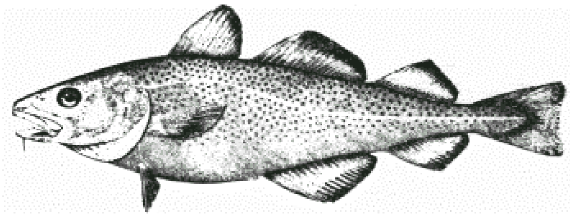
Fisheries and Oceans Canada   Pêches et Océans Canada

Newfoundland Region

DFO Science
Stock Status Report A2-01 (2001)



Northern (2J+3KL) Cod

Background

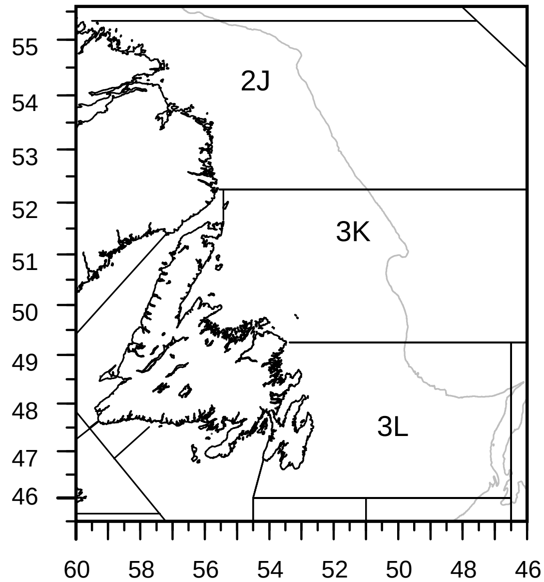
The northern (NAFO divisions 2J+3KL) cod stock has been and remains potentially one of the largest in the world.

Historically many cod migrated from overwintering areas offshore to feeding areas inshore. From the 1960s to the early 1990s the fishery was prosecuted with large otter trawlers offshore, mainly in the winter and spring, and a large fleet of smaller vessels that deployed traps, gillnets and hook and line inshore from late spring to autumn. Some fish overwintered inshore in the past. It appears that a substantial portion of the fish currently in the stock area remain inshore throughout the year.

Cod from this stock grow more slowly than those in warmer areas. An age 5 cod would be about 50 cm (about 20 inches) long. Throughout the area female cod have a variable age at maturity, presently about age 5.

Cod in 2J3KL feed on a wide variety of food items. Capelin has historically been the major prey of adults.

This stock has supported a commercial fishery since the 16th century. For the century prior to 1960 the catches were mainly between 200,000 metric tons and 300,000 metric tons. With high catches in the late 1960s, mainly by foreign fleets, the stock declined until the mid-1970s. After the extension of jurisdiction in 1977, the stock increased until the mid 1980s but has since declined to a very low level. A moratorium on commercial fishing was in effect from July 1992 to July 1999.



Summary

- Status of the 2J+3KL cod stock at the end of 2000 was updated from 1999 based on an additional year of research bottom-trawl surveys, sentinel surveys, a prerecruit survey, acoustic surveys in specific areas, returns from tagging studies, a questionnaire completed by fishing communities, and catches and catch rates from the commercial index fishery.

- Considerable uncertainty exists about the structure of this stock and consequently in this assessment the stock status was assessed under two hypotheses: a) the inshore constitutes a separate inshore subpopulation that is functionally separate from the offshore; and b) inshore and offshore fish together constitute a single functional population.

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Canada

- Results of tagging experiments indicate a harvest rate of the order of 10% in 2000 associated with a reported catch of 5400 t. A simple migration model estimated biomass in the inshore of 3K and northern 3L from 1998 to 2000 to have been of the order of 40,000 t. A more detailed model which considered gear selection, fish growth, and within seasonal harvest but not migration, indicated a biomass of no more than 77,000 t in 2000.

- Tagging results indicate that many of the fish currently caught in the southern 3L area are seasonal migrants from 3Ps and therefore it is not possible to estimate a biomass for southern 3L fish.

- Acoustic surveys in Smith Sound in January provided average indices of biomass of about 15,000 t in 1999, 22,000 t in 2000 and 31,000 t in 2001.

- Throughout the area covered by the research bottom-trawl survey, biomass remains extremely low with very few older fish. Bottom-trawl surveys and acoustic surveys in the offshore have failed to detect any substantial bodies of fish since 1995.

- All year-classes in the 1990s have been lower than those of the mid-1980s. The 1998 to 2000 year-classes appear to be stronger than earlier year-classes in the 1990s although the estimates for these year-classes are as yet quite uncertain.

- In the fall bottom-trawl surveys, few fish older than age 5 have been found and the age composition is consistent with a high overall mortality rate. Total mortality rates of fish in the offshore are estimated to be as high as levels in the 1980s when a substantial commercial fishery existed.

- The age structure (presence of older fish) in Smith Sound and the inshore commercial catch may indicate that the mortality in some areas of the nearshore is lower.

- Under the hypothesis of a separate inshore population, it is not clear whether the spawning stock has been sustained by recent levels of recruitment at the current levels of natural and fishing mortality. Catch rates from the sentinel survey, commercial logbooks and fall research bottom-trawl surveys in the inshore show a decreasing trend in exploitable biomass since 1998. However, estimates of exploitable stock size based on tagging studies have been relatively constant.

- Under the single functional population hypothesis, there is no doubt that the 2J+3KL cod spawner biomass remains at an extremely low level compared to historical size, and there is no evidence of a recovery. Any fishery on the remnant in the inshore will delay recovery of the stock.

- Predation by harp seals is estimated to be 37,000 t and may be preventing the recovery of the cod stock.

The Fishery

Catches by non-Canadian fleets increased rapidly in the late 1950s and 1960s, with the total catch peaking at 800,000 t in 1968 (Fig. 1). Catches both offshore and inshore declined during the 1970s. The stock declined to a low biomass by 1977.

Following extension of jurisdiction the stock began to recover as a consequence of smaller catches, entry of the strong 1973-1975 year-classes, and an increase in individual growth rate. However, recovery of the spawner biomass stopped after about 1982 as a result of higher fishing mortality, entry of the weak 1976-1977 year-classes and a decline in individual growth rate. The 1978-1982 year-classes were moderate to strong but experienced slow growth rates.

