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Science Sciences

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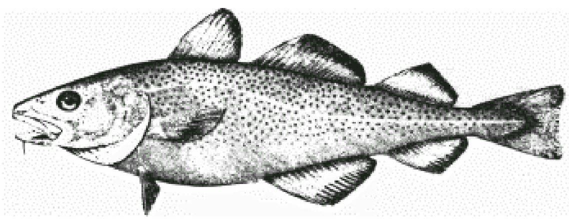
STOCK ASSESSMENT REPORT ON NORTHERN (2J+3KL) COD



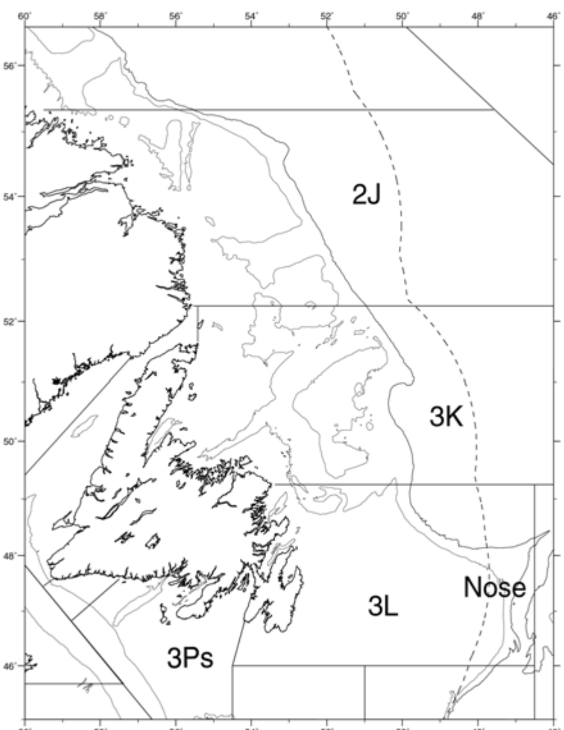


Figure 1: Map of the stock area of northern (2J+3KL) cod. The dashed line indicates Canada's 200 nautical mile Exclusive Economic Zone (EEZ).

Context

The biomass of the northern (2J+3KL) 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 the dense offshore overwintering aggregations. The stock declined to about 0.5 million t in the mid-1970s. After the extension of jurisdiction in 1977, the stock increased to just over 1 million t in the mid-1980s, but then collapsed to an extremely low level in the late 1980s and early 1990s. A moratorium on commercial fishing was declared in July 1992.

Historically, many cod migrated from overwintering areas offshore to feeding areas inshore, where they were exploited by the traditional inshore 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 reintroduced in 1998. Catch rates declined and the fishery was closed indefinitely in April 2003. A food/recreational fishery, which had been open for several years, was also closed.

Capelin has historically been the major prey of adults. Harp seals are important predators.

SUMMARY

- Status of the 2J+3KL cod stock was assessed based on data from research bottom-trawl surveys, sentinel surveys, prerecruit surveys, acoustic surveys in a specific area, tagging studies, a telephone survey of fish harvesters, and catches from the commercial and recreational fisheries.

- The spawner biomass of the 2J+3KL cod stock as a whole remains far below any conservation limit reference level as generally applied through the precautionary approach to fisheries management. Although such a level has not been defined precisely for 2J+3KL cod, it is anticipated to lie above 300,000 t.

- Due to differences in the dynamics of offshore and inshore populations of 2J+3KL cod since the mid-1990s, information is provided for the offshore and inshore separately.

- In the offshore, the 2004 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 2002-2004 is about 19,000 t, which is less than 2% of the average during the 1980s. An index of spawner biomass in the offshore is currently at about 1% of the level during the 1980s.

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

- In the inshore, catch rates in sentinel surveys (1995-2004) and commercial fisheries (1998-2002), as well as cod by-catch in fisheries targeted at other species (2003-2004), indicate that there has been relatively few cod in 2J and northern 3K. However, there have been high catch rates at various times and places in southern 3K and in 3L.

- Tagging studies have revealed that there are currently two main groups of cod in the inshore in southern 3K and in 3L. The first group comprises resident fish that overwinter in northern 3L and southern 3K and undertake seasonal migrations among Trinity, Bonavista and Notre Dame bays. The second group comprises migratory fish that overwinter in inshore and offshore areas of 3Ps, move into southern 3L in the spring-summer, and return to 3Ps in the autumn. It is thought that migrants from offshore 2J+3KL currently contribute little to the biomass of cod in the inshore of 2J+3KL.

- For the purpose of this assessment, the inshore is subdivided into three areas: 1) a northern area (2J and northern 3K) that contains relatively few cod; 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.

- Inshore catch-rate indices from linetrawl and gillnet sentinel surveys increased from 1995 to a peak in 1997 and 1998 respectively, declined by the early 2000s, and then increased during recent years to levels similar to those in 1995.

- Results from a fish harvester telephone survey and observations from industry participants in the assessment meeting show geographic trends in abundance similar to those seen in sentinel survey data and offshore research vessel survey data.

- A high proportion of telephone survey respondents in Bonavista, Trinity and St. Mary's bays were of the opinion that catch rates were higher in 2004 than in the late 1980s.

- Hydroacoustic surveys on the largest overwintering population (in Smith Sound, Trinity Bay) during the winters of 1999-2004 provided average indices of biomass that peaked at 26,000 t in 2001 and then declined to 18,000 t in 2004.

- Results from tagging experiments indicate that harvest rates averaged 10% of the exploitable biomass (approximately ages 4+) in the central inshore region from 1999 to 2002, associated with an average reported catch of 5,000 t. Based on these harvest rate estimates, exploitable biomass from 1999 to 2002 averaged approximately 50,000 t with no clear time trend.

- The tagging studies provided evidence of annual natural mortality of 48% in inshore 3K and 26% in inshore 3L for the period 1997-2002.

- A sequential population analysis (SPA) was conducted for the resident cod in the inshore central area. The analysis incorporated catches during 1995-2004 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 7,000 t in 2003, and has subsequently increased to 13,000 t by the beginning of 2005. This increase is due to reduced fishing mortality and improved recent recruitment. The estimate of age 4+ biomass at the beginning of 2005 is about 20,000 t. Fishing mortality increased from 1998 to a peak of about 35% in 2001 and 2002.

