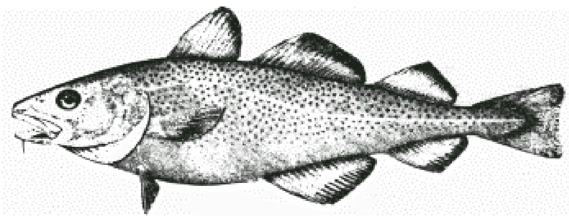
Fisheries and Oceans Canada / Pêches et Océans Canada
Science / Sciences
Newfoundland and Labrador Region
Canadian Science Advisory Secretariat
Science Advisory Report 2006/015

STOCK ASSESSMENT OF NORTHERN (2J3KL) COD IN 2006



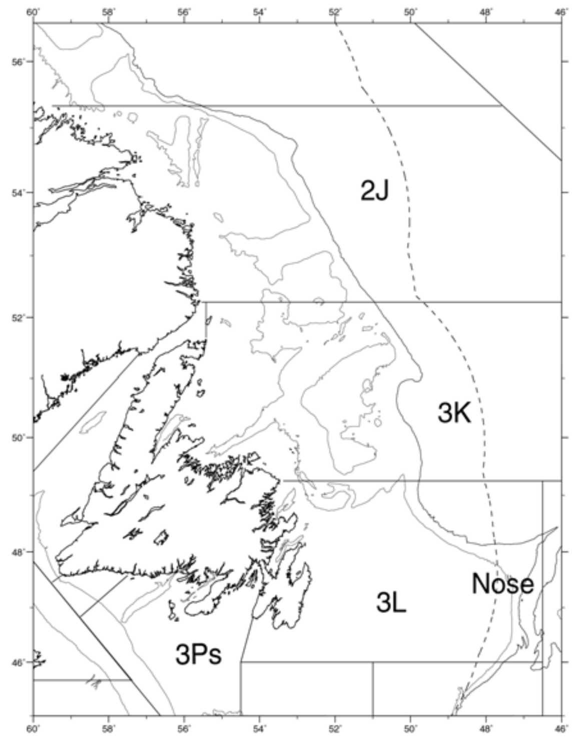


Figure 1: Map of the stock area of northern (2J3KL) cod. The dashed line indicates Canada's 200 nautical mile Exclusive Economic Zone (EEZ).

Context :

The biomass (of ages 3 and older) of the northern (2J3KL) cod stock off southern Labrador and eastern Newfoundland was about 3 million t in the early 1960s. Fishing intensity increased greatly in the 1960s as non-Canadian fleets exploited dense offshore overwintering aggregations. The stock collapsed to about 0.5 million t by the late 1970s. After extension of jurisdiction in 1977, the stock recovered partially to just over 1 million t in the mid-1980s, but it declined again during the late 1980s and collapsed to an extremely low level by the early to mid-1990s. A moratorium on commercial fishing was declared in 1992.

Historically, many cod migrated from overwintering areas offshore to feeding areas inshore, where they were exploited by the traditional inshore fixed-gear fishery. By the mid-1990s it was apparent that these offshore populations were barely detectable. At the same time, it was recognized that there were aggregations of cod in the inshore in Div. 3L and southern Div. 3K. These inshore populations appeared to be more productive during the 1990s than populations in the offshore. A small fishery directed at these inshore populations was introduced in 1998. Catch rates declined and the directed commercial fishery was closed indefinitely in 2003. A food/recreational fishery, which had been open for several years, was also closed.

Prior to the collapse of the stock, sequential population analysis (SPA) of the stock as a whole was the main tool used to estimate stock size and trends over time, and to provide a basis for projections. From 1999 to the present, information on stock status has been provided separately for the offshore and the inshore. Status and trends in the offshore were monitored by research bottom-trawl surveys of the whole of Div. 2J3KL in the autumn and Div. 3L only in the spring. Additional information came from *hydroacoustic studies conducted in two specific areas. Status and trends in the inshore were assessed and monitored by sentinel surveys, hydroacoustic surveys in one specific area, and tagging studies, which provided information on exploitation rates and biomass. No whole-stock SPA has been accepted since the early 1990s.*

In 2003, SPA was reintroduced to the assessment but applied solely to data collected in the inshore since the mid-1990s. The stock was closed to directed fishing following this assessment. In 2004, there was an update of the major indices (research bottom-trawl surveys offshore and sentinel surveys and the hydroacoacoustic survey inshore). In 2005, in response to demands that the inshore fishery be reopened, the stock was again assessed in detail. This time, the area to which SPA was applied was reduced from the whole of the inshore to a smaller area encompassing southern 3K and northern 3L. This SPA was tuned with three indices from the sentinel surveys. The offshore continued to be monitored by the bottom-trawl surveys.

The whole stock area remained closed to directed commercial and recreational fishing in 2005. Demands for an inshore fishery intensified, and a detailed assessment was again requested. Note that there are as yet no management goals against which current status and projected trends may be compared; there is no target for rebuilding, nor is there a target rebuilding rate.

The present assessment is a result of a request for science advice from the Fisheries and Aquaculture Management (FAM) Branch, Newfoundland and Labrador Region. The objectives were as follows:

- *Assess the current status of offshore populations, inshore populations and the stock as a whole. In particular, assess current spawning biomass, total (age 3+) biomass, exploitation rate, natural mortality and biological characteristics (including age composition, size at age, age at maturity, and distribution). Describe these variables in relation to historic observations.*
- *Highlight major sources of uncertainty in the assessment, and where appropriate, consider alternative analytical formulations of the assessment.*
- *To the extent possible with available information, provide information on the strengths of year-classes expected to enter the exploitable populations in the next 1-3 years.*
- *Assess the implications of inshore fishery removals varying from zero to 2,500 t annually in 2006 and the medium term. Implications are to be assessed with respect to growth of inshore populations, growth of offshore populations, and recovery of the stock as a whole.*
- *Assess the implications of conducting an inshore fishery on a bay-by-bay basis.*
- *Assess the effect of the Hawke Channel closed area (cod box).*

SUMMARY

- The stock remained closed to directed fishing during 2005, but 1060 t were caught as by-catch, mainly in the inshore in the winter flounder (blackback) fishery. An additional 160 t were taken in the sentinel surveys, for a total of 1220 t.
- Due to differences in the dynamics of offshore and inshore populations of 2J3KL cod since the mid-1990s, information is provided for the offshore and inshore separately.
- In the offshore, the 2005 research bottom-trawl surveys during both spring and autumn indicate that the biomass of cod remains extremely low. The average biomass index from autumn surveys during 2003-2005 is about 20,000 t, which is less than 2% of the average during the 1980s. An index of spawner biomass is at about 1%.

- Estimates from the autumn research bottom-trawl survey data indicate that recruitment in the offshore has been very low and total mortality has been extremely high since at least the mid-1990s. Few fish survive beyond age 5.

- In the inshore, catch-rate indices from linetrawl and gillnet sentinel surveys in the inshore as a whole increased from 1995 to a peak in 1997 and 1998 respectively, declined by the early 2000s, and then increased during recent years. Current estimates are similar to or above average.

- Fish harvesters who were contacted during a telephone survey differed geographically with respect to their opinions on the abundance of cod in inshore waters. In 2J, most felt that cod abundance during 2005 was lower than it had been during the late 1980s but higher than during 2004. In 3K and 3L, most felt that abundance during 2005 was higher than during the late 1980s, and had either not changed or had increased relative to 2004.

- Tagging studies have revealed that during the period from the late 1990s to 2003 there were two main groups of cod in the inshore in southern 3K and in 3L. The first group comprised resident fish that overwintered in northern 3L and southern 3K and undertook seasonal migrations among Trinity, Bonavista and Notre Dame bays. The second group comprised migratory fish that overwintered in inshore and offshore areas of 3Ps, moved into southern 3L in the spring-summer, and returned to 3Ps in the autumn. It was thought that migrants from offshore 2J3KL contributed little to the biomass of cod in the inshore of 2J3KL.

- Inshore stock composition is less clear in 2005, notably because of higher catch rates in sentinel surveys in 2J and northern 3K.

