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Recovery Potential Assessment (RPA) for the Southern Designatable Unit (NAFO Divisions 4X5Yb and 5Zjm) of Atlantic Cod (*Gadus morhua*)

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Foreword

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

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ABSTRACT

In its 2010 assessment of Atlantic Cod (*Gadus morhua*), the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated the Southern Designatable Unit (DU) as Endangered. Cod in the Southern DU are currently assessed as two separate management units: Southern Scotian Shelf and the Bay of Fundy (NAFO Division 4X and the Canadian portion of 5Yb) and Eastern Georges Bank (NAFO Division 5Zjm). A recovery potential assessment (RPA) was conducted in February 2011 by Fisheries and Oceans Canada (DFO) Science to provide the information and scientific advice required to meet various requirements of the *Species at Risk Act* (SARA), including decisions regarding the listing of Southern DU cod under the *Act* and developing a recovery strategy. This document addresses the terms of reference for the Atlantic Cod RPA in relation to the Southern DU.

The abundance of cod in the Southern DU has declined in number and biomass since the early-1990s. Trends differ between the two components in the Southern DU, with cod numbers in NAFO Division 5Zjm stabilizing at low levels over the past decade, while continuing to decline in Division 4X5Yb. The structure of cod populations in the Southern DU is complex, but there is no evidence of a decrease in the number of populations. The range and overall distribution of cod within the Southern DU has not changed since the 1970s and there is no indication that the amount of suitable habitat is currently limiting the recovery of cod in this DU.

Conservation Limit Reference Points (LRPs) were calculated for 4X5Yb and 5Zjm cod, based on Beverton-Holt stock recruitment models. The Precautionary Approach (PA) reference point, spawning stock biomass limit (B_{lim}), was calculated as 24,000t for cod in Division 4X5Yb and 21,000t for Division 5Zjm. Estimated 4X5Yb SSB has been below the LRP since 2002, and was estimated to be 10,600t at the beginning of 2009. Estimated 5Zjm cod spawning stock biomass has been below the LRP since 1994, and is currently estimated to be 9,260t. Average recruitment in the Southern DU stocks has decreased to less than half of the pre-1992 level. Thirty six year (five generation) projections were undertaken for both stocks using recruitment data from the entire time series. Biomass was projected to increase above the LRPs for both stocks within this time period if fishing mortality was maintained at or below reference levels.

Sources of potential mortality identified for Southern DU cod included natural mortality, fishing, discards and bycatch in other fisheries. Natural mortality of Division 4X5Yb cod aged 4 years and older was estimated to be unusually high, whilst natural mortality of Division 5Zjm cod aged 6 years and older was also elevated. The only mitigation measures for which increases in survivorship could be calculated were reductions in fishery removals.

Évaluation du potentiel de rétablissement (EPR) de la morue franche (*Gadus morhua*) de l'unité désignable du Sud (divisions 4X5Yb et 5Zjm de l'OPANO)

RÉSUMÉ

En 2010, lors de son évaluation de la situation de la morue franche (Gadus morhua), le Comité sur la situation des espèces en péril au Canada (COSEPAC) a désigné l'unité désignable (UD) du Sud comme étant « en voie de disparition ». Les morues de l'UD du Sud sont évaluées en tant que deux zones de gestion distinctes : le sud du plateau néo-écossais et la baie de Fundy (division 4X et partie canadienne de la division 5Yb de l'OPANO), ainsi que la partie est du banc de Georges (division 5Zjm de l'OPANO). Le secteur des Sciences de Pêches et Océans Canada a effectué une évaluation du potentiel de rétablissement (EPR) en février 2011 afin de fournir l'information et l'avis scientifique nécessaires au respect des diverses exigences de la Loi sur les espèces en péril (LEP), y compris la prise de décisions concernant l'inscription de la morue franche de l'unité désignable du Sud en vertu de la LEP et l'élaboration d'un programme de rétablissement. Le présent document porte sur le cadre de référence lié à l'évaluation du potentiel de rétablissement de la morue franche en ce qui a trait à l'UD du Sud.

L'abondance de la morue dans l'UD du Sud a décliné en nombre et en biomasse depuis le début des années 1990. Les tendances sont différentes pour les deux parties de l'UD du Sud, le nombre de morues s'étant stabilisé à de faibles niveaux dans la division 5Zjm de l'OPANO au cours de la dernière décennie tandis qu'il continuait à décliner dans les divisions 4X5Yb. La structure des populations de morue dans l'UD du Sud est complexe, mais il n'existe aucune donnée probante attestant d'une diminution du nombre de populations. L'aire de répartition et la répartition générale de la morue dans l'UD du Sud demeurent inchangées depuis les années 1970, et rien n'indique que la superficie d'habitat approprié limite actuellement le rétablissement de la morue dans cette UD.

On a établi des points de référence limite (PRL) de conservation pour la morue de 4X5Yb et de 5Zjm, d'après des modèles de stock-recrutement de Beverton-Holt. Le point de référence de l'approche de précaution (AP), soit la limite de la biomasse du stock reproducteur (Blim), se chiffre à 24 000 t pour la morue des divisions 4X5Yb et à 21 000 t pour la division 5Zjm. L'estimation de la biomasse du stock reproducteur (BSR) pour 4X5Yb est inférieure au PRL depuis 2002 et a été chiffrée à 10 600 t au début de 2009. L'estimation de la BSR pour 5Zjm est inférieure au PRL depuis 1994 et se chiffre actuellement à 9 260 t. Le recrutement moyen des stocks de l'UD du Sud a diminué pour atteindre moins de la moitié des niveaux observés avant 1992. Des prévisions sur trente-six (36) ans (cinq générations) ont été effectuées pour les deux stocks à l'aide de données sur le recrutement tirées de l'ensemble de la série chronologique. On prévoit une augmentation de la biomasse au-dessus des PRL pour les deux stocks durant cette période si la mortalité par pêche demeure aux niveaux de référence ou descend en deçà de ceux-ci.

Les sources de mortalité potentielle relevées pour la morue de l'UD du Sud comprenaient la mortalité naturelle, la pêche, les rejets et les prises accessoires dans le cadre d'autres pêches. La mortalité naturelle de la morue âgée d'au moins quatre ans dans les divisions 4X5Yb a été estimée comme étant anormalement élevée, et la mortalité naturelle de la morue d'au moins six ans dans la division 5Zjm était également élevée. Les seules mesures d'atténuation pour lesquelles une augmentation du taux de survie a pu être calculée consistaient en des réductions des prélèvements par les pêches.

INTRODUCTION

In 2003 the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated the Maritimes designatable unit (DU) Special Concern. In April 2010, COSEWIC re-assessed the designation of Atlantic Cod (*Gadus morhua*) and split the Maritimes DU into two populations: the Laurentian South DU and the Southern DU. The Southern DU, comprising of the Northwest Atlantic Fishery Organization (NAFO) Divisions 4X, 5Zjm and the Canadian portion of 5Yb (Figure 1), was designated as Endangered by COSEWIC due to the significant decline in abundance and evidence of an unexplained increase in natural mortality in the 4X5Yb portion of the DU (COSEWIC 2010).

ASSESSMENT BACKGROUND

Cod in the Southern DU are currently assessed as two separate management units: Southern Scotian Shelf and the Bay of Fundy (NAFO Division 4X and the Canadian portion of 5Yb) and Eastern Georges Bank (NAFO Division 5Zjm).

4X5Yb

The most recent assessment of 4X5Yb cod was conducted at the Zonal Advisory Process for Atlantic Cod, February 24 to March 6, 2009 (DFO 2009). A Virtual Population Analysis (VPA) model was used to provide estimates of abundance, fishing mortality and natural mortality. The commercial catch at age was included from 1980 to 2008. Indices used in the model are Fisheries and Oceans Canada (DFO) ecosystem research vessel survey indices for ages 2 to 8 for 1983 to 2008, and the Individual Transferable Quota (ITQ) fixed station survey indices for ages 1 to 8 for 1996 to 2008. The results of the analytical assessment for this stock indicated that mortality for cod of 4 years and older from causes other than reported landings, including natural mortality, increased in 1996 and it is currently estimated at 0.7. (Clark and Emberley 2009; DFO 2009).

5Zjm

An assessment of the eastern component of Georges Bank cod (Division 5Zjm) is conducted annually by the Transboundary Resources Assessment Committee (TRAC). The last assessment prior to the February 2011 recovery potential assessment (RPA) meeting was held in Woods Hole, Massachusetts, in July 2010.

The 2010 Eastern Georges Bank (Division 5Zjm) cod assessment (Clark et al. 2010; TRAC 2010) was conducted using the VPA model formulations that were peer reviewed at the Eastern Georges Bank Cod Benchmark Assessment Meeting in March and April 2009 (O'Brien and Worcester 2009; Wang et al. 2009a). At the benchmark, two consensus VPA model formulations were established for the 5Zjm stock: the 'split M 0.2' and the 'split M 0.5'. Both models assumed a change in survey catchability between 1993 and 1994 and used three surveys as tuning indices: DFO winter survey, National Marine Fisheries Service (NMFS) spring survey and NFMS fall survey. For the 'split M 0.5' model, a constant value of 0.2 was assumed for natural mortality (M) for all ages before the 1993/1994 split. From 1994 onwards, M remained at 0.2 for ages 1 to 5, but was increased to 0.5 for ages 6 and above. In the 'split M 0.2' model, M remained at 0.2 for all years and ages. At the Atlantic Cod Framework Meeting on Assessment Models, Medium-term Projections, Reference Points held on December 6-8, 2010, in Moncton, New Brunswick, it was concluded that for the 2011 RPA, only results obtained from the 'split M 0.5' model would be used in assessing the Southern DU (Clark et al. 2011).

RECOVERY POTENTIAL ASSESSMENT

A Zonal Advisory Process for the RPA of Atlantic Cod for four Designatable Units (Newfoundland and Labrador, Laurentian North, Laurentian South, and Southern) was held from February 21-25, 2011, at the Battery Hotel and Conference Centre, St. John's, Newfoundland (DFO 2012). The purpose of the RPA meeting was to provide data that would inform the listing decision, socio-economic analyses and consultations with the public and should cod in the Southern DU be legally listed pursuant to the *Species at Risk Act* (SARA) as Threatened or Endangered. The RPA would also inform the Recovery Strategy.

The terms of reference (ToR) for the RPA meeting (DFO 2012) addressed by this document cover historic and current abundance, distribution and trends; life-history parameters, habitat requirements and suitability; species at risk and management considerations; threats to survival and recovery and potential mitigation measures.

HISTORIC AND CURRENT ABUNDANCE, DISTRIBUTION AND TRENDS

ToR 1. Evaluate present Atlantic Cod status for abundance (i.e., numbers and biomass focusing on matures) and range and number of populations for the Southern DU.

ToR 2. Evaluate recent species trajectory for abundance (i.e., numbers and biomass focusing on matures) and range and number of populations for the Southern DU.

Abundance and Range

The accepted VPA models for 4X5Yb and 5Zjm cod ('split M 0.5 model') were used to calculate abundance of mature individuals and rates of population decline for Southern DU cod (Clark and Emberley 2009; Wang 2009a).

4X5Yb

The 2009 stock status evaluation using the VPA model described in Clark and Emberley (2009) showed a general decline in numbers and biomass throughout the assessment period (1980 to 2008) (Tables 1 and 2; Figures 2 and 3) and the relatively strong 1985, 1987 and 1992 year-classes resulted in only short-term improvements in biomass. Mature age 3+ spawning stock biomass (SSB) at the beginning of 2008 was estimated at 10,600t (5.2 million individuals); this is the lowest level in the time-series, which started in 1948 (Clark and Emberley 2009). The abundance of cod in 4X5Yb has shown a 75% reduction in mature individuals over the last three generations (22.5 years; 7.5 years per generation).

The Design Weighted Area of Occupancy (DWAO) for cod in Division 4X5Yb was calculated from the DFO ecosystem summer survey for 1970-2010 (Figure 4). The survey covers an area of approximately 18,600 nm^2 (64,000 km^2) from coastal Nova Scotia and Southwestern New Brunswick out to depths of 200 fathoms (370 m). The DWAO for 4X5Yb cod declined over time, but appears to be stable or even increasing since 2001 (Figure 4). Survey catches of cod in 4X5Yb are generally quite low, ranging from about 140 to 600 fish annually from 65 to 80 sets, but continue to span all strata. Thus, while the DWAO index has declined, there is no reduction in range for cod in 4X5Yb. Cod continue to be caught throughout 4X5Yb in lower numbers, in both the surveys and the commercial fishery, with the highest catches in 4Xp (Figure 5).

5Zjm

Stock status evaluations using the "split M 0.5" model (Clark et al 2010; TRAC 2010) indicate a substantial decline in 3+ adult population numbers and biomass in the mid-1990s, after which the stock has remained at a lower level (Tables 3 and 4; Figures 2 and 6). Mature biomass at the beginning of 2010 was estimated at 9,260t (3.4 million individuals). The abundance of cod in

Division 5Zjm remains below pre-1994 levels and has shown a 75% reduction in mature individuals over the last three generations.

The DWAO for Division 5Zjm cod was calculated from the DFO winter survey, 1987 to 2010 (Figure 4). The index was based on four strata that covered an area of approximately 4,900 nm^2 (16,800 km^2) at depths of 50 to 100 m (Figure 7). The DWAO was variable, and showed no trend (Figure 4).

The highest survey catches (biomass) from the DFO winter survey tended to be from stratum 5Z2, particularly the northeast corner of the Canadian side, although in some years catches were more spread out (Figure 8). This trend was consistent throughout the survey history (1986 to 2010) and there was no evidence of a contraction of range.

Southern DU

The abundance of cod in the Southern DU declined in number and biomass since the early-1990s (Figures 2 and 9). The number of mature individuals remains below pre-1992 levels and has shown a 76% reduction over the last three generations. As of the RPA meeting in February, mature cod biomass (age 3+) in the Southern DU was estimated at 19,900t, with an estimated mature abundance of 8.6 million fish (Figures 2 and 9). Abundance trends differed between the two components, with cod numbers in 5Zjm stabilizing at low levels over the past decade, while continuing to decline in 4X5Yb (Figure 2).

The DWAO for the Southern DU was based on DFO winter (1987-2010) and summer (1970-2010) survey data. Despite high variability, the DWAO index for the Southern DU decreased gradually over time but appeared to be stable since 2001 (Figure 4). Currently, cod occupy an area of 10,000 nm^2 (35,000 km^2) in 4X5Yb and 3,000 nm^2 (10,500 km^2) in 5Zjm. The highest catches (biomass) occurred most frequently in stratum 5Z2 for the Georges Bank population, and 4Xp for the Scotian Shelf and Bay of Fundy populations.

Despite decreases in the DWAO, the range and overall distribution of cod within the Southern DU had not changed since the 1970s (Figures 5 and 8). Survey catches continued to span all strata and the 2010 data showed a similar distribution to that of previous years (Figures 5E-F and 8D). The only notable increase in survey catches occurred in the southern half of the Canadian 5Zjm stock (5Z1, 5Z2), between the 1995-2002 (Figure 8B) and the 2003-2010 (Figure 8C) periods, when catch numbers more than doubled in size.

Population Structure

The structure of cod populations in the Southern DU is complex, involving seasonal migration patterns and mixing grounds, with some exchange between putative stocks. Although several localized populations may exist, evidence suggests three main concentrations of cod within this DU: Southern Scotian Shelf; Bay of Fundy/Gulf of Maine; and Eastern Georges Bank (Hunt et al. 2002; Clark and Perley 2006; Wang et al. 2009a). Tagging has shown some directional mixing between 4X5Yb and 5Zjm (Clark and Emberley 2009), though current agreements for cod stock management between Canada and the United States assume no significant exchange between Georges Bank and 4X5Yb (Wang et al. 2009a). Generally, cod tagged in the Bay of Fundy and those tagged in eastern 4X5Yb exhibit little mixing except for those found near the boundary between the two areas (Clark and Emberley 2009). Given these factors, precise delimitation of populations within the Southern DU is challenging, but there is no evidence of a decrease in the number of populations.

Spawning is distributed broadly throughout the Southern DU, both geographically and seasonally. Spring spawning tends to be spread out throughout the DU, with some concentration on Browns Bank and Eastern Georges Bank; fall spawning (October to

December) tends to occur along the coast of Nova Scotia (Clark and Emberley 2009). Fishermen have also identified the waters off Digby Neck and Grand Manan as areas where they encounter spawning fish in the spring.

LIFE-HISTORY PARAMETERS

ToR 3. Estimate, to the extent that information allows, the current or recent life-history parameters for Atlantic Cod (total mortality, natural mortality, fecundity, maturity, recruitment, etc.) or reasonable surrogates; and associated uncertainties for all parameters.

Life-history parameters for Atlantic Cod in each of the management units and for the Southern DU as a whole are documented below. It should be noted that combining components of the Southern DU stocks for DU-level management purposes may overshadow individual component trends. As these stocks sometimes exhibit differing trends, management decisions may not have the expected effect on all involved stocks.

Natural Mortality (M)

4X5Yb

At the Zonal Advisory Process for Atlantic Cod held February 24-March 6, 2009, a series of model formulations were explored for 4X5Yb cod that incorporated a change in natural mortality. Since there was no indication from survey data that total mortality (Z) had increased on young cod, M was estimated only for ages 4 to 11. In the accepted formulation, M was fixed at 0.2 for 1983-1995 and estimated as 0.76 in a single block for 1996 to 2008 for ages 4 to 11 (Clark and Emberley 2009).

5Zjm

The “split M 0.5” model for 5Zjm cod assumed a change in survey catchability between 1993 and 1994, a constant M=0.2 for all years prior to 1994 and for ages 1 to 5 from 1994 onwards, and an elevated constant M=0.5 for ages 6 and above from 1994 to the present (Wang et al. 2009b). At the TRAC Eastern Georges Bank Cod Benchmark Meeting held in 2009 it was noted that the survey indices showed an increase in the number of fish of age 4 to 6 in recent years, but no increase for the older fish, despite a substantial decrease in the catch for ages 4 to 6 since 1994 (Wang et al. 2009a). In addition, the calculated total mortality rate, Z, from survey and catch data remained high after 1994 suggesting that natural mortality might have increased in recent years. The starting year for an increase in natural mortality for the “split M 0.5” model was selected as 1994, the date when new management measures were introduced and stock abundance was low (Wang et al. 2009a).

Total Mortality (Z)

4X5Yb

The calculation of Z (fishing mortality plus natural mortality) for 4X5Yb cod is shown in Figure 10. The rapid decrease in fishing mortality in the mid-1990s was offset by the high estimate of M for ages 4+. As a result, there is no indication of a decline in total mortality.

5Zjm

The calculation of Z for 5Zjm cod is shown in Figure 11. Similar to Division 4X5Yb cod, there was a rapid decline in F in the mid-1990s. However, since M was not estimated to be as high for 5Zjm cod as it was for Division 4X5Yb cod, the estimates of total mortality showed a decrease after 1994.

Southern DU

The larger 4X5Yb component had a strong effect on the calculation of Z for the Southern DU. The estimates of Z did not show a decline over the last three decades and remained high after the 1990s, despite the decrease in F (Figure 12).

Maturity and Generation Time

Southern DU

The average age at 50% maturity for stocks in this DU is about 2.5 years (Trippel et al. 1997; Hunt and Hatt 2002). With no fishing influence, generation time for the stocks was estimated to be 7.5 years, yielding a three-generation time period of 22.5 years (COSEWIC 2010).

Growth, Weight-at-Age and Condition

4X5Yb

There are growth differences between cod from the Bay of Fundy (4X West: Divisions 4Xqrs5Yb) and the Southwest Scotian Shelf (4X East: Divisions 4Xmno) with cod in the Bay of Fundy growing at a faster rate (Clark and Emberley 2009). For younger ages (less than 6) there were no strong trends in weights-at-age for commercial landings from both the Bay of Fundy and the Southwestern Scotian Shelf (Figure 13). Given the very low numbers in the catch of ages 6 and above, the weights-at-age of these older fish were likely not reliable. Lengths-at-age for 4X5Yb cod from the DFO research survey were stable for both Eastern and Western regions of Division 4X5Yb (Figure 14). Again, the very low numbers of fish for some ages resulted in high inter-annual variability for older ages.

There was no trend in condition for cod in 4X West, but the condition factor declined for cod in 4X East (Figure 15).

5Zjm

In 5Zjm fishery weights-at-age showed a declining trend for ages 5+ starting in the early-1990s (Figure 16, left panel). The average beginning of year weights-at-age derived from the DFO surveys and U.S. NMFS spring surveys also displayed a declining trend since the early-1990s, but there was some improvement in 2010 for some ages (Figure 16, right panel).

Cod condition, derived from the DFO survey and measured as average weight-at-length at three representative length groupings, showed no notable trend (Figure 17).

Recruitment

4X5Yb

Recruitment above fifteen million was common for 4X5Yb cod in the 1980s although, since the 1992 year-class, no recruitment has approached this level. Recruitment for the 2006 (3.6 million) and 2007 (5.0 million) year-classes was below the long term average but about twice the abundance of the very low 2002 and 2004 year-classes (Figure 18). Recruitment has generally been higher when ages 3+ biomass have exceeded 25,000t (Clark and Emberley 2009). In recent years, with biomass less than this value, recruitment has been poor (Figure 19).

