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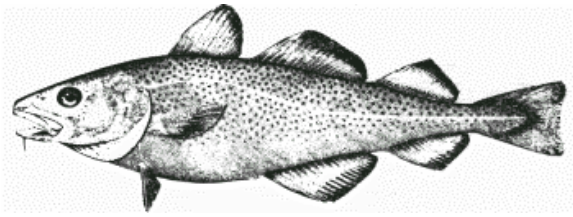
Newfoundland and Labrador Region
Canadian Science Advisory Secretariat
Science Advisory Report 2007/018

STOCK ASSESSMENT OF NORTHERN (2J3KL) COD IN 2007



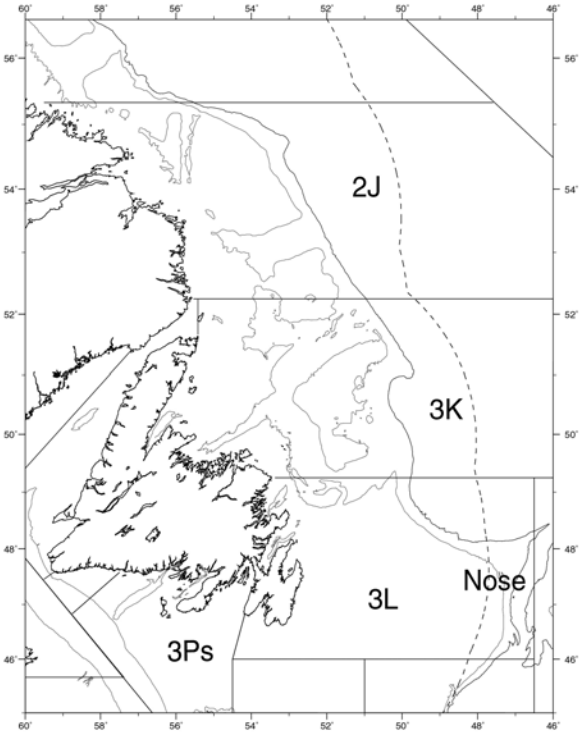


Figure 1: Stock area of northern (2J3KL) cod. The dashed line indicates Canada's 200 nautical mile Exclusive Economic Zone (EEZ).

Context :

The biomass (of ages 3 and older) of the northern (2J3KL) cod stock off southern Labrador and eastern Newfoundland (Fig. 1) was about 3 million t in the early 1960s. Fishing intensity increased greatly in the 1960s as non-Canadian fleets exploited dense offshore over-wintering 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 directed commercial fishing was declared in 1992.

Historically, many cod migrated from over-wintering 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.

Catches during 2003-2005 were limited mainly to bycatch during a winter flounder (blackback) fishery. Directed commercial and recreational fisheries were re-opened in the inshore in 2006. There continues to be 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. This stock is assessed annually.

The present assessment is the 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 to stock growth of inshore fishery removals varying from zero to 2,500 t in 2007 and annually in the medium term (2007-2009). Implications are to be assessed in terms of a risk analysis, specifically, the risk of the beginning of year SSB not meeting a growth rate of (0%, 5% and 10%) for inshore populations, offshore populations, and the stock as a whole where possible.*
- *Assess the implications of conducting an inshore fishery on a bay-by-bay basis.*
- *Assess the impact of the 2006 Inshore Fishery One Year Pilot Project on the stock population and prospects.*

A meeting of the Regional Advisory Process was held during 27 March to 10 April 2007 to conduct the assessment as requested above. Participants included DFO Scientists, fisheries managers, and representatives from the provincial government, industry, Memorial University, and the Fish, Food and Allied Workers Union.

SUMMARY

- 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.
- A directed fishery and a recreational fishery were re-opened in the inshore of 2J3KL during 2006, but the offshore portion of the stock area remained closed to directed fishing. Reported landings totaled 2,679 t, including 380 t in the recreational fishery, 159 t in the sentinel surveys, and 45 t of by-catch.
- Based on spring and autumn surveys, the average biomass of cod in the **offshore** over the last 3 years remains at less than 4% of the average during the 1980s.
- Total **mortality** in the offshore has been extremely high since at least the mid-1990s, with a low proportion of fish surviving beyond age 5. The high level of mortality is a major impediment to stock recovery.
- The moratorium on directed fishing in the offshore should be continued, and by-catch should be minimized.
- The industry telephone survey conducted during 2007 showed most harvesters in 2J3KL felt that cod were more abundant during 2006 than during 2005.

- For assessment purposes the inshore was divided into three areas: 1) a northern area (2J and northern 3K); 2) a southern area (southern 3L) that is largely dependent on migrant fish from 3Ps; and 3) a central area (southern 3K and northern 3L) where most of the resident inshore fish are located.

- In the **inshore northern area**, catch rates increased from 2005 to 2006 but remained lower than those in the inshore central area, suggesting lower cod densities in this area. Also, these fish appear to be immigrants, possibly from the offshore. Therefore it would be prudent to minimize removals from 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.

- A sequential population analysis (SPA) conducted for the **inshore central area** indicated that **spawner stock biomass** increased from 16,100 t on 1 Jan 2006 to 19,900 t by 1 Jan 2007, but is lower than the peak of 24,800 t estimated for 1998. The estimate of exploitable (age 4+) biomass at the beginning of 2007 is 25,800 t, a 6% decrease from 2006.

- The SPA also indicated that the 2006 Inshore Fishery One Year Pilot Project resulted in a **harvest rate** of 8% (by numbers) within the inshore central area. Harvest rates in the inshore northern and inshore southern areas could not be quantified.

- In the inshore central area, a **pre-recruit index** suggests that the strength of the 2003-2005 cohorts will be lower than those observed in the past decade. Recruitment in the offshore has been weak since the 1989 year-class.

- Deterministic **stock projections** were conducted from 2007 to 2008, based on the SPA for the inshore central area. Assuming no removals, spawner stock biomass is projected to increase by 12%. Assuming a catch of 2,500 t, spawner stock biomass is projected to increase by 1%.

- Deterministic stock projections from 2007 to 2010 were conducted for the inshore central area. Assuming no removals, spawner stock biomass is projected to increase slightly by 2% per year on average (6% total growth from 2007 to 2010). Assuming an annual catch of 2,500 t, spawner stock biomass is projected to decrease on average by 8% per year (22% decline from 2007 to 2010).

- Risk of the spawner stock biomass in the inshore central area growing by less than 5% by 1 January 2008 increases rapidly with a catch above 500 t and is very high (0.87) for a catch of 2,500 t.

- Risk of the spawner stock biomass in the inshore central area growing by less than 5% per year by 1 January 2010 is very high (0.93) even with no catch.

- 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.

INTRODUCTION

Species Biology

Cod off Labrador and eastern Newfoundland grow slowly compared with individuals in the eastern Atlantic and further south in the western Atlantic. Since the late 1980s females have been maturing at about age 5, which is younger than in previous years.

Historically much of the stock was highly migratory. They over-wintered 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; medium-sized cod feed on larger crustaceans and small fish; and large cod feed on medium-sized fish and 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 and other marine mammals. 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 predation by seals, especially harp seals.

Stock Structure

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. Inshore populations are small relative to the populations that historically migrated into the inshore from the offshore during spring/summer.

Tagging studies have revealed that from the late 1990s 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 (Fig. 2) and (2) a migrant group that over-wintered 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.