- Nevertheless, following the procedure adopted in 2005, the inshore is subdivided for assessment purposes into three areas: 1) a northern area (2J and northern 3K); 2) a central area (southern 3K and northern 3L) where most of the resident inshore fish are located; and 3) a southern area (southern 3L) that is, at present, largely dependent on cod that overwinter in inshore and offshore areas of 3Ps, move into southern 3L in the spring-summer, and return to 3Ps in the autumn.

- A sequential population analysis (SPA) was conducted for the inshore central area. The analysis incorporated catches during 1995-2005 and three indices from sentinel surveys. SPA estimates indicated that spawner biomass in this area increased from 10,000 t in 1995 to 22,000 t in 1998, declined during 1998-2002 (when there was a commercial fishery) to 7000 t in 2003, and has subsequently increased to 14,000 t by the beginning of 2006. This increase is due to reduced fishing mortality and improved recent recruitment. The estimate of age 4+ biomass at the beginning of 2006 is about 23,000 t.

- Deterministic projections from 2006 to 2007, based on the SPA, were conducted for the inshore central area under various annual catch and recruitment options. Assuming no removals or a catch option of 2500 t, spawner biomass is projected to increase.

- Due to uncertainties in future recruitment levels, deterministic projections from 2006 to 2009 were conducted for the inshore central area under various annual catch options and three recruitment assumptions. Assuming removals of 1250 t or less, spawner biomass is projected to increase for each recruitment assumption. At a catch option of 2500 t, spawner biomass is projected to decrease if recruitment is low, but to increase otherwise.

- Risk of the spawner stock biomass in the inshore central area growing by less than 5% during the next 1-3 years increases rapidly with TAC options above 1000 t and exceeds 0.3 for a TAC option of 2500 t.

- In the inshore northern area, it is not known if the large increase that occurred in sentinel catch rates in 2005 reflects an increase in fish abundance that will continue into 2006, or a temporary increase due to immigration, possibly of cod from the offshore. It would be prudent to keep catches low in this area.

- The inshore southern area is primarily dependent on seasonal immigration of fish, the magnitude of which cannot be predicted. Therefore, the effect of removals of various levels cannot be estimated.

- There is a risk that fishing in the inshore will impede recovery in the offshore. However, at this time the level of risk is difficult to quantify.

- There is no single measure of the biomass of the 2J3KL cod stock as a whole. The information from the bottom-trawl survey in the offshore and the SPA in the central part of the inshore are not directly comparable, but the offshore biomass index and the estimate of inshore biomass are of the same order of magnitude.

- The current biomass of the stock as a whole is a very small proportion of the approximately 3 million t (of ages 3 and older) estimated for the early 1960s.

INTRODUCTION

Species Biology

Cod off Labrador and eastern Newfoundland have historically lived to an age of 20 or more. They grow slowly compared with individuals in the eastern Atlantic and further south in the western Atlantic. In recent years the females have been maturing at about age 5, which is younger than had been the case.

Much of the stock has historically been highly migratory. They overwintered near the edge of the continental shelf and migrated in spring/summer to shallow waters along the coast and onto the plateau of Grand Bank.

Both prey and predators change as the cod grow. Small cod tend to feed on small crustaceans, such as mysids, euphausiids, amphipods, and small shrimp; medium-sized cod feed on larger crustaceans and small fish, especially capelin, sand lance and herring; and large cod feed on medium-sized fish and crabs, especially toad crabs and small snow crabs. Capelin in particular has historically been a very important part of the annual diet. Very small cod are eaten by squid, many species of groundfish, including larger cod, and some species of birds. Larger juveniles are eaten by larger groundfish, seals, certain toothed whales, and possibly minke whales. Large cod probably have few natural predators, but seals can prey upon them by belly-feeding. Much attention in recent years has been focused on seals, especially harp seals.

Stock Structure

Since the mid-1990s, there has been a dichotomy between the offshore and the inshore. Cod in the offshore have been small due to low survival and are at very low density, whereas cod in the inshore have included larger sizes and have been found in relatively high densities in some times and places. Various observations, both historic and recent, and much of the genetic information, are consistent with the hypothesis that there are populations in the inshore that are functionally distinct from those in the offshore. It is thought that these inshore populations have historically been small relative to the populations that migrated into the inshore from the offshore during spring/summer.

Tagging studies have revealed that during the period from the late 1990s to 2003 the inshore of 3KL was inhabited by at least two groups of cod: (1) a northern resident coastal group that inhabited an area from western Trinity Bay northward to western Notre Dame Bay and (2) a migrant group that overwintered in inshore and offshore areas of 3Ps, moved into 3L during late spring and summer, and returned to 3Ps during the autumn. Tagging studies also indicated considerable movement of cod among Trinity, Bonavista and Notre Dame bays. Historically, this stock structure was not evident because the majority of fish observed during inshore fisheries were migrants from the offshore.

The above understanding regarding groups of cod in the inshore became less clear in 2005, notably because catch rates increased in sentinel surveys in 2J and northern 3K (see below). The stock affinity of the fish that appeared in higher densities in the northern portion of the inshore needs to be clarified.

The extent of migration between the inshore and offshore of 2J3KL during recent years is not well understood. There has been only one reported offshore recapture of a cod tagged inshore after the mid-1990s, but of course there has been no directed offshore cod fishery during this period, so recaptures could come only from fisheries directed at other species. It is thought that migrants from offshore 2J3KL currently contribute little to the biomass of cod in the inshore of 2J3KL.

Fishery

Catches of northern cod increased during the 1960s to a peak of over 800,000 t in 1968, declined steadily to a low of 140,000 t in 1978, recovered to about 240,000 t through much of the 1980s, and then declined rapidly in the early 1990s in advance of a moratorium on directed fishing in 1992 (Fig. 2).

Catches during 1993-1997 came from by-catches, food/recreational fisheries, and DFO-industry sentinel surveys that started in 1995. A small index/commercial fishery limited to fixed gear deployed from small (<65 feet) vessels commenced in 1998. Catches from 1998 to 2002 came from directed cod fisheries, by-catches, sentinel surveys and food/recreational fisheries. The directed commercial and recreational fisheries were closed indefinitely in April 2003.

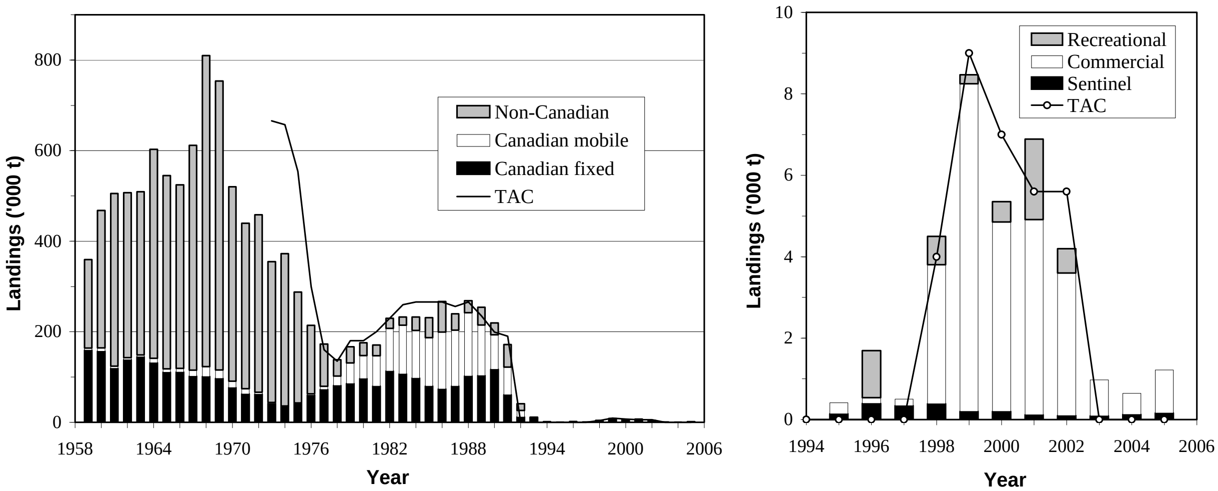


Figure 2: Total allowable catches (TACs) and landings (thousands of tons) in 1959-2005. The left panel shows landings by non-Canadian and Canadian fleets, with the latter divided into mobile gear (offshore) and fixed gear (mainly inshore). The right panel shows 1995-2005 in more detail, with the catch subdivided into food/recreational, index/commercial (including by-catch) and sentinel.

