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Assessment of Cod in Division 4X in 2008

Évaluation de la morue dans la division 4X en 2008

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ABSTRACT

A population model was used to provide estimates of abundance, fishing mortality and natural mortality for 4X cod. Mortality for causes other than reported landings, including natural mortality, for cod of ages 4 and older increased in 1996 and is currently 0.7. The high mortality greatly restricts productivity. Spawning stock biomass (SSB) at the beginning of 2008 is 9,000t; this is the lowest level in the time-series, which started in 1948.

RÉSUMÉ

Un modèle de population a servi à produire les estimations de l'abondance, de la mortalité par pêche et de la mortalité naturelle de la morue de la division 4X. La mortalité autre que celle qui est associée aux débarquements déclarés, y compris la mortalité naturelle, des morues de 4 ans et plus a augmenté en 1996 et est actuellement de 0,7 (46 %). Cette mortalité élevée réduit grandement la productivité. La biomasse du stock reproducteur (BSR) au début de 2008 se chiffrait à 9 000 t; cela représente le plus bas niveau de la série chronologique, commencée en 1948.

COD STOCK STRUCTURE IN NAFO DIVISION 4X

Cod ranges from Georges Bank to northern Labrador in the Canadian Atlantic. There are several concentrations of cod within this range, including those on the Southern Scotian Shelf and Bay of Fundy in Northwest Atlantic Fisheries Organization (NAFO) Divisions 4X and 5Y (Figure 1). Cod in 4X and the Canadian portion of 5Y (jointly referred to as 4X cod) have been managed as a unit since 1985, with a single quota for this area.

Cod in 4X are relatively fast growing. They begin to recruit to the fishery at age 2 and the majority begin spawning by age 3. Growth is faster and weight is higher for a given length in the Bay of Fundy/Gulf of Maine region (Figure 2a; Figure 2b). The average length at age 5 is about 70cm on the western Scotian Shelf (4Xmno and Browns Bank in 4Xp; referred to as 4X East) and 80cm in the Gulf of Maine/Bay of Fundy (4Xqrs5Y and deep water of 4Xp; referred to as 4X West). Similarly, condition (Fulton's K; weight/length^3) is generally higher for cod in the Gulf of Maine and Bay of Fundy.

Spawning is distributed broadly through the area, both geographically and seasonally. Spawning occurs in the fall (October-December) along the coast of Nova Scotia. This spawning has been described most thoroughly for Halifax Harbour and around Sambro Head to St. Margarets Bay (McKenzie 1940). Fish aggregating in the deeper water around Sambro Head were the target of a seasonal gill net fishery, which landed roughly 1,000t of cod annually, and for a period in the 1980s, were also targeted by large draggers in the winter fishery. This fishery began to decline in the early 1980s, and has now all but disappeared. Fish in spawning state have been caught in this area in recent years, and juvenile cod (3-5cm) were captured with a beach seine in Halifax Harbour in spring of 1999 and 2000. Fishermen also continue to catch ripe fish in the Shelburne area in the fall.

Spawning occurs in the spring, primarily on Browns Bank, but also in other areas. Ripe fish were caught in spring Research Vessel (RV) surveys conducted in the early 1980s in the Bay of Fundy and around Browns Bank. Fishermen have identified the waters off Digby Neck and Grand Manan as areas where they encounter spawning fish in the spring (Benham and Trippel 1998).

Egg and larval studies support these observations, showing eggs and larvae distributed along the coast of Nova Scotia and into the Bay of Fundy in fall, and on Browns Bank and in the Bay of Fundy in spring (Neilson and Perley 1996). The presence of both spring and fall spawners results in a bimodal length frequency for cod at age 1 in the RV and Individual Transferable Quota (ITQ) surveys (Clark and Paul 1999).

The degree to which fish spawning in different areas in 4X mix during the year is not clear. Tagging studies from the 1940s to 1960s generally showed that fish tagged in inshore areas show little dispersal from the tagging area, and those tagged in the Bay of Fundy tended to be returned from inside the bay (Halliday 1971; McKenzie 1956; Templeman 1962). A major tagging project in the 1980s showed that cod tagged on Browns Bank in spring, however, disperse widely through the 4X area, although the majority of tags were recaptured in 4Xp and further west (Campana and Simon 1985; Hunt et al. 1999). Similarly, some fish tagged on Georges Bank were recaptured in 4X. The proportion of fish tagged on Georges Bank that move into 4X has generally been considered small (Templeman 1962); however, analyses of tagging conducted in the 1990s concluded there was a high level of movement into 4X from Georges Bank (Hunt et al. 1999).

Given the conflicting results of past studies, and concern amongst some fishermen that there were separate spawning components in the Bay of Fundy that were being overfished (Clark et al. 1998), new tagging was undertaken starting in 2001. The work was planned as a joint project involving the Department of Fisheries and Oceans (DFO), the Scotia-Fundy Mobile Gear Fisherman's Association and the Centre for Community Based Management at St. Francis Xavier University, and received strong support from fixed gear fishermen's associations in Southwest (SW) Nova Scotia. In 2001 and 2002, much of the tagging was conducted during trips onboard 20 commercial fishing vessels, and release sites were widespread in 4X and 5Z (Figure 3). The majority of cod were released in the Bay of Fundy, off Digby, Nova Scotia, and the Wolves Islands of New Brunswick, or on the banks of the Scotian Shelf east of Browns Bank. Several trips were made on and around Browns Bank, but relatively few fish were tagged in this area. Most releases on the Scotian Shelf were from hook and line, while those in the Bay of Fundy were primarily from otter trawler. Approximately 14,000 cod were tagged and released.

Additional tagging of cod caught incidentally in lobster pots was conducted by commercial fishermen from 2003–2004. This tagging was primarily off SW Nova Scotia, with some releases also in the Bay of Fundy. Over 6000 tags were released by the 60 fishermen who took part in this initiative.

Tagging continued from May of 2003 to 2005 as part of the North-East Regional Cod Tagging Program, which included tag releases from south of Maryland across Georges Bank and throughout the Gulf of Maine into the Bay of Fundy (Figure 4). The tagging in Canadian waters as part of this study took part almost exclusively in the Bay of Fundy, with small numbers also released south of Browns Bank. Unfortunately, there was no tagging conducted as part of this study in Canadian waters on the northeast peak of Georges Bank. Over 115,000 cod were tagged in this program, with roughly 6,000 of them released during DFO tagging trips.

The general results relevant to the 4X management area are summarized below.

Cod released in the Bay of Fundy in 2001–2002 were generally recaptured west of Browns Bank in the Gulf of Maine and Bay of Fundy, with some returns on Georges Bank and in the Western Gulf of Maine (Figure 5). Cod tagged east of Browns Bank were predominantly recaptured on the Scotian Shelf, with few recaptured west of Browns Bank. This is consistent with the length-at-age data which suggest cod on the shelf are distinct from those in the Bay of Fundy.

Tagging on Browns Bank was conducted during spawning season in February–March of 1984 and 1985. Fish were tagged in two locations on Browns Bank, and over 1300 tags were returned in total. There are some intriguing differences in the pattern of returns between the two release sites. Roughly 10% of returns were from Georges Bank, but almost all of these came from one of the two release locations. However, tagged cod were recovered broadly in both eastern and western 4X from both release sites (Figure 6). Few cod were recaptured from tagging on and around Browns Bank in the recent tagging projects, but they also showed movement both into the Gulf of Maine, where many of the cod tagged in the Bay of Fundy were recaptured, as well as farther north and east onto the Scotian Shelf (Figure 7).

Juvenile cod tagged in coastal areas off SW Nova Scotia were recaptured primarily in 4Xpq and 5Z, with the proportion returned from Georges Bank increasing with duration after release (Figure 8).

Cod released in winter in 5Zm (2003 and 2004) all remained on Georges Bank (Figure 9). Cod released in winter in 5Zj dispersed more, with many recaptured in 4X, primarily in the Bay of

Fundy and Georges Basin (Figure 10). These results are similar to those from tagging on Georges Bank in 1994 (Hunt et al. 1999).

While cod tagged in the Bay of Fundy (4Xrs) and those tagged in eastern 4X (4Xno) exhibit little mixing, cod tagged near the boundary between the Gulf of Maine/Bay of Fundy and the Scotian Shelf (4Xp) are captured in both 4Xpqrs and 4Xmnop.

Roughly 25% of cod released in 5Zj are recaptured in 4X. Mixing from 5Zm to 4X is much lower. Reciprocal movement from 4X is also observed. Despite the apparent mixing, cod from spawning grounds in 5Zj, Browns Bank and Bay of Fundy can be resolved using microsatellite DNA (Ruzzante et al. 1998). A review of cod tagging results at the 5Zjm cod framework meeting (Worcester 2009; Wang et al. 2009) concluded that, despite the observed mixing, cod in 5Zjm and 4X could be managed and assessed separately.

While there are clearly separate spawning components in the 4X management area, some of which display very little mixing, separating landings into two regions in 4X for assessment may not be feasible. It is clear, however, that there is not broad mixing of cod throughout the management area, which means that a concentration of fishing effort could lead to overexploitation of some components of the resource while leaving others unharmed. Management of the fishery is recommended be conducted in a fashion which aims to avoid over-exploitation in any part of the stock area.

BRIEF HISTORY OF FISHERY AND ASSESSMENT

Prior to 1963, the cod fishery in 4X (including the Canadian portion of Division 5Y; Figure 1) was primarily an inshore fishery. The majority of fishing was done by Canadians, hand lining and long lining from small vessels (Table 1). Between 1957 and 1962, 82-87% of landings were ‘inshore’, with the remainder split between Canadian and U.S. vessels fishing Browns and LaHave banks (Halliday 1971). Landings showed a slow decline between 1948 and 1958 from 20,000t to 12,000t (Figure 11). This decline was attributed primarily to decreases in effort, as fishing was directed more for haddock, but also to declining abundance (Beverton and Hodder 1962). Foreign and Canadian otter trawlers (OT) began fishing for cod on Browns and LaHave banks in 1962. Due to the increased exploitation on the offshore banks, almost exclusively by OT, landings increased rapidly after 1962, to a maximum of about 35,500t in 1968.

In 1970, landings dropped by 10,000t. This reduction came almost entirely from Canadian OT landings, while landings by longline (LL) and handline (HL) were largely unaffected. There was no quota for cod in 4X at this time; however, due to the mixed species nature of the groundfish fishery in this area, management measures implemented to regulate fishing on one species inevitably influenced others. The large reduction in cod landings in 1970 has been linked to reductions in fishing effort due to the institution of quotas for haddock and the closure of Browns Bank to fishing for March and April, both of which occurred in 1970.

The 4X area was recognized as including a number of separate cod spawning stocks whose distributional boundaries were unclear, thus, it was felt to be inappropriate to assess it as a unit stock. Assessments were conducted for the offshore (primarily Browns and LaHave banks), which was thought to be a discrete stock, and Total Allowable Catch (TAC) was first established for this area in 1975. These TACs, however, are thought to have had limited impact on landings due to misreporting to the inshore area, where no TAC was in place (Gagne et al. 1983).

Landings throughout much of the 1970s remained in the region of 20-24,000t, increasing to 31,000t by 1980. As a result of this rapid increase in landings to near historically high levels, a TAC was imposed for 4X cod for the first time in 1982 (Figure 11). The TAC was set at 30,000t (a level selected to prevent landings from exceeding the maximum landings observed in the early 1980s), and held at this level for four years. It had little influence on the landings as a whole, which declined from 32,000t to 21,000t between 1982 and 1985. Aside from the <65ft draggers, no quota group met its allocation from 1983 to 1985 (Campana and Simon 1986).

The treatment of cod in 4X and 5Yb as a single stock for assessment purposes commenced in 1985. This step was taken partly in response to changes in fishing practices, and partly because mixing between inshore and offshore stocks appeared to be more extensive than had previously been thought. It was not considered possible to separate landings reliably between inshore and offshore areas (this was not a requirement for logbook records), and the increasing range of much of the fleet made the apportioning of landings to inshore or offshore on the basis of tonnage class unreliable. Furthermore, the results from tagging of cod on Browns Bank in spring suggested there may be mixing between inshore and offshore stocks, as well as among inshore spawning groups. It was felt that an assessment that grouped all of 4X would be acceptable due to the mixing occurring among spawning groups and the mixed nature of the fishery (Campana and Simon 1986).

With the imposition of more stringent quotas for 4X cod in 1986, there were suggestions that unreported landings and misreporting by species had become serious problems, particularly in 1987 and 1988 (Campana and Simon 1987; Campana and Hamel 1990). Reported landings since 1989 were considered more accurate due to increased enforcement, and the institution of mandatory weigh-outs in 1990 (Campana and Hamel 1992; Gavaris 1993).

Reported landings remained around 20,000t from 1985-1989, then increased to 28,000t in 1991. Fishing effort also peaked in 1992, declining rapidly as quota was restricted following 1992. For both otter trawl and longline, effort (days fished) declined by over 50% between 1992 and 1995 (Gavaris 1996; Clark et al. 1998). Fixed gear effort continued to decline through the 1990s, while for otter trawlers, groundfish directed effort (hours fished for main species cod, haddock or pollock) remained fairly stable through the 1990s but shifted almost entirely to direct for haddock (Clark and Hinze 2003).

Difficulties in predicting age composition of the catch accurately led to experimenting with model formulation, starting with the 1997 assessment. In 1997, an attempt was made to model cod in the Bay of Fundy and Gulf of Maine (4Xqrs5Yb) separately from cod on the western Scotian Shelf (4Xmnop). The results were quite similar to those from modelling it as a single stock, and suggested that recruitment patterns were very similar in the two areas. These results may, however, have been confounded by the degree of mixing of cod between these areas.

The 1998 and 1999 assessments provided multiple potential model formulations, without resolving which was most plausible. These included models that incorporated a change in survey catchability or an increase in natural mortality. Cohorts were being depleted more quickly than could be explained with these parameters held constant. All models confirmed that the population was low, and, in 1999, the quota was set at 6,000t for a three year period to promote rebuilding.

In 2000, a single model formulation was provided in the assessment. This model included the “around the corner” formulation, in which the oldest age is explicitly estimated for several years prior to the terminal year. The model results indicated that fishing mortality was strongly domed, with a very low partial recruitment at older ages. The model was used again in the 2002 assessment and displayed a strong retrospective pattern.

In 2003, the Virtual Population Analysis (VPA) was rejected. Assessments for this stock since 2003 have been based on a summary of fishery and survey data with no formal model results reviewed. These assessments concluded that the stock remained at a very low level and that removals should be as low as practicable to promote rebuilding.

Effort has continued to decline, with the handline fleet, which accounted for up to 20% of the landings as recently as 1996, almost disappearing from the fishery.

Reliability of Landings

As with all other stocks, there is some uncertainty regarding the accuracy of landings data, particularly before the 1990s. Both fishermen and plant owners have indicated that some landings went unreported in the past, and the extent of this is unclear. With the imposition of more stringent quotas for 4X cod in 1986, there were suggestions that unreported landings and misreporting by species had become serious problems, particularly in 1987 and 1988 (Campana and Simon 1987; Campana and Hamel 1990). Reported landings since 1989 were considered more accurate due to increased enforcement and the institution of mandatory weigh-outs in 1990 (Campana and Hamel 1992; Gavaris 1993). Anecdotal reports of substantial unreported landings in some communities were noted in 2000 and 2001, when cod quota was restrictive to the mixed fishery. While it was not possible to estimate how much cod was caught and not reported, it was still thought to be considerably less than the reported landings (Clark et al. 2002). With cod landings not reaching the quota in recent years, there would seem to be no incentive to discard cod, and landings are considered reliable.

DESCRIPTION OF THE FISHERY

Landings declined through the 1990s and these reductions were a reflection of the TAC, which declined from 26,000t in 1992 to 7,000t in 1999. The TAC was set at 6,000t for three years, starting in 2000, to promote an increase in biomass. This was not successful; biomass continued to decline, and the TAC was further reduced to 5000t in 2006. Landings have remained near 4,000 and below the TAC since 2005 (Figure 11).

For the 2008 fishing year, 4,064t of the 5,000t quota was landed, slightly higher than in 2005 - 2007. With the low quotas, many participants in the fishery are reserving cod as a bycatch in other directed fisheries. In 2008, the hook and line fishery accounted for 51% of the landings from 4X, the gill net fishery for 8%, and the dragger fleet for 41% (Table 2). The quota is allocated amongst gear sectors according to historical shares of the landings, with 60% of the cod quota allocated to the fixed gear sectors, and 40% to mobile gear.

The precision of geographic location recorded for landings has improved gradually over time. Latitude and longitude have been recorded for otter trawl trips since 1991 and for fixed gear since 1998. In the early 1990s, dragger landings were broadly distributed from Roseway Basin in 4Xo around into the Bay of Fundy (Figure 12). Through the 1990s, the proportion of landings coming from 4Xqrs increased (Figure 13; Table 3), primarily due to redirection of dragger and gillnet effort (Clark et al. 2000). From 2002 to 2004, much of the dragger fleet directed their effort to the Bay of Fundy to target a good yearclass of haddock concentrated in this area. The proportion of the cod catch coming from this area peaked in 2004 and has declined sharply since then. Since 2004, fishers have reported poor catches in the Bay of Fundy for cod, haddock and pollock. Effort has again shifted, with an increasing concentration in Georges and Crowell basins in 4Xp. The proportion of landings taken in 4Xp in 2008 is among the highest observed in the time series (Figure 13).

The groundfish fishery in 4X is prosecuted year round. Landings generally peak in June and July; however, in recent years, landings have been distributed more evenly throughout the year, peaking in the fall (Table 4). The change in the end of the quota year to March 30 has led to an increase in landings early in the year, as fishers attempt to catch any remaining quota.

Cod are captured as part of a multi-species fishery in 4X. For some sectors of the fishery, cod is an important part of the catch, while for others it comprises a small part of the overall multi-species landings. Observer coverage is very low in the 4X groundfish fishery (Table 5), and it is not sufficient for any detailed analysis of bycatch in the fishery. The longline fishery catches a mix of cod, haddock, halibut, white hake and cusk (Figure 14), with geographic variability in which species is dominant in the catch. The gillnet fishery catches a mix of cod, pollock and white hake (Figure 15). The otter trawl fishery lands a mix of haddock, pollock, cod, flounder and redfish (Figure 16). As a result, the distribution of fishing effort is impacted by the distribution of several species and by the relative level of quota for each of these species. Fishermen are attempting to maximize the financial return from a fishing trip while depleting the quota for each species simultaneously, rather than selecting areas based on abundance of any single species.

While there may be periodic issues with the accuracy of some landings data for 4X cod, during the period used for calibrating the assessment (1983–2008) it seems unlikely that these issues are of sufficient magnitude to render the modelling unreliable.

While fixed gear catch was widely distributed in 4X in the past (Figure 17), landings in 2008 are much more restricted to offshore areas in 4Xnop (Figure 18). Fishing in coastal areas and the Bay of Fundy with fixed gear has almost completely disappeared. Otter trawl catches were broadly distributed in 1991 (the first year with precise locations) but concentrated in Roseway Basin and the mouth of the Bay of Fundy (Figure 12). Catches by otter trawlers remain broadly distributed (Figure 19); however, catches are low in areas that had provided good catches in the past, and more of the cod are coming from areas of deep water. While cod continue to be caught in most areas of 4X either by fixed or mobile gear, the area where good catches were taken in 2008 was restricted to waters around Browns Bank.

In recent years, the cod quota has not been met by any quota sector, while most groups have landed their pollock quota and, in 2007, their haddock quota as well (Table 6). Shortfalls in landings of cod by small draggers reflect their success in targeting haddock in the winter fishery. The large dragger fleet often leave some quota uncaught, and may have held some cod in reserve for bycatch in the pollock fishery.

In 2008, most fixed gear groups reported improved fishing off SW Nova Scotia. Despite this, 464t of the 2907t fixed gear <45’ quota went uncaught. Almost half of the fixed gear shortfall was quota held by SW New Brunswick quota group. Their fishery was poor in 2008, and they were unwilling to have their uncaught quota taken from another area. The remaining 200t of cod quota left by the fixed gear fleet was split amongst a number of groups that did not land their full quota for any species. This may be a result of some quota groups leaving too much quota for the end of the year. Furthermore, many large longliners are fishing with individual quotas; some individuals will have landed all their cod and others all their haddock, resulting in some of each species being left in the water.

Effort by the otter trawl and the tonnage class (TC) 2 and 3 longline and gillnet fleets declined after the early 1990s, (Clark et al. 1998). The number of fishing trips made by TC1 fixed gear vessels also declined by about 50% between 1992 and 1996; however, detailed information on the effort (days fished) is only available for smaller TC1 vessels since 1996

The number of vessels actively engaged in the fishery has dropped since 1996 for all gear types (Table 7a), with handliners almost disappearing from the fishery. The number of vessels fishing declined again for 2008 and was the lowest in the series for each gear type Effort for all fixed gear vessels declined in 2008, with gillnet effort down almost 50% since 2005 (Table 7b).

CATCH- AND WEIGHT-AT-AGE

Fishery Samples

The 2007 catch-at-age was based on 33 samples that included otoliths, and 68 additional length frequency samples (Table 8a). Some cells were combined in the construction of length frequencies due to a lack of data. In the first half of 2008, 12 samples which include otoliths, and an additional 29 length frequency samples are available (Tables 9a).

Samples were aggregated by area, quarter and gear type. Aggregation by area was done to account for growth differences between the Bay of Fundy (4Xqrs5Yb) and SW Scotian Shelf (4Xmno). Variability in growth rates are also found within 4Xp, with cod caught in the deep water of 4Xp growing faster than on Browns Bank and the rest of the Scotian Shelf. In accordance with this, 4Xp is split, with catches from deep water grouped with the Bay of Fundy (4X West) and from shallower water grouped with the rest of the Scotian Shelf (4X East). The depth of separation was set at 90 fathoms.

The seasonal length-weight parameters used in deriving catch numbers at age (Table 8b and 9b) were those from Campana and Hamel (1992). These parameters were calculated as seasonal averages over the years for which seasonal survey information were available, and have been used since 1985 when seasonal surveys in 4X were discontinued.

Landings

Landings reported from 4Xu (unspecified area) were apportioned to 4X West and 4X East for each statistical district according to known area landings by gear type and tonnage class for that statistical district and quarter. Landings reported from 5Y from 1983 to 1986 for each statistical district were divided between 4X East and 4X West according to the same protocol. Misreporting to 5Y from 4X was identified as a problem in these years in past 4X cod assessments (Campana and Simon 1987; Campana and Simon 1988).

Fishery length frequencies from 2007 peaked at 49cm in 4X East (Figure 20a) and at 55cm in the 4X West (Figure 20b). Cod caught by gillnet were larger, but all other gear-types had similar length ranges. Modal length is slightly lower in 2008 for 4X East (Figure 21a) and slightly higher in 4X West (Figure 21b).

Catch-at-Age

The 2003 yearclass has been dominant in the fishery in 2007 and 2008, and the 2004 yearclass has made little contribution (Table 10; Figure 22). The catch-at-age for 2008 is only available to July 1. Later in 2008, small cod, likely age 2, dominated the catch. The contribution of cod over age 6 to the landings has been very low in the last decade, and remains low in 2007 and 2008.

Weights at age for commercial landings from both 4X East and 4X West in 2008 were generally lower than average, except for younger ages (Table 11). Given the very low numbers in the catch above age 6, these weights-at-age may not be reliable.

ABUNDANCE INDICES

Annual RV stratified random surveys have been conducted in NAFO Division 4X during the summer since 1970. Coverage begins at 50fm off the south shore of Nova Scotia, and 15fm in the Bay of Fundy, and extends out to 200 fathoms along the shelf edge. An area north of Browns Bank, while of suitable depth, is untrawlable bottom, and is excluded from coverage for this reason (Figure 23). Cod are generally abundant in the Bay of Fundy and on the Scotian Shelf banks.

From 1970 to 1981, surveys were conducted with the RV *A. T. Cameron*, a side trawler, using a Yankee 36 bottom trawl. The gear was changed to a Western IIA bottom trawl in 1982, when the research vessel was replaced with the RV *Lady Hammond*, a stern trawler. The current research vessel, the RV *Alfred Needler*, which uses the Western IIA bottom trawl, replaced the RV *Lady Hammond* in 1983.

A variety of difficulties were experienced in conducting comparative surveys in the early 1980s as part of the change in survey vessels (Koeller and Smith 1983; Fanning 1985). In particular, the speed sensor on the Cameron was not functioning properly. The speed of towing for this vessel was quite variable, and generally higher than 3.5nm/hr. The conversion factors calculated for cod have been deemed unreliable (Clark and Brown 1996; Mohn 1999) and, as a result, the indices are only used from 1983 on.

Following a fire on the *CCGS Alfred Needler* in 2004, the *CCGS Teleost* was used to conduct the surveys in 2004 and 2007, and the *CCGS Wilfred Templeman* was used to conduct the survey in 2006. The *Templeman* is the sister ship to the *Needler*, and has been assumed to require no conversion in comparison with the *Needler*. Comparative fishing between the *Teleost* and *Needler* has also indicated that no conversion factor is required between these vessels (Clark 2005).

The ITQ survey, which has been conducted by Industry annually since 1996, employs a fixed station design. The coverage includes some coastal areas missed by the RV survey, but there is less coverage of deep water and New Brunswick coastal areas. Three vessels, using a 300 balloon trawl with a 1/2in. codend liner and rockhopper ground gear are involved in the survey. Each vessel completed 60–65 tows, in separate geographic blocks. One of the three vessels was replaced in 2006, but it is assumed that no vessel conversion factor is required. The standard tow is 1nm. The duration of tow varies according to tidal current; 3 knots is the target towing speed. All sets are made during daylight hours. Much more small cod are caught during this survey than in the RV survey due to the rockhopper ground gear, which provides little avenue for escape below the footrope.

In 1998, 10 stations were added around St. Margarets Bay. The 10 stations added in 1998 account for roughly 1% of the survey catch each year; thus, 1% was added to the survey catch for 1996 and 1997 to account for these stations (Clark et al. 2000). The length distribution of fish in these 10 stations peaked around 20cm each year from 1998-2000, similar to the catch from the inshore stations farther west. In augmenting the length frequencies for 1996 and 1997, the length frequency for the inshore stations sampled in those years was used as a template, and the total catch at length for the survey was increased by an amount equivalent to 1% of the surveys catch by weight (Clark et al. 2000).

Indices for this survey are derived using the suite of 184 stations regularly occupied over the time-series (Clark et al. 2002).

Distribution of Catches and Catch per Tow

In both 2007 and 2008, there were some cod caught in most areas during the RV survey but no large catches (Figures 24 and 25). Catches of cod in the Bay of Fundy in 2008 are particularly small. The total catch for the RV survey (roughly 70 sets) averages around 400 fish, and is as low as 138; in 2008, 157 cod were caught.

Cod were caught in most areas in the ITQ survey in 2008, but, as in the RV survey, very few cod were caught in the Bay of Fundy (Figure 26). Catches on the Scotian Shelf were generally low, except on Roseway Bank, again consistent with the RV survey.

Since the ITQ survey is a fixed station survey, the catch at each station can be compared among years. Catches were below the median at almost all stations in the Bay of Fundy in 2008 (Figure 27). Catches were above median at many sets at the eastern end of the Scotian Shelf in 4X, but they were below the median for most stations west of Roseway Bank. The proportion of ITQ survey stations where cod were caught, and where catch was above the median for that location, has been fairly stable in 4X East throughout the 12 year series but declining in 4X West (Figure 28).

The RV survey biomass index in 4X East in 2008 is among the lowest in the series, while the ITQ survey biomass index in 4X East show little trend since 1997 and is only slightly below average in 2008 (Figure 29a). The biomass index in 4X West in 2008 remains low for the ITQ survey, has declined, and is the lowest in the series for the RV survey (Figure 29b). Overall biomass trends for 4X cod are quite consistent for the two surveys (Figure 29c). The 2008 value is the lowest in the RV survey series and second lowest in the ITQ survey series.

Length Frequencies

Catches at length from the RV survey were below the median in 4X East for all lengths above 28cm but above median for smaller sizes (age 0 and 1; Figure 30). Catches at length were very low in 4X West for commercial size cod and were close to median only for lengths below 30cm, consistent with length at age 1 (Figure 30). For the ITQ survey, catch at length was below the median at lengths greater than 34cm in 4X West (Figure 31), similar to the RV survey. In 4X East, catch at length was above the median at lengths <40cm and close to median for larger cod (Figure 31). This differs from the results of the RV survey; however, some of the discrepancy reflects the generally low catch of cod in 4X East since the inception of the ITQ survey.

Length-at-Age and Condition

Lengths-at-age for 4X cod from the RV survey are stable for both regions (Figure 32). The very low numbers of fish for some ages results in high interannual variability for older ages.

There is no trend in condition for cod in 4X West (Figure 2b). Condition factor has declined for cod in 4X East and in 2008 is the second lowest observed (Figure 2b).

Indices at Age

Again in 2008, very few cod over age 5 were caught in the RV survey (Table 12; Figure 33). There was no improvement in age structure for either region. The 2006 yearclass is dominant in both 4X East and 4X West. Indices are below the median for all ages in both regions except ages 0 and 1 in the east. The combined 4X indices, as used in the VPA, are very low for all ages (Table 13; Figure 34).

The ITQ survey index in 4X East is the second highest in the series for age 2 and third highest for age 1, but second lowest for ages 3 and 4 (Table 14; Figure 35). Indices for 4X West are low for all ages except age 1, which is the median for the series. The combined ITQ survey indices for 4X are above the median for ages 1 and 2, but they are very low for all older ages (Table 15; Figure 36).

Estimates of Relative Mortality and Total Mortality

The relative fishing mortality (catch biomass/RV survey biomass index), while generally lower for both 4X East and 4X West since 1995 than in the previous decade, appears to be increasing for 4X East in the last three years (Figure 37). Relative F (fishing mortality) has not declined since a rebuilding strategy was adopted in 2000. Despite low landings, the total mortality estimate from the RV survey remains high in 4X East and it has been increasing in 4X West (Figure 38). The continued high Z, while relative F has dropped, suggests there is additional mortality that has not been accounted for in the reported landings.

Total mortality, estimated from RV survey data, shows no trend for young cod in 4X over the time series (Figure 39). If mortality from sources other than reported landings has increased for older cod, it does not appear to have increased on young cod.

Mortality remains high for both regions as estimated from the ITQ survey (Figure 40). This is consistent with the data from the RV survey.

ESTIMATION OF STOCK PARAMETERS

A series of model formulations were explored for this assessment. Model formulations that had been used in past assessments were presented to illustrate the pathology which led to their rejection and as background for formulations which incorporate changes in assumptions about natural mortality (M) and survey catchability (q). This was consistent with the recommendations of the pre-zonal assessment process (ZAP) assessment meeting.

The adaptive framework (Gavaris 1988) was used to calibrate the sequential population analysis with the survey results in an illustrative base model, using the following data:

$C_{a,t}$ = catch for ages *a=1, 2,..., 12* during the time periods beginning at *t=1983, 1984..., 2008, 2008.5*

$I_{s,a,t}$ = survey abundance index for:
s= RV survey ages *a=2 to 8, years t = 1983.5 to 2008.5*
ITQ survey ages *a = 2 to 8, years t = 1996.5 to2008.5*

The summer survey results were compared to mid-year population abundance. Statistical error in the survey data was assumed to be independent and identically distributed after taking logarithms and the error in the catch at age was assumed negligible. Natural mortality, M, was assumed constant and equal to 0.2.

A model formulation using ln mid-year population abundances in 2008 (*t = 2008.5*) as parameters was employed. Define the model parameters:

$\phi_{a,2008.5}$ = ln population abundance for ages *a = 2, 3,...,12,* (age 1 abundance assumed equal to the geometric mean recruitment 2000-2007), and

κ_{sa} = calibration constants for RV and ITQ surveys for ages *a = 2,3,4,5,6,7,8.*

ADAPT was used to solve for the parameters by minimizing the objective function

$$\Sigma\ (\ln(I_{s,a,t}) - \ln(\kappa_{sa} N_{a,t}(\phi)))^2$$

where the population abundance $N_{a,t}$, is taken at the corresponding time, t, to the survey. Since the sequential population analysis was conducted using half-year catch at age data, the abundance at the mid-year time, *t = y+0.5*, is directly available.

For *t* = 2008.5, the population abundances are obtained directly from the parameter estimates,

$$N_{a,2008.5} = exp[\phi_{a,2008.5}].$$

For all other years, y = 1983 to 2008, the population abundance was computed using the virtual population analysis algorithm which incorporates the exponential decay model

$$N_{a,t} = N_{a+\Delta t,y+\Delta t}\ exp[(F_{a,t}+M)\Delta t]$$

where the fishing mortality is obtained by solving the catch equation using a Newton-Raphson algorithm,

$$N_{a,t} = C_{a,t}(F_{a,t} + M)\Delta t / F_{a,t}\Delta t(1 - exp[-(F_{a,t} + M)\Delta t]).$$

Statistical properties of estimators were obtained from model conditioned non-parametric bootstrap of the residuals (Efron and Tibshirani 1993) as described in Gavaris and Van Eeckhaute (1998).

A second illustrative formulation was presented, which was identical to the base model but excluded the ITQ survey indices. This formulation was included to show that removal of the ITQ survey indices does not eliminate the strong residual pattern apparent in results of the base model. Residuals switch from primarily negative to predominantly positive around the time the ITQ survey begins (1996).

A model formulation that incorporated a change in survey q was undertaken. The change in q was modeled as a step function beginning in 1994, the year in which residuals switch from negative to positive in the base model. Survey indices for 1994 and later are input as separate series from those before 1994. The assumption made for this model is that landings are reliable since 1994 and possibly unreliable earlier. It is also assumed that an M of 0.2 and reported landings account for all mortality in all years.

A series of formulations were explored that incorporate a change in natural mortality. ADAPT was used to estimate M in blocks of years. Since there is no indication from survey data that Z has increased on young cod, M was estimated only for ages 4-11. Illustrative VPA results included in the 2006 assessment (Clark and Perley 2006) had estimated M as 0.8. An increase from 0.2 to 0.8 is a large change in a single year. To allow for a phased increase, M was estimated in two time blocks. A gradual increase was simulated by estimating M separately for the periods 1993–2000, and 2001–2008. A sharp increase was simulated by calculating M separately for the periods 1993-1995 and 1996–2008. Based on the results of these models, an additional formulation was considered with M fixed at 0.2 for 1983-1995 and estimated in a single block for 1996–2008.

These model formulations are premised on the assumption that survey catch is representative of abundance with a constant q and a change in M is introduced to account for high recent Z at ages 4+.

Initial investigation of model formulations incorporating changes in M and q showed that the calibration constants (κ_{sa}) continued to increase slightly with age for the RV survey, but were consistent across older ages for the ITQ survey. Final formulations stipulated a single calibration constant for ages 5-8, as recommended at the pre-ZAP assessment meeting. In the absence of a reason why catchability should vary among ages that could be expected to be fully recruited to the survey gear, it had been recommended that q for these ages should be linked to reduce the number of parameters estimated.

A final formulation was investigated that included the ITQ survey index at age 1. It was noted during the assessment review that this age-class was caught consistently in the ITQ survey, and that strong and weak cohorts at age 1 seemed consistent with observations in subsequent years. Inclusion of this index would eliminate the need to use geometric mean recruitment for age 1 in the assessment year.

ASSESSMENT RESULTS

The base model was included for illustrative purposes (Appendix I). The residuals from this model formulation show a strong pattern, switching from almost all negative to almost all positive in about 1994 (Figure 41). This model is not given further consideration.

The timing of the switch from positive to negative residuals in the base model is roughly coincident with the inception of the ITQ survey. The second illustrative model includes only the RV survey indices and has the same strong pattern in residuals (Figure 42). Omitting the ITQ survey indices resulted in no improvement to model fit (Appendix II), and ITQ indices are included in all models given further consideration.

The residuals from the model formulation that includes a change in survey q in 1994 (Appendix III) do not show any strong pattern (Figure 43). Similarly, there is no strong pattern in residuals for a model formulation that estimates M for 1996–2008 (Figure 44; Appendix IV).

There is no improvement in residual pattern or mean squared residual when M is calculated separately for two time periods since 1993. Furthermore, when M is calculated for the period 1993-95, it gives an M of 0.17 (Appendix V). This is very similar to the assumed M of 0.2, thus, a sudden change in M in 1996 seems more consistent with the data. Only the formulation with a single change in M was considered further.

All model formulations examined are effectively in agreement on population status (Figure 45). For all model formulations, current biomass is estimated as the lowest in the series and a fraction of the biomass in 1980.

Trends in F, however, differ between ‘M change’ and other models (Figure 46). From the “M change” models, estimated F declines rapidly after 1992, as fishing effort declined, and remained relatively low after the mid-1990s. For other model formulations F remained very high throughout the 1990s, which seems inconsistent with the trends in fishing effort. The lack of any clear reduction in F with the large reduction in effort argues against those models which do not incorporate a change in M.

Catchability coefficients (q) for 1983–1995 from q-change model shows a slight increase with age after age 5 and all q are less than 1. Recent q estimated from the q-change model increase with age and are >1 for most ages and peak at over 2. This would indicate a several fold increase in the catching efficiency of the net. While in the 1980s, fewer than half the cod in the path of the net were caught, now the net catches more cod than are in the path of the net. This would mean a change in behaviour that led cod to be herded into the path of the net, rather than avoiding the net.

For the base model, the q values estimated are an average of the q values from the two time blocks in the q-change model. In the 1-index model: q values are closer to the 1983-1995 q values because the influence of the recent period is lessened by removal of ITQ survey. The q values derived from the ‘estimate M’ model are similar to those estimated for 1983–1995, and show only a modest increase above age 5.

If landings since 1996 are considered reliable, it might be most parsimonious to accept a q-change model. However, concerns with the reliability of reported removals from the groundfish fishery persisted until about 2003. Discards from other fisheries, particularly the lobster fishery, are suspected, but not estimated. It seems unlikely that an M of 0.2 and reported landings from the groundfish fishery account for all the mortality for cod in 4X.

The very high q estimated for recent years in the “q-change” model seems implausible for cod, again suggesting this formulation is not realistically modelling the population dynamics. In addition, the very high estimates of total mortality (Z) from survey data, while relative F is low, suggests there is a large unaccounted mortality.

The high M estimated from the model could incorporate both natural mortality, and unaccounted fishing mortality. The primary cause of increased natural mortality is likely an increase in seal population, as has been reported for other cod stocks (Swain et al. 2009). Gray seal abundance has increased continuously in recent decades on Sable Island, and much of 4X is in their foraging range. In addition, gray seal colonies have been established in the 4X/5Y area in recent years. The abundance of harp, harbour and gray seals have all increased in Gulf of Maine (Waring et al. 2007). Furthermore, the fishing industry reports increased levels of nematode parasites in groundfish fillets. As seals are the final host for these parasites, this is consistent with an increased population of seals residing in the area.

Some of the high mortality could also be a result of unreported mortality from the groundfish fishery and other fisheries. Unreported landings or discarding in groundfish fishery was reported as a problem from 1999–2002 (Clark and Hinze 2003), although it is thought to have ceased since then. There is some discarded bycatch of cod in other fisheries, including scallop, herring, and lobster fisheries**.** Lobster fishing effort has increased since early 1990s. The scale of bycatch is unknown but will be investigated for the scallop fishery in 2009 and the lobster fishery in 2010. Lobster bycatch has been estimated at about 40t from Halifax to Shelburne (Bundy et al. 2007) and are likely higher off SW Nova Scotia. Cod, however, can be released alive when caught in lobster gear, so mortality from this fishery will be difficult to quantify.

While it is not possible to clearly identify the causes of a high M with the data available, this appears to better fit the available data than does a formulation which assumes that survey catchability has changed.

With acceptance of this basic model structure, minor modifications were made for provision of advice. In accordance with the recommendations of the pre-ZAP assessment meeting, survey catchability for ages 5-8 were estimated as a single parameter to reduce the number of parameters estimated and eliminate the slight increase in q with age. Also, the ITQ index for age 1 was examined for inclusion in the model. The ITQ survey catches large numbers of age 1 cod, and the index appears to be a good predictor F yearclass strength. There is a relatively large standard error (SE) on age 1, but the q on age 1 has similar SE to other ages (Table 16). Estimates of the 2006 yearclass change little with addition of age 1 index; the age 1 index confirms the estimate which was previously based only on the age 2 index from 2008. The inclusion of this index means that the 2007 cohort can now be estimated, and is slightly higher than 5 million. Including this estimate reduces the importance of assumed recruitment in projections.

Accepted Model Output

For each cohort, the terminal population abundance estimates from ADAPT were adjusted for bias and used to construct the history of the stock status (Table 17). Beginning of year weights-at-age were back-calculated from RV survey weights–at-age, and used to calculate beginning of year population biomass (Table 18).

