

Proceedings of the Regional Groundfish Assessment Review for Newfoundland, May 9-13, 1994

Editors

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A1C 5X1

December 1994

Canadian Technical Report of
Fisheries and Aquatic Sciences 2020



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Canadian Technical Report of Fisheries and Aquatic Sciences

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Cat. No. FS97-6/2020, ISSN 0706-6457

Correct citation for this publication:

Shelton, P.A., and D.B. Atkinson (Editors). Proceedings of the Regional Grounfish Assessment Review for Newfoundland, May 9-13, 1994. Can. Tech. Rep. Fish. Aquat. Sci. 2020: 100 p.

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Abstract

The first Regional Groundfish Assessment Review for Newfoundland was held in St. John's from 9-13 May 1994. Overviews of the physical environment, and pelagic, invertebrate and marine mammal stocks were tabled. Full reviews of the assessments of the Divs. 2J3KL cod stock, the Subdiv. 3Ps cod stock, and the Unit 2 redfish stock were carried out. Reviews of stock status updates were carried out on the Divs. 2+2K redfish, Div. 3O redfish, Divs. 2+3K American plaice, Subdiv. 3Ps American plaice, Divs. 2J3KL witch flounder, and Subdiv. 3Ps witch flounder stocks. This report provides a record of the proceedings of the Review and recommendations for future work related to the assessment of these stocks. Titles of 41 working papers tabled at the Review are listed and summaries of these papers are provided in the Proceedings.

Résumé

Le premier examen régional de l'évaluation des stocks de poisson de fond de Terre-Neuve a lieu à St. John's, du 9 - 13 mai 1993. On y a présenté des vucs d'ensemble du milieu physique et des stocks de poissons pélagiques, d'invertébrés et de mammifères marins, et procédé à un examen approfondi de l'évaluation du stock de morue des divisions 2J3KL, du stock de morue de la subdivision 3Ps, et du stock de sébaste de l'unité 2. On y a également fait le point sur les stocks de sébaste et de plie canadienne de SA2 = div. 3K, de sébaste de la division 3O, de plie canadienne et de plie grise de la subdivision 3Ps, ainsi que de plie grise des divisions 2J3KL. Le présent rapport relate les délibérations auxquelles cet examen a donné lieu et contient des recommandations sur les activités futures d'évaluation de stocks considérés. Le compte rendu des délibérations comprend une liste et un résumé des 41 documents de travail présentés dans le cadre de l'examen.

Abbreviations and Definitions

ADAPT	–	The adaptive framework for SPA calibration
BIO	–	Bedford Institute of Oceanography
C/E – CPUE	–	Catch per unit of effort
CIL	–	Cold intermediate layer
CV	–	Coefficient of variation
CW	–	Carapace width
DFO	–	Department of Fisheries and Oceans
EU	–	European Union
f	–	Fishing effort
F	–	Instantaneous rate of fishing mortality
$F_{(50\%)}$	–	Fishing mortality corresponding to the 50% rule (see Section ix of Anon. 1992b)
$F_{0.1}$	–	The instantaneous rate of fishing mortality (calculated from a yield-per-recruit curve) at which a unit increase in fishing effort (proportional to fishing mortality) will give an increase in yield 1/10th that of a unit of effort on the virgin stock (dynamic pool model)
FAO	–	Food and Agriculture Organization
FG	–	Fixed gear
F_{max}	–	The instantaneous rate of fishing mortality which maximizes the yield per recruit (dynamic pool model)
FOS	–	Fisheries Oceanography Subcommittee
FRCC	–	Fisheries Resource Conservation Council
GM	–	Geometric mean
ICNAF	–	International Commission of the Northwest Atlantic Fisheries (ceased operation at the end of 1979)
IIE	–	Integrated index error
IOP	–	International Observer Program
ITQ	–	Individual transferable quotas
M	–	Instantaneous rate of natural mortality
NAFO	–	Northwest Atlantic Fisheries Organization
NCSP	–	Northern Cod Science Program
OTB	–	Bottom otter trawl
OTM	–	Midwater otter trawl
PR	–	Partial recruitment
PSU	–	Practical salinity unit
q	–	Catchability coefficient
RV	–	Research vessel
SPA	–	Sequential population analysis
SPM	–	St. Pierre & Miquelon
SPR	–	Spawning stock biomass per recruit
SSB	–	Spawning stock biomass
TAC	–	Total allowable catch
TC	–	Tonnage class
UNEP	–	United Nations Environment Program
VPA	–	Virtual population analysis
XSA	–	Extend survivors method of SPA calibration
Z	–	Instantaneous rate of total mortality
ZIF	–	Zonal interchange file

1. The new process for stock assessments - P.A. Shelton

On December 18, 1992, the then Minister of Fisheries, J.C. Crosbie, announced substantial changes to the way in which the Government would approach fisheries management in Atlantic Canada. The biggest of these changes was the creation of the Fisheries Resource Conservation Council (FRCC): "The new Council will include scientists from outside government, as well as knowledgeable persons drawn from the fishing industry and ex officio representatives of provincial governments. The Council will replace CAFSAC and AGAC for the purpose of setting TACs. CAFSAC will no longer exist. CAFSAC's role of recommending conservation measures will be undertaken by the Council. Scientific peer review of stock assessments will be done by an internal DFO Review Committee for the use of the Council." "...The Council will deal with the three main areas of: research, methodologies for assessment and the proposed TACs for all stocks." The Council was also charged by the Minister with the responsibility of determining research priorities. The creation of the Council was coupled with a new philosophy regarding fisheries management: "In substantive terms, scientific advice must be based on a greater understanding of the life cycle of each species, predator-prey relations and oceanographic factors, as well as the operation of various sectors of the fishing industry" - the so called "Ecosystem Approach".

The changes instituted by the Minister in October 1992 were widely seen as treatment for the apparent failure of the scientific process to prevent or predict the collapse of the Northern Cod stock. The annual scientific assessments of the Northern Cod stock and other groundfish stocks which have subsequently declined are well recorded in CAFSAC Groundfish Subcommittee Reports, NAFO Scientific Council Reports and the technical documents submitted to these two bodies. A careful evaluation of these records are required to fully understand the strengths and weaknesses of the scientific process relative to the rest of the fisheries management process over the period following extension of jurisdiction.