Table 1: Catch (thousand metric tons).

Year	62-76 Avg.	77-91 Avg.	1998	1999	00/01	01/02	02/03	03/04	04/05	05/06
TAC	N/A	N/A	4	9	7	6	6	0	0	0
Can. Fixed	88	90	5	9	5	7	4	1	1	1
Can. Mobile	9	84	+	0	+	+	+	+	+	+
Others	405	38	+	+	+	+	+	+	+	
Totals	502	212	5	9	5	7	4	1	1	1

Fishery management regulations in 2005 were similar to those in 2004. The whole of 2J3KL remained closed to directed cod fisheries, and by-catch regulations were in place for fisheries directed at other species. For the winter flounder (blackback) fishery in 3KL, the incidental catch of cod was not to exceed 20% or 300 pounds per day, whichever was greater (as in 2004). The maximum number of nets to be used was reduced from 30 to 15, and the mesh size limitation was broadened from 6½ - 8½ inches to 5½ - 8½ inches. The total quantity of cod taken in the blackback fishery was limited at 2000 lbs per licence holder. The fishery was to be open from August 4 to August 26, but was closed on August 17 because by-catch of cod was considered to be excessive. The total quantity of cod taken far exceeded the total quantity of blackback.

Reported landings during 2005 were approximately 1060 t of by-catch from commercial fisheries and 160 t from the sentinel surveys, for a total of 1220 t. Most of the by-catch came from gillnets during the winter (blackback) flounder fishery. The by-catch from Canadian trawlers in the offshore was 1 t. The catch comprised a range of ages, with ages 5-7 predominant. The 1990 and 1992 year-classes, which had been major contributors to growth of the inshore populations in the mid-1990s, were weakly represented.

Discarding occurs in the shrimp fishery and also possibly other fisheries. The quantity of cod discarded from the shrimp fishery has in recent years been less than 5 t annually. These fish are small (mode about 19 cm). The number of fish removed at age has not yet been computed.

An estimate is not yet available for the 2005 catch by non-Canadian trawlers outside the 200 nautical mile limit on the Nose of the Bank (Div. 3L). The Scientific Council of the Northwest Atlantic Fisheries Organization (NAFO) determined that annual catches during 2000-2004 were 80 t or less.

ASSESSMENT

Sources of Information

Due to differences in the dynamics of offshore and inshore populations since the mid-1990s, information is provided for the offshore and inshore separately.

For the offshore, indices of abundance and biomass are obtained from research bottom-trawl surveys conducted in the whole of Div. 2J3KL during the autumn and in Div. 3L during the spring. Information on recruitment and total mortality is obtained from catch rate at age in the autumn surveys. Additional information on biomass and age composition has been obtained from hydroacoustic surveys in Hawke Channel (Div. 2J).

For the inshore, indices of abundance are provided by fixed-gear sentinel surveys, which are conducted by two traditional gears (gillnets of 5½ inch mesh and linetrawls) and a non-traditional gear (3¼ inch mesh gillnet, which is intended to provide information on young fish). For several years, tagging studies provided information on distribution/migration and exploitation and, in conjuction with landings, also provided estimates of biomass. The tagging studies were considerably reduced following the reimposition of the moratorium in 2003. Hydroacoustic surveys were conducted in Smith Sound for many years, but 2004 was the last year in the time series. A telephone survey of fish harvesters' observations is conducted by the Fish, Food and Allied Workers (FFAW) Union. Information on the relative abundance of very young cod is provided by beach seine studies in Newman Sound in Bonavista Bay. Information on the size and age composition of the catch (only by-catch since 2003) is obtained from lengths and otoliths collected from cod sampled at ports.

Stock Trends – Offshore

Bottom-trawl surveys

The offshore biomass index values from the autumn **research bottom-trawl surveys** in 2J3KL have been very low for more than a decade (Fig. 3). The biomass index during 2003-2005 was 1-2% of the average during the 1980s.

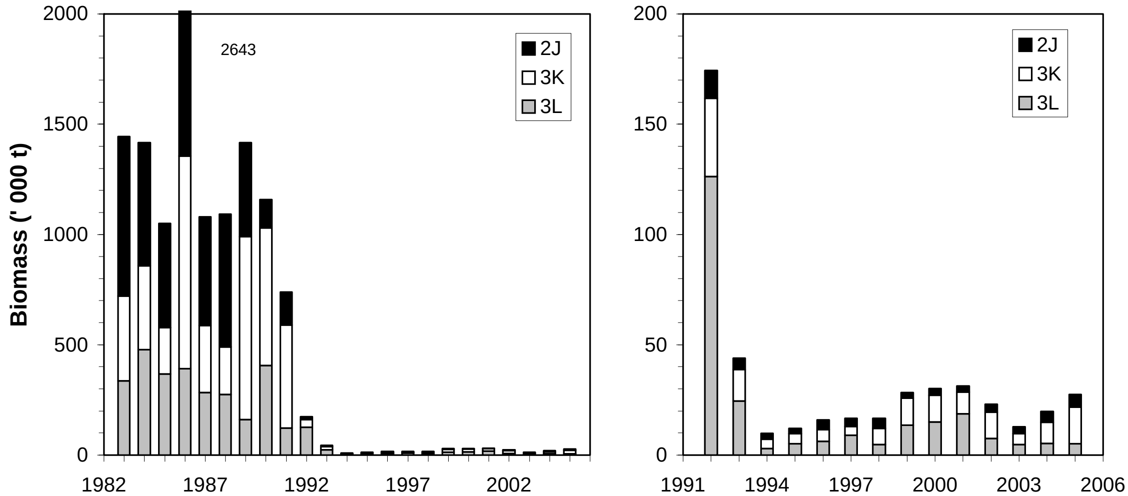


Figure 3: Offshore biomass index from autumn bottom-trawl surveys in 2J3KL. The left panel shows data from 1983 to 2005. The scale on the right panel shows just the lower 10% of the left panel, in order that the data from 1992 to 2005 may be more readily discerned.

The spawning stock biomass index computed from the autumn surveys has, during the most recent three years, been at about 1% of the average of the 1980s.

The biomass index from the spring research bottom-trawl survey in 3L was, during 2001-2004, less than 1% of the average in the 1980s (Fig. 4). However, the value in 2005 was about 2.5% of the 1980s average, similar to that in 1999.

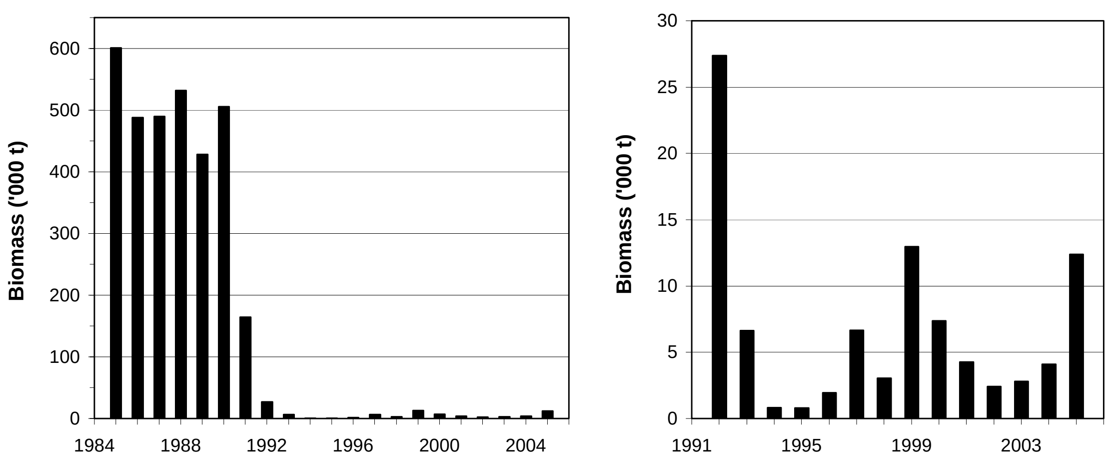


Figure 4: Biomass index from spring bottom-trawl surveys in 3L. The left panel shows data from 1985 to 2005. The scale on the right panel shows just the lower 5% of the left panel, in order that the data from 1992 to 2005 may be more readily discerned.