5Zjm

Recruitment for 5Zjm cod has been poor (≤ 5 million fish) since the early-1990s (Figure 20). Recruitment at Age 1 of the 2003 year class (5 million from the “split M 0.5” model) was the highest since the 1990 year-class, but was still lower than the pre-1990 average (10 million). The 2002 and 2004 year-classes were the lowest on record (Clark et al. 2010; TRAC 2010).

Recruitment has generally been higher when ages 3+ biomass exceeded 30,000t. The number of recruits per spawner has not increased in recent years when the biomass has been low (TRAC 2010). The current biomass is well below 30,000t, and when recruitment is plotted against 3+ biomass, all the data points since 1994 are clustered to the left of the graph (Figure 21).

Southern DU

Average recruitment in the Southern DU stocks has decreased to less than half of its pre-1992 level. However, amidst unprecedented historic lows (i.e. 2002, 2004 year-classes), periodically occurring stronger year-classes (1996, 1998 and 2003) have come close to pre-1992 recruitment levels (Figure 22). The most recent year-classes estimated (2006 and 2007) are below the long term average but are about twice as abundant as the 2002 and 2004 year-classes.

HABITAT REQUIREMENTS AND SUITABILITY

ToR 5. Evaluate residence requirements for the species, if any.

Pursuant to SARA, Threatened and Endangered species residences are protected. In section 2(1), the *Act* defines residence as “a dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating” (Bill C-5 2002).

As with cusk (*Brosme brosme*) (DFO 2008), cod do not have any known dwelling-place similar to a den or nest during any part of their life-cycle; hence, the concept of “residence” does not apply (DFO 2011a).

ToR 7. Provide functional descriptions (as defined in DFO 2007) of the properties of the aquatic habitat that Atlantic Cod needs for successful completion of all life-history stages.

In the early pelagic life stages, cod exist as eggs or larvae in the upper 10 to 50 m of the ocean. During these stages, habitat suitability is likely determined primarily by food availability, oceanographic features and water temperature. Oceanographic features can retain cod eggs and larvae, concentrate potential prey and prevent larval cod dispersion into waters poorly suited for their survival (Bradbury et al. 2000, 2001, 2008). Water temperature may be important, as low temperatures increase developmental time and prolong the period of high vulnerability to predation and advection for small cod (Bradbury et al. 2001).

For the first 1 to 4 years of their life, cod juveniles settle to the bottom and substrate composition likely becomes the most important factor in habitat suitability. Physical habitat associations, therefore, appear to be the strongest at the demersal juvenile stage (4 to 35 cm long) (DFO 2011a). Evidence suggests that juvenile cod prefer a heterogeneous benthic habitat consisting of vertical structures, as these structures reduce the risk of predation and allow for increased growth (Gotceitas et al. 1995, 1997; Tupper and Boutilier 1995; Gregory and Anderson 1997; Laurel et al. 2003a, 2003b, 2004). Eelgrass (*Zostera marina*) is thought to provide the necessary habitat heterogeneity in near-shore waters, while macroalgae, cobble, coral and other emergent structures may become important in deeper waters (Keats 1990; Gotceitas et al. 1995; Tupper and Boutilier 1995; Lindholm et al. 2007). In addition to ensuring protection from predators, physically diverse habitat is more likely to harbour small fish, invertebrates and other cod prey. This vertically heterogeneous habitat, composed of plants, cobble, rocks and corals, may be a limiting habitat for Atlantic Cod.

With age, habitat requirements for adult cod become increasingly diverse. Since preferences of older fish for either depth or substrate composition are unclear, distribution of mature cod is probably determined primarily by temperature and food availability. Similarly, specific spawning habitat preferences for cod in the Southern DU are also unknown, as spawning occurs in waters ranging from tens to hundreds of metres in depth. In this DU, spawning is distributed broadly, both geographically and seasonally. Spring spawning tends to be spread throughout the DU, with some concentration on Browns Bank and Eastern Georges Bank; fall spawning (October to December) tends to occur along the coast of Nova Scotia.

ToR 8. Provide information on the spatial extent of the areas in Atlantic Cod's range that are likely to have these habitat properties.

Cod are distributed throughout the Southern DU, with some concentration along the southern Scotian Shelf, Bay of Fundy and northeastern Georges Bank. Both the northeastern edge of Georges Bank and Browns Bank have been shown to consist of coarse, three-dimensional structures that are considered important cod habitat (Kostylev et al. 2001, 2005). Very little information is currently available at the appropriate spatial resolution to identify the extent of the habitat available to demersal juvenile cod (DFO 2011a). However, there is no indication that the amount of suitable habitat is currently limiting the recovery of cod in the Southern DU.

ToR 9. Identify the activities most likely to threaten the habitat properties that give the sites their value, and provide information on the extent and consequences of these activities.

Any activity which significantly modifies bottom composition (increases sedimentation, changes water currents or physical alters structures) may decrease the value of cod habitat. It is possible that the repeated use of mobile bottom-contact fishing gears in a given area may reduce the physical heterogeneity of the habitat, by flattening or breaking outstanding vertical structures (Collie et al. 1997, 2000). Mobile bottom-contact fishing gears have impacts on benthic populations, communities and habitats. These effects are not uniform, but depend on a variety of factors including: the specific features of the seafloor habitats; the species present; the type of gear used; the methods and timing of deployment of the gear; and the frequency with which a site is impacted by specific gears (DFO 2006a). The severity of any impact by other fishing gears, including those that do not contact the bottom, will depend on the nature of the impact, the location and scale of the fishery, and how the gear is rigged, deployed and retrieved (DFO 2010a).

ToR 16. Provide advice on the extent to which various threats can alter the quality and/or quantity of habitat that is available.

In addition to intensive use of trawling gear in a single area, as identified under term of reference 9, the presence of the European green crab (*Carcinus maenas*) can reduce critical habitat availability for juvenile cod. The highly invasive green crab has a known negative effect on eelgrass beds (Davis et al. 1998). Given the crab's presence and expansion along the Canadian east coast, a reduction of critical juvenile cod habitat in 4X5Yb is possible, leading to decreased juvenile survival (COSEWIC 2010). Reduction of human activities that aid in the crab's introduction and colonization could help limit critical habitat destruction.

SARA AND MANAGEMENT CONSIDERATIONS

Limit Reference Points

ToR 4. Estimate expected population and distribution targets for recovery, according to DFO guidelines (DFO 2005) and based on the limit reference points developed under the Precautionary Approach Framework.

The conservation limit reference point (LRP) is the SSB below which the stock is considered to have suffered serious harm and the probability of good recruitment is low. At the 2002 National Workshop for Reference Points for Gadoids (DFO 2002) five computational methods were retained for defining reference points in terms of spawning stock biomass. These methods were considered at the Atlantic Cod Framework Meeting on Assessment Models, Medium-term Projections, Reference Points held in Moncton, December 6 to 8 2010. At this meeting the methodology for calculating spawning stock biomass limit (B_{lim}) reference points for Atlantic Cod in the DFO Gulf and DFO Maritimes Regions was agreed upon and reference points were defined (Clark et al. 2011).

The Precautionary Approach (PA) reference point, B_{lim}, was calculated as 24,000t for cod in Division 4X5Yb and 21,000t for Division 5Zjm based on Beverton-Holt stock-recruitment models (Clark et al. 2011).

Projections

ToR 5. Project expected Atlantic Cod population trajectories over 36 years, which represents at least three generations for all populations, and trajectories over time to the recovery target (if possible to achieve), given current Atlantic Cod population dynamics parameters and associated uncertainties using DFO guidelines on long-term projections (Shelton et al. 2007).

ToR 21. Assess the probability that the recovery targets can be achieved under current rates of Atlantic Cod population dynamics parameters, and how that probability would vary with different mortality (especially lower) parameters.

Spawning Stock Biomass Projections

Spawning stock biomass for each of the components of the Southern DU (4X5Yb and 5Zjm) were projected forward over 36 years, a length of time which represents more than five generations for this DU. Long term projections and associated uncertainties are highly sensitive to the recruitment input data. For both 4X5Yb cod and 5Zjm cod, natural mortality has been high since the mid-1990s and biomass has been low. Recruitment data for the recent time period (1994 to 2009 for 5Zjm cod; 1996 to 2008 for 4X5Yb cod) is, therefore, restricted by the narrow range in biomass (Figures 19 and 21). Thus, longer term stock-recruitment information was used (1980 to the present for 5X5Yb and 1978 for 5Zjm).

4X5Yb

For the stock recruitment relationship Beverton-Holt models were fit, one to the SSB and recruitment data for the 1980 to 2008 year-classes, and one restricted to the more recent 1996 to 2008 year-classes (those years for which natural mortality is high) (Figure 23). There was some overlap between SSB values for 1996 to 2008 and pre-1996. The stock-recruit curve derived with recent data was poorly determined, highly influenced by individual points, and also by model form. The last three years of recruitment (2006 to 2008) closely matched the predicted values from the long-term data fit, and were well above the predicted values from the short-term stock recruit curve. For this reason, and for consistency with the 5Zjm portion of the DU, the stock-recruit data used to derive recruitment values for projections were the 1980 to 2008 data (Figure 23).

There have been no strong trends in weights-at-age for 4X5Yb cod over the 1980 to 2009 period (Figure 13). The DFO survey in 4X5Yb catches relatively low numbers of cod, so the average weights and standard error for the 1996 to 2008 period were used for the projections. For ages 9 to 12, all observations for 1980 to 2008 were used, as total numbers for each age over this period were less than 10 between 1996 and 2008.

Using the stock recruitment model based on the long term data (1980 to 2008) year-classes, the 36 year projection for the 4X5Yb component indicated that this component will likely increase to a level above the PA LRP of 24,000t (Figure 24). Three scenarios with different fishing mortalities were explored: F=0, F0.1=0.2 and F=0.1. Cod quotas in 4X5Yb have been low in recent years (3,000t in 2008 to 2010 and 1,650t in 2011). With such small catches, it is not practical or useful to conduct projections for a larger range of fishing mortalities. With no fishing, the median for the projection of 3+ biomass of 4X5Yb cod is expected to reach the LRP of 24,000t around 2014 (2.5th percentile 2011, 97.5th percentile 2020; Figure 24 top left panel). With fishing at the reference level for this stock (Fref=0.2), the biomass of 4X5Yb cod is also expected to increase but at a slower rate, and the median is expected to reach the LRP around 2025 (2.5th percentile 2011, 97.5th percentile >2050; Figure 24, top right panel). With fishing at half of Fref (F=0.1), the biomass of 4X5Yb cod is expected to increase at a rate between F=0 and F=0.2 and the median is expected to reach the LRP around 2016 (2.5th percentile 2011, 97.5th percentile 2033; Figure 24, bottom left panel).

The probability that SSB is less than the LRP is shown in the lower right panel of Figure 24. With no fishing (F=0), there is a greater than 95% probability of SSB being at or above the LRP of 24,000t by 2020 (50% probability of it occurring by 2013). The probability of SSB being at or above the LRP within 36 years when fishing at the reference level of 0.2 is 72%, with 50% probability of it occurring by 2025. For fishing at half the current fishing mortality reference level (F=0.1), there is a greater than 95% probability of SSB being at or above the LRP by 2033 (50% probability of it occurring by 2016).

5Zjm

For the stock recruitment relationship Beverton-Holt models were fit, one to the SSB and recruitment data for the 1978 to 2008 year-classes and one restricted to the more recent 1994 to 2008 year-classes. Prior to 1994, 5Zjm cod SSB ranged from 21,500t to 60,500t, but since then has consistently remained below 13,000t (Clark et al. 2010). Within this narrow range of low SSB, there is no relationship between SSB and recruitment (Figure 25). Thus, if only recent years of data are used to determine recruitment levels for projections, a constant low recruitment value would be applied. However, given the historic data, it seems overly-pessimistic and unrealistic to assume that if SSB were to increase, recruitment would continue to remain at the current low level. Based on the historic information for this component of the Southern DU, a longer term stock-recruitment curve was derived using the data from 1978 to 2008 (Figure 25).

There has been a decline in weight-at-age for 5Zjm cod over the recent 1994 to 2010 time period (Figure 16). For the projections, a year from the 1994 to 2008 period was randomly selected for weights-at-age.

Using the Stock Recruitment model based on 1978 to 2008 year-classes, the 36 year projection for the 5Zjm component indicated that this component will likely recover to a level above the PA LRP of 21,000t. Three scenarios with different fishing mortalities were explored: F=0, F=0.18 (the current Fref for Eastern Georges Bank cod) and F=0.09 (half of Fref). Cod quotas on

Eastern Georges Bank are low and are currently set close to Fref, ranging from 1,050t to 1,700t between 2009 and 2011. With such small catches, it was considered not practical or useful to conduct projections for a larger range of fishing mortalities. With no fishing, the median for the projection of 3+ biomass of 5Zjm cod is expected to reach the LRP of 21,000t around 2017 (2.5th percentile in 2013, 97.5th percentile in 2028) (Figure 26, top left panel). With fishing at the reference level for this stock (F=0.18), the biomass of 5Zjm cod also increases, but at a much slower rate, and the median is projected to reach the LRP around 2027 (2.5th percentile in 2015, 97.5th percentile >2050) (Figure 26, top right panel). With fishing at half Fref (F=0.09), the biomass of 5Zjm cod increases at a rate between F=0 and F=0.18, and the median is projected to reach the LRP around 2019 (2.5th percentile in 2013, 97.5th percentile in 2033) (Figure 26, bottom left panel).

The probability that SSB is less than the PA LRP is shown in the lower right panel of Figure 26. With no fishing, there is a greater than 95% probability of SSB being at or above the LRP by 2028. Fishing at half the current reference level, there is a greater than 95% probability of SSB being at or above the LRP by 2033 and the probability of SSB being at or above the LRP within 36 years when fishing is at the reference level of 0.18 is 82%.

ToR 25. Project expected population trajectory (and uncertainties) over 36 years, which represents at least three generations for all stocks, and to the time of reaching recovery targets when recovery is feasible; given mortality rates associated with specific scenarios identified for exploration. Include scenarios which provide as high a probability of survivorship and recovery as possible for biologically realistic parameter values.

Population Projections

Southern DU

Using a Stock Recruitment model based on the long term data (1980 to 2008) year-classes and assuming the persistence of current productivity conditions, projections done under a ‘no fishing’ condition (F=0) indicated that the combined mature abundance of 4X5Yb and 5Zjm cod is expected to increase over the next 36 years. The first year of the projections in which the spawning stock number (SSN) will exceed the SSN from 36 years earlier is 2027 (Figure 27).

With projections done under fishing at Fref conditions, the mature abundance of the 4X5Yb and the 5Zjm stocks is also expected to increase over the next 36 years, but at a slower rate. The first year of the projections in which the spawning stock number (SSN) will exceed the SSN from 36 years earlier is 2034 (Figure 28).

THREATS TO SURVIVAL AND RECOVERY

ToR 18. Quantify to the extent possible the magnitude of each major potential source of mortality identified in the pre-COSEWIC assessment, the COSEWIC Status Report, information from DFO sectors, and other sources.

A summary of potential sources of mortality is provided in Table 5. Directed fishing and bycatch were rated as medium risk, whilst natural mortality was rated as high risk for both 4X5Yb and 5Zjm cod. Increased seal abundance was rated as a medium risk for 4X5Yb cod.

Directed Fishing

4X5Yb

Cod in Division 4X5Yb are caught along with haddock, pollock, winter flounder, redfish, and other species in a mixed species fishery. In the past, cod was the main species caught by the hook and line fleet in the region. Cod has not been the primary focus of any fleet in the past fifteen years, but it is still caught in all fisheries targeting groundfish in Division 4X5Yb (Worcester et al. 2009).

In the 1960s, landings of Division 4X5Yb cod increased as domestic and foreign otter trawl fleets joined the fishery and then dropped in 1970 as effort declined due to restrictions on haddock fishing (Table 6; Figure 29). Landings averaged over 20,000t for several decades. Recent landings reflect the restrictive Total Allowable Catch (TAC). The TAC dropped to 6,000t in 2000, then to 5,000t in 2005 and 3,000t in 2009. In 2009, 3,166t of cod were landed in Division 4X5Yb.

The annual fishing mortality rate is shown in Table 7 and Figure 30. F has been variable, but high throughout the period examined. F increased rapidly to peak above 1.0 in 1992, and declined subsequently. F has remained above the target of 0.2 since 1948, and remained above that level at 0.3 in 2008.

5Zjm Cod

Combined Canada/United States catches averaged 17,508t between 1978 and 1992. Catches peaked at 26,463t in 1982, and then declined to 1,684t in 1995. They fluctuated around 3,000t until 2004 and subsequently declined again. Catches in 2009 were 1,858t, including 425t of discards (Table 8; Figure 31). Catches include Canadian and United States discards in all years where discard estimates were available.

Fishing mortality (population weighted average) for ages 4-9 was calculated using the “split M 0.5” model. F was higher prior to 1994 (Table 9; Figure 32) and declined in 1995 to 0.24 due to restrictive management measures. F in 2009 was estimated to be 0.20 from the “split M 0.5” model. Recent reductions in F are evident, but fishing mortality has consistently been above the reference level (Fref) of 0.18 (Table 9; Figure 32).

Southern DU

When the catches from Divisions 4X5Yb and 5Zjm are combined (Figure 33) the same trends that are seen in each of the components are evident. Catches show a dramatic decline in the early-1990s due to more restrictive management measures instituted as a result of the decline in biomass. Since the 1990s catches have been consistently lower.

Discards and Bycatch

4X5Yb

Cod in Division 4X5Yb are harvested as part of a mixed species groundfish fishery, and are not necessarily caught in proportion to their relative abundance (DFO 2006b, 2009). This may cause an imbalance in quotas which creates potential for discarding (DFO 2006b). Until the 2010/2011 fiscal year, observer coverage of the groundfish fleets in 4X5Yb has generally been below 1%, which is too low for any meaningful calculations of bycatch or discarding since experience with the 5Zjm groundfish fishery suggests that 10% observer coverage may not always be sufficient for detecting potential discarding (DFO 2003; Clark 2005). Additional observer coverage of the groundfish fishery in 4X5Yb was funded between April 1, 2010, and March 31, 2011, by the Species at Risk Coordination/ Espèces en Péril Committee (SARCEP). The analyses for this project are not yet complete; thus, no discard estimates are available.

Additional observer coverage of the Bay of Fundy scallop fishery and the inshore lobster fishery was provided as part of the same SARCEP funded project. The data are currently being analyzed, although results are not yet available on the bycatch of cod in these fisheries.

5Zjm

As with cod in 4X5Yb, cod in 5Zjm are harvested as part of a mixed species groundfish fishery. Lower cod quotas and higher haddock quotas of recent years may have led to discarding of cod by the groundfish fleets. Due to the international nature of the Eastern Georges Bank cod fishery, observer coverage is higher than in 4X5Yb. Discards of cod from the Eastern Georges Bank groundfish and scallop fisheries can, therefore, be calculated and are routinely included in the 5Zjm cod assessment by Canada and the United States (Clark et al. 2008, 2010; Wang et al. 2009b). Discards from the Canadian groundfish fishery have been estimated for 1997 to 1999 (Van Eeckhaute and Gavaris 2004) and for 2005 to 2010 (Clark et al. 2008, 2010; Gavaris et al. 2006, 2007a; Wang et al. 2009b) (Table 8). Discards by United States groundfish fleets are permitted because of trip and size limits. Estimates for discards by the United States groundfish and scallop fleets combined have been estimated for 1989 to the present, ranging range from 0t to 341t. (Clark et al. 2010; Wang et al. 2009b) (Table 8).

Since 1996, the Canadian scallop fishery on Eastern Georges Bank has not been permitted to land cod. Until 1995, total cod landings in the 5Zjm cod assessment included those catches reported by the scallop fishery. Discards of cod by the Canadian scallop fishery on Eastern Georges Bank have been estimated since 1978 and the estimates have ranged from 36t to 200t annually (Gavaris et al. 2007b; Van Eeckhaute et al. 2005, 2010) (Table 8).

Southern DU

Gavaris et al. (2010) used commercial landings and observer information to characterize the discards from Canadian commercial fisheries conducted in 4X5Yb and 5Zjm during 2002 to 2006. Although levels of at-sea observer coverage for the principal fisheries were generally too low and intermittent to give confidence in the reliability of discard estimates, the results were used to identify gaps in monitoring and to provide the basis for a triage on potential conservation concerns associated with higher discard amounts (Gavaris et al. 2010). While particular estimates from this broad scale analysis were in no way definitive, they did identify fisheries in which individual species were caught as bycatch. Aside from the groundfish fisheries, cod in 4X5Yb and 5Zjm were caught in the offshore lobster and jonah crab trap fishery and offshore scallop dredge fisheries. Furthermore, cod in 4X5Yb were also caught in the redfish small mesh fishery, the inshore scallop dredge fishery, herring purse seine and an experimental sculpin bottom trawl fishery. The estimated amounts of bycatch are in Table 10, but it should be noted that, except for the experimental sculpin fishery and the redfish fishery in 2002, observer coverage was 8% or much lower.

Natural Mortality

Historically, a value of 0.2 has been used as an estimate of natural mortality at all ages for cod in both Divisions 4X5Yb and 5Zjm (Clark and Perley 2006; Clark et al. 2008; Wang et al. 2009a).

