,340	762	1,075	-	1,215	125	187	-	-	-
FLOUNDER, UNSPECIFIED	3,568	1,822	1,211	1,290	2,527	1,517	3,148	2,147	-	-	-	-	-	-	-
YELLOWTAIL	5	68	7,096	6,053	705	55	793	1,975	-	-	146	-	-	-	-
AMERICAN PLAICE	34	531	1,247	466	3,182	792	63	460	4	23	217	-	-	-	-
WOLFFISH	341	1,056	1,142	1,799	2,308	149	89	65	5	3	21	19	-	-	-
CUSK	-	2,937	939	611	-	-	227	4	-	-	152	-	-	-	-
SHARK	438	21	41	197	105	349	104	357	-	-	75	-	3	-	-
SUMMER FLOUNDER	-	-	-	99	-	127	-	90	-	-	-	-	-	-	-
SHAD	-	-	-	-	257	-	-	-	-	-	-	-	-	-	-
DOGFISH	-	-	-	-	88	-	-	-	-	-	76	-	-	-	-
GREENLAND HALIBUT/ TURBOT	5	65	-	-	15	-	-	23	-	-	-	-	-	-	-
EELS/ HAGFISH	-	-	14	-	2	2	-	-	-	-	-	-	-	-	-
SILVER HAKE	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-

Table 8. Landings of other species on Cod-directed trips in 4X5Y from commercial logs for fixed gear. Cod-directed trip is defined as having > 50% catch of Cod by weight. Values in grey cells are in tonnes. Values in white cells are in kilograms. Zeroes are < 0.5 values; dashes are no value.

Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
COD	1,422	1,259	860	960	1,005	1,493	1,109	740	227	75	78	255	127	119	134
HADDOCK	158	126	111	197	232	341	207	217	66	21	20	63	29	17	10
CUSK	108	61	67	111	84	121	150	67	18	10	14	29	16	19	14
POLLOCK	138	171	89	34	37	82	63	40	6	6	6	6	5	5	8
WHITE HAKE	131	102	79	40	41	59	62	40	14	5	5	16	9	15	7
HALIBUT	31	26	36	52	44	66	84	61	41	9	12	44	22	22	34
MONKFISH	10,414	6,295	10,320	14,185	5,240	7,145	4,249	3,141	1,054	840	1,066	6,099	2,268	2,096	3,955
REDFISH	8,514	6,458	6,930	10,286	8,386	7,011	6,486	4,153	1,321	2,414	1,391	1,680	573	456	201
WOLFFISH	10,911	11,055	11,057	9,534	7,531	6,376	3,504	1,872	571	127	143	84	335	12	422
SHARK	5,627	5,495	5,867	3,280	3,857	4,359	3,445	6,105	4,626	546	48	169	-	-	70
DOGFISH	1,291	3,131	2,933	16,399	4,378	938	589	-	-	-	-	-	-	-	-
SKATE	811	34	414	132	204	365	254	5	45	872	2,258	4,023	-	-	-
SILVER HAKE	759	3,497	1,861	68	5	-	-	-	-	-	-	-	-	-	-
SHAD	1,772	290	148	14	2	-	-	-	-	-	-	-	-	-	-
SCULPIN	85	-	272	21	129	99	150	2	2	28	5	-	17	42	-
FLOUNDER, UNSPECIFIED	256	106	41	99	82	30	59	13	10	5	2	-	-	-	-
AMERICAN PLAICE	133	129	112	70	98	28	37	23	2	-	-	-	-	-	-
MACKEREL	-	63	223	-	-	-	-	-	227	-	-	-	-	-	-
GREENLAND HALIBUT/TURBOT	-	-	-	-	80	250	-	-	-	-	-	-	-	-	-
WINTER FLOUNDER	44	14	14	197	-	-	-	13	-	-	-	1	4	-	-
YELLOWTAIL	59	42	3	6	5	14	-	-	-	-	-	-	-	-	-
RED HAKE	-	-	-	2	-	-	-	35	-	-	-	-	-	-	-
TILEFISH	-	26	3	-	-	-	-	-	3	-	-	-	-	-	-
HERRING	-	-	-	18	2	4	-	-	-	-	-	-	-	-	-
GREYSOLE/WITCH	2	-	-	-	-	1	4	-	2	-	-	-	-	-	-

Table 9. Commercial landings (t) by fleet for 2002–2017. Landings for fleets with < 5 active licence holders per year (Mobile Gear 65'–100', Offshore fleet and First Nations) do not meet confidentiality requirements and are therefore grouped into the OTHER category with Fixed Gear 45'–65'.

CALENDAR YEAR	FG < 45	MG < 65	OTHER
2002	3,086	2,207	553
2003	2,944	1,959	743
2004	2,411	1,777	809
2005	2,066	1,436	508
2006	2,013	1,086	613
2007	2,130	1,163	512
2008	2,286	1,263	497
2009	1,791	1,028	363
2010	1,570	980	415
2011	888	293	267
2012	737	310	268
2013	553	415	213
2014	630	463	84
2015	394	251	60
2016	365	269	82
2017	391	339	61

Table 10. Percent of total landings (tonnes) which were observed caught on longline, gillnet and mobile (by mesh size class) gears in the 4X5Y groundfish fishery. The 'Total Mobile' column includes landings with mesh size of 0 or NA. The 'All Gears' column includes combined landings by mobile and fixed gears.

Year	Total Mobile			Mobile (mesh ≤ 65 mm)			Mobile (65–130 mm)			Mobile (≥ 130 mm)		
	Obs	Landed	%Obs	Obs	Landed	%Obs	Obs	Landed	%Obs	Obs	Landed	%Obs
2003	27.6	2,532	1.1%	0.002	2.049	0.1%	8.7	1,287	0.7%	18.9	679	2.8%
2004	84.2	2,445	3.4%	0.015	8.358	0.2%	4.2	53	8.0%	80.0	2,211	3.6%
2005	30.5	1,991	1.5%	0.001	1.153	0.1%	3.5	74	4.7%	27.0	1,820	1.5%
2006	36.1	1,604	2.2%	0.000	0.152	0.0%	1.0	73	1.3%	35.1	1,440	2.4%
2007	30.4	1,604	1.9%	0.001	2.381	0.0%	3.0	117	2.6%	27.4	1,427	1.9%
2008	21.6	1,697	1.3%	0.000	1.516	0.0%	2.0	97	2.0%	19.6	1,527	1.3%
2009	9.8	1,299	0.8%	0.000	1.888	0.0%	2.6	143	1.8%	7.2	1,142	0.6%
2010	117.1	1,340	8.7%	0.000	0.395	0.0%	14.0	102	13.7%	103.1	1,233	8.4%
2011	54.5	508	10.7%	0.010	1.161	0.9%	17.6	62	28.3%	36.9	438	8.4%
2012	46.8	538	8.7%	0.001	0.420	0.2%	7.8	141	5.5%	39.0	377	10.3%
2013	15.7	594	2.6%	0.000	3.181	0.0%	3.3	67	5.0%	12.4	509	2.4%
2014	21.6	525	4.1%	0.000	2.648	0.0%	2.8	40	7.0%	18.8	474	4.0%
2015	21.6	291	7.4%	0.031	0.036	86.3%	4.6	27	16.9%	17.0	260	6.5%
2016	17.4	328	5.3%	0.000	6.379	0.0%	2.3	44	5.2%	15.1	260	5.8%
2017	33.9	382	8.9%	0.000	0.970	0.0%	3.2	52	6.0%	30.8	322	9.6%

Year	All Gears			Fixed - Longline			Fixed - Gillnet		
	Obs	Landed	%Obs	Obs	Landed	%Obs	Obs	Landed	%Obs
2003	53.6	5,385	1.0%	14.7	1,832	0.8%	11.2	1,021	1.1%
2004	112.7	4,606	2.4%	18.7	1,061	1.8%	9.8	1,099	0.9%
2005	63.5	3,852	1.6%	12.0	1,071	1.1%	20.9	789	2.7%
2006	48.8	3,358	1.5%	12.7	1,447	0.9%	0.0	307	0.0%
2007	42.1	3,583	1.2%	11.8	1,701	0.7%	0.0	278	0.0%
2008	40.9	3,917	1.0%	18.3	1,928	1.0%	1.0	292	0.3%
2009	25.0	3,025	0.8%	15.2	1,508	1.0%	0.0	218	0.0%
2010	191.0	2,813	6.8%	69.4	1,277	5.4%	4.4	196	2.3%
2011	87.1	1,354	6.4%	26.6	730	3.7%	6.0	116	5.2%
2012	71.8	1,265	5.7%	23.2	652	3.6%	1.8	75	2.4%
2013	16.8	1,154	1.5%	1.1	458	0.2%	0.0	101	0.0%
2014	26.1	1,140	2.3%	3.8	482	0.8%	0.7	133	0.5%
2015	28.4	676	4.2%	6.8	305	2.2%	0.0	80	0.0%
2016	29.7	691	4.3%	12.3	294	4.2%	0.0	69	0.0%
2017	52.6	759	6.9%	18.6	291	6.4%	0.0	85	0.0%

Table 11. Percent of trips landing Cod (# of trips) which were observed using longline, gillnet and mobile (by mesh size class) gears in the 4X5Y groundfish fishery. The 'Total Mobile' column includes landings with mesh size of 0 or NA. The 'All Gears' column includes combined landings by mobile and fixed gears.

Year	Total Mobile			Mobile (mesh ≤ 65 mm)			Mobile (65–130 mm)			Mobile (≥ 130 mm)		
	Obs	Landed	%Obs	Obs	Landed	%Obs	Obs	Landed	%Obs	Obs	Landed	%Obs
2003	34	1,810	1.9%	1	4	25.0%	19	1,023	1.9%	14	410	3.4%
2004	59	1,583	3.7%	3	9	33.3%	7	130	5.4%	49	1,346	3.6%
2005	33	1,498	2.2%	1	9	11.1%	7	157	4.5%	25	1,232	2.0%
2006	39	1,240	3.1%	0	4	0.0%	7	166	4.2%	32	989	3.2%
2007	28	1,326	2.1%	1	9	11.1%	6	135	4.4%	21	1,111	1.9%
2008	23	981	2.3%	0	7	0.0%	3	140	2.1%	20	761	2.6%
2009	26	904	2.9%	0	11	0.0%	11	166	6.6%	15	686	2.2%
2010	79	802	9.9%	0	3	0.0%	24	181	13.3%	55	595	9.2%
2011	80	712	11.2%	1	6	16.7%	25	187	13.4%	54	490	11.0%
2012	59	850	6.9%	1	2	50.0%	19	305	6.2%	40	518	7.7%
2013	39	722	5.4%	0	4	0.0%	8	141	5.7%	31	550	5.6%
2014	17	527	3.2%	0	2	0.0%	3	76	3.9%	14	427	3.3%
2015	27	482	5.6%	1	2	50.0%	11	74	14.9%	15	389	3.9%
2016	33	597	5.5%	0	16	0.0%	9	126	7.1%	24	426	5.6%
2017	44	645	6.8%	0	12	0.0%	15	172	8.7%	29	428	6.8%

Year	All Gears			Fixed - Longline			Fixed - Gillnet		
	Obs	Landed	%Obs	Obs	Landed	%Obs	Obs	Landed	%Obs
2003	57	5,818	1.0%	16	2,859	0.6%	7	1,149	0.6%
2004	91	4,312	2.1%	26	1,820	1.4%	6	909	0.7%
2005	61	3,834	1.6%	19	1,553	1.2%	9	783	1.1%
2006	51	3,686	1.4%	12	1,803	0.7%	0	643	0.0%
2007	52	4,131	1.3%	24	2,069	1.2%	0	736	0.0%
2008	53	3,255	1.6%	27	1,670	1.6%	3	604	0.5%
2009	45	2,771	1.6%	19	1,383	1.4%	0	484	0.0%
2010	156	2,392	6.5%	66	1,136	5.8%	11	454	2.4%
2011	114	2,035	5.6%	30	993	3.0%	4	330	1.2%
2012	101	2,066	4.9%	38	989	3.8%	4	227	1.8%
2013	52	1,839	2.8%	13	982	1.3%	0	135	0.0%
2014	33	1,431	2.3%	15	779	1.9%	1	125	0.8%
2015	54	1,293	4.2%	27	716	3.8%	0	95	0.0%
2016	56	1,365	4.1%	23	664	3.5%	0	104	0.0%
2017	73	1,454	5.0%	29	712	4.1%	0	97	0.0%

Table 12. Discard estimates (kg) of Cod from various fisheries in NAFO areas 4X5Y by [a] Sameoto and Glass 2012, [b] Pezzack et al. 2014, [c] Clark et al. 2015, [d] Cook et al. 2017. Estimates are not considered reliable, and should only be used for broad comparisons across fisheries. Zeroes indicate < 0.5 values; dashes indicate no value.

Fishery	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
[a] Scallop SFA 28/29W	348	315	115	230	414	781	1,441	3,019	-	-	-	-	-	-
[b] Lobster LFA 33/34	-	-	-	-	-	-	-	306,820		-	-	-	-	-
[d] Lobster LFA 41	-	-	-	-	84	475	83	365	108	10	110	497	131	40
[c] Groundfish Gillnet	-	-	-	-	-	-	2957	69,467	-	7,165	-	-	-	-
[c] Groundfish Longline	-	-	-	-	-	1,669	820	57	781	378	-	-	-	-
[c] Groundfish Bottom Trawl	-	-	-	-	-	-	-	-	1,631	-	-	-	-	-
[c] Redfish Bottom Trawl	-	-	-	-	-	-	-	-	-	405	-	-	-	-
[c] Sculpin Bottom Trawl	-	-	-	-	-	-	-	6	23	-	-	-	-	-

Table 13. Quarterly alpha and beta parameters for the length-weight relationship of 4X5Y Cod.

Quarter	a	b
Q1	0.0081	3.0503
Q2	0.0084	3.041
Q3	0.0087	3.0233
Q4	0.0063	3.1152

Table 14. Commercial catch at age (numbers in thousands) for NAFO Division 4X Cod.

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	2+	3+	4+
1980	0	837	6,054	2,358	1,742	1,135	442	261	91	60	19	17	5	13,021	12,183	6,129
1981	0	818	3,870	4,265	1,844	1,045	587	297	184	75	39	19	19	13,061	12,244	8,373
1982	0	904	2,885	4,414	3,060	912	393	279	146	86	41	25	15	13,160	12,255	9,371
1983	9	1031	3,689	2,433	2,057	1,205	459	204	120	76	36	10	10	11,330	10,299	6,610
1984	33	917	2,393	3,081	1,930	965	465	176	63	49	29	18	5	10,090	9,173	6,781
1985	0	711	1,674	1,569	2,324	1,284	514	194	71	53	18	7	6	8,425	7,715	6,041
1986	0	251	2,789	1,941	994	1,008	409	200	93	50	23	20	10	7,788	7,537	4,748
1987	0	861	902	2,053	1,087	523	511	236	140	66	33	9	7	6,428	5,567	4,665
1988	0	403	3,517	1,659	1,553	656	178	192	85	53	28	6	9	8,338	7,935	4,418
1989	17	655	2,560	3,656	632	562	163	79	60	19	10	10	2	8,408	7,753	5,193
1990	0	144	2,863	2,805	2,462	497	279	78	40	38	14	15	1	9,235	9,091	6,228
1991	2	391	1,535	5,092	1,777	1,364	215	156	32	16	28	15	6	10,626	10,235	8,700
1992	0	751	3,391	1,878	3,276	878	513	63	50	16	9	4	0	10,828	10,077	6,685
1993	0	881	3,490	2,045	660	672	186	90	14	14	5	0	0	8,056	7,176	3,686
1994	0	475	2,280	2,233	887	195	181	42	18	0	2	0	0	6,314	5,838	3,558
1995	0	135	2,146	1,081	582	130	28	40	11	5	0	0	0	4,158	4,023	1,877
1996	0	50	883	2,594	441	212	29	16	8	2	1	1	0	4,237	4,187	3,304
1997	0	59	1,126	1,556	1,193	199	82	16	2	6	1	3	0	4,243	4,184	3,058
1998	0	234	886	1,021	615	441	54	20	6	2	3	1	1	3,284	3,050	2,164
1999	0	72	834	543	347	264	120	20	7	0	0	1	0	2,210	2,138	1,303
2000	0	218	575	905	247	189	66	27	8	1	1	0	0	2,237	2,019	1,444
2001	0	114	1,187	595	378	75	40	17	12	1	0	0	0	2,420	2,306	1,119
2002	0	22	365	1,099	221	138	31	16	13	4	1	0	0	1,909	1,887	1,521
2003	0	73	249	557	519	96	95	21	2	1	3	0	0	1,614	1,541	1,292
2004	0	33	1,029	367	291	153	19	20	5	1	0	0	0	1,920	1,887	858
2005	0	66	148	830	173	89	47	9	3	0	0	0	0	1,367	1,301	1,152
2006	0	42	760	215	491	103	20	9	6	0	1	1	0	1,649	1,607	847
2007	0	214	341	927	122	175	16	9	2	1	0	0	0	1,809	1,594	1,253
2008	0	427	492	401	594	75	63	11	2	1	0	0	0	2,065	1,637	1,146
2009	7	192	878	272	98	114	10	6	1	0	1	0	0	1,572	1,380	502
2010	0	39	185	88	8	6	1	1	0	0	0	0	0	329	290	105
2011	0	37	124	187	162	46	7	5	2	0	0	0	0	568	531	408
2012	0	65	246	116	66	49	22	2	0	0	0	0	0	565	500	254
2013	0	61	297	158	22	13	4	1	0	0	0	0	0	557	496	199
2014	0	31	213	195	38	5	1	0	0	0	0	0	0	1,573	1,381	503
2015	0	29	60	126	67	7	0	0	0	0	0	0	0	289	260	200
2016	0	7	113	47	51	36	5	1	0	0	0	0	0	259	259	253

Table 15a. Commercial mean weight at age for NAFO Division 4X5Y Cod by major area — Scotian Shelf. Dashes indicate no value.

Scotian Shelf	Age											
Year	1	2	3	4	5	6	7	8	9	10	11	12
1983	-	0.76	1.22	1.81	2.50	3.93	6.09	8.22	10.76	11.83	12.22	16.59
1984	-	0.96	1.30	1.69	2.34	3.37	4.68	6.83	8.60	11.06	13.21	14.03
1985	-	0.60	1.07	1.47	2.00	3.06	4.55	6.70	6.89	9.00	14.16	15.66
1986	-	0.78	1.13	1.63	2.21	3.47	4.69	7.15	8.83	8.81	13.11	13.10
1987	-	1.23	1.40	1.83	2.61	3.46	4.99	7.33	8.36	10.66	11.80	15.85
1988	-	0.94	1.30	1.90	2.69	3.98	5.23	8.06	9.88	10.93	13.05	16.04
1989	0.78	1.23	1.57	2.21	2.75	3.96	4.88	7.86	9.46	11.95	15.04	14.81
1990	-	0.82	1.29	1.97	2.86	3.72	5.59	8.10	10.46	11.93	14.12	15.24
1991	-	0.76	1.13	1.73	2.50	3.54	5.08	6.44	9.44	11.19	13.73	15.74
1992	-	0.78	1.14	1.63	2.58	3.58	4.44	6.50	8.37	12.10	14.50	19.15
1993	-	0.68	1.25	1.62	2.24	3.44	4.67	7.01	9.13	10.97	18.08	-
1994	-	0.76	1.04	1.92	2.41	3.15	4.97	5.21	9.28	15.98	13.56	-
1995	-	0.86	1.23	1.72	3.26	4.09	4.69	7.23	9.18	13.33	16.33	-
1996	-	0.75	1.21	2.06	2.96	4.77	5.53	6.39	9.80	12.02	10.12	-
1997	-	1.17	1.22	1.83	3.31	4.49	6.04	8.83	9.99	11.14	13.58	8.71
1998	-	0.86	1.12	1.71	2.54	4.42	4.72	7.33	9.76	9.66	10.83	16.17
1999	-	1.00	1.71	2.32	2.83	4.03	5.43	8.26	10.70	13.24	11.35	16.54
2000	-	0.93	1.50	2.32	2.85	3.14	4.05	5.57	9.44	10.98	10.25	12.53
2001	-	0.99	1.62	2.19	3.65	4.11	5.12	6.62	8.19	8.72	11.05	-
2002	-	0.75	1.29	2.39	3.08	4.55	5.70	7.24	7.32	8.54	7.61	-
2003	-	0.78	1.45	2.14	3.63	5.08	6.36	7.17	10.38	12.60	12.74	-
2004	-	0.75	1.41	2.48	3.77	4.95	5.33	7.26	11.15	-	14.04	-
2005	-	0.99	1.50	2.22	3.85	4.39	5.24	7.04	10.20	-	-	-
2006	-	0.71	1.26	1.58	2.92	3.77	5.55	6.74	6.93	-	11.64	-
2007	-	1.03	1.18	1.75	2.54	3.28	4.32	5.11	6.84	10.20	-	-
2008	-	0.95	1.21	1.50	2.51	3.10	4.26	3.33	7.19	8.83	-	-
2009	-	0.98	1.60	2.14	2.32	3.76	4.03	4.53	6.45	-	6.45	-
2010	0.10	0.93	1.54	2.28	2.77	3.51	4.24	4.52	3.95	-	-	-
2011	-	1.03	1.55	2.08	2.80	3.26	3.75	4.05	3.84	8.83	-	-
2012	-	1.12	1.64	2.24	2.47	3.34	3.18	4.01	4.25	-	-	-
2013	-	1.22	1.75	2.26	3.12	3.47	5.13	4.77	5.43	-	-	-
2014	-	0.92	1.66	2.27	3.39	4.93	6.23	6.82	-	-	-	-
2015	-	1.04	1.16	2.03	2.92	3.92	6.55	-	-	-	-	-
2016	-	1.01	1.66	2.2	3.18	4.16	4.40	-	-	5.55	-	-
Mean	0.44	0.91	1.36	1.97	2.83	3.86	4.99	6.51	8.40	10.80	12.61	15.01

Table 16b. Commercial mean weight at age for NAFO Division 4X5Y Cod by major area — Bay of Fundy. Dashes indicate no value.

Bay of Fundy	Age											
Year	1	2	3	4	5	6	7	8	9	10	11	12
1983	0.38	0.86	1.48	2.18	3.30	4.88	6.38	8.62	9.92	12.19	14.23	20.63
1984	0.39	0.93	1.62	2.48	3.52	4.67	6.98	7.94	12.10	13.45	4.75	-
1985	0.37	0.84	1.48	2.26	3.43	4.53	6.54	9.45	11.46	15.12	18.23	19.52
1986	0.37	0.80	1.41	2.33	4.30	6.24	7.36	8.18	9.50	14.25	7.99	11.98
1987	-	0.84	1.57	2.56	4.17	5.33	7.04	7.92	7.94	14.31	18.56	-
1988	-	0.86	1.46	2.24	4.09	5.36	8.99	10.14	8.89	14.69	-	-
1989	0.33	0.76	1.52	2.59	3.60	6.33	7.25	10.32	10.55	14.57	-	11.66
1990	-	1.05	1.69	2.69	3.77	4.37	7.31	8.15	11.32	11.95	12.75	14.74
1991	0.82	1.04	1.88	2.91	4.26	6.77	8.75	11.02	13.60	14.17	15.10	17.93
1992	-	1.18	1.73	2.73	4.49	6.51	8.78	9.93	13.13	14.55	11.10	-
1993	-	0.90	1.74	2.86	4.74	6.09	7.58	9.18	14.32	16.75	13.85	-
1994	-	0.98	1.75	3.19	5.72	7.96	9.31	11.61	11.56	-	17.46	-
1995	-	1.29	1.91	2.78	4.38	6.01	7.76	9.84	12.49	8.57	14.32	-
1996	-	1.06	1.70	2.85	4.71	6.12	5.97	10.56	11.05	-	-	13.19
1997	-	1.17	1.73	2.74	4.28	5.77	8.44	10.30	9.18	12.94	11.07	22.55
1998	-	1.16	1.99	3.14	4.49	5.91	8.13	9.20	12.75	-	14.32	-
1999	0.70	1.31	1.88	2.93	4.44	6.06	7.55	8.93	-	-	8.97	14.78
2000	-	1.28	2.17	3.49	3.96	5.66	7.80	8.65	11.44	13.67	10.59	11.55
2001	-	0.95	2.01	3.46	4.72	6.36	8.15	8.42	11.41	11.88	-	-
2002	-	1.33	2.15	3.51	5.27	7.04	8.14	10.13	12.03	18.09	-	-
2003	-	1.59	2.08	3.15	5.03	6.08	7.25	13.86	7.62	-	19.68	-
2004	-	0.86	1.75	2.68	4.17	5.44	7.33	7.52	8.12	8.71	14.66	14.01
2005	-	1.07	1.76	3.02	4.21	5.89	6.43	10.04	11.82	-	12.20	-
2006	-	0.97	1.75	2.11	3.65	4.29	5.44	7.31	6.63	12.16	10.58	10.85
2007	0.37	1.20	1.88	2.56	3.07	4.85	4.64	5.89	8.35	8.33	15.97	-
2008	-	1.29	1.85	2.28	3.51	3.64	5.76	4.49	8.33	6.58	-	-
2009	0.64	1.22	2.02	2.91	4.31	4.75	4.53	6.88	11.36	-	-	-
2010	0.48	0.96	1.77	2.86	3.73	4.14	4.17	6.26	6.46	-	-	-
2011	-	1.28	1.81	2.58	3.18	4.04	4.80	4.33	4.74	-	-	-
2012	0.95	1.13	2.17	3.15	4.12	4.57	3.69	5.68	-	-	-	-
2013	0.33	1.23	1.91	2.60	3.47	3.28	5.27	5.34	-	-	-	-
2014	0.58	1.55	2.23	3.19	3.92	3.28	8.52	7.44	11.10	-	-	-
2015	-	1.16	2.26	3.11	3.90	4.42	8.12	11.10	-	8.03	-	-
2016	0.15	1.06	1.97	3.08	3.98	4.61	5.42	5.23	7.53	-	-	-
Mean	0.49	1.09	1.83	2.80	4.11	5.33	6.93	8.52	10.22	12.62	13.32	15.28

Table 17a. RV Survey stratified numbers at age (thousands of fish) for Cod by major area — Scotian Shelf.

