Canadian Stock Assessment Secretariat Research Document 98/19

Not to be cited without permission of the authors ${ }^{1}$

Secrétariat canadien pour l'évaluation des stocks Document de recherche 98/19

Ne pas citer sans autorisation des auteurs ${ }^{1}$

# An assessment of the cod stock in NAFO Subdivision 3Ps 

by

D.E. Stansbury, P.A. Shelton, J. Brattey, E.F. Murphy, G.R. Lilly, N.G. Cadigan and M.J. Morgan<br>Science Branch, Department of Fisheries and Oceans<br>PO Box 5667, St John's, Newfoundland<br>Canada, AlC 5X1

${ }^{1}$ This series documents the scientific basis for the evaluation of fisheries resources in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.
${ }^{1}$ La présente série documente les bases scientifiques des évaluations des ressources halieutiques du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

Les documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au secrétariat.

ISSN 1480-4883
Ottawa, 1998
Canadä


#### Abstract

The current assessment attempts to determine the status of the stock on 1 January 1997 and evaluates alternative TAC options for 1998. Separate analyses are carried out on the inshore and offshore. For the offshore an ADAPT is calibrated with Canadian and French research vessel trawl indices. In addition a SPA based on quasi-likelihood theory is applied to the same indices. In a final analysis on offshore catch data, separate catchabilities were estimated for Canadian surveys carried out in winter and spring. No SPA was attempted on the inshore catch data. However, an estimate of the abundance of cod in Placentia Bay from an in-season tagging experiment was extrapolated across the whole of the inshore area based on commercial gillnet catch rates and relative area. From an offshore spawner biomass estimate of about $100,000 \mathrm{t}$ and an inshore extrapolation from the tagging study of about $115,000 \mathrm{t}$, a total spawner biomass for 1 January 1998 of about $215,000 \mathrm{t}$ was obtained (subsequently revised to $183,000 \mathrm{t}$ because of a revised inshore estimate of $82,765 \mathrm{t}$ ). This would equate to an $F_{0.1}$ TAC of about $40,000 \mathrm{t}$. In the absence of a full risk analysis for both the inshore and the offshore, it was considered that exploitation not exceeding about $50 \%$ of the $F_{0.1}$ level would provide an adequate margin of safety for this stock and be in keeping with the precautionary approach, indicating a TAC of about $20,000 \mathrm{t}$. It was noted however that for a $10,000 \mathrm{t}$ offshore quota in 1998 there is about a $30 \%$ probability that the offshore spawner biomass would not increase from 1998 to 1999.


## Résumé

La présente évaluation a pour objet de déterminer l'état du stock au 1 ${ }^{\mathrm{er}}$ janvier 1997 et d'évaluer des TAC possibles pour 1998. Des analyses distinctes ont été réalisées pour les zones côtière et hauturière. Pour la zone hauturière, le modèle ADAPT est étalonné à l'aide des indices de chalutage des bateaux de recherche canadiens et français. En outre, une ASP fondée sur la théorie de la quasi-vraisemblance est appliquée aux mêmes indices. Au moment de l'analyse finale des données sur les captures de la pêche hauturière, des taux de vulnérabilité distincts ont été estimés pour les relevés canadiens effectués en hiver et au printemps. Aucune ASP n'a été faite pour les données de la pêche côtière. Une estimation de l'abondance de la morue de la baie Placentia fondée sur une expérience de marquage en cours de saison a été extrapolée pour l'ensemble de la zone côtière en se fondant sur les taux de capture de la pêche commerciale au filet maillant et sur les superficies relatives. À partir d'une estimation de la biomasse de géniteurs en zone hauturière de 100000 t environ et d'une extrapolation pour la zone côtière fondée sur une étude de marquage donnant 115000 t environ, on a obtenu une biomasse totale de géniteurs au $1^{\text {er }}$ janvier 1998 de 215000 t environ (ultérieurement réduite à 183000 t suite à une révision à 82765 t de l'estimation pour la zone côtière). Cela correspondrait à un TAC de 40000 t environ au niveau $F_{0,1}$. En l'absence d'une analyse complète des risques pour les zones côtière et hauturière, il a été jugé que le taux d'exploitation ne devrait pas excéder $50 \%$ de la valeur du $F_{0,1}$. Cela devrait donner une marge de sécurité suffisante pour ce stock tout en étant conforme à l'approche de prudence. Le TAC serait alors de 20000 t . Il a cependant été signalé qu'à un quota de 10000 t pour la pêche hauturière en 1998 , il y avait une probabilité de $30 \%$ environ que la biomasse des géniteurs de cette zone n'augmente pas de 1998 à 1999 .

## Introduction

Cod in NAFO Subdiv. 3Ps are traditionally thought of in terms of fish that inhabit the outer slopes of St. Pierre Bank in winter, migrating across the top of the bank to the south coast in summer (Pinhorn 1976). However, tagging data indicate that the stock structure and migration patters of cod in NAFO Subdiv. 3Ps are extremely complex (Brattey 1996). At least five stocks or stock complexes are thought to contribute to the commercial fishery: the northern Gulf stock ( 3 Pn 4 RS ), the Burgeo Bank stock, the southern St. Pierre Bank stock, the Avalon-Burin stock complex and southern Grand Bank (3LNO) fish. In addition to tagging data, analysis of otolith elemental fingerprints (Campana et al. 1998) sampled in Janaury 1996 near the mouth of the Gulf of St Lawrence indicated that 3Ps cod were concentrated most heavily to the west of St. Pierre Bank, where they mixed extensively with 3Pn4RS cod. Application of this technique to samples collected at the time of the April survey could help elucidate stock affinities. Uncertainty regarding stock structure and what constitutes the 3Ps stock has not been formally taken into account in past assessments, although survey timing has been altered to April in an attempt to restrict the enumeration to 3Ps fish only.

Before 1959 landings data for 3Ps and 3Pn were not recorded separately (Pinhorn 1969), so that population reconstructions cannot go back further than this time. Maximum sustainable yield for this stock was estimated at about 60,000 t (Pinhorn 1976). Landings exceeded this level at various times in the 1960s. In the 1991 assessment of this stock (Bishop et al. 1991) it was estimated that the 3+ biomass reached a low level of about $80,000 \mathrm{t}$ in the mid -1970 s , increased to a level of $225,000 \mathrm{t}$ in 1985 , declined somewhat in the late 1980 s as a result of the weak 1983 and 1984 year classes, and then increased again to the highest estimated level in 1991 as a result of the strong 1986 and 1987 year classes. The TAC equivalent to $F_{0.1}$ for 1992 was estimated to have been about $40,000 \mathrm{t}$. The actual TAC in 1992 was set below this level at $35,400 \mathrm{t}$.

The 1992 survey indices for both Canada and France were considerably lower than the 1991 values and the 1992 assessment had difficulty in resolving the status of the stock (Bishop and Murphy 1992). The assessment concluded that if the large decline in the research vessel index in 1991 was a result of fish being temporarily out of the survey area (i.e. a "year effect") then the $3+$ biomass at the beginning of 1992 was estimated to be slightly less than that of 1991 . However, if the research vessel index reflected a real decline, then the biomass could be as low as $90,000 \mathrm{t}$, close to the lowest estimated biomass level for this stock. CAFSAC advised that if the stock size was in fact this low then the consequences of keeping the current TAC $(35,400 \mathrm{t})$ could be severe and therefore advised a decrease in the TAC to $20,000 \mathrm{t}$ in 1993. The TAC for 1993 was set at $20,000 \mathrm{t}$ but only $15,000 \mathrm{t}$ was caught by the time a moratorium was imposed in August 1993, based on the recommendation of the Fisheries Resource Conservation Council following the 1993 assessment of this stock.

The French survey was discontinued after 1992. The 1993 Canadian survey index was even lower than the 1992 value. Under the assumptions that were made regarding
constant natural mortality and survey catchability, the SPA carried out at the 1993 assessment (Bishop et al. 1993) could not reconcile the survey and catch data and the results were considered to be only "illustrative" of what might be taking place. Hence no TAC projection was attempted for 1994. It was estimated that a $20,000 \mathrm{t}$ catch in 1993 would have generated a fishing mortality in excess of $F_{0.1}$.

The 1994 survey was again low. The assessment (Bishop et al. 1994) suggested the apparent decline in the stock size was consistent with the declining length at age, increased total mortality from catch curve analysis and a loss of older age groups of fish. It was concluded that, similar to stocks in adjoining divisions, 3Ps cod appeared to have been declining since the mid-eighties. In contrast to the 1994 survey, the 1995 survey gave the highest index in the time series (1978 to 1995), however this resulted from one large set of about 15 t . Although it was not decided to treat this set as an outlier, the assessment recommended a cautious approach and considered that stock size was probably closer to that estimated for 1994 (Bishop et al. 1995).

In 1996 the survey switched from the Engel 145 otter trawl gear to the Campelen 1800 shrimp trawl. Despite extensive comparative fishing exercises and subsequent length based conversion of the Engels catches to Campelen equivalent catches (Warren 1997, Warren et. al. 1997, Stansbury 1996 , 1997) there is still uncertainty regarding whether or not the integrity of the time series has been maintained. The conversion makes a big difference to the appearance of the time series. For example, the 1995 index, which is the highest in the unconverted Engels data, is lower than the 1985, 1990 and 1991 indices in the converted series.

The 1996 assessment of this stock (Shelton et al. 1996) attempted, for the first time, to carry out separate quantitative analyses for inshore and offshore components of the stock. The results of the trawl surveys suggested that the biomass of cod in the survey area had declined to a low level in 1993 and may have increased only modestly since then. This decline and continuing low biomass in the offshore conflicted with trends in inshore catch rates, results of the 1995 and 1996 Sentinel Survey and limited acoustic data. The perception of many fishers was that there has been a good recovery of the stock in the inshore. An acoustic survey in the inner portion of Placentia Bay in November 1995 had found about 23,000 $t$ of cod (Rose 1996). ADAPT formulations carried out separately for inshore catch and fixed gear commercial catch rate data, and offshore catch and research vessel survey data were both considered to be flawed because of the large standard errors associated with the parameter estimates and the temporal pattern in the residuals. The Stock Status Report for 1996 (SSR 96/81E) reports on an attempt to extrapolate the Placentia Bay acoustic estimate to the area covered by the sentinel survey using the ratio of fish density in the acoustic survey to the catch rates experienced by sentinel fishermen. The biomass estimated in this manner exceeded $100,000 \mathrm{t}$. The estimate was reported as being "...considered extremely tenuous." (SSR 96/81E).

Based on the available data, it was concluded in the 1996 assessment that a limited reopening of the inshore fixed gear fishery may not compromise the recovery of the
stock, but that a re-opening of the offshore bottom trawl fishery in 1997 was not supported by trawl survey data (SSR 96/81E). It was pointed out that in 1993, prior to closure, about 10,000 metric tons was taken inshore by fixed gear. Given the uncertainties and risks associated with reopening, as outlined above, it was suggested that there was no basis for recommending catches above this level during the first year of any limited reopening. The Stock Status Report requested that detailed logbook information accurately reflecting catches and associated effort should be gathered from all vessel sizes involved in the fishery. Previously, vessels less than 35 ft were not required to fill in logbooks. The quality of the catch data for these vessels derived from purchase slips and other sources is not known. No record of fishing effort is available for these vessels. Logbooks for smaller vessels to collect catch and effort data was set as a condition of license for the 1997 3Ps fishery.

The 1997 assessment was postponed to February 1998 to allow the commercial catch at age data from the reopened fishery to be incorporated in analyses. This document provides the basis for the 1998 assessment, incorporating the April 1997 research vessel survey results and the catch at age from the $10,000 t$ commercial fishery in 1997. It provides an estimate of the abundance of fish on January 1, 1997 which is updated to January 1, 1998 by accounting for the 1997 catches and assumed natural mortality. Projections are then carried out from January 1, 1998 to January 1, 1999 for a range of TAC options for the current year. Associated risks are calculated and the results presented in the form of decision tables.

## Catch and catch at age

Cod catches from 3Ps for the period 1959 to 1997, by country and separated for fixed and mobile gear, are given in Table 1. Canadian landings are estimated from purchase slip records, logbooks and vessel hails by Statistics Division, Department of Fisheries and Oceans. Non-Canadian landings (mainly France) are compiled from individual countries national catch statistics as reported to NAFO. There is generally a two to three year lag in the submission of final statistics to NAFO, so the last few years entries in Table 1 are designated as preliminary. The reliability of the landings data is not known.

The 3Ps cod stock was heavily exploited in the 1960s and early 1970s by foreign fleets, mainly from Spain, with catches peaking at about $87,000 \mathrm{t}$ in 1961 (Table 1, Fig. 1). After extension of jurisdiction in 1977, cod catches averaged between $30,000 \mathrm{t}$ and $40,000 \mathrm{t}$ until the mid-1980s when increased fishing effort by France led to increased total landings, reaching a high for the post extension of jurisdiction period of about $59,000 \mathrm{t}$ in 1987. Catches then declined gradually to $36,000 \mathrm{t}$ in 1992. It is clear that catches exceeded the TAC throughout the 1980s and into the 1990s. The Canada-France boundary dispute led to an increase in the French catch in the late 1980s. A moratorium was imposed on all directed cod fishing in August 1993 after only $15,000 \mathrm{t}$ had been landed, the majority being taken by the Canadian inshore fixed gear fishery. In this year access by French vessels to Canadian waters was restricted.

Although offshore landings have fluctuated, the inshore fixed gear consistently reported landings around 20,000 to $25,000 \mathrm{t}$ each year up until the moratorium (Table 2, Fig. 2). Longline catches have dominated the landings over the period 1977 to 1993, reaching a peak of over $20,000 \mathrm{t}$ in 1981. Gillnet landings increased steadily from 1978 to a peak of over $9,000 \mathrm{t}$ in 1987 and then declined. Trap catches have varied over the time period but have not exceeded $8,000 t$ and handline catches have been a minor ( $<3,000 \mathrm{t}$ ), but relatively stable component of the fishery. There are nearly 1,200 groundfish license holders in 3Ps excluding license holders in 3L that can fish in 3Ps, French fisherman and Maritime license holders. There has been some decrease in potential fishing effort since the early 1990s in the smallest vessel class (less than 25 ft ), however potential effort in the other vessel classes has been relatively constant (Fig. 3).

The 1996 and 1997 landings by month and gear type for bycatch, sentinel survey and the directed fishery (1997 only), as well as the sampling used to estimate catch at age and the average length and average weight of fish in the landings (the latter derived from a length weight relationship where $\log \left(\right.$ weight $=3.0879^{*} \log ($ length $\left.)-5.2106\right)$ ), together with these estimates, are given in Tables 3 to 8. In 1996 the bycatch in the gillnet fishery for other species constituted the largest removals and was spread throughout the year. Sentinel catches came more or less equally from gillnet and linetrawl, and were mainly from July onwards. Fixed gear catches in 1997 were widespread within the inshore area, concentrating early in the season on aggregations of fish that were in spawning condition. Otter trawl fishing by trawlers chartered by St. Pierre and Miquelon to fish the French quota was concentrated on a small area on St. Pierre Bank. The 1997 landings were dominated by the directed gillnet fishery (nearly $3,800 \mathrm{t}$ ) with the remaining catch taken nearly equally by otter trawl (France), longline, handline and trap, with only small amounts taken by the remaining gears. Further, the gillnet fishery was pursued over a longer period of the year than the traditional gillnet season in this area. The 1997 conservation harvesting plan for vessels less than 65 ft . placed a number of restrictions on how the 3Ps fishery could be carried out, including seasonal quotas, weekly catch limits, restrictions on where fish could be landed and a small fish limit. These restrictions could complicate the interpretation of catch rates for 1997.

Sampling of the sentinel catch in 1996 was excellent given the small amount landed, while data on the bycatch was good with the exception of trawl landings in December ( 48 t ) for which no samples were available (Table 4). Sampling of the landings in 1997 was comprehensive with over 38,000 fish measured and more than 7,000 otoliths collected for age determination (Table 7). However, because of the timing of the assessment, sampling data for about 275 t landed by trawls in November and December (mostly under the French quota) were not available for analysis.

Detailed description of the port sampling and observer records for the 1997 fishery can be found in Inkpen and Kulka (1998). Length, maturity and age composition samples were collected from the inshore trap, gillnet, linetrawl and handline fisheries and the offshore otter trawl fishery by port samplers and fishery observers. Placentia Bay fish tended to be
slightly larger than in other areas for linetrawl and handline. Otter trawl catches from the southern portion of St. Pierre Bank and from the Halibut Channel were comprised of large fish, averaging 72 cm . Inshore trap catches averaged 52 cm fish. An analysis of the maturities of fish sampled from the catch indicated that the first part of the fishery in Placentia Bay took place during the peak spawning period in late May and early June. The spatial pattern of fishing in the offshore indicated three main areas: (i) northwest corner of St. Pierre Bank where fishing was limited and catch rates were low; (ii) southern Halibut Channel where catch rates were moderate, and (iii) south central St. Pierre Bank where catch rates were highest, averaging 5 t per hour. Many of these sets had almost the same starting position, indicating that the same area may have been repeatedly trawled, possibly on a single aggregation of fish.

Catch-at-age for 1996 and 1997 based on the available sampling is given in Tables 5 and 8. The limited 1996 landings were dominated by the 1990 and 1989 year classes whereas in the 1997 landings the 1992 year class was most abundant. The age composition of fixed gear catches in 1997 comprised a range of ages from 3 to 10 , but predominantly ages 5, 7, and 8 (Fig. 4). Otter trawl catches consisted mainly of 5, 7, and 8 year olds. Fish aged 6 were poorly represented in both fixed and mobile gears. The overall age composition for the 1997 catch (Fig. 4) shows the 1992 year class ( 5 year olds) dominating, followed by the 1990 and 1989 year classes ( 7 and 8 year olds respectively). Total catch at age for the period 1959 to 1997 is given in Table 12 under SPA inputs.

## Information from logbooks

A new science logbook was introduced to record catch and effort data for vessels less than 35 ft (the major portion of 3Ps licenses, see Fig. 3). The purpose of this logbook is for stock assessments and not for quota monitoring. Previously only purchase slip records were available for these size vessels, containing limited information on catch and no information on effort. Compliance with the new logbook appears to be high, with 634 vessels out of 1,099 having returned completed logbooks by the time of the assessment meeting in February, with more arriving subsequent to the assessment. Catch and effort data are recorded by area, 3Ps being divided into 9 areas (Fig. 5).

Gillnet catch rates (catch per net per day) were the highest in area 29, the eastern side of Placentia Bay (Fig. 6a) and lowest in area 34 (inner part of Fortune Bay). Linetrawl catch rates (catch per 1000 hooks per day) were highest in area 31 (western side of Placentia Bay) and area 36 (west of Fortune Bay) and lowest in areas 30 and 34 (inner reaches of Placentia and Fortune Bays) (Fig. 6b). Trap catch rates (catch per trap per day; not a significant contributor to the 1997 fishery) were highest in areas 31 and 30, (west side and inner part of Placentia Bay) (Fig. 6c).

The gillnet, linetrawl and trap catch rates plotted against day of the year for the 1997 fishery clearly indicate the pulses in fishing activity as determined by the conservation harvesting plan applied by DFO Fisheries Management (Fig. 7). What is of interest with
regard to stock status is whether or not there is any indication of a decline in catch rate within each pulse of fishing, or over the length of the season. The former could be indicative of local declines in abundance or dispersal of aggregations and the latter of a decline in the overall stock size in the course of the season. In the gillnet catch rates there is some evidence of a decline in the first, second, fourth and fifth pulses. Overall catch rates were lower in the latter part of the season. For linetrawls there is less evidence of declines within the pulses and, overall, catch rates were higher towards the end of the season. The trap season was short and there appears to be no pattern in the data.

In order to interpret catch rates of gears deployed for varying amounts of time, but standardized to a specific amount of soak time ( 24 hours or 1 day in this case) it is useful to examine how, on average, standardized catch rate varies with increasing soak time (Fig. 8). In all three gear types there was a decrease in standardized catch rate with increasing soak time in the 1997 fishery. This suggests that either gear saturation is taking place or that there is increased discarding with increased soak time. The consequence in either case is that catch rates from gear that have been in the water for different amounts of time may not comparable when standardized to a fixed time period. If further data indicates that the relationship between soak time and standardized catch rate is constant, it may be possible to remove the effect from the data.

In order to attempt to put the catch rates of the less than 35 ft vessels into context, a comparison was made between the data recorded in the new logbooks and data recorded previously (back to 1987) from logbooks for vessels greater than 35 ft (a small portion of the fishing fleet). LOWESS smoothers were fitted to the gillnet, linetrawl and trap catch rate data with the smoothing parameter chosen (by eye) to smooth out within year variability so as to reflect between-year trends in the data (top panel) as well as withinseason patterns (bottom panel) (Fig. 9a-c). Gillnet catch rates were increasing slowly prior to the moratorium and generally showed a decline from start to end of each season. In comparison to the pre-moratorium period, the 1997 gillnet catch rates for the $<35 \mathrm{ft}$ vessels are substantially higher. Linetrawl catch rates show little trend for the premoratorium period and the data for the 1997 fishery are quite similar to the earlier data. There appears to be a peak in linetrawl catch rates around the middle to late season in most years. Trap catch rates were declining prior to the moratorium but are much higher in the 1997 fishery than in any prior year for which data are available.

## Sentinel Survey

Sentinel Survey results for 1995, 1996 and 1997 are presented in detail in Davis and Jarvis (1998) and are only summarised here. An analysis of variance on the linetrawl (log(catch per thousand hooks)) and gillnet catch rates (log(catch per net)) was carried out to see if there were significant differences in the mean catch rates within each gear type over the three years. No significant differences were found indicating that mean catch rates in these two gear types have been fairly constant over the last three years.

In an attempt to place the sentinel catch rates in perspective, a comparison was made between the distributions of values from the sentinel survey fixed sites with those obtained from logbooks for vessels greater than or equal to 35 ft in length prior to the moratorium (vessels for which logbooks were kept) (Table 9). Both the mean and median gillnet catch rates are lower in the sentinel data than they are in the ZIF data. In the case of the line trawls, the mean catch rate in the sentinel is much higher than in the ZIF data but the median is lower. The quantiles indicate that the high mean value in the sentinel data is caused by a few very large sets.

Comparison of sentinel and pre-moratorium catch rates is probably not a valid exercise. Firstly, there are no catch rate data for vessels less than 35 ft for the pre-moratorium period. Secondly, in a commercial fishery fisherman attempt to derive maximum benefit from the resource, whereas the fixed site sentinel data reflect the variable availability of fish in time and space. Trends in the fixed site sentinel data may reflect changes in stock size, but it is not clear from the data whether or not this is this is so. At present the data cannot be used as an index of stock size in the assessment. Caution must also be exercised in the subjective evaluation of only the high sentinel catch rates in the postmoratorium period with pre-moratorium average levels because the comparison is not valid.

## Acoustic survey

An acoustic survey conducted in Placentia Bay in May 1997 (Rose and Lawson 1998) located a large dense school of spawning cod off St. Brides in the vicinity of Perch Rock comprising an estimated $40,000 \mathrm{t}$. Samples taken by handline indicated that fish aged 5, 7 and 8 predominated. Data from a second aggregation of cod in the Bar Haven area (inside Meresheen Island) have not yet been worked up, however preliminary estimates indicate that it is smaller than the first aggregation ( $<10,000 \mathrm{t}$ ) (Rose and Lawson 1998).

An acoustic survey was conducted during the winter of 1997 in the coastal waters of Fortune Bay, Newfoundland (Wheeler 1998). The survey area included water depths from the coastline to the 120 m contour. Echo integration along a series of equidistant parallel transects within the survey area provided distributional and behavioral information, densities and a biomass estimate of Atlantic Cod of about $2,600 \mathrm{t}$.

## Tagging experiments

Approximately 6,000 commercial sized ( $>40 \mathrm{~cm}$ ) cod were tagged and released at various locations in Placentia Bay and adjacent areas prior to and during the 1997 commercial fishery (Brattey and Cadigan, 1998). The tagging program and associated reward scheme were advertised widely among those participating in the fishery. Cod were tagged with single ( $\$ 10$ reward), double (\$20), or high-reward (\$100) spaghetti t-bar anchor tags. The high-reward tags were used to estimate the reporting rate of standard ( $\$ 10$ reward) tags;
double tags were applied to investigate the rate of long-term tag loss. Experiments involving retention of tagged cod in submersible enclosures were conducted to provide estimates of initial tag shedding and short-term tagging mortality. Exploitation rates (expressed as a proportion of cod removed by the fishery) were estimated for each stock component that was tagged; the estimates were based on numbers of single-tagged cod reported as recaptured during the fishery, adjusted to account for reporting rate, natural mortality, and various sources of tag loss and tagging mortality. Estimates of exploitation rate on inshore spawning aggregations tagged before the fishery began ranged from 0.126 to 0.213 ; the corresponding estimate for a large spawning aggregation tagged near St . Bride's 5-9 days after the fishery began was 0.078 . The 1997 commercial fishery consisted mainly of three periods of fishing activity. A model that used information on tag returns and commercial catch associated with each period of fishing was developed to provide overall estimates of the exploitation rate for each period and to back-calculate a population size for cod in Placentia Bay prior to reopening of the commercial fishery. Preliminary runs of the model gave estimates of exploitation rates of $0.042,0.041$ and 0.023 for the first, second, and third periods of fishing. Initial population size (1 January 1997) was estimated at about 26 million fish, or approximately $52,000 \mathrm{t}$ based on an average commercial weight of 2.0 kg per fish from the commercial catch. The reported catch for Placentia Bay during the 1997 commercial fishery was $4,300 \mathrm{t}$ suggesting an overall exploitation rate of about $8 \%$.