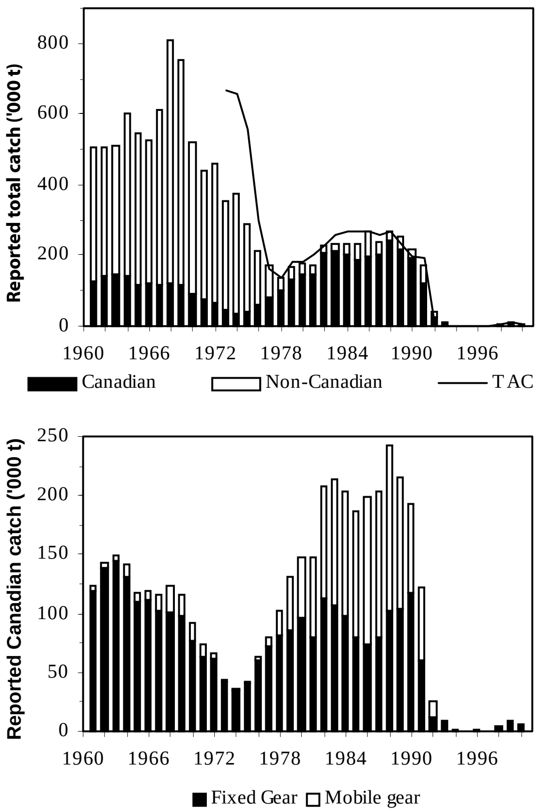

Figure 1. Reported catch for all countries (above) and for Canada alone (below).

Catches during the middle to late 1980s were relatively stable but fishing mortality was high and increasing. The 1986-1987 year-classes appeared strong at an early age but, in concert with older year-classes, appeared to decline very rapidly in the early 1990s. Fishing mortality was very high during this period but reported landings including documented discards are insufficient to account for the decline observed in the research vessel indices. A moratorium on directed commercial fishing was imposed in July 1992.

Reported catches in 1993-1997 came from by-catch, sentinel surveys (1995-1997) and estimates of catches during recreational/food fisheries (1994, 1996). The reported catch of about 4,500 t in 1998 came from sentinel surveys, a recreational/food fishery, and an inshore index fishery.

Landings (thousand metric tons)

Year	62-76 Avg.	77-91 Avg.	1995	1996[1]	1997[1]	1998[1]	1999[1]	2000[1]
TAC	N/A	N/A	0	0	0	4[2]	9	7[2]
Can. Fixed	88	90	+	2	1	5[3]	8[3]	5[3]
Can. Mobile	9	84	0	+	+	+	0	+
Others	405	38	0	0	0	0	+	+
Totals	502	212	+	2	1	5	8	5

[1] Provisional.
[2] TAC for an index fishery.
[3] Catch from by-catch, a food fishery, the sentinel surveys and the commercial or index fishery.
[+] Catch less than 500 metric t.

In 1999, the commercial fishery was re-opened with a TAC of 9,000 t in the inshore for vessels under 65 feet. Reported landings were approximately 8,000 t from the commercial fishery and 200 t from the sentinel surveys, which together with the estimate of 235 t for the food/recreational fishery totaled approximately 8,500 t.

In 2000, a TAC of 7,000 t was established for sentinel surveys and an index fishery in the inshore for vessels under 65 feet. Reported landings were approximately 4,700 t from the commercial index fishery and 200 t from the sentinel surveys, which together with the estimate of 500 t for the food/recreational fishery totaled approximately 5,400 t. The reported landings include a small by-catch in the large trawler fishery for yellowtail on the plateau of Grand Bank in Div. 3L.

The index fishery in 2000 was conducted on the basis of individual quotas. Participants were licenced to fish only in the Division of their home port, with an additional restriction within 3L to either north or south of Grates Point. Therefore, landings within each Division (or area within Division 3L) should reflect both the availability of fish and the number of licences in the area. Landings increased from 2J (< 1% by weight) to 3K (27%) to 3L (73%). In 1999, landings in 3K were 43% of the total.

Participants in the index fishery were permitted to direct for cod with a limited quantity of either gillnets or linetrawls. Handlines could be fished in conjunction with either gear, but traps were not permitted. Cod taken as by-catch in other fisheries were counted against individual quotas. When all sources of landings (index, sentinel and food/recreational) were combined, gillnets contributed 76% by weight, linetrawls 4% and handlines 18%. There was also a small catch from traps deployed in the sentinel surveys and a very small by-catch in the yellowtail fishery by large otter trawlers on Grand Bank (3L).

The total **catch-at-age** in 2000 comprised a range of ages, with ages 3 to 10 each contributing at least 5% by number and ages 5 and 6 most prominent. The 1992 year-class was considerably less prominent than it had been in 1999.

The total catch-at-age in 2000 strongly reflects the selectivity of the gillnets, which tend to select ages 6 and 7 but caught roughly equal numbers of ages 5 to 8 in 2000. Hook and line gears caught cod of a wide range in age, with ages 3-5 most prominent in linetrawls and ages 4-5 most prominent in handlines. The sentinel trap catch was dominated by age 4 and the otter trawl by-catch by ages 3-4. The small size of cod in the otter trawl by-catch presumably results from the use of restrictor grates in the yellowtail fishery. Only 2% (by number) of the total catch in 2000 were older than age 10.

The catch discussed above does not take into account any **discards**. Discarding in the cod directed fishery in 2000 is estimated to be 71 t based on observed sets. However, this may be a biased estimate. The quantity of discarding in the shrimp fishery appears to be small in both the large vessel and small vessel fleets. There are reports of discarding of cod in the Greenland halibut gillnet fishery, but the quantity of discarded cod was small in the relatively few sets seen by observers. There are no estimates of **unreported catches**.

Industry Perspective

A perspective on several aspects of the 2000 sentinel survey and commercial index fishery is available from the responses to a questionnaire sent by the Fish, Food and Allied Workers Union (FFAW) to the Fish Harvester Committees representing the 55 sites where a sentinel survey was conducted by the FFAW in 2000.

