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

Canadian Science Advisory Secretariat (CSAS)

Research Document 2015/022

Maritimes Region

4X5Y Haddock 2014 Framework Assessment: Data Inputs and Exploratory Modelling

H.H. Stone and S.C. Hansen

Fisheries and Oceans Canada
Maritimes Region, Science Branch
St. Andrews Biological Station
531 Brandy Cove Road
St. Andrews, New Brunswick E5B 2L9

May 2015

Canada

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.

Research documents are produced in the official language in which they are provided to the Secretariat.

Published by:

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

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

ISSN 1919-5044

Correct citation for this publication:

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

TABLE OF CONTENTS

ABSTRACT

In 2014/2015, the Maritimes Region of Fisheries and Oceans Canada will be undertaking a framework assessment of 4X5Y haddock (*Melanogrammus aeglefinus*). 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. The results of updated analyses on stock structure, spatial and temporal patterns in distribution, bycatch, biological attributes (length and weight at age, condition factor, growth and maturity) and revisions/updates to data inputs for stock assessment (fishery catch at age, survey indices of abundance, relative fishing mortality, total mortality) are described here. In addition, the ADAPT VPA software was used to evaluate the impacts of revisions and modifications to the 4X5Y haddock data inputs on estimates of age 1 recruits, age 4+ population biomass and ages 6-9 fishing mortality. This research document is intended to provide an update on several biological and fishery attributes for future framework evaluations.

Évaluation du cadre de travail de 2014 pour l'aiglefin des divisions 4X5Y : Saisie de données et modélisation exploratoire

RÉSUMÉ

En 2014-2015, la région des Maritimes de Pêches et Océans Canada entreprendra une évaluation du cadre de travail pour l'aiglefin (*Melanogrammus aeglefinus*) des divisions 4X5Y. Ces évaluations se veulent un examen exhaustif de la biologie, de la structure des stocks, de la pêche, des indices d'abondance, de la méthode d'évaluation actuelle et des approches en vue de déterminer les limites acceptables de récolte. Les résultats des analyses à jour sur la structure des stocks, les tendances spatiales et temporelles dans la répartition, les prises accessoires, les caractéristiques biologiques (longueur et poids selon l'âge, coefficient de condition, maturité et croissance) et des révisions/mises à jour des saisies de données aux fins d'évaluation des stocks (prises de la pêche selon l'âge, indices d'abondance des relevés, mortalité relative par la pêche, mortalité totale) sont décrits ici. En outre, le logiciel ADAPT/VPA a été utilisé pour évaluer l'incidence des révisions et des modifications des saisies de données relatives à l'aiglefin des divisions 4X5Y sur les estimations des recrues d'âge 1, de la biomasse de la population d'âges 4+ et la mortalité par pêche des âges 6-9. Ce document de recherche a pour but de faire le point sur plusieurs caractéristiques biologiques et halieutiques pour les évaluations futures du cadre de travail.

INTRODUCTION

Haddock (*Melanogrammus aeglefinus*) are found on both sides of the North Atlantic. They occur in the northwestern Atlantic from southwest Greenland to Cape Hatteras. The species is a bottom dwelling member of the gadid family that occurs most commonly at depths of 46-228m and at bottom temperatures above 2°C. Their diet consists mainly of small invertebrates. A major stock exists on the western Scotian Shelf and in the Bay of Fundy in the North Atlantic Fisheries Organization (NAFO) Divisions 4X5Y (Figure 1). Growth rates of haddock in the Bay of Fundy (4Xqrs5Y) are higher than those of haddock on the western Scotian Shelf (4Xmnop) (Hurley et al. 1998) so that separate age length keys (ALKs) have been used in the past for calculating the fishery catch at age (CAA) and survey indices of abundance. Major spawning grounds are found on Browns Bank and peak spawning occurs from April to May, although it can occur as early as February if conditions are favourable (Head et al. 2005).

The 4X5Y haddock stock has been modelled using Sequential Population Analysis (SPA) tuned to two surveys: the Fisheries and Oceans (DFO) summer multispecies ecosystem survey (1970 to present) and a joint industry/DFO survey (Individual Transfer Quota (ITQ) survey) (Showell et al. 2013). The latter commenced in 1995 but was discontinued after 2012. The fishery has been managed using a removal reference (F_{ref}=0.25). A limit reference point (LRP) of 40% Spawning Stock Biomass at Maximum Sustainable Yield (SSB_{MSY}) (20,800 t) and upper stock reference point (USR) of 80% SSB_{MSY} (41,600 t) based on estimates from a Sissenwine-Sheppard stock production model (Mohn et al. 2010) have been calculated as illustrative biological reference points for this stock.

The last analytical assessment conducted in 2012 (Showell et al. 2013) suggested that 4+ biomass (a proxy for spawning stock biomass) has remained relatively stable over the past two decades and is likely within the Cautious Zone. However, a strong retrospective pattern in the model results (i.e. a tendency to overestimate 4+ biomass when additional years of data are added) and mismatch between survey and catch information indicated that the recent increases in 4+ biomass were likely overestimates. Consequently, the SPA model results were not considered sufficiently reliable to produce meaningful projections for 2013 and 2014. A framework review for the 4X5Y haddock assessment was recommended for 2014/2015, given the continuing strong retrospective pattern in the model and its poor fit to the survey indices. A brief summary of past haddock assessments is provided in Appendix I, and a summary of important changes to the management of this stock is provided in Appendix II.

FRAMEWORK REVIEW AND OBJECTIVES

The objectives for the Framework Review meeting are to review the data inputs and indices of abundance for 4X5Y haddock, 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 (October 22, 2014):

- Review current stock structure.
- Review 4X5Y haddock fishery spatial and temporal distribution, bycatch, CAA, weight at age (WAA), maturity, growth and the appropriateness of using area-specific age-length keys (Bay of Fundy, Scotian Shelf).
- Review research vessel (RV) survey age-specific indices of abundance, weight/length at age (LAA), maturity, growth, condition and age-specific spatial distribution.
- Using exploratory virtual population analysis (VPA) runs, evaluate the influence of various input data revisions (i.e. exclusion of the ITQ index, revised ageing for 1985-1989, use of

2cm groupings, inclusion of a small mesh category), truncating the CAA time series (i.e. 1985-2013 vs 1970-2013), and the effects of removing mixed stock (i.e. 5Zjm and 4X5Y) haddock catches near the 4X5Y NAFO boundary line.

Part 2 - Assessment of Model(s) to Monitor Stock Status and Productivity (Fall 2015):

- Determine the methodology to estimate the current status of the stock, including methods for estimating stock size and fishing mortality.
- Determine the methodology to characterize stock productivity, including reference points for fishing mortality and spawning stock biomass.
- Determine forecasting methodology for providing advice on harvest levels, including the risk of falling below biological reference points.
- Provide guidance on inter-framework review activities, including the procedure and frequency of providing fisheries management advice and events that would trigger an earlier-than-scheduled assessment.

REVIEW OF MANAGEMENT UNIT

The definition of management units for North Atlantic haddock stocks for assessment and regulation is based on several considerations described by Halliday and Pinhorn (1990):

- Biological stock structure
- Considerations of other species and fishing distributions
- Oceanographic features
- Submarine topography
- Political and administrative boundaries
- Practicalities of data collection and fishery regulation

Six haddock stocks are currently recognized in the northwest Atlantic: Grand Banks (3LNO), St. Pierre Bank (3Ps), eastern Scotian Shelf plus Gulf of St. Lawrence (4TVW), western Scotian Shelf (4X and Canadian portion of 5Y), Georges Bank (5Z) and western Gulf of Maine (5Y). Needler (1930) proposed that the range of haddock in the northwest Atlantic was effectively divided by deep (>180m) channels (i.e. Laurentian, Fundian), which acted as barriers to dispersal. The best source of information on northwest Atlantic haddock stock structure is provided in a comprehensive review by Begg (1998) and an overview of tagging studies conducted since the 1920s by Fowler (2011). Much of what follows has been based on these publications.

Begg (1998) summarized stock identification studies of haddock in the northwest Atlantic conducted since the 1930s using a variety of approaches, including tag-recapture, growth rates, spawning patterns, meristics, parasites and genetics (Table 1). In this review, he concluded that "these techniques agree on major stock divisions between New England, Nova Scotia and Newfoundland waters but there are differences in the degree of separation within these regions". Based on a review by Page and Frank (1989), the main spawning locations in the northwest Atlantic include Georges Bank, the western Gulf of Maine, Browns Bank, Emerald/western banks, St. Pierre Bank and Grand Bank (Figure 2). Peak spawning occurs in late March-early April for the Georges Bank/western Gulf of Maine stock, from April-June on the Scotian Shelf and from June-July in Newfoundland waters. Surface circulation patterns and weak gyres over offshore banks tend to retain eggs and larvae in areas where they originate and, thereby, serve to maintain stock integrity (O'Boyle et al. 1984). Spawning periodicity is highly variable and is correlated with water temperature, i.e. it can be delayed in cold years and advanced in warmer years (Page and Frank 1989). The depth and strong currents of the Fundian Channel provide a natural boundary for separating spawning products from the

Georges Bank and Scotian Shelf spawning grounds, while the broad/deep central basin of the central Gulf of Maine may isolate eggs and larvae on the Scotian Shelf from the western Gulf of Maine (Smith and Morse 1985).

The catch (number) per tow of sexually mature haddock from a 10-year time series (1988-1997) from the National Marine Fisheries Service (NMFS) spring bottom-trawl survey series also indicates a relatively discontinuous distribution of haddock spawning aggregations (i.e. eastern and western Georges Bank, western Gulf of Maine, Browns Bank and off southwest Nova Scotia) (Figure 3). Synchrony of recruitment patterns can occur among stocks due to large scale physical and biological forcing (Koslow 1984; Koslow et al. 1987). Recently, there has been some synchrony in recruitment patterns among stocks as indicated by the strong 2010 and 2013 year classes on Georges Bank and the western Scotian Shelf, but this relationship does not appear to be consistent over the long term.

Fowler (2011) provided an overview of haddock tagging studies conducted since the 1920s. These earlier studies indicated three migratory populations (Figure 4), two of which still persist:

- 5Y: a coastal stock mainly resident in the Gulf of Maine, which moved north in to Bay of Fundy (4Xs) in summer and south to southern Gulf of Maine in winter. Bay of Fundy (4Xs) haddock were originally considered as part of the 5Y stock up to 1998, but are now included with the 4X stock along with the Canadian portion of 5Y.
- 4X: an offshore stock that moved inshore and northward in summer, then offshore to overwinter on the western Scotian Shelf.
- 4TVW: an offshore stock that moved into the southern Gulf of St. Lawrence in summer, then offshore to overwinter on the eastern Scotian Shelf. This stock is now mainly resident on the eastern Scotian Shelf.

During the 1980s, DFO and the National Marine Fisheries Service (NMFS) conducted tagging in 5Y, 5Z and 4X to evaluate haddock movements in the Gulf of Maine, Georges Bank, Browns Bank and Bay of Fundy regions. Browns Bank haddock undertook seasonal movements off southwestern Nova Scotia into the southern Bay of Fundy (4Xr) during summer, followed by offshore movement in winter (Figure 5). Fish tagged in St. Mary's Bay showed a similar pattern. Haddock tagged on northeastern Georges Bank were recaptured in the same area, with few recaptures on the Scotian Shelf (i.e. only 5 of 88 were recovered on Browns Bank). Fowler (2011) concluded that there may have been several discrete reproductive populations in the past, many of which were inshore, but currently the remaining populations are offshore and include the eastern Scotian Shelf/southern Gulf of St. Lawrence stock (4TWV), the western Scotian Shelf/Bay of Fundy stock (4X5Y) and the eastern Georges Bank stock (5Zjm).

DFO has conducted annual summer bottom trawl surveys of the Scotian Shelf/Bay of Fundy region since 1970. The main areas of haddock abundance have always been in the central and western Scotian Shelf, especially in the 1990s and 2000s and provide evidence for two stocks: 4X5Y and 4TVW (Figure 6). Total stratified abundance calculations from the DFO summer and Georges Bank surveys indicate differences in the dynamics of adjacent eastern (4TVW), western (4X5Y) and Georges Bank (5Zjm) stocks (Figure 7). Total biomass in 4TWV exceeded that of 4X5Y during the 1980s and late 2000s. The index is now comparable to 4X5Y but has exhibited a sharp decline in recent years. In contrast, total biomass in 5Zjm has been increasing since the early 2000s and in 2013 reached a level that was several times higher than the Scotian Shelf stocks.

CONCLUSIONS

Begg (1998) concluded that the various techniques used to identify haddock stock structure in the northwest Atlantic agreed on major divisions between New England, Nova Scotia and Newfoundland waters, but that there was uncertainty in the degree of separation between stocks on eastern and western Georges Bank and the eastern and western Scotian Shelf. Fowler (2011) concluded that there may have been five or more discrete haddock stocks in Canadian waters in the past, some of which were inshore, but only two offshore populations on the Scotian Shelf (4X5Y, 4TVW) currently remain discernable. Based on the review of Begg (1998) and re-analysis of tagging data by Fowler (2011), there is no reason to conclude that the current management unit for the 4X5Y haddock stock is not appropriate. Furthermore, there is no new information available to indicate otherwise.

The current 4X5Y management unit for haddock includes the Bay of Fundy and western Scotian Shelf (Figure 7). Growth rates of haddock in the Bay of Fundy (4Xqrs5Y) are higher than those of haddock on the southern Scotian Shelf (4Xmnop) so that separate ALKs are used to calculate fishery CAA and DFO summer survey indices. Haddock landed from 5Zjm are from the adjacent Georges Bank stock and are not included in this assessment.

THE FISHERY

4X5Y haddock are harvested as part of a mixed, multispecies fishery that includes cod, halibut, redfish, pollock, white hake and flounders. The haddock fishery is limited by the incidental catch of cod, which has strict bycatch limits. The fishing industry uses time/area strategies to reduce cod bycatch, and some vessels are using separator panels which allow cod to escape during fishing operations. The mandatory use of a 130mm square mesh cod end for bottom trawls was implemented in 1991 to allow for escapement of smaller fish; however, haddock are also captured as bycatch in the redfish fishery, which uses smaller 100-112mm diamond mesh cod ends. Major spawning grounds are found on Browns Bank, and peak spawning occurs from April-May. A seasonal spawning closure, implemented in 1970, currently extends from February 1st to June 15th. The history of this area closure is documented by Halliday (1988).

COMMERCIAL LANDINGS

Reported annual landings of 4X5Y haddock averaged 28,500t during the 1960s,18,500t during the 1970s and 19,800t during the 1980s with peaks occurring in the late 1960s and early 1980s (Table 2; Figure 8). Noteworthy is that from 1982-1984, the total allowable catch (TAC) peaked at 32,000t, but was quickly reduced to 4,600t by 1989. In 1991 and 1992, there was no TAC for haddock under a Management Plan that called for a bycatch fishery only, although landings exceeded 9,000t during these years (Hurley et al. 2009). The TAC of 8,100t established for the 12 month fishery in 1999 was increased to 9,800t for the 15-month period ending 31 March 2000. The fishing year since then has been April 1 to March 31. Annual landings dropped substantially in the 1990s and 2000s averaging 6,681t and 4,260t, respectively. Since 2009, they have averaged 4,260t and were 4,127t in 2012 and 3,518t in 2013, among the lowest in the 40 year time series. The Fishing Year TAC (FY, April 1-March 31) was 7,000t from 2006-2009, but was subsequently reduced to 6,000t for FYs 2010-2011 and 2011-2012 and to 5,100t for FYs 2012-2013 and 2013-2014 (Table 2). FY landings for 2012-2013 and 2013-2014 were 3,323t and 3,398t, respectively, well below the TAC.

Since the mid-1970s, the small mobile gear component (Tonnage Class (TC) 1-3) has accounted for most of the total landings from the 4X5Y haddock fishery, except during the early 1990s when the percentage taken by fixed gear (longline) was greater (Figure 9; Table 3). The percentage of landings taken by longline has steadily declined since 1994, whereas the small mobile gear share has increased. Over the past 10 years, small otter trawlers (TC 1-3) have taken an average of about 80% of the catch and longline vessels about 20%. There has been a declining trend in longline catches since 2011, with the 2013 catch representing only 12% of total landings. Large otter trawlers (TC 4+) contributed 30-40% of total landings in the 1970s, but there are few left in the fishery at present (their contribution is currently <1%). The contribution by the handline and gillnet sectors has also declined to very low levels (<1%) since the late 1990s.

In recent years, most landings have occurred during the 1st and 3rd quarters (approximately 32% for each), followed by the 4th (23%) and 2nd (12%) quarters (Table 4). The change to an April-March fishing year in 2000 has led to an increase in the proportion of fish landed during January to March, a seasonal change that has helped to reduce the bycatch of cod (Hurley et al. 2009). Since 2003, about 70% of total landings have been taken from Scotian Shelf statistical unit areas 4Xn and 4Xp (Figure 10). While the increase in 4Xn is largely a result of the winter (January-March) fishery, the increase in 4Xp reflects directing for larger haddock in the deeper waters of the Fundian Channel, where the bycatch of cod also tends to be lower (Hurley et al. 2009). Unspecified landings (4Xu), which originated mostly from the fixed gear sector, have declined substantially since the mid-1990s (i.e. 1985-1994 average: 22%; 1995-2013 average: 2%) with the implementation of the Dockside Monitoring Program in 1994 and mandatory log book submissions. Most of the 4X5Y haddock fishery catch is currently taken on the Scotian Shelf (4Xmnop) by the mobile gear sector followed by fixed gear, with the remainder taken in the Bay of Fundy (4Xqrs5Y) by mobile gear (Table 5; Figure 11). Fixed gear catches from the Bay of Fundy region (4Xqrs5Y) are now very low, and there has been an overall decline in catches from this area by both gear sectors since 2005.

Recently (i.e. 2011-2013), the 4X5Y haddock fishery has followed a general seasonal/geographic pattern in areas fished, with a winter fishery along the shelf slope in 4Xn and in the Crowell Basin area of 4Xp, followed by a spring fishery in the outer Bay of Fundy, Jordan Basin and around Browns and LaHave banks (Figures 12-14). Summer/fall fishing activity occurred in the outer Bay of Fundy, around Browns and LaHave banks (particularly for fixed gear), and in the Crowell Basin/Fundian Channel out to the 4X5Z NAFO area boundary. Showell et al. (2013) reported that the distribution of the fishery has changed in the last decade with effort shifting from the Bay of Fundy to Statistical Unit Area 4Xp, which, over the past 10 years, is where about 43% of the total haddock catches have occurred. Noteworthy is that in 2004, 2005, 2007 and 2009, 14-35% of total annual landings occurred in the southern portion of 4Xp in the Fundian Channel close to the 4X5Z NAFO boundary line (Table 6; Figure 14). Showell et al. (2013) hypothesized that these fish may be from the eastern Georges Bank (5Zjm) stock, rather than 4X5Y, but indicated that there has been no established method to estimate the degree to which this may be occurring. They also considered this to be a fishery effect rather than a change in distribution; however, it may well reflect periods when above average year classes from the Georges Bank stock (i.e. 2000, 2003) expand into Fundian Channel and are captured in 4X summer/fall fishery.

REVISIONS TO THE CATCH AT AGE

The 4X5Y haddock fishery CAA was updated for 2011-2013 and revised for 1985-2010 using the standard Population Ecology Division CAA application. In 1992, it was determined that there was a bias in haddock ageing since the early to mid-1980s (Hurley et al. 1996). Re-ageing was completed in the 1990s for the 1985-1995 DFO summer survey and commercial fishery age samples using revised ageing criteria developed during a workshop held at the Bedford Institute of Oceanography (BIO) in 1993 (Hurley et al. 1996). However, there was no re-ageing of samples collected prior to 1985 because the methodology used for age determination involved “cracking” the otoliths and not “sectioning” (the method used after 1984), which made them difficult to re-age.

The revised ages were used for DFO summer survey indices from 1995 back to 1985, and for fishery CAA calculations from 1995 back to 1990, but were never applied to the 1985-1989 fishery CAA calculations. There were also several years in the 1985-2010 fishery CAA time series that used 1cm groupings instead of 2cm groupings (which is the way the port sampling is conducted, with 2 otolith samples collected per 2cm length grouping). This resulted in more missing ages at length and, therefore, required additional substitutions (based on interpolation) for missing ages in the ALKs. For this framework, the CAA time series was re-calculated using 2cm length groupings and revised age determinations for 1985-1989, and 2cm length groupings for 1990-2010.

In addition, a separate gear category was created for haddock landings from the 4X redfish fishery (100-112mm diamond cod end mesh) since there is a tendency for more small fish (i.e. ages 2-3) to be retained by this gear, especially when a new strong year class is recruiting to the fishery. The small mesh gear category was created for the 2011-2013 CAA only since there were not enough small mesh gear port samples in earlier years. Also, small mesh catches represented <6% of total landings prior to 2011.

For the CAA calculations, length frequencies obtained by port samplers were grouped by Gear (Mobile, Fixed), Season (QTR or Half Year) and Area (Bay of Fundy: 4Xqrs5Y; Scotian Shelf: 4Xmnop). ALKs were grouped by Area and Season (QTR or Half Year) and not by Gear Type, as was sometimes done in the past, since changes in growth would not be expected (i.e. mean WAA) between gear types (although differences in age composition are seen). Annual length-weight relationships (a's and b's) for haddock from the DFO summer survey were calculated separately for Bay of Fundy strata (482-495) and Scotian Shelf strata (470-481) and applied to matching sample areas for CAA determinations. This approach follows that of Hurley et al. (2009) who concluded that it was more appropriate to use annual length/weight parameters rather than the constant quarterly parameters derived by O'Boyle (1983), given the declining trends in WAA that have been observed for this stock.

Since age determinations for 4X5Y haddock otolith collections from the DFO survey and port samples had not been updated for several years, the primary ager read the 4X5Y haddock reference collection as part of a routine check (intra-ager comparison) before starting production ageing in the fall of 2013. A pair-wise comparison of ages showed high precision (91% agreement) and little bias with an overall coefficient of variation of 1.9% (Figure 15). These results were considered acceptable for production ageing of the 2011-2013 otolith samples from the commercial fishery and summer survey.

FISHERY CATCH AT AGE AND WEIGHT AT AGE

Using the revised ages and 2cm groupings generally resulted in greater numbers of older fish (i.e. ages 6+ or 7+) in the new CAA for 1985-1989 (Figure 16). There also appeared to be better tracking of the 1980 and 1983 year classes. Using 2cm groupings and different ALK combinations for 1990-2010 resulted in some modest changes to the CAA, with more old fish present in some years but not in others (Figure 17). Overall, the effects of these changes were small, but the CAA for 1985-2010 is now consistent in terms of the approach used. The earlier part of the CAA time series (1970-1984) was not revised since no re-ageing was done for this time period. It is also unclear as to whether landings from 4Xs were included in CAA calculations for this earlier period. An option could be to remove 1970-1984 from the CAA time series.

Haddock catches from small mesh gear used in the 4X redfish fishery increased from <1% of total landings in the early 1990s to 8% by 2002, declined to <2% in 2003-2004, then increased steadily reaching 15% in 2012 and 13% in 2013 (Figure 18). For 2011-2013, small mesh gear landings were 325t, 623t and 460t, respectively. With the exception of 2011-2013, there were too few port samples available to size the small mesh catches from earlier years.

The CAA for 2011-2013 was characterized using three gear categories: large mesh otter trawl (OT; cod end mesh ≥ 130mm); small mesh otter trawl (cod end mesh=100-112mm), and longline. In 2011, large mesh OT contributed most to the catch followed by longline and small mesh OT. Haddock captured by longline had the highest average size, followed by large and small mesh OT (average fork length (FL); longline: 49cm; large mesh: 47cm; small mesh: 44cm) (Figure 19; upper panel). Proportionally more fish aged 2, 3 and 5 were present in small mesh catches but their overall contribution to the 2011 CAA was low (Figure 19; lower panel). The 2011 CAA was dominated by ages 5, 7 and 8 (2006, 2004 and 2003 year classes), which represented 25%, 18% and 23% of the total catch, respectively.

For 2012, large mesh OT contributed most to of the catch followed by longline and small mesh OT, with little difference in the average size among gear categories (average FL; longline: 47cm; large mesh: 46cm; small mesh: 45cm) (Figure 20; upper panel). The 2012 catch was dominated by ages 6 (2006 year class), 8 (2004 year class) and 9 (2003 year class), representing 24%, 13% and 17% of the total catch, respectively (Figure 20; lower panel). There were proportionally more fish aged 2 and 3 captured by small mesh, but their overall contribution to the 2012 CAA was low.

Large mesh OT contributed most to the 2013 catch followed by small mesh OT and then longline (Figure 21; upper panel). The average size was greatest for longline (47cm), but there was a decline in average size for large and small mesh OT compared to 2011 and 2012 (i.e. large mesh: 43cm; small mesh: 42cm). The 2013 catch was dominated by ages 3 (2010 year class), 4 (2009 year class) and 7 (2006 year class) representing 41%, 12% and 10% of total catch, respectively (Figure 21; lower panel). Age 3 comprised most of mobile gear catch (both large and small mesh) in 2013. The addition of the small mesh gear category will be included in future CAA calculations but generally there were only modest differences in the CAA for small mesh compared to large mesh.

The size composition of haddock from port (shore) samples and observer (at-sea) samples for redfish directed trips in 2011, 2012 and 2013 were compared to address the question of discarding of small haddock in the redfish fishery (Figure 22). The size compositions were generally similar in 2011 and 2012, but for 2013, it appears that the percentage of small haddock (28-35cm) was higher in observed trips compared to the port samples. This difference is small and could be attributed to spatial and temporal differences in haddock abundance at size between observed and port sampled trips rather than discarding. Over the past 10 years (2004-2013), observer coverage of the redfish fishery has averaged only 5% (observed redfish catch (t)/total redfish catch (t)) (see Figure 46), which is too low for accurate estimation of bycatch rates.

The revised/updated CAA for 1970-2013 shows the presence of some recent strong year classes (i.e. 2003, 2010) and a reduction in the catches of age 2 fish beginning in the early 1990s. The latter coincides with the mandatory use of 130mm square mesh in 1991, but also there has been a decline in LAA and WAA during this period, which has reduced the partial recruitment (PR)/selectivity of this age group (Table 7; Figure 23). Noteworthy is that older fish (age 10+) continue to appear in the time series right up to 2013. In the 2013 fishery, the 2010 year class at age 3 (the most recent strong year class) was predominant and represented 41% of the CAA. The 2003 year class, which made a significant contribution to the fishery back to 2006, represented only 7% of the 2013 fishery CAA 10.

A revised time series of fishery WAA for 1985-2013 was calculated from the CAA application and compared to the original WAA series used by Showell et al. (2013) in the last assessment (Figure 24; Table 8). This revised series, which is based on 2cm groupings for 1985-2013 and revised ages for 1985-1989, does not show the precipitous drop in WAA from 1987-1988 for ages 9 and 11, which occurs in the original series. Although the WAA was still high in 1979 for ages 9 and 11, the decline through to 1989 is more gradual compared to the original series, which exhibits such a dramatic change that it is difficult to reconcile. The revised series continues to show a declining trend in WAA from 2000-2008 and then levels off from 2009 to present. While it is not clear what caused the declining trend in the 1980s, its effect on stock productivity is significant and has been discussed in previous assessments (Hurley et al. 2009; Mohn et al. 2010).

Coincident with the decline in WAA, there has also been a decline in the LAA, which is evident from catch at length plots by age group selected from the CAA time series (Figure 25). For example, the distribution of LAA in the 2012 and 2013 catch is more truncated and exhibits a greater degree of overlap compared to earlier years in the time series (i.e. 1985, 1995, 2005 and 2010).

EXAMINATION OF MIXED STOCK CATCHES

Over the past 10 years, mixed stock catches of haddock (i.e. 4Xp and 5Zjm) from both mobile and fixed gear may have occurred in the deeper waters of the Fundian Channel near the 4X5Z NAFO boundary line, especially during the second half of the year. To determine the effects of removing these catches from CAA calculations, an area extending 5 nautical miles north of the 4X5Z NAFO line (referred to as 4Xp south) was arbitrarily selected as the mixed stock area in 4Xp (see Figure 14). Since 2003, haddock landings from 4Xp south have averaged 846t, or about 15% of total annual landings for 2004-2013 (Figure 26). In 2005 and 2007, landings from this area peaked at 1,350t and 2,400t, respectively, and represented 24% and 35% of total landings for these years. Between 2008 and 2011, catches from 4Xp south ranged from 450t-950t (9-18% of total landings); however, they have declined to low levels over the past two years (i.e. <200t or 5% of total landings).

One hypothesis for the occurrence of mixed stock catches is that they may occur when above average year classes from the eastern Georges Bank stock (i.e. 2000, 2003) expand into Fundian Channel and are captured in southern 4Xp during the summer/fall fishery. Examination of the size composition of haddock from port samples obtained quarterly between 2004 and 2011 indicated similar size compositions for fish from 4Xp south and 5Zjm (especially during quarters 3 and 4) which generally peaked at larger sizes than those from 4Xp north, the Bay of Fundy (4Xqrs5Y) and Scotian Shelf (4Xmno) areas (Figures 27 and 28). To determine if the age composition of haddock in the mixed area was similar to the faster growing eastern Georges Bank stock, the mean age at length was examined for aggregated data for two 5-year periods (i.e. 2000-2005 and 2006-2010) from the 3rd and 4th quarters, when mixing was assumed to be at its peak. The average age at length for 2000-2005 showed a progressive increase in haddock from 5Zjm to 4Xp south to 4Xp north (split at 42^{o}25' N) (Figure 29; upper panel). A similar pattern occurred for 2006-2010 but it was not as pronounced as the earlier period (Figure 29, lower panel). Based on this analysis, it was concluded that 4Xp south haddock may at times consist of a mixture of the two stocks.

A separate CAA for 2004-2013 was calculated, which excluded 4Xp south landings and port samples (lengths and ages) for both mobile and fixed gear. The selection criteria for removing landings and samples was based on latitude (i.e. if they occurred in 4Xp at a latitude less than 42^{o}25' they were excluded). Noteworthy is that the removal of ages from 4Xp south resulted in more interpolation/substitution for missing ages at length in the quarterly ALKs used for the western Scotian Shelf (4Xmnop), thereby increasing the subjectivity in CAA calculations. No clear pattern was apparent in the percentage CAA calculated with (new CAA) and without (excluding 4XpS) these samples and landings from 4Xp south (Figure 30), but this will be examined further using the modified CAA for 2004-2013 in a VPA sensitivity run.

SURVEYS

DFO SUMMER RESEARCH VESSEL SURVEYS

DFO has conducted a stratified random bottom trawl survey of the Scotian Shelf and Bay of Fundy every summer since 1970 using four RVs: the *A.T. Cameron* from 1970-1981, the *Lady Hammond* in 1982, the *CCGS Alfred Needler* from 1983-present and the *CCGS Teleost* in 2004 and 2007. Based on an analysis of comparative fishing experiments by Fanning (1985), a conversion factor of 1.2 for haddock has been applied to the total abundance, total biomass and age-specific abundance series prior to 1982 (i.e. for 1970-1981) to account for the effect of vessel and gear changes (Yankee 36 to Western IIA bottom trawl) between the *A.T. Cameron* and the *Hammond/Needler* (Note: this is not a length-based conversion). A more recent analysis of comparative fishing experiments between the *Alfred Needler* and the *Teleost* showed that no conversion factor was required for 4X5Y haddock for 2004 and 2007 (Fowler and Showell 2009).

CATCH DISTRIBUTION, INDICES OF ABUNDANCE, LENGTH/WEIGHT AT AGE AND GROWTH PARAMETERS

Over the 45-year time series, the main areas of haddock abundance have always been on Browns Bank, Baccaro Bank and the outer Bay of Fundy area. In the 1980s and 1990s, there was an increase in biomass in the Bay of Fundy, followed by decline in the 2000s which persists to 2014 (Figure 31).

Due to differences in growth rates (Hurley et al. 1998), the total biomass index has been calculated separately for the Bay of Fundy (strata 482-495) and western Scotian Shelf (strata 470-481) for 1970-2014 (Figure 32; Table 9). While both indices show high variability over the time series, the general pattern is one of decreasing biomass from the mid-1980s to mid-1990s, followed by a period of increasing biomass through the late 1990s to the mid-2000s, after which biomass is lower but remains relatively stable for both areas in recent years (Figure 33). In 2014 there was a modest increase in biomass for both areas. The total biomass index has been below the long term mean for the western Scotian Shelf since 2011 and for the Bay of Fundy since 2003. Scotian Shelf strata have accounted for approximately 67% of total biomass since 2004. In 2014, the total biomass estimate for the Bay of Fundy was 16,900t (1970-2014 mean: 21,500 t) and for the Scotian Shelf it was 26,000t (1970-2014 mean: 33,400 t). The total biomass index in 2014 for both areas combined was 43,000t, which is just above the illustrative USR (41,600 t).

The age-specific indices of abundance (total numbers at age) for 1970-2013 were calculated separately for Bay of Fundy strata (482-495) and western Scotian Shelf strata (470-481) and then combined to generate the indices of abundance for the entire 4X5Y management area (strata 470-495) (Figure 34; Table 10). During the late 1980s, there was a period of diminished numbers at age for all ages, which persisted until the early 1990s. The abundance at age increased from 1995-2002, especially for ages 1-5, and was followed by an overall improvement in age structure, with increased abundance of ages 6+ up to about 2011. The 2003, 2006 and 2010 year classes all appear to have been moderately strong, with indications that the 2012 year class (age 1 in 2013) is also strong. In 2013, ages 1-3 made up most of the survey catch (the 2012, 2011 and 2010 year classes) and represented 30%, 23% and 27% of the survey CAA, respectively.

Summer survey mean WAA (kg) and mean LAA (cm) for 4X5Y haddock was calculated separately for Bay of Fundy and western Scotian Shelf strata, then combined after weighting using total abundance at age for each area (Tables 11 and 12). There was a strong decline in survey mean WAA for ages 5 and older beginning in the early 1980s, similar to the trend observed for the fishery WAA (Figure 35; upper panel). While it is not clear what has caused this, re-ageing was not redone for the early part of the time series (1970-1984). A modest increase in WAA occurred in the late 1980s followed by another decline in the early 2000s; WAA has remained low but stable since 2004. Mean LAA shows a similar pattern to mean WAA for ages 5 and older but the decline in the early 1980s is not as steep as observed for mean WAA (Figure 35; lower panel). Noteworthy is that the mean LAA has been lower but stable or increasing since 2004.

Updated summer survey WAA comparisons between haddock from Bay of Fundy and western Scotian Shelf strata supports the observation by Hurley et al. (1998) that growth rates in the Bay of Fundy (4Xqrs5Y) are higher than those on the western Scotian Shelf (4Xmnop) (Figure 36; Tables 13 and 14). Mean WAA for older (5+) haddock from the Bay of Fundy were much higher than those from the western Scotian Shelf during the 1980s and 1990s, but with the trend of declining WAA in both areas, this difference has become less pronounced since the mid-2000s. Noteworthy is that the decline in WAA for age 5+ was steeper for Bay of Fundy haddock during the 1990s and 2000s compared to western Scotian Shelf haddock.

Von Bertalanffy growth model parameters also indicate that haddock from Bay of Fundy strata grow faster and attain a larger size than haddock from Scotian Shelf strata. Decadal Von Bertalanffy growth model parameters were calculated separately for the Bay of Fundy and western Scotian Shelf using annual survey mean LAA (cm) from three time periods: 1985-1994, 1995-2004, 2005-2013 (Figure 37; Table 15). For each time period, haddock from the Bay of Fundy exhibited higher growth parameters (K) and length at infinity (Linf) compared to haddock from the Scotian Shelf. Noteworthy is that Linf has been declining over the past 30 years for both areas, which is consistent with declining trends in survey mean LAA. In summary, this analysis indicates that it is still appropriate to use separate ALKs for these areas.

A comparison of 4X5Y haddock mean WAA for ages 3, 5, 7 and 9 from the commercial fishery and the summer survey indicates a higher mean WAA for age 3 in the fishery compared to the survey, with diminishing differences as age increases (Figure 38). Therefore, it is proposed that survey WAA for ages 1-5 and fishery WAA for ages 6+ (since there are fewer observations for older fish from RV survey) could be used to calculate beginning of year WAA for population biomass estimates and in projections.

MATURITY

Maturity stage data for male and female haddock was examined from fish sampled during DFO spring surveys of the western Scotian Shelf/Bay of Fundy area conducted during two time periods within the spawning season: 1979-1986 and 2011-2014. For these surveys, maturity stages were routinely assigned to haddock using a Groundfish Maturity Schedule that generally followed the classification scheme of Kesteven (1960). During the earlier period of sampling (1979-1986), 64% of sampled fish were either spent (stages 6-7) or recovering from spawning (stage 8), compared to 14% for the more recent period (2011-2014), where more fish were either immature (i.e. stage 1: 36%) or in the process of ripening and/or spawning (i.e. stages 2-5: 46%) (Figure 39). The higher proportion of immature fish during the recent period reflects the high abundance of 0-group and age 1 haddock in the survey catches (i.e. Figures 34 and 44). While the size at maturity for male haddock appears to be slightly smaller than females, there has been a temporal shift in the size at 50% mature for both sexes such that fish are currently maturing at smaller sizes in the recent period (i.e. 2011-2014 size at 50% mature: males 26cm, females 28cm) compared to the early part of the time series (i.e. 1979-1986 size at 50% mature: males 37cm, females 38cm) (Figure 40). No ageing was available for haddock sampled during recent spring surveys to determine if there has been a shift in the age at 50% maturity, but data collected from the early (1979-1986) period suggests that the age at 50% mature for both sexes is 3. Age 4+ haddock have been used as a proxy for spawning stock biomass in past assessments and will continue to be used for the framework modelling.

CONDITION FACTOR

A previous analysis by Showell et al. (2013) indicated that condition (measured as predicted weight at 43cm) and mean LAA have declined in both the Bay of Fundy and western Scotian Shelf stock components, with the two factors combining to produce very low mean WAA relative to the early period in the time series. An analysis of condition factor (updated from Emberley and Clark 2012) using Fulton's K (weight/length^3) rather than predicted weight at 43cm, showed that condition declined in haddock (length range: 28-55cm) from the early 1990s to mid-2000s for both areas, then increased to 2009 before falling off again in recent years (Figure 41). Fulton's K has generally been at or below the long term average (1970-2014) since 1993 for both areas. The overall pattern is consistent with declining trends in WAA and LAA and is similar to what has been observed for other species on the Scotian Shelf (i.e. silver hake, pollock).

CATCH AT SIZE, INCOMING RECRUITMENT AND SPATIAL DISTRIBUTION AT AGE

The summer survey catch at size for haddock in the 9-11cm size range (i.e. young-of-the-year) in 2013 and 2014 was well above the long term average (1970-2012) indicating potentially very strong and above average recruitment from the incoming 2013 and 2014 year classes, respectively (Figure 42). In 2014, the 2013 year class catch at size (age 1; 18-24cm) was not only well above average but was at the highest level observed in the 44 year time series and, therefore, may well develop into a significant recruitment event. The abundance of haddock in the 22-38cm size range was also above average in 2013 and 2014. The extremely high abundance of the 2013 year class was confirmed during the 2014 spring survey in 4X, with an estimated 168 million fish captured at 16.5cm (Figure 43). The abundance of this year class was lower during the 2014 summer survey (although still well above the long term average), which may, in part, reflect lower catchability at this time of year.

The 2013 year class abundance at age 0 was higher in Bay of Fundy strata (482-495) compared to western Scotian Shelf strata (470-481) (Figure 44). However, other strong year classes (i.e. 1999, 2000 and 2006) were actually more abundant on the western Scotian Shelf. The 1999 year class was considered exceptional because of early spawning (i.e. in February 1999) and because larval stages encountered an unusually plentiful food supply (Head et al. 2005). Also of interest is that there were very few 0-group haddock captured in summer surveys prior to 1995, suggesting that they may have been too small to catch during these years. This may be related to later spawning times due to colder water temperatures.

The distribution of 4X5Y haddock CAA 0 from the summer survey in 2013 was more widespread than the previous 10-ytear average (2003-2012) distribution and indicates high abundance in two separate areas: Browns Bank and outer the Bay of Fundy (Figure 45). This split distribution suggests there may have been two separate spawning components in 2013 or larval drift from Browns Bank following residual current patterns. Age 1 haddock were found mainly on Browns Bank in 2013, similar to the 10-year average distribution, with low occurrence in the outer Bay of Fundy. Ages 2-3 and 4+ haddock were mainly concentrated on Browns Bank in 2013, as was the case for average abundance over the past 10 years (Figure 46). For these age groups, the abundance in the Bay of Fundy was relatively low.

SURVEY Z AND RELATIVE F

Total mortality (Z) for 4X5Y haddock was calculated from the DFO summer survey CAA data (1970-2013) for several different age groups (i.e. ages 2-3, 4-5, 6-7 and 8-10) as:

$$Z = \ln\left(\frac{Catch\ Agex_{year\ y}}{Catch\ Agex+1_{year\ y+1}}\right)$$

Relative fishing mortality at age (Relative F) was calculated as the ratio of the age-specific fishery CAA over the age-specific summer RV survey CAA. Relative F and Survey Z were smoothed using a three-year running average and compared for ages 2-3, 4-5, 6-7 and 8-10 (Figure 47). For all age groups, there has been a decline in Relative F since the mid-1990s, but the trend is more pronounced for ages 4-5 and 8-10. In contrast, Survey Z for ages 4-5 and 6-7, and especially 8-10 has not declined in recent years. Since F appears to have declined but Z still remains relatively high, it is possible that natural mortality (M) on these ages has increased.