- Deterministic projections from 2005 to 2006, based on the SPA, were conducted for the inshore central area under various annual catch options. Assuming no removals or a catch option of 2,500 t, spawner biomass is projected to increase. At a catch option of 5,000 t, spawner biomass is projected to decrease.

- Due to uncertainties in future recruitment levels, deterministic projections from 2005 to 2008 were conducted for the inshore central area under various annual catch options and three recruitment assumptions (low, medium, high). Assuming no removals, spawner biomass is projected to increase for each recruitment assumption. At a catch option of 2,500 t, spawner biomass is projected to decrease if recruitment is low, but increase if recruitment is medium or high. At a catch option of 5,000 t, spawner biomass is projected to decrease for each of the recruitment scenarios.

- The inshore northern area appears to have very low densities of cod. Any catch option would likely impose high fishing mortality and further reduce stock size 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.

- There is no new information regarding the impact of seals on the dynamics of cod. Previous cod assessments 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.

DESCRIPTION OF THE ISSUE

Rationale for Assessment

The assessment of 2J+3KL cod is the result of a request for science advice from the Fisheries and Aquaculture Management (FAM) Branch – Newfoundland and Labrador Region. The Terms of Reference for the assessment were as follows:

- Review the evidence regarding whether populations of cod currently inhabiting inshore waters are self-sustaining and distinct from populations that historically overwintered and spawned in the offshore and migrated seasonally to the inshore.

- Assess 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 5,000 t annually in 2005 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 geographical and seasonal variability in the density and migration patterns of cod in the inshore, and the extent to which such variability affects the quantity of cod available to fish harvesters both regionally and seasonally. What are the implications for regional vulnerability to exploitation?

- The assessment will be conducted in manner which is inclusive of the principles of the precautionary approach, which acknowledges that caution must be exercised to safeguard fisheries resources and ocean ecosystems. The precautionary approach recognizes that the absence of full scientific certainty shall not be used as a reason to postpone decisions where there is risk of serious or irreversible harm.

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.

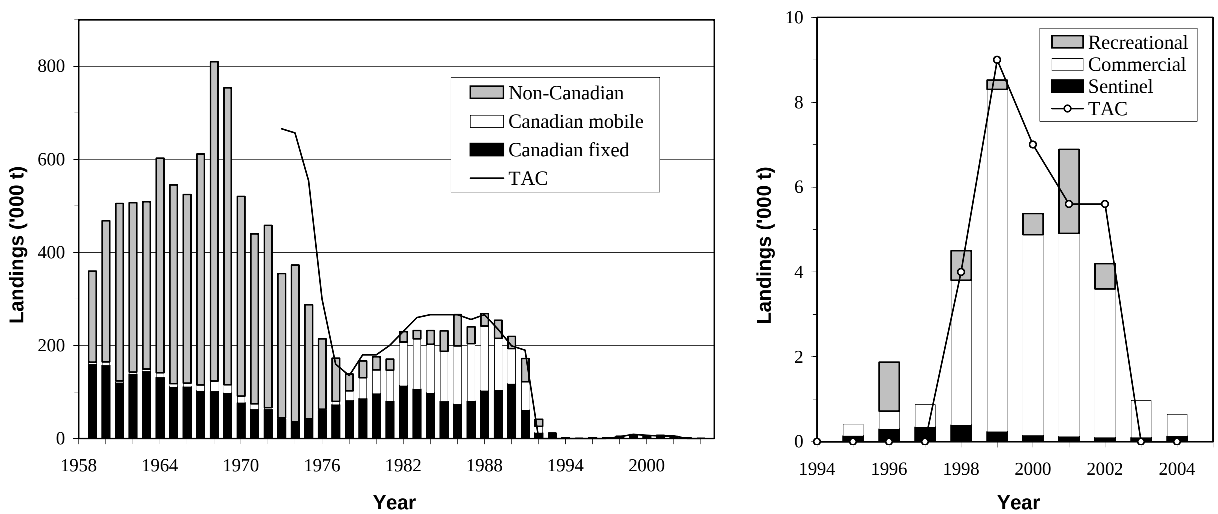


Figure 2: Total allowable catches (TACs) and landings (thousands of tons) in 1959-2004. The left panel illustrates landings by non-Canadian and Canadian fleets, with the latter divided into mobile gear (offshore) and fixed gear (mainly inshore). The right panel shows 1995-2004 in more detail, with the catch subdivided into food/recreational, index/commercial (including by-catch) and sentinel.

Table 1: Catch ('000 t).

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

Reported landings during 2003 were approximately 880 t from the commercial fishery and 90 t from the sentinel surveys, for a total of 970 t.

Most (780 t) of the commercial catch during 2003 came from a mass mortality of cod in Smith Sound, Trinity Bay, during April. The exact cause of the event remains uncertain, but it was clearly associated with unusually cold water within the Sound (Colbourne et al. 2003). The cod were collected from the surface of the water by gaff and dip net. Many of these fish were frozen, whereas others were torpid but still alive. The fish were generally large, with a high proportion in the range 55-85 cm.

The rest of the reported catch during 2003 was by-catch in fisheries directed at other species. Most (84 t) of this came from gillnets set for winter (blackback) flounder. The bulk of this catch came from Bonavista Bay and Trinity Bay in July. The by-catch from Canadian trawlers in the offshore was 3 t.

The catch by non-Canadian trawlers outside the 200 nautical mile limit on the Nose of the Bank (Div. 3L) in 2003 was 23 t.

In terms of numbers of fish, the landings during 2003 were dominated by the mass mortality in Smith Sound (68%), followed by gillnets of mesh size 5½ inches or greater (28%) and small mesh gillnets (3¼ inches) from the sentinel survey (4%). The catch comprised a range of ages (3-14), with ages 6-7 predominant. Older ages (11 and 13) were also strongly represented in the 2003 catch at age because of the Smith Sound incident. Consequently, the total catch at age was unusual compared with that of the previous five years.