Population numbers are estimated to be well below average for all ages (Table 17). Recruitment above 20 million was common in the 1980s; since the 1992 yearclass, no recruitment has approached this level. Recruitment for the 2006 and 2007 yearclasses are below average but about twice the abundance of the very low 2003 and 2004 yearclasses. While estimates of catch-at-age are less precise and likely underestimated in some years prior to 1980, for illustrative purposes, the results of an assessment that included landings starting in 1948 have been included for years before 1980. Spawning population numbers in 2008 are the lowest estimated in the 60 year time-series (Figure 47).

A fishing mortality (F) of 0.2 was adopted as the target for this stock during the 1980s. Fishing mortality has been above this level since 1980, and it was 0.34 in the first half of 2008 (Table 20; Figure 48).

There has been a general decline in biomass throughout the period assessed (Table 18; Figure 49). The relatively strong 1985, 1987 and 1992 yearclasses resulted in only short-term improvements in biomass. Spawning stock biomass (SSB) at the beginning of 2008 is 9,000t; this is the lowest level in the time-series, which started in 1948.

There is no consistent retrospective trend for this assessment (Figure 50). Following the high 2002 survey index, there is some pattern of decline in following biomass estimates, but the four most recent estimates are in close agreement. Similarly, there is no consistent retrospective pattern in fishing mortality estimates. Successive estimates of F are variable but without a clear trend, and they were anomalously high, with large positive residuals at several ages. This led to large retrospective increases in the estimate of F in the following years, but successive estimates of F have both increased and decreased as the past four years of data were added (Figure 50).

PROGNOSIS

A SSB limit reference point (LRP) of 25,000t has been adopted because, below this value, the likelihood of poor recruitment increases (Figure 51). Projections for this resource indicate, that at removals of 1,450t in 2009 (management target of F = 0.2), there is a >95% probability of at least 10% growth in SSB; however, SSB is unlikely to reach the LRP of 25,000t in 2010 even with no harvest (Figure 52).

Given the very high estimate for M, biomass increase for this resource appears to be entirely dependent on recruitment. With improved recruitment for the 2006 and 2007 yearclasses, the 3+ biomass (fishable biomass) is expected to increase above 2008 levels by 2010, if fishing mortality in 2009 is moderate. While a continuation of improved recruitment may lead to some additional biomass increase, some decline in M will be needed before the stock biomass can increase substantially.

Although point estimates of biomass and fishing mortality rate for alternative projected yields are provided, these numbers should not be treated as precise values. The risk plots are provided to give a general sense of the associated uncertainties and to assist in assessing the consequences of alternative choices. Further, these uncertainties are dependent on the set of assumptions, data, and model used in the analyses. Though these assumptions were deemed most suitable, there may be other plausible assumptions. The risk evaluation indicates that fairly significant changes in yield are required to influence the probability of not exceeding 10% growth in 4+ biomass (Figure 52). This reflects the reliance on recruitment, which is not estimated precisely, for growth.

Biomass has remained low since 2000 when the quota was reduced to 6,000t to promote rebuilding. There is no indication of a decline in total mortality or relative fishing mortality since 2000. Natural mortality is estimated to have increased to 0.7 and this greatly restricts productivity. Landings of about 3,900t in recent years have contributed to a continuing decline in abundance, and biomass is projected to decline further from 2008 to 2009. Survey recruitment estimates for the 2006 and 2007 yearclasses are improved over the preceding two yearclasses, and should result in an increase in stock biomass in the short-term.

A yield of 1,450t in 2009 would be consistent with the target exploitation rate of 16.5% (Table 19). At this yield, there is a high probability of 10% growth in SSB (>95%) between 2009 and 2010; however, this will only return the SSB to about the same level as in 2008. A reduction in the removal of cod from all fisheries to the lowest possible levels would be a strategy compliant with the principles of the precautionary approach. This would imply substantial reductions in TAC below current catch levels, and additional measures to reduce cod catch in the mixed-species groundfish fisheries and cod by-catch in other fisheries.

Cod in 4X are harvested as part of a mixed species groundfish fishery. With current fishing practices and species catch ratios, achieving rebuilding objectives for cod may constrain the harvesting of other groundfish. An imbalance in quotas creates potential for discarding and may require improved monitoring. Modifications to fishing gear and practices, with enhanced monitoring, may mitigate these concerns.

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TABLES

Table 1. Canadian landings of cod in NAFO Division 4X (and Canadian portion of 5Y) by gear and tonnage class.

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

	Otter Trawl					Gill Net		Long Line			Hand		
Year	**0&1**	**2**	**3**	**4**	**5+**	**0&1**	**2&3**	**0&1**	**2**	**3+**	**Line**	**Misc.**	**Total**
1983	638	4,735	6,306	518	1,118	2,180	235	5,747	2,757	883	3,750	604	29,471
1984	964	4,198	5,904	302	1,513	1,248	220	3,916	2,825	980	3,005	453	25,528
1985	523	3,954	5,562	90	1,185	1,837	161	2,617	1,740	635	2,755	440	21,499
1986	573	3,663	5,123	224	974	1,453	196	2,479	1,918	576	2,490	371	20,040
1987	312	2,645	3,504	531	929	1,968	241	3,075	2,175	499	2,670	456	19,005
1988	454	3,966	3,542	160	467	903	444	3,528	3,149	672	3,081	171	20,537
1989	409	3,933	4,184	67	713	1,254	475	2,915	2,167	623	2,937	208	19,885
1990	505	3,668	3,577	268	170	1,933	692	4,201	2,967	849	4,871	203	23,904
1991	355	4,598	5,805	298	751	2,225	619	4,712	3,679	842	3,737	128	27,749
1992	238	4,494	5,711	143	726	1,811	586	4,455	3,574	719	3,517	106	26,080
1993	176	2,778	3,598	68	241	1,387	523	2,768	1,693	310	2,439	45	16,026
1994	132	2,022	2,343	138	82	993	421	2,837	1,412	231	2,367	67	13,045
1995	100	1,387	1,619	112	75	470	507	1,632	959	182	1,706	18	8,767
1996	92	1,552	2,314	157	103	611	442	1,774	1,306	201	1,914	106	10,572
1997	79	2,094	2,430	136	35	694	471	2,013	1,255	231	1,794	6	11,238
1998	99	1,404	1,892	166	22	437	376	1,717	1,016	244	910	0	8,283
1999	86	779	1,253	63	11	501	408	1,551	771	120	762	0	6,304
2000	113	851	1,268	78	9	358	356	1,420	533	106	662	1	5,755
2001	120	975	1,292	29	9	383	390	1,532	423	72	409	0	5,707
2002	181	873	1,484	0	51	524	535	1,559	338	55	292	0	5,893
2003	299	704	1,518	8	5	610	435	1518	350	60	154	7	5,667
2004	269	667	1,513			590	591	1,048	187	20	125	1	5,010
2005	209	660	1,103	21		433	392	1,038	208	12	42	0	4,117
2006	245	561	735	69		259	71	1376	322	37	27	0	3,700
2007	265	471	861	10		252	42	1389	432	44	24	0	3,790
2008	266	452	982	0		236	72	1667	432	8	18	0	4,132

Table 2. Commercial landings and proportion by gear type for 2008.

	Otter Trawl	**Gill Net**	**Longline/Handline**	**Total**
2008 Landings (t)	1699	307	2125	4132
Proportion	41.1	7.4	51.4	100.0

Table 3. Nominal catch of NAFO Division 4X cod by unit area.

Year	4Xm	4Xn	4Xo	4Xp	4Xq	4Xr	4Xs	4Xu	5Y	Shelf	Fundy	Foreign	Total
1956	1,981	1,043	5,909		756	2,648	817	1,695		10,204	4,645	1,663	14,849
1957	1,929	1,447	6,369		934	2,041	616	283		9,957	3,662	1,083	13,619
1958	1,480	1,130	5,056		651	1,859	774	153		7,781	3,322	1,110	11,103
1959	2,212	937	5,302		1,123	2,339	957			8,451	4,419	862	12,870
1960	1,654	963	5,164		885	2,373	828	256		7,973	4,150	1,605	12,123
1961	1,630	1,279	5,275	24	892	2,449	905			8,208	4,246	1,272	12,454
1962	1,520	1,031	6,250	651	768	2,946	1,327	163		9,574	5,082	1,280	14,656
1963	1,862	829	6,861	1,443	767	2,419	1,579			10,995	4,765	1,995	15,760
1964	2,099	2,178	7,174	3,334	1,093	3,572	1,317			14,785	5,982	4,688	20,767
1965	1,665	2,088	6,526	7,733	962	4,091	1,215			18,012	6,268	2,693	24,280
1966	2,201	1,521	5,444	7,254	1,099	4,607	2,032			16,420	7,738	6,746	24,158
1967	2,384	1,400	7,120	8,041	1,276	5,425	2,051			18,945	8,752	4,651	27,697
1968	3,251	2,059	8,159	9,341	1,327	4,785	1,849	4	65	22,813	8,027	4,776	30,840
1969	2,413	2,923	7,355	5,523	947	3,686	1,120	59	60	18,258	5,828	8,704	24,086
1970	2,851	1,300	6,966	2,310	1,077	2,621	847	23	26	13,444	4,577	4,308	18,021
1971	2,750	1,728	9,029	2,157	1,395	2,355	754	13	119	15,674	4,626	3,197	20,300
1972	3,124	1,585	8,908	1,421	1,938	2,818	977	7	52	15,044	5,786	1,902	20,830
1973	2,130	1,478	10,180	1,228	1,742	2,186	802	179	67	15,159	4,833	2,222	19,992
1974	2,243	1,122	9,369	955	1,526	2,839	768	1	120	13,690	5,253	2,166	18,943
1975	81	1,374	967	1,033	864	2,867	133	12,180	86	13,199	6,386	1,598	19,585
1976	1,973	1,408	8,267	743	1,061	2,034	601	40	16	12,423	3,720	519	16,143
1977	184	1,706	1,229	1,487	907	2,686	122	13,562	105	15,456	6,532	378	21,988
1978	2,812	2,864	8,522	3,591	2,286	2,246	676	341	382	18,062	5,658	301	23,720
1979	6,565	2,750	10,495	1,748	2,325	2,550	1,646	229	379	21,741	6,946	78	28,687
1980	5,205	3,325	9,899	1,561	3,571	4,684	2,278	47	166	20,023	10,712	541	31,276
1981	4,767	2,114	12,097	1,830	2,413	5,072	2,031	419	599	21,051	10,290	179	31,520
1982	5,255	2,922	10,451	2,079	3,715	4,571	2,009	538	1,349	20,956	11,933	245	33,134
1983	3,437	1,690	8,537	2,497	3,160	3,787	1,674	1,826	2,543	16,891	12,258	320	29,469
1984	2,255	2,251	6,192	1,655	2,244	2,959	1,414	3,583	2,698	14,110	11,141	277	25,528
1985	3,006	1,199	5,438	1,026	1,999	2,301	1,511	3,608	1,364	12,236	9,216	47	21,499
1986	2,914	1,762	4,670	544	1,754	1,802	1,500	4,469	557	11,748	8,224	68	20,040
1987	2,676	1,611	4,777	1,131	1,240	858	1,207	5,116	360	12,783	6,179	29	18,991
1988	1,502	1,086	5,458	1,271	1,124	850	1,103	7,990	142	14,814	5,711	11	20,536
1989	1,370	1,019	5,506	2,820	1,360	1,112	915	5,267	478	13,855	5,994	38	19,887

Year	4Xm	4Xn	4Xo	4Xp	4Xq	4Xr	4Xs	4Xu	5Y	Shelf	Fundy	Foreign	Total
1990	1,846	764	7,915	1,746	2,238	1,721	1,722	5,404	326	15,551	8,119	222	23,892
1991	2,552	1,584	8,963	2,440	2,763	4,243	2,560	2,246	307	17,275	10,383	91	27,749
1992	1,523	1,818	10,347	1,455	2,919	3,352	1,503	2,876	278	17,556	8,515	9	26,080
1993	1,364	1,646	4,845	1,436	1,959	2,428	1,399	760	189	9,406	6,620	0	16,026
1994	828	561	4,414	1,128	1,662	1,883	892	1,540	137	7,942	5,166	0	13,108
1995	293	696	1,737	1,586	1,306	1,032	510	1,528	79	3,349	5,500	0	8,849
1996	466	813	2,787	1,484	1,608	1,659	930	654	171	4,885	5,755	0	10,640
1997	453	837	2,213	1,327	1,793	2,240	1,070	1,303	183	4,490	7,058	0	11,548
1998	478	907	1,657	1,800	993	1,288	615	394	152	3,369	4,916	0	8,283
1999	401	593	1,591	1,296	964	784	415	140	121	2,748	3,553	0	6,304
2000	291	395	1,433	1,198	1,071	680	413	151	124	2,222	3,535	0	5,756
2001	257	535	1,049	1,395	985	814	441	125	106	2,289	3,418	0	5,707
2002	231	422	901	1,485	1,152	867	487	132	216	1,663	4,219	0	5,893
2003	186	421	700	1,276	723	1,112	695	280	274	1,808	3,853	0	5,668
2004	88	245	360	1,211	926	928	709	289	254	1,081	3,922	0	5,010
2005	99	403	444	1,085	726	584	409	166	201	1,453	2,664	0	4,117
2006	130	420	721	1124	352	293	382	223	54	2122	1578	0	3,700
2007	129	626	761	693	678	415	279	172	38	2043	1747	0	3,790
2008	123	884	866	1053	347	157	481	199	23	2476	1656	0	4,132

Table 4. Monthly landings for NAFO Division 4X cod.

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Unknown	Calendar year	Fishing year	TAC
1960	119	428	235	388	1,565	1,329	2,924	1,365	1,703	934	662	417	0	12,069		
1961	225	298	246	597	964	2,324	2,527	1,397	1,250	1,299	880	416	0	12,423		
1962	63	108	363	904	1,181	1,984	3,473	1,846	1,988	1,157	926	556	0	14,549		
1963	309	122	309	577	1,564	2,896	2,570	2,660	1,933	1,714	777	359	0	15,790		
1964	474	320	832	1,690	1,727	3,182	3,592	2,856	2,417	2,362	899	367	349	21,067		
1965	392	367	1,229	1,881	2,603	3,724	4,694	2,634	2,708	2,377	927	685	0	24,221		
1966	911	755	838	2,061	2,034	3,419	4,299	3,323	2,555	2,470	910	588	0	24,163		
1967	874	823	820	1,462	2,304	5,155	4,210	4,052	3,334	2,962	1,304	513	0	27,813		
1968	871	1,107	1,406	2,377	3,121	5,009	4,952	4,116	2,742	3,037	1,328	774	0	30,840		
1969	1,876	1,694	1,071	1,845	2,160	4,176	3,722	2,797	1,943	1,483	827	518	0	24,112		
1970	805	500	617	970	2,024	2,745	2,775	2,279	1,969	1,874	921	541	0	18,020		
1971	526	848	584	814	1,725	3,939	3,328	2,483	2,487	1,902	1,110	555	0	20,301		
1972	862	633	473	744	1,258	3,832	3,982	2871	2038	2663	925	250	0	20,531		
1973	1,009	925	514	1,056	1,381	3,919	2,937	2,623	2,264	1,544	818	1,001	0	19,991		
1974	771	397	399	695	1,335	3,583	3,150	2,538	1,968	1,765	877	1,464	0	18,942		
1975	648	169	394	712	3,223	3,250	3,355	2,647	1,796	1,457	668	1,267	0	19,586		
1976	363	555	376	581	1,220	2,824	2,869	2,064	1,968	1,399	782	1,140	0	16,141		
1977	580	940	861	1,580	2,232	3,782	3,366	2,444	1,740	2,048	1,443	973	0	21,989		
1978	862	2,042	911	1,371	1,987	3,411	3,379	2,920	2,454	1,473	1,085	1,828	0	23,723		
1979	889	752	1,973	1,400	1,846	4,276	3,638	3,555	3,218	2,233	2,992	1,935	0	28,707		
1980	706	2,188	1,704	2,485	3,317	5,316	3,433	3,346	2,603	2,876	1,547	1,756	0	31,277		
1981	1,649	2,451	2,529	1,533	2,881	4,093	3,845	4,067	2,253	3,119	1,728	1,373	0	31,521		
1982	757	2,390	2,569	1,491	3,415	5,109	4,734	3,258	3,540	2,890	1,244	1,737	0	33,134		30,000
1983	1,713	1,654	1,648	1,888	2,743	5,713	4,554	2,832	3,183	1,787	1,037	719	0	29,471		30,000
1984	1,798	2,021	752	817	1,796	3,471	3,688	4,567	2,773	1,668	1,201	976	0	25,528		30,000
1985	779	1,699	956	1,268	1,974	2,586	3,199	2,650	2,737	1,801	787	1,063	0	21,499		30,000
1986	904	1,633	1,775	1,450	1,437	1,939	2,739	1,995	2,576	1,714	771	1,107	0	20,040		20,000
1987	1,208	1,837	1,242	1,059	1,870	2,778	2,663	1,821	1,679	1,403	910	535	0	19,005		18,000
1988	2,104	1,531	535	939	1,620	2,931	3,104	2,122	2,524	1,441	636	1,050	0	20,537		16,000
1989	2,150	2,347	1,362	1,707	1,292	3,562	1,830	1,772	1,535	1,278	637	413	0	19,885		13,000
1990	2,619	2,027	707	778	1,560	3,104	3,751	3,123	2,598	1,689	1,158	790	0	23,904		22,000
1991	2,023	2,651	993	1,666	2,322	3,167	3,963	2,881	2,967	2,208	1,650	1,258	0	27,749		26,000
1992	2,088	1,740	1,297	1,502	1,685	3,622	3,366	2,803	2,625	2,353	1,478	1,521	0	26,080		26,000
1993	657	903	994	996	1,617	2,312	2,834	2,221	1,804	1,048	562	78	0	16,026		16,000

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Unknown	Calendar year	Fishing year	TAC
1994	734	972	547	847	824	1,771	2,246	1,503	1,267	1,154	726	454	0	13,045		14,000
1995	610	229	317	827	574	1,236	1,771	774	1,071	521	276	561	0	8,767		9,000
1996	503	331	446	531	819	1,755	1,805	1,317	880	887	679	619	0	10,572		11,000
1997	98	362	378	806	644	1,440	1,779	1,382	1,548	1,424	710	668	0	11,239		13,000
1998	285	348	402	313	512	955	1,290	978	1,150	793	528	729	0	8,283		9,300
1999	186	105	124	331	416	1,056	1,296	868	872	479	333	239	0	6,304	7,330	7,910
2000	215	255	556	113	368	906	1,104	755	545	507	324	107	0	5,755	5,834	6,000
2001	361	103	641	315	449	745	870	672	594	470	318	169	0	5,707	5,908	6,000
2002	376	278	561	624	493	677	841	744	567	360	230	141	0	5,893	5,817	6,000
2003	296	160	685	289	475	442	565	776	800	569	401	209	0	5,668	5,399	6,000
2004	118	224	529	451	513	432	641	569	593	424	245	271	0	5,010	4,857	6,000
2005	194	289	235	351	281	245	457	583	445	437	315	289	0	4,121	3,850	5,500
2006	229	68	150	68	118	357	658	626	647	364	335	79	0	3,700	3,712	5,000
2007	77	100	282	140	196	372	593	661	526	394	259	190	0	3,790	3,938	5,000
2008	146	210	250	279	150	269	488	548	641	736	319	96	0	4,132	4,064	5,000

Table 5. Proportion of NAFO Division 4X cod landings caught during trips with Observer coverage in the 4X groundfish fishery.

Year		Otter trawl Tonnage	Otter trawl Proportion	Longline Tonnage	Longline Proportion
2001	observed	45.4	3.80%	11.1	0.74%
	landed	1188		1500	
2002	observed	0.266	0.01%	6.3	0.30%
	landed	1777		1867	
2003	observed	20.2	0.79%	6.9	0.82%
	landed	2540		842	
2004	observed	88.3	3.60%	12.3	0.99%
	landed	2453		1243	
2005	observed	30.4	1.52%	8.9	0.72%
	landed	1990		1233	
2006	observed	33	2.05%	6.2	0.36%
	landed	1609		1735	
2007	observed	31.3	1.95%	2.0	0.11%
	landed	1607		1865	
2008	observed	21.1	1.24%	15.7	0.007%
	landed	1699		2107	

Table 6. Proportion of groundfish quotas landed in the NAFO Division 4X fishery by gear sector.

2005 Quota Report	cod	haddock	pollock
FIXED < 45'	66%	42%	87%
MOBILE <65' (ITQ)	80%	77%	97%
VESSELS >100'	81%	80%	102%
Aboriginal Fishery	68%	64%	88%
2006 Quota Report	**cod**	**haddock**	**pollock**
FIXED < 45'	74%	63%	82%
MOBILE <65' (ITQ)	82%	72%	93%
VESSELS >100'	51%	74%	100%
Aboriginal Fishery	83%	68%	88%
2007 Quota Report	**cod**	**haddock**	**pollock**
FIXED < 45'	78%	73%	98%
MOBILE <65' (ITQ)	80%	100%	97%
VESSELS >100'	95%	108%	99%
Aboriginal Fishery	83%	111%	90%

Table 7a. Number of fishing vessels reporting landings of cod, haddock, pollock or white hake in NAFO Division 4X annually.

Year	Otter trawl	Gill net	Longline	Handline
1996	142	205	528	779
1997	142	197	497	657
1998	129	163	398	422
1999	129	126	357	354
2000	121	101	376	326
2001	112	97	366	201
2002	113	110	381	162
2003	108	103	339	92
2004	103	98	312	59
2005	91	90	281	41
2006	85	92	294	26
2007	82	96	322	28
2008	66	80	266	20

Table 7b. Fishing days by gear type in NAFO Division 4X.

Year	Gill net	Longline	Handline
1996	4,912	5,210	9,880
1997	6,281	6,179	9,650
1998	4,178	5,352	5,721
1999	3,370	4,156	4,234
2000	2,321	3,794	3,287
2001	2,116	3,895	2,093
2002	2,253	4,232	1,390
2003	2,432	3,960	711
2004	2,237	3,089	468
2005	2071	2647	250
2006	1469	3274	121
2007	1397	3686	110
2008	1149	3063	85

Table 8a. Construction of Age-Length keys for NAFO Division 4X cod for 2007.

Area	Bay			Shelf		
Quarter	H1	Q3	Q4	H1	Q3	Q4
No. Samples	10	4	4	7	4	4
No. Aged	437	196	202	276	196	144

Table 8b. Construction of length frequencies for NAFO Division 4X cod for 2007, and Age-Length keys against which they are matched.

Gear	Quarter	Area	a	b	Number of Samples	Number Measured	Landings (t)	ALK used
OT	1	Bay	0.0081	3.0503	5	1801	249	BayH1
GN					0	GNc1*	<1	
LL + HL					0	Q2Bayllcopy*	3	
OT	1	Shelf			2	572	88	ShelfH1
GN					0	GNc2*	<1	
LL + HL					2	705	117	
OT	2	Bay	0.0084	3.041	9	2484	330	BayH1
GN					0	GNc3*	36	
LL + HL					3	564	47	
OT	2	Shelf			7	1370	102	ShelfH1
GN					0	GNc4*	26	
LL + HL					5	1433	167	
OT	3	Bay	0.0087	3.0233	3	754	367	BayQ3
GN					0	GNc5*	95	
LL + HL					7	1956	256	
OT	3	Shelf			2	548	121	ShelfQ3
GN					0	GNc6*	127	
LL + HL					6	1557	813	
OT	4	Bay	0.0063	3.1152	5	965	300	BayQ4
GN					0	GNc7*	2	
LL + HL					2	573	60	
OT	4	Shelf			3	720	49	ShelfQ4
GN					0	323	8	
LL + HL					7	1912	424	

*LF substituted due to absence of commercial sampling for this gear/area/quarter combination.

Table 9a. Construction of Age-Length keys for NAFO Division 4X cod for 2008 (January-July).

Area	Bay	Shelf
Quarter	H1	H1
No. Samples	6	6
No. Aged	241	203

Table 9b. Construction of length frequencies for NAFO Division 4X cod for 2008, and Age-Length keys against which they are matched (January-July).

Gear	Quarter	Area	a	b	Number of Samples	Number Measured	Landings (t)	ALK used
OT	1	Bay	0.0081	3.0503	3	875	187	BayH1
GN					0	0	0	
LL + HL					0	q2BayLLcopy*	14	
OT	1	Shelf			3	666	293	ShelfH1
GN					0	q2BayGNcopy1*	<1	
LL + HL					2	560	112	
OT	2	Bay	0.0084	3.041	7	3221	313	BayH1
GN					3	741	97	
LL + HL					1	300	27	
OT	2	Shelf			3	740	94	ShelfH1
GN					0	q2BayGNcopy2*	20	
LL + HL					7	1827	147	

*LF substituted due to absence of commercial sampling for this gear/area/quarter combination.

Table 10. Catch at age (numbers in thousands) for NAFO Division 4X cod (to July 1, 2008).

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	2+	3+	4+
1980	0	837	6,054	2,358	1,742	1,135	442	261	91	60	19	17	5	13,021	12,183	6,129
1981	0	818	3,870	4,265	1,844	1,045	587	297	184	75	39	19	19	13,061	12,244	8,373
1982	0	904	2,885	4,414	3,060	912	393	279	146	86	41	25	15	13,160	12,255	9,371
1983	9	1,031	3,689	2,433	2,057	1,205	459	204	120	76	36	10	10	11,330	10,299	6,610
1984	33	917	2,393	3,081	1,930	965	465	176	63	49	29	18	5	10,090	9,173	6,781
1985	0	711	1,674	1,569	2,324	1,284	514	194	71	53	18	7	6	8,425	7,715	6,041
1986	0	251	2,789	1,941	994	1,008	409	200	93	50	23	20	10	7,788	7,537	4,748
1987	0	861	902	2,053	1,087	523	511	236	140	66	33	9	7	6,428	5,567	4,665
1988	0	403	3,517	1,659	1,553	656	178	192	85	53	28	6	9	8,338	7,935	4,418
1989	17	655	2,560	3,656	632	562	163	79	60	19	10	10	2	8,408	7,753	5,193
1990	0	144	2,863	2,805	2,462	497	279	78	40	38	14	15	1	9,235	9,091	6,228
1991	2	391	1,535	5,092	1,777	1,364	215	156	32	16	28	15	6	10,626	10,235	8,700
1992	0	751	3,391	1,878	3,276	878	513	63	50	16	9	4	0	10,828	10,077	6,685
1993	0	881	3,490	2,045	660	672	186	90	14	14	5	0	0	8,056	7,176	3,686
1994	0	475	2,280	2,233	887	195	181	42	18	0	2	0	0	6,314	5,838	3,558
1995	0	135	2,146	1,081	582	130	28	40	11	5	0	0	0	4,158	4,023	1,877
1996	0	50	883	2,594	441	212	29	16	8	2	1	1	0	4,237	4,187	3,304
1997	0	59	1,126	1,556	1,193	199	82	16	2	6	1	3	0	4,243	4,184	3,058
1998	0	234	886	1,021	615	441	54	20	6	2	3	1	1	3,284	3,050	2,164
1999	0	72	834	543	347	264	120	20	7	0	0	1	0	2,210	2,138	1,303
2000	0	218	575	905	247	189	66	27	8	1	1	0	0	2,237	2,019	1,444
2001	0	114	1,187	595	378	75	40	17	12	1	0	0	0	2,420	2,306	1,119
2002	0	22	365	1099	221	138	31	16	13	4	1	0	0	1,909	1,887	1,521
2003	0	73	249	557	519	96	95	21	2	1	3	0	0	1,614	1,541	1,292
2004	0	33	1,029	367	291	153	19	20	5	1	0	0	0	1,920	1,887	858
2005	0	66	148	830	173	89	47	9	3	0	0	0	0	1,367	1,301	1,152
2006	0	42	760	215	491	103	20	9	6	0	1	1	0	1,649	1,607	847
2007	0	214	341	927	122	175	16	9	2	1	0	0	0	1,809	1,594	1,253
2008	0	14	172	148	264	33	22	6	0	0	0	0	0	659	646	473

Table 11. Mean weight-at-age for NAFO Division 4X cod by area (to July 1, 2008).

4X East	1	2	3	4	5	6	7	8	9	10	11	12
1983		0.76	1.22	1.81	2.50	3.93	6.09	8.22	10.76	11.83	12.22	16.59
1984		0.96	1.30	1.69	2.34	3.37	4.68	6.83	8.60	11.06	13.21	14.03
1985		0.60	1.07	1.47	2.00	3.06	4.55	6.70	6.89	9.00	14.16	15.66
1986		0.78	1.13	1.63	2.21	3.47	4.69	7.15	8.83	8.81	13.11	13.10
1987		1.23	1.40	1.83	2.61	3.46	4.99	7.33	8.36	10.66	11.80	15.85
1988		0.94	1.30	1.90	2.69	3.98	5.23	8.06	9.88	10.93	13.05	16.04
1989	0.78	1.23	1.57	2.21	2.75	3.96	4.88	7.86	9.46	11.95	15.04	14.81
1990		0.82	1.29	1.97	2.86	3.72	5.59	8.10	10.46	11.93	14.12	15.24
1991		0.76	1.13	1.73	2.50	3.54	5.08	6.44	9.44	11.19	13.73	15.74
1992		0.78	1.14	1.63	2.58	3.58	4.44	6.50	8.37	12.10	14.50	19.15
1993		0.68	1.25	1.62	2.24	3.44	4.67	7.01	9.13	10.97	18.08	
1994		0.76	1.04	1.92	2.41	3.15	4.97	5.21	9.28	15.98	13.56	
1995		0.86	1.23	1.72	3.26	4.09	4.69	7.23	9.18	13.33	16.33	
1996		0.75	1.21	2.06	2.96	4.77	5.53	6.39	9.80	12.02	10.12	
1997		1.17	1.22	1.83	3.31	4.49	6.04	8.83	9.99	11.14	13.58	8.71
1998		0.86	1.12	1.71	2.54	4.42	4.72	7.33	9.76	9.66	10.83	16.17
1999		1.00	1.71	2.32	2.83	4.03	5.43	8.26	10.70	13.24	11.35	16.54
2000		0.93	1.50	2.32	2.85	3.14	4.05	5.57	9.44	10.98	10.25	12.53
2001		0.99	1.62	2.19	3.65	4.11	5.12	6.62	8.19	8.72	11.05	0.00
2002		0.75	1.29	2.39	3.08	4.55	5.70	7.24	7.32	8.54	7.61	
2003		0.78	1.45	2.14	3.63	5.08	6.36	7.17	10.38	12.60	12.74	
2004		0.75	1.41	2.48	3.77	4.95	5.33	7.26	11.15		14.04	
2005		0.99	1.50	2.22	3.85	4.39	5.24	7.04	10.20			
2006		0.71	1.26	1.58	2.92	3.77	5.55	6.74	6.93		11.64	
2007		1.03	1.18	1.75	2.54	3.28	4.32	5.11	6.84	10.20		
2008		0.95	1.21	1.50	2.51	3.10	4.26	3.33	7.19	8.83		
Mean	0.78	0.88	1.30	1.91	2.82	3.88	5.08	6.90	9.10	11.11	12.87	14.01

4X West	1	2	3	4	5	6	7	8	9	10	11	12
1983	0.38	0.86	1.48	2.18	3.30	4.88	6.38	8.62	9.92	12.19	14.23	20.63
1984	0.39	0.93	1.62	2.48	3.52	4.67	6.98	7.94	12.10	13.45	4.75	
1985	0.37	0.84	1.48	2.26	3.43	4.53	6.54	9.45	11.46	15.12	18.23	19.52
1986	0.37	0.80	1.41	2.33	4.30	6.24	7.36	8.18	9.50	14.25	7.99	11.98
1987		0.84	1.57	2.56	4.17	5.33	7.04	7.92	7.94	14.31	18.56	
1988		0.86	1.46	2.24	4.09	5.36	8.99	10.14	8.89	14.69		
1989	0.33	0.76	1.52	2.59	3.60	6.33	7.25	10.32	10.55	14.57		11.66
1990		1.05	1.69	2.69	3.77	4.37	7.31	8.15	11.32	11.95	12.75	14.74
1991	0.82	1.04	1.88	2.91	4.26	6.77	8.75	11.02	13.60	14.17	15.10	17.93
1992		1.18	1.73	2.73	4.49	6.51	8.78	9.93	13.13	14.55	11.10	
1993		0.90	1.74	2.86	4.74	6.09	7.58	9.18	14.32	16.75	13.85	
1994		0.98	1.75	3.19	5.72	7.96	9.31	11.61	11.56		17.46	
1995		1.29	1.91	2.78	4.38	6.01	7.76	9.84	12.49	8.57	14.32	
1996		1.06	1.70	2.85	4.71	6.12	5.97	10.56	11.05			13.19
1997		1.17	1.73	2.74	4.28	5.77	8.44	10.30	9.18	12.94	11.07	22.55
1998		1.16	1.99	3.14	4.49	5.91	8.13	9.20	12.75		14.32	
1999	0.70	1.31	1.88	2.93	4.44	6.06	7.55	8.93			8.97	14.78
2000		1.28	2.17	3.49	3.96	5.66	7.80	8.65	11.44	13.67	10.59	11.55
2001		0.95	2.01	3.46	4.72	6.36	8.15	8.42	11.41	11.88		
2002		1.33	2.15	3.51	5.27	7.04	8.14	10.13	12.03	18.09		
2003		1.59	2.08	3.15	5.03	6.08	7.25	13.86	7.62		19.68	
2004		0.86	1.75	2.68	4.17	5.44	7.33	7.52	8.12	8.71	14.66	14.01
2005		1.07	1.76	3.02	4.21	5.89	6.43	10.04	11.82		12.20	
2006		0.97	1.75	2.11	3.65	4.29	5.44	7.31	6.63	12.16	10.58	10.85
2007	0.37	1.20	1.88	2.56	3.07	4.85	4.64	5.89	8.35	8.33	15.97	
2008		1.29	1.85	2.28	3.51	3.64	5.76	4.49	8.33	6.58		
Mean	0.47	1.06	1.77	2.76	4.20	5.70	7.35	9.14	10.62	12.85	13.32	15.28

Table 12. RV survey stratified numbers at age for cod in 4X East and 4X West.

4X East	Age												
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12+**
1983	136	107	571	3157	1914	937	546	146	0	13	0	0	6
1984	0	354	1417	1376	1201	1507	538	416	0	36	0	0	0
1985	69	90	837	834	343	456	483	314	77	0	13	0	6
1986	0	19	616	947	509	151	435	349	195	0	19	0	51
1987	6	79	1229	305	325	250	106	68	187	26	0	0	0
1988	27	793	1602	5143	1317	887	228	107	57	91	38	13	0
1989	301	136	2910	1789	1723	230	227	89	0	30	18	14	0
1990	28	151	213	2187	1419	1319	113	108	0	0	0	0	7
1991	34	147	1107	599	1833	722	545	80	7	19	0	0	0
1992	35	108	547	981	359	946	405	224	104	29	0	0	0
1993	14	33	296	664	502	80	82	32	61	0	6	41	0
1994	92	380	1073	626	610	268	19	51	50	50	0	0	33
1995	216	33	534	2107	1059	248	229	47	32	34	0	7	0
1996	31	207	374	1307	2378	303	429	148	0	24	15	0	0
1997	30	126	399	560	850	1225	128	109	100	0	26	0	0
1998	39	0	441	599	495	557	503	97	55	6	0	0	0
1999	677	69	330	730	675	736	165	98	0	0	0	0	0
2000	3263	86	151	246	265	230	223	144	148	0	0	0	21
2001	908	150	487	1441	477	406	22	60	0	31	0	0	0
2002	110	59	247	430	547	306	141	49	0	25	0	0	0
2003	258	11	234	210	227	144	15	30	0	0	0	0	0
2004	122	31	74	480	192	205	34	27	8	0	0	0	0
2005	11	159	924	142	632	60	57	15	0	35	0	17	0
2006	60	13	135	574	218	171	63	0	0	0	0	0	0
2007	72	112	138	297	351	154	255	25	0	0	0	0	0
2008	147	121	464	265	225	252	19	0	0	0	0	0	0

4X West	Age												
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12+**
1983	71	34	514	1069	456	543	400	244	0	63	37	0	0
1984	0	466	4328	2015	1161	313	150	66	63	23	25	0	0
1985	0	404	7923	3497	1184	995	283	169	190	165	0	0	20
1986	25	749	718	1974	717	163	114	99	21	97	0	0	0
1987	0	313	1118	313	855	278	154	177	117	49	40	63	0
1988	233	1837	2323	4103	179	661	268	103	187	0	0	0	0
1989	9	658	3179	1632	826	190	262	20	27	52	19	0	0
1990	0	364	660	3335	1044	1002	128	306	80	42	0	21	21
1991	0	466	620	532	1253	372	206	48	109	0	21	12	0
1992	0	144	2184	588	322	765	66	237	21	56	0	0	0
1993	0	336	659	1854	423	49	183	20	0	0	0	0	0
1994	657	878	2240	2113	996	180	16	143	38	20	0	32	32
1995	996	89	313	2671	418	351	45	47	60	0	42	0	0
1996	0	132	465	740	3149	578	324	0	0	32	0	0	0
1997	65	223	170	629	594	1236	194	85	0	0	31	0	0
1998	26	211	1488	1209	923	465	868	128	61	0	0	0	0
1999	192	313	457	561	207	115	29	199	46	0	0	0	0
2000	61	346	1346	585	734	179	102	12	0	0	0	0	0
2001	1262	0	567	1449	474	240	22	0	0	0	0	0	0
2002	0	4269	1743	2143	1954	214	183	73	19	73	0	0	0
2003	457	488	2771	334	875	601	174	49	20	19	0	0	0
2004	45	0	199	2497	127	119	79	0	0	0	0	0	0
2005	43	91	818	226	1187	162	151	20	0	0	0	0	0
2006	209	95	678	1257	175	178	99	20	0	56	35	38	0
2007	30	222	1154	339	714	0	127	0	0	0	0	16	0
2008	12	229	653	173	132	119	0	0	0	0	0	0	0

Table 13. RV survey stratified numbers at age for NAFO Division 4X cod.

4X	Age											
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12+**
1983	208	141	1085	4226	2369	1480	946	389	0	77	37	0	6
1984	0	820	5746	3390	2362	1820	688	482	63	58	25	0	0
1985	69	495	8760	4331	1527	1451	766	483	267	165	13	0	26
1986	25	768	1333	2920	1226	314	549	448	217	97	19	0	51
1987	6	392	2348	618	1180	528	260	245	304	75	40	63	0
1988	260	2630	3926	9246	1496	1548	496	210	244	91	38	13	0
1989	309	794	6089	3420	2549	420	489	108	27	82	37	14	0
1990	28	515	873	5523	2463	2321	240	414	80	42	0	21	27
1991	34	614	1727	1131	3086	1094	751	128	116	19	21	12	0
1992	35	252	2731	1569	681	1710	471	460	124	85	0	0	0
1993	14	369	955	2518	925	129	265	52	61	0	6	41	0
1994	748	1258	3313	2739	1605	449	36	195	88	70	0	32	65
1995	1212	122	847	4779	1477	598	274	94	91	34	42	7	0
1996	31	339	839	2048	5527	880	753	148	0	56	15	0	0
1997	95	349	569	1189	1444	2462	321	194	100	0	57	0	0
1998	65	211	1929	1808	1418	1022	1371	225	116	6	0	0	0
1999	869	382	787	1291	882	850	194	297	46	0	0	0	0
2000	3324	432	1497	830	999	409	325	157	148	0	0	0	21
2001	908	150	1984	2272	1476	816	347	217	148	31	0	0	0
2002	110	5196	1990	2565	2472	496	302	121	19	98	0	0	0
2003	715	499	3005	544	1102	745	189	78	20	19	0	0	0
2004	167	31	272	2977	319	324	113	27	8	0	0	0	0
2005	54	250	1741	368	1820	223	208	35	0	35	0	17	0
2006	269	108	812	1831	393	348	162	20	0	0	0	0	0
2007	102	334	1292	636	1066	154	383	25	0	0	0	16	0
2008	159	350	1117	439	358	372	19	0	0	0	0	0	0

Table 14. ITQ survey stratified numbers at age for cod in 4X East and 4X West.