In response to whether commercial catch rates in 2000 were low, average or high compared with historical results, 67% said low, 23% said average and 10% said high. All responses but one from southern Labrador to White Bay were “low”. “Low” responses also came from some areas on the Baie Verte Peninsula, two areas in eastern Notre Dame Bay, and several areas in the region from inner Trinity Bay to the southern Avalon Peninsula. “High” responses came from two sites in inner Bonavista Bay, two on the western side of Trinity Bay and one on the southern Avalon Peninsula.

In response to whether commercial catch rates were lower, the same or higher than during the 1999 commercial fishery, 67% said lower, 27% said they were the same, and 6% said higher. The "lower" responses came from most sites from southern Labrador to eastern 3K and all sites from inner Trinity Bay to the southeastern Avalon Peninsula.

In response to whether "signs" of small (up to 18 inches) fish were worse, the same or better than in 1999, 7% said worse, 25% said the same and 68% said better. In response to whether the overall condition of cod caught during 2000 was poor, average or good, 2% said poor, 25% said average and 73% said good. In 1999, 90% had said good.

The Fish Harvester Committees felt that warm water, inclement weather and restrictions imposed by the 2000 Conservation Harvesting Plan negatively affected catch rates in the commercial index fishery.

Resource Status

Status of the 2J+3KL cod stock at the end of 2000 was updated from 1999 based on an additional year of research bottom-trawl surveys, sentinel surveys, a prerecruit survey, acoustic surveys in specific areas, returns from tagging studies and catches and catch rates from the commercial index fishery.

Stock Structure

Various studies prior to the early 1990s revealed structure in the 2J+3KL cod stock. For example, there was a north-south cline in size-at-age and spawning time, there was a change in vertebral counts at approximately the north slope of Grand Bank, and cod tagged at specific locations in the offshore in winter tended to migrate to specific but broad areas of the inshore for feeding and then returned to approximately the area of tagging in subsequent winters. It was also known that cod overwintered in various locations inshore and that some spawning occurred inshore.

The stock collapsed during the late 1980s and early 1990s, and by 1994 there seemed to be very few cod anywhere in the stock area. Beginning in 1995 the perception of stock size and distribution changed when a large aggregation of cod was located in Smith Sound (Trinity Bay). The sentinel surveys, which started that year, achieved good catch rates in much of the area from White Bay in central 3K southward to the boundary with 3Ps.

Tagging studies, conducted during the post-moratorium period while the overall stock size remains extremely low, 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 from inshore and offshore areas of 3Ps that moves into 3L during late spring and summer and returns to 3Ps during the autumn. Only a small number of tagged cod from 3Ps were caught north of Trinity Bay. The tagging also indicates considerable movement of cod among Trinity, Bonavista and Notre Dame Bays. It is not known if there is currently movement between the inshore and the offshore in 2J3KL; there is no directed offshore cod fishery and there have been no reported offshore recaptures of cod tagged inshore from fisheries directed at other species.

There are two conflicting interpretations of **genetic studies.** One is that cod in the inshore and offshore are genetically distinct from one another while the other is that there is no differentiation among groups of 2J+3KL cod. However, neither interpretation would preclude the possibility that functional subpopulations exist without significant genetic differentiation or the possibility that inshore populations could colonize the offshore areas.

In light of the uncertainty about stock structure, in this assessment the stock status is assessed under two hypotheses regarding stock structure: a) the inshore constitutes a separate inshore subpopulation which is functionally separate from the offshore; and b) inshore and offshore fish together constitute a single functional population.

Population Indices

The abundance index from the **autumn research bottom-trawl survey** in 2J3KL remains extremely low compared to the mid-1980s. In the recent period it declined from 1995 to 1997, increased a little in 1998, doubled from 1998 to 1999 and increased slightly in 2000. The recent increase occurred in 3K and 3L but not in 2J. The increase occurred only at ages less than 5. As in the previous 6-7 years, very few fish larger than 50 cm and older than age 5 were caught in 2000.

The biomass index from the autumn survey in 2000 remains extremely low at only 2.5% of the average in the period 1983-1988 (excluding 1986). The index increased a little from 1995 to 1997, remained unchanged in 1998, increased 70% from 1998 to 1999, and increased slightly in 2000 (Fig. 2).

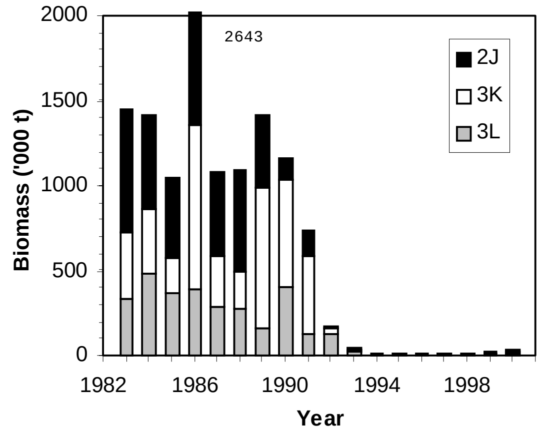

Figure 2. Biomass index from autumn bottom-trawl surveys in 1983-2000 (top). The data from 1992-2000 are displayed more clearly in the bottom panel.

There has been no trend during the last 3 years in the autumn survey index of **spawning stock biomass**, which remains at 1% of the level of the mid-1980s (Fig. 3).

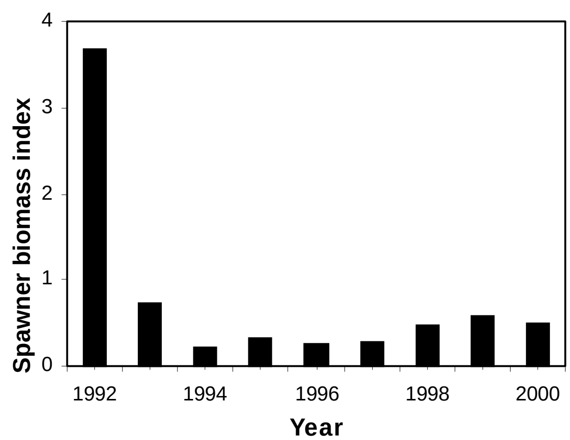

Figure 3. Index of spawner biomass from autumn bottom-trawl surveys in 1992-2000.