Fishery management regulations were changed for 2004 such that individual fish harvesters were limited to a maximum by-catch of 2000 pounds (907 kg) in any and all groundfish fisheries. In addition, for the winter (blackback) flounder fishery, the incidental catch of cod was not to exceed 20% or 300 pounds per day. Many harvesters took much or all of their 2000 pound cod limit while directing for winter flounder, and in many cases the catch of winter flounder was much less than the catch of cod. The gillnet mesh size in the winter flounder fishery was 6½ - 8½ inches, which is greater than the 5½ - 6½ inches in the directed cod fisheries of 1998-2002.

Reported landings during 2004 were approximately 520 t of by-catch from commercial fisheries and 120 t from the sentinel surveys, for a total of 640 t. Most of the by-catch came from the winter (blackback) flounder fishery. The by-catch from Canadian trawlers in the offshore was 6 t. The catch comprised a range of ages (3-14), with ages 6-7 predominant. The 1990 and 1992 year-classes (ages 14 and 12) were weakly represented.

An estimate is not yet available for the 2004 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 catches during 2000-2003 were 20-80 t annually.

ASSESSMENT

Stock Structure

Since the mid-1990s, there has been a dichotomy between the offshore and the inshore. Cod in the offshore have been small and 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 conducted during the post-moratorium period indicate that the inshore of 3KL is currently inhabited by at least two groups of cod: (1) a northern resident coastal group that inhabits an area from western Trinity Bay northward to western Notre Dame Bay and (2) a migrant group that overwinters in inshore and offshore areas of 3Ps, moves into 3L during late spring and summer, and returns to 3Ps during the autumn. Tagging studies also indicate 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.

It is not known if there is currently movement of adult cod between the inshore and the offshore in 2J3KL. 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 2J+3KL currently contribute little to the biomass of cod in the inshore of 2J+3KL.

Key Indicators

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

Offshore

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 slight improvement toward the end of the 1990s has not been sustained. The biomass index during 2002-2004 was 1-2% of the average during the 1980s.

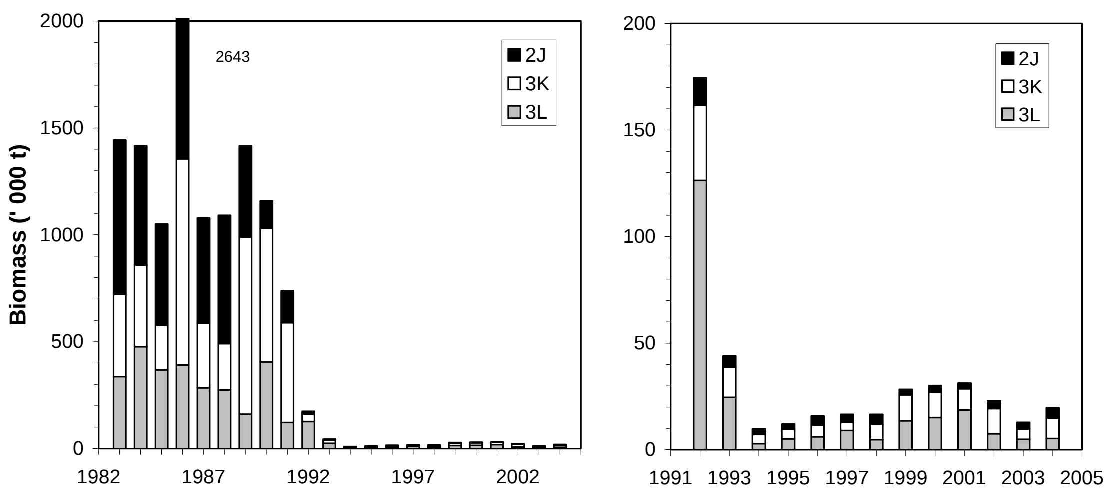


Figure 3: Offshore biomass index from autumn bottom-trawl surveys in 2J3KL. The left panel illustrates data from 1983 to 2004. The scale on the right panel illustrates just the lower 10% of the left panel, in order that the 1992-2004 data may be more readily discerned.

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 has, during 2002-2004, been at less than 1% of the average in the 1980s (Fig. 4).

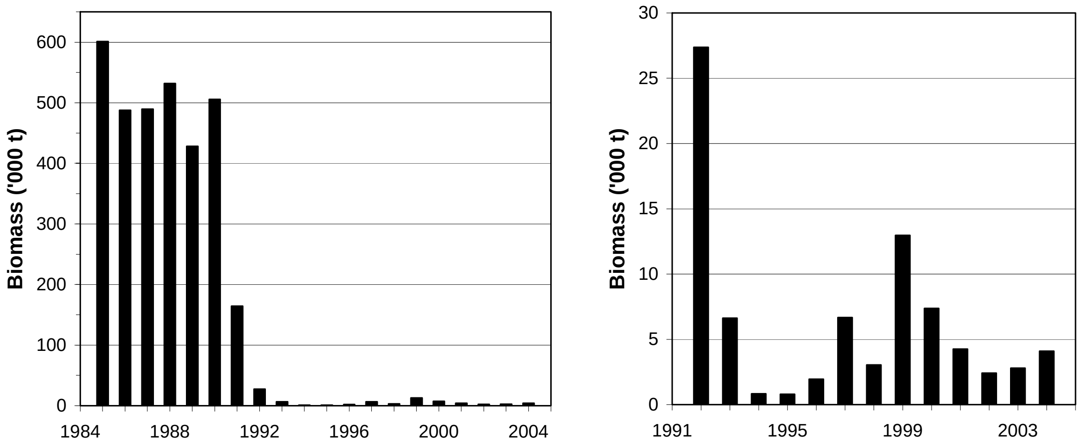


Figure 4: Biomass index from spring bottom-trawl surveys in 3L. The left panel illustrates data from 1985 to 2004. The scale on the right panel illustrates just the lower 5% of the left panel, in order that the 1992-2004 data may be more readily discerned.

Inshore

For the purpose of this assessment, the inshore is subdivided into three areas (Fig. 5): 1) a northern area (2J and northern 3K) that contains relatively few cod; 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.