Scotian Shelf	Age												
Year	0	1	2	3	4	5	6	7	8	9	10	11	12+
1983	136	107	571	3,157	1,914	937	546	146	0	13	0	0	6
1984	0	354	1,417	1,376	1,201	1,507	538	416	0	36	0	0	0
1985	69	90	837	834	343	456	483	314	77	0	13	0	6
1986	0	19	616	947	509	151	435	349	195	0	19	0	51
1987	6	79	1,229	305	325	250	106	68	187	26	0	0	0
1988	27	793	1,602	5,143	1,317	887	228	107	57	91	38	13	0
1989	301	136	2,910	1,789	1,723	230	227	89	0	30	18	14	0
1990	28	151	213	2,187	1,419	1,319	113	108	0	0	0	0	7
1991	34	147	1,107	599	1,833	722	545	80	7	19	0	0	0
1992	35	108	547	981	359	946	405	224	104	29	0	0	0
1993	14	33	296	664	502	80	82	32	61	0	6	41	0
1994	92	380	1,073	626	610	268	19	51	50	50	0	0	33
1995	216	33	534	2,107	1,059	248	229	47	32	34	0	7	0
1996	31	207	374	1,307	2,378	303	429	148	0	24	15	0	0
1997	30	126	399	560	850	1,225	128	109	100	0	26	0	0
1998	39	0	441	599	495	557	503	97	55	6	0	0	0
1999	677	69	330	730	675	736	165	98	0	0	0	0	0
2000	3,263	86	151	246	265	230	223	144	148	0	0	0	21
2001	908	150	487	1,441	477	406	22	60	0	31	0	0	0
2002	110	59	247	430	547	306	141	49	0	25	0	0	0
2003	258	11	234	210	227	144	15	30	0	0	0	0	0
2004	122	31	74	480	192	205	34	27	8	0	0	0	0
2005	11	159	924	142	632	60	57	15	0	35	0	17	0
2006	60	13	135	574	218	171	63	0	0	0	0	0	0
2007	72	112	138	297	351	154	255	25	0	0	0	0	0
2008	133	128	554	215	224	207	27	0	0	0	0	0	0
2009	257	423	2,613	3,460	485	284	252	0	0	0	0	0	0
2010	435	91	146	270	574	20	10	40	0	0	0	0	0
2011	550	93	251	253	365	249	17	0	18	0	0	0	0
2012	7	18	75	152	143	70	24	0	0	11	0	0	0
2013	2,688	69	133	158	229	65	0	0	0	0	0	0	0
2014	204	0	98	84	242	21	0	0	0	0	0	0	0
2015	533	44	541	311	332	173	12	0	0	0	0	0	0
2016	208	32	25	177	34	40	22	7	0	0	0	0	0
2017	82	27	43	84	280	212	18	52	62	7	0	0	0

Table 18b. RV Survey stratified numbers at age (thousands of fish) for Cod by major area — Bay of Fundy.

Bay of Fundy	Age												
Year	0	1	2	3	4	5	6	7	8	9	10	11	12+
1983	71	34	514	1,069	456	543	400	244	0	63	37	0	0
1984	0	466	4,328	2,015	1,161	313	150	66	63	23	25	0	0
1985	0	404	7,923	3,497	1,184	995	283	169	190	165	0	0	0
1986	25	749	718	1,974	717	163	114	99	21	97	0	0	0
1987	0	313	1,118	313	855	278	154	177	117	49	40	63	0
1988	233	1,837	2,323	4,103	179	661	268	103	187	0	0	0	0
1989	9	658	3,179	1,632	826	190	262	20	27	52	19	0	0
1990	0	364	660	3,335	1,044	1,002	128	306	80	42	0	21	21
1991	0	466	620	532	1253	372	206	48	109	0	21	12	0
1992	0	144	2,184	588	322	765	66	237	21	56	0	0	0
1993	0	336	659	1,854	423	49	183	20	0	0	0	0	0
1994	657	878	2,240	2,113	996	180	16	143	38	20	0	32	32
1995	996	89	313	2,671	418	351	45	47	60	0	42	0	0
1996	0	132	465	740	3,149	578	324	0	0	32	0	0	0
1997	65	223	170	629	594	1,236	194	85	0	0	31	0	0
1998	26	211	1,488	1,209	923	465	868	128	61	0	0	0	0
1999	192	313	457	561	207	115	29	199	46	0	0	0	0
2000	61	346	1,346	585	734	179	102	12	0	0	0	0	0
2001	1,262	0	567	1,449	474	240	22	0	0	0	0	0	0
2002	0	4,269	1,743	2,143	1,954	214	183	73	19	73	0	0	0
2003	457	488	2,771	334	875	601	174	49	20	19	0	0	0
2004	45	0	199	2,497	127	119	79	0	0	0	0	0	0
2005	43	91	818	226	1,187	162	151	20	0	0	0	0	0
2006	209	95	678	1,257	175	178	99	20	0	0	0	0	0
2007	30	222	1,154	339	714	0	127	0	0	0	0	0	16
2008	21	149	533	131	85	70	0	0	0	0	0	0	0
2009	74	122	520	1,356	392	72	168	0	0	0	0	0	0
2010	318	115	263	154	74	79	0	50	0	0	0	0	0
2011	109	151	430	90	249	33	0	0	0	0	0	0	0
2012	39	274	1,492	304	59	29	0	0	0	0	0	0	0
2013	396	25	218	431	43	0	0	0	0	0	0	0	0
2014	98	100	358	481	150	0	0	0	0	0	0	0	0
2015	1,285	91	645	136	193	22	15	0	0	0	0	0	0
2016	261	218	623	1,739	145	103	0	0	0	0	0	0	0
2017	185	23	135	247	158	213	0	0	0	0	0	0	0

Table 19. RV Survey stratified numbers at age for NAFO Division 4X5Y Cod.

Year	Age												
	0	1	2	3	4	5	6	7	8	9	10	11	12+
1983	208	141	1,085	4,226	2,369	1,480	946	389	0	77	37	0	6
1984	0	820	5,746	3,390	2,362	1,820	688	482	63	58	25	0	0
1985	69	495	8,760	4,331	1,527	1,451	766	483	267	165	13	0	26
1986	25	768	1,333	2,920	1,226	314	549	448	217	97	19	0	51
1987	6	392	2,348	618	1,180	528	260	245	304	75	40	63	0
1988	260	2,630	3,926	9,246	1,496	1,548	496	210	244	91	38	13	0
1989	309	794	6,089	3,420	2,549	420	489	108	27	82	37	14	0
1990	28	515	873	5,523	2,463	2,321	240	414	80	42	0	21	27
1991	34	614	1,727	1,131	3,086	1,094	751	128	116	19	21	12	0
1992	35	252	2,731	1,569	681	1,710	471	460	124	85	0	0	0
1993	14	369	955	2,518	925	129	265	52	61	0	6	41	0
1994	748	1,258	3,313	2,739	1,605	449	36	195	88	70	0	32	65
1995	1,212	122	847	4,779	1,477	598	274	94	91	34	42	7	0
1996	31	339	839	2,048	5,527	880	753	148	0	56	15	0	0
1997	95	349	569	1,189	1,444	2,462	321	194	100	0	57	0	0
1998	65	211	1,929	1,808	1,418	1,022	1,371	225	116	6	0	0	0
1999	869	382	787	1,291	882	850	194	297	46	0	0	0	0
2000	3,324	432	1,497	830	999	409	325	157	148	0	0	0	0
2001	2,170	150	1,053	2,891	951	646	44	60	0	31	0	0	0
2002	110	4,329	1,990	2,573	2,501	520	324	122	19	98	0	0	0
2003	715	43	3,014	546	1,082	752	191	78	20	19	0	0	0
2004	167	0	303	2,977	319	325	113	27	8	0	0	0	0
2005	54	198	1,750	363	1,848	224	223	33	0	29	0	14	0
2006	272	102	813	1,844	398	354	162	20	0	0	0	0	0
2007	102	300	1,307	707	1,028	113	410	25	0	0	0	0	16
2008	154	277	1,086	346	309	277	27	0	0	0	0	0	0
2009	331	545	3,133	4,817	877	356	420	0	0	0	0	0	0
2010	752	206	408	424	648	99	10	89	0	0	0	0	0
2011	659	245	682	343	614	282	17	0	18	0	0	0	0
2012	46	292	1,567	456	202	99	24	0	0	11	0	0	0
2013	3,084	94	351	589	272	65	0	0	0	0	0	0	0
2014	301	100	456	565	393	21	0	0	0	0	0	0	0
2015	1,818	135	1,186	446	524	195	27	0	0	0	0	0	0
2016	469	250	648	1,916	179	143	22	7	0	0	0	0	0
2017	268	50	178	331	438	426	18	52	62	7	0	0	0

Table 20. Sample size for length at maturity and age at maturity estimates from the RV Spring Survey for 4X5Y Cod.

Time Period	Length at Maturity		Age at Maturity	
	Bay of Fundy	Scotian Shelf	Bay of Fundy	Scotian Shelf
Early (pre-2000)	1285	1622	1151	1304
Late (post-2000)	138	357	128	320

Table 21. Stomach contents of juvenile (< 37 cm) and adult (≥ 37 cm) Cod by weight. Greyed out cells show the composition of the group above. N is indicative of the number of stomachs analyzed.

Cod < 37 cm (N = 280)		Cod ≥ 37 cm (N = 1112)	
Group	**Weight %**	**Group**	**Weight %**
Krill	35.27%	Herring	35.97%
Northern Sand Lance	17.48%	Crabs (general)	12.83%
Shrimp (general)	11.36%	• *Cancer sp*	*8.64%*
• *Pandalus sp*	*5.88%*	• *Toad Crab*	*1.96%*
• *Shrimp species*	*5.48%*	• *Hermit Crab*	*1.37%*
Crabs (general)	9.07%	• *Jonah Crab*	*0.86%*
• *Hermit Crab*	*4.26%*	Silver Hake	6.80%
• *Toad Crab*	*3.58%*	Krill	4.75%
• *Cancer sp*	*1.22%*	Scallop viscera	2.25%
Amphipod (general)	4.20%	Sand Lance	2.19%
Silver Hake	2.35%	Haddock	1.88%
Scallop viscera	2.11%	Squid (general)	1.78%
Anemone	2.06%	Debris	1.71%
Crustacean (general)	1.55%	Plaice	1.63%
Debris	1.40%	Redfish	1.58%
Squid (general)	1.30%	White Hake	1.35%
Red Hake	0.97%	Shrimp (general)	1.29%
Worms (general)	0.88%	Sculpin Eggs	1.08%
Sea Cucumber	0.82%	Cod	0.92%
Starfish (general)	0.75%	Snails and Slugs	0.83%
Herring	0.59%	Unidentified	21.17%
Snails	0.57%	• *Fish*	*20.16%*
Unidentified	7.27%	• *Other*	*1.02%*
• *Fish*	*4.11%*		
• *Other*	*3.15%*		

FIGURES

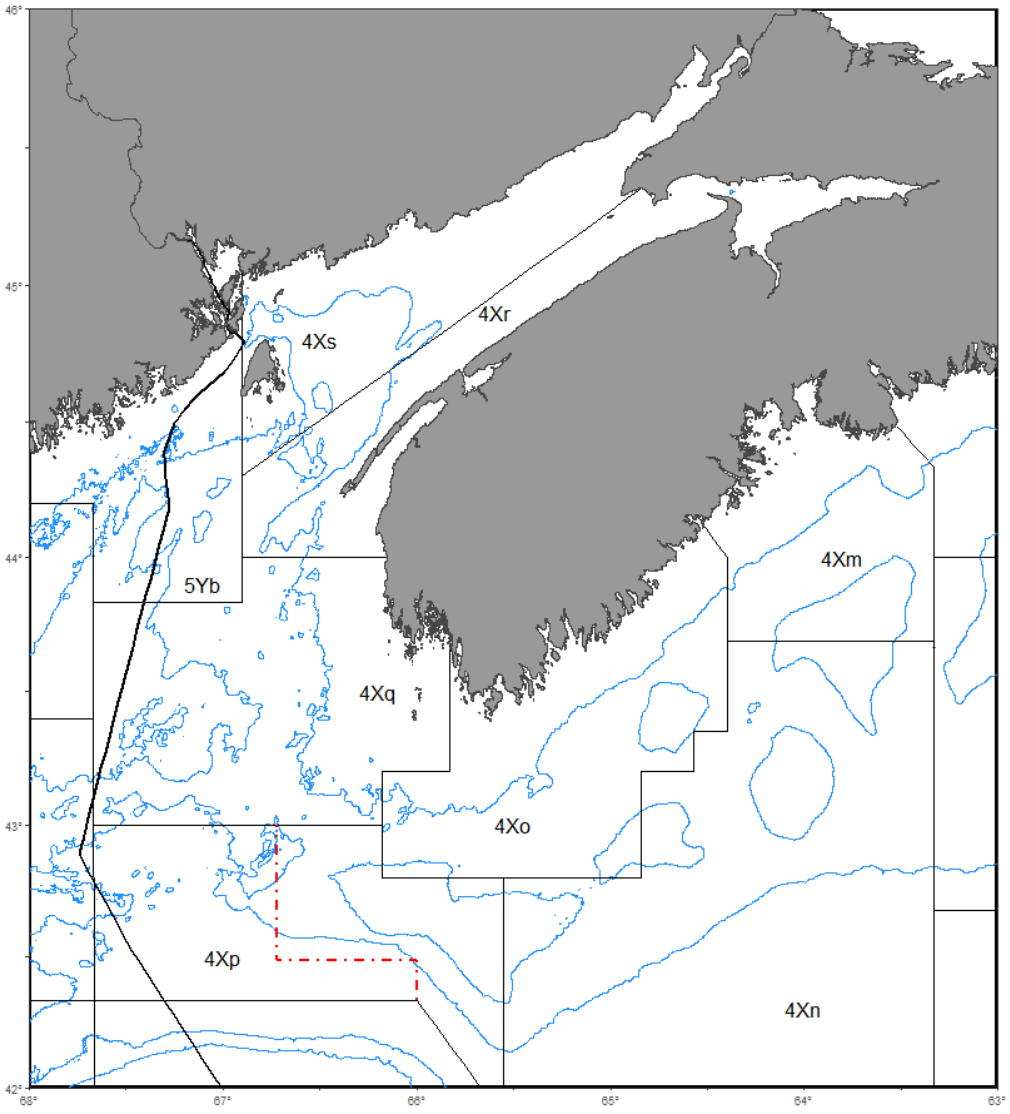

Figure 1. Unit areas for the 4X5Y Cod management unit (4Xmnopqrs and Canadian portion of 5Yb). Red line depicts how landings are within 4Xp.

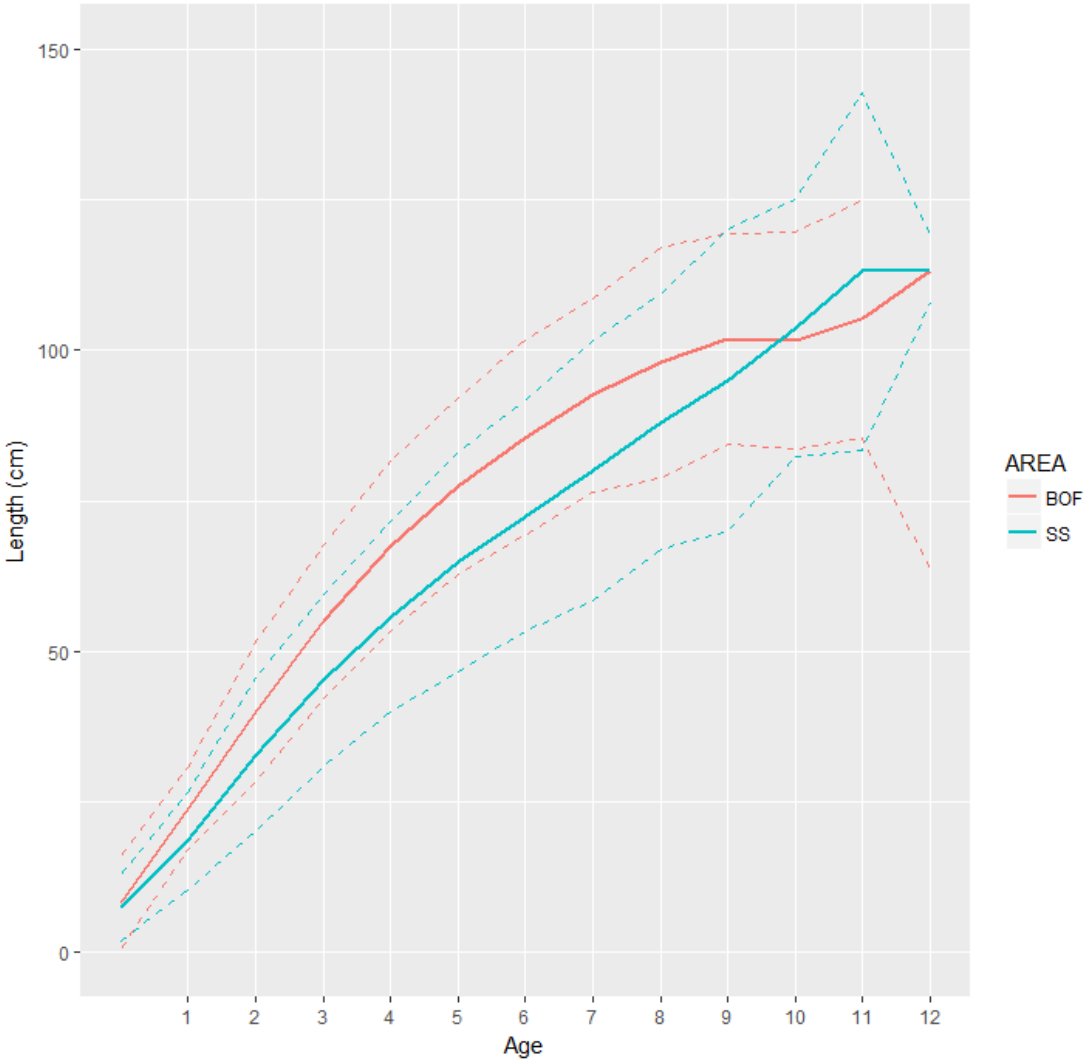

Figure 2. Age-Length relationship from the RV summer survey data (1983–2017) for Scotian Shelf (blue) and Bay of Fundy (red) components of 4X5Y. Dashed lines represent 95% confidence intervals.

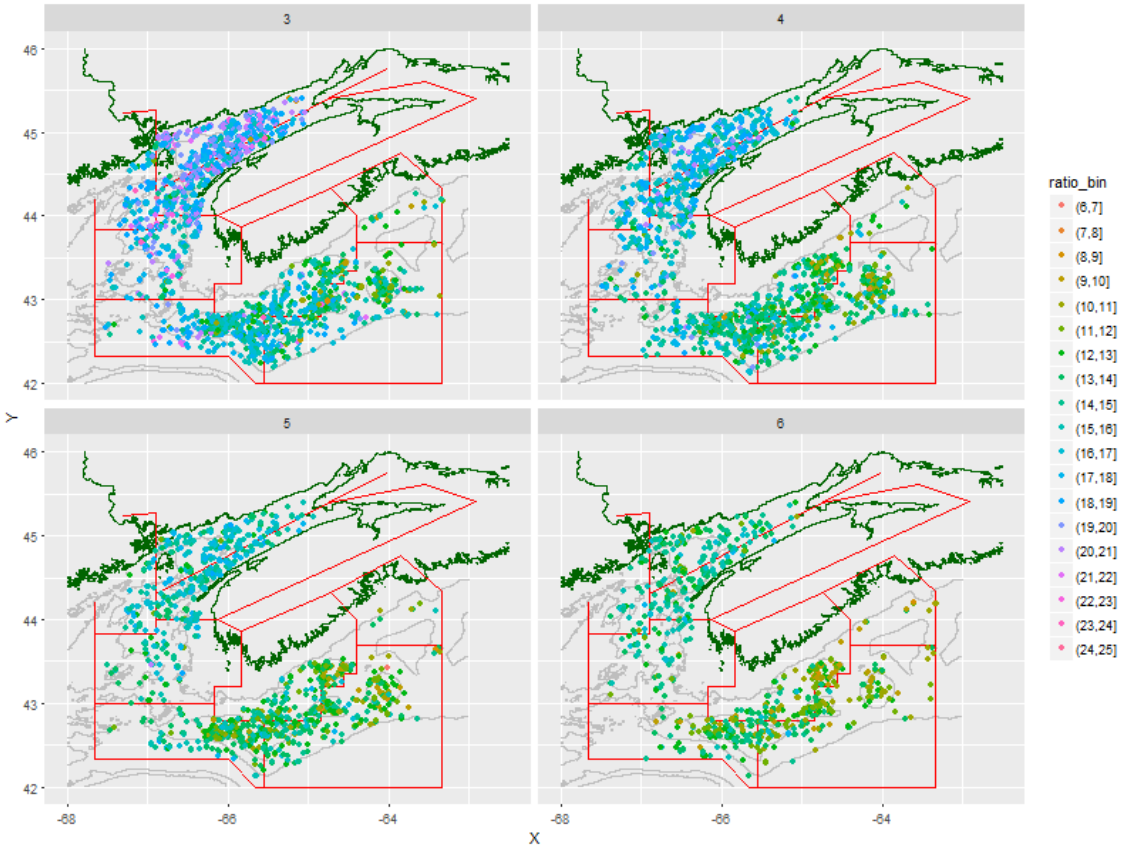

Figure 3. Proxy rates of growth at age (mean length at given age per set) for 4X5Y Cod caught on the summer RV survey (1983–2017). Panels are ages, with top left being age 3. Higher ratio_bin values are indicative of faster growth rates.

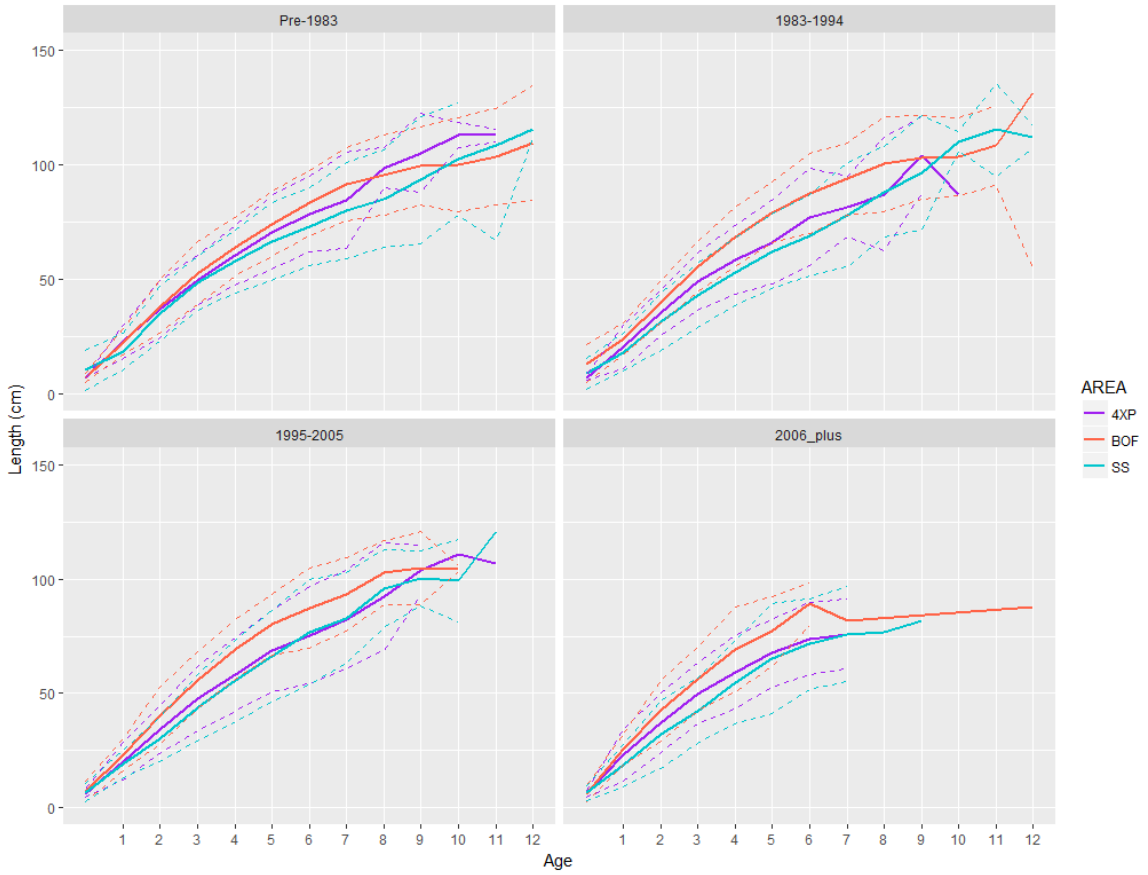

Figure 4. Age-Length relationships from RV summer survey data for Scotian Shelf (blue), Bay of Fundy (red) and NAFO area 4Xp (purple) over four time periods (panels). Dashed lines represent 95% confidence intervals.