4X East	Age									
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1996	0	43	175	476	310	23	17	5	0	1
1997	1	18	106	198	189	83	7	7	1	1
1998	0	29	103	126	89	71	44	11	6	0
1999	2	95	287	182	78	48	7	2	0	1
2000	2	108	301	196	98	42	55	11	9	0
2001	0	119	249	195	84	59	3	16	5	6
2002	2	37	454	233	89	39	14	4	0	4
2003	1	5	328	418	109	30	3	3	2	1
2004	1	22	50	385	225	70	32	7	1	2
2005	0	28	492	49	133	10	9	0	0	0
2006	3	10	141	463	58	37	19	2	2	0
2007	3	48	60	188	253	34	57	4	0	0
2008	0	105	483	107	68	45	2	2	2	0

4X West										
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1996	1	259	487	359	427	61	13	1	0	1
1997	0	207	126	529	204	182	10	17	5	1
1998	16	150	754	493	186	40	69	4	1	0
1999	2000	506	412	526	92	50	8	22	5	0
2000	3	955	738	156	135	21	6	4	4	0
2001	907	115	2120	3196	298	83	2	5	0	0
2002	35	343	97	277	253	25	20	17	2	0
2003	36	278	771	133	213	137	32	9	2	0
2004	6	348	92	361	33	28	16	1	1	1
2005	10	148	703	22	115	8	7	1	0	0
2006	11	64	117	87	18	14	9	1	0	0
2007	20	258	137	25	69	0	16	0	0	0
2008	0	258	299	27	30	33	0	4	0	0

Table 15. ITQ survey stratified numbers at age for cod in NAFO Division 4X.

4X	Age									
Year	0	1	2	3	4	5	6	7	8	9
1996	1	302	662	835	737	84	31	6	0	2
1997	1	225	232	727	393	265	17	24	6	2
1998	16	179	857	619	276	112	112	15	7	0
1999	2002	601	700	708	170	98	15	24	5	1
2000	5	1063	1039	351	234	62	61	15	13	0
2001	907	234	2369	3391	382	142	5	21	5	6
2002	37	380	551	510	343	63	35	21	2	4
2003	37	283	1099	551	322	167	36	12	4	1
2004	7	370	142	746	258	98	48	8	2	3
2005	10	176	1196	71	248	18	16	1	0	0
2006	14	74	257	549	76	52	27	3	2	0
2007	23	294	295	234	232	22	68	4	0	0
2008	0	363	782	134	97	78	2	6	2	0

Table 16. Statistical properties of population estimates for mid-year 2008, natural mortality for ages 4 and older and survey calibrations for the 4X cod assessment model obtained from a bootstrap with 1000 replicates.

Parameter	Estimate	Standard Error	Bias
N[2008.5 1]	7663.77	5864.58	1432.48
N[2008.5 2]	5666.05	2136.78	368.66
N[2008.5 3]	1579.47	501.04	72.10
N[2008.5 4]	1011.02	265.98	36.97
N[2008.5 5]	787.483	215.529	37.263
N[2008.5 6]	32.496	12.029	2.264
N[2008.5 7]	108.052	37.216	3.873
N[2008.5 8]	15.475	5.308	0.431
N[2008.5 9]	9.949	4.534	0.278
N[2008.5 10]	0.743	1.054	0.302
M[1996 4]	0.764	0.036	0.000
q ID#[1] RV age 2	0.207	0.024	0.000
q ID#[2] RV age 3	0.326	0.041	0.000
q ID#[3] RV age 4	0.412	0.050	-0.001
q ID#[4 5 6 7] RV age 5,6,7,8	0.627	0.046	0.002
q ID#[8] ITQ age 1	0.047	0.009	0.001
q ID#[9] ITQ age 2	0.118	0.020	0.002
q ID#[10] ITQ age 3	0.118	0.022	0.002
q ID#[11] ITQ age 4	0.101	0.018	0.001
q ID#[12] ITQ age 5	0.085	0.014	0.001
q ID#[13] ITQ age 6	0.082	0.015	0.002
q ID#[14] ITQ age 7	0.086	0.015	0.002
q ID#[15] ITQ age 8	0.122	0.024	0.004

Table 17. Population abundance (number in thousands) for cod in NAFO Division 4X from a virtual population analysis using the bootstrap bias adjusted population abundance (average is for 1980-2007).

	Age											
Year	1	2	3	4	5	6	7	8	9	10	11	12
1948	17634	13438	9046	8923	7152	1769	1050	1155	1202	667	193	223
1949	24729	14438	10969	6680	5850	4382	843	616	619	658	309	67
1950	12596	20247	11379	7652	4182	3953	2771	630	410	372	393	206
1951	16001	10313	15981	7563	3339	2133	2541	1611	479	290	222	310
1952	8731	13100	8177	10720	4487	1424	1296	1659	1070	319	214	87
1953	18373	7148	10037	5555	6148	2606	668	737	1205	648	234	156
1954	9111	15043	5744	7442	3896	3769	1728	347	537	829	334	126
1955	14051	7459	12081	4268	4275	2372	2142	1093	160	324	557	192
1956	16483	11500	6058	8739	2899	2391	1474	1230	724	79	234	401
1957	18045	13495	9321	4399	5004	1716	1432	754	587	488	30	122
1958	15943	14774	11049	7440	3273	2803	1194	634	360	177	143	24
1959	23689	13053	11951	8296	4960	2153	1573	902	369	161	61	96
1960	28830	19395	10687	9491	5008	2514	788	913	373	224	132	28
1961	18704	23604	15879	8749	7522	3231	1337	401	447	131	87	63
1962	22468	15314	19316	12762	6794	4416	1836	807	241	295	70	55
1963	33084	18395	12536	15100	8596	3117	2553	1043	448	124	192	52
1964	42404	27087	15060	9906	10586	5620	1581	1260	584	169	67	120
1965	20672	34717	22177	12234	7433	5881	2323	536	350	137	69	31
1966	16288	16925	28395	16806	7700	3487	2850	1273	197	217	76	36
1967	16246	13335	13844	21526	9537	3290	1292	1341	722	122	119	38
1968	14238	13301	10903	9891	11950	4505	1556	628	749	463	67	56
1969	20439	11657	10880	7405	5785	4304	1417	862	343	393	326	19
1970	19682	16734	9132	6610	4224	2699	1726	628	530	156	118	244
1971	17134	16115	13455	6269	4154	2057	1332	1022	444	241	81	81
1972	19254	14028	12695	9843	4204	2214	738	686	490	216	57	38
1973	17642	15764	11162	8193	5304	1742	960	456	452	274	117	43
1974	21952	14444	12608	7467	4525	2594	821	521	306	227	163	50
1975	26743	17973	11735	8349	4239	2081	1078	433	240	147	89	47
1976	26221	21896	14278	8686	4449	2016	1071	500	230	116	88	47
1977	19497	21468	17026	9565	5335	2382	1069	632	323	120	86	70
1978	33863	15958	15787	11313	6054	3282	1317	590	256	161	56	26
1979	28355	27724	12428	9741	6409	2998	1603	620	330	169	109	35
1980	22727	23240	22414	8477	4822	3085	1393	879	312	212	79	77
1981	25617	18607	18272	12914	4823	2388	1509	744	485	174	120	48
1982	13820	20973	14496	11479	6749	2298	1021	711	343	233	75	63
1983	13727	11315	16355	9274	5447	2792	1066	484	332	151	114	24
1984	17208	11230	8334	10073	5407	2618	1209	463	214	165	56	61
1985	9341	14059	8368	4675	5483	2698	1279	573	221	118	91	20
1986	26865	7648	10869	5345	2421	2411	1063	587	295	117	50	58
1987	18255	21995	6035	6393	2638	1094	1072	504	301	158	52	20
1988	26761	14946	17231	4129	3393	1187	428	422	202	121	71	13
1989	8926	21910	11873	10944	1896	1391	388	192	174	90	52	33
1990	13256	7292	17347	7418	5683	985	637	172	86	89	56	34
1991	14804	10853	5841	11625	3562	2452	364	272	71	35	39	33
1992	12057	12119	8533	3403	4967	1331	794	107	84	30	15	7
1993	30537	9872	9245	3951	1115	1167	313	196	32	25	10	5

	Age											
Year	1	2	3	4	5	6	7	8	9	10	11	12
1994	16054	25002	7288	4444	1412	326	358	91	80	14	8	4
1995	12994	13144	20040	3921	1647	369	94	132	37	49	11	5
1996	9041	10638	10639	14473	2240	827	186	52	72	21	35	9
1997	11505	7402	8665	7914	5062	758	248	68	14	28	8	16
1998	7212	9420	6007	6080	2679	1588	225	63	21	5	9	3
1999	11596	5905	7501	4120	2174	850	456	70	17	6	1	2
2000	7021	9494	4769	5389	1570	789	227	135	20	3	3	0
2001	5051	5748	7576	3386	1923	572	246	63	45	4	1	1
2002	11823	4136	4603	5134	1193	651	218	89	18	13	1	0
2003	2188	9680	3366	3439	1680	413	214	82	31	1	4	0
2004	9217	1792	7859	2532	1240	450	131	40	24	14	0	0
2005	3537	7546	1437	5507	941	389	112	48	6	8	5	0
2006	3043	2896	6119	1042	2026	326	123	22	17	1	3	2
2007	7168	2492	2333	4324	346	626	86	44	5	4	0	1
2008	6887	5869	1847	1603	1413	83	179	29	15	1	1	0
Avg	13263	11477	9765	6493	3019	1315	552	261	127	67	35	19

Table 18. Beginning of year population biomass (thousands of tonnes) for NAFO Division 4X cod from a virtual population analysis using the bootstrap bias adjusted population abundance.

	Age											
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1980	1374	7695	20838	15441	14294	13459	8131	6851	2995	2296	921	956
1981	1549	6161	16987	23521	14299	10416	8809	5805	4663	1877	1403	590
1982	835	6944	13477	20908	20007	10027	5959	5541	3301	2516	870	786
1983	830	3746	15205	16891	16147	12181	6222	3774	3195	1631	1324	303
1984	1040	3718	7748	18348	16031	11420	7055	3608	2054	1779	653	753
1985	565	4655	7779	8516	16255	11772	7463	4468	2124	1279	1062	247
1986	1624	2532	10105	9736	7178	10520	6204	4575	2839	1268	583	724
1987	1104	7282	5611	11645	7820	4771	6259	3932	2891	1709	603	252
1988	1618	4948	16019	7521	10059	5179	2499	3292	1942	1312	824	161
1989	540	7254	11038	19933	5621	6069	2264	1495	1677	969	611	408
1990	801	2414	16127	13512	16846	4299	3715	1338	828	966	655	422
1991	895	3593	5430	21173	10559	10699	2123	2122	685	379	454	415
1992	729	4013	7933	6198	14725	5809	4635	834	810	324	172	86
1993	1846	3268	8595	7197	3306	5090	1824	1525	306	268	122	57
1994	970	8278	6776	8094	4187	1424	2088	708	767	150	94	50
1995	786	4352	18631	7142	4883	1611	550	1029	356	529	133	64
1996	547	3522	9891	26362	6640	3608	1085	404	694	226	411	116
1997	696	2451	8056	14416	15007	3306	1450	529	133	308	98	196
1998	436	3119	5584	11074	7942	6928	1312	493	204	56	109	41
1999	701	1955	6974	7504	6446	3709	2662	544	160	65	13	30
2000	424	3143	4434	9816	4655	3443	1323	1053	188	35	29	3
2001	305	1903	7043	6168	5702	2496	1436	492	436	44	10	7
2002	715	1369	4279	9351	3536	2839	1273	693	177	145	14	2
2003	132	3205	3130	6264	4980	1800	1247	637	302	12	43	2
2004	557	593	7307	4611	3677	1963	762	311	235	147	2	3
2005	214	2498	1336	10031	2791	1699	652	378	58	85	62	1
2006	184	959	5688	1899	6006	1423	720	175	160	9	40	30
2007	433	825	2169	7876	1026	2731	502	344	47	43	3	10
2008	416	1943	1717	2920	4190	363	1042	229	141	7	17	1

Table 19. Projection results for NAFO Division 4X cod using the bootstrap bias adjusted population abundance.

Year	Age Group															
	1	2	3	4	5	6	7	8	9	10	11	12	1+	2+	3+	4+
Projected Population Numbers (000s)																
2008.5	6256	5304	1510	975	758	31	103	15	9	0	1	0				
2009.25	5500	5384	4457	998	341	265	11	36	5	3	0	0				
2010.25	5500	4503	4364	3269	382	131	101	4	14	2	1	0				
Partial Recruitment to the fishery																
2008.5	0	0.05	0.55	1	1	1	1	1	1	1	1	1				
2009.25	0	0.05	0.55	1	1	1	1	1	1	1	1	1				
Fishing Mortality																
2008.5	0	0.032	0.353	0.641	0.641	0.641	0.641	0.641	0.641	0.641	0.641	0.641				
2009.25	0	0.01	0.11	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2				
M																
2008.5	0.2	0.2	0.2	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76				
2009.25	0.2	0.2	0.2	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76				
Weight at beginning off year for population (kg)																
2008.5	0.11	0.4	1.3	2.28	3.19	4.32	5.44	7.5	9.26	10.71	12.4	14.05				
2009.25	0.11	0.31	1.18	1.97	2.84	3.89	5.05	7.15	8.84	10.37	11.95	13.65				
2010.25	0.11	0.31	1.18	1.97	2.84	3.89	5.05	7.15	8.84	10.37	11.95	13.65				
Beginning of year Projected Population Biomass(t)																
2008.5	688	2122	1963	2222	2416	132	561	110	87	5	12	1	10319	9631	7510	5547
2009.25	605	1669	5244	1964	970	1032	54	257	46	34	2	5	11881	11276	9607	4363
2010.25	605	1396	5135	6434	1087	508	513	29	122	20	15	1	15865	15260	13864	8729
Projected Catch Numbers(000s)																
2008.5	0	117	327	290	226	9	31	4	3	0	0	0				
2009.25	0	49	422	128	44	34	1	5	1	0	0	0				

Year	Age Group															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1+**	**2+**	**3+**	**4+**
Average weight at age for catch (kg)																
2008.5	0.7	0.98	1.68	2.59	3.53	4.74	5.83	7.85	9.68	11.06	12.85	14.45				
2009.25	0.7	0.98	1.68	2.59	3.53	4.74	5.83	7.85	9.68	11.06	12.85	14.45				
Projected Yield (t)																
2008.5	0	115	549	751	796	43	179	34	27	2	4	0	2500	2500	2385	1837
2009.25	0	48	707	332	155	162	8	36	6	5	0	1	1460	1460	1412	705

Table 20. Fishing mortality rate (F) for NAFO Division 4X cod from a virtual population analysis using the bootstrap bias adjusted population abundance.

	1	2	3	4	5	6	7	8	9	10	11	12	Avg F
1980	0.000	0.041	0.351	0.364	0.503	0.515	0.427	0.394	0.385	0.368	0.307	0.281	0.414
1981	0.000	0.050	0.265	0.449	0.541	0.649	0.553	0.574	0.535	0.644	0.442	0.564	0.474
1982	0.000	0.049	0.247	0.545	0.683	0.568	0.547	0.560	0.622	0.517	0.918	0.580	0.596
1983	0.001	0.106	0.285	0.339	0.533	0.637	0.635	0.617	0.504	0.792	0.428	0.594	0.411
1984	0.002	0.094	0.378	0.408	0.495	0.516	0.546	0.539	0.391	0.391	0.834	0.391	0.439
1985	0.000	0.057	0.248	0.458	0.622	0.732	0.579	0.463	0.434	0.662	0.246	0.513	0.546
1986	0.000	0.037	0.331	0.506	0.595	0.610	0.546	0.468	0.425	0.618	0.702	0.480	0.534
1987	0.000	0.044	0.180	0.433	0.599	0.738	0.732	0.714	0.708	0.605	1.185	0.673	0.482
1988	0.000	0.030	0.254	0.578	0.692	0.918	0.603	0.684	0.613	0.639	0.565	0.623	0.629
1989	0.002	0.034	0.270	0.455	0.455	0.582	0.616	0.600	0.469	0.267	0.233	0.401	0.455
1990	0.000	0.022	0.200	0.534	0.640	0.796	0.650	0.679	0.698	0.629	0.319	0.663	0.580
1991	0.000	0.041	0.340	0.650	0.784	0.927	1.024	0.973	0.667	0.664	1.523	0.666	0.682
1992	0.000	0.071	0.570	0.916	1.249	1.249	1.201	1.011	1.022	0.853	0.978	0.978	1.113
1993	0.000	0.103	0.532	0.829	1.028	0.981	1.035	0.694	0.626	0.925	0.757	0.000	0.873
1994	0.000	0.021	0.419	0.792	1.140	1.042	0.796	0.695	0.288	0.000	0.245	0.000	0.876
1995	0.000	0.011	0.125	0.358	0.488	0.484	0.397	0.400	0.369	0.126	0.000	0.000	0.397
1996	0.000	0.005	0.095	0.287	0.321	0.439	0.246	0.553	0.169	0.144	0.041	0.163	0.292
1997	0.000	0.009	0.152	0.320	0.396	0.452	0.604	0.396	0.226	0.348	0.182	0.308	0.350
1998	0.000	0.028	0.174	0.264	0.384	0.483	0.406	0.572	0.493	0.751	0.580	0.543	0.301
1999	0.000	0.013	0.130	0.202	0.250	0.558	0.454	0.511	0.871	0.113	0.669	0.669	0.219
2000	0.000	0.026	0.141	0.267	0.246	0.399	0.515	0.327	0.813	0.554	0.776	0.000	0.263
2001	0.000	0.022	0.188	0.280	0.320	0.202	0.255	0.468	0.457	0.423	0.896	0.000	0.295
2002	0.000	0.006	0.090	0.353	0.298	0.350	0.220	0.277	2.036	0.530	1.401	1.401	0.343
2003	0.000	0.008	0.084	0.254	0.552	0.387	0.914	0.442	0.077	1.379	2.087	0.000	0.352
2004	0.000	0.021	0.154	0.225	0.388	0.622	0.229	1.127	0.367	0.168	0.296	0.296	0.279
2005	0.000	0.010	0.120	0.235	0.294	0.371	0.804	0.306	1.168	0.079	0.046	0.000	0.243
2006	0.000	0.015	0.144	0.337	0.402	0.558	0.243	0.640	0.665	0.324	0.651	0.651	0.380
2007	0.000	0.093	0.168	0.344	0.648	0.466	0.297	0.280	0.077	0.237	0.157	0.000	0.367
2008	0.000	0.004	0.190	0.221	0.477	1.172	0.283	0.519	0.020	0.000	0.000	0.000	0.341

FIGURES

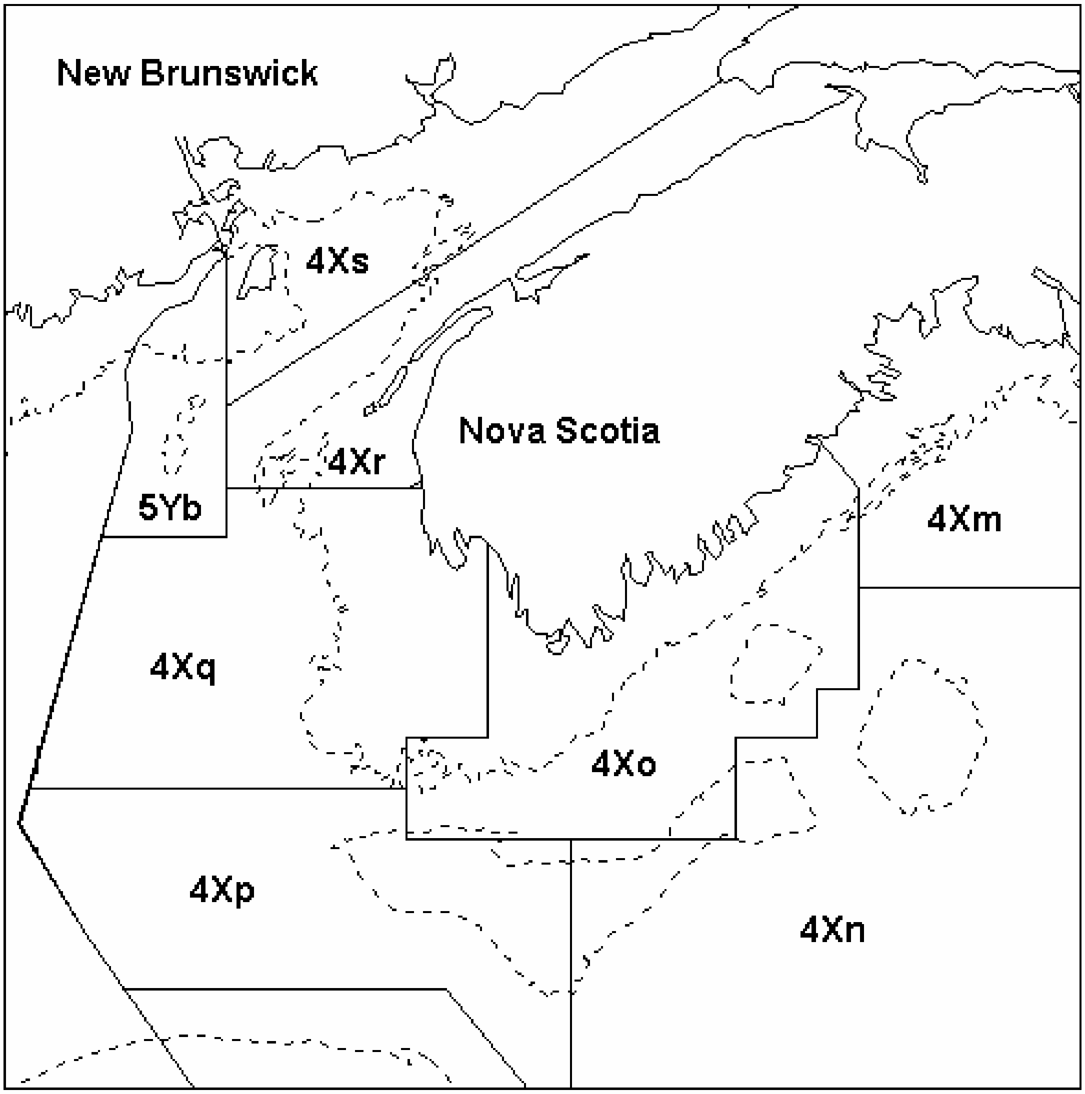


Figure 1. Unit areas of NAFO Divisions 4X5Yb.

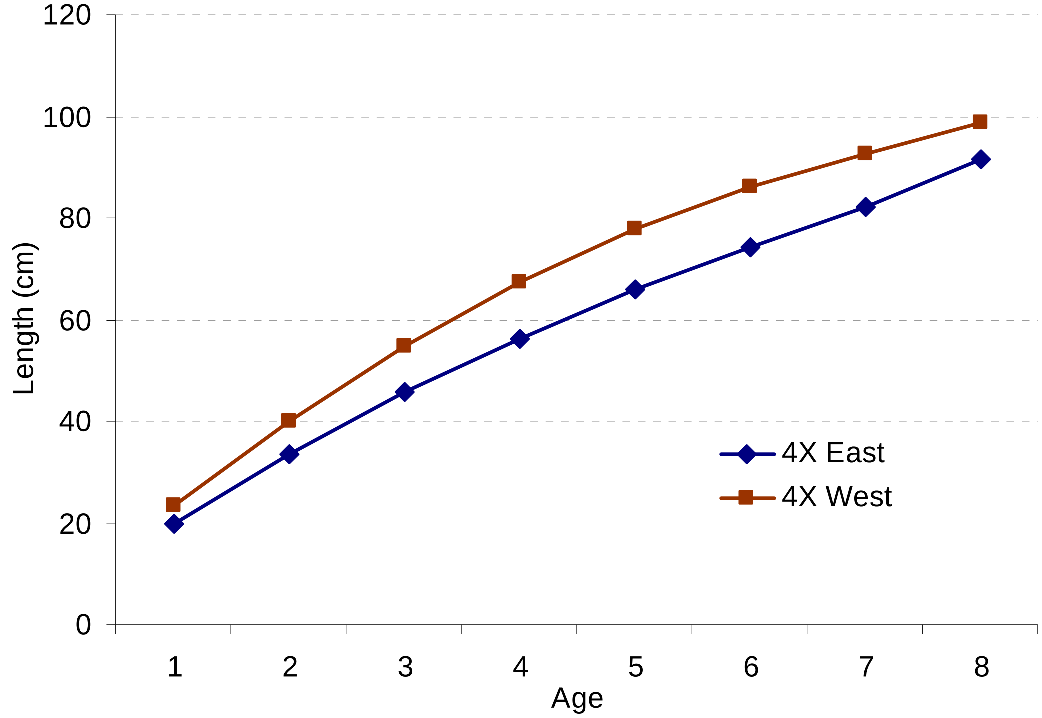


Figure 2a. Length-at-age compared for cod from 4X East (western Scotian Shelf) and 4X West (Bay of Fundy and Gulf of Maine).

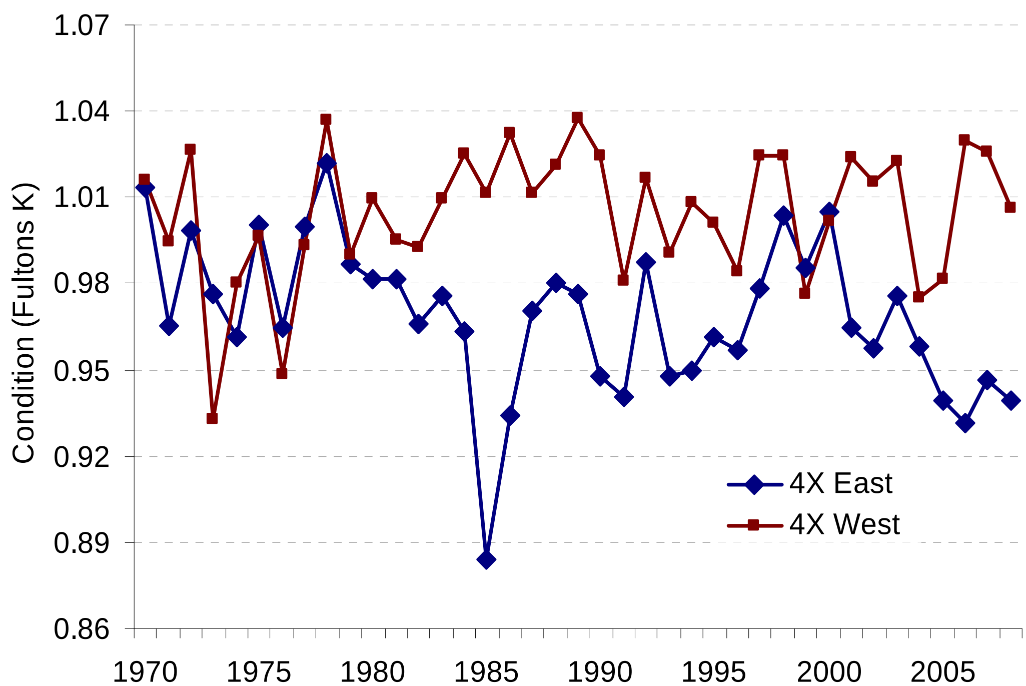


Figure 2b. Condition factor (Fultons K: weight/length^3) for NAFO Division 4X cod by region.

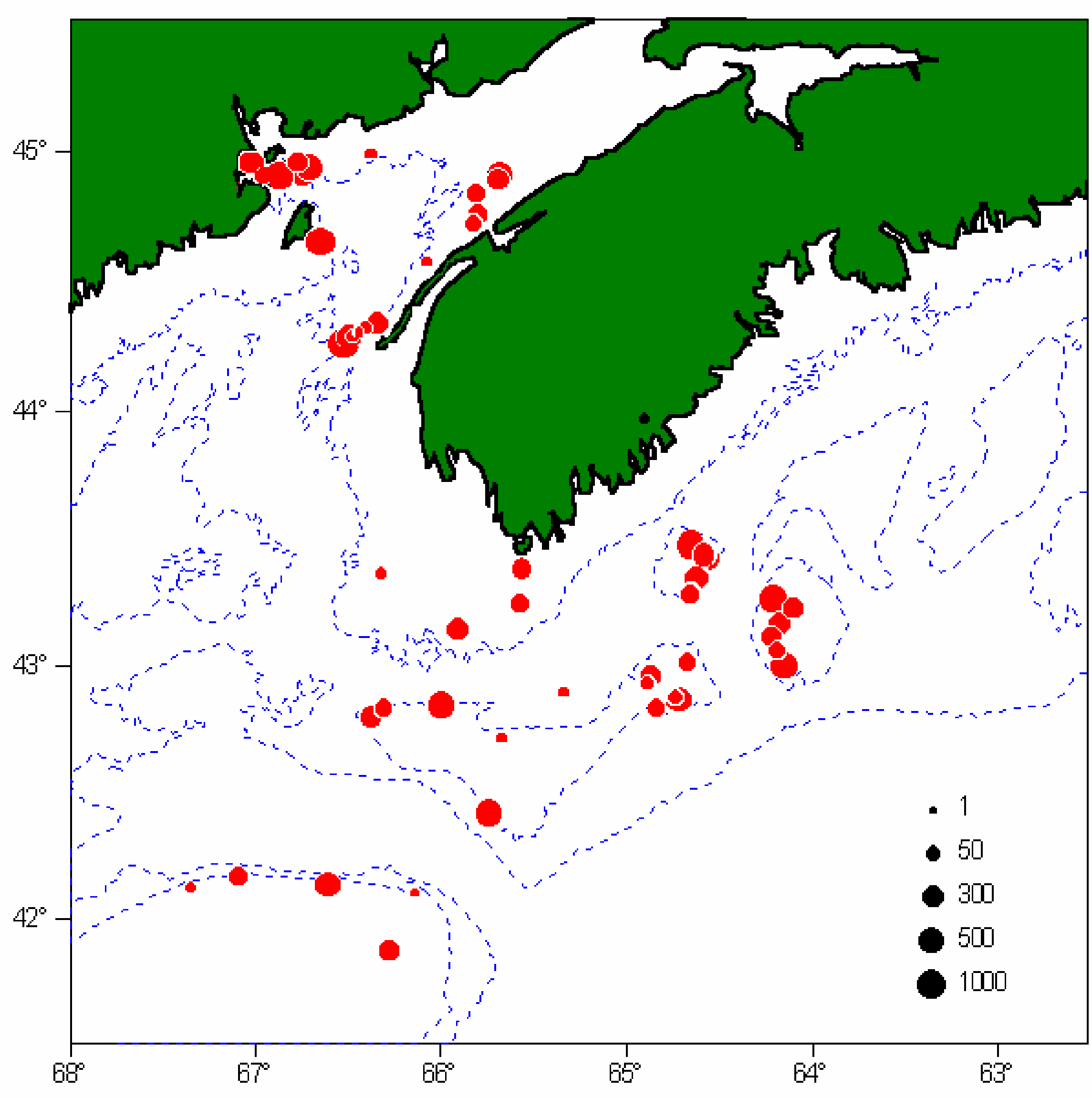


Figure 3. Distribution of tag releases 2001-2002.

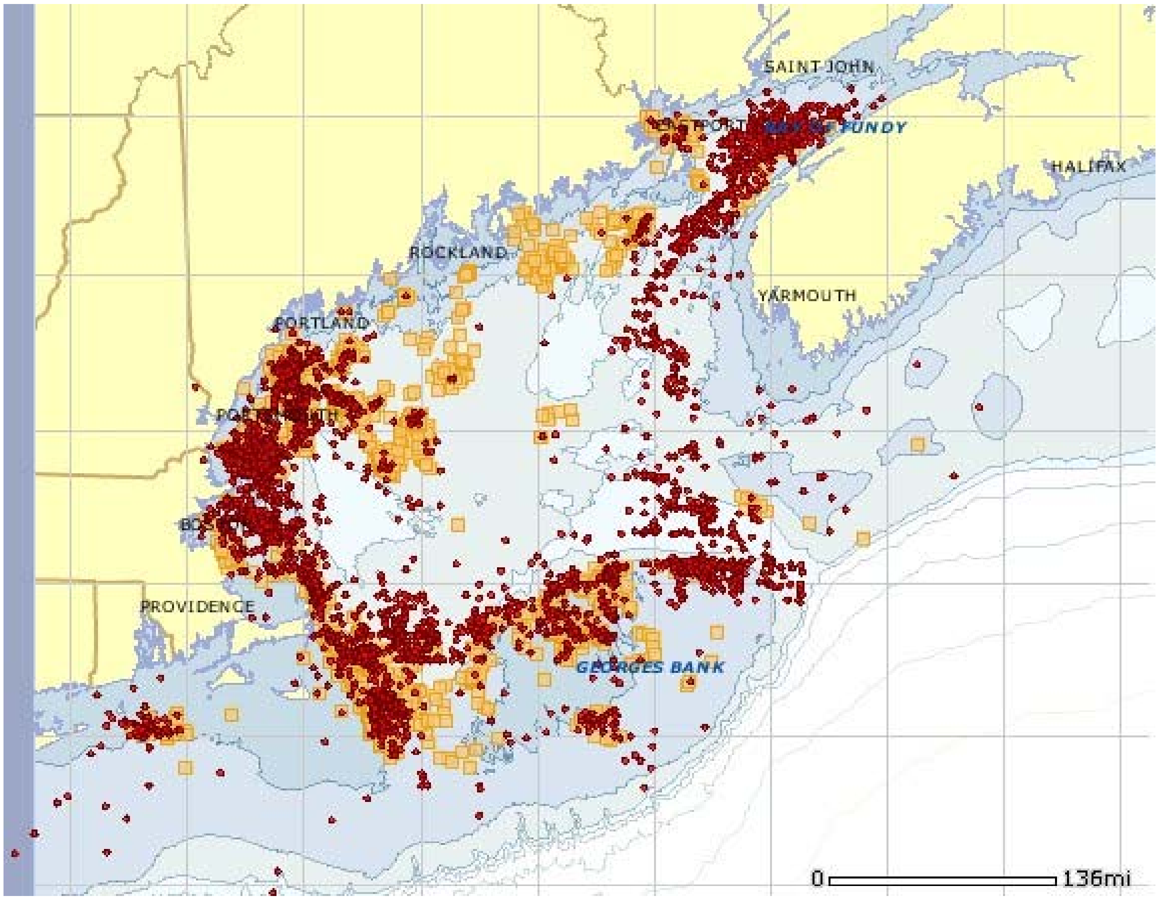


Figure 4. Results from the 2003–2005 North-East Regional cod tagging program; (release locations = yellow; recaptures = red).

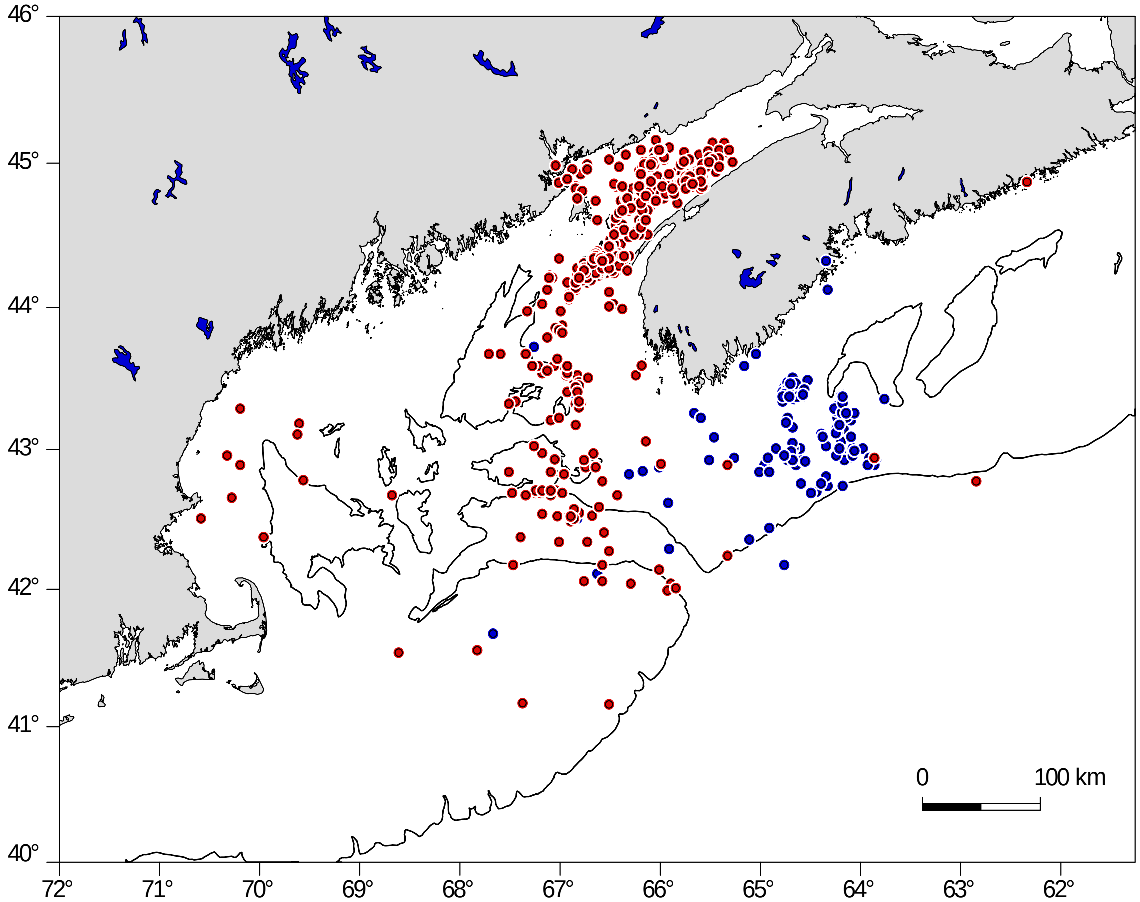


Figure 5. Recapture locations of cod tagged and released in 2001-2002 (red = recaptures of releases in the Bay of Fundy (4Xrs); blue = recapture locations of cod released east of Browns Bank on LaHave, Roseway and Baccaro banks (4Xno).

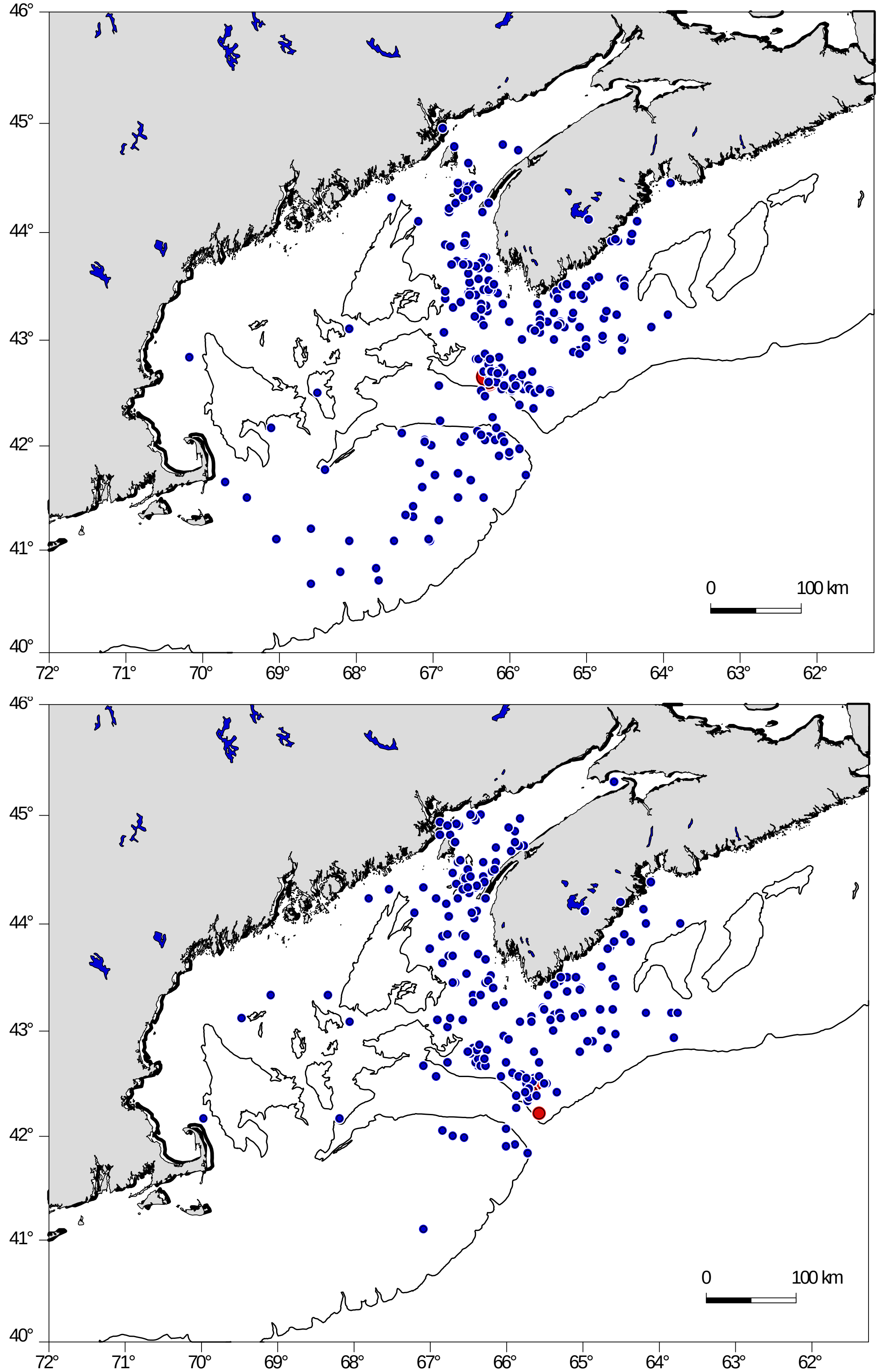


Figure 6. Recapture locations for cod tagged at two locations on Browns Bank, February-March, 1984 and 1985. (Release locations marked as red circles).