INDIVIDUAL TRANSFERABLE QUOTA FIXED STATION SURVEY

A mobile gear fixed station survey of NAFO Area 4X was conducted by the Individual Transferable Quota (ITQ) mobile gear <65' fleet from 1996 to 2012. This survey covered the western Scotian Shelf/Bay of Fundy area and included nearshore areas of 4X that were not accessible to the DFO summer survey (Figure 48). The ITQ survey was conducted in July by three commercial trawlers at about the same time as the summer survey. The three vessels used a standardized Balloon 300 trawl equipped with a codend liner of the same mesh size as used during the summer survey. Abundance and biomass indices were calculated for the entire 4X area and not separately for Bay of Fundy and western Scotian Shelf. The ITQ survey biomass index (kg/tow) shows similar trends to the DFO summer survey (combined strata 470-495) up to 2007, but then has a stronger decline from 2007-2009 (Figure 49). The ITQ survey appeared to track year classes fairly well as indicated by the progression of the CAA for the 2003 and 2006 year classes (Figure 50). The age-specific indices for ages 2-13 for 1996-2010 were used for tuning the SPA model during the last assessment (Table 16), but have not been updated for 2011 and 2012. This survey was discontinued in 2013 and because of this and the fact that the index has not been calculated using a standard methodology (i.e. core set of fixed stations sampled throughout the time series), it is probably not worth revising.

BYCATCH ANALYSIS

The data for bycatch analyses were extracted from the Industry Surveys Database (ISDB), which includes information on kept and discarded species and their estimated weights recorded by at-sea observers during commercial fishing trips. The percentage of bycatch kept and discarded was calculated as a proportion of total observed catches for 2004-2013 combined for the 4X5Y haddock directed fisheries (i.e. mobile and fixed gear), as well as for haddock bycatch fisheries, specifically the 4X redfish mobile gear fishery, which has landed an average of 470t haddock annually over past three years. The pollock gillnet fishery also catches haddock but at low levels and was not examined further.

A proxy for annual observer coverage for each fishery/gear category was calculated as the observed catch (t)/total landings (t) X 100. Over the past 10 years, the percent observer coverage for haddock-directed fisheries was low up to 2009 (<2 %), then increased for both mobile and fixed gear in 2010 with additional funding for bycatch monitoring in 2010-2011 from the Species at Risk Program (Figure 51). The percent coverage peaked at 5% for fixed gear in 2010 and 16% for mobile gear in 2011 but has dropped off to lower levels again since then. Average coverage for 2004-2013 has been about 4% for mobile gear and 2% for fixed gear. Observer coverage of the redfish fishery has generally been higher (average approximately 5% for 2004-2013), peaking at 9% in 2010, but declining to 5% in 2013. The level of coverage for haddock-directed and haddock bycatch fisheries in 4X5Y should be higher (approximately 10-20%) in order accurately to estimate bycatch rates of commonly discarded species.

For haddock-directed mobile gear trips, the observed sets (*n*=1738) covered much of the 4X5Y fishing area and occurred in the Fundian Channel, Crowell and Jordan basins, the Bay of Fundy, western Brown Bank and along the shelf slope south of Browns and LaHave banks (Figure 52). Overall, 92% of the catch was kept and 8% was discarded. Haddock represented 62% of the kept catch with a bycatch of cod (11%), pollock (10%), winter flounder (4%), redfish (2%) and white hake (1%), all of which were landed (Figure 52; Table 17). Discarded bycatch species included dogfish (3%), American lobster (1%), winter skate, halibut and thorny skate (all <1%), plus several other species at very low levels.

For haddock-directed fixed gear trips (mainly longline), observer coverage for 2004-2013 was low (*n*=746). Observed sets occurred mainly in the Fundian Channel and around Browns, LaHave and Roseway banks (Figure 53). Overall, 90% of the catch was kept, with 10% discarded. Haddock represented 43% of total kept catch followed by cod (25%), white hake (10%), cusk (8%), halibut (2%) and pollock (1%), all of which were landed (Figure 53; Table 18). Discarded bycatch species included: dogfish (3%), barndoor skate (3%), thorny skate (1%), and winter skate (<1%) plus other species at very low levels.

For redfish-directed mobile gear trips, observed sets (*n*=1792) provided good coverage of the fishery and occurred in Crowell, Jordan and La Have basins, along the shelf slope and east of Roseway and LaHave banks (Figure 54). Overall, 91% of the catch was kept, with 9% discarded. Redfish represented 70% of total catch, pollock 11%, haddock 5%, white hake 3% and cod (2%); all were landed (Figure 54; Table 19). Discarded bycatch species were mainly dogfish (8%), followed by lobster, barndoor skate and silver hake (all <1%), plus several other species at very low levels.

CONCLUSIONS

FISHERY

- The current 4X5Y Management Area is appropriate for this stock; there is no new information to indicate otherwise.
- Landings have been less than 4,000t for the past two years (2012 and 2013) and were taken mainly by small otter trawlers (TC 1-3, 80%), followed by longline (20%). The share taken by longline has declined further since 2011.
- Most landings currently come from Scotian Shelf statistical unit areas 4Xn and 4Xp during the 1st and 3rd quarters, with a general seasonal/geographic pattern in areas fished. This pattern has evolved to reduce cod bycatch.
- Haddock landings from the mixed stock area in 4Xp south (i.e. within 5 nautical miles north of 4X5Z line) were as high as 1350t and 2400t in 2005 and 2007, respectively, but have declined to low levels in the past two years.
- Past occurrences of high catches in 4Xp south may reflect periods when above average year classes from the eastern Georges Bank stock (i.e. 2000, 2003) expand into the Fundian Channel and are captured in 4X summer/fall fishery.

COMMERCIAL FISHERY CATCH AT AGE

- The CAA time series was re-calculated using 2cm groupings for 1985-2010 and revised age determinations for 1985-1989.
- Overall, the effects of these changes were small but the CAA for 1985-2010 is now consistent in terms of the approach used.
- A separate category was created in the CAA for haddock landings from the redfish fishery for 2011-2013 (proportion has increased in recent years).

- For exploratory VPA analyses, a separate CAA was calculated for 2004-2013 that removed landings, length frequencies and ALKs from port samples for trips in 4Xp south.
- The revised fishery WAA does not have the precipitous drop in WAA for ages 9 and 11, which occurred in the old series from 1987-1988; the revised series continues to show a declining trend from 2000-2008 and then levels off.
- The 2010 year class at age 3 represented 41% of the 2013 CAA.
- The distribution of LAA in the 2012 and 2013 catch is more truncated and exhibits a greater degree of overlap compared to earlier years in the time series (i.e. 1985, 1995, 2005 and 2010).

DFO SUMMER SURVEY

- Survey indices, WAA and LAA were re-calculated for Scotian Shelf (470-481) and Bay of Fundy strata (482-495) and then combined.
- Main areas of haddock abundance have been Browns, Baccaro and LaHave bank regions; there was an increase in biomass in Bay of Fundy in 1980s and 1990s followed by a decline in the 2000s.
- The summer survey biomass index declined for both the western Scotian Shelf and Bay of Fundy areas from 2009 to 2012 and then showed a modest increase in 2013 and 2014.
- There has been a large decline in survey WAA for ages 5 and older beginning in the early 1980s, similar to the trend in fishery WAA but it occurs earlier; WAA has been lower but stable since 2004. Stock productivity is lower now compared to the past.
- Von Bertalanffy growth model parameters indicate that haddock from Bay of Fundy strata grow faster and attain a larger size than haddock from Scotian Shelf strata.
- There has been a temporal shift in the size at 50% mature for both sexes such that fish are currently maturing at smaller sizes in the recent period (i.e. 2011-2014) compared to the early part of the time series (i.e. 1979-1986).
- No age data are available for the recent spring surveys to determine if there has been a shift in the age at 50% maturity. Haddock age 4+ will continue to be used as a proxy for spawning stock biomass.
- Fulton’s K has been declining since 1990, more rapidly for Bay of Fundy haddock.
- There has been an improvement in age structure since the late 1990s (increase in age 6+)
- The 2013 age-specific indices were dominated by ages 1-3 (2012, 2011 and 2010 year classes).
- Indications from 2013 and 2014 surveys that 2013 year class is the strongest in the 44 year time series.

OBSERVER COVERAGE AND BYCATCH

- Observer coverage for directed haddock trips over the past 10 years has averaged approximately 4% for mobile gear and approximately 2% for fixed gear, which is too low for estimating bycatch rates.
- Discards are low in haddock directed and non-directed fisheries; dogfish, lobster and skates are the primary discarded species.

DATA AND MODELLING

- The proposed data available for modelling work and exploratory analyses includes: CAA for ages 1-14 (1970-2013) and summer survey age-specific indices for ages 2-13 (1983-2013; *Needler* time series only).
- There may have been an increase in M for ages 8+ since 1994; this needs to be evaluated.

- The ITQ survey was discontinued after 2012; it is proposed that it be excluded from population modelling.
- For population biomass estimates, it was proposed to use summer survey WAA for ages 1-5 and fishery WAA for ages 6+, then adjust to beginning of year WAA using the method of Rivard (1980). Yield projections will use fishery WAA.

EFFECTS OF INPUT DATA REVISIONS ON POPULATION MODEL RESULTS

BACKGROUND

The impacts of the various revisions and modifications to the 4X5Y haddock data inputs (i.e. CAA, survey indices, WAA) on population model results (i.e. estimates of age 1 recruitment, ages 4+ biomass and ages 6-9 fishing mortality) were evaluated using the ADAPT VPA software of Gavaris (1988). The main advantage of this modelling software is that it is relatively easy to set up and modify compared to the ACON software used during the 2012 assessment.

The VPA formulation developed by D. Clark during the 2012 assessment for comparative estimates of population biomass was used as the ADAPT Base Model from which changes in the data series could be evaluated. The input data for this model included: CAA for ages 1-14 (1970-2010); summer survey indices of abundance for ages 2-10 (1983-2010; *Needler* time series only); and ITQ survey indices of abundance for ages 2-10 (1996-2010). For the model set-up in the terminal year (2011), N was estimated for ages 3-14 and a “ragged F” was calculated for the oldest ages using a population weighted average F for ages 9-12. The ADAPT (Clark) and ACON (Mohn) VPA results for 4+ B were quite similar except for the most recent year estimates, which were slightly higher for the ACON model (Figure 55). This difference was attributed to the ACON model set up for the oldest ages, which could not be reproduced exactly for the ADAPT model run. For the purpose of this exercise, however, the results of the ADAPT VPA were considered to be acceptable.

VIRTUAL POPULATION ANALYSIS MODEL COMPARISONS AND RESULTS

Five different ADAPT model runs were conducted to evaluate the influence of data revisions.

1. The ITQ survey was discontinued in 2013; ***Compare Base VPA model with and without ITQ survey (1996-2010) as tuning index.***

Results

The Base Model without the ITQ survey as a tuning index had slightly more recruits for 1997-2007, higher estimates of ages 4+ biomass (4+B) and lower estimates of ages 6-9 fishing mortality (6-9 F) in the recent period compared to the Base Model, which included the ITQ series (Figure 56). Noteworthy was that the DFO summer survey biomass index did not show same increase and decline as the ITQ biomass index after 2006 (Figure 49), which likely contributed to the observed differences in population biomass trends (i.e. higher in the recent period when the ITQ survey was excluded). Thus, the ITQ survey did have some influence on recent year estimates of population biomass, but these are considered to be relatively minor.

2. Revisions to 1985-2010 CAA: new ages used for 1985-1989, 2cm groupings consistently applied to all years from 1985-2010, summer survey indices calculated for separate areas then combined for ages 2-13 (results in slightly different age specific indices and beginning of year WAA); ***Compare Base VPA (no ITQ, RV 2-10) before and after data revisions.***

Results

Using the Clark Base VPA Model, with revised CAA and survey data, resulted in higher past estimates of recruitment for some years, higher 4+B from 1979 to1987 and after 2003, and some past differences in F, but with similar trends since the mid-1990s (Figure 57). Overall, differences in contemporary population model results for recruitment, 4+ biomass and F were relatively minor. Although the effects of these changes were small, the CAA for 1985-2010 has now been calculated using a more consistent approach.

A further comparison (not shown) using the Clark Base Model with revised data (as above), which excluded CAA from 1970-1984, indicated no difference in model results for the two different time series (i.e. 1970-2010 vs 1985-2010). This run was done to investigate the impact of truncating the time series if the unrevised ages from 1970-1984 were considered to be problematic. However, leaving these early years out of the time series gives a different impression of stock productivity, which may have been quite high during this early period.

3. Extend Revised Base Model time series to 2013 (with small mesh category for 2011-2013 CAA); ***Compare Revised Base VPA (1970-2010) with Updated Base VPA (1970-2013) using summer survey ages 2-13 and CAA 1-14 as data inputs.***

Results

Adding three years of CAA and summer survey data (2011-2013) illustrates the persistent retrospective issue identified in previous analytical assessments of this resource; i.e. recent estimates of age 1 recruits and 4+ biomass are lower, while F is higher compared to estimates from assessments conducted in previous years (Figure 58). Clearly, the data revisions were not enough to alleviate the retrospective problem, and there are other issues within the model that need to be resolved.

4. Exclude landings, length frequency samples and ages from 4Xp south (<42^{o}25' N) for 2004-2013; ***Compare Updated Base Model with and without CAA data from 4Xp south (i.e. use different CAA for 2004-2013).***

Results

The new Base Model with summer survey and CAA data for 2011-2013 was run with and without landings, port sample length frequencies and ages from 4Xp south (<42^{o}25' N) from 2004-2013. Removing these catches had only minor effects on past estimates of age 1 recruitment, 4+B and ages 6-9 F when catches from this area were high (Figure 59). At this point, it does not appear to be worth pursuing this analysis further.

5. Has there been a change in M during the time series? ***Compare Revised Base VPA with M=0.2 vs Revised Base VPA, which estimates M on ages 8+ from 1995 to present.***

Results

The rationale for this analysis was based on the comparison of Survey Z with Relative F for haddock aged 8-10 (Figure 47). This comparison indicated that while Relative F had declined since the 1990s, Survey Z had not, suggesting that M on these ages may have increased. To further investigate this scenario, the Base Model was set up to estimate M for ages 8+ from 1995 to 2013 and compared with the Base Model with M=0.2 for all ages (1970-2013). The model which estimated M had higher recruitment since 1996, higher 4+ biomass and lower ages 6-9 F since 1990 (Figure 60), and estimated M at 0.472 for ages 8+. The model that estimated M also had a slightly better fit than the M=0.2 model (i.e. MSR=0.552 vs 0.651 when M=0.2).

For the Benchmark Modelling Meeting, it is recommended that models that use higher M should be explored (i.e. Random Walk M approach).

The 4X5Y haddock fishery has exhibited a trend of increasing PR on older fish (ages 7+) in the 1990s and 2000s, which is not consistent with the pattern from earlier time periods (Figure 61). This may indicate either a difference in ageing for the earlier period or the influence of declining WAA. The causes for this change in PR need to be explored for the Benchmark Modelling meeting.

CONCLUSIONS FROM VIRTUAL POPULATION ANALYSIS MODEL COMPARISONS

- Removing the ITQ survey series has a small influence on estimates of R, 4+B and 6-9 F for the recent period up to 2010 because biomass trends from this survey are different from the summer RV series for 2006-2010. The ITQ Survey has been discontinued as of 2013.
- Revisions to the CAA up to 2010 (i.e. new ages for 1985-1989, 2cm groupings, recalculated RV indices for ages 2-13) results in some changes to past estimates of 4+B and 6-9 F; however, the revised CAA has been calculated using a more consistent approach than the previous CAA.
- Removing early years from the CAA time series (1970-1984) has no impact on model results but would give a different impression of stock productivity, which may have been higher during the early period.
- Extending time series to 2013 illustrates persistence of the retrospective issue. The various data revisions were not enough to alleviate the retrospective problem, and there are other issues with the VPA model that need to be resolved.
- Removing catches and port sample LF's/ages from 4Xp south, an area where 5Zjm and 4X5Y stocks may overlap, particularly when there are strong year classes in 5Z, does not have much impact on estimates of R, 4+B and 6-9 F and will not be considered for further analysis.
- Allowing the model to estimate M on ages 8+ from 1995 to present suggests that M has increased on older fish in the recent period (i.e. since 1994, M=0.472). Using higher M in the VPA model may help to reduce retrospective pattern. Further exploration of models that use higher M (i.e. Random Walk M) is recommended. Increasing PR on older ages since 1990s may also reflect declining WAA and/or problems with ageing during the early period.

ACKNOWLEDGEMENTS

The authors thank P. Comeau for updating the 4X5Y haddock ageing and conducting the inter-ager comparisons. They also thank D. Busawan for completing the analysis on Von Bertalanffy growth parameters and for reviewing the manuscript.

REFERENCES CITED

Begg, G.A. 1998. A review of stock identification of haddock, *Melanogrammus aeglefinus*, in the northwest Atlantic Ocean. Marine Fisheries Review. 60(4): 1-13.

Emberley, J. and D.S. Clark. 2012. Update of the 2011 summer Scotian Shelf and Bay of Fundy research vessel survey. Can. Data Rep. Fish. Aquat. Sci. 1240. x + 95 p.

Fanning, L.P. 1985. Intercalibration of research survey results obtained by different vessels. CAFSAC Res. Doc. 85-3. 43 p.

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

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

Gavaris, S. 1988. An adaptive framework for the estimation of population size. CAFSAC Res. Doc. 88/29. 12 p.

Halliday, R.G. 1988. Use of seasonal spawning area closures in the management of haddock fisheries in the northwest Atlantic. NAFO Sci. Counc. Studies 12:27-36.

Halliday, R.G., and A.T. Pinhorn. 1990. The delimitation of fishing areas in the northwest Atlantic. J. Northw. Atl. Fish. Sci. Vol. 10: 1-51.

Head, E.J.H, D. Brickman, and L.R. Harris. 2005. An exceptional haddock year class and unusual environmental conditions on the Scotian Shelf in 1999. Journal of Plankton Research. 27(6): 597-602.

Hurley, P.C.F , G.A.P. Black, R.K. Mohn, and P.A. Comeau. 1996. Assessment of 4X haddock in 1995. DFO Can. Sci. Advis. Sec. Res. Doc. 1996/30. 66 p.

Hurley, P.C.F , G.A.P. Black, P.A. Comeau, R.K. Mohn, and K. Zwanenburg. 1998. Assessment of 4X haddock in 1997 and the first half of 1998. DFO Can. Stock Assess. Sec. Res. Doc. 98/135. 96 p.

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

Kesteven, G.L. 1960. Manual of field methods in fisheries biology. F.A.O. Manuals in Fisheries Sciences, No. 1, F.A.O. Rome. 152 p.

Koslow, J.A. 1984. Recruitment patterns in northwest Atlantic fish stocks. Can. J. Fish. Aquat. Sci. 41: 1722-1729.

Koslow, J.A., K.R. Thompson, and W. Silvert. 1987. Recruitment to northwest Atlantic cod (*Gadus morhua*), and haddock (*Melanogrammus aeglefinus*) stocks: influence of stock size and climate. Can. J. Fish. Aquat. Sci. 44: 26-39.

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

Needler, A.W.H. 1930. The migrations of haddock and the interrelationships of haddock populations in North American waters. Contrib. Can. Biol. 6:241–313.

O'Boyle, R.N., K. Waiwood, and J.I. McMillan. 1983. An evaluation of the 4X haddock population characteristics during 1962-82 with yield projected to 1984. Can. Alt. Fish. Sci. Advis. Comm. Res. Doc. 83/73. 52 p.

O'Boyle, R.N., M. Sinclair, R.J. Conover, K.H. Mann, and A.C. Kohler. 1984. Temporal and spatial distribution of ichthyoplankton communities of the Scotian Shelf in relation to biological, hydrological, and physiographicfeatures. *Rapp. P.-v. Reun. Cons. Int. Explor. Mer.* 183: 27-40.

Page, F.H., and K.T. Frank. 1989. Spawning time and egg stage duration in northwest Atlantic haddock (*Melanogrammus aeglefinus*) stocks with emphasis on Georges and Browns Bank. Can. J. Fish. Aquat. Sci.46 (Suppl. 1) 68-81.

Rivard, D. 1980. Back-calculating production from cohort analysis, with discussion on surplus production for two redfish stocks. CAFSAC Res. Doc. 80/23: 26 p.

Showell, M.A., D. Themelis, R.K. Mohn, and P. Comeau. 2013. Haddock on the southern Scotian Shelf and Bay of Fundy in 2001 (NAFO Division 4X5Y). DFO Can. Sci. Advis. Sec. Res. Doc. 2013/101. v + 57 p.

Smith, W.G, and W.W. Morse. 1985. Retention of larval haddock *Melanogrammus aeglefinus* in the Georges Bank region, a gyre-influenced spawning area. Mar. Ecol. Prog. Ser. 24: 1-13.

TABLES

Table 1. Results of stock identification studies to differentiate haddock stocks in the northwest Atlantic (from Begg 1998). Div. 5Zjm - Georges Bank, Canada; Div. 5Z - Georges Bank, USA; Div. 5Y - Gulf of Maine; N.Sh. – Nantucket Shoals; Div. 4X - western Nova Scotia; Div. 4Xs - Bay of Fundy; Div. 4W - central Nova Scotia; Div. 4V - eastern Nova Scotia; Div. 4T - Gulf of St. Lawrence; Div. 3Ps - St. Pierre Bank; Div. 3LNO - Grand Bank. N/A = No data available. ? = Results uncertain.

	Stock Structure (no. of stocks identified within)		
Stock ID Method	**New England**	**Nova Scotia**	**Newfoundland**
Tag-recapture	1-2 (5Y; 5Z/N.Sh.?)	2 (4X; 4TVW)	N/A
Growth rates	2-3 (5Y; 5Z/N.Sh.?)	2 (4X; 4TVW)	2 (3Ps; 3LNO)
Spawning patterns	2-3 (5Y; 5Z/N.Sh.?)	2 (4X; 4TVW)	2 (3Ps; 3LNO)
Meristics	N/A	3-4 (4X, 4V, 4W, 4T?)	N/A
Parasites	N/A	3	N/A
Genetics	?	?	N/A
Current management units	1(Canada) / 2(USA) (5Zjm-Canada; 5Z, 5Y-USA	2 (4X; 4TVW)	2 (3Ps; 3LNO)

Table 2. Reported annual and fishing year catch (t) of haddock from NAFO Division 4X, 1970-2013. Canadian landings include 5Y. FY: fishing year (April 1- March 31); TAC: total allowable catch. Dashed line indicates no TAC or FY TAC for that year.

Year	Catch	TAC	FY Catch[1]	FY TAC[1]
1970	18,072	18,000	-	-
1971	17,592	18,000	-	-
1972	13,483	9,000	-	-
1973	13,106	9,000	-	-
1974	13,378	0	-	-
1975	18,298	15,000	-	-
1976	17,498	15,000	-	-
1977	21,281	15,000	-	-
1978	27,323	21,500	-	-
1979	25,193	26,000	-	-
1980	29,210	28,000	-	-
1981	31,475	27,850	-	-
1982	25,729	32,000	-	-
1983	27,405	32,000	-	-
1984	21,156	32,000	-	-
1985	16,131	15,000	-	-
1986	15,555	15,000	-	-
1987	13,780	15,000	-	-
1988	11,272	12,400	-	-
1989	6,800	4,600	-	-
1990	7,556	4,600	-	-
1991	9,826	0	-	-
1992	10,530	0	-	-
1993	6,968	6,000	-	-
1994	4,406	4,500	-	-
1995	5,669	6,000	-	-
1996	6,245	6,500	-	-
1997	6,527	6,700	-	-
1998	7,843	8,100	-	-
1999	6,621	8,100	9,291	9,800
2000	6,961	-	7,761	8,100
2001	8,466	-	7,411	8,100
2002	7,997	-	7,930	8,100
2003	8,706	-	8,617	8,100
2004	6,553	-	5,964	10,000
2005	5,633	-	5,142	8,000
2006	4,746	-	4,687	7,000
2007	6,876	-	6,767	7,000
2008	5,372	-	5,684	7,000
2009	5,504	-	5,831	7,000
2010	5,663	-	5,379	6,000
2011	3,733	-	4,467	6,000
2012	4,127	-	3,323	5,100
2013	3,518	-	3,393	5,100

[1] Fishing year in 1999 was extended to March 3, 2000. TAC prorated upwards. Subsequent fishing years begin on April 1.

Table 3. Reported annual catch (t) of haddock from NAFO Division 4X5Y landed in the Maritimes by gear type and tonnage class, 1970-2013. MG = mobile gear tonnage class 1-3 and 4+, LL = longline, HL = handline, GN = gillnet, TC = tonnage class.

Year	MG[1] (TC 1-3)	MG (TC 4+)	LL	HL	GN	Misc[2]	Total of Gear Categories
1970	5519	6503	2961	539	88	402	16012
1971	4743	7716	3227	456	79	183	16404
1972	2942	4755	4048	498	59	268	12570
1973	1929	4233	5853	377	143	145	12680
1974	4113	1628	6211	258	166	58	12434
1975	6183	4406	4944	275	176	75	16059
1976	4390	6157	4642	714	389	46	16338
1977	6290	8346	4032	411	337	177	19593
1978	9588	8099	6072	865	573	198	25395
1979	10293	8638	4349	838	399	63	24580
1980	13131	7444	5723	1281	797	228	28604
1981	14912	6649	7008	923	856	17	30365
1982	11960	3122	6763	875	814	31	23565
1983	12988	2560	7787	786	664	56	24841
1984	12081	615	6307	492	183	4	19682
1985	10244	563	4028	336	110	33	15314
1986	9854	209	4875	469	88	13	15507
1987	8177	511	4572	286	215	3	13763
1988	7269	377	3356	126	81	23	11233
1989	3829	90	2469	221	158	27	6794
1990	3329	110	3391	396	278	0	7504
1991	4182	206	4588	539	257	1	9772
1992	3469	258	5587	974	215	5	10508
1993	2632	123	3227	865	100	1	6947
1994	2081	97	1578	600	48	2	4405
1995	3062	106	2171	250	69	2	5660
1996	3685	151	2053	298	50	0	6237
1997	4238	65	2066	110	58	0	6538
1998	5155	80	2461	141	50	0	7887
1999	4475	120	1955	40	31	0	6621
2000	4129	105	2670	29	28	0	6961
2001	6140	88	2227	11	21	0	8486
2002	5630	37	2252	55	23	0	7997
2003	6616	29	2008	26	26	0	8706
2004	5376	0	1140	15	22	0	6553
2005	4611	53	950	5	13	0	5633
2006	3255	174	1309	3	6	0	4746
2007	5240	50	1583	0	3	0	6876
2008	4185	0	1176	0	8	0	5369
2009	4563	0	933	0	7	0	5504
2010	4371	0	1263	0	4	25	5663
2011	2800	22	906	0	4	0	3733
2012	3297	38	790	0	2	0	4122
2013	3048	46	412	0	2	0	3518

[1] Mobile gears include all kinds of trawls (e.g. otter, midwater, shrimp) and pair Seine.
[2] Miscellaneous gears include trap, unknown gears, Dredge, Jigger, Pot, squid jig and weir.

Table 4. Reported commercial haddock landings (t) by month and quarter from NAFO Divisions 4X and 5Y, 1985-2013 (from ZIF and MARFIS databases).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Qtr1	Qtr2	Qtr3	Qtr4	Total
1985	789	3898	626	1000	1164	2060	1599	1291	1585	1096	436	562	5313	4224	4475	2094	16106
1986	859	2913	1071	481	1109	1059	1262	1254	2652	1613	635	599	4843	2649	5168	2847	15507
1987	1168	2320	2085	594	1363	1381	961	777	1458	1057	347	253	5573	3338	3196	1657	13764
1988	2119	1523	216	637	808	1289	876	529	1697	790	231	503	3858	2734	3102	1524	11218
1989	996	1447	836	371	245	906	485	504	444	330	147	83	3279	1522	1433	560	6794
1990	1371	1262	288	293	429	597	739	640	864	408	309	305	2921	1319	2243	1022	7505
1991	1057	1361	318	241	542	942	1086	877	978	742	585	1042	2736	1725	2941	2369	9771
1992	1519	1052	366	228	606	1131	1297	1027	1127	801	529	825	2937	1965	3451	2155	10508
1993	361	924	452	316	676	897	909	1085	797	267	195	69	1737	1889	2791	531	6948
1994	404	280	139	209	278	692	838	366	421	289	220	268	823	1179	1625	777	4404
1995	539	387	518	230	314	445	697	570	572	492	256	640	1444	989	1839	1388	5660
1996	396	463	481	282	273	539	659	578	602	699	707	559	1340	1094	1839	1965	6238
1997	109	614	572	439	194	395	642	664	899	867	598	544	1295	1028	2205	2009	6537
1998	419	939	1103	650	132	354	743	654	1042	645	503	705	2461	1136	2439	1853	7889
1999	531	526	252	269	324	420	716	976	1114	587	495	412	1309	1012	2807	1494	6621
2000	644	1129	897	146	325	383	769	745	788	609	344	182	2670	853	2302	1135	6961
2001	1371	603	1496	343	413	389	606	840	942	628	545	292	3469	1145	2388	1464	8466
2002	982	670	772	568	361	599	902	936	816	578	428	388	2424	1528	2654	1394	8000
2003	809	398	1190	277	569	323	760	903	1243	898	832	503	2397	1169	2906	2233	8705
2004	340	617	1351	245	366	228	397	618	855	596	550	391	2308	838	1870	1537	6553
2005	402	577	741	191	176	178	420	823	875	636	456	157	1720	546	2118	1249	5633
2006	206	589	435	82	141	390	688	570	706	370	409	160	1230	614	1964	939	4746
2007	278	362	531	284	209	306	313	1059	1269	1384	522	359	1171	799	2641	2264	6876
2008	150	375	537	288	90	142	413	492	727	1008	835	314	1063	520	1632	2157	5372
2009	179	846	350	72	159	288	1021	488	837	672	349	243	1375	519	2346	1264	5504
2010	302	860	540	608	183	337	500	588	777	472	319	177	1702	1129	1864	968	5663
2011	235	886	290	47	122	295	230	353	369	351	310	245	1411	464	952	906	3733
2012	820	848	478	95	94	107	149	387	265	255	389	241	2145	296	801	885	4127
2013	272	267	802	115	97	130	538	436	241	268	193	158	1341	342	1216	619	3518

Table 5. Landings (t) of 4X5Y haddock for mobile and fixed gear aggregated for Scotian Shelf (4Xmnop) and Bay of Fundy (4Xqrs) unit areas used in CAA calculations, 1985-2013.

	Mobile		Fixed	
Year	**4Xmnop**	**4Xqrs**	**4Xmnop**	**4Xqrs**
1985	5876	5504	4456	259
1986	5255	4826	5308	129
1987	6152	2535	4911	165
1988	5969	1672	3384	309
1989	2796	1118	2803	134
1990	2107	1332	3879	340
1991	2366	2039	5120	266
1992	2143	1582	6107	673
1993	1390	1364	3725	467
1994	740	1438	2044	183
1995	1527	1641	2278	212
1996	1528	2308	2192	210
1997	1661	2642	2090	144
1998	2956	2279	2466	187
1999	2395	2202	1948	78
2000	2406	1828	2526	201
2001	3696	2531	2155	86
2002	2702	2966	2206	138
2003	2830	3816	1949	113
2004	3083	2293	1074	103
2005	3221	1443	873	96
2006	2240	1188	1231	87
2007	4197	1093	1506	81
2008	3346	839	1136	48
2009	3994	569	906	35
2010	3965	429	1212	55
2011	2531	291	876	35
2012	2833	502	780	12
2013	2496	608	397	17

Table 6. Landings (t) and number of port samples of haddock for mobile and fixed gear from 4Xp south (i.e. within 5 nautical miles north of the 4X5Z NAFO Area boundary), 2004-2013. MG - mobile gear; FG - fixed gear.

	Total	4Xp south MG		4Xp south FG		4Xp south (All)	
Year	**Land (t)**	**Land (t)**	**Samples**	**Land (t)**	**Samples**	**Land (t)**	**%**
2004	6532	897	11	44	2	941	14
2005	5633	1172	8	177	0	1349	19
2006	4743	471	2	117	0	588	6
2007	6876	2308	15	119	1	2427	35
2008	5369	907	6	42	2	949	14
2009	5504	391	7	81	0	472	7
2010	5663	773	5	125	0	898	11
2011	3733	390	5	68	2	458	11
2012	4127	121	2	63	1	184	1
2013	3518	192	4	6	0	198	5

Table 7. Commercial fishery CAA (000s) for 4X5Y haddock, 1970-2013. Separate length-weight relationships and age-length keys were applied to landings and catch at size for unit areas 4Xmnop and 4Xqrs5Y.

	Age																
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
1970	0	1088	747	1549	391	541	4679	1922	137	99	181	28	38	0	0	0	11400
1971	0	809	1660	809	1460	415	71	3404	1047	167	186	150	108	0	0	0	10286
1972	42	22	3490	1871	517	656	91	58	1185	520	26	196	93	0	0	0	8767
1973	152	3114	114	2274	1080	533	607	326	262	621	56	13	6	0	0	0	9158
1974	1	713	4783	318	1829	523	194	277	191	277	567	25	4	0	0	0	9702
1975	37	2198	4617	5220	490	1115	250	174	63	32	167	231	11	0	0	0	14605
1976	18	1306	1657	4295	3712	437	813	155	72	96	39	104	158	0	0	0	12862
1977	2	1289	3137	2026	3204	2891	361	390	107	72	23	8	87	0	0	0	13597
1978	0	77	3453	7221	2156	2916	1071	141	110	27	9	6	49	0	0	0	17236
1979	0	83	1184	6862	3970	1094	1272	269	58	70	11	1	18	0	0	0	14892
1980	16	164	2497	3071	5527	3573	538	636	173	35	21	3	10	0	0	0	16264
1981	1	1210	2268	6369	4300	3272	1191	366	331	99	14	24	9	0	0	0	19454
1982	0	526	3895	2648	4954	1823	1560	364	196	101	48	17	15	0	0	0	16147
1983	0	70	3621	6020	4104	2454	1033	434	206	131	76	27	27	0	0	0	18203
1984	2	763	1195	5046	3708	2583	1022	367	119	83	39	22	13	0	0	0	14962
1985	3	769	3778	1285	3844	1419	684	472	397	277	111	42	19	16	6	0	13124
1986	0	547	1466	3981	1781	2660	689	383	283	112	68	38	21	6	2	0	12037
1987	0	156	951	1256	3273	1252	2227	581	224	212	53	38	20	3	2	2	10252
1988	9	172	468	933	905	1839	841	947	421	245	161	56	39	23	8	4	7071
1989	0	118	461	457	825	358	836	433	476	222	80	65	33	14	4	0	4381
1990	0	314	1280	385	373	550	424	734	307	229	84	51	10	10	3	1	4754
1991	1	45	1053	2509	644	356	380	278	339	291	129	149	62	16	4	6	6264
1992	30	199	261	2699	2358	214	241	351	236	234	130	158	31	8	2	0	7150
1993	0	135	741	566	1814	1143	192	98	74	48	60	48	12	8	1	0	4940
1994	8	154	448	689	302	950	255	21	13	14	19	14	5	0	0	1	2895
1995	1	56	835	836	659	295	534	371	144	24	26	18	10	11	4	2	3827
1996	0	29	990	1084	672	428	350	467	377	130	15	1	2	1	1	3	4551
1997	0	19	578	1810	1049	457	268	146	117	108	36	8	1	0	0	1	4598
1998	0	43	143	1153	1841	1203	592	380	174	169	114	34	2	5	5	1	5859
1999	0	38	464	563	1237	942	598	230	55	49	54	25	5	0	0	0	4261
2000	0	253	456	836	561	1328	930	558	223	114	36	8	11	7	5	0	5328
2001	0	100	1654	1053	776	646	1326	923	379	124	25	16	4	15	0	0	7044
2002	1	43	511	2557	710	489	494	737	527	232	111	42	7	0	0	0	6459
2003	0	25	710	1530	2889	648	366	280	249	133	51	21	11	0	0	0	6913
2004	0	12	247	940	1207	1818	601	290	229	162	64	43	20	6	0	0	5639
2005	1	36	70	493	1509	1166	965	335	111	90	76	29	1	0	0	9	4891
2006	0	36	806	256	702	1000	868	585	193	27	50	12	10	4	0	0	4549
2007	0	206	421	3855	296	462	792	563	391	142	39	16	5	1	0	0	7189
2008	0	96	328	597	2179	352	382	689	484	261	90	33	35	1	0	0	5527
2009	4	31	372	505	589	1772	418	256	406	238	169	34	9	4	0	0	4808
2010	0	14	73	585	541	734	1837	369	170	347	161	106	17	18	0	0	4973
2011	3	68	85	284	877	422	625	794	176	73	31	30	38	5	0	0	3511
2012	8	289	307	279	272	1016	410	569	702	200	56	90	32	10	17	0	4258
2013	35	315	1721	512	240	194	468	320	140	288	106	16	21	8	3	0	4387

Table 8. Commercial fishery mean WAA (kg) for 4X5Y haddock, ages 1-16, 1970-2013. Cells with dashes have no data available.

	Age															
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1970	0.290	**0.570**	0.900	1.050	1.160	1.430	1.650	1.950	2.300	2.820	2.800	2.850	3.600	-	-	-
1971	0.290	0.500	0.960	1.250	1.400	1.500	1.750	1.950	2.300	2.650	3.250	3.000	3.000	-	-	-
1972	0.290	0.450	0.900	1.350	1.600	1.750	1.900	2.100	2.300	2.800	3.000	3.700	3.300	-	-	-
1973	0.270	0.510	0.750	1.250	1.800	2.000	2.200	2.300	2.500	2.700	3.300	3.400	4.200	-	-	-
1974	0.180	0.460	0.820	1.100	1.700	2.300	2.500	2.600	2.800	2.950	3.200	3.800	3.900	-	-	-
1975	0.230	0.520	0.820	1.200	1.550	2.250	2.850	3.000	3.200	3.450	3.500	3.700	4.400	-	-	-
1976	0.230	0.520	0.810	1.190	1.600	2.100	2.950	3.500	3.600	3.800	4.100	4.000	4.200	-	-	-
1977	0.280	0.460	0.710	1.220	1.720	2.200	2.940	3.300	3.570	3.770	3.690	3.940	3.910	-	-	-
1978	0.290	0.440	0.870	1.330	1.850	2.330	2.700	3.390	3.770	4.170	4.030	3.620	4.630	-	-	-
1979	0.290	0.510	0.870	1.330	1.840	2.360	2.830	3.300	4.030	4.150	4.960	6.000	5.680	-	-	-
1980	0.160	0.522	0.882	1.326	1.777	2.355	2.906	3.278	3.811	4.332	4.200	4.963	5.711	-	-	-
1981	0.230	0.593	0.877	1.260	1.721	2.219	2.654	3.134	3.608	3.688	4.546	4.823	4.680	-	-	-
1982	-	0.493	0.907	1.294	1.653	2.130	2.577	2.947	3.470	4.033	3.946	4.033	4.908	-	-	-
1983	-	0.394	0.758	1.141	1.714	2.146	2.607	2.869	3.108	3.550	3.630	3.780	4.064	-	-	-
1984	0.250	0.527	0.785	1.069	1.411	1.932	2.287	2.683	3.054	3.431	3.841	4.114	4.000	-	-	-
1985	0.300	0.624	0.841	1.025	1.243	1.506	1.860	2.003	2.085	2.195	2.585	3.034	3.268	3.259	3.359	4.125
1986	-	0.581	0.919	1.089	1.244	1.449	1.748	2.007	2.313	2.710	3.172	3.703	4.618	6.554	9.079	-
1987	-	0.694	0.840	1.073	1.191	1.377	1.573	1.872	2.116	2.365	2.716	2.607	2.307	3.570	3.765	4.527
1988	0.438	0.768	1.097	1.183	1.501	1.547	1.716	1.843	2.070	2.269	2.417	2.706	2.524	3.352	3.518	4.415
1989	-	0.703	1.105	1.286	1.419	1.531	1.694	1.725	1.823	2.005	2.363	2.391	2.490	2.785	3.064	6.008
1990	-	0.648	1.064	1.447	1.781	1.782	1.997	2.030	2.113	2.281	2.235	2.510	2.551	3.062	3.182	4.427
1991	0.492	1.053	1.006	1.364	1.684	1.948	1.983	2.038	2.104	2.107	2.208	2.198	2.360	2.579	3.355	3.190
1992	0.528	0.824	1.088	1.234	1.524	1.870	1.798	1.884	2.059	2.115	1.884	1.892	2.363	2.400	3.082	5.465
1993	0.000	0.733	0.933	1.092	1.352	1.695	1.994	2.077	2.267	2.216	2.296	2.057	2.347	2.620	4.297	4.668
1994	0.580	0.853	1.151	1.310	1.468	1.764	2.041	2.439	2.182	2.584	2.187	2.261	2.711	4.128	3.951	2.401
1995	0.145	0.703	1.004	1.274	1.490	1.594	1.827	1.982	2.262	2.116	2.390	2.185	2.436	2.638	2.945	3.038
1996	-	0.828	0.988	1.167	1.342	1.540	1.530	1.742	1.962	1.987	2.357	3.275	2.836	3.071	3.384	2.948
1997	-	0.758	0.968	1.230	1.472	1.758	1.932	1.908	2.082	2.193	2.521	2.035	2.698	4.163	0.000	3.451
1998	-	0.625	0.916	0.979	1.189	1.405	1.628	1.821	1.962	2.044	2.261	2.656	2.681	2.361	2.190	2.982
1999	-	0.916	1.136	1.380	1.373	1.597	1.928	2.162	2.075	2.091	2.600	2.418	2.118	5.496	5.090	-
2000	-	0.717	0.877	1.133	1.199	1.237	1.441	1.626	2.044	2.237	2.034	2.907	2.506	3.124	2.507	-
2001	-	0.714	0.958	1.054	1.177	1.171	1.270	1.449	1.636	2.018	2.320	2.409	2.530	1.743	3.002	-
2002	0.274	0.766	0.973	1.140	1.228	1.265	1.267	1.286	1.484	1.726	2.004	1.916	2.830	-	3.678	-
2003	-	0.856	1.008	1.106	1.318	1.326	1.335	1.405	1.330	1.671	2.041	2.194	2.218	-	-	-
2004	-	0.475	0.799	0.980	0.969	1.214	1.344	1.470	1.388	1.553	1.836	1.722	2.008	2.834	-	-
2005	0.181	0.583	0.675	0.808	1.055	1.129	1.325	1.375	1.646	1.652	1.595	1.773	3.129	-	-	1.147
2006	-	0.738	0.769	0.808	0.924	1.114	1.133	1.243	1.271	1.522	1.561	1.871	2.023	2.088	-	-
2007	-	0.736	0.718	0.895	0.876	0.995	1.138	1.089	1.190	1.297	1.413	1.665	1.357	2.188	-	-
2008	-	0.626	0.731	0.827	0.971	0.895	0.995	1.047	1.089	1.197	1.243	1.352	1.290	1.854	-	3.979
2009	0.484	0.612	0.697	0.937	1.060	1.192	1.284	1.352	1.285	1.316	1.322	1.487	1.302	2.177	-	0.000
2010	0.000	0.610	0.744	0.832	1.006	1.119	1.218	1.209	1.279	1.210	1.407	1.338	1.835	1.427	-	2.191
2011	0.222	0.626	0.731	0.772	0.910	1.065	1.061	1.270	1.372	1.368	1.508	1.465	1.284	1.624	-	4.045
2012	0.358	0.582	0.686	0.766	0.885	0.919	1.013	1.089	1.154	1.274	1.269	1.268	1.319	0.971	1.115	-
2013	0.358	0.473	0.672	0.736	0.876	0.868	0.968	0.998	1.129	1.161	1.320	1.348	1.225	1.124	1.535	-

Table 9. Summer survey total biomass index (t) for 4X5Y haddock calculated separately for Bay of Fundy strata (482-495), western Scotian Shelf strata (470-481) and both areas combined, 1970-2013. (Average is for 1970-2014). A conversion factor of 1.2 has been applied to indices from 1970-1981 to account for vessel and gear changes.