There is at present no analytical model of the dynamics of cod in the offshore of 2J3KL. Information on recruitment and mortality is derived from analyses of mean catch rate at age during the autumn offshore bottom trawl surveys.

An index of **recruitment** (Fig. 5) shows the 1980-1982 year-classes to be relatively strong, and the 1986 and especially the 1987 year-classes to be equally strong. This latter peak of young fish seemed to disappear rapidly from the surveys and commercial catches and made only a very small contribution to the spawning stock. All year-classes since the very late 1980s have been very weak in the offshore.

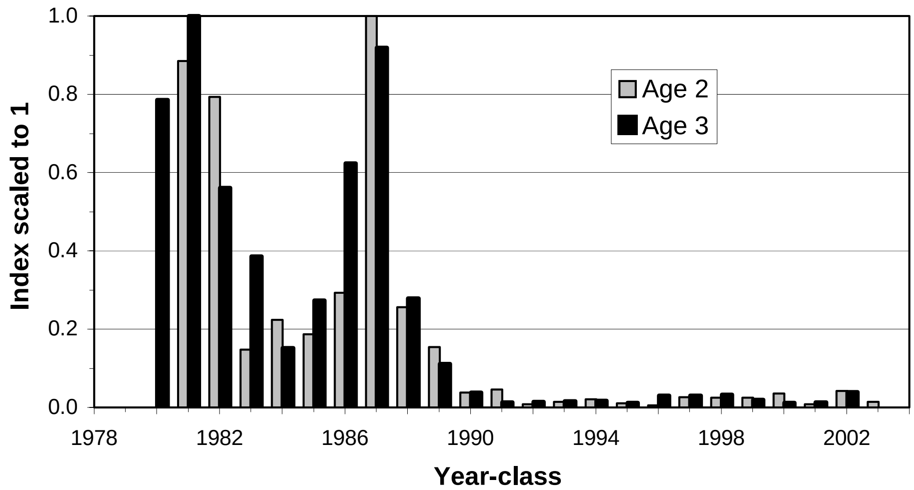


Figure 5: Relative sizes of the 1980-2002 year-classes in the offshore of 2J3KL, as measured by the mean catch per tow at ages 2 and 3 during the autumn offshore bottom-trawl surveys. Number per tow has been scaled to a maximum of 1 within the time-series for each age.

The annual **mortality** rate (percentage of population dying in a year) rose to a very high level by the early 1990s, and remained extremely high for a few years after the start of the moratorium in 1992. The paucity of older fish (ages 8 and older) in the survey since the early 1990s prevents estimating total mortality on these older ages. For younger ages, mortality has remained very high since the mid-1990s, averaging about 60-70% per year (Fig. 6).

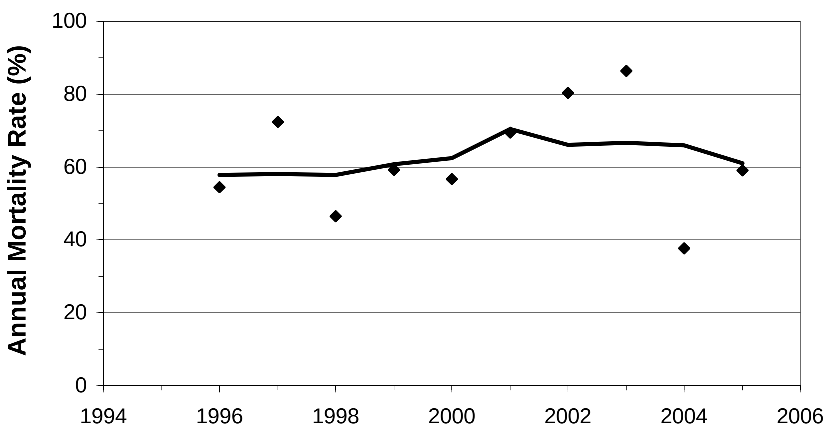


Figure 6: Annual mortality rate (percentage dying) calculated from catch per tow at age during the autumn bottom-trawl surveys in the offshore of 2J3KL. As an example, the value of 54% in 1996 is the mortality experienced by the 1991-1989 year-classes from ages 4-6 in 1995 to ages 5-7 in 1996. The smooth line is a moving average.

To date it has not been possible to distinguish the relative contributions of fishing and natural mortality to this high total mortality. Reported by-catches in the offshore have been small, so considerable attention has focused on the possibility that natural mortality is high.

Hydroacoustic studies

Hydroacoustic studies were conducted in Hawke Channel (Div. 2J), initially by DFO and then by the Fisheries Conservation Chair at Memorial University of Newfoundland, during June 1994-1996 and 1998-2003. The purpose was "to measure the abundance of adult and demersal juvenile cod off southern Labrador during the spring post-spawning period" and the study was "designed to target the historical northern spawning component of the 2J3KL cod stock" (Anderson and Rose 2001). The area covered tended to centre on inner Hawke Channel, but varied somewhat from year to year. Hence, the biomass estimates refer to the magnitude of an identified aggregation; not the biomass of cod in a specific area. Biomass estimates declined from a high in 1994 to a low in 2000, and then increased to an intermediate level in 2002-2003 (Fig. 7). Estimates of abundance at age indicated that mortality remained high for cod older than ages 5 or 6 during the period of increase, so the increase must have been due to increased numbers of younger fish. This could reflect increased recruitment or immigration from elsewhere.

The trend from the hydroacoustic surveys in Hawke Channel contrasts with the index of biomass from the autumn bottom-trawl survey in the whole of Div. 2J. The latter increased to a lesser degree after 2000.

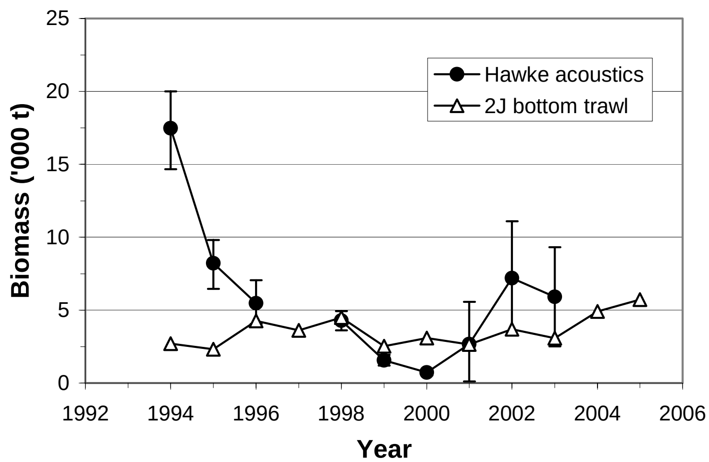


Figure 7: Biomass estimates (with 95% confidence limits) from hydroacoustic studies in Hawke Channel (Div. 2J) during June and indices of biomass from bottom-trawl surveys in the whole of Div. 2J during the autumn.

Stock Trends – Inshore

Following the procedure adopted in 2005, the inshore is subdivided for assessment purposes into three areas (Fig. 8): 1) a northern area (2J and northern 3K); 2) a central area (southern 3K and northern 3L) where most of the resident inshore fish are located; and 3) a southern area (southern 3L) that is, at present, largely dependent on cod that overwinter in inshore and offshore areas of 3Ps, move into southern 3L in the spring-summer and return to 3Ps in the autumn. The dividing lines for these areas are Partridge Point at the western end of Unit Area 3Kh and Grates Point at the southern end of Unit Area 3Lb.

