

Subdivision 3Ps cod

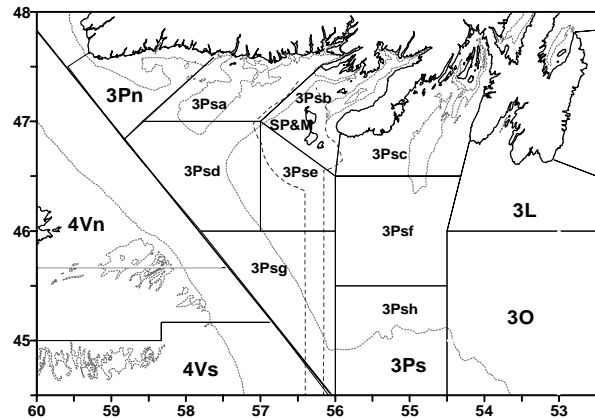
Background

In the Northwest Atlantic, cod are distributed from Greenland to Cape Hatteras and are managed as 12 stocks. The 3Ps stock off southern Newfoundland extends from Cape St. Mary's to just west of Burgeo Bank, and over St. Pierre Bank and most of Green Bank.

The distribution of 3Ps cod does not conform well to management boundaries and the stock is considered a complex mixture of sub-components. These may include fish that move seasonally between adjacent areas as well as fish that migrate seasonally between inshore and offshore. The extent to which the different components contribute to the fisheries is not fully understood.

Cod from this stock generally grow faster than those from areas further northward. At least 50% of the females are mature by age 5 (~53cm) in recent cohorts, compared to age 6 (~58cm) among cohorts present in the 1970s-early 1980s.

Catches from this stock have supported an inshore fixed gear fishery for centuries and are of vital importance to the area. Fish are caught offshore by mobile and fixed gear and inshore by fixed gear. The stock was heavily exploited by Spain and other non-Canadian fleets in the 1960s and early 1970s. French catches increased in the offshore throughout the 1980s. A moratorium on fishing initiated in August 1993 ended in 1997 with a quota set at 10,000 t. The TAC was increased to 20,000 t for 1998 and to 30,000 t for 1999. Beginning in 2000, the management year was changed to begin on 1 April. An interim quota of 6,000 t was set for the first three months of 2000. The TAC for 1 April 2000 to 31 March 2001 was set at 20,000 t and for 1 April 2001 to 31 March 2002 at 15,000.



Summary

- Stock status was estimated from commercial landings in conjunction with abundance indices from Canadian (1972-2001) research vessel trawl surveys, an industry trawl survey (1997-2000), and sentinel surveys (1995-2000). Exploitation rates and biomass for different regions of 3Ps during 2000 were also estimated from tag returns.
- Spawning stock biomass increased from 1993 to 1998 due to good growth, early maturation and good survival over the moratorium period by the 1989 and 1990 year-classes. This increase in spawner biomass was not sustained by subsequent recruitment, and spawning stock biomass has declined during 1998-2001.
- The downward trend in 3Ps spawner biomass in recent years was a consistent feature of all sequential population analysis (SPA) formulations considered in the current and previous assessment.
- Estimates of population size from various sequential population analyses covered a wide range, but trends were similar.

Consequently, inferences regarding the risk of fishing at various catch levels are given as the basis for scientific advice in this assessment.

- Risk analyses indicate that it is unlikely that the spawner biomass will continue to decrease between April 1 2002 and April 1 2003 over a TAC range of 10,000 – 20,000 t.
- The risk of exceeding the $F_{0.1}$ limit reference level was greater than 5% in 2 of the 5 formulations for a TAC of 10,000 t and greater than 5% in 3 out of 5 formulations for a TAC of 15,000 t.
- The risk of exceeding the target reference point of half $F_{0.1}$ was above 50% for 3 out of 5 formulations at a TAC of 10,000 t and above 50% for 4 out of 5 formulations for a TAC of 15,000 t.
- During 1999 and 2000, exploitation was high (0.24-0.45) for cod tagged in Placentia Bay (3Psc) and intermediate (0.07-0.19) for cod tagged west of the Burin Peninsula (3Psa/b/d/e), indicating a combined exploitable biomass for these areas of approximately 70,000-73,000 t.
- Estimates of year-class strength show that all cohorts produced in the 1991-1996 period were substantially weaker than those produced in the 1980's. Although based on fewer data, the 1997 and 1998 year-classes appear strongest in the recent period. These encouraging signs of recruitment are likely to result in an increase in biomass.
- The status of the 3Ps cod stock remains difficult to assess because of variability in the indices, incomplete reporting of all mortality caused by fishing, low fishing

levels during the moratorium, and the mixing of fish between adjacent stocks. In particular, variable mixing of 3Pn4RS and 3Ps cod in the Burgeo Bank/Hermitage Channel area during their over-wintering period creates difficulties for interpretation of catches and indices of stock abundance.

The Fishery

The stock was heavily exploited in the 1960s and early 1970s by non-Canadian fleets, mainly from Spain, with catches peaking at 84,000 t in 1961 (Fig. 1).

After the extension of jurisdiction in 1977, catches averaged around 30,000 t until the mid-1980s when fishing effort by France increased and total landings reached about 59,000 t in 1987. Catches then declined gradually to 36,000 t in 1992.

A moratorium was imposed in August 1993 after only 15,000 t had been landed. Although offshore landings have fluctuated, the inshore fixed gear fishery reported landings around 20,000 t each year up until the moratorium (Fig. 2).

The fishery reopened in May 1997 with a TAC of 10,000 t. This was subsequently increased to 20,000 t for 1998 and to 30,000 t for 1999. In 2000 the management year was changed to begin on 1 April. An interim quota of 6,000 t was set for the first three months of 2000. For 1 April 2000 to 31 March 2001 the TAC was set at 20,000 t and for 1 April 2001 to 31 March 2002 the TAC was 15,000 t.