In keeping with the Minister's announcement, the Department of Fisheries and Oceans instituted internal changes to the process for scientific assessments, primarily to facilitate servicing the requirements of the FRCC. The central component of the "Renewed Process for Assessment of Atlantic Stocks" is the Stock Status Report (SSR). The SSR is the main vehicle for providing information from Science Branch to the FRCC and provides the basis for setting TACs and recommending conservation measures. The SSR is required to be a non-technical document easily understood by a lay person. Responsibility for the preparation and review of the SSR rests with each Regional Science Branch for those stocks assigned to it.

This Proceedings reports on the first implementation of the Regional Groundfish Assessment Review in the Newfoundland Region. The Regional Review attempted to evaluate all available scientific information relating to those groundfish stocks under consideration. This forms the basis for the preparation of the SSR. Documents tabled at the Review included first draft of sections of the SSR as well as Working Papers devoted to related topics. This Proceedings contains summaries of the working papers, sections that form the basis for the SSR, expanded sections on Available Data, Estimation of Stock Parameters, and Assessment Results for each stock. Discussion sections document the debate on the assessment that took place at the review. Where possible, authors responsible for the individual sections are noted and the relevant Working Papers are referred to. The Discussion sections reflect the deliberations that followed the presentation of working papers and are not necessarily consensus views.

2. Overview of the Newfoundland Region

2.1 General overview and environmental summary - D.B. Atkinson, WP#41

Region

The Newfoundland region comprises NAFO Statistical Area 2 and divisions 3K, 3L, 3M, 3N, 3O and Subdiv. 3Ps (Fig. 2.1).

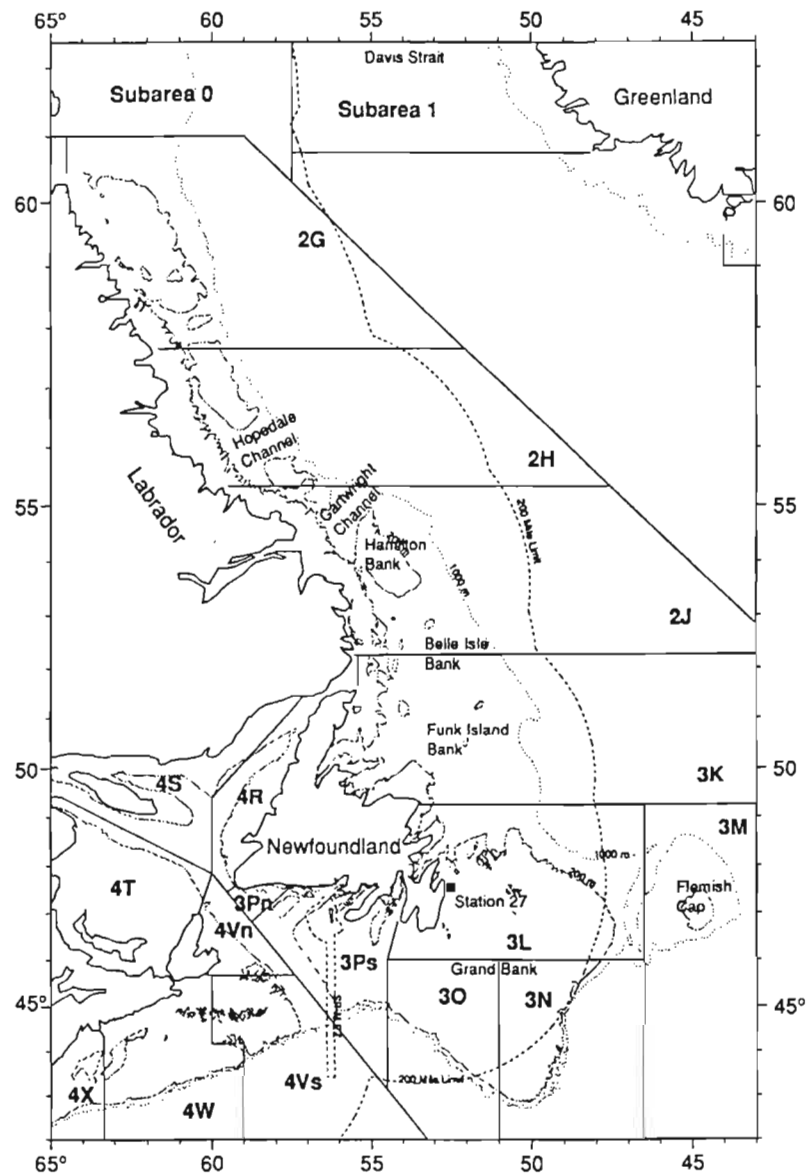


Fig. 2.1. NAFO Statistical Areas 2, 3 and 4 showing Divisions and Subdivisions.

Groundfish

Three main species groups of groundfish have traditionally been pursued in the waters around Newfoundland. These are the gadoids (mainly cod with some haddock, pollock and hake), flatfish (American plaice, yellowtail flounder, witch flounder, Greenland halibut and Atlantic halibut) and “others” such as redfish and grenadiers. Overall, the status of the groundfish resources today is very different from that as reflected by average catches from extension of jurisdiction and 1991 (Fig. 2.2).