	Total biomass index (t)		
Year	**Strata 482-495 (BoF)**	**Strata 470-481 (Western SS)**	**Strata 470-495 (Combined)**
1970	17822	21262	39083
1971	13963	36963	50925
1972	6271	17682	23953
1973	10112	21207	31319
1974	19146	47486	66632
1975	8985	28773	37758
1976	14996	24808	39804
1977	31059	200867	231926
1978	16485	32625	49110
1979	45566	36244	81810
1980	36446	60651	97098
1981	46729	33594	80323
1982	65379	26365	91744
1983	21164	25852	47016
1984	38019	29227	67246
1985	24561	50678	75239
1986	13795	45613	59409
1987	9685	20011	29696
1988	13265	15001	28266
1989	8686	12855	21541
1990	23768	17525	41293
1991	32407	28573	60981
1992	16806	17832	34638
1993	5109	7692	12800
1994	11997	11855	23853
1995	28661	20681	49342
1996	58139	24929	83068
1997	19550	25661	45210
1998	23372	20153	43525
1999	15475	40958	56433
2000	32001	28230	60231
2001	23239	62160	85399
2002	21530	44263	65793
2003	36754	31176	67929
2004	12231	28044	40275
2005	10639	32882	43522
2006	13763	32882	46646
2007	20511	34316	54827
2008	14866	28428	43293
2009	11262	49565	60827
2010	18702	26835	45537
2011	12901	34961	47862
2012	13821	15160	28981
2013	12729	23852	36581
2014	16875	26038	42913
Average	**21539**	**33387**	**54926**

Table 10. Summer survey total abundance index at age (000s) for 4X5Y haddock calculated separately for Scotian Shelf strata (470-481) and Bay of Fundy strata (482-495) then combined, 1970-2013. A conversion factor of 1.2 has been applied to indices from 1970-1981 to account for vessel and gear changes.

	Age												
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1970	8194	6550	1932	3640	1471	3377	8671	1203	494	470	111	28	0
1971	165	15854	6879	3017	4258	2030	3094	8671	1115	131	61	160	0
1972	7425	327	4836	2051	1312	1428	918	1466	2273	78	9	8	19
1973	9082	32303	1108	4514	2109	714	1143	846	510	970	10	0	20
1974	16193	32610	46851	1490	5917	1340	790	869	472	381	563	0	0
1975	9471	5090	7600	11273	584	2545	646	485	202	166	529	410	0
1976	7828	9216	5928	6201	10452	918	1138	206	108	28	13	215	152
1977	9074	57182	89094	25359	24567	13536	1845	2220	256	221	29	237	120
1978	8711	7374	17294	5856	2442	4668	1889	120	0	0	65	50	31
1979	2891	19505	11732	14866	7510	3148	4701	2032	347	162	0	0	0
1980	31199	9933	21875	11254	17467	6697	2481	1790	960	370	54	0	0
1981	51826	39958	9373	13386	5398	6091	1951	258	504	241	122	61	0
1982	18418	39422	18736	7413	12041	5027	5403	945	567	333	220	0	0
1983	9600	6352	20262	8964	5288	3331	1374	485	458	330	265	83	85
1984	5895	33711	17271	26029	8177	4177	2005	856	564	132	46	47	56
1985	9921	13649	32716	15005	20684	5308	2636	1675	921	339	98	46	46
1986	5415	13421	10615	21302	8342	8900	3179	1637	929	532	89	151	97
1987	1885	2169	3855	4763	5763	4015	2924	1273	382	453	103	22	0
1988	10122	3017	1438	2995	4167	4412	2114	1647	1020	565	185	22	0
1989	8470	13828	2765	1296	2606	1110	2307	825	688	203	164	129	0
1990	107	15039	13520	2491	2014	2233	2036	1702	711	579	287	129	84
1991	6063	1950	17855	16311	3420	1886	1670	1428	1054	1254	126	121	27
1992	4418	3527	1379	10876	7730	1482	545	563	413	305	59	24	6
1993	6551	1501	2473	942	2706	1634	268	199	81	68	145	31	41
1994	30025	8397	3117	2792	564	2751	1602	213	74	121	15	79	141
1995	65744	35234	16710	5933	2693	1097	2254	586	145	0	0	30	0
1996	7124	38001	35704	18176	7349	2414	1688	2356	576	477	191	35	105
1997	14188	8328	30275	18268	5655	2361	863	263	448	276	30	14	0
1998	14127	10919	6704	19686	10591	2706	2187	1423	400	249	178	21	0
1999	51122	28975	13702	9190	15602	8693	4273	1644	1240	274	267	172	65
2000	38697	63060	9735	6743	5475	7562	2687	1068	472	94	33	20	0
2001	43613	45158	58527	17149	6528	3116	7957	3071	1695	1149	124	0	48
2002	5986	24017	32706	36171	8609	4509	3282	4998	2696	1431	982	43	56
2003	3317	7516	20246	22433	19375	3689	4107	2379	4077	1497	622	0	53
2004	11651	5254	7652	15912	11900	10059	3494	2134	790	920	423	172	12
2005	3365	21234	5056	7306	12913	12368	7104	3528	1149	1042	512	189	0
2006	9539	5163	21094	7640	4664	10719	6646	9327	2059	1478	884	184	7
2007	14461	15744	7266	25721	3742	4477	9176	5694	3559	859	685	127	68
2008	961	19145	8983	6292	16109	2052	2249	4967	3806	2176	1324	96	187
2009	2007	1899	22183	12096	7070	13719	3186	3262	5835	5463	1457	524	0
2010	5259	3203	1586	12893	6387	6623	9388	4870	2014	1512	1021	581	296
2011	17701	10722	3564	3584	15157	5174	5715	7258	3030	1263	2133	523	670
2012	10427	16385	8745	1935	2117	4879	2937	2170	2326	1990	145	380	140
2013	25684	20310	23063	6651	910	1900	2943	2758	1147	878	440	26	37

Table 11. Weighted summer survey mean WAA (kg) of 4X5Y haddock for ages 0-14 calculated separately for Scotian Shelf strata (470-481) and Bay of Fundy strata (482-495) then combined after weighting by total number, 1970-2013. Cells with dashes have no data available.

	Age														
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1970	-	0.082	0.393	0.771	1.086	1.403	1.607	2.035	2.346	2.384	2.951	3.632	2.225	-	-
1971	-	0.102	0.250	0.761	1.098	1.435	1.617	1.717	2.180	2.590	4.073	3.516	4.738	-	-
1972	-	0.078	0.203	0.666	1.287	1.638	1.985	2.079	2.476	2.895	3.966	3.700	4.600	6.200	-
1973	-	0.096	0.297	0.511	1.343	1.815	2.362	2.396	2.452	2.685	2.886	3.600	-	4.000	-
1974	-	0.093	0.310	0.708	1.010	1.713	2.204	2.516	2.704	2.705	2.803	3.395	-	-	-
1975	-	0.104	0.369	0.759	1.271	1.800	2.317	2.828	3.013	3.251	3.169	3.314	3.326	-	-
1976	-	0.093	0.367	0.695	1.160	1.523	1.926	2.411	2.384	2.685	2.600	3.500	3.056	3.374	-
1977	-	0.103	0.463	0.838	1.258	1.771	2.009	2.870	2.973	4.021	2.972	3.500	3.531	3.631	3.693
1978	-	0.078	0.411	0.900	1.466	1.955	2.260	2.644	3.422	-	-	2.600	4.200	3.900	4.195
1979	-	0.084	0.347	0.786	1.369	1.757	2.383	2.738	3.368	4.034	3.477	-	-	-	3.600
1980	-	0.086	0.440	0.794	1.309	1.752	2.112	2.502	2.730	3.455	3.323	3.400	-	-	-
1981	-	0.093	0.401	0.861	1.193	1.852	2.294	2.747	3.098	3.302	4.102	3.811	4.000	-	-
1982	-	0.065	0.224	0.680	1.308	1.698	2.315	2.870	3.333	3.477	4.212	4.468	-	-	-
1983	-	0.067	0.250	0.560	1.103	1.586	1.886	2.383	2.665	2.818	3.176	3.146	3.690	4.366	-
1984	-	0.095	0.290	0.468	0.836	1.273	1.847	2.073	2.447	2.830	3.769	2.350	3.500	2.300	-
1985	-	0.076	0.331	0.550	0.728	1.010	1.380	2.023	1.977	1.936	2.483	2.635	3.200	3.100	3.036
1986	-	0.072	0.285	0.603	0.776	1.017	1.178	1.431	1.693	2.173	2.200	2.803	2.836	2.119	-
1987	-	0.099	0.345	0.581	0.968	1.154	1.139	1.436	1.660	2.090	1.816	2.328	6.000	-	2.870
1988	-	0.097	0.520	0.689	1.001	1.348	1.384	1.654	1.645	1.989	1.903	2.203	2.900	-	-
1989	-	0.090	0.356	0.747	0.911	1.292	1.510	1.543	1.612	1.555	1.799	2.310	1.310	-	2.400
1990	-	0.109	0.424	0.819	1.338	1.690	1.879	2.132	2.187	2.531	1.644	2.450	2.479	3.513	3.300
1991	-	0.089	0.600	0.839	1.331	1.503	2.083	2.064	2.123	2.005	1.679	3.511	2.564	3.555	3.400
1992	-	0.082	0.307	0.624	1.141	1.666	2.010	2.299	1.761	2.004	2.537	2.786	2.760	3.500	0.000
1993	-	0.098	0.366	0.770	1.109	1.394	1.777	1.941	1.859	1.396	2.226	2.191	1.995	1.682	4.540
1994	0.007	0.139	0.423	0.865	1.234	1.341	1.657	1.926	2.319	1.567	1.705	2.195	1.274	2.179	-
1995	0.005	0.063	0.353	0.829	1.157	1.436	1.536	1.793	2.197	2.648	-	-	1.510	-	-
1996	0.010	0.053	0.210	0.680	1.210	1.450	1.780	1.878	1.898	2.503	2.454	2.233	2.019	3.879	-
1997	0.005	0.114	0.231	0.428	0.793	1.187	1.392	1.648	1.902	1.895	1.535	2.045	1.358	-	-
1998	0.007	0.065	0.261	0.409	0.621	1.069	1.448	1.790	2.136	2.024	1.581	2.171	1.465	-	-
1999	0.009	0.104	0.188	0.540	0.606	0.820	0.966	1.171	1.314	1.373	1.890	1.809	1.642	1.347	3.260
2000	0.010	0.108	0.393	0.569	0.888	0.802	1.013	1.332	1.574	1.991	2.458	1.858	2.200	-	-
2001	0.007	0.087	0.235	0.542	0.642	0.925	0.933	1.040	1.211	1.424	1.143	1.644	-	1.450	3.810
2002	0.003	0.078	0.209	0.396	0.635	0.711	0.915	0.980	0.993	1.147	1.167	0.905	1.887	2.430	-
2003	0.005	0.068	0.215	0.356	0.670	1.076	1.045	1.109	1.133	1.288	1.316	1.442	-	2.802	-
2004	0.005	0.088	0.175	0.457	0.569	0.704	0.868	0.949	0.922	1.045	1.123	1.310	1.805	1.304	-
2005	0.002	0.080	0.236	0.408	0.608	0.661	0.771	0.941	0.991	1.143	1.095	1.126	1.204	-	1.830
2006	0.005	0.089	0.180	0.446	0.490	0.638	0.814	0.870	0.924	1.163	1.028	1.195	0.988	1.765	-
2007	0.003	0.075	0.184	0.419	0.721	0.780	0.897	0.928	1.089	1.100	1.403	1.200	2.180	1.491	-
2008	0.005	0.111	0.324	0.475	0.615	0.743	0.899	0.970	0.911	1.013	1.033	1.053	1.390	1.260	1.867
2009	0.006	0.118	0.299	0.484	0.650	0.744	1.002	0.937	0.949	1.025	1.047	1.148	1.247	-	1.382
2010	0.007	0.143	0.308	0.574	0.694	0.799	0.965	1.120	1.076	1.009	1.064	1.277	1.268	1.589	0.998
2011	0.006	0.120	0.318	0.646	0.672	0.782	0.904	0.873	1.040	1.086	0.912	1.027	1.292	1.102	1.342
2012	0.011	0.118	0.336	0.474	0.708	0.749	0.856	0.898	0.944	1.134	1.157	1.136	1.077	1.176	0.917
2013	0.007	0.146	0.300	0.507	0.651	0.782	0.866	0.829	0.881	1.038	1.284	1.075	1.108	1.882	-

Table 12. Weighted summer survey mean LAA (FL, cm) of 4X5Y haddock for ages 0-12 calculated separately for Scotian Shelf strata (470-481) and Bay of Fundy strata (482-495) then combined after weighting by total number, 1970-2013. Cells with dashes have no data available.

	Age												
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1970	-	20.98	33.83	41.05	45.70	49.86	52.02	56.20	59.57	60.54	65.10	68.17	60.50
1971	-	20.64	29.28	41.61	46.95	51.34	53.08	54.82	58.73	63.02	70.54	69.44	72.92
1972	-	19.92	26.92	39.40	48.56	52.83	55.93	56.36	60.07	63.21	69.13	68.50	76.50
1973	-	21.27	30.14	35.70	49.60	54.74	59.26	60.04	60.74	62.66	64.01	70.50	-
1974	-	21.02	31.10	40.02	45.23	54.38	59.19	61.26	63.12	62.80	63.50	67.97	-
1975	-	21.93	32.60	41.36	48.54	54.18	59.27	63.63	64.69	65.60	67.52	67.01	66.80
1976	-	20.99	32.34	40.01	48.41	53.12	58.07	62.82	61.32	65.69	66.50	72.50	66.88
1977	8.50	21.86	35.08	42.39	48.13	54.06	56.62	63.56	65.20	69.78	65.15	66.50	68.98
1978	-	18.97	33.72	43.00	50.22	54.74	57.66	61.25	66.17	-	-	62.50	68.50
1979	7.28	19.86	31.95	41.01	49.64	54.39	60.23	62.78	65.59	71.62	69.07	-	-
1980	6.50	19.95	33.26	40.81	49.27	54.81	58.11	61.49	62.99	67.17	67.52	70.50	-
1981	8.29	19.86	32.81	41.34	47.63	55.09	59.75	62.65	64.34	67.40	73.70	72.27	74.50
1982	6.50	17.90	26.86	38.79	48.80	53.50	59.50	63.90	67.65	68.90	74.56	74.86	0.00
1983	7.84	18.65	28.22	37.13	46.73	53.50	56.80	61.39	63.71	64.76	66.93	67.57	70.83
1984	8.18	20.53	29.39	34.49	42.22	49.13	55.77	58.92	61.43	65.54	69.43	70.50	72.50
1985	-	19.47	30.77	36.58	41.18	45.73	50.71	57.49	58.13	57.78	62.91	62.73	66.50
1986	6.50	19.50	30.07	38.20	41.01	45.38	48.27	51.21	54.22	59.77	60.10	64.82	65.53
1987		20.98	31.90	37.46	44.09	47.07	47.22	51.34	53.62	58.04	56.79	61.67	76.50
1988	6.50	20.87	34.61	40.11	44.86	49.63	49.13	51.63	52.88	54.82	54.40	59.16	62.50
1989	10.50	20.42	32.04	40.72	43.44	49.00	52.02	51.97	52.12	52.66	55.96	60.86	50.90
1990	8.50	21.53	33.12	41.64	48.80	53.84	54.66	57.25	57.69	59.82	52.33	60.67	58.09
1991	-	20.72	37.51	42.68	49.69	52.10	58.26	58.40	57.92	55.83	53.85	66.32	61.04
1992	-	19.38	30.75	39.28	47.23	53.36	57.34	59.15	54.69	55.16	61.09	64.23	62.50
1993	-	22.10	32.67	41.80	47.26	51.47	55.95	57.41	56.64	51.03	58.03	58.29	56.50
1994	8.69	23.82	34.23	42.67	48.89	49.86	53.23	56.02	60.43	53.29	54.50	58.50	51.48
1995	7.46	18.63	32.64	42.85	48.60	52.49	53.65	56.34	59.68	65.65	-	-	54.50
1996	9.66	17.84	27.37	39.94	48.62	51.66	54.77	56.82	57.55	62.51	60.51	58.50	59.55
1997	8.38	22.11	28.10	34.21	42.06	48.35	50.32	53.96	57.86	56.45	53.97	60.35	62.50
1998	8.72	18.68	29.48	34.18	38.86	46.72	51.68	54.64	58.38	56.40	54.53	60.40	54.50
1999	9.74	21.67	25.81	37.10	38.60	42.48	45.09	47.65	49.82	50.00	55.25	55.59	55.08
2000	10.01	22.33	33.68	37.86	43.78	42.72	45.59	49.95	52.00	56.36	61.52	56.50	62.50
2001	9.03	20.57	28.66	37.24	39.45	45.11	45.39	46.68	49.10	51.63	46.88	53.86	-
2002	6.50	19.93	27.59	33.97	39.76	41.41	45.54	46.54	46.57	48.87	49.06	41.64	59.60
2003	7.84	18.85	27.46	32.31	39.92	46.95	46.82	48.11	48.88	50.45	50.76	53.57	-
2004	8.51	21.57	25.94	35.92	38.39	41.28	44.01	45.81	45.46	46.89	48.58	51.11	58.28
2005	4.88	20.40	28.55	33.68	39.11	39.98	41.85	45.16	45.80	48.76	46.77	47.66	48.52
2006	8.27	21.08	26.42	35.18	36.67	40.39	43.04	43.91	45.07	48.51	46.80	49.64	47.63
2007	6.81	19.69	25.65	34.47	40.73	42.12	43.74	44.60	46.61	47.07	51.62	48.99	59.32
2008	7.96	22.02	31.83	36.45	39.02	41.68	44.23	46.01	44.53	45.83	46.08	46.98	52.30
2009	8.93	22.70	30.78	36.03	39.75	41.00	45.32	44.68	44.67	45.45	45.39	48.41	48.53
2010	9.33	24.99	31.53	37.78	41.42	43.41	45.86	48.23	47.45	46.82	47.05	50.15	50.64
2011	8.56	23.21	31.94	40.12	41.51	43.23	45.08	44.61	47.10	47.62	44.75	46.43	51.60
2012	10.61	22.99	31.85	36.70	41.56	42.48	44.70	45.47	45.82	48.81	48.70	51.50	49.82
2013	9.07	24.43	30.77	36.87	40.09	42.50	44.67	43.91	44.69	47.73	50.39	48.08	50.50

Table 13. Summer survey mean WAA (kg) of 4X5Y haddock for ages 1-12 calculated separately for Scotian Shelf strata (470-481), 1970-2013. Cells with dashes have no data available.

	Age											
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1970	0.082	0.390	0.772	1.062	1.383	1.665	2.057	2.457	2.688	3.255	3.594	2.225
1971	0.102	0.247	0.701	1.056	1.404	1.575	1.696	2.035	2.533	4.041	3.516	3.294
1972	0.078	0.203	0.638	1.255	1.614	1.952	2.053	2.427	2.782	3.057	3.700	4.600
1973	0.095	0.290	0.472	1.247	1.700	2.258	2.308	2.449	2.577	2.933	3.600	-
1974	0.092	0.307	0.639	0.942	1.661	2.102	2.556	2.664	2.771	2.640	3.129	-
1975	0.104	0.324	0.709	1.195	1.800	2.201	2.828	3.013	3.251	3.501	3.516	3.060
1976	0.085	0.319	0.594	1.108	1.390	1.899	2.266	2.350	-	-	-	2.350
1977	0.101	0.440	0.823	1.219	1.693	1.908	2.801	2.918	4.360	2.775	-	3.354
1978	0.078	0.377	0.798	1.311	1.828	2.208	2.571	-	-	-	2.600	-
1979	0.082	0.269	0.538	1.162	1.539	2.136	2.410	2.726	3.514	-		-
1980	0.085	0.347	0.644	1.164	1.610	2.000	2.505	2.696	3.391	3.323	3.400	-
1981	0.060	0.261	0.742	1.103	1.609	1.994	2.386	3.121	3.063	3.671	3.900	-
1982	0.063	0.144	0.503	1.023	1.349	1.814	2.215	2.639	3.448	-	3.100	-
1983	0.055	0.167	0.393	0.908	1.438	1.683	2.188	2.253	2.454	2.275	2.353	3.890
1984	0.057	0.143	0.339	0.688	1.105	1.594	1.843	2.046	2.150	-	-	-
1985	0.072	0.259	0.397	0.683	0.914	1.192	1.618	1.707	1.853	2.109	-	-
1986	0.071	0.273	0.487	0.607	0.946	1.103	1.372	1.690	1.924	1.899	2.803	3.352
1987	0.071	0.273	0.535	0.749	0.877	1.117	1.321	1.431	1.687	1.721	2.100	-
1988	0.057	0.343	0.600	0.797	0.969	1.014	1.245	1.353	1.629	1.477	2.203	2.900
1989	0.086	0.296	0.671	0.780	1.143	1.311	1.299	1.380	1.411	1.648	1.658	1.310
1990	0.109	0.315	0.693	0.989	1.322	1.434	1.357	1.545	1.851	1.343	2.186	1.816
1991	0.084	0.435	0.668	1.038	1.282	1.603	1.627	1.687	1.550	1.213	2.763	2.322
1992	0.076	0.282	0.630	0.984	1.238	1.640	1.810	1.513	1.630	2.719	2.100	2.760
1993	0.098	0.322	0.630	0.984	1.211	1.563	1.702	1.695	1.396	2.226	1.621	1.995
1994	0.110	0.360	0.629	0.942	1.158	1.282	1.466	1.748	1.567	1.705	2.195	1.274
1995	0.059	0.271	0.613	0.946	1.172	1.290	1.483	1.812	2.153	-	-	1.510
1996	0.053	0.181	0.491	0.777	0.976	1.248	1.410	1.467	1.770	1.234	2.000	2.019
1997	0.089	0.219	0.360	0.655	0.959	1.014	1.270	1.532	1.592	1.535	2.045	1.358
1998	0.065	0.210	0.380	0.514	0.742	0.975	1.220	1.537	1.439	1.581	2.058	1.465
1999	0.100	0.180	0.445	0.544	0.694	0.861	0.958	1.166	1.153	1.349	1.645	1.642
2000	0.096	0.299	0.466	0.689	0.759	0.912	1.101	1.205	1.263	1.482	1.858	2.200
2001	0.083	0.227	0.472	0.567	0.821	0.879	0.990	1.067	1.259	1.080	1.644	-
2002	0.061	0.174	0.342	0.547	0.625	0.831	0.885	0.927	1.022	1.083	0.747	1.740
2003	0.066	0.190	0.335	0.507	0.693	0.791	0.866	0.974	0.984	1.042	1.235	-
2004	00.077	0.176	0.417	0.513	0.616	0.736	0.813	0.843	1.004	1.077	1.203	1.164
2005	0.080	0.201	0.346	0.540	0.613	0.713	0.811	0.939	1.046	1.068	1.132	1.204
2006	0.074	0.174	0.371	0.441	0.553	0.720	0.798	0.841	0.985	0.962	1.173	0.988
2007	0.074	0.175	0.387	0.546	0.707	0.754	0.825	0.947	0.990	1.208	1.142	1.378
2008	0.072	0.247	0.395	0.588	0.669	0.861	0.961	0.885	0.922	0.955	1.005	1.655
2009	0.112	0.247	0.450	0.610	0.712	0.951	0.935	0.902	1.012	1.034	1.144	1.289
2010	0.124	0.251	0.429	0.648	0.729	0.852	0.972	0.993	0.940	0.999	1.198	1.151
2011	0.100	0.297	0.530	0.662	0.737	0.826	0.823	0.927	1.013	0.912	1.023	1.227
2012	0.097	0.241	0.435	0.590	0.760	0.760	0.819	0.834	0.938	0.884	1.081	1.057
2013	0.139	0.278	0.454	0.597	0.741	0.841	0.793	0.811	0.968	1.064	0.933	1.108

Table 14. Summer survey mean WAA (kg) of 4X5Y haddock for ages 1-12 calculated separately for Bay of Fundy strata (482-495), 1970-2013. Cells with dashes have no data available.

	Age											
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1970	0.105	0.478	0.763	1.134	1.432	1.530	2.020	2.263	2.038	2.626	3.700	-
1971	-	0.363	0.954	1.283	1.637	1.778	1.814	2.468	2.692	4.200	-	5.418
1972	0.063	-	1.005	1.535	1.866	2.167	2.315	2.605	3.020	4.704	-	-
1973	0.125	0.331	0.679	1.574	2.063	2.713	2.556	2.456	2.953	2.852	-	-
1974	0.096	0.336	0.850	1.299	2.236	2.648	2.344	3.049	2.528	3.182	3.664	-
1975	0.120	0.535	1.100	1.530	1.800	3.006	-	-	-	2.700	3.121	3.383
1976	0.134	0.426	0.896	1.311	1.752	2.100	3.068	2.600	2.685	2.600	3.500	3.292
1977	0.126	0.642	1.164	1.597	2.212	2.539	3.335	3.370	3.738	3.099	3.500	4.200
1978	0.088	0.599	1.199	1.731	2.185	2.492	2.835	3.422	-	-	-	4.200
1979	0.097	0.432	0.964	1.624	2.242	2.688	3.109	3.771	4.204	3.477	-	-
1980	0.117	0.518	0.967	1.514	1.998	2.617	2.414	3.031	3.775	-	-	-
1981	0.113	0.423	0.895	1.434	2.349	2.758	3.219	3.000	3.663	4.209	3.800	4.000
1982	0.111	0.365	0.822	1.437	1.977	2.600	3.074	3.461	3.482	4.212	4.643	-
1983	0.116	0.401	0.863	1.390	1.961	2.552	2.870	3.117	3.221	4.013	3.875	3.400
1984	0.144	0.358	0.574	1.131	1.572	2.149	2.424	2.846	3.055	3.769	2.350	3.500
1985	0.133	0.512	0.879	1.170	1.554	2.451	2.744	2.889	2.678	3.250	2.635	3.200
1986	0.140	0.555	1.041	1.466	1.658	1.998	1.903	1.900	2.781	2.809	-	2.611
1987	0.170	0.536	1.093	1.496	1.728	2.233	2.575	2.246	2.906	4.100	2.675	6.000
1988	0.164	0.686	1.198	1.445	1.884	2.275	3.038	2.392	3.230	2.981	-	-
1989	0.119	0.519	0.824	1.441	1.572	1.937	2.110	1.864	2.900	2.575	2.601	-
1990	-	0.590	1.127	1.744	1.842	2.296	2.425	2.873	3.176	2.853	2.937	3.200
1991	0.155	0.930	1.158	1.672	1.770	2.552	2.531	2.918	3.270	2.206	4.535	3.420
1992	0.119	0.477	0.400	1.576	2.183	2.184	2.868	2.789	3.716	2.495	3.775	-
1993	0.115	0.599	1.014	1.521	1.770	2.093	2.319	2.140	-	-	3.173	-
1994	0.163	0.522	1.183	1.710	3.482	2.596	2.860	3.146	-	-	-	-
1995	0.077	0.432	0.967	1.376	1.878	2.091	2.339	2.551	3.101	-	-	-
1996	0.083	0.291	0.796	1.416	1.829	2.183	2.246	2.257	2.733	3.221	2.255	-
1997	0.130	0.305	0.643	1.053	1.574	2.222	2.228	3.331	3.767	-	-	-
1998	0.093	0.399	0.703	1.000	1.321	1.805	2.029	2.285	2.601	-	2.350	-
1999	0.135	0.375	0.886	1.127	1.248	1.442	1.702	2.115	2.472	4.171	2.265	-
2000	0.183	0.468	0.690	1.029	1.120	1.241	1.806	2.075	2.641	4.445	-	-
2001	0.137	0.313	0.775	0.955	1.161	2.055	1.461	1.635	1.904	1.996	-	-
2002	0.127	0.312	0.569	0.824	1.155	1.246	1.321	1.535	1.725	1.849	2.228	2.025
2003	0.106	0.317	0.649	1.048	1.349	1.510	1.551	1.453	1.665	1.832	1.576	-
2004	0.105	0.173	0.589	0.857	0.983	1.303	1.407	1.470	2.230	1.640	1.555	2.501
2005	0.075	0.357	0.666	0.817	0.962	1.243	1.312	1.370	1.854	2.362	1.086	-
2006	0.099	0.235	0.674	0.664	0.974	1.239	1.287	1.345	1.404	1.876	1.349	-
2007	0.098	0.330	0.657	0.977	1.041	1.259	1.387	1.554	1.688	1.716	2.705	3.296
2008	0.159	0.380	0.599	0.651	0.945	1.405	1.022	1.679	1.420	1.450	1.304	1.188
2009	0.143	0.402	0.672	0.810	1.052	1.152	0.945	1.271	1.266	1.509	1.204	1.117
2010	0.168	0.461	0.827	0.831	0.960	1.132	1.269	1.199	1.226	1.408	1.749	1.725
2011	0.146	0.394	0.783	0.743	0.972	1.134	1.185	1.358	1.264	-	1.064	1.508
2012	0.153	0.421	0.560	0.806	0.725	1.070	1.213	1.084	1.473	1.385	1.247	1.218
2013	0.173	0.358	0.594	0.858	0.948	1.076	1.127	1.159	1.228	1.451	1.552	-

Table 15. Decadal (1985-1994, 1995-2004, 2005-2013) Von Bertalanffy growth model parameters for 4X5Y haddock from the DFO summer RV survey estimated separately for the Bay of Fundy (strata 482-495) and Scotian Shelf (strata 470-481). K = growth rate; Linf = length at infinity or maximum size; t_0 = starting time when length=0.

Year	Strata	K	Linf	t_0
1985-1994	Bay of Fundy	0.3236698	67.71673	-0.3707919
1985-1994	Scotian Shelf	0.2488255	61.74990	-0.6703525
1995-2004	Bay of Fundy	0.2658003	66.12859	-0.5257162
1995-2004	Scotian Shelf	0.2419173	56.98771	-0.7422053
2005-2013	Bay of Fundy	0.3560932	54.19263	-0.5432960
2005-2013	Scotian Shelf	0.2886169	50.84362	-0.7437252

Table 16. Mean numbers per tow by age and year for 4X5Y haddock from the ITQ Survey, 1996-2010.

Age	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	6.9	14.7	14.9	98.8	75.6	58.9	17.3	6.2	38.6	7.2	20.3	48.8	2.5	2.4	25.9
2	41.3	9.5	29.3	39.7	75.1	54.5	29.3	17.1	12.8	35.9	8.7	47.1	43.8	3.4	8.5
3	25.1	33.1	8.3	18.2	11.7	56.5	30.4	30.6	12.3	4.1	23.7	14.3	18.3	16.6	2.3
4	9.0	19.4	21.5	7.1	7.5	13.5	29.9	26.3	16.1	4.7	7.2	34.8	7.3	6.5	11.2
5	3.5	5.0	8.0	11.1	7.0	5.0	6.5	13.9	10.0	7.7	3.5	4.0	15.9	3.1	4.6
6	0.9	1.6	1.2	4.6	7.6	2.1	3.0	2.4	6.9	6.9	6.4	4.0	1.3	5.4	3.6
7	0.7	0.6	0.8	2.1	2.4	5.3	2.2	2.4	2.2	3.6	3.8	7.6	1.5	1.6	4.3
8	0.8	0.2	0.4	0.6	0.9	1.9	3.0	1.2	1.3	1.8	4.8	4.47	3.26	1.4	2.5
9	0.2	0.3	0.2	0.5	0.3	1.0	1.6	2.0	0.6	0.6	0.8	2.84	2.46	2.5	1.1
10	0.2	0.2	0.2	0.1	0.1	0.7	0.9	0.8	0.6	0.5	0.7	0.67	1.4	2.1	0.8
11	0.0	0.0	0.1	0.1	0.0	0.1	0.8	0.3	0.3	0.2	0.4	0	0	0	0
12	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0	0	0	0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0	0	0	0	0

Table 17. Kept vs discarded bycatch for 2004-2013 from haddock-directed mobile gear trips in 4X5Y (n=1738 observed sets).

Species	Total Kept (t)	Total Discarded (t)	% Kept	% Discarded
Haddock	1385.752	0.773	61.92	0.03
Atlantic Cod	236.302	0.157	10.56	0.01
Pollock	226.712	0.184	10.13	0.01
Winter Flounder	82.026	0.057	3.67	0.00
Redfish Unseparated	39.174	0.004	1.75	0.00
White Hake	21.677	0.907	0.97	0.04
Witch Flounder	18.024	0.01	0.81	0.00
Monkfish	14.366	0.123	0.64	0.01
American Plaice	10.742	0.049	0.48	0.00
Atlantic Halibut	7.959	10.219	0.36	0.46
Yellowtail Flounder	7.416	0.008	0.33	0.00
Sea Raven	4.548	2.953	0.20	0.13
Striped Atlantic Wolffish	3.85	0.139	0.17	0.01
Flounder (Unidentified)	1.854	0	0.08	0.00
Cusk	1.574	0.08	0.07	0.00
Black Belly Rosefish	1.314	0	0.06	0.00
Hake (Not specified)	1.244	0.001	0.06	0.00
Longhorn Sculpin	0.872	1.464	0.04	0.07
Skate (Not specified)	0.48	4.289	0.02	0.19
Smooth Skate	0.328	2.824	0.01	0.13
Thorny Skate	0.325	9.176	0.01	0.41
American Lobster	0.186	29.266	0.01	1.31
Winter Skate	0.178	11.625	0.01	0.52
Little Skate	0.125	1.574	0.01	0.07
Silver Hake	0.093	0.171	0.00	0.01
Shortfin Mako	0.08	0.714	0.00	0.03
Barndoor Skate	0.024	7.332	0.00	0.33
Spiny Dogfish	0.01	77.955	0.00	3.48
American Shad	0.005	1.876	0.00	0.08
Lumpfish	0.004	0.509	0.00	0.02
Porbeagle	0	1.809	0.00	0.08
Swordfish	0	0.373	0.00	0.02
Black Dogfish	0	0.26	0.00	0.01
Seal (Not specified)	0	0.236	0.00	0.01
Common Ocean Pout	0	0.233	0.00	0.01
Total	**2067.244**	**167.35**	**92.37**	**7.48**

Table 18. Kept vs discarded bycatch for 2004-2013 from haddock-directed fixed gear trips in 4X5Y (n=746 observed sets).

Species	Total Kept (t)	Total Discarded (t)	% Kept	% Discarded
Haddock	181.706	0.298	43.28	0.07
Atlantic Cod	103.753	0.269	24.71	0.06
White Hake	41.922	0.071	9.98	0.02
Cusk	32.428	1.4	7.72	0.33
Atlantic Halibut	8.901	1.723	2.12	0.41
Pollock	3.756	0.011	0.89	0.00
Monkfish	1.384	0.021	0.33	0.01
Redfish Unseparated	1.091	0.006	0.26	0.00
Porbeagle Shark	0.888	0.239	0.21	0.06
Striped Atlantic Wolffish	0.747	0.087	0.18	0.02
Barndoor Skate	0.393	12.92	0.09	3.08
Hake (Not specified)	0.33	0	0.08	0.00
Shortfin Mako	0.285	0.011	0.07	0.00
Shark (Not specified)	0.127	0.15	0.03	0.04
Red Hake	0.073	0	0.02	0.00
Silver Hake	0.048	0	0.01	0.00
Sea Raven	0.027	0.045	0.01	0.01
Thorny Skate	0.002	5.07	0.00	1.21
Spiny Dogfish	0	13.948	0.00	3.32
Winter Skate	0	2.109	0.00	0.50
Skate (Not specified)	0	1.426	0.00	0.34
Little Skate	0	1.022	0.00	0.24
Black Dogfish	0	0.567	0.00	0.14
Blue Shark	0	0.388	0.00	0.09
American Lobster	0	0.086	0.00	0.02
Total	**377.861**	**41.867**	**90.00**	**9.97**

Table 19. Kept vs discarded bycatch for 2004-2013 from redfish-directed mobile gear trips in 4X5Y (n=1792 observed sets).

Species	Total Kept (t)	Total Discarded (t)	% Kept	% Discarded
Redfish Unseparated	2425.541	1.318	69.47	0.04
Pollock	372.191	0.025	10.66	0.00
Haddock	164.71	0.02	4.72	0.00
White Hake	92.034	0.72	2.64	0.02
Atlantic Cod	54.361	0.001	1.56	0.00
Spiny Dogfish	15.715	263.69	0.45	7.55
Monkfish	13.051	0.038	0.37	0.00
Witch Flounder	8.972	0.007	0.26	0.00
Silver Hake	5.214	6.5	0.15	0.19
Cusk	4.268	0.076	0.12	0.00
Black Belly Rosefish	4.017	0.048	0.12	0.00
Atlantic Halibut	2.371	1.335	0.07	0.04
Red Hake	2.175	0.009	0.06	0.00
Hake (Not specified)	1.265	0.027	0.04	0.00
American Plaice	0.435	0.008	0.01	0.00
Winter Flounder	0.359	0.011	0.01	0.00
Barndoor Skate	0.318	13.585	0.01	0.39
American Shad	0.088	2.253	0.00	0.06
Lobster	0.052	16.898	0.00	0.48
Smooth Skate	0.04	0.837	0.00	0.02
Alewife	0.036	1.069	0.00	0.03
Winter Skate	0.022	0.899	0.00	0.03
Atlantic Herring	0.011	0.648	0.00	0.02
Thorny Skate	0.008	1.991	0.00	0.06
Basking Shark	0	2.445	0.00	0.07
Black Dogfish	0	2.124	0.00	0.06
Porbeagle Shark	0	1.706	0.00	0.05
Skate (Not specified)	0	0.834	0.00	0.02
Total	**3167.254**	**319.122**	**90.72**	**9.14**

FIGURES

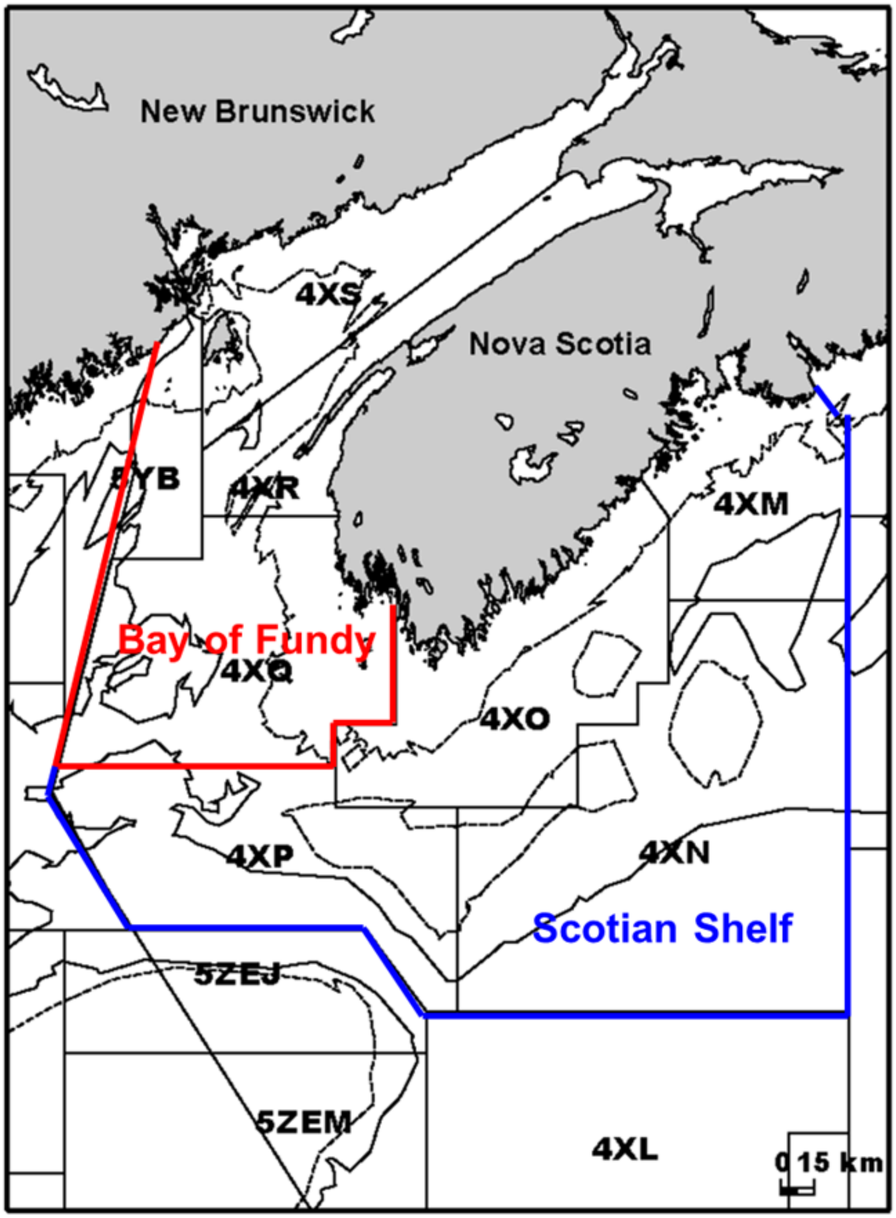


Figure 1. Map of the 4X5Y haddock management area and Canadian Statistical unit areas for the Bay of Fundy (4Xqrs) and western Scotian Shelf (4Xmnop). Separate ALKs for the western Scotian Shelf and Bay of Fundy are used for calculating the CAA and survey age-specific indices of abundance. Haddock landed from statistical areas 5ZEM and 5ZEJ are not included in the 4X5Y haddock stock assessment.