Lawson et al. (1998) addressed movements of cod in 3Ps based on mark-recapture experiments during 1996 and 1997. Cod were tagged with spaghetti t-bar tags at thirteen locations in Placentia Bay and adjacent areas at times representing important stages in cod life history. Spawning cod tagged in the inner reaches of Placentia Bay during spring 1996 and 1997 moved outwards along both the east and west sides of Placentia Bay during spring and summer, with the movement continuing farther out the bay on the East side. A portion of these east side migrants crossed the stock boundary between NAFO subdivision 3Ps and Div. 3L, and continued northward around the Avalon Peninsula. Smaller fish ( $<50 \mathrm{~cm}$ ) tended to remain resident in the inner portions of Placentia Bay, and did not migrate as far as larger ( $>50 \mathrm{~cm}$ ) individuals. Fish tagged at the mouth of Placentia Bay (Cape St. Mary's) did not move into the bay during spring and summer, but instead remained in the area or migrated into Div. 3L. Exchange of cod occurred between Fortune and Placentia Bays, but fish tagged in Fortune Bay were never recaptured farther west. No tagged cod were reported as recaptured from offshore areas in 3Ps or from the Gulf of St. Lawrence (3Pn4RS).

## Industry survey

Two industry bottom-trawl surveys were carried out on St. Pierre Bank in the fall of 1997. The first used a grid survey design. This survey constitutes the beginning of a new time series and the results were not used to determine stock status in the current assessment. The second industry survey used the same basic stratified random design applied in the research vessel surveys, but with a tow duration of 30 minutes using a
commercial Engels 96 high lift trawl with a 135 mm diamond mesh unlined cod end. A total of 84 sets were surveyed. Cod were encountered in the southern Halibut Channel area, on the top of St. Pierre Bank and along the western edge of the Bank. The preliminary estimate of trawlable biomass was $105,000 \mathrm{t}$ but this needs to be updated when estimates of the swept area (based on SCANMAR measurements of wingspread and duration) and the appropriate survey area is used in the computation. Fish aged 5, 7 and 8 dominated the catches and there were few fish older than age 9 .

## Research vessel trawl survey

Stratified-random surveys have been conducted in the offshore areas of 3 Ps during the winter-spring period by Canada since 1972 and by France for the period 1978-92. The two surveys were similar with regard to the stratification scheme used, sampling methods and analysis, but differed in the type of fishing gear and the daily timing of trawls (daylight hours only for French surveys). Canadian surveys were conducted by the research vessels A.T. Cameron (1972-82), Alfred Needler (1983-84) and Wilfred Templeman (1985-95). From the limited amount of comparable fishing data available, it has been concluded that the three vessels had similar fishing power and no adjustments were necessary to achieve comparable catchability factors, even though the A.T. Cameron was a side trawler. The French surveys were conducted by the research vessels Cyros (1978-91) and Thalassa (1992) and the results are summarised in Bishop et al. (1994). Canadian surveys have covered strata in depth ranges to 300 ftm since 1980. Five new inshore strata were added to the survey in 1994 (779-783) and a further eight inshore strata were added and in 1997 (293-300). For surveys from 1983 to 1995 the Engel 308 highrise bottom trawl was used. The trawl catches for these years were converted to Campelen 1800 shrimp trawl-equivalent catches using a length-based conversion formulation which was derived from comparative fishing experiments (Warren 1997, Warren et al. 1997, Stansbury 1996, Stansbury 1997).

The Canadian survey results (in Campelen-equivalent units) are summarised by stratum in terms of numbers and biomass in Tables 10 and 11 respectively for the period 1983 to 1997. Timing of the survey has varied considerably over the period. In 1983 and 1984 the mean date of sampling was in April, in 1985 to 1987 it was in March, and from 1988 to 1992 it was in February. Both a February and an April survey were carried out in 1993 and subsequently the survey has been carried out in April. The recent change from February to April was aimed at reducing the effect of mixing of fish between the northern Gulf of St Lawrence (3Pn4RS) and 3Ps which occurs in winter.

The Campelen-equivalent abundance and biomass for the index strata (depths less than or equal to 300 ftm , excluding the new inshore strata) are plotted, together with one standard deviation either side of the estimate, in Fig. 10. Strata for which no samples are available were filled in using a multiplicative model. The abundance and biomass time series from 1983 to 1997 shows considerable variability, but both are low after 1991 with the exception of 1995. The 1995 estimate is influenced by a single enormous catch
contributing $87 \%$ of the biomass index and therefore has a very large standard deviation. The 1997 Canadian index was the lowest observed in the time series which goes back to 1983, being less than half of the 1996 index. The minimum trawlable biomass, including new inshore strata added in 1994, and extended further shoreward in 1997, was 9,500 t ( $95 \%$ confidence interval $=4,500 \mathrm{t}-15,000 \mathrm{t}$ ), less than one third of the 1996 survey. The size composition of fish in the 1997 research vessel survey were very different from 1996 and suggested that the most recent survey missed aggregations of older fish. These fish were, however, present in the 1996 research vessel survey, the fall 1997 industry trawl survey and the commercial and sentinel catches in 1997.

The spatial distribution of the numbers per tow (standardised to Campelen equivalent units) are plotted in Fig. 11 for surveys from 1994 to 1997. Cod appear to have been relatively scarce over the St. Pierre Bank in the 1990s. In this period abundances have been highest in the southern Halibut Channel area towards the edge of the survey, and on the slopes in the vicinity of Burgeo Bank and the Hermitage Channel. Fish appeared to be somewhat more widespread over the survey area in 1997 than in previous recent years, albeit at low abundance.

Survey numbers at age are obtained by applying an age-length key to the numbers of fish at length in the samples. The current sampling instructions for 3Ps require that an attempt be made to obtain 2 otoliths per one centimetre length class from each of the following locations - Northwest St. Pierre Bank (strata 310-314, 705, 713), Burgeo Bank (strata 306-309, 714-716), Green Bank-Halibut Channel (strata 318-319, 325-326, 707710), Placentia Bay (strata 779-783) and remaining area (strata 315-317, 320-324, 706, 711-712). This is done in order to spread the sampling effort over the survey area. The otoliths are then combined into a single age-length key and applied to the survey data. The resulting estimates of mean numbers per tow are given in Table 12. It is in this form that the data are used in the calibration of sequential population analysis models. These data can be transformed into trawlable population at age by multiplying the mean numbers per tow at age by the number of trawlable units in the survey area. This is obtained by dividing the area of the survey by the number of trawlable units. For 3Ps, the survey area is 16,732 square nautical miles including only strata out to 300 ftms and excluding the relatively recent strata created in Placentia Bay. The swept area for a standard 15 minute tow of the Campelen net is 0.00727 square nautical miles. Thus the number of trawlable units in the 3Ps survey is $16,732 / 0.00727=2.3 \times 10^{6}$.

The mean numbers per tow in the 1990s (Table 12) indicated a relatively low abundance beyond age 7 compared to the early to mid-1980s. Few fish older than age 9 were encountered in the 1997 survey and there was no indication of incoming year classes of any significance.

## Lengths, weights and condition of cod from surveys

The sampling protocol for obtaining lengths-at-age (1972-1997) and weights-at-age (1978-1997) has varied over time (Lilly 1996), but has consistently involved stratified sampling by length. For this reason, calculation of mean lengths and weights included weighting observations by population abundances of the size groups (Morgan and Hoenig 1997), where the abundances were calculated by areal expansion of the stratified arithmetic mean catch at length per tow (Smith and Somerton 1981).

Mean lengths-at-age (Table 13; Fig. 12) varied over time. For the period 1972-1997, peak length-at-age occurred in the mid-1970s for young ages (3-4) and progressively later to 1980 for older ages. Since the mid-1980s, length-at-age has varied with no trend (younger ages) or declined (older ages). An exploration of the potential effects of environmental factors such as temperature has not been conducted, because there appears to be negative growth for at least 2 cohorts during each of the intervals 1977-1978, 19801981, 1989-1990 and 1993-1994 (Lilly 1996). The next step in exploration of these data is to test whether differences in length-at-age exist among the various groups of fish occurring in Subdivision 3Ps at the time of the surveys, and to determine whether annual variability in the rate at which these groups were sampled might explain some of the year effects in length-at-age.

As expected, the patterns in mean weight-at-age (Table 14, Fig. 13) appear to be very similar to those in length-at-age. However, the weight-at-age data are based on smaller sample sizes. The weight-at-age data also include variability in weight at length (condition) associated with differences in timing of the surveys (Lilly 1996).

Average annual weights at age and beginning of the year weights at age derived from mean lengths at age in the commercial fishery and the standard length-weight relationship are give in Tables 15 and 16.

## Maturity-at-age

Age at $50 \%$ maturity for females dropped dramatically from a high of 7.2 years during 1988 to a low of 5 during 1994 (Fig. 14). An apparent reversal of the declining trend during 1995 and 1996 has not continued and the current (1997) estimate of age at 50\% maturity is the lowest in the time series at 4.6 years. This early age at maturity has a substantial effect on spawner biomass production by the 3Ps cod stock, but could also be interpreted as indicating that the stock is under stress.

The model estimates of proportions mature at age from 1978, including projected values to 1999 , are given in Table 17 and Fig. 15. To project the maturities for 3Ps cod to 1998 and 1999 the estimated proportion mature at age was computed for each of the previous four years (1994-1997 inclusive), then the model was fit to these estimates (i.e. four
estimates for each age class) to get new estimates comparable to average maturation for the recent period. These values were used for both 1998 and 1999.

## Yearclass strength

Mean catches per tow at ages 1-3 during the research bottom-trawl surveys have been low in recent years (Fig. 16). The 1989 year-class, which is strongly represented in commercial and sentinel fisheries, was weakly represented in the surveys at age 1 but appeared very strong when expressed in terms of Campelen equivalent units at age 2 and moderately strong at age 3 . The 1990 yearclass was reasonable well represented in catches and the sentinel surveys, but did not appear strong in the bottom trawl surveys, except at age 1. The 1991 yearclass appears to be very weak in both catches and the bottom trawl surveys. The 1992 yearclass was well represented in the 1997 commercial catch, particularly in the linetrawl and handline catches, but this yearclass and all subsequent yearclasses have been poorly represented in the bottom trawl surveys.

## Estimates of total mortality from survey data

Total mortality ( $Z$ ) was calculated from the research vessel mean numbers per tow by means of the equation

$$
Z_{a, y}=\ln \left(\frac{R V_{a+1, y+1}}{R V_{a, y}}\right),
$$

where $R_{a, y}$ is the research vessel mean number per tow index at age $a$ in year $y$. Estimates are plotted by age against year in Fig. 17.

For those ages that are not fully recruited to the survey, the relative $Z$ values provide an indication of possible changes in total mortality, although not reflective of the absolute mortality. For those ages that are fully recruited to the survey the estimate can be considered to an estimate of actual $Z$. The estimates are quite variable suggesting considerable year effects in the survey data. Mortality rate appeared to increase on most ages in the late 1980s and early 1990s, prior to the moratorium, and then to initially decrease substantially, as would be anticipated, with the introduction of the moratorium in 1993. However, mortality rate as inferred from the surveys is quite variable in the most recent years and it is not possible to determine with any confidence whether or not the current mortality rate is higher than what would be predicted based on the assumed value of $M=0.2$ and the additional fishing mortality that has taken place since the moratorium and during the reopened fishery in 1997.

## Sequential population analysis

Attempts in recent years to carry out sequential population analysis on this stock have been plagued by the pattern and magnitude of the residuals from the fitted model. For example, in the 1993 assessment Bishop et al. (1993) concluded that "the calibrations of Sequential Population Analysis (SPA) were not possible with these indices." The indices used were Canadian surveys (1978-93) alone, and together with the French surveys (1978-91). Similarly, in 1994 it was concluded that "Residual patterns indicate some strong year effects and suggested a poor fit." (Bishop et al. 1994). No ADAPT was attempted in 1995. In the 1996 assessment an attempt was made to carry out separate ADAPT reconstructions for the inshore and the offshore (Shelton et al. 1996). The basis for following this approach was the differences in the dynamics of the two components suggested by the converged portions of uncalibrated SPAs constructed from the catch data, as well as reports of high catch rates by sentinel fishermen in the inshore and the existence of an acoustic estimate of $23,000 \mathrm{t}$ of cod in Placentia Bay, in comparison to the scarcity of fish observed in recent years in the research bottom trawl survey taking place further offshore. The inshore formulation comprised the fixed gear catch at age and catch rate at age indices derived from gillnet, linetrawl and trap catch and effort data from logbooks kept by vessels greater than or equal to 35 ft in length for the period 1987 to the moratorium. The offshore formulation comprised trawler catch at age data and the Canadian bottom trawl survey index at age. Based on large coefficients of variation in the estimates and the presence of strong year effects in the residuals, it was concluded that neither the inshore nor the offshore analysis could be used as a basis for determining stock status in 1997.

In the present assessment of the stock, it was decided to carry out a number of analyses using the standard ADAPT framework and a new quasi-likelilhood approach (QLSPA, Cadigan 1998). The quasi-likelihood SPA (QLSPA) is similar to the ADAPT framework; however, inferences are based on a semi-parametric stochastic model involving only assumptions about the first two central moments of abundance indices (Cadigan 1998). QLSPA can accommodate Normal, Poisson-type, Gamma/Lognormal, and other types of variation in abundance indices. The quasi-likelihood method is commonly used in semiparametric inference (see McCullagh and Nelder 1989). Because it does not require a completely specified stochastic model for the data used in estimation, it is particularly useful for fisheries data where assumed distributions (such as the lognormal assumption in ADAPT) are tenuous. The quasi-likelihood approach is robust to the exact stochastic nature of the data.

The following SPA analyses were considered:
(i) ADAPT applied to the total catch and calibrated with the Canadian and French research vessel indices;
(ii) ADAPT applied to the total catch and calibrated with the Canadian research vessel index;
(iii) ADAPT applied to the offshore (trawler) catch and calibrated with the Canadian and French research vessel indices;
(iv) ADAPT applied to the total catch and calibrated with the Canadian research vessel index, standardized for month effects using a multiplicative model.
(v) QLSPA applied to total catch and calibrated with the Canadian and French research vessel indices;
(vi) QLSPA applied to the offshore catch and calibrated with the Canadian and French research vessel indices;
(vii) QLSPA applied to the offshore catch and calibrated with the Canadian and French research vessel indices, but with separate catchabilities for February-March Canadian surveys and April Canadian surveys.

Selected results from five of the above analyses (i, iii, v, vi and vii) are presented below:
Standard ADAPT applied to total catch and calibrated with French and Canadian RV indices (model (i)) The parameters estimated in the model were:
$\mathrm{N}_{\mathrm{i}, \mathrm{t}} \quad$ where $\mathrm{i}=4$ to $14, \mathrm{t}=1998$,
and Catchabilities
$\mathrm{K}_{\mathrm{i}} \quad$ where $\mathrm{i}=3$ to 12 for the Canadian Research Vessel survey and
$\mathrm{K} 2_{\mathrm{i}} \quad$ where $\mathrm{i}=3$ to 12 for the French Research Vessel survey.
The following structure was imposed:
(i) natural mortality was assumed to be 0.2 ;
(ii) fishing mortality on the oldest age (14) set equal to the mean for ages 710;
(iii) no "plus" age class;
(iv) no error in the catch numbers-at-age.

Input data were:
Catch numbers at age
$\mathrm{C}_{\mathrm{i}, \mathrm{t}} \quad$ where $\mathrm{i}=3$ to 14 and $\mathrm{t}=1959$ to 1997,
Canadian Research Vessel survey estimates of mean numbers per tow-at-age (Campelen or Campelen equivalent values)
$R V 1_{i, t}$ where $\mathrm{i}=3$ to 12 and $\mathrm{t}=1983$ to 1997 , and French Research Vessel survey estimates of mean numbers per tow-at-age
$R V 2_{i, t}$ where $\mathrm{i}=3$ to 12 and $\mathrm{t}=1980$ to 1991.
The objective function which was minimised was

$$
S S=\sum_{i, t}\left(\ln \left(R V 1_{i, t}\right)-\ln \left(K 1_{i} N_{i, t}\right)\right)^{2}+\sum_{i, t}\left(\ln \left(R V 2_{i, t}\right)-\ln \left(K 2_{i} N_{i, t}\right)\right)^{2} .
$$

The parameter estimates are given in Table 18 and model predicted indices are compared with observed indices in Fig. 18 to illustrate the model fit. Estimates of population size
and fishing mortality at age are given in Tables. 19 and 20. The 3+, 5+ and spawner biomass estimates are plotted in Fig. 19.

Standard ADAPT applied to offshore catch and calibrated with French and Canadian RV indices (model (iii)). This model has the same structure as (i) but is applied only to the offshore, mobile (predominantly trawler) catch data (i.e. catches excluding those by gillnets, linetrawls, handlines and traps). Parameter estimates for this model are given in Table 21.

QLSPA applied to total catch and calibrated with French and Canadian RV indices (model (v)). The QLSPA model with constant CV (see Cadigan 1998 for more information) was applied using the same basics structure as the ADAPT formulation (model (i)) described above. Parameter estimates are given in Table 22 and model predicted indices are compared with observed indices in Fig. 20. Estimates of population size and fishing mortality at age are given in Tables. 23 and 24. The 3+, 5+ and spawner biomass estimates are plotted in Fig. 21.

QLSPA applied to the offshore catch and calibrated with the Canadian and French research vessel indices (model (vi)). This formulation is similar to model (v) described above, but is applied only to the offshore catch (ie. the same catch data as model (iii)). Parameter estimates are given in Table 25 and model predicted indices are compared with observed indices in Fig. 22.

QLSPA applied to the offshore catch and calibrated with the Canadian and French research vessel indices, with separate catchabilities for February-March surveys and April surveys. (model (vii)). In this model, separate catchability at age vectors are estimated for Canadian surveys taking place in the February-March and the April periods. Parameter estimates are given in Table 26 and model predicted indices are compared with observed indices in Fig. 23. Estimates of population size and fishing mortality at age are given in Tables. 27 and 28. The 3+, 5+ and spawner biomass estimates are plotted in Fig. 24.

## Comparison of SPA results

The ADAPT and QLSPA estimates of spawner biomass from the five selected models described above are plotted in Fig. 25. ADAPT and QLSPA models applied to the total catch both indicate a growth in spawner biomass after 1994, but differ in the magnitude of this growth. ADAPT estimates a January 1,1997 spawner biomass of about $50,000 \mathrm{t}$ whereas the equivalent estimate from QLSPA is about $90,000 \mathrm{t}$. For the models applied to the offshore catch only, all three models indicate a growth in spawner biomass after 1993. The estimate of current spawner biomass from the QLSPA with seasonal catchability estimated for the Canadian survey is substantially higher than the other two models at about $95,000 \mathrm{t}$.

A plot of the catchability parameters at age for the two QLSPA models applied to the offshore catch (Fig. 26) shows that for the non-seasonal catchability version of the QLSPA, catchability increases steadily with age. For the seasonal catchability version of the QLSPA, the estimates for the February-March surveys are close to those for the nonseasonal model up to age 6 , are higher for ages 7 and 8 , lower for ages 9 and 10 , and similar to those for the nonseasonal model for ages 11 and 12. April catchabilities are lower than those for the nonseasonal model up to age 8 , substantially higher for fish aged $9-11$ and then lower again for fish age 12. These estimates imply that fish age 8 and younger are relatively more abundant in the survey area in April and that fish age 9 to 11 are relatively more abundant in the survey area in February-March. It is not clear whether or not these age-specific seasonal differences in catchability estimates make biological sense in terms of what is known regarding spatial patterns of abundance at age, and this requires further investigation. The intent of the shifting of the survey from February-March to April was to have the survey closer to the spawning season so that the distribution of fish spawning in the Gulf and fish spawning in 3Ps would be more separate.

## Precautionary plots

A number of plots were suggested by Sissenwine and Shepherd (1987) as being potentially useful in determining appropriate reference points for use in a "precautionary approach" to fisheries management. These plots, here termed "precautionary plots", were constructed for the ADAPT model including total catch and both Canadian and French research vessel indices (Fig. 27), for the equivalent QLSPA model (Fig. 28) and for the QLSPA model applied to the offshore catch only, including both Canadian and French research vessel indices (Fig. 29), i.e. models (i), (iv) and (v) respectively.

The left top and middle panels in each set of plots are the standard spawner biomass per recruit and yield per recruit calculations for a range of fishing mortality values and are not dependent on the SPA models except for determining the partial recruit vector to be used to determine age-specific $F$ values from the fully recruited $F$ value (plotted on the x-axis). In the analyses presented here the partial recruitment vector was determined from the average $F$ for the period 1991 to 1993, as estimated by the appropriate SPA, assuming flat-topped partial recruitment beyond the first fully recruited age. The spawner biomass per recruit plot requires vectors of proportion mature and weight at age. Projected values for 1998 were taken from Tables 16 and 17. The yield per recruit plot requires a partial recruitment vector (as described above) and a vector of catch weights at age. The weight vector used is the projected mid-year weights at age for 1998 given in Table 15.

The remaining plots that make up the precautionary plots require the fitting of a stockrecruit model to the SPA estimates of recruitment and spawner biomass. A Beverton and Holt stock-recruit model was fit to the data using maximum likelihood estimation assuming lognormal error (middle right panel). The top right panel is the spawner biomass per recruit values for the estimated recruitment values (points) and for the fitted
stock-recruit model (line). The bottom two panels of the precautionary plots were obtained by constructing a population model in which recruitment is obtained from the modelled spawner biomass through the fitted stock-recruit model. In this model numbers from one age to the next were updated using Pope's (1972) equation, assuming $M=0.2$. The weights, proportion mature and partial recruit values at age that were used in the model were the average sampled/estimated values for the years for which data are available (i.e. long-term average values). The population was allowed to grow from some arbitrary initial age composition to an equilibrium at $F=0$ (i.e. carrying capacity; in terms of biomass this is $\left.B_{\max }\right)$. A range of fishing motalities from 0 to 1.2 were then applied to the modelled population and in each case the corresponding equilibrium yield and equilibrium spawner biomass was recorded and used to construct the bottom two panels in the precautionary plots.

The precautionary plots for the ADAPT and QLSPA models with total catch and both the Canadian and French research vessel indices are quite similar (Figs. 27 and 28), differing only in the recent, unconverged period. Although quite noisy, the stock-recruit scatter does suggest a probability of lower recruitment at lower spawner biomass. MSY estimated from both model estimates is similar, at about $30,000 \mathrm{t}$. The removals have exceeded this level in most years. For both models, the spawner biomass at MSY is estimated to be about $500,000 \mathrm{t}$. Spawner biomass estimates for the time period covered in the this assessment have all been well below this level.

The precautionary plots for the QLSPA model fitted to the offshore catch together with the Canadian and French RV indices are illustrated in Fig. 29. The Beverton and Holt model fit does not describe the stock-recruit scatter. Estimated recruitment peaked in the 1980 and 1981 year classes, leading to a growth in spawner biomass to around $35,000 \mathrm{t}$. The recent estimates of spawner biomass have ranged between about $15,000 \mathrm{t}$ and 25,000 t , but with no evidence of any year classes as strong as the 1980 and 1981 year classes. The 1989 year class is estimated to be the strongest in the recent years and the 1991 year class is estimated to be the weakest ever.

## Biological reference points

A number of reference points can be derived from the precautionary plots. A selection of reference points for the three models are summarized in Table 29. Standard reference points include $F_{0.1}$ and $F_{\max }$ from the yield per recruit curve, $F_{\text {msy }}$ and $B_{\text {msy }}$ from the production curve and \%SPR (the percentage of the spawner biomass per recruit at an $F$ value, of that achieved at $F=0$ ). A value of $35 \%$ SPR has been suggested by Mace and Sissenwine (1993) as a possible reference point.

In addition to these reference points derived from the precautionary plots, a number of simpler reference points can be considered. The first set of reference points used in this assessment and presented in the decision tables that follow evaluated the probability that the $3+, 5+$ and mature (spawner) biomass would not grow from beginning of 1998 to
beginning of 1999 under different TAC options for 1998. The second set evaluated the probability of the biomass growing by $10 \%$ or less, and the third the probability that it would grow by $20 \%$ or less, under the range of TAC options. The fourth set evaluated the probability that the beginning of 1999 biomass would be less than the biomass at the start of the moratorium (1993). The fifth set evaluated the probability that the beginning of 1999 biomass would be less than half the biomass at MSY ( $\left.B_{0.5 \mathrm{msy}}\right)$. The sixth set evaluated whether or not the beginning of 1999 biomass would be less than the biomass in the 1980s, a period when reasonable yields had been obtained. The last reference point evaluated the probability of $F_{0.1}$ being exceeded by the 1998 TAC - a $10 \%$ probability was considered to be precautionary.