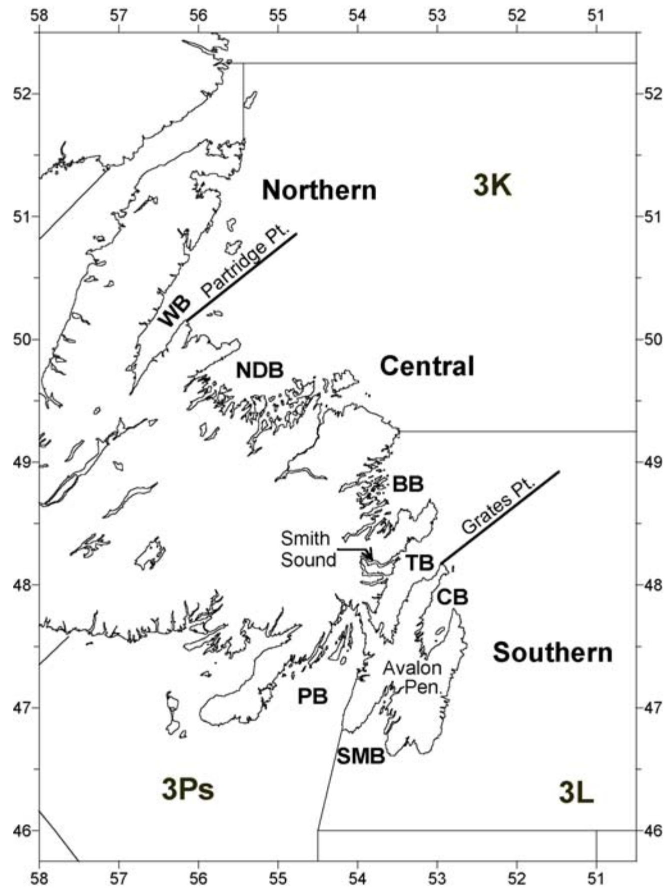


Figure 8: Map of the inshore of eastern Newfoundland, indicating the locations of the northern, central and southern inshore areas as defined for the present assessment. Also indicated are the locations of Smith Sound, the Avalon Peninsula, and the major bays: White Bay (WB), Notre Dame Bay (NDB), Bonavista Bay (BB), Trinity Bay (TB), Conception Bay (CB) and St. Mary's Bay (SMB). Placentia Bay (PB) is in Subdiv. 3Ps.

Sentinel surveys

The sentinel surveys in 2J3KL were initiated in 1995 to provide information on relative density of cod on traditional inshore fishing grounds with two gears commonly used in the commercial fishery; 5½ inch mesh gillnets and linetrawls. Since 1996, small mesh (3¼ inch) gillnets have been used at many sentinel sites to provide information on the size of incoming year-classes. These gillnets are selective for small fish (approximately 34-44 cm; ages 3-4), but also catch larger fish. Catch rates from each of these gears were standardized to remove site and seasonal effects.

Catch-rate indices from gillnet (5½ inch mesh) increased from 1995 to a peak in 1998, declined by the early 2000s, and then increased during recent years (Fig. 9). Current estimates are about average. In the northern area, mean catch rates were low from 1995 to 2004, but increased considerably in 2005. In the central and southern areas, the trends over time were very similar to one another and to the trend in the combined index, but with some differences in recent years. In the central area there has been a gradual increase from the low point in 2002, whereas in the southern area there was a more rapid increase after 2002 followed by a decline from 2004 to 2005.

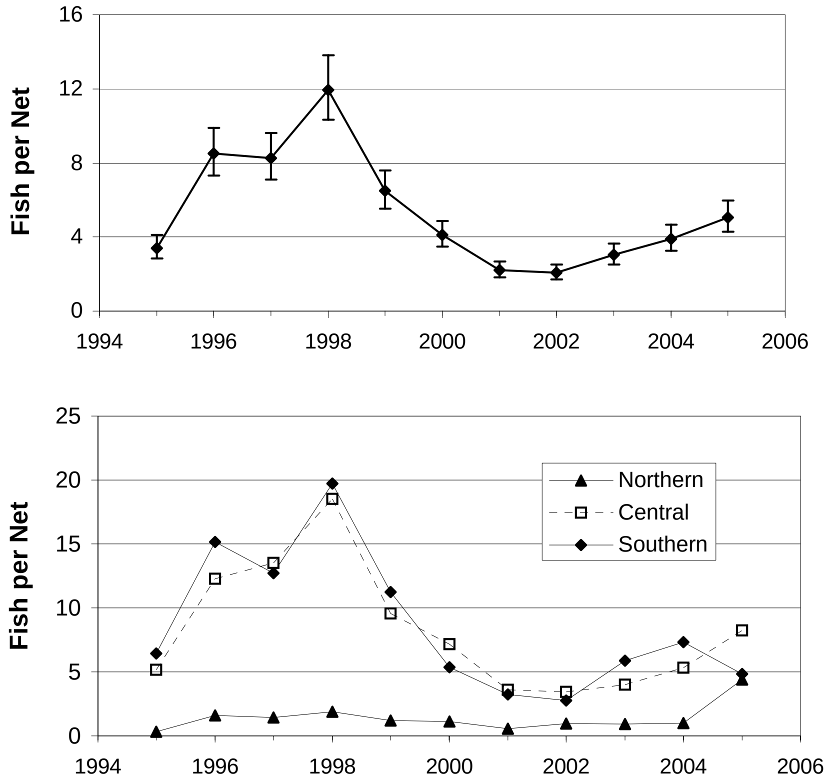


Figure 9: Standardized catch rates from sentinel surveys using gillnets (5½ inch mesh). The upper panel shows all sentinel sites combined and the lower panel shows each of the three inshore areas.

Catch-rate indices from linetrawls increased from 1995 to a peak in 1997, declined by the early 2000s, and then increased during recent years to about average (Fig. 10). In the central area, mean catch rates followed a pattern similar to that for all sites combined, but tended to be higher in the early and later parts of the time series.

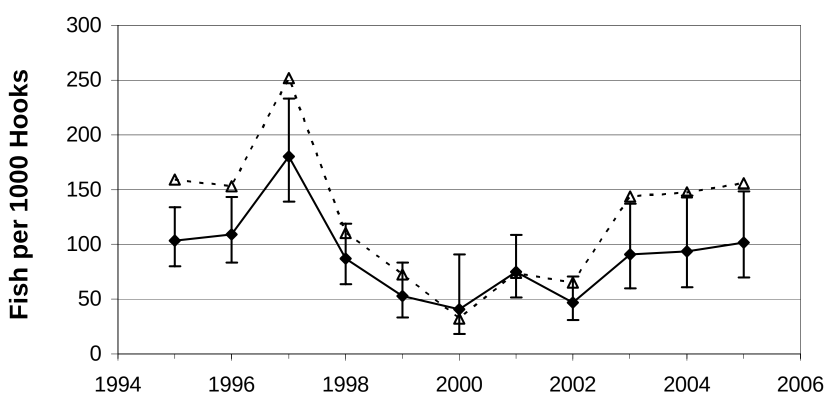


Figure 10: Standardized catch rates from sentinel surveys using linetrawls. The solid line shows all sentinel sites combined and the dashed line shows the index from the central inshore area.

Catch-rate indices from the small mesh (3¼ inch) gillnets declined from 1996 to a low in 1999-2001 and then increased to an intermediate level (Fig. 11). In the central area, mean catch rates followed a very similar pattern to that for all sites combined, but were higher. Fig. 11 does not illustrate changes in catch rates of small fish alone; it includes larger fish, which tended to be caught in higher numbers in the early years.

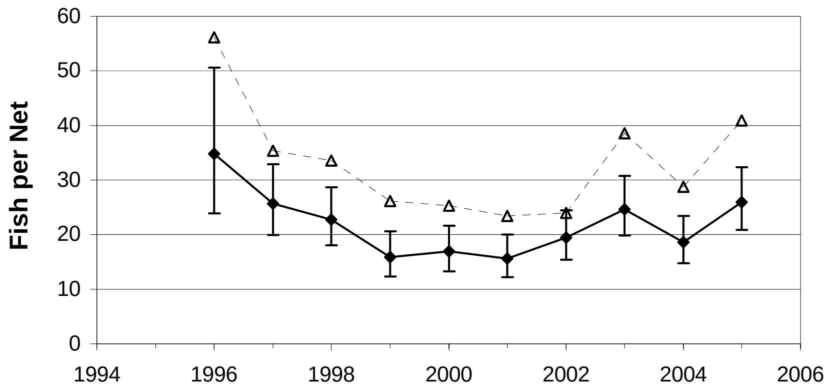


Figure 11: Standardized catch rates from sentinel small mesh (3¼ inch) gillnet surveys. The solid line shows all sentinel sites combined and the dashed line shows the index from the central inshore area.