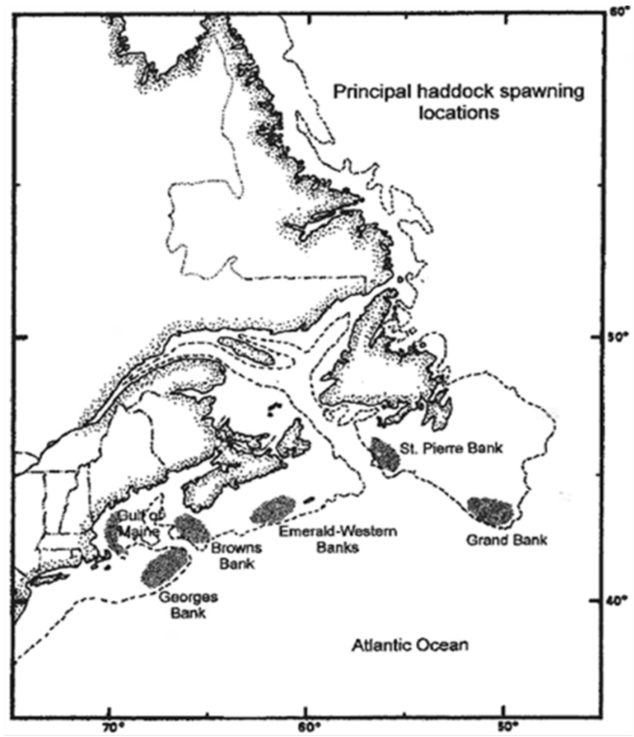


Figure 2. Principal spawning locations of haddock in the northwest Atlantic (Page and Frank 1989).

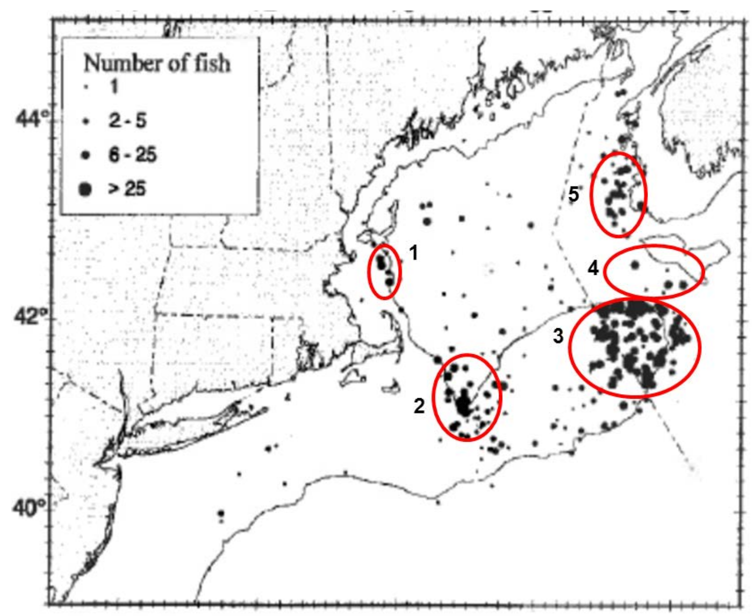


Figure 3. NMFS Northeast Fisheries Science Centre spring bottom trawl survey catch (number) per tow of sexually mature haddock (from Begg 1998). (1-Western Gulf of Maine; 2-Nantucket Shoals, 3-Eastern Georges Bank; 4-Browns Bank; 5-Southwest Nova Scotia).

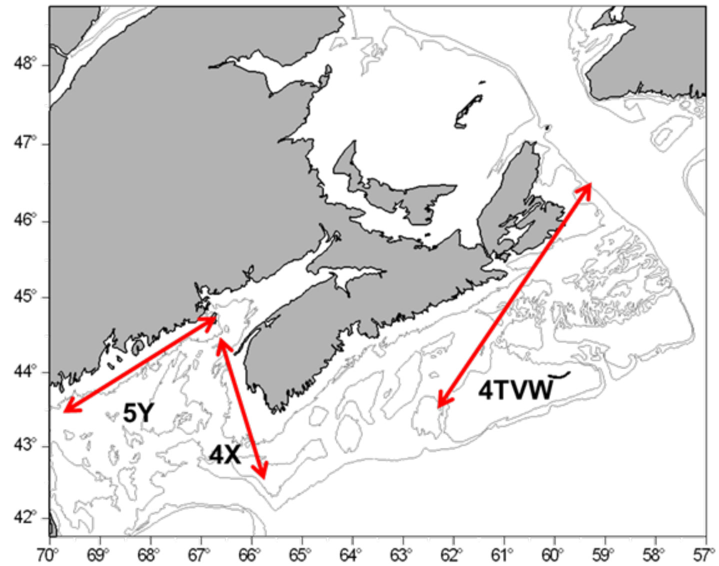


Figure 4. Simplified schematic of seasonal movements for three migratory haddock populations from early tagging studies (1920s-1950s) described by Fowler (2011). western Scotian Shelf (4X), eastern Scotian Shelf (4TVW) and Gulf of Maine (5Y).

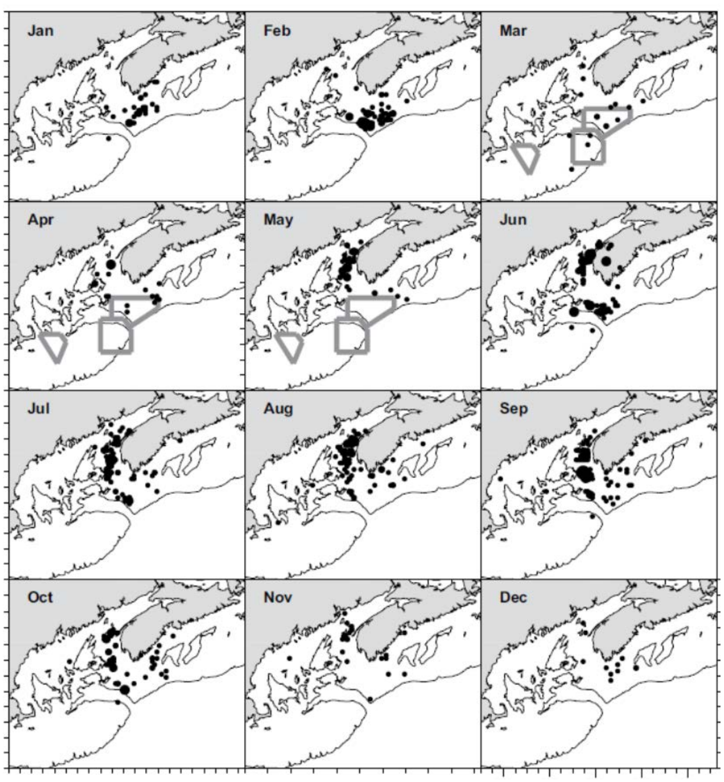


Figure 5. Recoveries from haddock tagged on Browns Bank, Scotian Shelf, springs of 1983-1985 from Fowler (2011). Recoveries are aggregated over years and five minute squares, and plotted separately for each month. Grey boundaries delineate seasonal spawning area closures to fisheries.

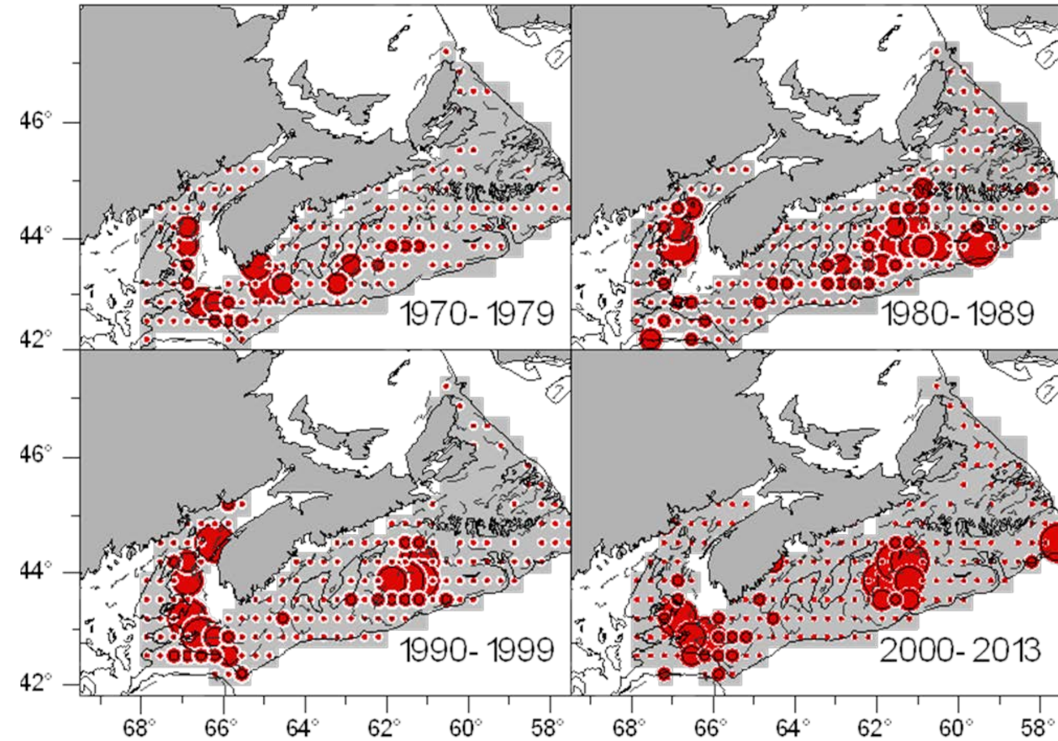


Figure 6. Distribution of haddock catches (10-year average weight (kg)/tow aggregated by 20-minute squares) from the DFO summer RV survey, 1970-2013. Grey shading indicates extent of area surveyed.

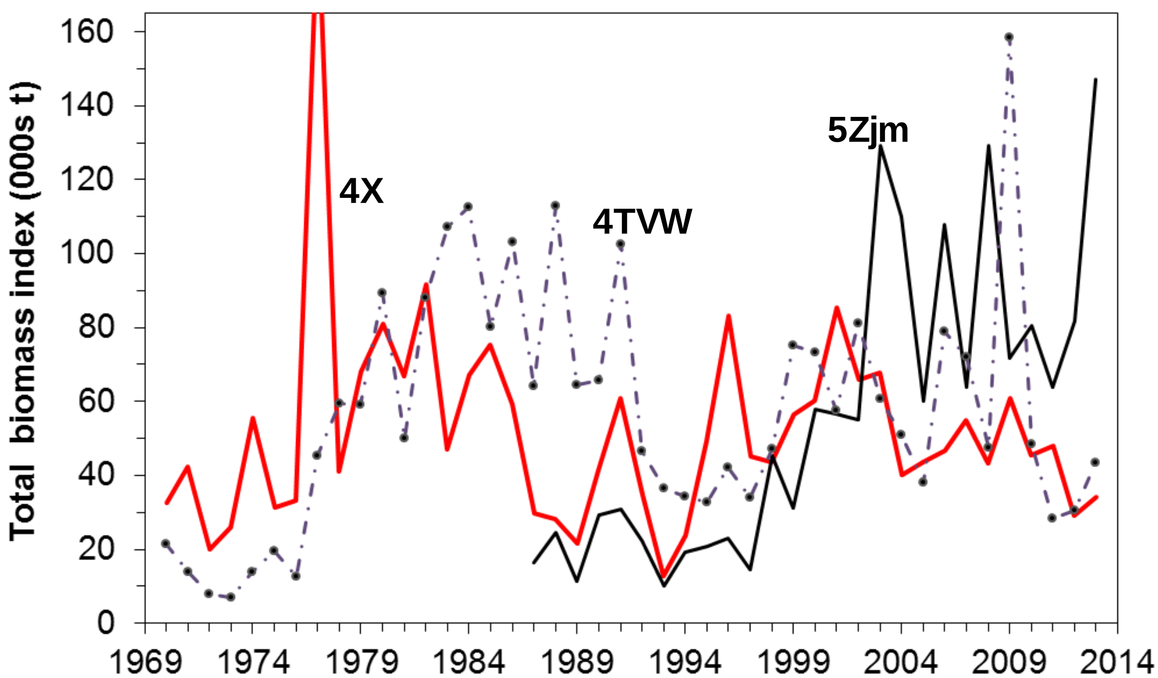


Figure 7. Trends in DFO summer survey total biomass indices (000t) for adjacent stocks on Georges Bank (5Zjm; 1987-2013), the eastern Scotian Shelf (4TVW; 1970-2013) and the western Scotian Shelf (4X; 1970-2013).

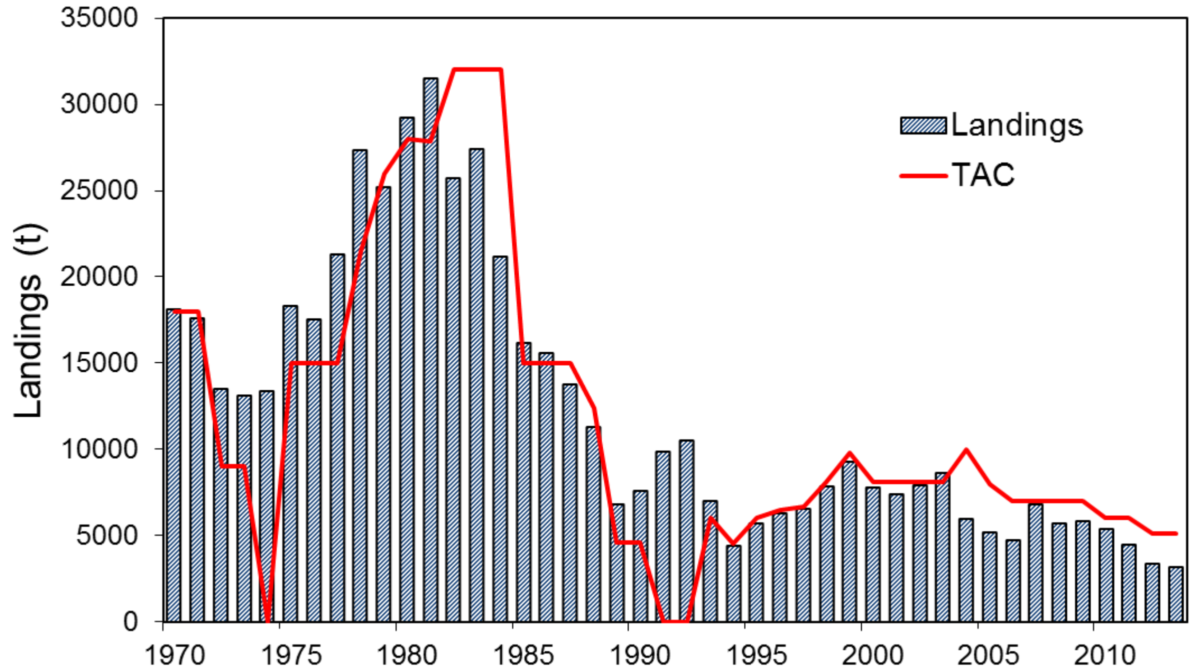


Figure 8. Reported landings (t) and TAC for the 4X5Y haddock fishery, 1970-2013.

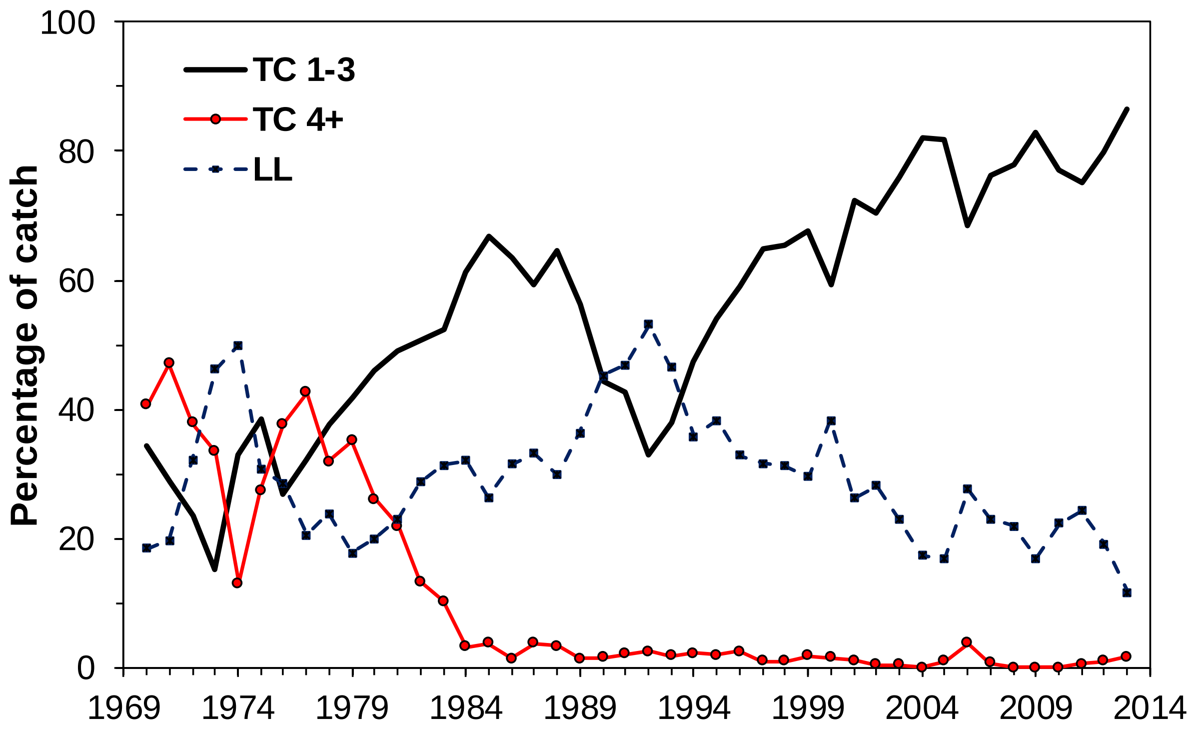


Figure 9. Percentage of annual landings (t) by gear type for the 4X5Y haddock fishery, 1970-2013. TC 1-3 = otter trawl tonnage class 1-3; TC 4+ = otter trawl tonnage class 4+; LL = longline.

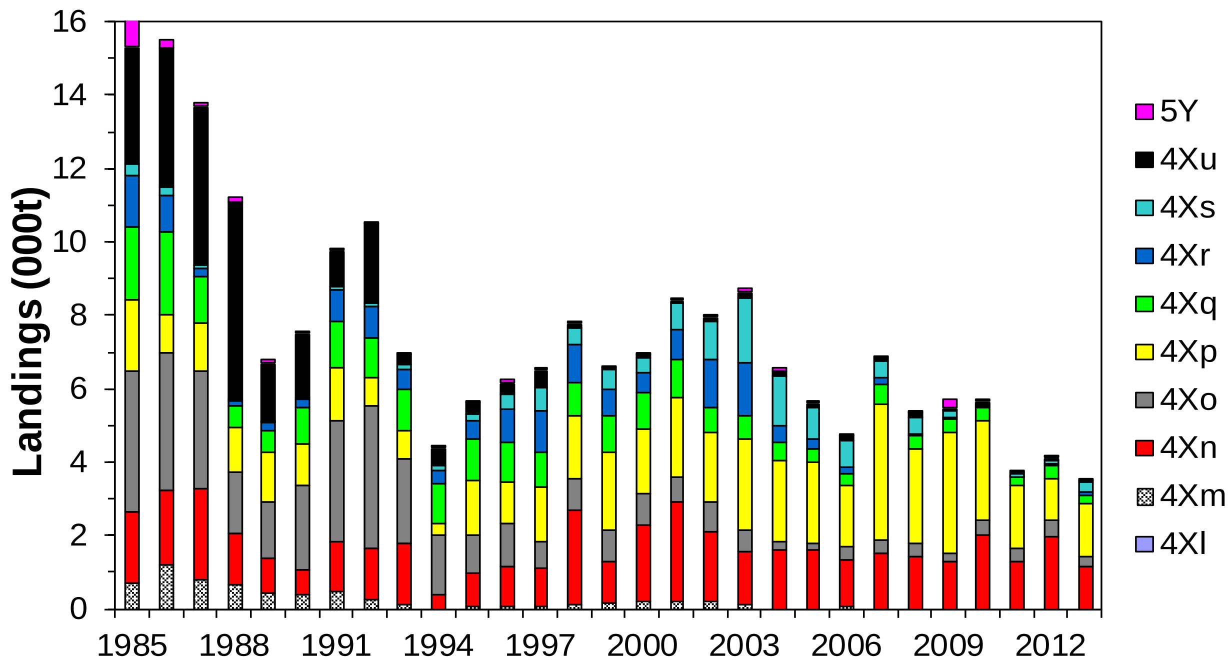


Figure 10. Annual landings (t) by Canadian statistical unit area for the 4X5Y haddock fishery, 1985-2013.

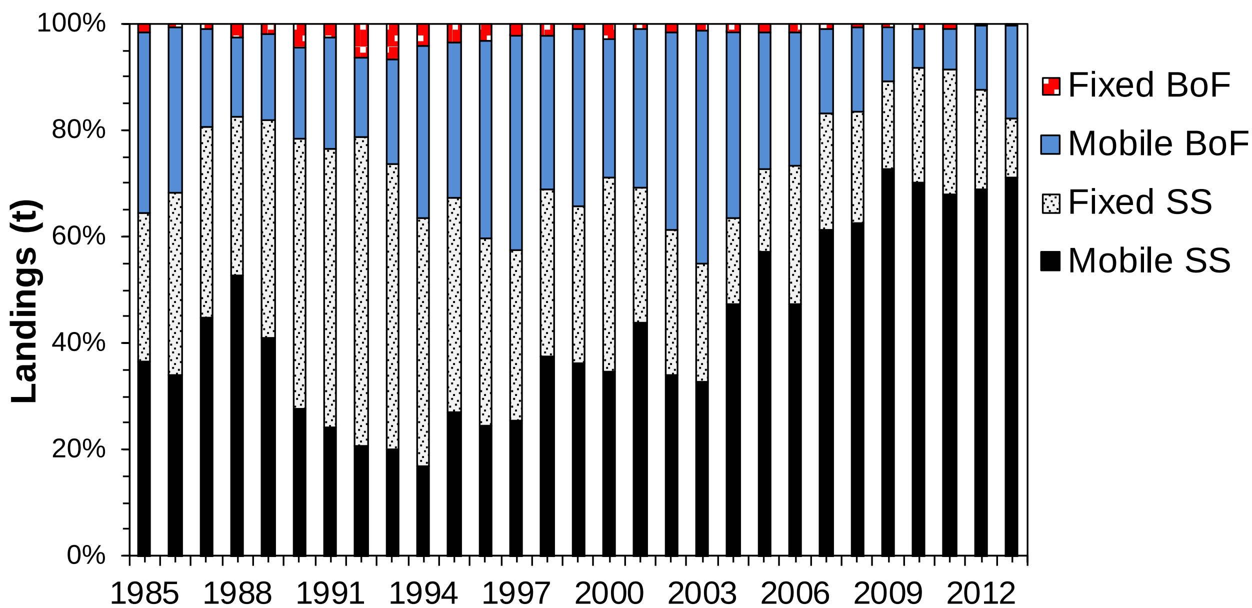


Figure 11. Annual landings (%) by gear sector for Canadian statistical unit areas representing the western Scotian Shelf (SS; 4Xmnop) and Bay of Fundy (BoF; 4Xqrs5Y) areas of the 4X5Y haddock fishery, 1985-2013.

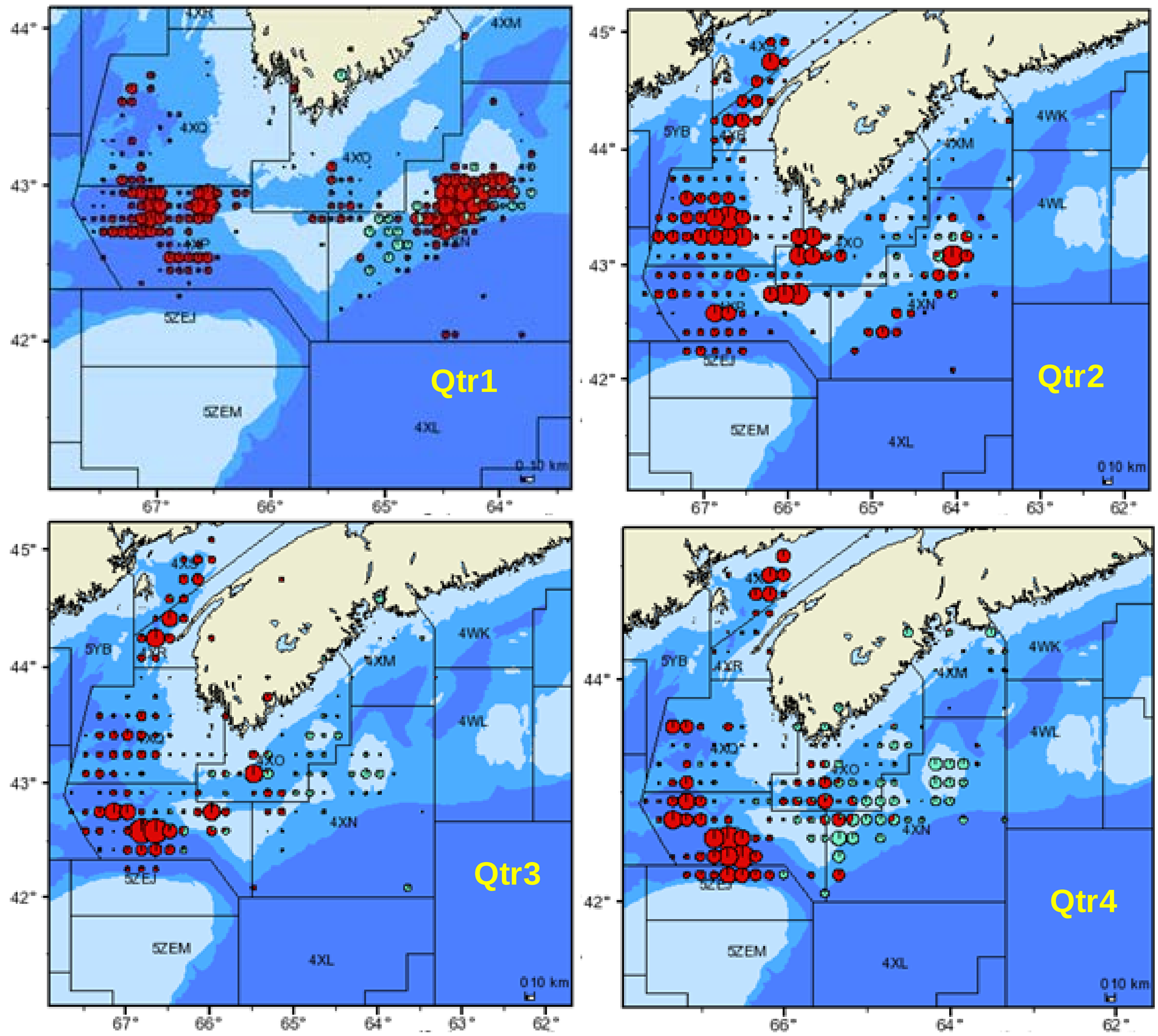


Figure 12. Distribution of 4X5Y haddock catches (t) by quarter for mobile gear (red circles) and fixed gear (blue circles) in 2013.

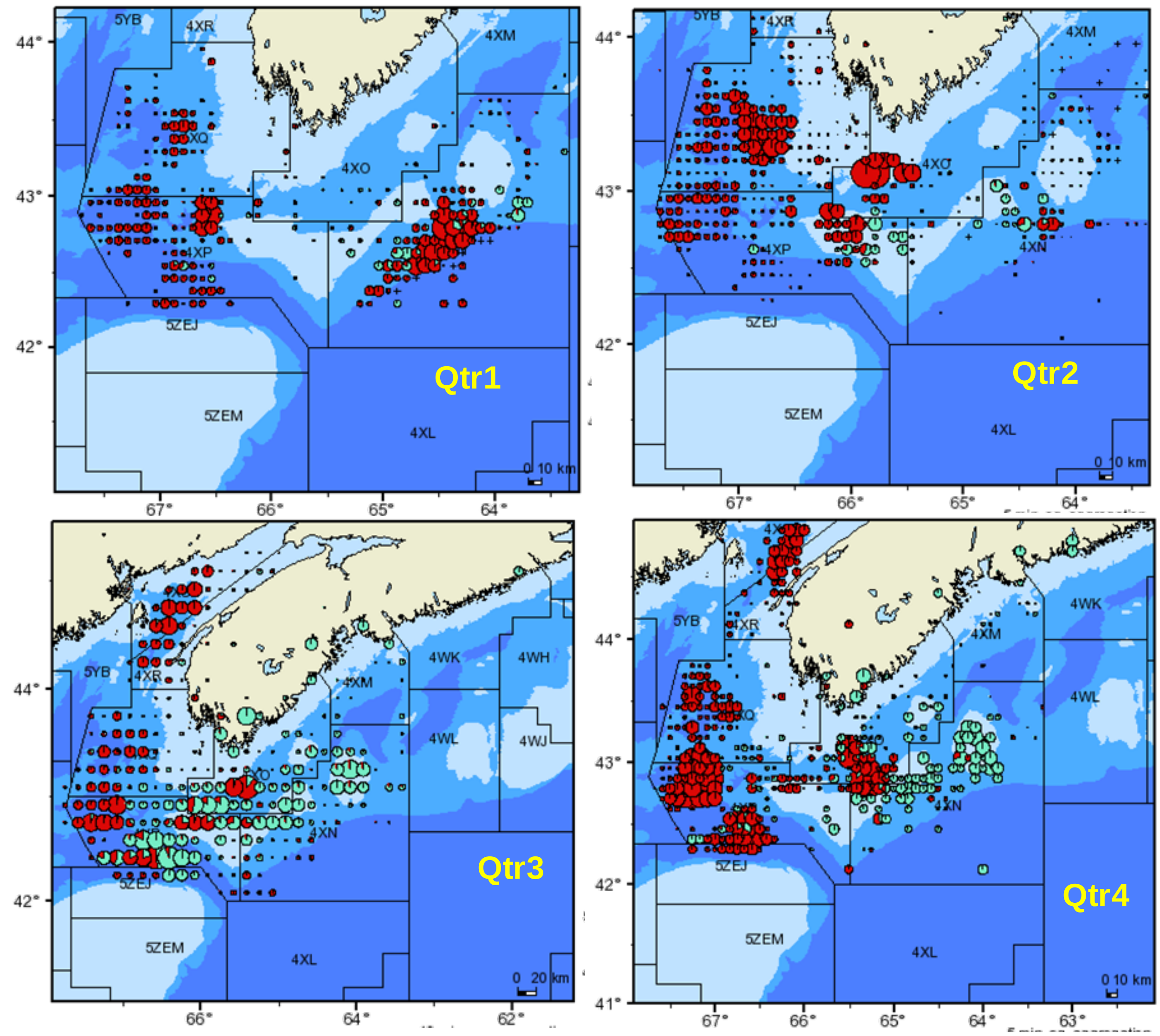


Figure 13. Distribution of 4X5Y haddock catches (t) by quarter for mobile gear (red circles) and fixed gear (blue circles) in 2012.

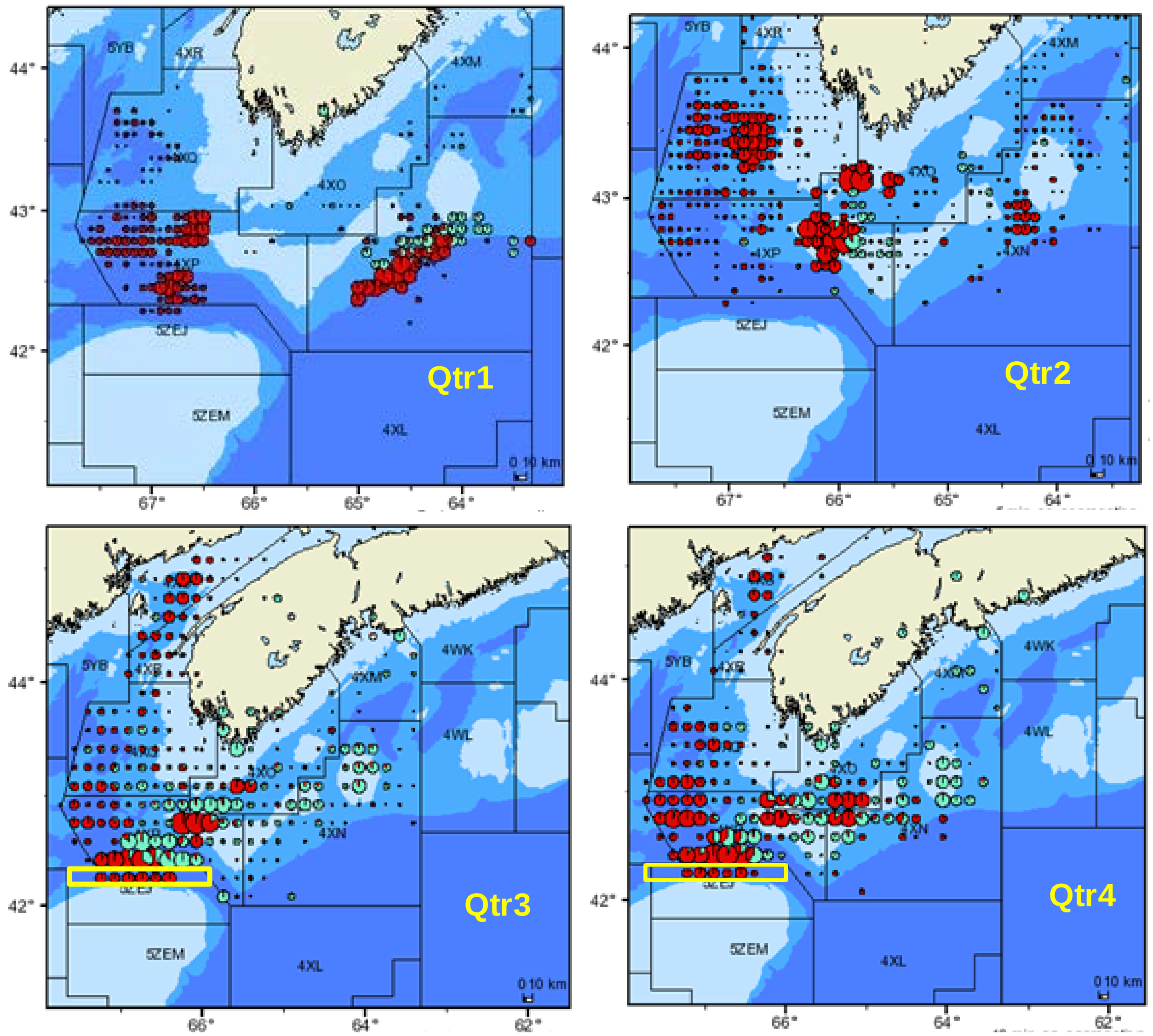


Figure 14. Distribution of 4X5Y haddock catches (t) by quarter for mobile gear (red circles) and fixed gear (blue circles) in 2011. The yellow rectangle indicates the approximate location for the region of statistical unit area 4Xp which is 5 nautical miles north of the 4X5Z NAFO boundary (note: the rectangle is not to scale).

Test Age	Production Age 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
0	3															3
1		43	2													45
2		3	68	1												72
3			3	103	1											107
4				4	101	3										108
5					5	31	4									40
6						3	24	2								29
7							3	21	1							25
8								1	15	3						19
9									1	13						14
10										1	5					6
11											1	5				6
12												1	1			2
13																0
14															1	1
Total	3	46	73	108	107	37	31	24	17	17	6	6	1	0	1	477

% Agreement= 91%

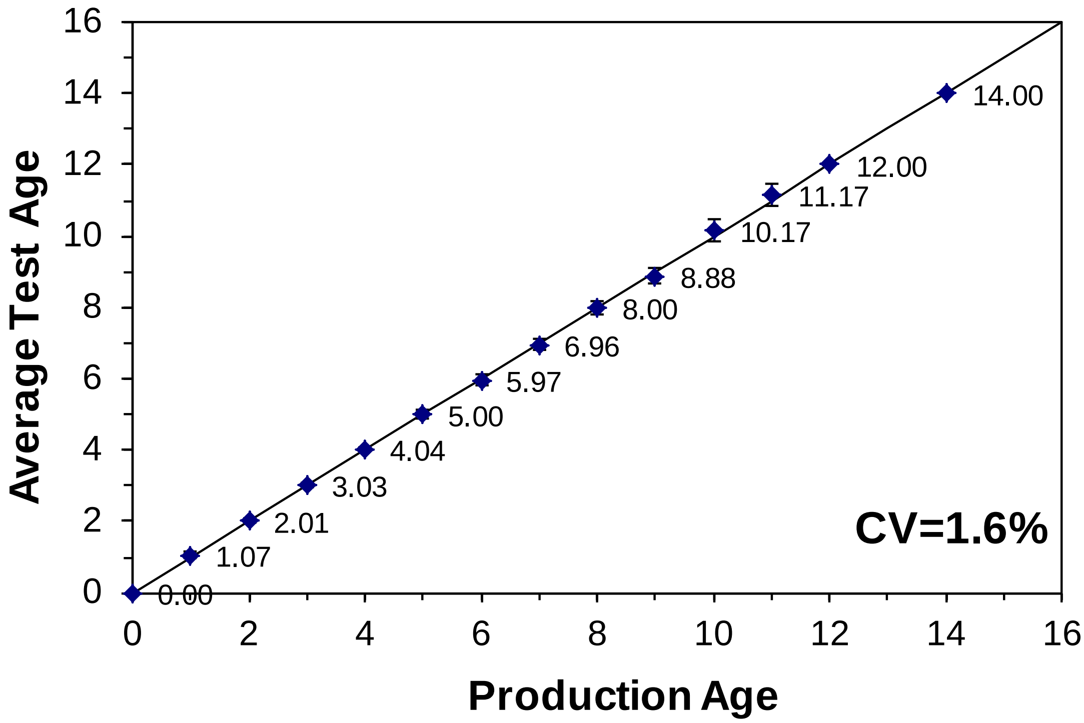


Figure 15. Age frequency (upper panel) and age bias (lower panel) plots comparing age interpretations by the primary age reader (P. Comeau) with the 4X5Y haddock reference collection. The mean age obtained by the primary age reader is shown relative to all ages (0 to 14) from the reference collection.

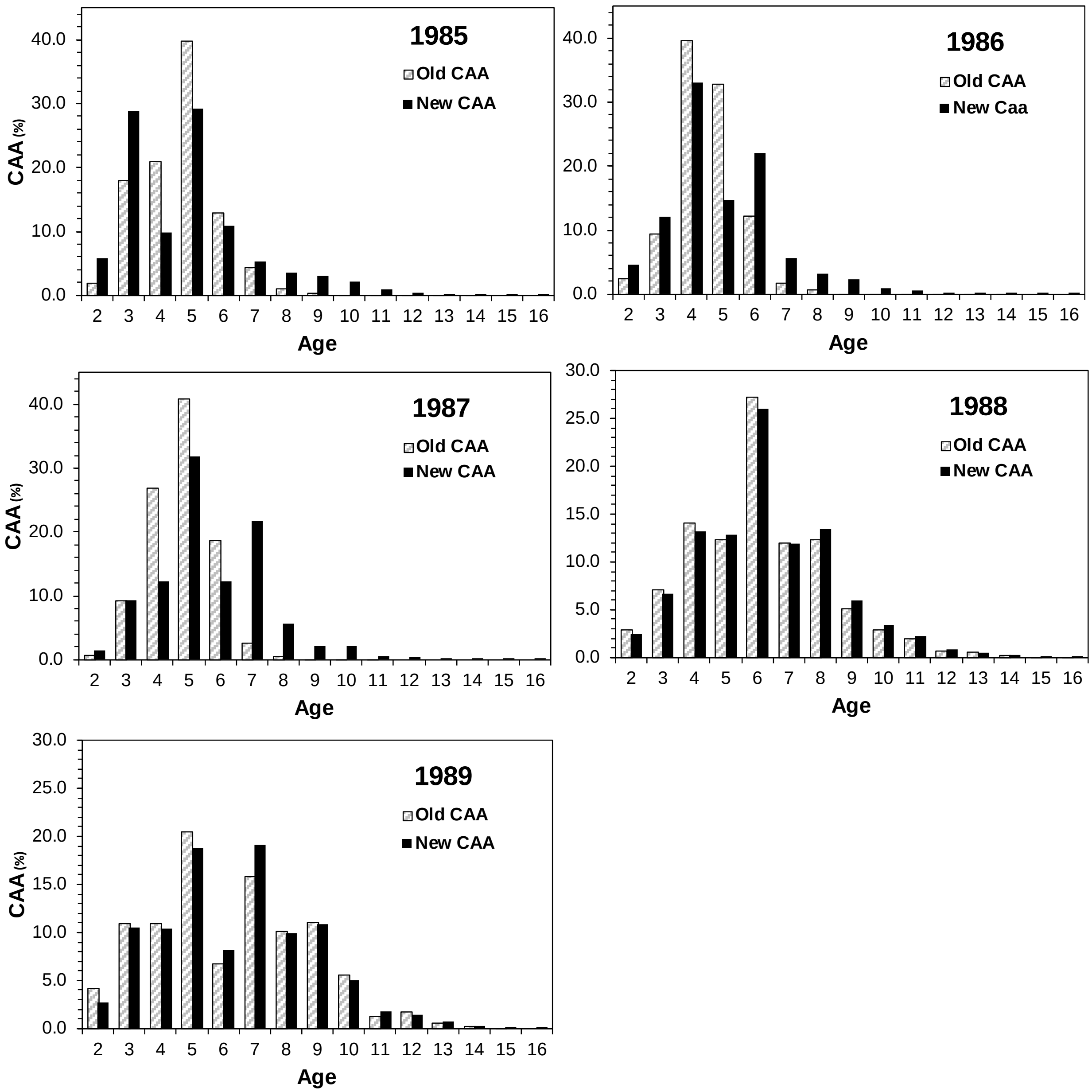


Figure 16. Comparisons of % CAA for 1985-1989 calculated using the old ageing (Old CAA) with 1cm length groupings and the revised ageing with 2cm length groupings (new CAA) for ages 2-16.