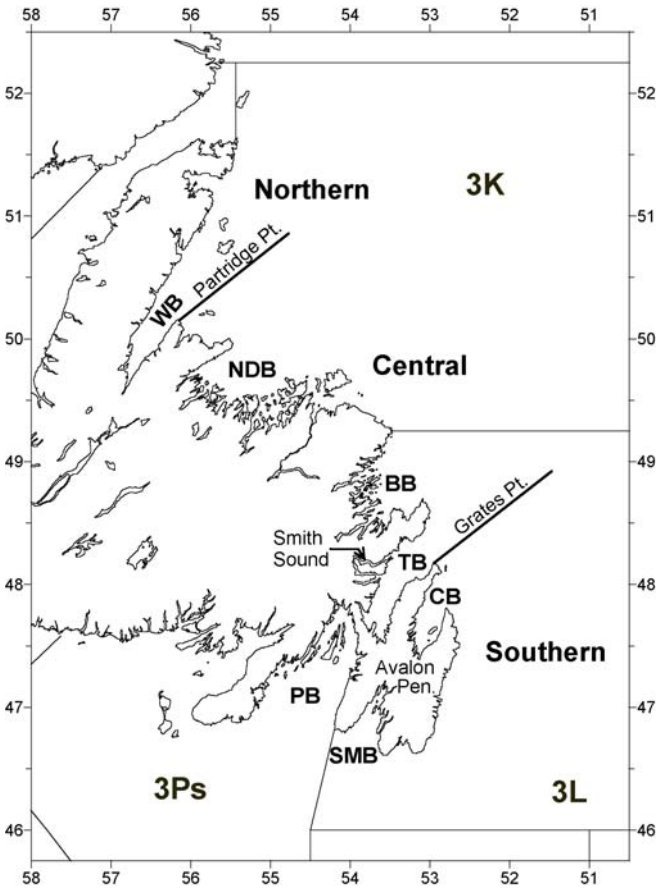


Figure 2: Eastern Newfoundland indicating the locations of the inshore northern, inshore central and inshore southern areas as defined for the present assessment. Major bays are indicated: White Bay (WB), Notre Dame Bay (NDB), Bonavista Bay (BB), Trinity Bay (TB), Conception Bay (CB), and St. Mary's Bay (SMB);. Placentia Bay (PB) is in Subdiv. 3Ps.

Some aspects of current stock structure remain uncertain. Catch rates in 2005 and 2006 increased in sentinel surveys in 2J and northern 3K (see below), but the origin of the fish that generated these higher catch rates is unknown. The extent of migration between the inshore and offshore of 2J3KL during recent years is not well understood. The offshore biomass of cod in 2J3KL remains low, and their current contribution to the inshore biomass during summer is unknown.

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. 3).

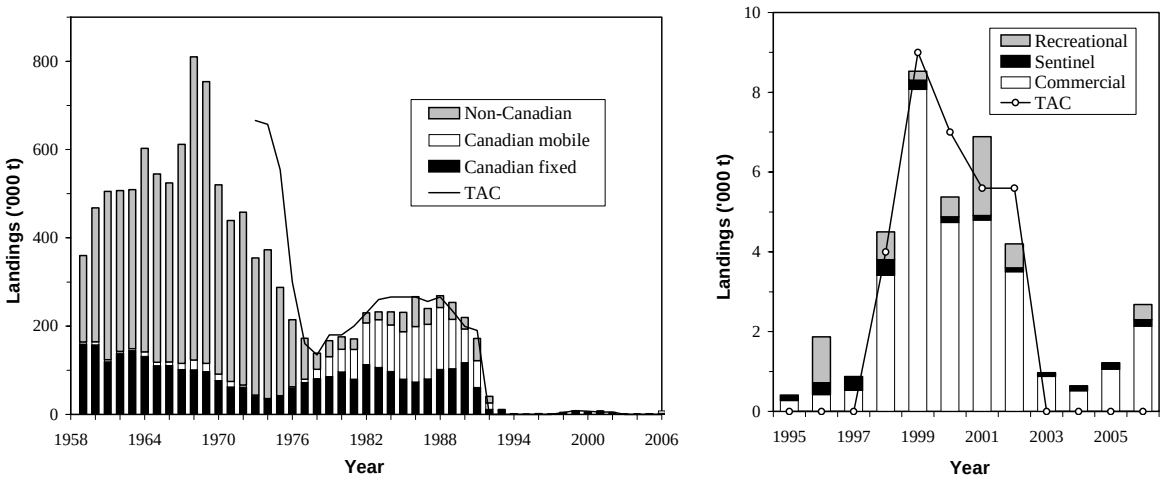


Figure 3: TACs and landings (thousands of tons) in 1959-2006. The right panel is re-scaled to show trends from 1995 onwards. Non-Canadian catch since 1995 is estimated at less than 80 t per year.

Catches during 1993-1997 came from by-catches, food/recreational fisheries, and DFO-industry sentinel surveys that started in 1995. In addition, catches from 1998-2002 also came from a limited index/commercial inshore fishery restricted to fixed gear and small vessels (<65 feet)(Table 1). The directed commercial and recreational fisheries were closed in April 2003. During 2004 and 2005, substantial by-catches (>600 t) of cod were taken in the inshore, mostly in 3KL, in the winter flounder (blackback) fishery.

Table 1: Catch in NAFO Divs. 2J3KL (nearest thousand metric tons).

Year	62-76 Avg.	77-91 Avg.	1998	1999	00/01	01/02	02/03	03/04	04/05	05/06	06/07
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	3
Can. Mobile	9	84	-	-	-	-	-	-	-	-	-
Others	405	38	-	-	-	-	-	-	-	-	-
Totals	502	212	5	9	5	7	4	1	1	1	3

* There was no TAC in 2006/07 but an allowance of 3,000 lb of cod per license holder.

A directed commercial fishery and recreational fishery for cod was re-opened during 2006 in the inshore of 2J3KL for a six-week period. Reported landings in 2006 were 2,679 t, including 380 t in the recreational fishery, 159 t in the sentinel surveys, and 45 t of by-catch, 20 t of which came from the offshore.

An estimate is not yet available for the 2006 catch by non-Canadian fleets outside the 200 nautical mile limit on the Nose of the Grand Bank (Div. 3L). The Scientific Council of the Northwest Atlantic Fisheries Organization (NAFO) estimated that annual catches during 2000-2005 were 80 t or less.

ASSESSMENT

Sources of Data

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. A new offshore hydroacoustic survey conducted in February-March 2007 provides information on the winter distribution of cod along the continental shelf edge of 2J3KL.

For the inshore, indices of abundance are provided by DFO-Industry 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). Logbooks from vessels under 35 feet for 1998-2002 and 2006 are examined. For several years, tagging studies provide information on distribution/migration and exploitation and, in conjunction with landings, also provide estimates of biomass. Tagging studies were considerably reduced following the re-imposition of the moratorium in 2003, but these studies were resumed in 2006. Hydroacoustic surveys were conducted in Smith Sound for many years, particularly during winter and spring 1997-2004 and these were continued in 2006 and 2007. 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, Bonavista Bay. Information on the size and age composition of the catch (including by-catch during 2003-2005) is obtained from lengths and otoliths collected from cod sampled at ports. A new DFO-Industry survey conducted during July-August 2007 using mobile gear fished from small (<65 ft) commercial vessels provides information on the age composition and distribution of cod inhabiting the coastal and nearshore area of 2J3KL.

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. 4). The biomass index during 2004-2006 was 3% of the average during the 1980s.