The autumn bottom-trawl survey has included **inshore strata** since 1996 (excluding 1999). The survey in this area has shown little trend over the period for fish less than age 5 but a decreasing trend in the abundance of older fish.

The biomass index from the **spring research bottom-trawl survey** in 3L increased from 1998 to 1999 and declined in 2000 (Fig. 4). The biomass index for 2000 was only 1.5% of the average in the period 1986-1989.

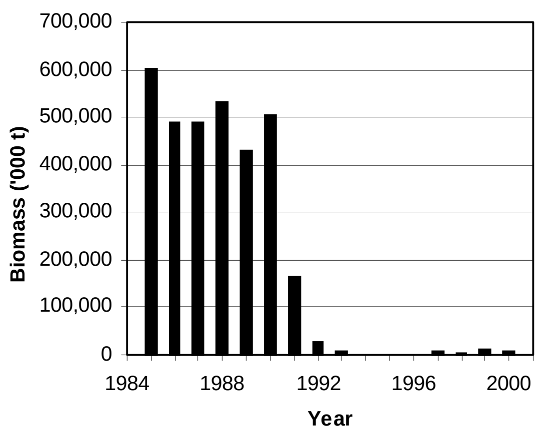

Figure 4. Biomass index from spring bottom-trawl surveys in 3L during 1985-2000.

Acoustic studies have been conducted in **Smith Sound** in western Trinity Bay at various times since spring 1995. The quantity of cod detected in the Sound at any specific time will depend not only on their abundance but also on where the cod are in their annual cycle of movements. Fish overwinter in deep water in the Sound and some of them spawn there in the spring. Most of them move into shallow water and northward along the coast from late spring to early autumn. They then return to the Sound in late autumn or early winter. Acoustic surveys in January provided average indices of biomass of about 15,000 t in 1999, 22,000 t in 2000 and 31,000 t in 2001. Sampling by bottom-trawling showed that the 1995, 1996 and 1997 year-classes formed a substantial portion of the fish in Smith Sound over the past few years and that the 1990 and 1992 year-classes continue to be present in relatively large numbers. The presence of older fish in Smith Sound may be an indication of better survival rates in this area than those observed in areas covered by the research bottom-trawl surveys.

Acoustic studies were also conducted in Hawke Channel in 2J in June 1994-1996 and 1998-2000. The biomass decreased by half from 1994 to 1995, decreased further in 1996, and has since remained rather stable at this lower level.

The **sentinel surveys** in 2J3KL, initiated in 1995 to provide catch rates of cod in inshore waters, have been conducted primarily with gillnets. Linetrawls have been used extensively in only a few areas. Handlines and cod traps have been used much less. In 2J and in 3K north of White Bay, catch rates have been low since the start of the surveys. From White Bay to the southern boundary of the stock, fish have existed in sufficient density to enable moderate to high catch rates in some times and places.

The sentinel survey data were standardized to remove site and seasonal effects and produce annual indices of total catch rate and catch rate at age for 3K and 3L combined. Gillnets and linetrawls were treated separately (Fig. 5). Gillnet catch rates increased from 1995 to 1998 but declined from 1998 to 1999 and decreased further in 2000. Linetrawl catch rates showed relatively little change from 1995 to 1996, increased in 1997, and declined again in 1998,1999 and 2000.

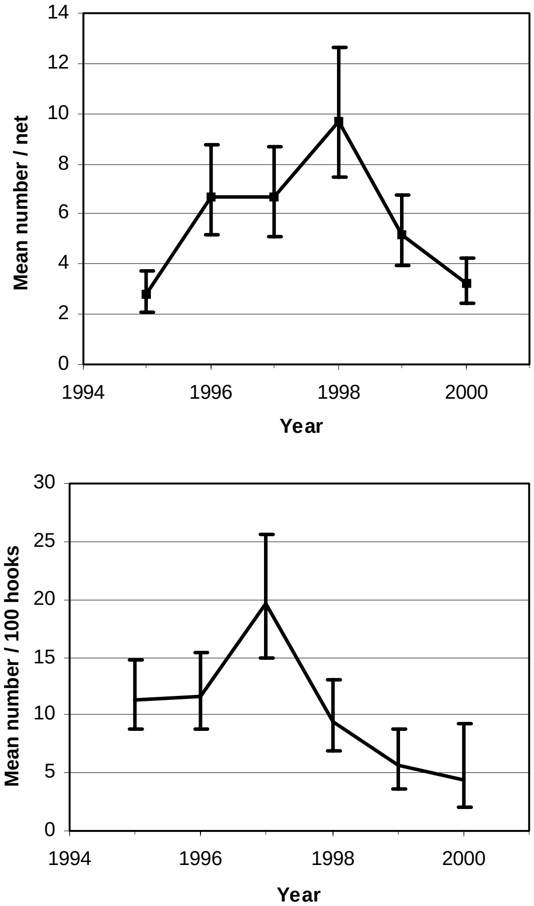

Figure 5. Standardized catch rates from sentinel surveys in 3KL; gillnets above and linetrawls below.

Catch rate at age decreased in 2000, especially at ages 5 to 7. The catch rate at age 4 by 3 ¼ inch gillnets in the last 3 years has been less than half compared to the level in 1996 and 1997. The catch rates at age indicated that the 1990 and 1992 year-classes were relatively strong and that all subsequent year-classes are weaker. The pattern in age-aggregated gillnet catch rates is consistent with the 1990 and 1992 year-classes entering and then passing through the fishery and being replaced by the weaker year-classes. It is also possible that the decline from 1998 to 2000 could be attributed in part to decreased availability of fish to the gear, such as a distribution over a greater range of depths.

Catch rates were calculated from catch and effort data recorded in logbooks maintained by participants in the **index fisheries** in 1998 and 2000 and the **commercial fishery** in 1999. The spatial pattern since fishing re-commenced in 1998 has been similar among years. Catch rates were very low north of White Bay, increasing from White Bay to eastern Notre Dame Bay, generally highest from northern Bonavista Bay to western Trinity Bay, lower from eastern Trinity Bay to the eastern Avalon Peninsula and increasing again on the southern Avalon Peninsula (Fig. 6). In 1999 and 2000 catch rates on the eastern and southern Avalon were much lower than in 1998.

