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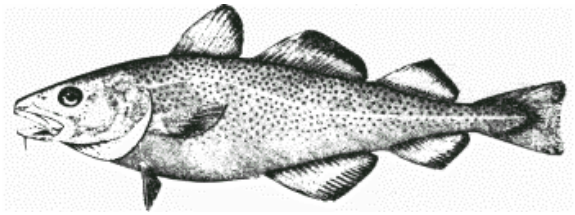
STOCK ASSESSMENT OF NORTHERN (2J3KL) COD IN 2009



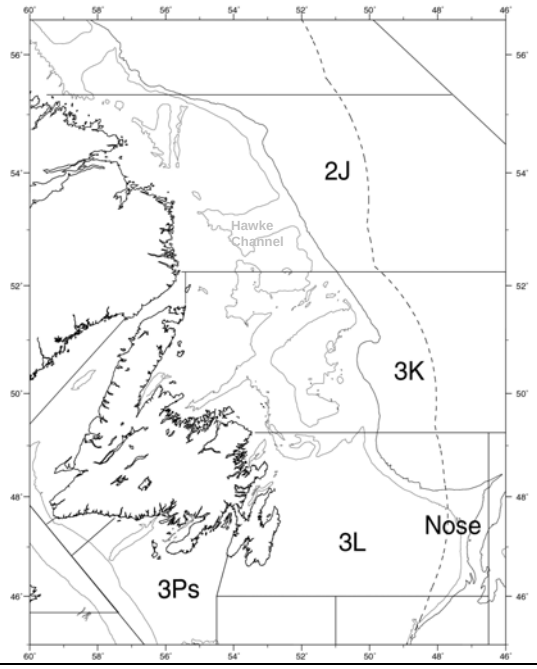


Figure 1: Stock area of northern (2J3KL) cod. The dashed line indicates Canada's 200 nautical mile Exclusive Economic Zone (EEZ). ➔

Context :

The biomass (of ages 3 and older) of the northern cod (Gadus morhua) stock off southern Labrador and eastern Newfoundland (NAFO Divisions 2J3KL; 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 in 2003. A food/recreational fishery, which had been open for several years, was also closed. Catches during 2003-05 were limited mainly to bycatch in the winter flounder (blackback) fishery.

A directed stewardship fishery and recreational fisheries were re-opened in the inshore in 2006 and continued in 2007-08. There are no management goals against which current status and 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 main objectives were to evaluate the status of the stock and to provide scientific advice concerning conservation outcomes related to various fishery management options.

The current evaluation of the stock was conducted through a zonal assessment process where the status of 5 cod stocks in Atlantic Canada (2J3KL, 3Ps, 3Pn 4RS, 4TVn and 4X/5Y cod) was assessed. The meeting was held 24 February to 6 March 2009 in St. John's (NL). Participants included DFO scientists, fisheries managers, and officials from provincial governments, fishing industry members, external experts and academia.

SUMMARY

- Reported total landings from all fisheries in 2008 (stewardship, recreational, Sentinel survey, and by-catch) were 4,162 t. Landings from the stewardship fishery were 3,089 t, which includes 121 t of by-catch in the winter flounder and turbot test fisheries. In addition, 254 t were landed in the Sentinel surveys.

- Landings from the 2008 recreational fishery were estimated at 818 t based on results from a telephone survey. This estimate is likely to be revised when weights based on actual sampling of recreational fishery catches become available. Tag returns also suggest that recreational landings may be higher than the available estimate.

- Based on autumn DFO research vessel (RV) trawl surveys, offshore abundance and biomass indices have been increasing since 2003; spawning stock biomass (SSB) has been increasing since 2005. The average abundance, biomass, and SSB of cod in the offshore over the last 3 years are 8% of the average during the 1980's.

- Most of the autumn offshore RV survey abundance (50%) and biomass (75%) is concentrated adjacent to the 3K/3L boundary. This region encompasses only 14% of the total surveyed offshore area of 2J3KL, and in the 1980s contained <20% of survey abundance and biomass.

- Total mortality in the offshore was extremely high during 1996-2003 and has been a major impediment to stock recovery. Total mortality has declined substantially since 2003 and the prospects for stock recovery have improved.

- The recent increase in offshore biomass is mostly due to improved survival and the continued growth of the 2002 year-class, and the appearance offshore after 2005 of the 2000-01 year-classes.

- Winter acoustic surveys in 2007 and 2008 found a dense aggregation of cod in a traditional over-wintering area along the shelf edge in southern 3K. The aggregation in 2008 was much larger than was observed in 2007, and included approximately 20% mature fish.

- Offshore tagging and telemetry in 2008 indicated that a substantial portion of cod from the offshore aggregation migrated to the inshore of 3KL during the summer, and some were caught in inshore fisheries. Exploitation of offshore cod in the inshore was estimated at 6%.

- The new evidence of inshore migration indicates that the moratorium in the offshore is no longer sufficient to protect the offshore stock until recovery is well established.

- The 2008 industry telephone survey showed most harvesters in 2J3KL felt that cod were more abundant during 2008 than during 2007.

- Current cod growth rates and condition indicate that some aspects of stock productivity have improved over values in the 1990s and early 2000s; however, age at maturation remains low. These components of productivity are below the levels observed in the 1980s when biomass and harvests were much larger.

- Year-class strength in the offshore in the 1990s and 2000s has been poor compared to the 1980s.

- Although a specific limit reference point has not been established, the stock is clearly below any reasonable value. The application of the precautionary approach would require catches

in 2009 to be at the lowest possible level. This would include no directed fishing and measures to reduce cod by-catch in other fisheries.

- Although status offshore has improved, the stock has not increased across much of its historical range and overall remains far below historical biomass levels. Management should focus on promoting further increases in SSB and improved recruitment until the stock is more resilient to the effects of fishing.
- Exploitation rates on offshore cod by inshore fisheries have been low enough to permit growth in biomass of some offshore components; exploitation rates should not be allowed to increase.
- For assessment purposes the inshore was divided into three areas: 1) a northern area (2J and northern 3K); 2) a central area (southern 3K and northern 3L); and 3) a southern area (southern 3L).
- During 2008, mean exploitation rates from tagging studies ranged from 3-7% among inshore central and southern areas.
- However, recruitment information suggests that exploitable biomass in inshore areas in 2009-10 is likely to be similar to 2008-09. To achieve the same exploitation rates as in 2008, total removals (recreational plus commercial) should not increase.
- In the inshore southern area, catches are partly dependent on seasonal immigration of fish from 3Ps where the stock is declining. Future removals may therefore rely more heavily on cod from the offshore of 3KL.
- In the inshore northern area, catch rates are lower than those in the central area suggesting lower cod abundance in the northern area. Fisheries in this area depend on seasonal immigration of fish, possibly from offshore regions, including 2J where offshore biomass remains low. Therefore, it is recommended to minimize removals from this area.
- Any fishery should be managed such that catches are not concentrated in ways that result in high exploitation rates on any stock components.

INTRODUCTION

History of the 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, increased 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).