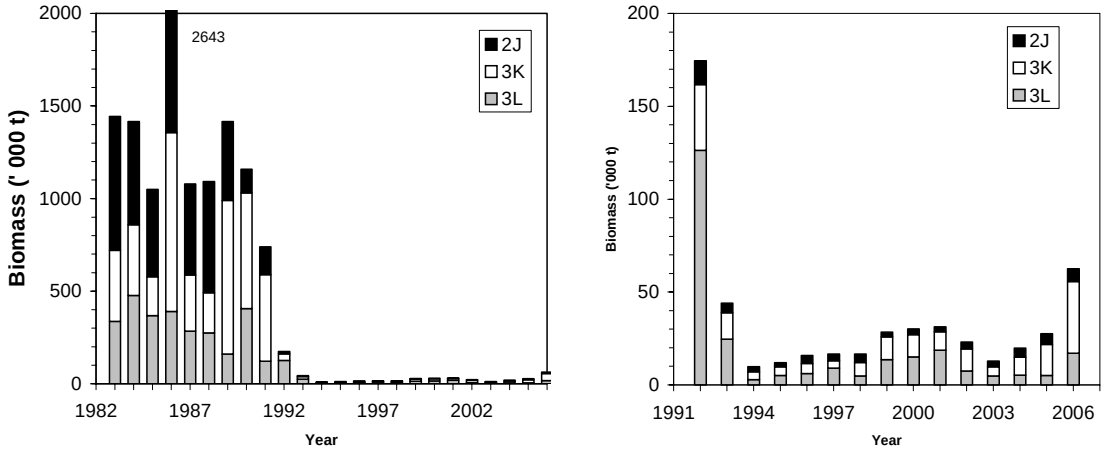


Figure 4: Offshore biomass index from autumn research bottom-trawl surveys in 2J3KL. The right panel is re-scaled to show trends from 1992 onwards.

The biomass index from the spring research bottom-trawl survey in 3L was, during 2004-2006, less than 4% of the average in the 1980s (Fig. 5). The value in 2006 was the highest since 1992.

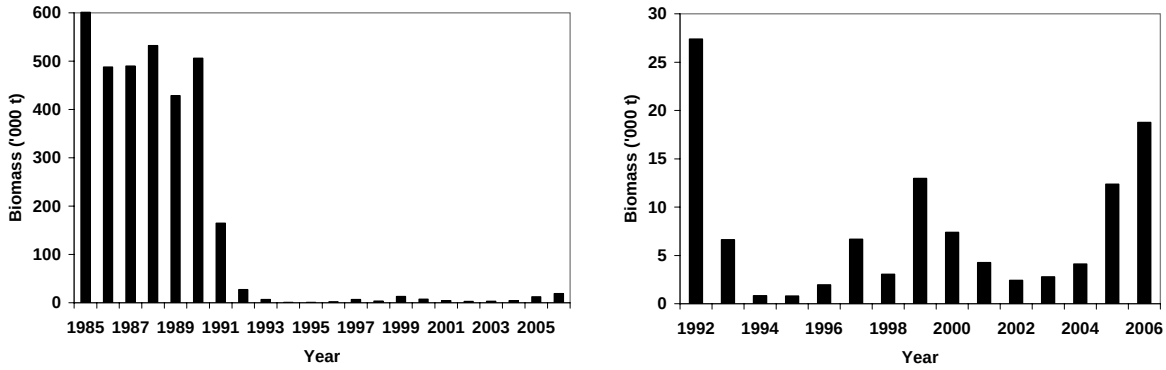


Figure 5: Offshore biomass index from spring research bottom-trawl surveys in 3L. The right panel is re-scaled to show trends from 1992 onwards.

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. 6) shows all year-classes since 1989 to be relatively weak.

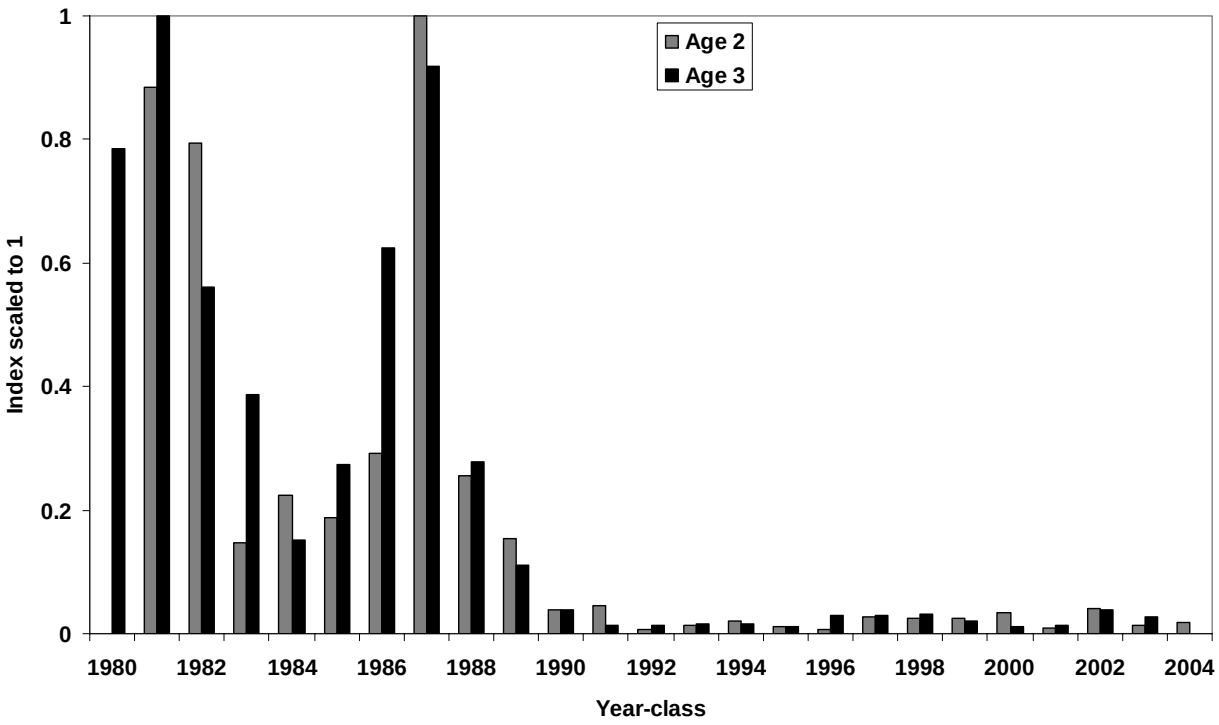


Figure 6: Relative sizes of the 1980-2004 year-classes in the offshore of 2J3KL, as measured by the mean catch per tow at ages 2 and 3 during the autumn research bottom-trawl surveys. Number per tow has been scaled to a maximum of 1 within the time-series for each age.

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 lack of older fish (ages 8 and older) in the survey since the early 1990s prevents estimating total mortality on these older ages. For ages 4 - 8, mortality has remained very high since the mid-1990s, typically about 60-70% per year (Fig. 7). The negative 2006 value results from an apparent year-effect in the survey, as the numbers at age 5, 6, and 7 in the 2006 survey were all higher than the 4, 5, and 6 values in the 2005 survey.