Landings (000s t)

Year	77-93 Avg.	1994	1995	1996	1997	1998	1999	2000 ¹ (J-M)	2000-2001-2001 ¹	2002 ¹
TAC	-	0	0	0	10.0	20.0	30.0	6.0 ²	20.0	15.0
Can.	25.0	1	1	1	7.4	16.6	20.4	3.5	20.3	9.4
French	14.7	0	0	0	1.6	3.1	3.2	4.7 ³	4.7	0.9
Others	0.03	-	-	-	-	-	-	-	-	-
Totals	39.7	1	1	1	9	19.6	23.6	8.2	25.0	10.3 ⁴

¹ Provisional.

² During 2000 the management year was changed to begin on 1 April (rather than 1 January) and an interim TAC of 6,000 t was allocated for the first three months (Jan.-Mar.) of 2000

³ France is allocated 15.6% of the TAC but carried forward a portion the 1999 allocation to the first three months (Jan-Mar) of 2000.

⁴ Approximate landings to end of September 2001.

In 2000, total reported landings were 25,100 t, mostly (68.2%) from the inshore fixed gear sector. The total includes a French catch of about 4,700 t, of which approximately 3,800 t was caught by otter trawlers and the remainder by fixed gear, particularly gillnets.

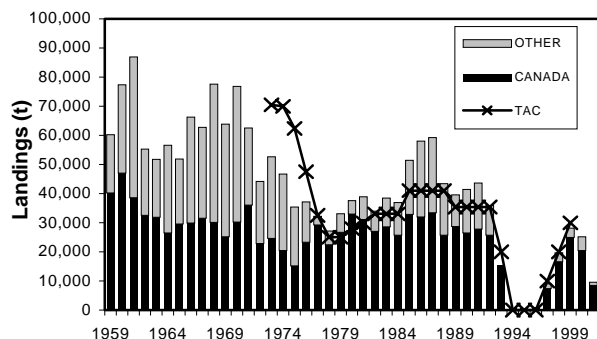


Figure 1. Reported annual landings (t) by country.

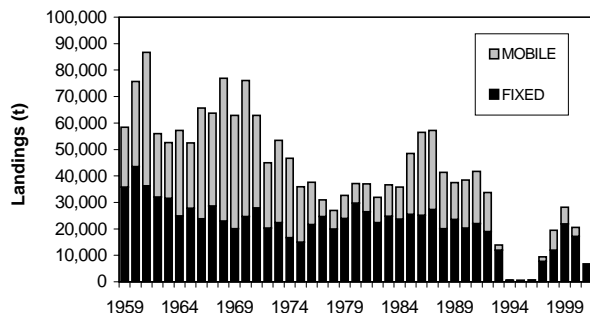


Figure 2. Reported annual landings (t) by gear sector.

The **age composition** of the fixed gear catch from 2000 comprised a range of ages from 3 to 15 with most of the catch comprised of 5-11 yr olds with ages 6-8 (1992-1994 year-classes) predominating. The total catch at age strongly reflects the selectivity of gillnets, on ages around 6-8. Mobile gear catches in the offshore commercial fishery also consisted mostly of 6-11 yr olds, but older ages (10-11) were more strongly represented compared to fixed gear catches.

The fixed gear catch in the first three months of 2001 was dominated by 7-9 yr olds with ages 11 and 12 also well represented in the line-trawl portion. The mobile gear catch for the corresponding period was dominated by 7-8 and 11-12 yr olds.

Species biology

Stock structure and migration patterns of 3Ps cod are complex and poorly understood. Migration of offshore components of the stock to inshore areas during spring and summer, as well as the existence of inshore components that remain outside the research vessel trawl survey areas throughout the year, complicate the assessment of stock status.

Annually variable **mixing** of northern Gulf (3Pn4RS) cod with 3Ps cod in the Burgeo Bank-Hermitage Channel area of 3Ps during winter may cause problems with respect to assigning survey and commercial catches to the appropriate stock. The offshore portion of this area (3Psd) was closed to directed cod fishing from 15 November to 15 April in 1998-1999, 1999-2000, and 2000-2001.

Tagging studies initiated in spring 1997 in Placentia Bay were expanded in subsequent years (1998-2001) to include inner and outer Fortune Bay and two offshore areas

(Burgeo/Hermitage Channel and Halibut Channel). In these five years over 42,000 fish have been tagged and 6,500 reported as recaptured. Cod tagged inshore were mostly recaptured inshore, even 4-5 yr after release. Returns also indicated that some cod tagged offshore were recaptured in the inshore fixed gear fishery on the south coast during the summer and fall. Among cod tagged in the Burgeo/Hermitage Channel area in April, recaptures came from 3Pn4RS as well as along the inshore of 3Ps; the proportions recaptured in each region varied annually, but in two of three years more recaptures came from 3Pn4RS.

Recaptures also indicated a spring-summer **movement** of cod from the inner reaches of Placentia Bay toward the mouth of the bay. Several of these cod, as well as others tagged offshore in Halibut Channel, were recaptured in 3L during 1998, 1999, and 2000. The pattern of recaptures suggests a movement of some 3Ps cod across the stock management boundary into 3L during late spring, with a return migration during late fall. Historical and recent tagging of cod offshore in southern 3Ps also revealed some movement of cod between this area and the southern Grand Banks (3NO).

Maturation in female cod was re-evaluated in the current assessment and is estimated by cohort rather than by year. Proportion mature at age in female cod sampled during research trawl surveys has increased among younger cod, particularly between the late 1980s and early 1990s (Fig. 3). For example, the proportion of 6 yr old females that are mature has increased from about 30% in the 1970s and early 1980s to over 80% in the early 1990s. Proportion mature at age for young cod has high during the mid-1990s, but there is some indication that the trend may be reversing in the most recent years.