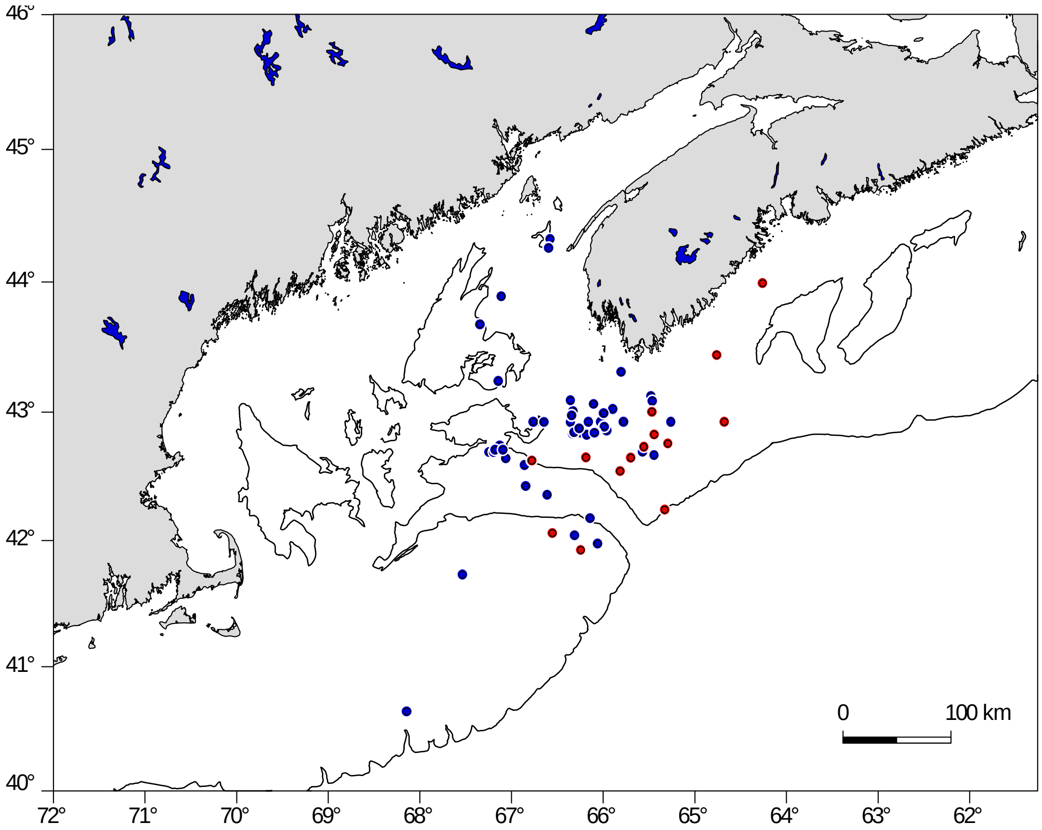


Figure 7. Recapture locations for cod tagged in 2001-2002 on eastern (red) and western (blue) Browns Bank.

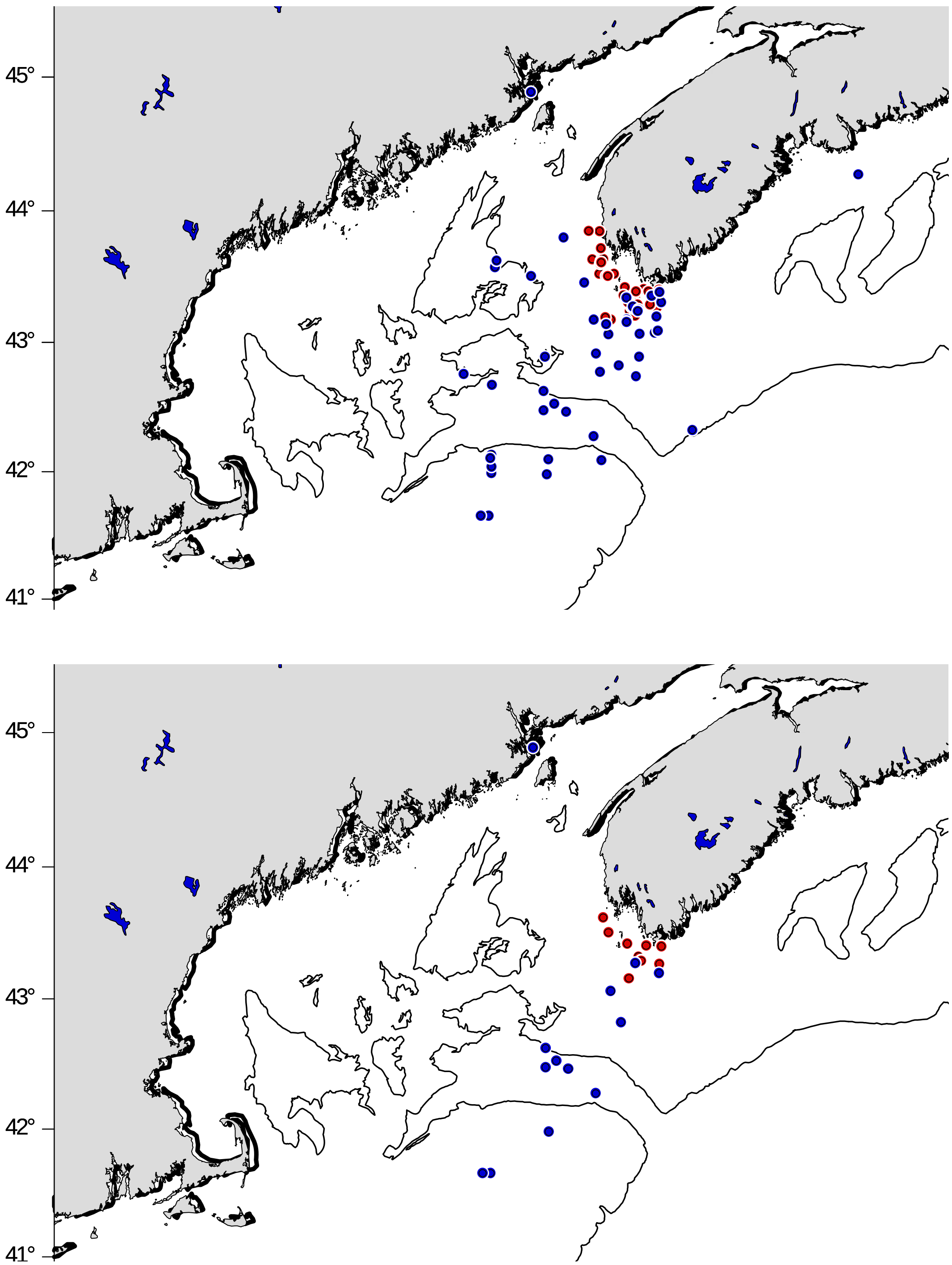


Figure 8. Juvenile cod tagged in coastal waters off SW Nova Scotia: release locations in red, recaptures in blue (top – all recaptures; bottom - >2 yrs at large).

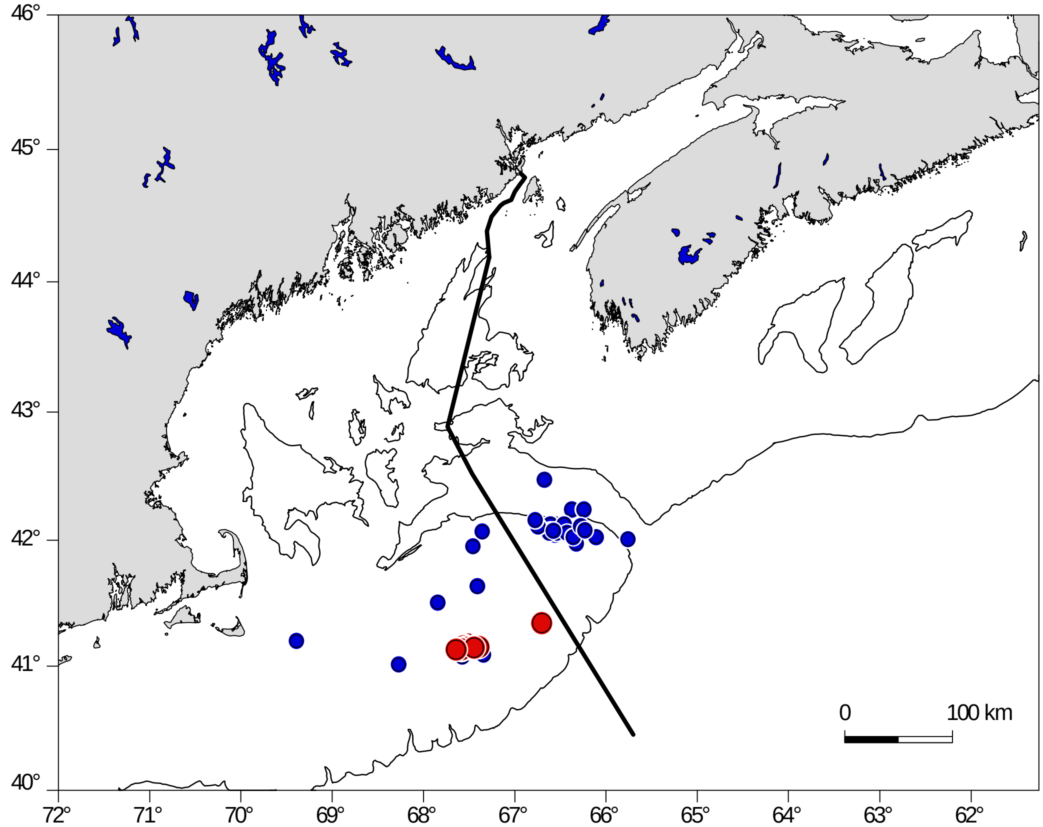


Figure 9. Recapture locations (blue) for cod tagged and released in NAFO Divisions 5Zm (red) during winter (February-March, 2003/2004).

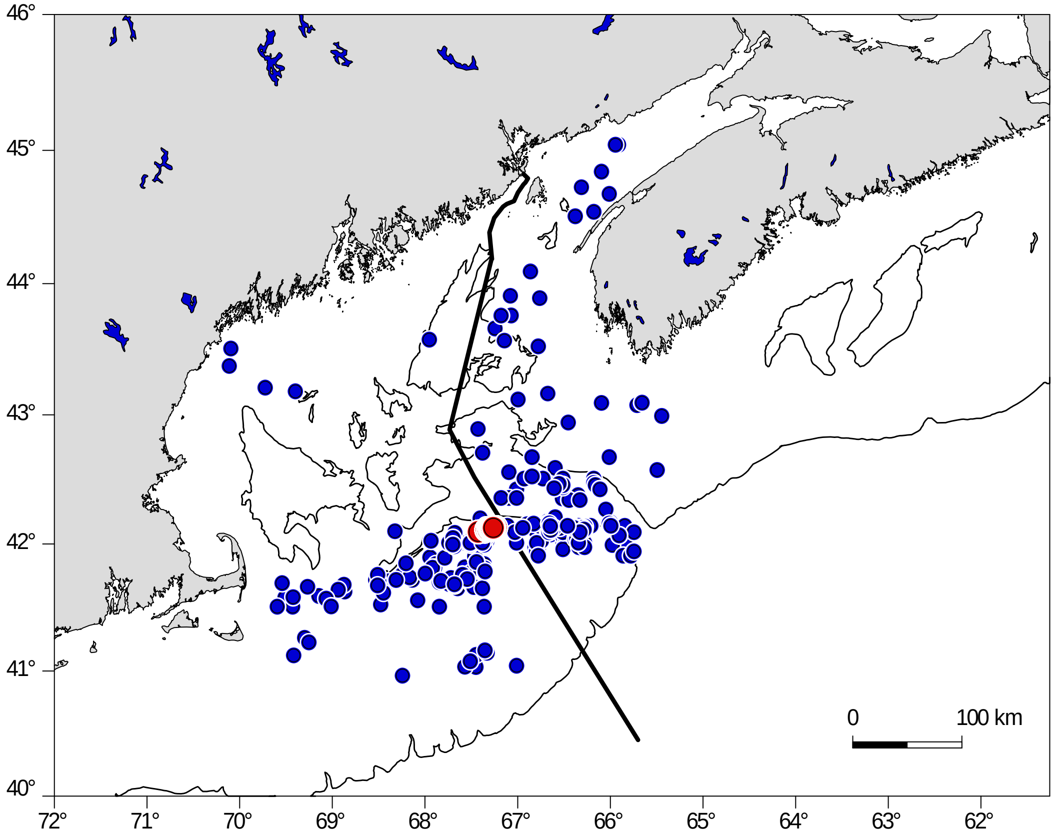


Figure 10. Recapture locations (blue) for cod tagged and released in NAFO Divisions 5Zj (red) during winter (March, 2003 and 2004).

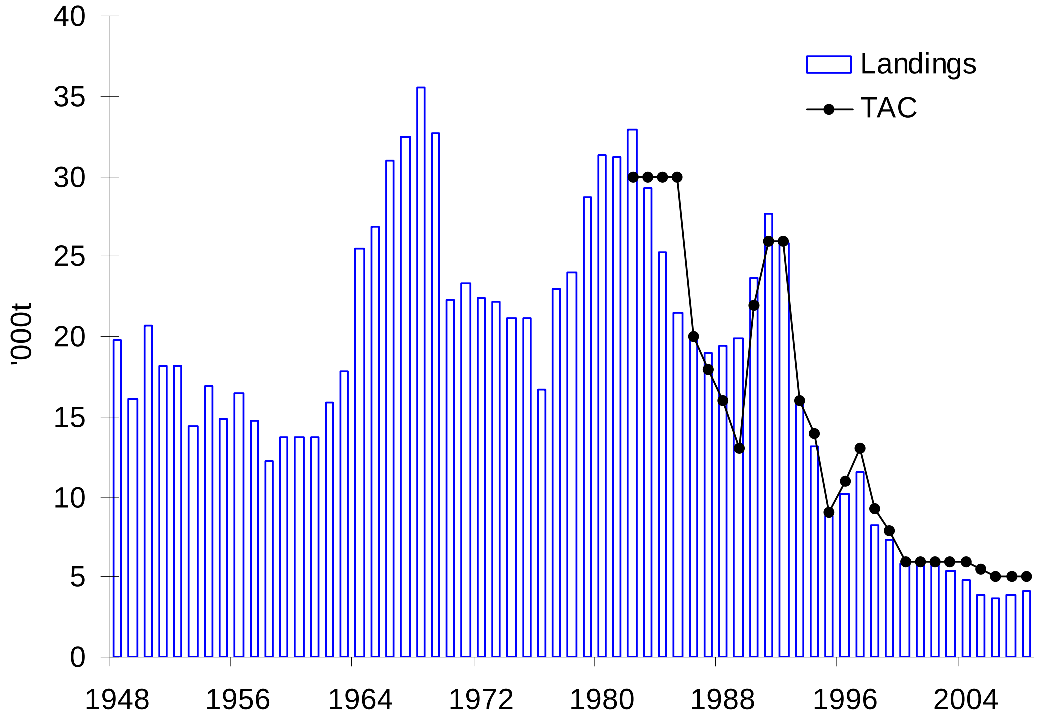


Figure 11. Landings and TAC for NAFO Division 4X cod by quota (commencing in 2000, landings and TAC refer to the fishing year period (April 1st of the current year to March 31st of the following year).

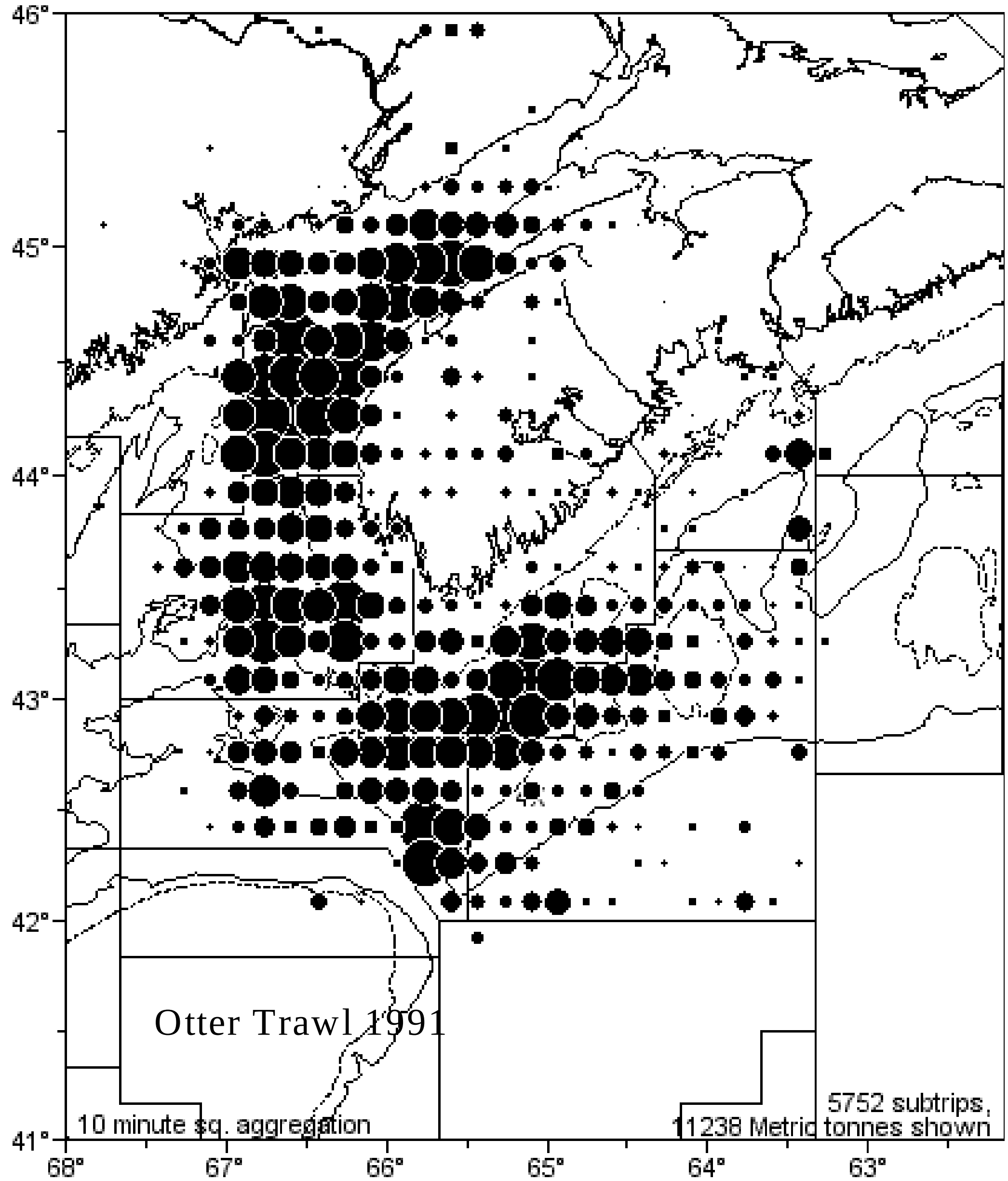


Figure 12. Distribution of cod catches in the otter trawl fishery for NAFO Division 4X (1991); area of circle proportional to tonnage caught.

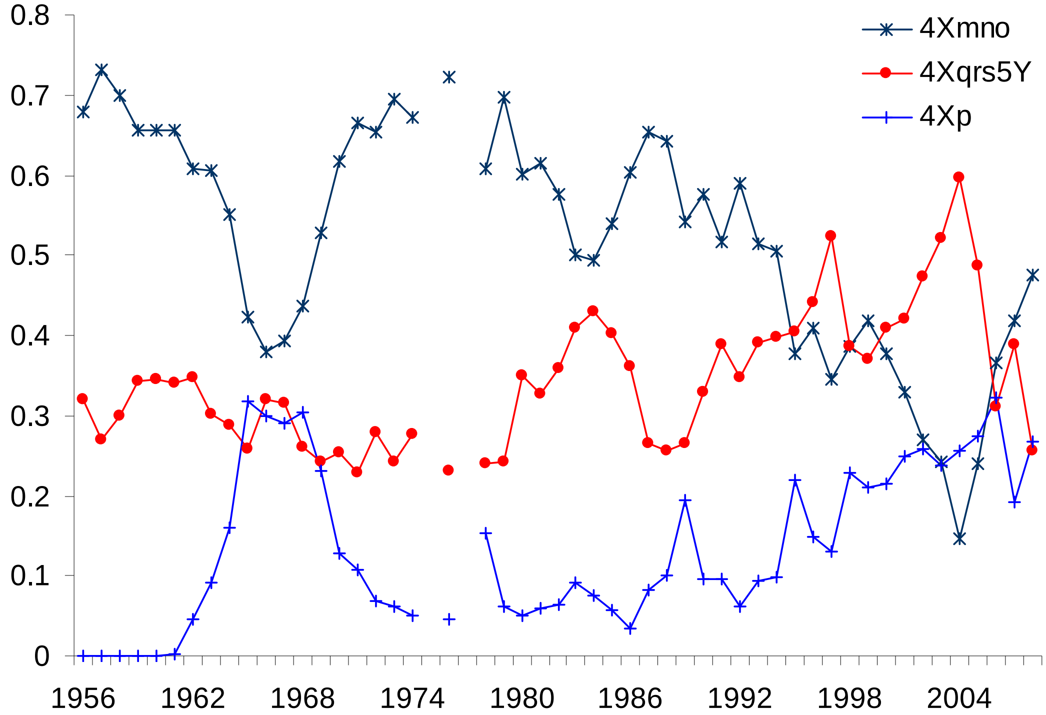


Figure 13. Proportion of NAFO Division 4X cod landings by region.

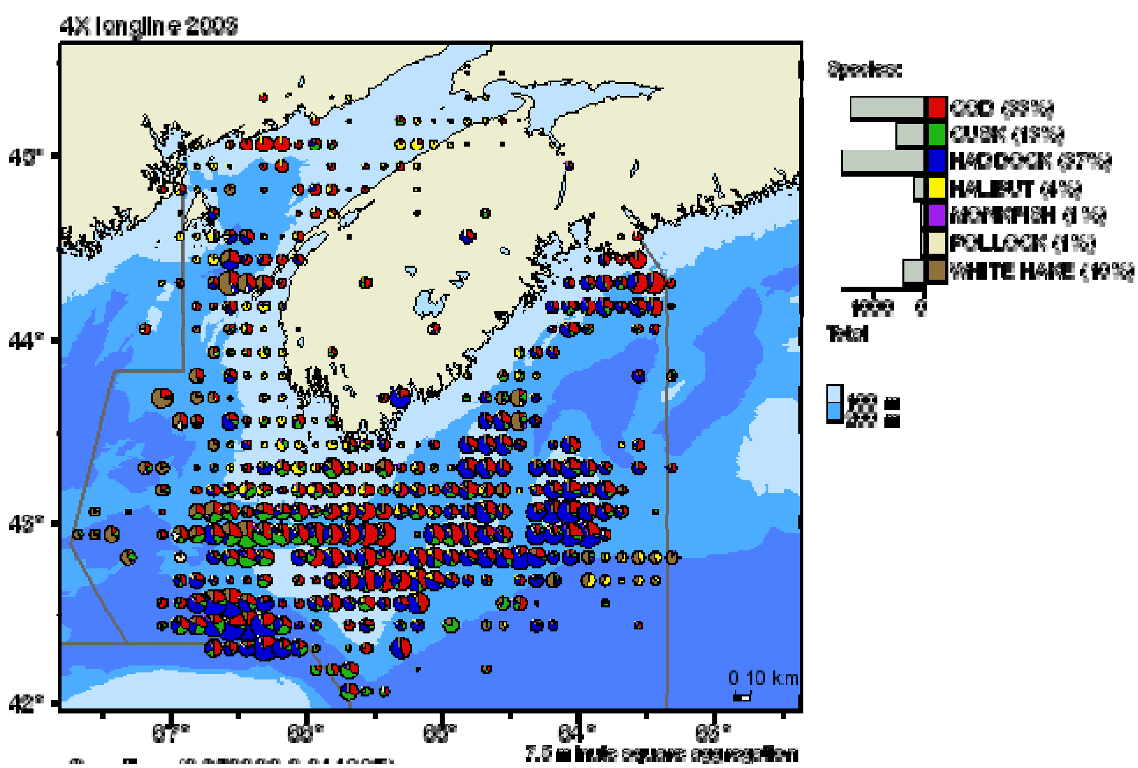


Figure 14. Longline fishery catch composition in NAFO Division 4X.

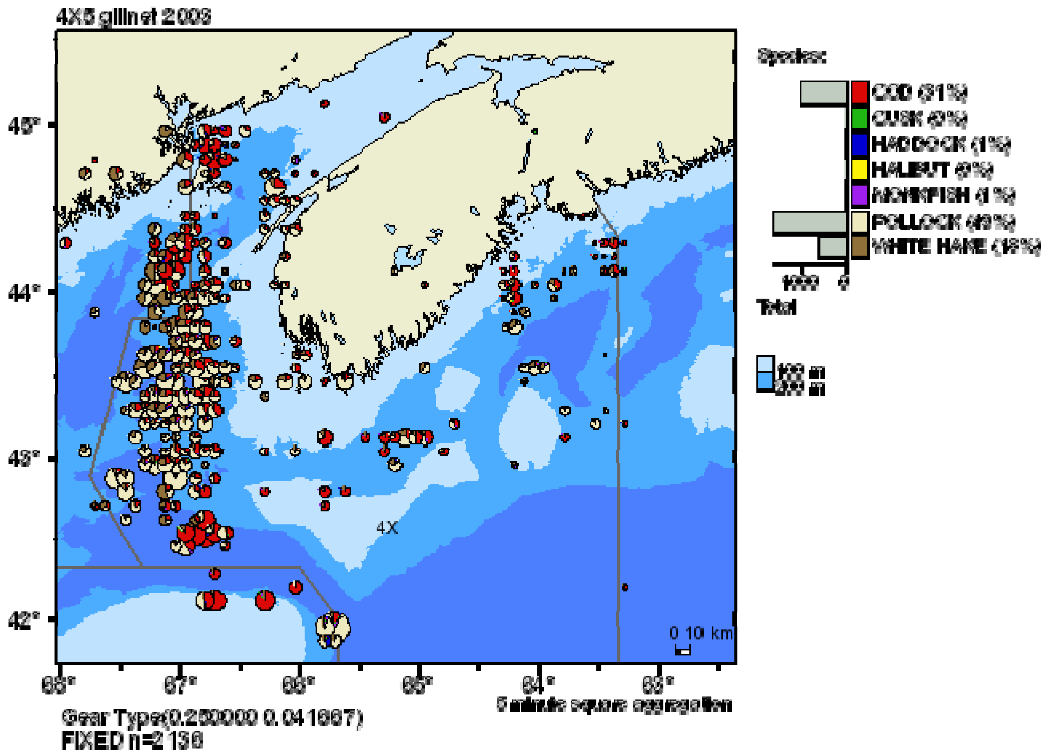


Figure 15. Gillnet fishery catch composition in NAFO Division 4X.

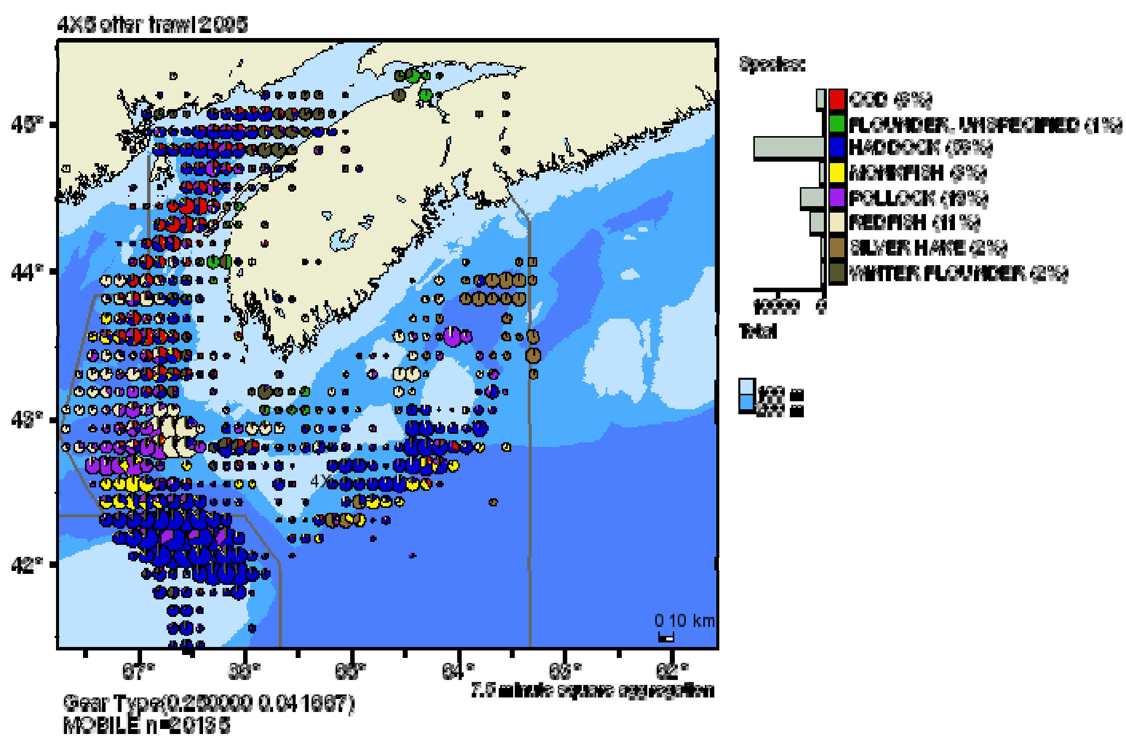


Figure 16. Otter trawl fishery catch composition in NAFO Division 4X.

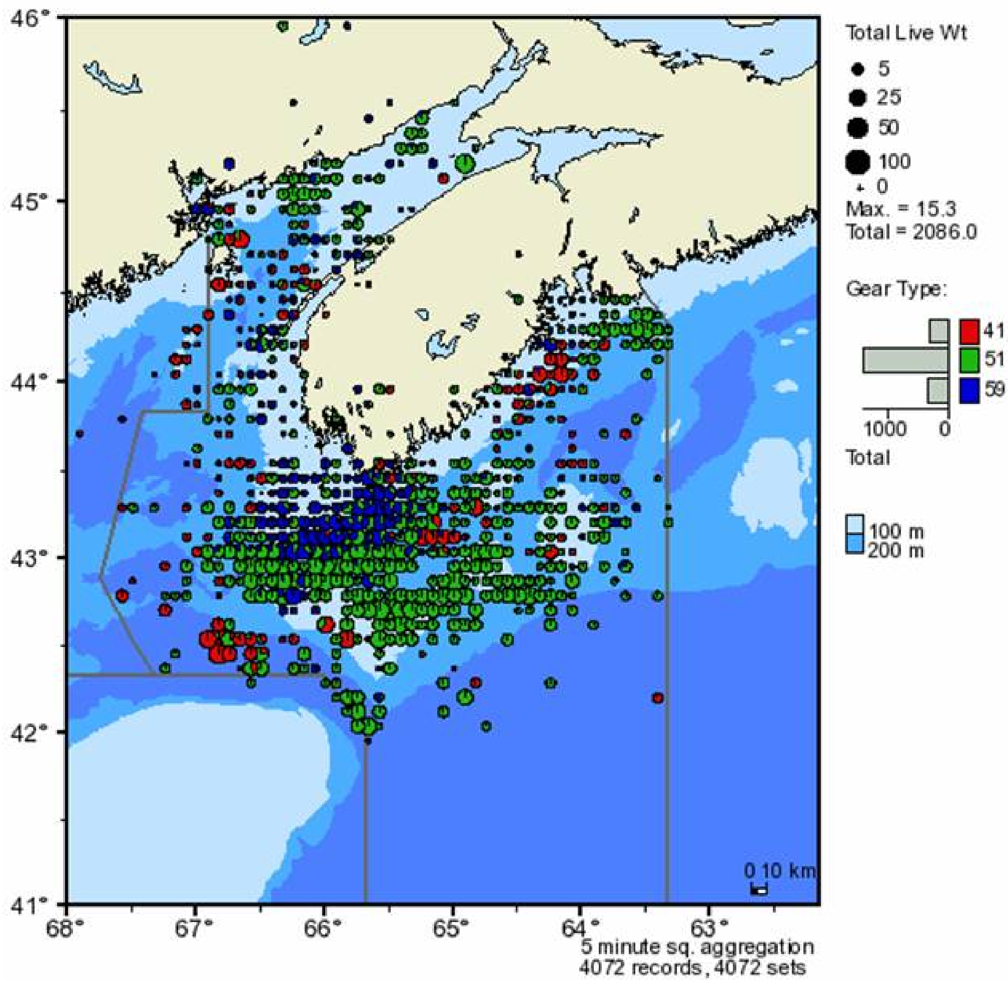


Figure 17. Distribution of cod catches in the fixed gear fishery for NAFO Division 4X in 1998. Gear type 41 is gillnet, 51 is longline and 59 is handline.

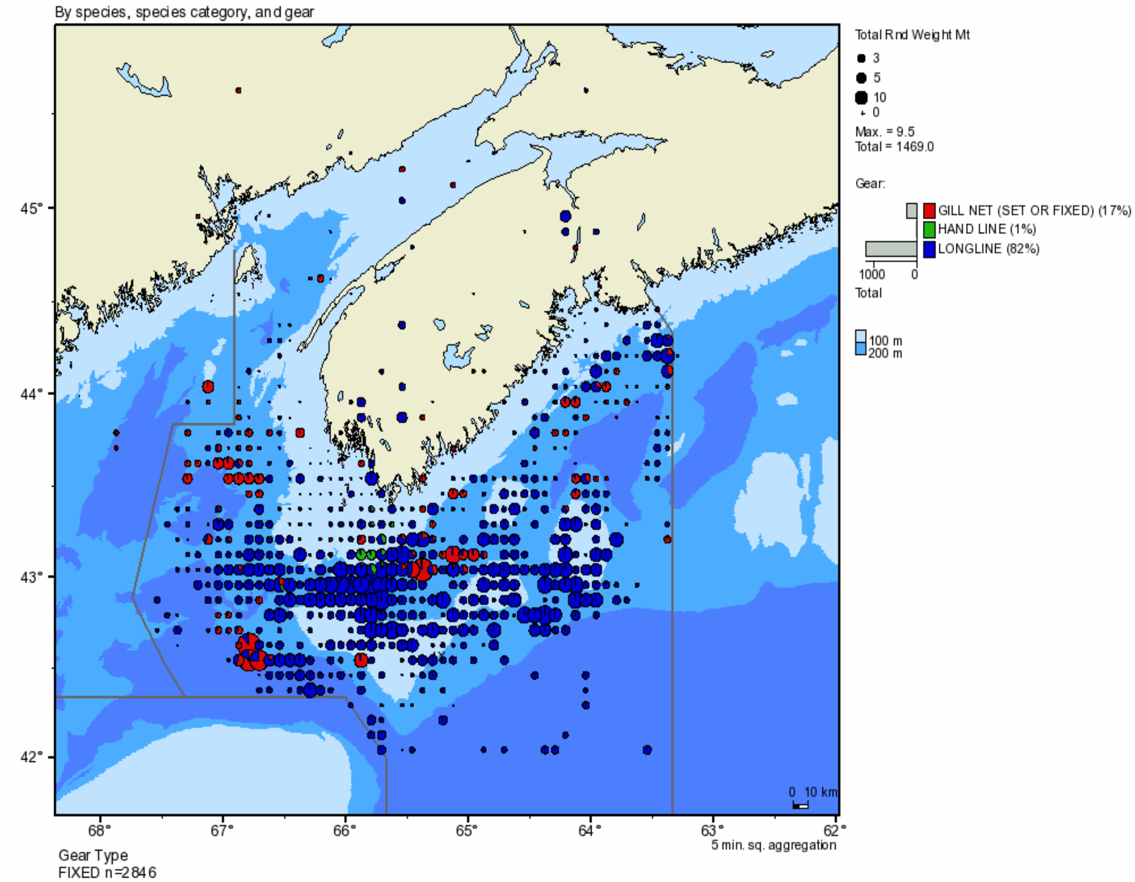


Figure 18. Distribution of cod catches in the fixed gear fishery for NAFO Division 4X in 2008.

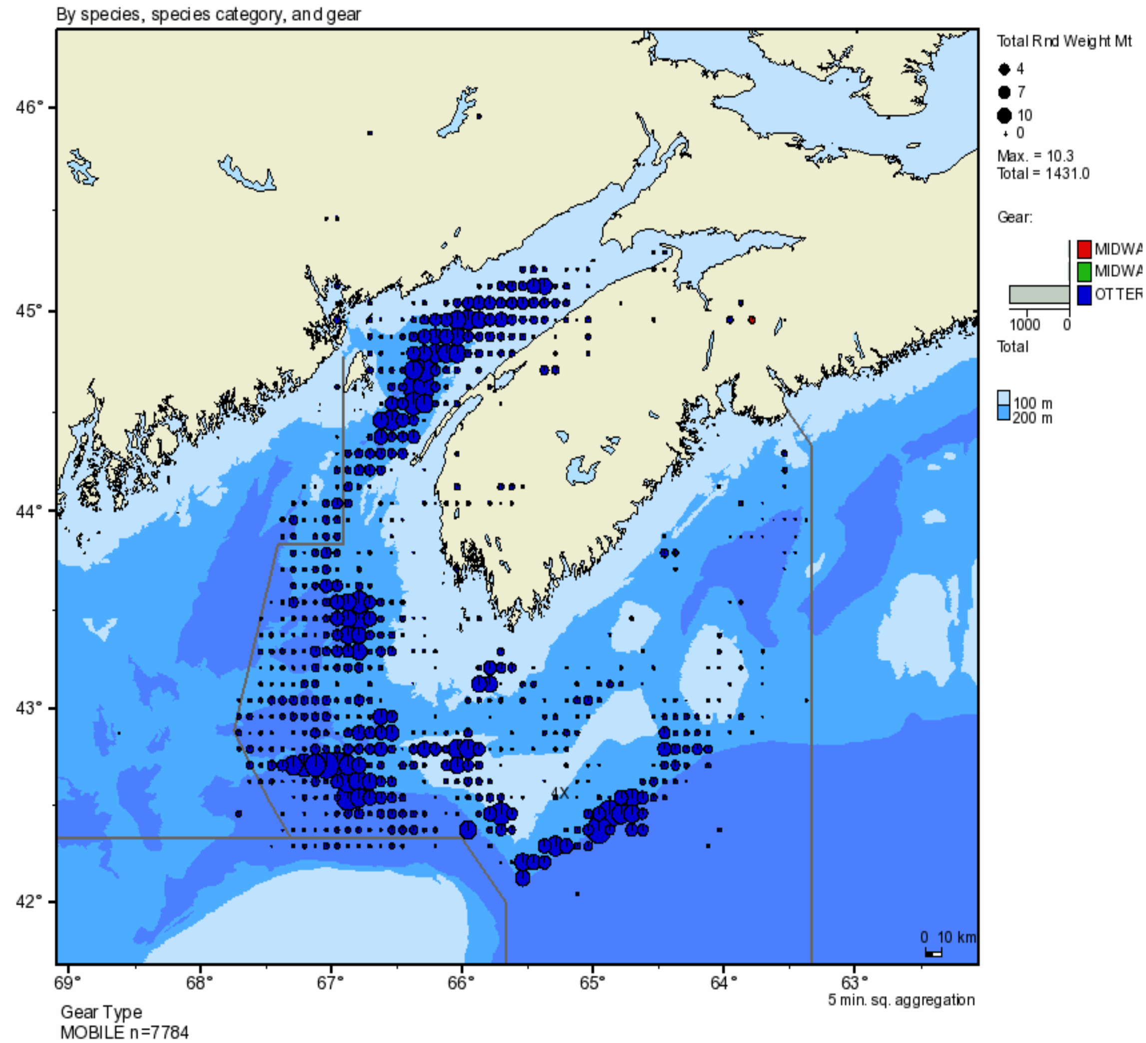


Figure 19. Distribution of cod catches in the otter trawl fishery for NAFO Division 4X in 2008.