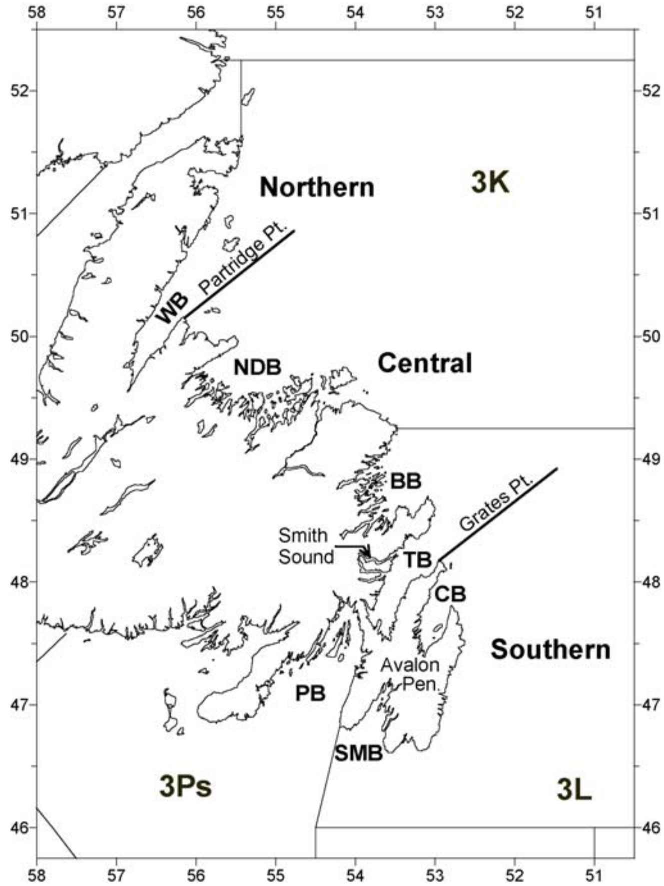


Figure 5: Map of the inshore of eastern Newfoundland, indicating the locations of the northern, central and southern inshore areas as defined for the present assessment. Also indicated are the locations of Smith Sound, the Avalon Peninsula, and the major bays: White Bay (WB), Notre Dame Bay (NDB), Bonavista Bay (BB), Trinity Bay (TB), Conception Bay (CB) and St. Mary's Bay (SMB). Placentia Bay (PB) is in Subdiv. 3Ps.

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.

Hydroacoustic studies have been conducted in Smith Sound in western Trinity Bay (3L) at various times since spring 1995. Winter (January-February) surveys have been conducted in a standard manner by the Fisheries Conservation Chair at Memorial University of Newfoundland since 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. The fish sampled during the 2004 survey were of a wide size range (35-120 cm).

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). Catch rates in the two commercial gears have been relatively low since the start of the survey in 2J and in 3K north of White Bay. However, fish have existed in sufficient density to enable moderate to high catch rates in some times and places from White Bay to the southern boundary of the stock. In 2004, the highest catch rates generally occurred in southern Bonavista Bay and Trinity Bay in northern 3L and in St. Mary's Bay in southern 3L adjacent to 3Ps.

To provide continuity with previous assessments (DFO 2003), the catch rate data from 2J3KL combined were standardized to remove site and seasonal effects and produce annual indices of total catch rate and catch rate at age. Age-aggregated catch-rate indices from linetrawls and gillnet (5½ inch mesh) increased from 1995 to a peak in 1997 and 1998 respectively, declined by the early 2000s, and then increased during recent years to levels similar to those in 1995 (Fig. 6) .

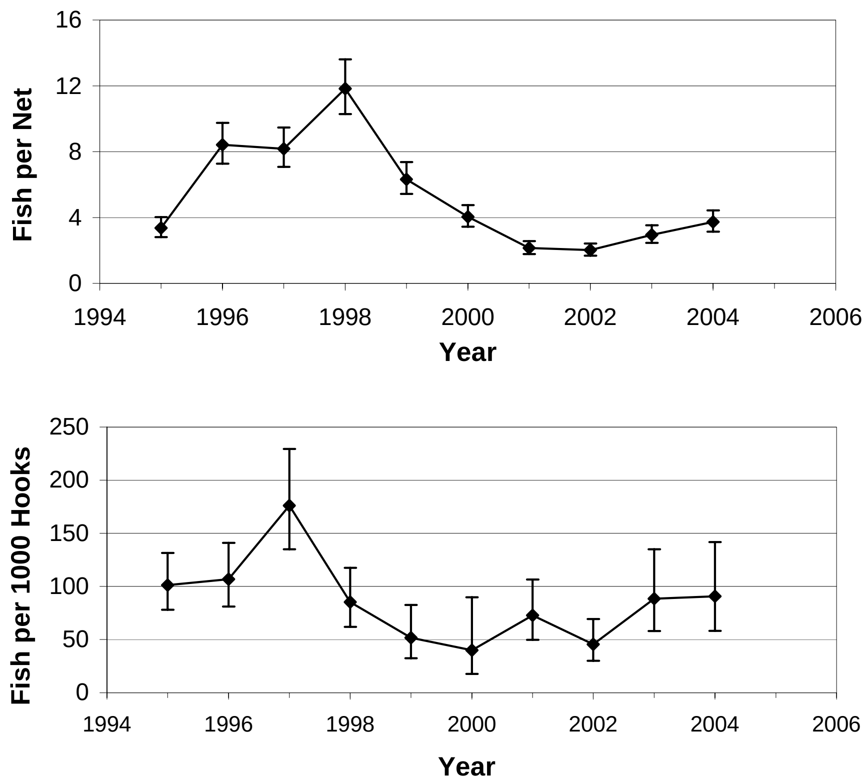


Figure 6: Standardized catch rates from sentinel surveys in 2J3KL combined; gillnets (5½ inch mesh) above and linetrawls below.

Catch rates at ages 3 and 4 combined from the small mesh (3¼ inch) gillnets were high in the early years, declined during the late 1990s, increased to a level in 2003 that was approximately equal to that in the early years, but declined again in 2004 (Fig. 7).