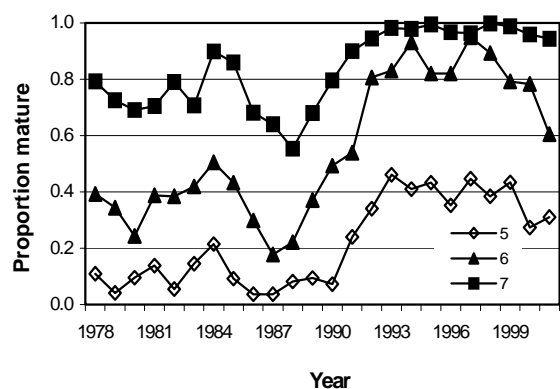


Figure 3. Estimated proportion mature at ages 5-7 (females)

Males generally mature about one year younger than females but show a similar trend over time.

Spawning is spatially widespread in 3Ps, occurring close to shore as well as on Burgeo Bank, St. Pierre Bank, and in Halibut Channel. Timing of spawning is variable and extremely protracted, with spawning fish present from March until August in Placentia Bay. The proportions of fish at various stages of maturation during the 2001 spring research vessel survey were similar to those observed in recent years.

Growth, calculated from length-at-age in research trawl survey samples, has varied over time. For the period 1972-2001, peak lengths-at-age occurred in the mid-1970s for young ages and progressively later for older ages (Fig. 4). From the mid-1980s to the mid 1990s, length at age varied with no trend (younger ages) or declined (older ages). There is some indication of a slight increase in length-at-age among older ages in the late 1990s.

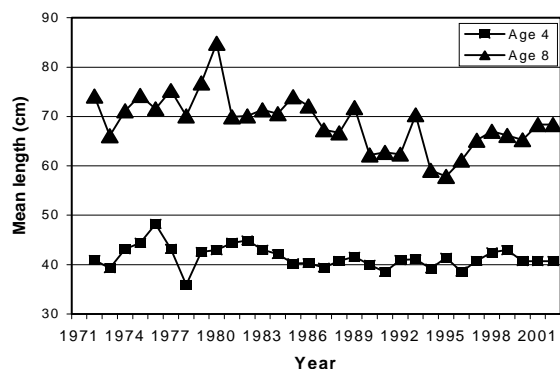


Figure 4. Mean lengths (cm) at age from RV survey.

The **condition** of cod is typically expressed as W/L^3 , where W is the gutted weight or liver weight, and L is the length. Cod collected during the April 2001 research vessel survey were generally in better condition than those sampled at the same time of year during 1993-95. Comparison of post-1992 condition with that observed during 1985-1992 is difficult because survey timing has changed. Condition varies seasonally and tends to decline during winter and early spring. Nonetheless, condition of cod in the 1995-2001 surveys appeared to be normal.

Resource Status

Sources of information

Stock status at the end of March 2001 was updated using age-disaggregated data from **commercial landings** and **abundance indices** from Canadian (1972-2001) research vessel trawl surveys, an industry trawl survey (GEAC, 1997-2000), acoustic surveys (1996-2001), and sentinel surveys (1995-2000). Age-aggregated catch rate data from logbooks (1997-2000) were also examined. Exploitation rates and biomass for different

regions of 3Ps during 2000 were also estimated from tag returns.

Research vessel surveys

Canadian research vessel bottom **trawl surveys** were conducted from 1972-1982 by the research vessel A. T. Cameron using a Yankee 41.5 otter trawl. Surveys from 1983 to 1995 were conducted by the Wilfred Templeman, or the sister vessel the Alfred Needler, using the Engel 145 Hi-Lift otter trawl. Since 1996, the survey has been conducted by the Wilfred Templeman using the Campelen 1800 shrimp trawl. Data collected with the gear used in 1983-1995 were converted to Campelen equivalents based on comparative fishing experiments.

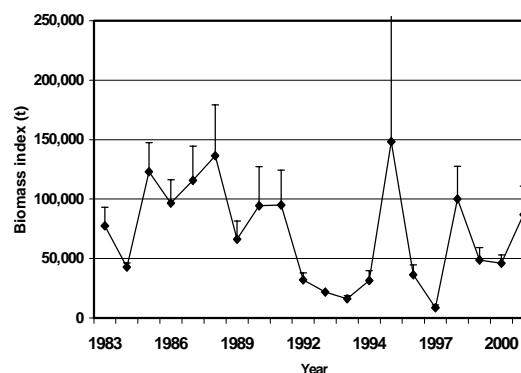


Figure 5. Research vessel survey biomass index (t) (+SD).

The survey **biomass index** is variable but shows a declining trend from the mid-1980s to the early 1990s and a general upward trend in the more recent period (Fig. 5). The biomass index for the entire survey area in 2001 was 86,000 t, approximately 40% higher than the 2000 survey. To account for mixing with 3Pn4RS cod, the survey index was split into two series, Burgeo Bank (western portion) and the remainder of the 3Ps area (eastern portion), as in the previous assessment.

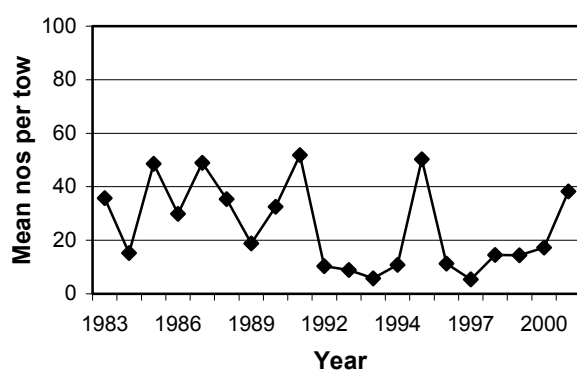
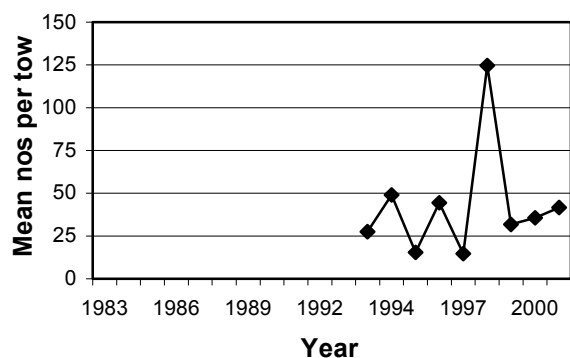


Figure 6. Research vessel survey catch rate index (mean nos per tow) for the western portion (upper panel) and eastern portion (lower panel) of 3Ps.