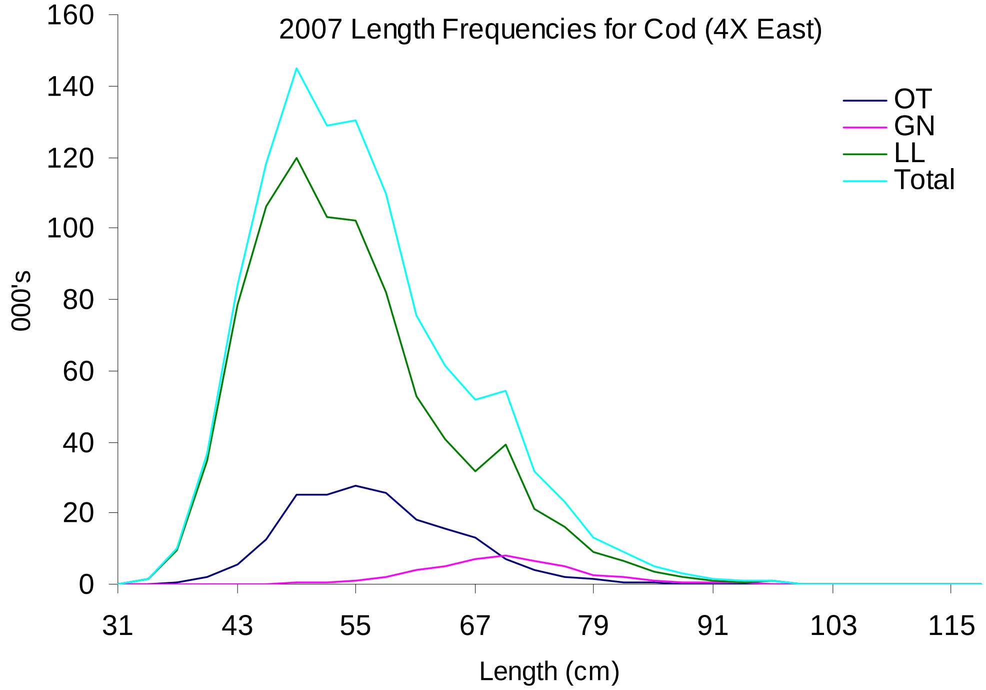


Figure 20a. 2007 length frequencies for NAFO Division 4X cod in the commercial catch by gear type (4X East).

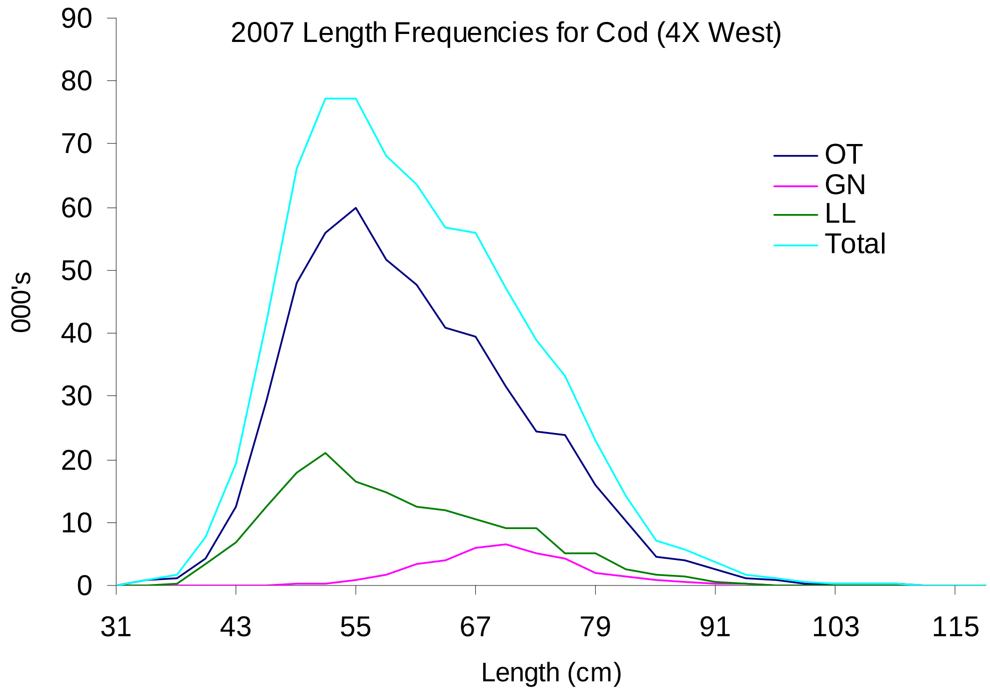


Figure 20b. 2007 length frequencies for NAFO Division 4X cod in the commercial catch by gear type (4X West).

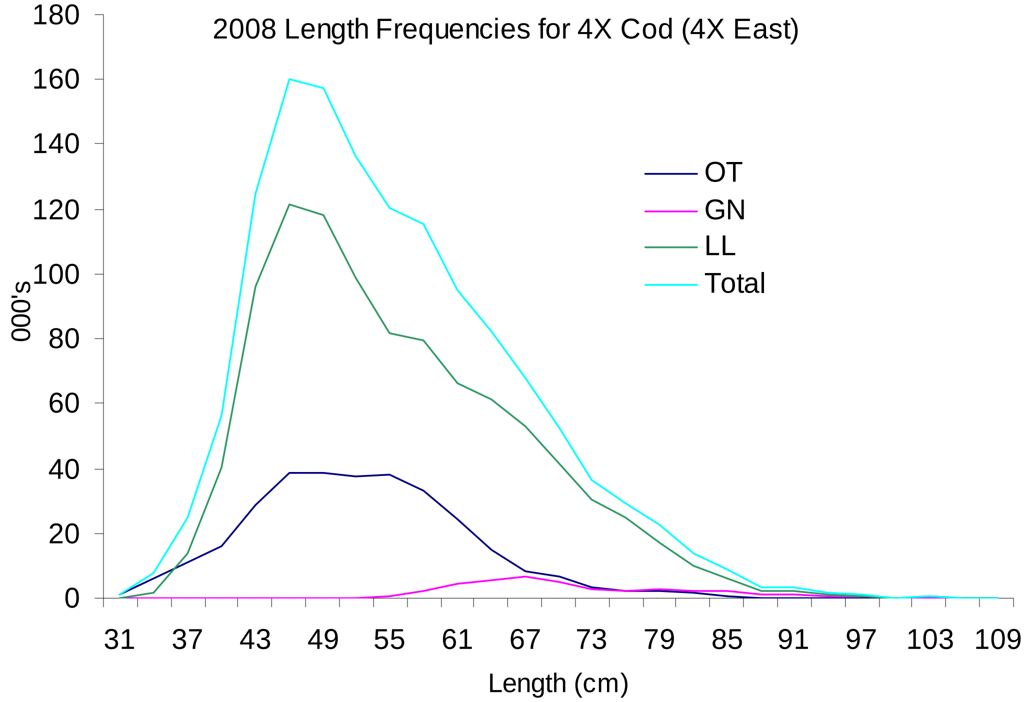


Figure 21a. 2008 length frequencies for NAFO Division 4X cod in the commercial catch by gear type (4X East).

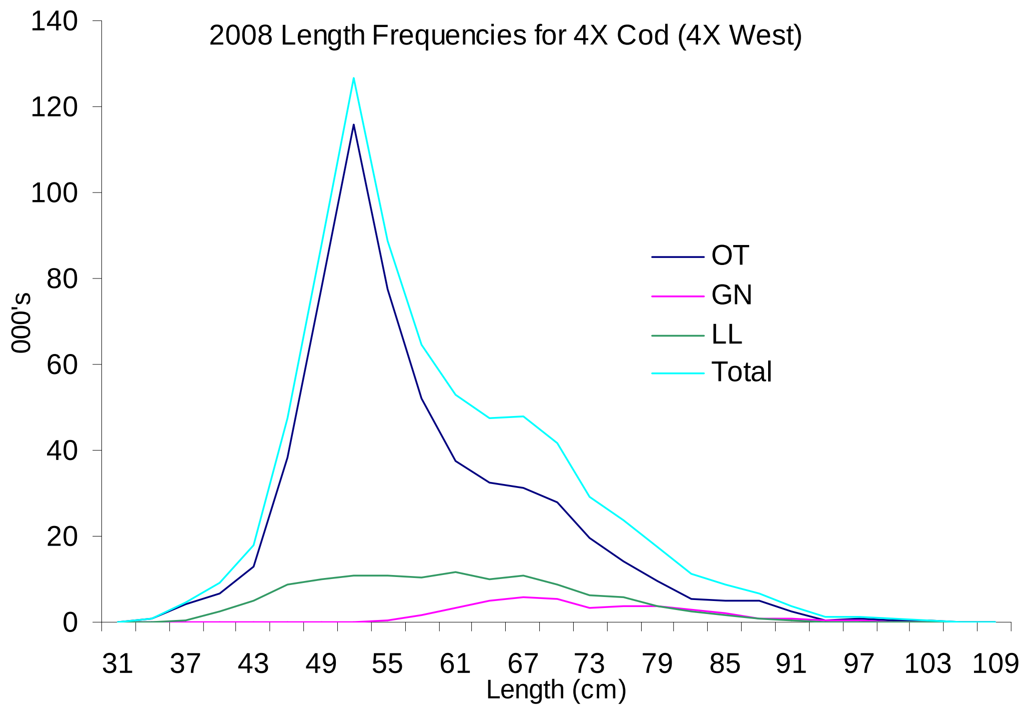


Figure 21b. 2008 length frequencies for NAFO Division 4X cod in the commercial catch by gear type (4X West).

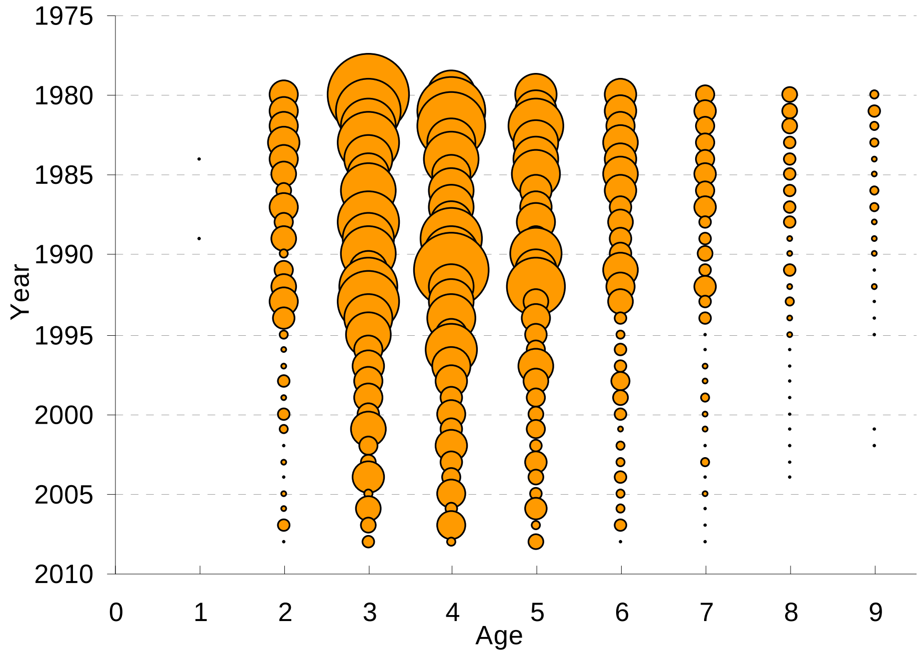


Figure 22. Commercial catch-at-age by year for NAFO Division 4X cod (bubble area proportional to abundance; to July 1, 2008).

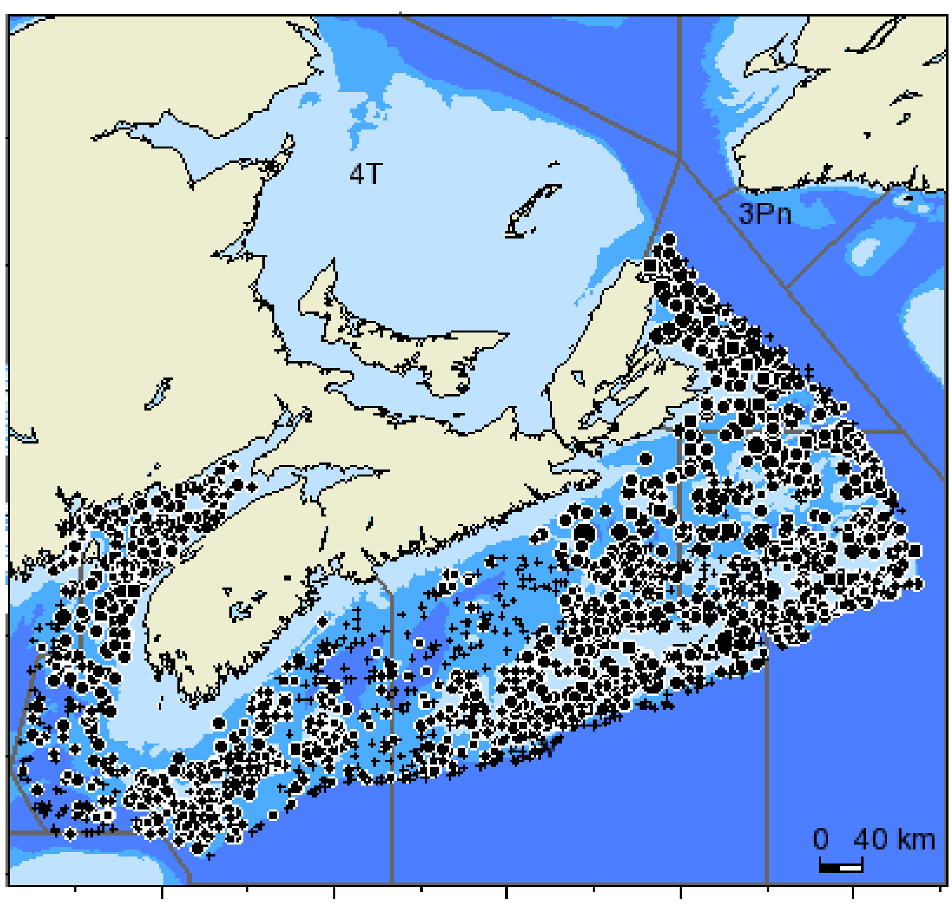


Figure 23. Cod catch distribution from sets in all years of the summer RV survey series (1970–2008).

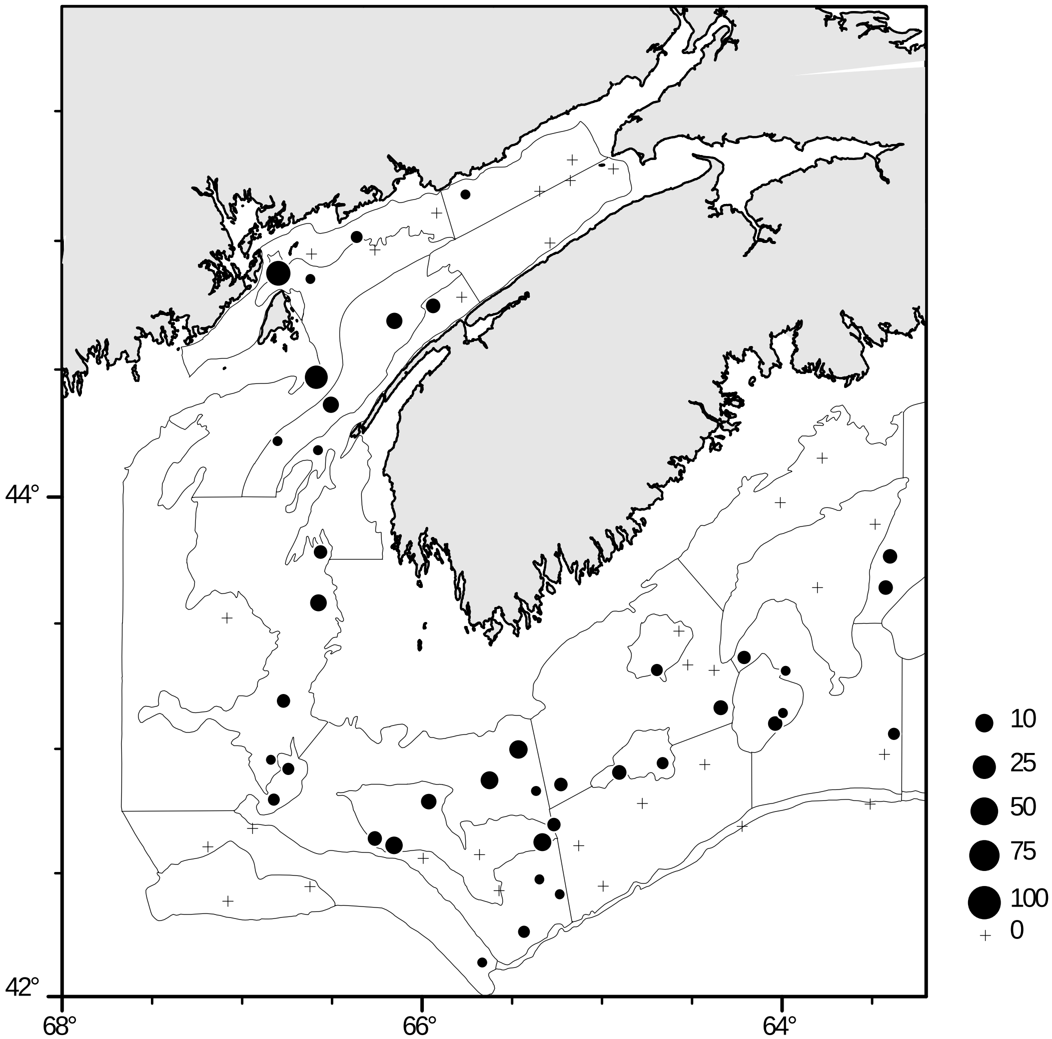


Figure 24. Distribution and magnitude of RV survey catches of NAFO Division 4X cod in 2007.

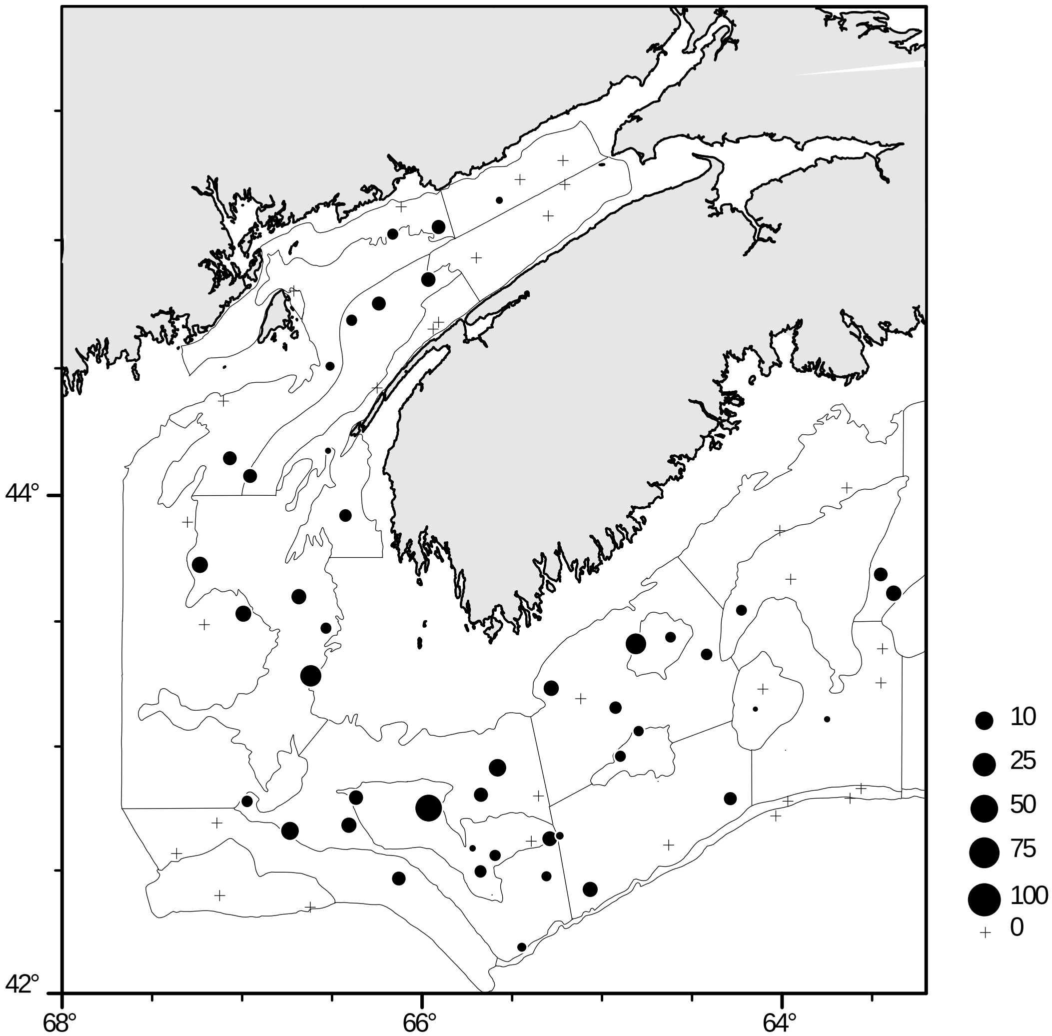


Figure 25. Distribution and magnitude of RV survey catches of NAFO Division 4X cod in 2008.

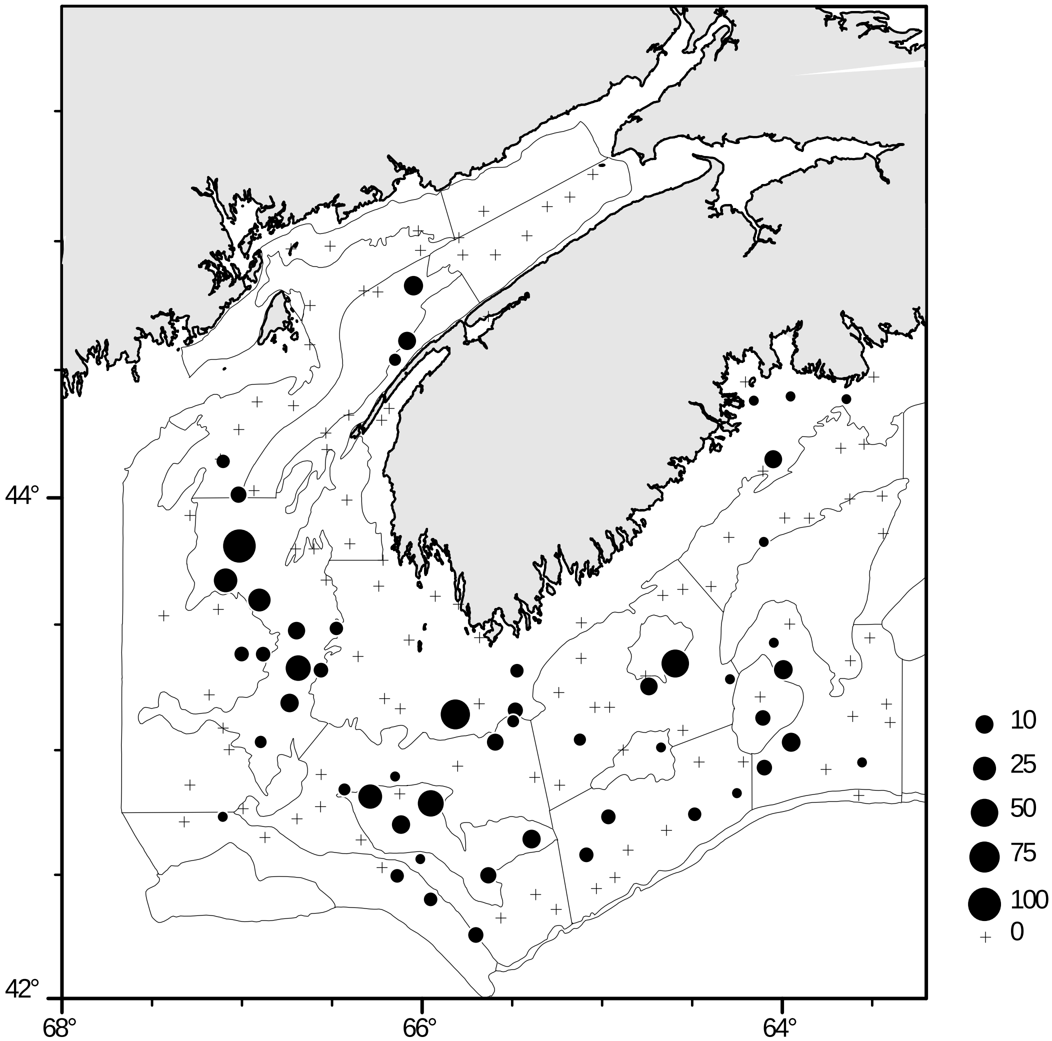


Figure 26. Distribution and magnitude of ITQ survey catches of NAFO Division 4X cod in 2008.

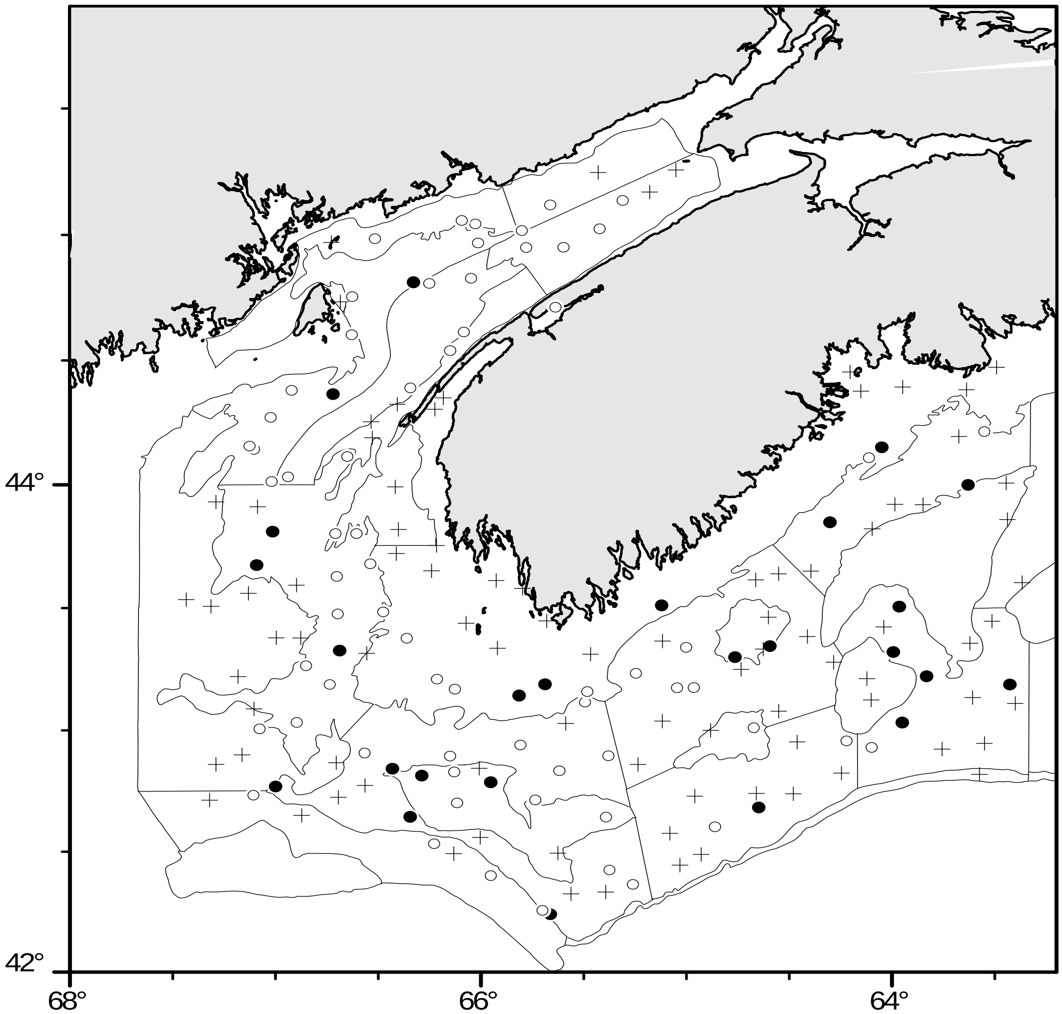


Figure 27. A comparison of ITQ survey cod catches for 2008 with median value for each station since 1996. • 2008 value > median; + 2008 value is within 1 of the median; o 2006 value < median.

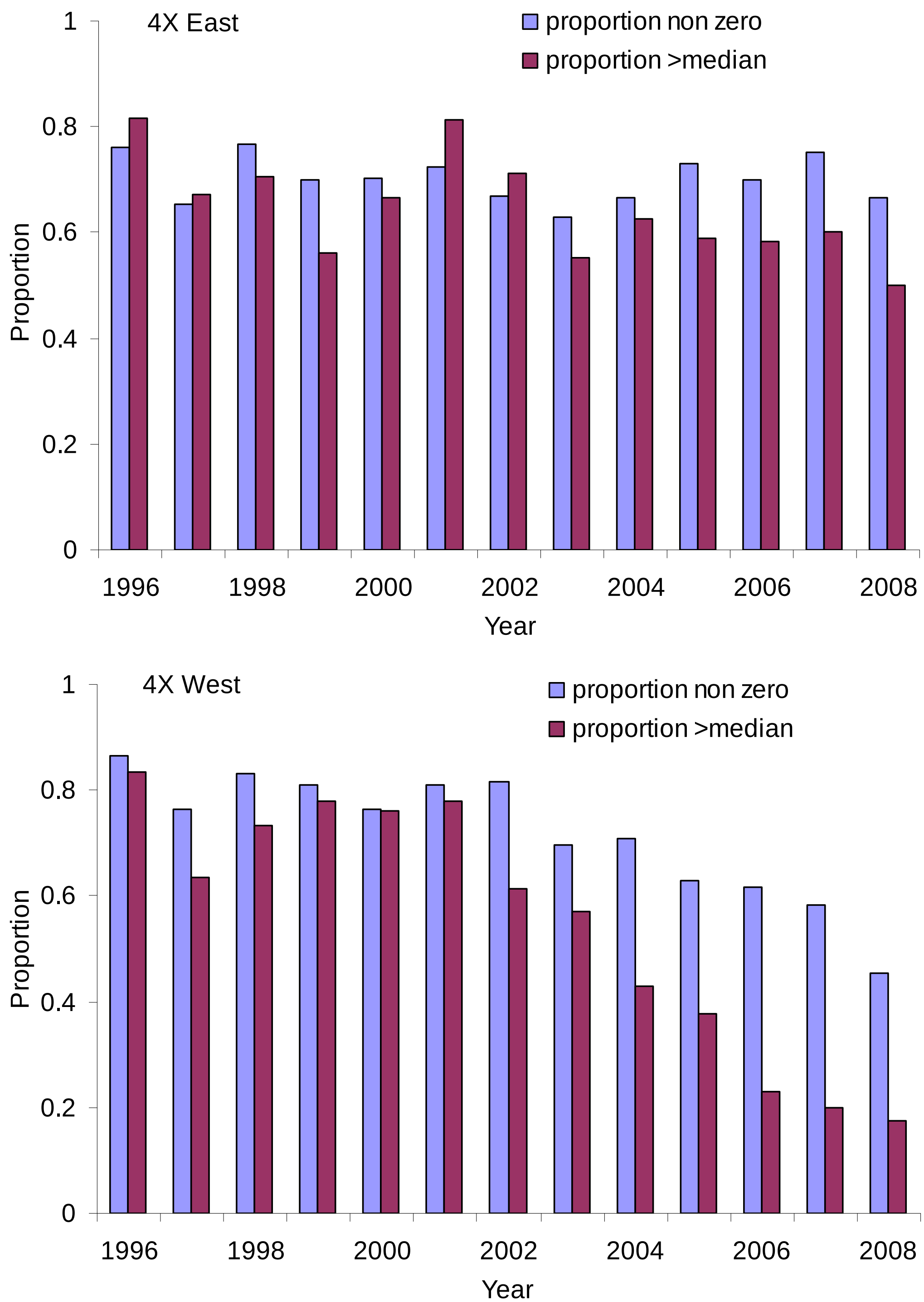


Figure 28. Proportion of ITQ survey stations where cod where caught, and where catch was above the median for that location.

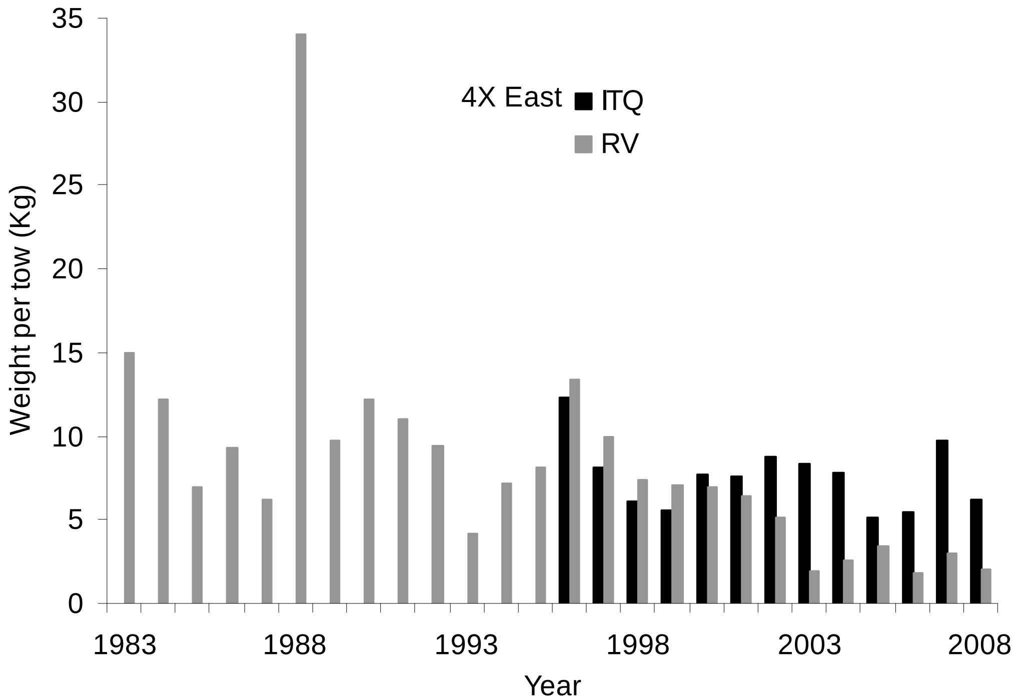


Figure 29a. RV and ITQ survey biomass indices (Kg/tow) for NAFO Division 4X cod in 4X East.

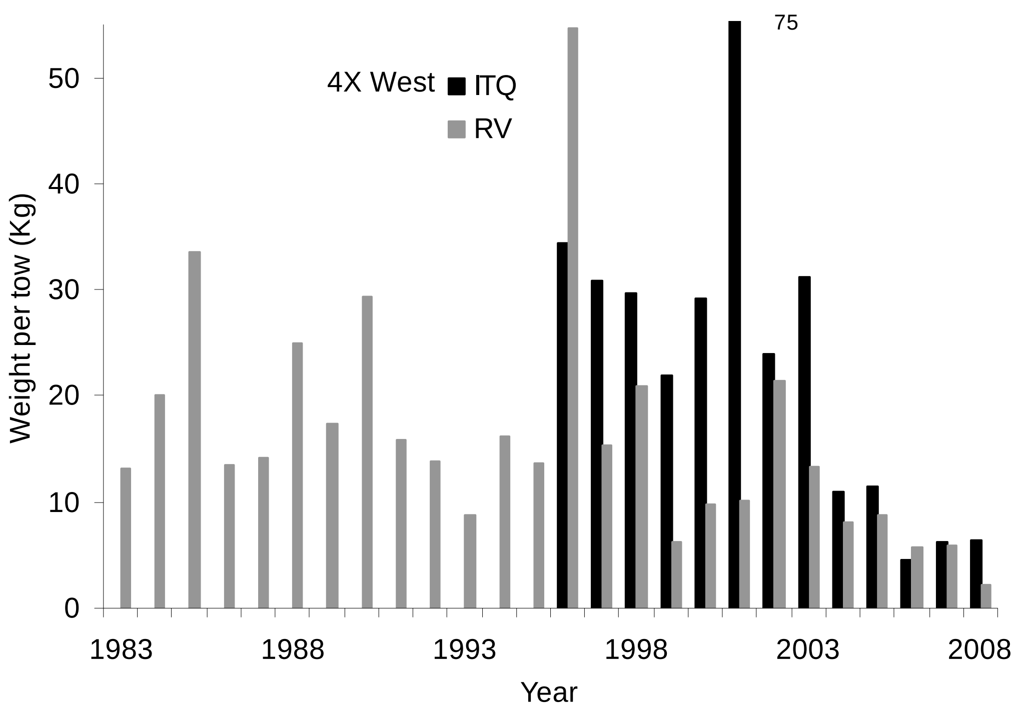


Figure 29b. RV and ITQ survey biomass indices (Kg/tow) for NAFO Division 4X cod in 4X West (ITQ survey catch in 2001 = 75 kg/tow).

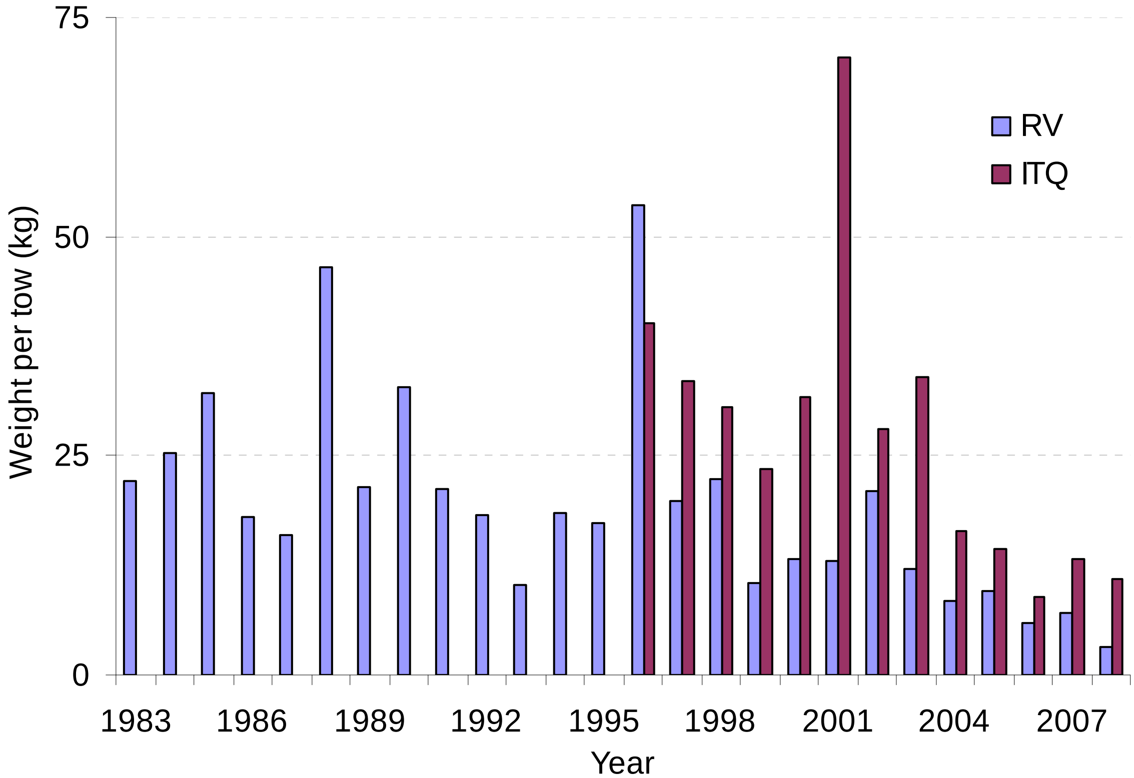
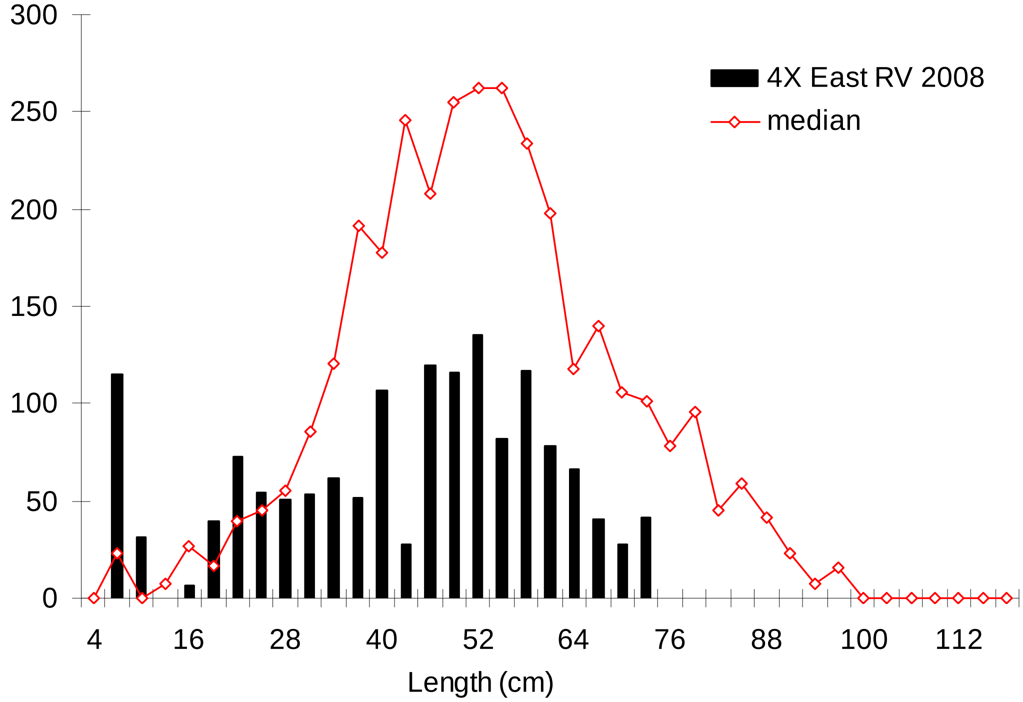


Figure 29c. RV and ITQ survey biomass indices (Kg/tow) for NAFO Division 4X cod.