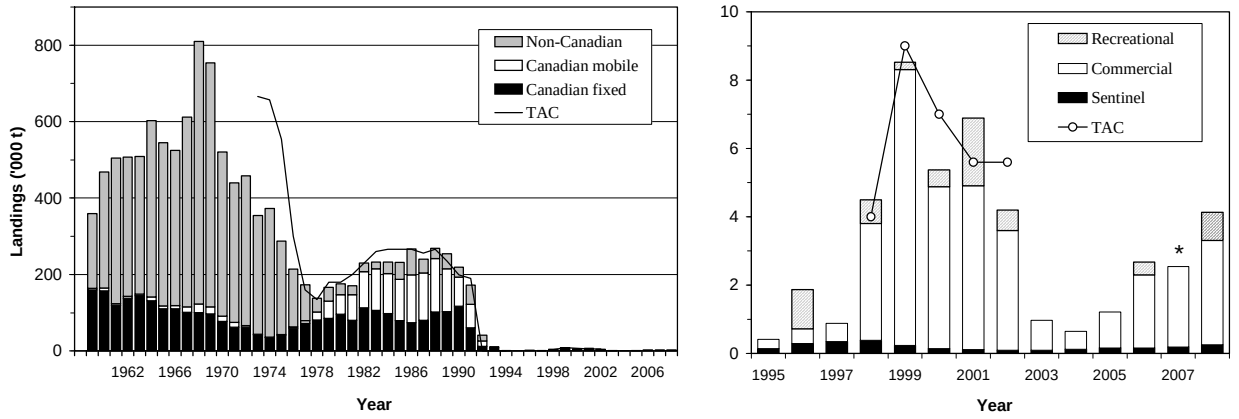


Figure 2: TACs and landings (thousands of tons) in 1959-2007. The right panel is expanded to show trends from 1995 onwards. Asterisk indicates that recreational catch in 2007 is uncertain (see text).

Catches during 1993-97 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 ft). The directed commercial and recreational fisheries were closed in April 2003; most of the landings in 2003 came from an unusual mortality event in Smith Sound, Trinity Bay (Colbourne et al. 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.

A stewardship fishery and a recreational fishery for cod were re-opened in 2006 and continued in 2007 and 2008. Commercial fishers were permitted an allowance of 3,000 lb of cod per license holder in 2006, 2,500 lb in 2007, and 3,300 lb in 2008. Reported total landings from all fisheries in 2008 (stewardship, recreational, Sentinel survey, and by-catch) were 4,162 t. This is comprised of 3,089 t in the stewardship fishery, which includes 121 t of by-catch in the winter flounder and turbot test fisheries. An additional 254 t were landed in the Sentinel surveys.

Landings from the 2007 recreational fishery are uncertain. A telephone survey suggested the recreational catch (2,200 t) was comparable to the stewardship fishery catch, monitoring by fisheries officers suggested the recreational catch was much lower (371 t).

Landings from the 2008 recreational fishery were estimated at 818 t based on results from a telephone survey. This estimate assumed an average weight per fish of 1.5 kg in all areas; this estimate is provisional and likely to be revised when weights based on actual sampling of recreational fishery catches become available. The tag returns from handline catch in recreational versus commercial fisheries suggest that recreational landings may be higher than the available estimate.

Estimates of commercial catch are also uncertain. Commercial fishers often report that commercial landings are underestimated. If the level is substantial then there is more uncertainty in catch-based assessments and in the evaluation of the impact of future removals.

An estimate is not yet available for the 2008 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 catch during 2000-07 were 80 t or less and have been declining.

Landings

Table 1: Landings by management year in NAFO Divs 2J3KL (nearest thousand metric tons).

Year	62-76 Avg.	77-91 Avg.	'98	'99	00/ 01	01/ 02	02/ 03	03/ 04	04/ 05	05/ 06	06/ 07[1]	07/ 08[1,2]	08/ 09[1]
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	3	4
Can. Mobile	9	84	-	-	-	-	-	-	-	-	-	-	-
Others	405	38	-	-	-	-	-	-	-	-	-	-	-
Totals	502	212	5	9	5	7	4	1	1	1	3	3	4

[1] There was no TAC in the last three years, but fishers were permitted an allowance per license holder of 3,000 lb in 2006/07, 2,500 lb in 2007/08, and 3,300 lb in 2008/09.
[2] Does not include Canadian recreational fisheries.

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.

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 an 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.

Stock Structure

There is evidence that there are cod 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 revealed that during the late 1990s to the mid 2000s the inshore of 3KL was inhabited by at least two groups of cod: (1) a resident coastal group that inhabited an area from eastern Trinity Bay northward to western Notre Dame Bay (Fig. 3) and (2) a migrant group that over-wintered in inshore and offshore areas of 3Ps, moved into southern 3L during late spring and summer, and returned to 3Ps in the autumn. Tagging studies also indicated considerable movement of cod among Trinity, Bonavista and Notre Dame bays.

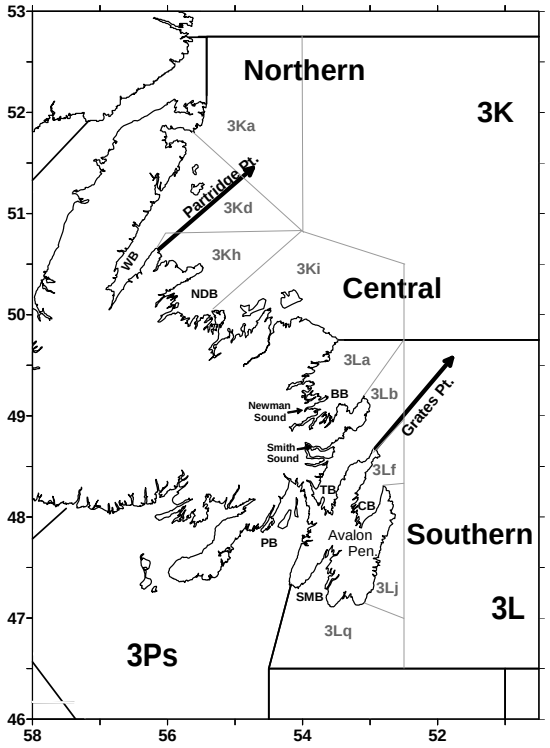


Figure 3: Eastern Newfoundland indicating the locations of the inshore northern, inshore central and inshore southern areas. Major bays are indicated: White Bay (WB), Notre Dame Bay (NDB), Bonavista Bay (BB), Trinity Bay (TB), Conception Bay (CB), and St. Mary's Bay (SMB); Placentia Bay (PB) is in Subdiv. 3Ps. Grey lines delimit boundaries of inshore statistical unit areas (i.e. 3Ka, 3Kd, etc.) referred to in the text.

Some aspects of current stock structure require further study. Catch rates increased in Sentinel surveys in 2J and northern 3K in 2005 (see below), but the origin of the fish that generated these higher catch rates is uncertain. The extent of migration between the inshore and offshore of 2J3KL during recent years is not well understood, but new tagging results indicate that the historical shoreward seasonal migration pattern of the pre-moratorium period did occur during 2008. The offshore biomass of cod in 2J3KL is low but has been increasing since 2003; the current contribution of offshore cod to the inshore biomass during summer may be increasing.