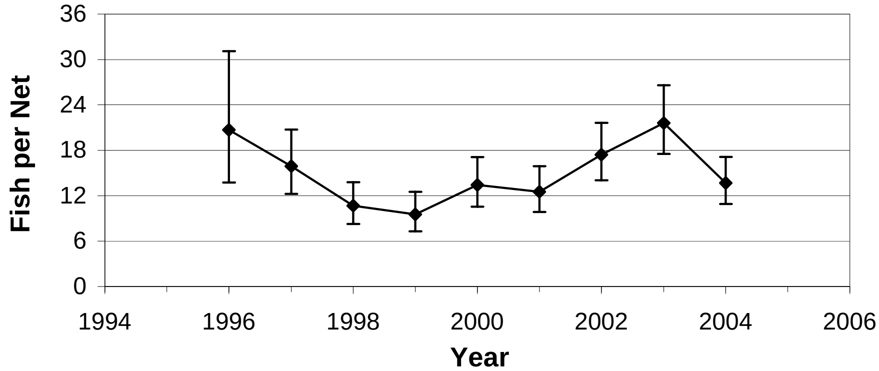


Figure 7: Standardized catch rates at ages 3 and 4 combined from 3¼ inch sentinel gillnet surveys in 2J3KL combined.

The sentinel gillnet (5½ inch) data were also subdivided into the northern, central and southern areas described above in order to provide information on trends in specific areas (Fig. 8). In the northern area, mean catch rates have been low since 1995, but were somewhat higher during the late 1990s than during the 2000s. In the central and southern areas, the trends over time were very similar to one another and to the trend in the combined index. In addition, the magnitude of catch rates in the central and southern areas were very similar.

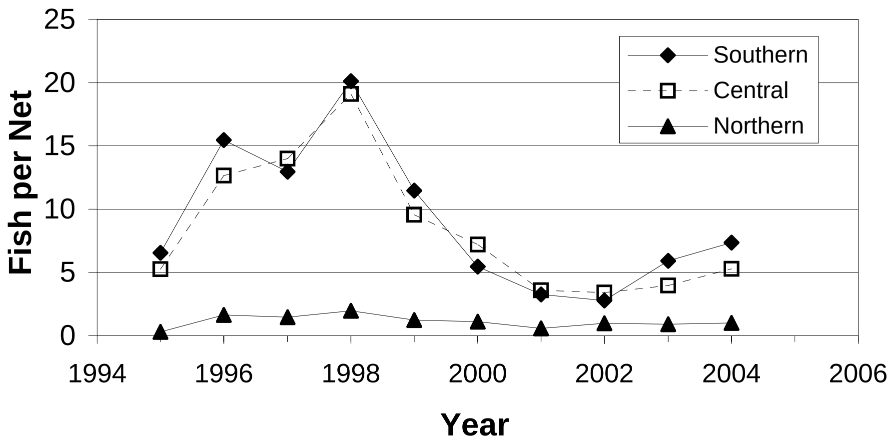


Figure 8: Standardized catch rates from sentinel 5½ inch gillnet surveys in northern, central and southern areas.

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-1990s were weak, and year-classes of the late 1990s and 2000 were moderately strong.

Catch rates from the 1998-2002 directed cod fishery had geographic and temporal trends that were similar to those of the sentinel catch rates during the same period (DFO 2003).

Population Biology

The **proportion mature at age** increased among young female cod sampled during the offshore autumn bottom-trawl surveys during the early 1990s and has fluctuated since (Fig. 9).

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.

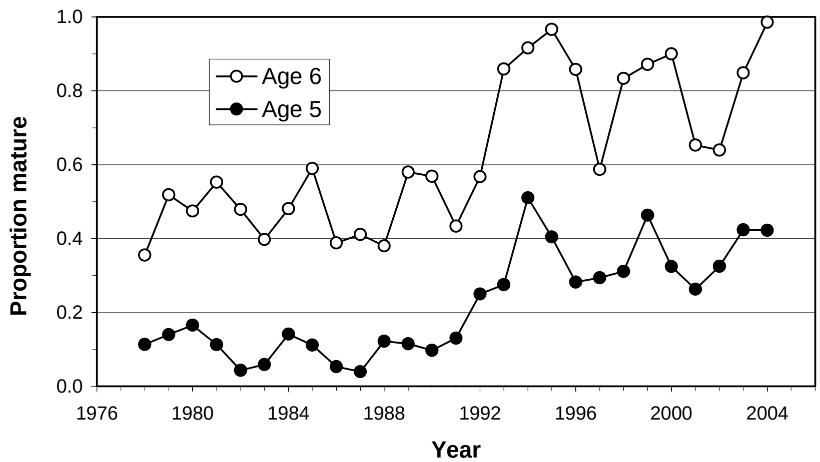


Figure 9: Percentage of females mature at ages 5 and 6 as predicted from modeling the maturity data from autumn offshore bottom-trawl surveys.

Size-at-age of cod sampled during the autumn surveys of the offshore declined during 1983-1985 and again in the early 1990s, especially in 2J (Fig. 10). Size-at-age has increased in recent years but is below peak values observed in the late 1970s. Much of the variability in growth is related to variability in water temperature.

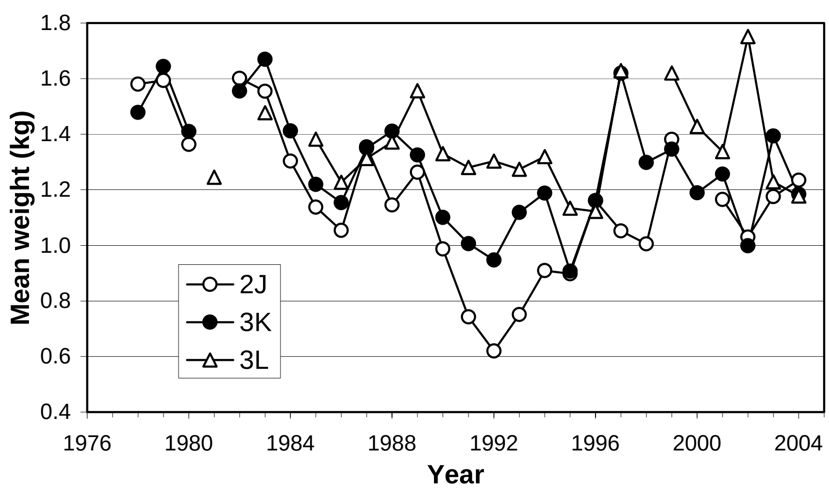


Figure 10: Mean weight (kg) at age 5 of cod sampled during autumn offshore bottom-trawl surveys.

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.

Stock Trends

Offshore

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. 11) 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.