4X5Yb

Despite low landings in recent years, the total mortality estimate, Z, from the research vessel survey remains high in the eastern portion of 4X and has been increasing in the western portion (Clark and Emberley 2009) (Figure 34). The continued high Z, despite a drop in relative F, suggested that there was additional mortality that had not been accounted for in the reported landings. However, total mortality, estimated from DFO survey data, showed no trend for young cod in 4X over the time series (Figure 35). If mortality from sources other than reported landings had increased for older cod, it did not appear to have increased on young cod. Mortality also remained high for both the eastern and western regions as estimated from the ITQ survey (Figure 36).

At the 2009 Zonal Advisory Process for Atlantic Cod, a series of modeled formulations were explored that incorporated changes in natural mortality. The adaptive framework (ADAPT) (Gavaris 1988) was used to estimate M in blocks of years, but since there was no indication from survey data that Z had increased on young cod, M was estimated only for ages 4 to 11 (Clark and Emberley 2009). The accepted model formulation showed that mortality for causes other than reported landings, including natural mortality, for cod ages 4 and older increased in 1996 and is currently 0.76 (DFO 2009).

5Zjm

The VPA model formulation used for the projections in this Recovery Potential Assessment assumes a change in survey catchability between 1993 and 1994, a constant M=0.2 for all years prior to 1994 and for ages 1 to 5 from 1994 onwards, and an elevated constant M=0.5 for ages 6 and above from 1994 to the present. At the 2009 benchmark meeting it was noted that the survey indices showed an increase in the number of fish of ages 4-6 in recent years, but no increase for the older fish, despite a substantial decrease in the catch for ages 4-6 since 1994. In addition, the calculated total mortality rate, Z, from survey and catch data remained high after 1994 suggesting that natural mortality might have increased in recent years (Figure 37). The starting year for an increase in natural mortality for the “split M 0.5” model was selected as 1994, the date when new management measures were introduced and stock abundance was low (Wang et al. 2009a).

Seal Predation

Southern DU

An increase in seal populations may contribute to the higher values of natural mortality in Division 4X5Yb. Grey seal abundance has increased in recent decades on Sable Island, and much of 4X is in their foraging range (Clark and Emberley 2009). Grey seal colonies have been established in the area of 4X5Yb in recent years and the abundance of harbour and grey seals have all increased in the 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 (Clark and Emberley 2009). However, the degree to which seals contribute to the natural mortality of cod in 4X5Yb or 5Zjm has yet to be quantified. A Zonal Advisory Process held October 4-8, 2010, on Impacts of Grey Seals on Fish Populations in Eastern Canada, concluded that information currently was not available to determine mortality inflicted by grey seals on cod in 4X (DFO 2011b).

Other Sources of Mortality

COSEWIC’s Assessment and Update Status Report on the Atlantic Cod (*Gadus morhua*) in Canada (COSEWIC 2010) included fishing-induced natural changes to the ecosystem and habitat alteration as potential threats. The impact of these threats on productivity of cod in the Southern DU is unknown.

MEASURES FOR PROMOTING RECOVERY

Mitigation and Alternatives to Activities

ToR 21. Using input from all DFO sectors and other sources as appropriate, develop an inventory of all feasible measures to minimize/mitigate the impacts of activities that are threats to the species and its habitat.

ToR 22. Using input from all DFO sectors and other sources as appropriate, develop an inventory of all reasonable alternatives to the activities that are threats to the species and its habitat.

The major potential sources of mortality identified for Southern DU cod were natural mortality (including seal predation), directed fishing, discards and bycatch. A table of potential management options and mitigation measures was provided by DFO Fisheries Management, National Capital Region (Table 11). Comments are provided on these measures below, where there is additional information specific to the Southern DU.

Directed Fishing

The PA LRP were determined for the two components of the Southern DU at the Atlantic Cod Framework Meeting on Assessment Models, Medium-term Projections, Reference Points held on December 6-8, 2010, in Moncton, New Brunswick (Clark et al. 2011). Both components of the Southern DU are below their LRP and are, therefore, in the critical zone, according to the PA (DFO 2006c).

Due to the transboundary nature of 5Zjm cod, Canada is required to account for all fishing mortality of Georges Bank cod, and aims to reduce cod bycatch in the offshore scallop fishery (DFO 2010b). In order to reduce bycatch and to minimize disturbance to spawning aggregations of cod by the offshore scallop fishery on Georges Bank, since 2005 DFO has implemented area/time closures from early February to the end of March. Cod abundance data from the annual DFO winter RV survey and scallop catches are used to identify areas of high aggregations of adult (3+) cod. The distribution of age 3+ cod is plotted as the average number of cod per tow in cells of 5-minute longitude by 3.33-minute latitude. Cells are then ranked in terms of decreasing cod abundance, and this ranking is compared to historical data (DFO 2010b). A decision is then made by DFO Fisheries and Aquaculture Management to close a specific number of cells to scallop fishing in February through March.

Since the 1970s, there has been a seasonal closure on groundfish fishing on Browns Bank in Division 4X5Yb from February 1 to June 1 (Clark and Emberley 2009). Similarly, Georges Bank fishing has been restricted from March through May on spawning grounds since the early-1970s (Wang et al. 2009a). Between 1995 and 2004, fishing by the Canadian groundfish fishery on Georges Bank was not permitted from January 1 to May 30. In 2005, increasing haddock abundance led to permission to conduct an exploratory Canadian groundfish fishery in January and February that has continued since that time. So as not to adversely affect spawning cod, the exploratory winter fishery is closed around the beginning of the second week in February when it is determined that cod are actively spawning (i.e., when 30% of cod are in the spawning or post-spawning stages) (Van Eeckhaute et al. 2009; Wang et al. 2009a).

Discards and Bycatch

Cod in Division 4X5Yb and Division 5Zjm are harvested as part of mixed species groundfish fisheries. They are not necessarily caught in proportion to their relative abundance (DFO 2006b, 2009). This may cause an imbalance in quotas which creates potential for discarding (DFO 2006b).

The use of a separator panel is now mandatory for members of the Canadian mobile gear fleet fishing on Georges Bank. This separator panel reduces the catch of cod whilst fishing for other species. On the United States side of the bank, the Ruhle Trawl has been authorized for use by American bottom trawlers as of 2009 (Clark et al. 2010).

Until the 2010/2011 fiscal year, observer coverage of the groundfish fleets in 4X5Yb has generally been below 1%; too low for any meaningful calculations of bycatch or discarding (Clark 2005; DFO 2003). When the data are analyzed, the additional observer coverage of the groundfish fishery in 4X5Yb funded by SARCEP between April, 2010, and March, 2011, will provide updated estimates of bycatch. Data from increased observer coverage of the Bay of Fundy scallop fishery and the inshore lobster fishery, also funded through SARCEP, will also provide estimates of the bycatch of cod in these fisheries.

Due to the international nature of the 5Zjm cod fishery, observer coverage is higher in this division than in 4X5Yb. Discards and bycatch of cod from the Eastern Georges Bank groundfish and scallop fisheries can therefore be calculated, and are routinely included in the 5Zjm cod assessment by Canada and the United States (Clark et al. 2010; Wang et al. 2009b).

Natural Mortality

No mitigation measures can be proposed until the cause of high natural mortality in the Southern DU is identified. More research is required.

Seal Predation

An increase in seal populations may contribute to the higher values of natural mortality in Division 4X5Yb and Division 5Zjm. However, the degree to which seals contribute to the natural mortality of cod in the Southern DU has yet to be quantified.

Activities that Could Increase Survivorship

ToR 23. Using input from all DFO sectors and other sources as appropriate, develop an inventory of activities that could increase the survivorship parameters.

ToR 24. Estimate, to the extent possible, the reduction in mortality rate expected by each of the mitigation measures in term of reference 21 or alternatives in term of reference 22 and the increase in survivorship associated with each measure in term of reference 23.

Reductions in directed fishing and bycatch mortality are the only identified mitigation measures that could increase survivorship. Whilst natural mortality is higher on older fish than fishing mortality, there is no identified mechanism for reducing M. The degree to which seal predation contributes to the elevated natural mortality on older ages is unknown; thus, the impact on M from a reduction in seal populations cannot be estimated.

ToR 26. Recommend parameter values for starting mortality rates, and where necessary, specialized features of population models that would be required to allow exploration of additional scenarios as part of the assessment of economic, social, and cultural impacts of listing the species.

The starting parameter values and population model setup for the Division 4X5Yb and Division 5Zjm Atlantic Cod assessments are documented in Canadian Science Advisory Secretariat Research Documents and Science Advisory Reports, as well as, Transboundary Resources

Assessment Committee Research Documents and Status Reports (Clark and Emberley 2009; Clark et al. 2010; DFO 2009; TRAC 2010; Wang et al. 2009a, Wang et al. 2009b).

ALLOWABLE HARM ASSESSMENT

ToR 27. Evaluate maximum human-induced mortality which the species can sustain and not jeopardize survival or recovery of the species.

According to the projections discussed in the 'SARA and Management Considerations' section of this document, cod in the Southern DU will increase in abundance in the absence of fishing and have a high probability of increasing at moderate fishing levels (i.e., Fref). Allowable Harm assessment indicators for individual stocks and the combined DU are summarized in Table 12.

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TABLES

Table 1. Population abundance (number in thousands) for cod in NAFO Division 4X5Yb from a virtual population analysis using the bootstrap bias adjusted population abundance.

Year	Age												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**3+**
1948	17634	13438	9046	8923	7152	1769	1050	1155	1202	667	193	223	31380
1949	24729	14438	10969	6680	5850	4382	843	616	619	658	309	67	30993
1950	12596	20247	11379	7652	4182	3953	2771	630	410	372	393	206	31948
1951	16001	10313	15981	7563	3339	2133	2541	1611	479	290	222	310	34469
1952	8731	13100	8177	10720	4487	1424	1296	1659	1070	319	214	87	29453
1953	18373	7148	10037	5555	6148	2606	668	737	1205	648	234	156	27994
1954	9111	15043	5744	7442	3896	3769	1728	347	537	829	334	126	24752
1955	14051	7459	12081	4268	4275	2372	2142	1093	160	324	557	192	27464
1956	16483	11500	6058	8739	2899	2391	1474	1230	724	79	234	401	24229
1957	18045	13495	9321	4399	5004	1716	1432	754	587	488	30	122	23853
1958	15943	14774	11049	7440	3273	2803	1194	634	360	177	143	24	27097
1959	23689	13053	11951	8296	4960	2153	1573	902	369	161	61	96	30522
1960	28830	19395	10687	9491	5008	2514	788	913	373	224	132	28	30158
1961	18704	23604	15879	8749	7522	3231	1337	401	447	131	87	63	37847
1962	22468	15314	19316	12762	6794	4416	1836	807	241	295	70	55	46592
1963	33084	18395	12536	15100	8596	3117	2553	1043	448	124	192	52	43761
1964	42404	27087	15060	9906	10586	5620	1581	1260	584	169	67	120	44953
1965	20672	34717	22177	12234	7433	5881	2323	536	350	137	69	31	51171
1966	16288	16925	28395	16806	7700	3487	2850	1273	197	217	76	36	61037
1967	16246	13335	13844	21526	9537	3290	1292	1341	722	122	119	38	51831
1968	14238	13301	10903	9891	11950	4505	1556	628	749	463	67	56	40768
1969	20439	11657	10880	7405	5785	4304	1417	862	343	393	326	19	31734
1970	19682	16734	9132	6610	4224	2699	1726	628	530	156	118	244	26067
1971	17134	16115	13455	6269	4154	2057	1332	1022	444	241	81	81	29136
1972	19254	14028	12695	9843	4204	2214	738	686	490	216	57	38	31181
1973	17642	15764	11162	8193	5304	1742	960	456	452	274	117	43	28703

Year	Age												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**3+**
1974	21952	14444	12608	7467	4525	2594	821	521	306	227	163	50	29282
1975	26743	17973	11735	8349	4239	2081	1078	433	240	147	89	47	28438
1976	26221	21896	14278	8686	4449	2016	1071	500	230	116	88	47	31481
1977	19497	21468	17026	9565	5335	2382	1069	632	323	120	86	70	36608
1978	33863	15958	15787	11313	6054	3282	1317	590	256	161	56	26	38842
1979	28355	27724	12428	9741	6409	2998	1603	620	330	169	109	35	34442
1980	22727	23240	22414	8477	4822	3085	1393	879	312	212	79	77	41750
1981	25617	18607	18272	12914	4823	2388	1509	744	485	174	120	48	41477
1982	13820	20973	14496	11479	6749	2298	1021	711	343	233	75	63	37468
1983	13727	11315	16355	9274	5447	2792	1066	484	332	151	114	24	36039
1984	17208	11230	8334	10073	5407	2618	1209	463	214	165	56	61	28600
1985	9341	14059	8368	4675	5483	2698	1279	573	221	118	91	20	23526
1986	26865	7648	10869	5345	2421	2411	1063	587	295	117	50	58	23216
1987	18255	21995	6035	6393	2638	1094	1072	504	301	158	52	20	18267
1988	26761	14946	17231	4129	3393	1187	428	422	202	121	71	13	27197
1989	8926	21910	11873	10944	1896	1391	388	192	174	90	52	33	27033
1990	13256	7292	17347	7418	5683	985	637	172	86	89	56	34	32507
1991	14804	10853	5841	11625	3562	2452	364	272	71	35	39	33	24294
1992	12057	12119	8533	3403	4967	1331	794	107	84	30	15	7	19271
1993	30537	9872	9245	3951	1115	1167	313	196	32	25	10	5	16059
1994	16054	25002	7288	4444	1412	326	358	91	80	14	8	4	14025
1995	12994	13144	20040	3921	1647	369	94	132	37	49	11	5	26305
1996	9041	10638	10639	14473	2240	827	186	52	72	21	35	9	28554
1997	11505	7402	8665	7914	5062	758	248	68	14	28	8	16	22781
1998	7212	9420	6007	6080	2679	1588	225	63	21	5	9	3	16680
1999	11596	5905	7501	4120	2174	850	456	70	17	6	1	2	15197
2000	7021	9494	4769	5389	1570	789	227	135	20	3	3	0	12905
2001	5051	5748	7576	3386	1923	572	246	63	45	4	1	1	13817
2002	11823	4136	4603	5134	1193	651	218	89	18	13	1	0	11920
2003	2188	9680	3366	3439	1680	413	214	82	31	1	4	0	9230

Year	Age												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**3+**
2004	9217	1792	7859	2532	1240	450	131	40	24	14	0	0	12290
2005	3537	7546	1437	5507	941	389	112	48	6	8	5	0	8453
2006	3043	2896	6119	1042	2026	326	123	22	17	1	3	2	9681
2007	7168	2492	2333	4324	346	626	86	44	5	4	0	1	7769
2008	6887	5869	1847	1603	1413	83	179	29	15	1	1	0	5171

Table 2. Beginning of year population biomass (t) for NAFO Division 4X5Yb cod from a virtual population analysis using the bootstrap bias adjusted population abundance.

Year	Age												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**3+**
1980	1374	7695	20838	15441	14294	13459	8131	6851	2995	2296	921	956	86182
1981	1549	6161	16987	23521	14299	10416	8809	5805	4663	1877	1403	590	88370
1982	835	6944	13477	20908	20007	10027	5959	5541	3301	2516	870	786	83392
1983	830	3746	15205	16891	16147	12181	6222	3774	3195	1631	1324	303	76873
1984	1040	3718	7748	18348	16031	11420	7055	3608	2054	1779	653	753	69449
1985	565	4655	7779	8516	16255	11772	7463	4468	2124	1279	1062	247	60965
1986	1624	2532	10105	9736	7178	10520	6204	4575	2839	1268	583	724	53732
1987	1104	7282	5611	11645	7820	4771	6259	3932	2891	1709	603	252	45493
1988	1618	4948	16019	7521	10059	5179	2499	3292	1942	1312	824	161	48808
1989	540	7254	11038	19933	5621	6069	2264	1495	1677	969	611	408	50085
1990	801	2414	16127	13512	16846	4299	3715	1338	828	966	655	422	58708
1991	895	3593	5430	21173	10559	10699	2123	2122	685	379	454	415	54039
1992	729	4013	7933	6198	14725	5809	4635	834	810	324	172	86	41526
1993	1846	3268	8595	7197	3306	5090	1824	1525	306	268	122	57	28290
1994	970	8278	6776	8094	4187	1424	2088	708	767	150	94	50	24338
1995	786	4352	18631	7142	4883	1611	550	1029	356	529	133	64	34928
1996	547	3522	9891	26362	6640	3608	1085	404	694	226	411	116	49437
1997	696	2451	8056	14416	15007	3306	1450	529	133	308	98	196	43499
1998	436	3119	5584	11074	7942	6928	1312	493	204	56	109	41	33743
1999	701	1955	6974	7504	6446	3709	2662	544	160	65	13	30	28107
2000	424	3143	4434	9816	4655	3443	1323	1053	188	35	29	3	24979
2001	305	1903	7043	6168	5702	2496	1436	492	436	44	10	7	23834
2002	715	1369	4279	9351	3536	2839	1273	693	177	145	14	2	22309
2003	132	3205	3130	6264	4980	1800	1247	637	302	12	43	2	18417
2004	557	593	7307	4611	3677	1963	762	311	235	147	2	3	19018
2005	214	2498	1336	10031	2791	1699	652	378	58	85	62	1	17093
2006	184	959	5688	1899	6006	1423	720	175	160	9	40	30	16150
2007	433	825	2169	7876	1026	2731	502	344	47	43	3	10	14751
2008	416	1943	1717	2920	4190	363	1042	229	141	7	17	1	10627

Table 3. Beginning of year population abundance (numbers in thousands) for 5Zjm cod ("split M 0.5" benchmark model formulation).

Year	Age											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**	**1+**	**3+**
1978	12300	3350	10862	4025	1324	709	621	105	111	200	33607	17957
1979	10102	10063	2645	5626	2247	730	434	394	66	225	32533	12367
1980	9944	8257	7437	1506	3242	1352	434	289	268	223	32953	14751
1981	17443	8136	5884	4604	962	1785	789	268	213	342	40425	14847
1982	5682	14250	5951	3330	2638	533	985	467	128	377	34341	14409
1983	5072	4639	8508	3105	1590	1187	262	449	243	325	25380	15669
1984	14192	4133	3093	4712	1382	798	615	109	205	311	29549	11225
1985	5140	11604	3175	1808	2642	643	317	254	54	280	25920	9173
1986	23704	4200	6931	1342	889	1280	284	161	110	222	39124	11219
1987	7726	19370	3033	3643	573	421	640	172	89	235	35901	8806
1988	13488	6306	12157	1724	1953	322	226	367	104	233	36881	17086
1989	4639	11023	4902	6197	802	834	147	81	138	196	28960	13297
1990	6512	3767	8409	3283	3299	452	350	70	31	197	26371	16091
1991	8996	5314	2423	4094	1757	1472	240	150	47	148	24642	10331
1992	2610	7307	3431	1081	1635	633	540	103	61	117	17517	7601
1993	3438	2078	3693	1577	475	546	238	162	44	105	12354	6840
1994	2316	2806	1253	1332	482	123	129	77	46	82	8646	3524
1995	1492	1891	2131	594	390	155	41	33	24	60	6812	3428
1996	2660	1220	1497	1532	402	225	80	20	17	48	7700	3821
1997	4235	2171	963	1015	897	258	91	38	9	37	9714	3308
1998	1674	3461	1647	604	510	414	93	27	13	24	8467	3332
1999	4002	1368	2744	1065	349	276	150	39	7	18	10016	4648
2000	1692	3270	1050	1809	570	188	121	48	13	12	8774	3811
2001	1169	1377	2611	759	1140	331	86	56	20	13	7562	5016
2002	2482	907	1004	1688	427	575	122	28	21	14	7267	3879
2003	717	2031	732	709	989	253	232	51	10	15	5740	2991
2004	5001	587	1629	457	366	448	93	74	17	11	8682	3095
2005	767	4075	469	1202	239	168	167	30	22	10	7149	2307
2006	1707	627	3259	334	812	147	76	73	10	15	7060	4726
2007	2407	1395	494	2450	206	493	54	33	31	12	7573	3773
2008	1535	1968	1075	331	1644	142	235	24	14	21	6989	3486
2009	1513	1256	1574	763	215	1111	73	115	11	19	6650	3881
2010	2300	1230	970	1102	510	139	550	36	62	17	6915	3386

Table 4. Beginning of year population biomass (t) for 5Zjm cod ("split M 0.5" benchmark model formulation).