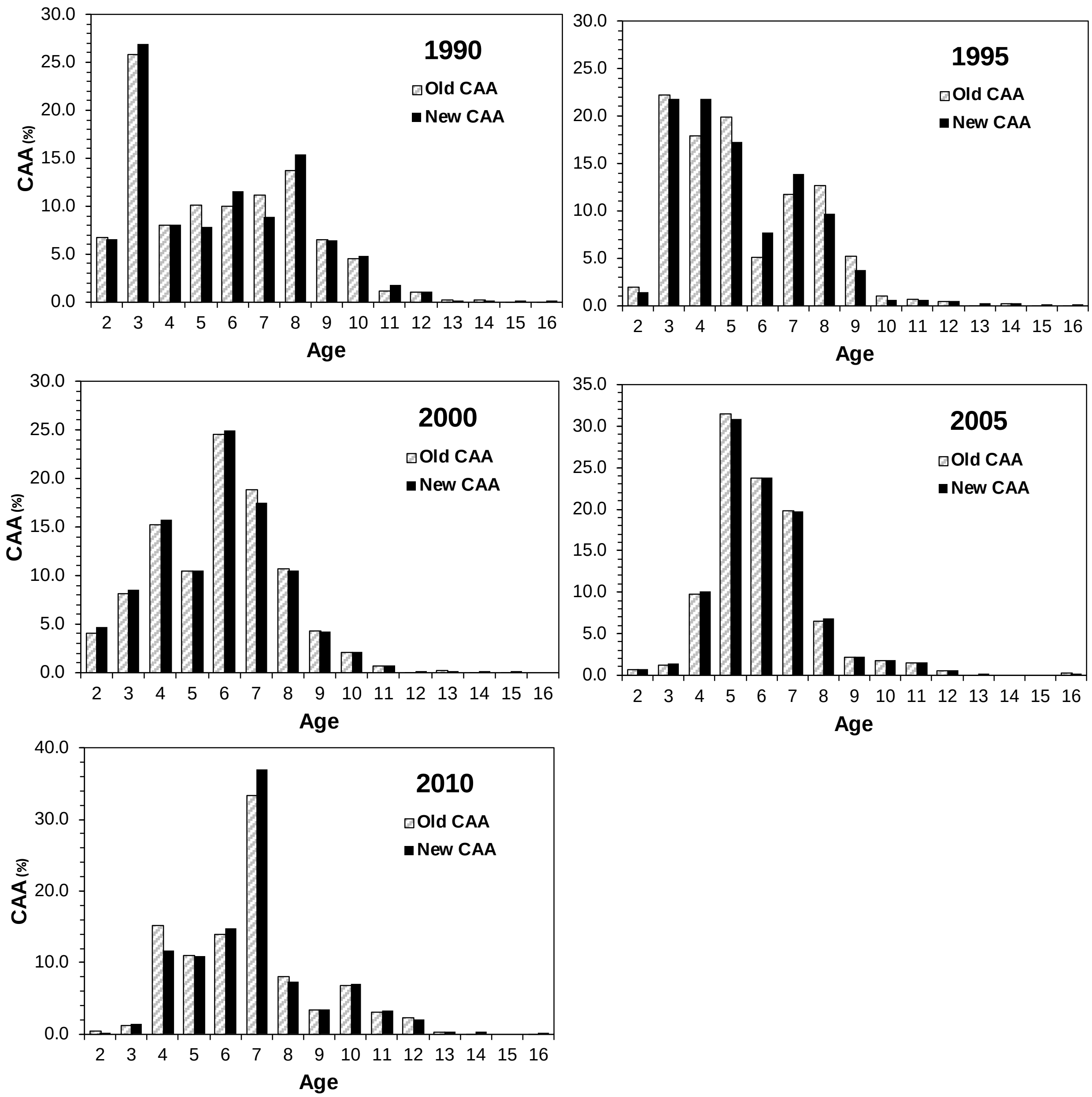


Figure 17. Comparisons of % CAA for 1990-2010 calculated using 1cm length groupings (Old CAA) and 2cm length groupings and different ALK combinations (new CAA) for ages 2-16. Selected CAA comparisons for 1990,1995, 2000, 2005 and 2010 are presented for illustration.

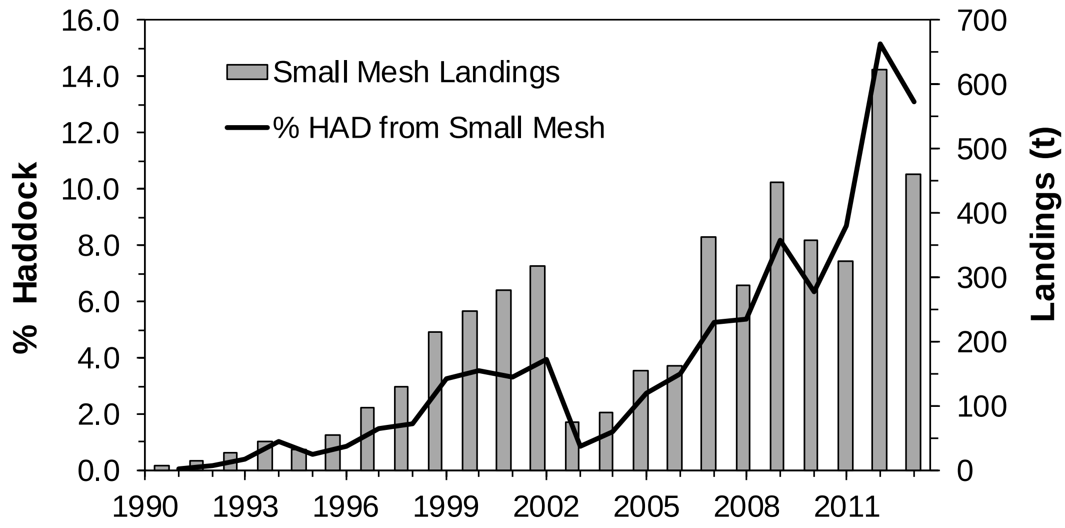


Figure 18. 4X5Y haddock landings (t)from Small Mesh Otter trawl (cod end mesh size:110-112mm diamond) and % of total annual landings,1991-2013.

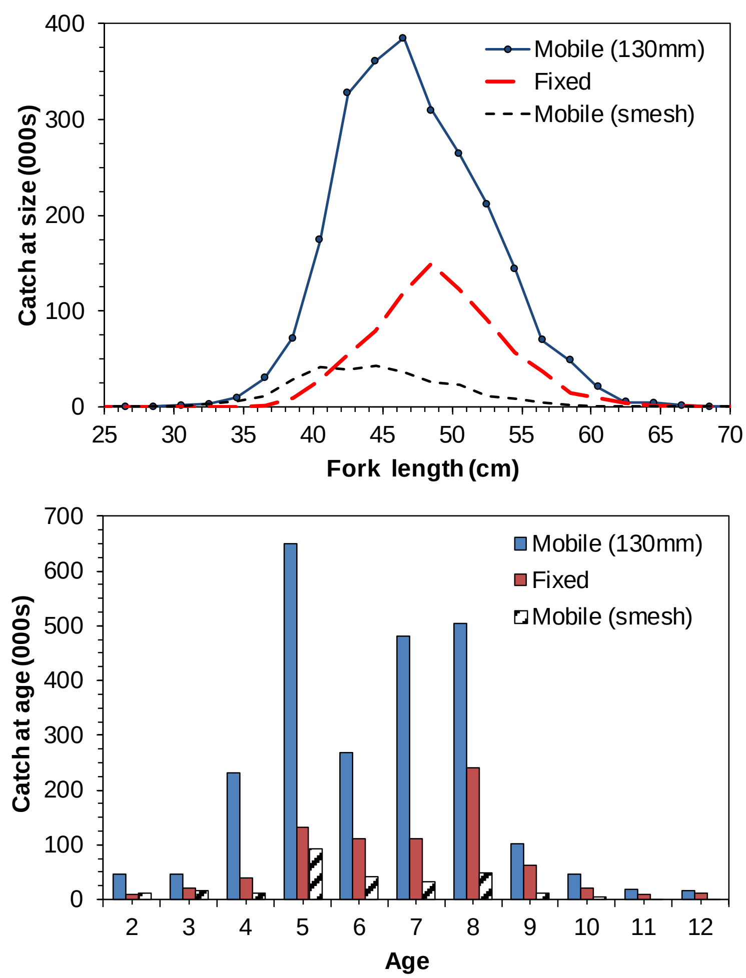


Figure 19. 4X5Y haddock fishery catch at size (000s; top panel) and CAA (%; lower panel) by gear category for 2011.

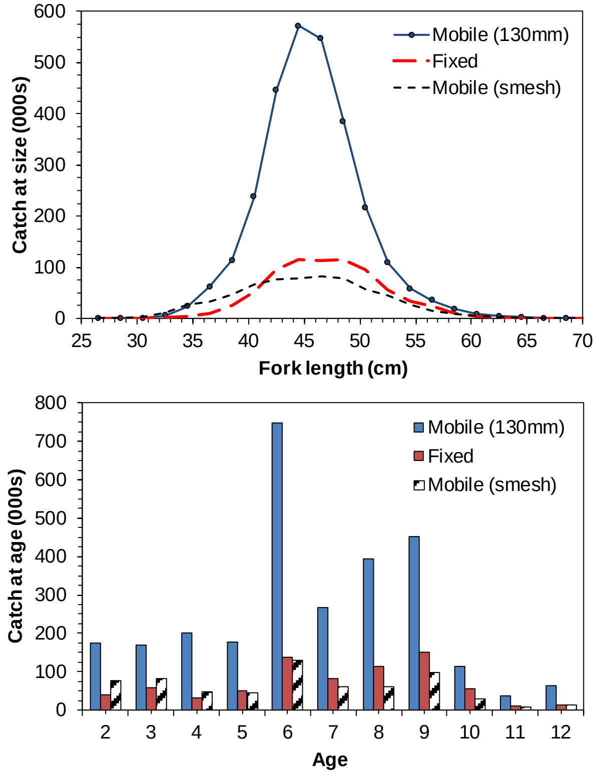


Figure 20. 4X5Y haddock fishery catch at size (000s; top panel) and CAA (%; lower panel) by gear category for 2012.

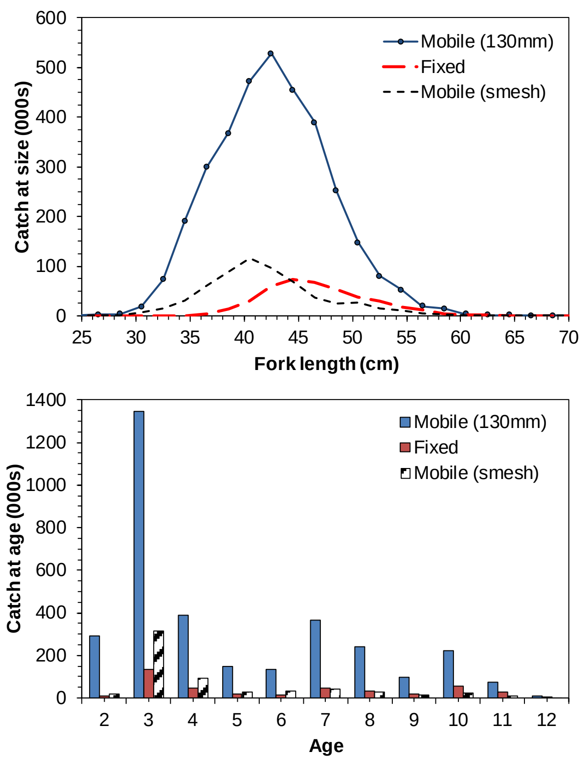


Figure 21. 4X5Y haddock fishery catch at size (000s; top panel) and CAA (%; lower panel) by gear category for 2013.

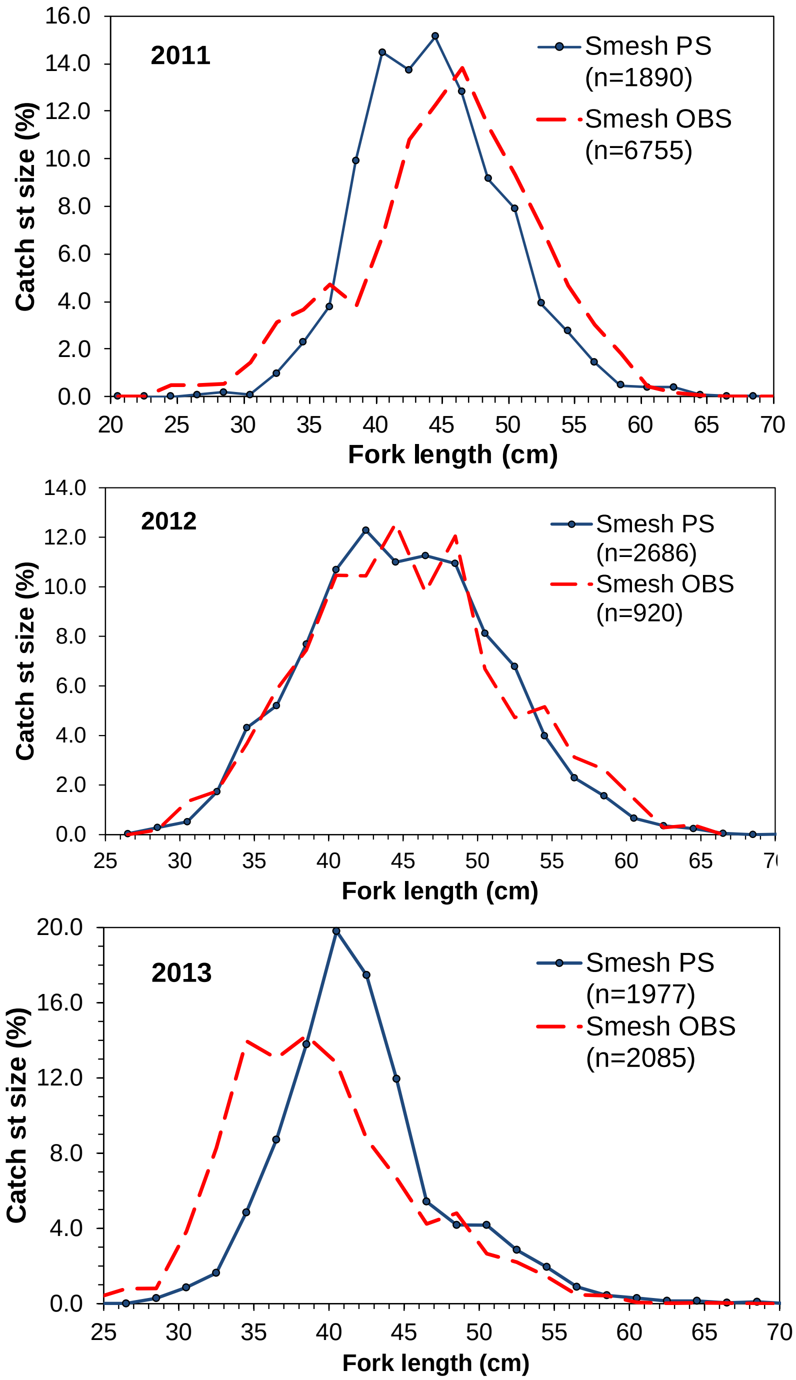


Figure 22. 4X5Y haddock fishery % catch at size comparisons from Port (shore) Samples (PS) and Observer (at-sea) Samples (OBS) for redfish directed trips (cod end mesh size:110-112mm diamond) in 2011, 2012 and 2013. (n=number of fish measured).

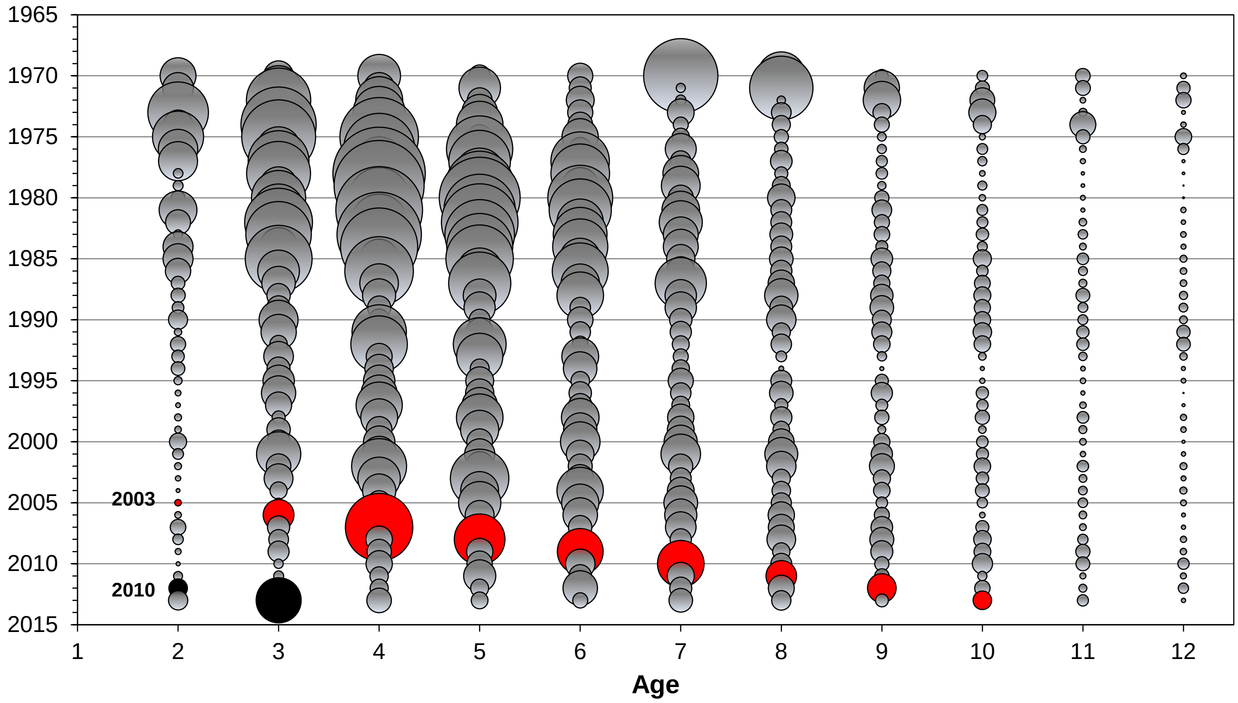


Figure 23. Revised CAA for 4X5Y haddock for ages 2-12, 1970-2013. The area of the circle is proportional to the catch at that age and year. Two examples of recent strong cohorts are highlighted: 2003 (red) and 2010 (black).

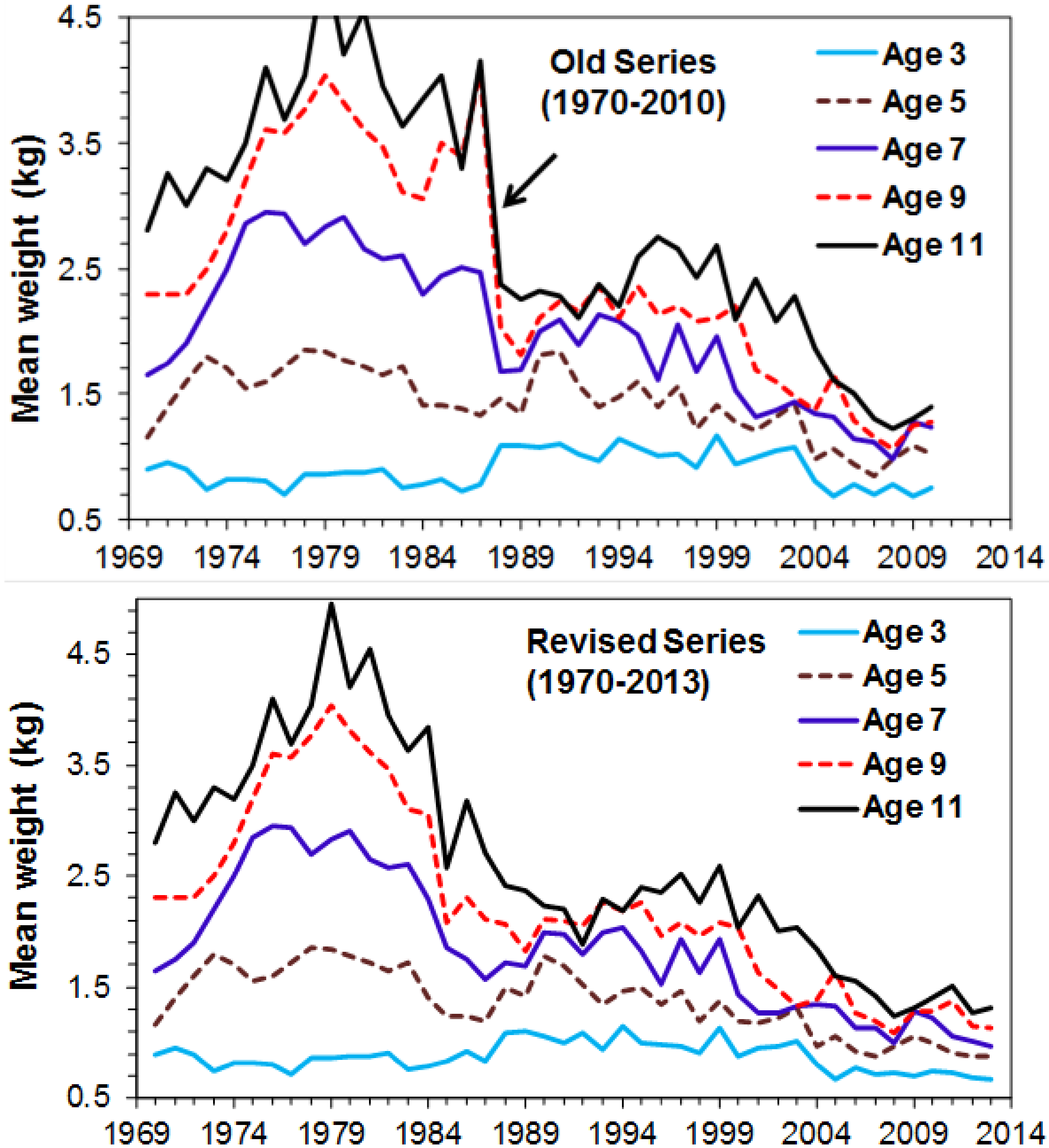


Figure 24. Commercial fishery mean WAA (kg) for 4X5Y haddock ages 3, 5, 7, 9 from 1970-2013. The top panel shows the original WAA series used by Showell et al. (2013) in the last assessment, and the bottom panel shows the revised WAA series, which is based on the CAA with 2cm groupings for 1985-2013 and revised ageing for 1985-1989. The black arrow indicates the precipitous drop in WAA for ages 9 and 11 from the old series that occurs from 1987-1988.

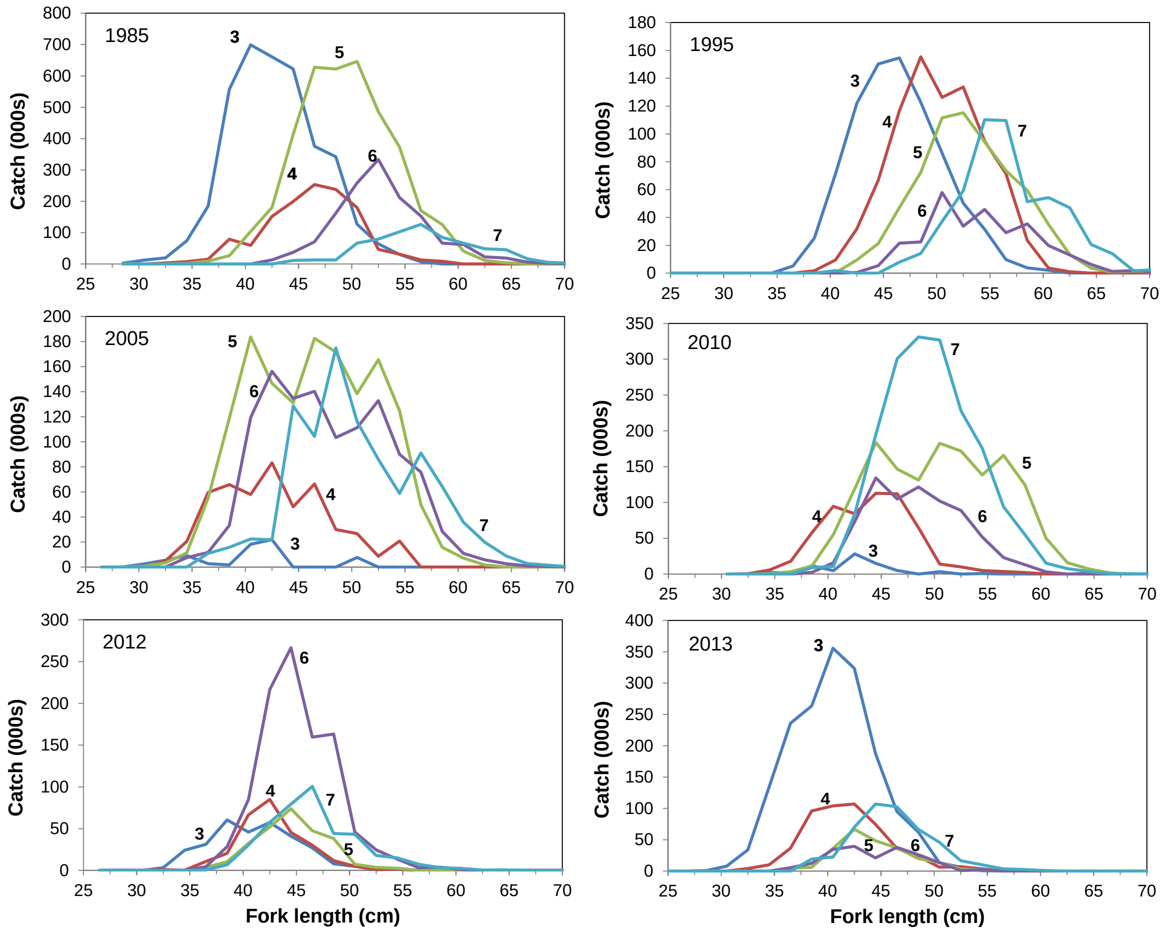


Figure 25. 4X5Y haddock catch at size (000s t) by age group for selected years from the commercial fishery CAA time series (1985, 1995, 2005, 2010, 2012, 2013), which illustrates a declining trend in LAA.

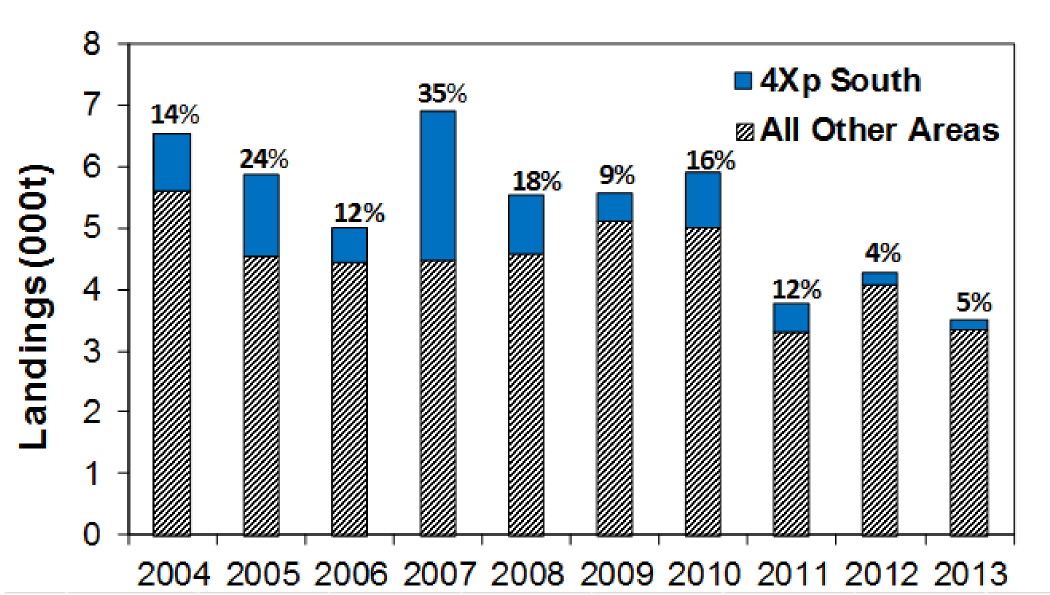


Figure 26. Haddock landings (000s t) from 4Xp south (i.e. within 5 nautical miles north of 4X5Z line), and all other statistical unit areas within the 4X5Y management unit for 2004-2013. Numerical values represent the percentage of total catch taken from the 4Xp south area.

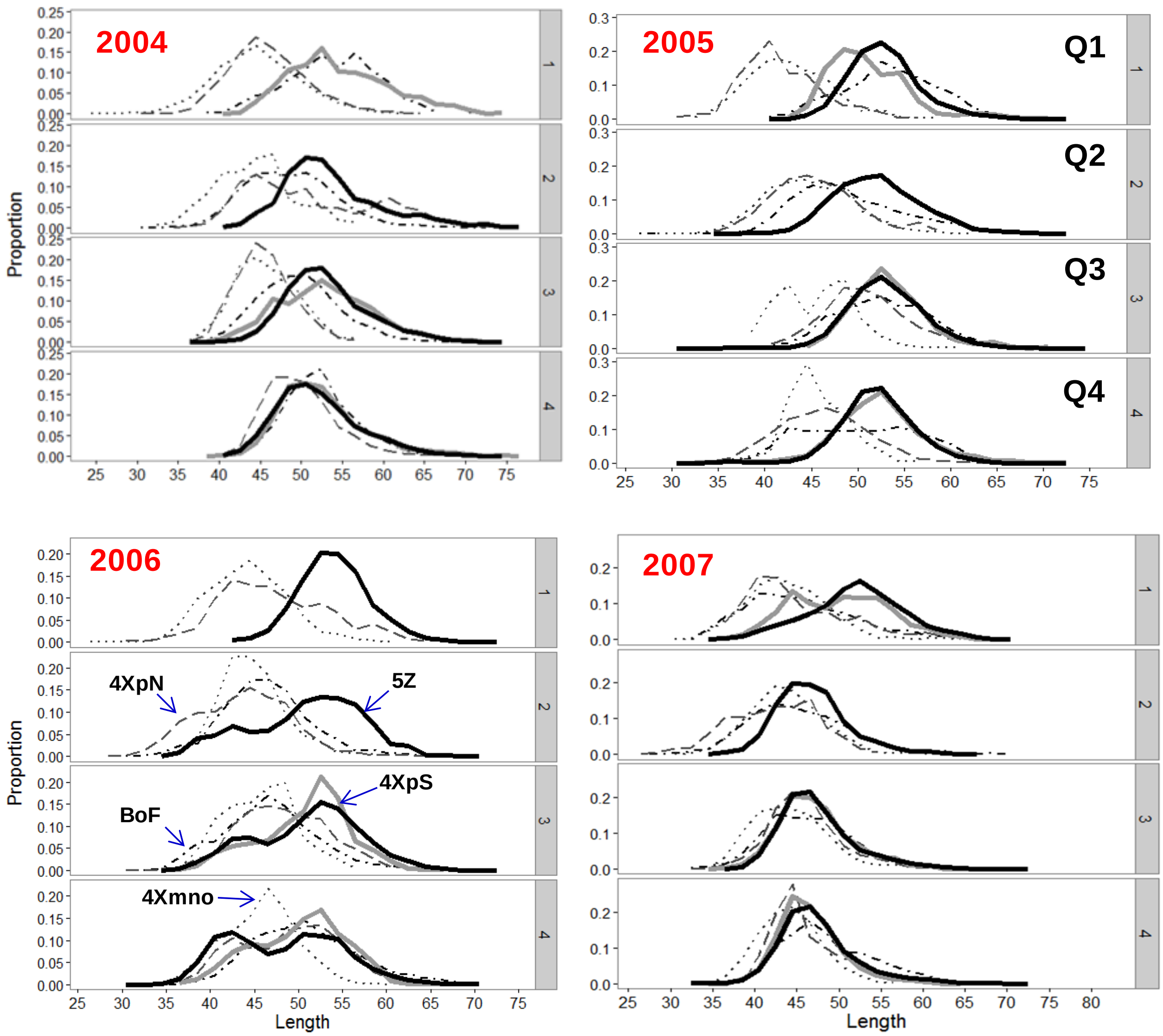


Figure 27. Haddock Port Sample size frequency (%) by quarter and area for 2004-2007. Areas are: Scotian Shelf (4Xmno), Bay of Fundy (BoF; 4Xqrs5y), 4Xp north (4XpN), 4Xp south (4XpS) and eastern Georges Bank (5Z). Length = fork length (cm).

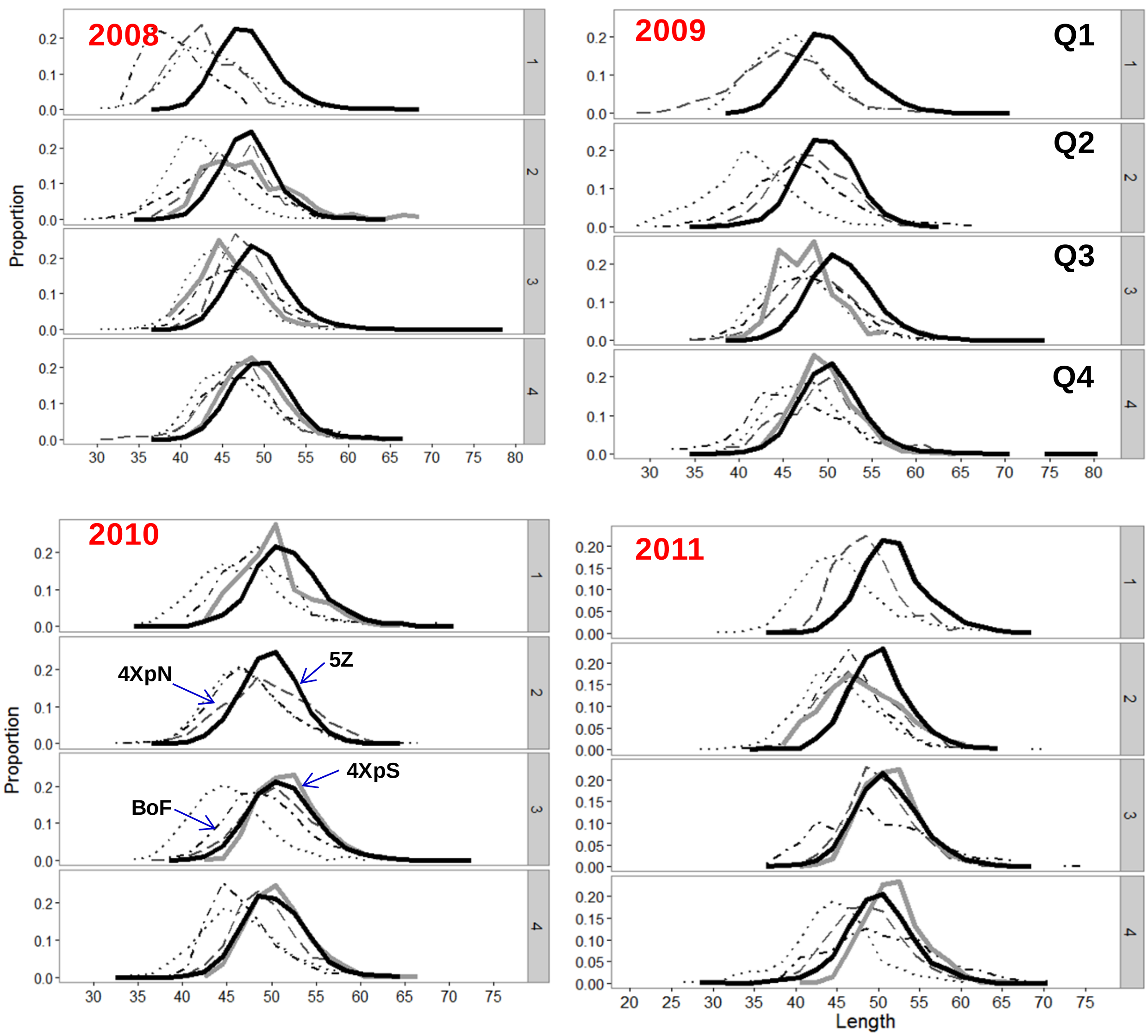


Figure 28. Haddock Port Sample size frequency (%) by quarter and area for 2008-2011. Areas are: Scotian Shelf (4Xmno), Bay of Fundy (BoF; 4Xqrs5y), 4Xp north (4XpN), 4Xp south (4XpSN) and eastern Georges Bank(5Z). Length = fork length (cm).

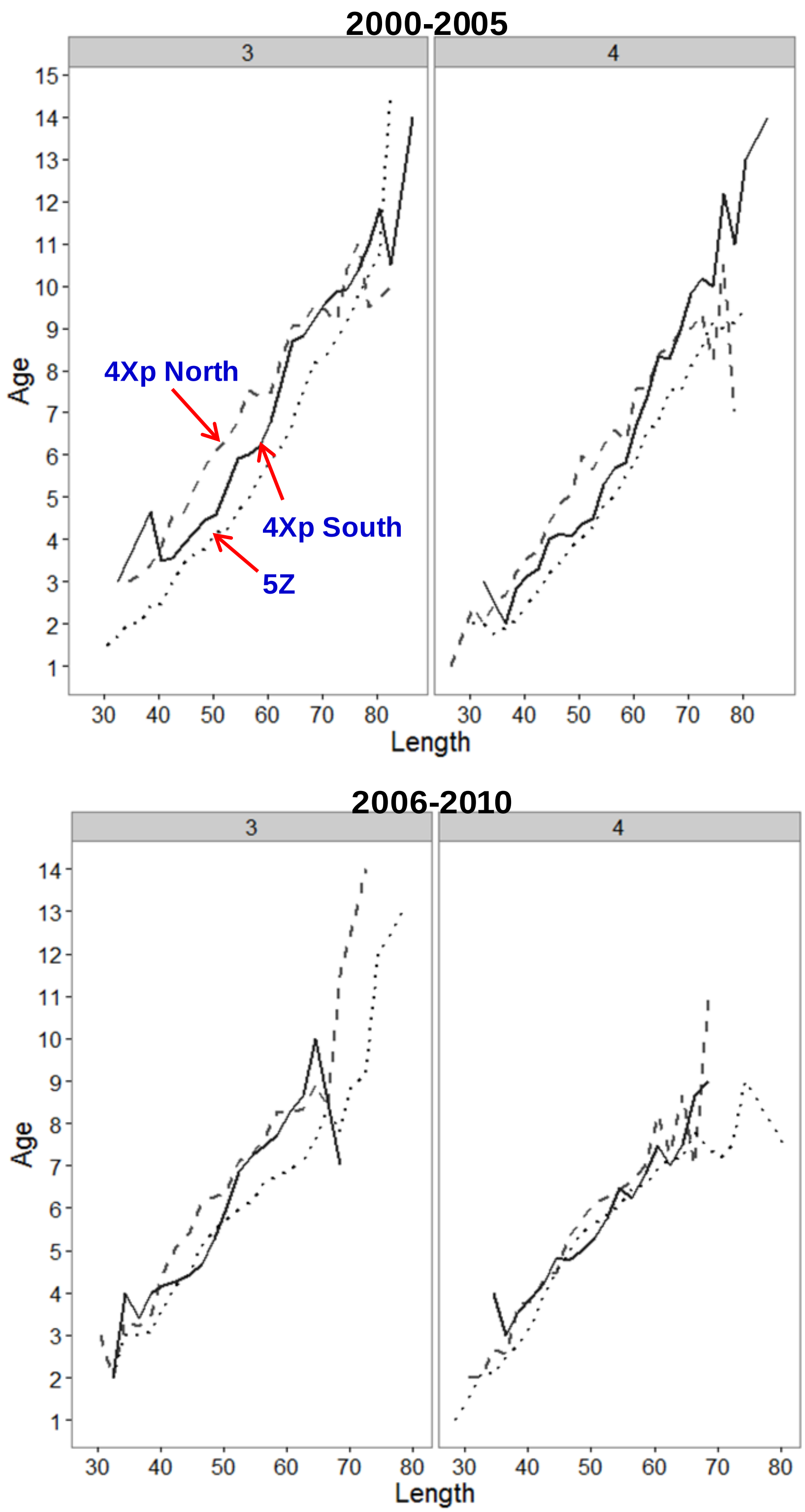


Figure 29. Mean age at length for haddock from port samples for quarters 3 and 4 from 4XP north, 4Xp south and 5Z (eastern Georges Bank), aggregated into two 5-year periods: 2000-2005 (upper panel) and 2006-2010 (lower panel). Length = fork length.