The usefulness of any reference point in terms of being more precautionary than previous management approaches needs to be carefully evaluated through extensive simulation trials which look at the risk of low stock size and also look at the cost of being risk averse in terms of fish yield that is forgone. It should be noted that $F_{0.1}$ was selected previously as a reference point for Atlantic groundfish stocks because it allowed the stock to be fished in a much more precautionary manner for only a small decrease in yield per recruit. Any further reduction in $F$ (i.e. a more precautionary approach) will be quite costly in term of yield that must be forgone (Shelton 1998). If objective functions can be formally defined for the 3Ps cod stock, then the performance of harvest control rules could be evaluated through simulation and the one that is judged to be most robust with respect to a set of performance criteria could be used as the basis for setting TACs. In the absence of formalized objectives for the 3Ps cod stock, it is anticipated that decisionmakers will use the scientific advice regarding stock status and the risk associated with alternative TACs and reference points in a qualitative manner. As a minimum, a consistent attitude to risk is desirable so that risk-prone TACs are not chosen when the stock is low and risk-averse TACs are not chosen only when the stock is high and in little danger.

## Risk analysis and decision tables

Risk was evaluated using two approaches: Monte Carlo (MC) simulation and Profile Likelihood (PL) estimation. The Monte Carlo analysis of the risk followed the general approach given in Sinclair and Gavaris (1996) except that both the variance and the covariance of the population estimates were taken into account in generating 300 realizations of the beginning of 1997 population size for ages 3 to 14 for each TAC option. In each realization the 1997 reported catch at age was removed and the standard natural mortality rate of $M=0.2$ was applied following Pope's approximation to give beginning of year numbers at age for 1998. The number at age 3 at the beginning of 1998 was taken as the geometric mean of the numbers at age 3 for the period 1995-97. A range of alternative TAC options for $1998(0,5,000,10,000,15,000$, and $20,000 \mathrm{t})$ were evaluated with respect to the set of reference points described above. The TAC was applied to each realization of the population using the average partial recruitment vector from the last three years of the fishery and assumed weights at age in the catch (1998
values, Table 15). Population biomass (3+), $5+$ and mature biomass at the beginning of 1999 for each realization was obtained using projected maturity and weights at age based on recent estimates (Tables 16 and 17). The number at age 3 at the beginning of 1999 was taken as the geometric mean of the numbers at age 3 for the period 1996-98. The profile likelihood approach to determining risk is described in detail in Cadigan (1998).

Both the MC and PL approaches only consider uncertainty in the estimate of the population size at age at the beginning of the projection and how this propagates to the beginning of 1999 under alternative TAC options for 1998. This approach assumes that the SPA model that is fit to the data is correctly specified and that the standard assumptions associated with the projection hold. To provide meaningful analyses of risk for the decision makers it would be desirable to capture the major sources of risk. In the present rudimentary analyses, there is no guarantee that this has been achieved.

Decision tables were produced for model (i) - ADAPT applied to total catch together with the Canadian and French research vessel indices using the MC risk approach (Table 30); model (v) - QLSPA applied to total catch together with Canadian and French research vessel indices using both the MC risk approach (Table 31) and the PL risk approach (Table 32); and for model (vi) - QLSPA applied to offshore catch, together with Canadian and French research vessel indices, for both MC risk (Table 33) and PL risk (Table 34).

Although only spawner biomass risks are described below, the risks for the $3+$ and $5+$ biomass follow similar patterns. For model (i) - MC risk (Table 30) it was estimated that, while there was a probability of about $20 \%$ that the spawner biomass would not grow at a TAC $=5,000 \mathrm{t}$, this probability rose to about $52 \%$ for a TAC $=10,000 \mathrm{t}$. However, at all except the highest TAC level it was estimated that there was a very low probability that the spawner biomass would be less than or equal to the spawner biomass when the the moratorium was introduced in 1993. For all TAC options, the probability that the spawner biomass would be less than half the spawner biomass corresponding to MSY was very high. The probability that the spawner biomass would be less than the average spawner biomass over the 1980s was about $16 \%$ for TAC $=0$ but rose to about $60 \%$ at the highest TAC level evaluated. The probability that the $F$ corresponding to the TAC would exceed $F_{0.1}$ was low for TAC $=5,000 \mathrm{t}$, but rose to $30 \%$ for TAC $=10,000 \mathrm{t}$ and $86 \%$ for $\mathrm{TAC}=15,000 \mathrm{t}$.

For model (v) risk was estimated using both the MC and PL approaches (Tables 31 and 32). For both approaches the risk of the spawner biomass not growing at a TAC of 5,000 t was estimated to be above $20-25 \%$, slightly higher than for the ADAPT model (i). Even at TAC=0 t both MC and PL estimates of risk of the spawner biomass not growing by more than $10 \%$ was calculated to be high ( $40-50 \%$ ) compared to about $20 \%$ for model (i). Although still high, the probability of falling below half of the spawner biomass at MSY was lower than for the corresponding ADAPT model over the range of TAC options. The probability of falling below the average spawner biomass in the 1980s was relatively low for all TAC options evaluated by both MC and PL for model (v). The
probability of exceeding $F_{0.1}$ was low for all TAC options below $20,000 \mathrm{t}$ for the MC approach, but was $35 \%$ or higher for TAC of $10,000 \mathrm{t}$ and above for the PL approach.

For model (vi) both the MC and the PL risks were evaluated (Tables 33 and 34). For a $\mathrm{TAC}=5,000 \mathrm{t}$ the probability of the spawner biomass not growing was estimated to be about $52 \%$ for MC risk and $66 \%$ for PL risk. The probability of exceeding $F_{0.1}$ at $\mathrm{TAC}=5,000 \mathrm{t}$ was estimated to be low by both the MC and PL approaches. For a $\mathrm{TAC}=10,000 \mathrm{t}$ the probability of exceeding $F_{0.1}$ was estimated to be $37 \%$ by the MC approach and $45 \%$ by the PL approach.

In summary, for the SPAs based on the total catch, the TAC would have to be less than $5,000 \mathrm{t}$ if a low probability ( $<20 \%$ ) of the spawner biomass not growing is to be achieved. Even with TAC=0 $t$ there is a high probability ( $20 \%-50 \%$ ) that the spawner biomass will grow by less than $10 \%$. For the QLSPA based on offshore catch only, a $\mathrm{TAC}=5,000 \mathrm{t}$ would have a $50 \%-65 \%$ probability of resulting in no growth in the spawner biomass. For TAC=0 $t$ there is about a $60 \%$ probability that the stock will grow by less than $10 \%$. Both MC and PL risk calculations indicated a probability $>35 \%$ of exceeding $F_{0.1}$ with a $10,000 \mathrm{t} \mathrm{TAC}$.

The above analyses of risk were completed prior to the Zonal Cod Assessment Meeting St John's, February 1998. The analyses based on the total catch were not considered by those at the Zonal meeting to be representative of the dynamics of the stock because of the poor fit of the model and the evidence of significant cod aggregations inshore of the index strata compared with the generally low abundance found in the bottom trawl survey further offshore. The Zonal meeting decided an estimate of inshore biomass from tagging data or acoustic survey data, extrapolated over the inshore area using commercial catch rate data should be made. For the offshore, concern was expressed regarding the change in the timing of the Canadian survey that had taken place. After reviewing SPAs in which the survey indices were pre-treated in an attempt to remove the effect of timing of the survey, it was decided by the Zonal meeting that advice on stock status and risk would be based on model (vii)- QLSPA applied to the offshore catch together with the Canadian and French research vessel indices, but with separate catchabilities for Canadian February-March surveys and April surveys.

Extrapolation at the assessment meeting of the biomass estimated from the tagging study to the entire inshore area of 3Ps, using gillnet catch rate data reported by fishermen in the new log-book introduced in 1997 and the relative area of Placentia Bay to the entire inshore gave an initial estimate of $115,000 \mathrm{t}$. Reanalysis after the meeting and subsequent to the preparation of the stock-status report gave a revised estimate of 82,765 $t$ for the inshore. This extrapolation was considered to be extremely tentative and was adopted as a last resort.

An abridged risk analysis was carried out in the course of the Zonal assessment meeting to evaluate alternative options for an offshore TAC of between $0 t$ and $30,000 t$ based on the profile likelihood approach and the results from model (vii). This was used to draw
up a risk plot for: (a) no growth in the spawner population; (b) $<10 \%$ probability of spawner biomass growth; (c) < 20\% probability of spawner biomass growth; (d) probability of $F$ being greater than $F_{0.1}$. Risk curves for these criteria are plotted in Fig. 30. In addition to the risk plots, the so-called "Armstrong Plot" was constructed (Fig. 31) for the same range of TAC options. This plot shows the increase in fully recruited $F$ with increasing TAC and the percentage change in spawner biomass that could be expected over the range of TAC options.

The risk analysis based on model (vii) indicated that for a 12,500 $t$ offshore quota in 1998 the probability of fishing mortality exceeding $F_{0.1}$ is less than $10 \%$. With this quota it was estimated that there is a $50 \%$ probability that the offshore spawner biomass would not increase from 1998 to 1999. For a quota of $10,000 \mathrm{t}$ in the offshore there is about a $30 \%$ probability that the offshore spawner biomass would not increase.

From the offshore spawner biomass estimate of about $100,000 \mathrm{t}$ and the inshore extrapolation of about $115,000 \mathrm{t}$, a total spawner biomass for 1 January 1998 of about $215,000 \mathrm{t}$ was obtained (subsequently revised to $183,000 \mathrm{t}$ because of a revised inshore estimate of $82,765 \mathrm{t}$ ). This would equate to an $F_{0.1}$ TAC of about $40,000 \mathrm{t}$. In the absence of a full risk analysis for both the inshore and the offshore combined, it was considered that exploitation not exceeding about $50 \%$ of the $F_{0.1}$ level would be consistent with a precautionary approach (i.e. a TAC of $20,000 \mathrm{t}$ ). It was noted that a TAC for the offshore component of the stock corresponding to half of $F_{0.1}(0.5 \times 0.24=0.12)$ would give $<10 \%$ chance of exceeding $F_{0.1}$.

## References

Anderson, J.P., J. Brattey, E. Colbourne, D.S. Miller, D.R. Porter, C.R. Stevens and J.P. Wheeler. 1998. Distribution and abundance of Atlantic cod from the 1997 Division 3KL inshore acoustic survey. DFO Can. Stock Assess. Sec. Res. Doc. 98/49.
Bishop, C.A., J.W. Baird and E.F. Murphy. 1991. An assessment of the cod stock in NAFO Subdivision 3Ps. CAFSAC Res. Doc. 91/36, 56p.
Bishop, C.A. and E.F. Murphy. 1992. An assessment of the cod stock in NAFO Subdivision 3Ps. CAFSAC Res. Doc. 92/111, 43p.
Bishop, C.A., E.F. Murphy and M.B. Davis. 1993. An assessment in 1993 of the cod stock in NAFO Subdivision 3Ps. DFO Atl. Fish. Res. Doc. 93/70, 39p.
Bishop, C.A., E.F. Murphy and M.B. Davis. 1994. An assessment of the cod stock in NAFO Subdivision 3Ps. DFO Atl. Fish. Res. Doc. 94/33, 33p.
Bishop, C.A., E.F. Murphy and D.E. Stansbury. 1995. Status of the cod stock in NAFO Subdivision 3Ps. DFP Atl. Fish. Res. Doc. 95/31, 21 p.
Brattey, J. 1996. Overview of Atlantic cod (Gadus morhua) stock structure in NAFO Subdivision 3Ps inferred from tagging studies. DFO Can. Stock Assess. Sec. Res. Doc. 96/93, 19p.

Brattey J. and N. Cadigan. 1998. Exploitation rates and population size of cod in Placentia Bay, Subdivision 3Ps: estimates from a new mark-recapture study. DFO Can. Stock Assess. Sec. Res. Doc. 98/20.
Cadigan, N. 1998. Semi-parametric inferences about fish stock size using sequential population analysis (SPA) and quasi-lilelihood theory. DFO Can. Stock Assess. Sec. Res. Doc. 98/25.
Campana, S.E., G. Chouinard, M. Hanson, A. Fréchet and J. Brattey. 1998. Stock composition of cod aggregations near the mouth of the Gulf of St. Lawrence in January 1996 based on an analysis of otolith elemental fingerprints. DFO Can. Stock Assess. Sec. Res. Doc. 98/55.
Davis, M.B and H. Jarvis. 1998. Results from the inshore Sentinel Survey for cod in NAFO Subdivision 3Ps. DFO Can. Stock Assess. Sec. Res. Doc. 98/22.
Inkpen, T. and D. W. Kulka. 1998. Summary of the food fishery for cod in NAFO Division 3Ps in 1997 with comparison to 1994 and 1996. DFO Can. Stock Assess. Sec. Res. Doc. 98/59, 25p.
Lawson, G.L., G. A. Rose and J. Brattey. 1998. Size and age based post-spawning dispersion patterns of cod tagged in Placentia Bay. DFO Can. Stock Assess. Sec. Res. Doc. 98/24.
Lilly, G.R. 1996. Growth and condition of cod in Subdivision 3Ps as determined from trawl surveys (1972-1996) and sentinel surveys (1995). DFO Atl. Fish. Res.Doc. 96/69, 39p.
Lilly, G.R. 1998. Size-at-age and condition of cod in Subdivision 3Ps in 1972-1997. DFO Can. Stock Assess. Sec. Res. 98/94.
Mace, P.M. and M.P. Sissenwine. 1993. How much spawning per recruit is enough? P. 101-118. In S.J. Smith, J.J. Hunt and D. Rivard. (ed.) Risk evaluation and biological reference points for fisheries management. Can. Spec. Publ. Fish. Aquat. Sci. 120.
McCullagh, P. and J.A. Nelder, 1989. Generalized Linear Models 2nd Ed. New York: Chapman and Hall.
Morgan, M.J., and J.M. Hoenig. 1997. Estimating maturity-at-age from length stratified sampling. J. Northw. Atl. fish. Sci. 21: 51-63.
Pinhorn, A.T. 1969. Fishery and biology of Atlantic Cod (Gadus morhua) off the southwest coast of Newfoundland. J. Fish. Res. Bd. Can. 26:3133-3164.
Pinhorn, A.T. 1976. Living Marine Resources of Newfoundland-Labrador: Status and Potential. Bull. Fish. Res. Bd. Can. 194, 64p.
Pope, J.G. 1972. An investigation of the accuracy of virtual population analysis. ICNAF Res. Bull. 9:65-74.
Rose, G.A. 1996. Preliminary report of an acoustic survey of inner Placentia Bay, November 1995. DFO Atl. Fish. Res. Doc. 96/96.
Rose, G.A. and G.L. Lawson. 1998. Acoustic survey of cod spawning aggregations in Placentia Bay, May 1997. DFO Can. Stock Assess. Sec. Res. Doc. 98/16.
Shelton, P.A. 1998. A comparison between a fixed and a variable fishing mortality control rule used to manage the cod stock off southern Labrador and the east coast of Newfoundland. Fish. Res. 37:275-286.

Shelton, P.A., D.E. Stansbury, E.F. Murphy, J. Brattey and G.R. Lilly. 1996. An assessment of the cod stock in NAFO Subdivision 3Ps. DFO Atl. Fish. Res. Doc. 96/91, 82p.
Sinclair and Gavaris. 1996. Some examples of probabilistic catch projections using ADAPT output. DFO Stock. Asses. Sec. Res. Doc. 96/51, 11p.
Sissenwine, M.P., and Shepherd, J.G. 1997. An alternative perspective on recruitment overfishing and biological reference points. Can. J. Fish. Aquat. Sci. 44:913-918.
Smith, S. J., and G.D. Somerton. 1981. STRAP: A user-oriented computer analysis system for groundfish research trawl survey data. Can. Tech. Rep. Fish. Aquat. Sci. 1030: iv +66 p.
Stansbury, D.E. 1996. Conversion factors from comparative fishing grids for Engels 145 otter trawl on the FRV Gadus Atlantica and the Campelen 1800 shrimp trawl on the FRV Teleost. NAFO SCR Doc. 96/77.
Stansbury, D.E. 1997. Conversion factors from comparative fishing grids for Engels 145 otter trawl and the Campelen 1800 shrimp trawl used on research vessels. NAFO SCR Doc. 97/31.
Warren, W.G. 1997. Report on the comparative fishing trial between the Gadus Atlantica and Teleost. NAFO Sci. Coun. Studies 2: 81-92.
Warren, W.G., Brodie, W., Stansbury, D., Walsh, S., Morgan, J., and Orr, D. 1997. Analysis of the 1996 comparative fishing trial between the Alfred Needler with the Engel 145 trawl and the Wilfred Templeman with the Campelen 1800 trawl. NAFO SCR Doc. 97/68.
Wheeler, J.P. 1998. Distribution and abundance of Atlantic cod from an acoustic survey of Fortune Bay, Newfoundland during the winter of 1997. DFO Can. Stock Assess. Sec. Res. Doc. 98/26.

Table 1. Cod catches (t) from NAFO Subdivision 3Ps, 1959-1997 by country and separated for fixed and mobile gear.

| Year |  | Can ( N ) |  | Can (M) | France |  |  |  | Spain | Portugal | Others | Total | TAC |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Offshore (Mobile) | Inshore (Fixed) | (All gears) | Inshore | St.P\&M | Offshore | Metro All gears) | (All gears) | (All gears) | (All gears) |  |  |
| 1959 |  | 2,726 | 32,718 | 4,784 | 3,078 |  |  | 4,952 | 7,794 | 3,647 | 471 | 60,170 |  |
| 1960 |  | 1,780 | 40,059 | 5,095 | 3,424 |  | 210 | 2,460 | 17,223 | 2,658 | 4,376 | 77,285 |  |
| 1961 |  | 2,167 | 32,506 | 3,883 | 3,783 |  | 347 | 11,490 | 21,015 | 6,070 | 5,553 | 86,824 |  |
| 1962 |  | 1,176 | 29,888 | 1,474 | 2,171 |  | 70 | 4,138 | 10,289 | 3,542 | 2,491 | 55,239 |  |
| 1963 |  | 1,099 | 30,447 | 331 | 1.112 |  | 645 | 324 | 10,826 | 209 | 6,828 | 51,821 |  |
| 1964 |  | 2,161 | 23,897 | 370 | 1,002 |  | 1,095 | 2,777 | 15,216 | 169 | 9,880 | 56,567 |  |
| 1965 |  | 2,459 | 25,902 | 1,203 | 1,863 |  | 707 | 1,781 | 13,404 |  | 4,534 | 51,853 |  |
| 1966 |  | 5,473 | 23,785 | 583 | - |  | 3,207 | 4,607 | 23,678 | 518 | 4.355 | 66,207 |  |
| 1967 |  | 3.861 | 26,331 | 1,259 |  | 2,244 |  | 3,204 | 20,851 | 980 | 4,044 | 62,774 |  |
| 1988 |  | 6,538 | 22,938 | 585 | - |  | 880 | 1,126 | 26,868 | 8 | 18,613 | 77,556 |  |
| 1969 |  | 4,269 | 20,009 | 849 | - |  | 2,477 | 15 | 28,141 | 57 | 7,982 | 63,799 |  |
| 1970 |  | 4,650 | 23,410 | 2,166 | 1,307 |  | 663 | 35 | 35,750 | 143 | 8,734 | 76,858 |  |
| 1971 |  | 8,657 | 26,651 | 731 | 1,196 |  | 455 | 2,730 | 19,169 | 81 | 2,778 | 62,448 |  |
| 1972 |  | 3,323 | 19.276 | 252 | 990 |  | 446 | - | 18,550 | 109 | 1,267 | 44,213 |  |
| 1973 |  | 3,107 | 21,349 | 181 | 976 |  | 189 | - | 19,952 | 1,180 | 5,707 | 52,641 | 70,500 |
| 1974 |  | 3,770 | 15,999 | 657 | 600 |  | 348 | 5,366 | 14,937 | 1,246 | 3,789 | 46,712 | 70,000 |
| 1975 |  | 741 | 14,332 | 122 | 586 |  | 189 | 3,549 | 12,234 | 1,350 | 2,270 | 35,373 | 62,400 |
| 1976 |  | 2,013 | 20,978 | 317 | 722 |  | 182 | 1.501 | 9,236 | 177 | 2,007 | 37,133 | 47,500 |
| 1977 |  | 3,333 | 23,755 | 2,171 | 845 |  | 407 | 1,734 | - | - |  | 32,245 | 32,500 |
| 1978 |  | 2,082 | 19,560 | 700 | 360 |  | 1,614 | 2,860 | - | - | 45 | 27,221 | 25,000 |
| 1979 |  | 2,381 | 23,413 | 863 | 495 |  | 3,794 | 2,060 | - | - | . | 33,006 | 25,000 |
| 1980 |  | 2,809 | 29,427 | 715 | 214 |  | 1,722 | 2,681 | - | - | - | 37,568 | 28,000 |
| 1981 |  | 2,696 | 26,068 | 2,321 | 333 |  | 3,768 | 3,706 | - | - | - | 38,892 | 30,000 |
| 1982 |  | 2,639 | 21,351 | 2,948 | 1,009 |  | 3,771 | 2,184 | - | - | - | 33,902 | 33,000 |
| 1983 |  | 2,100 | 23,815 | 2,580 | 843 |  | 4,775 | 4,238 | - | - | - | 38,451 | 33,000 |
| 1984 |  | 895 | 22,865 | 1,969 | 777 |  | 6,773 | 3,671 | - | - | - | 36,950 | 33,000 |
| 1985 |  | 4,529 | 24,854 | 3,476 | 642 |  | 9,422 | 8,444 | - | - | - | 51,367 | 41,000 |
| 1988 |  | 5,218 | 24,821 | 1,963 | 389 |  | 13,653 | 11,839 | - | . | 7 | 57,990 | 41,000 |
| 1987 |  | 4,133 | 26,735 | 2,517 | 551 |  | 15,303 | 9,965 | - | - | . | 59,204 | 41,000 |
| 1988 |  | 3,662 | 19,742 | 2,303 | 282 |  | 10,011 | 7,373 | - | - | 4 | 43,377 | 41,000 |
| 1989 |  | 3,098 | 23,208 | 2,361 | 339 |  | 9,642 | 892 | - | - | - | 39,540 | 35,400 |
| 1990 |  | 3,266 | 20,128 | 3,082 | 158 | 14,929 | 14,771 | - | - | - | - | 41,405 | 35,400 |
| 1991 |  | 3,916 | 21,778 | 2,106 | 204 | 15,789 | 15,585 | - | - | - | - | 43,589 | 35,400 |
| 1992 |  | 4.468 | 19,025 | 2,238 | 2 | 10,164 | 10,162 | - | - | - | - | 35,895 | 35,400 |
| 1993 | 1 | 1,987 | 11,878 | 1,351 | - |  | - | - | - | - | - | 15,216 | 20,000 |
| 1994 | 1 | 82 | 493 | 84 | - |  | - | - | - | - | - | 659 | 0 |
| 1995 | 1 | 26 | 555 | 57 | - |  | - | - | - | - | - | 638 | 0 |
| 1996 | 1 | 60 | 707 | 118 | - |  | - | - | - | - | . | 885 | 0 |
| 1997 | 1 | 122 | 7.205 | 62 | 448 |  | 1,191 | - | - | - | - | 9,028 | 10,000 |

[^0]Table 2. Fixed gear catches for NAFO Subdivision 3Ps by gear.

| Year | Gillnet | Longline | Handline | Trap | Total |
| ---: | ---: | ---: | ---: | ---: | ---: |
| 1975 | 4995 | 4083 | 1364 | 3902 | 14344 |
| 1976 | 5983 | 5439 | 2346 | 7224 | 20992 |
| 1977 | 3612 | 9940 | 3008 | 7205 | 23765 |
| 1978 | 2374 | 11893 | 3130 | 2245 | 19642 |
| 1979 | 3955 | 14462 | 3123 | 2030 | 23570 |
| 1980 | 5493 | 19331 | 2545 | 2077 | 29446 |
| 1981 | 4998 | 20540 | 1142 | 948 | 27628 |
| 1982 | 6283 | 13574 | 1597 | 1929 | 23383 |
| 1983 | 6144 | 12722 | 2540 | 3643 | 25049 |
| 1984 | 7275 | 9580 | 2943 | 3271 | 23069 |
| 1985 | 7086 | 10596 | 1832 | 5674 | 25188 |
| 1986 | 8668 | 11014 | 1634 | 4073 | 25389 |
| 1987 | 9304 | 11807 | 1628 | 4931 | 27670 |
| 1988 | 6433 | 10175 | 1469 | 2449 | 20526 |
| 1989 | 5997 | 10758 | 1657 | 5996 | 24408 |
| 1990 | 6948 | 8792 | 2217 | 3788 | 21745 |
| 1991 | 6791 | 10304 | 1832 | 4068 | 22995 |
| 1992 | 5314 | 10315 | 1330 | 3397 | 20356 |
| 1993 | 3975 | 3783 | 1204 | 3557 | 12519 |
| 1994 | 90 | 0 | 381 | 0 | 471 |
| 1995 | 383 | 182 |  | 5 | 570 |
| 1996 | 467 | 158 | 137 | 10 | 772 |
| 1997 | 3760 | 1158 | 1172 | 1167 | 7258 |

Table 3. Cod landings (t) from bycatch and the sentinel survey, by month from 3Ps from 1996.