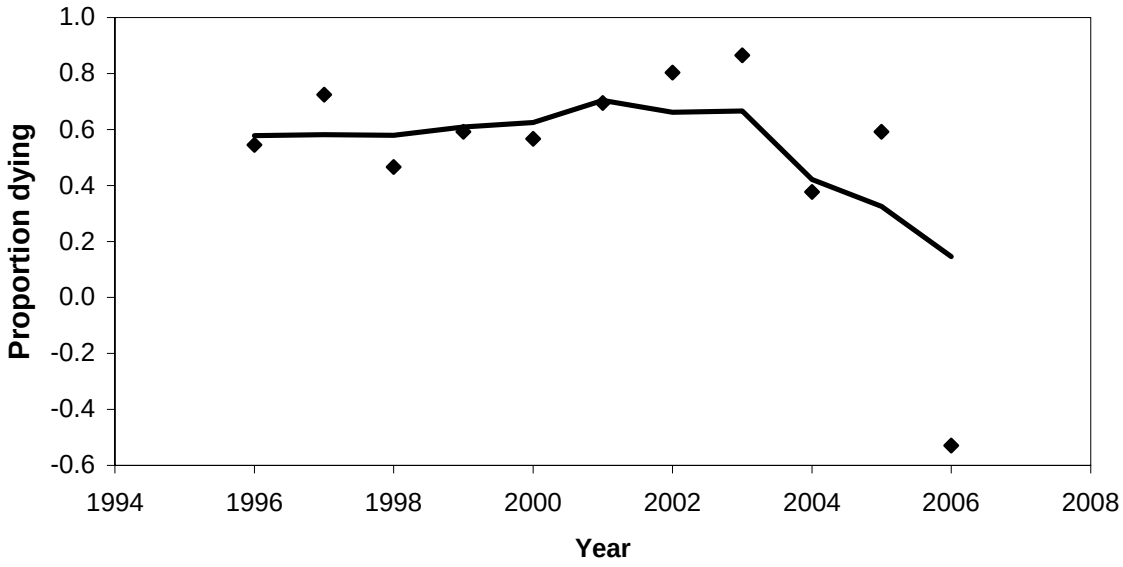


Figure 7: Annual mortality rate (proportion dying) calculated from the autumn research bottom-trawl surveys in the offshore of 2J3KL. For example, the value of 54% in 1996 is the mortality experienced by the 1991-1989 year-classes from ages 4-6 in 1995 to ages 5-7 in 1996. The solid line is a moving average.

The relative contributions of fishing and natural mortality to the high total mortality are difficult to quantify. Reported by-catches in the offshore have been small, which suggests that natural mortality is high.

An acoustic and tagging survey directed at cod was conducted on the outer edge of the continental shelf from southern Labrador southward to nose of the Grand Bank during February-March 2007. Aggregations of cod were found in the Hawke Channel (Div. 2J) and in the outer reaches of the Bonavista Corridor (Div. 3KL). These two aggregations accounted for more than 85% of the acoustically detectable cod in the study area. The size of these aggregations has not yet been quantified.

Stock Trends – Inshore

The inshore is subdivided for assessment purposes into three areas (Fig. 2): 1) a northern area (2J and northern 3K); 2) a southern area (southern 3L) that is largely dependent on migrant fish from 3Ps; and 3) a central area (southern 3K and northern 3L) where most of the resident inshore fish are located. The dividing lines for these areas are Partridge Point at the western side of Notre Dame Bay and Grates Point at the eastern side of Trinity Bay.

Sentinel surveys

The gillnet (5½ inch mesh) catch-rate indices have generally increased during recent years (Fig. 8). In the inshore northern area, mean catch rates were low from 1995 to 2004, increased in 2005 and 2006, but remained lower than those in the inshore central area. There has been a gradual increase in the inshore central area from the low point in 2002 and current catch rates are about average for the time series. In the inshore southern area there was an increase from 2002-2004, with a decline in 2005 and a marginal increase in 2006.

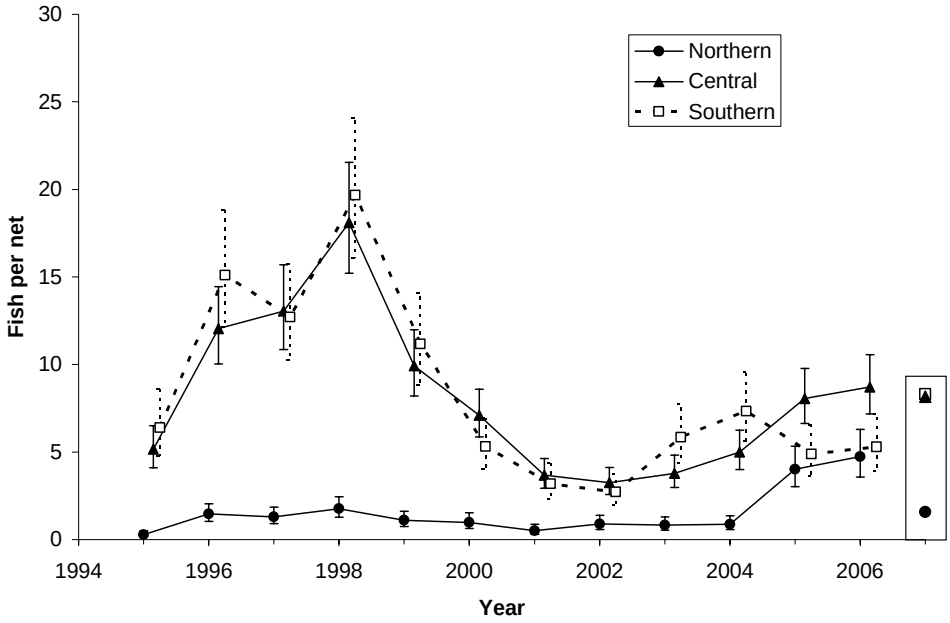


Figure 8: Standardized catch rates with 95% confidence limits from sentinel surveys using gillnets (5½ inch mesh) for each of the three inshore areas. Series means are plotted within the rectangle.

Catch-rate indices from linetrawls in the inshore central area increased during recent years to about average (Fig. 9), although the 2006 estimates are slightly lower than those for 2005. In the inshore southern area, catch rates have been slightly below average in recent years. There are insufficient linetrawl data in the inshore northern area to produce a time series.

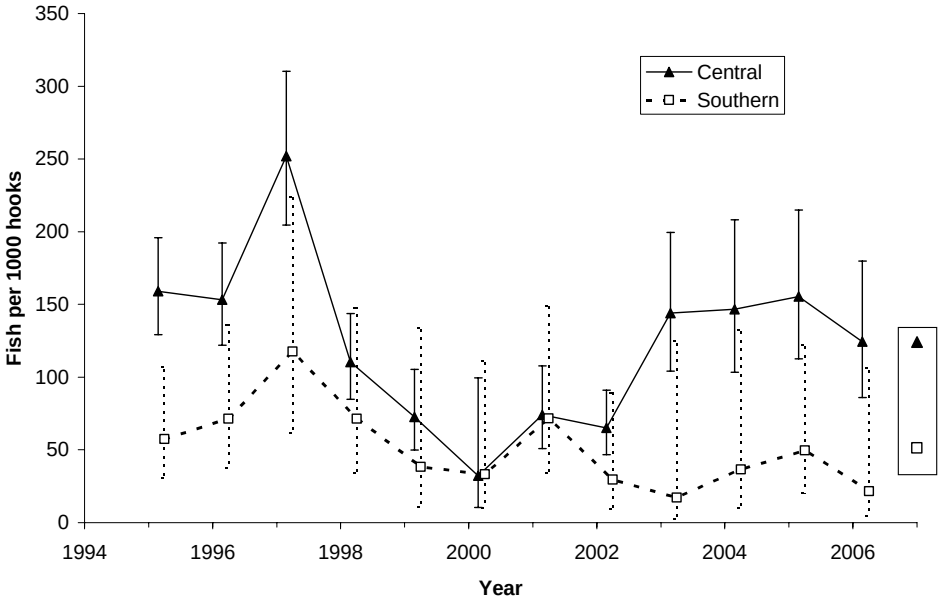


Figure 9: Standardized catch rates with 95% confidence limits from sentinel surveys using linetrawls for the inshore central and inshore southern areas. Series means are plotted within the rectangle.