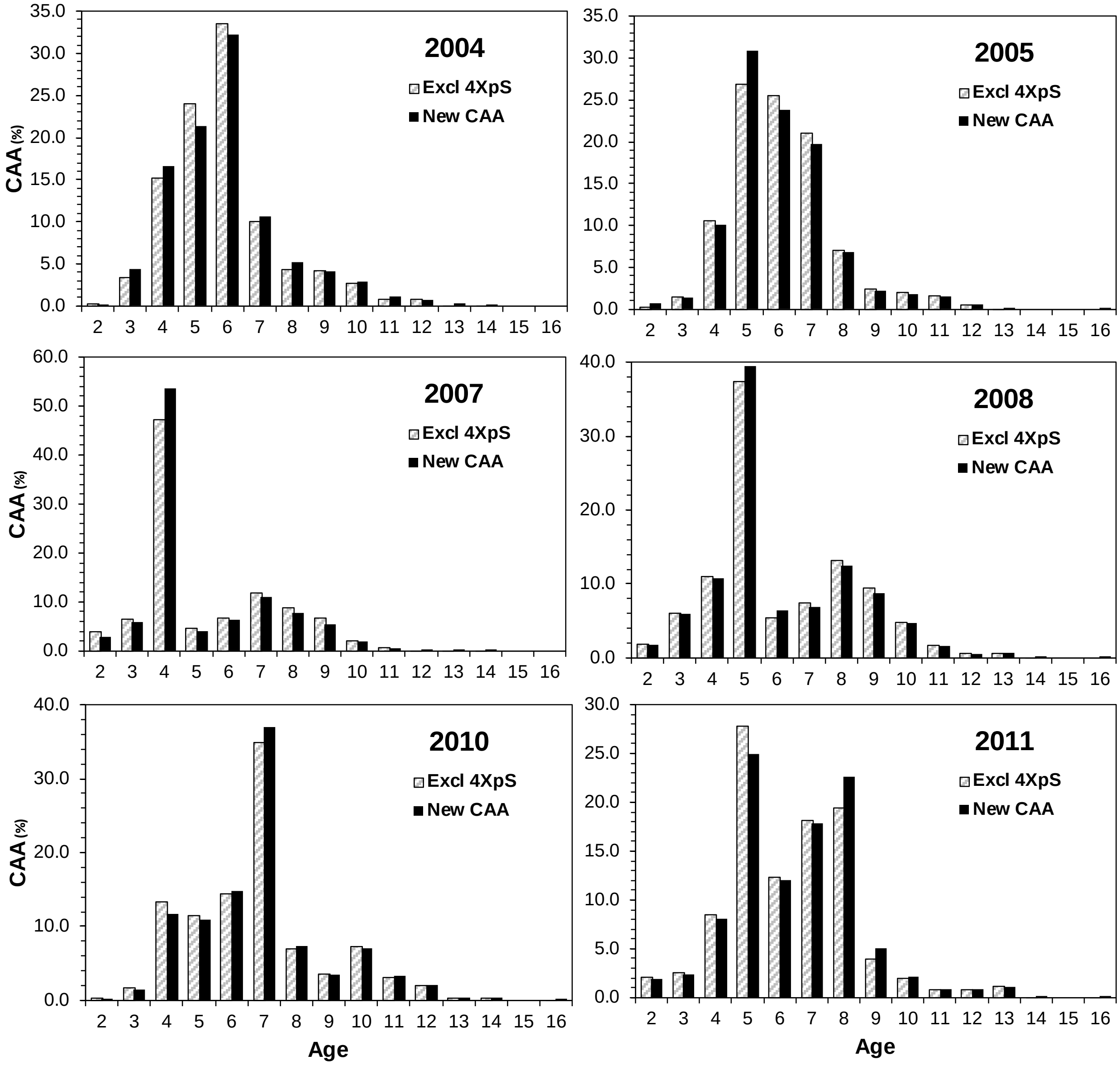


Figure 30. Comparisons of % CAA for 2004-2011 calculated with (new CAA) and without (excluding 4XpS) landings and port samples (lengths and ages) for both fixed and mobile gear from 4Xp south (i.e. within 5 nautical miles north of the 4X/5Z NAFO boundary). Only years where landings from 4XpS were greater than 12% of total landings are shown here for illustration.

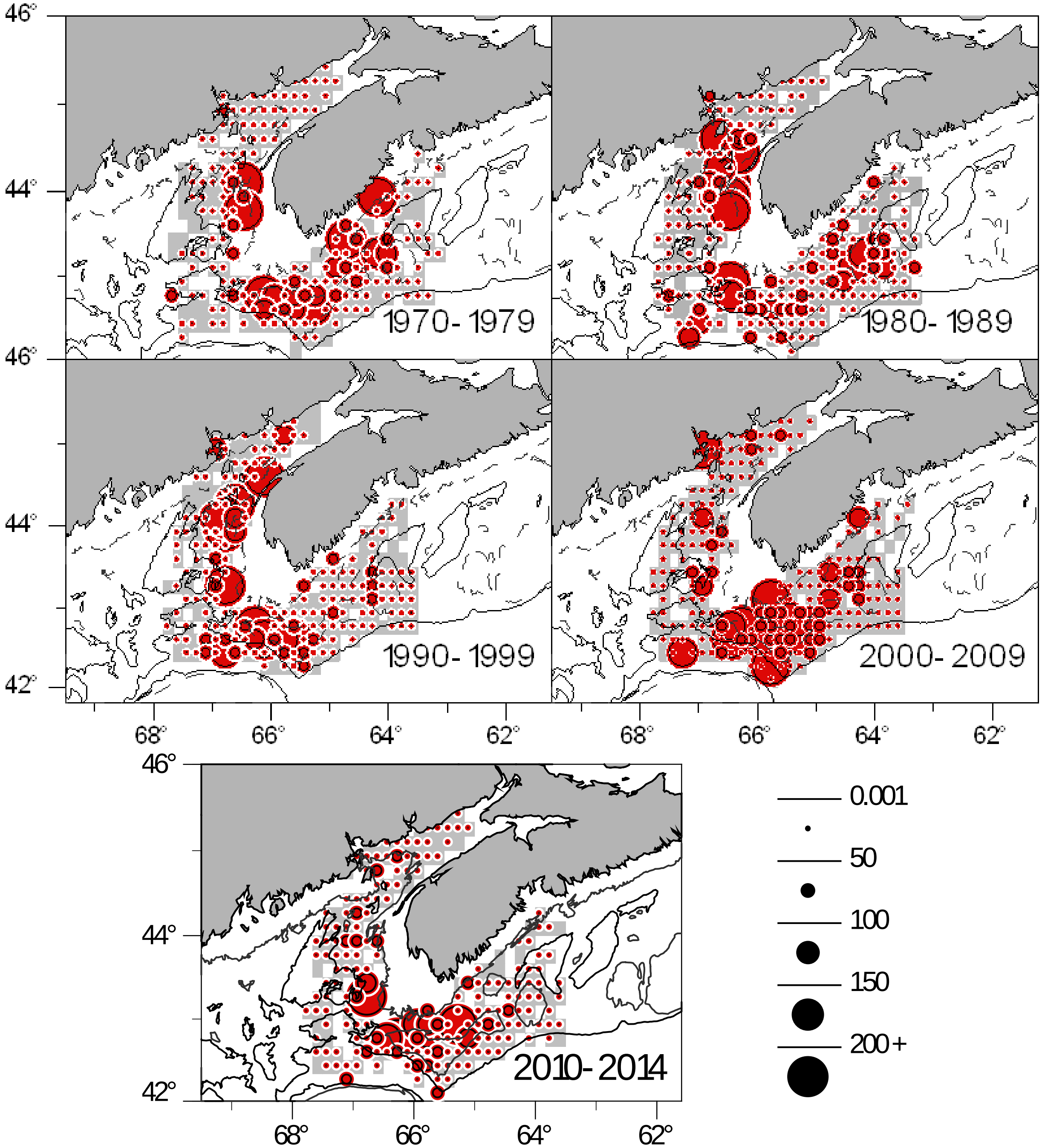


Figure 31. Distribution of 4X5Y haddock catches (5- and 10-year average weight (kg)/tow aggregated by 10 minute squares) from DFO summer survey strata 470-495, 1970-2014. Grey shading indicates extent of area surveyed.

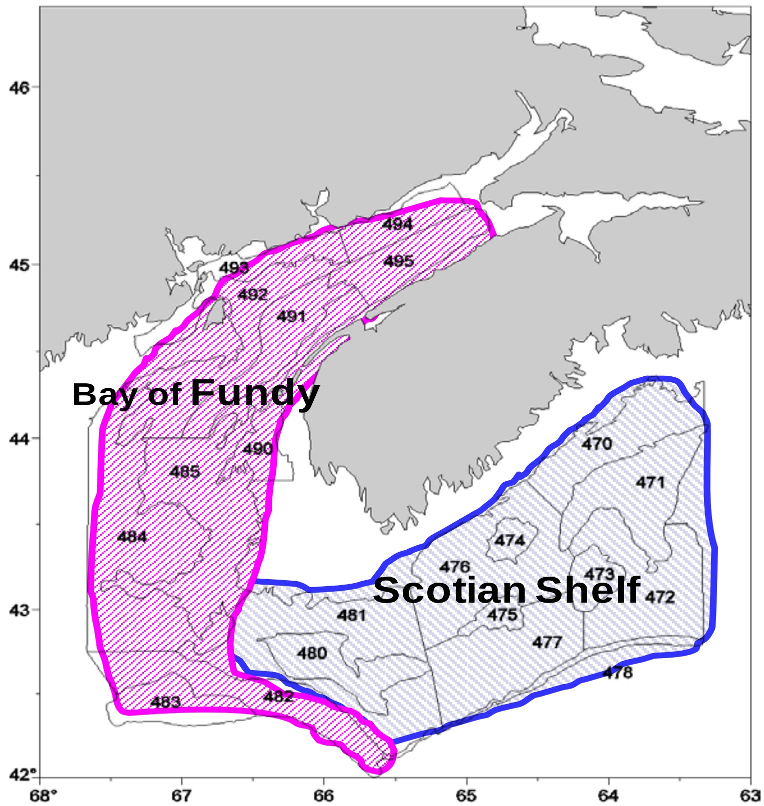


Figure 32. DFO summer survey strata and area of coverage for Scotian Shelf (strata 470-481, blue shading) and Bay of Fundy (strata 482-495; pink shading) areas of 4X5Y.

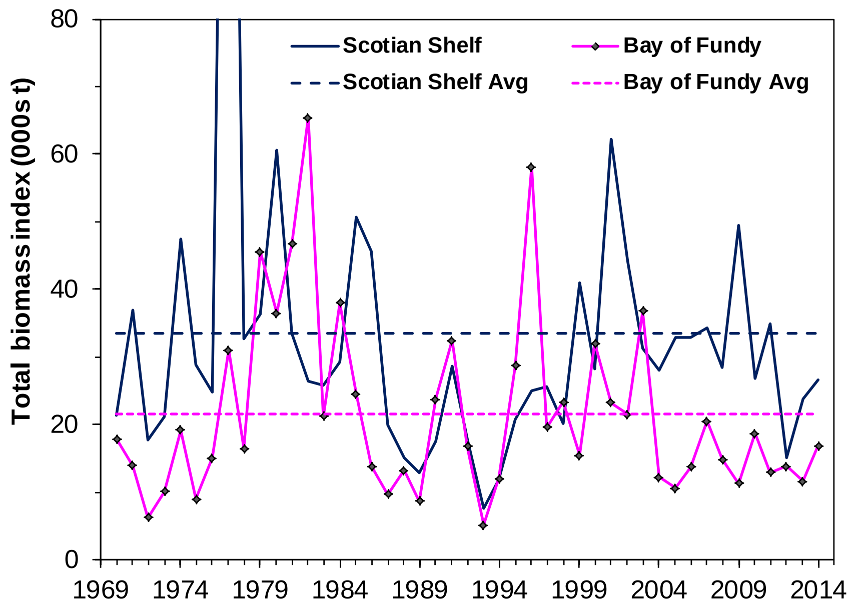


Figure 33. Trends in the haddock total biomass index (000 t) from the DFO summer survey for Scotian Shelf (strata 470-481), Bay of Fundy (strata 482-495) compared to the long term average from each area for 1970-2014. A conversion factor of 1.2 has been applied to total biomass estimated for 1970-1981 to account for vessel and gear changes.

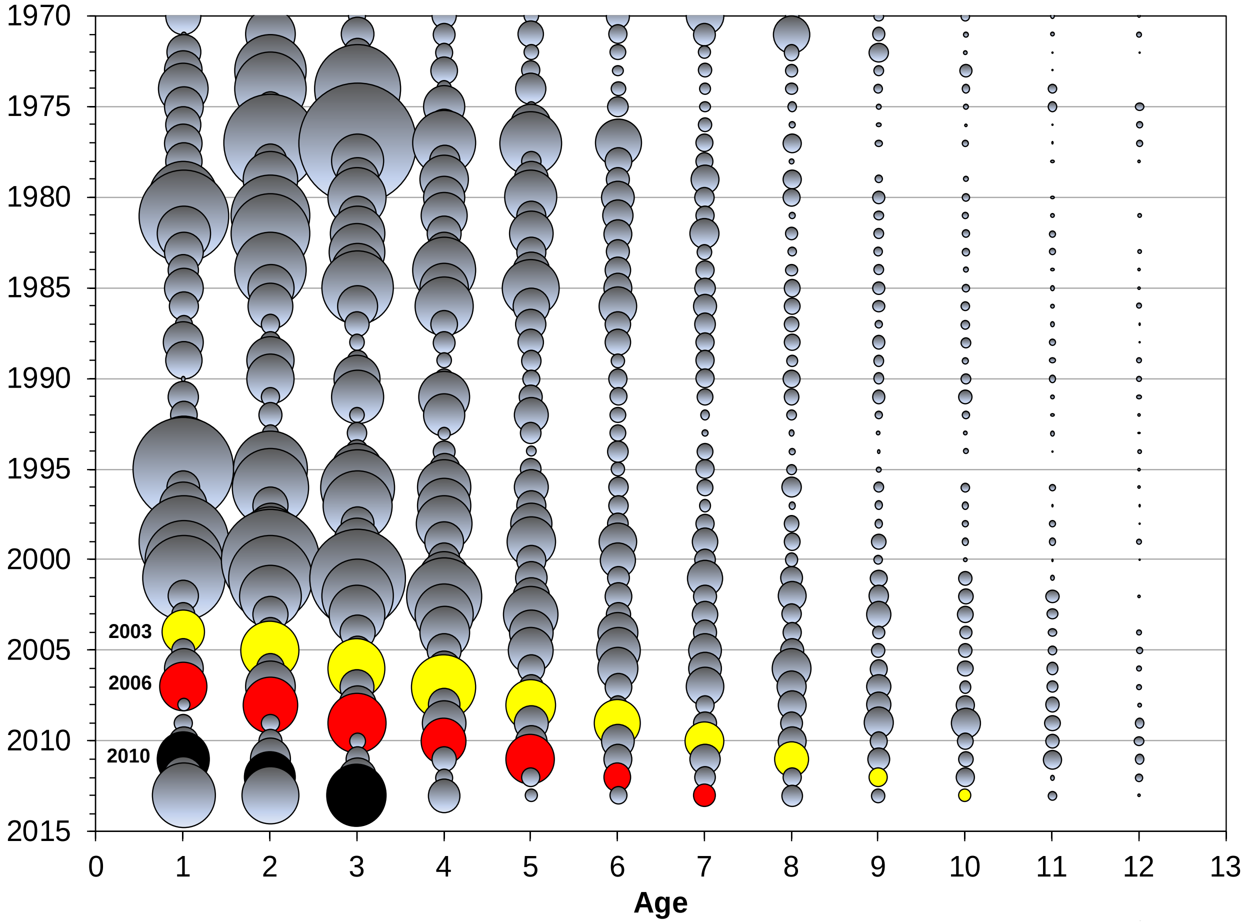


Figure 34. Stratified total number per tow at age (1-12 for 4X5Y haddock from DFO summer survey, strata 470-495, 1970-2013. Recent strong year classes are indicated by the yellow (2003), red (2006) and black (2010) circles. The area of the circle is proportional to the catch at that age and year. A conversion factor of 1.2 has been applied to indices from 1970-1981 to account for vessel and gear changes.

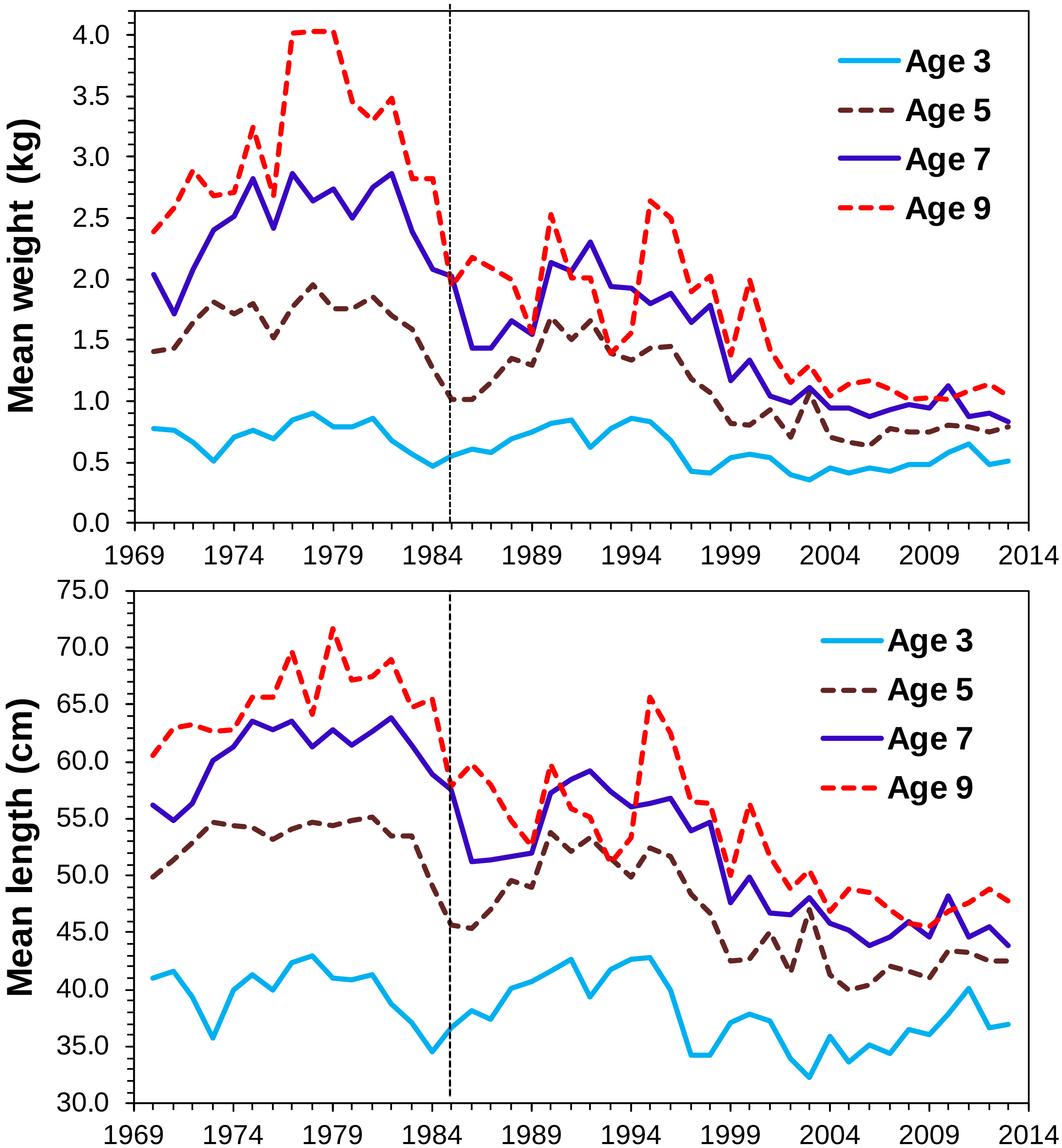


Figure 35. Summer survey mean WAA (kg; upper panel) and mean LAA (cm; lower panel) for 4X5Y haddock ages 3, 5, 7, and 9, 1970-2013. WAA and LAA were calculated separately for Bay of Fundy and western Scotian Shelf strata, then combined after weighting using total abundance at age from strata 470-495. The dashed line at 1985 is the year from which haddock otoliths were re-aged.

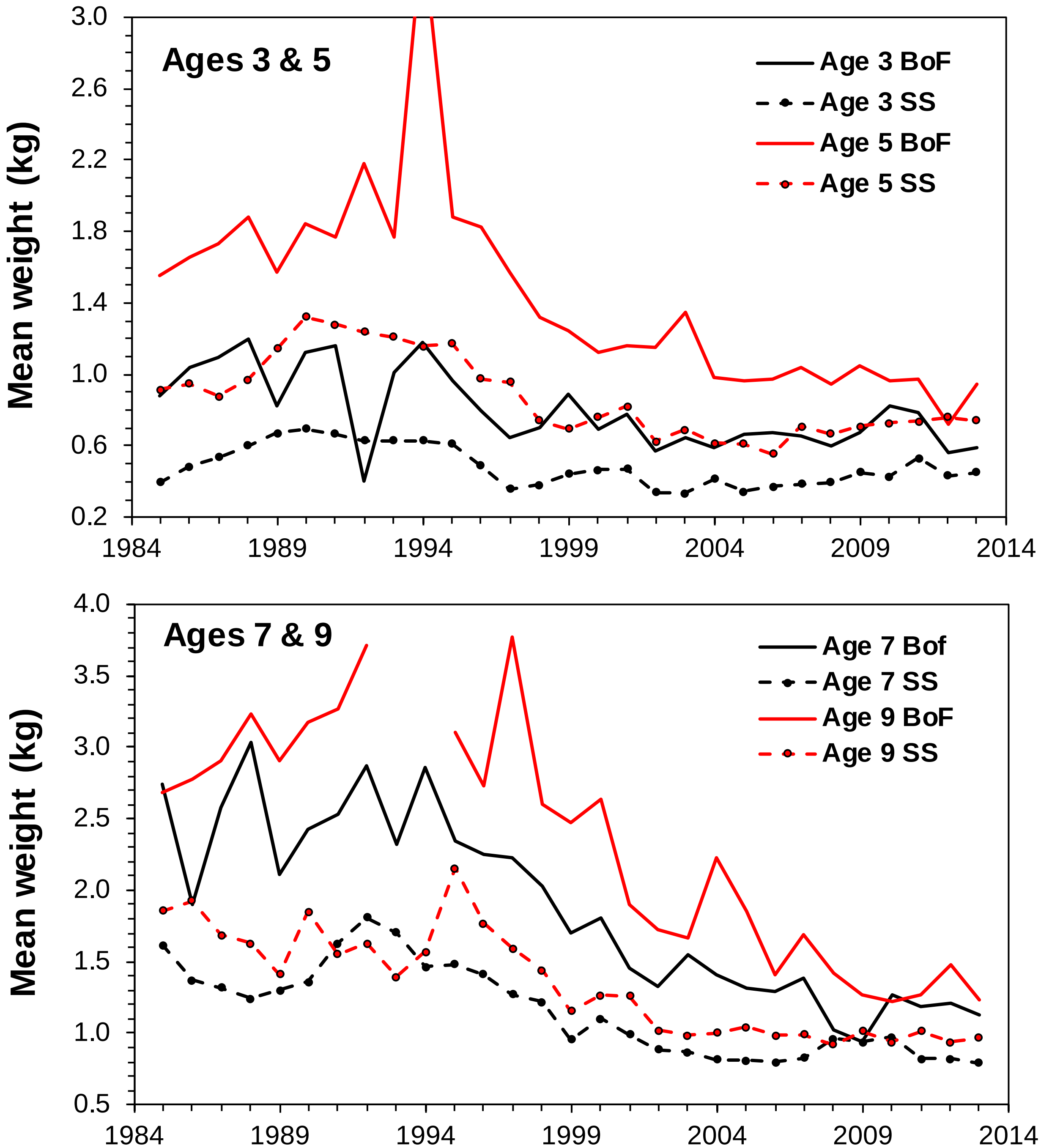


Figure 36. Comparison of summer survey mean WAA (kg) for ages 3 and 5 (upper panel) and 7 and 9 (lower panel) between haddock from Bay of Fundy (BoF) strata (482-495) and western Scotian Shelf (SS) strata (470-481), 1985-2013.

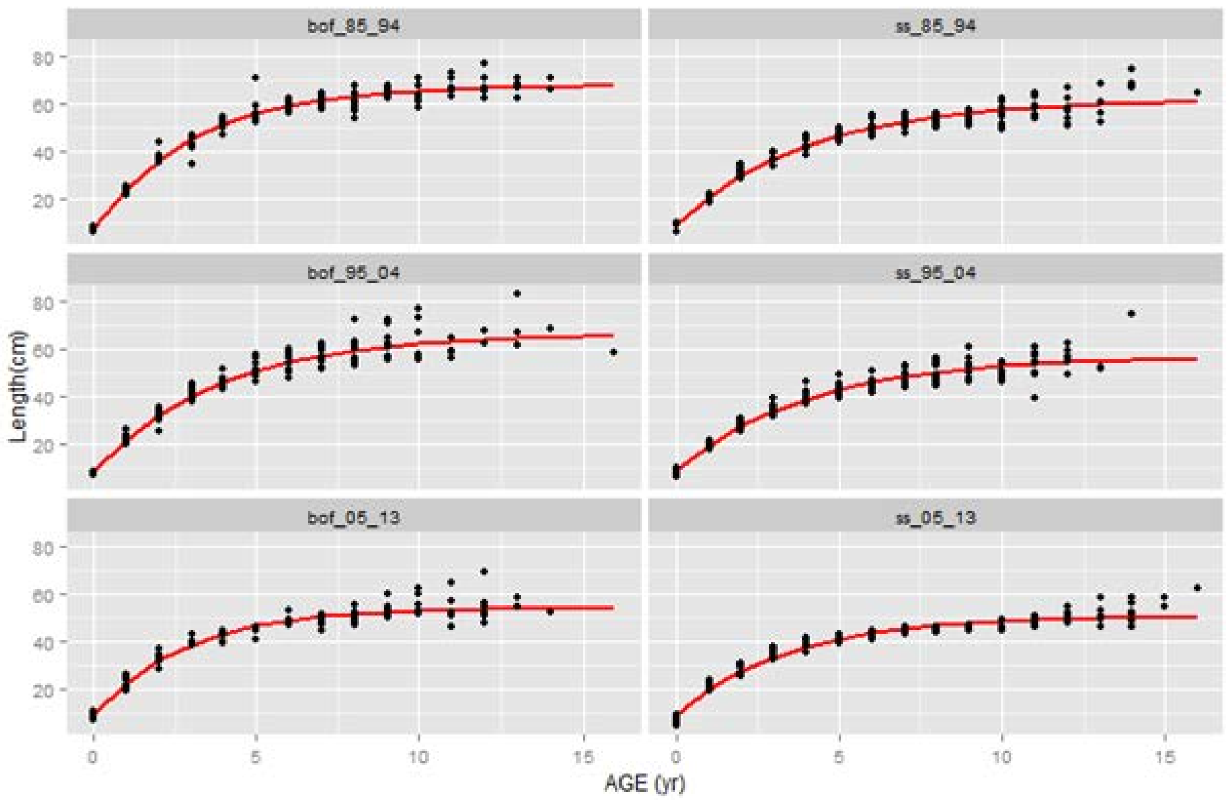


Figure 37. Decadal mean length-age (black dots) for 4X5Y haddock from the DFO summer survey (1985-1994, 1995-2004, 2005-2013) calculated separately for Bay of Fundy (bof) and Scotian Shelf (ss) strata, and the estimated decadal Von Bertalanffy growth curve (red line) for the LAA distribution.

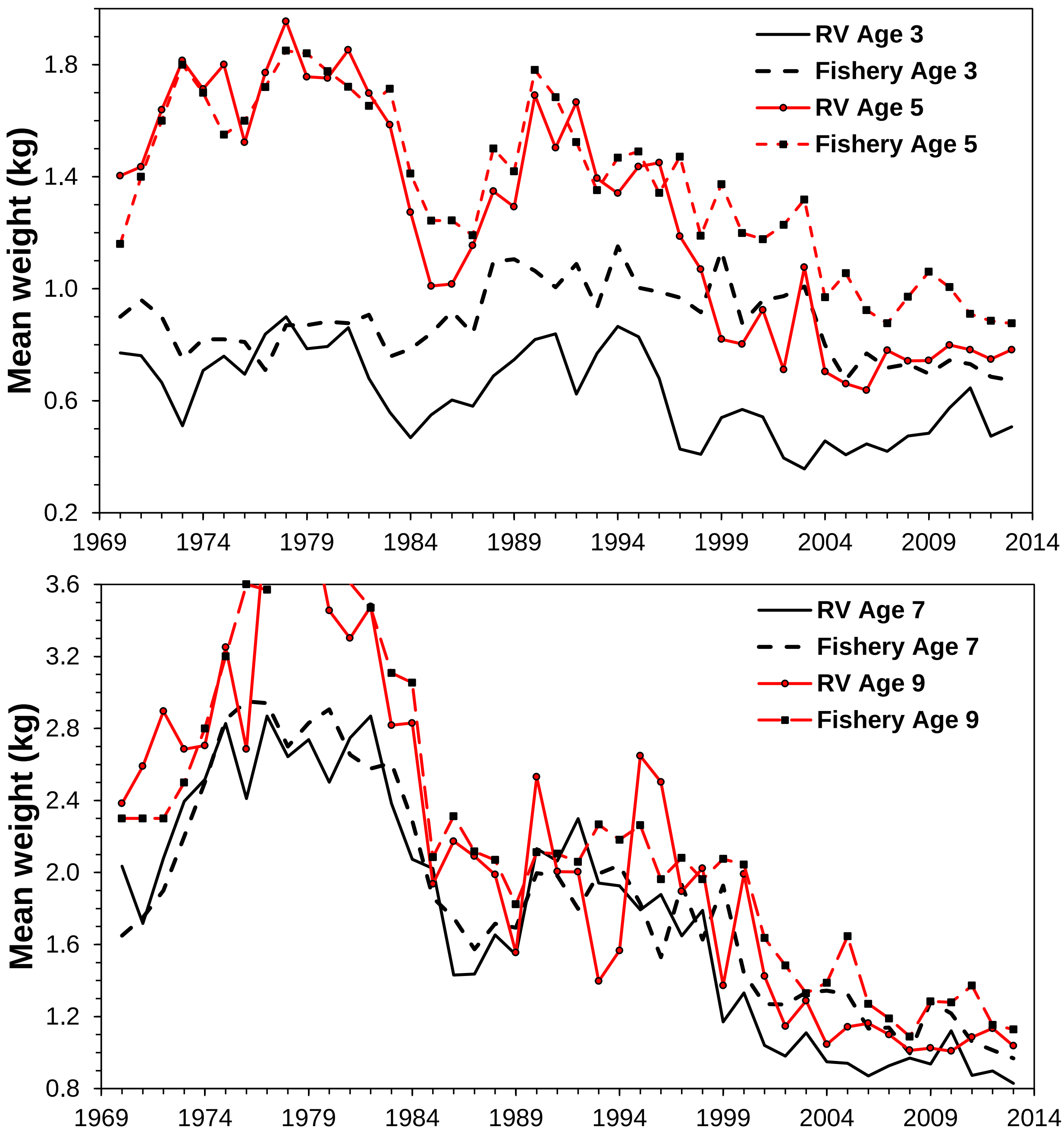


Figure 38. Comparison of summer survey and commercial fishery mean WAA (kg) for ages 3 and 5 (upper panel) and 7 and 9 (lower panel) for haddock from the 4X5Y management area, 1970-2013.

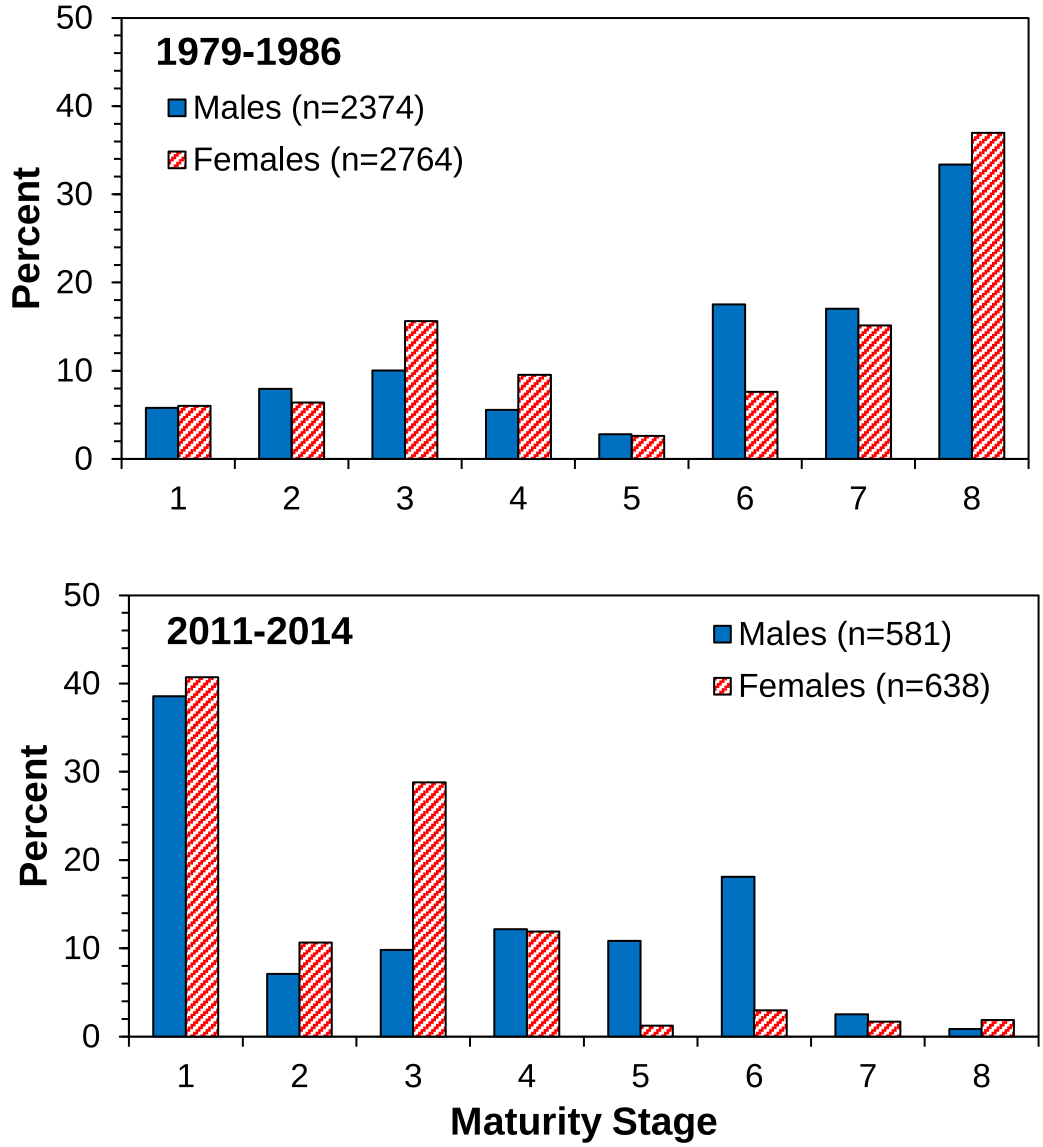


Figure 39. Maturity stages of male and female haddock (based on the Groundfish Maturity Schedule) sampled from DFO spring surveys conducted in 4X5Y from 1979-1986 (upper panel) and 2011-2014 (lower panel). Maturity stage data has been aggregated for each time period. n = sample size.

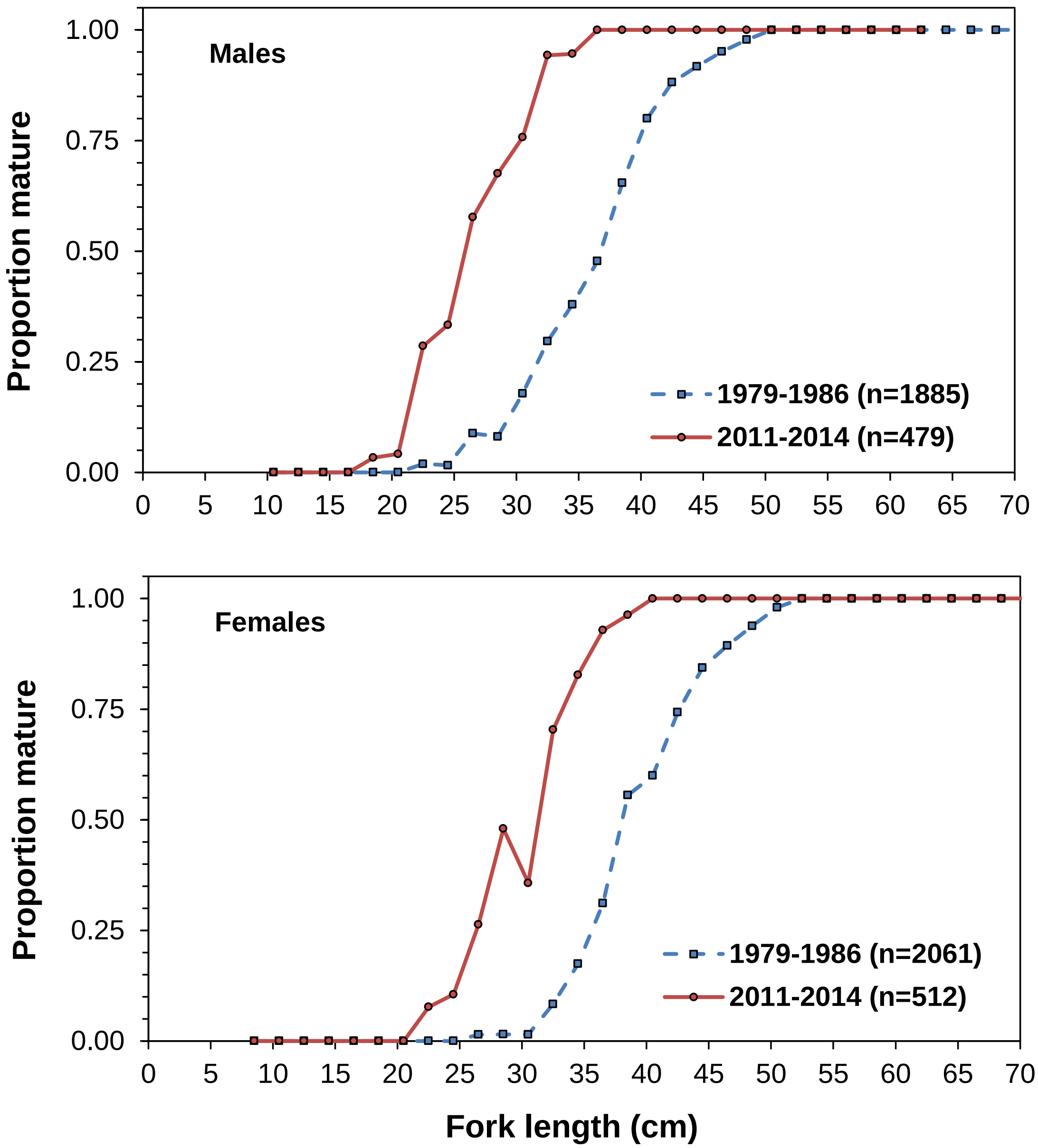


Figure 40. Proportion mature (stages 2-8) at length for male (upper panel) and female (lower panel) haddock sampled from DFO spring surveys conducted in 4X5Y from 1979-1986 and 2011-2014. Maturity at length data has been aggregated for each time period. This analysis was based on sampled fish and was not scaled to population level.

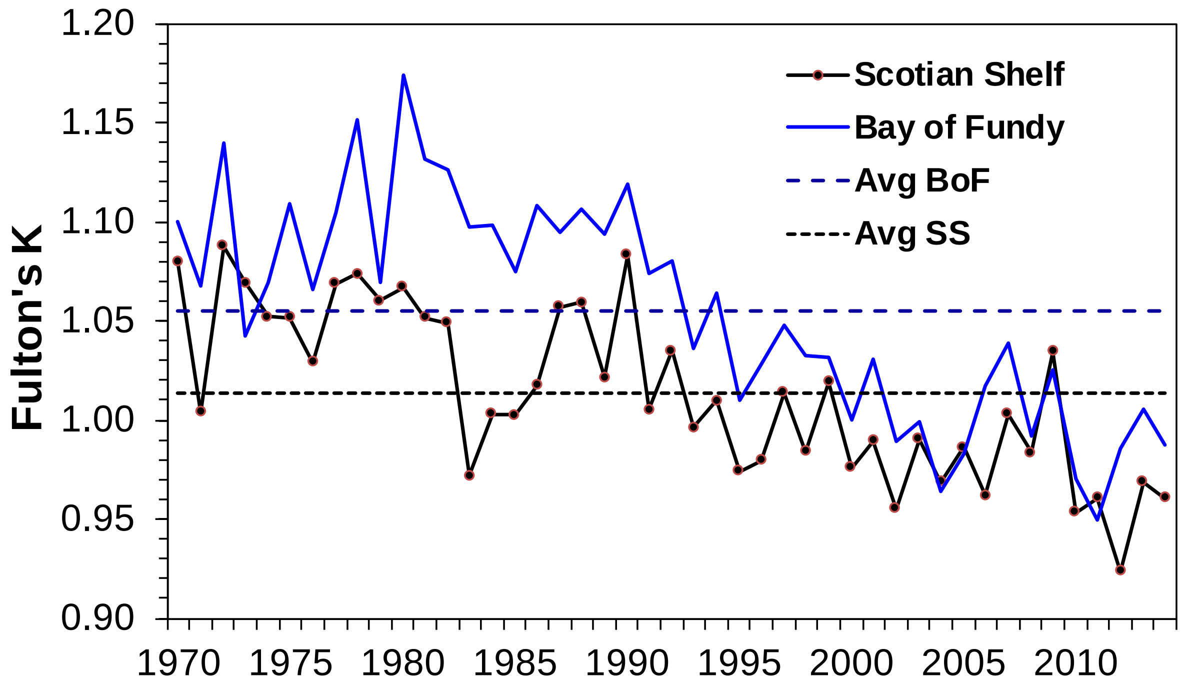


Figure 41. Comparison of Fulton's condition factor (weight/length^3) for 28-55cm haddock from the Bay of Fundy (BoF) and the western Scotian Shelf (SS) sampled during the summer survey, 1970-2014. Dashed lines indicate the average values for the 44 year time series (Bay of Fundy: 1.055; western Scotian Shelf: 1.013).