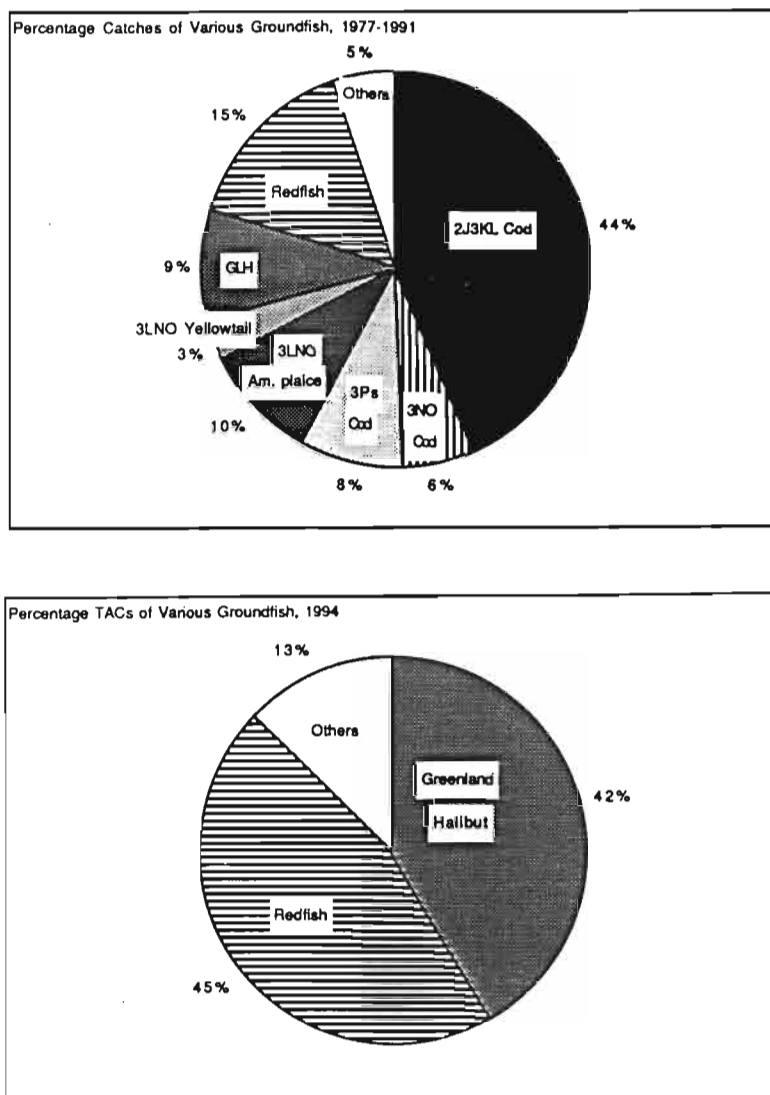


Fig. 2.2. Pie diagrams comparing the percentage catch by species in the groundfish fishery in the Newfoundland Region over the period 1977-91 and in 1994.

Cod traditionally dominated catches, with the most important stock being that in Div. 2J3KL or "northern" cod. Important cod fisheries also take place on the southern Grand Banks (Div. 3NO stock) and off the south coast (Subdiv. 3Ps stock). Catches from all of these stocks peaked in the 1960s, before declining again until the extension of jurisdiction, primarily the result of excessive fishing. After 1977 the trajectories of the different stocks have shown both similarities and differences. The northern cod increased in biomass through the mid 1980s before declining somewhat to 1990. In Div. 3NO on the other hand, the biomass increased rapidly until the mid to late 1980s then declined rapidly thereafter. The biomass of cod in Subdiv. 3Ps also increased until about 1988 before declining.

The causes for the recent declines appear to be different in the different areas. After 1990, the biomass of northern cod declined very rapidly based on survey data; by 50% between 1990 and 1991, about 70% between 1991 and 1992, and by about 80% between 1992 and 1993. The 1993 survey estimate is only about 3% of that for 1990. The reasons for this dramatic decline are still unclear. Fishing on spawning grounds, foreign fisheries, traps, gillnets, dumping and discarding, seals and the environment have all been implicated to various degrees for the decline in northern cod. All have probably played a role but the relative importance of each remains unknown. It is clear that since the moratorium was put in effect in July, 1992, estimated catches cannot account for the continuing declines observed.

On the southern Grand Banks, the declines appear to be more easily understood. Beginning around 1986, fishing effort increased significantly outside 200 miles such that TACs were exceeded for many years. To add to this problem, the foreign fleets were taking mainly small, undersized fish probably through the use of illegal small gear. At the same time the effort was increasing, there were a number of successive years of poor recruitment. Fishing mortality has been very high over the past number of years. The fishery is closed for 1994 because of the low stock size.

Catches of cod in Subdiv. 3Ps increased significantly after 1985 because of increased effort by the French. After settlement of the boundary dispute, their catches again declined and none were reported taken in 1993. Survey results for cod have fluctuated considerably between years, but suggest a decline in the recent period. It is not possible to determine the exact status of this stock, but a number of indicators suggest a declining population. These are: declining age at maturity, declining numbers of older fish in the area and declining size at age. Some of the fish in the area may be from adjacent stocks (Div. 3Pn4RS, Div. 3O) but these stocks are also at low levels at present.

Of the flatfish stocks, American plaice on the Grand Banks (Div. 3LNO) is the most important historically, but American plaice fisheries also take place in Subarea 2+Div. 3K, and Subdiv. 3Ps. As with cod on the Grand Banks, foreign catches of the 3LNO stock outside 200 miles have been greater than allocations since 1986, and they have caught smaller fish than taken in the Canadian fishery. This has resulted in exploitation rates exceeding reference levels, and the most recent survey estimates show the biomass to be the lowest in the time series. There are however, indications that the declines in biomass in Div. 3L are greater than can be explained by the fishery alone. It is unknown if this is related to factors contributing to the decline in Div. 2J3KL cod or not. NAFO has closed this fishery for 1994 because of the low stock size.

Further north, research vessel survey results indicate that through the 1980s, the greatest proportion of biomass of American plaice was in Div. 2J where it peaked in 1983 then gradually declined thereafter. In Div. 3K, biomass was stable until about 1987 then declined. Estimates in the

1990s from both divisions continued to decline, and the 1993 estimates are the lowest on record. The observed declines cannot be accounted for by the fishery alone. For 1994, the fishery is restricted to by-catch only. Recruitment has been declining in recent years, and because of this, recovery cannot be anticipated before at least 10 years.

In Subdiv. 3Ps through the 1980s, survey estimates of trawlable biomass of American plaice fluctuated but there has been a gradual and systematic decline since about 1989. The decline continued into 1994 based on the most recent survey results. Although fishing mortality has probably been above $F_{0.1}$ in recent years, it is not believed that catches in the range of 2,500 – 5,000 t could be fully responsible for declines of about 90% (from surveys) since 1986–1988. As with other American plaice stocks around Newfoundland, it appears that non-fishery related factors may be contributing to the observed declines. The fishery in this area is also restricted to by-catch only for 1994.