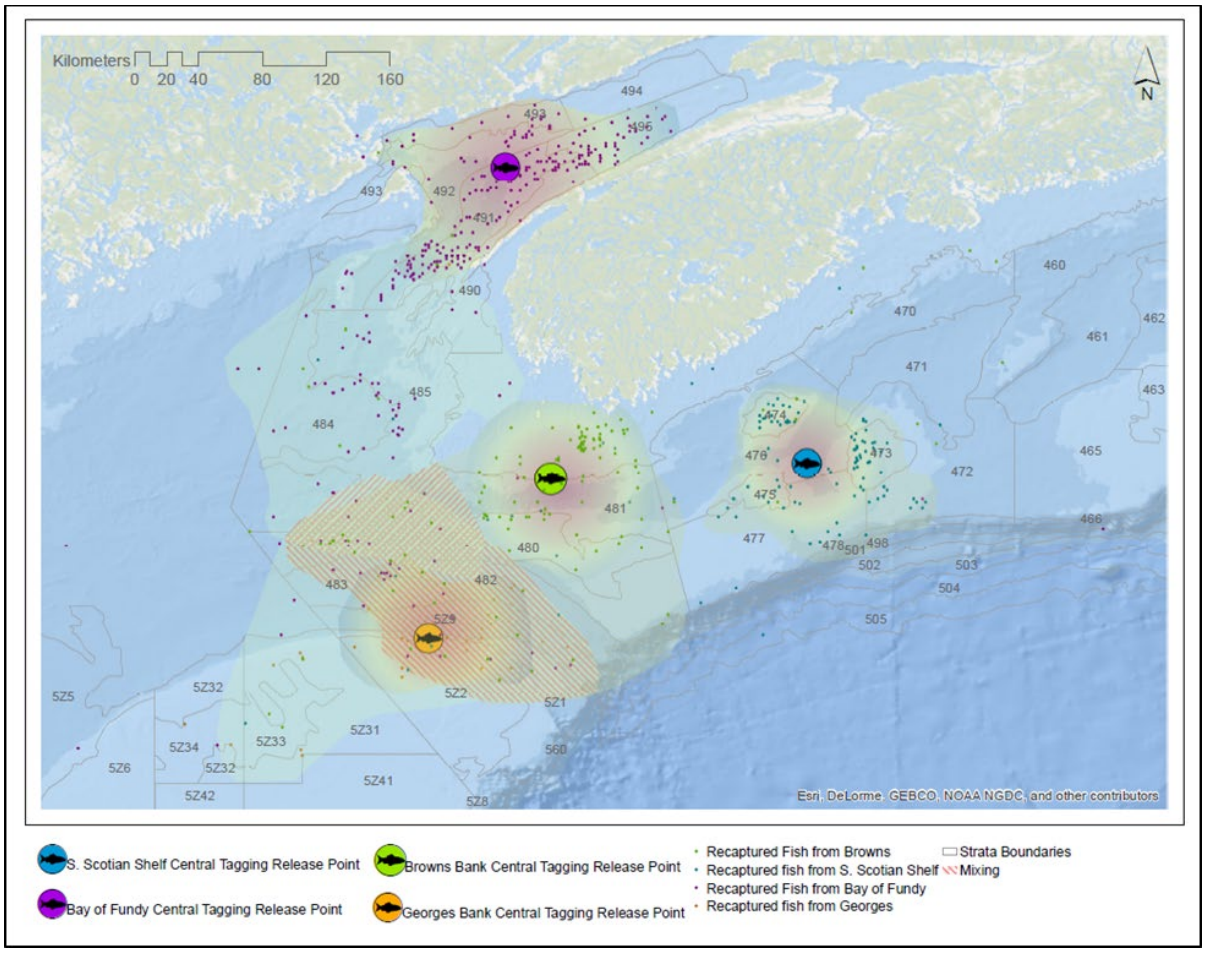

Figure 5. Aggregated plot of tag release locations (cloud with centroid), recapture locations (coloured points) and area of high mixing rates (hashed cloud).

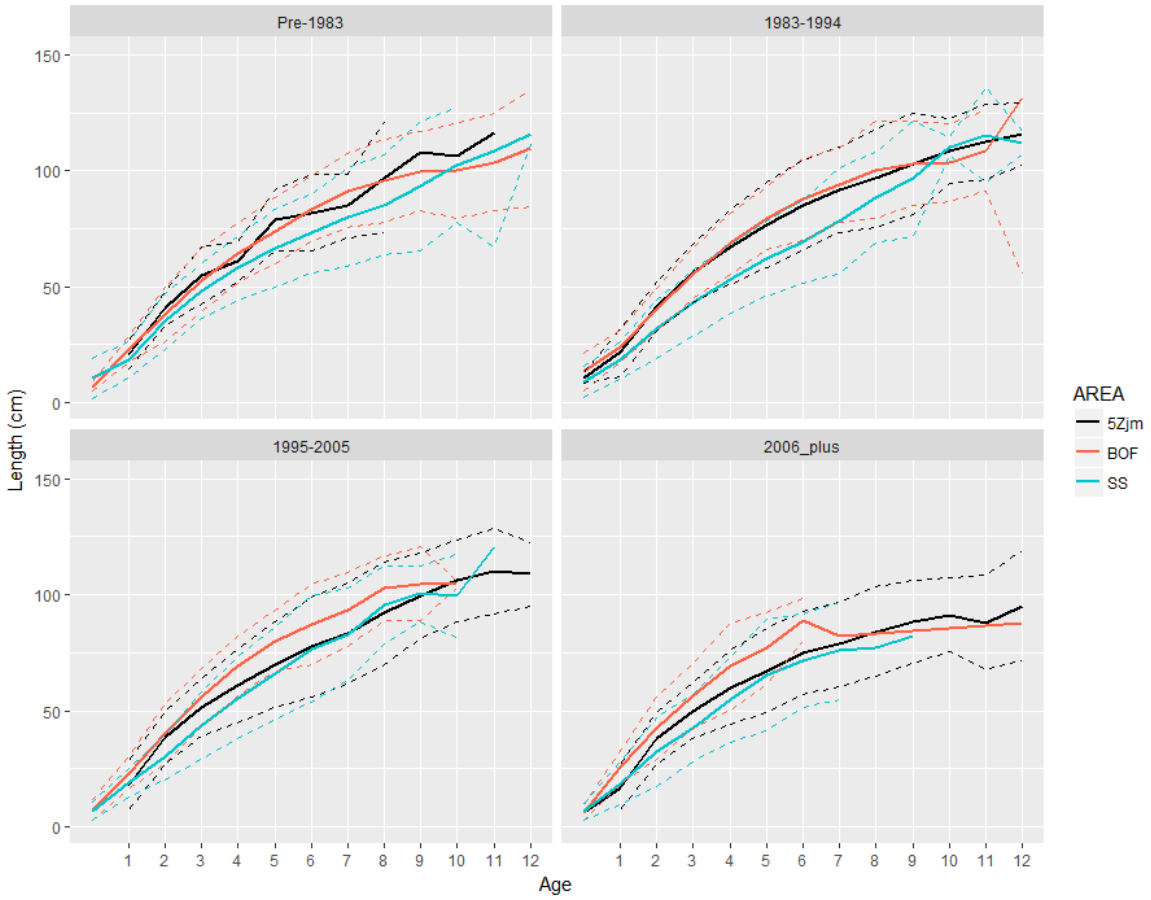

Figure 6. Age-Length relationships from RV survey data for Scotian Shelf (blue), Bay of Fundy (red) and NAFO area 5Zjm (black) over four time periods (panels). Dashed lines represent 95% confidence intervals.

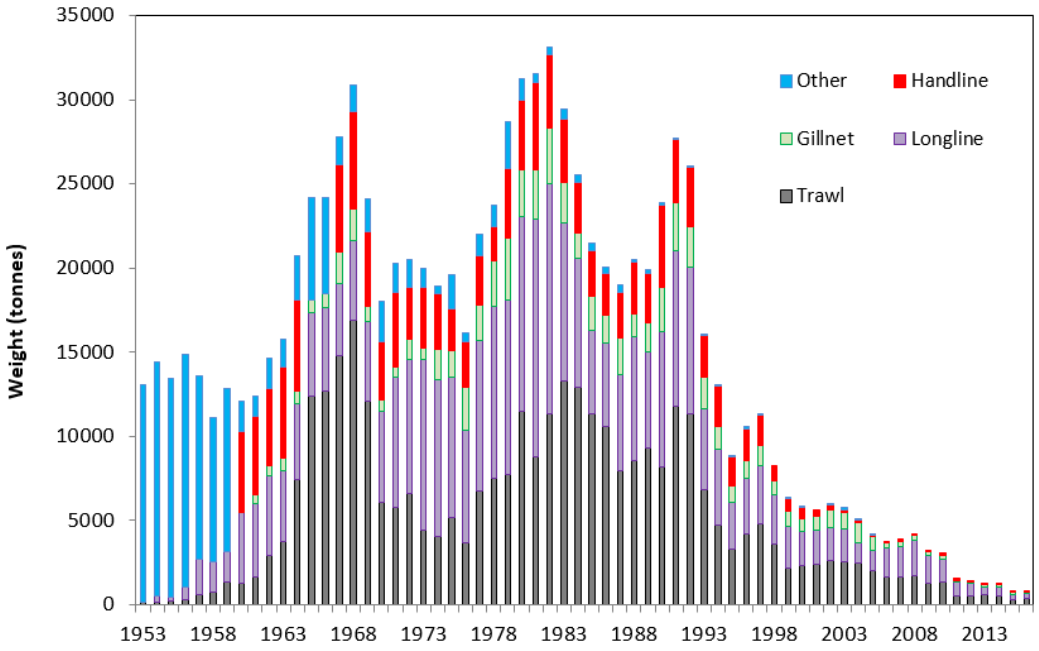

Figure 7. Annual (Calendar Year) landings of 4X5Y Cod by gear type. Prior to 1960, 'other' gear consists primarily of catches by handline and longline gears which cannot be separated. Since 1960, 'other' identifies unspecified gear type or gears not falling into one of the identified categories (e.g., seine).

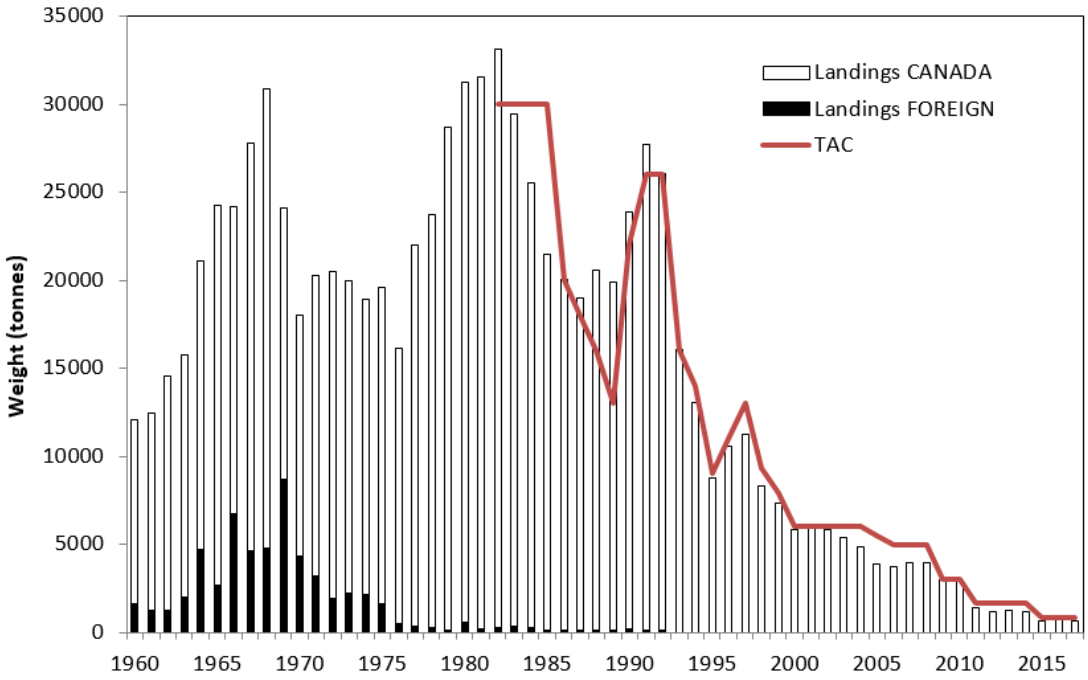

Figure 8. Landings and TAC for NAFO Division 4X5Y Cod by calendar year (January 1st – December 31st). After 1999, landings and TAC are reported by fishing year (April 1st – March 31st).

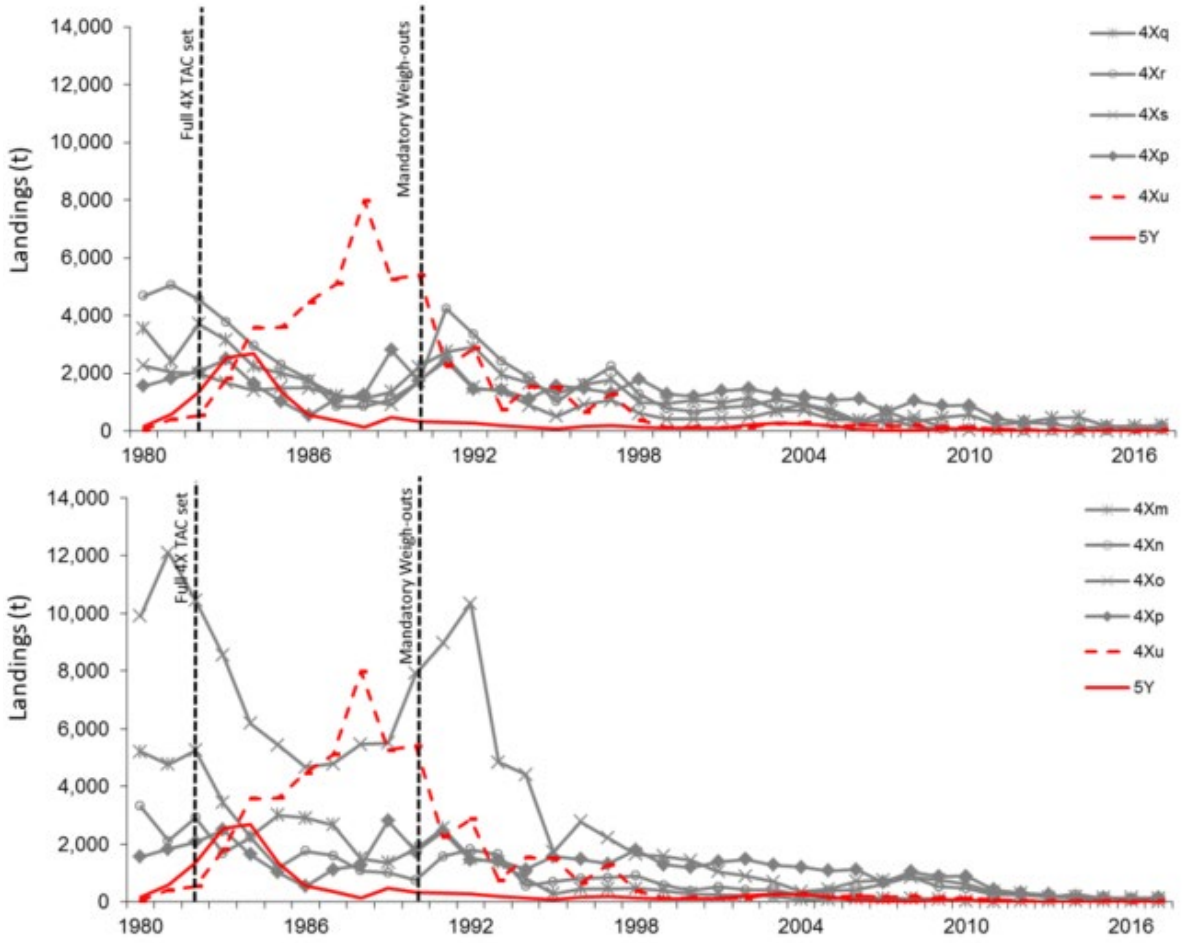

Figure 9. Total landings by NAFO area since 1980. Upper panel is Bay of Fundy (4Xqrs) and lower panel is Scotian Shelf (4Xmno). Reported landings from 4Xp, 4Xu and 5Yb are included on both panels.

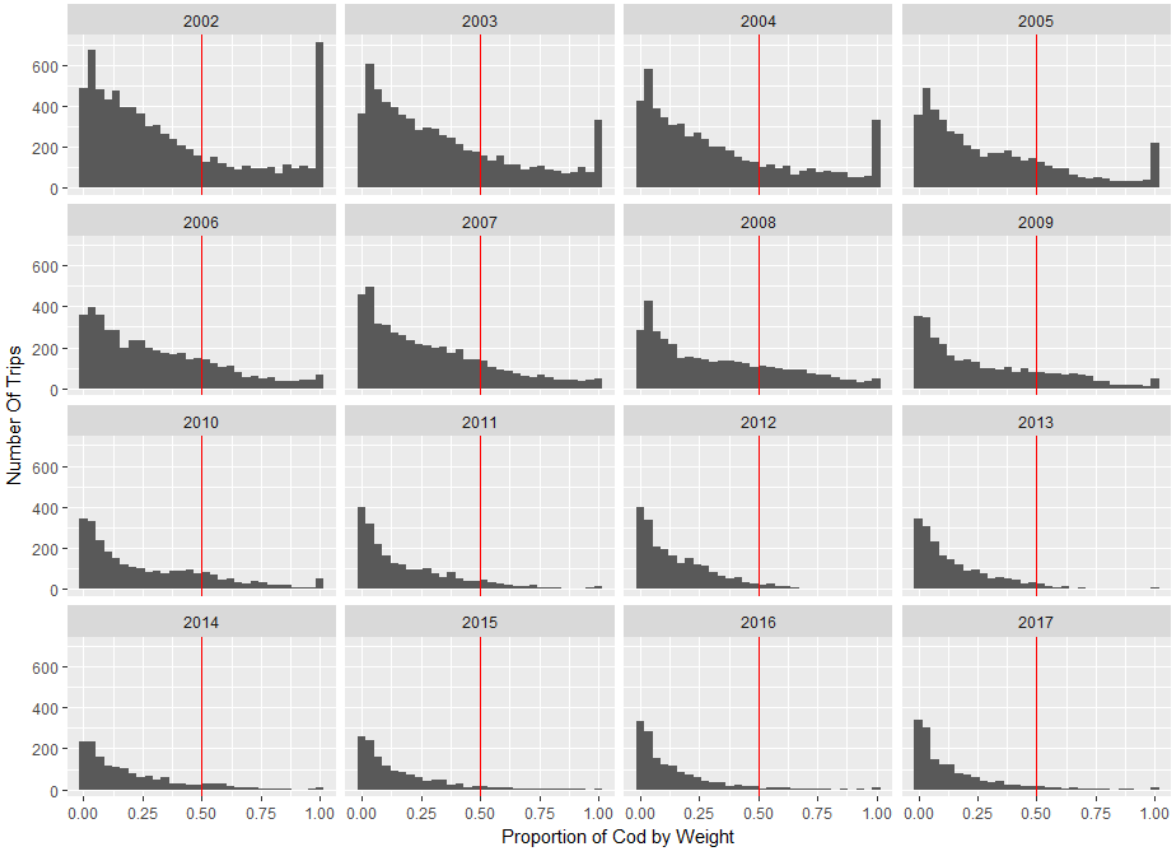

Figure 10. Proportion of Cod (Cod weight per trip / all species weight per trip) on groundfish trips since 2002. Red line identifies 50% of catch weight being Cod.

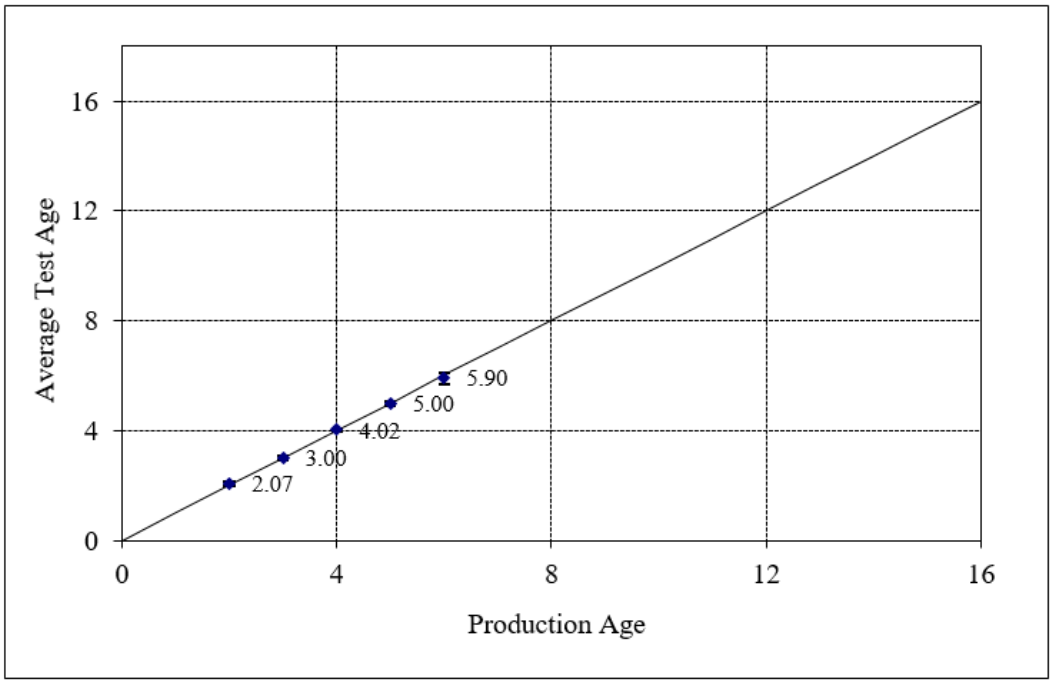

Figure 11. Bias plot for the 2017 ager test (N=215). Error bars indicate 95% confidence intervals.

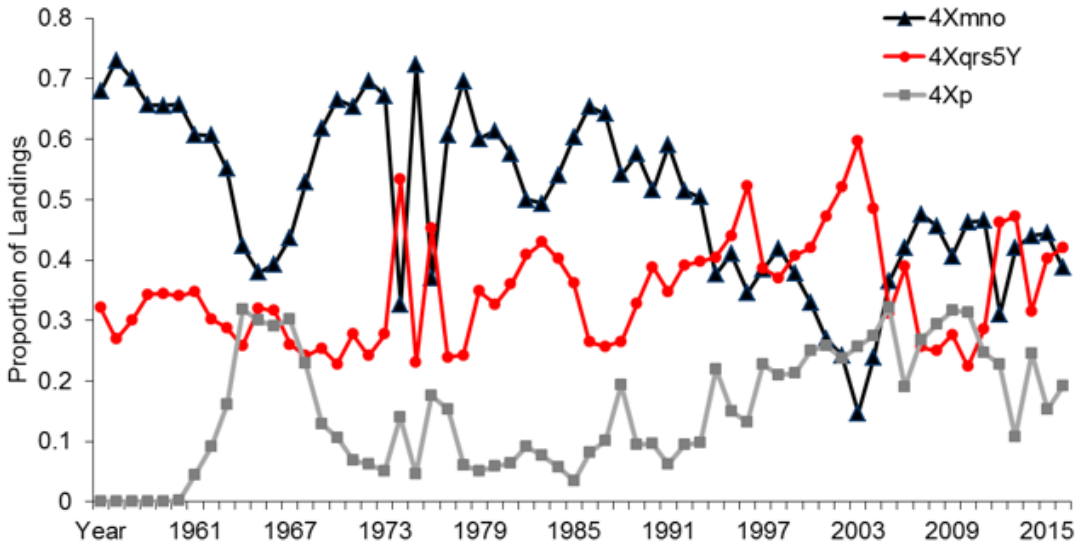

Figure 12. Proportion of landings of 4X5Y Cod by Scotian Shelf (4Xmno), Bay of Fundy (4Xqrs5Yb) and mixing area 4Xp. Catches from NAFO area 4Xu are excluded from the figure.