Ecosystem information

During the late 1980s and early 1990s the fish community in the Newfoundland and Labrador large marine ecosystem collapsed. This collapse was more dramatic in the northern regions and involved commercial and non-commercial species. Since 2002-03 there is an increasing trend in the fish biomass in 2J3K and 3LNO. Some components of the fish community (e.g. piscivores such as Atlantic cod, turbot, and Atlantic halibut) and large benthivores (e.g. American plaice) appear to be showing some positive signals, but still remain at a significantly lower level in comparison to the pre-collapse period. These are the first significant changes observed in ecosystem structure since the collapse.

Oceanography

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 2006 at a record high, but temperatures in 2007 declined to nearer normal values.

It is anticipated that cod in this area may be more productive when water temperatures are toward the warm end of the regional norm; cod in the offshore have shown slight increases in growth rates but not recruitment, but there are indications that biomass is increasing mainly through improved survival.

Recent environmental indicators are generally positive. Water temperatures are at the high end of historic range, primary & secondary productivity show signs of improvement around 2003, and capelin biomass is improving. Recent trends in these indicators coincide with the recent increases in cod abundance and biomass in the offshore.

Predators

Summary information from the second workshop to review the impacts of seals on Atlantic cod stocks in eastern Canadian waters indicated an increase in the amount of cod consumed by harp seals since the late 1980s due, primarily, to increased occurrence of Atlantic cod in near shore diet samples. Estimates of total Atlantic cod consumption by harp seals are imprecise. Analyses presented in 2001 indicated that harp seals may have an impact on the recovery of 2J3KL cod; however, recent results from a simple biomass based model exploring the impact of harp seals on cod under a wide range of consumption estimates suggests that seal predation is not a significant factor in the lack of recovery to date.

Hooded seals and cetaceans are also found in significant numbers in the 2J3KL stock area; diet studies indicate that cod are eaten by hooded seals and some cetacean species but their impacts are not known.

White hake (*Urophycis tenuis*) have been identified as an important predator of cod < 1yr old in the nearshore environment.

Prey

An index of offshore capelin biomass, based on hydroacoustic surveys, indicates that capelin biomass was high in the 1980s, but dropped dramatically in the early 1990s and remained low for several years. No offshore biomass estimates are available for 2005 and 2006 due to incomplete or missed surveys; however, there is an increasing trend in capelin biomass offshore in the most recent years. In the inshore, indices of capelin biomass did not show such extensive declines in the early 1990's; inshore indices are no longer available. Overall, the status of capelin appears to be improving and the timing coincides with the recent increases observed in biomass of cod in portions of the offshore.

ASSESSMENT

This assessment is based on trends in indices and harvest rates inferred from tagging studies. Total landings are uncertain, the view on stock structure has changed, and analytical models such as sequential population analysis (SPA) could not be used.

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

Sources of information

The main sources of data for this assessment are as follows. For the offshore, indices of abundance, biomass and other biological characteristics are obtained from multi-species research vessel (RV) bottom-trawl surveys conducted by Fisheries and Oceans Canada (DFO) 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. An offshore hydroacoustic-tagging survey was initiated in February-March 2007 and repeated in March 2008. This survey provides information on the distribution, abundance and subsequent migration of cod that over-wintered 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 line-trawls, and a non-traditional 3¼ inch mesh gillnet, which is intended to provide information on young fish. Logbooks from vessels less than 35 feet for post-moratorium fisheries are typically examined, but results from the 2008 fishery were not available. Tagging studies provide information on exploitation, distribution and migration. Tagging studies initiated in 1997 were continued in 2006-08. Hydro-acoustic surveys (Rose 2003) were conducted in Smith Sound in winter and spring 1997-2004 and 2006-08. An annual telephone survey of fish harvesters' observations is conducted by the Fish, Food and Allied Workers (FFAW) Union. Information on the relative abundance of young cod (Ages 0 and 1) is provided by beach seine studies in Newman Sound, Bonavista Bay (Fig 3). Information on the size and age composition of the catch is obtained from lengths and otoliths collected from cod sampled at ports and at sea. A DFO-Industry bottom-trawl survey conducted during July-August 2006 using small (<65 ft) commercial vessels was continued in 2007 and 2008. This inshore trawl survey provides information on the relative abundance, age composition and distribution of cod inhabiting the coastal and nearshore area of 2J3KL.

Oceanographic information (physical, chemical and biological) is also considered and broad ecosystem trends are reviewed.

Stock Trends – Offshore

Bottom-trawl surveys

In 2004, the autumn survey did not complete a portion of northeastern 3L that includes seven strata where cod have often been found at higher density in previous surveys. The survey estimate for 2004 is probably low.

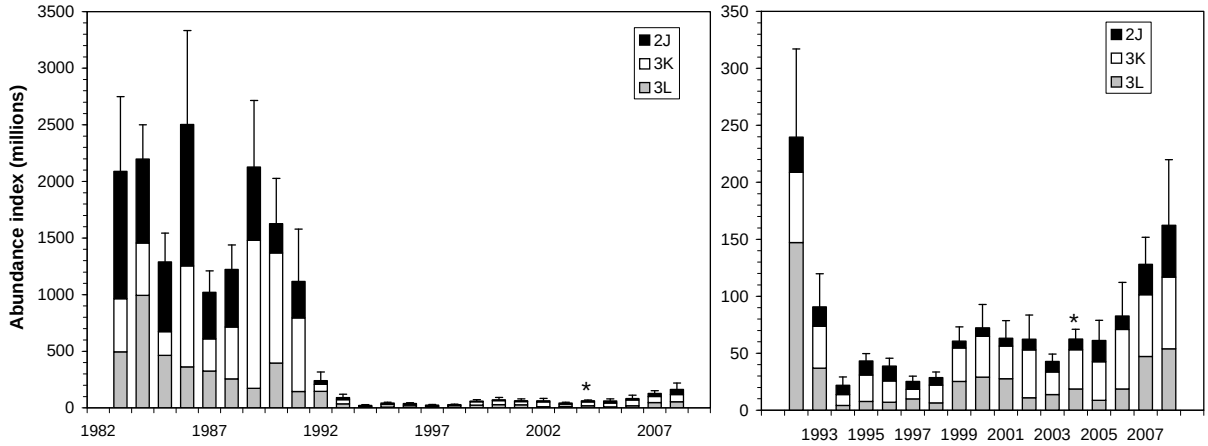


Figure 4: Offshore abundance index (+2 SE's) from autumn RV surveys in 2J3KL. The right panel is expanded to show trends from 1992 onwards. Asterisks indicate partial estimates from incomplete survey coverage of 3L in 2004.

The abundance and biomass indices from the autumn RV surveys during 2006-08 are both 8% of the average during the 1980s. Survey abundance and biomass have been increasing since 2003 (Figs. 4 & 5), but still remain low relative to levels in the 1980s. The 2008 survey abundance index and biomass index values are 162 million and 148,000 t; the values in 2008 are the highest since 1992. Most of the autumn offshore RV survey abundance (50%) and biomass (75%) is concentrated adjacent to the 3K/3L boundary. This region encompasses only 14% of the total surveyed offshore area of 2J3KL, and in the 1980's contained <20% of survey abundance and biomass. There has been little increase in biomass in 2J.