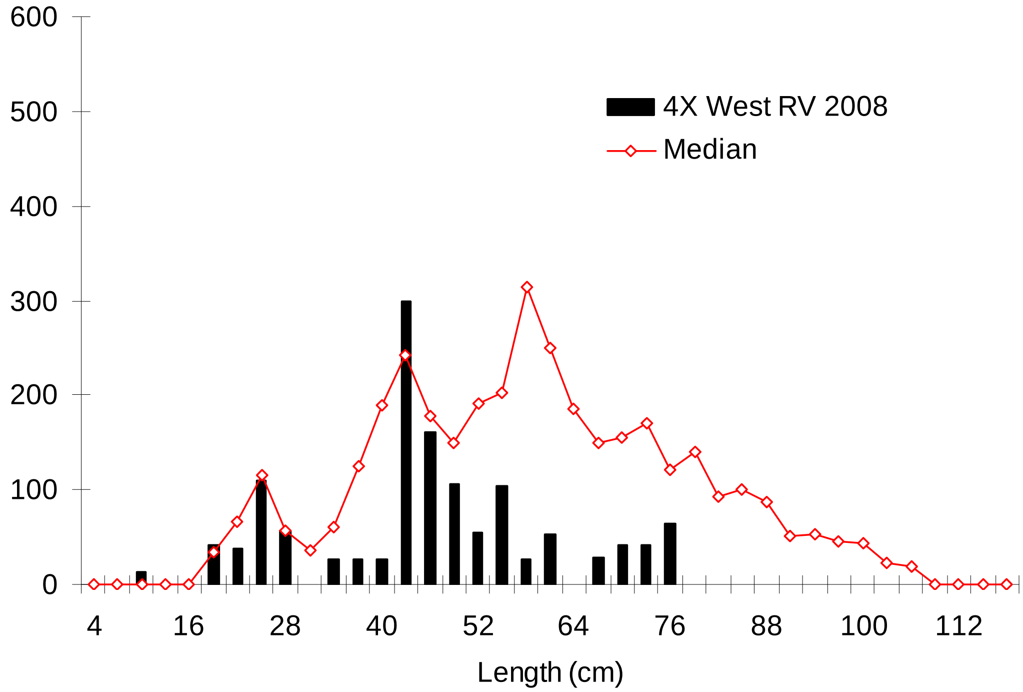
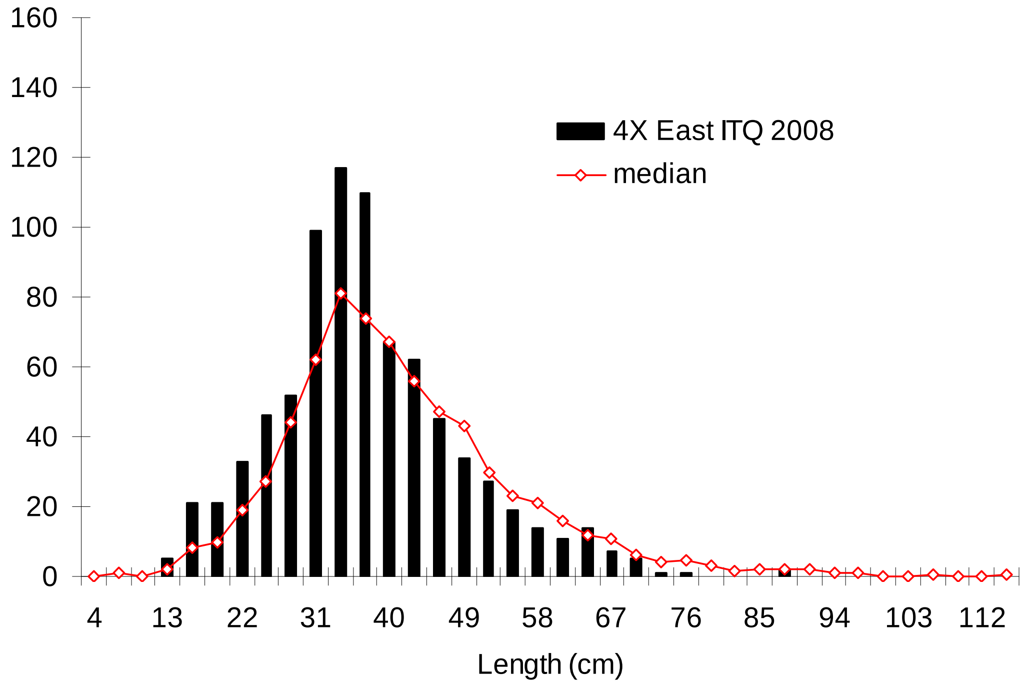


Figure 30. Length frequencies by area for NAFO Division 4X cod caught in the 2008 RV survey.



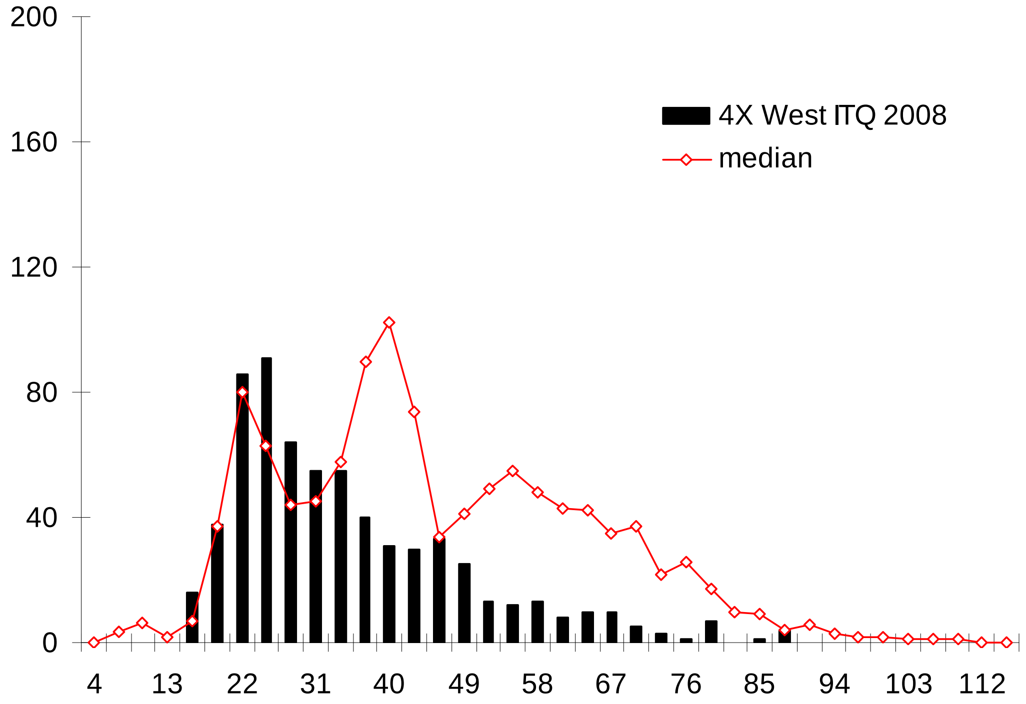


Figure 31. Length frequencies by area for NAFO Division 4X cod caught in the 2008 ITQ survey.

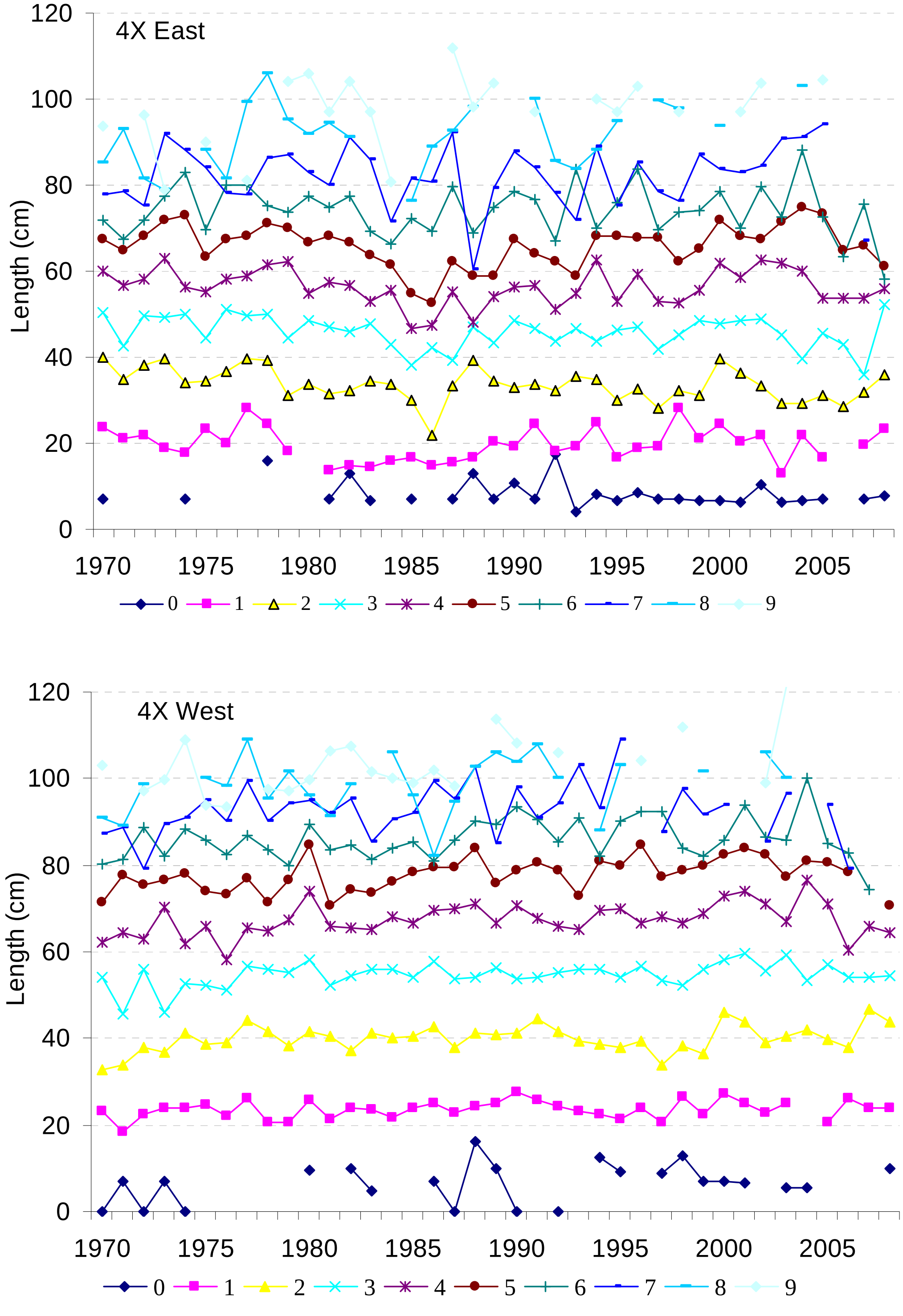


Figure 32. Lengths-at-age for NAFO Division 4X cod caught in the RV survey by region.

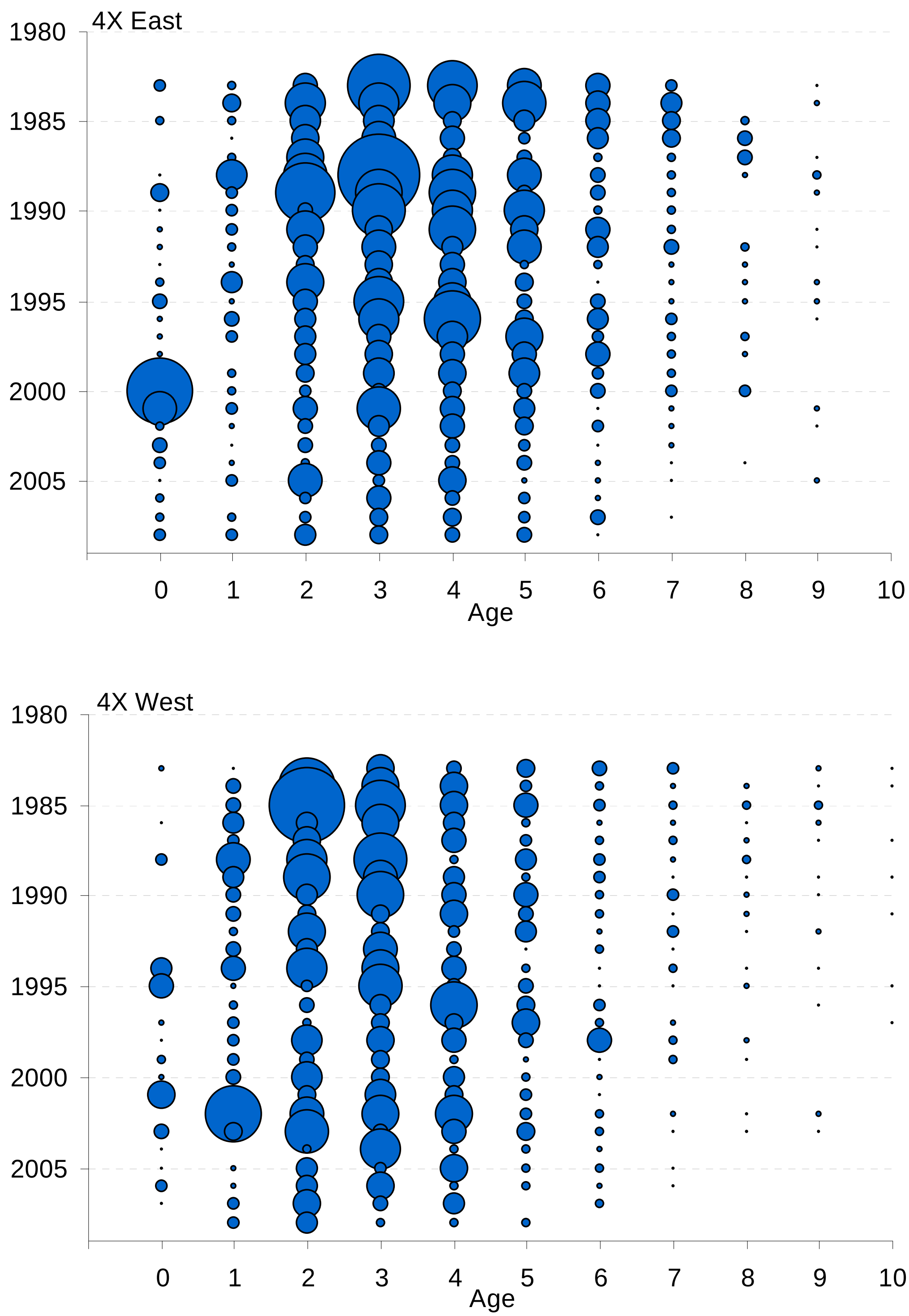


Figure 33. RV survey indices at age for cod in 4X East and 4X West (bubble area proportional to survey catch).

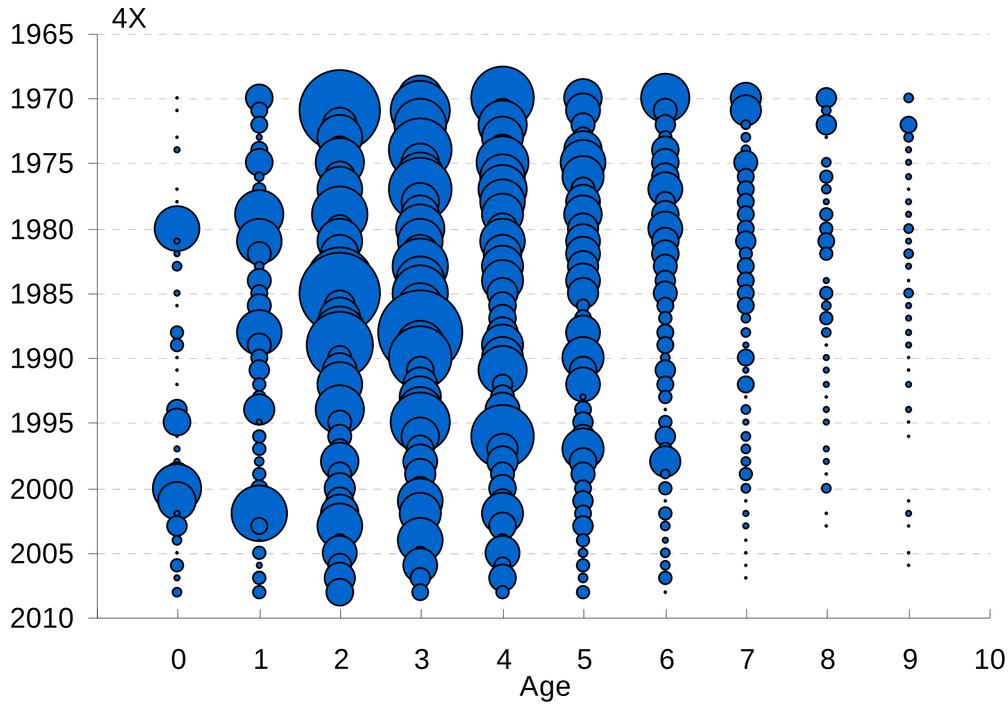
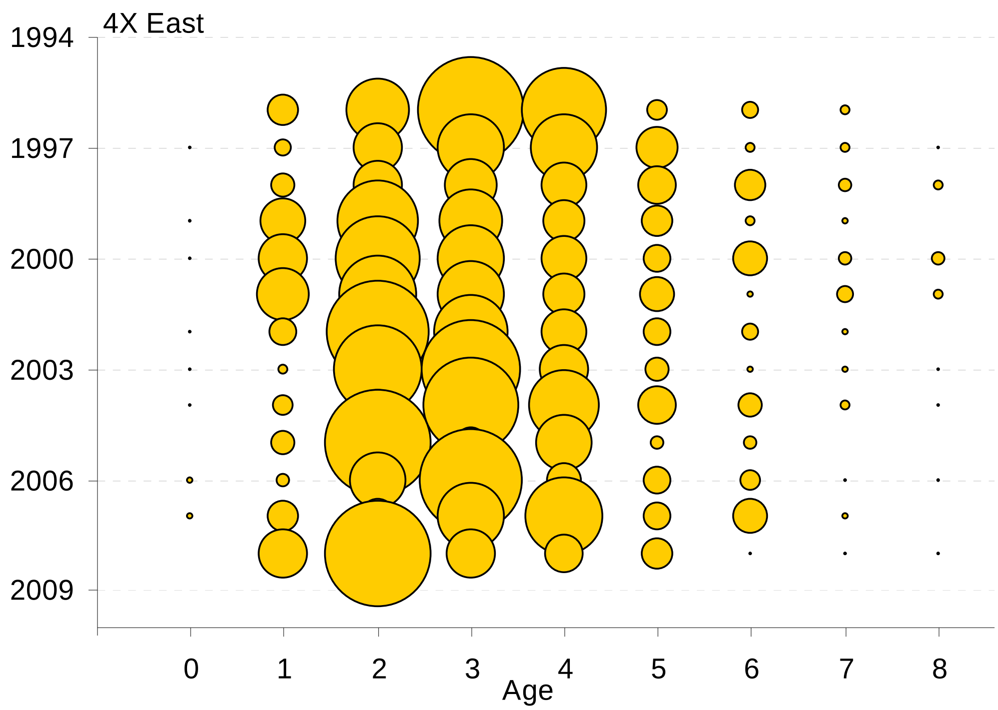


Figure 34. RV survey indices at age for NAFO Division 4X cod (bubble area proportional to survey catch).



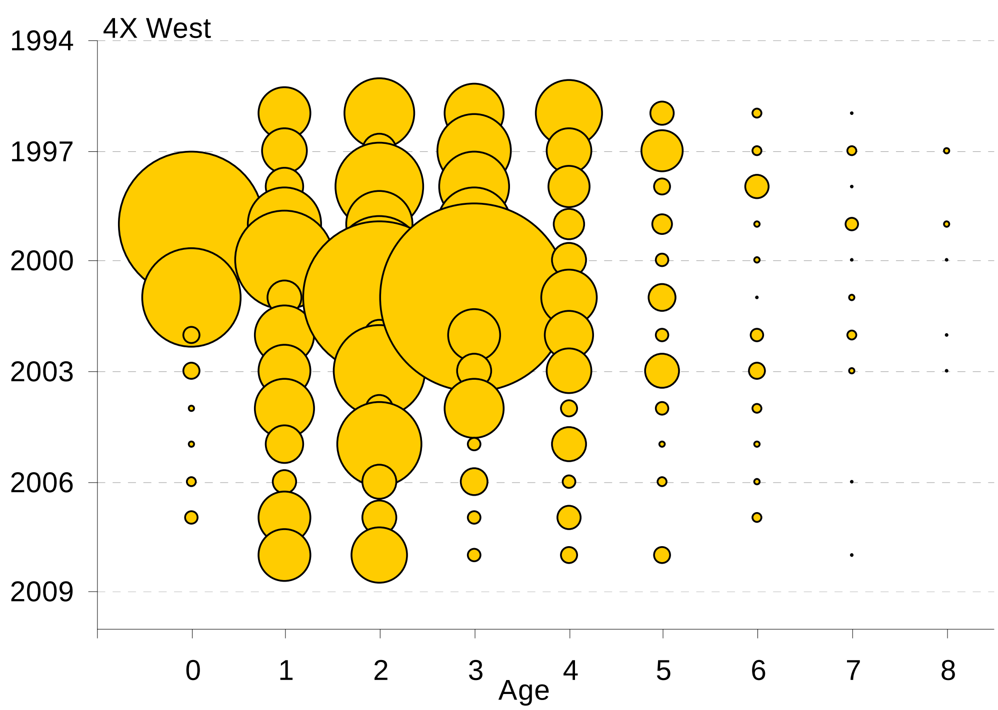


Figure 35. ITQ survey indices at age for cod in 4X East and 4X West (bubble area proportional to survey catch).

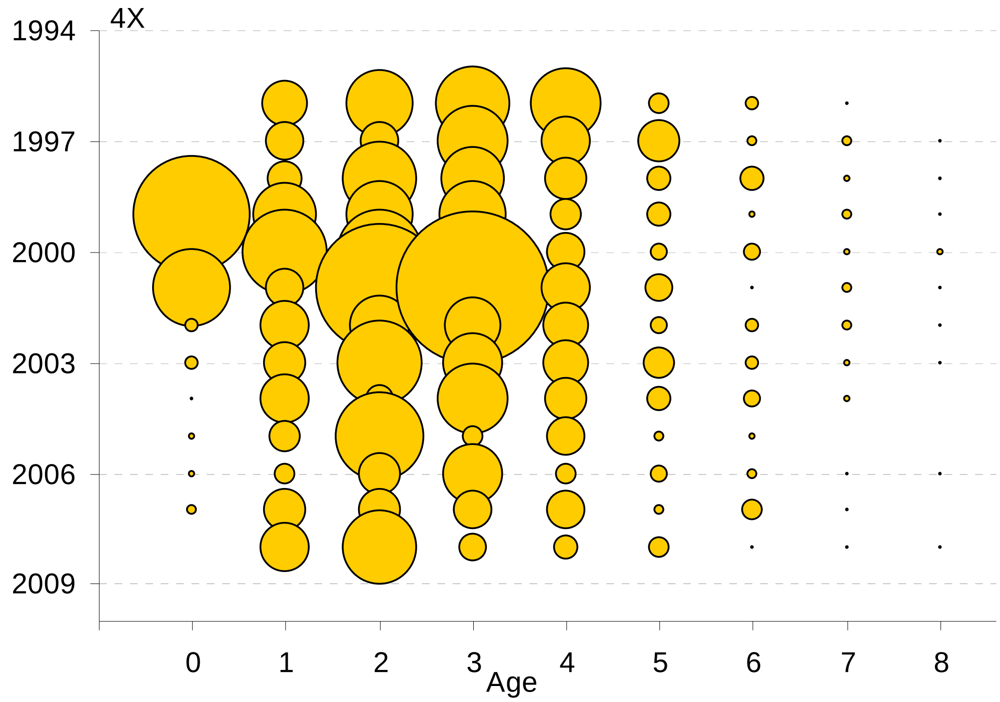


Figure 36. ITQ survey indices at age for NAFO Division 4X cod (bubble area proportional to survey catch).

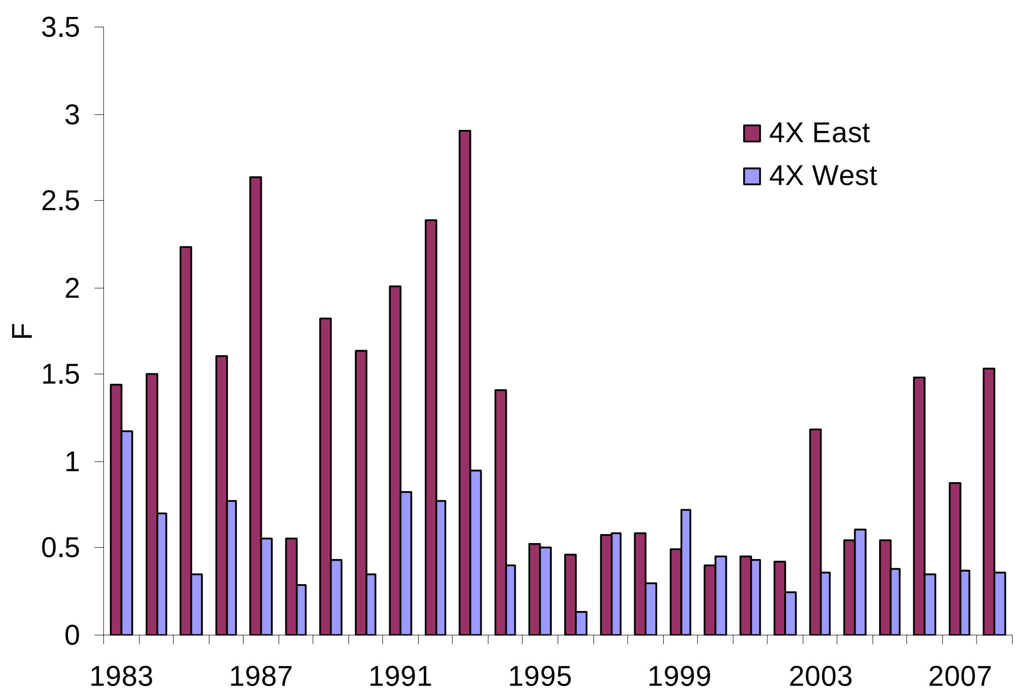


Figure 37. Relative fishing mortality by region for NAFO Division 4X cod.

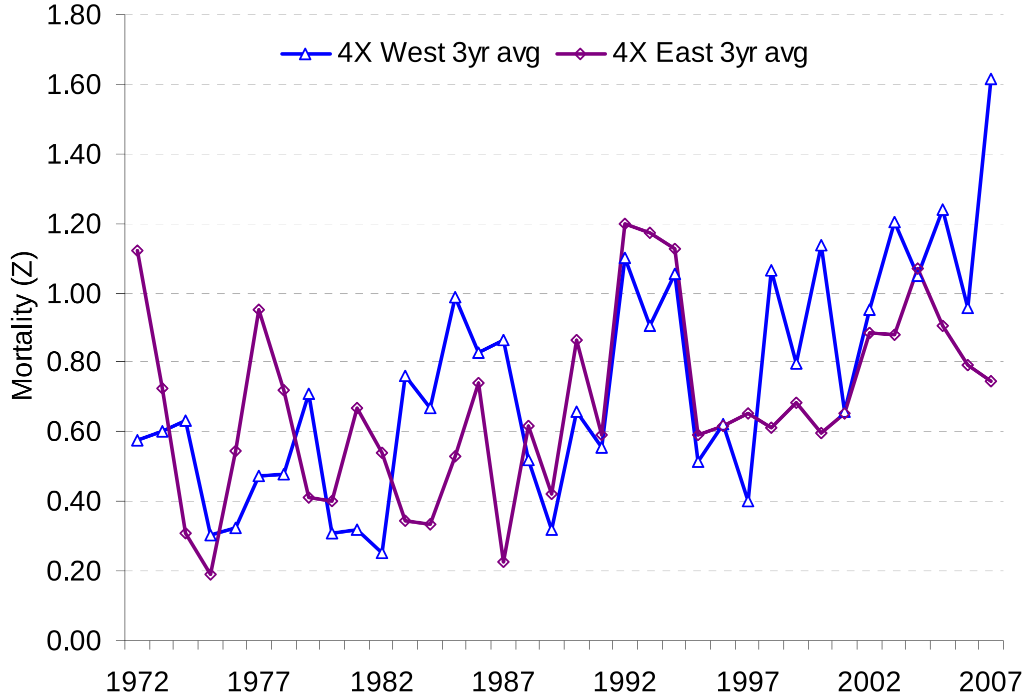


Figure 38. RV survey total mortality estimates (Z) by region for NAFO Division 4X cod (3 year average).

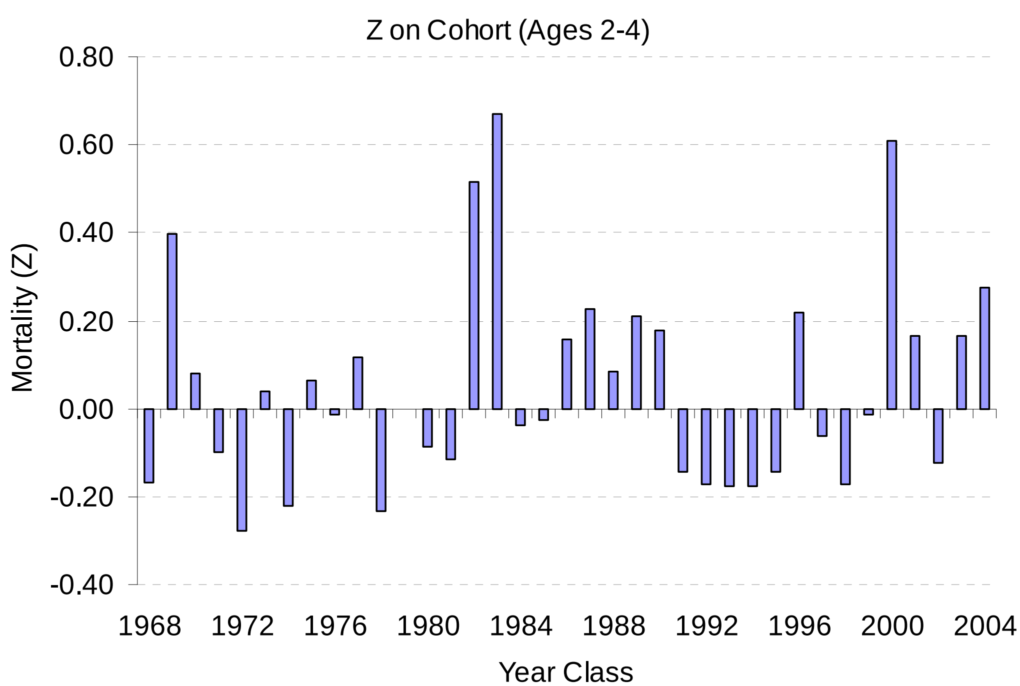


Figure 39. RV survey total mortality estimate of NAFO Division 4X cod for a cohort (ages 2-4).

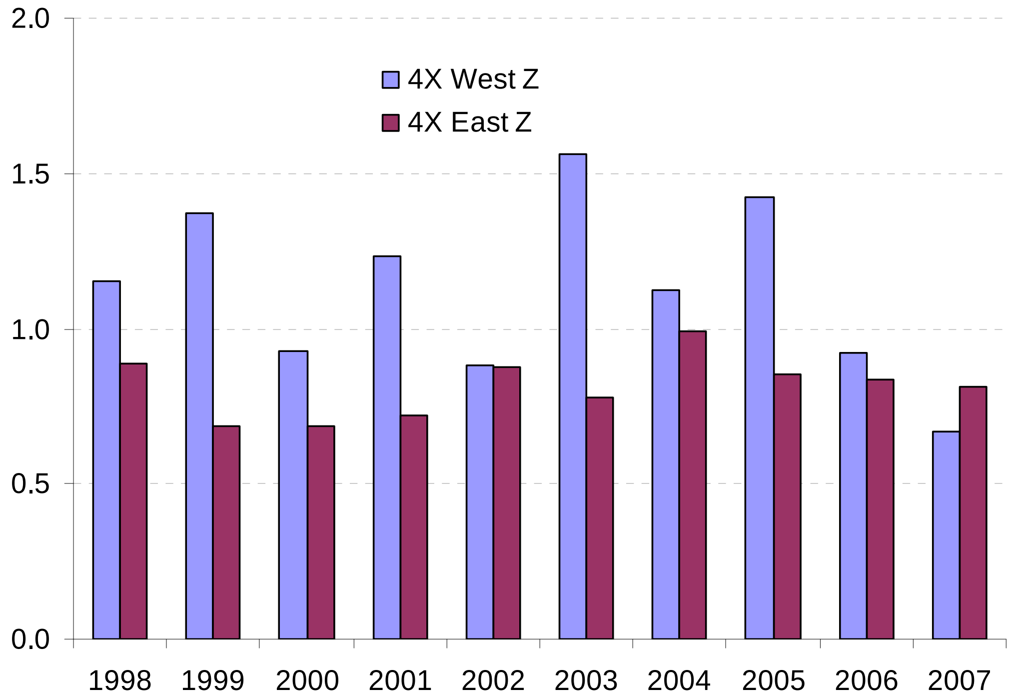


Figure 40. ITQ survey total mortality (Z) estimate of NAFO Division 4X cod by region (3 year average).

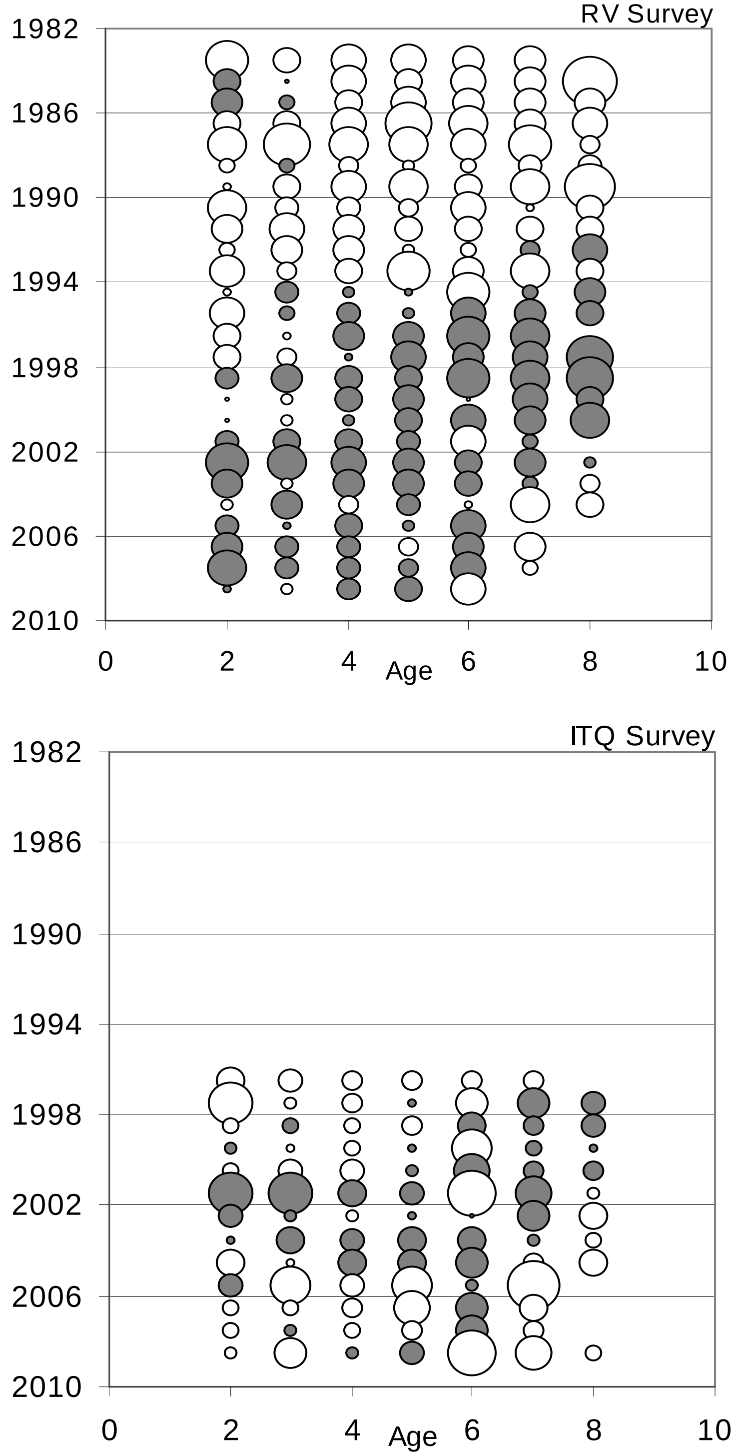


Figure 41. Base model SPA residuals by year and age group for the RV and ITQ surveys. Solid symbols indicate positive values, open symbols indicate negative values. Bubble area is proportional to magnitude.

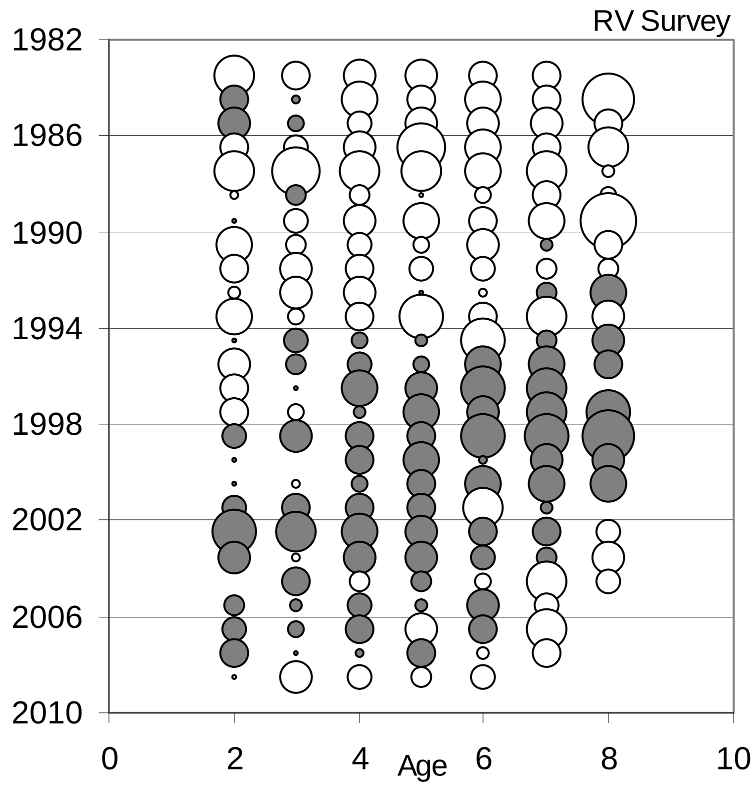


Figure 42. SPA residuals by year and age group for a model which uses only the RV survey for indices. Solid symbols indicate positive values, open symbols indicate negative values. Bubble area is proportional to magnitude.