The only significant fishery for yellowtail flounder is on the Grand Banks (Div. 3LNO). After extension of jurisdiction, catches fluctuated between 10,000 – 20,000 t, but were about 30,000 t in 1985 and 1986. This increase was due to increased foreign effort on the "tail." Subsequent catches dropped back to about 15,000 t, but have been about double the TACs in the 1990s again because of the foreign fishery. It is important to note that recent foreign catches have been primarily of juveniles so the catch in numbers has not decreased as much as suggested by the tonnage change. After remaining stable through most of the 1980s, biomass as estimated from Canadian surveys steadily declined and in 1992 was only about one third that estimated from the 1985 and 1986 surveys. The fishery is closed for 1994.

Witch flounder fisheries take place in Div. 2J3KL, Div. 3NO and Subdiv. 3Ps. Biomass estimates from surveys in the north peaked in Div. 2J in 1986 but declined during the more recent period. In Div. 3K, estimates were stable through the early 1980s (about 30,000 t) but declined subsequently. The total estimated biomass in these two divisions in 1993 was only 900 t. In Div. 3L, estimates were between 6,000 – 7,000 t until 1988 but declined to only 1500 t in 1992, and 400 t in 1993. In 1993, the total estimated biomass, at 1,300 t, is the lowest in the time series, and only slightly greater than the 1994 TAC of 1,000 t. As with other flatfish stocks in the area, current fishing effort cannot account for the observed declines in biomass.

On the Grand Banks (Div. 3NO) TACs (5,000 t) were exceeded in 1985–1988, again due to increased foreign effort, but declined below that reference level since. Survey estimates of biomass show considerable fluctuation over the time series, but are generally lower now than in the mid 1980s. Whether this indicates a decline in stock size, or a movement of the fish to deeper water outside the survey area is unclear. The fishery is closed for 1994.

Biomass estimates of witch from surveys in Subdiv. 3Ps have fluctuated substantially between years, but there does not appear to be any long term trend in the estimates. The fluctuations may be the result of some portion of the stock being distributed in deeper water outside the survey area. Possible impacts of the fishery cannot be determined, but current by-catch restrictions related to other species will probably result in relatively low exploitation.

It is currently believed that with the exception of those in the Gulf of St. Lawrence, Greenland halibut in the northwest Atlantic constitute one stock extending from Davis Strait (subareas 0+1) to around the Grand Banks (Subarea 3). Results of surveys in Div. 2GH in the 1978-81 period and in the late 1980s indicated that the biomass had decreased by about 50% between the 2 periods. The biomass in Div. 2J3K also declined by about 50% between 1987 and 1990. Catches in

subareas 2 and 3 began to increase dramatically in 1990 with the development of a foreign fishery in Div. 3LM outside 200 miles. This fishery has since extended into Div. 3NO. The 1993 catch has been estimated to be about 62,000 t. At present there are no data to suggest that this foreign fishery is being prosecuted on a separate stock, and the high catches of recent years from this fishery are cause for concern. There is also concern about the expanding Canadian fisheries to deeper water and further north. It is expected that the gillnet fishery in Div. 2J3K over the past 4 years significantly reduced the resource in that area. This effort is now being displaced further north and the same declines are anticipated. Only through reduced effort will the future of this resource be secured.

There are 4 stocks of redfish in the Newfoundland area; Subarea 2 + Div. 3K, Div. 3LN, Div. 3O and the Unit 2 (Laurentian Channel stock). In Subarea 2 + Div. 3K, estimated biomass declined from over 100,000 t in the early 1980s to only about 1,180 t in 1993 in Div. 2J. In Div. 3K, the decline over the same period was from over 200,000 t to only 686 t in 1993. There can be no optimistic outlook for this resource until about 9–10 years after good recruitment occurs. None is apparent at present.

In Div. 3LN, much of the redfish resource is distributed outside the 200 mile limit in both Div. 3L and 3N. Catches increased to over 78,000 t in 1987 due to a greatly expanded foreign fishery. This catch was three times the TAC of 25,000 t. Since then catches declined to 24,000 t in 1992, but this was still above the reduced TAC of 14,000 t. There are indications that the foreign fishery continues to be excessive, and concern exists that this stock is being rapidly depleted. This is supported by the fact that the Baltic states vessels returned home early in 1994 because of the very low catch rates achieved.

In Div. 3O, redfish catches increased to about 35,000 t in 1986 because of increased foreign activity. After 1988, catches again declined to about 15,000 t. Whether this decline is reflective of a decrease in the size of the stock or a reduction of effort is unknown. Because of rough bottom in much of the area, it is difficult to carry out trawling and the fleets are restricted to shallower water where smaller fish reside. These are unsuitable to the Canadian processors although acceptable to the foreign fleets which fish in the area outside 200 miles. Little is known about the status of this resource, but research survey data suggest an increase in biomass in the area in recent years. This increase is difficult to interpret.

Catches of Unit 2 redfish increased from about 23,000 t in 1959 to between 30,000 t and 60,000 t from 1963 to 1978. After that they declined somewhat and have fluctuated between 10,000 t and 20,000 t since then. The 1993 catch was about 27,000 t, the highest since extension of jurisdiction. Estimates of biomass in Div. 3P have fluctuated considerably over the period of surveys, but there are no long term trends in the data. There are concerns that the size of this resource is declining, and survey data suggest that the year-classes of the mid- 1980s are not strong enough to reverse this trend.

In the more northern areas, trends in groundfish biomass for exploited and unexploited species generally show the same downward trend in recent times. Fishing pressure alone cannot account for this, and although fishing may well have played a significant role, other factors such as the environment are considered to be involved. It is not yet possible to clarify the mechanisms at work. Further south, it appears that the stocks have declined primarily in response to fishing pressure. Non-commercial species do not exhibit the same downward trends as indicated for most of the commercial species. Catches taken outside 200 miles have been significant, and since these fisheries have taken primarily small fish, the fishing mortalities exerted are greater than suggested

by comparisons of tons caught alone. There are some indications that declines in American plaice in the southern areas may not be totally fishery related.

Pelagics and Invertebrates

During the 1990s, declines were also observed in the estimated offshore capelin biomass although information from inshore indices suggest that biomass has remained at normal levels for the period covered by the indices. If the biomass has not declined, then results from the recent acoustic surveys would suggest distributional or behavioural changes. There are also reports of capelin appearing on Flemish Cap, as well as increases on the Scotian Shelf. These too are suggestive of behavioural changes possibly induced by the environment. It is presently unclear how these changes may have impacted on the predator fish species and seals.