Year	Age											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**	**1+**	**3+**
1978	1374	2969	17636	14344	7166	4429	5360	942	1138	2927	58285	53942
1979	1135	8730	4602	16852	10258	3789	4179	4290	725	3299	57859	47994
1980	2748	5831	14073	4196	17001	8492	2570	2593	3154	3269	63927	55348
1981	1650	6935	10744	15387	4783	12246	6454	3408	2400	5005	69011	60426
1982	523	12384	13207	10158	10853	3429	7943	4119	1380	5519	69514	56607
1983	1136	5246	15922	7026	4981	7136	2133	3889	2555	4754	54780	48398
1984	715	2403	6043	11512	3730	3288	3622	977	2109	4545	38946	35827
1985	448	7501	6115	5796	9992	3748	2781	2510	769	4098	43757	35808
1986	3110	3235	12073	4316	4374	7293	2115	1446	1174	3252	42389	36044
1987	1159	16368	5160	9784	3249	3150	4786	1144	898	3438	49135	31608
1988	2053	5868	21704	5206	8143	2020	1906	3206	1285	3413	54803	46882
1989	660	9170	8358	17096	3455	5366	1123	634	1567	2863	50291	40461
1990	1398	2966	15498	9517	14392	2716	3005	670	416	2879	53457	49093
1991	790	4765	4730	12966	7455	7206	1811	1508	464	2171	43865	38311
1992	331	6183	7018	3019	6804	3879	3770	879	604	1705	34192	27677
1993	241	1984	6812	4583	2142	3216	1666	1194	406	1530	23773	21548
1994	331	1843	1796	3501	1908	920	944	663	410	1194	13510	11336
1995	273	1502	3383	1333	1355	727	276	258	287	880	10273	8499
1996	233	1023	2324	3978	1570	1377	435	237	199	704	12080	10824
1997	804	1556	1631	2209	2888	1598	563	373	93	538	12254	9894
1998	131	2250	2276	1363	1547	1869	544	211	108	350	10648	8267
1999	443	1369	3703	2382	1039	1278	976	326	55	261	11832	10020
2000	102	2929	1666	4208	1842	839	788	396	154	181	13106	10075
2001	12	1062	3701	1960	4108	1684	592	427	205	147	13897	12823
2002	39	449	1218	3830	1509	2520	713	237	212	158	10886	10398
2003	11	895	836	1335	3012	852	1189	344	80	167	8721	7815
2004	108	169	2368	1117	1262	1830	401	468	179	125	8026	7749
2005	44	2399	548	2128	709	554	657	229	144	117	7528	5084
2006	52	192	3752	525	2128	468	350	343	59	164	8035	7790
2007	129	872	530	4321	539	2021	312	221	249	132	9326	8324
2008	70	1136	1558	676	4117	491	979	194	142	232	9595	8389
2009	173	910	2314	1893	581	3918	328	558	53	211	10939	9856
2010	182	808	1525	2448	1624	487	2177	194	617	189	10250	9260

Table 5. Relative risk of current threats for Atlantic Cod. Table prepared by Jennifer Shaw, Fish Population Science Branch, DFO National Capital Region.

Threats	Southern Canada DU	
	4X5Yb	**5Zjm**
Directed fishing (commercial, recreational, aboriginal)	Medium	Medium
Bycatch	Medium	Medium
Unreported catch (discards, misreporting, illegal)	Low	Low
Natural mortality	High	High
Disease	Low	Low
Contaminants	Low	Low
Decreased prey availability (starvation)	Low	Low
Life history changes	Low	Low
Increased seal abundance	Medium	Low
Other predation	Low	Low
Climate change	Low	Low
Habitat alteration	Low	Low
Coastal eutrophication/hypoxia	Low	Low
Oil and gas exploration	Low	Low

Table 6. Landings (t) of cod from Division 5Zjm (1978 to 2009), Division 4X5Yb (1948 to 2009) and the Southern Canada DU (1978-2009).Cells with a dash (-) indicate no data.

Year	5Zjm Landings	4X5Yb Landings	Southern DU Landings
1948	-	19,760	-
1949	-	16,081	-
1950	-	20,669	-
1951	-	18,182	-
1952	-	18,221	-
1953	-	14,364	-
1954	-	16,929	-
1955	-	14,810	-
1956	-	16,512	-
1957	-	14,419	-
1958	-	12,060	-
1959	-	14,115	-
1960	-	13,472	-
1961	-	13,726	-
1962	-	15,773	-
1963	-	17,755	-
1964	-	25,847	-
1965	-	26,973	-
1966	-	30,904	-
1967	-	32,348	-
1968	-	35,615	-
1969	-	32,756	-
1970	-	22,328	-
1971	-	23,497	-
1972	-	22,433	-
1973	-	22,214	-
1974	-	21,110	-
1975	-	21,185	-
1976	-	16,662	-
1977	-	22,368	-
1978	14,377	24,024	38,401
1979	12,490	28,766	41,256
1980	14,567	31,276	45,843
1981	16,698	31,520	48,218
1982	26,463	33,134	59,597
1983	20,769	29,469	50,238
1984	16,379	25,528	41,907
1985	17,186	21,499	38,685
1986	14,251	20,040	34,291
1987	16,713	18,991	35,704
1988	20,470	20,536	41,006
1989	14,257	19,887	34,144
1990	20,943	23,892	44,835
1991	20,034	27,749	47,783
1992	16,997	26,080	43,077
1993	12,676	16,026	28,702
1994	6,344	13,045	19,389

Year	5Zjm Landings	4X5Yb Landings	Southern DU Landings
1995	1,684	8,767	10,451
1996	2,658	10,572	13,230
1997	3,962	11,422	15,384
1998	2,959	8,169	11,128
1999	3,365	6,190	9,555
2000	2,439	5,756	8,195
2001	3,993	5,636	9,629
2002	3,064	5,869	8,933
2003	3,486	5,622	9,108
2004	2,334	4,994	7,328
2005	1,281	3,597	4,878
2006	1,707	3,700	5,407
2007	1,779	3,790	5,569
2008	1,782	4,132	5,914
2009	1,858	3,166	5,024

Table 7. Fishing mortality rate (F) for NAFO Division 4X5Yb cod from a virtual population analysis using the bootstrap bias adjusted population abundance.

Year	Age												Avg F
	1	2	3	4	5	6	7	8	9	10	11	12	
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	0.300

Table 8. Catches (t) of cod from Eastern Georges Bank (Division 5Zjm), 1978-2009. Cells with a dash (-) indicate no data.

Year	Canada				USA			Total
	Landings	Discards Scallop	Discards Groundfish	Total	Landings	Discards	Total	
1978	8,777	98	-	8,875	5,502	-	5,502	14,377
1979	5,979	103	-	6,082	6,408	-	6,408	12,490
1980	8,066	83	-	8,149	6,418	-	6,418	14,567
1981	8,508	98	-	8,606	8,092	-	8,092	16,698
1982	17,827	71	-	17,898	8,565	-	8,565	26,463
1983	12,131	65	-	12,196	8,572	-	8,572	20,769
1984	5,761	68	-	5,829	10,550	-	10,550	16,379
1985	10,442	103	-	10,545	6,641	-	6,641	17,186
1986	8,504	51	-	8,555	5,696	-	5,696	14,251
1987	11,844	76	-	11,920	4,793	-	4,793	16,713
1988	12,741	83	-	12,824	7,645	-	7,645	20,470
1989	7,895	76	-	7,971	6,182	104	6,286	14,257
1990	14,364	70	-	14,434	6,414	95	6,509	20,943
1991	13,467	65	-	13,532	6,353	149	6,501	20,034
1992	11,667	71	-	11,738	5,080	179	5,259	16,997
1993	8,526	63	-	8,589	4,019	67	4,087	12,676
1994	5,277	63	-	5,340	998	6	1,005	6,344
1995	1,102	38	-	1,140	544	0	544	1,684
1996	1,924	56	-	1,980	676	2	677	2,658
1997	2,919	58	428	3,405	549	8	557	3,962
1998	1,907	92	273	2,272	679	7	686	2,959
1999	1,818	85	253	2,156	1,195	14	1,208	3,365
2000	1,572	69	-	1,641	772	26	798	2,439
2001	2,143	143	-	2,286	1,487	220	1,708	3,993
2002	1,278	94	-	1,372	1,680	12	1,692	3,064
2003	1,328	200	-	1,528	1,854	105	1,959	3,486
2004	1,112	145	-	1,257	1,007	70	1,077	2,334
2005	630	84	144	859	174	249	423	1,281
2006	1,096	112	237	1,445	134	128	262	1,707
2007	1,108	114	-	1,222	216	341	557	1,779
2008	1,390	36	103	1,529	231	22	253	1,782
2009	1,003	69	137	1,209	430	219	649	1,858

Table 9. fishing mortality rate (F) for Eastern Georges Bank cod (Division 5Zjm) using the "split M 0.5" benchmark model formulation.

Year	Age									
	1	2	3	4	5	6	7	8	9	4-9	10+
1978	0.001	0.036	0.458	0.383	0.395	0.291	0.255	0.263	0.256	0.360	0.055
1979	0.002	0.102	0.363	0.351	0.308	0.320	0.207	0.185	0.196	0.324	0.031
1980	0.001	0.139	0.279	0.248	0.397	0.339	0.282	0.105	0.211	0.328	0.108
1981	0.002	0.113	0.369	0.357	0.390	0.394	0.325	0.539	0.379	0.372	0.083
1982	0.003	0.316	0.450	0.539	0.598	0.512	0.585	0.453	0.543	0.557	0.157
1983	0.005	0.205	0.391	0.610	0.490	0.458	0.676	0.584	0.618	0.556	0.268
1984	0.001	0.063	0.337	0.378	0.566	0.723	0.683	0.493	0.654	0.479	0.278
1985	0.002	0.315	0.662	0.510	0.525	0.615	0.478	0.640	0.550	0.533	0.154
1986	0.002	0.126	0.443	0.651	0.548	0.493	0.304	0.393	0.337	0.536	0.064
1987	0.003	0.266	0.365	0.423	0.375	0.422	0.355	0.300	0.343	0.405	0.058
1988	0.002	0.052	0.474	0.565	0.651	0.582	0.825	0.777	0.795	0.636	0.195
1989	0.008	0.071	0.201	0.430	0.373	0.669	0.540	0.767	0.620	0.458	0.165
1990	0.003	0.241	0.520	0.425	0.607	0.434	0.648	0.213	0.575	0.515	0.183
1991	0.008	0.237	0.607	0.718	0.821	0.803	0.649	0.700	0.669	0.755	0.225
1992	0.028	0.482	0.578	0.623	0.896	0.778	1.006	0.653	0.950	0.814	0.112
1993	0.003	0.305	0.820	0.984	1.147	1.245	0.934	1.053	0.982	1.056	0.227
1994	0.003	0.075	0.547	1.028	0.937	0.594	0.875	0.655	0.793	0.956	0.042
1995	0.001	0.034	0.130	0.191	0.349	0.162	0.241	0.169	0.209	0.239	0.006
1996	0.003	0.037	0.189	0.335	0.244	0.408	0.238	0.263	0.243	0.321	0.012
1997	0.002	0.077	0.267	0.488	0.574	0.516	0.710	0.563	0.666	0.535	0.059
1998	0.002	0.032	0.236	0.347	0.415	0.517	0.360	0.919	0.486	0.421	0.112
1999	0.002	0.064	0.217	0.425	0.419	0.322	0.632	0.585	0.622	0.429	0.058
2000	0.005	0.025	0.125	0.261	0.343	0.286	0.264	0.384	0.298	0.282	0.063
2001	0.053	0.117	0.236	0.376	0.485	0.500	0.615	0.480	0.561	0.458	0.108
2002	0.000	0.015	0.147	0.335	0.321	0.407	0.363	0.486	0.386	0.350	0.336
2003	0.000	0.021	0.272	0.462	0.592	0.503	0.644	0.608	0.637	0.547	0.159
2004	0.005	0.024	0.104	0.449	0.579	0.488	0.634	0.700	0.663	0.521	0.285
2005	0.002	0.023	0.141	0.192	0.283	0.294	0.324	0.573	0.362	0.234	0.198
2006	0.002	0.038	0.086	0.285	0.299	0.503	0.348	0.354	0.351	0.322	0.191
2007	0.001	0.061	0.200	0.199	0.173	0.241	0.293	0.330	0.307	0.208	0.063
2008	0.001	0.023	0.143	0.231	0.192	0.159	0.211	0.260	0.215	0.198	0.060
2009	0.007	0.058	0.157	0.203	0.236	0.203	0.209	0.130	0.161	0.203	0.046

Table 10. Estimated discards of Atlantic Cod from fisheries in 4X5Yb and 5Zjm. The percent observer coverage is the percent observed of total landings of all species (data from Gavaris et al. 2010). Cells with a dash (-) indicate no data.

Area	**Fishery**	**2002**		**2003**		**2004**		**2005**		**2006**	
		Discards (t)	**Obs (%)**	**Discards (t)**	**Obs (%)**	**Discards (t)**	**Obs (%)**	**Discards (t)**	**Obs (%)**	**Discards (t)**	**Obs (%)**
4X5Yb	Herring Purse Seine	0.51	4%	2.16	4%	3.383	4%	-	1%	-	1%
	Lobster/Jonah Trap Offshore	0.135	4%	2.017	4%	1.161	2%	0.955	5%	1.201	8%
	Redfish Bottom Trawl	0.035	25%	-	3%	-	4%	-	3%	-	4%
	Scallop Dredge	0.312	2%	1.332	1%	0.348	2%	0.171	1%	0.432	2%
	Scallop Dredge Offshore	-	-	-	-	17.064	1%	-	-	-	-
	Sculpin Bottom Trawl	-	28%	-	28%	0.004	52%	0.002	48%	0.007	73%
5Zjm	Lobster/Jonah Trap Offshore	2.57	1%	2.49	3%	-	-	3.387	4%	0.306	4%
	Scallop Dredge Offshore	122.834	1%	-	-	139.831	3%	77.911	8%	134.756	6%

Table 11. Potential threats and mitigation measures for Atlantic cod. Table courtesy of Fisheries Management, DFO National Capital Region.

Potential Threats and Limiting Factors to Recovery	Potential Management Options and Mitigation Measures
Unsustainable anthropic mortality in various directed fishing Commercial (includes Index and stewardship fishery): High exploitation rates in commercial fishing is the single most anthropogenic activity that is responsible for the decline of cod stocks Recreational: While recreational fishing is not as big of a threat as commercial fishing, it is nonetheless an important component in the overall fishing mortality for some stocks Aboriginal: Food, Social and Ceremonial (FSC) fishing activities	• Implementation of the Precautionary Approach (PA) and the adoption of harvest control rules and decisions compliant with the PA. o In some circumstances this could lead to fishing closure in some areas and the continuation of moratoria in others. • Development of Integrated Fishery Management Plan for all cod stocks. • Establishment of Conservation Harvesting Plans. • Implementation of Quota Reconciliation for all Gulf Groundfish in 2010 and full implementation across fisheries in Canada by 2012. • Allow a commercial, index, or stewardship fishery whereby all licensed fish harvesters would be permitted to harvest only a specified amount (harvesting cap or IQ). • Allow a commercial, index, or stewardship fishery for specified seasons (i.e. a week to 10 days per month over a spatial time frame). • Consider establishing a Marine Recreational Licence system to better assess the level of cod caught by this type of removals. • Create zones to protect high concentration of individuals. • Limit participants and/or fishing effort by restricting the number of boats or gear allowed to direct on a particular stock. • Maintain or create no fishing zones during certain time of the year in areas where cod spawn. • Reduce fishing mortality by a certain percentage from the current TAC or harvesting rate that would stabilize the decline over three generations and/or allow some growth over a certain pre-agreed period of time (See previous internal document on “Elements of discussion for Projection Scenarios” develop for the Cod RPA under point 4. Possible Scenarios for Fishing Mortality).
Bycatch Bycatch in some fishery continues to contribute to the decline of cod stocks	• Application of By-catch and Small Fish Protocol, as well as, measures included in Conservation Harvest Plans (such as gear type, mesh size, % or weight of allowable incidental catches per trip in certain areas or during certain time of the year). • Adopt more stringent requirements, where necessary, for the management, control and monitoring of by-catch in other directed fisheries.

Potential Threats and Limiting Factors to Recovery	Potential Management Options and Mitigation Measures
Unreported Catch (discards, misreporting and illegal fishing)	• Continue efforts to improve the Dockside Monitoring Program (DMP). • Increase observer coverage in directed cod fisheries when (and where) the catch and discarding of small fish is likely to be high. • Conduct a review, in conjunction with industry, of additional measures such as seasonal closures or gear restrictions to address the discarding of fish. • Mandatory hail out. • Completion of log books. • Expansion of the requirement for Vessel Monitoring Systems (VMS). • Compliance monitoring activities (such as DFO Conservation & Protection Patrols, Dockside Inspections, At-Sea Inspections and Aerial Surveillance).
Natural mortality	• Natural mortality is considered to be a medium to high risk for all cod stocks. There are, however, no plausible mitigation measures that could be put in place to decrease the risk of this threat.
Disease	• Considered to be a low risk for all cod stocks.
Contaminants	• Considered to be a low risk for all cod stocks.
Decreased prey availability (starvation)	• Considered to be a low risk for all cod stocks. The management of capelin and other forage fish already takes into account their role as food in the ecosystem.
Life history changes	• Considered to be a low risk for all cod stocks. While changes in mean weight and age of maturity have been documented, there are no plausible mitigation measures that could be put in place to decrease the risk of this threat.
Increased seal abundance	• This threat has a high level of risk for 4TVn and a medium level of risk for 3Pn4RS and 4X5Yb. All remaining cod stocks have a low level of risk for this threat. At this time, however, it is not known if a seal removal would help rebuild these cod stocks and decrease the risk of this threat (DFO 2011b).
Other predation	• Considered to be a low risk for all cod stocks.

Potential Threats and Limiting Factors to Recovery	Potential Management Options and Mitigation Measures
Climate change	• Considered to be a low risk for all cod stocks. DFO will continue to monitor environmental factors and to study them in relation to their impact on the dynamics of cod.
Habitat alteration	• Considered to be a low risk for all cod stocks.
Coastal eutrophication/hypoxia	• This threat has a medium level of risk for 3Pn4RS and a low level of risk for all other cod stocks. There are, however, no mitigation measures that the Department could put in place to decrease the risk of this threat other than continue to monitor these factors.
Oil and gas exploration	• This threat has a medium level of risk for 3Pn4RS and a low level of risk for all other cod stocks. There are no mitigation measures that DFO could put in place to decrease the risk of this threat other than continue to advise regulatory boards in a manner that takes into account the status of cod stocks and rebuilding efforts.

Table 12. Summary of status indicators for allowable harm assessment. The generation time for 4X5Yb and 5Zjm cod is 7.5 years.

Reduction in Fishing Mortality (F_{ref})	4X5Yb Cod: B_{lim} (24,000t), F_{ref} = 0.20			5Zjm Cod: B_{lim} (21,000t), F_{ref} = 0.18		
	Probability of no decline in abundance over 36 years	Years to Reach B_{lim}		Probability of no decline in abundance over 36 years	Years to Reach B_{lim}	
		with 50% Certainty	with 95% Certainty		with 50% Certainty	with 95% Certainty
0%	77.4%	14	>36	68.1%	16	>36
50%	97.4%	5	23	98.1%	8	22
100%	99.9%	3	10	99.8%	6	17

FIGURES

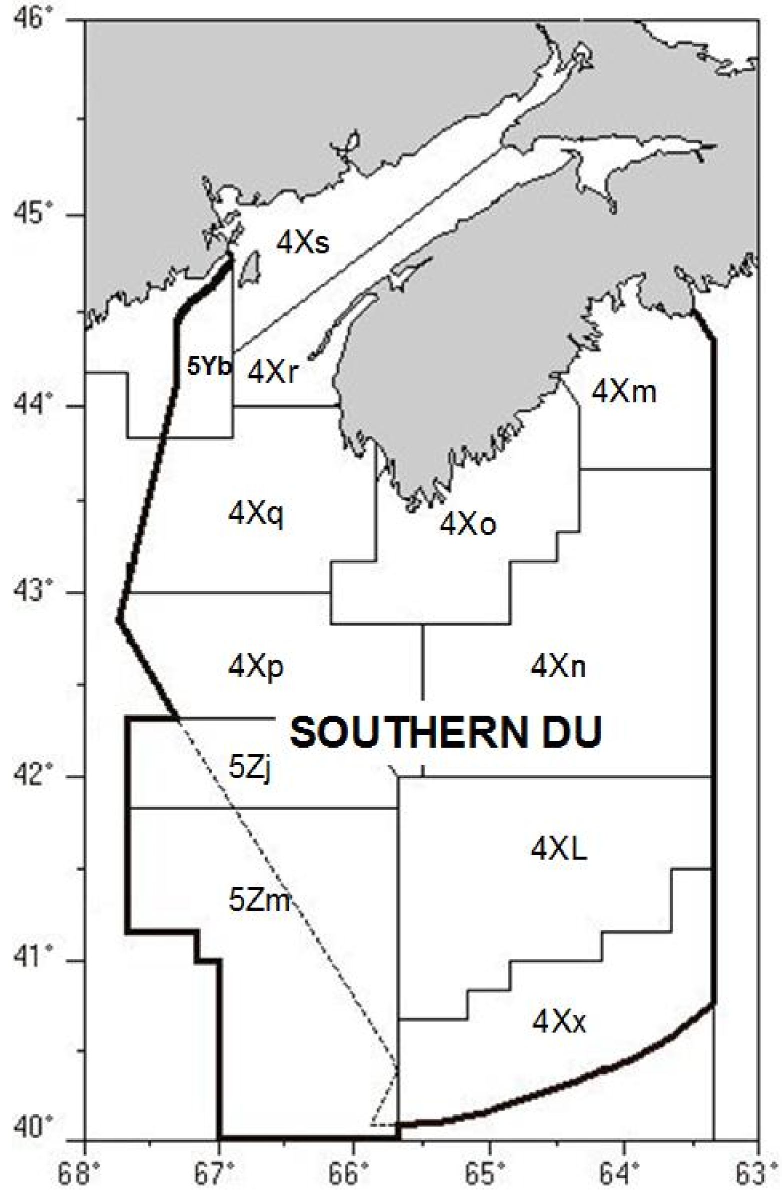

Figure 1. Southern Designatable Unit (NAFO Divisions 4X5Yb and 5Zjm)

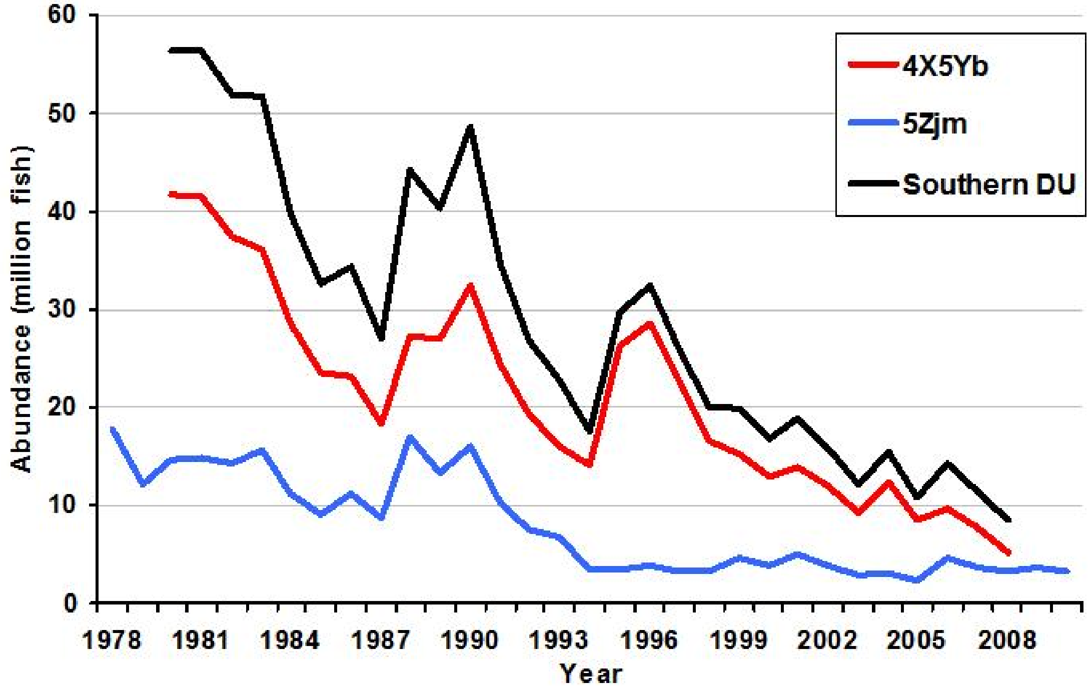

Figure 2. Temporal variation in the estimated number (million) of mature (3+) individuals for NAFO Division 4X5Yb cod, 5Zjm cod and the Southern DU (4X5Yb and 5Zjm combined).