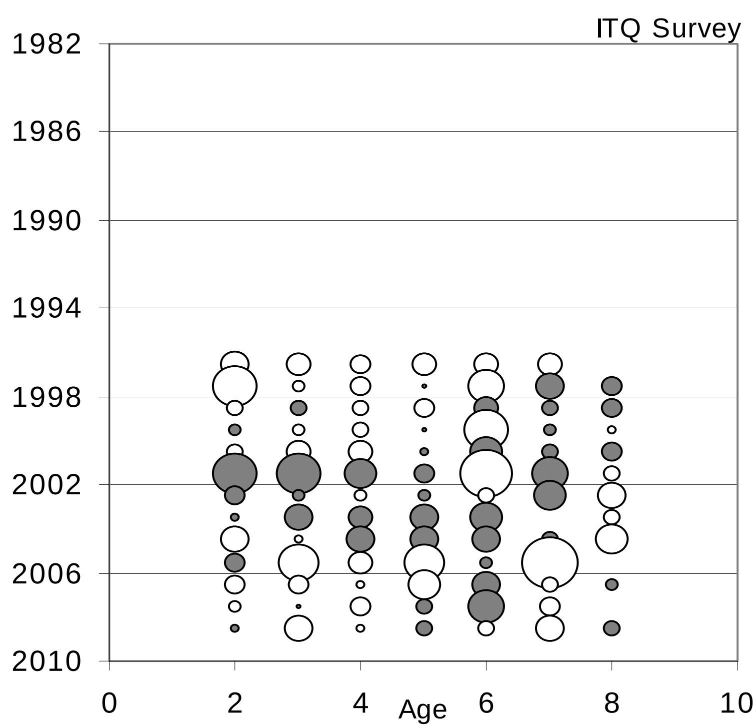
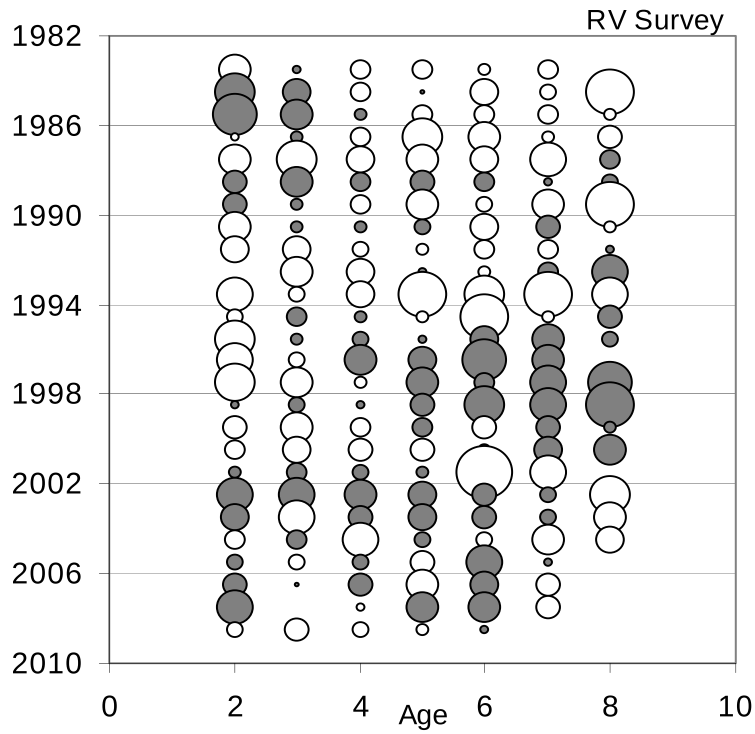


Figure 43. SPA residuals by year and age group for a model which incorporates a change in RV survey q in 1993. Solid symbols indicate positive values, open symbols indicate negative values. Bubble area is proportional to magnitude.



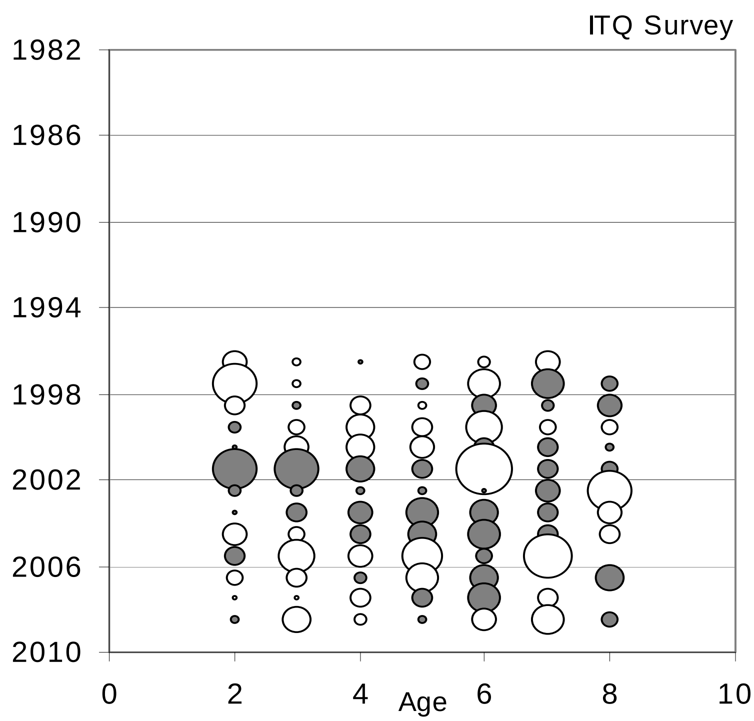


Figure 44. SPA residuals by year and age group for a model which includes an M of 0.2 prior to 1983, and estimates M for ages 4 and over since 1983. Solid symbols indicate positive values, open symbols indicate negative values. Bubble area is proportional to magnitude.

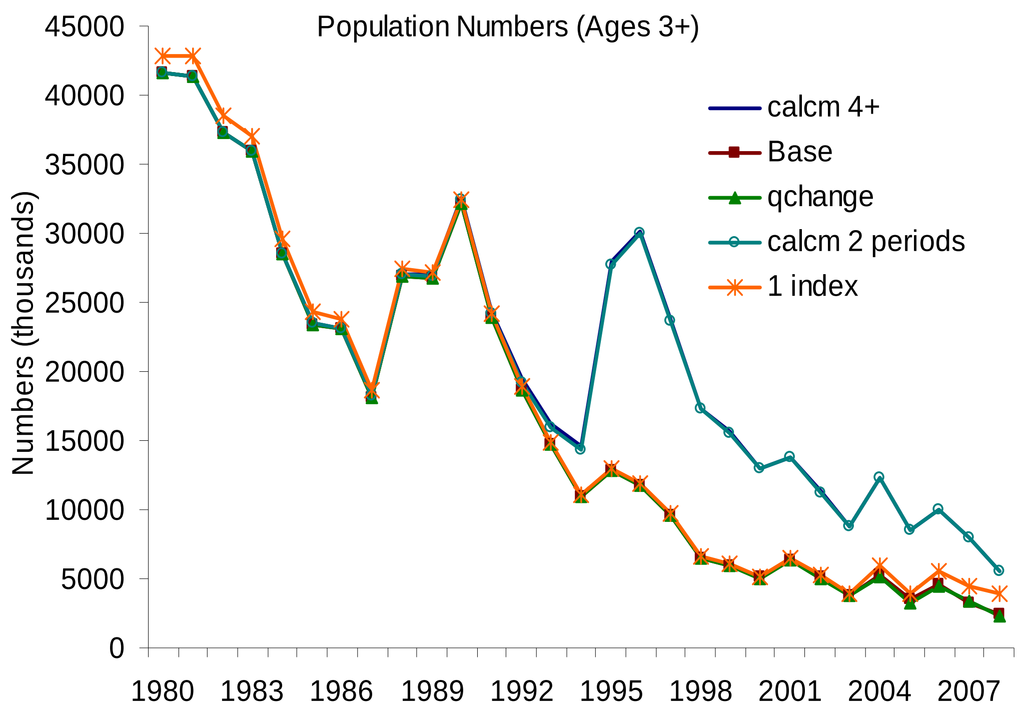


Figure 45. Comparison of 3+ population numbers for all models examined.

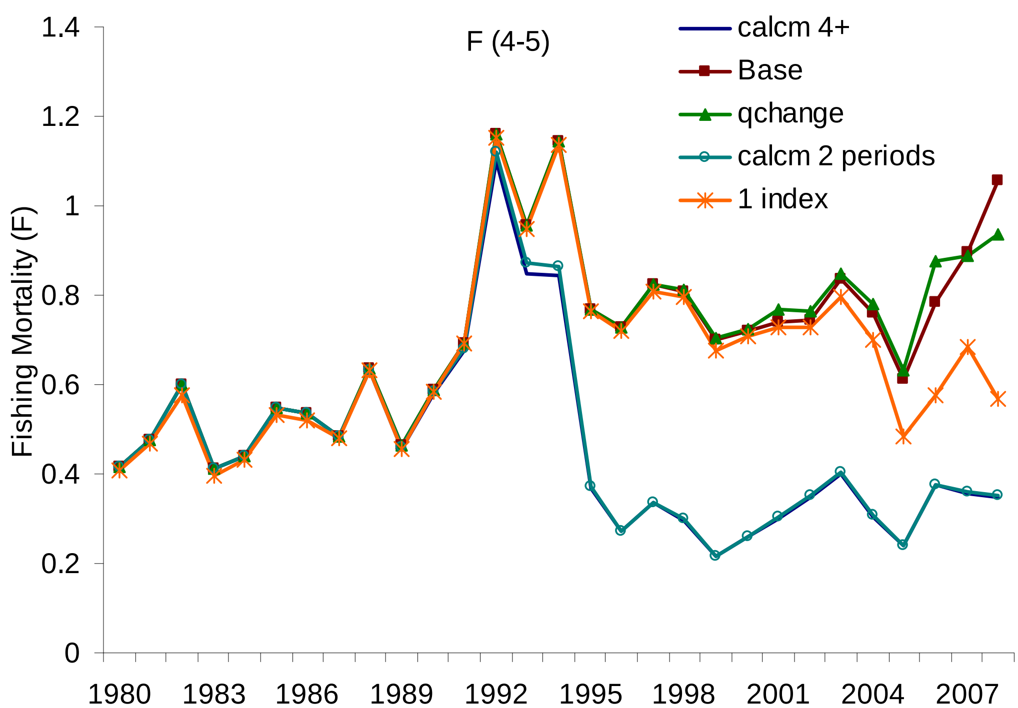


Figure 46. Comparison of trends in fishing mortality (F) for all models examined.

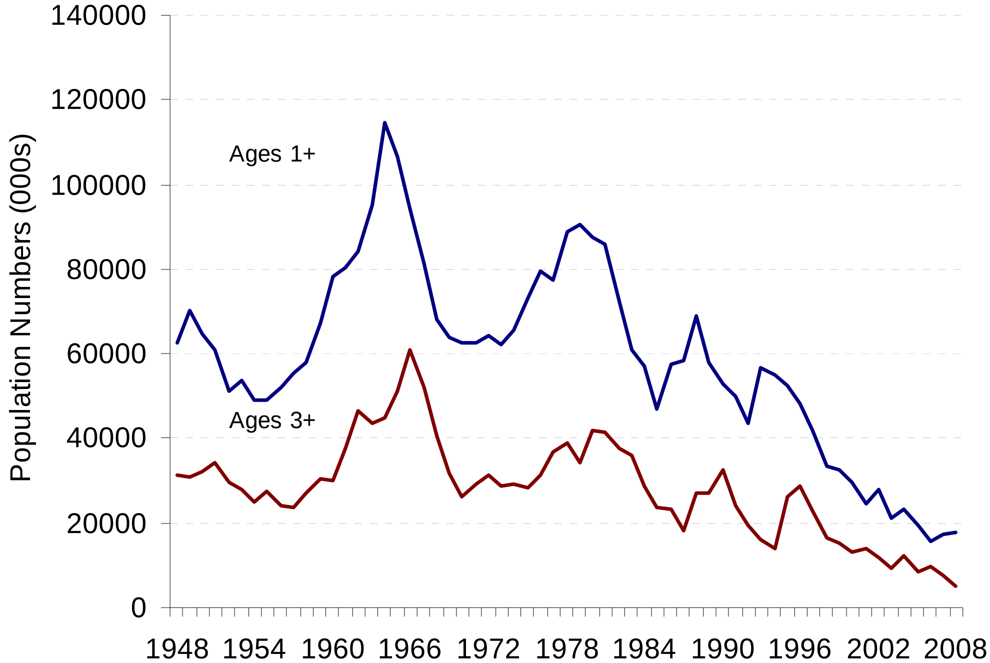


Figure 47. Population abundance for NAFO Division 4X cod from 1948 to 2008.

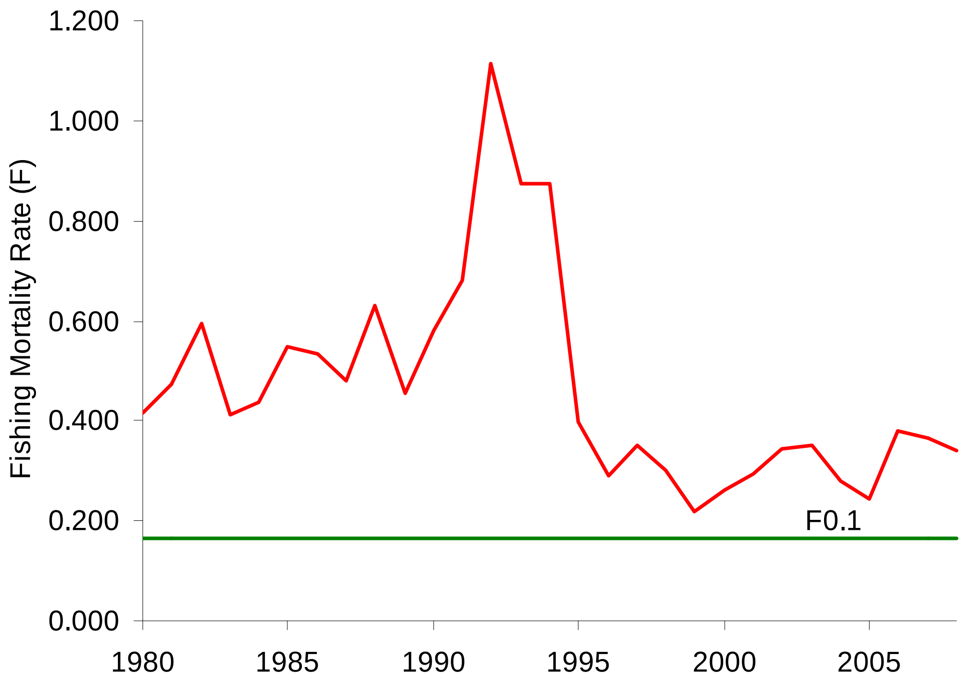


Figure 48. Fishing mortality rate for NAFO Division 4X cod for ages fully recruited to the fishery.

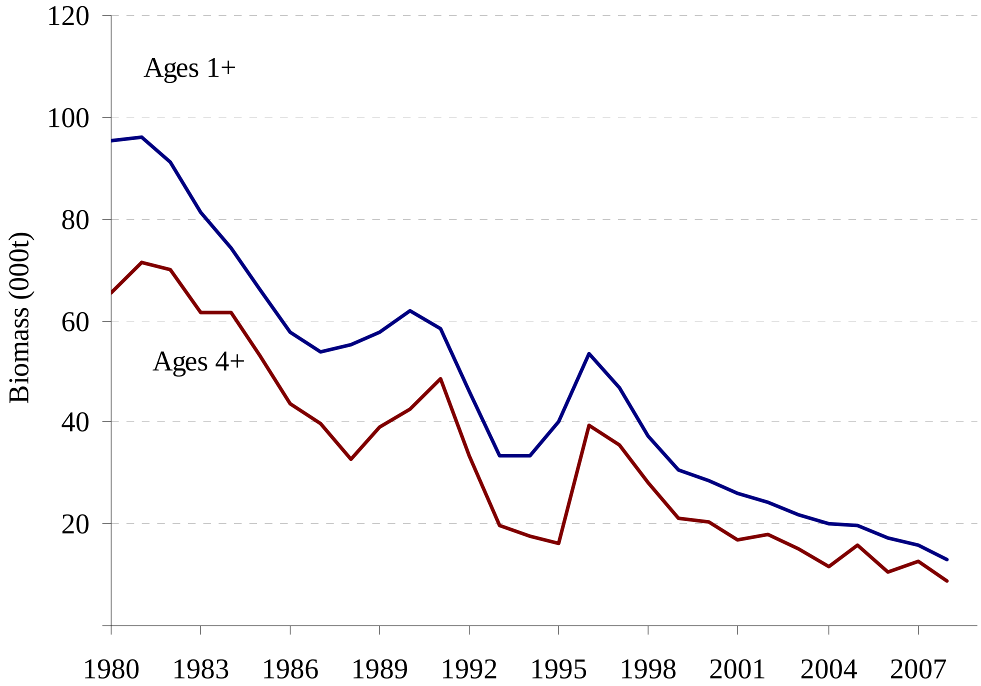


Figure 49. Biomass estimated for NAFO Division 4X cod from SPA.

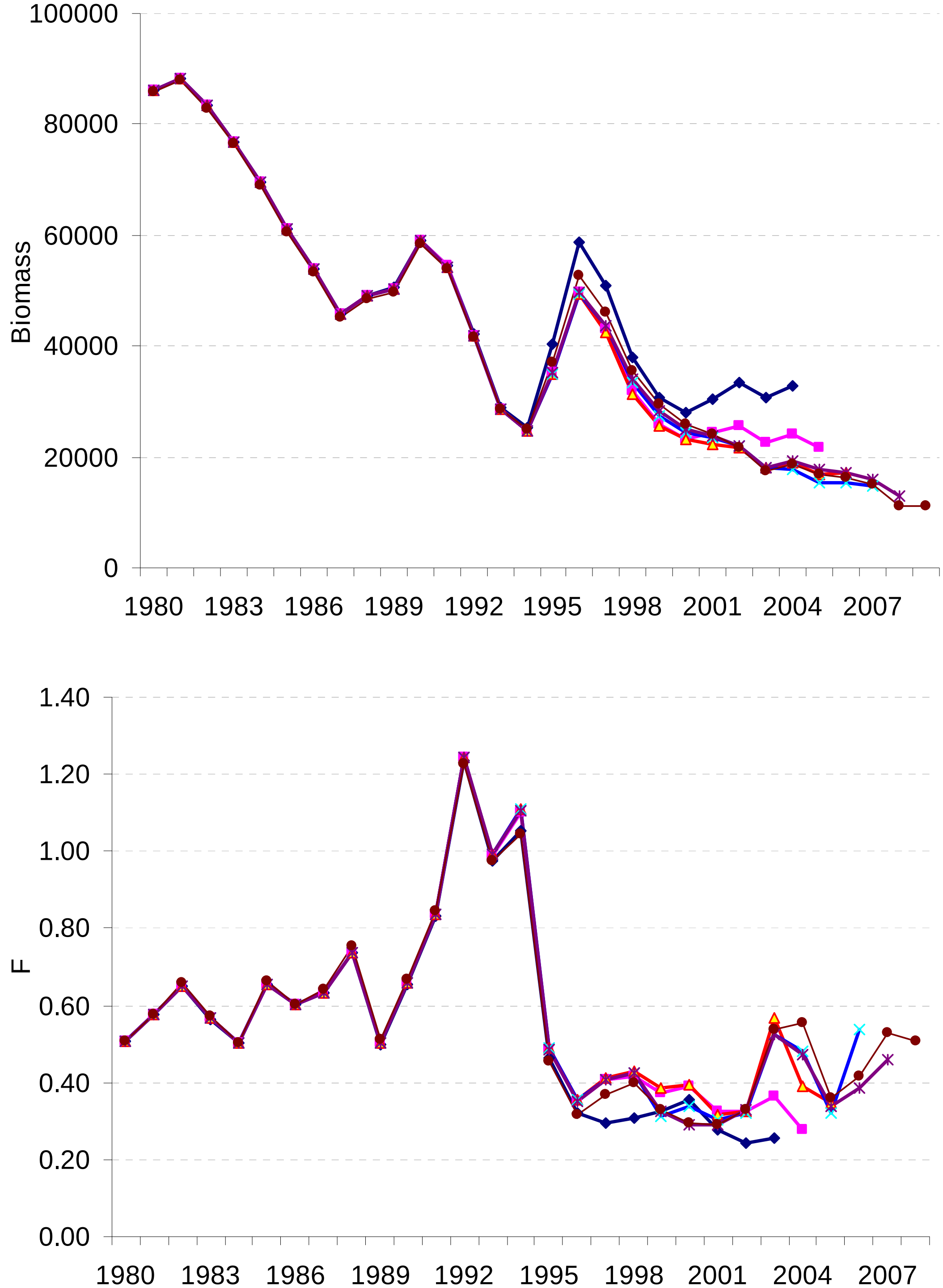


Figure 50. Retrospective estimates of biomass and fishing mortality for NAFO Division 4X cod as successive years of data were excluded in the assessment.

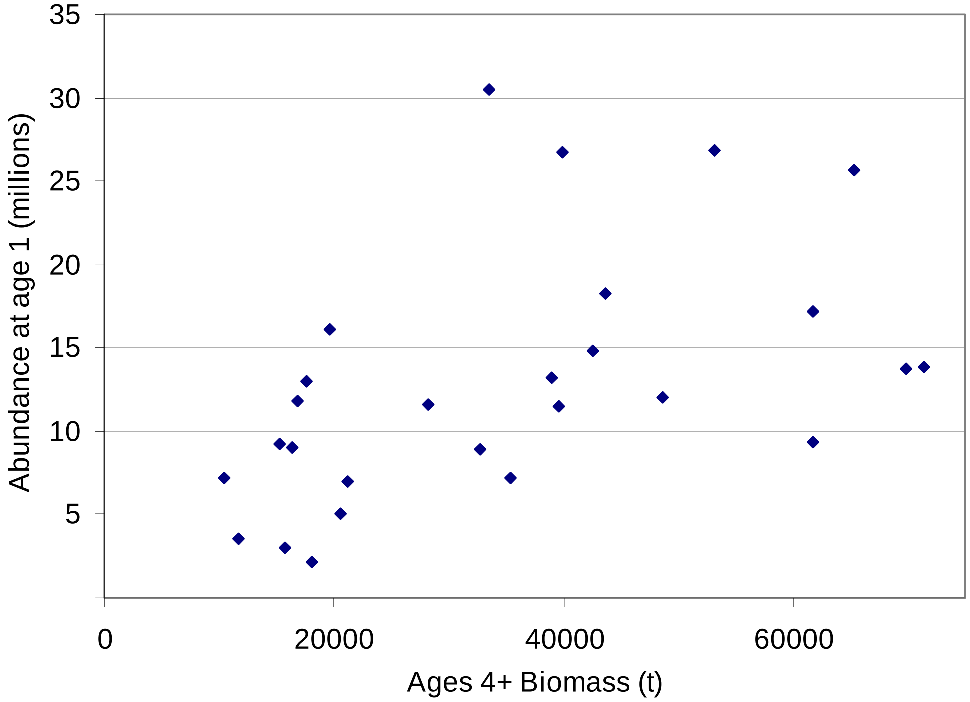


Figure 51. Spawning stock biomass and recruitment relationship for NAFO Division 4X cod.

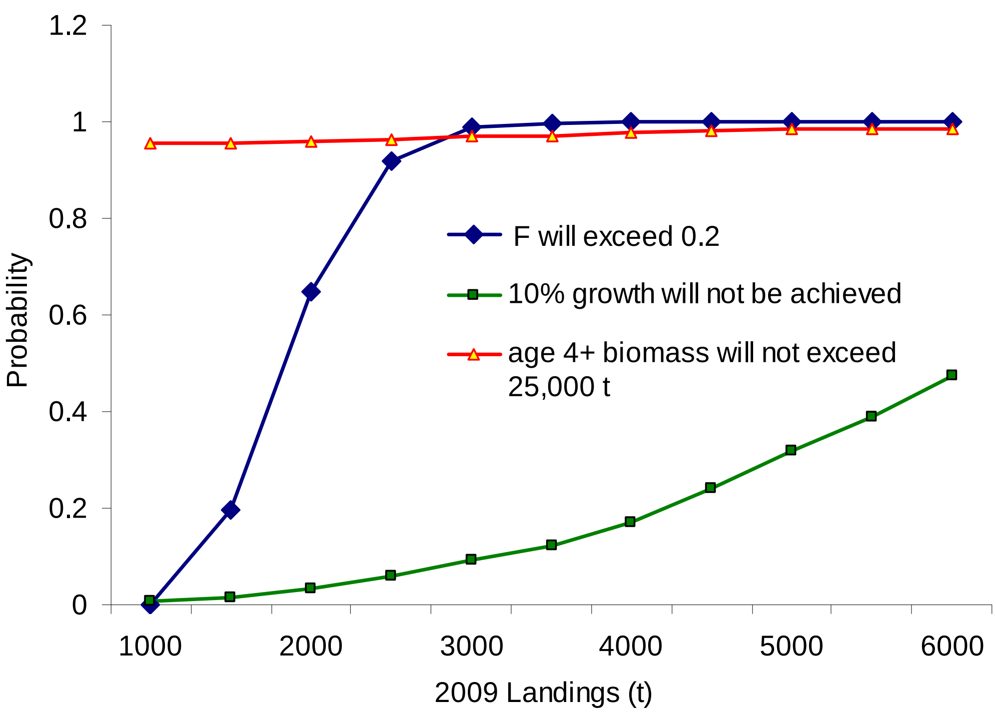


Figure 52. Risk of exceeding the target fishing mortality rate, of not achieving 10% growth in SSB and of not exceeding the LRP of 25,000t SSB for various catch levels in 2009.

APPENDICES

Appendix I. Base Model

Population abundance (number in thousands) for cod in NAFO Division 4X from a virtual population analysis using the bootstrap bias adjusted population abundance.

	1	2	3	4	5	6	7	8	9	10	11	12	1+	2+	3+	4+
1980	22,658	23,229	22,362	8,475	4,817	3,080	1,394	854	312	213	79	50	87,522	64,864	41,636	19,273
1981	25,606	18,551	18,262	12,872	4,821	2,383	1,506	745	465	174	121	47	85,552	59,947	41,396	23,134
1982	13,801	20,964	14,450	11,471	6,714	2,296	1,018	707	344	217	75	64	72,122	58,320	37,356	22,906
1983	13,704	11,300	16,348	9,236	5,440	2,764	1,065	481	330	152	100	25	60,943	47,239	35,940	19,592
1984	17,165	11,212	8,322	10,067	5,376	2,612	1,186	461	211	162	56	50	56,882	39,717	28,505	20,184
1985	9,269	14,024	8,352	4,665	5,478	2,673	1,274	554	220	116	89	20	46,738	37,468	23,444	15,092
1986	26,649	7,589	10,841	5,333	2,413	2,407	1,042	583	280	116	48	57	57,359	30,710	23,121	12,281
1987	18,158	21,818	5,987	6,370	2,628	1,087	1,069	488	298	146	51	19	58,118	39,961	18,142	12,155
1988	26,505	14,866	17,086	4,090	3,374	1,179	423	419	189	119	61	12	68,323	41,818	26,952	9,866
1989	8,808	21,700	11,807	10,825	1,864	1,376	381	187	172	79	51	25	57,275	48,468	26,767	14,960
1990	12,840	7,195	17,175	7,365	5,586	959	624	166	83	88	47	32	52,161	39,321	32,125	14,950
1991	13,584	10,513	5,761	11,484	3,518	2,374	343	262	67	32	38	26	48,001	34,417	23,904	18,143
1992	9,043	11,120	8,254	3,338	4,853	1,296	731	90	76	26	12	6	38,845	29,803	18,682	10,428
1993	14,172	7,404	8,427	3,724	1,063	1,076	285	145	18	18	8	3	36,341	22,169	14,766	6,339
1994	7,372	11,603	5,268	3,778	1,229	284	285	68	39	3	3	2	29,934	22,562	10,959	5,691
1995	5,583	6,036	9,071	2,275	1,109	223	60	73	19	16	2	1	24,469	18,885	12,849	3,779
1996	3,682	4,571	4,820	5,498	898	390	67	24	24	6	8	2	19,990	16,308	11,737	6,917
1997	5,254	3,014	3,697	3,152	2,186	341	130	29	6	13	3	6	17,831	12,577	9,563	5,865
1998	3,286	4,301	2,415	2,017	1,192	728	103	34	10	3	5	2	14,094	10,809	6,507	4,093
1999	6,350	2,690	3,310	1,183	741	428	204	36	10	3	1	1	14,958	8,608	5,918	2,607
2000	2,974	5,198	2,137	1,961	484	297	116	60	11	2	2	0	13,243	10,269	5,071	2,933
2001	2,016	2,435	4,059	1,233	797	176	75	37	25	2	1	1	10,858	8,841	6,407	2,347
2002	5,448	1,651	1,891	2,258	479	315	77	26	15	10	1	0	12,171	6,723	5,072	3,181
2003	1,242	4,461	1,332	1,219	868	195	135	36	8	1	5	0	9,501	8,258	3,798	2,466
2004	4,416	1,017	3,586	867	501	250	74	27	11	5	0	2	10,754	6,338	5,321	1,735
2005	1,546	3,616	802	2,012	381	151	69	44	4	4	2	0	8,631	7,086	3,470	2,668
2006	1,902	1,266	2,900	523	905	158	44	15	28	0	3	2	7,746	5,844	4,578	1,678
2007	3,869	1,557	999	1,692	236	303	38	18	5	17	0	1	8,735	4,866	3,309	2,310
2008	5,000	3,167	1,082	511	560	84	93	16	7	2	14	0	10,536	5,536	2,369	1,287
2008.5	4,524	2,853	815	322	257	45	63	9	6	2	12	0	8,908	4,384	1,531	716

Fishing mortality rate (F) for NAFO Division 4X cod from a virtual population analysis using the bootstrap bias adjusted population abundance.

	1	2	3	4	5	6	7	8	9	10	11	12	Avg F (4-5)	Expl. (4-5)
1980	0.00	0.04	0.35	0.36	0.50	0.52	0.43	0.41	0.38	0.37	0.31	0.47	0.41	0.31
1981	0.00	0.05	0.27	0.45	0.54	0.65	0.56	0.57	0.57	0.64	0.44	0.56	0.48	0.35
1982	0.00	0.05	0.25	0.55	0.69	0.57	0.55	0.56	0.62	0.57	0.91	0.58	0.60	0.41
1983	0.00	0.11	0.28	0.34	0.53	0.65	0.64	0.62	0.51	0.79	0.50	0.59	0.41	0.31
1984	0.00	0.09	0.38	0.41	0.50	0.52	0.56	0.54	0.40	0.40	0.82	0.50	0.44	0.32
1985	0.00	0.06	0.25	0.46	0.62	0.74	0.58	0.48	0.44	0.68	0.25	0.50	0.55	0.39
1986	0.00	0.04	0.33	0.51	0.60	0.61	0.56	0.47	0.45	0.62	0.73	0.50	0.54	0.38
1987	0.00	0.04	0.18	0.44	0.60	0.74	0.74	0.75	0.72	0.68	1.21	0.73	0.48	0.35
1988	0.00	0.03	0.26	0.59	0.70	0.93	0.61	0.69	0.67	0.66	0.70	0.66	0.64	0.43
1989	0.00	0.03	0.27	0.46	0.46	0.59	0.63	0.62	0.48	0.31	0.24	0.58	0.46	0.34
1990	0.00	0.02	0.20	0.54	0.66	0.83	0.67	0.71	0.74	0.65	0.39	0.71	0.59	0.41
1991	0.00	0.04	0.35	0.66	0.80	0.98	1.14	1.04	0.73	0.75	1.66	0.97	0.69	0.46
1992	0.00	0.08	0.60	0.94	1.31	1.32	1.42	1.39	1.23	1.05	1.35	1.35	1.16	0.63
1993	0.00	0.14	0.60	0.91	1.12	1.13	1.23	1.11	1.60	1.68	1.31	0.00	0.96	0.57
1994	0.00	0.05	0.64	1.03	1.50	1.35	1.16	1.09	0.71	0.00	0.99	0.00	1.14	0.63
1995	0.00	0.02	0.30	0.73	0.85	1.00	0.71	0.90	0.93	0.46	0.00	0.00	0.77	0.49
1996	0.00	0.01	0.22	0.72	0.77	0.90	0.63	1.24	0.45	0.44	0.15	0.77	0.73	0.47
1997	0.00	0.02	0.41	0.77	0.90	1.00	1.15	0.90	0.48	0.73	0.42	0.84	0.82	0.52
1998	0.00	0.06	0.51	0.80	0.82	1.07	0.85	1.02	1.10	1.33	1.05	0.99	0.81	0.51
1999	0.00	0.03	0.32	0.69	0.72	1.10	1.02	0.94	1.50	0.23	1.15	1.15	0.70	0.46
2000	0.00	0.05	0.35	0.70	0.81	1.17	0.96	0.67	1.39	0.90	1.01	0.00	0.72	0.47
2001	0.00	0.05	0.39	0.75	0.73	0.62	0.86	0.71	0.73	0.63	1.23	0.00	0.74	0.48
2002	0.00	0.01	0.24	0.76	0.70	0.65	0.57	1.04	2.40	0.58	1.34	1.34	0.75	0.48
2003	0.00	0.02	0.23	0.69	1.04	0.77	1.42	1.02	0.28	0.91	0.91	0.00	0.84	0.52
2004	0.00	0.04	0.38	0.62	1.00	1.09	0.33	1.70	0.82	0.44	0.00	0.00	0.76	0.49
2005	0.00	0.02	0.23	0.60	0.68	1.03	1.31	0.26	1.94	0.12	0.09	0.00	0.61	0.42
2006	0.00	0.04	0.34	0.60	0.89	1.23	0.69	0.98	0.27	0.62	0.65	0.65	0.78	0.50
2007	0.00	0.16	0.47	0.91	0.83	0.98	0.65	0.78	0.82	0.04	0.75	0.00	0.90	0.54
2008	0.00	0.01	0.37	0.72	1.36	1.06	0.56	1.00	0.13	0.00	0.00	0.00	1.06	0.60

Statistical properties of population estimates for mid-year 2008 and survey calibrations for the 4X cod assessment model obtained from a bootstrap with 1000 replicates.

Parameter	Estimate	Standard Error	Bias
N[2008.5 2]	3268.77	1628.39	416.09
N[2008.5 3]	880.31	345.42	64.98
N[2008.5 4]	341.70	127.98	19.52
N[2008.5 5]	276.77	113.39	19.87
N[2008.5 7]	72.25	39.02	8.79
N[2008.5 8]	10.22	5.81	1.30
N[2008.5 9]	7.75	8.83	2.00
N[2008.5 11]	14.32	11.04	2.06
q ID#[1] RV age 2	0.33	0.04	0.00
q ID#[2] RV age 3	0.54	0.07	0.00
q ID#[3] RV age 4	0.69	0.09	0.01
q ID#[4] RV age 5	0.78	0.11	0.01
q ID#[5] RV age 6	0.88	0.12	0.01
q ID#[6] RV age 7	1.06	0.15	0.01
q ID#[7] RV age 8	1.21	0.19	0.02
q ID#[8] ITQ age 2	0.25	0.05	0.00
q ID#[9] ITQ age 3	0.29	0.06	0.00
q ID#[10] ITQ age 4	0.26	0.05	0.00
q ID#[11] ITQ age 5	0.19	0.04	0.00
q ID#[12] ITQ age 6	0.16	0.03	0.00
q ID#[13] ITQ age 7	0.17	0.03	0.00
q ID#[14] ITQ age 8	0.23	0.05	0.01

Appendix II. Research Survey Index Only

Population abundance (number in thousands) for cod in NAFO Division 4X from a virtual population analysis using the bootstrap bias adjusted population abundance.

	1	2	3	4	5	6	7	8	9	10	11	12	13	1+	2+	3+	4+
1980	22,849	23,791	22,565	8,521	4,920	3,359	1,497	1,038	374	314	155	55		89,437	66,588	42,797	20,232
1981	25,773	18,707	18,723	13,037	4,858	2,468	1,733	830	615	224	203	110		87,281	61,508	42,801	24,078
1982	14,085	21,101	14,578	11,848	6,849	2,327	1,086	893	413	339	116	131		73,766	59,681	38,580	24,002
1983	13,803	11,532	16,460	9,340	5,747	2,874	1,089	537	481	207	200	58	25	62,354	48,551	36,994	20,559
1984	17,218	11,293	8,512	10,159	5,462	2,862	1,275	482	257	286	102	131	16	58,055	40,837	29,528	21,032
1985	9,296	14,068	8,419	4,821	5,553	2,743	1,478	627	236	154	190	57	19	47,661	38,365	24,278	15,879
1986	26,825	7,611	10,876	5,387	2,540	2,468	1,099	750	340	130	79	139	26	58,269	31,444	23,807	12,957
1987	18,186	21,963	6,005	6,399	2,672	1,190	1,119	534	434	194	62	44	14	58,816	40,629	18,652	12,661
1988	26,557	14,890	17,204	4,104	3,398	1,215	507	460	226	230	100	21	20	68,931	42,374	27,464	10,280
1989	8,827	21,743	11,827	10,922	1,876	1,395	410	256	205	109	141	57	7	57,773	48,946	27,197	15,377
1990	12,871	7,211	17,210	7,381	5,665	969	640	190	138	114	72	106	3	52,569	39,698	32,485	15,278
1991	13,587	10,538	5,774	11,512	3,531	2,438	351	275	86	78	59	46	14	48,289	34,702	24,150	18,390
1992	9,057	11,123	8,274	3,348	4,876	1,307	783	96	86	42	49	23	16	39,081	30,023	18,885	10,626
1993	14,280	7,416	8,429	3,741	1,071	1,094	293	186	23	26	20	33	5	36,616	22,337	14,916	6,492
1994	7,394	11,691	5,278	3,780	1,242	291	299	75	72	7	9	12	9	30,160	22,765	11,066	5,796
1995	5,629	6,054	9,143	2,283	1,110	234	66	85	24	43	6	6	17	24,700	19,071	12,999	3,874
1996	3,737	4,609	4,835	5,557	904	391	76	29	34	10	30	5	16	20,232	16,495	11,870	7,051
1997	5,259	3,060	3,728	3,164	2,233	347	131	36	9	20	7	24	51	18,069	12,810	9,699	6,022
1998	3,325	4,306	2,452	2,042	1,202	766	107	35	15	6	11	5	57	14,328	11,003	6,641	4,246
1999	6,401	2,722	3,314	1,214	761	436	235	39	10	7	3	7	31	15,181	8,780	6,027	2,744
2000	3,065	5,240	2,163	1,964	509	313	123	85	14	2	5	2	64	13,550	10,485	5,181	3,082
2001	2,069	2,509	4,094	1,255	800	196	89	42	46	5	1	4	58	11,165	9,096	6,529	2,493
2002	6,270	1,694	1,951	2,286	496	317	93	37	19	27	3	0		13,194	6,924	5,230	3,279
2003	1,186	5,134	1,367	1,269	891	209	137	49	16	4	18	2		10,282	9,095	3,962	2,595
2004	5,183	971	4,137	895	541	269	86	28	21	12	3	13		12,159	6,975	6,004	1,867
2005	2,199	4,244	765	2,462	405	184	84	53	5	12	8	2		10,423	8,225	3,981	3,216
2006	2,706	1,800	3,415	493	1,272	177	71	27	35	1	10	7		10,012	7,307	5,507	2,092
2007	3,574	2,215	1,436	2,112	211	601	53	40	14	23	1	7		10,288	6,714	4,499	3,063
2008	5,000	2,925	1,620	869	901	64	335	29	24	10	19	1		11,797	6,797	3,871	2,251
2008.5	4,524	2,634	1,303	645	565	27	283	20	22	9	17	1		10,049	5,525	2,890	1,588

Fishing mortality rate (F) for NAFO Division 4X cod from a virtual population analysis using the bootstrap bias adjusted population abundance.