Recent exploratory fishing for shrimp indicates that they are widely distributed, and commercial concentrations are now found in areas which were unproductive previously. At present, quantitative links with various groundfish species are unknown but it is clear that during the period when many groundfish species have declined to very low levels in divisions 2J and 3K, the shrimp resource has increased. The significance of these relationships is not understood, but it may represent a complex process rather than a simple predator–prey relationship. It is known that shrimp are prey for groundfish, most notably cod and Greenland halibut.

The crab resources have also show dramatic increases in recent years. Not only have the densities increased in some areas, but there has also been an expansion of the fishing grounds. It is not possible to relate these changes to changes in the groundfish resources. Because crab of commercial size are about 7–10 years of age, the increased survival possibly occurred before the major observed declines in many of the groundfish species. Also, most recent data suggest that the crab resource will decline because of recent poor recruitment.

Squid are migrants to Canadian waters from the south, and their presence is thought to be in part related to water temperatures in the area since fluctuations in local catches contrast with stable catches (and recruitment) further south. Extended periods of low squid abundance are coincident with cool periods (1968–1974, and 1983–1993). The most recent period of absence is the longest recorded. Squid are predators, competitors and prey for groundfish in coastal Newfoundland waters. Otoliths from small 0-group cod were common in squid stomachs until the early 1990s when sand lance and hake otoliths became most prevalent.

Marine Mammals

The total population of harp seals in the Northwest Atlantic was estimated to be approximately 3.1 million in 1990. Abundance has likely increased but the rate cannot yet be estimated. No clear assessment of the harp seal's impact on cod can be made at this time. Available feeding data suggest that capelin is important in their diet offshore, while Arctic cod is more important inshore. The amounts of Atlantic cod found varied greatly between years, but is generally small. It is presently not possible to quantify overall consumption. Limited information on the feeding of hooded seals indicates that any potential impacts may be greater for deeper species such as witch flounder and Greenland halibut.

The Environment

Oceanographic data suggest a gradual cooling trend in the area through the 1980s. This can be seen in the trend in bottom temperature deviations from the long term mean (1949–1993) at Station 27 off St. John's (Fig. 2.3).

In many ways, environmental conditions in 1993 resembled those in 1992. Ice coverage was near the long term maximum during the first three months, and persisted longer than normal during spring. The areal extent of the CIL below 0 °C remained above normal during both summer and fall of 1993. During the last 3 years the fall CIL has increased from about 22 km² in 1991 to 30 km² in 1993, compared to a 1981–93 average of 24 km². The summer CIL increased from 28 km² in 1992 to 33 km² in 1993 compared to a 1950–93 average of 27 km². Air temperatures were below normal throughout the year except in late summer. Although recent temperatures are anomalously low relative to the 1945–93 average, they are actually returning to conditions reflective of the longer term average from the early 1800s to the present.

It is still unclear how these conditions may be impacting on the groundfish resources in the area. It is unknown if the decreased or complete cessation of fishing will result in improvements in stock status in the short term. No meaningful predictions concerning the future of these resources can therefore be made based on environmental conditions.

2.2 Physical environment

2.2.1 Summary - G. Mertz, WP#1, WP#2, WP#3, WP#4, WP#5

Following the 1960s period of relatively warm oceanic conditions over the shelves of Newfoundland and Labrador, there has been a series of three colder episodes, 1972–73, 1984–85, and 1989 to present. These cold spells correspond to cold winter air temperatures, generally imparted by strong winter northwesterly winds.

The near bottom temperature at Station 27, in the inshore branch of the Labrador Current, is an accepted index for marine climate (Fig. 2.3). Since mid-1990 the bottom temperature anomaly has changed little, consistently occupying the range of -0.5 to -0.75 °C (departures are calculated from the average over the period 1946 to present). The most recent reported measurements at Station 27, mid-March 1994, show significant cold anomalies throughout the water column, with a bottom temperature anomaly of about -0.75 °C.

Since the summer warming has little effect on waters at depths greater than 50 m, we can safely anticipate that the intermediate and deeper waters of the Newfoundland Shelf will remain colder than normal until at least late fall of 1994, when the autumn mixing effects the transfer of heat from the surface layer to the deeper zones. Spring air temperatures in 1994 climbed to higher than normal values over southern Newfoundland, perhaps heralding a return to the climatic norm for the summer surface temperature of the shelf waters. There is no available evidence bearing on the termination or prolongation of the recent series of cold winters (1989 to present).