Bycatch
Can (N) Bycatch 3Ps
Can (M) Bycatch 3Ps

|  | Can (M) Bycatch 3Ps |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Month | OTS | OTM | PS/DS | Gillnet | Trap | Longline | Handline | $\begin{array}{r} \text { Total } \\ \operatorname{Can}(\mathrm{N}) \end{array}$ | OT | MWT | Gillnet | Longline | Other | $\begin{aligned} & \text { Total } \\ & \text { Can(M) } \end{aligned}$ |
| Jan |  | 7.79 |  |  |  |  |  | 7.79 | 0.90 |  |  | 4.60 |  | 5.50 |
| Feb | 0.46 | 1.08 |  | 0.52 |  |  |  | 2.06 | 7.70 | 0.624 |  |  |  | 8.32 |
| Mar | 12.76 | 9.08 |  | 5.48 |  |  |  | 27.32 | 0.10 | 7.164 |  | 2.03 |  | 9.29 |
| Apr | 3.78 | 0.02 |  | 30.85 |  | 0.21 |  | 34.85 | 0.13 | 0.759 | 35.878 | 3.31 |  | 40.07 |
| May | 4.23 |  | 0.93 | 16.03 |  |  |  | 21.19 |  |  |  |  |  | 0.00 |
| Jun |  |  | 0.32 | 39.14 | 0.49 |  |  | 39.95 |  |  |  |  |  | 0.00 |
| Jul |  |  | 0.08 | 80.61 | 3.53 | 0.66 |  | 84.87 |  |  |  |  |  | 0.00 |
| Aug |  |  | 0.13 | 49.58 | 0.19 | 1.71 |  | 51.60 |  |  | 0.172 | 16.78 |  | 16.95 |
| Sep |  |  | 1.09 | 15.33 |  | 3.94 | 137.10 | 157.46 | 0.08 |  | 2.279 |  |  | 2.36 |
| Oct | 0.25 |  | 1.09 | 45.12 |  | 1.88 | 0.11 | 48.45 |  |  |  |  |  | 0.00 |
| Nov | 3.87 |  | 0.45 | 10.15 |  |  |  | 14.47 | 0.32 |  |  |  |  | 0.32 |
| Dec | 12.52 |  |  | 12.99 |  |  |  | 25.51 | 20.18 | 14.815 |  |  |  | 35.00 |
| TOTAL | 37.88 | 17.96 | 4.08 | 305.79 | 4.20 | 8.40 | 137.21 | 515.52 | 29.40 | 23.36 | 38.33 | 26.71 | 0.00 | 117.81 |


| Catch from Sentinel Survey |  |  |  |  |  | Catch by gear all sectors combined |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Month | Gilinet longline |  | handline | $\begin{gathered} \text { Total } \\ \text { trap sentinel } \end{gathered}$ |  | OTS | OTM | PS/DS | Gillnet longline |  | handline | Total all trap sectors |  |
| Jan | 9.54 | 5.22 |  |  | 14.76 | 0.90 | 7.79 | 0.00 | 9.54 | 9.82 | 0.00 | 0.00 | 28.05 |
| Feb | 2.29 |  |  |  | 2.29 | 8.16 | 1.70 | 0.00 | 2.80 | 0.00 | 0.00 | 0.00 | 12.66 |
| Mar |  |  |  |  | 0.00 | 12.86 | 16.25 | 0.00 | 5.48 | 2.03 | 0.00 | 0.00 | 36.61 |
| Apr |  |  |  |  | 0.00 | 3.91 | 0.78 | 0.00 | 66.73 | 3.51 | 0.00 | 0.00 | 74.92 |
| May |  |  |  |  | 0.00 | 4.23 | 0.00 | 0.93 | 16.03 | 0.00 | 0.00 | 0.00 | 21.19 |
| Jun | 2.88 |  |  | 0.90 | 3.78 | 0.00 | 0.00 | 0.32 | 42.02 | 0.00 | 0.00 | 1.39 | 43.73 |
| Jul | 17.05 | 5.21 |  | 5.09 | 27.36 | 0.00 | 0.00 | 0.08 | 97.66 | 5.88 | 0.00 | 8.62 | 112.23 |
| Aug | 12.64 | 7.96 |  |  | 20.61 | 0.00 | 0.00 | 0.13 | 62.40 | 26.45 | 0.00 | 0.19 | 89.16 |
| Sep | 6.80 | 24.68 |  |  | 31.48 | 0.08 | 0.00 | 1.09 | 24.41 | 28.62 | 137.10 | 0.00 | 191.30 |
| Oct | 12.26 | 27.84 |  |  | 40.10 | 0.25 | 0.00 | 1.09 | 57.38 | 29.71 | 0.11 | 0.00 | 88.55 |
| Nov | 40.45 | 32.31 |  |  | 72.76 | 4.19 | 0.00 | 0.45 | 50.60 | 32.31 | 0.00 | 0.00 | 87.55 |
| Dec | 18.97 | 19.38 |  |  | 38.35 | 32.71 | 14.82 | 0.00 | 31.95 | 19.38 | 0.00 | 0.00 | 98.85 |
| TOTAL | 122.89 | 122.60 | 0.00 | 5.99 | 251.48 | 67.28 | 41.33 | 4.08 | 467.01 | 157.71 | 137.21 | 10.20 | 884.81 |

Table 4. Sampling used to estimate catch at age for Divisions 3Ps in 1996.

| DIVISION | GEAR | MONTH | No. measured | No. aged | Catch wt (t) |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 3Ps | GN | 1 | 3653 |  | 9.54 |
|  |  | 2 | 948 | 147 | 2.80 |
|  |  | 3 | 134 |  | 5.48 |
|  |  | 4 | 709 |  | 66.73 |
|  |  | 5 |  | 210 | 16.03 |
|  |  | 6 | 1583 |  | 42.02 |
|  |  | 7 | 7590 |  | 97.66 |
|  |  | 8 | 4939 | 365 | 62.40 |
|  |  | 9 | 2472 |  | 24.41 |
|  |  | 10 | 4605 |  | 57.38 |
|  |  | 11 | 22992 | 514 | 50.60 |
|  |  | 12 |  |  | 31.95 |
|  |  |  | 49625 | 1236 | 467.01 |
| 3Ps | Longline | 1 | 2835 |  | 9.82 |
|  |  | 2 |  | 60 | 0.00 |
|  |  | 3 | 591 |  | 2.03 |
|  |  | 4 |  |  | 3.51 |
|  |  | 5 |  |  | 0.00 |
|  |  | 6 |  |  | 0.00 |
|  |  | 7 | 2101 |  | 5.88 |
|  |  | 8 | 3744 | 167 | 26.45 |
|  |  | 9 | 12669 |  | 28.62 |
|  |  | 10 | 14424 |  | 29.71 |
|  |  | 11 | 26564 | 1248 | 32.31 |
|  |  | 12 |  |  | 19.38 |
|  |  |  | 62928 | 1475 | 157.71 |


| $O T^{1}$ | 1 | 416 |  | 8.69 |
| :---: | :---: | :---: | :---: | :---: |
|  | 2 | 177 | 482 | 9.86 |
|  | 3 | 1397 |  | 29.10 |
|  | 4 | 306 |  | 4.68 |
|  | 5 | 191 | 115 | 5.16 |
|  | 6 |  |  | 0.32 |
|  | 7 |  |  | 0.08 |
|  | 8 |  |  | 0.13 |
|  | 9 | 49 | 29 | 1.17 |
|  | 10 |  |  | 1.34 |
|  | 11 | 196 |  | 4.64 |
|  | 12 |  |  | 47.52 |
|  |  | 2732 | 626 | 112.69 |
| TRAP | 6 | 801 |  | 1.39 |
|  | 7 | 4425 |  | 8.62 |
|  | 8 |  | 222 | 0.19 |
|  |  | 5226 | 222 | 10.19 |
| Handline | 9 | 6109 | 234 | 137.10 |
|  | 10 |  |  | 0.11 |
|  |  | 6109 | 234 | 137.21 |
| Total |  | 126620 | 3793 | 0884.8111 |
| ${ }^{1}$ (includes midwater trawl and danish seine) |  |  |  |  |

Table 5. Catch, average weight and average length estimated for 3Ps cod landed in 1996.

| Total (all gears comblined) |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| AGE | VERAGE WEIGHT <br> (kg.) | LENGTH (cm.) | nUmber (000'S) |  | cv |
| 1 |  |  |  |  |  |
| 2 | 0.26 | 31.07 | 0.16 | 0.39 | 2.54 |
| 3 | 0.67 | 42.31 | 8.81 | 2.97 | 0.34 |
| 4 | 0.98 | 47.87 | 43.22 | 6.57 | 0.15 |
| 5 | 1.48 | 54.56 | 43.23 | 6.57 | 0.15 |
| 6 | 2.05 | 60.77 | 100.91 | 10.05 | 0.10 |
| 7 | 2.53 | 64.90 | 125.34 | 11.20 | 0.09 |
| 8 | 2.94 | 68.05 | 35.30 | 5.94 | 0.17 |
| 9 | 3.23 | 70.00 | 23.68 | 4.87 | 0.21 |
| 10 | 4.03 | 74.41 | 8.43 | 2.90 | 0.34 |
| 1 | 4.82 | 78.71 | 2.24 | 1.50 | 0.67 |
| 12 | 4.68 | 79.18 | 0.85 | 0.82 | 1.09 |
| 13 | 7.26 | 90.75 | 0.19 | 0.44 | 2.29 |
| 14 | 9.92 | 100.92 | 0.02 | 0.15 | 6.75 |


| Otter trawl landings |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| AGE | AVERAGE |  | CATCH |  | CV |
|  | WEIGHT (kg.) | LENGTH (em.) | NUMBER |  |  |
| 1 |  |  |  |  |  |
| 2 |  |  |  |  |  |
| 3 | 0.55 | 40.00 | 0.07 | 0.07 | 1.01 |
| 4 | 0.74 | 43.93 | 1.74 | 0.32 | 0.19 |
| 5 | 0.91 | 46.83 | 3.91 | 0.47 | 0.12 |
| 6 | 1.41 | 53.49 | 7.99 | 0.66 | 0.08 |
| 7 | 2.42 | 63.84 | 16.64 | 0.90 | 0.05 |
| 8 | 3.23 | 69.17 | 4.00 | 0.58 | 0.15 |
| 9 | 2.94 | 67.29 | 5.61 | 0.66 | 0.12 |
| 10 | 4.63 | 77.82 | 3.28 | 0.42 | 0.13 |
| 11 | 5.31 | 80.94 | 1.06 | 0.25 | 0.24 |
| 12 | 5.32 | 81.74 | 0.16 | 0.06 | 0.38 |
| 13 | 7.45 | 91.58 | 0.16 | 0.10 | 0.62 |
| 14 | 0.00 | 0.00 | 0.00 | 0.00 |  |


| Line traw |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| AGE | AVERAGE |  | CATCH |  | CV |
|  | WEIGHT | LENGTH | NUMBER |  |  |
|  | (kg.) | (cm.) | (000'S) | STD ERR. |  |
|  | 0.00 | 0.00 |  |  |  |
|  | 0.28 | 31.07 | 0.16 | 0.03 | 0.19 |
|  | 0.58 | 40.33 | 2.62 | 0.23 | 0.09 |
|  | 0.85 | 45.79 | 10.09 | 0.56 | 0.06 |
|  | 1.25 | 51.84 | 10.10 | 0.77 | 0.08 |
|  | 1.77 | 57.78 | 17.83 | 1.03 | 0.06 |
|  | 2.47 | 64.11 | 25.34 | 1.06 | 0.04 |
|  | 2.86 | 67.13 | 6.30 | 0.63 | 0.10 |
|  | 3.29 | 69.75 | 3.61 | 0.44 | 0.12 |
|  | 3.60 | 70.84 | 0.91 | 0.23 | 0.26 |
|  | 4.08 | 73.85 | 0.54 | 0.21 | 0.39 |
|  | 4.78 | 78.51 | 0.16 | 0.08 | 0.51 |
|  | 5.39 | 82.98 | 0.03 | 0.02 | 0.85 |
|  | 9.92 | 100.92 | 0.02 | 0.01 | 0.46 |


| Trap |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| AGE |  | AVERAGE WEIGHT (kg.) | LENGTH (cm.) | NUMBER <br> (000'S) | CATCH STD ERR. | CV |
|  | 1 |  |  |  |  |  |
|  | 3 | 0.43 | 37.00 | 0.27 | 0.08 | 0.29 |
|  | 4 | 0.76 | 44.04 | 4.67 | 0.23 | 0.05 |
|  | 5 | 1.12 | 49.76 | 1.33 | 0.22 | 0.17 |
|  | 6 | 1.61 | 56.39 | 1.64 | 0.20 | 0.12 |
|  | 7 | 1.98 | 60.18 | 0.65 | 0.14 | 0.22 |
|  | 8 | 2.35 | 83.69 | 0.17 | 0.07 | 0.43 |
|  | 9 | 2.74 | 68.92 | 0.13 | 0.06 | 0.44 |
|  | 10 | 2.33 | 64.00 | 0.02 | 0.02 | 1.00 |
|  | 11 |  |  |  |  |  |
|  | 12 |  |  |  |  |  |
|  | 13 |  |  |  |  |  |
|  | 14 |  |  |  |  |  |


${ }_{0}^{\circ}$

Table 6. Cod landings (t) from bycatch, sentinel survey and the commercial fishery by month from 3Ps in 1997.

| Can (N) Bycatch 3Ps and directed fishery |  |  |  |  |  |  |  |  | Can (M) Bycatch 3Ps |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Month | OTS | OTM | PS/DS | Gillnet | Trap | Longline | Handline | $\begin{gathered} \text { Totait } \\ \text { Can }(N) \end{gathered}$ | OT | MWT | Gillnet | Longline | Other | $\begin{gathered} \text { Total } \\ \text { Can }(M) \end{gathered}$ |
| Jan |  | 0.14 |  | 0.03 |  |  |  | 0.16 |  |  |  | 18.97 |  | 18.97 |
| Feb | 8.41 | 5.84 |  |  |  |  |  | 14.25 |  | 0.10 |  | 11.05 |  | 11.15 |
| Mar | 11.64 | 12.87 |  |  |  |  |  | 24.51 | 1.53 | 5.39 |  | 0.02 |  | 6.94 |
| Apr | 3.76 |  |  | 14.44 |  | 1.57 | 2.50 | 22.26 |  | 2.29 |  | 1.40 |  | 3.69 |
| May | 37.08 |  |  | 1370.45 | 278.28 | 140.54 | 370.41 | 2194.75 |  |  | 0.41 |  |  | 0.41 |
| Jun | 0.11 |  | 0.26 | 338.38 | 416.65 | 47.65 | 38.80 | 841.83 |  |  | 21.32 |  |  | 21.32 |
| Jul | 1.16 |  | 0.24 | 854.89 | 422.85 | 133.77 | 128.01 | 1539.02 |  |  |  |  |  | 0.00 |
| Aug | 2.38 |  | 0.40 | 336.85 |  | 134.95 | 84.70 | 556.28 |  |  |  |  |  | 0.00 |
| Sep | 0.21 |  |  | 52.45 |  | 9.54 | 312.13 | 374.33 |  |  |  |  |  | 0.00 |
| Oct | 0.84 |  | 0.57 | 653.36 |  | 597.98 | 210.09 | 1462.83 |  |  |  |  |  | 0.00 |
| Nov | 21.29 |  |  | 13.86 |  | 30.69 |  | 65.84 |  |  |  |  |  | 0.00 |
| Dec | 15.01 |  |  |  |  |  |  | 15.01 |  |  |  |  |  | 0.00 |
| TOTAL | 101.88 | 18.84 | 1.46 | 3634.82 | 1115.75 | 1093.68 | 1144.63 | 7111.08 | 1.53 | 7.79 | 21.73 | 31.44 | 0.00 | 62.49 |


| Catch from Sentinel Sunvey vessels contains competetive fishery catch |  |  |  |  |  | Catch by gear all sectors combined |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Month | Gillnet | tongline | handline | trap | $\begin{array}{r} \text { Total } \\ \text { sentinel } \end{array}$ | OTS | OTM | PSSDS | Gillnet | longline | handline | trap | Total all sectors |
| Jan |  |  |  |  |  | 0.00 | 0.14 | 0.00 | 0.03 | 18.97 | 0.00 | 0.00 | 19.14 |
| Feb |  |  |  |  |  | 8.41 | 5.94 | 0.00 | 0.00 | 11.05 | 0.00 | 0.00 | 25.41 |
| Mar |  |  |  |  |  | 13.17 | 18.26 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 31.45 |
| Apr |  |  |  |  |  | 3.76 | 2.29 | 0.00 | 14.44 | 2.97 | 2.50 | 0.00 | 25.96 |
| May | 27.493 | 1.74 | 12.90 | 1.16 | 43.29 | 37.08 | 0.00 | 0.00 | 1398.38 | 142.28 | 383.31 | 277.42 | 2238.45 |
| June | 12.444 | 0.31 | 3.65 | 28.61 | 43.01 | 0.11 | 0.00 | 0.28 | 372.14 | 47.86 | 42.45 | 443.26 | 906.17 |
| Jul | 18.602 | 2.44 | 1.18 | 23.75 | 45.96 | 1.16 | 0.00 | 0.24 | 873.59 | 136.20 | 127.19 | 446.59 | 1584.96 |
| Aug | 4.334 | 0.89 | 1.98 |  | 7.21 | 2.38 | 0.00 | 0.40 | 341.19 | 132.84 | 88.69 | 0.00 | 563.48 |
| Sep | 1.33 |  |  |  | 1.33 | 0.21 | 0.00 | 0.00 | 53.78 | 9.54 | 312.13 | 0.00 | 375.66 |
| Oct | 5.022 | 8.88 | 7.98 |  | 19.88 | 0.84 | 0.00 | 0.57 | 658.38 | 604.85 | 218.08 | 0.00 | 1482.71 |
| Nov | 27.053 | 13.07 |  |  | 40.12 | 21.29 | 0.00 | 0.00 | 40.92 | 43.76 | 0.00 | 0.00 | 105.96 |
| Dec | 7.229 | 7.68 |  |  | 14.91 | 15.01 | 0.00 | 0.00 | 7.23 | 7.68 | 0.00 | 0.00 | 29.92 |
| TOTAL | 103.51 | 33.00 | 27.68 | 51.52 | 215.72 | 103.41 | 26.63 | 1.48 | 3760.05 | 1158.12 | 1172.32 | 1167.27 | 7389.26 |

Table 7. Sampling used to estimate catch at age for Divisions 3Ps in 1997.


Includes danish seine and purse catch

Table 8. Catch average weight and average length estimated for cod landed in Subdivision 3Ps in 1997.


Table. 9. Comparison of univariate statistics for commercial catch rate data from logbooks for vessels greater than 35 ft ( ZIF data) with catch rate data from three years of the Sentinel fishery. Gillnet catch rates are in $\mathrm{kg} / \mathrm{net} / \mathrm{day}$ and linetrawl catch rates are in kg/1000 hooks.

| Gear | ZIF | Sentinel |
| :--- | ---: | ---: |
| Gillnets |  |  |
| N | 2057 | 444 |
| Mean | 37.76 | 25.51 |
| Median | 16.58 | 0.52 |
| Standard deviation | 85.30 | 76.65 |
| 75th percentile | 34.00 | 4.95 |
| 25th percentile | 8.15 | 0.06 |
| Linetrawls |  |  |
| N | 5222 | 444 |
| Mean | 297.40 | 1062.86 |
| Median | 225.00 | 21.47 |
| Standard deviation | 292.31 | 3193.71 |
| 75th percentile | 362.83 | 206.44 |
| 25th percentile | 137.06 | 2.55 |

Table 10. Cod abundance estimates (thousands of fish ) from research vessel surveys in NAFO Division 3Ps. Shaded cells are model estimates.

' These strata were added to the stratification schene in 1994.
Strata 709 was redrawn in 1994 and indudes the area covered by strata 710 in previous surveys. All sets dons in 710 prior to 1994 have been recoded to 709 .
For index strata 0 -300 fathoms in the offshore and induces esitmates (shaded cells) for non-sampled strate.
totals are for all strata fished
${ }^{5}$ These strata were added to the stratification schene in 1997.

Table 11. Cod biomass estimates (t) from research vessel surveys in NAFO Division 3Ps. Shaded cells are model estimates.

${ }^{2}$ Strata 709 was redrawn in 1994 and includes the area covered by strata 710 in previous surveys. All sets done in 710 prior to 1994 have been recoded to 709
'For index strata $0-300$ fathoms in the offshore and includes esitmates (shaded cells) for non-sempled strata
totals are for all strata ifished
${ }^{5}$ These strata were added to the stratification schene in 1897.

Table 12. Input tables for SPA analysis.

| Canadlan RV Index <br> Year/age | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| 1983 | 6.52 | 1.14 | 3.72 | 1.62 | 0.48 | 0.89 | 1.61 | 0.75 | 0.36 | 0.14 |
| 1984 | 2.33 | 1.55 | 0.63 | 2.11 | 0.77 | 0.37 | 0.46 | 0.71 | 0.18 | 0.15 |
| 1985 | 14.88 | 12.57 | 9.96 | 3.28 | 2.66 | 0.79 | 0.48 | 0.42 | 0.42 | 0.49 |
| 1986 | 5.65 | 6.48 | 7.95 | 6.33 | 2.13 | 1.47 | 0.84 | 0.29 | 0.24 | 0.29 |
| 1987 | 5.67 | 4.97 | 13.82 | 8.31 | 3.35 | 1.29 | 0.69 | 0.28 | 0.23 | 0.16 |
| 1988 | 5.93 | 2.96 | 2.84 | 6.50 | 5.84 | 3.65 | 1.49 | 0.84 | 0.74 | 0.35 |
| 1989 | 4.66 | 3.17 | 1.51 | 1.16 | 2.15 | 1.21 | 0.67 | 0.37 | 0.41 | 0.13 |
| 1990 | 9.82 | 14.49 | 10.89 | 5.67 | 3.84 | 3.14 | 1.15 | 0.71 | 0.32 | 0.16 |
| 1991 | 5.03 | 10.00 | 11.24 | 5.75 | 2.84 | 1.58 | 1.19 | 0.74 | 0.56 | 0.22 |
| 1992 | 6.95 | 2.11 | 4.15 | 2.03 | 1.03 | 0.53 | 0.26 | 0.24 | 0.08 | 0.04 |
| 1993 | 1.99 | 4.04 | 1.49 | 1.35 | 0.47 | 0.10 | 0.04 | 0.03 | 0.04 | 0.01 |
| 1994 | 1.46 | 4.31 | 6.10 | 1.73 | 1.62 | 0.50 | 0.08 | 0.04 | 0.03 | 0.02 |
| 1995 | 1.19 | 1.54 | 12.04 | 18.08 | 4.05 | 5.29 | 2.01 | 0.23 | 0.18 | 0.01 |
| 1996 | 3.52 | 3.74 | 1.26 | 2.56 | 2.77 | 0.51 | 0.44 | 0.09 | 0.09 | 0.02 |
| 1997 | 2.33 | 1.04 | 0.50 | 0.28 | 0.30 | 0.24 | 0.14 | 0.05 | 0.02 | 0.00 |
|  |  |  |  |  |  |  |  |  |  |  |
| French RV Index |  |  |  |  |  |  |  |  |  |  |
| Year/age | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1980 | 1.72 | 0.50 | 2.67 | 4.52 | 1.66 | 0.67 | 0.29 | 0.22 | 0.18 | 0.11 |
| 1981 | 4.91 | 4.94 | 5.14 | 7.45 | 5.64 | 1.60 | 1.19 | 0.47 | 0.15 | 0.14 |
| 1982 | 1.96 | 8.32 | 7.97 | 6.06 | 4.55 | 5.30 | 1.58 | 0.87 | 0.42 | 0.15 |
| 1983 | 5.40 | 2.98 | 7.21 | 6.11 | 4.55 | 2.77 | 2.08 | 0.75 | 0.25 | 0.19 |
| 1984 | 7.64 | 15.07 | 8.74 | 18.97 | 5.59 | 2.13 | 3.09 | 2.21 | 0.61 | 0.16 |
| 1985 | 14.49 | 7.47 | 3.93 | 1.06 | 1.95 | 1.14 | 0.78 | 0.88 | 1.09 | 1.32 |
| 1986 | 4.21 | 15.19 | 26.47 | 21.66 | 9.12 | 6.97 | 3.85 | 0.79 | 0.59 | 0.72 |
| 1987 | 11.51 | 2.83 | 8.30 | 12.49 | 8.32 | 2.95 | 1.94 | 0.95 | 0.20 | 0.36 |
| 1988 | 14.89 | 9.22 | 3.62 | 6.53 | 4.69 | 1.60 | 0.78 | 0.35 | 0.35 | 0.16 |
| 1989 | 16.02 | 8.20 | 5.81 | 3.48 | 4.43 | 2.03 | 1.01 | 0.27 | 0.13 | 0.06 |
| 1990 | 18.26 | 20.11 | 7.66 | 2.46 | 0.73 | 1.00 | 0.44 | 0.26 | 0.11 | 0.09 |
| 1991 | 7.08 | 12.96 | 12.68 | 7.56 | 2.42 | 1.07 | 0.91 | 0.62 | 0.06 | 0.15 |