Catch-rate indices from the small mesh (3¼ inch) gillnets tended to be lower in the inshore northern area than in other areas, but have increased in the last two years and are now well above average (Fig. 10). In the inshore central and inshore southern areas, catch rates have fluctuated but are about average. Fig. 10 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.

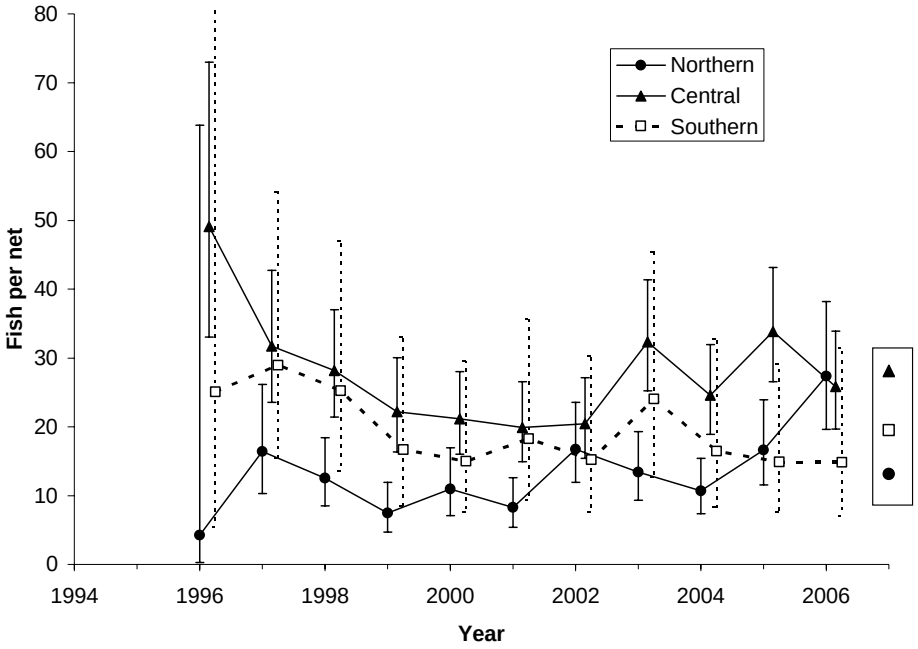


Figure 10: Standardized catch rates with 95% confidence intervals from sentinel small mesh (3¼ inch) gillnet surveys for each of the three inshore areas. Series means are plotted within the rectangle.

Median commercial gillnet catch rates (Fig. 11) were calculated from catch and effort data for the < 35 foot sector. Catch rates were consistently low in the inshore northern area, but in 2006 were comparable to those from the inshore southern area. Catch rates in inshore central area have generally been higher than those in the northern and southern areas. Due to changes in management regulations it is not clear if these commercial catch rates are indicative of stock size.

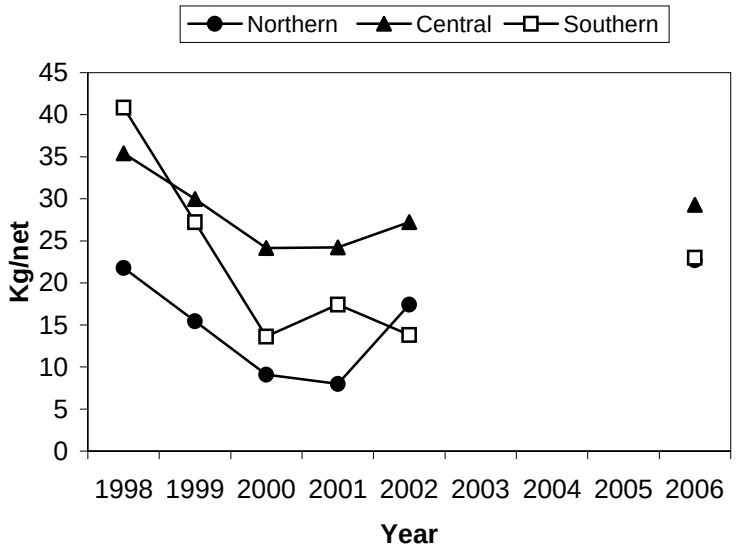


Figure 11: Median gillnet catch rates from fixed gear logbooks. There was no directed fishery from 2003-2005.

Hydroacoustic surveys

Winter hydroacoustic studies were conducted in Smith Sound in western Trinity Bay starting in 1999 (Rose, 2002). 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. These surveys were suspended in 2005 but resumed in 2006. Average indices of biomass were stable in 2006 at 16,500-18,500 t, but declined in 2007 to 7,000-8,000 t, the lowest in the time series. These estimates may not be directly comparable as survey coverage varied from year to year.

Beach seine surveys

Information on recent year-classes is available from a beach seining survey in Newman Sound in Bonavista Bay (northern 3L). The survey catches cod mainly of ages 0 and 1, with age 0 being much more strongly represented. These pre-recruit ages are not adequately represented in other indices. The area of spatial coverage is small, but the age 1 information from this study is consistent with year-class strength estimates from the SPA for the inshore central area (see below). Results indicate that recent year-classes are weak and the 2005 year-class is the lowest in the time-series (Fig. 12).

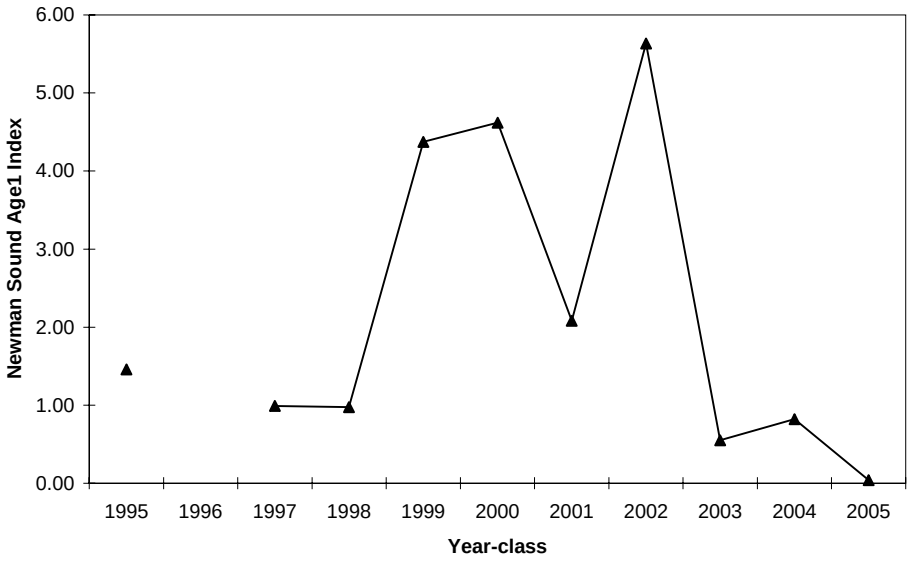


Figure 12: Trends in the numbers of age 1 cod from beach seine surveys in Newman Sound.