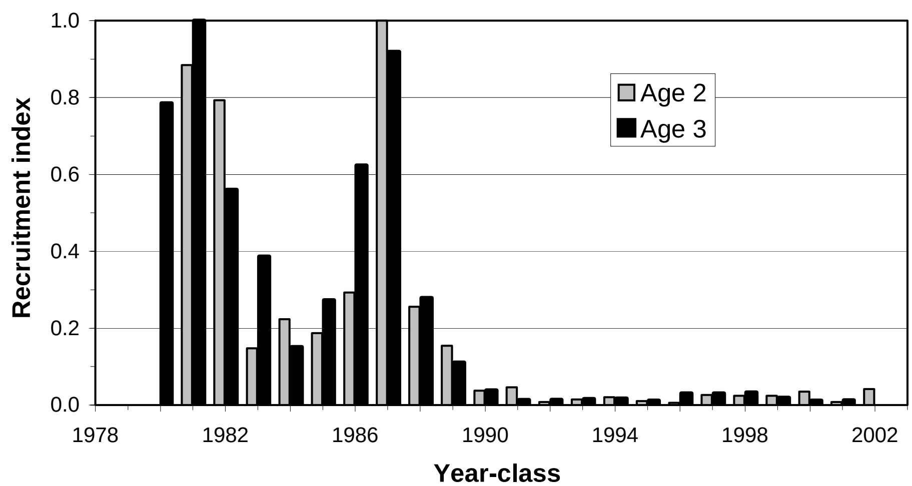


Figure 11: Relative sizes of the 1980-2002 year-classes in the offshore of 2J3KL, as measured by the mean catch per tow at ages 2 and 3 during the autumn offshore bottom-trawl surveys. Number per tow has been scaled to a maximum of 1 within the time-series for each age.

Age specific **mortality** rates (proportion of population dying in a year) rose to very high levels 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 (7+) in the survey since the early 1990s prevents estimating total mortality on these older ages. For younger ages (Fig. 12), mortality has been very high (40-60% per year at age 4 and 60-90% per year at age 6).

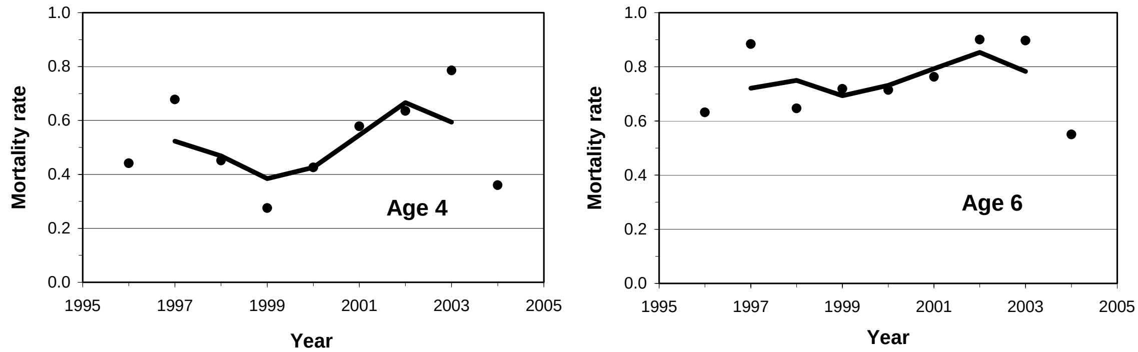


Figure 12: Age specific mortality calculated from catch per tow at age during the autumn bottom-trawl surveys in the offshore of 2J3KL. As an example, in the age 4 panel, the value of 0.7 in 1997 is the mortality experienced by the 1993 year-class from age 3 in 1996 to age 4 in 1997. The line is a 3-year 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.

Inshore

A large-scale **tagging study** of adult (>45 cm) cod was initiated in spring 1997 in the 2J3KL and 3Ps cod stock areas. During 1997-2004 a total of about 92,000 cod were tagged and released and approximately 17,000 of these tagged cod have been reported as recaptured to date. Analyses of these data (first reported in 1999) have provided estimates of exploitation rates, exploitable biomass and information about natural mortality rates. In these analyses, the central inshore area is further subdivided into southern 3K (Baie Verte Peninsula and eastward) and northern 3L (Bonavista Bay and Trinity Bay). These regions were constructed to reflect potential sub-stock structure and spatial variation in exploitation rates.

Results of tagging experiments indicate that harvest rates averaged 10% of the exploitable biomass (approximately ages 4+) in the central inshore region from 1999-2002 associated with an average reported catch of 5,000 t. Based on these harvest rate estimates, exploitable biomass from 1999 to 2002 averaged approximately 50,000 t with no clear trend. There were insufficient tag returns and landings to provide comparable estimates for 2003 and 2004.

The tagging studies provided evidence of annual inshore natural mortality of 48% in 3K and 26% in 3L for the period 1997-2002.

Prior to the collapse of the 2J3KL cod stock, **sequential population analysis** (SPA) for the stock as a whole was the main tool used to estimate stock size and trends over time. This method was reintroduced during the 2003 assessment and applied to those cod in the inshore since the mid-1990s. The area for which the analysis was applied was further restricted during the present assessment to the central inshore area. The landings from the Smith Sound mass mortality in 2003 were included. The model also included indices from each of the three gears employed in the sentinel surveys in this area. Natural mortality was fixed at 33% (M=0.4) for all years and ages in this SPA based on evidence from tagging results.

SPA estimates indicate 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 7,000 t in 2003, and has subsequently increased to 13,000 t by the beginning of 2005 (Fig. 13). This increase is due to reduced fishing mortality and improved recent recruitment. The estimate of age 4+ biomass at the beginning of 2005 is about 20,000 t (Fig. 13).