In terms of mean numbers of fish per tow, the survey catch rate index for the western (Burgeo) portion of 3Ps shows no trend during 1993-2001. The 1998 survey encountered large numbers of 3-5 yr olds that were not strongly represented in subsequent surveys in this area. The survey catch rate index for the eastern portion of 3Ps is variable, but shows a declining trend from the mid-1980s to the early 1990s. There is a general upward trend since the early 1990s. The 1995 catch rate index was strongly influenced by a single large catch and the 1997 survey did not encounter aggregations of fish that were observed in subsequent surveys and commercial catches.

Spatial distribution: In the April 2001 survey, cod were less widely distributed across the top of St. Pierre Bank compared to 1999 and 2000; this change in distribution correlates well with the return to cooler temperatures in 2001. As in previous years, largest catches were localized in the southern Halibut Channel, Fortune Bay, on the northwest corner of St. Pierre Bank, and in the Burgeo Bank-Hermitage Channel area.

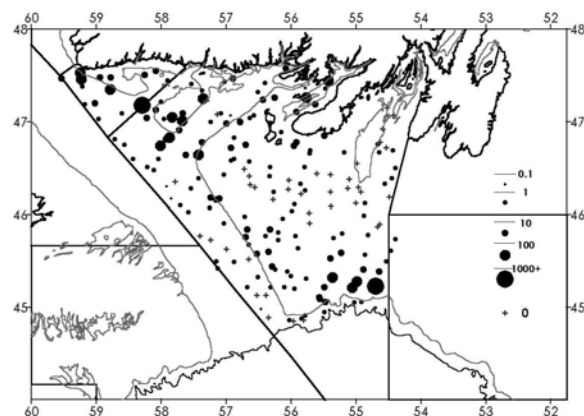


Figure 7. Spatial distribution of 2001 research vessel trawl survey catches.

Age composition: The most numerous ages in the 2001 survey were 3 and 4 (1997 and 1998 year-classes). Among older ages, the 1989 year-class is also well represented. However, survey catches over the post-moratorium period have consistently shown few survivors from year-classes prior to 1989.

Industry (GEAC) trawl survey

During fall 2000 a fourth consecutive industry (Groundfish Enterprise Allocation Council) trawl survey directed at cod in the offshore was conducted. In all years this survey has shown aggregations of cod in the southern Halibut Channel and on or adjacent to St. Pierre Bank.

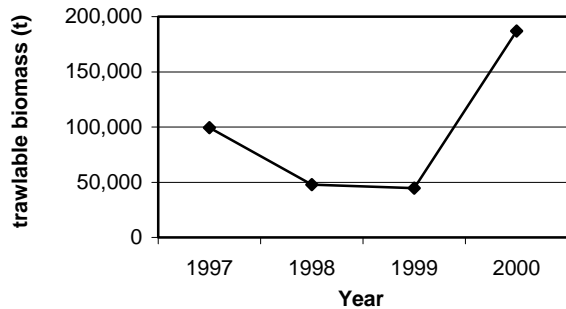


Figure 8. Biomass index from the industry trawl survey.

The biomass index is variable and much higher in 2000 due mainly to more large fish in the catch.

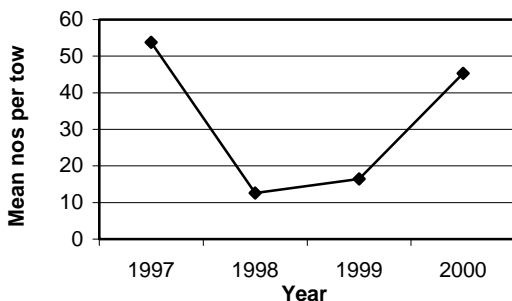


Figure 9. Catch rate index from the industry trawl survey.

In terms of mean numbers per tow, the catch rate index has ranged from 12.6 to 52.6 fish per tow and shows no clear trend over time.

The 1989 and 1990 year-classes are strongly represented in the industry trawl survey and in the most recent year the 1997 and 1998 year-classes are also well represented. These results are in general agreement with the spring research vessel trawl survey.

Acoustic surveys

Acoustic surveys of Placentia Bay, including untrawlable inshore regions that are shoreward of the research vessel survey area, have been conducted during 1996-2001. The

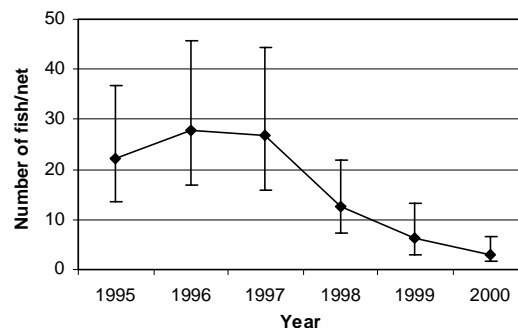
spatial coverage has varied over the time series and in two years (1996 and 1998) coverage was extended offshore to include the Halibut Channel area. The acoustic index for Placentia Bay derived from the survey for the period 1996-2001 shows a biomass in the range of 20,000 to 35,000 t. The 1997 year-class appears abundant in the 2001 survey; however, a model fitted to the data did not show a significant difference in strength among cohorts.