An examination of catch rates at age from all three sentinel gears reveals that the 1990 and 1992 year-classes were strong, year-classes of the mid- to late 1990s were weak, and year-classes of the early 2000s were moderately strong.

Hydroacoustic surveys

Hydroacoustic studies were conducted in Smith Sound in western Trinity Bay (3L) at various times from spring 1995 to the present. Winter (January-February) surveys were conducted in a standard manner by the Fisheries Conservation Chair at Memorial University of Newfoundland starting in 1999. Average indices of biomass increased to a peak of about 26,000 t in 2001 and then declined to 23,000 t in 2002, 20,000 t in 2003, and 18,000 t in 2004. Hydroacoustic studies in Smith Sound have continued, but the timeseries described above has ended.

Beach seine

Information on recent year-classes is available from beach seining in Newman Sound in Bonavista Bay (northern 3L). There is concern that information from this study may not be informative, because the area of spatial coverage is small. The survey catches cod mainly of ages 0 and 1, with 0 being much more strongly represented. These ages are not adequately represented in other indices. A comparison between catches at age 1 from the beach seine and year-class strength at age 3 from the SPA (see below) reveals a promising correlation. The beach seining indicates that the 2003 and 2004 year-classes may be weak.

Telephone survey of fish harvesters

A telephone survey was conducted by the Fish, Food and Allied Workers (FFAW) Union to assess the opinions of fish harvesters regarding the abundance of cod in inshore waters, the size and condition of the cod, and the abundance of prey. In 2J, most fish harvesters felt that cod abundance during 2005 was lower than it had been during the late 1980s but higher than during 2004. In 3K and 3L, most fish harvesters felt that cod abundance during 2005 was higher than it had been during the late 1980s. Most felt that cod abundance during 2005 had not changed or had increased relative to 2004.

Bottom-trawl survey inshore

Extension of the bottom-trawl survey into the inshore since 1996 has resulted in higher average catch rates and broader age composition than in the offshore, but a narrower age composition than in sentinel and commercial catches. The inshore strata have not been used to derive information on trends in stock status.

Sequential population analysis (SPA)

Following the procedure adopted during 2005, sequential population analysis (SPA) was applied to data collected in the central inshore area since 1995. The model included indices from each of the three gears employed in the sentinel surveys. Natural mortality was fixed at 33% (M=0.4) for all years and ages.

SPA estimates indicate that spawner biomass in the central inshore area increased from 10,000 t in 1995 to 22,000 t in 1998, declined during 1998-2002 (when there was a commercial fishery) to 7000 t in 2003, and has subsequently increased to 14,000 t by the beginning of 2006 (Fig. 12). This increase is due to reduced fishing mortality and improved recent recruitment. The estimate of age 4+ biomass at the beginning of 2006 is about 23,000 t (Fig. 12). Information is provided for 4+ biomass, instead of 3+ as specified in the objectives, because 4+ more closely approximates exploitable biomass.

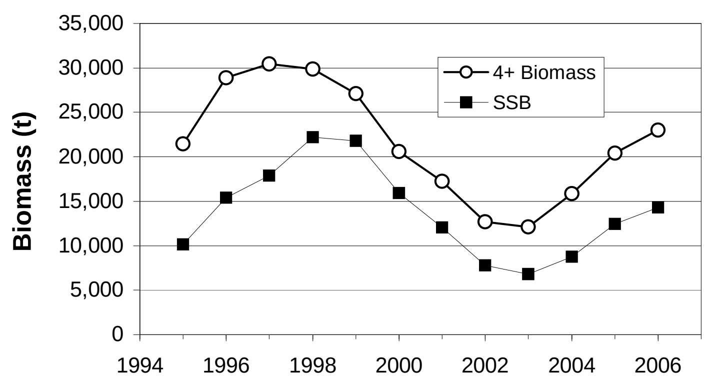


Figure 12: SPA estimates of exploitable (4+) biomass and spawner biomass (SSB) for the inshore central area.

Fishing mortality expressed as a percentage (Fig. 13) increased when the fishery opened in 1998 and reached a peak of about 36% in 2001 and 2002. Fishing mortality has been relatively low for the past two years, but higher than in the three years prior to the opening of the fishery (1995-1997).

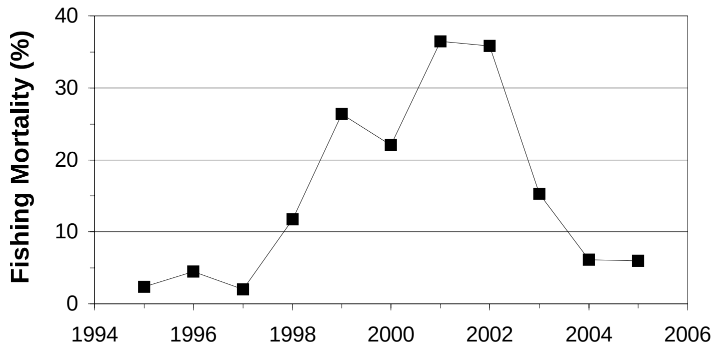


Figure 13: SPA estimates of average fishing mortality (ages 5-10+) for the inshore central area.

Within the short period covered by the SPA, year-class strength (abundance at age 3) was relatively high in 1992, after which there was a decline to 1996-1997, and an increase to 2000 (Fig. 14). Year-class strength has been estimated to vary at a relatively high level in 2001 and 2002.

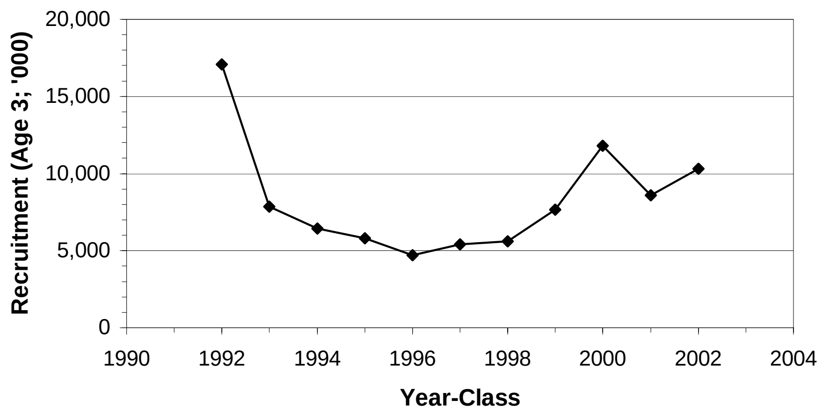


Figure 14: SPA estimates of recruitment (abundance at age 3) for the inshore central area.

Current Status

Offshore

The autumn bottom-trawl survey is the only data source that provides information on the status of cod throughout the offshore. The biomass index in 2005 was 27,500 t, which is about 2% of the level in the 1980s. Recruitment remains very low and mortality extremely high.

Inshore

For the central inshore area, sequential population analysis (SPA) was used to estimate that, on January 1, 2006, the spawner biomass was about 14,000 t and the 4+ biomass (approximately equivalent to the exploitable biomass) was about 23,000 t. These levels are about average for the 1995-2006 time period.

There are no quantitative biomass estimates for the northern and southern inshore areas. Sentinel gillnet catch rates in the northern area increased in 2005 to a level well above the

1995-2005 average, whereas catch rates in the southern area declined to a level well below the average.

Stock as a whole

There is no single measure of the biomass of the stock as a whole. The information from the bottom-trawl survey in the offshore and the SPA in the central part of the inshore are not directly comparable, but the offshore biomass index and the estimate of inshore biomass are of the same order of magnitude.

The current biomass of the stock as a whole is a very small proportion of the approximately 3 million t (of ages 3 and older) estimated for the early 1960s.

Biological Information

The information presented in this section comes entirely from the autumn offshore research vessel bottom-trawl surveys. Much of the year-to-year variability in the estimates since the mid-1990s may be due to small sample sizes.

Maturity

The proportion mature at age increased among young female cod during the early 1990s and has fluctuated since (Fig. 15). For example, the proportion of age 6 cod that are mature increased from about 0.4-0.6 in the 1980s to greater than 0.6 since the early 1990s. Males generally mature about one year younger than females and show a similar trend over time.