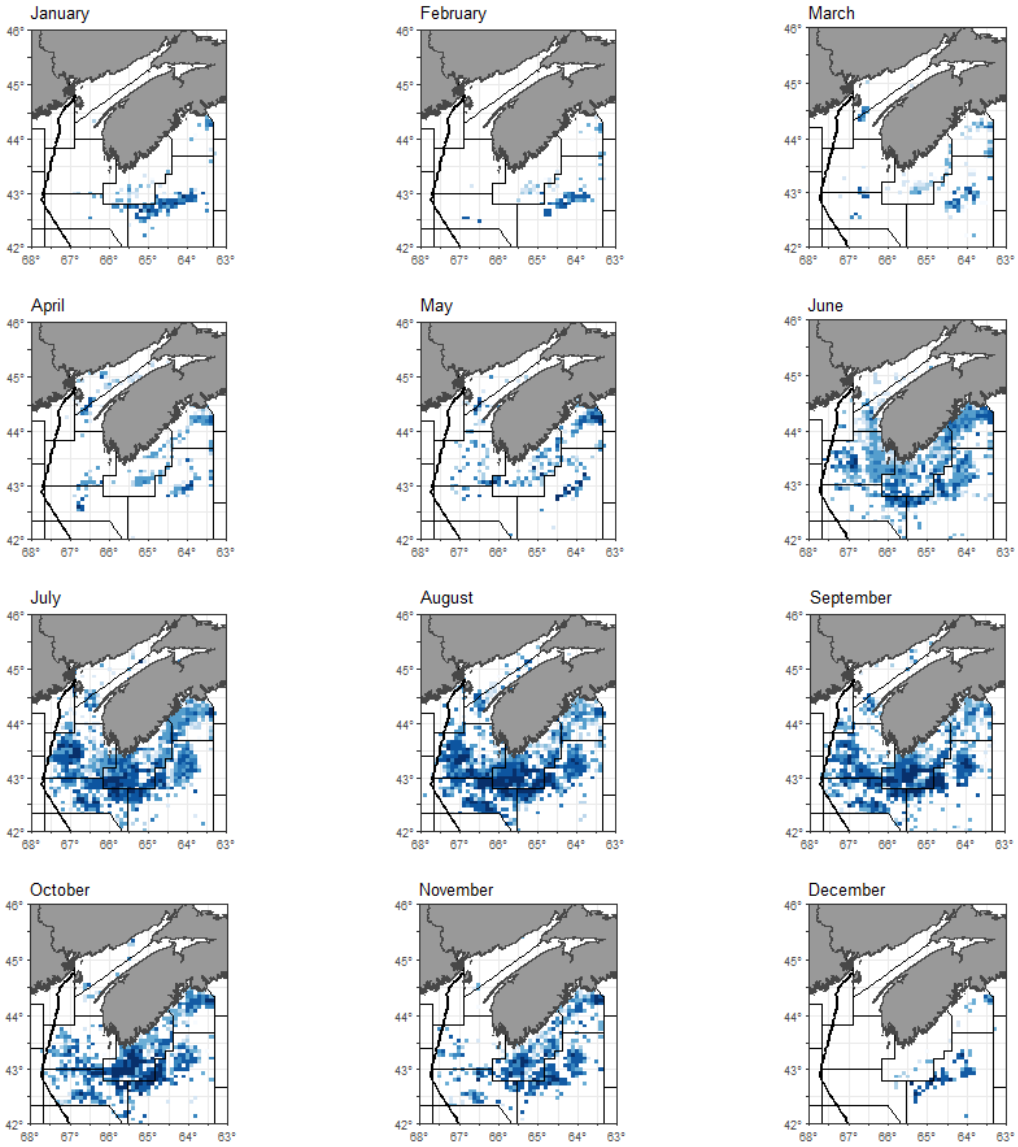

Figure 13. Distribution of Cod catches by fixed gear for NAFO Division 4X5Y by month (facets) between 2009 and 2017. Catches are aggregated by 6 minute squares, with darker color indicative of higher catch.

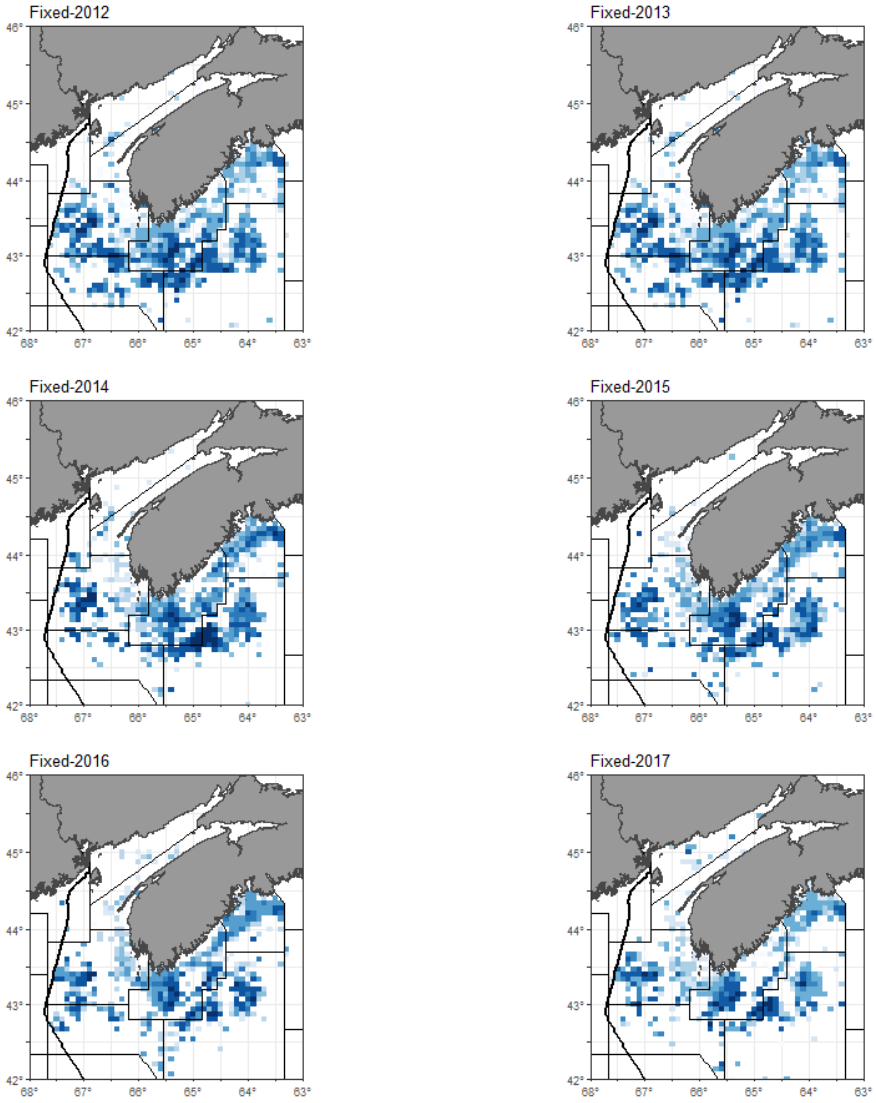

Figure 14. Distribution of commercial Cod catches by fixed gear by calendar year (2012–2017). Catches are aggregated by 6 minute squares, with darker color indicative of higher catch.

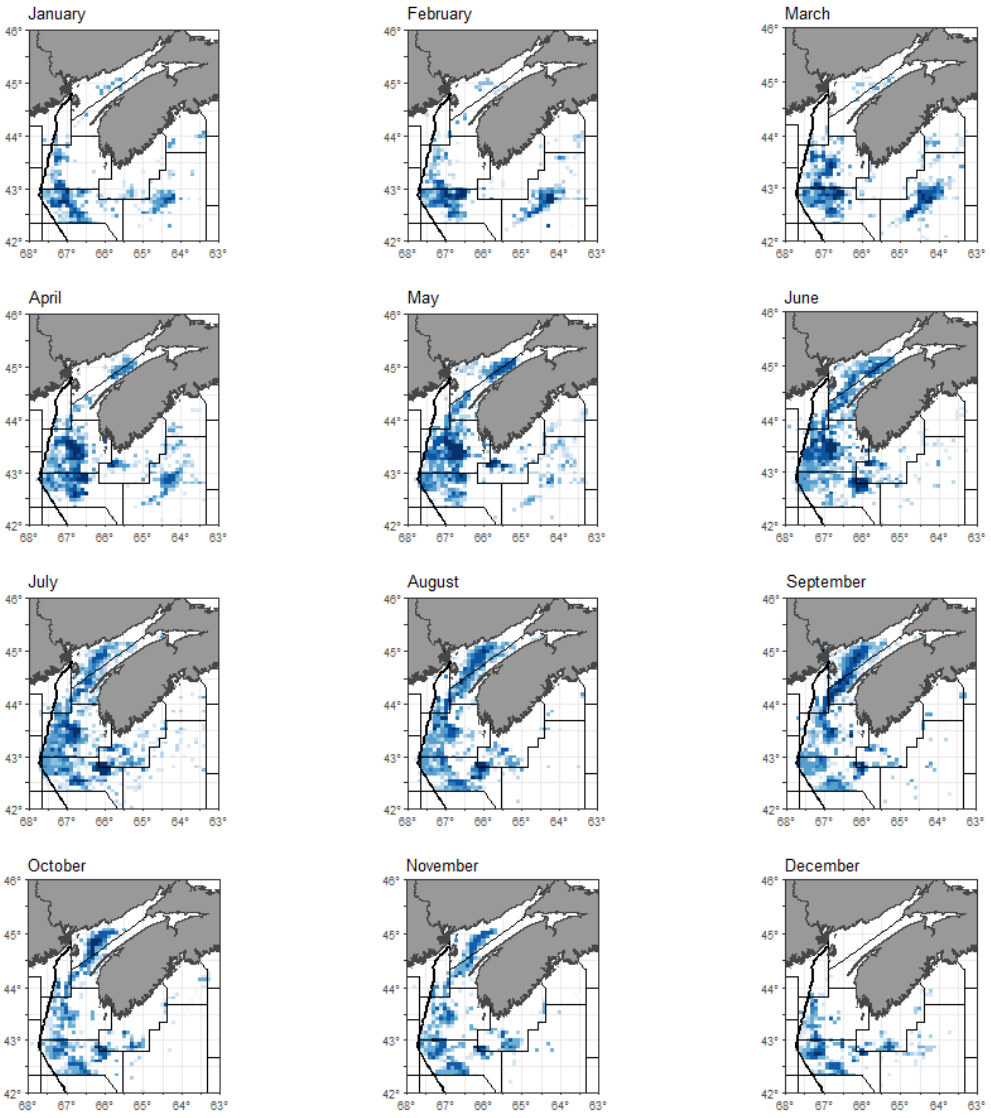

Figure 15. Distribution of Cod catches by mobile gear for NAFO Division 4X5Y by month (facets) between 2009 and 2017. Catches are aggregated by 6 minute squares, with darker color indicative of higher catch.

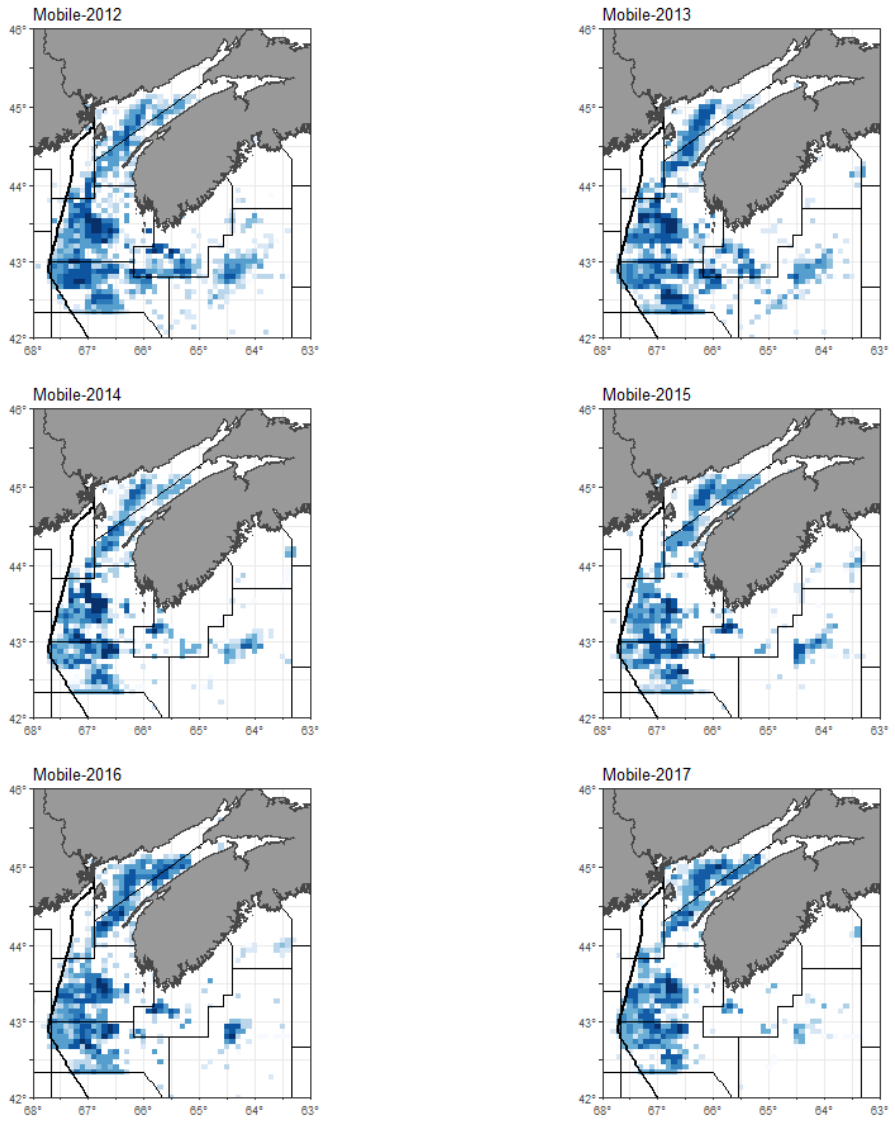

Figure 16. Distribution of commercial Cod catches by mobile gear by calendar year (2012–2017). Catches are aggregated by 6 minute squares, with darker color indicative of higher catch.

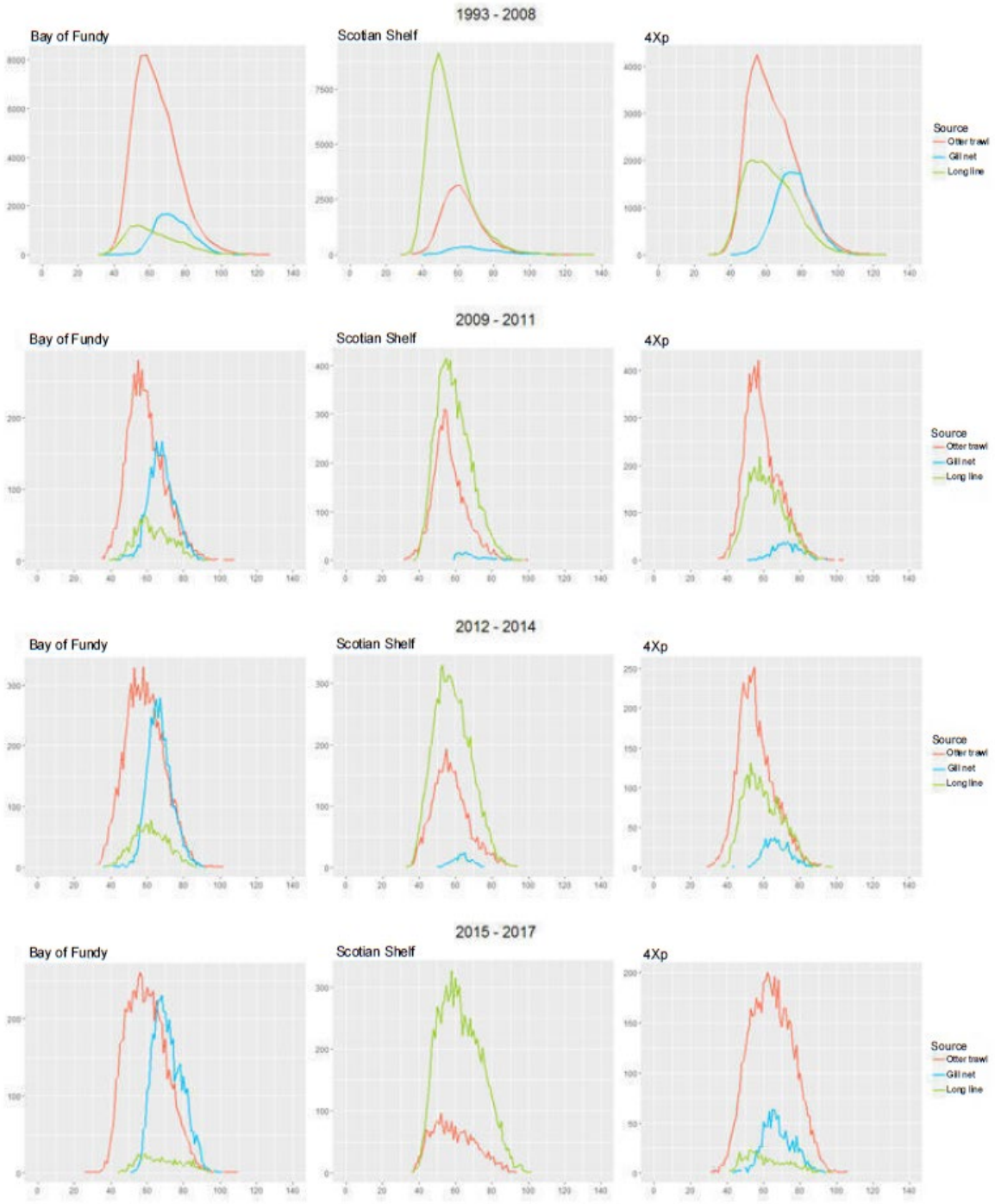

Figure 17. Length-frequency distributions of commercial catch by time period, gear and major area.

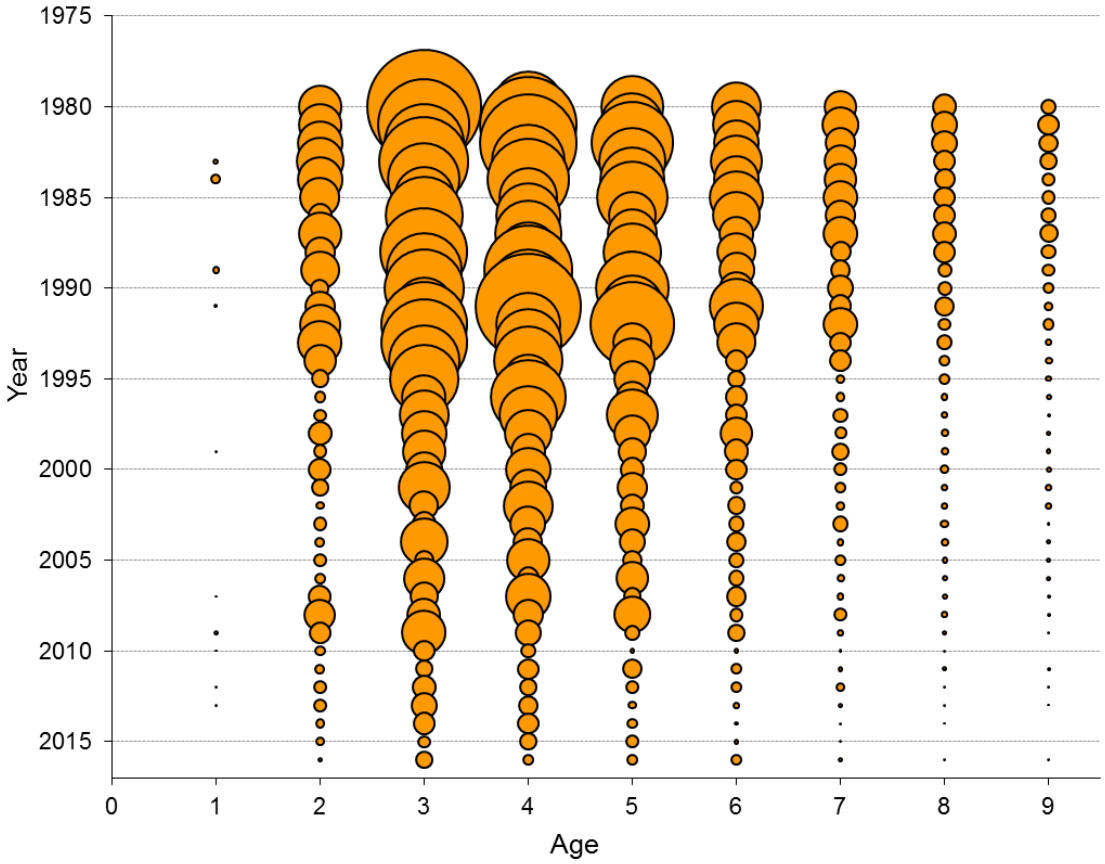

Figure 18. Commercial fishery Catch at Age (CAA) for 4X5Y Cod. Bubble area is proportional to abundance.

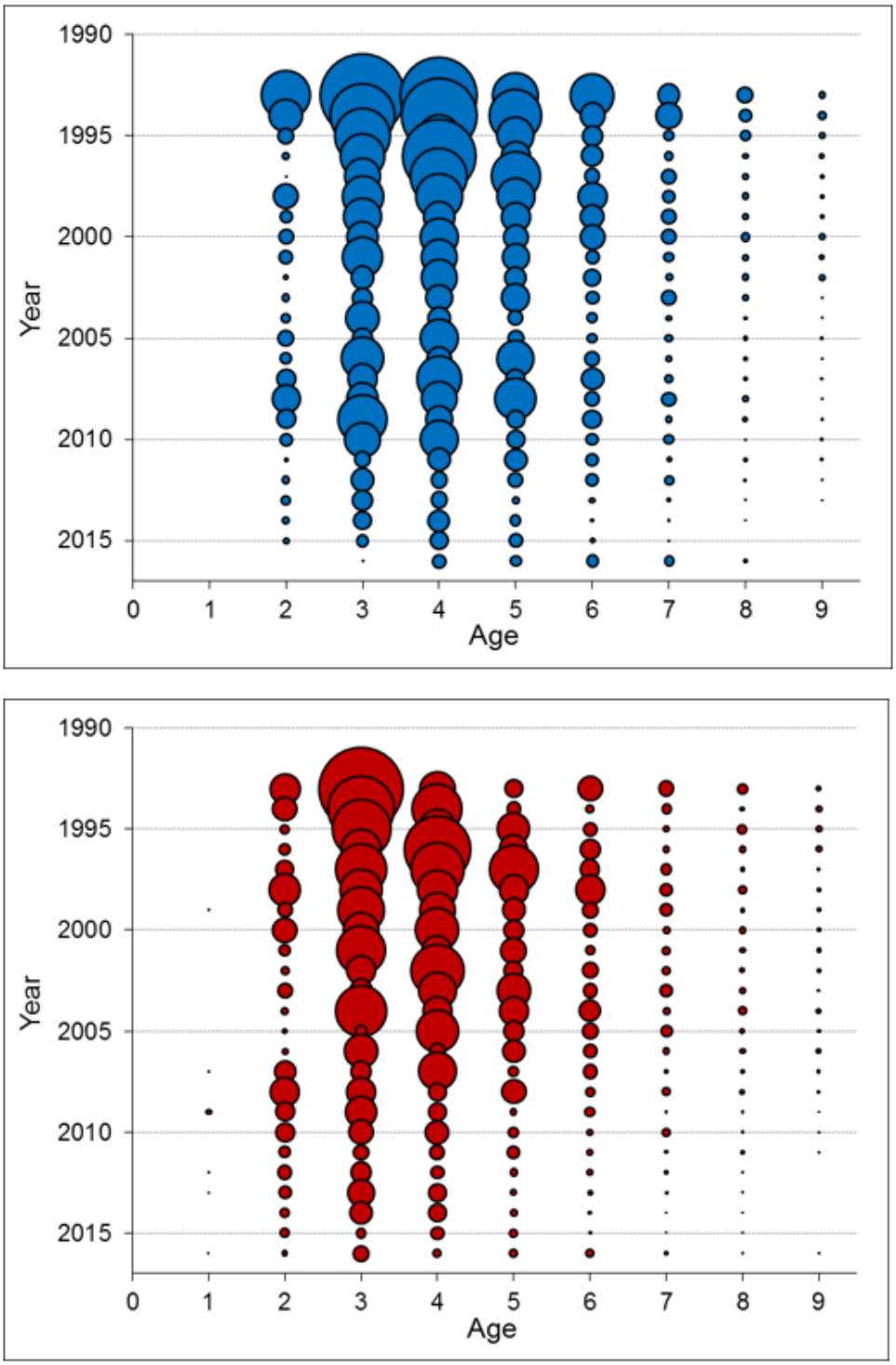

Figure 19. Commercial catch at age for Scotian Shelf (upper panel, blue) and Bay of Fundy (lower panel, red) Cod.