Sentinel survey

A fixed gear **sentinel survey** has been conducted at 16 sites along the south coast of Newfoundland from St. Brides to Burgeo. The survey began in late February of 1995 and continued in 2001. However, the 2001 survey is not yet complete and the analysis could not be extended to include the current year.

Gillnet catch rates, mostly from sites in Placentia Bay, show strong seasonality and are consistently highest during fall in the eastern side of Placentia Bay. Line-trawl catch rates, mostly from sites west of the Burin Peninsula exhibit strong seasonality.

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.



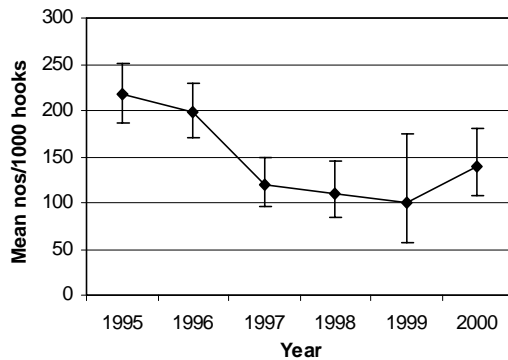


Figure 10. Standardized sentinel catch rate indices for gill nets (upper panel) and line-trawls (lower panel).

The standardized total annual **catch rate index** for gillnets shows no clear trend during 1995-1997, but was progressively lower in 1998, 1999 and 2000 (Fig. 10, upper panel). The index for line-trawls shows a declining trend during 1996 to 1999 that is reversed in the most recent year (Fig. 10, lower panel).

The standardized age-disaggregated indices for gillnets and line-trawls show similar trends with the relatively strong 1989 and 1990 year-classes being replaced by weaker year-classes resulting in an overall decline in catch rates. The increase in line-trawl catch rates but not gillnets in 2000 is due to incoming 1997 and 1998 year-classes which appear to be relatively strong; fish from these year-classes are still too small to be caught in significant numbers by gillnets.

Log-books

Further analyses of the catch rate data from science logbooks (<35' sector) and new analyses of data from logbooks of larger vessels (>35' sector) were conducted. There have been substantial changes in the management plans in the post-moratorium period, with respect to timing of the fishery, amount of gear fished, trip and weekly limits, as well as a trend toward individual quotas (IQs) rather than a competitive fishery. In addition, experience has shown that catch rates from more mobile fleets are often a poor reflection of overall trends in stock abundance, particularly for stocks in decline. Consequently, these data remain difficult to interpret and are treated with caution in terms of providing information about changes in stock size.

Science logbooks (<35' sector): Standardized annual catch rates from the logbooks for vessels fishing gillnets show similar declining trends to those observed in the sentinel survey. A declining trend is also observed for line-trawls, but in contrast to the sentinel survey, there is no indication of a reversal of the declining trend in the most recent year. This is partly because the commercial index is based on weight of fish caught whereas the sentinel index is based on numbers; however, it is also suspected that the smallest fish are being discarded in the line-trawl fishery and are therefore not being reflected in the commercial catch.

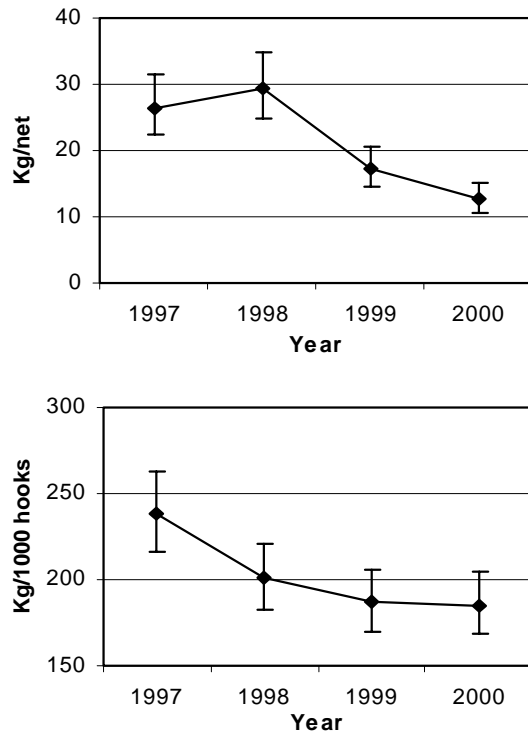


Figure 11. Standardized catch rates for gill nets (upper panel) and line-trawls (lower panel) from science logbooks for vessels <35'.

Large vessel (>35' sector) logbooks: There was substantially less information about catch rates from this sector because fewer large vessels participate in the fishery. There were no data available for the offshore for 1997; thus, only data for 1998-2000 were examined. To illustrate possible trends, monthly and annual median catch rates for various gear sectors and areas were computed. Catch rates for gillnet and line-trawl tended to be higher when fished in offshore (3Psd-h) compared to inshore (3Psa-c) areas. During 1998-2000, line-trawl catch rates appeared to increase in 3Psb/c/d and decrease in 3Psa; gillnet catch rates increased in 3Psb/e/h, but decreased in 3Psa/c/d/g and showed no trend in 3Psf. There were indications that a portion of the gillnet fleet redirected effort in 2000 to 3Psh rather than Placentia Bay where catch rates were

declining. Small otter trawlers fishing in 3Psf/h showed a downward trend in catch rates, whereas the largest vessels (>65') fishing in 3Psh showed an increase in catch rates and caught a significant portion of their allocation using Norwegian seines. Overall, there were no clear trends in catch rates in these data.