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. Most harvesters in 2J felt that there were less cod during 2006 than there was during the late 1980's, whereas in 3K and 3L most felt abundance was better during 2006 than the late 1980's. Most harvesters in 2J and 3K felt that cod were more abundant during 2006 than during 2005. In 3L, fish harvester's opinion was evenly split between 2006 abundance being about the same and abundance being better than it was during 2005. While there was a wide range of opinion about the distribution of cod in 2J, in 3K and 3L most felt that cod were widely distributed or distributed throughout the area. Most fish harvesters in 2J, 3K and 3L felt that cod were in good condition during 2006.

Mobile gear survey inshore

A new DFO-Industry stratified-random mobile gear survey for cod was conducted in the inshore of 2J3KL during July-August 2006 using bottom trawls fished from commercial vessels. The surveyed area included the coastal zone from 15 to 200 m depth. Catch rates of cod (mean number per tow) were variable but tended to be higher closer to shore. For example, in this survey catch rates were 44 times higher at depths less than 50 m than at greater depths in the inshore central area. Overall catch rates were highest in the inshore central area (95.0), intermediate in the inshore southern area (52.6) and much lower in the inshore northern area (2.6). Ages of cod caught ranged from 1-10 years.

Sequential population analysis (SPA)

Sequential population analysis (SPA) was applied to data collected in the inshore central area since 1995. The analysis included indices from each of the three gears employed in the sentinel surveys. Natural mortality (M) was fixed at 33% (M=0.4 per year) for all years and ages.

SPA estimates indicate that spawner stock biomass (SSB) in the inshore central area increased since 2003 to 19,900 t by the beginning of 2007 (Fig. 13). Age 4+ biomass also increased from

2003-2006 but declined to about 25,800 t in 2007. The difference in trends between SSB and age 4+ biomass is due to decreased biomass of fish at age 4. Both age 4+ biomass and SSB are below the peak of the late 1990s.

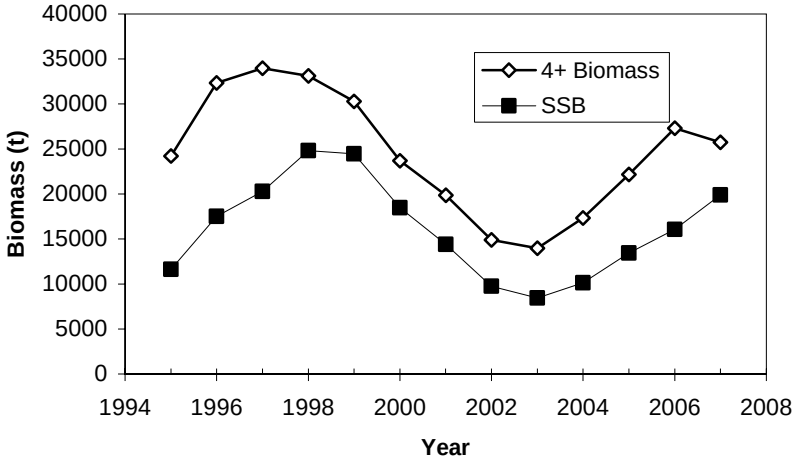


Figure 13: SPA estimates of exploitable (age 4+) biomass and spawner stock biomass (SSB) for the inshore central area.

Fishing mortality expressed as a percentage (Fig. 14) increased when the fishery opened in 1998 and reached a peak of about 30% in 2001 and 2002. Fishing mortality has been relatively low for the past four years, but increased slightly to 8% in 2006 with the reopening of the commercial and recreational fisheries.

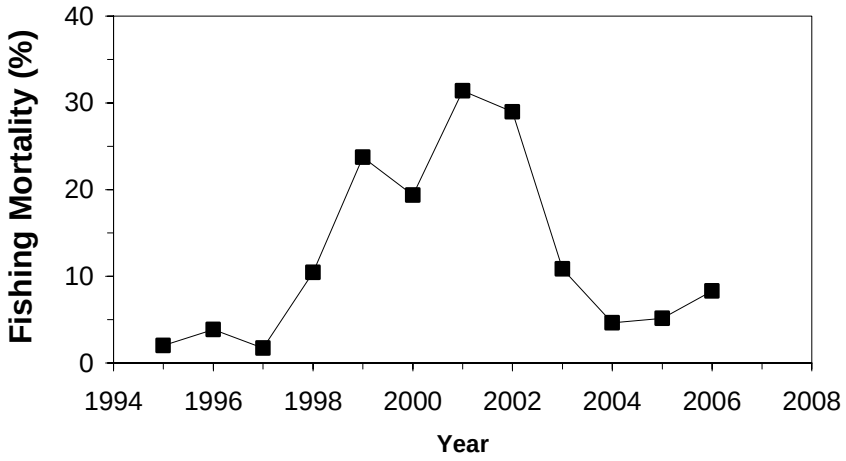


Figure 14: SPA estimates of average fishing mortality (ages 5-10+) for the inshore central area.

Year-class strength (SPA abundance at age 3, Fig. 15) improved from 1999 to 2002 but the 2003 value is one of the lowest in the time series.

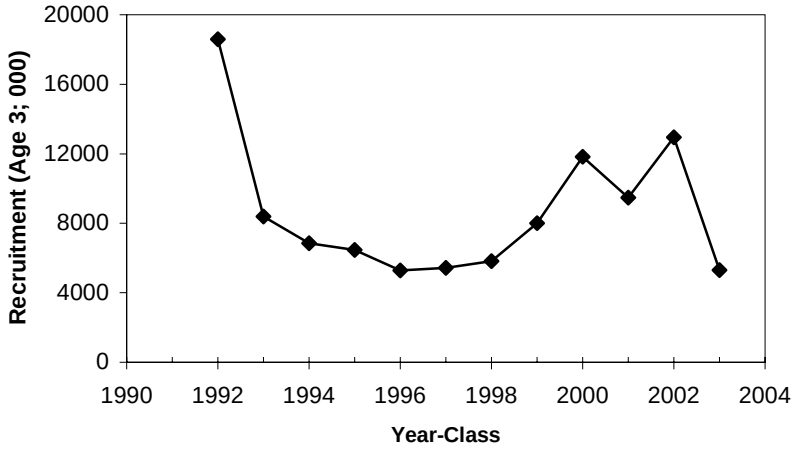


Figure 15: SPA estimates of recruitment (abundance at age 3) for the inshore central area.

Tagging studies

Information from recaptures of cod tagged in various inshore regions of 3KL since 1997 was used to estimate average annual exploitation (harvest) rates. During 1998-2002, the mean exploitation rate for the inshore central area ranged from 12-20% and was highest in 1999 when reported landings peaked at 6,500 t. Exploitation rates were lower (3-11%) during 2003-2005 when the directed fishery was closed and annual landings were reduced to <1,000 t.

During 2006, mean annual exploitation estimates increased to 10% for the inshore central area where the reported landings were 1,750 t. Exploitation was much higher in southern 3K (21%) than in Bonavista Bay and Trinity Bay combined (7%).

Annual estimates of exploitation rate from tagging were generally consistent with those obtained independently from the SPA for the inshore central area.

Current Status

Offshore

The autumn research bottom-trawl survey is the only data source that provides information on the status of cod throughout the offshore. The biomass index in 2006 was 62,500 t, which is about 5% of the level in the 1980s. Recruitment remains very low and mortality extremely high.