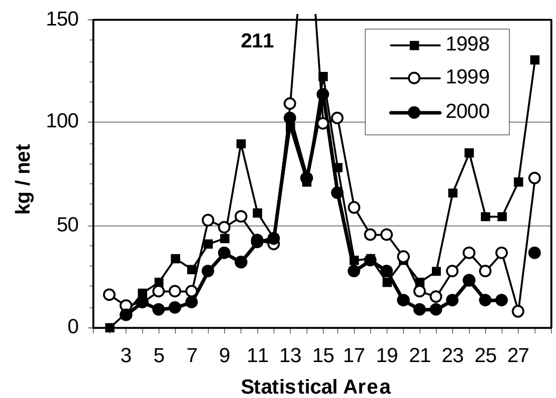

Figure 6. Median gillnet catch rates by statistical section during the 1998 and 2000 index fisheries and the 1999 commercial fishery. From north to south, Section 2 starts at Cape Bauld, 6 at Cape St. John, 10 at Cape Freels, 14 at Cape Bonavista, 20 at Grates Point, 24 at Cape St. Francis and 27 at Cape Race.

Catch and effort data from logbooks maintained by the <35 foot sector fishing gillnets were standardized to remove site and seasonal effects to produce an annual estimate of total catch rate for 3K and 3L combined. Gillnet catch rates declined from 1998 to 1999 to 2000 (Fig. 7). Data were insufficient to fit the same model for linetrawl.

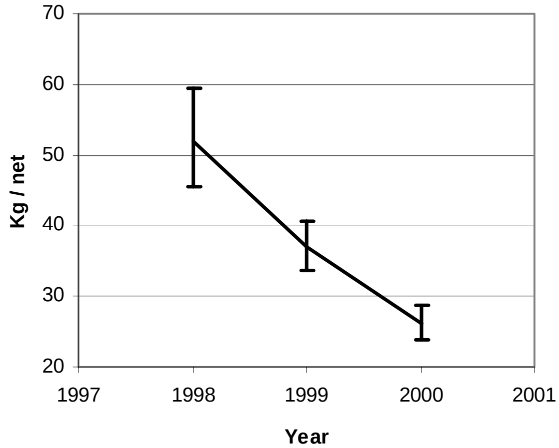

Figure 7. Standardized catch rates from the gillnet fisheries for cod by vessels <35 feet in 3KL in 1998-2000.

The 2000 total **catch-at-age** from the index fishery is comprised of fish age 2 to 13 (mainly 4 to 8) and is strongly influenced by gillnet selectivity, however, no age dominates. Two percent by number of the total catch was older than age 10. Hook and line gears caught mainly ages 4 and 5 in 2000. A substantial portion of the catch in recent years has been made up of immature fish.

Population Biology

The **percentage mature at age** increased among young female cod sampled during the autumn bottom-trawl surveys during the early 1990s and has fluctuated since (Fig. 8).

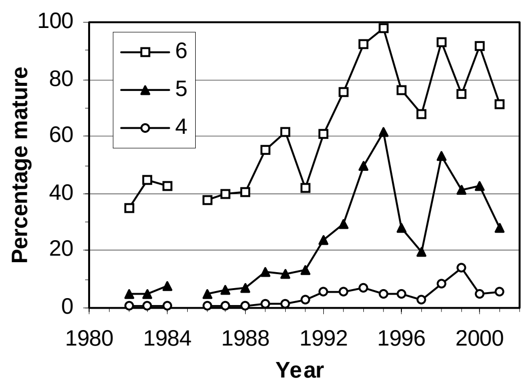

Figure 8. Observed percentage mature at age (females).

For example, the proportion of age 6 cod that are mature increased from about 40% in the 1980s to 70% or more in most recent years. Males generally mature about one year younger than females and show a similar trend over time.

Size-at-age of cod sampled during the autumn surveys declined during 1983-1985 and again in the early 1990s, especially in 2J (Fig. 9). Size-at-age has increased in recent years but is still below peak values observed in the late 1970s. Much of the variability in growth is related to variability in water temperature.

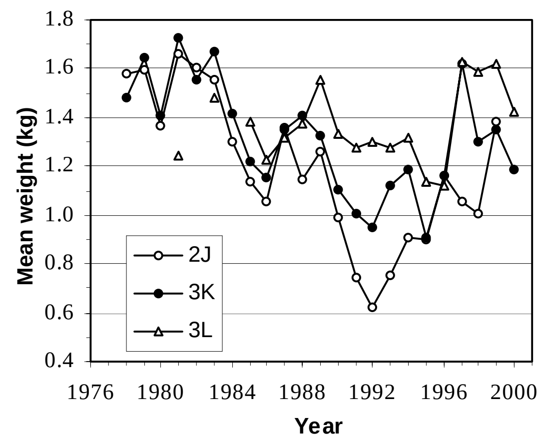

Figure 9. Mean weight (kg) at age 5 of cod sampled during autumn research surveys.

Condition of cod sampled during the autumn surveys, as measured by both gutted body weight and liver weight relative to fish length, declined in both 2J and 3K in 2000. Fish harvesters in sentinel survey communities reported that the condition of cod caught inshore was good.

Population Analysis

An attempt to combine catch data and various indices in an analytical assessment was considered unsuccessful. Therefore, there is currently no synthesis that can provide an estimate of the size of the 2J+3KL cod stock as a whole.

Estimates of the biomass of exploitable fish in the inshore were derived from tagging studies in conjunction with reported catches. A new series of **tagging studies** in inshore areas of 2J3KL and in 3Ps was initiated in 1997. Since then a total of 50,000 fish have been tagged. Of the 2553 fish tagged in 3K and 3L in the early part of year 2000, 6.3% have been recovered suggesting a harvest rate for the tagged population of at least this amount. In practice however not all fish survive tagging, some tags fall off the fish particularly in the first year, and not all recaptured tagged fish are reported. Accounting for these effects leads to a higher estimate of **harvest rate** of 11.2%. However, harvest rates clearly vary between fish tagged in different areas; for example, in 1999 harvest rates were particularly high (43%) on fish tagged in 3K compared to northern 3L (13.2%) and southern 3L (23.6%). Results for 2000 give harvest rates of 10.3% for fish tagged in 3K, 10.7% in northern 3L (Trinity and Bonavista Bays), and 22% in southern 3L.