	1	2	3	4	5	6	7	8	9	10	11	12	Avg F (4-5)	Expl. (4-5)
1980	0.00	0.04	0.35	0.36	0.49	0.46	0.39	0.32	0.31	0.23	0.14	0.42	0.41	0.31
1981	0.00	0.05	0.26	0.44	0.54	0.62	0.46	0.50	0.40	0.46	0.24	0.21	0.47	0.34
1982	0.00	0.05	0.25	0.52	0.67	0.56	0.50	0.42	0.49	0.33	0.49	0.24	0.58	0.40
1983	0.00	0.10	0.28	0.34	0.50	0.61	0.62	0.54	0.32	0.51	0.22	0.21	0.40	0.30
1984	0.00	0.09	0.37	0.40	0.49	0.46	0.51	0.51	0.31	0.21	0.38	0.16	0.43	0.32
1985	0.00	0.06	0.25	0.44	0.61	0.71	0.48	0.41	0.40	0.47	0.11	0.15	0.53	0.38
1986	0.00	0.04	0.33	0.50	0.56	0.59	0.52	0.35	0.36	0.54	0.39	0.17	0.52	0.37
1987	0.00	0.04	0.18	0.43	0.59	0.65	0.69	0.66	0.44	0.46	0.87	0.26	0.48	0.35
1988	0.00	0.03	0.25	0.58	0.69	0.89	0.48	0.61	0.53	0.29	0.36	0.33	0.63	0.43
1989	0.00	0.03	0.27	0.46	0.46	0.58	0.57	0.41	0.38	0.21	0.08	0.21	0.46	0.34
1990	0.00	0.02	0.20	0.54	0.64	0.82	0.65	0.59	0.38	0.46	0.24	0.17	0.58	0.40
1991	0.00	0.04	0.34	0.66	0.79	0.94	1.09	0.96	0.52	0.25	0.73	0.43	0.69	0.46
1992	0.00	0.08	0.59	0.94	1.29	1.30	1.24	1.22	0.98	0.53	0.21	0.21	1.15	0.63
1993	0.00	0.14	0.60	0.90	1.10	1.10	1.16	0.75	1.00	0.84	0.32	0.00	0.95	0.56
1994	0.00	0.05	0.64	1.02	1.47	1.29	1.06	0.93	0.33	0.00	0.21	0.00	1.13	0.63
1995	0.00	0.02	0.30	0.73	0.84	0.92	0.63	0.72	0.64	0.15	0.00	0.00	0.77	0.49
1996	0.00	0.01	0.22	0.71	0.76	0.89	0.54	0.93	0.30	0.24	0.04	0.27	0.72	0.47
1997	0.00	0.02	0.40	0.77	0.87	0.98	1.13	0.66	0.27	0.39	0.18	0.15	0.81	0.51
1998	0.00	0.06	0.50	0.79	0.81	0.98	0.80	0.99	0.55	0.48	0.34	0.27	0.80	0.50
1999	0.00	0.03	0.32	0.67	0.69	1.07	0.81	0.82	1.35	0.08	0.16	0.16	0.68	0.45
2000	0.00	0.05	0.34	0.70	0.75	1.06	0.88	0.43	0.94	0.67	0.22	0.00	0.71	0.47
2001	0.00	0.05	0.38	0.73	0.72	0.54	0.68	0.59	0.34	0.27	0.63	0.00	0.73	0.47
2002	0.00	0.01	0.23	0.74	0.67	0.64	0.45	0.62	1.27	0.18	0.31	0.31	0.73	0.47
2003	0.00	0.02	0.22	0.65	1.00	0.69	1.38	0.64	0.12	0.16	0.16	0.00	0.80	0.50
2004	0.00	0.04	0.32	0.59	0.88	0.96	0.28	1.51	0.33	0.15	0.00	0.00	0.70	0.46
2005	0.00	0.02	0.24	0.46	0.63	0.76	0.93	0.21	1.16	0.04	0.03	0.00	0.48	0.35
2006	0.00	0.03	0.28	0.65	0.55	1.00	0.38	0.44	0.20	0.19	0.14	0.14	0.58	0.40
2007	0.00	0.11	0.30	0.65	0.99	0.38	0.42	0.29	0.20	0.03	0.13	0.00	0.68	0.45
2008	0.00	0.01	0.24	0.39	0.73	1.54	0.14	0.50	0.03	0.00	0.00	0.00	0.57	0.40

Statistical properties of population estimates for mid-year 2008, natural mortality for ages 4 and older and survey calibrations for the 4X cod assessment model obtained from a bootstrap with 1000 replicates.

Parameter	Estimate	Standard Error	Bias
N[2008.5 2]	3618.68	2640.45	984.66
N[2008.5 3]	1532.49	847.52	229.75
N[2008.5 4]	736.73	385.70	91.28
N[2008.5 5]	665.51	391.75	100.73
N[2008.5 6]	33.94	22.85	7.15
N[2008.5 7]	338.25	229.88	55.43
N[2008.5 8]	26.48	23.01	6.30
N[2008.5 9]	26.97	23.08	5.35
N[2008.5 10]	13.97	18.49	5.33
N[2008.5 11]	21.15	19.03	4.25
q ID#[1] RV age 2	0.31	0.04	0.00
q ID#[2] RV age 3	0.50	0.07	0.00
q ID#[3] RV age 4	0.64	0.09	0.00
q ID#[4] RV age 5	0.72	0.10	0.00
q ID#[5] RV age 6	0.78	0.12	0.01
q ID#[6] RV age 7	0.88	0.14	0.01
q ID#[7] RV age 8	0.93	0.16	0.01

Appendix III. q-change

Population abundance (number in thousands) for cod in NAFO Division 4X from a virtual population analysis using the bootstrap bias adjusted population abundance.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1+	2+	3+	4+
1980	22,645	23,235	22,359	8,475	4,816	3,074	1,391	848	310	214	79	77			87,523	64,878	41,643	19,284
1981	25,604	18,540	18,267	12,869	4,821	2,383	1,500	743	460	173	121	47			85,530	59,925	41,385	23,118
1982	13,799	20,963	14,442	11,475	6,712	2,297	1,017	703	342	212	74	64			72,101	58,302	37,339	22,897
1983	13,706	11,298	16,347	9,229	5,444	2,762	1,065	481	326	150	97	24	25	10	60,963	47,257	35,924	19,612
1984	17,164	11,214	8,320	10,067	5,371	2,615	1,185	461	211	159	55	47	16	11	56,896	39,732	28,492	20,198
1985	9,271	14,023	8,354	4,664	5,478	2,668	1,277	553	220	116	87	19	19	8	46,758	37,487	23,437	15,110
1986	26,641	7,590	10,840	5,334	2,412	2,407	1,039	585	279	116	48	55	26	10	57,383	30,742	23,115	12,312
1987	18,159	21,812	5,988	6,369	2,629	1,086	1,069	485	299	145	51	19	14	12	58,138	39,979	18,140	12,179
1988	26,506	14,867	17,081	4,090	3,373	1,180	422	419	186	120	60	12	20	6	68,343	41,838	26,944	9,890
1989	8,808	21,701	11,808	10,821	1,865	1,375	382	187	172	77	52	24	7	9	57,286	48,478	26,762	14,969
1990	12,841	7,196	17,176	7,366	5,583	960	624	167	82	87	46	33	3	4	52,165	39,324	32,122	14,953
1991	13,585	10,513	5,761	11,484	3,519	2,371	343	262	67	32	37	25	14	1	48,015	34,430	23,901	18,156
1992	9,044	11,121	8,254	3,338	4,853	1,297	729	90	76	27	12	6	16	6	38,869	29,824	18,681	10,449
1993	14,165	7,405	8,427	3,725	1,063	1,076	285	143	19	18	8	2	5	13	36,353	22,188	14,765	6,356
1994	7,371	11,598	5,269	3,778	1,229	284	285	69	38	3	3	2	9	4	29,941	22,570	10,960	5,703
1995	5,578	6,035	9,066	2,276	1,109	224	61	73	19	15	3	1	17	7	24,483	18,905	12,846	3,804
1996	3,675	4,567	4,819	5,494	898	390	68	24	24	6	7	2	16	14	20,006	16,330	11,733	6,945
1997	5,253	3,009	3,694	3,151	2,183	342	130	29	6	13	3	5	51	13	17,882	12,629	9,556	5,926
1998	3,185	4,301	2,410	2,014	1,192	725	103	34	10	3	5	2	57	42	14,082	10,897	6,498	4,186
1999	6,344	2,608	3,310	1,180	739	428	202	36	10	3	1	2	31	45	14,938	8,594	5,910	2,676
2000	2,941	5,194	2,070	1,960	481	295	116	59	12	2	2	0	64	26	13,221	10,280	4,997	3,016
2001	2,003	2,408	4,056	1,178	797	174	74	36	24	3	1	1			10,754	8,751	6,343	2,287
2002	5,350	1,640	1,869	2,255	434	315	75	25	14	9	1	0			11,989	6,638	4,998	3,129
2003	1,134	4,381	1,323	1,201	866	158	135	34	7	1	4	0			9,243	8,110	3,729	2,406
2004	4,536	928	3,520	859	486	248	45	27	9	4	0	1			10,664	6,128	5,200	1,679
2005	1,636	3,714	730	1,959	376	139	68	20	4	3	2	0			8,649	7,013	3,299	2,569
2006	1,708	1,339	2,981	464	861	153	35	14	8	0	2	1			7,567	5,859	4,520	1,539
2007	3,507	1,398	1,059	1,757	188	268	34	10	4	1	0	1			8,228	4,721	3,323	2,264
2008	5,000	2,871	952	561	613	45	65	13	1	1	1	0			10,122	5,122	2,251	1,299
2008.5	4,524	2,585	698	367	305	10	38	6	0	1	1	0			8,535	4,010	1,426	728

Fishing mortality rate (F) for NAFO Division 4X cod from a virtual population analysis using the bootstrap bias adjusted population abundance.

	1	2	3	4	5	6	7	8	9	10	11	12	Avg F (4-5)	Expl. (4-5)
1980	0.00	0.04	0.35	0.36	0.50	0.52	0.43	0.41	0.39	0.37	0.31	0.28	0.41	0.31
1981	0.00	0.05	0.26	0.45	0.54	0.65	0.56	0.58	0.57	0.65	0.44	0.57	0.48	0.35
1982	0.00	0.05	0.25	0.55	0.69	0.57	0.55	0.57	0.63	0.58	0.93	0.57	0.60	0.41
1983	0.00	0.11	0.28	0.34	0.53	0.65	0.64	0.62	0.52	0.80	0.52	0.61	0.41	0.31
1984	0.00	0.09	0.38	0.41	0.50	0.52	0.56	0.54	0.40	0.41	0.86	0.54	0.44	0.33
1985	0.00	0.06	0.25	0.46	0.62	0.74	0.58	0.48	0.44	0.68	0.26	0.54	0.55	0.39
1986	0.00	0.04	0.33	0.51	0.60	0.61	0.56	0.47	0.46	0.62	0.73	0.52	0.54	0.38
1987	0.00	0.04	0.18	0.44	0.60	0.74	0.74	0.76	0.71	0.68	1.21	0.74	0.48	0.35
1988	0.00	0.03	0.26	0.59	0.70	0.93	0.62	0.69	0.69	0.65	0.71	0.66	0.64	0.43
1989	0.00	0.03	0.27	0.46	0.46	0.59	0.63	0.62	0.48	0.32	0.24	0.59	0.46	0.34
1990	0.00	0.02	0.20	0.54	0.66	0.83	0.67	0.71	0.75	0.65	0.41	0.68	0.59	0.41
1991	0.00	0.04	0.35	0.66	0.80	0.98	1.14	1.04	0.72	0.76	1.68	1.06	0.69	0.46
1992	0.00	0.08	0.60	0.94	1.31	1.32	1.43	1.38	1.24	1.02	1.41	1.41	1.16	0.63
1993	0.00	0.14	0.60	0.91	1.12	1.13	1.22	1.14	1.56	1.74	1.21	0.00	0.96	0.57
1994	0.00	0.05	0.64	1.03	1.50	1.35	1.16	1.08	0.75	0.00	1.11	0.00	1.14	0.63
1995	0.00	0.02	0.30	0.73	0.85	1.00	0.71	0.90	0.91	0.51	0.00	0.00	0.77	0.49
1996	0.00	0.01	0.22	0.72	0.77	0.90	0.63	1.23	0.45	0.43	0.17	0.72	0.73	0.47
1997	0.00	0.02	0.41	0.77	0.90	1.00	1.14	0.89	0.47	0.72	0.40	1.08	0.83	0.52
1998	0.00	0.06	0.51	0.80	0.82	1.08	0.84	1.02	1.07	1.29	1.02	0.90	0.81	0.51
1999	0.00	0.03	0.32	0.70	0.72	1.11	1.04	0.92	1.48	0.22	1.04	1.04	0.70	0.46
2000	0.00	0.05	0.36	0.70	0.82	1.18	0.96	0.70	1.31	0.86	0.90	0.00	0.72	0.47
2001	0.00	0.05	0.39	0.80	0.73	0.64	0.89	0.72	0.79	0.55	1.10	0.00	0.77	0.49
2002	0.00	0.01	0.24	0.76	0.81	0.65	0.59	1.14	2.59	0.68	0.96	0.96	0.77	0.49
2003	0.00	0.02	0.23	0.70	1.05	1.06	1.42	1.10	0.34	1.32	1.32	0.00	0.85	0.53
2004	0.00	0.04	0.39	0.63	1.05	1.10	0.62	1.71	1.00	0.56	0.00	0.00	0.78	0.50
2005	0.00	0.02	0.25	0.62	0.70	1.19	1.37	0.70	2.06	0.17	0.13	0.00	0.63	0.43
2006	0.00	0.03	0.33	0.71	0.97	1.30	1.00	1.14	1.57	0.75	1.11	1.11	0.87	0.54
2007	0.00	0.18	0.44	0.85	1.22	1.22	0.75	2.44	1.21	0.65	1.15	0.00	0.89	0.54
2008	0.00	0.01	0.42	0.65	1.20	2.83	0.86	1.32	1.64	0.00	0.00	0.00	0.94	0.56

Statistical properties of population estimates for mid-year 2008 and survey calibrations for the 4X cod assessment model obtained from a bootstrap with 1000 replicates.

Parameter	Estimate	Standard Error	Bias
N[2008.5 2]	2810.32	1107.34	225.38
N[2008.5 3]	732.90	231.06	34.98
N[2008.5 4]	383.58	119.90	16.72
N[2008.5 5]	323.65	114.33	18.70
N[2008.5 6]	10.78	4.18	0.82
N[2008.5 7]	41.89	19.48	3.89
N[2008.5 8]	6.80	3.26	0.64
N[2008.5 11]	1.52	4.69	1.00
q ID#[1] RV age 2	0.23	0.04	0.00
q ID#[2] RV age 3	0.37	0.06	0.00
q ID#[3] RV age 4	0.38	0.06	0.00
q ID#[4] RV age 5	0.41	0.07	0.01
q ID#[5] RV age 6	0.49	0.08	0.01
q ID#[6] RV age 7	0.62	0.10	0.01
q ID#[7] RV age 8	0.68	0.12	0.01
q ID#[8] RV age 2	0.43	0.06	0.00
q ID#[9] RV age 3	0.72	0.10	0.01
q ID#[10] RV age 4	1.09	0.15	0.01
q ID#[11] RV age 5	1.31	0.18	0.01
q ID#[12] RV age 6	1.57	0.22	0.01
q ID#[13] RV age 7	1.80	0.26	0.02
q ID#[14] RV age 8	2.34	0.42	0.04
q ID#[15] ITQ age 2	0.26	0.04	0.00
q ID#[16] ITQ age 3	0.29	0.04	0.00
q ID#[17] ITQ age 4	0.26	0.04	0.00
q ID#[18] ITQ age 5	0.20	0.03	0.00
q ID#[19] ITQ age 6	0.20	0.03	0.00
q ID#[20] ITQ age 7	0.20	0.03	0.00
q ID#[21] ITQ age 8	0.25	0.04	0.00

Appendix IV. Calculated M for Ages 4+

Population abundance (number in thousands) for cod in NAFO Division 4X from a virtual population analysis using the bootstrap bias adjusted population abundance.

	1	2	3	4	5	6	7	8	9	10	11	12	1+	2+	3+	4+
1948	17634.3	13438	9046.1	8923	7152	1769	1050	1155	1202	666.7	193.4	223.5	62452	44817	31380	22334
1949	24729.3	14438	10969	6680	5850	4382	843	616.5	618.6	657.9	309	66.67	70160	45431	30993	20024
1950	12596	20247	11379	7652	4182	3953	2771	629.9	410.2	371.8	392.8	206.2	64791	52195	31948	20569
1951	16001.1	10313	15981	7563	3339	2133	2541	1611	479.5	290.2	222.5	309.7	60783	44782	34469	18488
1952	8730.63	13100	8176.7	10720	4487	1424	1296	1659	1070	319.2	213.9	86.92	51284	42554	29453	21277
1953	18373.3	7148	10037	5555	6148	2606	667.7	737.5	1205	647.9	234.3	155.9	53516	35143	27995	17958
1954	9110.69	15043	5744.1	7442	3896	3769	1728	347.4	537.3	829	334.3	126	48906	39796	24753	19009
1955	14050.9	7459.2	12081	4268	4275	2372	2142	1093	160.5	323.6	556.6	192	48975	34924	27465	15383
1956	16482.8	11500	6058.5	8739	2899	2391	1474	1230	723.5	79.42	233.9	401.2	52211	35729	24229	18170
1957	18044.5	13495	9320.5	4399	5004	1716	1432	754.1	586.9	487.7	29.8	121.8	55392	37348	23853	14532
1958	15942.6	14774	11049	7440	3273	2803	1194	634.4	359.9	177.2	143.4	24.4	57815	41872	27099	16050
1959	23689.4	13053	11951	8296	4960	2153	1573	902.3	368.7	161.2	61.4	96.35	67266	43576	30524	18572
1960	28830.1	19395	10687	9491	5008	2514	788.2	913.2	373	223.6	132	28.17	78383	49553	30157	19471
1961	18704	23604	15879	8749	7522	3231	1337	400.9	447	131.1	87.38	62.79	80156	61452	37848	21969
1962	22467.5	15314	19316	12762	6794	4416	1836	806.9	240.7	294.6	70.43	55.17	84372	61905	46591	27276
1963	33083.8	18395	12536	15100	8596	3117	2553	1043	448.2	124.5	191.9	51.8	95240	62156	43761	31225
1964	42403.9	27087	15060	9906	10586	5620	1581	1260	583.6	168.9	66.83	120.1	114443	72039	44953	29892
1965	20672.1	34717	22177	12234	7433	5881	2323	536.1	350.1	137.3	68.96	30.56	106561	85889	51171	28994
1966	16287.5	16925	28395	16806	7700	3487	2850	1273	196.9	216.5	75.9	35.75	94248	77961	61036	32641
1967	16245.8	13335	13844	21526	9537	3290	1292	1341	721.9	121.8	119	38.48	81412	65166	51831	37987
1968	14237.8	13301	10903	9891	11950	4505	1556	628.3	749.5	463.2	67.21	56.29	68308	54070	40769	29867
1969	20439.1	11657	10880	7405	5785	4304	1417	861.8	343.3	393.3	326.4	19.5	63831	43392	31735	20855
1970	19682.4	16734	9132.3	6610	4224	2699	1726	628	530.3	155.8	118.4	244.5	62485	42802	26068	16936
1971	17134	16115	13455	6269	4154	2057	1332	1022	444.1	241.5	81.21	81.46	62387	45253	29138	15683
1972	19254.4	14028	12695	9843	4204	2214	737.5	685.7	489.7	216.1	57.34	37.68	64462	45208	31180	18485
1973	17642.4	15764	11162	8193	5304	1742	960.4	455.8	452.1	274.2	117.1	43.07	62110	44467	28703	17541
1974	21952.3	14444	12608	7467	4525	2594	821.1	521.3	306.1	227.5	163.3	49.84	65680	43728	29283	16675
1975	26743.5	17973	11735	8349	4239	2081	1078	433	239.5	147.1	89.04	46.94	73154	46411	28438	16703
1976	26221.3	21896	14278	8686	4449	2016	1071	499.8	229.9	115.5	88.1	46.89	79597	53375	31480	17202
1977	19496.7	21468	17026	9565	5335	2382	1069	631.7	322.8	120.1	86.45	70.32	77573	58077	36609	19583
1978	33862.6	15958	15787	11313	6054	3282	1317	589.9	256.4	161.3	56.23	26.34	88663	54800	38842	23055
1979	28354.7	27724	12428	9741	6409	2998	1603	619.7	330.4	169.4	108.6	35.25	90522	62168	34443	22015
1980	22,652	23,237	22,360	8,475	4,817	3,074	1,391	848	311	214	79	77	87,533	64,881	41,645	19,284
1981	25,608	18,546	18,269	12,870	4,821	2,383	1,500	743	460	173	121	47	85,541	59,934	41,388	23,119
1982	13,805	20,966	14,446	11,476	6,713	2,297	1,018	703	342	212	74	64	72,117	58,311	37,346	22,899
1983	13,718	11,303	16,349	9,232	5,445	2,763	1,065	481	326	150	97	24	60,953	47,235	35,932	19,583
1984	17,172	11,223	8,324	10,069	5,374	2,616	1,185	462	211	160	55	47	56,898	39,725	28,502	20,178
1985	9,318	14,030	8,362	4,667	5,479	2,671	1,277	554	220	116	87	19	46,801	37,483	23,453	15,091
1986	26,786	7,629	10,845	5,340	2,415	2,408	1,041	586	280	117	48	55	57,549	30,763	23,134	12,289
1987	18,301	21,930	6,020	6,374	2,634	1,088	1,070	486	300	145	51	19	58,418	40,117	18,187	12,167
1988	26,847	14,983	17,178	4,116	3,377	1,184	424	420	187	121	60	12	68,910	42,063	27,080	9,902
1989	8,956	21,980	11,903	10,901	1,886	1,378	385	188	173	78	52	24	57,904	48,948	26,968	15,065
1990	13,399	7,317	17,404	7,443	5,647	977	626	170	83	88	46	34	53,234	39,835	32,518	15,114
1991	14,940	10,970	5,860	11,671	3,582	2,424	357	264	70	33	38	25	50,234	35,294	24,324	18,463
1992	12,683	12,231	8,629	3,419	5,005	1,348	771	101	77	29	13	6	44,312	31,629	19,398	10,769
1993	32,284	10,384	9,336	4,029	1,128	1,197	326	177	27	19	9	3	58,920	26,636	16,252	6,916
1994	16,368	26,432	7,708	4,518	1,475	337	382	101	65	10	4	3	57,404	41,036	14,604	6,896
1995	13,299	13,401	21,211	4,264	1,707	420	103	152	46	37	8	2	54,649	41,350	27,949	6,738
1996	9,290	10,888	10,850	15,432	2,520	876	227	59	88	28	25	7	50,290	41,000	30,112	19,262
1997	11,706	7,606	8,869	8,087	5,466	881	269	86	17	36	12	11	43,046	31,340	23,734	14,865
1998	7,035	9,584	6,174	6,247	2,739	1,761	280	72	30	7	13	5	33,945	26,910	17,326	11,153
1999	11,589	5,760	7,635	4,257	2,231	872	532	95	21	10	2	4	33,006	21,417	15,658	8,022
2000	6,124	9,488	4,650	5,499	1,619	808	235	169	31	5	4	1	28,632	22,509	13,021	8,371
2001	5,149	5,014	7,571	3,289	1,960	590	253	66	61	9	2	1	23,965	18,816	13,802	6,231
2002	12,191	4,216	4,002	5,130	1,138	663	224	91	20	20	4	1	27,700	15,509	11,293	7,291
2003	2,208	9,981	3,432	2,947	1,666	384	218	84	32	2	7	1	20,962	18,754	8,773	5,341
2004	9,683	1,808	8,106	2,586	1,004	440	116	42	25	14	0	2	23,826	14,142	12,335	4,229
2005	3,515	7,928	1,450	5,709	959	279	107	42	7	8	5	0	20,009	16,494	8,565	7,116
2006	3,461	2,878	6,431	1,053	2,105	332	72	20	13	1	4	2	16,373	12,912	10,034	3,603
2007	7,497	2,834	2,319	4,580	349	658	88	20	4	3	0	1	18,352	10,855	8,022	5,703
2008	5,000	6,137	2,127	1,591	1,522	84	192	30	4	0	1	0	16,688	11,688	5,551	3,424
2008.5	4,524	5,540	1,761	963	822	30	113	16	2	0	1	0	13,772	9,247	3,707	1,947

Fishing mortality rate (F) for NAFO Division 4X cod from a virtual population analysis using the bootstrap bias adjusted population abundance.

	1	2	3	4	5	6	7	8	9	10	11	12	Avg F (4-5)	Expl. (4-5)
1980	0.00	0.04	0.35	0.36	0.50	0.52	0.43	0.41	0.39	0.37	0.31	0.28	0.41	0.31
1981	0.00	0.05	0.26	0.45	0.54	0.65	0.56	0.58	0.57	0.65	0.44	0.57	0.48	0.35
1982	0.00	0.05	0.25	0.55	0.69	0.57	0.55	0.57	0.63	0.58	0.93	0.57	0.60	0.41
1983	0.00	0.11	0.28	0.34	0.53	0.65	0.64	0.62	0.52	0.80	0.52	0.61	0.41	0.31
1984	0.00	0.09	0.38	0.41	0.50	0.52	0.56	0.54	0.40	0.41	0.86	0.54	0.44	0.32
1985	0.00	0.06	0.25	0.46	0.62	0.74	0.58	0.48	0.44	0.68	0.26	0.54	0.55	0.39
1986	0.00	0.04	0.33	0.51	0.60	0.61	0.56	0.47	0.46	0.62	0.73	0.52	0.53	0.38
1987	0.00	0.04	0.18	0.44	0.60	0.74	0.73	0.75	0.71	0.68	1.21	0.74	0.48	0.35
1988	0.00	0.03	0.25	0.58	0.70	0.92	0.61	0.69	0.68	0.64	0.70	0.66	0.63	0.43
1989	0.00	0.03	0.27	0.46	0.46	0.59	0.62	0.62	0.48	0.31	0.24	0.59	0.46	0.34
1990	0.00	0.02	0.20	0.53	0.65	0.81	0.66	0.69	0.73	0.64	0.40	0.68	0.58	0.40
1991	0.00	0.04	0.34	0.65	0.78	0.95	1.06	1.03	0.69	0.73	1.63	1.01	0.68	0.45
1992	0.00	0.07	0.56	0.91	1.23	1.22	1.27	1.11	1.19	0.92	1.25	1.25	1.10	0.62
1993	0.00	0.10	0.53	0.80	1.01	0.94	0.97	0.80	0.78	1.47	0.90	0.00	0.85	0.53
1994	0.00	0.02	0.39	0.77	1.06	0.99	0.72	0.60	0.37	0.00	0.66	0.00	0.84	0.52
1995	0.00	0.01	0.12	0.33	0.47	0.41	0.36	0.34	0.29	0.17	0.00	0.00	0.37	0.28
1996	0.00	0.01	0.09	0.27	0.28	0.41	0.20	0.48	0.14	0.11	0.06	0.23	0.27	0.22
1997	0.00	0.01	0.15	0.32	0.36	0.38	0.55	0.30	0.18	0.27	0.13	0.47	0.34	0.26
1998	0.00	0.03	0.17	0.26	0.38	0.43	0.32	0.49	0.33	0.55	0.40	0.35	0.30	0.23
1999	0.00	0.01	0.13	0.20	0.25	0.54	0.38	0.36	0.65	0.07	0.39	0.39	0.22	0.18
2000	0.00	0.03	0.15	0.26	0.24	0.40	0.49	0.26	0.45	0.33	0.40	0.00	0.26	0.21
2001	0.00	0.03	0.19	0.29	0.32	0.20	0.25	0.44	0.33	0.17	0.41	0.00	0.30	0.24
2002	0.00	0.01	0.11	0.36	0.32	0.34	0.22	0.28	1.73	0.32	0.32	0.32	0.35	0.27
2003	0.00	0.01	0.08	0.31	0.56	0.43	0.89	0.43	0.08	0.70	0.70	0.00	0.40	0.30
2004	0.00	0.02	0.15	0.22	0.51	0.65	0.26	1.07	0.36	0.17	0.00	0.00	0.31	0.24
2005	0.00	0.01	0.12	0.23	0.29	0.59	0.90	0.37	1.04	0.07	0.05	0.00	0.24	0.19
2006	0.00	0.02	0.14	0.34	0.39	0.56	0.50	0.90	0.91	0.30	0.63	0.63	0.38	0.29
2007	0.00	0.09	0.18	0.33	0.66	0.46	0.31	0.91	1.71	0.41	0.46	0.00	0.36	0.27
2008	0.00	0.00	0.18	0.24	0.47	1.25	0.29	0.55	0.27	0.00	0.00	0.00	0.35	0.27

Statistical properties of population estimates for mid-year 2008, natural mortality for ages 4 and older and survey calibrations for the 4X cod assessment model obtained from a bootstrap with 1000 replicates.

Parameter	Estimate	Standard Error	Bias
N[2008.5 2]	6056.78	2468.92	516.88
N[2008.5 3]	1848.27	572.20	87.65
N[2008.5 4]	998.81	276.87	36.29
N[2008.5 5]	853.43	246.66	31.64
N[2008.5 6]	32.31	11.55	1.85
N[2008.5 7]	118.81	39.84	5.32
N[2008.5 8]	16.32	5.83	0.78
N[2008.5 9]	2.70	2.52	0.45
N[2008.5 10]	0.48	0.88	0.26
N[2008.5 11]	0.70	0.93	0.18
M[1996 4]	0.77	0.04	0.00
q ID#[1] RV age 2	0.20	0.02	0.00
q ID#[2] RV age 3	0.32	0.04	0.00
q ID#[3] RV age 4	0.41	0.05	0.00
q ID#[4] RV age 5	0.49	0.06	0.00
q ID#[5] RV age 6	0.58	0.07	0.00
q ID#[6] RV age 7	0.70	0.08	0.01
q ID#[7] RV age 8	0.76	0.10	0.01
q ID#[8] ITQ age 2	0.12	0.02	0.00
q ID#[9] ITQ age 3	0.12	0.02	0.00
q ID#[10] ITQ age 4	0.10	0.02	0.00
q ID#[11] ITQ age 5	0.08	0.01	0.00
q ID#[12] ITQ age 6	0.08	0.01	0.00
q ID#[13] ITQ age 7	0.08	0.01	0.00
q ID#[14] ITQ age 8	0.11	0.02	0.00

Appendix V. Calculated M for Two Periods (1993-1996)

Population abundance (number in thousands) for cod in NAFO Division 4X from a virtual population analysis using the bootstrap bias adjusted population abundance.

	1	2	3	4	5	6	7	8	9	10	11	12	1+	2+	3+	4+
1980	22,672	23,246	22,365	8,476	4,817	3,075	1,391	848	311	214	79	77	87,569	64,898	41,652	19,287
1981	25,620	18,562	18,276	12,874	4,822	2,384	1,501	743	460	173	122	47	85,583	59,963	41,401	23,125
1982	13,826	20,976	14,459	11,482	6,716	2,297	1,018	704	342	212	74	64	72,172	58,346	37,370	22,910
1983	13,765	11,320	16,357	9,243	5,450	2,765	1,065	481	327	150	97	24	61,045	47,280	35,960	19,603
1984	17,225	11,261	8,338	10,075	5,383	2,620	1,187	462	212	160	55	47	57,026	39,801	28,539	20,201
1985	9,438	14,073	8,393	4,679	5,485	2,678	1,281	555	220	117	87	19	47,026	37,588	23,514	15,121
1986	27,329	7,727	10,881	5,366	2,424	2,413	1,047	588	281	117	49	55	58,276	30,947	23,220	12,339
1987	18,957	22,375	6,101	6,403	2,655	1,096	1,073	491	302	146	51	19	59,670	40,712	18,337	12,237
1988	28,832	15,521	17,542	4,182	3,401	1,201	430	423	191	122	61	13	71,919	43,087	27,567	10,025
1989	10,363	23,606	12,343	11,198	1,940	1,397	399	193	175	81	53	25	61,774	51,411	27,805	15,462
1990	17,866	8,469	18,735	7,803	5,890	1,021	642	181	87	90	49	35	60,867	43,001	34,533	15,798
1991	19,025	14,627	6,804	12,760	3,875	2,621	393	276	79	36	39	28	60,564	41,539	26,911	20,107
1992	13,953	15,575	11,623	4,190	5,891	1,586	931	130	88	36	16	7	54,025	40,072	24,497	12,874
1993	25,336	11,424	12,073	6,472	1,753	1,909	517	305	51	28	15	5	59,888	34,551	23,128	11,055
1994	13,240	20,744	8,559	6,752	2,036	480	554	147	101	18	5	5	52,640	39,400	18,656	10,098
1995	11,485	10,840	16,554	4,959	2,057	478	122	171	50	41	9	2	46,767	35,283	24,443	7,888
1996	8,887	9,403	8,753	11,620	1,893	693	165	46	63	19	18	5	41,566	32,679	23,276	14,522
1997	12,635	7,276	7,653	6,370	4,394	703	223	68	13	28	9	9	39,382	26,748	19,471	11,818
1998	7,227	10,344	5,904	5,252	2,316	1,516	237	62	25	6	11	4	32,905	25,678	15,333	9,429
1999	12,176	5,917	8,258	4,036	2,091	808	503	89	19	9	2	4	33,912	21,736	15,819	7,561
2000	6,431	9,969	4,779	6,009	1,777	874	249	184	33	5	5	1	30,315	23,885	13,916	9,137
2001	5,511	5,265	7,965	3,395	2,108	636	271	70	65	10	2	1	25,298	19,787	14,522	6,558
2002	12,799	4,512	4,208	5,452	1,138	701	236	96	20	22	4	1	29,188	16,389	11,877	7,670
2003	2,308	10,479	3,674	3,115	1,739	368	226	86	33	2	7	1	22,038	19,730	9,251	5,577
2004	10,002	1,889	8,513	2,784	1,038	452	104	43	25	14	0	2	24,865	14,863	12,974	4,461
2005	3,597	8,189	1,517	6,042	1,010	281	107	35	7	8	5	0	20,796	17,199	9,010	7,494
2006	3,531	2,945	6,645	1,108	2,170	341	70	19	10	1	3	2	16,845	13,313	10,368	3,724
2007	7,660	2,891	2,374	4,755	358	659	88	18	3	1	0	1	18,808	11,148	8,257	5,883
2008	5,000	6,271	2,174	1,636	1,536	84	184	29	3	0	0	0	16,916	11,916	5,646	3,472
2008.5	4,524	5,661	1,803	974	814	30	106	14	2	0	0	0	13,928	9,404	3,743	1,940

Fishing mortality rate (F) for NAFO Division 4X cod from a virtual population analysis using the bootstrap bias adjusted population abundance.

	1	2	3	4	5	6	7	8	9	10	11	12	Avg F (4-5)	Expl. (4-5)
1980	0.00	0.04	0.35	0.36	0.50	0.52	0.43	0.41	0.39	0.37	0.31	0.28	0.41	0.31
1981	0.00	0.05	0.26	0.45	0.54	0.65	0.56	0.58	0.57	0.65	0.44	0.56	0.48	0.35
1982	0.00	0.05	0.25	0.55	0.69	0.57	0.55	0.57	0.63	0.58	0.93	0.57	0.60	0.41
1983	0.00	0.11	0.28	0.34	0.53	0.65	0.64	0.62	0.51	0.80	0.52	0.61	0.41	0.31
1984	0.00	0.09	0.38	0.41	0.50	0.52	0.56	0.54	0.40	0.40	0.85	0.54	0.44	0.33
1985	0.00	0.06	0.25	0.46	0.62	0.74	0.58	0.48	0.44	0.68	0.26	0.54	0.55	0.39
1986	0.00	0.04	0.33	0.50	0.59	0.61	0.56	0.47	0.45	0.62	0.73	0.51	0.54	0.38
1987	0.00	0.04	0.18	0.43	0.59	0.74	0.73	0.74	0.70	0.67	1.20	0.73	0.48	0.35
1988	0.00	0.03	0.25	0.57	0.69	0.90	0.60	0.68	0.66	0.63	0.69	0.64	0.63	0.43
1989	0.00	0.03	0.26	0.44	0.44	0.58	0.59	0.59	0.47	0.30	0.23	0.56	0.46	0.34
1990	0.00	0.02	0.18	0.50	0.61	0.76	0.64	0.63	0.68	0.62	0.38	0.64	0.58	0.40
1991	0.00	0.03	0.28	0.57	0.69	0.84	0.90	0.95	0.58	0.64	1.48	0.89	0.68	0.45
1992	0.00	0.05	0.39	0.67	0.93	0.92	0.91	0.74	0.96	0.65	0.90	0.90	1.12	0.62
1993	0.00	0.09	0.38	0.53	0.67	0.61	0.63	0.49	0.44	1.02	0.57	0.00	0.87	0.54
1994	0.00	0.03	0.35	0.57	0.83	0.75	0.55	0.47	0.28	0.00	0.50	0.00	0.87	0.53
1995	0.00	0.01	0.15	0.34	0.46	0.44	0.36	0.37	0.33	0.19	0.00	0.00	0.37	0.28
1996	0.00	0.01	0.12	0.35	0.37	0.51	0.27	0.61	0.18	0.15	0.08	0.30	0.27	0.22
1997	0.00	0.01	0.18	0.39	0.44	0.46	0.65	0.37	0.22	0.33	0.16	0.57	0.34	0.26
1998	0.00	0.03	0.18	0.30	0.43	0.48	0.36	0.54	0.38	0.61	0.45	0.39	0.30	0.23
1999	0.00	0.01	0.12	0.20	0.25	0.56	0.38	0.36	0.66	0.08	0.38	0.38	0.22	0.18
2000	0.00	0.02	0.14	0.24	0.22	0.37	0.47	0.24	0.41	0.31	0.37	0.00	0.26	0.21
2001	0.00	0.02	0.18	0.29	0.30	0.19	0.24	0.42	0.30	0.16	0.39	0.00	0.30	0.24
2002	0.00	0.01	0.10	0.34	0.32	0.33	0.21	0.27	1.68	0.31	0.31	0.31	0.35	0.27
2003	0.00	0.01	0.08	0.29	0.54	0.46	0.86	0.43	0.08	0.68	0.68	0.00	0.40	0.30
2004	0.00	0.02	0.14	0.21	0.50	0.64	0.30	1.04	0.37	0.17	0.00	0.00	0.31	0.24
2005	0.00	0.01	0.11	0.22	0.28	0.59	0.92	0.47	1.04	0.08	0.06	0.00	0.24	0.19
2006	0.00	0.02	0.13	0.32	0.39	0.55	0.53	1.00	1.61	0.31	0.73	0.73	0.38	0.29
2007	0.00	0.09	0.17	0.33	0.65	0.47	0.31	1.10	2.97	2.18	0.52	0.00	0.36	0.27
2008	0.00	0.00	0.17	0.23	0.46	1.26	0.31	0.59	0.39	0.00	0.00	0.00	0.35	0.27

Statistical properties of population estimates for mid-year 2008, natural mortality for ages 4 and older for two periods and survey calibrations for the 4X cod assessment model obtained from a bootstrap with 1000 replicates.

Parameter	Estimate	Standard Error	Bias
N[2008.5 2]	6033.11	2466.19	523.97
N[2008.5 3]	1839.86	571.91	89.90
N[2008.5 4]	993.89	276.98	37.47
N[2008.5 5]	848.60	246.87	32.64
N[2008.5 6]	32.07	11.54	1.89
N[2008.5 7]	117.98	39.87	5.46
N[2008.5 8]	16.19	5.84	0.80
N[2008.5 9]	2.64	2.52	0.46
N[2008.5 10]	0.46	0.88	0.27
N[2008.5 11]	0.68	0.93	0.18
M[1993 4]	0.17	0.15	-0.01
M[1996 4]	0.76	0.04	0.00
q ID#[1] RV age 2	0.21	0.02	0.00
q ID#[2] RV age 3	0.32	0.04	0.00
q ID#[3] RV age 4	0.41	0.05	0.00
q ID#[4] RV age 5	0.50	0.06	0.00
q ID#[5] RV age 6	0.59	0.07	0.00
q ID#[6] RV age 7	0.71	0.09	0.01
q ID#[7] RV age 8	0.77	0.11	0.01
q ID#[8] ITQ age 2	0.12	0.02	0.00
q ID#[9] ITQ age 3	0.12	0.02	0.00
q ID#[10] ITQ age 4	0.10	0.02	0.00
q ID#[11] ITQ age 5	0.08	0.01	0.00
q ID#[12] ITQ age 6	0.08	0.01	0.00
q ID#[13] ITQ age 7	0.08	0.02	0.00
q ID#[14] ITQ age 8	0.11	0.02	0.00