Inshore

For the inshore central area, SPA estimates of the 1 January 2007 SSB were 19,900 t and the age 4+ biomass (approximately equivalent to the exploitable biomass) was 25,800 t. These levels are above the average for the 1995-2006 period, and are at 80% of the peak observed for 1997-1998.

There are no quantitative biomass estimates for the inshore northern and inshore southern areas. Sentinel gillnet catch rates in the northern area increased in 2005 and again in 2006 to a level well above average for that region, but are lower than those in the inshore central area.

Catch rates in the inshore southern area have been variable in recent years and have not increased as much as the inshore central and inshore northern areas.

Stock as a whole

There is no single measure of the biomass of the stock as a whole. The information from the research 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.

Stock Projections

The consequences of various catch options for the **inshore central area** (southern 3K and northern 3L) were explored through deterministic and stochastic projections of the 1 Jan 2007 survivors based on the SPA.

Medium-term (3 year) projection results are highly dependent on the recruitment assumption applied. The SPA does not provide estimates of the 2004 and 2005 year-classes. The most recent Newman Sound beach seine results do provide information on these pre-recruit year-classes. A comparison of the cohort information at age 1 from the Newman Sound beach seine survey and the cohort information at age 3 from the SPA for the inshore central area revealed a strong correlation (Fig. 12 and Fig. 16). The beach seine survey results indicate that the 2003-2005 year-classes are the lowest in the time series. The recruitment used in the projections incorporated these results.

In the 2005 and 2006 assessments, alternative recruitment options (low, medium and high) were considered in projections because there were no estimates of recruitment for the projection period. With the information from the Newman Sound pre-recruit index, it would be misleading to consider alternative recruitment options in the projections of the SSB; this index provides information on recruitment for two year-classes in the projection and these year-classes are estimated to be weak. The strength of subsequent year-classes (2006-2008) has minimal impact on the projected SSB over the three year period to 2010.

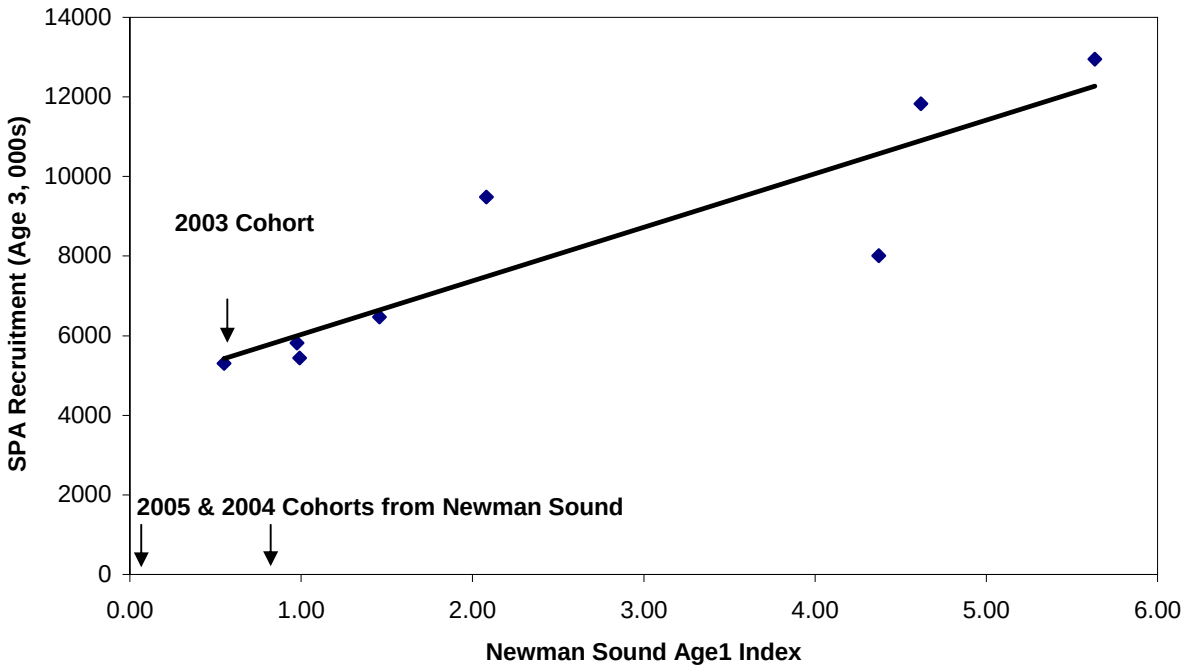


Figure 16: Estimates of recruitment from the Newman Sound beach seine pre-recruit index (age 1) and the SPA (abundance at age 3) for the inshore central area. The Newman Sound index values for the 2004 and 2005 cohorts are indicated on the horizontal axis.

Deterministic projections of stock size to 2010 were computed from the SPA results under catch options of 0 t, 1,250 t, and 2,500 t. The value of natural mortality used in the projections was the same as that in the SPA (M=0.4 per year).

In the one-year projection (to 1 January 2008), SSB is projected to increase for all catch options evaluated. Assuming no removals, SSB is projected to increase by 12%. SSB increases by 6% assuming 1,250 t removals, and by 1% assuming a catch of 2,500 t.

In the three-year projection (to 1 January 2010), assuming no removals, spawner stock biomass is projected to increase slightly by 2% per year on average (6% total growth from 2007 to 2010). Under an annual catch option of 1,250 t, SSB is projected to decline by about 3% per year on average (8% decline from 2007 to 2010) Assuming an annual catch of 2,500 t, spawner stock biomass is projected to decrease by about 8% per year on average (22% decline from 2007 to 2010).

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. The risk of the SSB not growing, of growing at less than 5% and at less than 10% per year was computed for 1 and 3 years at catch options between 0 and 2,500 t. The risk that is calculated includes only the uncertainty in both the numbers of survivors at the beginning of 2007 and incoming recruitment. Recruitment values are consistent with the Newman Sound pre-recruit index.

The risk of 0% growth in SSB by 1 January 2008 at catches below 1,250 t is less than 0.01, and increases to 0.30 at catches of 2,500 t (Fig. 17, upper panel). The risk of SSB growing by less than 5% increases rapidly with catch options above 500 t; assuming catches of 2,500 t in 2007,

the risk is 0.87. The risk of not achieving 10% growth in one year increases rapidly with increasing catch options, and is near 1 at removals of 2,500 t.

In the three year risk analysis (2008-2010), there is a 0.50 probability of 0% growth in the SSB for annual catch options exceeding 600 t (Fig. 17, lower panel). The risk of not achieving 5% annual growth in the SSB is extremely high (0.93) even if there are no removals from 2007-2009. The risk analysis indicates that this stock will not grow by 10% annually in the next three years.