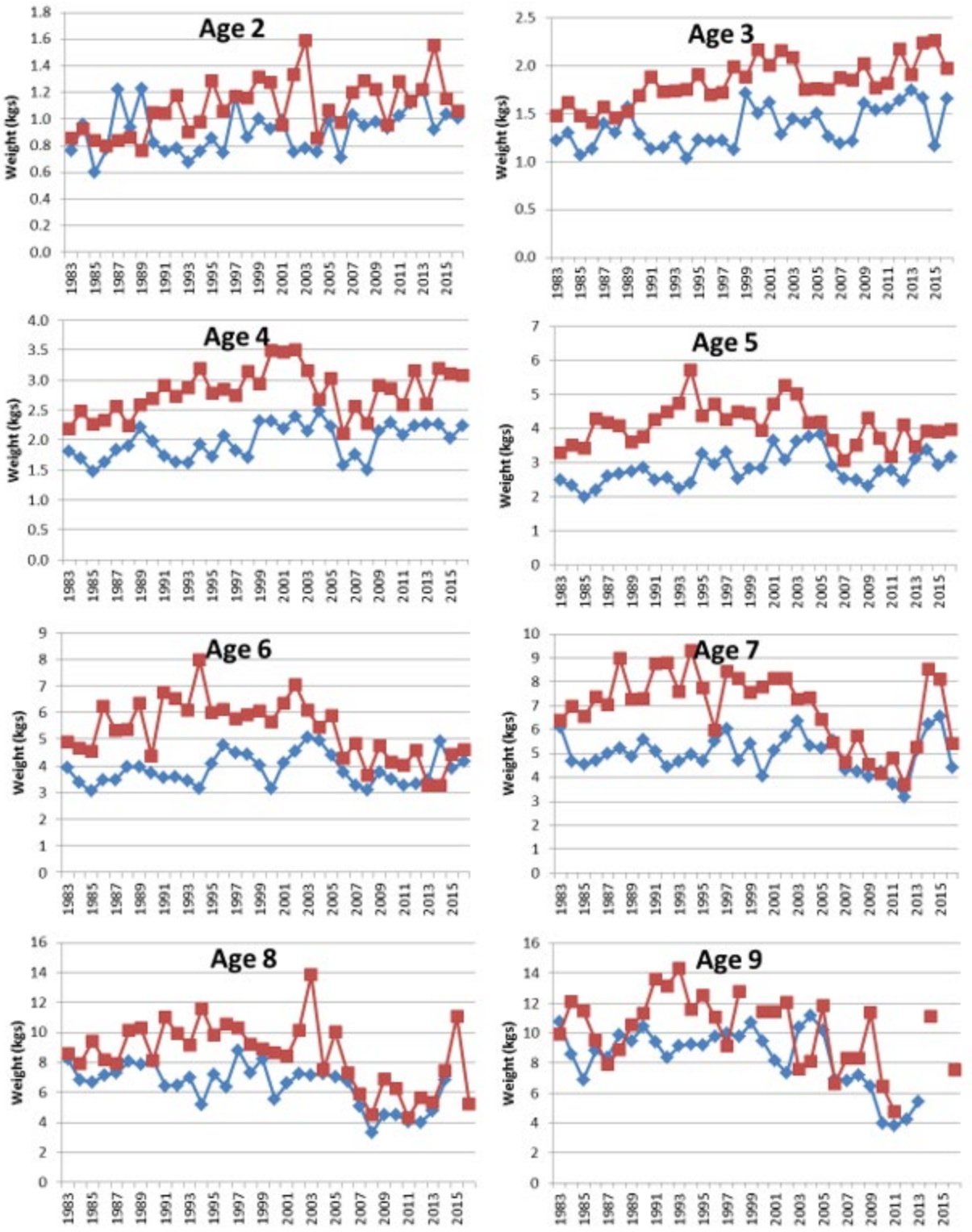

Figure 20. Commercial Fishery Weight at Age (kgs) for Scotian Shelf (blue diamonds) and Bay of Fundy (red squares).

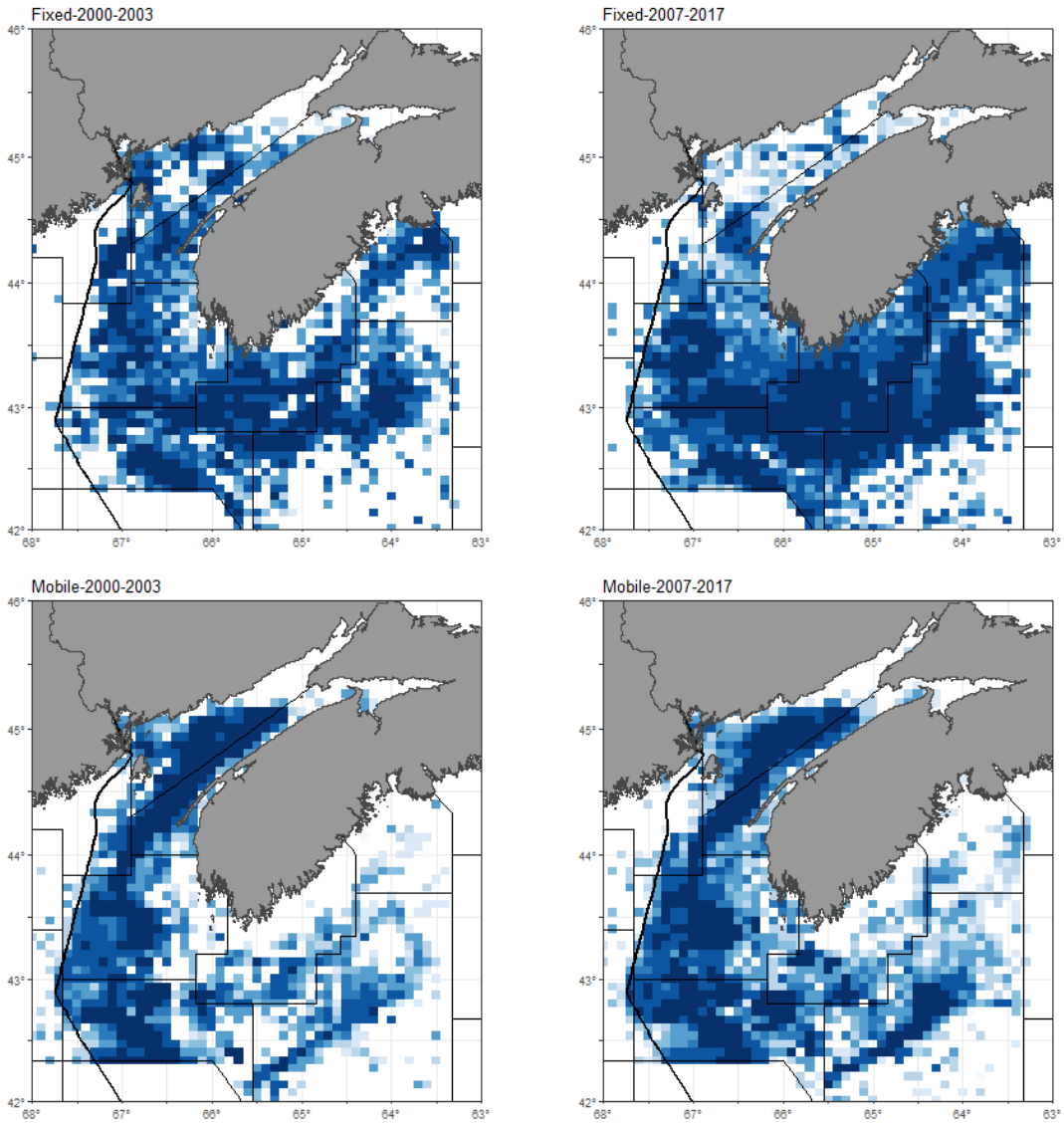

Figure 21. Distribution of Cod catches by Fixed (upper panels) and Mobile (lower panels) gears for 2000–2003 (left panels) and 2007–2017 (right panels), aggregated by 6 minute squares. Darker colour is indicative of more catch.

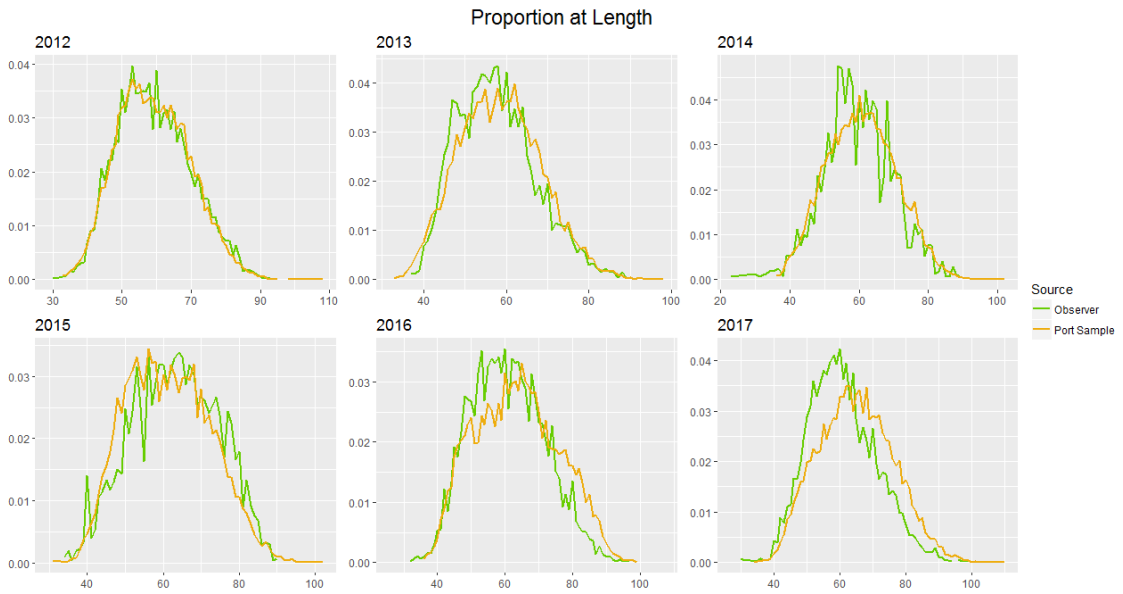

Figure 22. Cumulative annual proportions at lengths of Cod in 4X5Y as measured by observers (green) and port samplers (yellow).

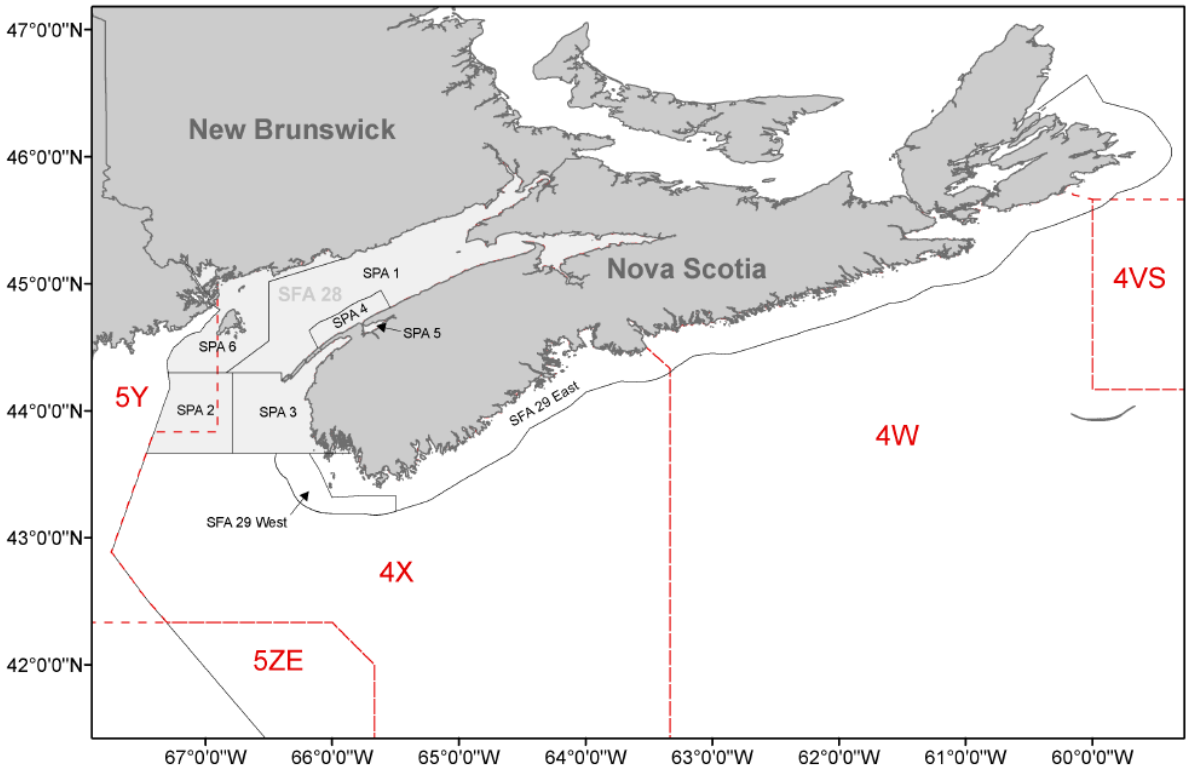

Figure 23. Inshore Scallop Fishing Areas (SFA), Scallop Production Areas (SPA) and NAFO divisions in the Maritimes Region, Canada. Sameoto and Glass 2012.

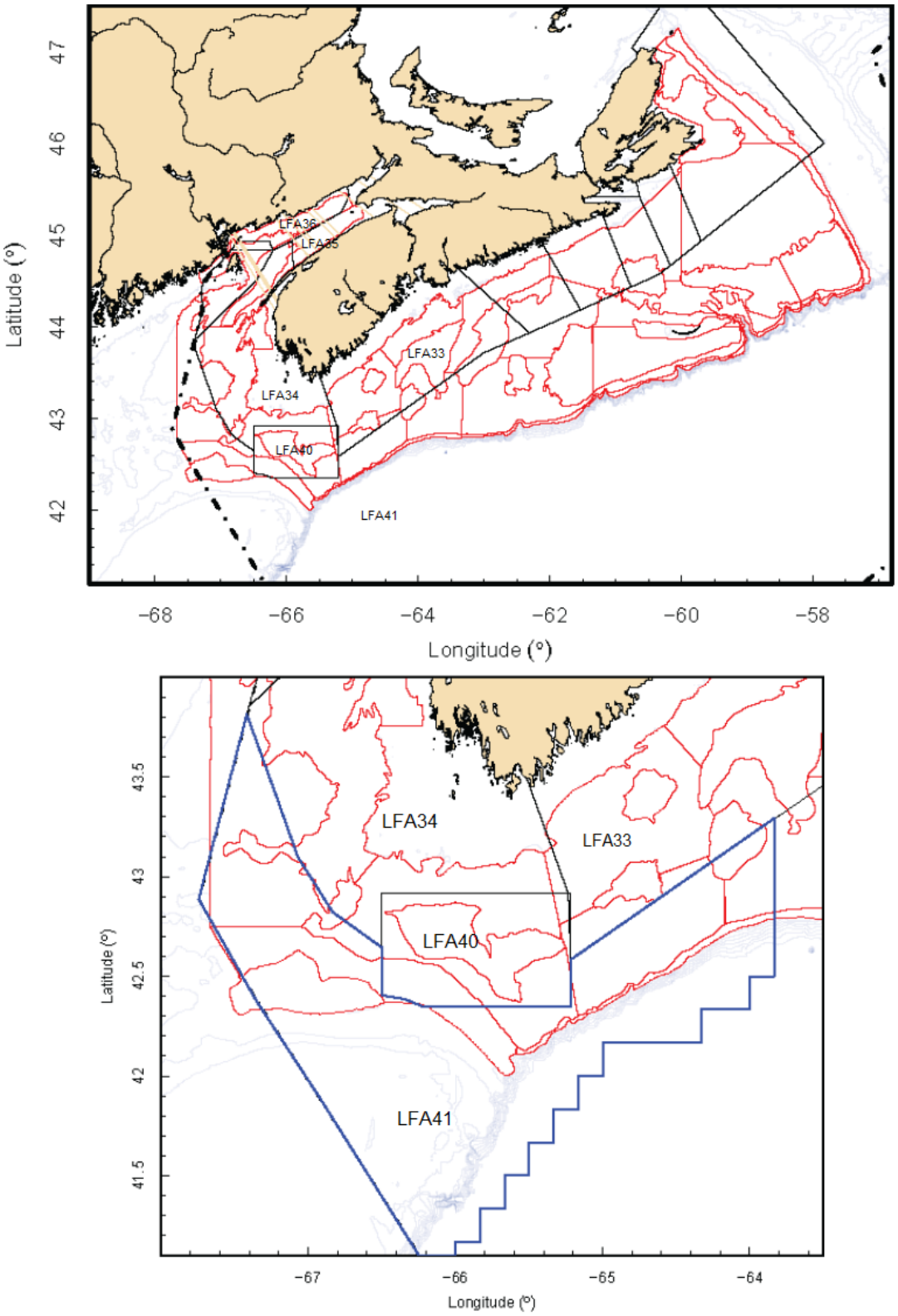

Figure 24. Map of Lobster Fishing Areas (LFA) in the 4X5Y region. Bottom panel is close-up of the fished areas of LFA41 in blue. Red contours indicate RV survey strata. Cook et al. 2017.

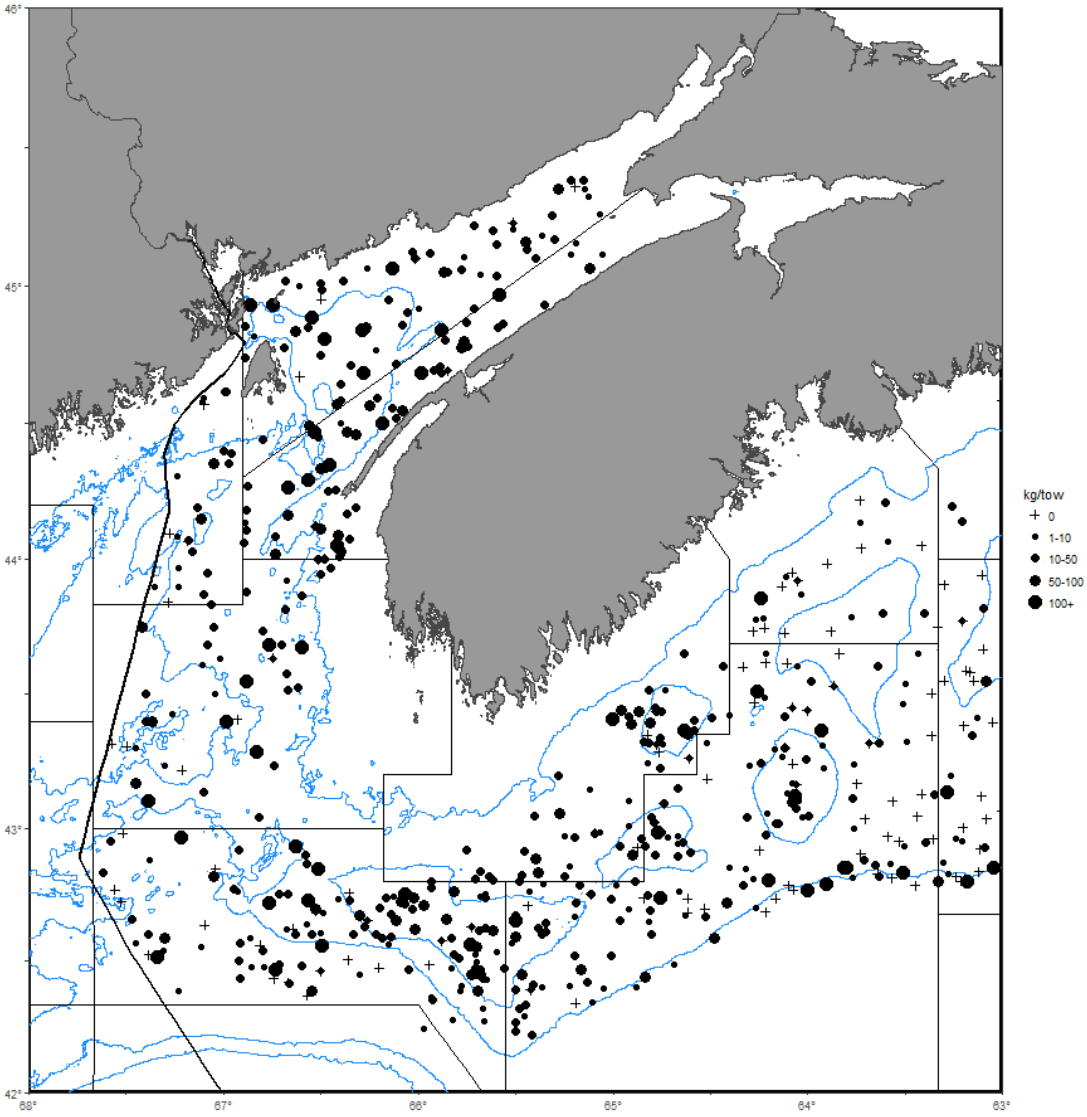

Figure 25. 4X5Y Cod catch distribution (kg/tow) for all valid summer RV survey sets between 1985 and 1994.

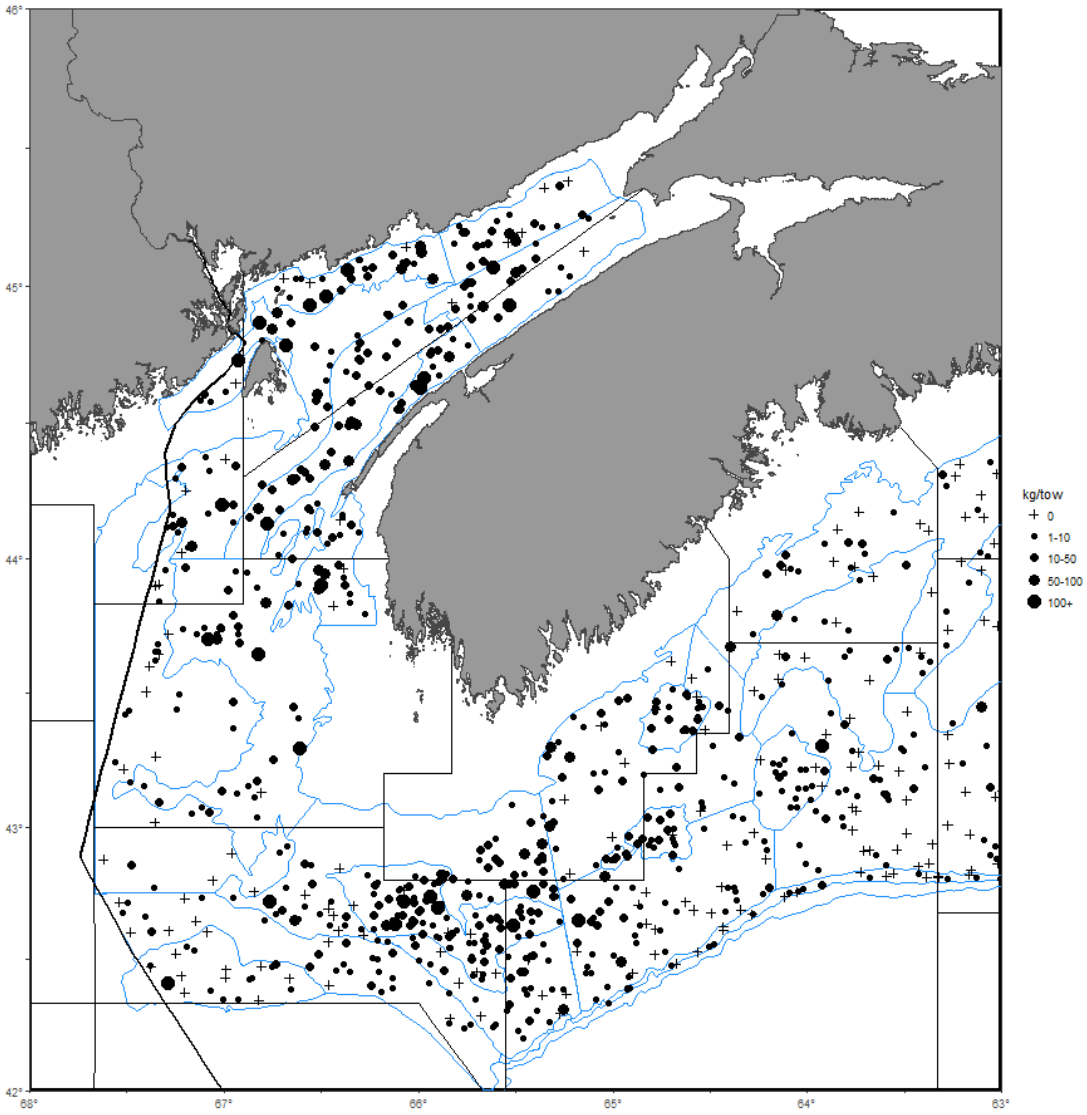

Figure 26. 4X5Y Cod catch distribution (kg/tow) for all valid summer RV survey sets between 1995 and 2005.