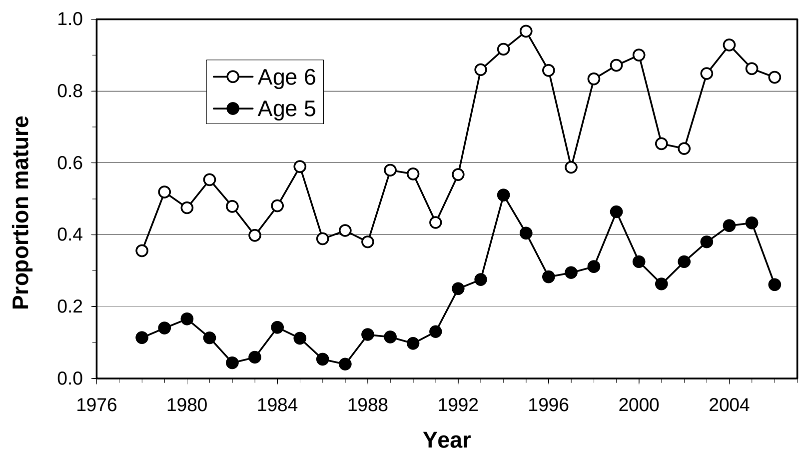


Figure 15: Proportion of females mature at ages 5 and 6. Information derived from the autumn in one year is assumed to represent spawning during spring of the following year.

There have been substantial changes in the estimates of the proportion mature at younger ages. This is partially the result of low sample sizes. The estimates of the proportion of females at young ages that contribute to the spawner stock biomass is thus uncertain.

Size at age

Size at age of cod declined during 1983-1985 and again in the early 1990s, especially in 2J (Fig. 16). Size at age has improved since the early to mid-1990s but is below peak values observed in the late 1970s.

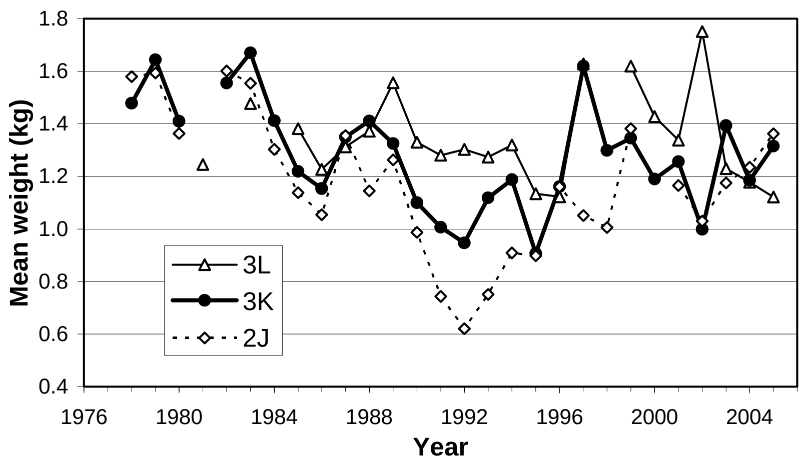


Figure 16: Mean weight (kg) at age 5 of cod sampled during autumn offshore bottom-trawl surveys.

Condition

Condition of cod, as measured by both gutted body weight and liver weight relative to fish length, declined in the offshore during the early 1990s, especially in 2J. Since the mid-1990s, condition levels have been similar to those measured in the mid-1980s.

Respondents to the fish harvester telephone survey reported that the condition of cod in the inshore was good.

Sources of Uncertainty

For the past four years, the autumn bottom-trawl surveys have extended well beyond their normal time and into the winter because of vessel problems. These changes may affect survey estimates of abundance and biomass. In addition, distribution, growth, condition and maturity vary seasonally, and changes in survey timing complicate the comparison of recent survey results with those from previous years. In addition, the 2004 survey was not completed. This resulted in an underestimation of population size, but not necessarily an underestimation of mean catch rate.

The difference in trends between biomass estimates from hydroacoustic surveys in Hawke Channel and bottom-trawl surveys in Div. 2J as a whole, plus the discussion on the efficacy of the Hawke Channel closed area, indicate some uncertainty regarding the abundance of medium-sized fish in the offshore and highlight the paucity of recent information on locations and sizes of overwintering aggregations and spawning aggregations.

The SPA for the central inshore area is based on a short time series of indices (1995-2005), and catches that have varied considerably among years. This increases the uncertainty in the magnitude of stock size estimates, but should have less influence on the trends.

The value of natural mortality (M=0.4) used in the SPA was inferred from tagging studies during 1997-2002 and is considered uncertain. The results of the SPA are sensitive to this value.

Projection results are dependent upon the value of natural mortality applied in both the SPA and the projections. There is insufficient information on spatial and temporal variability in natural mortality to explore informative alternatives. However, if future natural mortality differs from the assumed value, then the projected changes in SSB will differ from the above results.

Maturity estimates from sampling during offshore research vessel surveys were used to compute spawner stock biomass from the inshore SPA and in the projection. It is unknown whether fish in the inshore are maturing at the same rate as those in the offshore.

The level of unreported catch is unknown. If this level is substantial, then there is more uncertainty in the assessment and in the evaluation of the impact of future removals.

CONCLUSIONS AND ADVICE

Central inshore area

The consequences of various catch options for the inshore central area (southern 3K and northern 3L) were explored in two ways.

Deterministic projections of stock size to 2009 were computed from the SPA results under catch options of 0 t, 1250 t, and 2500 t. Due to uncertainties in future recruitment, three values (low, medium, and high) were considered in the projections. The low recruitment value was the minimum estimate from 1995 to 2004 of age 2 abundance from the SPA; medium recruitment was the 2002-2004 geometric mean; and high recruitment was the maximum estimated value (at age 2) in the SPA. The value of natural mortality used in the projections was the same as that in the SPA (M=0.4).

In the one-year projection, assuming no removals or a catch option as high as 2500 t, spawner biomass is projected to increase, regardless of the assumed recruitment level (Table 2).

Table 2: Projected changes in spawner stock biomass (SSB) for various fixed catch options and various recruitment levels from 2006 to 2007.

% Change in SSB between 2006-2007 (Jan.1)				
		Catch Option		
		0t	1250t	2,500t
Recruitment	Low	18%	11%	4%
	Medium	19%	12%	5%
	High	19%	12%	6%

In the three year projection (from 2006-2009), assuming no removals or a catch option of 1250 t, spawner biomass is projected to increase for each recruitment assumption (Table 3). At a catch option of 2500 t, spawner biomass is projected to decrease if recruitment is low, but increase if recruitment is medium or high.

Table 3: Projected changes in spawner stock biomass (SSB) for various fixed catch options and various recruitment levels from 2006 to 2009.

% Change in SSB between 2006-2009 (Jan.1)				
		Catch Option		
		0t	1250t	2,500t
Recruitment	Low	34%	14%	-5%
	Medium	59%	39%	20%
	High	66%	47%	28%

In the medium term projection, the sizes of the 2003-2007 year-classes are assumed to be equal to the geometric mean of the 2000-2002 year-classes. A comparison between catches at age 1 from the beach seine studies and year-class strength at age 3 from the SPA reveals a promising correlation. The beach seine survey results for the 2003 and 2004 year-classes are the lowest in the time series. This indicates that the projections assuming low recruitment may be more realistic.

The second method of exploring consequences of various catch options for the inshore central area was to compute the risk of not attaining a specified rate of population growth. No target rebuilding rate is in place for northern cod. An illustration is presented (Table 4) of the risk of the SSB not growing at all, of growing at less than 5% and of growing at less than 10% per year, at TAC options between 0 and 3000 t, for time intervals of 1 and 3 years. The risk that is calculated includes only the uncertainty in the numbers of survivors at the beginning of 2006 and incoming recruitment, which is most comparable to the medium recruitment scenario in the deterministic projection described above.

Risk of SSB growing by less than 5% increases rapidly with TAC options above 1000 t. At 3000 t the risk is 0.5 or greater over 1 and 3 year time horizons.

Table 4. Risk that the annual percentage growth of spawning stock biomass (SSB) will be less than specified target rates over 1 and 3 year time intervals.