| Year/age | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1959 | 1001 | 13940 | 7525 | 7265 | 4875 | 942 | 1252 | 1260 | 631 | 545 | 44 | 0 |
| 1960 | 567 | 5496 | 23704 | 6714 | 3476 | 3484 | 1020 | 827 | 406 | 407 | 283 | 27 |
| 1961 | 450 | 5586 | 10357 | 15960 | 3616 | 4680 | 1849 | 1376 | 446 | 265 | 560 | 58 |
| 1962 | 1245 | 6749 | 9003 | 4533 | 5715 | 1367 | 791 | 571 | 187 | 140 | 135 | 241 |
| 1963 | 961 | 4499 | 7091 | 5275 | 2527 | 3030 | 898 | 292 | 143 | 99 | 107 | 92 |
| 1964 | 1906 | 5785 | 5635 | 5179 | 2945 | 1881 | 1891 | 652 | 339 | 329 | 54 | 27 |
| 1965 | 2314 | 9636 | 5799 | 3609 | 3254 | 2055 | 1218 | 1033 | 327 | 68 | 122 | 36 |
| 1966 | 949 | 13662 | 13065 | 4621 | 5119 | 1586 | 1833 | 1039 | 517 | 389 | 32 | 22 |
| 1967 | 2871 | 10913 | 12900 | 6392 | 2349 | 1364 | 604 | 316 | 380 | 95 | 149 | 3 |
| 1968 | 1143 | 12602 | 13135 | 5853 | 3572 | 1308 | 549 | 425 | 222 | 111 | 5 | 107 |
| 1969 | 774 | 7098 | 11585 | 7178 | 4554 | 1757 | 792 | 717 | 61 | 120 | 67 | 110 |
| 1970 | 756 | 8114 | 12916 | 9763 | 6374 | 2456 | 730 | 214 | 178 | 77 | 121 | 14 |
| 1971 | 2884 | 6444 | 8574 | 7266 | 8218 | 3131 | 1275 | 541 | 85 | 125 | 62 | 57 |
| 1972 | 731 | 4944 | 4591 | 3552 | 4603 | 2636 | 833 | 463 | 205 | 117 | 48 | 45 |
| 1973 | 945 | 4707 | 11386 | 4010 | 4022 | 2201 | 2019 | 515 | 172 | 110 | 14 | 29 |
| 1974 | 1887 | 6042 | 9987 | 6365 | 2540 | 1857 | 1149 | 538 | 249 | 80 | 32 | 17 |
| 1975 | 1840 | 7329 | 5397 | 4541 | 5867 | 723 | 1196 | 105 | 174 | 52 | 6 | 2 |
| 1976 | 4110 | 12139 | 7923 | 2875 | 1305 | 495 | 140 | 53 | 17 | 21 | 4 | 3 |
| 1977 | 935 | 9156 | 8326 | 3209 | 920 | 395 | 265 | 117 | 57 | 43 | 31 | 11 |
| 1978 | 502 | 5146 | 6096 | 4006 | 1753 | 653 | 235 | 178 | 72 | 27 | 17 | 10 |
| 1979 | 135 | 3072 | 10321 | 5066 | 2353 | 721 | 233 | 84 | 53 | 24 | 13 | 10 |
| 1980 | 368 | 1625 | 5054 | 8156 | 3379 | 1254 | 327 | 114 | 56 | 45 | 21 | 25 |
| 1981 | 1022 | 2888 | 3136 | 4652 | 5855 | 1622 | 539 | 175 | 67 | 35 | 18 | 2 |
| 1982 | 130 | 5092 | 4430 | 2348 | 2861 | 2939 | 640 | 243 | 83 | 30 | 11 | 7 |
| 1983 | 760 | 2682 | 9174 | 4080 | 1752 | 1150 | 1041 | 244 | 91 | 37 | 18 | 8 |
| 1984 | 203 | 4521 | 4538 | 7018 | 2221 | 584 | 542 | 338 | 134 | 35 | 8 | 8 |
| 1985 | 152 | 2639 | 8031 | 5144 | 5242 | 1480 | 626 | 545 | 353 | 109 | 21 | 6 |
| 1986 | 306 | 5103 | 10253 | 11228 | 4283 | 2167 | 650 | 224 | 171 | 143 | 79 | 23 |
| 1987 | 585 | 2956 | 11023 | 9763 | 5453 | 1416 | 1107 | 341 | 149 | 78 | 135 | 50 |
| 1988 | 935 | 4951 | 4971 | 6471 | 5046 | 1793 | 630 | 284 | 123 | 75 | 53 | 31 |
| 1989 | 1071 | 8995 | 7842 | 2863 | 2549 | 1112 | 600 | 223 | 141 | 57 | 29 | 26 |
| 1990 | 2006 | 8622 | 8195 | 3329 | 1483 | 1237 | 692 | 350 | 142 | 104 | 47 | 22 |
| 1991 | 812 | 7981 | 10028 | 5907 | 2164 | 807 | 620 | 428 | 108 | 76 | 50 | 22 |
| 1992 | 1422 | 4159 | 8424 | 6538 | 2266 | 658 | 269 | 192 | 187 | 83 | 34 | 41 |
| 1993 | 278 | 3712 | 2035 | 3156 | 1334 | 401 | 89 | 38 | 52 | 13 | 14 | 5 |
| 1994 | 9 | 78 | 173 | 74 | 62 | 28 | 12 | 3 | 2 | 0 | 0 | 0 |
| 1995 | 3 | 7 | 56 | 119 | 57 | 37 | 7 | 2 | 0 | 0 | 0 | 0 |
| 1996 | 9 | 43 | 43 | 101 | 125 | 35 | 24 | 8 | 2 | 1 | 0 | 0 |
| 1997 | 66 | 427 | 1130 | 497 | 937 | 826 | 187 | 93 | 31 | 4 | 1 | 0 |

Table 13. Mean length-at-age ( cm ) of cod sampled during resource assessment bottom-trawl surveys in Subdivision 3Ps in winter-spring 1972-1997. Shaded entries are based on fewer than 5 fish. Some entries are different from those in Lilly (MS 1996; Table 6) because only data from successful sets in the index strata are included in the present analyses.

| Age | 72 | 73 | 74 | 75 | 76 | 77 |
| :---: | ---: | ---: | ---: | ---: | ---: | ---: |
| 1 | 14.0 | 11.6 | 12.2 | 12.7 | 13.2 | 11.0 |
|  | 23.2 | 22.6 | 21.7 | 23.1 | 22.8 | 20.3 |
| 3 | 31.5 | 31.7 | 33.4 | 35.3 | 35.4 | 31.7 |
| 4 | 41.0 | 39.3 | 43.1 | 44.4 | 48.2 | 43.2 |
| 5 | 51.9 | 50.1 | 50.8 | 55.4 | 57.4 | 55.6 |
| 6 | 58.5 | 56.6 | 55.6 | 61.0 | 64.6 | 63.5 |
| 7 | 63.0 | 62.1 | 63.6 | 66.5 | 68.1 | 73.9 |
| 8 | 74.1 | 66.1 | 71.2 | 74.3 | 71.6 | 75.2 |
| 9 | 81.8 | 68.4 | 69.3 | 74.2 | 78.5 | 88.0 |
| 10 | 90.4 | 81.1 | 79.0 | 75.2 | 81.6 | 83.8 |
| 11 | 95.0 | 88.2 | 93.3 | 76.2 | 94.8 | 77.6 |
| 12 | 88.3 | 87.1 | 95.6 | 107.2 | 110.5 | 87.0 |


| Age | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1 |  | 10.8 | 14.6 | 14.6 | 13.2 | 10.3 | 12.0 |  | 11.0 | 10.7 |  | 12.0 |  | 9.5 |  |  |  |  | 12.6 | 12.7 |
| 2 | 19.6 | 22.1 | 21.0 | 22.4 | 22.0 | 20.2 | 19.2 | 17.9 | 18.7 | 19.9 | 19.7 | 19.2 | 20.0 | 19.2 | 20.7 |  | 19.1 | 21.2 | 20.6 | 24.1 |
| 3 | 28.0 | 32.2 | 28.1 | 32.4 | 33.3 | 31.2 | 30.6 | 29.0 | 26.8 | 29.5 | 29.0 | 30.1 | 29.9 | 29.5 | 30.5 | 30.9 | 32.3 | 30.1 | 30.0 | 31.7 |
| 4 | 35.9 | 42.6 | 42.9 | 44.4 | 44.9 | 43.0 | 42.1 | 40.3 | 40.3 | 39.4 | 40.8 | 41.6 | 40.0 | 38.5 | 40.9 | 41.1 | 39.2 | 41.4 | 38.6 | 40.8 |
| 5 | 48.0 | 47.4 | 50.6 | 50.6 | 53.4 | 52.6 | 51.8 | 50.9 | 48.6 | 48.1 | 47.5 | 47.9 | 48.0 | 46.9 | 47.1 | 48.0 | 48.0 | 50.3 | 44.0 | 47.9 |
| 6 | 59.0 | 56.3 | 58.2 | 58.6 | 59.3 | 57.8 | 60.6 | 60.0 | 55.5 | 53.9 | 56.2 | 56.0 | 53.7 | 53.3 | 55.1 | 52.6 | 50.2 | 56.4 | 52.9 | 51.5 |
| 7 | 65.6 | 70.5 | 71.3 | 63.2 | 66.4 | 65.4 | 66.2 | 66.3 | 62.1 | 61.1 | 61.9 | 63.9 | 56.6 | 57.4 | 61.1 | 62.2 | 53.6 | 58.2 | 60.9 | 60.6 |
| 8 | 70.1 | 76.8 | 84.8 | 69.9 | 70.1 | 71.4 | 70.6 | 74.0 | 72.1 | 67.3 | 66.7 | 71.8 | 62.2 | 62.7 | 62.4 | 70.3 | 59.1 | 57.9 | 61.1 | 65.2 |
| 9 | 84.1 | 85.8 | 94.9 | 72.6 | 75.6 | 73.3 | 75.6 | 74.3 | 76.4 | 77.8 | 74.6 | 75.9 | 70.1 | 68.1 | 66.6 | 77.1 | 68.0 | 63.0 | 63.3 | 66.9 |
| 10 | 86.3 | 95.3 | 98.0 | 83.2 | 90.6 | 79.4 | 78.9 | 79.3 | 82.6 | 85.4 | 79.7 | 84.4 | 76.1 | 73.7 | 73.4 | 80.5 | 88.0 | 79.8 | 76.7 | 67.3 |
| 11 | 88.3 | 94.3 | 97.2 | 97.8 | 98.7 | 89.6 | 84.1 | 89.1 | 93.3 | 83.1 | 79.7 | 88.5 | 79.4 | 73.8 | 83.6 | 96.0 | 79.3 | 81.2 | 74.7 | 82.5 |
| 12 | 79.3 | 116.0 | 106.6 | 90.1 | 104.6 | 94.1 | 98.2 | 93.0 | 93.8 | 89.9 | 87.5 | 96.5 | 88.7 | 77.2 | 81.8 | 106:0 | 90.3 | 83. | 86.1] |  |

Table 14. Mean weight-at-age (kg) of cod sampled during resource assessment bottom-trawl surveys in Subdivision 3Ps in winter-spring 1978-1997. Shaded entries are based on fewer than 5 fish. Some entries are different from those in Lilly (MS 1996; Table 7) because only data from successful sets in the index strata are included in the present analyses.

| Age | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1 |  | 0.011 | 0.027 |  | 0.040 | 0.010 |  |  |  |  |  |  |  | 0.012 |  |  |  |  | 0.018 | 0.016 |
| 2 | 0.057 | 0.070 | 0.068 | 0.060 | 0.103 | 0.068 | 0.073 |  | 0.045 |  | 0.057 | 0.060 | 0.062 | 0.054 | 0.064 |  | 0.053 | 0.062 | 0.072 | 0.108 |
| 3 | 0.177 | 0.258 | 0.147 | 0.265 | 0.420 | 0.232 | 0.268 | 0.214 | 0.168 | 0.248 | 0.193 | 0.239 | 0.208 | 0.217 | 0.230 | 0.220 | 0.254 | 0.212 | 0.218 | 0.257 |
| 4 | 0.396 | 0.633 | 0.618 | 0.704 | 0.829 | 0.718 | 0.632 | 0.505 | 0.462 | 0.538 | 0.582 | 0.613 | 0.538 | 0.465 | 0.574 | 0.550 | 0.460 | 0.540 | 0.461 | 0.552 |
| 5 | 0.979 | 0.879 | 1.005 | 1.079 | 1.299 | 1.301 | 1.212 | 1.039 | 0.905 | 0.950 | 0.915 | 0.901 | 0.954 | 0.865 | 0.865 | 0.894 | 0.898 | 1.017 | 0.673 | 0.878 |
| 6 | 1.735 | 1.565 | 1.634 | 1.673 | 1.539 | 1.652 | 1.853 | 1.566 | 1.332 | 1.273 | 1.494 | 1.331 | 1.348 | 4.324 | 1.461 | 1.150 | 1.044 | 1.514 | 1.283 | 1.076 |
| 7 | 2.368 | 3.029 | 3.457 | 2.081 | 2.555 | 1.861 | 2.790 | 2.279 | 2.384 | 1.885 | 2.214 | 2.361 | 1.621 | 1.702 | 2.032 | 1.987 | 1.236 | 1.687 | 2.009 | 1.904 |
| 8 | 3.192 | 5.666 | 5.791 | 3.496 | 2.612 | 3.555 | 3.828 | 3.206 | 3.337 | 2.297 | 2.423 | 3.778 | 2.185 | 2.346 | 2.258 | 3.003 | 1.814 | 1.585 | 2.084 | 2.608 |
| 9 | 4.676 | 5788 | 8.459 | 4.890 | 4.007 | 4.042 | 4.225 | 3.143 | 5.023 | 4.483 | 3.943 | 4.505 | 3.060 | 3.087 | 2.859 | 4.281 | 2.891 | 2.209 | 2.136 | 2.867 |
| 10 | 5.711 | 7.108 | 8,333 | 7.591 | 6.441 | 4.896 | 5.029 | 3.760 | 4.654 | 6.344 | 4.839 | 5.820 | 4.225 | 3.956 | 3.983 | 3440 | 6.450 | 4.767 | 4.464 | 3.083 |
| 11 | 4.901 | 9.030 | 9.085 | 88.374 | 8.885 | 8.848 | 7.866 |  | 6.633 | 6.616 | 4.262 | 8.285 | 4.934 | 4.050 | 5.796 | 8.673 | 4470 | 5.446 | 3.897 | -5,456 |
| 12 | 5.760 |  | 10.158 | 11.463 | 13.068 | 10.270 | 9.818 | 3.970 | 8.867 | 5.945 | 9.103 | 9.061 | 7.365 | 4.906 | 5.240 | 13:20 | 6.748 | 5.644 | 6.793 |  |

Table 15. Average annual weights at age in kilograms from mean lengths at age based on samples of the catch by commercial gear between 1976 (extraplolated back to 1959) and 1997 (extrapolated to 1998).

| Yearfage | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1859 | 0.28 | 0.69 | 1.08 | 1.68 | 2.40 | 3.21 | 4.10 | 5.08 | 6.03 | 7.00 | 8.05 | 9.16 |
| 1960 | 0.28 | 0.69 | 1.08 | 1.68 | 2.40 | 3.21 | 4.10 | 5.08 | 6.03 | 7.00 | 8.05 | 9.16 |
| 1981 | 0.28 | 0.69 | 1.08 | 1.68 | 2.40 | 3.21 | 4.10 | 5.08 | 6.03 | 7.00 | 8.05 | 9.16 |
| 1982 | 0.28 | 0.69 | 1.08 | 1.68 | 2.40 | 3.21 | 4.10 | 5.08 | 6.03 | 7.00 | 8.05 | 9.16 |
| 1983 | 0.28 | 0.69 | 1.08 | 1.68 | 2.40 | 3.21 | 4.10 | 5.08 | 6.03 | 7.00 | 8.05 | 9.16 |
| 1964 | 0.28 | 0.69 | 1.08 | 1.68 | 2.40 | 3.21 | 4.10 | 5.08 | 6.03 | 7.00 | 8.05 | 9.16 |
| 1965 | 0.28 | 0.69 | 1.08 | 1.68 | 2.40 | 3.21 | 4.10 | 5.08 | 6.03 | 7.00 | 8.05 | 9.16 |
| 1988 | 0.28 | 0.69 | 1.08 | 1.68 | 2.40 | 3.21 | 4.10 | 5.08 | 6.03 | 7.00 | 8.05 | 9.16 |
| 1967 | 0.28 | 0.69 | 1.08 | 1.68 | 2.40 | 3.21 | 4.10 | 5.08 | 6.03 | 7.00 | 8.05 | 9.16 |
| 1988 | 0.28 | 0.69 | 1.08 | 1.68 | 2.40 | 3.21 | 4.10 | 5.08 | 6.03 | 7.00 | 8.05 | 9.16 |
| 1969 | 0.28 | 0.69 | 1.08 | 1.68 | 2.40 | 3.21 | 4.10 | 5.08 | 6.03 | 7.00 | 8.05 | 9.16 |
| 1970 | 0.28 | 0.69 | 1.08 | 1.68 | 2.40 | 3.21 | 4.10 | 5.08 | 6.03 | 7.00 | 8.05 | 9.16 |
| 1971 | 0.28 | 0.69 | 1.08 | 1.68 | 2.40 | 3.21 | 4.10 | 5.08 | 6.03 | 7.00 | 8.05 | 9.16 |
| 1972 | 0.28 | 0.69 | 1.08 | 1.68 | 2.40 | 3.21 | 4.10 | 5.08 | 6.03 | 7.00 | 8.05 | 9.16 |
| 1973 | 0.28 | 0.69 | 1.08 | 1.68 | 2.40 | 3.21 | 4.10 | 5.08 | 6.03 | 7.00 | 8.05 | 9.16 |
| 1974 | 0.28 | 0.69 | 1.08 | 1.68 | 2.40 | 3.21 | 4.10 | 5.08 | 6.03 | 7.00 | 8.05 | 9.16 |
| 1975 | 0.28 | 0.69 | 1.08 | 1.68 | 2.40 | 3.21 | 4.10 | 5.08 | 6.03 | 7.00 | 8.05 | 9.16 |
| 1976 | 0.28 | 0.69 | 1.08 | 1.68 | 2.40 | 3.21 | 4.10 | 5.08 | 6.03 | 7.00 | 8.05 | 9.16 |
| 1977 | 0.55 | 0.68 | 1.30 | 1.86 | 2.67 | 3.42 | 4.19 | 4.94 | 5.92 | 6.76 | 8.78 | 10.90 |
| 1978 | 0.45 | 0.70 | 1.08 | 1.75 | 2.45 | 2.99 | 4.10 | 5.16 | 5.17 | 7.20 | 7.75 | 8.72 |
| 1979 | 0.41 | 0.65 | 1.01 | 1.65 | 2.55 | 3.68 | 4.30 | 6.49 | 7.00 | 8.20 | 9.53 | 10.84 |
| 1980 | 0.52 | 0.72 | 1.13 | 1.66 | 2.48 | 3.60 | 5.40 | 6.95 | 7.29 | 8.64 | 9.33 | 9.58 |
| 1981 | 0.48 | 0.79 | 1.32 | 1.80 | 2.30 | 3.27 | 4.36 | 5.68 | 7.41 | 9.04 | 8.39 | 9.56 |
| 1982 | 0.45 | 0.77 | 1.17 | 1.78 | 2.36 | 2.88 | 3.91 | 5.28 | 6.18 | 8.62 | 8.64 | 11.41 |
| 1983 | 0.58 | 0.84 | 1.33 | 1.99 | 2.58 | 3.26 | 3.77 | 5.04 | 6.56 | 8.45 | 10.06 | 11.82 |
| 1884 | 0.66 | 1.04 | 1.40 | 1.97 | 2.64 | 3.77 | 4.75 | 5.56 | 6.01 | 9.04 | 11.20 | 10.40 |
| 1985 | 0.63 | 0.85 | 1.23 | 1.79 | 2.81 | 3.44 | 5.02 | 6.01 | 6.11 | 7.18 | 9.84 | 10.48 |
| 1986 | 0.54 | 0.75 | 1.18 | 1.84 | 2.43 | 3.15 | 4.30 | 5.50 | 6.19 | 8.72 | 8.05 | 11.91 |
| 1987 | 0.56 | 0.77 | 1.21 | 1.63 | 2.31 | 3.02 | 4.33 | 5.11 | 6.20 | 6.98 | 7.08 | 8.34 |
| 1988 | 0.63 | 0.82 | 1.09 | 4.67 | 2.17 | 2.92 | 3.58 | 4.98 | 5.61 | 6.60 | 7.46 | 8.92 |
| 1889 | 0.63 | 0.81 | 1.16 | 1.63 | 2.25 | 3.37 | 4.11 | 5.18 | 6.29 | 7.30 | 7.75 | 8.73 |
| 1890 | 0.58 | 0.86 | 1.27 | 1.85 | 2.45 | 3.00 | 4.22 | 5.09 | 6.35 | 7.60 | 8.31 | 10.37 |
| 1991 | 0.60 | 0.75 | 1.17 | 1.74 | 2.37 | 2.91 | 3.69 | 4.23 | 6.34 | 7.68 | 8.64 | 9.72 |
| 1892 | 0.46 | 0.69 | 1.04 | 1.56 | 2.23 | 2.89 | 4.14 | 5.54 | 6.42 | 7.82 | 10.40 | 11.88 |
| 1893 | 0.36 | 0.68 | 1.08 | 1.48 | 2.13 | 2.82 | 4.34 | 4.30 | 4.68 | 7.49 | 6.85 | 8.24 |
| 1994 | 0.62 | 0.82 | 1.30 | 1.85 | 2.05 | 2.75 | 3.59 | 4.38 | 6.29 | 7.77 | 6.78 | 8.07 |
| 1995 | 0.52 | 0.85 | 1.57 | 2.03 | 2.47 | 2.78 | 3.46 | 4.30 | 4.27 | 4.16 | 5.59 | 9.24 |
| 1996 | 0.67 | 0.98 | 1.48 | 2.05 | 2.53 | 2.94 | 3.23 | 4.03 | 4.82 | 4.68 | 7.26 | 9.92 |
| 1997 | 0.62 | 0.90 | 1.30 | 1.87 | 2.51 | 3.24 | 3.47 | 3.52 | 4.59 | 6.37 | 8.58 | 10.73 |
| 1998 | 0.62 | 0.90 | 1.30 | 1.87 | 2.51 | 3.24 | 3.47 | 3.52 | 4.59 | 6.37 | 8.58 | 10.73 |

Table 16. Beginning of the year weights at age derived from samples of catches by commercial gear.