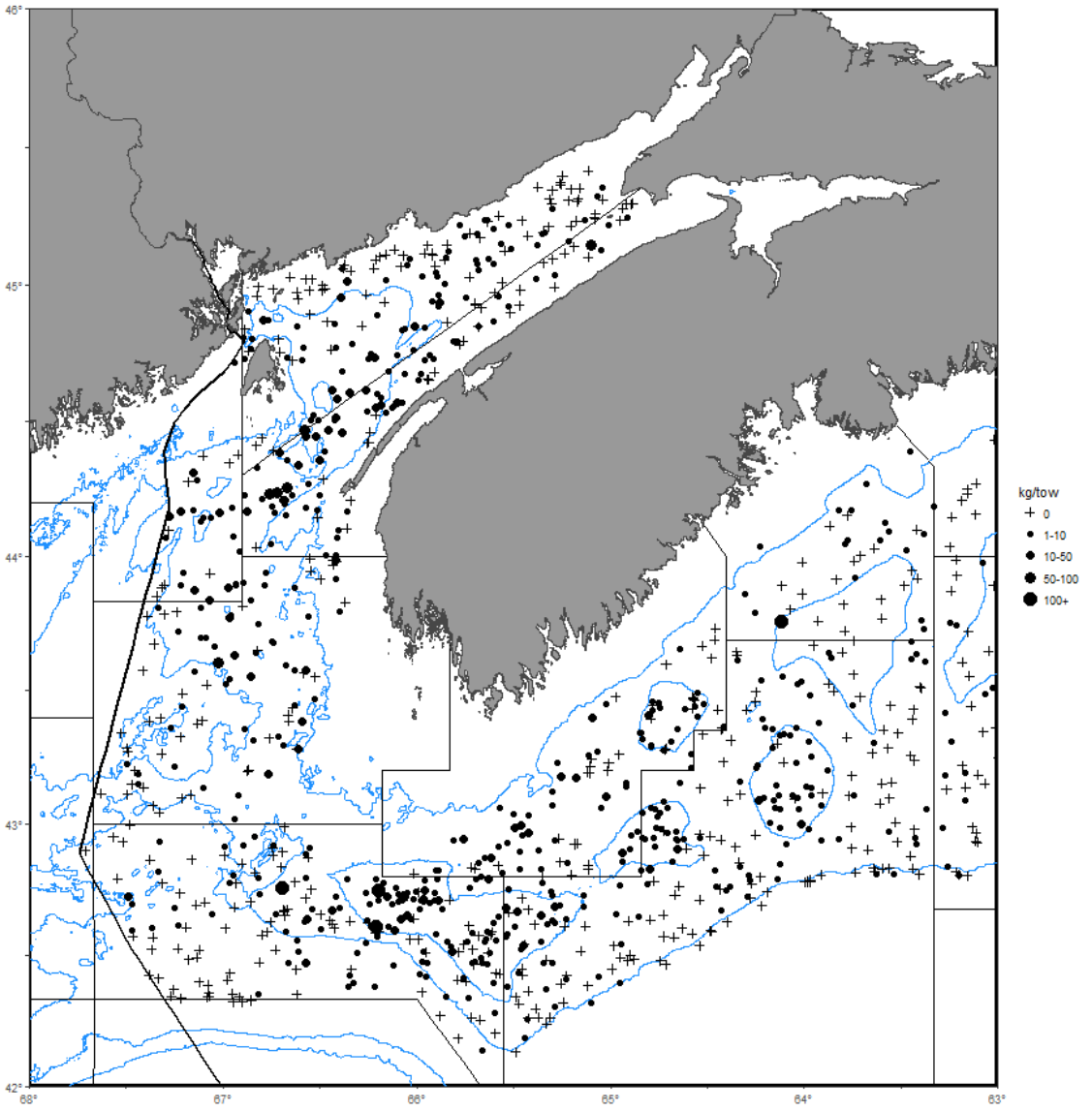

Figure 27. 4X5Y Cod catch distribution (kg/tow) for all valid summer RV survey sets between 2006 and 2016.

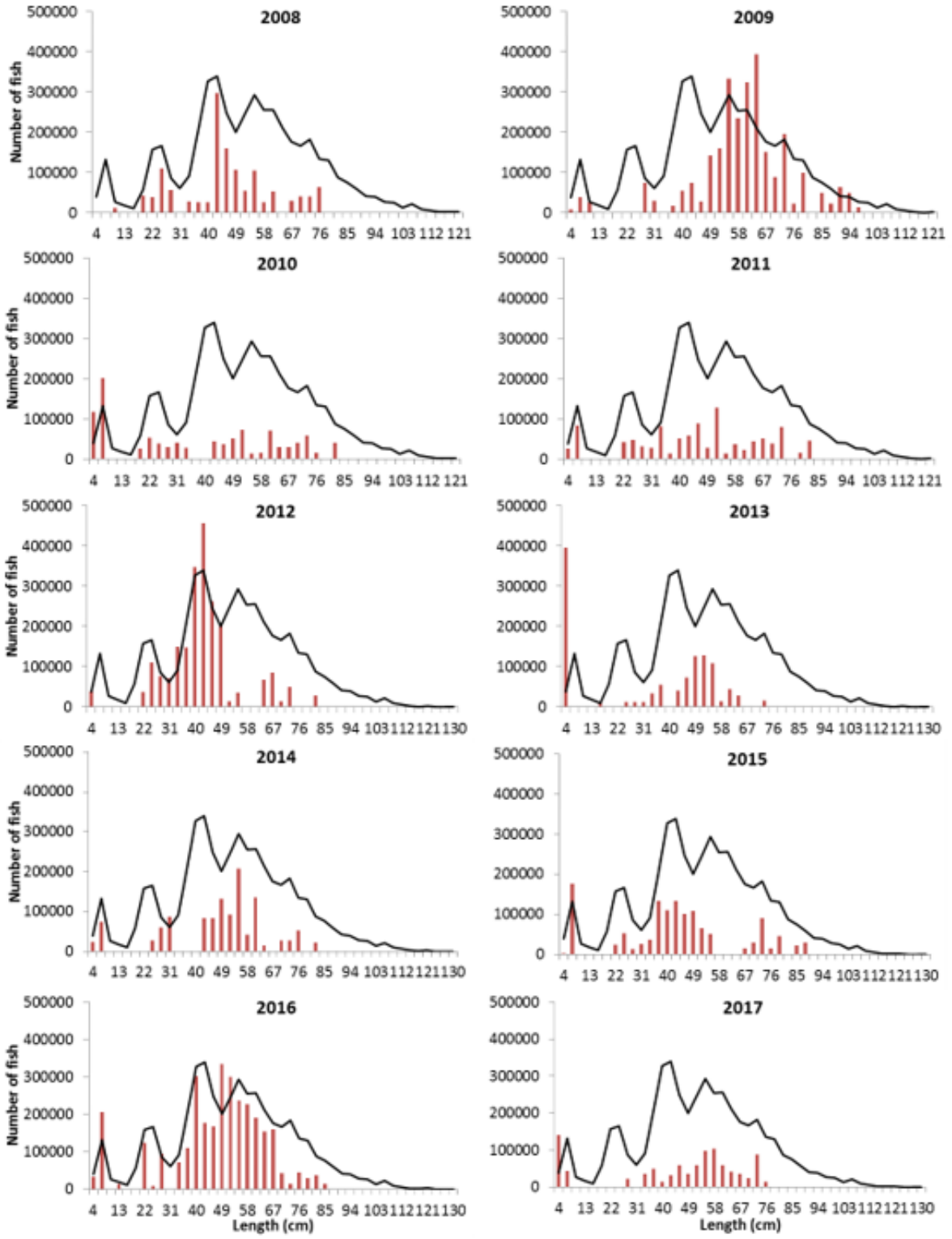

Figure 28. Annual numbers at length of Bay of Fundy Cod from the RV Summer Survey. Black line is average number at length from 1983 to 2017.

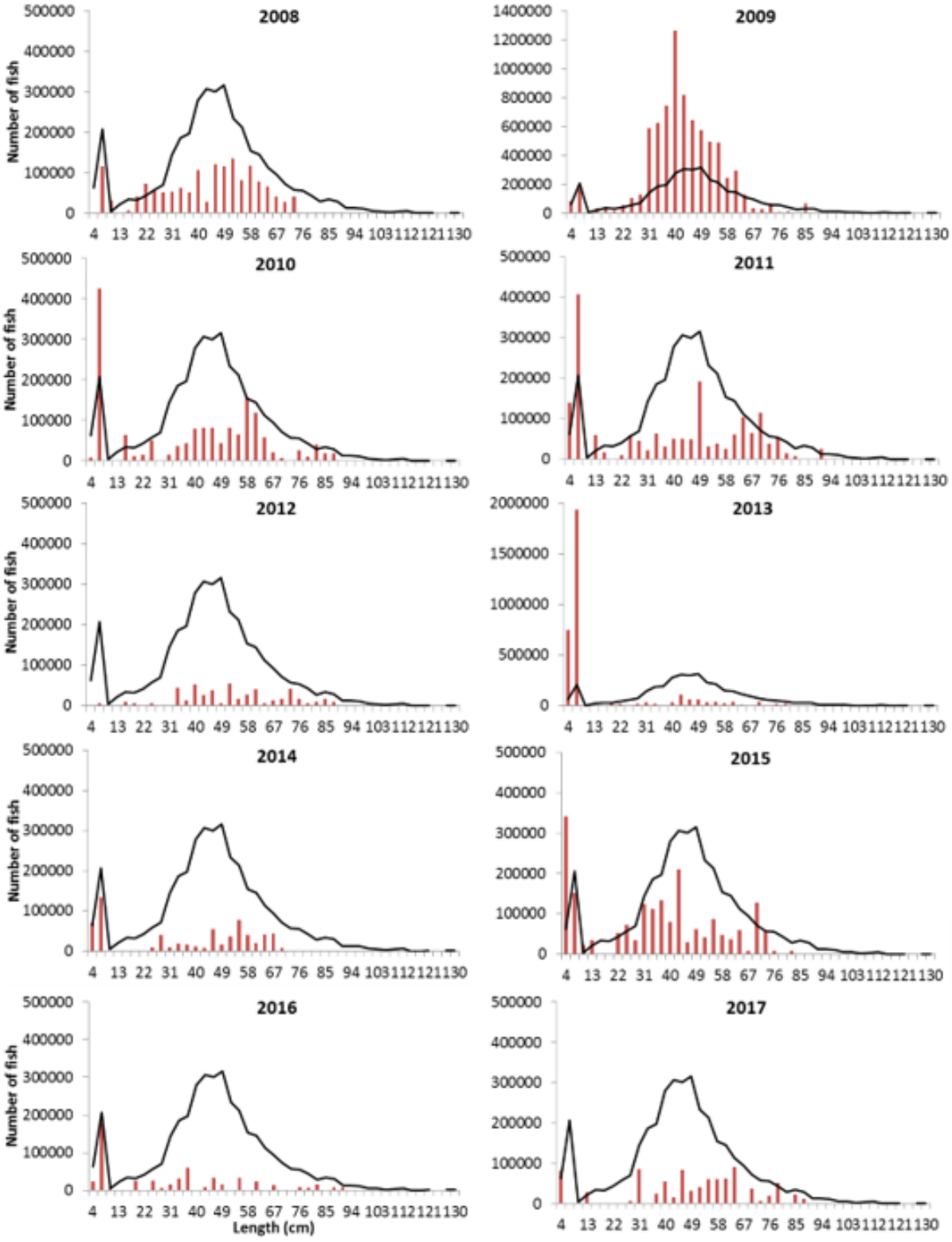

Figure 29. Annual numbers at length of Scotian Shelf Cod from the RV Summer Survey. Black line is average number at length from 1983 to 2017.

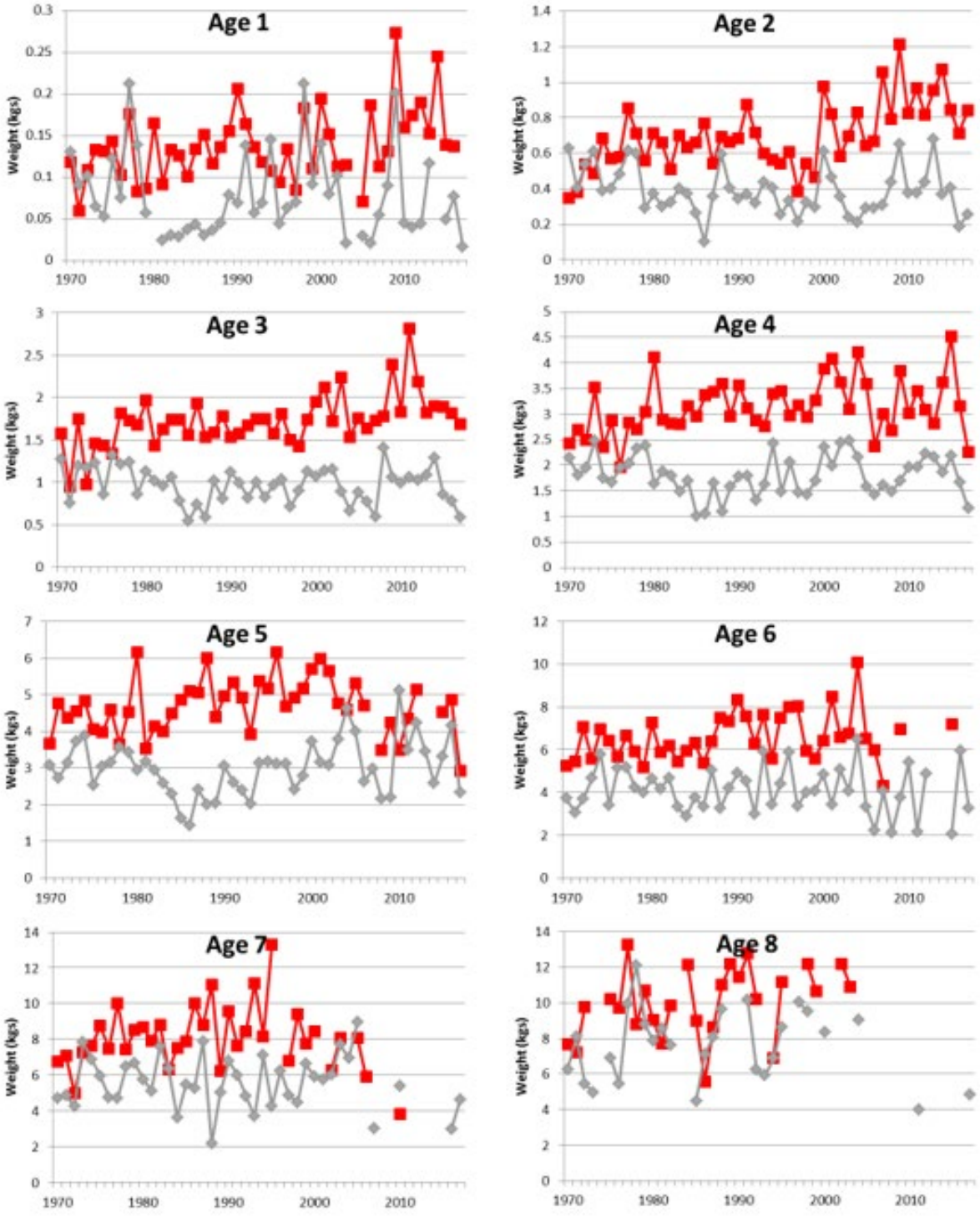

Figure 30. RV Summer Survey weight at age for Bay of Fundy (red squares) and Scotian Shelf (grey diamonds) fish.

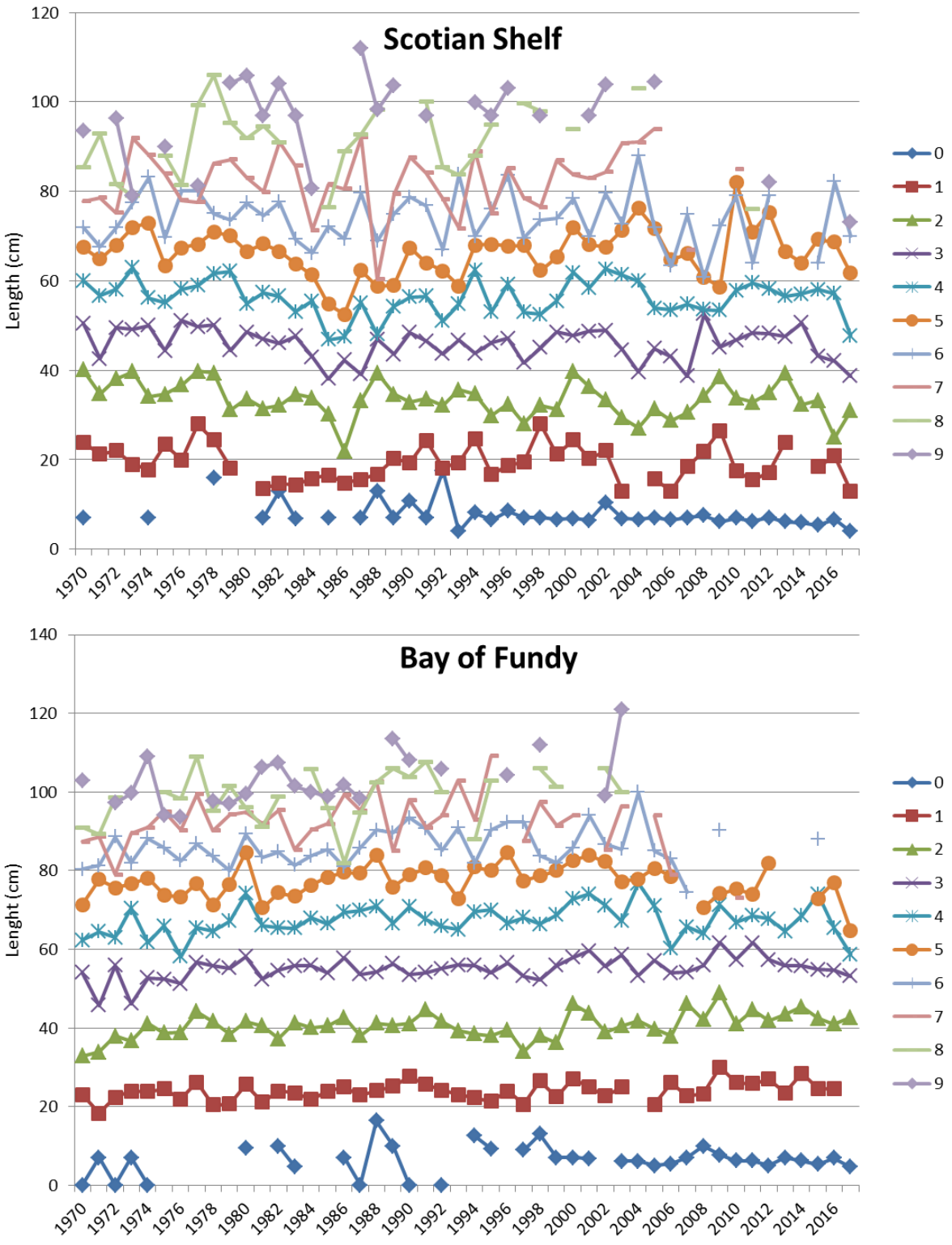

Figure 31. Length at age from the RV survey for Scotian Shelf (upper panel) and Bay of Fundy (lower panel) Cod.

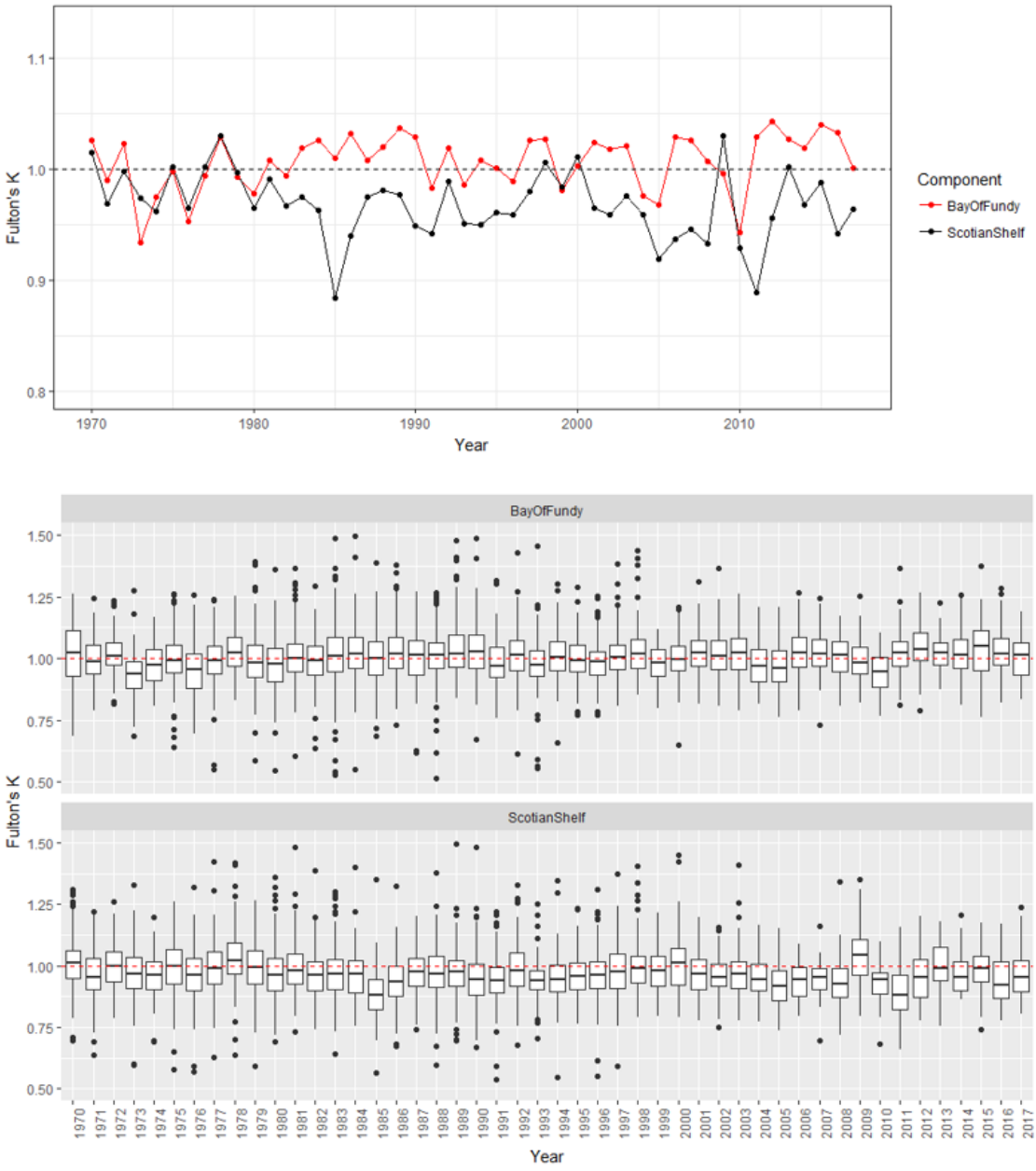

Figure 32. Fulton's K (weight/length^3) condition factor for NAFO Division 4X5Y Cod for Scotian Shelf and Bay of Fundy components.

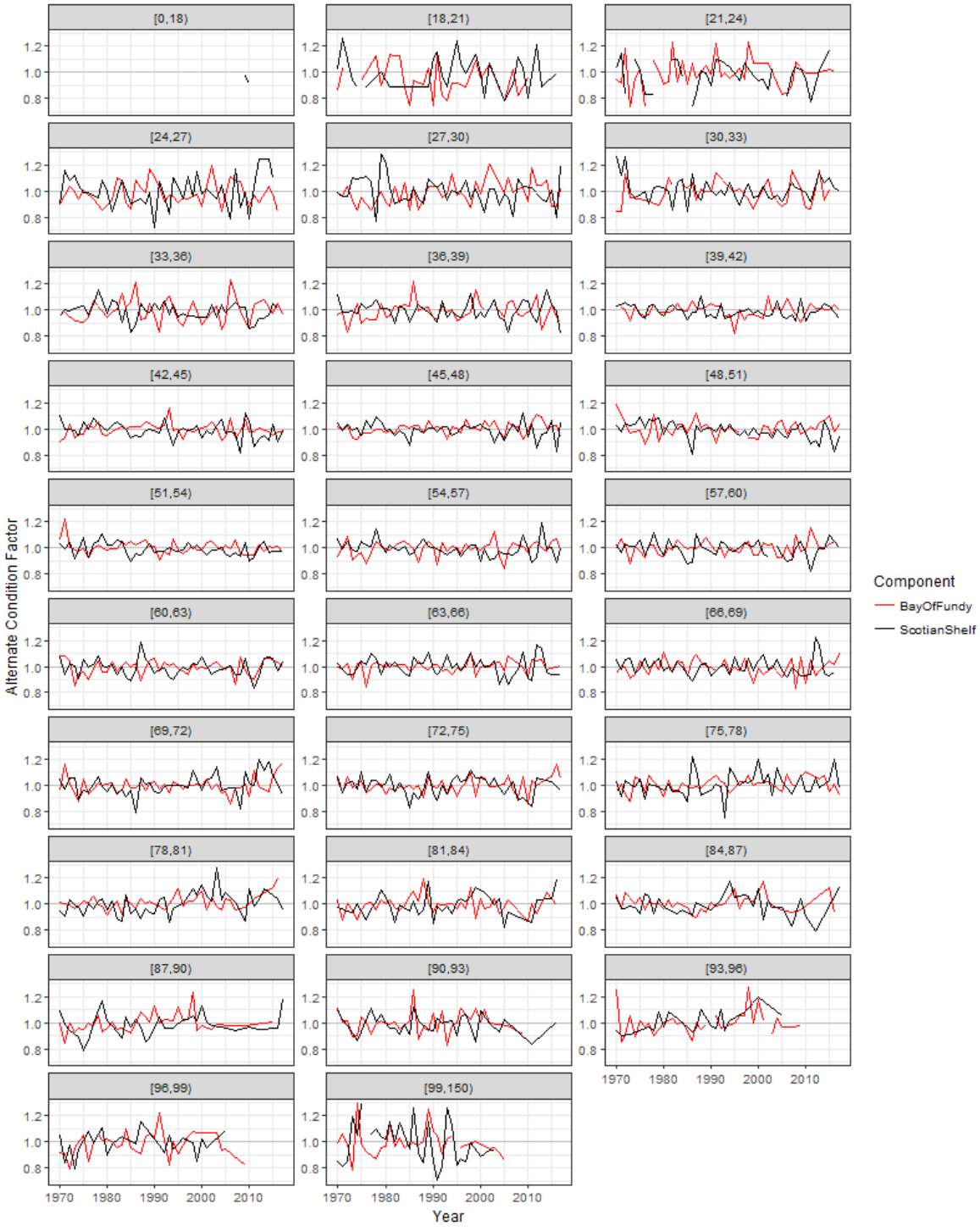

Figure 33. Alternate Condition Factor (Weight at Length$_{YearY}$ / Weight at Length$_{AllYears}$) per 3 cm length bin (facets) for Bay of Fundy and Scotian Shelf.