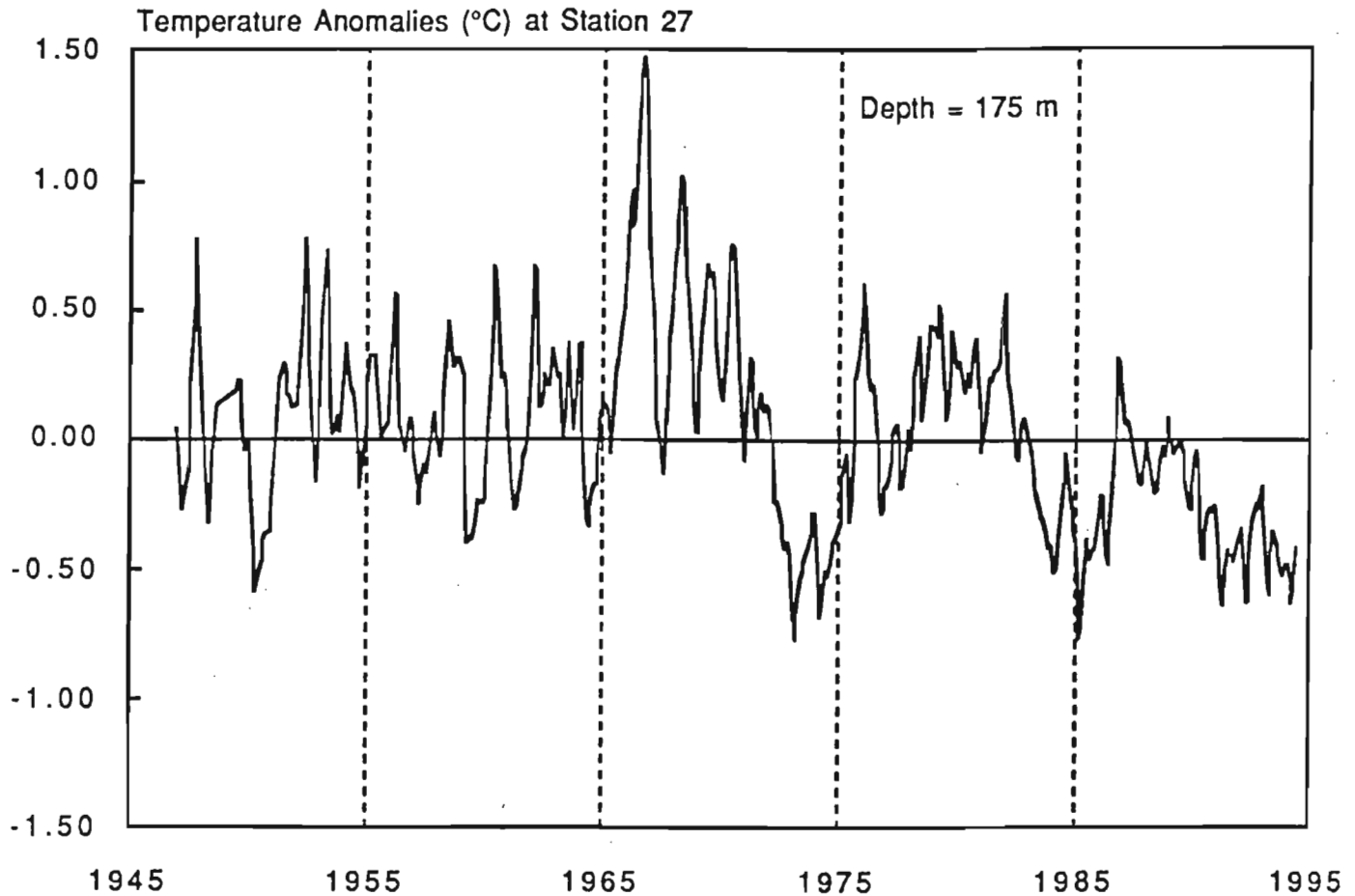


Fig. 2.3. Ocean bottom temperature anomalies (°C) from the long term mean (1949–1993) measured at Station 27, just off St John's.

2.2.2 Discussion

Consideration of the recent period as anomalously cold is based on comparison with the mean for the period 1946 to present. A longer-term perspective going back to the 1800s suggests that the post 1946 period is relatively warm and that sea temperatures may in fact be closer to the 1895 to 1993 average. Although Station 27 may be indicative of general conditions within the region, it is not necessarily very informative about conditions actually experienced by cod. Recent abundance patterns for cod indicate that information on the temperature of the slope water may be of most interest at present. In areas where cod are found during surveys it is apparent that water temperature can change quite rapidly on the scale of days. It is not clear how this may affect survey results. Year effects in the phase of the seasonal cycle, a potentially important influence on the seasonal behaviour of cod, appear to have resulted in shifts in the minima not exceeding one month. The effect of such variation on survey results is not known at this stage. There is

substantially more variation in phase with depth in a year than there is among years at the same depth. Amplitude of the seasonal signal also varies with depth.

Physical factors can influence groundfish body growth rate, birth rate, survival, and spatial abundance patterns. The first three processes directly influence population dynamics, whereas the fourth process may indirectly influence the first three, but directly influences survey results and commercial catch rates. There have been two empirical studies in recent years to look at environment-fish relationships: analysis of temperature effects on cod growth rates and the relationship between salinity and year-class strength in cod. The temperature effect on cod growth rate has been documented several times for the Northwest Atlantic, including the Div. 2J3KL stock (Millar and Myers 1990) as well as in other areas of the North Atlantic, and appears to be robust with respect to the time period or data analysed. Changes in weight at age influence estimates of $F_{0.1}$ and the relationship between catch and fishing mortality. Projections should be based on predicted weights at age using temperature. The relationships for the Div. 2J3KL cod stock require updating.

Predictions from the salinity-recruitment relationship for Div. 2J3KL cod proposed by Sutcliffe et al. (1983) were compared to recruitment estimates from the 1992 assessment (Baird et al. 1992) by Myers et al. (1993) and found to be reasonable, explaining 49% of the variance. Myers et al. (1993) fitted a model including both spawner stock biomass and salinity terms to the 1992 assessment data and suggested this model could be used to forecast year-class strength in short-term stock projections. The Sutcliffe and Myers model predictions were re-examined (WP #5) based on an additional year's salinity, spawner stock biomass and recruitment data (Bishop et al. 1993). Estimates of year class strength for recent years differ from those estimated in the 1992 assessment. The Sutcliffe model only explains 20% of the variance in recruitment when fitted to the 1993 assessment data. The Myers model fitted to the 1992 assessment data overestimates year-class strength in recent years. Fits of the Myers model to the 1993 assessment data explain 46% of the variance in recruitment; the salinity term is not significant. Comparison of the cross-validated prediction sums of squares indicates that a model (either parametric or nonparametric) including only spawner biomass predicts better than either the traditionally used geometric mean of past year-class strengths, or the Myers model, based on the 1993 assessment data. The use of salinity to forecast year-class strength in short-term projections for Div. 2J3KL cod is not recommended without further validation.

2.3 Pelagic fish stocks

2.3.1 Summary - G.H. Winters, WP#8

The current status of the capelin stocks in Div. 2J3KL has been determined from an evaluation of a variety of stock indicators. These are offshore acoustic surveys, inshore commercial catch-rates of capelin traps and purse-seines, aerial surveys of capelin schools near the spawning beaches and egg deposition studies at selected sites along eastern Newfoundland. Other sources of information were also examined to help evaluate capelin stock status, including capelin by-catches from groundfish research vessel surveys, seal feeding data, cod feeding data and capelin distribution data. In general, all sources of information, with the exception of the 1993 acoustic survey, indicate that abundance in 1993 was at or above average levels. The 1993 acoustic survey for Div. 2J3KL was again low (Miller 1994), but it is possible that capelin distribution in recent years has been abnormal and a portion of the stock has been outside the survey area. The abundance of mature fish in the inshore fishery in 1994 is predicted to be good, based on the catch rates of

younger fish in the inshore fishery in 1993. No fishery or biological data were available for the Subdiv. 3Ps capelin stock and therefore the status of this stock is unclear.