| Yearfage | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1959 | 0.18 | 0.44 | 0.86 | 1.35 | 2.01 | 2.78 | 3.63 | 4.56 | 5.53 | 6.50 | 7.51 | 8.59 |
| 1980 | 0.18 | 0.44 | 0.86 | 1.35 | 2.01 | 2.78 | 3.63 | 4.56 | 5.53 | 6.50 | 7.51 | 8.59 |
| 1981 | 0.18 | 0.44 | 0.86 | 1.35 | 2.01 | 2.78 | 3.63 | 4.56 | 5.53 | 6.50 | 7.51 | 8.59 |
| 1962 | 0.18 | 0.44 | 0.86 | 1.35 | 2.01 | 2.78 | 3.63 | 4.56 | 5.53 | 6.50 | 7.51 | 8.59 |
| 1983 | 0.18 | 0.44 | 0.86 | 1.35 | 2.01 | 2.78 | 3.63 | 4.56 | 5.53 | 6.50 | 7.51 | 8.59 |
| 1984 | 0.18 | 0.44 | 0.86 | 1.35 | 2.01 | 2.78 | 3.63 | 4.56 | 5.53 | 6.50 | 7.51 | 8.59 |
| 1965 | 0.18 | 0.44 | 0.86 | 1.35 | 2.01 | 2.78 | 3.63 | 4.56 | 5.53 | 6.50 | 7.51 | 8.59 |
| 1866 | 0.18 | 0.44 | 0.86 | 1.35 | 2.01 | 2.78 | 3.63 | 4.56 | 5.53 | 6.50 | 7.51 | 8.59 |
| 1967 | 0.18 | 0.44 | 0.86 | 1.35 | 2.01 | 2.78 | 3.63 | 4.56 | 5.53 | 6.50 | 7.51 | 8.59 |
| 1968 | 0.18 | 0.44 | 0.86 | 1.35 | 2.01 | 2.78 | 3.63 | 4.56 | 5.53 | 6.50 | 7.51 | 8.59 |
| 1969 | 0.18 | 0.44 | 0.86 | 1.35 | 2.01 | 2.78 | 3.63 | 4.56 | 5.53 | 6.50 | 7.51 | 8.59 |
| 1970 | 0.18 | 0.44 | 0.86 | 1.35 | 2.01 | 2.78 | 3.63 | 4.56 | 5.53 | 6.50 | 7.51 | 8.59 |
| 1971 | 0.18 | 0.44 | 0.86 | 1.35 | 2.01 | 2.78 | 3.63 | 4.56 | 5.53 | 6.50 | 7.51 | 8.59 |
| 1972 | 0.18 | 0.44 | 0.86 | 1.35 | 2.01 | 2.78 | 3.63 | 4.56 | 5.53 | 6.50 | 7.51 | 8.59 |
| 1973 | 0.18 | 0.44 | 0.86 | 1.35 | 2.01 | 2.78 | 3.63 | 4.56 | 5.53 | 6.50 | 7.51 | 8.59 |
| 1974 | 0.18 | 0.44 | 0.86 | 1.35 | 2.01 | 2.78 | 3.63 | 4.56 | 5.53 | 6.50 | 7.51 | 8.59 |
| 1975 | 0.18 | 0.44 | 0.86 | 1.35 | 2.01 | 2.78 | 3.63 | 4.56 | 5.53 | 6.50 | 7.51 | 8.59 |
| 1976 | 0.18 | 0.44 | 0.86 | 1.35 | 2.01 | 2.78 | 3.63 | 4.56 | 5.53 | 6.50 | 7.51 | 8.59 |
| 1977 | 0.49 | 0.44 | 0.95 | 1.42 | 2.12 | 2.86 | 3.67 | 4.50 | 5.48 | 6.38 | 7.84 | 9.37 |
| 1978 | 0.37 | 0.62 | 0.86 | 1.51 | 2.13 | 2.83 | 3.74 | 4.65 | 5.05 | 6.53 | 7.24 | 8.75 |
| 1979 | 0.31 | 0.54 | 0.84 | 1.33 | 2.11 | 3.00 | 3.59 | 5.16 | 6.01 | 6.51 | 8.28 | 9.17 |
| 1980 | 0.42 | 0.54 | 0.86 | 1.29 | 2.02 | 3.03 | 4.46 | 5.47 | 6.88 | 7.78 | 8.75 | 9.55 |
| 1981 | 0.38 | 0.64 | 0.97 | 1.43 | 1.95 | 2.85 | 3.96 | 5.54 | 7.18 | 8.12 | 8.51 | 9.44 |
| 1982 | 0.33 | 0.61 | 0.96 | 1.53 | 2.06 | 2.57 | 3.58 | 4.80 | 5.92 | 7.99 | 8.84 | 9.78 |
| 1983 | 0.43 | 0.61 | 1.01 | 1.53 | 2.14 | 2.77 | 3.30 | 4.44 | 5.89 | 7.23 | 9.31 | 10.11 |
| 1984 | 0.58 | 0.78 | 1.08 | 1.62 | 2.29 | 3.12 | 3.94 | 4.58 | 5.50 | 7.70 | 9.73 | 10.23 |
| 1985 | 0.58 | 0.75 | 1.13 | 1.58 | 2.35 | 3.01 | 4.35 | 5.34 | 5.83 | 6.57 | 9.42 | 10.83 |
| 1988 | 0.45 | 0.69 | 1.00 | 1.50 | 2.09 | 2.98 | 3.85 | 5.25 | 6.10 | 7.30 | 7.60 | 10.81 |
| 1987 | 0.46 | 0.64 | 0.95 | 1.39 | 2.06. | 2.71 | 3.69 | 4.69 | 5.84 | 6.57 | 7.86 | 8.19 |
| 1988 | 0.56 | 0.68 | 0.92 | 1.42 | 1.88 | 2.60 | 3.29 | 4.64 | 5.35 | 6.40 | 7.22 | 7.95 |
| 1989 | 0.54 | 0.71 | 0.98 | 1.33 | 1.94 | 2.70 | 3.46 | 4.31 | 5.60 | 6.40 | 7.15 | 8.07 |
| 1990 | 0.51 | 0.74 | 1.01 | 1.46 | 2.00 | 2.60 | 3.77 | 4.57 | 5.74 | 6.91 | 7.79 | 8.96 |
| 1991 | 0.56 | 0.66 | 1.00 | 1.49 | 2.09 | 2.67 | 3.33 | 4.22 | 5.68 | 6.98 | 8.10 | 8.99 |
| 1892 | 0.38 | 0.65 | 0.88 | 1.35 | 1.97 | 2.62 | 3.47 | 4.52 | 5.21 | 7.04 | 8.94 | 10.13 |
| 1993 | 0.23 | 0.56 | 0.86 | 1.24 | 1.82 | 2.51 | 3.54 | 4.22 | 5.09 | 6.94 | 7.32 | 9.25 |
| 1994 | 0.53 | 0.54 | 0.94 | 1.42 | 1.74 | 2.42 | 3.19 | 4.36 | 5.20 | 6.03 | 7.13 | 7.43 |
| 1995 | 0.38 | 0.72 | 1.13 | 1.63 | 2.14 | 2.39 | 3.08 | 3.93 | 4.32 | 5.12 | 6.59 | 7.88 |
| 1998 | 0.58 | 0.72 | 1.12 | 1.79 | 2.26 | 2.70 | 3.00 | 3.73 | 4.55 | 4.47 | 5.49 | 7.45 |
| 1997 | 0.51 | 0.78 | 1.13 | 1.67 | 2.27 | 2.86 | 3.20 | 3.37 | 4.30 | 5.54 | 6.34 | 8.83 |
| 1998 | 0.51 | 0.74 | 1.08 | 1.56 | 2.17 | 2.85 | 3.35 | 3.50 | 4.02 | 5.40 | 7.39 | 9.60 |

Table 17. Model estimates of the proportion of female cod mature at age in each year, extrapolated to 1999.

| Yearlage | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1978 | 0.000 | 0.000 | 0.000 | 0.006 | 0.076 | 0.355 | 0.753 | 0.959 | 0.997 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1979 | 0.000 | 0.000 | 0.001 | 0.010 | 0.073 | 0.285 | 0.623 | 0.885 | 0.981 | 0.998 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1980 | 0.000 | 0.000 | 0.000 | 0.004 | 0.057 | 0.315 | 0.731 | 0.957 | 0.998 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1981 | 0.000 | 0.000 | 0.001 | 0.014 | 0.110 | 0.396 | 0.758 | 0.952 | 0.996 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1982 | 0.000 | 0.000 | 0.000 | 0.003 | 0.051 | 0.290 | 0.701 | 0.946 | 0.996 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1983 | 0.000 | 0.001 | 0.007 | 0.051 | 0.200 | 0.482 | 0.774 | 0.939 | 0.991 | 0.999 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1984 | 0.000 | 0.000 | 0.007 | 0.057 | 0.242 | 0.573 | 0.857 | 0.975 | 0.998 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1985 | 0.000 | 0.000 | 0.000 | 0.002 | 0.047 | 0.348 | 0.813 | 0.985 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1986 | 0.000 | 0.000 | 0.000 | 0.002 | 0.047 | 0.313 | 0.760 | 0.971 | 0.999 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1987 | 0.000 | 0.000 | 0.000 | 0.003 | 0.042 | 0.233 | 0.606 | 0.897 | 0.988 | 0.999 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1988 | 0.000 | 0.000 | 0.000 | 0.005 | 0.037 | 0.165 | 0.436 | 0.743 | 0.929 | 0.989 | 0.999 | 1.000 | 1.000 | 1.000 |
| 1989 | 0.000 | 0.000 | 0.001 | 0.018 | 0.123 | 0.412 | 0.763 | 0.951 | 0.995 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1990 | 0.000 | 0.001 | 0.008 | 0.047 | 0.181 | 0.441 | 0.730 | 0.915 | 0.984 | 0.998 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1991 | 0.000 | 0.000 | 0.003 | 0.030 | 0.165 | 0.475 | 0.802 | 0.961 | 0.996 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1992 | 0.000 | 0.000 | 0.002 | 0.050 | 0.369 | 0.835 | 0.989 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1993 | 0.000 | 0.000 | 0.000 | 0.030 | 0.372 | 0.890 | 0.997 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1994 | 0.000 | 0.002 | 0.017 | 0.117 | 0.498 | 0.881 | 0.982 | 0.998 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1995 | 0.000 | 0.005 | 0.026 | 0.124 | 0.430 | 0.802 | 0.956 | 0.991 | 0.998 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1996 | 0.000 | 0.001 | 0.006 | 0.045 | 0.255 | 0.713 | 0.947 | 0.992 | 0.999 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1997 | 0.000 | 0.002 | 0.018 | 0.174 | 0.709 | 0.966 | 0.997 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1998 | 0.001 | 0.003 | 0.021 | 0.119 | 0.463 | 0.846 | 0.972 | 0.996 | 0.999 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1999 | 0.001 | 0.003 | 0.021 | 0.119 | 0.463 | 0.846 | 0.972 | 0.996 | 0.999 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |

Table 18. Parameter estimates (logged values for catchabilities) for an ADAPT applied to total catch and calibrated with the Canadian and French research vessel indices.

|  | Age | Parameter estimate | Standard error | Relative error | Bias | Relative bias |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\begin{aligned} & \hline \text { Canadian RV } \\ & \text { (logged) } \end{aligned}$ | 3 | -8.618 | 0.245 | -0.028 | -0.007 | 0.001 |
|  | 4 | -8.585 | 0.237 | -0.028 | -0.006 | 0.001 |
|  | 5 | -8.230 | 0.233 | -0.028 | -0.004 | 0.000 |
|  | 6 | -7.955 | 0.231 | -0.029 | -0.004 | 0.000 |
|  | 7 | -7.791 | 0.230 | -0.030 | -0.004 | 0.000 |
|  | 8 | -7.552 | 0.230 | -0.031 | -0.003 | 0.000 |
|  | 9 | -7.278 | 0.231 | -0.032 | -0.001 | 0.000 |
|  | 10 | -7.216 | 0.231 | -0.032 | 0.003 | 0.000 |
|  | 11 | -6.871 | 0.231 | -0.034 | 0.007 | -0.001 |
|  | 12 | -7.056 | 0.236 | -0.033 | 0.010 | -0.001 |
| French RV (logged) | 3 | -8.600 | 0.249 | -0.029 | -0.003 | 0.000 |
|  | 4 | -8.459 | 0.249 | -0.029 | -0.001 | 0.000 |
|  | 5 | -7.997 | 0.249 | -0.031 | 0.000 | 0.000 |
|  | 6 | -7.566 | 0.249 | -0.033 | 0.000 | 0.000 |
|  | 7 | -7.388 | 0.249 | -0.034 | 0.000 | 0.000 |
|  | 8 | -7.271 | 0.249 | -0.034 | 0.000 | 0.000 |
|  | 9 | -7.049 | 0.249 | -0.035 | 0.000 | 0.000 |
|  | 10 | -6.976 | 0.249 | -0.036 | 0.000 | 0.000 |
|  | 11 | -7.048 | 0.249 | -0.035 | 0.000 | 0.000 |
|  | 12 | -6.586 | 0.249 | -0.038 | 0.000 | 0.000 |
| Population | 3 | 8264 | 0 | 0 | 0 | 0 |
| Jan1 1998 | 4 | 11230 | 10112 | 0.9 | 4610 | 0.41 |
| ('000) | 5 | 7877 | 5216 | 0.66 | 1710 | 0.22 |
|  | 6 | 3447 | 2253 | 0.65 | 616 | 0.18 |
|  | 7 | 2082 | 1130 | 0.54 | 269 | 0.13 |
|  | 8 | 4473 | 2114 | 0.47 | 478 | 0.11 |
|  | 9 | 4609 | 2090 | 0.45 | 450 | 0.1 |
|  | 10 | 1051 | 495 | 0.47 | 107 | 0.1 |
|  | 11 | 609 | 299 | 0.49 | 69 | 0.11 |
|  | 12 | 111 | 61 | 0.55 | 14 | 0.12 |
|  | 13 | 0 | 0 | 2.71 | 0 | 3.64 |
|  | 14 | 29 | 15 | 0.52 | 3 | 0.12 |
|  | 15 | 6 | 1 | 0.25 | 0 | -0.05 |

Table 19. ADAPT estimates of numbers at age from the SPA applied to total catch and calibrated with both Canadian and French RV indices.

|  | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1959 | 58935 | 105929 | 35598 | 23905 | 16092 | 5740 | 3997 | 3399 | 3553 | 1137 | 148 | 3 | 0 |
| 1960 | 58776 | 47348 | 74168 | 22377 | 13053 | 8801 | 3851 | 2150 | 1654 | 2341 | 444 | 82 |  |
| 1961 | 50503 | 47609 | 33812 | 39463 | 12296 | 7565 | 4088 | 2237 | 1020 | 990 | 1550 | 113 | 43 |
| 1962 | 48229 | 40942 | 33945 | 18390 | 18031 | 6822 | 2042 | 1695 | 610 | 436 | 572 | 768 | 41 |
| 1963 | 42570 | 38363 | 27444 | 19705 | 10983 | 9636 | 4355 | 963 | 876 | 332 | 232 | 347 | 412 |
| 1964 | 70193 | 33986 | 27354 | 16099 | 11396 | 6720 | 5171 | 2758 | 527 | 588 | 183 | 94 | 202 |
| 1965 | 80265 | 55748 | 22618 | 17327 | 8536 | 6684 | 3813 | 2540 | 1672 | 131 | 189 | 101 | 53 |
| 1966 | 83586 | 63626 | 36969 | 13308 | 10940 | 4075 | 3629. | 2030 | 1156 | 1075 | 47 | 47 | 51 |
| 1967 | 97535 | 67578 | 39806 | 18560 | 6754 | 4387 | 1917 | 1337 | 736 | 484 | 531 | 10 | 19 |
| 1968 | 69444 | 77263 | 45502 | 21022 | 9467 | 3425 | 2368 | 1028 | 810 | 264 | 311 | 301 | 5 |
| 1969 | 53872 | 55824 | 51911 | 25463 | 11956 | 4552 | 1633 | 1445 | 461 | 464 | 117 | 250 | 51 |
| 1970 | 35044 | 43408 | 39309 | 32085 | 14403 | 5711 | 2154 | 630 | 544 | 323 | 272 | 36 | 106 |
| 1971 | 59298 | 28009 | 28238 | 20602 | 17509 | 6097 | 2481 | 1109 | 324 | 286 | 195 | 115 | 17 |
| 1972 | 38803 | 45946 | 17139 | 15426 | 10357 | 6998 | 2201 | 895 | 426 | 189 | 122 | 104 | 43 |
| 1973 | 30187 | 31109 | 33161 | 9909 | 9436 | 4366 | 3370 | 1056 | 320 | 166 | 51 | 57 | 45 |
| 1974 | 40467 | 23862 | 21231 | 16944 | 4525 | 4130 | 1612 | 966 | 405 | 109 | 38 | 29 | 21 |
| 1975 | 53769 | 31428 | 14108 | 8467 | 8173 | 1445 | 1722 | 306 | 312 | 111 | 19 | 3 |  |
| 1976 | 56435 | 42361 | 19143 | 6719 | 2888 | 1516 | 539 | 354 | 157 | 101 | 44 | 10 |  |
| 1977 | 73975 | 42498 | 23785 | 8587 | 2931 | 1199 | 797 | 315 | 242 | 113 | 64 | 33 |  |
| 1978 | 39527 | 59721 | 26560 | 12012 | 4157 | 1574 | 628 | 415 | 153 | 147 | 54 | 24 | 17 |
| 1979 | 23418 | 31908 | 44255 | 16266 | 6243 | 1836 | 705 | 303 | 181 | 61 | 96 | 29 | 11 |
| 1980 | 35138 | 19051 | 23355 | 26955 | 8772 | 3005 | 858 | 368 | 173 | 100 | 29 | 67 | 15 |
| 1981 | 63839 | 28436 | 14132 | 14576 | 14750 | 4157 | 1339 | 409 | 199 | 91 | 42 | 5 | 32 |
| 1982 | 40927 | 51344 | 20678 | 8751 | 7762 | 6837 | 1952 | 614 | 179 | 103 | 43 | 18 |  |
| 1983 | 65947 | 33390 | 37446 | 12945 | 5056 | 3792 | 2970 | 1024 | 285 | 72 | 57 | 26 | 9 |
| 1984 | 61112 | 53307 | 24919 | 22414 | 6939 | 2569 | 2073 | 1499 | 619 | 152 | 26 | 31 | 14 |
| 1985 | 51511 | 49851 | 39566 | 16318 | 12055 | 3689 | 1578 | 1210 | 923 | 387 | 93 | 14 | 18 |
| 1986 | 25318 | 42036 | 38433 | 25170 | 8745 | 5185 | 1696 | 732 | 504 | 440 | 219 | 57 | 6 |
| 1987 | 34416 | 20452 | 29818 | 22257 | 10576 | 3339 | 2307 | 807 | 398 | 259 | 232 | 108 | 26 |
| 1988 | 44799 | 27650 | 14082 | 14540 | 9498 | 3799 | 1468 | 901 | 356 | 193 | 142 | 70 | 44 |
| 1989 | 46014 | 35834 | 18181 | 7075 | 6123 | 3282 | 1510 | 639 | 483 | 181 | 91 | 69 | 30 |
| 1990 | 36245 | 36706 | 21257 | 7876 | 3231 | 2733 | 1690 | 699 | 323 | 269 | 97 | 48 | 33 |
| 1991 | 14678 | 27864 | 22302 | 10067 | 3471 | 1321 | 1133 | 765 | 260 | 138 | 127 | 38 | 20 |
| 1992 | 23659 | 11285 | 15649 | 9301 | 2994 | 923 | 365 | 376 | 245 | 117 | 45 | 59 | 11 |
| 1993 | 13860 | 18087 | 5514 | 5312 | 1842 | 458 | 175 | 62 | 136 | 36 | 22 |  | 12 |
| 1994 | 5121 | 11097 | 11470 | 2692 | 1545 | 332 | 26 | 64 | 17 | 65 | 18 | 6 |  |
| 1995 | 7069 | 4185 | 9015 | 9234 | 2137 | 1209 | 246 | 11 | 50 | 12 | 53 | 15 | 4 |
| 1996 | 9785 | 5785 | 3420 | 7330 | 7453 | 1698 | 957 | 195 | 7 | 41 | 10 | 44 | 11 |
| 1997 | 8159 | 8003 | 4697 | 2761 | 5910 | 5989 | 1359 | 762 | 153 | 4 | 32 | 8 | 35 |
| 1998 | 8264 | 6620 | 6167 | 2830 | 1813 | 3995 | 4159 | 944 | 540 | 97 | , | 26 | 5 |

Table 20. ADAPT estimates of fishing mortality at age from the SPA applied to total catch and calibrated with both Canadian and French RV indices.

|  | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1959 | 0.019 | 0.156 | 0.264 | 0.405 | 0.403 | 0.199 | 0.420 | 0.520 | 0.217 | 0.739 | 0.395 | 386 |
| 1960 | 0.011 | 0.137 | 0.431 | 0.399 | 0.345 | 0.567 | 0.343 | 0.546 | 0.314 | 0.212 | 1.170 | 0.450 |
| 1961 | 0.010 | 0.138 | 0.409 | 0.583 | 0.389 | 1.110 | 0.680 | 1.099 | 0.649 | 0.348 | 0.503 | 0.819 |
| 1962 | 0.029 | 0.200 | 0.344 | 0.315 | 0.427 | 0.249 | 0.551 | 0.460 | 0.409 | 0.433 | 0.300 | 0.422 |
| 1963 | 0.025 | 0.138 | 0.333 | 0.348 | 0.291 | 0.422 | 0.257 | 0.404 | 0.198 | 0.396 | 0.701 | 0.344 |
| 1964 | 0.030 | 0.207 | 0.257 | 0.434 | 0.333 | 0.367 | 0.511 | 0.300 | 1.192 | 0.935 | 0.391 | 0.378 |
| 1965 | 0.032 | 0.211 | 0.330 | 0.260 | 0.539 | 0.41 | 0.431 | 0.588 | 0.242 | 0.833 | 1.198 | 0.492 |
| 1966 | 0.013 | 0.269 | 0.489 | 0.478 | 0.714 | 0.554 | 0.799 | 0.815 | 0.670 | 0.504 | 1.352 | 0.720 |
| 1967 | 0.033 | 0.196 | 0.438 | 0.473 | 0.479 | 0.417 | 0.423 | 0.300 | 0.826 | 0.243 | 0.367 | 0.405 |
| 1968 | 0.018 | 0.198 | 0.381 | 0.364 | 0.532 | 0.541 | 0.294 | 0.601 | 0.357 | 0.616 | 0.018 | 0.492 |
| 1969 | 0.016 | 0.151 | 0.281 | 0.370 | 0.539 | 0.548 | 0.752 | 0.778 | 0.157 | 0.334 | 0.978 | 0.654 |
| 1970 | 0.024 | 0.230 | 0.446 | 0.406 | 0.660 | 0.634 | 0.464 | 0.465 | 0.444 | 0.304 | 0.664 | 0.556 |
| 1971 | 0.055 | 0.291 | 0.405 | 0.488 | 0.717 | 0.819 | 0.820 | 0.758 | 0.339 | 0.650 | 0.428 | 0.778 |
| 1972 | 0.021 | 0.126 | 0.348 | 0.291 | 0.664 | 0.531 | 0.534 | 0.829 | 0.744 | 1.111 | 0.562 | 0.639 |
| 1973 | 0.035 | 0.182 | 0.471 | 0.584 | 0.626 | 0.796 | 1.050 | 0.758 | 0.879 | 1.266 | 0.358 | 0.808 |
| 1974 | 0.053 | 0.326 | 0.719 | 0.529 | 0.941 | 0.675 | 1.461 | 0.930 | 1.097 | 1.570 | 2.229 | 1.002 |
| 1975 | 0.038 | 0.296 | 0.542 | 0.875 | 1.485 | 0.787 | 1.383 | 0.471 | 0.931 | 0.717 | 438 | 1.031 |
| 1976 | 0.084 | 0.377 | 0.602 | 0.630 | 0.679 | 0.443 | 0.336 | 0.180 | 0.127 | 0.260 | 0.105 | 0.409 |
| 1977 | 0.014 | 0.270 | 0.483 | 0.526 | 0.422 | 0.447 | 0.453 | 0.521 | 0.300 | 0.539 | 0.758 | 0.461 |
| 1978 | 0.014 | 0.100 | 0.290 | 0.454 | 0.617 | 0.604 | 0.527 | 0.631 | 0.718 | 0.226 | 0.424 | 0.595 |
| 1979 | 0.006 | 0.112 | 0.296 | 0.417 | 0.531 | 0.561 | 0.450 | 0.362 | 0.388 | 0.560 | 0.162 | 0.476 |
| 1980 | 0.012 | 0.099 | 0.271 | 0.403 | 0.547 | 0.609 | 0.539 | 0.415 | 0.438 | 0.671 | 1.557 | 0.527 |
| 1981 | 0.018 | 0.119 | 0.279 | 0.430 | 0.569 | 0.556 | 0.580 | 0.629 | 0.460 | 0.543 | 0.630 | 0.583 |
| 1982 | 0.004 | 0.116 | 0.268 | 0.349 | 0.516 | 0.634 | 0.445 | 0.567 | 0.706 | 0.385 | 0.325 | 0.540 |
| 1983 | 0.013 | 0.093 | 0.313 | 0.424 | 0.477 | 0.404 | 0.484 | 0.303 | 0.431 | 0.816 | 0.421 | 0.417 |
| 1984 | 0.004 | 0.098 | 0.223 | 0.420 | 0.432 | 0.287 | 0.338 | 0.284 | 0.271 | 0.292 | 0.408 | 0.335 |
| 198 | 0.003 | 0.060 | 0.252 | 0.424 | 0.644 | 0.577 | 0.568 | 0.676 | 0.541 | 0.370 | 0.286 | 0.616 |
| 1986 | 0.013 | 0.143 | 0.346 | 0.667 | 0.763 | 0.610 | 0.543 | 0.408 | 0.464 | 0.440 | 0.503 | 0.581 |
| 1987 | 0.019 | 0.173 | 0.518 | 0.652 | 0.824 | 0.622 | 0.740 | 0.619 | 0.526 | 0.400 | 0.998 | 0.701 |
| 1988 | 0.023 | 0.219 | 0.488 | 0.665 | 0.863 | 0.723 | 0.632 | 0.424 | 0.476 | 0.554 | 0.523 | 0.660 |
| 1989 | 0.026 | 0.322 | 0.637 | 0.584 | 0.607 | 0.464 | 0.570 | 0.482 | 0.386 | 0.423 | 0.432 | 0.530 |
| 1990 | 0.063 | 0.298 | 0.547 | 0.619 | 0.694 | 0.681 | 0.593 | 0.788 | 0.653 | 0.550 | 0.750 | 0.689 |
| 1991 | 0.063 | 0.377 | 0.675 | 1.013 | 1.125 | 1.085 | 0.904 | 0.937 | 0.604 | 0.917 | 0.563 | 1.012 |
| 1992 | 0.069 | 0.516 | 0.881 | 1.419 | 1.678 | 1.464 | 1.572 | 0.813 | 1.706 | 1.459 | 1.666 | 1.375 |
| 1993 | 0.022 | 0.256 | 0.517 | 1.035 | 1.515 | 2.652 | 0.808 | 1.087 | 0.539 | 0.495 | 1.151 | 1.481 |
| 1994 | 0.002 | 0.008 | 0.017 | 0.031 | 0.045 | 0.098 | 0.684 | 0.053 | 0.137 | 0.000 | 0.000 | 0.213 |
| 1995 | 0.000 | 0.002 | 0.007 | 0.014 | 0.030 | 0.034 | 0.032 | 0.225 | 0.000 | 0.000 | 0.000 | 0.077 |
| 1996 | 0.001 | 0.008 | 0.014 | 0.015 | 0.019 | 0.023 | 0.028 | 0.046 | 0.367 | 0.028 | 0.000 | 0.026 |
| 1997 | 0.009 | 0.061 | 0.307 | 0.220 | 0.192 | 0.165 | 0.164 | 0.144 | 0.252 | 17.514 | 0.035 | 0.144 |