The above values are estimates of the rate at which tagged fish were harvested but the harvesting may occur in an area different from where they were tagged. For example more fish tagged in southern 3L were harvested in 3Ps than in 3L. This makes it difficult to use these rates to convert local catches to estimates of local fishable **biomass**.

It is possible to estimate local harvest rates (except for southern 3L) using more detailed models. Harvest rates from these models are broadly similar to those given above. A simple migration model estimated biomass in Northern 3L and in 3K from 1998 to 2000 to have been of the order of 40,000 t. The majority of this estimated biomass (about 30,000 t) was in Bonavista Bay and Trinity Bay. A more detailed model which considered gear selection, fish growth, and within seasonal harvest but not migration indicated a biomass of not more than 77,000 t for 2000, of which 42,000 t was in 3K and 35,000 t in northern 3L. Estimates for 3K in 2000 may be affected by the inability to find concentrations of fish to tag in that year prior to the beginning of the fishery.

Tagging results indicate that many of the fish currently caught in the southern 3L area are seasonal migrants from 3Ps and therefore it is not possible to estimate a biomass for southern 3L fish.

Age specific **mortality** estimates were calculated for the autumn 2J3KL bottom-trawl survey for ages 1-14. Mortality for ages 4 and 6 are provided as an illustration (Fig. 10). In general, the estimates increased up until 1992, coinciding with the beginning of the moratorium. The rates then declined until 1995, and since then have remained constant at levels similar to those observed in the late-1980s when there was a substantial fishery. The paucity of older fish (7+) in the survey since 1990 prevents estimating total mortality on these older ages. The decline in the survey index estimates for cohorts after they reach age 2 is indicative of high levels of mortality given what is known about the selectivity of the gear and the distribution of young fish. The age structure (presence of older fish) in Smith Sound and the inshore commercial catch may indicate that the mortality in some areas of the nearshore has been less than in the offshore.

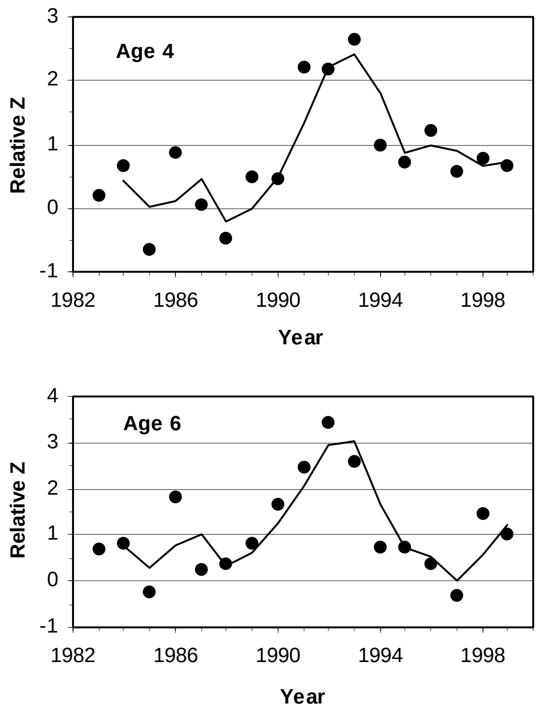

Fig. 10. Age specific mortality calculated from catch per tow at age during the autumn bottom-trawl surveys in 2J3KL. As an example, in the age 4 panel, the value of 0.7 in 1984 is the mortality experienced by the 1980 year-class from age 4 in 1984 to age 5 in 1985. The smoother is a two year forward moving average.

A **recruitment index** was derived from catch rates of juvenile (ages 0-3) cod during the following studies: experimental squid traps; experimental fixed-station bottom-trawling (FS BT) with a Campelen trawl, both inshore and offshore; beach seining from White Bay to St. Mary's Bay (Fleming survey); beach seining in Newman Sound, Bonavista Bay (BB); pelagic 0-group monitoring with an IYGPT trawl, both inshore and offshore; sentinel survey linetrawl (LT); sentinel survey 5.5 inch gillnet (GN); sentinel survey 3.25 inch gillnet (GN); stratified-random bottom-trawl (SR BT) monitoring with a Campelen trawl, both inshore and offshore. The years during which each series was operational and the ages of cod caught and considered during this analysis are:

Data source	Cod ages	Years
Squid trap	0-3	1991-1994
FS BT inshore	0-3	1992-1995
FS BT offshore	0-3	1992-1995
Beach seine Fl	0-2	1992-1997
Beach seine BB	0-1	1995-96, 1998-2000
IYGPT inshore	0	1994-1999
IYGPT offshore	0	1994-1999
Sentinel LT	3	1995-2000
Sentinel GN 5.5	3	1995-2000
Sentinel GN 3.25	2-3	1996-2000
SR BT inshore	1-3	1996-98, 2000
SR BT offshore	0-3	1995-2000

The recruitment data from inshore and offshore were treated together because the inshore appears to be an important nursery area for cod spawning in both the inshore and the offshore. These data were combined to produce a single index of relative year-class strength (Fig. 11).

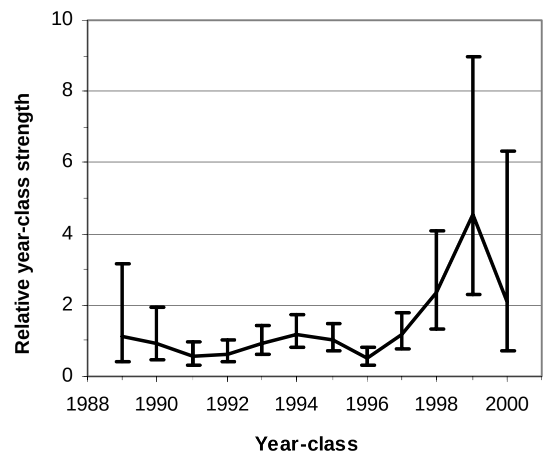

Figure 11. Standardized year-class strength.