East and southeast Newfoundland herring stocks reached peak levels in the early 1970s as the result of good recruitment of year-classes produced in the late 1960s. Poor recruitment and fishery removals depleted these stocks during the 1970s and fishery closures were invoked in the early 1980s. Since then, these stocks have rebuilt with the recruitment of the 1982 and 1987 year-classes. However acoustic biomass estimates and research gillnet catch rates suggest that these stocks have not increased to the levels observed during the early 1970s. There are indications of small herring of the 1991 and 1992 year-classes in most areas and the outlook for the future will depend critically on the actual strength of these year-classes.

2.3.2 Discussion

The by-catch of capelin on the Scotian Shelf increased by a couple of orders of magnitude in the late 1980s and early 1990s. A local stock is known to exist in this area, but previously this stock has been quite small. The increase in abundance on the Scotian Shelf could be the result of an increase in the local stock or a southward shift in distribution from the Gulf and/or Newfoundland regions. On the east coast of Newfoundland the capelin spawning season has increased from 30 days to 60 days, extending into the period of the September/October acoustic surveys. This could be an explanation for the lack of capelin offshore during the survey. Alternatively, capelin could be so dispersed during the time of the survey that they are undetectable against the background noise. Capelin are detectable offshore during the cod acoustic survey in spring and in fall groundfish trawl survey - both in the trawl and in cod stomachs. Observations suggest that capelin have been distributed closer to the bottom in recent years but the impact of this behaviour on acoustic estimates remains unknown. An acoustically dead zone where fish cannot be detected exists with respect to the equipment used in capelin surveys, and this zone increases with depth of the water column. The discrepancy between the inshore indices and the offshore acoustic survey remains unreconciled. Information on cod stomach contents collected offshore relates to this problem (see Section 3.1.2).

The lack of a time series of capelin abundance for Div. 2J3KL is a problem in ecological studies of the impact of capelin on predators such as cod and harp seals, and, reciprocally, the impact of predators on capelin. In the past an attempt was made to derive the best possible index of abundance from a composite of all available information Fahrig et al. (1990). An update of this index could be important for ecological studies. In this regard, capelin abundance and dynamics should be examined for effects of the two big declines in cod (late 1960s/early 1970s and late 1980s/1990s).

2.4 Invertebrate stocks

2.4.1 Summary - D.G. Parsons and E.G. Dawe WP#7

Northern shrimp (*Pandalus borealis*) landings from eastern Newfoundland, Labrador and Davis Strait increased from 2,700 t in 1977 to 8900 t in 1981, declining, thereafter, to a low of 3,100 t in 1984. The fishery expanded rapidly in the late 1980s with effort deployed in several new areas. Catches increased to a high of 28,000 t in 1989 and have ranged between 22,000 and 26,000 t since then. In 1993, approximately 3,700 t were taken for the first time in the new Flemish Cap

(Div. 3M) fishery. TACs in 1994 total 36,400 t, including some exploratory quota in Div. 0A and 0B. There is currently no TAC for the international fishery on Flemish Cap.

Assessments are conducted annually for each management area. Commercial CPUE, distribution of catch and effort, and catch composition are used extensively to infer the relative health of the resource. In the southern Div. 2J3K area, the resource is healthy and catch rates suggest that abundance is increasing. Exploratory fisheries have shown that shrimp is distributed over a broad range and that commercial concentrations now exist on grounds which were previously unproductive. The fishery in the Hopedale and Cartwright Channel area has produced stable catch rates since 1986. The resource appears healthy in that there has been no decline in the proportion of female (large) shrimp and the prospects for recruitment appear favourable. In Div. 2G, the continuation of high catch rates of large, female shrimp in recent years indicates a healthy spawning stock and implies the fishery is not significantly impacting the resource. The status of shrimp in Div. 0B is uncertain. The catch rate and commercial sampling data are not considered to be representative of overall stock conditions in this area.

Shrimp are prey for many species of groundfish, notably cod and Greenland halibut. Ecological linkages with various groundfish species are quantitatively unknown. It is clear, however, that during the period when many groundfish species have declined to very low levels, the shrimp resource, particularly in the southern 2J and 3K area, has increased. Further, the colder temperatures experienced since the late 1980s have had no apparent negative effect on either mortality of adults or survival of larvae and juveniles.

Groundfish biomass estimates from trawl surveys in Div. 2J3K for the 1978 - 1992 period show clear, inverse relationships with shrimp catch rates in the following year (Fig. 2.4). Some of the "best" fits are with species such as American plaice, witch flounder, roughhead grenadier and skates, none of which have been reported to prey heavily on shrimp. The significance of such relationships is yet to be determined but, initially, it is believed that they might reflect a complex process, not simply a predator-prey situation. The newly-formed regional Multispecies Working Group intends to examine the issue more closely in the coming year.

The snow crab (*Chionoecetes opilio*) fishery is prosecuted in near-shore as well as offshore areas around insular Newfoundland and off Labrador. The fishery is arbitrarily divided among 19 crab management areas to facilitate regulation of the fishery by TAC. Fishery statistics show that annual snow crab catches for Newfoundland and Labrador declined progressively in the 1980s to a low of 7,471 t in 1987. This decline was associated with increasing effort and a gradual decline in CPUE. In more recent years, since 1989, catches increased regularly to a record high of 21,718 t in 1993. Increasing catches were associated with increasing CPUE despite the maintenance of relatively stable and high effort levels. Such high levels of fishery performance, especially in 1993, have been attributed to both increasing commercial biomass and expansion of fishing grounds. However, any possible relationship to the decline in groundfish abundance is unclear at this stage.