The recent increase in offshore biomass is mostly due to improved survival and the continued growth of the 2002 year-class, and the appearance offshore after 2005 of the 2000-01 year-classes, particularly in 3K. There is uncertainty about the origins of the 2000-01 year-classes. There is no evidence from tagging that they represent inshore fish that have moved offshore; no inshore tags were returned from cod taken as by-catch in the turbot test fishery in northern 3L.

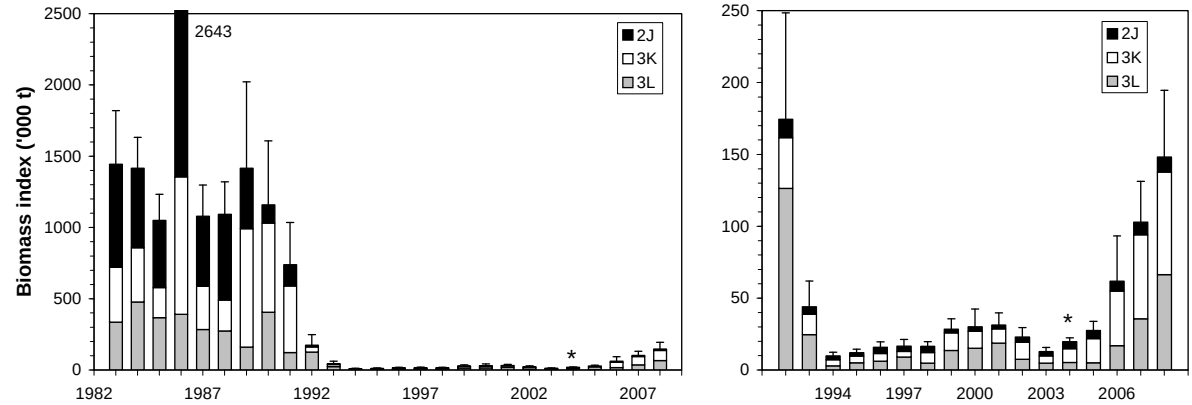


Figure 5: Offshore biomass index (+2 SE's) from autumn RV surveys in 2J3KL. The right panel is expanded to show trends from 1992 onwards. Asterisks indicate partial estimates from incomplete survey coverage of 3L in 2004.

The spawning stock biomass (SSB) index from the fall RV survey during 2006-08 was 8% of the average in the 1980s (Fig. 6). However, the SSB index from this survey has been increasing since 2005. The spawner biomass index value for 2008 is 113,000 t. The value in 2008 was the highest since 1991.

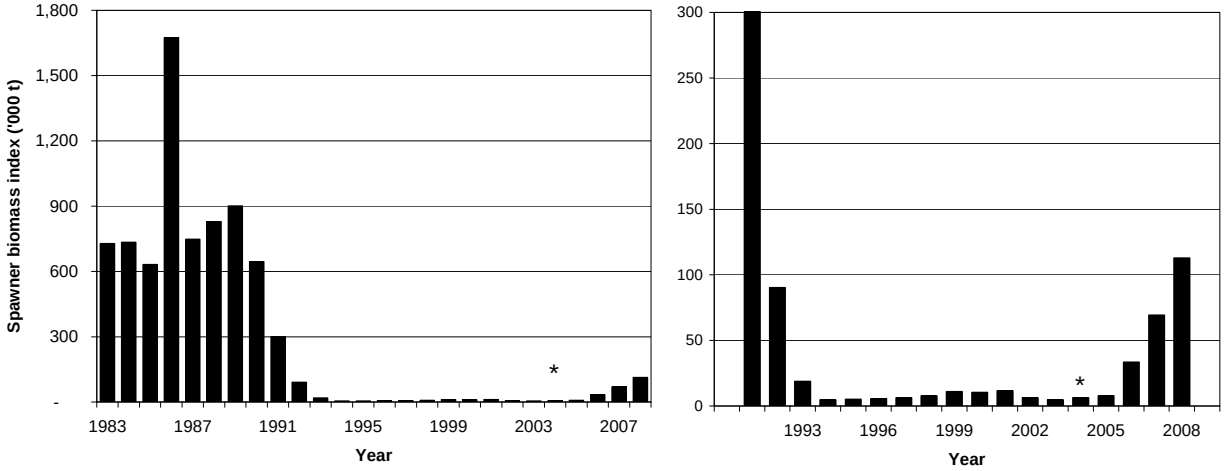


Figure 6: Offshore spawning stock biomass index from autumn RV surveys in 2J3KL. The right panel is expanded to show trends from 1992 onwards. Asterisks indicate partial estimates from incomplete survey coverage of 3L in 2004.

Information on recruitment and mortality is derived from analyses of mean catch rate at age during the autumn RV surveys.

Year-class strength in the offshore (Fig. 7) in the 1990s and 2000s has been poor compared to the 1980s.

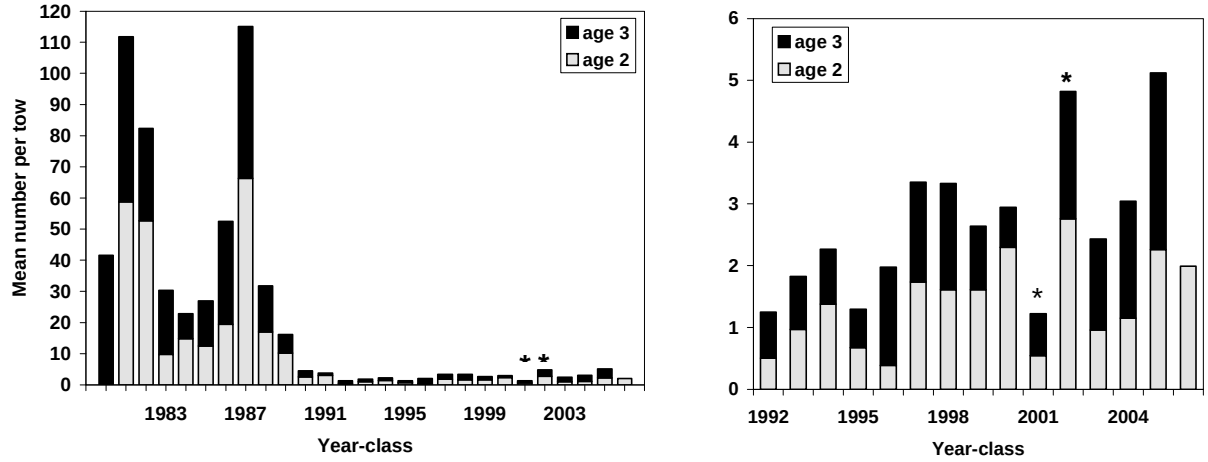


Figure 7: Abundance of the 1980-2006 year-classes in the offshore of 2J3KL from the autumn RV surveys. The right panel is expanded to show trends for the 1992 year-class onwards. Asterisks indicate partial estimates from incomplete survey coverage of 3L in 2004.