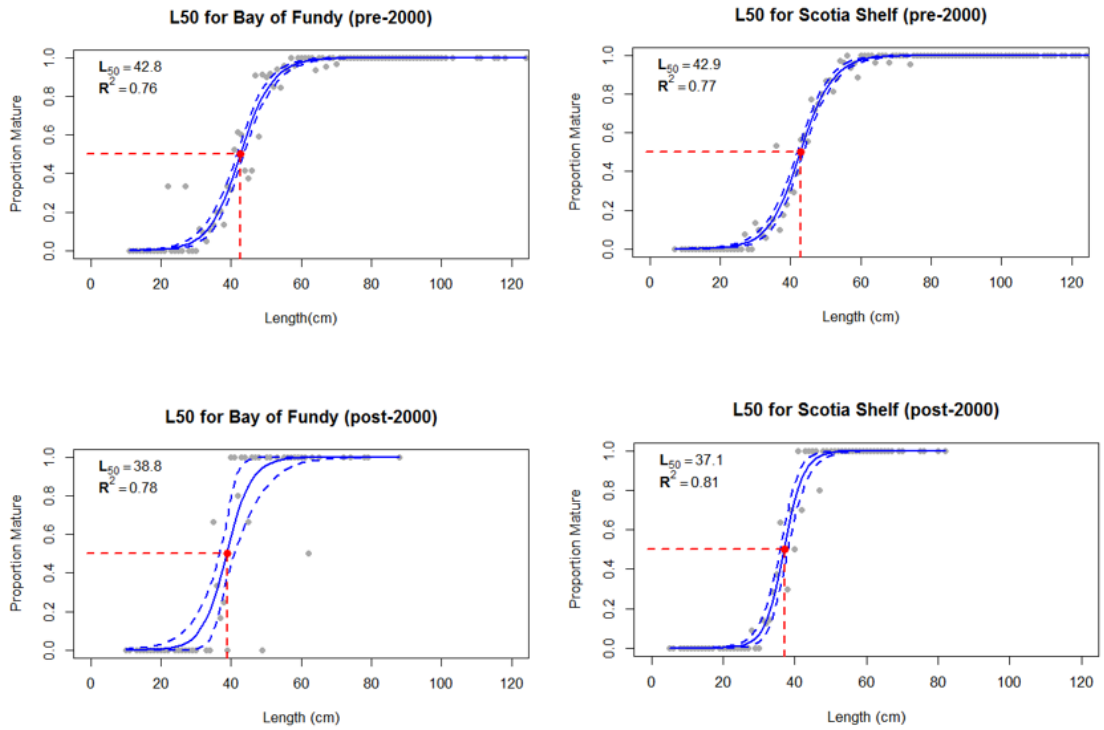

Figure 34. Length (cm) at 50% maturity of 4X5Y Cod caught on the RV Spring Survey during the early (pre-1990, upper panels) and late (post-2000, bottom panels) time periods. Panels indicate the Bay of Fundy (BF) or Scotian Shelf (SS) areas.

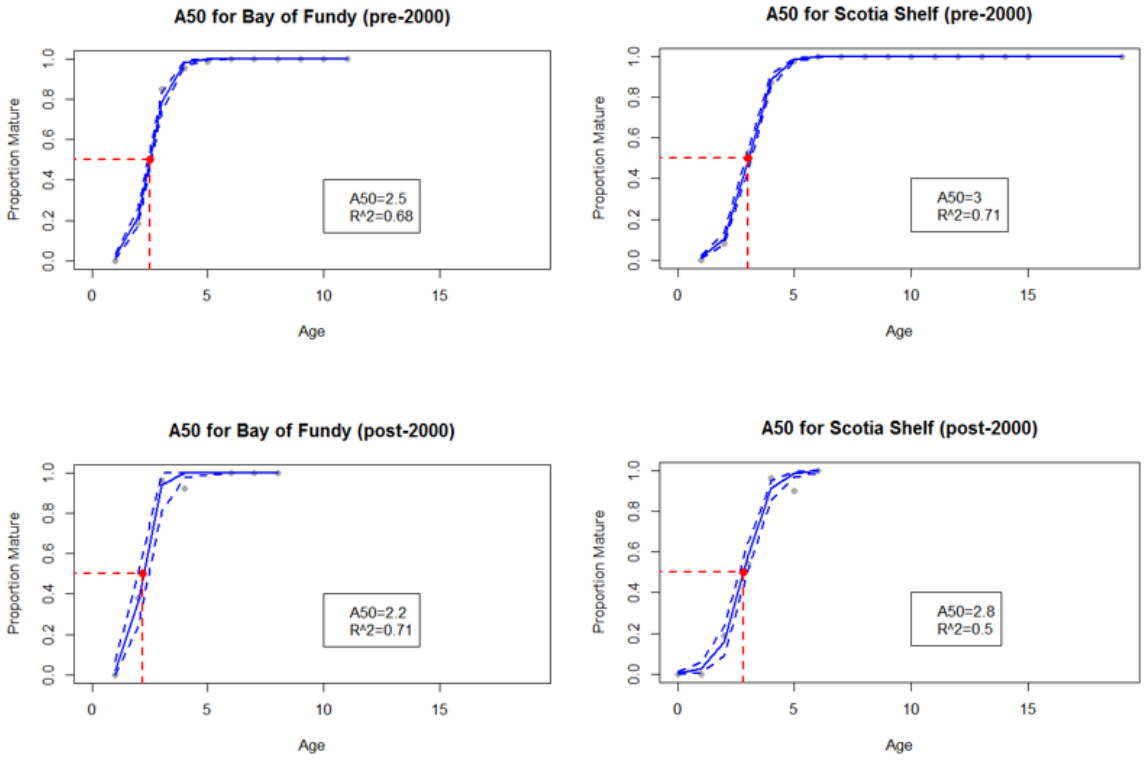

Figure 35. Age (years) at 50% maturity of 4X5Y Cod caught on the RV Spring Survey during the early (pre-1990, upper panels) and late (post-2000, bottom panels) time periods. Panels indicate the Bay of Fundy (BF) or Scotian Shelf (SS) areas.

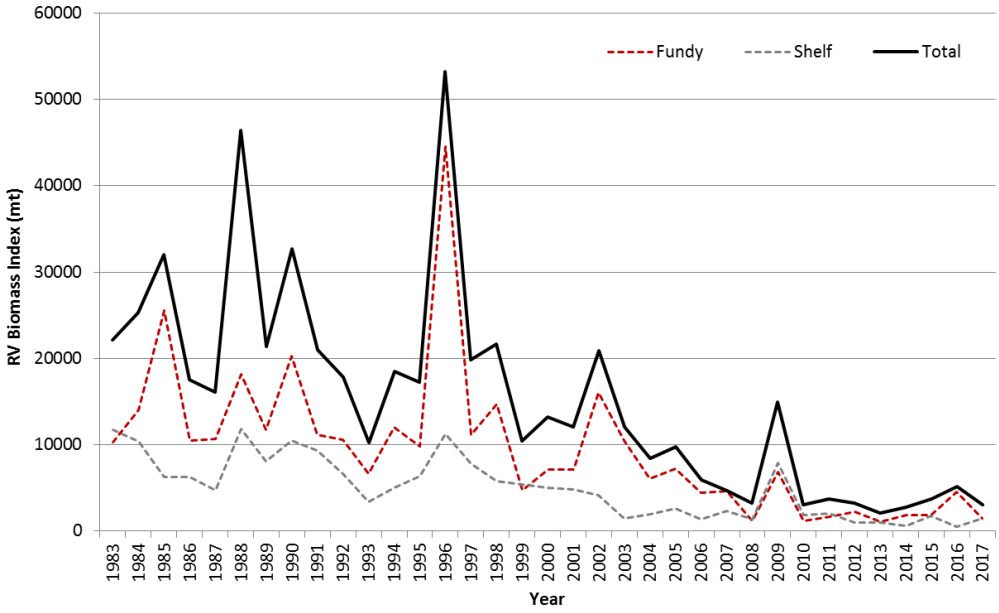

Figure 36. Total biomass index from the Summer RV Survey for all of 4X5Y (black line), as well as Bay of Fundy (dashed red) and Scotian Shelf (dashed grey) stock components, since 1983.

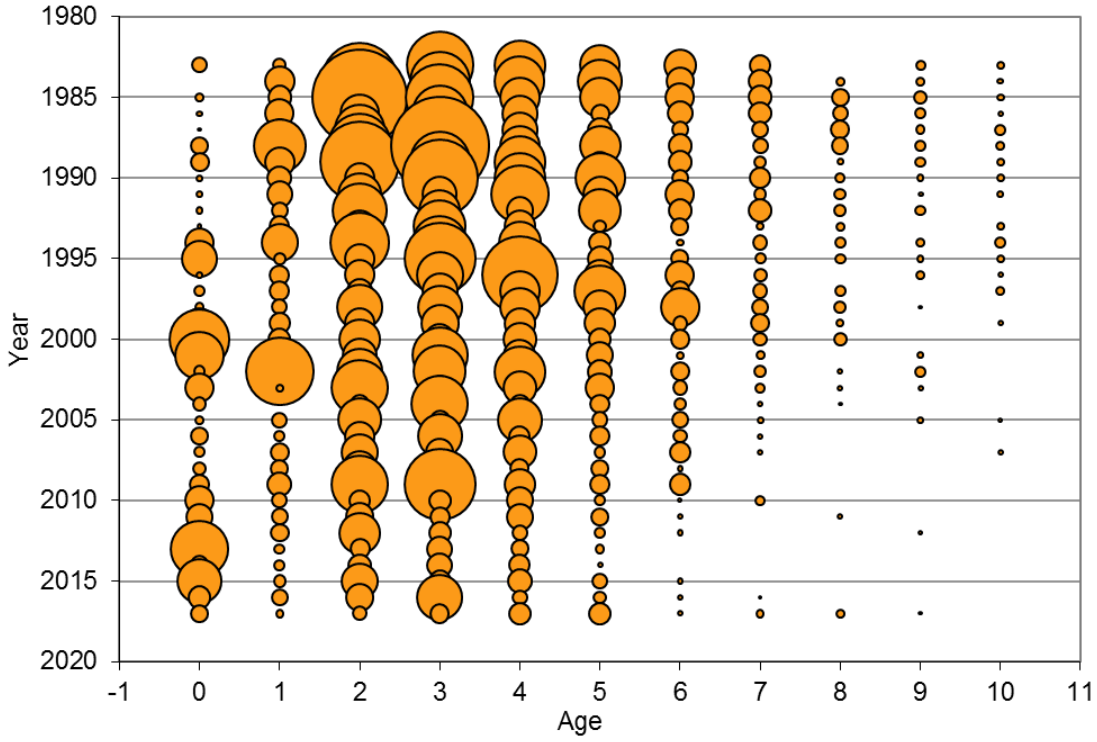

Figure 37. RV Survey indices at age for 4X5Y Cod. Bubble area is proportional to survey catch.

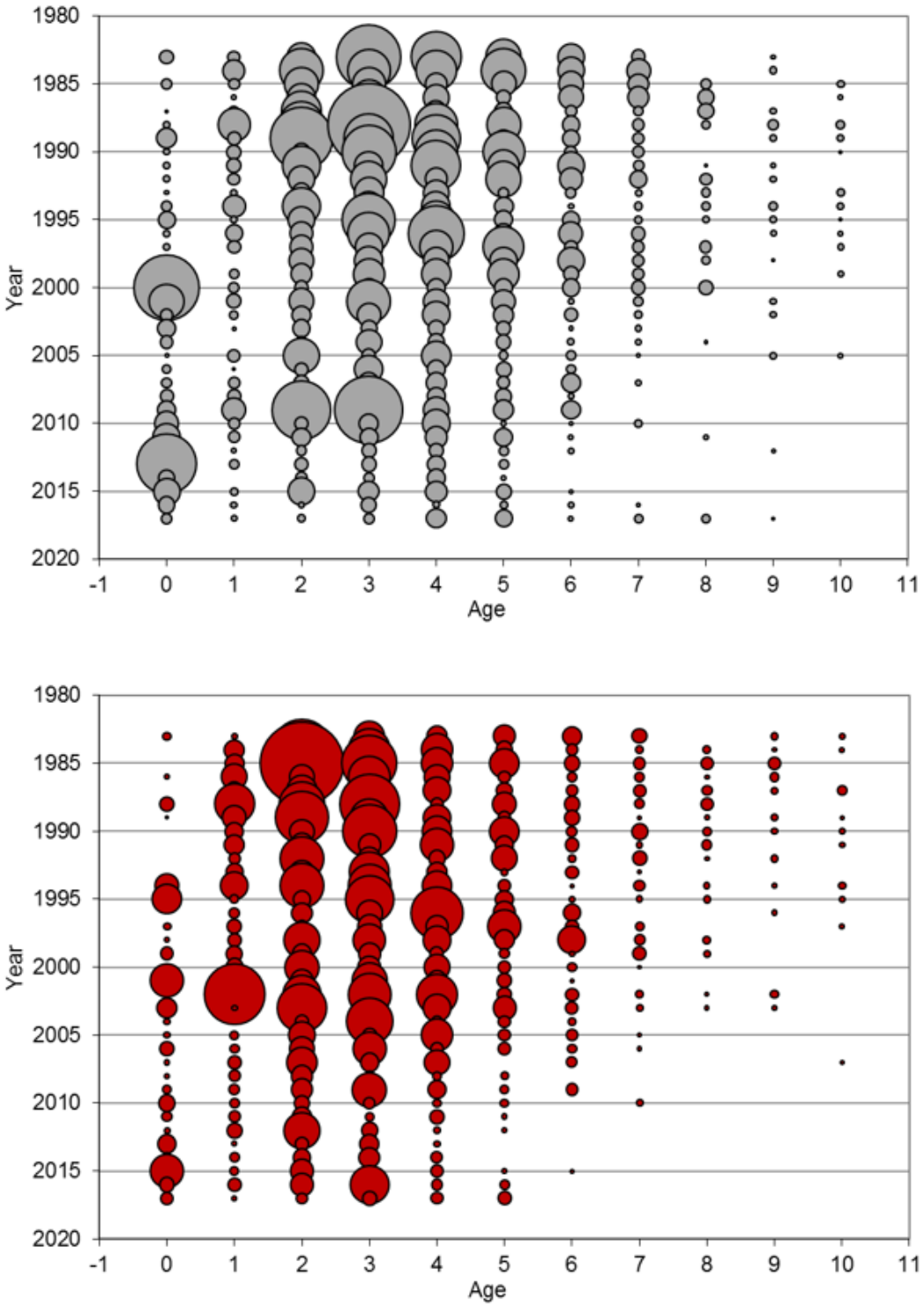

Figure 38. RV Survey indices at age for Cod in Scotian Shelf (upper panel; grey) and Bay of Fundy (lower panel, red). Bubble area proportional to survey catch.

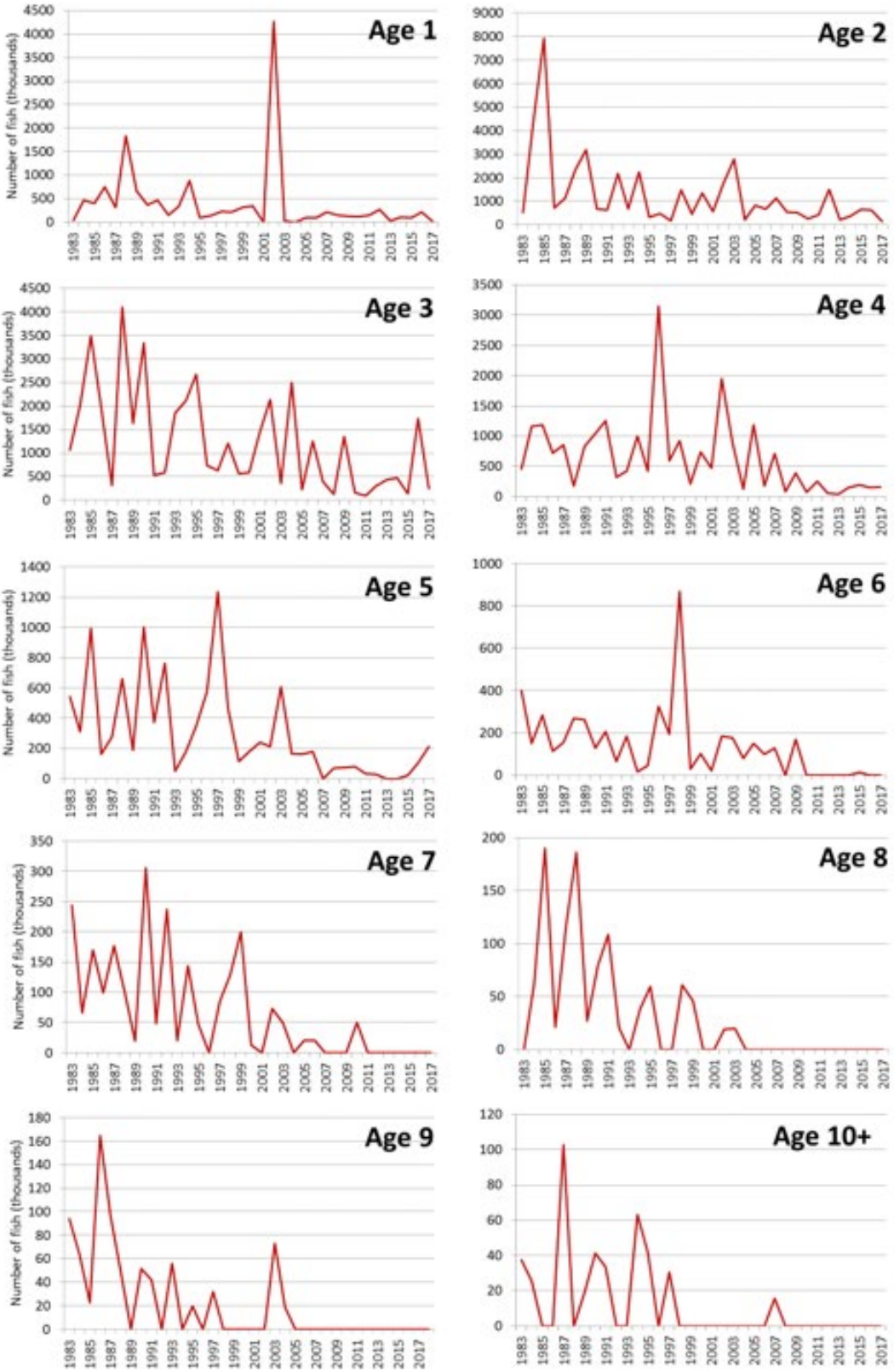

Figure 39. Indices at age (number of fish, thousands) for the Bay of Fundy portion of 4X5Y.

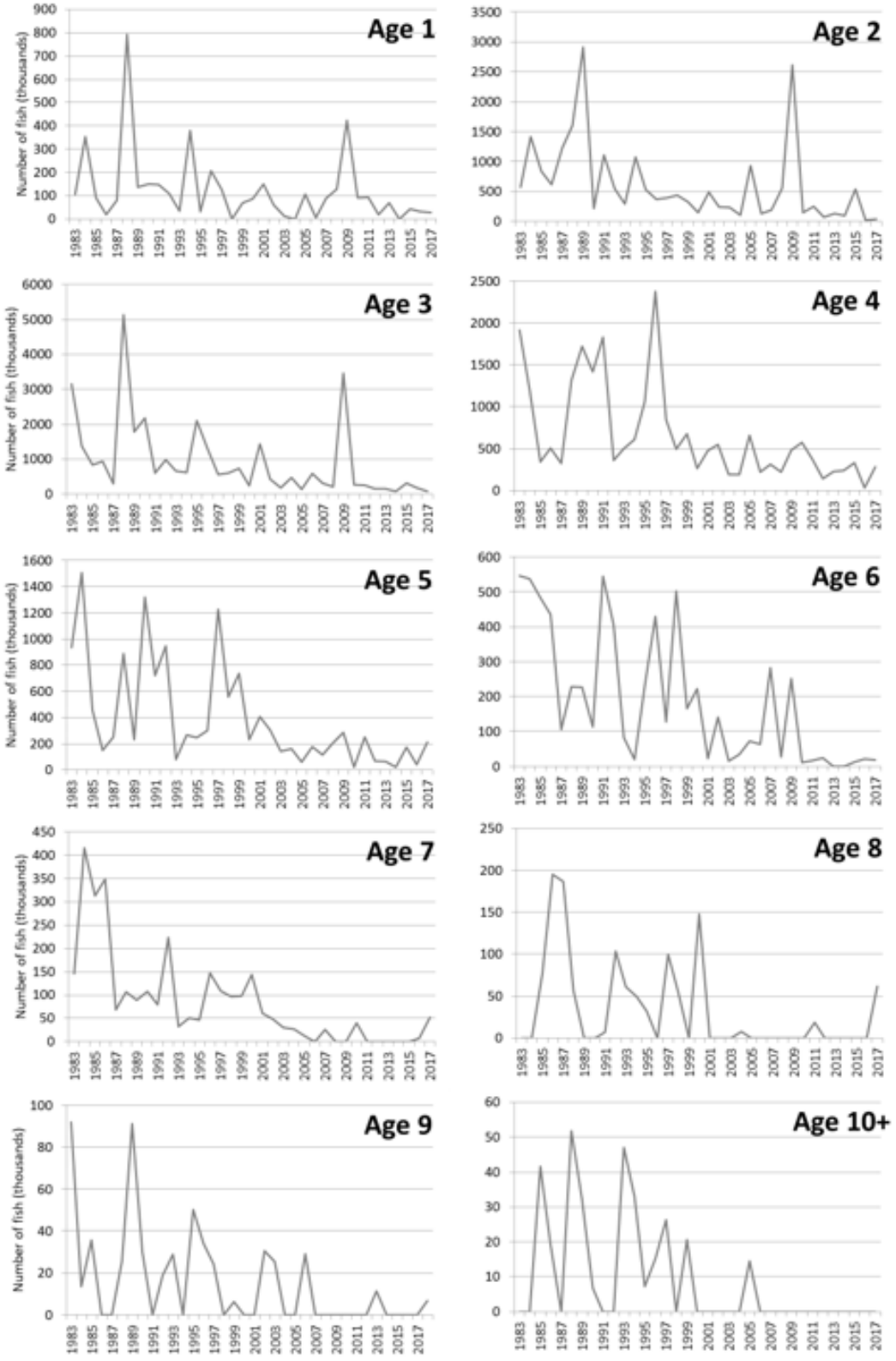

Figure 40. Indices at age (number of fish, thousands) for the Scotian Shelf portion of 4X5Y.