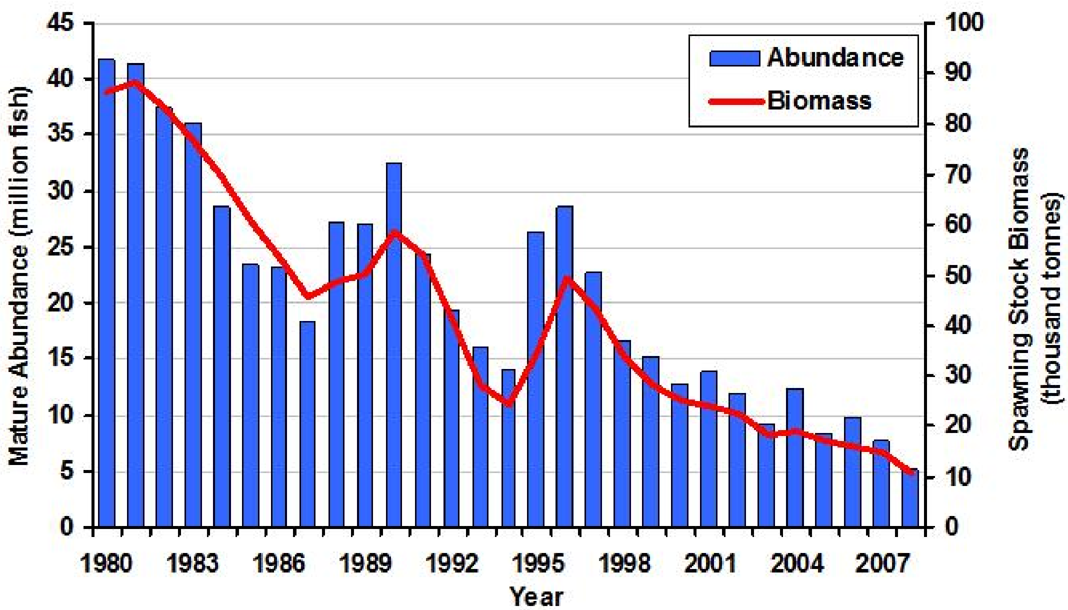

Figure 3. Total mature abundance (3+) and spawning stock biomass (3+) for cod in Division 4X5Yb.

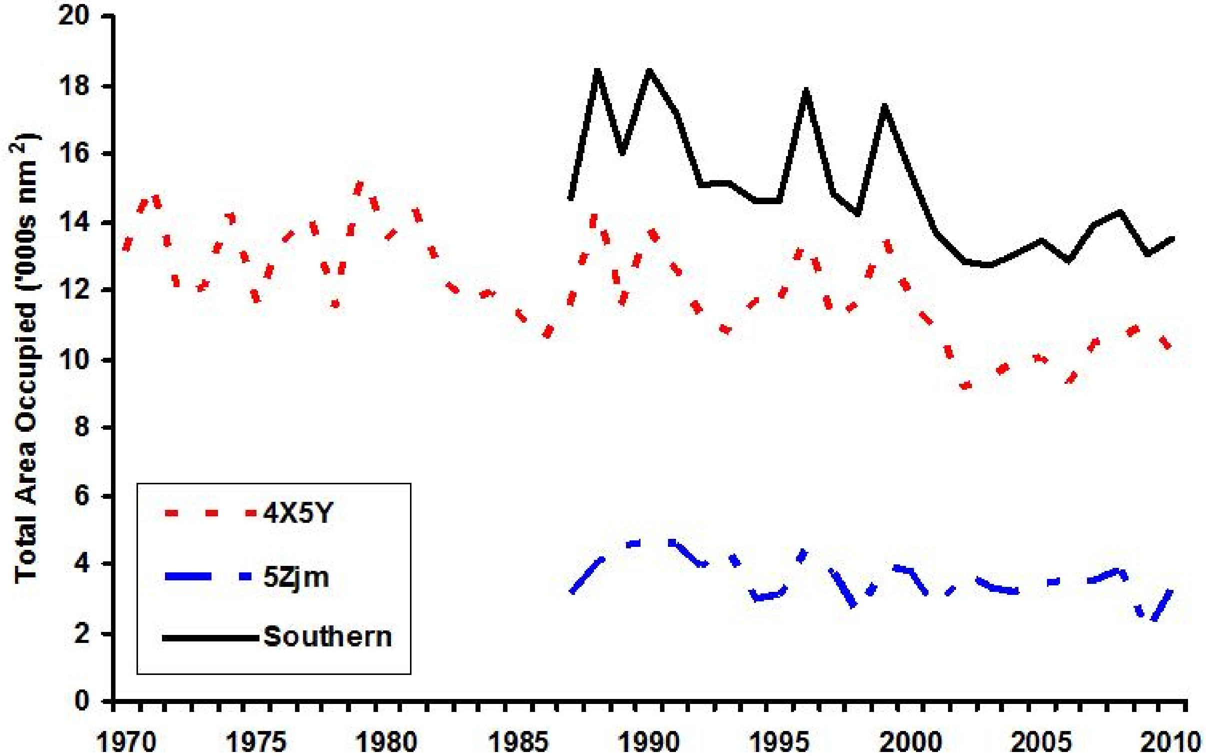

Figure 4. Area of occupancy for cod in NAFO Divisions 4X5Yb and 5Zjm and the Southern DU from the DFO summer (4X5Yb) and winter (5Zjm) surveys.

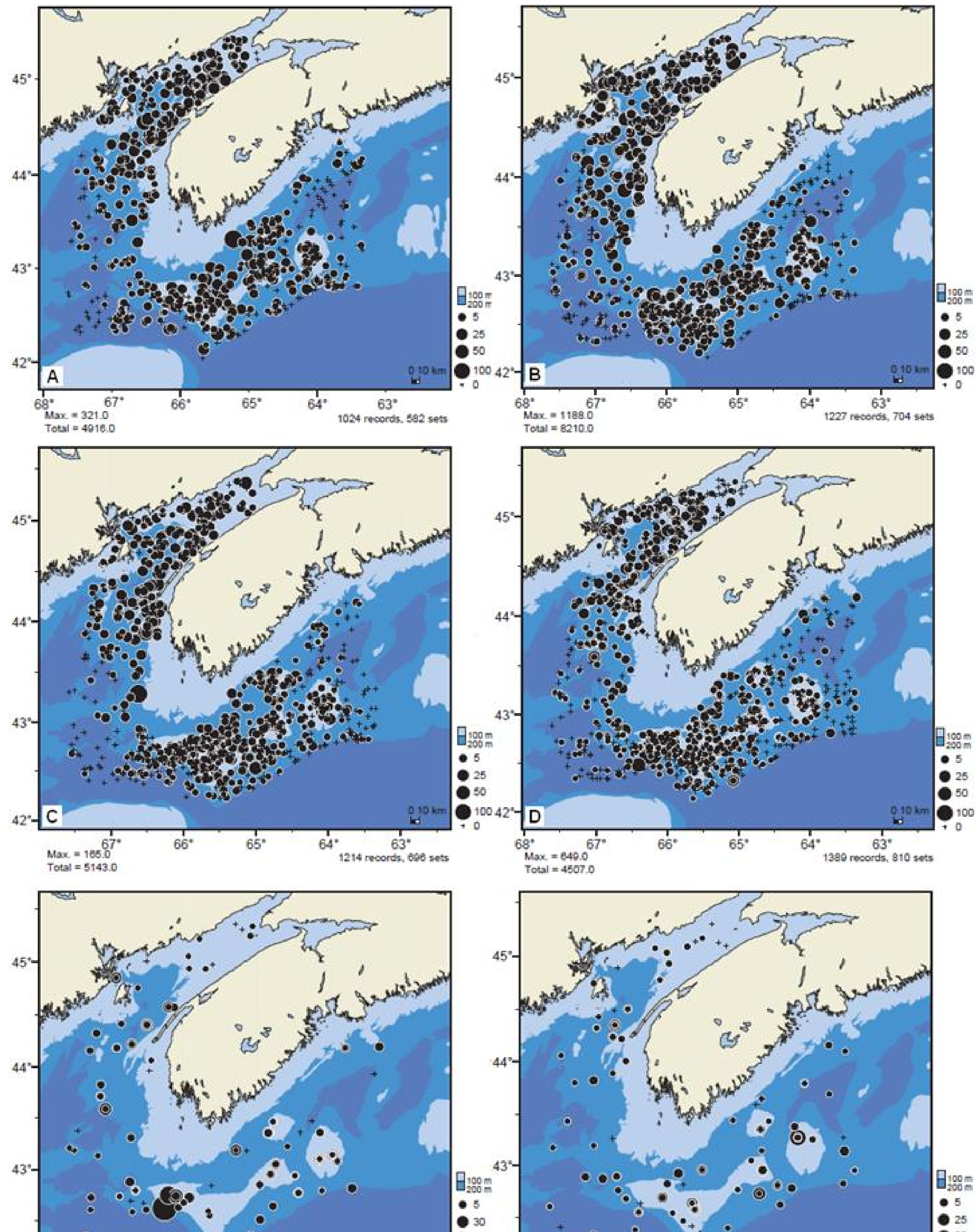

Figure 5. Observed fish counts in NAFO Division 4X5Yb from Canadian Ecosystem Summer Surveys (DFO) for 1970-1979 (A), 1980-1989 (B), 1990-1999 (C), 2000-2009(D), 2009 (E) and 2010 (F).

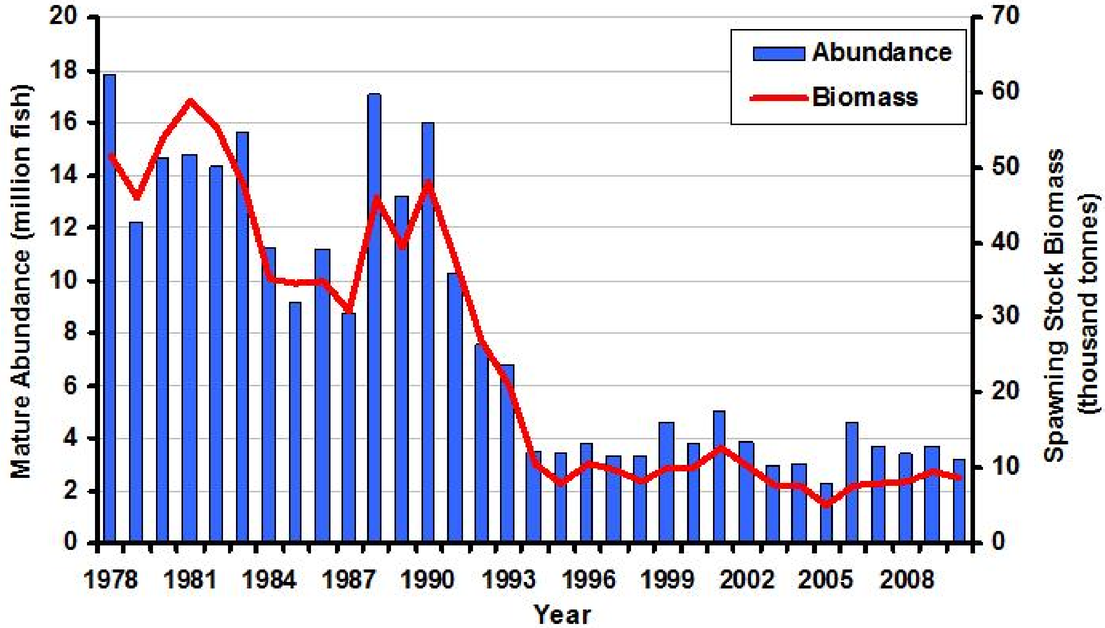

Figure 6. Total mature abundance (3+) and spawning stock biomass (3+) for cod in Division 5Zjm.

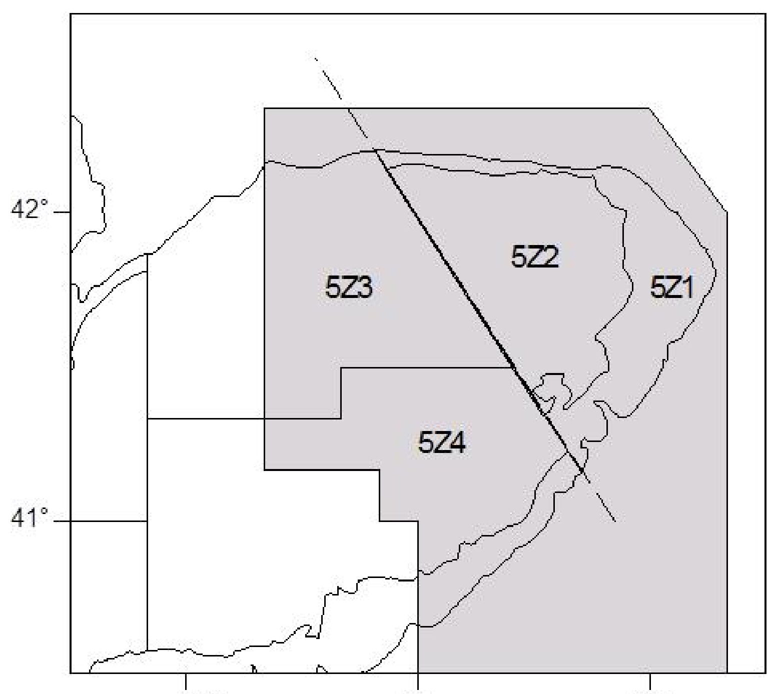

Figure 7. Stratification used for the DFO survey. The Eastern Georges Bank management unit is indicated by shading.

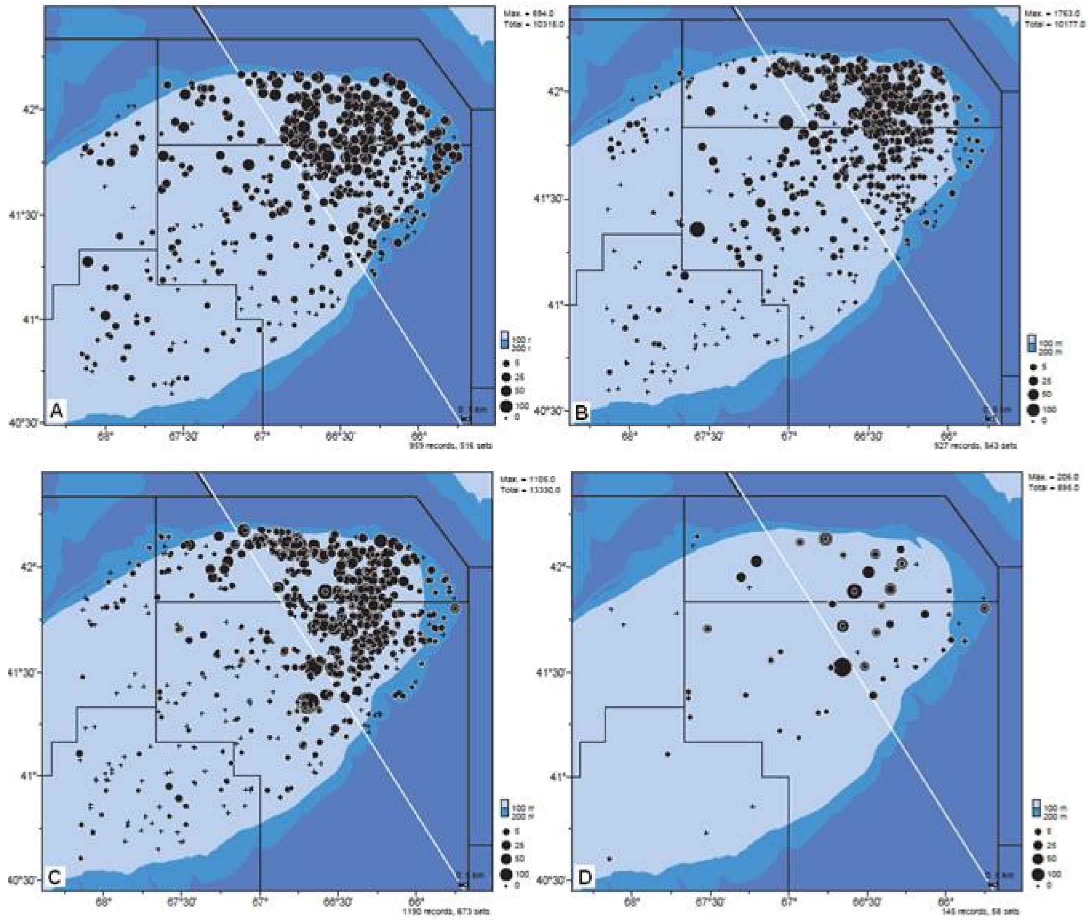

Figure 8. Observed fish counts in NAFO Division 5Zjm from Canadian Ecosystem Winter Surveys (DFO) for 1987-1994 (A), 1995-2002 (B), 2003-2010 (C) and 2010 (D). White line indicates the Canada (NE) – US (SW) boundary. Black lines indicate NAFO division boundaries.

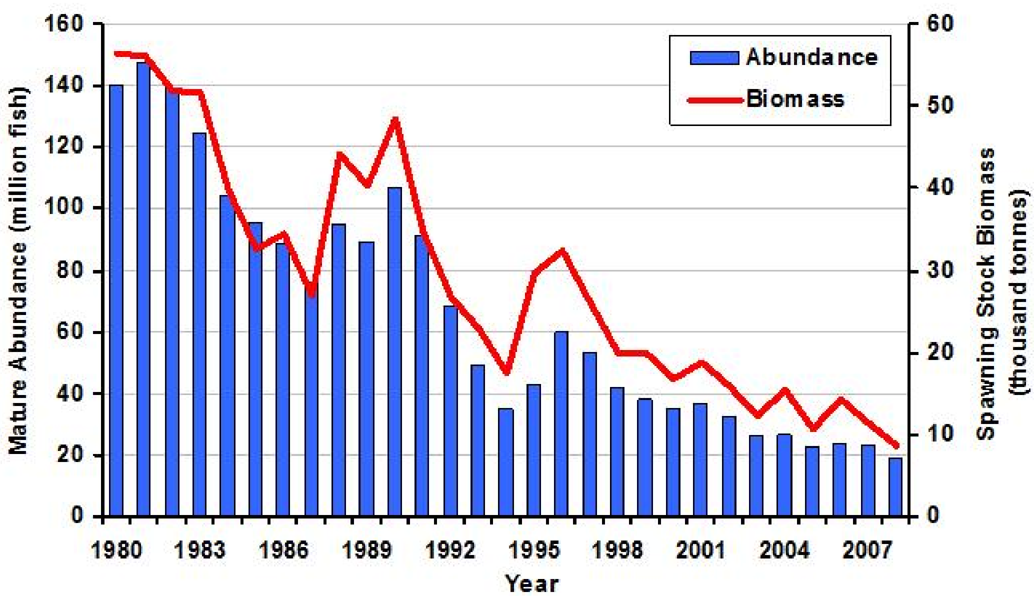

Figure 9. Total mature abundance (3+) and spawning stock biomass (3+) for cod in the Southern DU.