The total mortality rate remained at a high level throughout the mid-1990s, and increased further during 2001-03 (Fig. 8); this high level of mortality has been a major impediment to stock

recovery. Total mortality has declined substantially since 2003 and prospects for stock recovery have improved. The negative 2006 value may have resulted from year-effects in the surveys; the numbers at age 5, 6, and 7 in the 2006 survey were all higher than the age 4, 5, and 6 values in the 2005 survey. The lack of older fish (ages 8 and older) in the survey since the early 1990s is a consequence of the high rate of mortality; however, in the last few years the age composition has been expanding. The total mortality rate in 2007-08 averaged 0.23, which corresponds to 21% mortality per year. The total mortality rate during 1996-2008 averaged 0.82, which corresponds to 56% mortality each year.

Total mortality rate is lower in the past three years in spite of re-opening of the inshore fishery, suggesting that natural mortality rates have declined substantially.

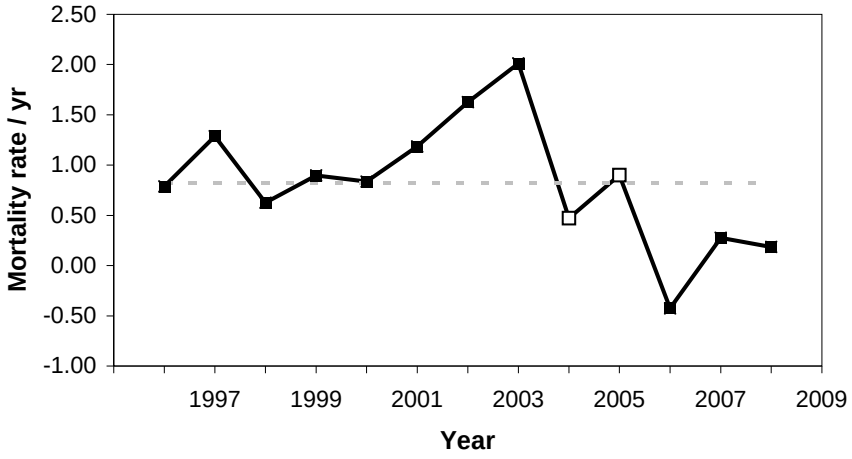


Figure 8: Total mortality rate (Z) of cod aged 4-6 calculated using data from the autumn RV surveys in the offshore of 2J3KL. For example, the value in 1996 is the mortality experienced by the 1991-1989 year-classes from ages 4-6 in 1995 to ages 5-7 in 1996. The dashed line is the time-series average. Open symbols indicate estimates based on an incomplete survey in 2004.

Biological Information

The information presented in this section comes mostly from the autumn offshore RV surveys.

Growth

Length-at-age and weight-at-age have improved since the low values of the early 1990s. Current values are marginally above average.

Condition

Condition of cod, as measured by both gutted body weight and liver weight relative to fish length, are lower in Div 2J but higher in 3K and 3L relative to the early 1980s.

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

Maturity

The age at 50% maturity is variable but decreased during the early 1990s and remains low; current values for age at 50% maturity among recent cohorts are near the lowest values observed in the time series. 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. The reasons for the change towards earlier age at maturity are not fully understood, but may have a genetic component and partly be associated with high levels of mortality and low stock size.

There has been substantial annual variability in the estimates of the proportion mature at younger ages for recent cohorts. This may be partly the result of low sample sizes. The estimates of the proportion of females at young ages that contribute to the spawning stock are thus uncertain.

Current cod growth rates and condition indicate that some aspects of stock productivity have improved over values in the 1990s and early 2000s; however, age at maturation remains low. These components of productivity are below the levels observed in the 1980s when biomass and harvests were much larger.

Offshore winter acoustic / tagging surveys

An acoustic and tagging survey directed at cod was conducted on the outer edge of the continental shelf (depths from 200 m to 700 m) from southern Labrador southward to the nose of the Grand Bank during February-March 2007. The survey was repeated in 2008.

In the 2007 survey, two aggregations of cod were detected, both at low densities; one in the Hawke Channel (Div. 2J, Fig. 1) and the other in southern 3K near the slope edge (Divs. 3KL).

In the 2008 survey, two aggregations were detected, in the same two areas as in 2007, but the aggregation in southern 3K was much larger than was detected in 2007. Biomass in the surveyed portion of each division in 2008 was estimated at 4,800 t in 2J, 101,200 t in 3K and 771 t in 3L. The estimate of SSB for 3K was 42,000 t. In 2J, most sampled cod were aged 2-3, but in 3K cod aged 4-7 were most abundant with small numbers of ages 8-9 also observed; approximately 20% of the cod sampled in 3K were mature fish.

During the 2008 survey, 2,200 cod were tagged and released, including some with implanted transmitters that could be detected on inshore receiver arrays if the fish migrated inshore. Cod were captured for tagging at shallower depths (340 m) than in the 2007 survey, but likely suffered considerable post-release mortality; ongoing research indicates that post-release mortality of cod trawled from deep water is variable but can be substantial. In the summer and fall, offshore tagged cod were recaptured inshore in the recreational and commercial fisheries; recaptures were widely distributed through 3K and 3L as far south as Petty Harbour (3Lj). Offshore cod with implanted transmitters were detected on inshore receiver arrays; these were widely distributed from Twillingate (3Ki) southward to Petty Harbour; inshore recaptures included cod with transmitters. A substantial portion of cod from the offshore migrated to the inshore of 3KL during summer, rendering them vulnerable to inshore fisheries. The estimated exploitation rate of offshore cod in the inshore based on tag returns was 6%.

This new evidence of inshore migration from tagging indicates that the moratorium in the offshore is no longer sufficient to protect the offshore stock until recovery is well established.

By-catch of cod in the turbot fishery

Commercial-sized cod were taken as by-catch in the turbot gillnet test fishery, and the level of by-catch increased from about 2% in 2004-06 to 18% in 2007 and 24% in 2008, suggesting that the abundance of cod in the offshore increased. Cod were captured over a wide area of northern 3L during August-October when catch rates in adjacent inshore areas were high. This increase in cod by-catch is consistent with the increased cod biomass observed in the same area of 3L during the autumn RV survey in 2007 and 2008.

Stock Trends – Inshore

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

Fishery catch rates

Catch and effort data for the < 35 ft. sector from log-books for the 2008 fishery were not available at the time of the assessment. Catch rates during 2007 were higher than those observed in 2006 in all three areas.

Sentinel surveys

In the northern area, catch rates with gillnets (5½ inch mesh) were low in 1995-2004, increased in 2005, and are currently above the average of the time series (Fig. 9). In the central area, catch rates have generally increased since 2002 and are currently above average. In the southern area, catch rates have remained stable since 2003 but are marginally below average.