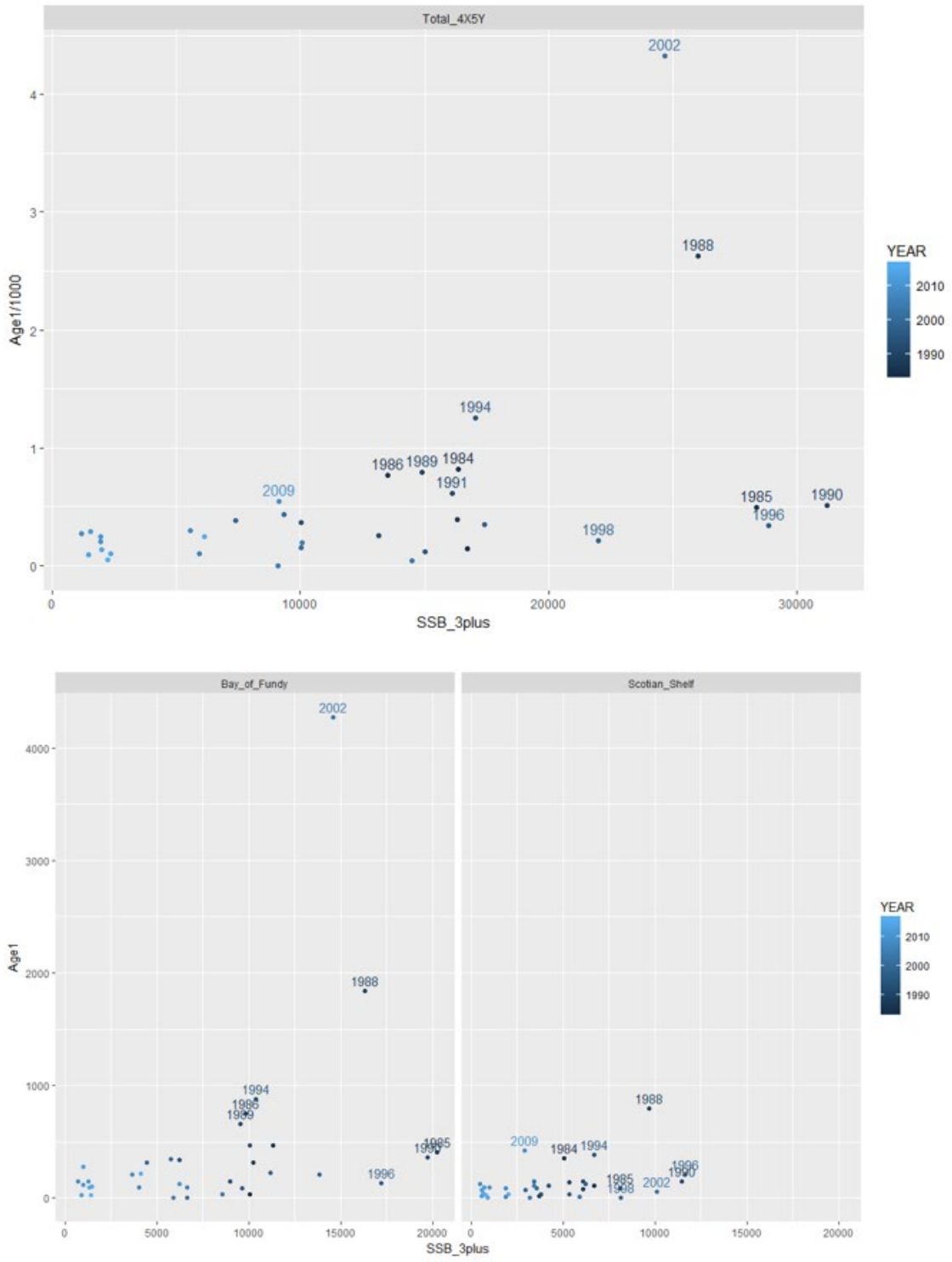

Figure 41. Stock-Recruitment relationship (Age 1 abundance vs. SSB) derived from the RV Summer Survey for 4X5Y management unit (top), Bay of Fundy (bottom left) and Scotian Shelf (bottom right) area Cod.

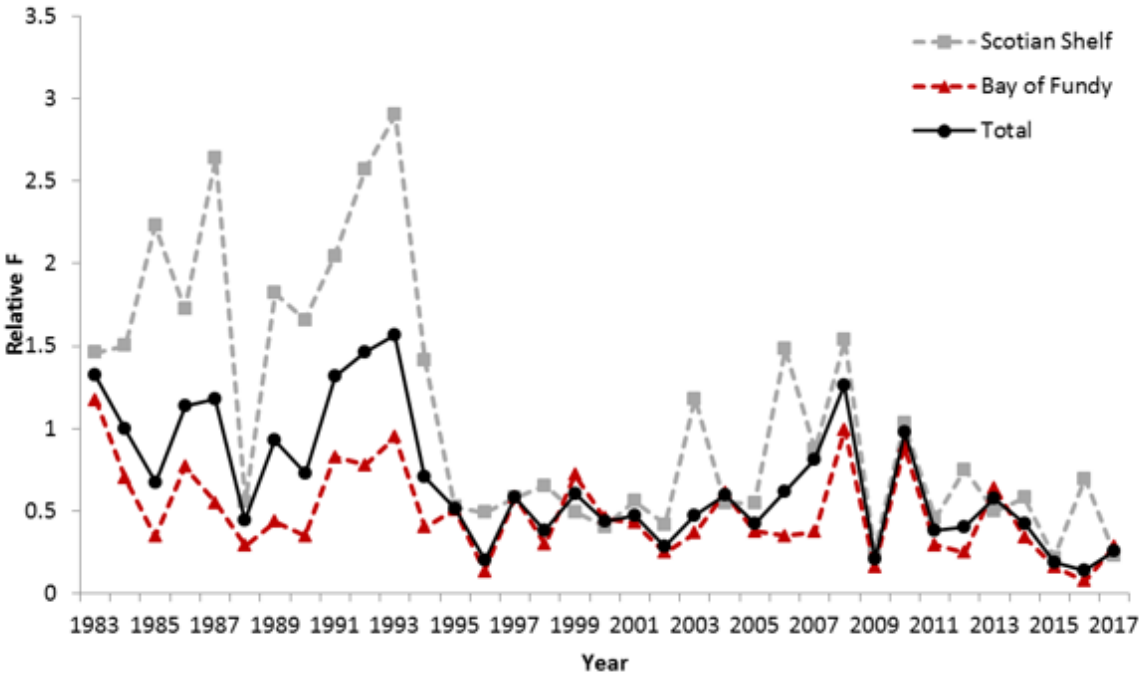

Figure 42. Relative fishing mortality (catch biomass/survey biomass) for Scotian Shelf (grey squares), Bay of Fundy (red triangles) and total 4X5Y area (black circles).

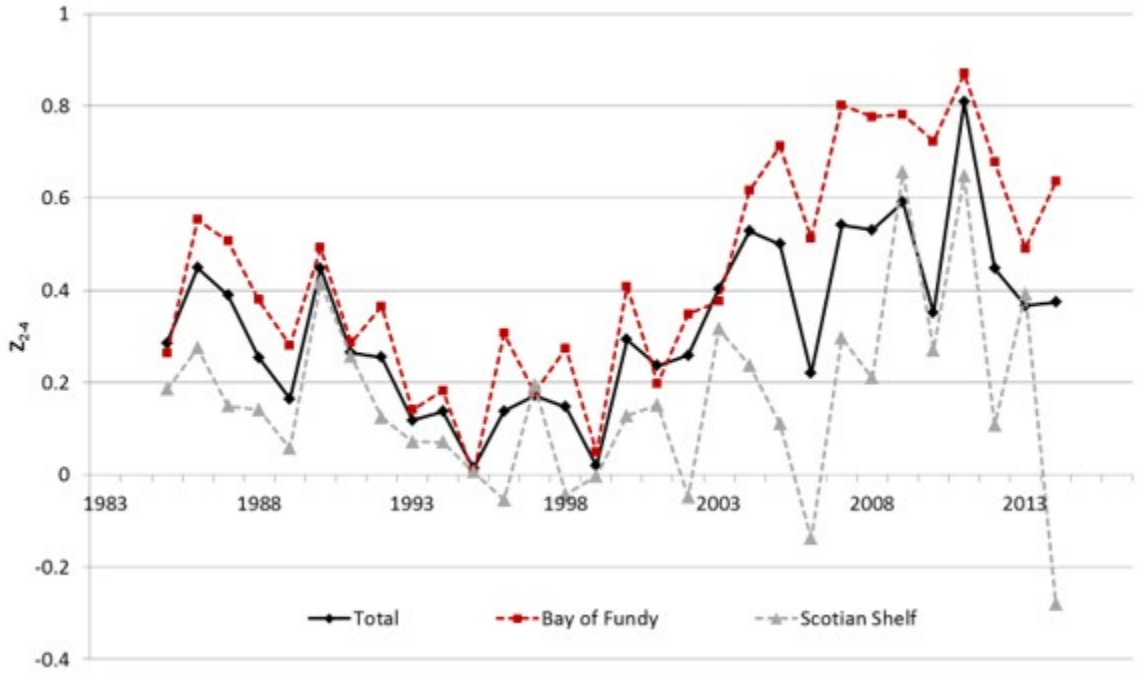

Figure 43. Five-year running average of total mortality on ages 2, 3 and 4 for all of 4X5Y (black diamond), Bay of Fundy (dashed red squares) and Scotian Shelf (dashed grey triangles).

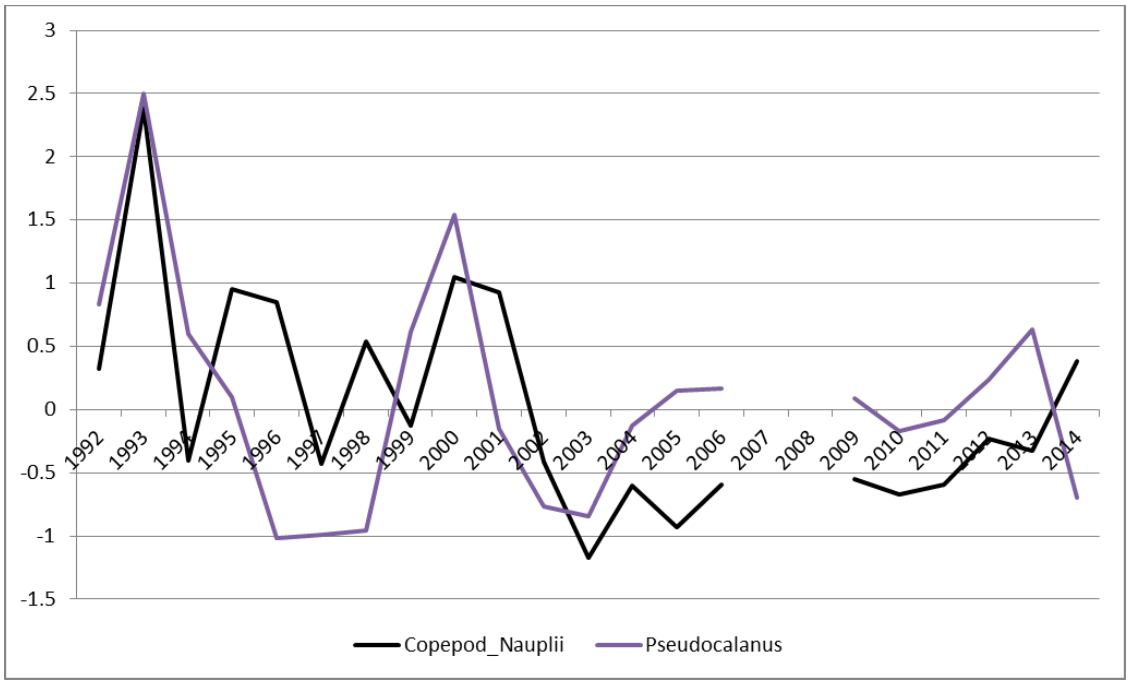

Figure 44. Standardized time series of Copepod naupii and Pseudocalanus abundance anomalies along western Scotian Shelf. Johnson et al. 2017.

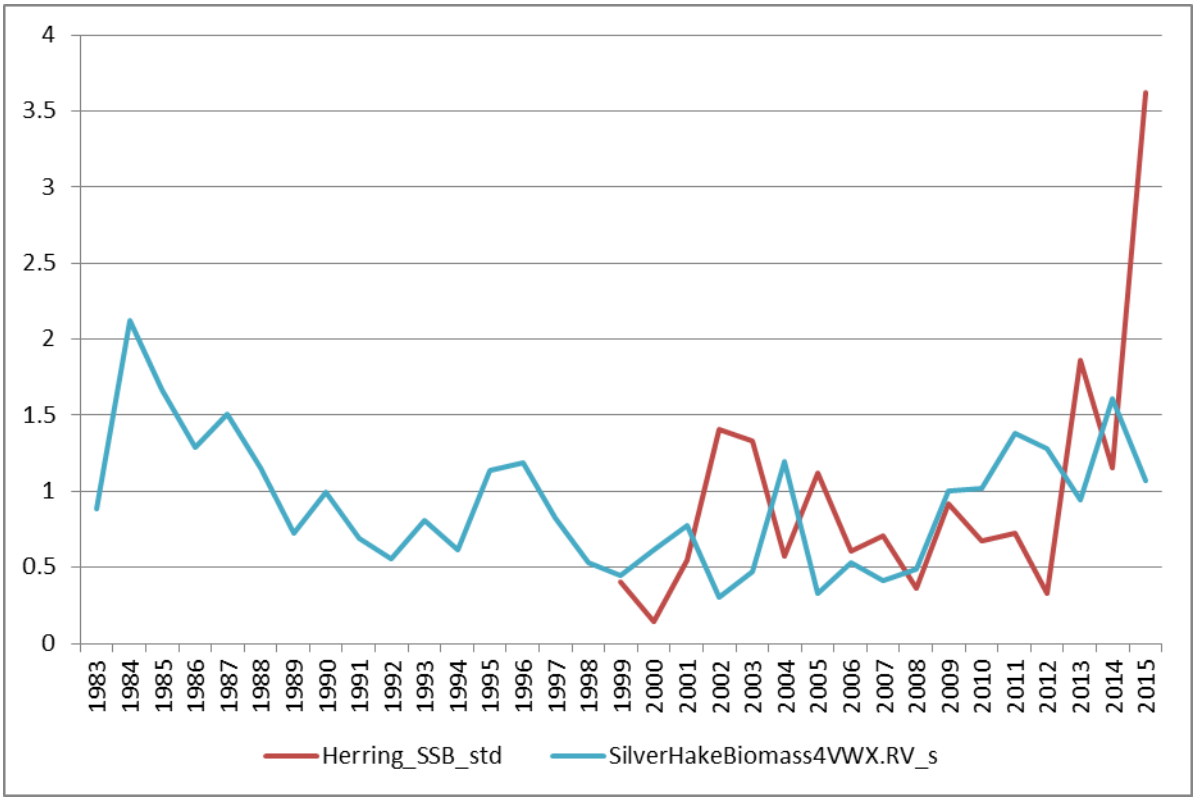

Figure 45. Standardized time series of relative Herring (DFO 2015) and Silver Hake biomass (DFO 2017).

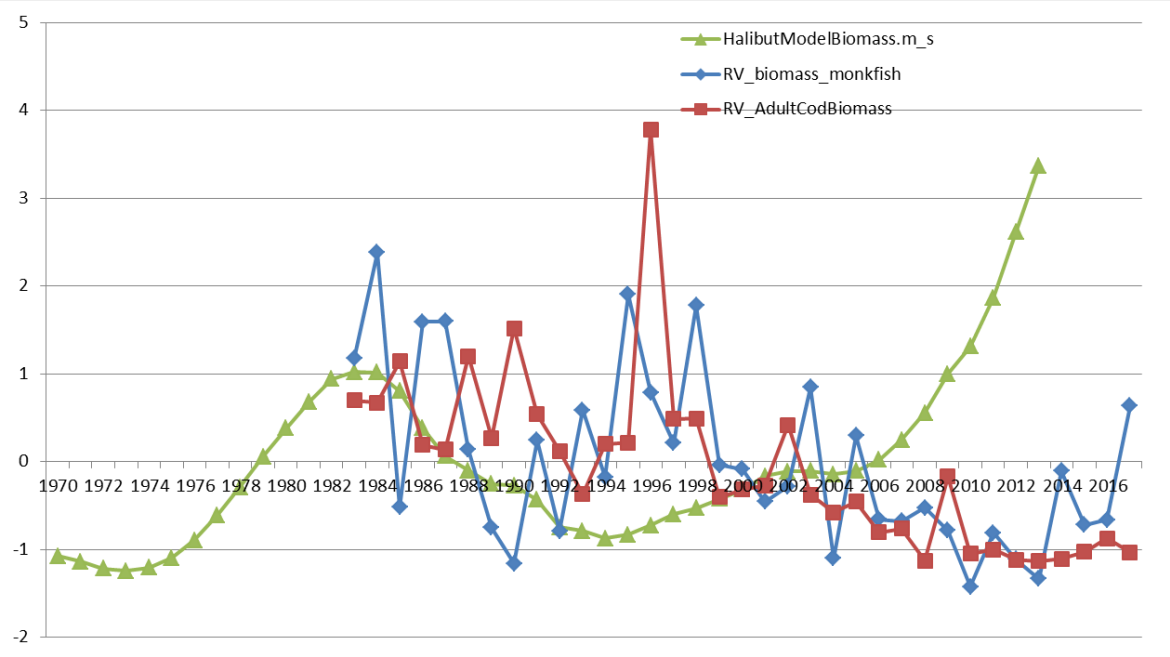

Figure 46. Standardized indices for Halibut (DFO 2017e), Monkfish (DFO 2017e) and adult Cod biomass (DFO 2017d).

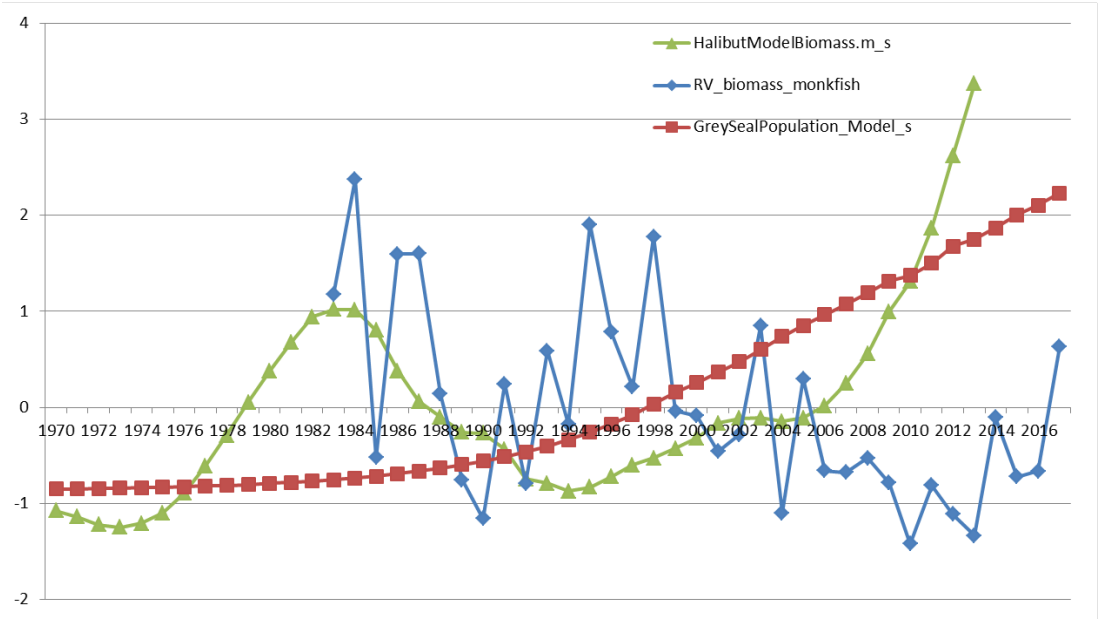

Figure 47. Standardized indices for Halibut (DFO 2017e), Monkfish (DFO 2017) and Grey Seals (Hamill et al. 2017).

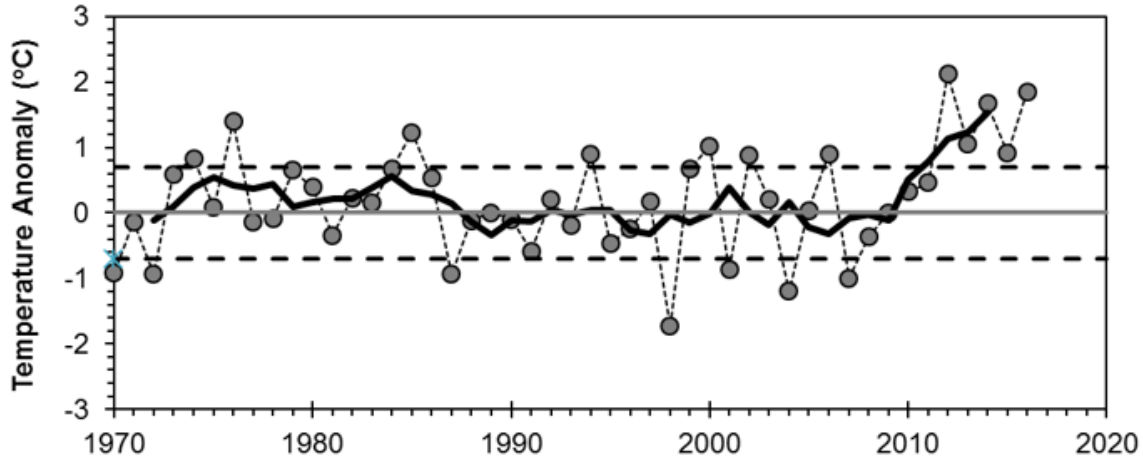

*Figure 48. Bottom temperature anomaly (*C) for NAFO sub-area 4X. Area is bounded by 100m and 1000m depths (AZMP - DFO 2018).*

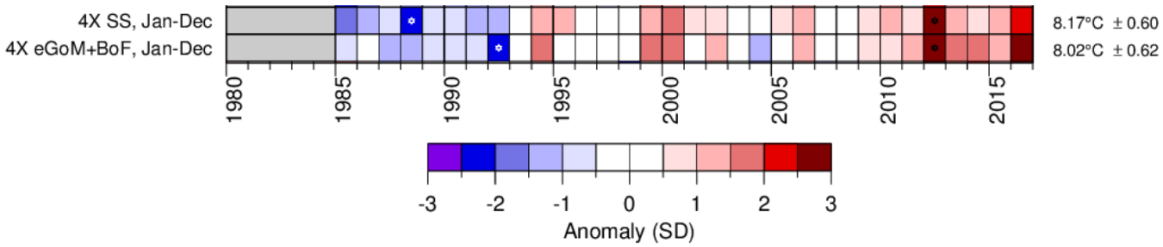

Figure 49. Time series of Sea Surface Temperature (1985–2016). A white cell is within 0.5 SD of the long-term mean; red cell is above normal, blue cell is below normal. Minimums and maximums are indicated by a star. Long term means are displayed on the far right hand side. DFO 2017f.

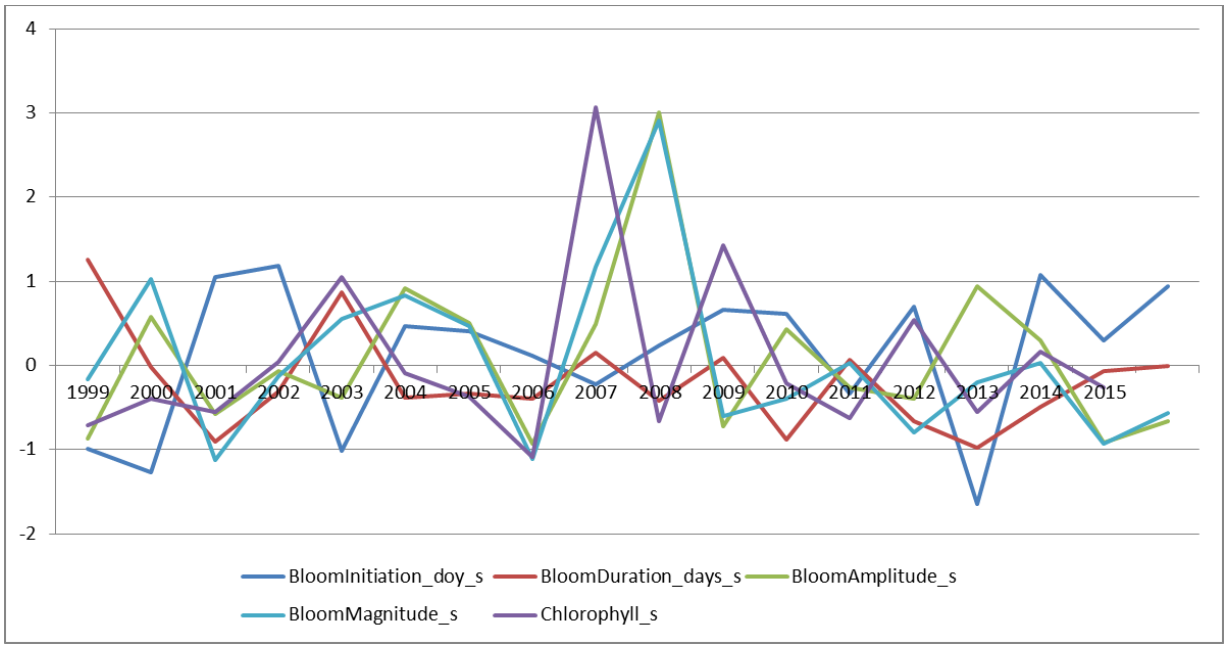

Figure 50. Standardized time series (1999–2016) of Chlorophyll and Bloom parameter fluctuations (DFO 2017f, DFO 2018).