Tagging

Information from recaptures of cod tagged in various regions of 3Ps since 1997 was used to estimate average **annual exploitation rates**. Three analyses of the tagging data were conducted. In the first analysis, which did not incorporate length selectivity of the fishery, exploitation rates were calculated for cod tagged in specific regions. A portion of the exploitation typically occurred in regions other than where fish were tagged and these estimates could not be converted to exploitable biomass using local catches. The second analysis estimated exploitation rates and exploitable biomass in 1999 and 2000 within specific regions and accounted for migration between regions, but did not incorporate length selectivity. The third analysis estimated weekly exploitation and exploitable biomass by region in 1997-2000 and accounted for growth, length selectivity of the fishery, and migration.

In all of these analyses tag reporting rates (i.e. fraction of tagged cod that were caught and tags actually returned to DFO) were estimated from a high-reward tagging study. Double tags were used to estimate the rate of tag loss over time. The number of tags returned was adjusted upward by the reporting rate. The number available to be caught in each year was obtained by adjusting the number of releases to account for tagging

mortality, tag loss, assumed natural mortality, and exploitation in preceding years.

All three methods gave broadly similar results. During 1999 and 2000, exploitation was high (0.24-0.45) for cod tagged in Placentia Bay (3Psc) and intermediate (0.07-0.19) for cod tagged west of the Burin Peninsula (3Psa/b/d/e), indicating a combined exploitable biomass for these areas of approximately 70,000-73,000 t. Exploitation was much lower (0.01 to 0.04) among cod tagged offshore (3Psh) in 1998-2000. These low exploitation rates suggest a large offshore biomass, but the estimates were considered implausibly high for the area of known distribution of cod and given the history of the fishery. Possible reasons for the high estimates include restricted offshore tagging coverage and restricted distribution of fishing activity in the offshore, more uncertainty in the reporting rates of tags from the offshore, and lower survival of fish caught for tagging offshore in deep water.

Relative Year-Class Strength

A simple multiplicative model that incorporated data from several surveys was used to estimate the relative strength of year-classes produced during 1970-1999. Catch rates for ages 1-4 inclusive from the research vessel trawl survey (1972-2001), the sentinel gillnet and line-trawl indices (1995-2000), an industry trawl survey (GEAC, 1997-2000), and acoustic estimates (1996-2001) were used in the analysis.

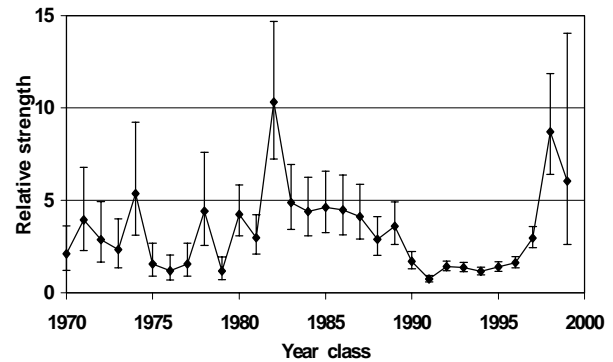


Figure. 12. Relative year-class strength (\pm SE).

Estimates for cohorts in the earlier part of the time series are based on one index and are thus more variable. All cohorts in the late 1980s were estimated to be substantially stronger than those in the 1991-1996 period. The 1997, 1998, and 1999 year-classes appear strongest in the recent period, but are based on fewer data and consequently are estimated with less certainty. The 1989 and 1990 year-classes do not appear particularly strong in this analysis; however, their survival rate was good during the moratorium leading to their strong representation in the fishery in the early post-moratorium period.

Industry perspective

Collection of information on the 2000 fishing season was carried out through questionnaires, but the proportion returned was considered too low (16%) to accurately reflect industry perspective. However, trends in sentinel and commercial catch rate indices were consistent and showed declines in recent years.

Other considerations

Temperature

The warming trend seen during 1998-2000 has not continued and water temperatures in 2001 cooled to values observed in the mid-1990s. The areal extent of relatively warm ($>1^{\circ}\text{C}$) water in 2001 also declined, and there was an increase in the areal extent of relatively cold ($< 0^{\circ}\text{C}$) water, which covered about 30% of St. Pierre Bank during 2001.

Cold water in the late 1980s and early 1990s was associated with a disappearance of cod from the shallow strata on top of St. Pierre Bank and a shift to deeper water at the time of year when the research trawl survey was conducted. Survey results from recent years (1998-2000) when waters were warmer indicate some reappearance of cod in these shallow strata; however, in 2001 the numbers of cod in these shallow strata appear to have declined again.

Sequential Population Analyses

Several **sequential population analyses** (SPAs) were conducted. In addition to the total reported commercial catch, the following tuning indices were available: the Cameron RV index for 1972-82, the Templeman RV index for the Burgeo strata for 1993-2001, the Templeman RV index for the non-Burgeo strata for 1983-2001, the GEAC index for 1997-2000; the sentinel gillnet and line-trawl indices for 1995-2000, and an acoustic index for 1996-2001 for Placentia Bay.

Extensive analyses of the catch data and the tuning indices were carried out prior to including them in SPAs. This led to concerns regarding the accuracy of the pre-

1977 catch at age data. Other concerns were the lack of cohort strength information in the inshore acoustic data and inconsistent trends in gillnet catch rate indices over the recent period.

Various SPA formulations were applied to the data to examine the sensitivity of the assessment to the method used. Within these analyses self-weighting of the indices, as opposed to equal weighting, and various partial recruitment assumptions on the oldest age in the model were examined.

In the 2000 assessment, the issue of stock mixing was addressed by splitting the Templeman index into two series: one for spring surveys in the Burgeo Bank/Hermitage Channel area and one for the remaining 3Ps area (winter and spring series combined). As in the last assessment, additional analyses were also considered in which the Templeman survey index was considered as a single series.

When self-weighting of indices is applied, the SPA estimates the accuracy of each index to determine how much weight it should be given in the final result. The SPA gives the Templeman survey index for the Burgeo Bank/Hermitage Channel area lower weight, as would be expected if this were a poorer index of 3Ps stock abundance as a consequence of stock mixing.