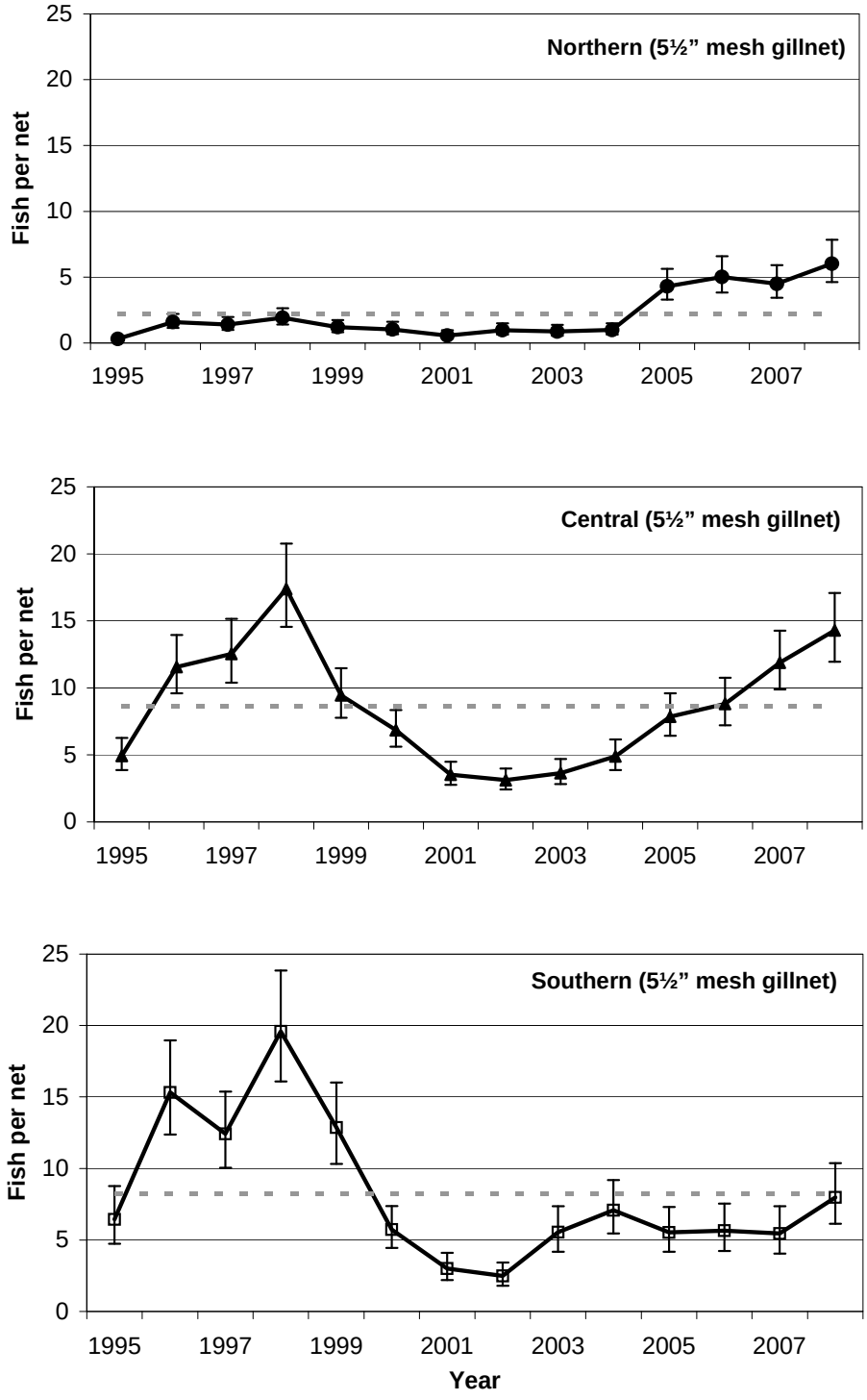


Figure 9: Standardized catch rates, with 95% confidence limits, from Sentinel surveys using gillnets (5½ inch mesh) for each of the three inshore areas. Series means are plotted as dashed lines.

In the central area, catch-rate indices from line-trawls have been variable but show an increasing trend since 2002 and are above the average of the time-series (Fig. 10). There are insufficient line-trawl data in the northern and southern areas to produce a standardized index time series.

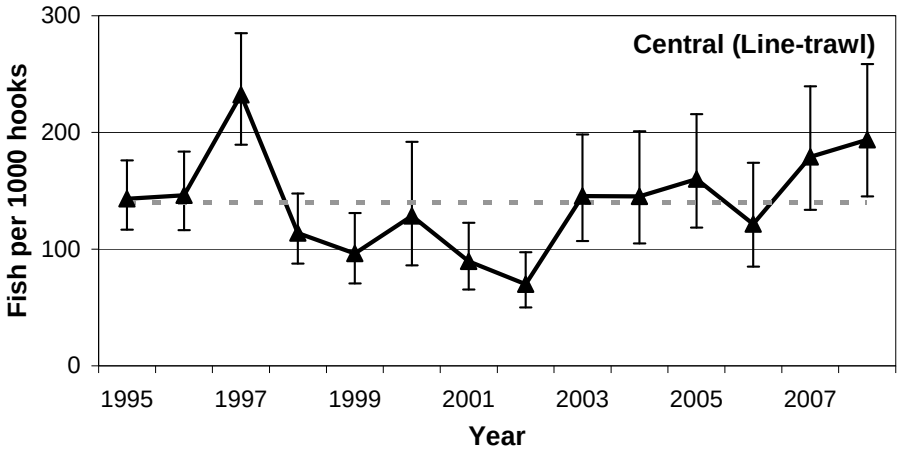


Figure 10: Standardized catch rates, with 95% confidence limits, from Sentinel surveys using line-trawls for the inshore central area. Series mean is plotted as a dashed line.

Sentinel survey – recruitment

Catch-rate indices from the small mesh (3¼ inch mesh) gillnets provide an index of recruitment. There are sufficient data to provide a recruitment index only for the inshore central area. Age-aggregated catch rates from small mesh gillnets are difficult to interpret; they do not reflect changes in abundance of small fish alone but include larger fish which tended to be caught in higher numbers in earlier years. Therefore, to investigate recruitment trends, information is provided for ages 3-4 for the central area only (Fig. 11). These catch rates suggest the 2003-05 year-classes are weaker than those produced in 2000 and 2002. These results are consistent with those from the beach seine survey (see below). The 2006 and 2007 year-classes are not yet sampled by the Sentinel small mesh gear.

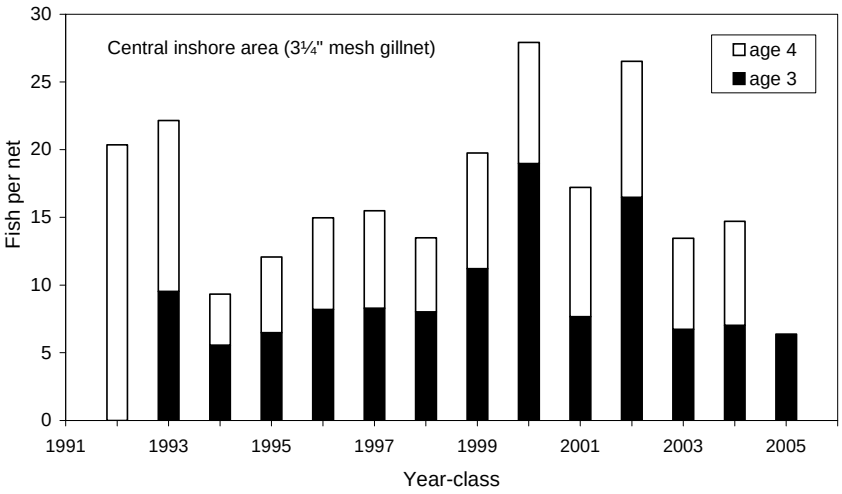


Figure 11: Standardized catch rates from Sentinel surveys for ages 3 and 4 using small mesh (3¼ inch mesh) gillnets for the inshore central area.