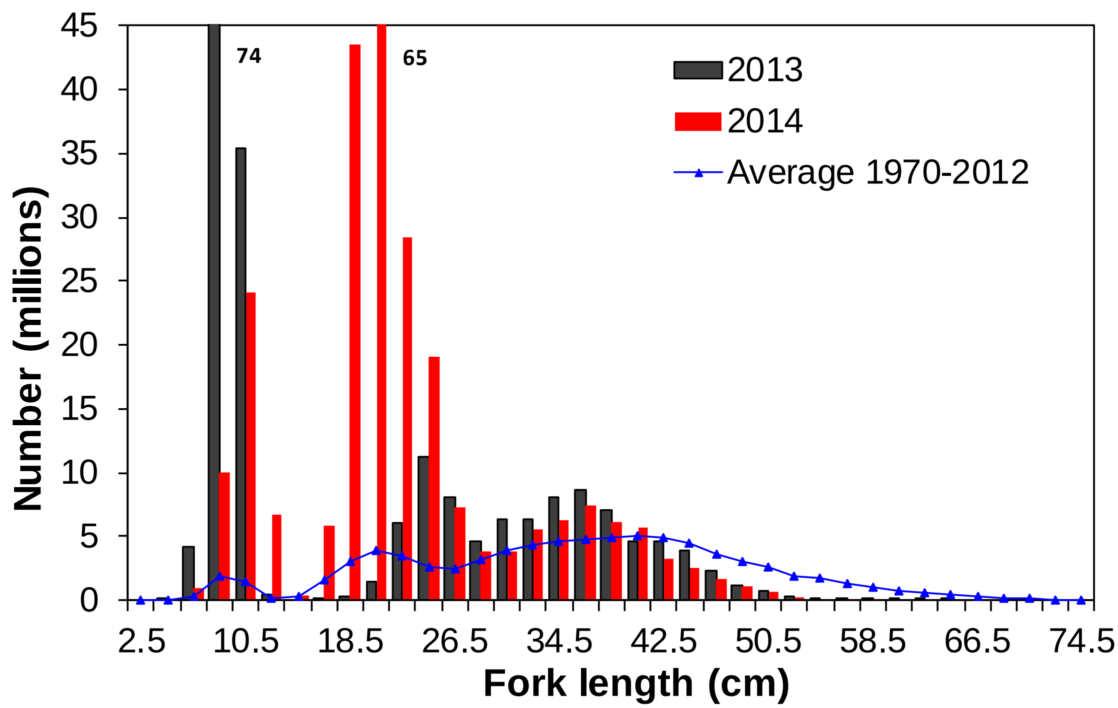


Figure 42. Length stratified total number (millions) for 4X5Y haddock from DFO summer survey strata 470-495 for 2013 and 2014 compared to the average for 1970-2012.

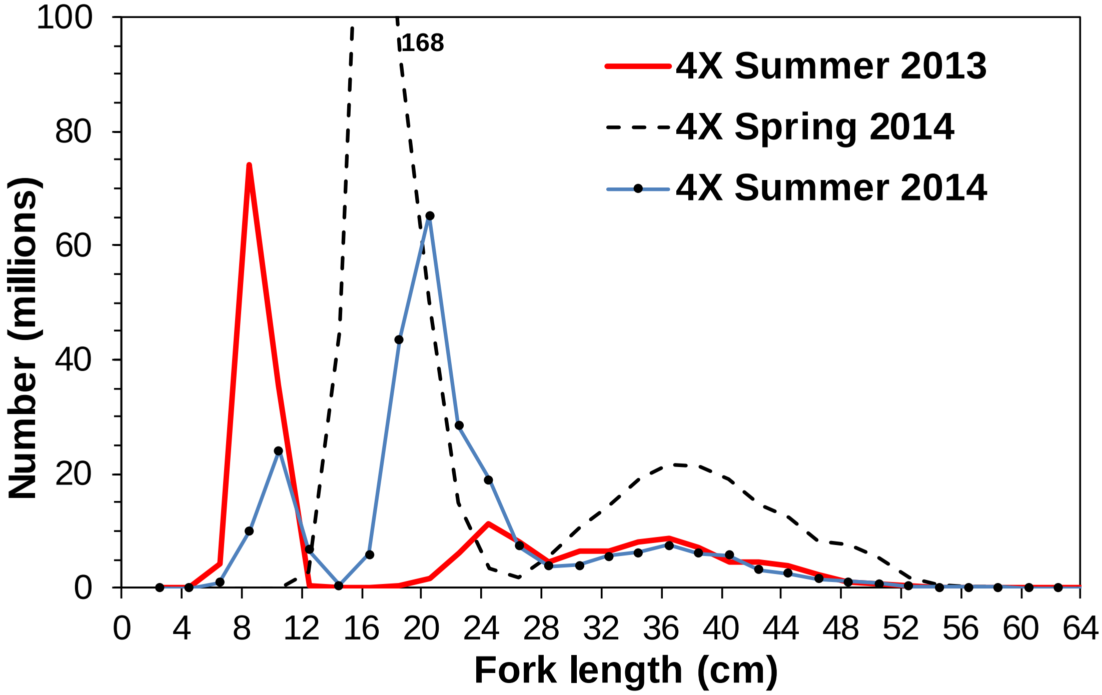


Figure 43. Length stratified total number (millions) for 4X5Y haddock from three DFO surveys: 2013 summer, 2014 spring and 2014 summer.

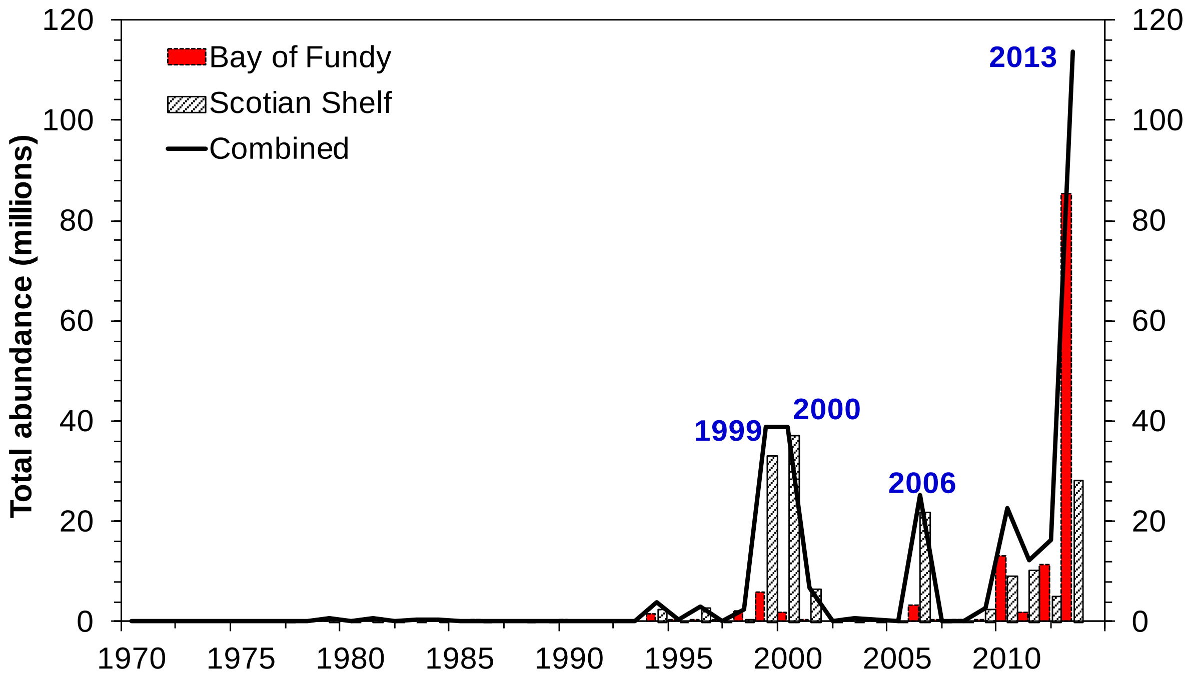


Figure 44. Total abundance index (millions) of age 0 haddock from the DFO summer survey for the Bay of Fundy (strata 482-495) and western Scotian Shelf (strata 470-481) areas, 1970-2013.

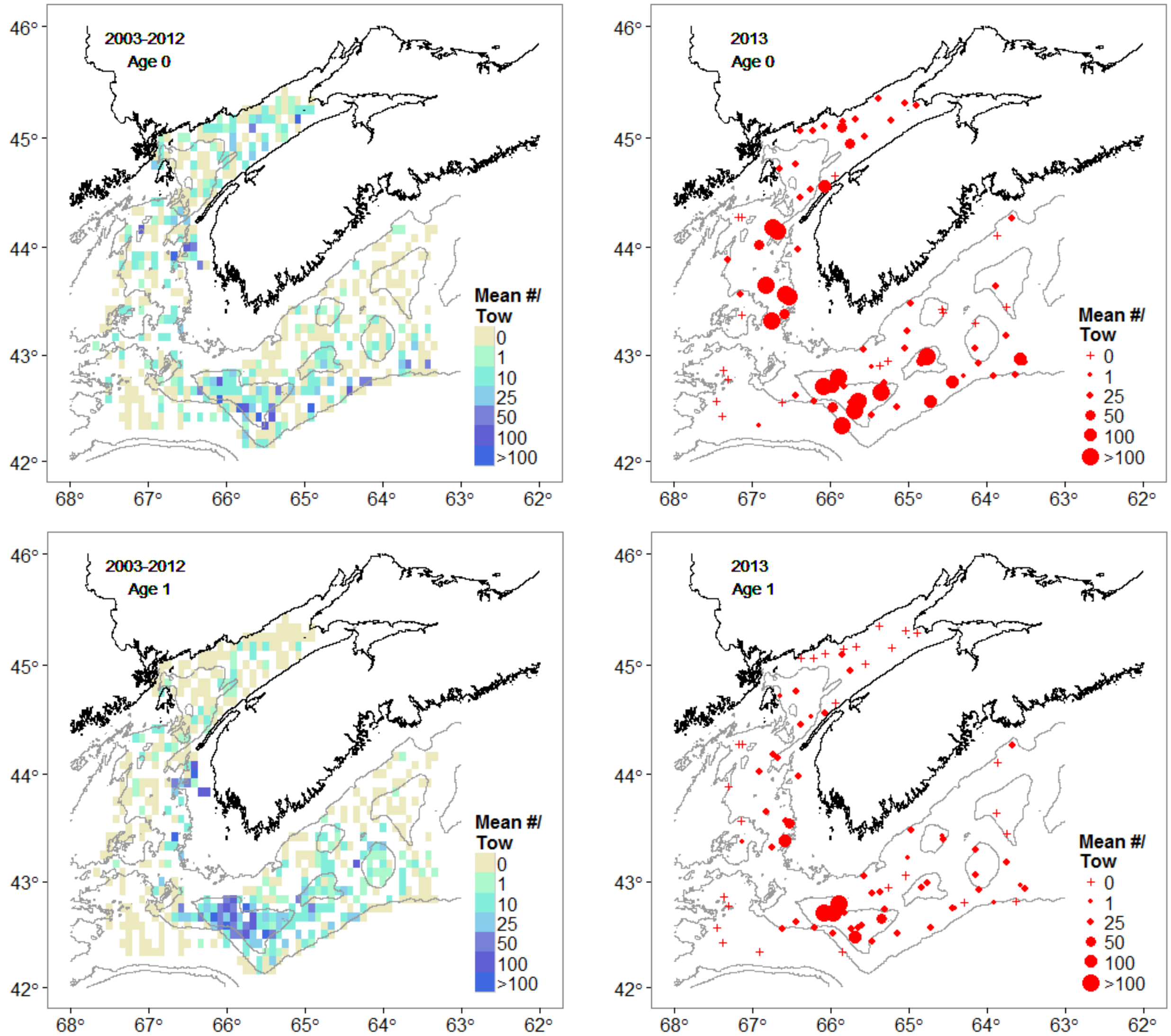


Figure 45. Distribution of 4X5Y haddock catches (mean number/tow) at age 0 (upper panels) and age 1 (lower panels) from the DFO summer survey. Left panels show previous 10-year averages (2003-2012); right panels most recent data (2013).

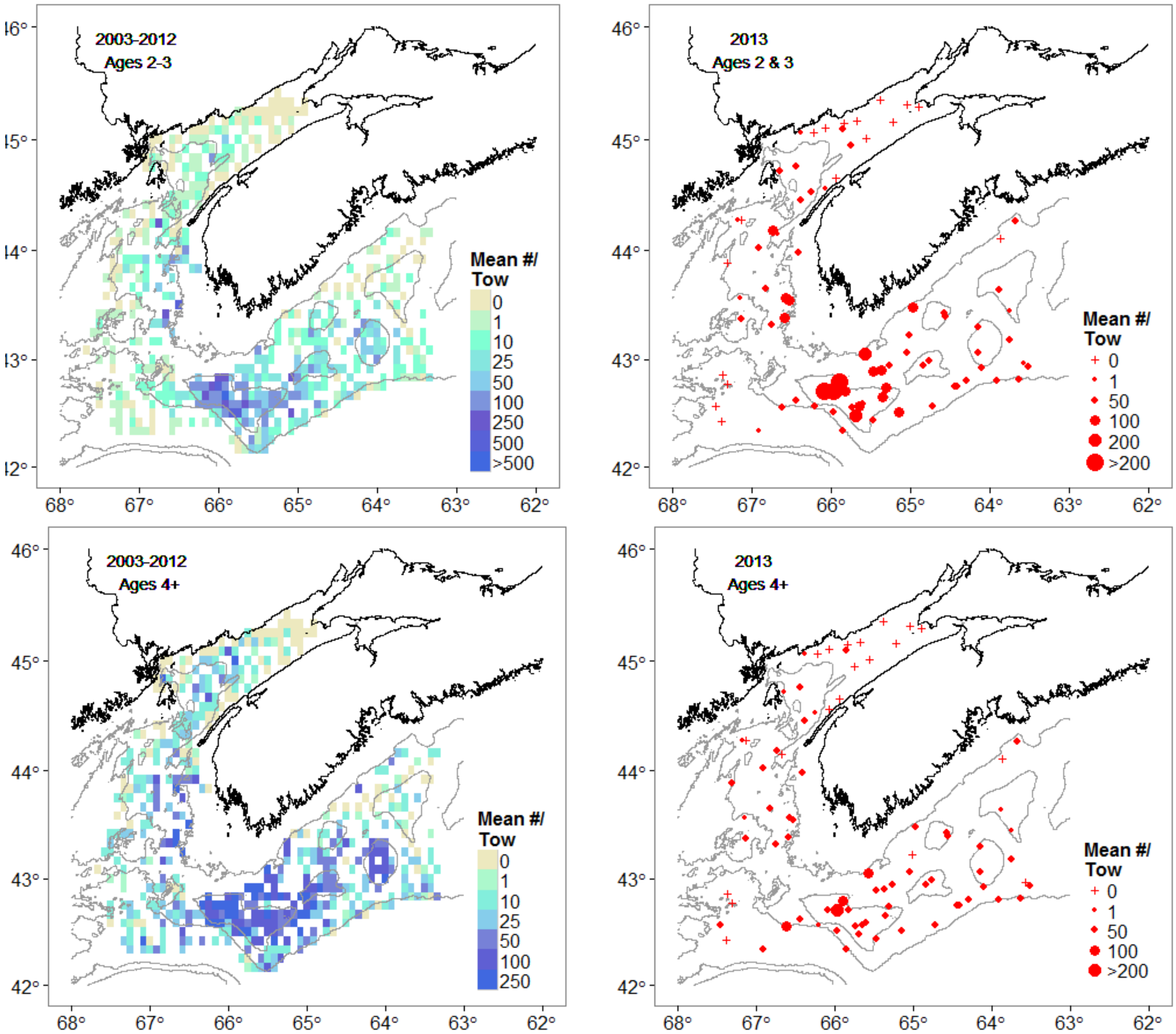


Figure 46. Distribution of 4X5Y haddock catches (mean number/tow) at ages 2-3 (upper panels) and ages 4+ (lower panels) from the DFO summer survey. Left panels show previous 10-year averages (2003-2012); right panels most recent data (2013).

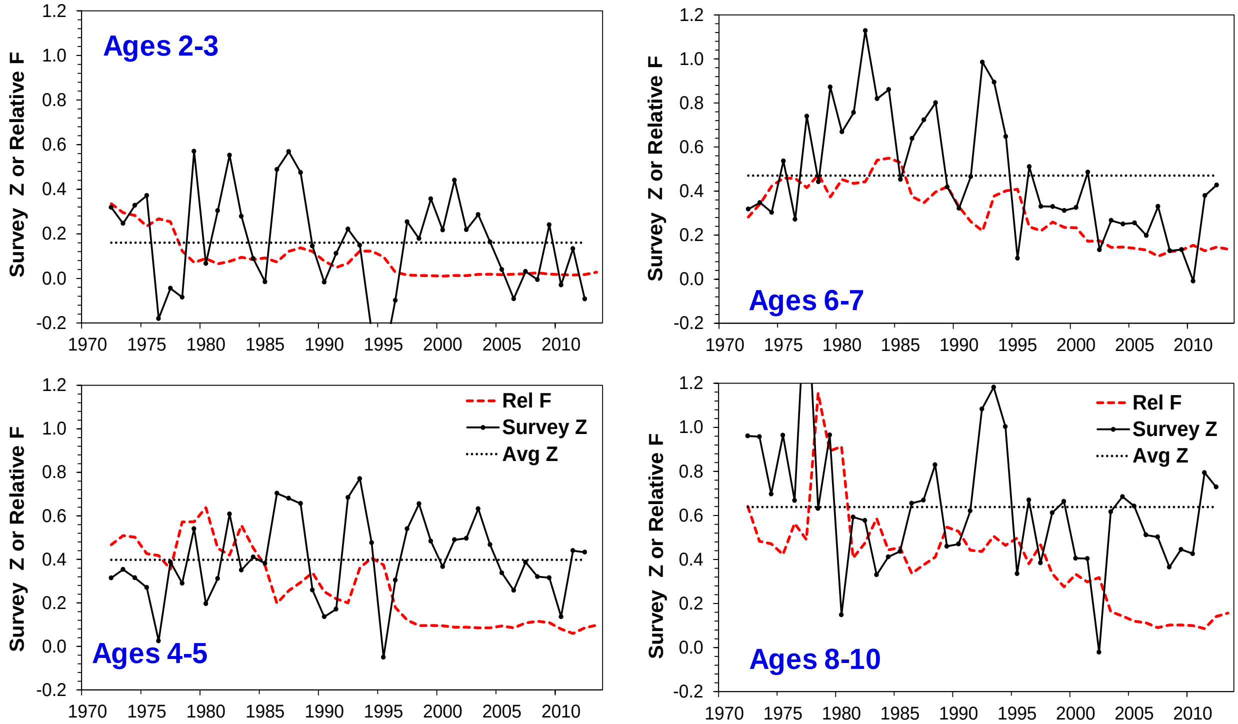


Figure 47. Total mortality (Survey Z) and relative fishing mortality (Rel F) for 4X5Y haddock age groups 2-3, 4-5, 6-7 and 8-10 for 1970-2013. Survey Z was calculated from DFO summer survey CAA data, while relative F was based on fishery CAA/survey CAA for each age group. The dashed line is the average Z (Avg Z) for each age group.

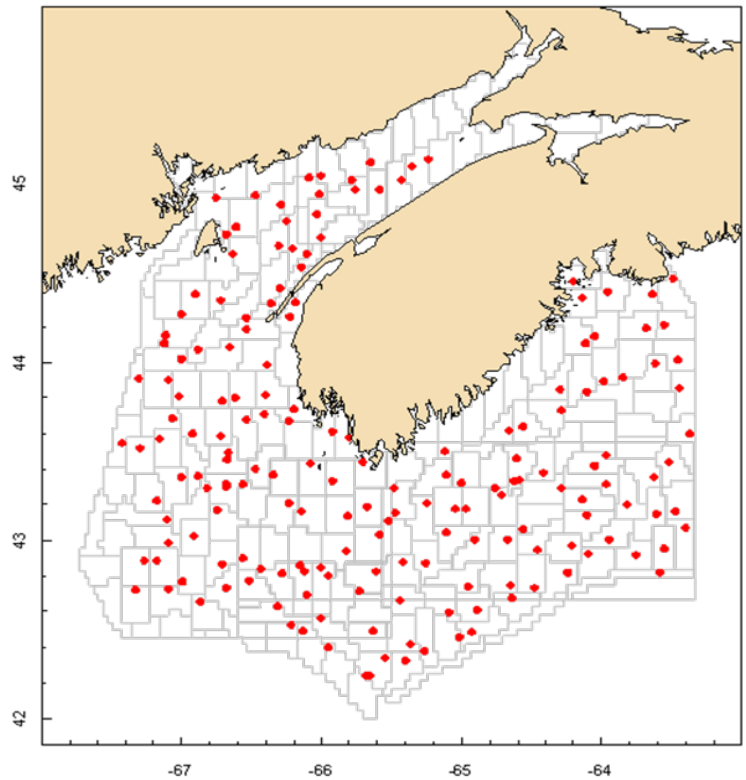


Figure 48. Location of grid blocks and fixed set locations within each used for the 4X ITQ fixed station industry survey.

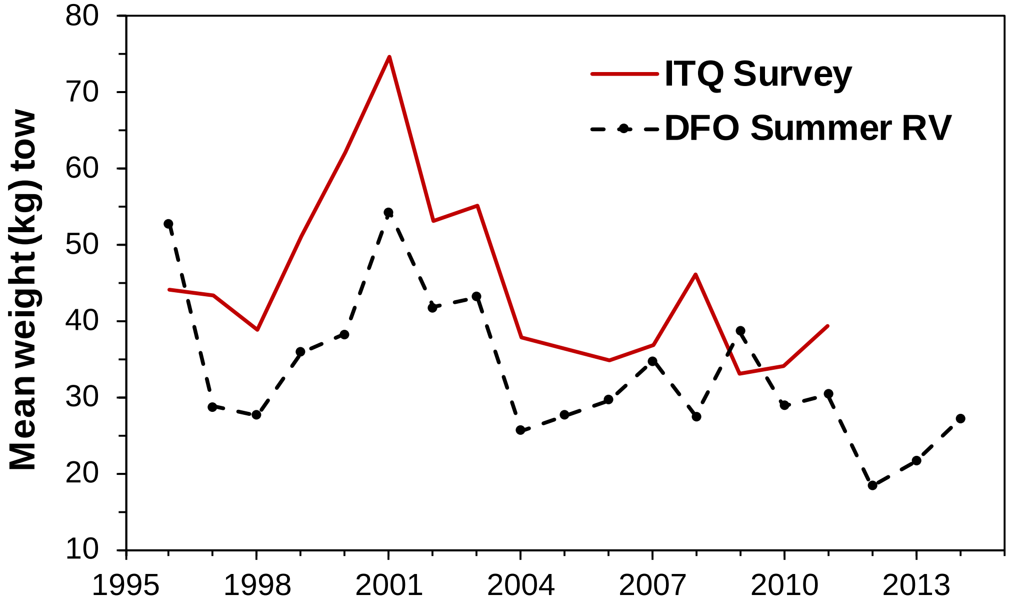


Figure 49. Trends in biomass (mean weight (kg)/tow) for 4X5Y haddock from the ITQ survey, 1996-2011, and the DFO summer survey, 1996-2014.

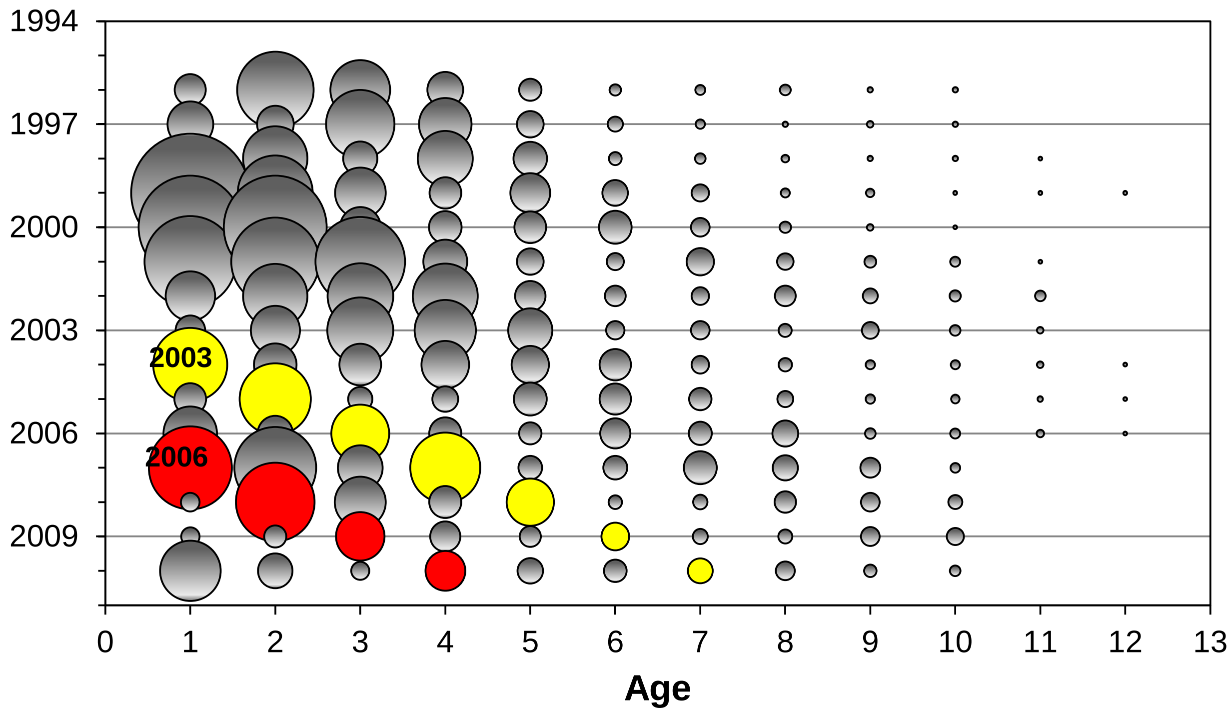


Figure 50. Stratified total number per tow at age (1-12) for 4X5Y haddock from the ITQ survey, 1996-2010. Recent strong year classes are indicated by the yellow (2003) red (2006) and black (2010) circles. The area of the circle is proportional to the catch at that age and year.

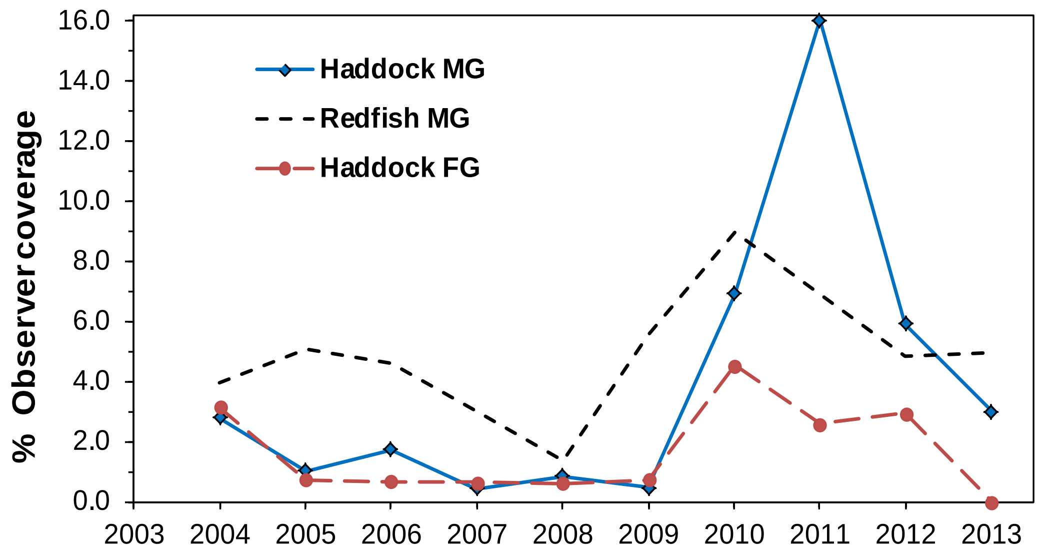
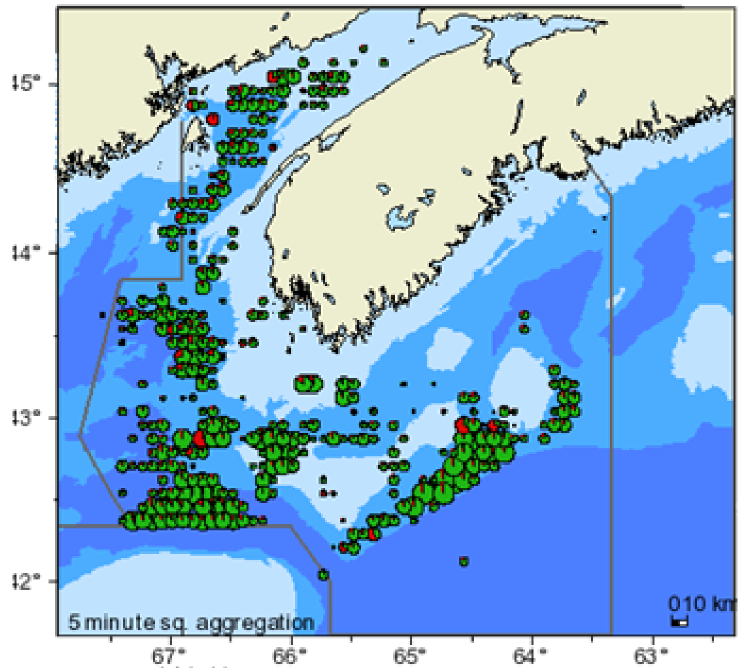


Figure 51. Annual percentage of observer coverage for haddock-directed fisheries (mobile and fixed gear) and haddock bycatch fisheries (redfish-directed mobile gear) in 4X5Y, 2004-2013.



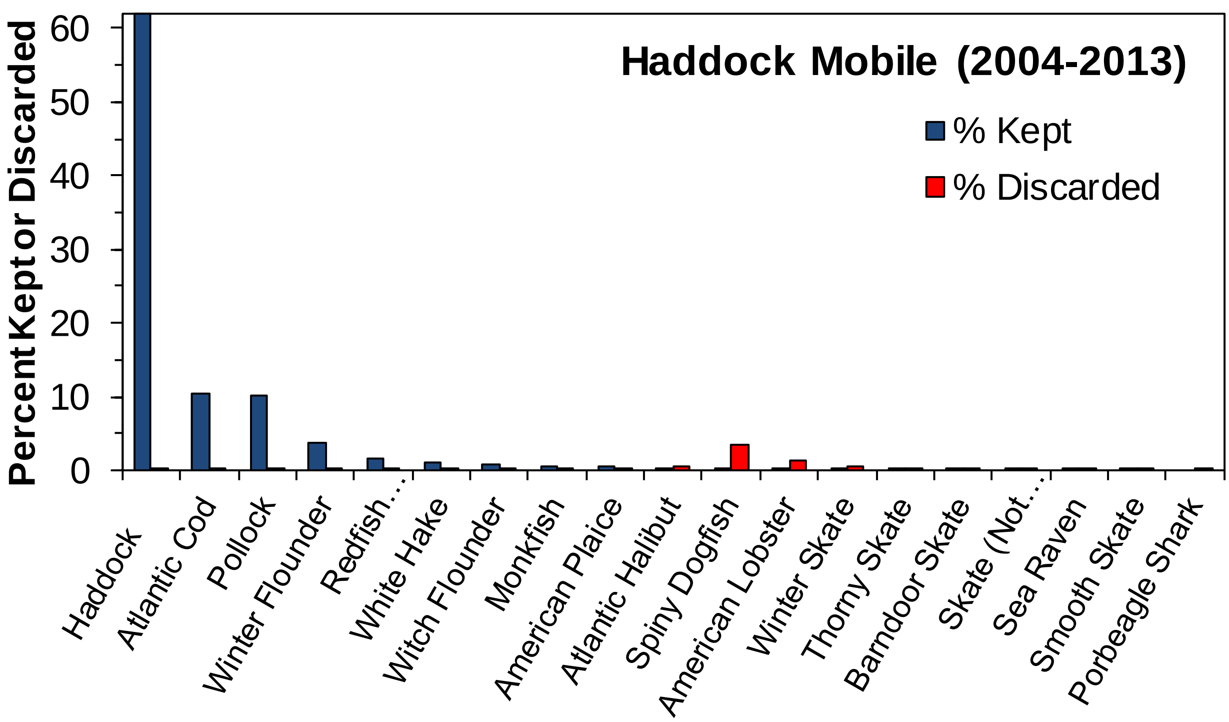


Figure 52. Kept vs discarded bycatch reported for 2004-2013 combined observed trips in 4X5Y from haddock-directed mobile gear trips. Top panel: observed set locations; bottom panel: percentage of catch kept and discarded by species.

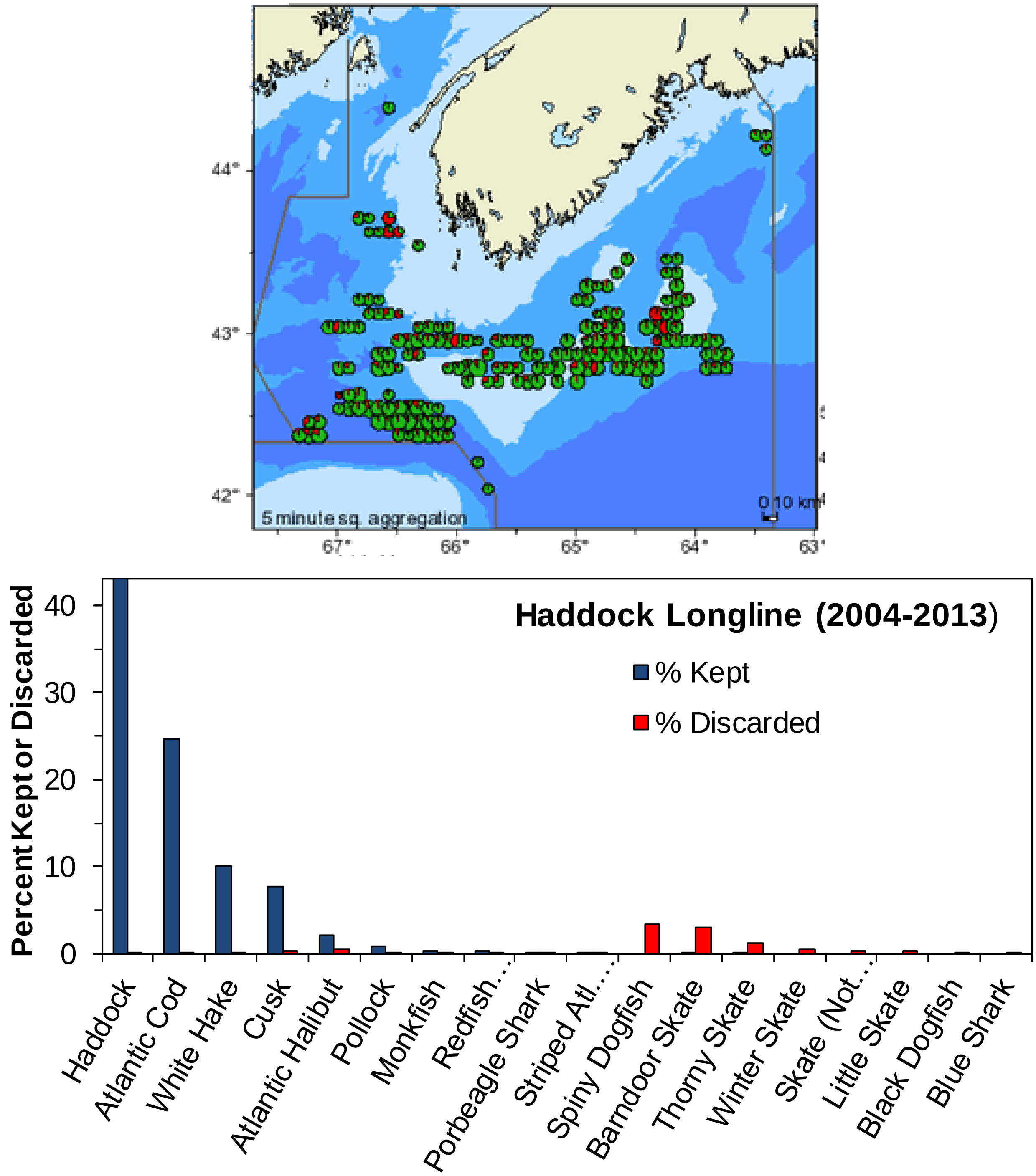
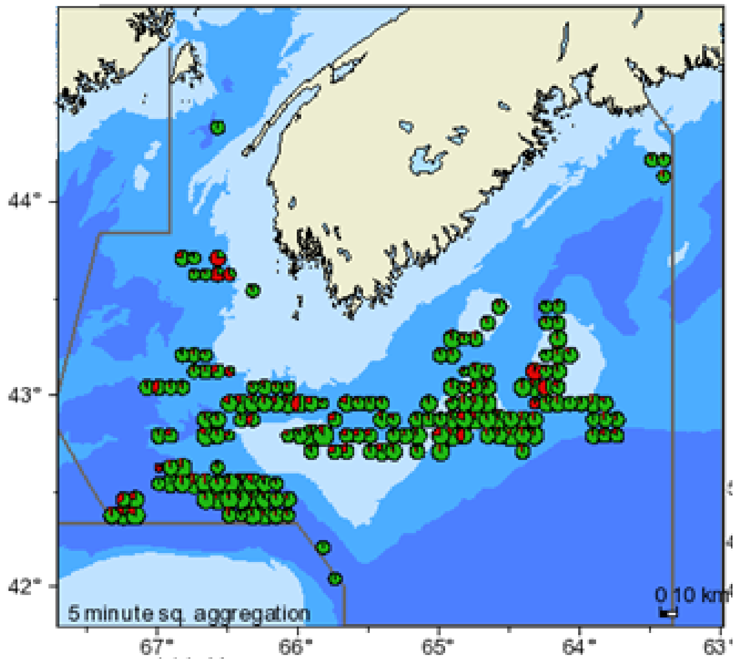


Figure 53. Kept vs discarded bycatch reported for 2004-2013 combined observed trips in 4X5Y from haddock-directed fixed gear trips. Top panel: observed set locations; bottom panel: percentage of catch kept and discarded by species.



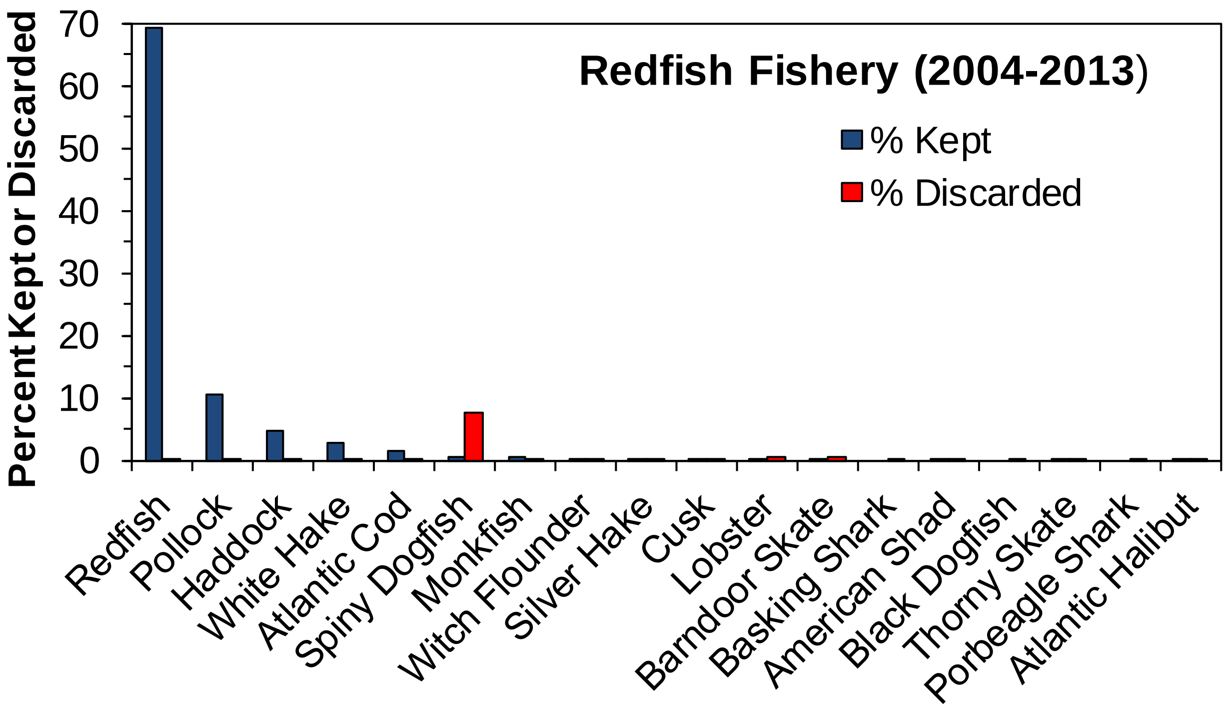


Figure 54. Kept vs discarded bycatch reported for 2004-2013 combined observed trips in 4X5Y from redfish-directed mobile gear trips. Top panel: observed set locations; bottom panel: percentage of catch kept and discarded by species.