The **SPA sensitivity runs** suggested that there is considerable uncertainty about the absolute size of the cod population, but trends in population size and spawner biomass were similar. The downward trend in 3Ps spawner biomass in recent years was a consistent feature of all SPA formulations considered in the current and previous assessment.

SPA estimates of current spawner stock biomass ranged from 50,000 to 150,000 t. This wide range is due to uncertainty in assumptions made in model formulation, primarily with regard to partial recruitment and whether or not to split the RV survey index into two series.

The estimated trends in the relative spawner biomass from the sequential population analyses and inferences regarding risk were found to be more robust than the absolute estimates of stock size. The inferences regarding risk for the fishing mortality reference levels were less robust than was anticipated; however, they are presented together with the risks of spawner stock biomass declining as the basis for providing scientific advice in this assessment.

In an SPA run using the same tuning indices and model structure as was used in the previous assessment updated with one more year of data (**comparison SPA run**), population biomass and spawner biomass increased from the late 1970s to a peak in 1985 (Fig. 13). The stock declined from the mid-1980s to the early 1990s, but increased rapidly during 1993-1997 following the moratorium. Population biomass and spawner biomass are estimated to have decreased during 1998-2000. In this analysis the current (1 Jan. 2001) **population biomass** is estimated to be 156,000 t. and **spawner biomass** is estimated to be 92,000 t. Spawner biomass is predicted to decline further during the course of the current fishing year if the 15,000 t TAC is taken. The resulting estimate of spawner biomass for 1 April 2002 is 78,000 t.

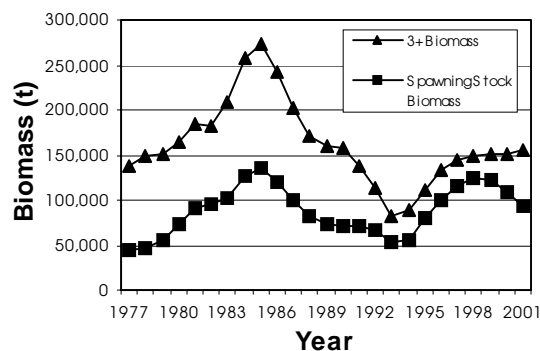


Figure 13. Spawning stock biomass and population (3+) biomass.

Recruitment estimated from the comparison SPA has been variable in 3Ps, but shows a long-term decline between the mid 1970s and the early 1990s (Fig. 14). Recruitment during the mid- to late-1990s does not appear to be strong, but has increased in 1997-1998. Note that the recent estimates of recruitment have more uncertainty than the historic estimates. These trends in recruitment are similar to those obtained from the year-class strength analyses (Fig. 12).

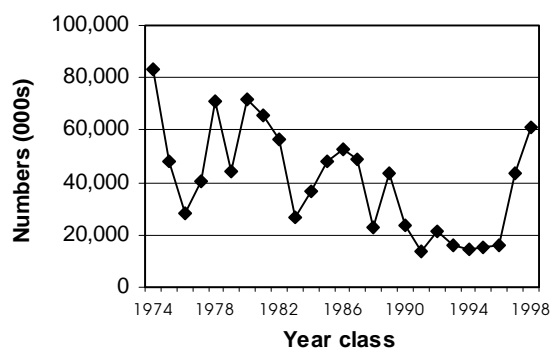


Figure 14. Recruitment (numbers at age 3).

Estimates of annual **exploitation rate**, expressed as percentage of 3+ numbers removed by the fishery, varied over time. Exploitation during the late 1970s to 1984 was typically between 10 and 15%, but increased rapidly to between 18 and 26% just prior to the moratorium in 1993 (Fig. 15). With the reopening of the fishery in 1997, exploitation rates were low in 1997 relative

to the pre-moratorium period and increased to 12.7% in 1999, but declined to under 10% in 2000, the last completed year of the fishery. Although overall exploitation has not been particularly high in the reopened fishery, exploitation on some year-classes is estimated to have exceeded the $F_{0.1}$ reference level. Tagging results also indicate that exploitation rates have been high in Placentia Bay.

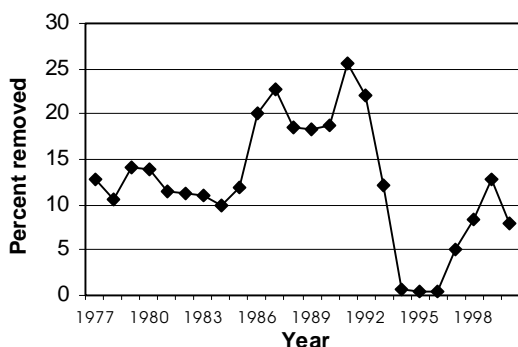


Figure 15. Exploitation rate.

Risk analyses

Several risk analyses based on different SPA formulations were used to propagate the uncertainty in the estimated population size to 1 April 2003, under a range of TAC options for the 2002-2003 fishing season. The risk of the spawning stock declining and the risk of exceeding the $F_{0.1}$ and half $F_{0.1}$ exploitation rate reference levels were considered for a range of catch options for each model formulation. In the absence of a more fully developed precautionary framework for the stock, $F_{0.1}$ is considered a limit reference point and half $F_{0.1}$ a target reference point.

TAC (kt)	SPA formulation				
	A	B	C	D	E
10	<5	<5	<5	<5	10
15	<5	<5	<5	<5	15
20	<5	<5	<5	<5	19

TAC	Probability of exceeding $F > F_{0.1}$				
	A	B	C	D	E
10	<5	<5	<5	19	12
15	<5	<5	25	88	66
20	27	<5	95	100	98

TAC	Probability of exceeding $F > \text{one half } F_{0.1}$				
	A	B	C	D	E
10	28	1	95	100	96
15	87	26	95	100	100
20	99	69	95	100	100

The improvement in recruitment in recent years is predicted to result in an increase in spawner biomass. Four out of five of the SPA formulations (labeled A-E) predicted a <5% probability of spawner biomass declining between 1 April 2002 and 1 April 2003 over a range of TAC options from 10,000 to 20,000 t.