Beach seine surveys

Information on the strength of recent year-classes is available from a beach seine survey in Newman Sound, Bonavista Bay (northern 3L). This 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 information on age 1 from this study has been consistent with the Sentinel indices for the same year-classes at older ages. Recent year-classes (2003-06) are all weak at age 1 and the 2005 year-class is the lowest in the time-series (Fig. 12); however, the 2007 year class at age 1 is close to the average for year-classes produced during 1995-2007. Numbers of age 0 cod caught at Newman Sound and several other sites during 2008 surveys were lower than those observed in 2007. However, survival to age 1 can be highly variable; therefore, the strength of the 2008 year-class is currently uncertain.

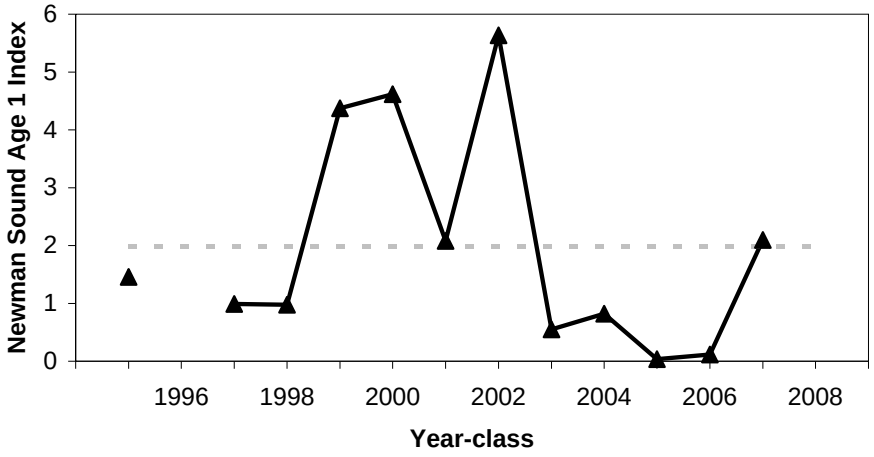


Figure 12: Trends in the numbers of age 1 cod from beach seine surveys in Newman Sound. Series mean is plotted as dashed line.

Stock mixing in the inshore southern area

The 1997 year-class is well represented in Sentinel catches in the southern area during 2001-07, but not in the northern or central areas. This year-class has been strongly represented in survey and commercial catches in NAFO Subdiv. 3Ps. However, the 1998 year-class was also strong in 3Ps but not in the southern area. The 2002 year-class is well represented in the southern and central area, and offshore in 2J3KL, but not in 3Ps. Tagging and telemetry in 2007-08 also revealed that some offshore cod over-wintering along the slope edge in the offshore of 3K migrated to the inshore southern area late in the summer of 2008; others tagged in the southern area in 2007 were captured in 3Ps in 2007 and 2008. These findings indicate that inshore southern 3L is dependant on migrant fish, from the offshore of 3K and from 3Ps.

Hydroacoustic surveys

Winter hydroacoustic studies were conducted in Smith Sound in western Trinity Bay (Fig. 2) starting in 1999 (Rose, 2003). Biomass indices increased to a peak of about 26,000 t in 2001 and then declined to 18,000 t in 2004. The surveys were suspended in 2005 but resumed in 2006. Biomass indices were stable in 2006 at 16,500-18,500 t, but declined to 14,000 t in 2007 and to 7,200 t in 2008, the lowest in the time series. Low exploitation rates from tagging and high survival rates of telemetred cod suggest the decline is not solely due to the combined

effects of fishing and natural mortality. The decline more likely reflects a redistribution of some over-wintering cod to other inshore areas or to the offshore.

Inshore trawl survey

This survey was initiated in July-August 2006 and continued in August 2007 and 2008. The surveyed area included the coastal zone from 15 to 200 m depth. The time series is too short to interpret trends in catch rates, but catches have generally been higher in the shallowest strata (<50 m depth) and lowest in the northern area. Ages of cod caught ranged from 1-10 years, but ages 2 and 3 were most strongly represented in 2006 and 2007, comprising about 70% of the numbers caught in each year. In contrast, cod of age 1 (2007 year class) were more strongly represented in 2008, and this result is consistent with the results of the beach seine survey.

Inshore tagging and telemetry

Information from recaptures of cod tagged in various inshore regions of 3KL during 1997-2008 was used to estimate average annual exploitation (harvest) rates. During 1998-2002, exploitation rates for the inshore central area ranged from 10-17% and were highest in 1999, particularly in area 3Ki (37%), when reported landings peaked at 6,500 t. Exploitation rates were lower (2-9%) during 2003-05 when the directed fishery was closed and annual landings were reduced to <1,000 t.

During 2006, exploitation rate estimates increased to 10% for the inshore central area where the reported landings were 1,750 t; the exploitation rate was much higher in southern 3K (20%) than in Bonavista Bay and Trinity Bay combined (7%). In the past two years, exploitation rates were consistently low among central and southern areas, ranging from 6–7% in 2007 and from 3-7% in 2008. No tagging was conducted in the northern area.

The reporting rate of tags has declined slightly during 2006-08 compared with previous years (1997-2005) indicating that fishers are becoming less inclined to return tags and recapture information. This adds uncertainty to the estimates of exploitation rates, and analyses of movement patterns and stock structure.

A telemetry study initiated in 2005 indicated a minimum annual survival rate of 79% for cod >60 cm released with transmitters in Smith Sound during winter/spring 2005-06 and 73% for those released during winter/spring 2006-07. Most telemetred cod left Smith Sound in spring (March-June) but showed strong over-wintering site fidelity, with >70% returning to over-winter in Smith Sound during the following winter. Dispersal of these cod during summer was monitored by arrays of receivers moored throughout the inshore of southern 3K and 3L. Cod dispersed widely, particularly around northwestern Trinity Bay and Bonavista Bay during summer, and several were captured during the stewardship and recreational fisheries.

Sources of Uncertainty

The relative proportions of inshore versus offshore cod that contribute to the inshore fishery catches is uncertain. However, the proportion of offshore cod is likely to have increased in the past three years.

Some of the autumn RV surveys have extended well beyond their normal time and into the winter because of vessel problems (Brodie and Stansbury 2007). In addition, the survey was not

fully completed in some years and coverage in some regions was sparse. These changes add uncertainty to survey estimates of mortality rates, abundance, and biomass.

Estimates of commercial catch are also uncertain. At stock assessment meetings commercial fishers often report that commercial landings are underestimated. If the level is substantial, then there is more uncertainty in catch-based assessments and in the evaluation of the impact of future removals.

Estimates of landings from recreational fisheries in 2007 and 2008 are uncertain. Estimates of the amount of effort (number of boat trips per day) from the phone survey and from at-sea observations by fisheries officers differ considerably. In addition, tag returns from handline in commercial versus recreational fisheries suggest that the 2008 estimate for recreational landings is too low. Until a reliable method of estimating recreational catch is determined, total catch for northern cod remains uncertain. Estimates of recreational catch for previous years may also require revision.