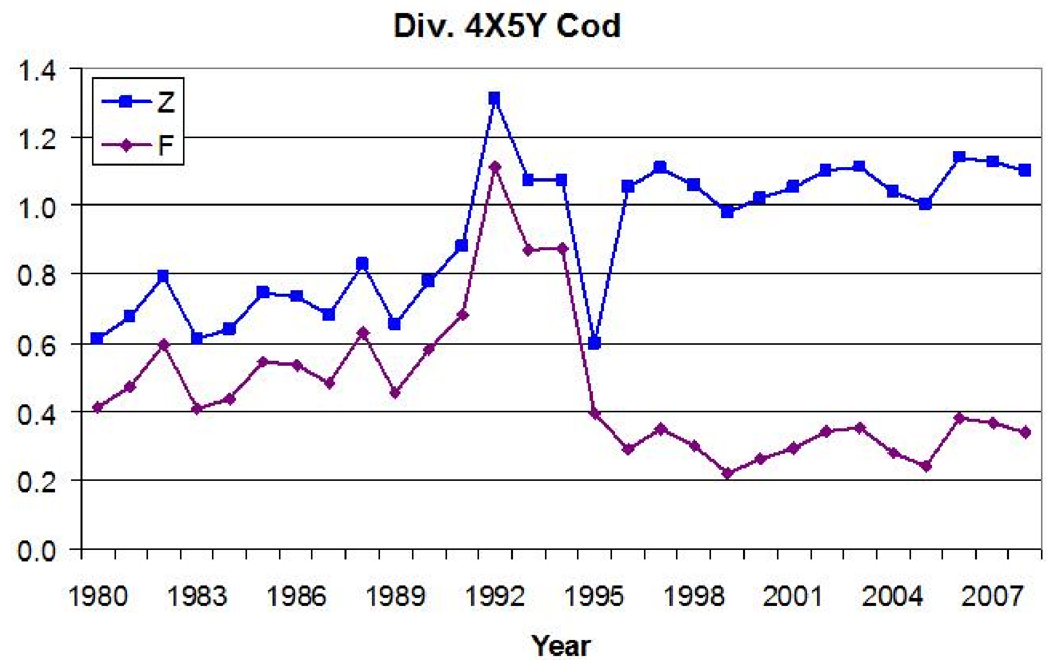

Figure 10. Total mortality (Z) and Fishing Mortality (F) estimates for Division 4X5Yb cod.

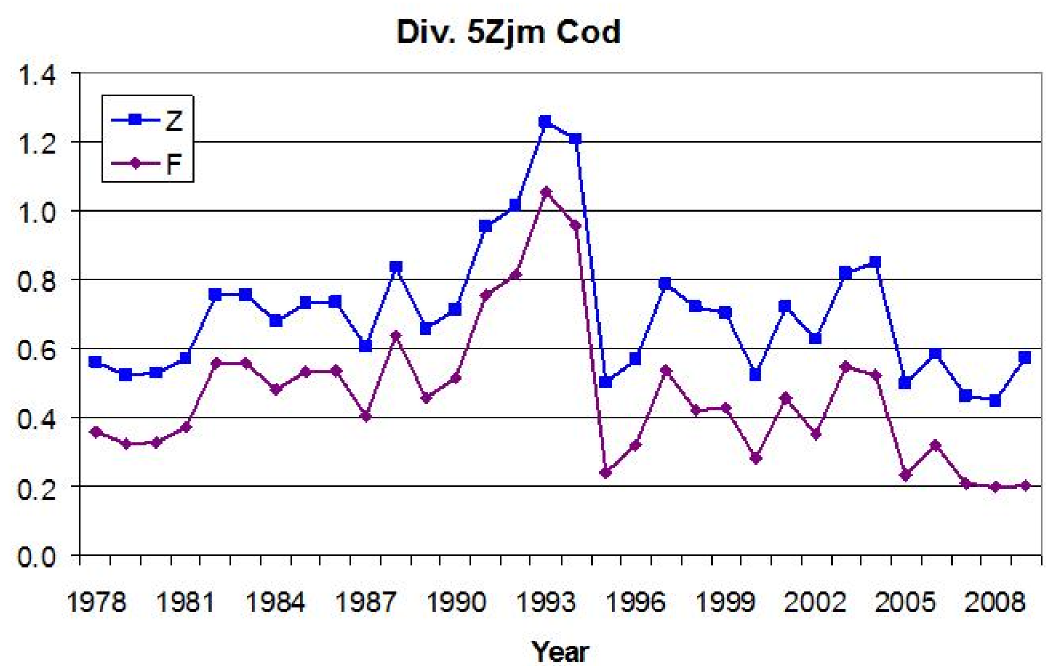

Figure 11. Total mortality (Z) and Fishing Mortality (F) estimates for Division 5Zjm cod.

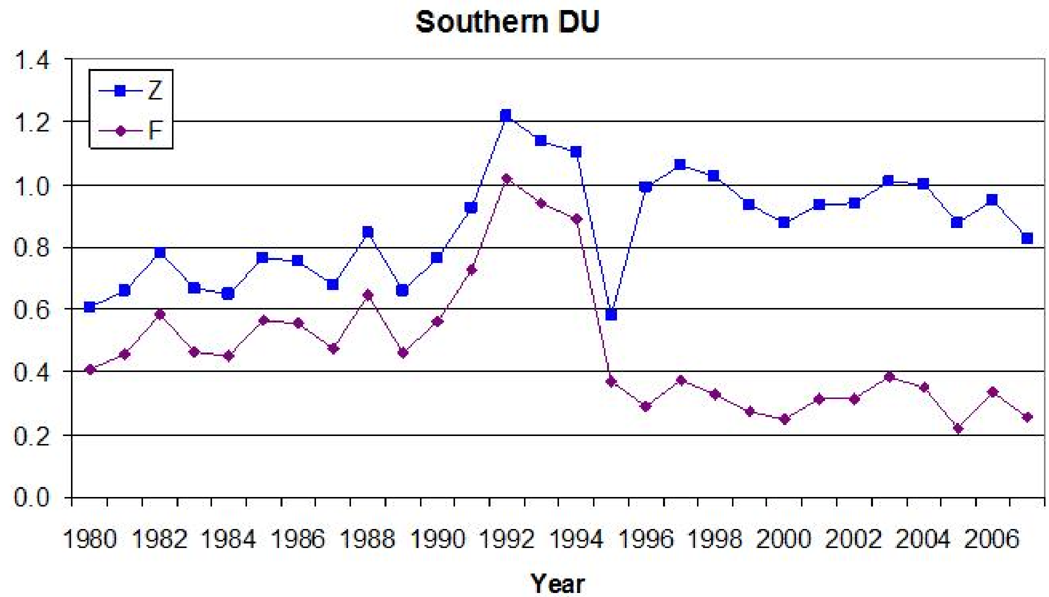

Figure 12. Total mortality (Z) and Fishing Mortality (F) estimates for the Southern DU.

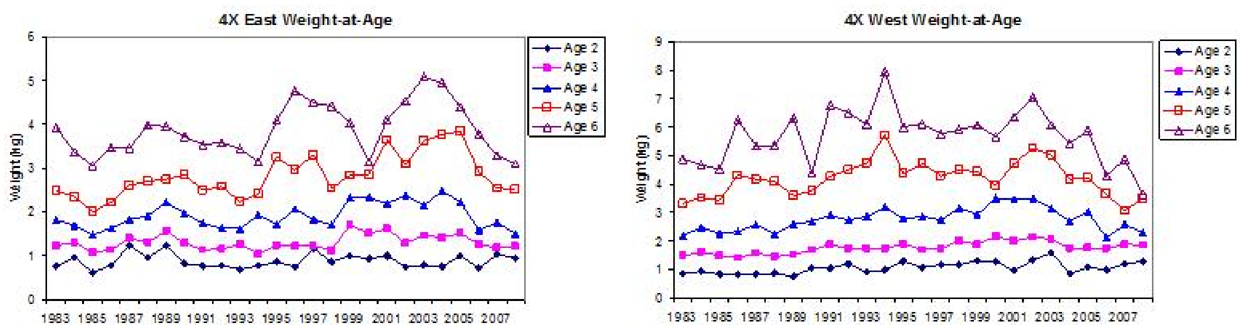

Figure 13. Weights-at-age by region for NAFO Division 4X5Yb cod caught in the commercial fishery.

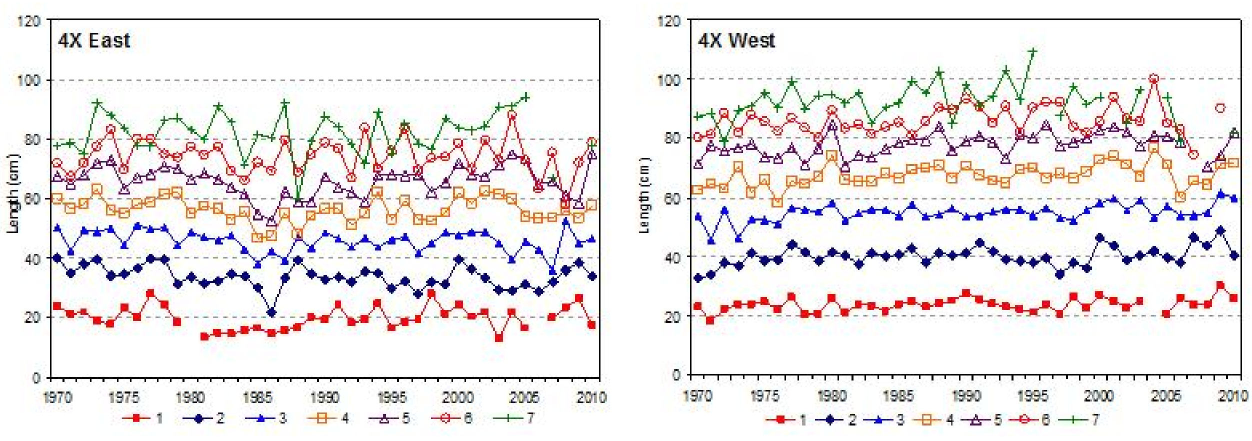

Figure 14. Lengths-at-age by region for NAFO Division 4X5Yb cod caught in the DFO Research Vessel survey.

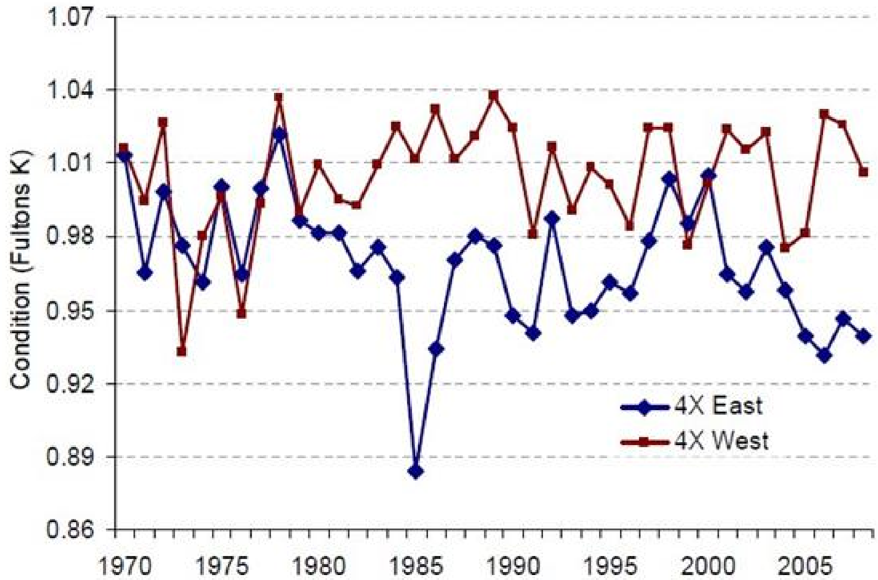

Figure 15. Condition factor (Fultons K: weight/length^3) for NAFO Division 4X5Yb cod by region.

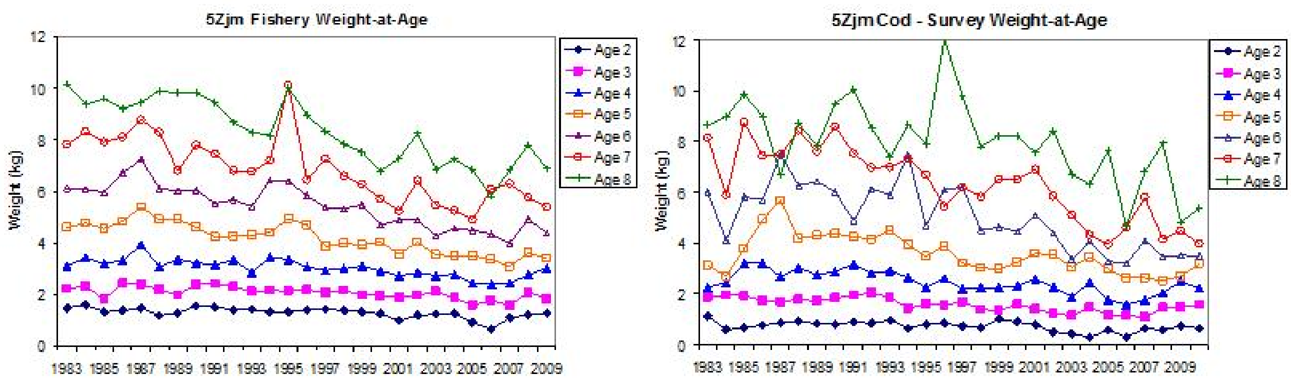

Figure 16. Weights-at-age by region for NAFO Division 5Zjm cod caught in the commercial fishery (left panel) and in the DFO and NMFS spring surveys (right panel).

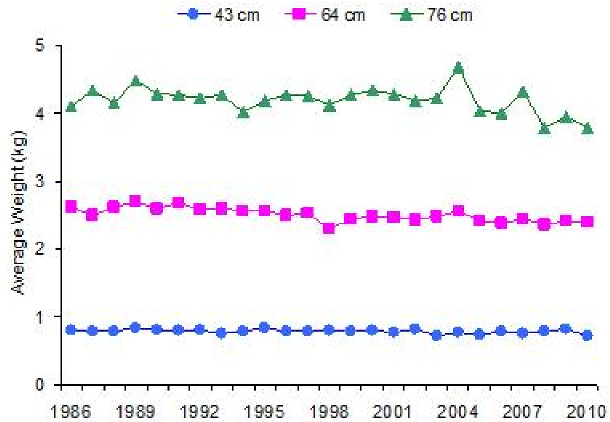

Figure 17. Condition, measured as average weight at three representative length groupings, for 5Zjm cod from the DFO survey.

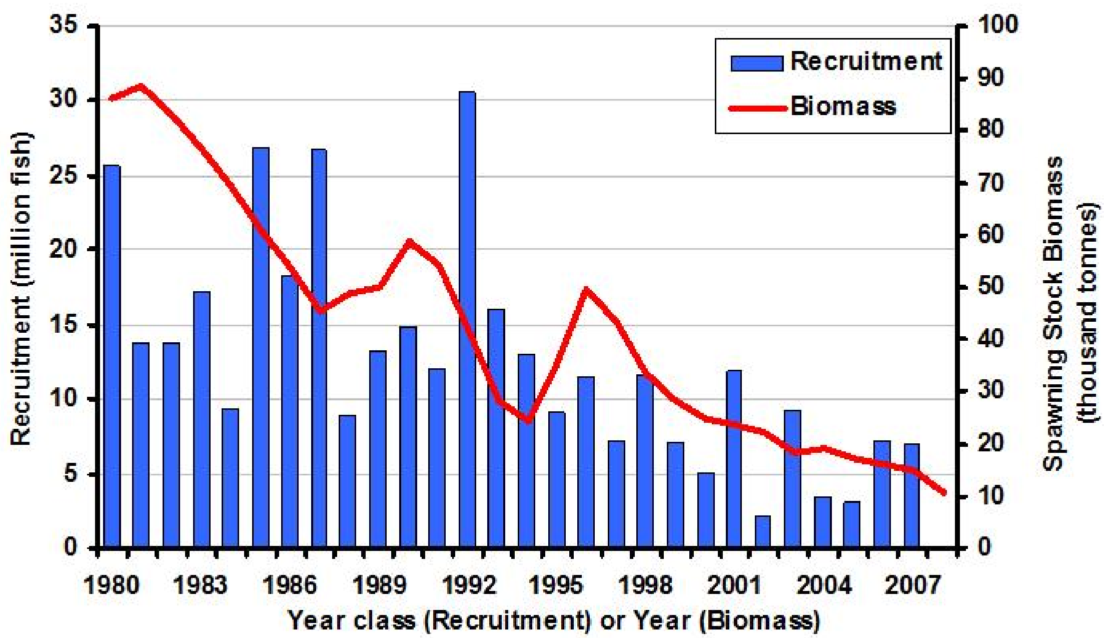

Figure 18. Recruitment (age 1) and spawning stock biomass (age 3+) of NAFO Division 4X5Yb cod.

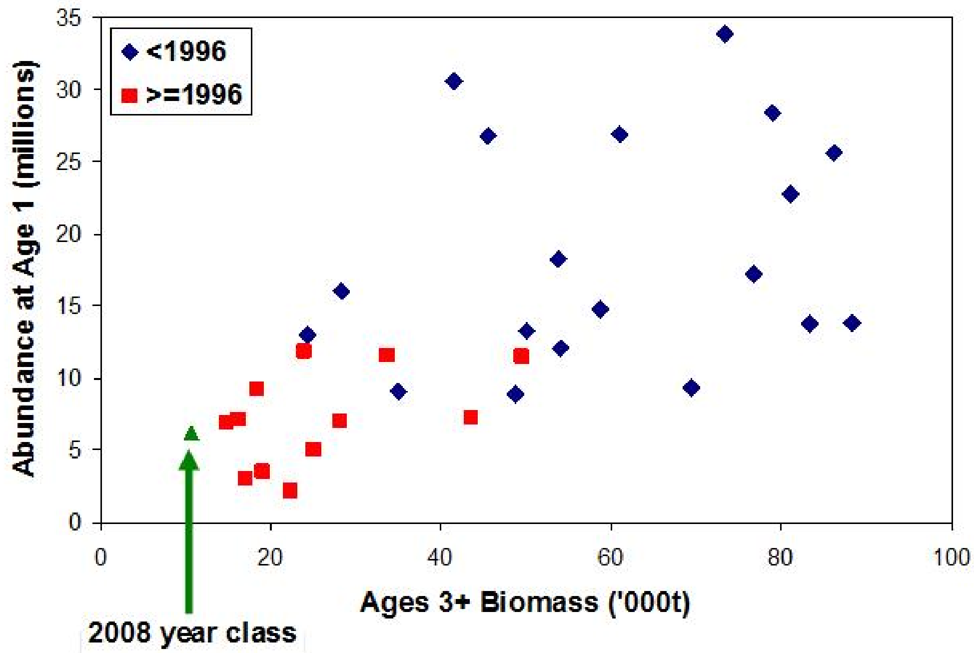

Figure 19. Relationship between adult biomass (ages 3+) and recruits at age 1 for 4X5Yb cod. The arrow indicates the 2007 year class (green triangle). Blue diamonds are from before 1996 and the red squares are from 1996 to 2006.

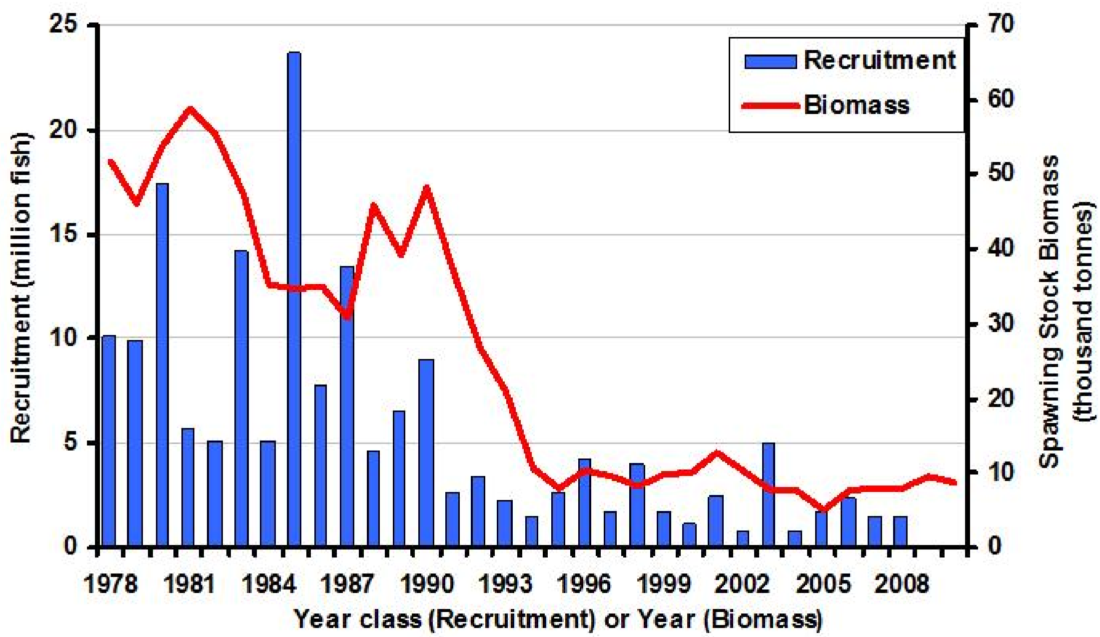

Figure 20. Recruitment (age 1) and spawning stock biomass (age 3+) of NAFO Division 5Zjm cod.