The 1998 to 2000 year-classes are higher than earlier year-classes in the time series. Their present strength is known only imprecisely and their ultimate strength is yet to be determined.

It should be noted that strength of all of these year-classes is much lower than the strength of those that occurred during the 1980s. Moreover, the ability of the index to predict recruitment to the fishable population remains uncertain, particularly because it does not pick up the 1992 year-class that was relatively strong in sentinel and commercial catches.

Multispecies Considerations

The quantity of cod consumed by **harp seals** during the period 1965-2000 was calculated using 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. An average diet was calculated for each of the four combinations of area (inshore and offshore) and season (winter and summer) using all stomach content data collected in 2J3KL during the years 1982 and 1986-1998. Stomachs collected since 1998 have not yet been analyzed. Uncertainty in the estimates of numbers at age, diets, residency time in 2J3KL and the proportion of seals in nearshore areas, were used to evaluate the possible range in consumption estimates. The only factor effecting annual changes in the estimates of prey consumption is the estimate of seal population numbers. Recent estimates of harp seal population size show that the population reached about 5 million in 1996 and has been fairly stable since.

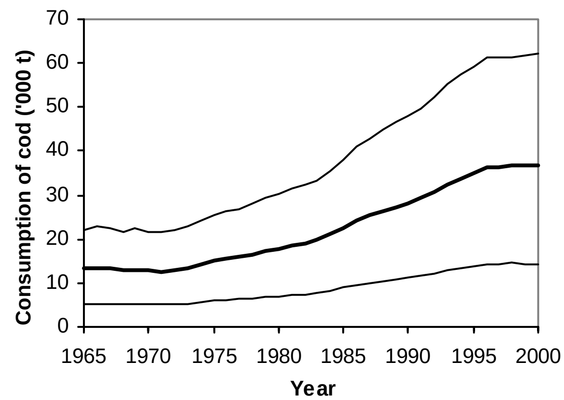

Figure 12. Consumption (with 95% confidence intervals) of cod by harp seals in 1965-2000, based on diets averaged over 1982 and 1986-1998.

Based on the average diets, it is calculated that harp seals consumed 37,000 t of cod in 2000 (with a 95% confidence interval of 14,000 – 62,000 t) (Fig. 12). The estimate for 1998 is also about 37,000 t. This is less than previous estimates of consumption for that year (50,000 t estimated in 1999 and 108,000 t estimated in 1998). Reasons for the change in the estimate from 1998 to 1999 were described in the 1999 SSR (DFO 1999). The single change that contributed most to the additional decrease in the current analysis was the removal of some offshore samples that were obtained in the vicinity of research vessels conducting surveys for cod. Examination of these samples indicated that these seals might have been feeding on discards from the vessel or cod in the survey net. In addition, the equations used to estimate the lengths of Atlantic cod, squid, American plaice, and other flatfish from hard parts were revised. The new equations were based on additional data and/or equations developed using local data that are more appropriate for the area. The previous estimate incorporated a 10% ‘correction factor’ for unidentified prey to account for biases associated with using hard parts to identify prey. Because the degree of potential bias associated with the consumption of soft-bodied prey, the digestion of small otoliths, and belly feeding could not be estimated, this correction factor was removed.

Diet data from the inshore show that the per capita consumption of cod by harp seals has not declined with the collapse of the cod stock. In 1998 there was an increase in per capita consumption in the inshore, especially in the winter. This increase occurred in various areas from White Bay to Trinity Bay.

Numbers of cod at age consumed by harp seals from 1986 to 1998 were estimated from otoliths found in seal stomachs and total consumption estimates calculated from the seal consumption model. From 1986 to 1996 cod age 0 and 1 were the predominant age groups found in harp seal stomachs. In 1997 and 1998 older fish (ages 3-5) were the dominant age groups and fish as old as age 7 were found more frequently than in previous years. With this shift to older, larger cod the total number of fish consumed has decreased in recent years while the estimates of total biomass consumed have been relatively constant.

The estimates of cod consumption may be biased upwards because stomach content analysis relies on the presence and identification of hard parts (such as cod otoliths) and diet contributions from soft bodied animals or species with small otoliths may be missed. The estimates may be biased downwards because incidences of belly-feeding will go undetected. Belly-feeding may be an important source of mortality for local cod aggregations, especially in the area from White Bay to Bonavista Bay. The occurrence of harp seals is reported to be increasing in Trinity Bay, notably in Smith Sound

The trend in biomass of **capelin**, the major **prey** of cod in 2J3KL, has been uncertain since the late 1980s (DFO 2000). The 2000 SSR for capelin reports that they returned to their more normal distribution in the offshore in 1998 and 1999. There were no reports of the distribution of capelin in 2000. There remains concern that there may not be sufficient capelin in the offshore, particularly in the north, to support good condition in cod.

Sources of uncertainty

There is substantial uncertainty regarding the stock structure of 2J+3KL cod. The two hypotheses presented in this assessment have very different implications for stock recovery.

If fish currently in the inshore could recolonize the shelf, then removals in the inshore could delay or even prevent the recovery of the whole stock, even if the inshore is a separate stock. Allowing the inshore biomass to increase makes it more likely that inshore fish may move offshore.

It is unknown whether inshore removals from late spring to autumn would capture some portion of any cod from the offshore that may continue the historic summer feeding migration to the inshore. 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.

There is considerable uncertainty in the trend in the biomass of cod in the inshore. Sentinel catch rates, commercial catch rates and the fall research bottom-trawl survey data for inshore strata in 3K and 3L all indicate a downward trend in the biomass of commercial size fish. In contrast, acoustic estimates for Smith Sound and analyses based on tagging data are inconsistent with a decreasing biomass.

There is uncertainty in the magnitude of the biomass of cod in the inshore. Absolute estimates of biomass are currently only available from analysis of tagging data, and these analyses have yet to properly account for migration within and between the 2J+3KL and 3Ps stocks.

The 1998-2000 year-classes, although still relatively poor compared with historical levels, appear to be stronger than other year-classes since the moratorium. However, these year-classes are estimated with considerable uncertainty. The relationship between the index and subsequent recruitment to the fishable biomass is uncertain.