Time interval of 1 year

Risk of Jan.1 SSB in 2007 not meeting growth target						
		Catch Option (t)				
		0	1000	2000	2500	3000
Growth Target (%)	0%	0	0	0.01	0.08	0.22
	5%	0.00	0.02	0.22	0.43	0.64
	10%	0.03	0.21	0.63	0.80	0.91

Time interval of 3 years

Risk of Jan.1 SSB in 2009 not meeting growth target						
		Catch Option (t)				
		0	1000	2000	2500	3000
Growth Target (%)	0%	0	0	0.01	0.04	0.12
	5%	0.00	0.02	0.14	0.33	0.50
	10%	0.04	0.24	0.61	0.78	0.88

Northern inshore area

For the inshore northern area (2J plus northern 3K), it is inferred from the low catch rates in the sentinel surveys (1995-2004) and the commercial fishery (1998-2002) that cod densities have been very low. However, catch rates in the sentinel surveys increased during 2005. Nevertheless, to date this increase has been seen in just one year. In addition, the stock affinities of the fish remain uncertain. They appear to be immigrants, possibly from the offshore. It would be prudent to keep catches low in this area.

Southern inshore area

For the inshore southern area (southern 3L), it is clear that catch rates have been relatively high at certain times and in some areas. The tagging data illustrated that fisheries in the area during 1998-2002 were primarily dependent on fish that migrate seasonally between 3Ps and 3L. Since the magnitude of migration in future years cannot be predicted, the effect of removals of various levels cannot be estimated. However, fisheries in southern 3L will contribute additional mortality to groups of fish that migrate between 3Ps and southern 3L. Some of these groups already experience high fishing mortality within Placentia Bay.

Offshore

Mortality of cod in the offshore is exceedingly high. The extent to which ongoing fishing activities may be contributing to this mortality, as both by-catch and incidental mortality, has not been determined. Nevertheless, it is recommended that the moratorium on directed fishing be continued, and that by-catch be reduced to the lowest level possible.

OTHER CONSIDERATIONS

Management Issues

Consequences of an inshore fishery for offshore recovery

There is a possibility that cod currently offshore in 2J3KL undergo spring/summer feeding migrations to the inshore, similar to their historic pattern. At current offshore population levels, any offshore fish exploited in an inshore fishery could further impede recovery in the offshore.

The potential for cod currently in the inshore to repopulate the offshore of 2J3KL remains uncertain. Studies with one specific genetic technique have demonstrated a population substructure between most inshore and offshore areas. It has been suggested that this substructure indicates a low likelihood that inshore-spawning cod will contribute to offshore recovery. Nevertheless, it is well known that fish populations can expand into new environments, and that this is more likely to occur as population levels increase. It is possible, then, that cod from inshore populations might expand into the offshore, and allowing the inshore populations to grow might increase the likelihood of this happening.

In consideration of the above, there is a risk that fishing in the inshore will impede recovery in the offshore. However, at this time the level of risk is difficult to quantify.

Implications of fishing bay-by-bay

During the inshore fisheries of 1998-2002, all participants were given the same individual quota but were limited with respect to the area in which they were permitted to fish. However, the distribution of fish harvesters does not match the distribution of cod. This has the potential of causing geographic variability in fishing mortality. For example, after the fishery was opened in 1998, catch rates in the index/commercial fishery declined very rapidly in southern 3K, and analysis of tagging data revealed that exploitation rate was much higher in southern 3K than in Trinity Bay.

One possible explanation for the above difference in fishing mortality is that fisheries in Trinity Bay (particularly northern Trinity Bay) exploit primarily one relatively large local population that overwinters in Smith Sound and migrates along the coast in summer. In contrast, the many fish harvesters in Notre Dame Bay may exploit several small local stocks, each of which is much smaller than the Smith Sound population and can be heavily exploited if there is not a large influx of fish from elsewhere.

Care must be taken to preserve and enhance population spatial structure and diversity within the stock.

Hawke Channel closed area

A small area (20 nm by 20 nm) in Hawke Channel was closed to shrimp trawling in September 2002 to prevent damage to crabs. This area was expanded to 50 nm by 50 nm in July 2003 to protect spawning and juvenile concentrations of cod and their habitat.

An increase in hydroacoustic estimates of cod biomass in the area was observed after 2000 but prior to the closure. This was coincident with a reduction in shrimp fishing in the same area. There were no hydroacoustic surveys after the closed area was fully implemented in mid-2003. It was not possible to conclude if the increase in local biomass in the area during 2000-2003 was caused by the reduction in shrimp fishing, nor was it possible to conclude anything about the impact of the closed area on the stock as a whole. There is a concern that shrimp fishing diverted from the Hawke Channel closed area will catch cod elsewhere.

Physical Environment

The marine environment off Labrador and eastern Newfoundland experienced considerable variability since the start of standardized measurements in the mid-1940s. A general warming phase reached its maximum by the mid-1960s. Beginning in the early 1970s there was a general downward trend in ocean temperatures, with particularly cold periods in the early 1970s, early to mid-1980s and early 1990s. Ocean temperatures have been above normal for the past decade, with some years near record highs.

Studies based on data up to the mid-1990s have demonstrated that growth declines when temperature declines, but there has been no analysis of more recent data. Whether or not the cold water of the early 1990s influenced recruitment and natural mortality is contentious.

It is anticipated that the cod in this area will be more productive when water temperatures are toward the warm end of the regional norm, but to date the populations of cod in the offshore have not started to increase.

Predators (notably seals)

No new information regarding the impact of seals on the dynamics of cod was presented to the meeting. Previous cod assessments (DFO 2003) have concluded, based on seal feeding behaviour and trends in the abundance of both seals and cod, that predation by seals is a factor contributing to the high total mortality of cod in the offshore and the high natural mortality of adult cod in the inshore.

Estimates of the quantity of cod consumed by harp seals are based on estimates of harp seal population numbers, energy requirements of individual seals, the average duration of seal occurrence within 2J3KL, the relative distribution of seals between inshore and offshore, and stomach contents of seals sampled in the inshore and offshore in winter and summer. A major shortcoming is that there are very few stomach samples from the offshore, where most of the feeding by seals occurs. A two-year programme of enhanced study of seals, initiated in 2003, has included new population surveys, new studies of distribution, and new studies of diet, both inshore and offshore. The information from this programme is not yet available for review.

The estimates of prey consumption by seals rely on the presence and identification of hard parts (such as cod otoliths) in the seal stomachs. Seals also prey on cod by belly-feeding, a mode of predation on fish which are usually too large to be consumed whole. The seal takes a bite from the belly of the fish, removing the liver and gut, but not consuming the muscle or hard parts. Observations of belly-feeding were more frequent during 1998-2000 than in recent years, and occurred mainly in Notre Dame Bay and southern Bonavista Bay.

A pilot study on the efficacy of seal exclusion zones is currently underway in Smith Sound (Bowen 2004).

Prey (notably capelin)

The trend in biomass of capelin, historically the major prey of cod in 2J3KL, has been uncertain since the late 1980s. Biomass estimates from hydroacoustic surveys in the offshore have been much lower since the early 1990s compared with the 1980s, but indices of capelin biomass from the inshore have not shown such extensive declines. Some studies of cod condition and feeding indicate that cod may not be faring well in certain seasons and areas, and that this is due to low availability of capelin. Other studies and observations do not suggest any concerns at present about cod growth or condition. Whatever the present circumstances, there remains concern that there may not be sufficient capelin to support a recovery of the cod stock, especially in the offshore and in the north.

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FOR MORE INFORMATION

Contact: George Lilly
Fisheries and Oceans Canada
PO Box 5667
St. John's, NL A1C 5X1
Tel: (709) 772-0568
Fax: (709) 772-4105
E-Mail: lillyg@dfo-mpo.gc.ca

This report is available from the:

Fisheries and Oceans Canada
Newfoundland and Labrador Region
PO Box 5667
St. John's, NL A1C 5X1

Telephone: (709) 772-8892/2302
Fax: (709) 772-6100
E-Mail: richardsed@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas

ISSN 1480-4913 (Printed)

La version française est disponible à l'adresse ci-dessus.

CORRECT CITATION FOR THIS PUBLICATION

DFO, 2006. Stock Assessment of Northern (2J3KL) cod in 2006. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2006/015.