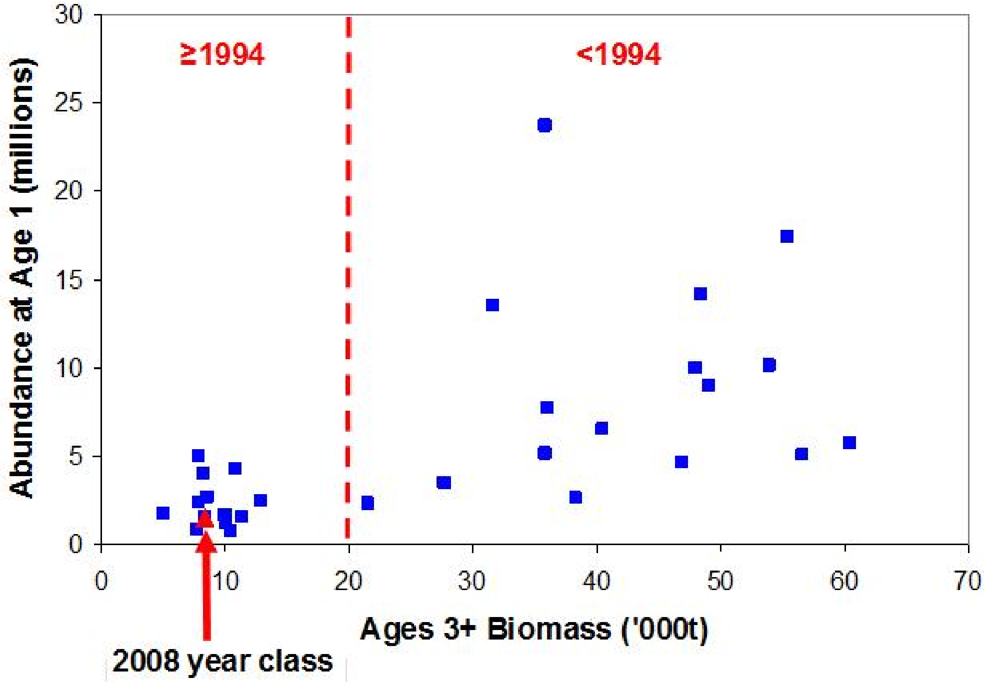

Figure 21. Relationship between adult biomass (ages 3+) and recruits at age 1 for 5Zjm cod using the "Split M0.5" model. The arrow indicates the 2008 year class (red circle). All data points to the right of the dotted line are from before 1994 and data points to the left are from 1994 to the 2008.

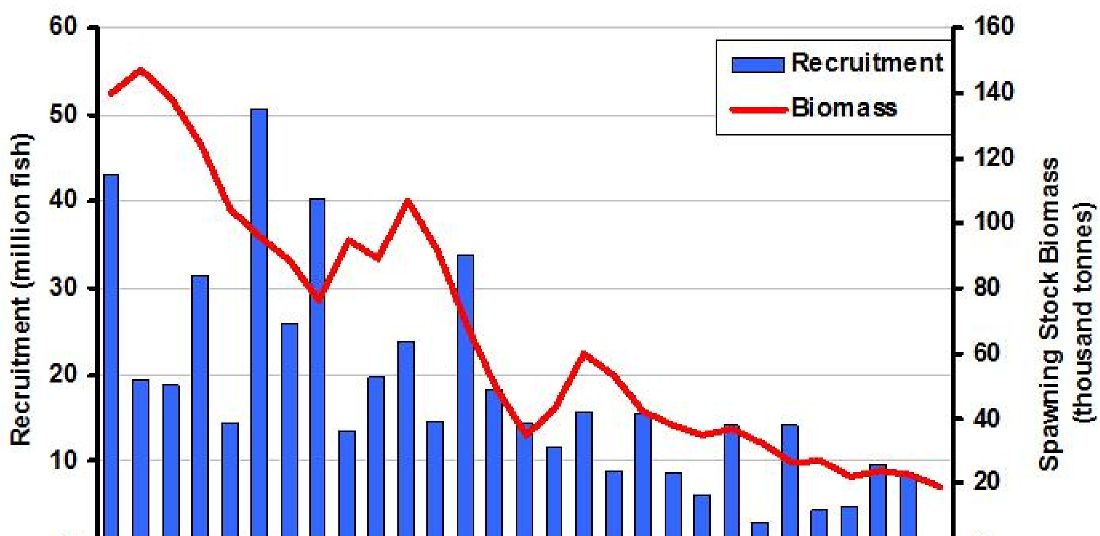

Figure 22. Recruitment (age 1) and spawning stock biomass (age 3+) of Southern DU cod.

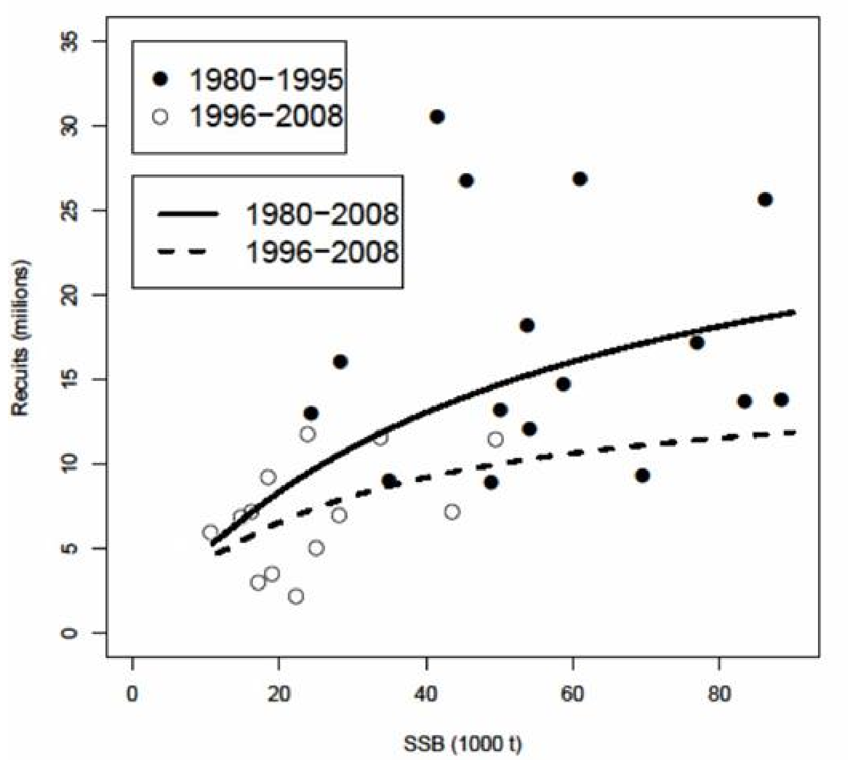

Figure 23. Stock-recruit relationship for 4X5Yb cod.

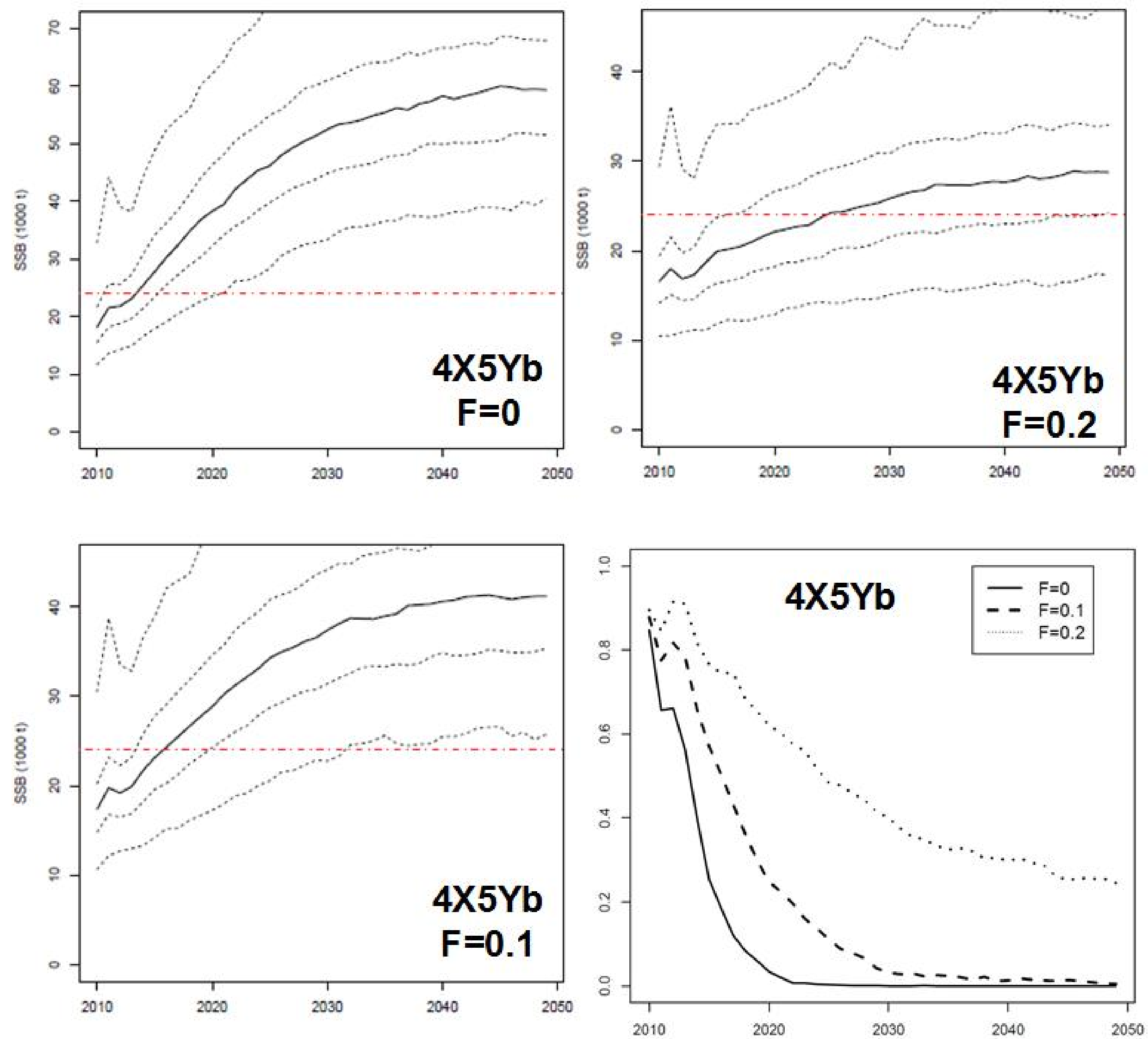

Figure 24. Projected SSB of Division 4X5Yb cod relative to the LRP at different levels of fishing mortality, assuming that current productivity conditions were to persist in the future. Heavy lines show the median projection and light lines the 2.5th, 25th, 75th and 97.5th percentiles. The dash-dotted horizontal line in the panels labelled F=0, 0.2 and 0.1 is the LRP of 24,000t. The panel on the bottom right shows the probability that SSB is less than the LRP at three different levels of fishing.

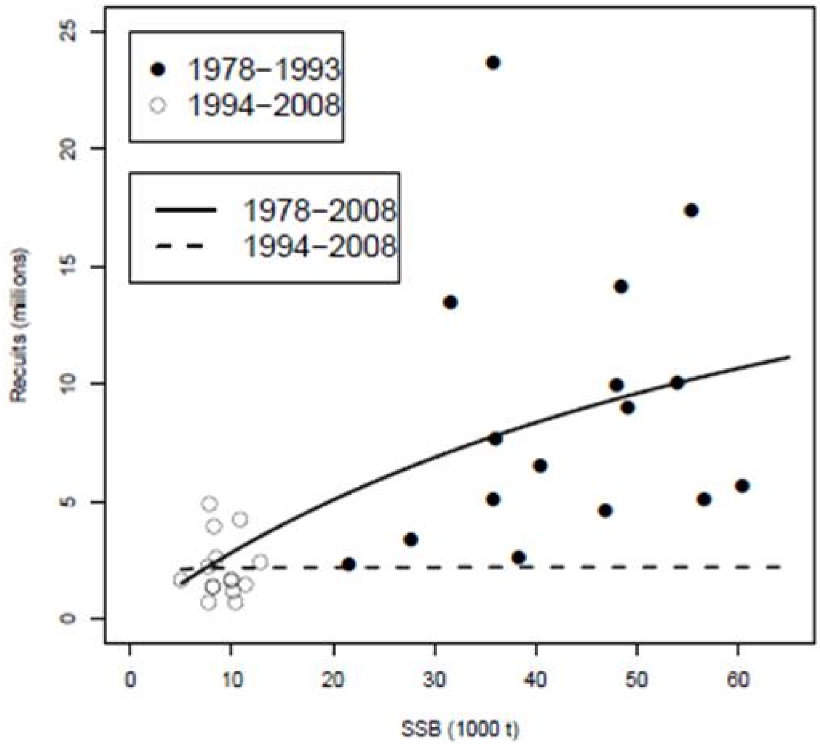

Figure 25. Short (1994 to 2008) and long term (1978 to 2008) stock-recruit relationships for 5Zjm cod.

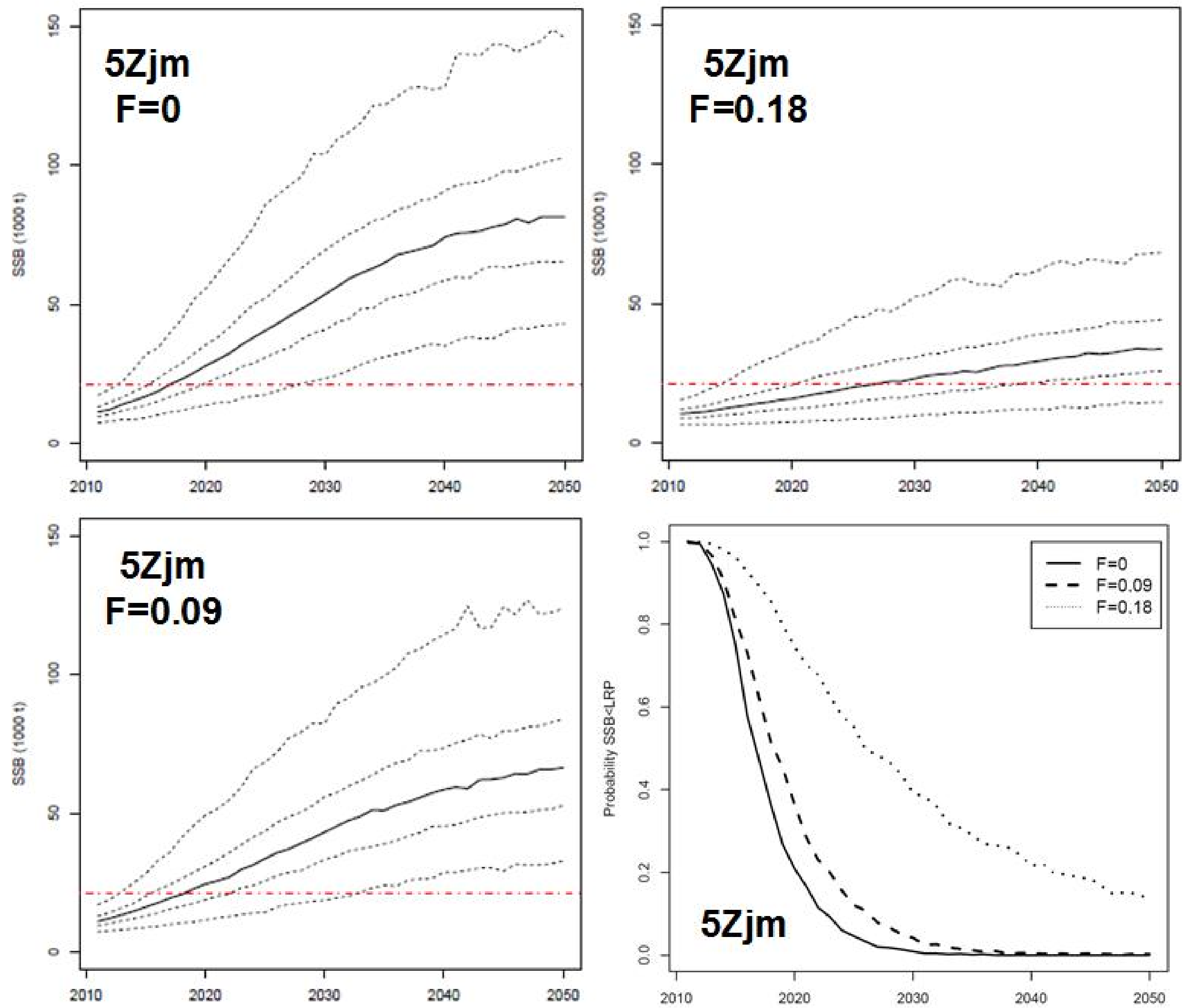

Figure 26. Projected SSB of Division 5Zjm cod relative to the LRP at different levels of fishing mortality, assuming that current productivity conditions were to persist in the future. Heavy lines show the median projection and light lines the 2.5th, 25th, 75th and 97.5th percentiles. The dash-dotted horizontal line in the panels labelled F=0, 0.18 and 0.09 is the LRP of 21,000t. The panel on the bottom right shows the probability that SSB is less than the LRP at three different levels of fishing.

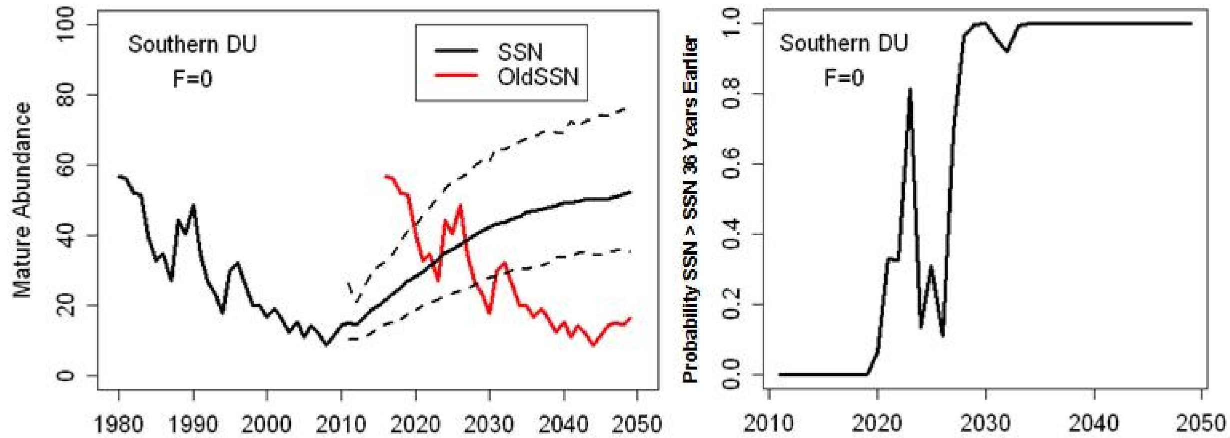

Figure 27. Left Panel - combined mature abundance of Southern DU cod with no fishing. Solid line is estimated abundance prior to 2010, and projected abundance under F = 0. Dashed lines are 2.5th and 97.5th percentiles. The lighter solid line is for comparison purposes and shows abundance 36 years prior to each projected year. Right Panel - probability that the spawning stock number (SSN) projected under F=0 conditions will exceed the SSN from 36 years earlier.