There is uncertainty in the amount of fish that die as a consequence of fishing activity but do not appear in the catch statistics used in this assessment. There are no direct estimates of unreported catches and high-grading. There is particular concern that the by-catch and discards of cod in the Greenland halibut gillnet fishery may be under-estimated because of the low observer coverage and the lack of a scientific design to observer deployment.

The influence of the large harp seal population on the recovery of the northern cod stock remains uncertain. Harp seal stomach content data are sparse in some areas and seasons. The paucity or poor quality of data on the diet of other predators of cod and the productivity of other harp seal prey (e.g. capelin, Arctic cod and sand lance) make it very difficult to predict the extent to which changes in the abundance of harp seals would change the productivity of cod.

There are concerns that the capelin stock may not be sufficiently large in the offshore to support a recovery of offshore cod. The degree to which cod have been successful in finding capelin and other prey in recent years cannot be investigated because the collection of cod stomach contents ceased in 1998.

Outlook

The stock is assessed under two hypotheses regarding stock structure: a) the inshore constitutes a separate inshore subpopulation that is functionally separate from the offshore; and b) inshore and offshore fish together constitute a single functional population.

Separate inshore subpopulation hypothesis

The acoustic data for Smith Sound show an increase in the biomass index from about 15,000 t in 1999 to about 31,000 t in 2001 while the research bottom-trawl index for inshore strata in 3K and 3L suggests that the inshore biomass of fish age 1-4 in has been increasing since 1997 but the biomass of older fish has been decreasing since 1996. Catch rates from the sentinel survey and from the commercial logbooks show decreasing trends from 1998. The fishing community questionnaire indicates that overall the catch rates in 2000 were low compared with the historical average. In the fall surveys, few fish older than age 5 have been found in inshore 3K and 3L and the age composition is consistent with a high overall mortality rate. The age structure (presence of older fish) in Smith Sound and the inshore commercial catch may indicate that the mortality in some areas of the nearshore is lower.

Tagging data indicate that the 1999 fishery resulted in a 43% harvest rate for fish tagged in 3K compared to northern 3L (13.2%) and southern 3L (23.6%). Tag returns indicate harvest rates in 2000 of about 10% for fish tagged in 3K and northern 3L and 22% for fish tagged in southern 3L. Based on reported catches, the corresponding exploitable biomass estimates from a simple migration model were roughly 40,000 t in 3K and northern 3L combined over the period 1998-2000. A more detailed model without migration gives a biomass of no more than 77,000 t in 3KL in 2000.

The recruitment model, based on both inshore and offshore data, estimates that the 1998 to 2000 year-classes are stronger than earlier year-classes in the 1990s. It is considered that these levels are extremely low compared to recruitment to the whole 2J+3KL stock in the 1980s. The inshore is thought to be a preferred nursery area for young cod (ages 0 and 1) irrespective of whether they originate from spawning in the inshore or the offshore. Year-classes after 1996 are slightly stronger and may lead to increases in the abundance of commercial size fish and the spawning biomass in the inshore in the future if mortality rates are low.

The overall decreasing trend in indices of the abundance of commercial size and spawning age fish suggest that, at current levels of mortality, stock size has not been sustained by recent levels of recruitment. The particularly weak 1996 year-class is likely to exacerbate this situation. However, declining levels of biomass are not apparent in tagging results.

There is no information on what levels of biomass could be supported in the inshore, or on what would constitute an undesirably low spawner biomass under a precautionary approach. If the inshore biomass is considered to be above any such low level, then a harvest rate of 10% could be considered consistent with a precautionary approach under the hypothesis of a functionally separate inshore subpopulation. Indices of exploitable biomass from commercial and sentinel catch rates and the fall bottom-trawl survey in inshore strata appear to be inconsistent with estimates from tagging in their information about trends. Therefore, we cannot say whether recent levels of exploitation have been sustainable. The fact that only about 70% of the TAC was taken in the 2000 index fishery may be further cause for concern.

Single functional population hypothesis

Overall, there is no doubt that the 2J+3KL cod spawner biomass remains at an extremely low level and there is no evidence of a recovery. The offshore research bottom-trawl survey results show extremely low abundance levels, although the remaining fish are widespread. Mortality rate of fish in the offshore is estimated to be as high as levels in the 1980s when a substantial commercial fishery existed. Slightly elevated abundances of fish have been detected in 1999-2000 in acoustic surveys and bottom trawl surveys on the shelf near the boundary between southern 3K and northern 3L. This overlaps the areas in which the Greenland halibut and shrimp directed fisheries are being carried out. Although reported by-catches on observed vessels are low (less than 40 t in 2000), there is concern that by-catch mortality could delay or impede the recovery of the stock.

Although there was a substantial decline in spawner biomass in this stock over the 1960s to a level of less than 200,000 t by the time of extension of jurisdiction in 1977, several strong year-classes arose during the 1980s at a spawner biomass level of about 400,000 t. There has been no good recruitment at spawning stock biomass levels below 200,000 t. Although it is difficult to define a B_{lim} at this stage, it would clearly be desirable to have the spawning stock above 200,000 t. It is generally accepted that an approach of no directed fishing is consistent with the precautionary approach for a stock that is below B_{lim}. Any fishery on the remnant in the inshore will delay recovery of the stock.

Impact of harp seals

The estimates of removals of cod by harp seals, based on reconstructed diets, are high (37,000 t in 2000) and do not incorporate the mortality caused by seals feeding on cod bellies alone. It appears that predation by seals has been an important source of mortality of cod since the start of the moratorium. There is also the possibility that predation by seals is preventing the recovery of the cod stock, not simply because considerable numbers of cod are being consumed but also because some of those cod eaten are mature fish.

Management Considerations

There are no direct estimates of unreported catches, which are rumored to be substantial. The level of observer coverage in some fisheries may be too low to permit accurate estimation of discarding, which includes high-grading and dumping. There is particular concern regarding both by-catch and discarding of cod in the **Greenland halibut gillnet fishery**. Even though the by-catch should be counted against any quota that may be set, it should be noted that this fishery operates offshore in areas where cod occur at densities that are very low compared to the 1980s. Thus, even small catches of cod may impose high mortality on offshore portions of the 2J+3KL cod stock. Any discarding of cod in the Greenland halibut gillnet fishery will exacerbate the situation.

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