Table 21. Parameter estimates (logged values for catchabilities) for ADAPT applied to the offshore catch and calibrated with the Canadian and French research vessel indices.

|  | Age | Parameter <br> estimate | Standard <br> error |  | Relative <br> Error | Bias |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | | Relative |
| :--- |
| bias |

Table 22. Parameter estimates for QLSPA applied to total catch and calibrated with Canadian and French research vessel indices.

|  | Age | Parameter estimate | CV | ower 95 <br> Cl | pper 95\% Cl |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Populatio | 3 | 13924.13 | 0.95 | 2163.8 | 89602.12 |
| Jan 1199 | 4 | 11333.47 | 0.67 | 3074.71 | 41775.52 |
| ('000) | 5 | 7419.12 | 0.53 | 2618.37 | 21021.99 |
|  | 6 | 3594.99 | 0.47 | 1424.14 | 9074.88 |
|  | 7 | 10434.42 | 0.42 | 4588.28 | 23729.4 |
|  | 8 | 11366.36 | 0.4 | 5228.07 | 24711.6 |
|  | 9 | 2292.95 | 0.4 | 1052.59 | 4994.9 |
|  | 10 | 2189.64 | 0.42 | 966.64 | 4959.97 |
|  | 11 | 606.74 | 0.43 | 262.47 | 1402.57 |
|  | 12 | 77.92 | 0.46 | 31.82 | 190.82 |
|  | 13 | 52.81 | 0.51 | 19.34 | 144.25 |
|  |  | Parameter estimate | Standard error |  |  |
| $\begin{aligned} & \hline \text { Canadian } \\ & \text { RV } \\ & (\times 1000) \end{aligned}$ | 3 | 0.17766 | 0.04196 |  |  |
|  | 4 | 0.20299 | 0.04795 |  |  |
|  | 5 | 0.29737 | 0.07024 |  |  |
|  | 6 | 0.36578 | 0.08640 |  |  |
|  | 7 | 0.45676 | 0.10789 |  |  |
|  | 8 | 0.57171 | 0.13504 |  |  |
|  | 9 | 0.63744 | 0.15056 |  |  |
|  | 10 | 0.65529 | 0.15478 |  |  |
|  | 11 | 0.86899 | 0.20526 |  |  |
|  | 12 | 0.98953 | 0.23373 |  |  |
| French | 3 | 0.22703 | 0.04344 |  |  |
| $\begin{aligned} & \text { RV } \\ & (\times 1000) \end{aligned}$ | 4 | 0.25210 | 0.04824 |  |  |
|  | 5 | 0.35877 | 0.06865 |  |  |
|  | 6 | 0.57507 | 0.11004 |  |  |
|  | 7 | 0.65908 | 0.12611 |  |  |
|  | 8 | 0.71644 | 0.13709 |  |  |
|  | 9 | 0.92654 | 0.17729 |  |  |
|  | 10 | 0.94623 | 0.18106 |  |  |
|  | 11 | 0.99301 | 0.19001 |  |  |
|  | 12 | 1.55628 | 0.29779 |  |  |

Table 23. QLSPA estimates of numbers at age from the SPA applied to total catch and calibrated with both Canadian and French RV indices.

|  | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1959 | 59419 | 107000 | 35864 | 24209 | 16269 | 5809 | 4039 | 3431 | 3584 | 1155 | 149 | 3 |
| 1960 | 59250 | 47742 | 74902 | 22554 | 13247 | 8908 | 3904 | 2174 | 1669 | 2364 | 452 | 83 |
| 1961 | 50925 | 47996 | 34115 | 39876 | 12390 | 7701 | 4141 | 2273 | 1031 | 999 | 1567 | 114 |
| 1962 | 48648 | 41286 | 34242 | 18560 | 18206 | 6872 | 2070 | 1717 | 616 | 441 | 578 | 776 |
| 1963 | 42939 | 38703 | 27696 | 19889 | 11094 | 9735 | 4390 | 979 | 889 | 335 | 234 | 351 |
| 1964 | 70843 | 34286 | 27617 | 16259 | 11510 | 6796 | 5229 | 2782 | 537 | 599 | 185 | 95 |
| 1965 | 81001 | 56277 | 22837 | 17512 | 8626 | 6759 | 3862 | 2570 | 1687 | 133 | 193 | 103 |
| 1966 | 84380 | 64224 | 37357 | 13450 | 11072 | 4118 | 3674 | 2060 | 1169 | 1086 | 48 | 47 |
| 1967 | 98464 | 68226 | 40221 | 18763 | 6831 | 4433 | 1936 | 1350 | 747 | 490 | 537 | 10 |
| 1968 | 70175 | 78018 | 45984 | 21257 | 9578 | 3467 | 2395 | 1039 | 819 | 267 | 315 | 305 |
| 1969 | 54402 | 56420 | 52473 | 25763 | 12108 | 4610 | 1655 | 1464 | 466 | 470 | 118 | 253 |
| 1970 | 35407 | 43840 | 39770 | 32479 | 14598 | 5793 | 2185 | 638 | 550 | 326 | 276 | 36 |
| 1971 | 60044 | 28305 | 28551 | 20874 | 17757 | 6185 | 2520 | 1128 | 329 | 289 | 197 | 117 |
| 1972 | 39272 | 46550 | 17343 | 15618 | 10516 | 7103 | 2231 | 910 | 434 | 192 | 124 | 106 |
| 1973 | 30474 | 31492 | 33639 | 10045 | 9573 | 4445 | 3430 | 1072 | 326 | 170 | 52 | 58 |
| 1974 | 40863 | 24095 | 21524 | 17238 | 4596 | 4198 | 1647 | 981 | 412 | 111 | 40 | 30 |
| 1975 | 54261 | 31748 | 14260 | 8586 | 8354 | 1465 | 1757 | 309 | 317 | 112 | 19 | 3 |
| 1976 | 56882 | 42761 | 19362 | 6792 | 2921 | 1531 | 545 | 356 | 158 | 102 | 45 | 10 |
| 1977 | 74627 | 42852 | 24026 | 8683 | 2959 | 1210 | 806 | 319 | 244 | 114 | 64 | 33 |
| 1978 | 39870 | 60253 | 26800 | 12137 | 4205 | 1591 | 634 | 420 | 156 | 148 | 54 | 25 |
| 1979 | 23627 | 32189 | 44675 | 16426 | 6312 | 1857 | 711 | 306 | 183 | 62 | 97 | 29 |
| 1980 | 35454 | 19222 | 23574 | 27238 | 8864 | 3039 | 868 | 372 | 175 | 102 | 29 | 67 |
| 1981 | 64461 | 28694 | 14267 | 14728 | 14921 | 4200 | 1353 | 415 | 201 | 92 | 43 | 5 |
| 1982 | 41355 | 51852 | 20880 | 8843 | 7849 | 6918 | 1971 | 620 | 181 | 104 | 44 | 19 |
| 1983 | 66873 | 33741 | 37845 | 13086 | 5116 | 3837 | 3005 | 1035 | 288 | 73 | 58 | 26 |
| 1984 | 62374 | 54063 | 25198 | 22684 | 7022 | 2603 | 2101 | 1518 | 626 | 153 | 26 | 31 |
| 1985 | 52552 | 50884 | 40173 | 16524 | 12222 | 3740 | 1603 | 1230 | 937 | 392 | 94 | 14 |
| 1986 | 25639 | 42888 | 39272 | 25624 | 8874 | 5263 | 1723 | 746 | 514 | 448 | 222 | 58 |
| 1987 | 34999 | 20715 | 30496 | 22876 | 10820 | 3390 | 2348 | 822 | 408 | 266 | 237 | 110 |
| 1988 | 45895 | 28125 | 14285 | 14994 | 9895 | 3924 | 1495 | 921 | 365 | 199 | 147 | 72 |
| 1989 | 48953 | 36730 | 18547 | 7198 | 6421 | 3536 | 1590 | 654 | 497 | 187 | 95 | 73 |
| 1990 | 42466 | 39111 | 21933 | 8090 | 3302 | 2951 | 1889 | 759 | 333 | 279 | 102 | 52 |
| 1991 | 17874 | 32953 | 24219 | 10542 | 3611 | 1362 | 1297 | 920 | 305 | 144 | 135 | 41 |
| 1992 | 38312 | 13899 | 19758 | 10756 | 3286 | 998 | 385 | 501 | 366 | 152 | 49 | 65 |
| 1993 | 23930 | 30080 | 7616 | 8554 | 2890 | 640 | 222 | 72 | 236 | 131 | 49 | 10 |
| 1994 | 6641 | 19341 | 21269 | 4394 | 4148 | 1159 | 161 | 101 | 24 | 146 | 95 | 28 |
| 1995 | 11129 | 5429 | 15765 | 17257 | 3531 | 3340 | 924 | 121 | 80 | 18 | 120 | 78 |
| 1996 | 13853 | 9109 | 4438 | 12856 | 14021 | 2839 | 2701 | 750 | 97 | 66 | 15 | 98 |
| 1997 | 13924 | 11333 | 7419 | 3595 | 10434 | 11366 | 2293 | 2190 | 607 | 78 | 53 | 12 |

Table 24. QLSPA estimates of fishing mortality at age from the SPA applied to total catch and calibrated with both Canadian and French RV indices.

|  | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1959 | 0.019 | 0.156 | 0.264 | 0.403 | 0.402 | 0.197 | 0.419 | 0.521 | 0.216 | 0.737 | 0.394 | 0.385 |
| 1960 | 0.011 | 0.136 | 0.430 | 0.399 | 0.342 | 0.566 | 0.341 | 0.546 | 0.313 | 0.211 | 1.175 | 0.449 |
| 1961 | 0.010 | 0.138 | 0.409 | 0.584 | 0.389 | 1.114 | 0.680 | 1.106 | 0.650 | 0.347 | 0.502 | 0.822 |
| 1962 | 0.029 | 0.199 | 0.343 | 0.315 | 0.426 | 0.248 | 0.549 | 0.458 | 0.409 | 0.432 | 0.299 | 0.420 |
| 1963 | 0.025 | 0.138 | 0.333 | 0.347 | 0.290 | 0.422 | 0.256 | 0.400 | 0.196 | 0.395 | 0.703 | 0.342 |
| 1964 | 0.030 | 0.206 | 0.256 | 0.434 | 0.332 | 0.365 | 0.510 | 0.300 | 1.195 | 0.934 | 0.390 | 0.377 |
| 1965 | 0.032 | 0.210 | 0.329 | 0.258 | 0.539 | 0.409 | 0.429 | 0.587 | 0.241 | 0.830 | 1.204 | 0.491 |
| 1966 | 0.013 | 0.268 | 0.489 | 0.478 | 0.715 | 0.555 | . 0.801 | 0.815 | 0.671 | 0.504 | 1.362 | 0.722 |
| 1967 | 0.033 | 0.195 | 0.438 | 0.472 | 0.478 | 0.416 | 0.423 | 0.299 | 0.827 | 0.241 | 0.366 | 0.404 |
| 1968 | 0.018 | 0.197 | 0.379 | 0.363 | 0.531 | 0.540 | 0.292 | 0.602 | 0.356 | 0.614 | 0.018 | 0.491 |
| 1969 | 0.016 | 0.150 | 0.280 | 0.368 | 0.537 | 0.547 | 0.753 | 0.779 | 0.156 | 0.332 | 0.981 | 0.654 |
| 1970 | 0.024 | 0.229 | 0.445 | 0.404 | 0.659 | 0.632 | 0.461 | 0.463 | 0.443 | 0.302 | 0.662 | 0.554 |
| 1971 | 0.055 | 0.290 | 0.403 | 0.486 | 0.716 | 0.820 | 0.819 | 0.755 | 0.336 | 0.649 | 0.426 | 0.778 |
| 1972 | 0.021 | 0.125 | 0.346 | 0.289 | 0.661 | 0.528 | 0.532 | 0.826 | 0.738 | 1.115 | 0.560 | 0.637 |
| 1973 | 0.035 | 0.181 | 0.469 | 0.582 | 0.624 | 0.793 | 1.051 | 0.757 | 0.875 | 1.258 | 0.356 | 0.806 |
| 1974 | 0.052 | 0.325 | 0.719 | 0.524 | 0.944 | 0.671 | 1.473 | 0.931 | 1.102 | 1.584 | 2.247 | 1.005 |
| 1975 | 0.038 | 0.295 | 0.542 | 0.878 | 1.497 | 0.789 | 1.396 | 0.471 | 0.935 | 0.719 | 0.438 | 1.038 |
| 1976 | 0.083 | 0.376 | 0.602 | 0.631 | 0.681 | 0.442 | 0.334 | 0.180 | 0.127 | 0.259 | 0.104 | 0.409 |
| 1977 | 0.014 | 0.269 | 0.483 | 0.525 | 0.421 | 0.447 | 0.452 | 0.519 | 0.299 | 0.539 | 0.760 | 0.460 |
| 1978 | 0.014 | 0.099 | 0.290 | 0.454 | 0.617 | 0.605 | 0.527 | 0.632 | 0.715 | 0.225 | 0.423 | 0.595 |
| 1979 | 0.006 | 0.111 | 0.295 | 0.417 | 0.531 | 0.561 | 0.449 | 0.361 | 0.386 | 0.554 | 0.161 | 0.476 |
| 1980 | 0.012 | 0.098 | 0.270 | 0.402 | 0.547 | 0.609 | 0.539 | 0.414 | 0.438 | 0.672 | 1.568 | 0.527 |
| 1981 | 0.018 | 0.118 | 0.278 | 0.429 | 0.569 | 0.557 | 0.580 | 0.628 | 0.459 | 0.543 | 0.631 | 0.583 |
| 1982 | 0.003 | 0.115 | 0.267 | 0.347 | 0.516 | 0.634 | 0.444 | 0.567 | 0.706 | 0.384 | 0.324 | 0.540 |
| 1983 | 0.013 | 0.092 | 0.312 | 0.422 | 0.476 | 0.402 | 0.483 | 0.302 | 0.430 | 0.817 | 0.420 | 0.416 |
| 1984 | 0.004 | 0.097 | 0.222 | 0.418 | 0.430 | 0.285 | 0.336 | 0.282 | 0.270 | 0.291 | 0.406 | 0.333 |
| 1985 | 0.003 | 0.059 | 0.250 | 0.422 | 0.642 | 0.575 | 0.565 | 0.673 | 0.538 | 0.368 | 0.284 | 0.614 |
| 1986 | 0.013 | 0.141 | 0.340 | 0.662 | 0.762 | 0.607 | 0.540 | 0.403 | 0.459 | 0.435 | 0.500 | 0.578 |
| 1987 | 0.019 | 0.172 | 0.510 | 0.638 | 0.814 | 0.619 | 0.736 | 0.613 | 0.517 | 0.392 | 0.991 | 0.696 |
| 1988 | 0.023 | 0.216 | 0.485 | 0.648 | 0.829 | 0.703 | 0.627 | 0.417 | 0.466 | 0.538 | 0.507 | 0.644 |
| 1989 | 0.024 | 0.316 | 0.630 | 0.579 | 0.578 | 0.427 | 0.539 | 0.473 | 0.376 | 0.410 | 0.410 | 0.504 |
| 1990 | 0.054 | 0.279 | 0.533 | 0.607 | 0.686 | 0.622 | 0.519 | 0.712 | 0.636 | 0.530 | 0.714 | 0.635 |
| 1991 | 0.052 | 0.312 | 0.612 | 0.966 | 1.086 | 1.064 | 0.752 | 0.722 | 0.497 | 0.872 | 0.528 | 0.906 |
| 1992 | 0.042 | 0.402 | 0.637 | 1.114 | 1.436 | 1.304 | 1.480 | 0.551 | 0.831 | 0.926 | 1.426 | 1.193 |
| 1993 | 0.013 | 0.147 | 0.350 | 0.524 | 0.714 | 1.179 | 0.585 | 0.881 | 0.279 | 0.117 | 0.377 | 0.840 |
| 1994 | 0.001 | 0.004 | 0.009 | 0.019 | 0.017 | 0.027 | 0.086 | 0.033 | 0.095 | 0.000 | 0.000 | 0.041 |
| 1995 | 0.000 | 0.001 | 0.004 | 0.008 | 0.018 | 0.012 | 0.008 | 0.018 | 0.000 | 0.000 | 0.000 | 0.014 |
| 1996 | 0.001 | 0.005 | 0.011 | 0.009 | 0.010 | 0.014 | 0.010 | 0.012 | 0.023 | 0.017 | 0.000 | 0.011 |
| 1997 | 0.005 | 0.043 | 0.184 | 0.166 | 0.105 | 0.084 | 0.094 | 0.048 | 0.058 | 0.058 | 0.021 | 0.000 |

Table 25. Parameter estimates for QLSPA applied to offshore catch and calibrated with Canadian and French research vessel indices.

|  | Age | Parameter <br> estimate | CV | Lower <br> $95 \% \mathrm{Cl}$ | Upper <br> $95 \% \mathrm{Cl}$ |
| :--- | ---: | ---: | ---: | ---: | ---: |
| Population | 3 | 6107.37 | 1.02 | 825.73 | 45172.22 |
| Jan 1 1997 | 4 | 5001.71 | 0.72 | 1223.29 | 20450.71 |
| ('000) | 5 | 3359.95 | 0.58 | 1077.87 | 10473.72 |
|  | 6 | 1653.63 | 0.51 | 607.13 | 4503.99 |
|  | 7 | 4930.2 | 0.45 | 2047.35 | 11872.35 |
|  | 8 | 5583.14 | 0.41 | 2494.98 | 12493.66 |
|  | 9 | 1431.44 | 0.4 | 656.68 | 3120.24 |
|  | 10 | 1991.91 | 0.39 | 930.71 | 4263.11 |
|  | 11 | 220.28 | 0.4 | 99.81 | 486.14 |
|  | 12 | 22.22 | 0.41 | 10.03 | 49.18 |
|  | 13 | 29.39 | 0.53 | 10.4 | 83.04 |


|  | Parameter <br> estimate |  |  |
| :--- | ---: | ---: | ---: |
| Standard |  |  |  |
| error |  |  |  |

Table 26. Parameter estimates for QLSPA applied to offshore catch and calibrated with Canadian and French research vessel indices. Separate catchabilities estimated for February-March surveys and April surveys for the Canadian index.

|  | Age | Parameter estimate | CV | Upper 95\% CI | Lower 95\% CI |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Population | 3 | 18529.24 | 1.1 | 2156.64 | 159198.2 |
| Jan 11997 | 4 | 14803.12 | 0.78 | 3198.07 | 68520.15 |
| ('000) | 5 | 9259.06 | 0.63 | 2710.16 | 31632.88 |
|  | 6 | 4417.7 | 0.56 | 1478.73 | 13197.88 |
|  | 7 | 11939.46 | 0.49 | 4606.04 | 30948.66 |
|  | 8 | 11339.32 | 0.43 | 4878.46 | 26356.75 |
|  | 9 | 2441.6 | 0.39 | 1128.97 | 5280.39 |
|  | 10 | 2720.37 | 0.39 | 1269.8 | 5828 |
|  | 11 | 196.53 | 0.4 | 89.75 | 430.34 |
|  | 12 | 14.59 | 0.42 | 6.44 | 33.07 |
|  | 13 | 20.13 | 0.58 | 6.52 | 62.15 |
|  | 14 | 5.11 | 0.73 | 1.21 | 21.5 |
|  | Age | Month | Parameter estimate | Standard error |  |
| $\begin{aligned} & \hline \text { Canadian RV } \\ & (\times 1000) \end{aligned}$ | 3 | APR | 0.133299 | 0.049645 |  |
|  | 4 | APR | 0.166706 | 0.062087 |  |
|  | 5 | APR | 0.276567 | 0.103003 |  |
|  | 6 | APR | 0.368993 | 0.137426 |  |
|  | 7 | APR | 0.428748 | 0.159681 |  |
|  | 8 | APR | 0.701346 | 0.261207 |  |
|  | 9 | APR | 1.853975 | 0.690487 |  |
|  |  | APR | 2.393971 | 0.891601 |  |
|  |  | APR | 2.912222 | 1.084617 |  |
|  |  | APR | 1.365923 | 0.508719 |  |
|  | 3 | FEB-MAR | 0.415662 | 0.144809 |  |
|  | 4 | FEB-MAR | 0.469085 | 0.163421 |  |
|  | 5 | FEB-MAR | 0.676725 | 0.235759 |  |
|  | 6 | FEB-MAR | 0.837956 | 0.291929 |  |
|  | 7 | FEB-MAR | 1.140846 | 0.39745 |  |
|  | 8 | FEB-MAR | 1.186425 | 0.413329 |  |
|  | 9 | FEB-MAR | 1.045051 | 0.364077 |  |
|  | 10 | FEB-MAR | 1.011318 | 0.352325 |  |
|  | 11 | FEB-MAR | 1.696953 | 0.591188 |  |
|  | 12 | FEB-MAR | 1.970704 | 0.686558 |  |
| $\begin{aligned} & \text { French RV } \\ & (\times 1000) \end{aligned}$ | 3 | FEB | 0.493516 | 0.107519 |  |
|  | 4 | FEB | 0.563168 | 0.122694 |  |
|  | 5 | FEB | 0.782346 | 0.170445 |  |
|  | 6 | FEB | 1.222370 | 0.266310 |  |
|  | 7 | FEB | 1.323017 | 0.288238 |  |
|  | 8 | FEB | 1.463056 | 0.318747 |  |
|  |  | FEB | 2.015848 | 0.43918 |  |
|  | 10 | FEB | 2.392412 | 0.52122 |  |
|  | 11 | FEB | 2.656506 | 0.578757 |  |
|  |  | FEB | 4.232750 | 0.922163 |  |

Table 27. QLSPA esimates of numbers at age from the SPA applied to offshore catch and calibrated with both Canadian and French RV indices, with seasonal catchabilities for the Canadian survey.

|  | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1977 | 22660 | 12951 | 6720 | 2138 | 621 | 218 | 130 | 51 | 23 | 11 | 4 | 6 |
| 1978 | 13397 | 18279 | 8652 | 3589 | 1152 | 354 | 116 | 70 | 26 | 12 | 6 | 2 |
| 1979 | 8995 | 10704 | 13844 | 5369 | 1507 | 428 | 123 | 67 | 37 | 14 | 6 | 3 |
| 1980 | 14164 | 7342 | 7798 | 8250 | 2763 | 731 | 214 | 56 | 38 | 26 | 7 | 3 |
| 1981 | 24417 | 11472 | 5757 | 5445 | 5006 | 1341 | 364 | 129 | 37 | 29 | 19 | 3 |
| 1982 | 22594 | 19847 | 8936 | 4022 | 3165 | 2432 | 645 | 198 | 77 | 20 | 14 | 12 |
| 1983 | 40970 | 18457 | 15137 | 6006 | 2345 | 1635 | 1161 | 346 | 99 | 38 | 7 | 8 |
| 1984 | 41033 | 33428 | 14550 | 9672 | 3464 | 1281 | 928 | 658 | 228 | 58 | 27 | 4 |
| 1985 | 26541 | 33512 | 25575 | 10306 | 5918 | 1872 | 816 | 511 | 428 | 146 | 34 | 19 |
| 1986 | 11541 | 21642 | 25064 | 15929 | 5916 | 2803 | 939 | 442 | 224 | 191 | 60 | 21 |
| 1987 | 13706 | 9420 | 16052 | 14453 | 6670 | 2318 | 1304 | 429 | 262 | 102 | 93 | 15 |
| 1988 | 19975 | 11130 | 7019 | 8259 | 6273 | 2522 | 1001 | 480 | 165 | 126 | 59 | 26 |
| 1989 | 18763 | 15724 | 6942 | 3119 | 3800 | 2261 | 1079 | 433 | 270 | 89 | 59 | 26 |
| 1990 | 18862 | 14849 | 9949 | 3352 | 1574 | 2363 | 1368 | 627 | 218 | 166 | 61 | 36 |
| 1991 | 10743 | 14941 | 9129 | 4853 | 1488 | 736 | 1161 | 697 | 314 | 102 | 82 | 28 |
| 1992 | 31513 | 8402 | 10233 | 3351 | 1213 | 385 | 188 | 580 | 279 | 206 | 30 | 41 |
| 1993 | 26630 | 25678 | 5974 | 6916 | 799 | 179 | 80 | 33 | 352 | 126 | 121 | 4 |
| 1994 | 8064 | 21800 | 20747 | 4477 | 4982 | 371 | 31 | 37 | 35 | 261 | 95 | 95 |
| 1995 | 13818 | 6601 | 17840 | 16969 | 3659 | 4073 | 301 | 24 | 30 | 8 | 214 | 78 |
| 1996 | 18082 | 11313 | 5404 | 14601 | 13880 | 2990 | 3330 | 244 | 19 | 25 | 6 | 175 |
| 1997 | 18529 | 14803 | 9259 | 4418 | 11939 | 11339 | 2442 | 2720 | 197 | 15 | 20 |  |