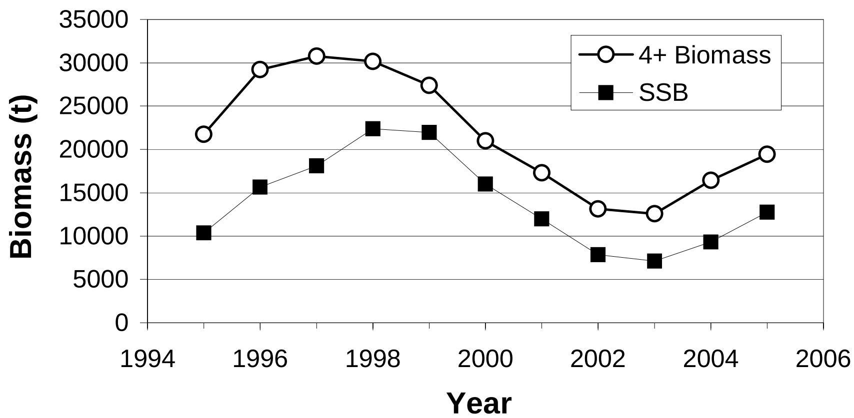


Figure 13: SPA estimates of exploitable (4+) biomass and spawner biomass (SSB) for the inshore central area.

Fishing mortality (Fig. 14) increased from 1998 to a peak of 0.42 (about 35%) in 2001 and 2002.

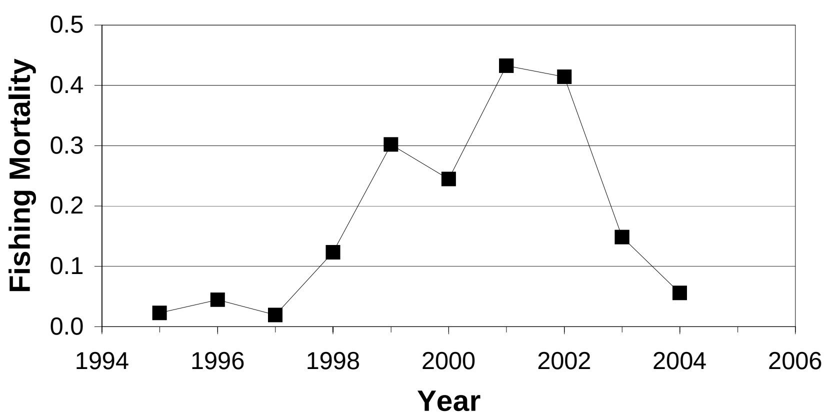


Figure 14: SPA estimates of fishing mortality (age 5-10) for the inshore central area.

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. 15).

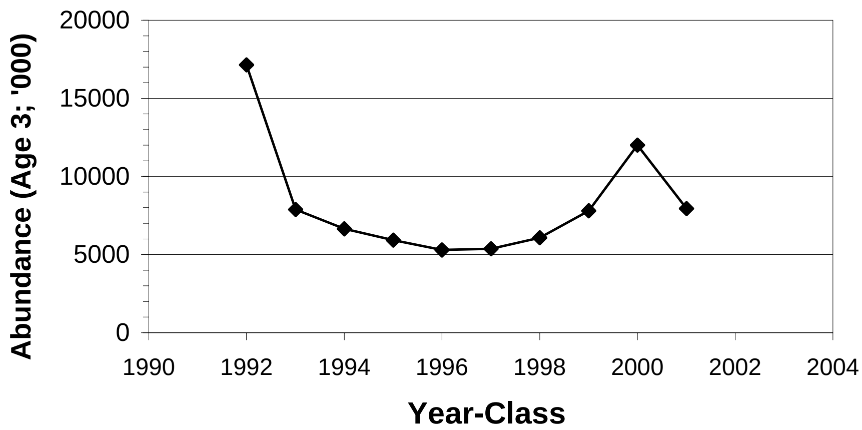


Figure 15: SPA estimates of recruitment (abundance at age 3) for the inshore central area.

Age 3 is the youngest age from the tuning indices used in the SPA because earlier ages have not reliably indicated subsequent recruitment to the fishery. Information on recent year-classes is available from research bottom-trawl surveys within the bays, small mesh gillnets, and beach seining in Bonavista Bay. Some data from these indices suggest that the 2002 year-class was at least moderately strong, but other data do not indicate such strength. The beach seining indicates that the 2003 and 2004 year-classes may be weak. Fish harvesters noted higher abundance of small cod (<25cm; approximately ages 0-2) in inshore areas in the past 2-3 years compared to levels in the mid- 1990s.

Sources of Uncertainty

For the past three 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. The 2004 survey was not completed. This resulted in an underestimation of population size, but not necessarily an underestimation of mean catch rate.

It was not possible to estimate exploitation, natural mortality, and migration rates for 2003 and 2004 from tagging information because of the limited catch, tag returns and much reduced tagging of cod in those years.

The number of tags that are returned from fisheries in 2J3KL are complicated by factors such as gear selectivity, migration, tag retention and tag reporting rates. Methods to analyze this type of data are not well developed and understood compared to more standard methods like SPA. This is particularly true with respect to estimating natural mortality.

The SPA for the central inshore area is based on a short time series of indices and catches (1995-2004). This increases the uncertainty in 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.

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 2J3KL ecosystem has experienced dramatic changes since the 1980s. The relative importance of fishing, physical environment and biological interactions in causing and sustaining those changes is difficult to discern. There is considerable uncertainty regarding the extent to which climate variability and climate change may be influencing various aspects of cod population dynamics, particularly at the early life history stages. There is also much uncertainty about the biomass and availability of prey for cod at various stages of its growth, notably macrozooplankton during its larval and juvenile stages and capelin during its mid-life.

ADDITIONAL STAKEHOLDER PERSPECTIVES

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 2004 was lower than it had been during the late 1980s but higher than it was during 2002, the last year of the commercial index cod fishery. In 3K, there was no clear indication of how cod abundance in 2004 compared with abundance during the late 1980s, but most harvesters felt that abundance in 2004 was about the same or better than it had been during 2002. In 3L, most harvesters in Bonavista, Trinity and St. Mary's bays felt that cod abundance during 2004 was better than it had been in the late 1980s and better than during 2002. In Conception Bay and along the eastern Avalon Peninsula, there was no clear indication of how abundance in 2004 compared with abundance during the late 1980s, but most harvesters felt that abundance during 2004 was better than it had been during 2002.

Fish harvesters participating in the assessment meeting stated that catch rates in Trinity, Bonavista and St. Mary's bays were much higher in recent years than during the 1980s. Abundance is not only higher on traditional fishing grounds, but also higher in non-traditional areas. It was difficult to set any fixed gear, including lobster pots, without catching cod. This problem has intensified in the past few years.