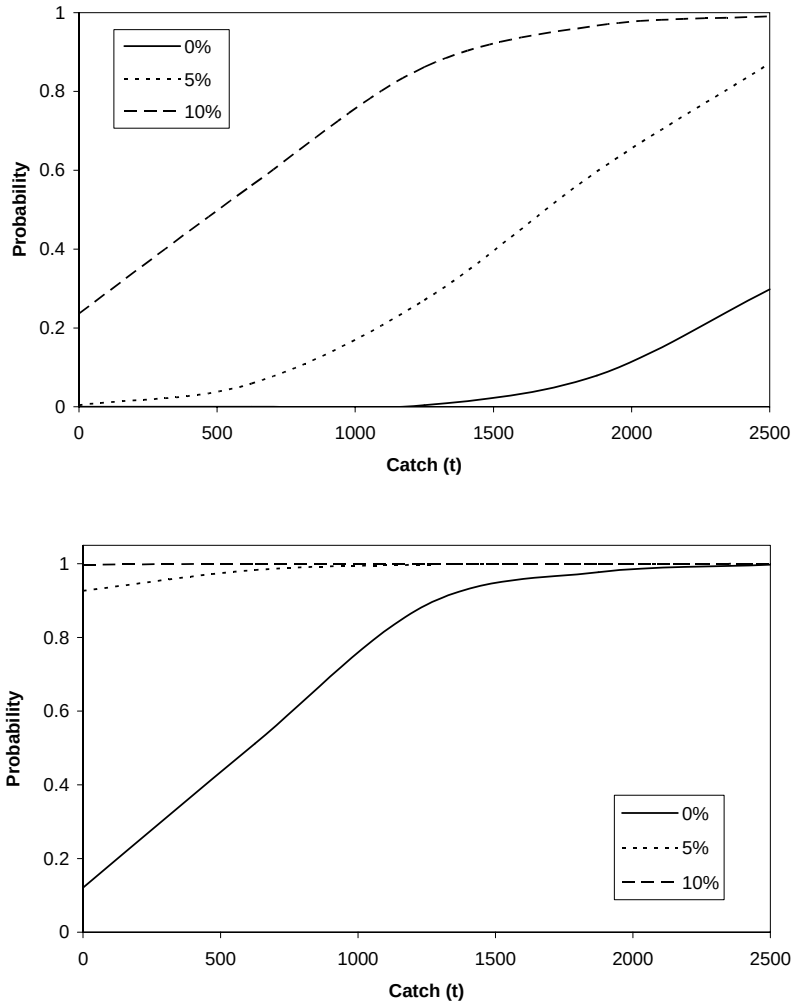


Figure 17: Probability that spawner stock biomass will not meet specified annual growth rates for various catch options by 1 January 2008 (upper panel) and by 1 January 2010 (lower panel).

Biological Information

The information presented in this section comes entirely from the autumn offshore research bottom-trawl surveys.

Maturity

The proportion mature at age among young female cod is variable but increased during the early 1990s. For example, the proportion of age 6 cod that are mature averaged about 0.5 in the 1980's but has increased to about 0.8 since the early 1990s. Males generally mature about one year younger than females and show a similar trend over time.

There have been substantial changes in the estimates of the proportion mature at younger ages for recent cohorts. This is partially the result of low sample sizes. The estimates of the proportion of females at young ages that contribute to the SSB are thus uncertain.

Weight at age

Weight at age has improved since the early to mid-1990s and current values are about average.

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

The contribution of offshore cod to inshore biomass during summer is uncertain. If offshore cod are migrating inshore the reopened fishery will be imposing some level of fishing mortality on offshore cod.

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.

The value of natural mortality (M=0.4 per year) 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 in the projections themselves. There is insufficient information on spatial and temporal variability in natural mortality to explore informative alternatives.

The cohort information at age 1 from the Newman Sound beach seine study is consistent with cohort information at age 3 from the SPA for the inshore central area. The beach seine study alone provided estimates for the strength of the 2004-2005 cohorts used in the projections and the estimates were very low. There is some uncertainty whether the strength of the 2004-2005 cohorts from the beach seine study will represent the strength of these cohorts in the inshore central area.

Several of the recent autumn research bottom-trawl surveys have extended well beyond their normal time and into the winter because of vessel problems. In addition, the survey was not fully completed in some years. 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.

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

ADDITIONAL STAKEHOLDER PERSPECTIVES

Fish harvesters throughout 2J3KL felt that the overall catch is a source of uncertainty. Harvesters believe the amount landed in the recreational fishery was significantly higher than 380 t. The recreational catch in 2001 was about 1,700 t, when cod were less abundant, less time was available to fish, and more restrictions were placed on participants. These facts coupled with harvesters' observations of the recreational fishery suggest the catch in 2006 was actually much higher.

CONCLUSIONS AND ADVICE

Offshore

Mortality of cod in the offshore is extremely high. The high rate of mortality is a major impediment to stock recovery. The extent to which ongoing fishing activities may be contributing to this mortality, from by-catch, incidental mortality, or directed fishing on seasonal migrants that move inshore, has not been determined. Nevertheless, it is recommended that the moratorium on directed fishing be continued, and that by-catch be minimized.

Inshore northern 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 and again in 2006. The origins of the fish generating these increases remain uncertain. They appear to be immigrants, possibly from the offshore; therefore, it would be prudent to keep catches low in this area.

Inshore southern area

For the inshore southern area (southern 3L), the tagging data illustrated that fisheries during 1998-2002 were primarily dependent on fish that migrate seasonally between 3Ps and 3L. Since the magnitude of annual migration cannot be predicted, the effect of various levels of removals cannot be estimated. However, fisheries in southern 3L will contribute additional mortality to fish that migrate between 3Ps and southern 3L. Some of these fish already experience high fishing mortality within Placentia Bay.

Inshore central area

Although SSB increased by 3,800 t (24%) from 2006 to 2007, exploitable biomass (age 4+) decreased by 6%. Incoming recruitment is estimated to be substantially weaker, which will result in a decline in exploitable biomass and SSB. The risk of the SSB growing by less than 5% by 1 January 2008 increases rapidly with a catch above 500 t and is very high (0.87) for a catch of 2,500 t. The risk of the SSB growing by less than 5% per year by 1 January 2010 is very high (0.93) even with no catch.

OTHER CONSIDERATIONS

Management Issues

Recreational fishery

There were concerns with methods used to estimate the number of boat trips per day during the recreational fishery.

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 inshore and most 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. Cod from inshore populations may expand into the offshore habitat; 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

The distribution of fish harvesters does not match the distribution of cod. This will cause geographic variability in fishing mortality. For example, in the 2006 fishery, tagging data indicated that exploitation was much higher in southern 3K (21%) compared to Bonavista Bay and Trinity Bay combined (7%). Therefore, fishing bay-by-bay may result in local over-exploitation and managers should attempt to preserve and enhance population spatial structure and diversity within the stock.

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 the most recent year (2006) at a record high.

Studies based on data up to the mid-1990s have demonstrated that growth of cod 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 cod in this area may 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.

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. A pilot study on the efficacy of seal exclusion zones was conducted in Smith Sound (Bowen 2004). The information from these programmes is not yet available for review.

Prey (notably capelin)

The trend in capelin biomass has been uncertain since the late 1980s. Biomass estimates from hydroacoustic surveys in an index area offshore have been much lower since the early 1990s compared with the 1980s. No offshore biomass estimates are available for 2005 and 2006 due to incomplete or missed surveys. Indices of capelin biomass from the inshore did not show such extensive declines in the early 1990's. However, these same inshore indices are no longer available. Concurrent with the decline in capelin abundance offshore, capelin underwent dramatic changes in their biological and behavioural characteristics. These included: decreased size of spawners, delayed timing of spawning, reduced beach spawning and perceived increase in off beach spawning. There have also been changes in horizontal and vertical distribution, decreases in condition and changes in prey composition. In the last two years it would appear that size of spawners are increasing, spawning times are getting earlier and beach spawning, especially in the northern areas has increased, but none of these attributes have yet approached levels observed in the late 1980s.

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