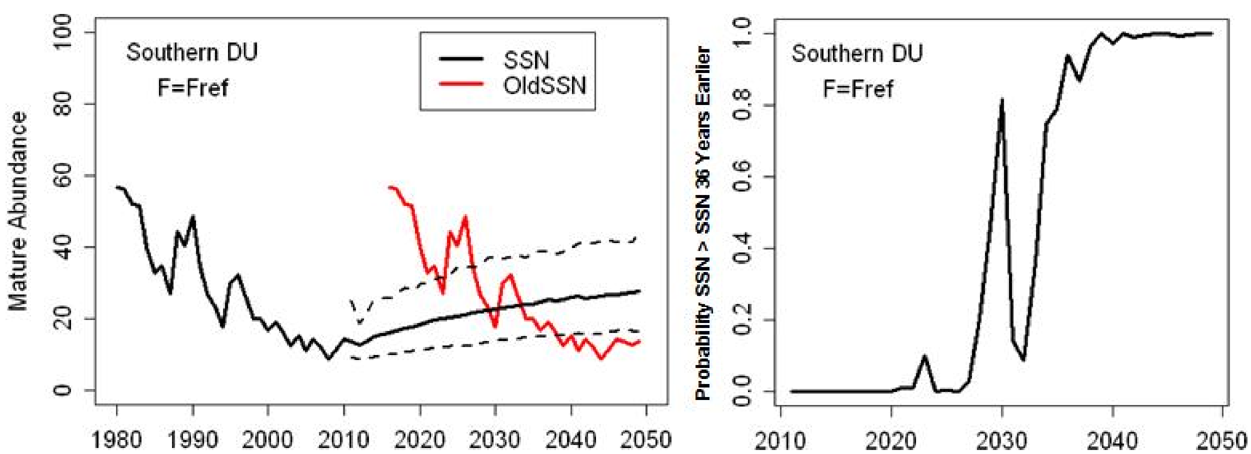

Figure 28. Left Panel - combined mature abundance of Southern DU cod fishing at F_{ref}. Solid line is estimated abundance prior to 2010, and projected abundance under F_{ref}. Dashed lines are 2.5th and 97.5th percentiles. The lighter solid line is for comparison purposes and shows abundance 36 years prior to each projected year. Right Panel - probability that the spawning stock number (SSN) projected under F=F_{ref} conditions will exceed the SSN from 36 years earlier.

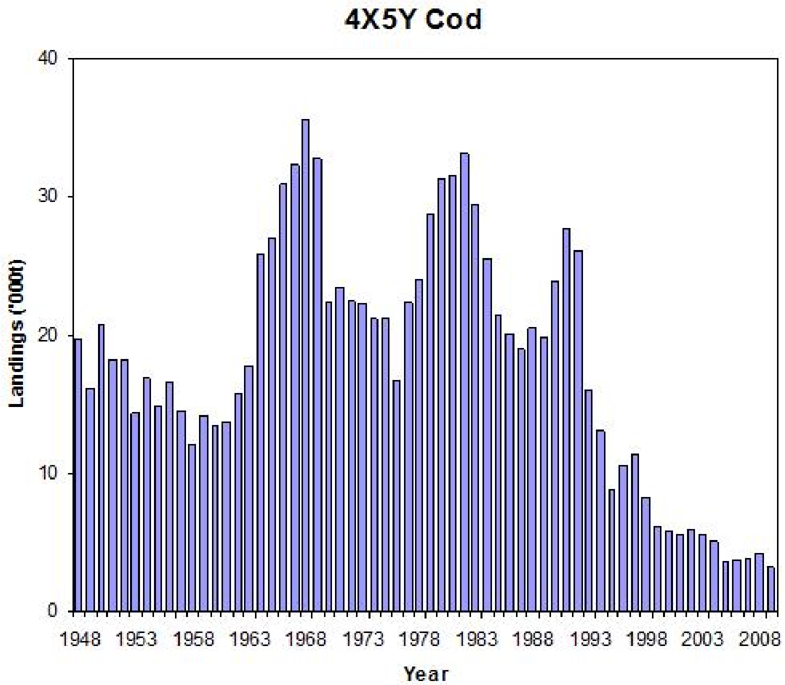

Figure 29. Catches (t) of cod from Division 4X5Yb, 1948 to 2009.

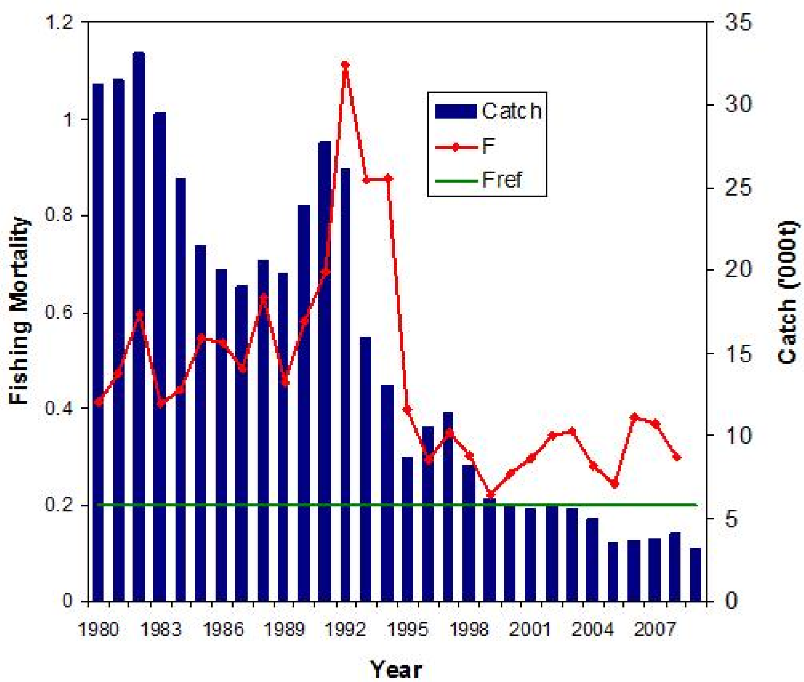

Figure 30. Fishing mortality rate for NAFO Division 4X cod for ages fully recruited to the fishery. The established fishing mortality threshold reference, F_{ref}=0.2, is indicated.

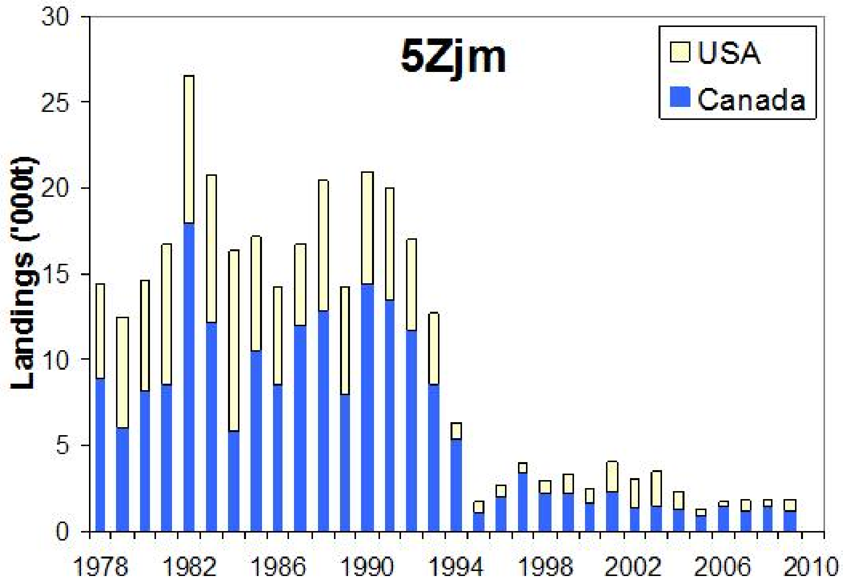

Figure 31. Catches (t) of cod from Eastern Georges Bank, 1978 to 2009.

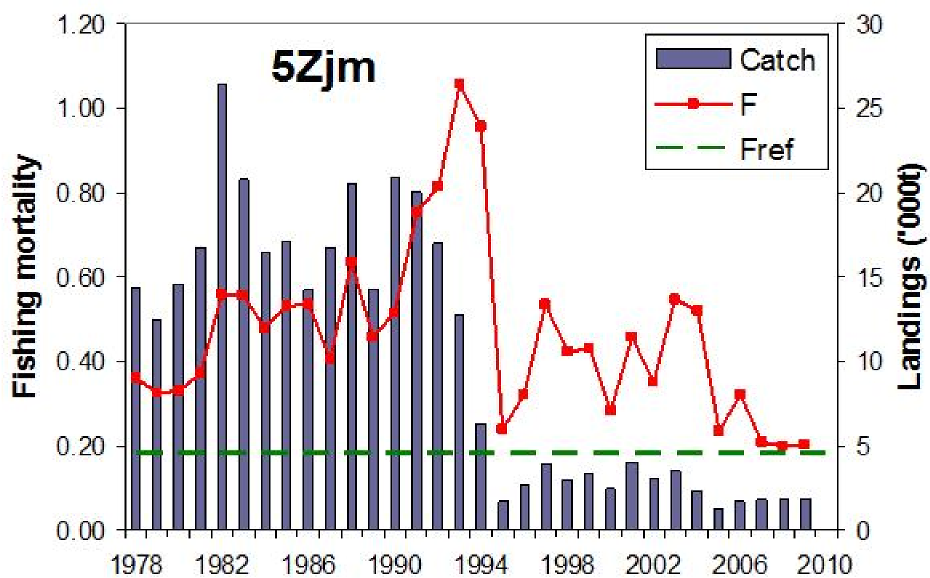

Figure 32. Fishing mortality rate at ages 4 to 9 and catches for Eastern Georges Bank cod. The established fishing mortality threshold reference, F_{ref}=0.18, is indicated.

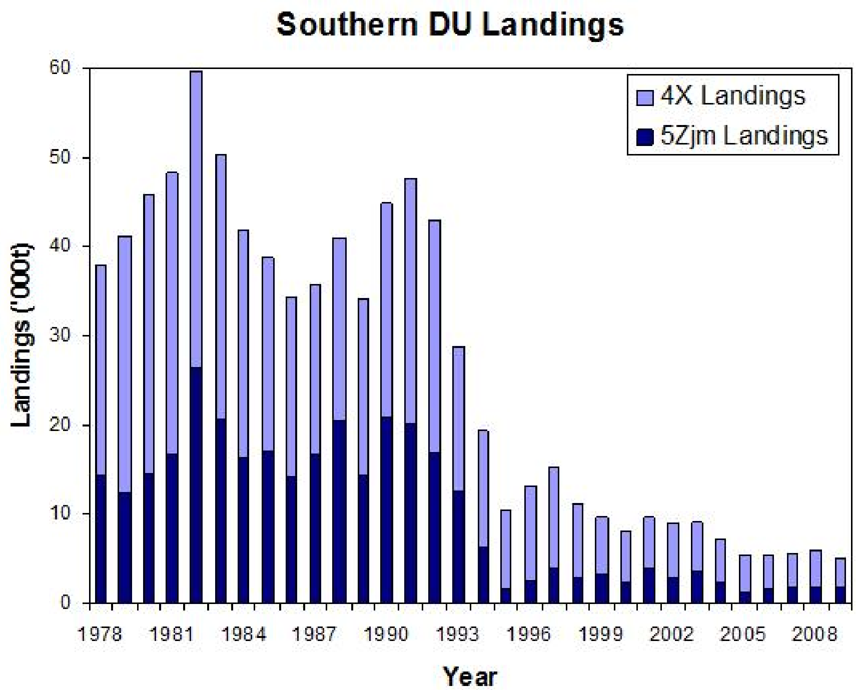

Figure 33. Catches (t) of cod from the Southern DU (4X and 5Zjm landings combined), 1978 to 2009.

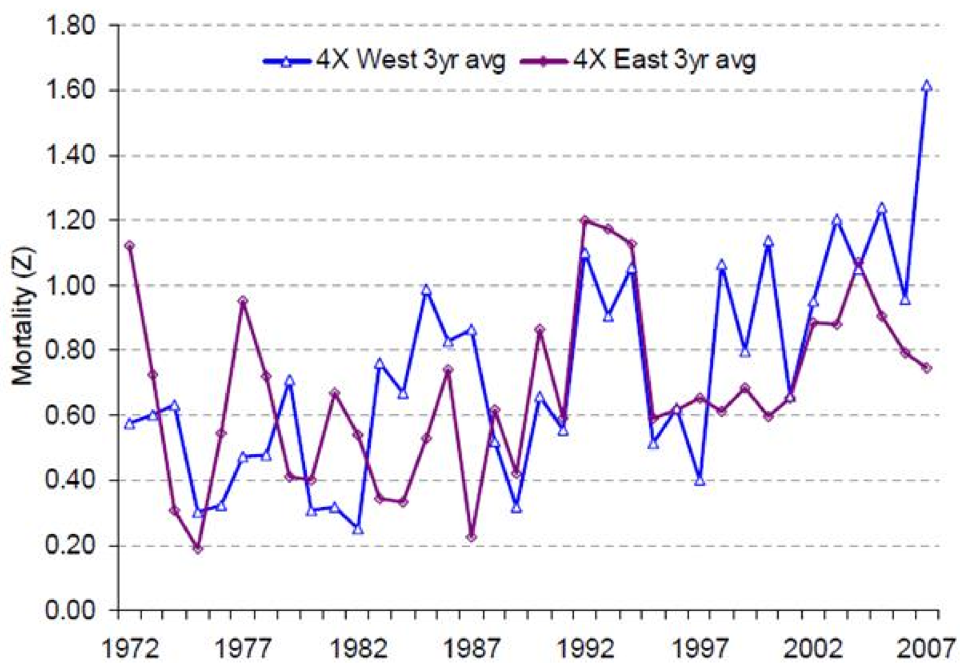

Figure 34. Research vessel survey total mortality estimates (Z) by region for NAFO Division 4X5Yb cod (3 year average).

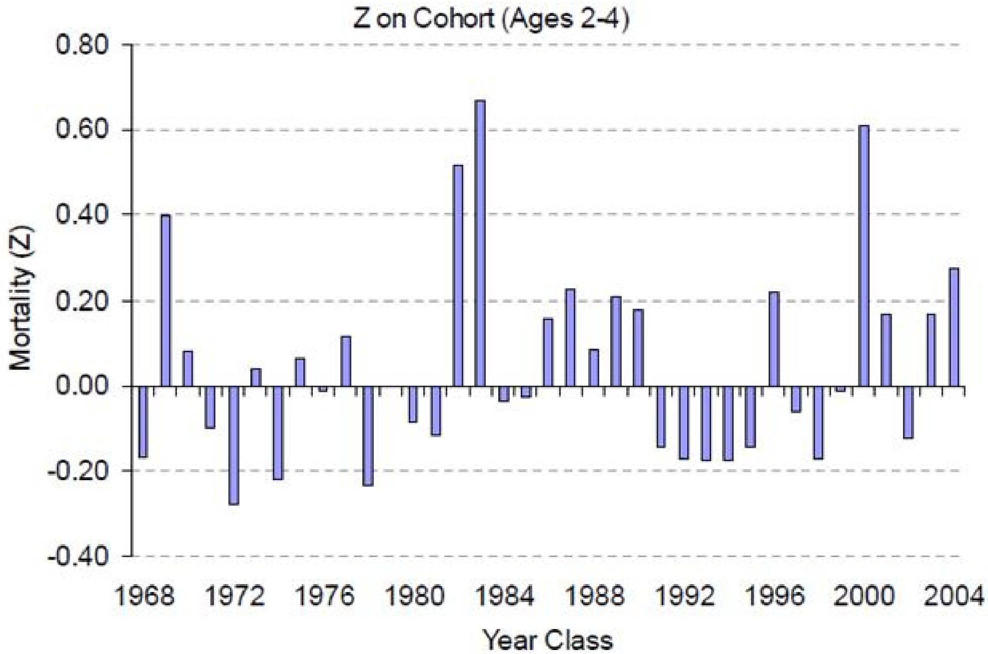

Figure 35. Research vessel survey total mortality estimate of NAFO Division 4X cod for a cohort (ages 2-4).

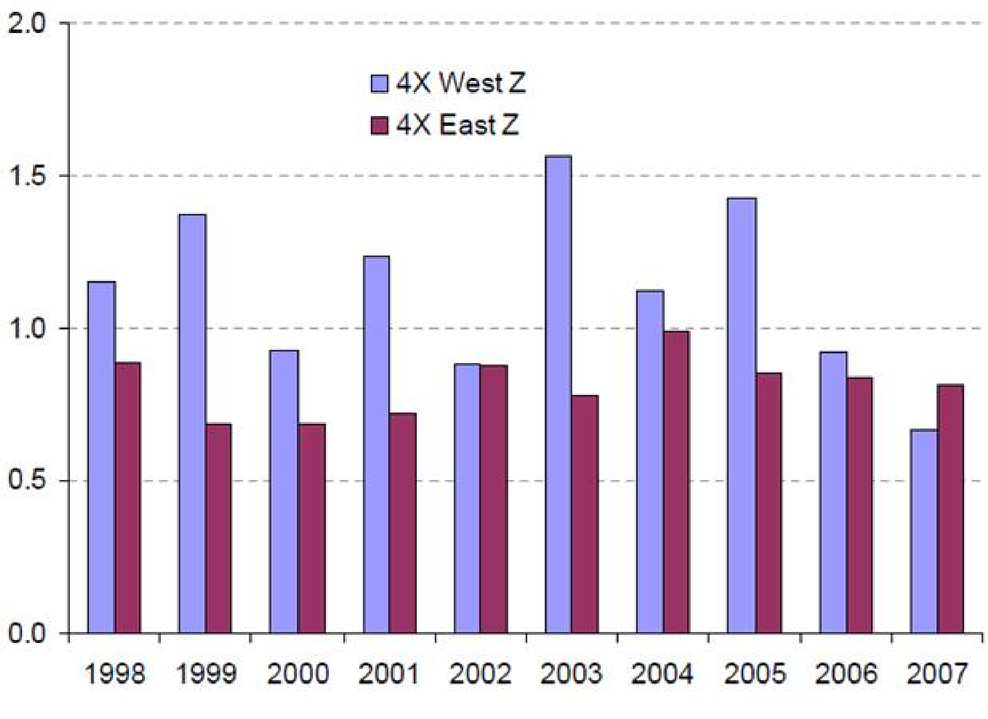

Figure 36. Individual Transferable Quota (ITQ) survey total mortality (Z) estimate of NAFO Division 4X cod by region (3 year average).

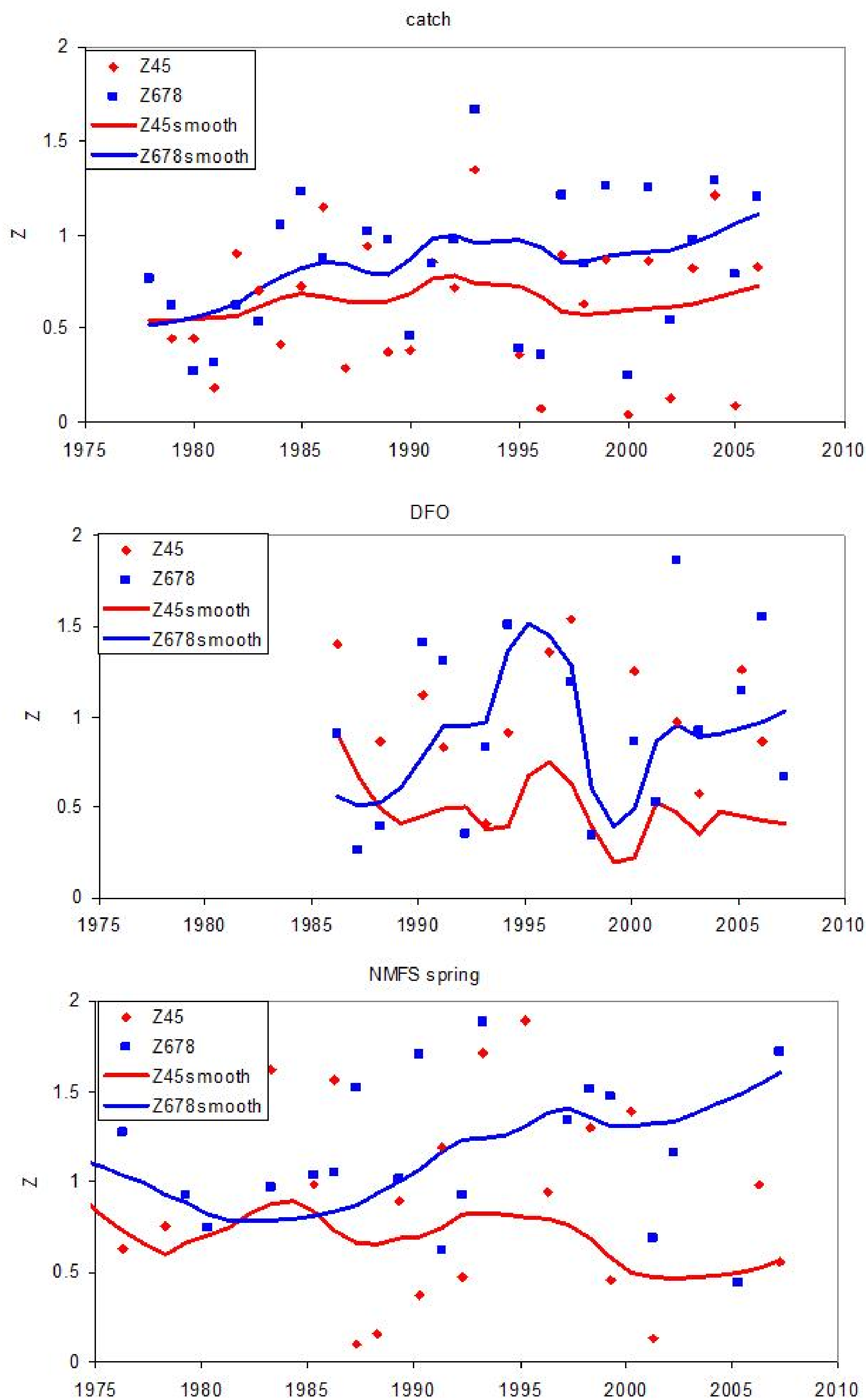

Figure 37. Total mortality calculations from the catch, DFO survey and NMFS spring survey for cod on Eastern Georges Bank.