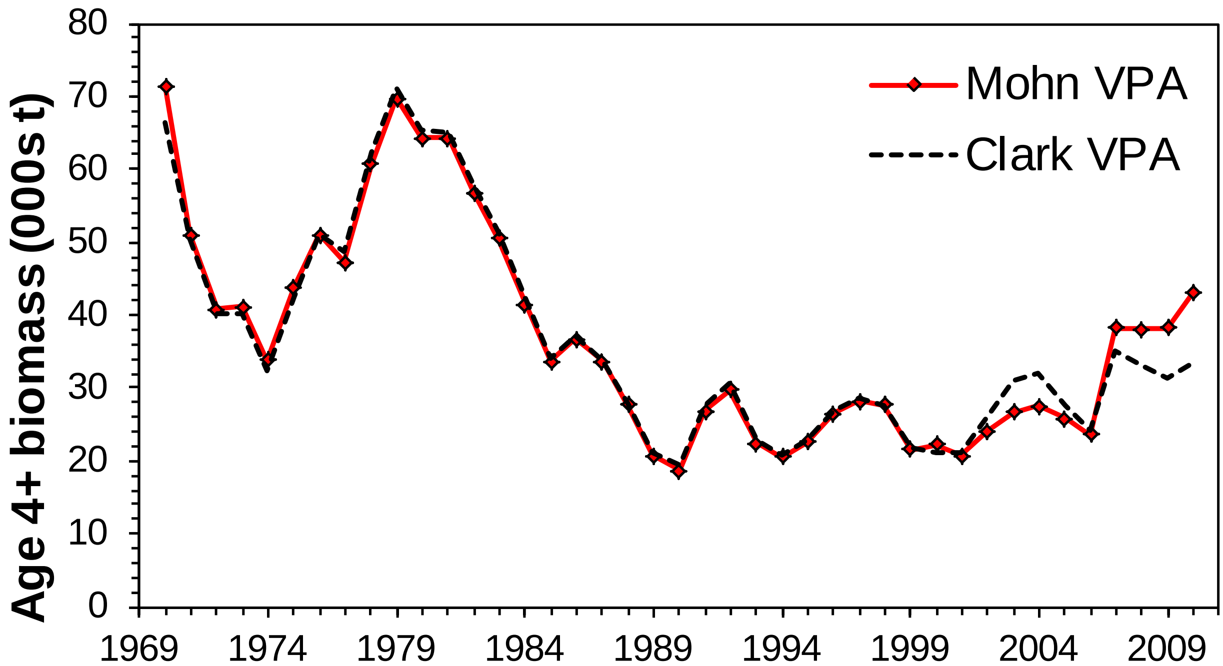


Figure 55. Comparison of trends in age 4+ population biomass using the VPA model formulations from ACON (Mohn VPA) and ADAPT (Clark VPA) from the 2012 assessment. Both models use slightly different approaches for estimating F on the oldest ages.

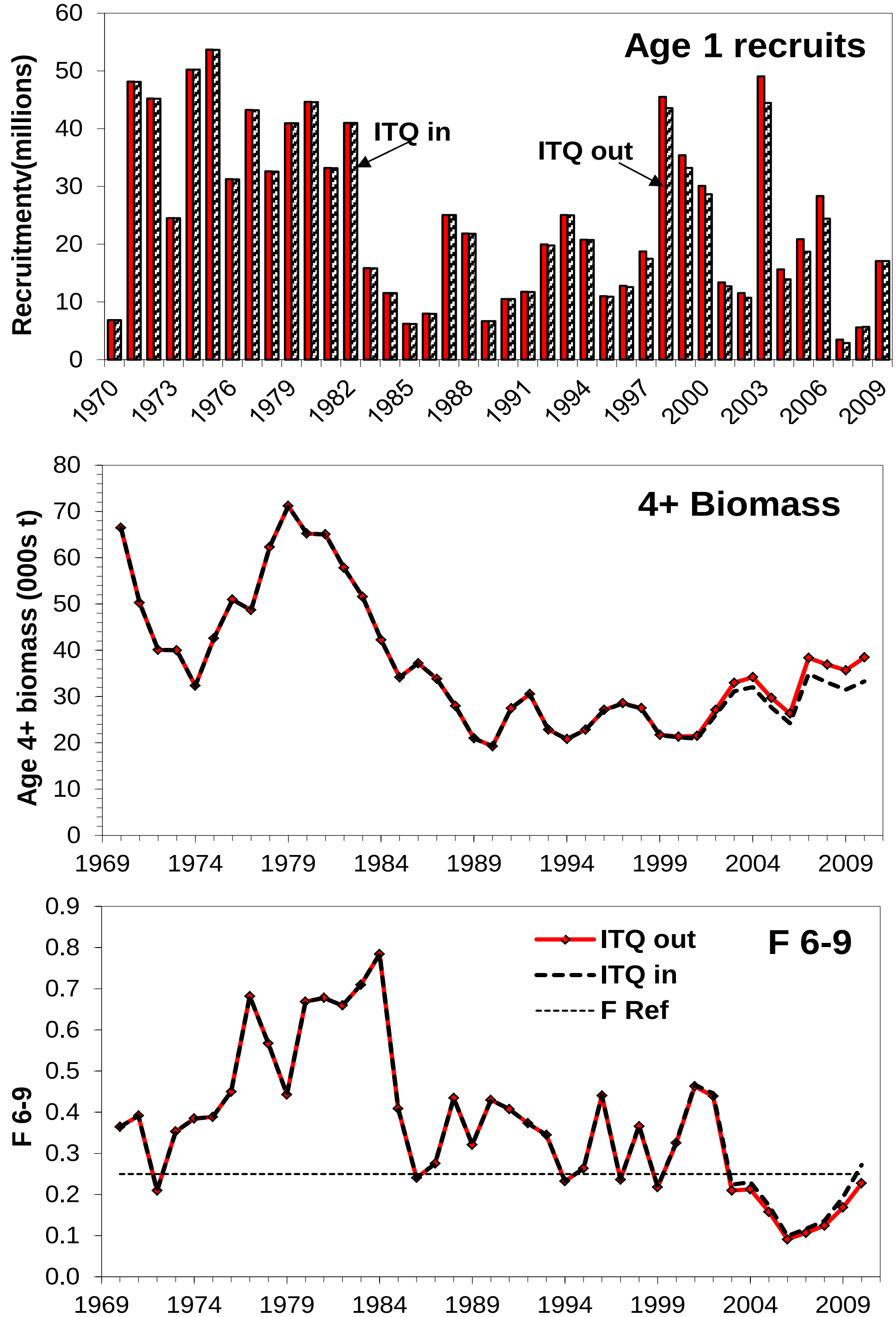


Figure 56. Comparison of trends in age 1 recruitment, 4+ biomass and ages 6-9 fishing mortality for 4X5Y haddock from the ADAPT Base VPA model formulation of Clark with and without the ITQ survey age-specific indices of abundance.

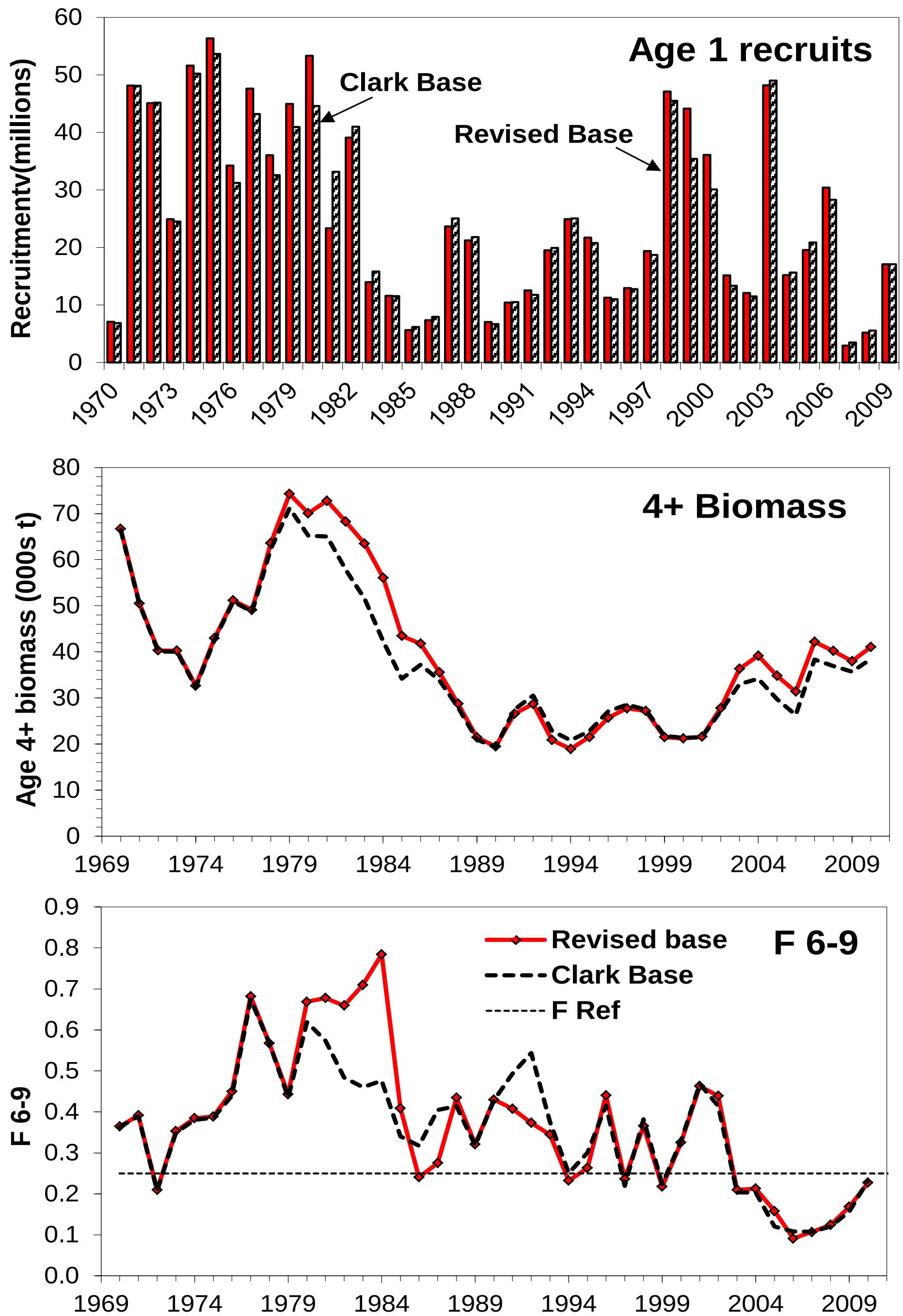


Figure 57. Comparison of trends in age 1 recruitment, 4+ biomass and ages 6-9 fishing mortality for 4X5Y haddock from the ADAPT Base VPA model formulation of Clark and the Revised Base Model (i.e. new ageing (1985-1989), 2cm groupings and revised summer survey indices).

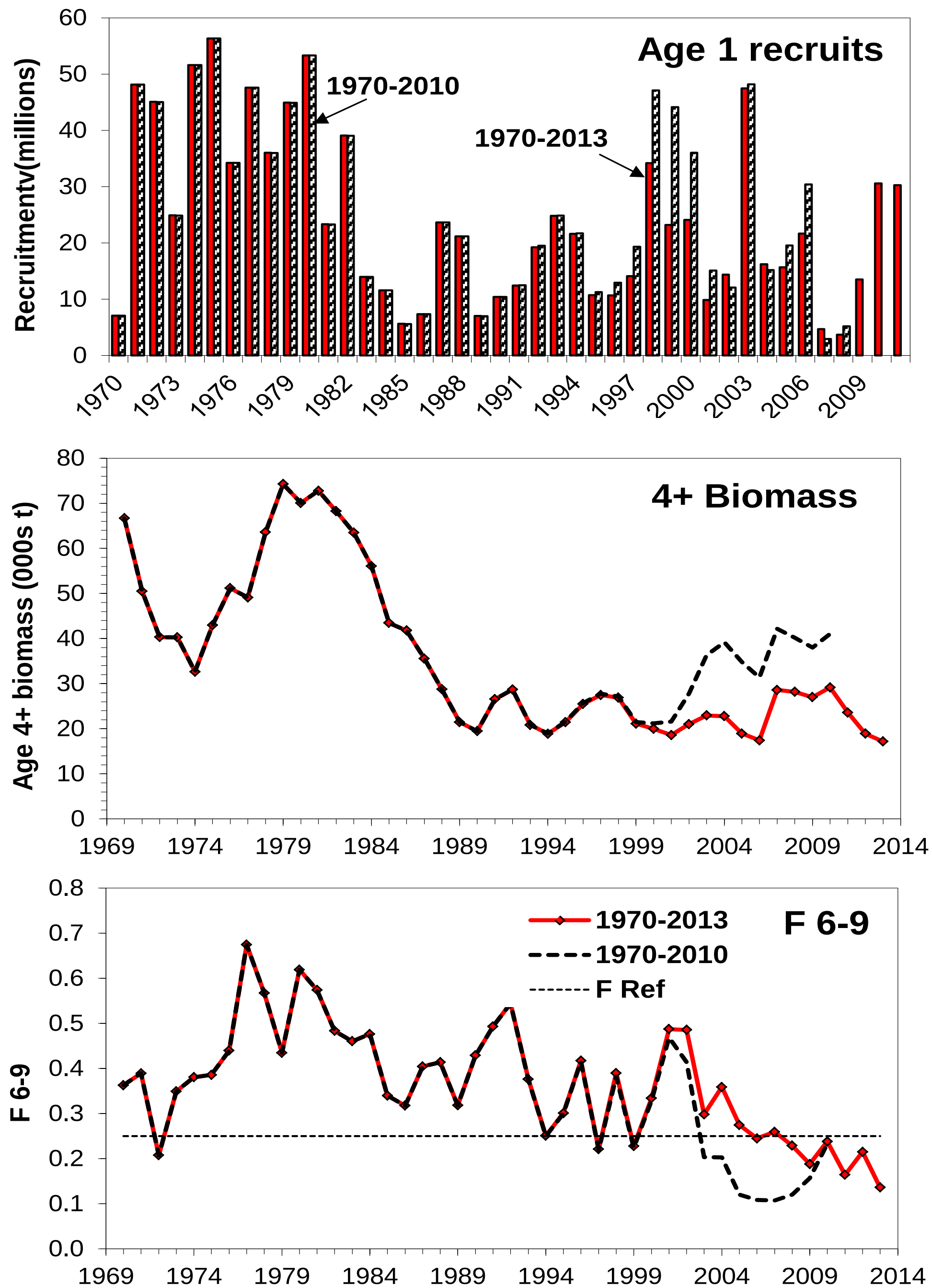


Figure 58. Comparison of trends in age 1 recruitment, 4+ biomass and ages 6-9 fishing mortality for 4X5Y haddock from the ADAPT Base VPA model formulation of Clark using the original (1970-2010) and extended (1970-2013) time series, each with revised data (i.e. new ageing (1985-1989), 2cm groupings and revised summer survey indices for ages 2-13).

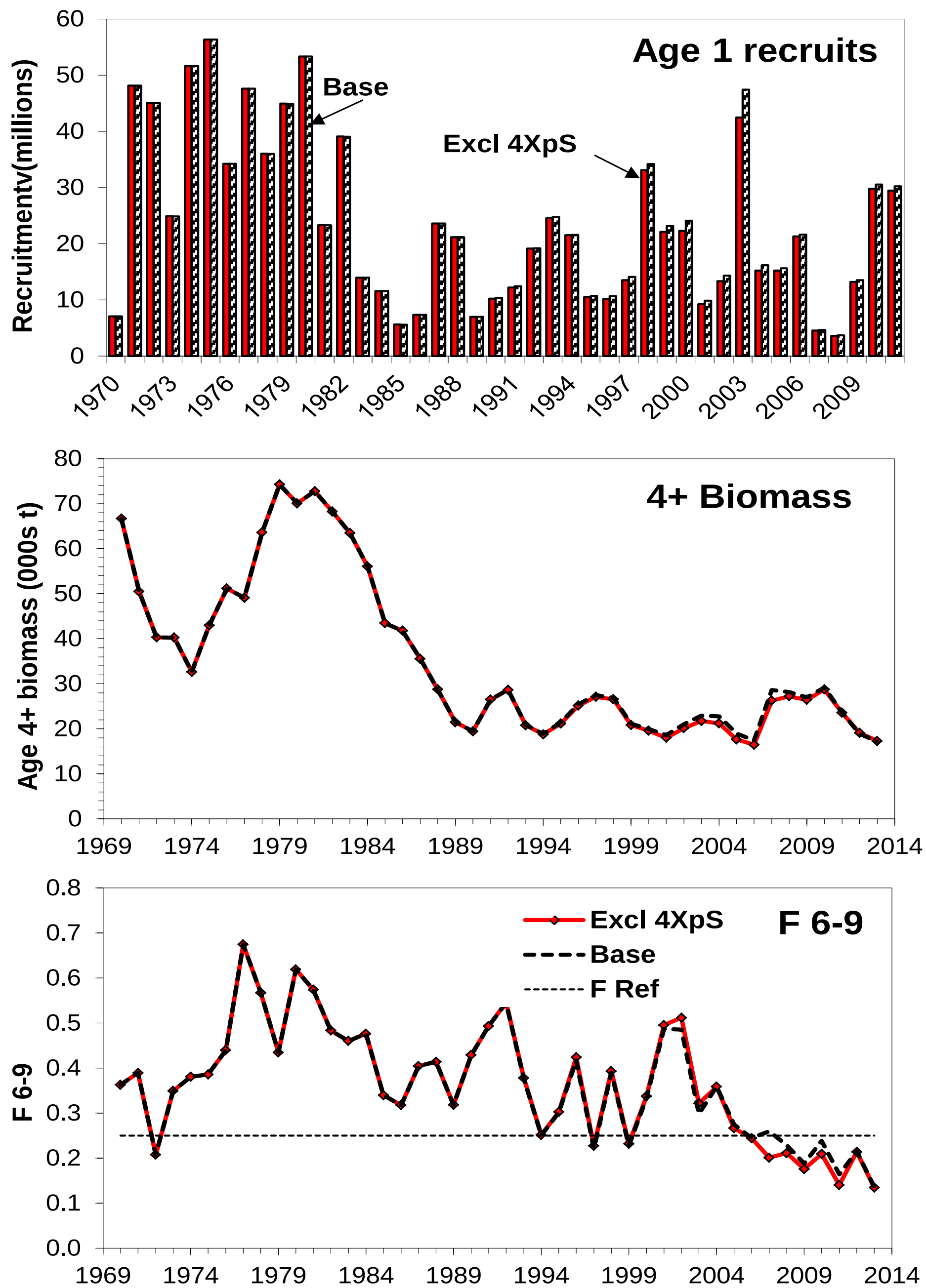


Figure 59. Comparison of trends in age 1 recruitment, 4+ biomass and ages 6-9 fishing mortality for 4X5Y haddock from the ADAPT Base VPA model formulation of Clark using the extended time series (1970-2013) that includes (Base) or excludes (Excl 4XpS) landings, port sample length frequencies and ages from 4Xp south.

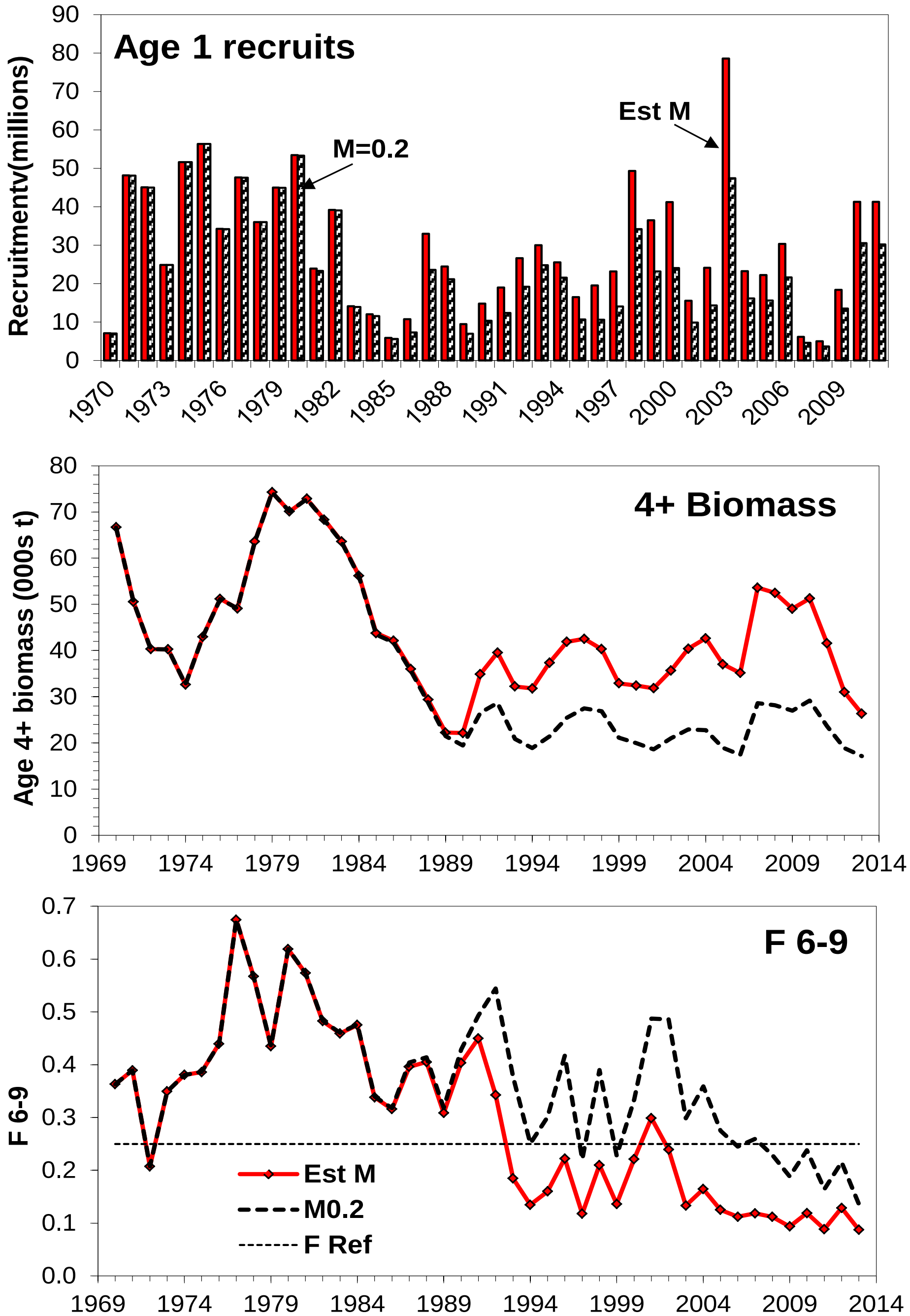


Figure 60. Comparison of trends in age 1 recruitment, 4+ biomass and ages 6-9 fishing mortality for 4X5Y haddock from the ADAPT Base VPA model formulation of Clark with M=0.2 for 1970-2013, and a model formulation which estimates M for ages 8+ from 1995 to 2013.

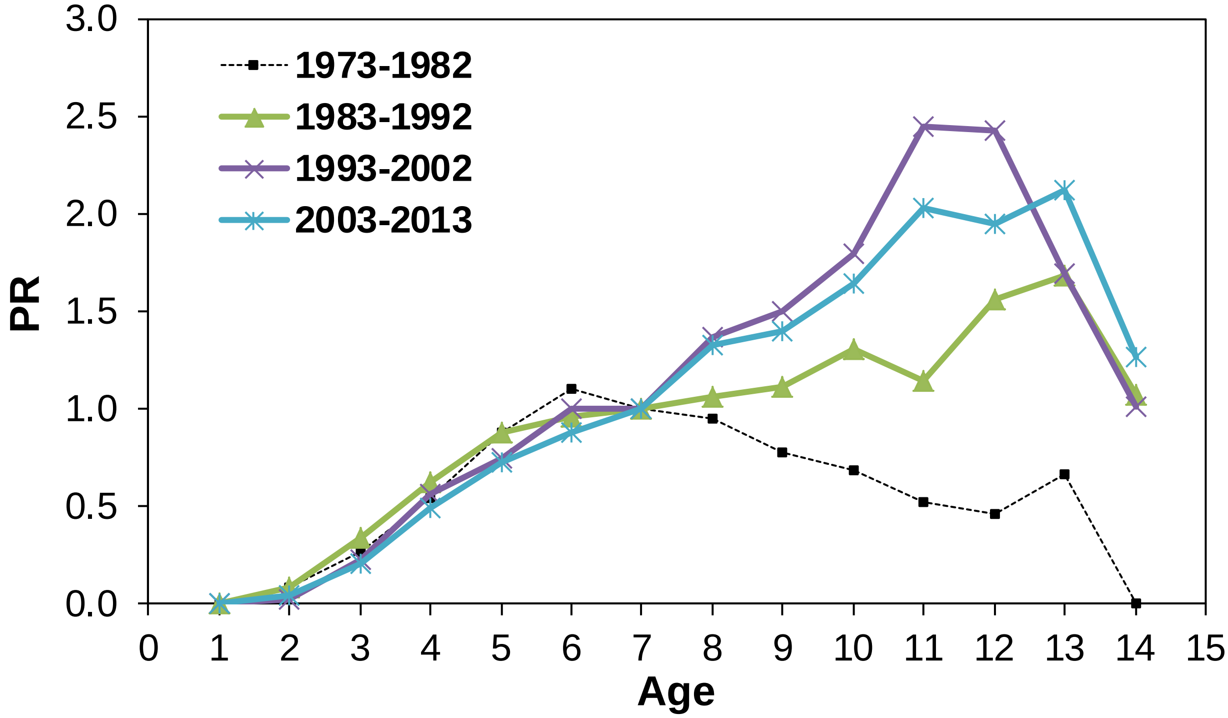


Figure 61. Comparison of trends in partial recruitment (PR) for four 10-year periods (1973-1982, 1983-1992, 1993-2002, 2003-2013) based on F calculations from the ADAPT Base VPA using the revised input data series, ages 1-14.

APPENDICES

Appendix I. A brief history of 4X5Y haddock stock assessments based on a review of published Research Documents published by the Canadian Science Advisory Secretarial (CSAS) from 1974-2010.

- Biological evaluations prior to 1974 involved examination of trends in commercial catch rates and/or survey abundance indices.
- Sequential Population Analysis (SPA) first used by Halliday (1974).
- Comparing methods in pre-1980 assessments is complicated by the use of different terms. 'SPA' is not mentioned, yet O'Boyle (1981) states that it has been in use since 1974. It is referred to as a 'Cohort Analysis' by O'Boyle et al. (1983).
- Mean LAA and selectivity ogives used to calculate partial recruitment (PR; O'Boyle 1978)
- Rivard (1980) introduced the Survivor Method to tune the SPA in a more objective manner and make the choice of terminal fishing mortality a more objective process.
- Two SPA procedures used in 1981: (1) survivor method, and (2) utilizing the survey information in cohort analysis (i.e. linearity between cohort analysis results and survey data taken as the criterion for good fit). These two methods are described in detail in O'Boyle (1981). The second method was also used previously. In general, the Cohort Analysis leads to lower estimated terminal fishing mortalities than the Survivor Analysis (O'Boyle et al. 1983).
- O'Boyle et al. (1981) convert selectivity ogives and ALKs to PR patterns.
- O'Boyle and White (1982): Mixture of Survivor and SPA methodology; growth trends also analysed.
- O'Boyle et al. (1983): Survivor method (aka Survivor analysis) and Cohort analyses. Vessel conversion factors (1.2) introduced. Multiplicative Model of Gavaris (1980) used to adjust for differences in catch rates.
- Method for tuning the analysis: in 1983 and earlier, maximization of the r^2, and proximity of the intercept to the origin; in 1984, minimization of the residual of the last point; in 1985, minimization of the residuals of the last 3 points in time and along a cohort.
- O'Boyle and Gregory (1985): Attempted various transformation procedures rather than removing large sets from the data or using a Winsorizing technique (past methods).
- O'Boyle and Wallace (1986): "a number of new technical innovations were introduced". Transformed ("delta transformation") and untransformed data, and two models: logarithmic and linear. Minimization of all standardized residuals.
- O'Boyle and Wallace (1987): Survivor method discontinued; delta transformation discontinued, arithmetic mean used instead (survey), and log transformation for homogeneity of variance in SPA. Non-linear least squares (NLLS) procedure (Newton-Raphson numerical technique) used. Reference to a "cohort minimization procedure" in O'Boyle et al. (1988).
- O'Boyle et al. (1988): Survey data again untransformed. Cohort minimization procedure dropped and replaced with more flexible (but similar) ADAPT framework approach. Still using multiplicative model for catch/effort data. Med 3R method used to smooth arithmetic mean catch rates. Intercept dropped from calibration model. Flat-topped PR ogive assumed in calibration, but evidence suggests dome-shaped PR. One projection for flat-topped exploitation and one for dome-shaped exploitation.

- O'Boyle et al. (1989): ADAPT framework. Contradictory description on whether log transform was used. No intercept. Calibrated with survey data only, as per usual. Mid-year population #s used and total catch assumed to be uniform throughout the year. Flat-top model of PR used again.
- Frank et al. (1990): Problems with the ADAPT formulation (strong retrospective pattern in F), therefore, SPA not reported. Total mortality calculated by Paloheimo's method.
- Hurley et al. (1991): ADAPT formulation problems not yet resolved, therefore, SPA not to be used for harvest advice. Total mortality calculated by Paloheimo's method. LFs of haddock bycatch from foreign small mesh gear fishery in 4X examined and used to indicate year class strength.
- Hurley et al. (1992): ADAPT formulation/retrospective problem still not resolved, therefore, no SPA. Smith's (1991) survey efficiency estimator used. Total mortality calculated by Paloheimo's method. Pope's Leapfrog procedure used to project catch.
- Hurley et al. (1994): Ageing criteria being evaluated, no age data available for 92-93. Length-based data and historical growth rates used. Three methods used to convert NAL to NAA:
    - Cohort slicing
    - Kimura-Chikuni (rejected)
    - SP-Key

  Two minimization techniques: NLLS gradient technique (Marquardt algorithm) and Partitioned Search Algorithm.
- Hurley et al. (1995): No age data available for 92-93 (commercial and survey) or 94 commercial. Age data available for a subsample of the 94 survey data (using new ageing criteria). Numbers at length converted to NAA for BoF and SShelf separately due to spatial variation in growth, and then combined within SP-Key model. Four models used to estimate mean LAA:
    - Average
    - Average Linear
    - Average Prorated
    - 94 Ages Prorated

  Minimization technique: NLLS gradient technique (Marquardt algorithm) only.
  Vessel conversion factor of 0.55 (not the 1.2 or 1.22 usually used), improves retrospective pattern.
- Smith (1995): Predicted weight at 50cm (for female haddock; i.e. condition) is the best predictor of recruitment for 4X haddock.
- Hurley et al. (1996): New ageing protocols; historic survey samples (87-95) re-aged, commercial samples not yet re-aged. Survey ALKs used to generate both the survey and commercial CAA (interim measure). Sample size was variable and low, ∴ annual keys were combined to give one multiyear key (1987-1995) for each stock component. Then normalized and weighted bycatch #s in a given year to make an ALK for each year and stock component.
  Inter-reader comparisons established.
  ITQ survey initiated in 1995. Vessel conversion factor back to 1.2.
  SSB calculated using Waiwood and Buzeta's maturity ogive.

Estimates corrected for retrospectivity using a Gompertz function fit through contemporaneous and converged estimates of age 2 numbers.

- Hurley et al. (1997): Revised ageing data now available for 85-97 (survey) and 88-97 (commercial). Commercial CAA for 85-87 constructed using survey ALK and commercial length composition. Exploitation levels estimated for the 1980s thought to be too low (possibly due to use of survey ALK for commercial CAA). Year-class size corrected for retrospectivity and 10-year geometric mean recruitment used in post-SPA projections.
- Hurley et al. (1998): 4Xs and Canadian portion of 5Y now included in 4X stock. Revised ageing data now available for 85-97 commercial AND survey. Not possible for pre-1985 because otoliths were cracked, not sectioned, at that time. SPA with revised age data generates estimates of F for the 1980s that meet expectations. SPA included ITQ for first time (all available years). GIS potential mapping technique used to estimate annual trawlable biomass from ITQ surveys.
- Hurley et al. (1999): Fishing year changed from calendar to fiscal year. Non-zero sets used as an indicator of distribution. SPA methods largely unchanged.
- Hurley et al. (2002): Fulton's K (fish condition) and Traffic Light method introduced. ITQ survey used in calibration of SPA, but 1995 omitted due to differences in survey design.
- Hurley et al. (2003): No apparent changes. Mention of seasonal length/weight parameters derived by O'Boyle et al. (1983) used in constructing CAA in this assessment (and historically).
- Hurley et al. (2009): The practice of using constant quarterly length weight parameters of O'Boyle et al. (1983) for CAA calculations was replaced by using annual Length/Weight parameters from the DFO summer survey due to declining trends in WAA. Surplus production analysis performed (methods of Mohn and Chouinard 2004).
- Mohn et al. (2010): Four models used for separate SPAs (the base model and three others):
    - ACON 2 survey (DFO RV and ITQ) – base model (no change from previous years)
    - ACON 1 survey model (DFO RV)
    - ADMB 1 survey model (DFO RV)
    - ADMB 1 survey model (DFO RV) – M estimated as a random walk

  Single index models were developed to use in a Sissenwine-Shepherd production model with moving windows since the ITQ survey time series is too short for inclusion.

REFERENCES CITED

Frank, K.T., P.C.F. Hurley, and J. Simon. 1990. Assessment of haddock on 1989. Can. Alt. Fish. Sci. Advis. Comm. Res. Doc. 1990/058. 48p.

Gavaris, S. 1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. Can. J. Fish. Aquat. Sci. 37: 2272-2275.

Halliday, R.G. 1974. Current status of the ICNAF Div. 4X haddock stock. ICNAF Res. Doc. 74/91.

Hurley, P.C.F., K. Frank, and J.E. Simon. 1991. Assessment of 4X haddock in 1990. Can. Alt. Fish. Sci. Advis. Comm. Res. Doc. 1991/067. 48p.

Hurley, P.C.F., K. Frank, and J.E. Simon. 1992. Assessment of 4X haddock in 1991. Can. Alt. Fish. Sci. Advis. Comm. Res. Doc. 1992/063. 40p.

Hurley, P.C.F., P.A. Comeau, and G.A.P. Black. 1994. Assessment of 4X haddock in 1993. Can. Alt. Fish. Sci. Advis. Comm. Res. Doc. 1994/039. 42p.

Hurley, P.C.F., G.A.P. Black, and P.A. Comeau. 1995. Assessment of 4X haddock in 1993. Can. Alt. Fish. Sci. Advis. Comm. Res. Doc. 1995/029. 53p.

Hurley, P.C.F., G.A.P. Black, R.K. Mohn, and P.A. Comeau. 1996. Assessment of 4X haddock in 1993. Can. Alt. Fish. Sci. Advis. Comm. Res. Doc. 1996/030. 66p.

Hurley, P.C.F., R.K. Mohn, and P.A. Comeau. 1997. Assessment of 4X haddock in 1996 and the first half of 1997. Can. Alt. Fish. Sci. Advis. Comm. Res. Doc. 1997/108. 101p.

Hurley, P.C.F., G.A.P. Black, P.A. Comeau, and R.K. Mohn. 1998. Assessment of 4X haddock in 1997 and the first half of 1998. Can. Alt. Fish. Sci. Advis. Comm. Res. Doc. 1998/136. 96p.

Hurley, P.C.F., G.A.P. Black, P.A. Comeau, and R.K. Mohn. 1999. Assessment of 4X haddock in 1998 and the first half of 1999. Can. Alt. Fish. Sci. Advis. Comm. Res. Doc. 1999/147. 80p.

Hurley, P.C.F., G.A.P. Black, P.A. Comeau, and R.K. Mohn. 2002. Assessment of the status of Div. 4X/5Y haddock in 2002. Can. Alt. Fish. Sci. Advis. Comm. Res. Doc. 2002/098. 77p.

Hurley, P.C.F., G.A.P. Black, J.E. Simon, R.K. Mohn, and P.E. Comeau. 2003. Assessment of the status of Div. 4X/5Y haddock in 2002. Can. Alt. Fish. Sci. Advis. Comm. Res. Doc. 2003/104. 73p.

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

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

O'Boyle, R.N. 1978. ICNAF Div 4X - Haddock Spring 1978 Status Report. Can. Alt. Fish. Sci. Advis. Comm. Res. Doc. 78/19. 18p.

O'Boyle, R.N. 1981. An assessment of the 4X haddock stock for the 1962-80 period. Can. Alt. Fish. Sci. Advis. Comm. Res. Doc. 81/24. 54p.

O'Boyle, R.N., and G.N. White III. 1982. An evaluation of the 4X haddock population characteristics during 1962-81 with yield projected to 1983. Can. Alt. Fish. Sci. Advis. Comm. Res. Doc. 82/53. 51p.

O'Boyle, R.N., and R.S. Gregory. 1985. An evaluation of the population dynamics of 4X haddock during 1962-84 with yield projected to 1986. Can. Alt. Fish. Sci. Advis. Comm. Res. Doc. 85/109. 81p.

O'Boyle, R.N., and D. Wallace. 1986. An evaluation of the population dynamics of 4X haddock during 1962-85 with yield projected to 1987. Can. Alt. Fish. Sci. Advis. Comm. Res. Doc. 86/098. 71p.

O'Boyle, R.N., and D. Wallace. 1987. An evaluation of the population dynamics of 4X haddock during 1962-87 with yield projected to 1988. Can. Alt. Fish. Sci. Advis. Comm. Res. Doc. 1987/097. 57p.

O'Boyle, R.N., K.Waiwood, and J. I. McMillan. 1983. An evaluation of the 4X haddock population characteristics during 1962-82 with yield projected to 1984. Can. Alt. Fish. Sci. Advis. Comm. Res. Doc. 83/73. 52 p.

O'Boyle, R.N., J.E. Simon, and K. Frank. 1988. An evaluation of the population dynamics of 4X haddock during 1962-88 with yield projected to 1989. Can. Alt. Fish. Sci. Advis. Comm. Res. Doc. 1988/072. 60p.

O'Boyle, R.N., K. Frank, and J.E Simon. 1989. An evaluation of the population dynamics of 4X haddock during 1962-88 with yield projected to 1990. Can. Alt. Fish. Sci. Advis. Comm. Res. Doc. 1989/058. 59p.

Rivard, D. 1980. Back-calculating production from cohort analysis, with discussion on surplus production for two redfish stocks. CAFSAC Res. Doc. 80/23: 26 p.

Smith, S.J. 1991. Assessing the efficiency of the groundfish survey design for the Scotian Shelf summer trawl surveys - 1980-1990. Can. Alt. Fish. Sci. Advis. Comm. Res. Doc. 1991/039. 15p.

Smith, S.J. 1995. Update of information on the 4X haddock stock. Can. Alt. Fish. Sci. Advis. Comm. Res. Doc. 1995/101. 27p.

Appendix II. A brief history of 4X5Y haddock fishery management measures, from 1957 to 1999.

Year	Foreign Fleet	Domestic Fleet	Regulatory measure
1957			Minimum cod-end mesh size 114mm for otter trawlers in Subarea 4
1963	USSR enters fishery		
1966	last year of USSR directed fishery for 4X haddock	Tonnage class 5 vessels enter fishery	
1970			Seasonal spawning closure (Mar-April) ; Establishment of TAC (ICNAF)
1973			Minimum mesh size increased from 114mm to 130mm (polyethylene, polypropylene and manila fibers) or 120mm (polyamide and polyester fibres)
1974			4X closed to directed fishing; managed through bycatch regulations (Res Doc 80/2)
1975			Bycatch regulation (Res Doc 78/19)
1976			Offshore fleet allocation divided into sub-annual quotas
1977	Silver hake fishery restricted to "small mesh gear box" (area with depths of 100-150m); haddock bycatch limit = 1%		Extension of jurisdiction; Start setting TACs for F0.1 not Fmax
1981			Minimum mesh size 130mm irrespective of material
1986			Seasonal allocations established
1989		Mobile gear fleet closed mid season	Management Plan calling for bycatch fishery only (1989-1992); Recommendation for maintaining fishery at lowest possible level; BUT CHP management: combined quota for cod/haddock/pollock (i.e. directed fishery); So management plan not in effect?
1990			Brown's Bank closure (March1-May 31) extended to June 15
1991			ITQs introduced to MG <65 fleet; in March, FG <65 fleet placed on trip limits of 30% haddock or 1500kg haddock; Minimum mesh size increased to 140mm (square) or 155mm (diamond); due to controversy, reduced to 130mm (square) or 145mm (diamond) later in year
1992			Introduction of dockside monitoring, mandatory 130mm square mesh for draggers and elimination of conditions of license to fish in either Divisions 4X or 5Z.
1993			Much of "Eastern Component" (4Xmn, 4VW) closed to cod-directed fishing (Neilson and Perley 2005)
1994	Small Mesh Gear Box coordinates redefined (shift to the east and deeper water; 190m depth contour); Mandatory separator grates (silver hake fishery); haddock bycatch limit = 0.05%		Small fish protocols introduced; Mandatory reporting system (data on fishing effort and location from logbooks)
1995			All fleets required to submit Conservation Harvesting Plans prior to fishing; Browns Bank spawning closure extended: Feb 1 - Jun 15
1996			FG <45 adopted a community structure for quota groups
1999			12-month fishery extended to 15-month fishery; Subsequent fishing years run from April 1- March 31; Detailed study of Roseway Bank haddock size composition and catches (i.e. not closed)