There is uncertainty about the origins of the 2000-01 year-classes that appeared in the offshore after 2005. At present, there is no evidence from tagging that they represent inshore fish that have moved offshore; no inshore tags were returned from cod taken as by-catch in the turbot gillnet test fishery in northern 3L in the past three years. These year-classes are important contributors to the recent increase in offshore biomass.

There is uncertainty in the survival of fish caught in deep water (>300 m) offshore and released after tagging and implantation of transmitters. Ongoing research indicates that post-release mortality of cod trawled from deep water is variable but can be substantial.

INDUSTRY PERSPECTIVE

2008 fishery

The current stewardship fishery for cod (as prosecuted by commercial fish harvesters) is a limited entry fishery with gear restrictions (amount and type of gear), seasonal and duration restrictions, and landings are closely monitored and recorded. The data collected by commercial fish harvesters, during their participation in this fishery is very important to the continued monitoring of the recovery of this stock (inshore and offshore).

Fish harvesters feel that while the high catch rates during the late 1990s were largely driven by a narrow band of cod aggregations close to shore, much has changed in recent years. While current catch rates are about the same as those of the late 1990s cod are much more widely distributed over traditional inshore and offshore fishing grounds. Harvesters feel that the current level of abundance combined with the current distribution and migration patterns that resemble historical patterns is evidence that a significant recovery has and is taking place. Based on observations of the range of year classes and the level of abundance, harvesters feel that the current allowance can be increased and recovery can continue to take place.

Telephone survey of fish harvesters

Two hundred and thirty seven 2J3KL fish harvesters participated in a telephone questionnaire completed by the FFAW during January and February 2009. Most harvesters in 2J felt cod were less abundant in 2008 than in the late 1980s. However, most 3K and 3L harvesters felt cod abundance was better in 2008 than during the late 1980s. Harvesters in 2J3KL found cod to be more abundant in 2008 than in 2007. Most harvesters felt that cod were distributed throughout their area and felt that cod were in good condition. The majority of harvesters in all areas felt squid and mackerel abundance is low and decreasing. Most harvesters said herring abundance is good and increasing. Harvesters in 3K and 3L said capelin abundance is good and increasing.

CONCLUSIONS AND ADVICE

Conclusions are presented for offshore and inshore separately, and advice is provided for the stock as a whole.

Offshore

Based on autumn surveys, offshore abundance and biomass indices have been increasing since 2003; spawning stock biomass (SSB) has been increasing since 2005. The average abundance, biomass, and SSB of cod in the offshore over the last 3 years are 8% of the average during the 1980s. During 2003-08 the biomass has been increasing at an average rate of 66% per year.

Total mortality in the offshore was extremely high during 1996-2003 and has been a major impediment to stock recovery. Total mortality has declined substantially since 2003 and the prospects for recovery have improved. The value of Z for 2007-08 was 0.23, corresponding to 21% mortality per year.

Offshore tagging and telemetry in 2008 indicated that a substantial portion of cod from the offshore aggregation migrated to the inshore of 3KL during the summer, and some were caught in inshore fisheries. Exploitation of offshore cod in the inshore was estimated at 6%. This rate has not prevented recent rebuilding.

Current cod growth rates and condition indicate that some aspects of stock productivity have improved over values in the 1990s and early 2000s; however, age at maturation remains low. These components of productivity are below the levels observed in the 1980s when biomass and harvests were much larger.

Inshore

For assessment purposes the inshore was divided into three areas: 1) a northern area (2J and northern 3K); 2) a central area (southern 3K and northern 3L); and 3) a southern area (southern 3L).

During 2008, mean exploitation rates from tagging studies ranged from 3-7% among inshore central and southern areas. These exploitation rates are similar to the estimate for offshore cod captured in inshore fisheries (6%).

In the inshore southern area, catches are partly dependent on seasonal immigration of fish from 3Ps where the stock is declining. Future removals may therefore rely more heavily on cod from the offshore of 3KL. The similarity in the recent age compositions from the Sentinel gillnet survey for the southern area and the 2J3KL DFO offshore RV survey reflect this concern.

Stock as a whole

In the inshore northern area, catch rates are lower than those in the central area suggesting lower cod abundance in the northern area. Fisheries in this area depend on seasonal immigration of fish, possibly from offshore regions, including 2J where offshore biomass remains low. Therefore, it is recommended to minimize removals from this area.

The new evidence of inshore migration from tagging indicates that the moratorium in the offshore is no longer sufficient to protect the offshore stock until recovery is well established.

Although a specific limit reference point has not been established, the stock as a whole is clearly below any reasonable value given historical biomass estimates. The application of the precautionary approach would require catches in 2009 to be at the lowest possible level. This would include no directed fishing and measures to reduce cod by-catch in other fisheries.

Although status offshore has improved, the stock has not increased across much of its historical range and overall remains far below historical biomass levels. Management should focus on promoting further increases in SSB and improved recruitment until the stock is more resilient to the effects of fishing.

Exploitation rates on offshore cod by inshore fisheries have been low enough to permit growth in biomass of some offshore components; exploitation rates should not be allowed to increase.

However, recruitment information suggests that inshore exploitable biomass in 2009-10 is likely to be similar to 2008-09. To achieve the same exploitation rates as in 2008, total removals (recreational plus commercial) should not increase.

Any fishery should be managed such that catches are not concentrated in ways that would increase exploitation on individual stock components.

OTHER CONSIDERATIONS

Management Issues

Recreational fishery

The management of recreational fisheries should be improved so that total removals can be effectively controlled and more accurate catch information provided to science to evaluate the impacts of fishing.

Consequences of an inshore fishery

Cod currently offshore in 2J3KL have now been shown to undergo spring/summer feeding migrations to the inshore during 2008, similar to their historic pattern. The moratorium in the

offshore is therefore no longer sufficient to protect the offshore stock until recovery is well established. At current levels of exploitation, the risk that fishing inshore will prevent stock growth offshore seems low.

The fisheries in 2006-08 have not resulted in an increase in total mortality offshore, or a reduction in catch rates inshore, and tagging suggests that exploitation (harvest) rates were low in 2008. However, if exploitation rates increase in the future then this situation may change. Managers should be aware that a recent reduction in the strength of year-classes entering the fishery, as indicated by the beach-seine surveys and small-mesh Sentinel catch rates, will likely result in no increase in exploitable biomass in the 2009-10 management year, even if total catches remain unchanged.

Implications of fishing bay-by-bay

The distribution of fish harvesters is not uniform and does not match the distribution of cod. In some years this has caused geographic variability in fishing mortality rates, as evidenced by tagging studies. Therefore, fishing bay-by-bay may result in local over-exploitation, particularly in areas such as 3Ki, where resident inshore cod are less abundant and effort is high. In addition, some areas such as 2J depend on seasonal immigration of fish, possibly from offshore regions, including the offshore of 2J where biomass remains low. Managers should attempt to keep exploitation rates low on all components. This will encourage further rebuilding and preserve and enhance population spatial structure and diversity within the stock.

The high values of total mortality in the offshore in the late 1990s and early 2000s may also have been due to inshore fishery exploitation, if the remnant offshore components of the stock were migrating inshore and were exploited by the fishery in 1998-2002. Offshore cod that migrated to 3Ki would be particularly vulnerable, as the effort on this area is high and resident inshore cod are less abundant.

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