Fish harvesters note higher abundance of small cod (<25cm) in the most recent 2-3 years compared to levels in mid-1990s.

There are few observations from large offshore trawlers because of limited activity in the area. However, one company reported that no cod were taken during the spring and summer fishery for Greenland halibut, and that no offshore concentrations of cod were seen on the sounder as their ships steamed between Trinity Bay and shrimp fishing grounds to the north.

CONCLUSIONS AND ADVICE

In the current assessment, 3-year deterministic projections of stock size to 2008 were computed from the SPA results for the inshore central area (southern 3K and northern 3L). Projections were conducted under catch options of 0 t, 2,500 t, and 5,000 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 2003 of age 2 abundance from the SPA; medium recruitment was the 2001-2003 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).

The projection of spawner biomass from 2005 to 2006 is insensitive to the assumed value of recruitment. With no removals or a catch option of 2,500 t, spawner biomass is projected to increase, regardless of the assumed recruitment level (Table 2). This is the result of the relatively strong 2000 year-class entering into the spawner biomass. At a catch option of 5,000 t, spawner biomass is projected to decrease.

Table 2: Projected changes in spawner biomass (SSB) for various fixed catch options and various recruitment levels from 2005 to 2006.

% Change in SSB between 2005-2006 (Jan.1)				
Recruitment		Catch Option		
		0t	2,500t	5,000t
	Low	26%	9%	-7%
	Medium	27%	10%	-6%
	High	27%	11%	-5%

In the three year projection (from 2005-2008), assuming no removals, spawner biomass is projected to increase for each recruitment assumption (Table 3). At a catch option of 2,500 t, spawner biomass is projected to decrease if recruitment is low, but increase if recruitment is medium or high. At a catch option of 5,000 t, spawner biomass is projected to decrease for each of the recruitment scenarios.

Table 3: Projected changes in spawner biomass (SSB) for various fixed catch options and various recruitment levels from 2005 to 2008.

% Change in SSB between 2005-2008 (Jan.1)				
Recruitment		Catch Option		
		0t	2,500t	5,000t
	Low	35%	-8%	-50%
	Medium	57%	14%	-28%
	High	75%	32%	-10%

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.

The above projections are applicable for just the inshore central 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 are very low. Any catch option would likely impose high fishing mortality and further reduce stock size in this 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 seasonal immigration. Since the magnitude of immigration 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 Placentia Bay and southern 3L. These fish already experience high fishing mortality within Placentia Bay.

Under a **precautionary approach**, conservation limit reference points indicate when a stock is considered to have impaired productivity and is thus in a situation in which serious harm has occurred. The biomass of the 2J+3KL cod stock as a whole is not known, but it is clearly far below any limit reference point. A spawning stock biomass limit reference point has not been identified for 2J+3KL cod, but it was anticipated that the limit would be higher than 300,000 t for the stock as a whole (Rivard and Rice 2002). Given the lack of any recovery in the offshore during the past decade, it is clear that the productivity of the stock as a whole is seriously impaired.

The risk of fishing the inshore populations extends beyond a consideration of limit reference points. There is a strong possibility that cod currently offshore in 2J3KL undergo spring/summer feeding migrations to the inshore. At current offshore population levels, any offshore fish exploited in an inshore fishery could further impede recovery in the offshore. Many of the fish historically caught in the inshore were immature, so inshore removals may capture some offshore fish before they have a chance to spawn.

The potential for cod currently in the inshore to repopulate the offshore of 2J3KL remains uncertain. Genetic studies using microsatellites 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. However, evidence of substructure may not preclude inshore-spawning cod playing a role in future offshore recovery. If fish currently in the inshore could recolonize the shelf, then allowing the inshore biomass to increase makes it more likely that inshore fish may move offshore.

In consideration of the above, there is a risk that fishing in the inshore will impede recovery in the offshore.

There may be numerous over-wintering inshore populations, with the largest by far being that in Smith Sound. Small populations of cod residing adjacent to large populations of fish harvesters (such as in parts of Notre Dame Bay) are more vulnerable to over-exploitation than the relatively large population in Smith Sound. To protect small populations, it is essential that removals be kept low in areas of low cod density.

OTHER CONSIDERATIONS

Predation by Seals

There is no new information regarding the impact of seals on the dynamics of cod. 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 is in progress. This programme includes new population surveys, new studies of distribution, and new studies of diet, both inshore and offshore.

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 participant in this cod assessment meeting reported that belly-feeding is still occurring in Smith Sound (Trinity Bay).

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

Availability of 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.

SOURCES OF INFORMATION

Bowen, W.D. (Chairperson). 2004. Report of the seal exclusion zone workshop. 11-13 May 2004, Cambridge Suites, Halifax, N.S. DFO Can. Sci. Advis. Sec. Proceed. Series 2004/022.

DFO 2003. Northern (2J+3KL) cod. DFO Can. Sci. Advis. Sec. Stock Status Rep. 2003/018.

DFO 2004. Northern (2J+3KL) cod. DFO Can. Sci. Advis. Sec. Stock Status Rep. 2004/011.

Colbourne, E.B., Brattey, J., Lilly, G., and Rose, G.A. 2003. The AZMP program contributes to the scientific investigation of the Smith Sound mass fish kill of April 2003. DFO Atlantic Zone Monitoring Program Bulletin 3: 45-48.

Lilly, G.R., and Murphy, E.F. 2004. Biology, fishery and status of the 2GH and 2J3KL (northern) cod stocks: information supporting an assessment of allowable harm under the Species at Risk Act for the COSEWIC-defined Newfoundland and Labrador population of Atlantic cod (*Gadus morhua*). DFO Can. Sci. Advis. Sec. Res Doc. 2004/102.

Lilly, G.R., Brattey, J,, Cadigan, N.G., Healey, B.P., and Murphy, E.F. 2005. An assessment of the cod (*Gadus morhua*) stock in NAFO Divisions 2J+3KL in March 2005. DFO Can. Sci. Advis. Sec. Res. Doc. 2005/018.

Rivard, D., and Rice, J. (Chairpersons) 2002. National workshop on reference points for Gadoids. Ottawa, November 5-8, 2002. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2002/033.

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