The risk of exceeding the $F_{0.1}$ limit reference level was greater than 5% in 2 of the 5 formulations for a TAC of 10,000 t and greater than 5% in 3 out of 5 formulations for a TAC of 15,000 t.

The risk of exceeding the target reference point of half $F_{0.1}$ was above 50% for 3 out of 5 formulations at a TAC of 10,000 t and above 50% for 4 out of 5 formulations for a TAC of 15,000 t.

Sources of uncertainty

The status of the 3Ps cod stock remains difficult to assess because of variability in some of the tuning indices, incomplete reporting of all mortality caused by fishing, low fishing levels during the moratorium, and the mixing of fish between adjacent stocks.

Uncertainty in the interpretation of the survey index is aggravated by past changes in the

timing of the survey. In the present assessment, the Burgeo/Hermitage Channel portion of the survey was again treated as a separate index in some analyses due to possible mixing between 3Pn4RS and 3Ps cod extending into April.

To estimate population numbers it is necessary to make assumptions about how commercial fishery selectivity changes with cod size and hence age. Different assumptions about how this selectivity changes, as well as different treatments of the survey data, can produce estimates that differ substantially. A particular concern is that the model estimates that larger, older fish are caught in a much lower proportion relative to their abundance than younger fish and this is not easy to explain. If larger, older fish are selected more strongly than estimated, then spawner biomass is overestimated and the presented risk associated with the catch options considered would be too low.

There is uncertainty with regard to the amount of weight that should be given to each index. Methods that apply self-weighting tend to give estimates that are more precise but possibly less robust, and it is not clear when self-weighting provides an improvement over equal-weighting each index.

There is considerable uncertainty regarding the origins of fish found in 3Ps at various times of year. Tagging experiments suggest that the amount of mixing with adjacent stocks can vary from year to year. The assessment is sensitive to mortality on 3Ps cod occurring when fish are outside 3Ps and to the incursions of non-3Ps fish into the stock area at the time of the survey and the fishery.

The risk analyses, although more comprehensive than those conducted in the past, reflect only part of the uncertainties. They do not include those associated with stock mixing, survey catchability, misreported catches, and assumptions about natural mortality.

Outlook

In this assessment the absolute size of the spawner biomass in sequential population analyses was found to be very sensitive to model formulations.

Spawner biomass estimates for 1 April 2001 from the sequential population analysis sensitivity runs ranged from 50,000 t to 150,000 t. In a comparison SPA run, using the same tuning indices and model structure as was used in the previous assessment updated with one more year of data, spawner biomass for 1 April 2001 is estimated to be 85,000 t. Spawner biomass is predicted to decline further during the course of the current fishing year if the 15,000 t TAC is taken. The resulting estimate of spawner biomass for 1 April 2002 is 78,000 t.

Exploitable biomass estimates for year 2000 applying a simplified tagging model to the tag return data gave estimates of about 73,000 t for Placentia Bay, the northern area of St Pierre Bank, Fortune Bay and Burgeo Bank combined. The estimate for the same area from a more detailed model was about 70,000 t. Estimates for the Halibut Channel and southern St Pierre Bank were considered implausibly high for the area of known distribution of cod in the offshore and given the history of the fishery.

The estimated trends in the relative spawner biomass from the sequential population analyses and inferences regarding risk were found to be more robust than the absolute estimates of stock size. The inferences regarding risk for the fishing mortality reference levels were less robust than was anticipated; however, they are presented together with the risks of spawner stock biomass declining as the basis for providing scientific advice in this assessment.

All the SPA analyses estimate that the spawner biomass declined from 1985 to 1993 when the moratorium was imposed and subsequently increased up until 1998. Thereafter the spawner biomass is estimated to have declined up to 2001. Exploitation rates estimated by sequential population analyses indicate that some year classes experienced heavy fishing mortality during 1999. Analyses of tagging data indicate overall exploitation rates were high in Placentia Bay.

The year class analysis estimates and the SPA model estimates agree that year-classes were weak between 1991 and 1996 and that the 1997 and 1998 year-classes are stronger. There is uncertainty regarding the strength of the 1999 year-class because the only information available to date comes from the 2001 Templeman RV survey.

The improved recruitment in recent years is encouraging and is predicted in short-term projections to result in an increase in biomass.

Risk analyses indicate that it is unlikely that the spawner biomass will decrease between April 1 2002 and April 1 2003 over a TAC range of 10,000 – 20,000 t.

The risk of exceeding the $F_{0.1}$ limit reference level was greater than 5% in 2 of the 5 formulations for a TAC of 10,000 t and greater than 5% in 3 out of 5 formulations for a TAC of 15,000 t.

The risk of exceeding the target reference point of half $F_{0.1}$ was above 50% for 3 out of 5 formulations at a TAC of 10,000 t and above 50% for 4 out of 5 formulations for a TAC of 15,000 t.

Management Considerations

The incentive for under-reporting of catches remains with the implementation of trip limits, IQ's, as well as size-based and quality-based price differentials. Increased monitoring of catches and landings would result in better estimates of deaths caused by fishing.

Because of uncertainties in stock structure, excessive exploitation on components of the stock should be avoided. Measures should be implemented to reduce the high exploitation rate in Placentia Bay (3Psc) that is evident from analyses of the tagging data and sentinel catch rate indices.

The consequences of further area/time closures should be carefully considered as these may result in higher exploitation rates on the components of the stock that remain open to fishing.

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