Table 28. QLSPA esimates of fishing mortality at age from the SPA applied to offshore catch and calibrated with both Canadian and French RV indices, with seasonal catchabilities for the Canadian survey.

|  | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| 1977 | 0.015 | 0.203 | 0.427 | 0.419 | 0.363 | 0.430 | 0.417 | 0.462 | 0.415 | 0.495 | 0.316 | 0.418 |
| 1978 | 0.024 | 0.078 | 0.277 | 0.668 | 0.790 | 0.855 | 0.350 | 0.427 | 0.412 | 0.444 | 0.496 | 0.606 |
| 1979 | 0.003 | 0.117 | 0.318 | 0.464 | 0.524 | 0.494 | 0.596 | 0.376 | 0.160 | 0.493 | 0.418 | 0.497 |
| 1980 | 0.011 | 0.043 | 0.159 | 0.300 | 0.523 | 0.497 | 0.306 | 0.197 | 0.060 | 0.136 | 0.630 | 0.381 |
| 1981 | 0.007 | 0.050 | 0.159 | 0.343 | 0.522 | 0.531 | 0.407 | 0.309 | 0.439 | 0.543 | 0.271 | 0.442 |
| 1982 | 0.002 | 0.071 | 0.197 | 0.339 | 0.461 | 0.540 | 0.422 | 0.494 | 0.510 | 0.823 | 0.386 | 0.479 |
| 1983 | 0.003 | 0.038 | 0.248 | 0.350 | 0.405 | 0.367 | 0.367 | 0.216 | 0.327 | 0.157 | 0.374 | 0.339 |
| 1984 | 0.002 | 0.068 | 0.145 | 0.291 | 0.416 | 0.252 | 0.397 | 0.231 | 0.246 | 0.334 | 0.133 | 0.324 |
| 1985 | 0.004 | 0.090 | 0.273 | 0.355 | 0.547 | 0.490 | 0.412 | 0.626 | 0.607 | 0.690 | 0.298 | 0.519 |
| 1986 | 0.003 | 0.099 | 0.351 | 0.671 | 0.737 | 0.565 | 0.583 | 0.325 | 0.580 | 0.520 | 1.202 | 0.552 |
| 1987 | 0.008 | 0.094 | 0.465 | 0.635 | 0.773 | 0.640 | 0.799 | 0.756 | 0.534 | 0.344 | 1.062 | 0.742 |
| 1988 | 0.039 | 0.272 | 0.611 | 0.576 | 0.820 | 0.649 | 0.638 | 0.375 | 0.418 | 0.548 | 0.625 | 0.62 |
| 1989 | 0.034 | 0.258 | 0.528 | 0.484 | 0.275 | 0.302 | 0.344 | 0.486 | 0.287 | 0.176 | 0.301 | 0.352 |
| 1990 | 0.033 | 0.286 | 0.518 | 0.612 | 0.560 | 0.511 | 0.474 | 0.491 | 0.563 | 0.509 | 0.570 | 0.509 |
| 1991 | 0.046 | 0.178 | 0.802 | 1.186 | 1.152 | 1.165 | 0.495 | 0.717 | 0.219 | 1.026 | 0.498 | 0.882 |
| 1992 | 0.005 | 0.141 | 0.192 | 1.234 | 1.714 | 1.370 | 1.525 | 0.298 | 0.594 | 0.334 | 1.912 | 1.227 |
| 1993 | 0.000 | 0.013 | 0.088 | 0.128 | 0.568 | 1.563 | 0.582 | 1.080 | 0.099 | 0.082 | 0.047 | 0.948 |
| 1994 | 0.000 | 0.000 | 0.001 | 0.002 | 0.001 | 0.009 | 0.037 | 0.000 | 0.000 | 0.000 | 0.000 | 0.012 |
| 1995 | 0.000 | 0.000 | 0.000 | 0.001 | 0.002 | 0.001 | 0.007 | 0.047 | 0.000 | 0.000 | 0.000 | 0.014 |
| 1996 | 0.000 | 0.000 | 0.001 | 0.001 | 0.002 | 0.003 | 0.002 | 0.018 | 0.060 | 0.000 | 0.000 | 0.006 |
| 1997 | 0.000 | 0.002 | 0.006 | 0.008 | 0.012 | 0.013 | 0.008 | 0.000 | 0.034 | 0.000 | 0.000 | 0.000 |

Table 29. Biological reference points for the 3Ps cod stock derived from the precautionary plots illustrated in Figs. 27-29. See text for an explantion of the reference points.

| Model/Catch/RV <br> Model <br> Catch data <br> RV indices | ADAPT | QLSPA <br> Total <br>  <br> French | Total <br>  <br> French |
| :--- | ---: | ---: | ---: |

Table 30.

| Decision Table - 3Ps cod - ADAPT - Canadian and French RV - total catch - MC Risk TAC options for 1998 |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| TAC Option | Ot | 5,000t | 10,000t | 15,000t | 20,000t |
| Reference Point |  |  |  |  |  |
| $P(B 399 / B 398 \leq 1)$ | 0.000 | 0.050 | 0.590 | 0.920 | 0.973 |
| $P(B 599 / B 598 \leq 1)$ | 0.007 | 0.243 | 0.483 | 0.690 | 0.780 |
| $\mathrm{P}(\mathrm{Bm} 99 / \mathrm{Bm} 98 \leq 1)$ | 0.003 | 0.193 | 0.523 | 0.737 | 0.853 |
| $P(B 399 / B 398 \leq 1.1)$ | 0.220 | 0.860 | 0.993 | 1.000 | 1.000 |
| $P(B 599 / B 598 \leq 1.1)$ | 0.297 | 0.547 | 0.703 | 0.810 | 0.847 |
| $P(B m 99 / B m 98 \leq 1.1)$ | 0.190 | 0.550 | 0.817 | 0.903 | 0.930 |
| $P(B 399 / B 398 \leq 1.2)$ | 0.987 | 1.000 | 1.000 | 1.000 | 1.000 |
| $P(B 599 / B 598 \leq 1.2)$ | 0.610 | 0.707 | 0.850 | 0.880 | 0.893 |
| $P\left(\right.$ Bm99/Bm98 ${ }^{\text {1.2 }}$ ) | 0.563 | 0.823 | 0.907 | 0.947 | 0.973 |
| $\mathrm{P}(\mathrm{B} 399 / \mathrm{B} 393 \leq 1)$ | 0.000 | 0.000 | 0.000 | 0.007 | 0.020 |
| P(B599/B593 ${ }^{\text {1 }}$ ) | 0.000 | 0.000 | 0.000 | 0.003 | 0.010 |
| P (Bm99/Bm93 1 1) | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 |
| P(B399/B3_0.5msy ${ }^{\text {1 }}$ ) | 0.930 | 0.947 | 0.950 | 0.967 | 0.973 |
| P (B599/B5_0.5msy 1 $^{\text {) }}$ | 0.907 | 0.937 | 0.947 | 0.963 | 0.970 |
| P (Bm99/Bm_0.5msy 1 ) | 0.837 | 0.870 | 0.880 | 0.927 | 0.967 |
| $P(B 399 / B 3 A v e 80 s \leq 1)$ | 0.960 | 0.973 | 0.970 | 0.987 | 0.973 |
| $P(B 599 / B 5 A v e 80 s \leq 1)$ | 0.877 | 0.893 | 0.927 | 0.937 | 0.957 |
| $P(B m 99 / B m A v e 80 s \leq 1)$ | 0.157 | 0.313 | 0.430 | 0.570 | 0.610 |
| P(F98>F0.1) | 0.000 | 0.000 | 0.300 | 0.863 | 0.990 |

Table 31.

| Decision Table - 3Ps cod - QLSPA - Canadian and French RV - total catch - MC Risk TAC options for 1998 |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| TAC Option | Ot | 5,000t | 10,000t | 15,000t | 20,000t |
| Reference Point |  |  |  |  |  |
| $P(B 399 / B 398 \leq 1)$ | 0.003 | 0.107 | 0.480 | 0.887 | 0.960 |
| $P(B 599 / B 598 \leq 1)$ | 0.080 | 0.267 | 0.470 | 0.680 | 0.783 |
| P (Bm99/Bm98 1 $^{\text {) }}$ | 0.027 | 0.207 | 0.440 | 0.727 | 0.823 |
| $P(B 399 / B 398 \leq 1.1)$ | 0.657 | 0.970 | 0.997 | 1.000 | 1.000 |
| $P(B 599 / B 598 \leq 1.1)$ | 0.517 | 0.687 | 0.727 | 0.847 | 0.873 |
| $\mathrm{P}(\mathrm{Bm} 99 / \mathrm{Bm} 98 \leq 1.1)$ | 0.427 | 0.693 | 0.817 | 0.920 | 0.947 |
| P (B399/B398 1 $^{\text {1.2 }}$ ) | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| P (B599/B598 ${ }^{\text {1.2 }}$ ) | 0.780 | 0.863 | 0.847 | 0.907 | 0.923 |
| $\mathbf{P}(\mathrm{Bm} 99 / \mathrm{Bm} 98 \leq 1.2)$ | 0.810 | 0.933 | 0.947 | 0.987 | 0.970 |
| $P(B 399 / B 393 \leq 1)$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.007 |
| P(B599/B593 ${ }^{\text {1 }}$ ) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| P (Bm99/Bm93<1) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| P (B399/B3_0.5msy $\leq 1)$ | 0.743 | 0.773 | 0.797 | 0.853 | 0.850 |
| P(B599/B5_0.5msy $\leq 1$ ) | 0.680 | 0.720 | 0.737 | 0.787 | 0.813 |
| P (Bm99/Bm_0.5msy $\leq 1)$ | 0.383 | 0.453 | 0.487 | 0.530 | 0.633 |
| P(B399/B3Ave80s $\leq 1$ ) | 0.743 | 0.777 | 0.797 | 0.857 | 0.850 |
| $\mathrm{P}(\mathrm{B599} / \mathrm{B} 5$ Ave80s $\leq 1)$ | 0.333 | 0.397 | 0.423 | 0.467 | 0.583 |
| $\mathrm{P}(\mathrm{Bm} 99 / \mathrm{BmAve80s} \leq 1)$ | 0.000 | 0.003 | 0.010 | 0.023 | 0.057 |
| P (F98>F0.1) | 0.000 | 0.000 | 0.000 | 0.090 | 0.553 |

Table 32.

|  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  |
| Reference Point |  |  |  |  |  |
| P(B399/B398 ${ }^{\text {c }}$ ) | 0.049 | 0.243 | 0.582 | 0.819 | 0.923 |
| P(B599/B598 ${ }^{\text {c }}$ ) | 0.079 | 0.305 | 0.544 | 0.690 | 0.774 |
| $P($ Bm99/Bm98 51$)$ | 0.054 | 0.258 | 0.604 | 0.823 | 0.899 |
| P(B399/B398 1 $^{\text {1.1) }}$ | 0.624 | 0.823 | 0.917 | 0.962 | 0.988 |
| P (B599/B598 ${ }^{\text {1.1) }}$ ) | 0.517 | 0.661 | 0.750 | 0.808 | 0.847 |
| $P(B m 99 / B m 98 \leq 1.1)$ | 0.533 | 0.756 | 0.865 | 0.912 | 0.936 |
| $P(B 399 / B 398 \leq 1.2)$ | 0.942 | 0.973 | 0.988 | 0.997 | 1.000 |
| P (B599/B598 ${ }^{\text {1.2 }}$ ) | 0.734 | 0.794 | 0.835 | 0.865 | 0.887 |
| $\mathrm{P}(\mathrm{Bm} 99 / \mathrm{Bm} 98 \leq 1.2)$ | 0.842 | 0.899 | 0.928 | 0.945 | 0.956 |
| $P($ B399/B393 $\leq 1)$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| $P(B 599 / B 593 \leq 1)$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| $P($ Bm99/Bm93 1 1) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| P(B399/B3_0.5msy 1 $^{\text {1 }}$ ) | 0.796 | 0.823 | 0.847 | 0.867 | 0.884 |
| P(B599/B5_0.5msy 1 $^{\text {) }}$ | 0.786 | 0.824 | 0.856 | 0.881 | 0.900 |
|  | 0.515 | 0.591 | 0.661 | 0.722 | 0.776 |
| $P($ B399/B3Ave80s $\leq 1)$ | 0.797 | 0.824 | 0.848 | 0.868 | 0.885 |
| $\mathrm{P}(\mathrm{B} 599 / \mathrm{B5Ave80s} \leq 1)$ | 0.478 | 0.552 | 0.621 | 0.684 | 0.741 |
| P (Bm99/BmAve80s $\leq 1$ ) | 0.010 | 0.024 | 0.049 | 0.086 | 0.136 |
| P (F98>F0.1) | 0.000 | 0.000 | 0.361 | 0.347 | 0.573 |

Table 33.

| Decision Table -3Ps cod - QLSPA - Canadian and French RV - offshore catch - MC RiskTAC options for 1998 |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| TAC Option | Ot | 5,000t | 10,000t | 15,000t | 20,000t |
| Reference Point |  |  |  |  |  |
| $P(B 399 / B 398 \leq 1)$ | 0.017 | 0.673 | 0.957 | 1.000 | 1.000 |
| P(B599/B598 ${ }^{\text {1 }}$ ) | 0.100 | 0.573 | 0.770 | 0.893 | 0.937 |
| $P\left(\right.$ Bm99/Bm98 ${ }^{\text {c }}$ ) | 0.053 | 0.520 | 0.867 | 0.967 | 0.993 |
| $P(B 399 / B 398 \leq 1.1)$ | 0.867 | 1.000 | 0.997 | 1.000 | 1.000 |
| $P(B 599 / B 598 \leq 1.1)$ | 0.627 | 0.823 | 0.857 | 0.960 | 0.967 |
| $P(B m 99 / B m 98 \leq 1.1)$ | 0.600 | 0.867 | 0.957 | 0.993 | 0.997 |
| $P($ B399/B398 51.2$)$ | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| $P(B 599 / B 598 \leq 1.2)$ | 0.857 | 0.907 | 0.917 | 0.983 | 0.983 |
| $P(B m 99 / B m 98 \leq 1.2)$ | 0.893 | 0.963 | 0.987 | 1.000 | 0.997 |
| P(B399/B393 1 $^{\text {1 }}$ ) | 0.000 | 0.000 | 0.000 | 0.010 | 0.033 |
| $P(B 599 / B 593 \leq 1)$ | 0.000 | 0.000 | 0.000 | 0.003 | 0.010 |
| $\mathrm{P}(\mathrm{Bm} 99 / \mathrm{Bm} 93 \leq 1)$ | 0.000 | 0.000 | 0.000 | 0.003 | 0.007 |
| $P\left(B 399 / B 3 \_0.5 \mathrm{msy}\right.$ <1) | 0.960 | 0.987 | 0.983 | 0.993 | 0.997 |
| $P\left(B 599 / B 5 \_0.5 \mathrm{msy}\right.$ <1) | 0.953 | 0.967 | 0.973 | 0.993 | 0.990 |
| $P($ Bm99/Bm_0.5msy $\leq 1)$ | 0.797 | 0.890 | 0.897 | 0.963 | 0.987 |
| $P(B 399 / B 3 A v e 80 s \leq 1)$ | 0.627 | 0.730 | 0.780 | 0.863 | 0.917 |
| $P(B 599 / B 5 A v e 80 s \leq 1)$ | 0.197 | 0.270 | 0.437 | 0.570 | 0.660 |
| P(Bm99/BmAve80s $\leq 1)$ | 0.000 | 0.000 | 0.013 | 0.060 | 0.120 |
| $\mathrm{P}(\mathrm{F98} \times \mathrm{F0.1})$ | 0.000 | 0.000 | 0.370 | 0.913 | 1.000 |

Table 34.

| Decision Table - 3Ps cod - QLSPA - Canadian and French RV - offshore catch - PL Risk TAC options for 1998 |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| TAC Option | Ot | 5,000t | 10,000t | 15,000t | 20,000t |
| Reference Point |  |  |  |  |  |
| P (B399/B398 ${ }^{\text {1 }}$ ) | 0.070 | 0.649 | 0.919 | 0.984 | 1.000 |
| P (B599/B598<1) | 0.102 | 0.588 | 0.787 | 0.863 | 0.902 |
| $P(B m 99 / B m 98 \leq 1)$ | 0.066 | 0.655 | 0.842 | 1.000 | 1.000 |
| $P(B 399 / B 398 \leq 1.1)$ | 0.716 | 0.874 | 1.000 | 1.000 | 1.000 |
| $P(B 599 / B 598 \leq 1.1)$ | 0.588 | 0.777 | 0.855 | 0.896 | 0.921 |
| $P(B m 99 / B m 98 \leq 1.1)$ | 0.625 | 0.853 | 1.000 | 1.000 | 1.000 |
| P ( $\mathrm{B} 399 / \mathrm{B} 398 \leq 1.2$ ) | 0.959 | 0.988 | 0.999 | 1.000 | 1.000 |
| P (B599/B598 1.2 ) | 0.774 | 0.851 | 0.892 | 0.917 | 0.934 |
| $\mathrm{P}(\mathrm{Bm99} / \mathrm{Bm} 98 \leq 1.2)$ | 0.877 | 0.934 | 0.956 | 0.967 | 0.974 |
| $P($ B399/B393 51$)$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| $P(B 599 / B 593 \leq 1)$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| P (Bm99/Bm93<1) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| $P\left(\right.$ B399/B3_0.5msy ${ }^{\text {c }}$ ) | 0.941 | 0.948 | 0.954 | 0.959 | 0.963 |
| P(B599/B5_0.5msy 1 1) | 0.942 | 0.950 | 0.956 | 0.961 | 0.965 |
|  | 0.882 | 0.925 | 0.953 | 0.973 | 0.979 |
| $P($ B399/B3Ave80s $\leq 1)$ | 0.730 | 0.798 | 0.849 | 0.885 | 0.909 |
| $P($ B599/B5Ave80s $\leq 1)$ | 0.322 | 0.470 | 0.608 | 0.730 | 0.835 |
| $P($ Bm99/BmAve80s $\leq 1)$ | 0.001 | 0.011 | 0.047 | 0.120 | 0.205 |
| P (F98>F0.1) | 0.000 | 0.000 | 0.448 | 0.780 | 1.000 |

Fig. 1. Annual catch of 3Ps cod by fixed and mobile gear and for the two gears combined to give total catch, for the period1959 to 1997. The TAC set in each year is also indicated.

..... Gillnet $\rightarrow$ Longline $-\Delta-$ Handline $-x$ - Trap


Fig. 2. Fixed gear catch by gear type for the period 1975 to 1997.


Fig. 3. Number of groundfish licenses to fish in 3Ps, by vessel size class.



Fig. 4. Catch at age by gear type (top) and all gears combined (bottom) for the total catch from Div. 3Ps in 1997.


Fig. 5. The 9 fishing areas used to record catch and effort data in logbooks for vessels $<35 \mathrm{ft}$. in 3Ps.

Fig. 6a. Gillnets from Fixed Gear Logbook (vessels less than 35 ft.)

$$
\text { lcpue }=\log ((\text { catch/amount of gear }) *(\text { soak time } / 24))
$$



Fig. 6b. Longline from Fixed Gear Logbook (vessels less than 35 ft.$)$

```
lcpue = log((catch/(amount of gear/1000)) / (soak time/24))
```



Fig. 6c. Traps from Fixed Gear Logbook (vessels less than 35 ft. )

```
lcpue = log((catch/amount of gear) *(soak time/24))
```



Fig. 7a. Gillnets from Fixed Gear Logbook (vessels less than 35 ft.$)$

```
lcpue = log((catch/amount of gear) *(soak time/24))
```



Fig. 7b. Longline from Fixed Gear Logbook (vessels less than 35 ft.$)$

$$
\text { lcpue }=\log ((\text { catch } /(\text { amount of gear/1000)) } /(\text { soak time/24)) }
$$



Fig. 7c. Traps from Fixed Gear Logbook (vessels less than 35 ft.$)$

```
lcpue = log((catch/amount of gear) *(soak time/24))
```



Fig. 8a. Gillnets from Fixed Gear Logbook (vessels less than 35 ft .)
lcpue $=\log (($ catch $/$ amount of gear $) /($ soak time $/ 24))$


Fig. 8b. Longline from Fixed Gear Logbook (vessels less than 35 ft .)

$$
\text { lcpue }=\log ((\text { catch } /(\text { amount of gear/1000) }) /(\text { soak time } / 24))
$$



Fig. 8c. Trap from Fixed Gear Logbook (vessels less than 35 ft.$)$

$$
\text { lcpue }=\log ((\text { catch/amount of gear) } /(\text { soak time } / 24))
$$





Figure ${ }^{9 \mathrm{a}}$ Division 3Ps gillnet catch/net/day with smoothers showing annual (top) and seasonal (bottom) trends.


Figure 9b Division 3Ps linetrawl catch/1000 hooks/hr with smoothers showing annual (top) and seasonal (bottom) trends.



Figure 9c Division 3Ps trap catch/net/hr with smoothers showing annual (top) and seasonal (bottom) trends.


Fig. 10. Abundance and biomass estimates for the 3Ps Canadian research vessel bottom trawl survey for the period 1983 to 1997. Error bars show plus and minus one standard deviation.


Figure 11. Distribution of cod catches (number per tow) during the Canadian Research Vessel Survey in NAFO Subdivision 3Ps


Fig 12 Mean length at ages 1-10 of cod in Subdivision 3Ps in 1972-1997, as determined from sampling during bottom-trawl surveys in winter-spring.


Fig. 13 Mean round weight at ages 2-7 of cod in Subdivision 3Ps in 1978-1997, as determined from sampling during bottom-trawl surveys in winter-spring.


Fig. 14. Age at $50 \%$ maturity for 3 Ps female cod sampled in the bottom trawl surveys in winter-spring from 1972 to 1997.


Fig. 15. Model estimates of the annual proportion of female cod mature at age. The maturity for age 6 is indicated by the bold line with solid circle symbols.


Fig. 16 Mean catch per tow at ages 1-3 for the 1969-1996 year-classes during research bottom-trawl surveys in Subdivision 3Ps. Data obtained prior to the introduction of the Campelen trawl in 1996 are shown as actual (unconverted) numbers and in numbers converted to Campelen equivalents.


Fig. 17. Estimates of total mortality from annual winter-spring research vessel surveys. Mortality rates are assigned to the start year and age.


Fig. 18. Predicted and observed research vessel indices for the Canadian and French surveys from an ADAPT based on total catch.


Fig. 19. Age 3+, $5+$ and spawner biomass estimates from an ADAPT applied to total catch and calibrated with Canadian and French RV indices.

QLSPA - model fit to Canadian index


QLSPA - model fit to Fench index


Fig. 20. QLSPA model fit to Canadian and French RV indices and applied to total catch.


Fig. 21. Age 3+, $5+$ and spawner bimass estimates from QLSPA applied to total catch and calibrated with Canadian and French RV indices.


Fig. 22. Predicted and observed research vessel indices for the Canadian and French surveys from QLSPA based on offshore catch.


Fig. 23. Observed and predicted survey values summed across ages for the QLSPA model fit to Canadian and French research vessel indices, for the case of offshore catch and seasonal catchabilities for the Canadian survey.


Fig. 24. Age 3+, $5+$ and spawner biomass estimates from QLSPA applied to total catch and calibrated with Canadian and French RV indices with seasonal catchabilities for the Canadian survey.

## Total catch - Canadian \& French RV



Offshore catch - Canadian \& French RV


Fig. 25. Comparion of ADAPT and QLSPA estimates of spawner biomass from total catch (top panel) and offshore catch (bottom panel for models including both Canadian and French RV indices and for the QLSPA model including a seasonal catchability (QLSPA_Q).


Fig. 26. Plot of catchability at age estimates for two QLSPA models (non-seasonal catchability and seasonal catchability) applied to the offshore catch data.


Fig. 27. Precuationary plots for ADAPT applied to total catch and calibrated with French and Canadian RV indices.

| Spawner biomass per recruit - 3Ps cod | Spawner biomass per recruit - 3Ps cod |
| :---: | :---: |
| Yield per recruit - 3Ps cod | Spawner stock and recruit - 3Ps cod |
| Yield - 3Ps cod | Yield - 3Ps cod |

Fig. 28. Precuationary plots for QLSPA applied to total catch and calibrated with French and Canadian RV indices.


Fig. 29. Precuationary plots for QLSPA applied to offshore catch and calibrated with French and Canadian RV indices.



Fig. 30. Cumulative probability plots for no growth in offshore spawner biomass from January 1998 to January 1999, less than $10 \%$ growth and less than $20 \%$ growth, as well as the probability of exceeding F0.1, for a range of TAC options.

Fig. 31. The corresponding values of fishing mortality and percent change in offshore spawner biomass for a range of TAC options.


[^0]:    'Provisional catches
    ${ }^{2}$ Includes 137 t from food fishery and 251 t from sentinel fishery.
    ${ }^{3}$ Includes food fishery and sentinel fishery.