An initial analysis of a 12-year data series of catch rate and morphometric data from trapping surveys also showed that catch rate of legal-sized crabs (>95 mm carapace width) was high during 1991-93. However the catch rate of crab of immediate pre-recruit size (76-94 mm carapace width) declined in 1993, suggesting that future recruitment may decline, beginning as early as 1994. The morphometric data further supported the likelihood of declining future recruitment. A very high proportion of those crabs of immediate prerecruit size in 1993 had achieved the secondary sexual characteristic of enlarged chelae. Such crabs are believed to have molted for their last time

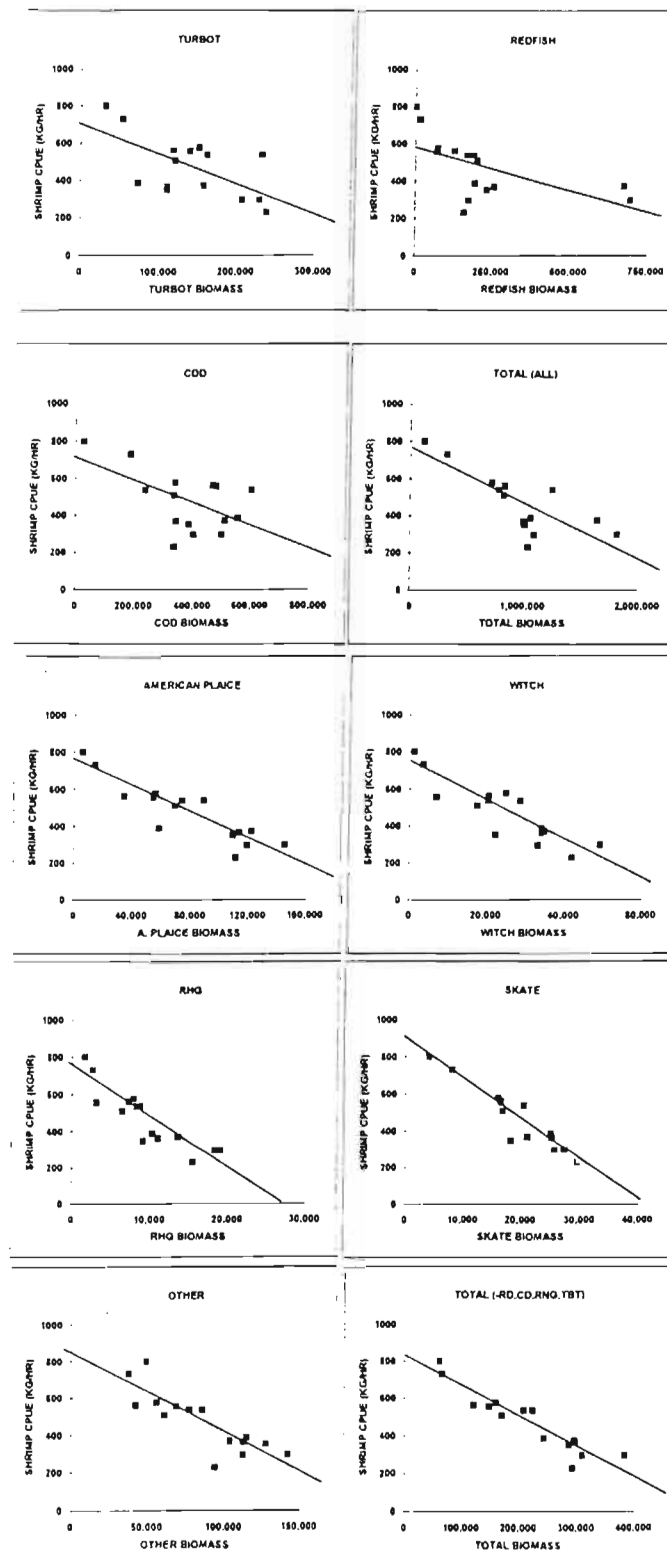


Fig. 2.4. Relationships between shrimp catch per unit effort (year $i+1$) and biomass of various groundfish species (year i) estimated from fall research trawl surveys.

(terminally-molted) and so will never recruit.

The fishery for short-finned squid (*Illex illecebrosus*) around the coast of insular Newfoundland expanded rapidly following an extended period of low abundance during 1968-74. Catch increased from 17 t in 1974 to about 89,000 t in 1979. This great increase was due to increased abundance of squid in Canadian waters concurrent with the expansion of squid markets. Since 1979 annual catch declined regularly to 421 t in 1983. Squid abundance has remained low since 1983 with a maximum annual catch of only 4,400 t (in 1990) within the past 11 years. Extended periods of low squid abundance, during 1968-74 and 1983-93, coincided with unusually cold periods.

The great variability in annual catch off squid off Newfoundland contrasts with relatively stable annual catches (and recruitment levels) at the southern-most fishery area, on the northeastern USA shelf. This suggests that Newfoundland, most remote from the tropical spawning site, represents marginal habitat for this widely-distributed unit population. Recruitment of the single year-class to the most northern fishery area is therefore likely to be regulated by the environment.

This squid interacts with Atlantic cod in coastal Newfoundland waters, as a predator, competitor and prey. Fish species preyed upon by squid at Newfoundland have been identified from collections of otoliths from squid stomachs since 1980. The most common otoliths encountered were those of Atlantic cod smaller than 9 cm in fork length (0-group). At the most commonly sampled site (Holyrood) the prevalence of cod among otoliths collected has declined in 1991 and 1992. In those years, respectively, otoliths of sand lance and hakes were the most prevalent. Unfortunately, no squid samples could be acquired from Holyrood in 1993.

2.5 Marine mammal stocks

2.5.1 Summary - G.B Stenson and B. Sjare, WP#6

Six species of pinnipeds (harp, hooded, grey, harbour, ringed, bearded) are present in the Newfoundland Region. A review of the status of all six can be found in Stenson (1993). Research on interactions between marine mammals and commercial fisheries in Newfoundland concentrates on harp and hooded seals. To determine the impact (regardless of how it is defined) of seals upon groundfish stocks, it is necessary to first determine the annual consumption of prey by seals. To accomplish this we need to know the abundance, energy requirements, distribution and diet of the predator. Current research is focused on improving our knowledge in all of these areas.

The last estimate of abundance of harp seals was based on an aerial survey estimate of pup production carried out in 1990. The annual pup production was estimated to be 578,000 (SE=39,000; Stenson et al. 1993) and the total population 3.1 million (Shelton et al. 1992). Hooded seal pup production was estimated to be 82,000 (SE=12,600; Stenson et al. 1994).

To determine the current abundance of harp seals, another pup production survey was completed in March 1994 using the same techniques as in 1990. All of the approximately 10,000 photos taken must be read before an estimate of pup production is available, likely in early 1995. It will then be possible to update the harp seal estimation model to provide an estimate of total abundance.

Data on the seasonal distribution of harp and hooded seals are obtained by using sighting surveys, the Offshore Observers Program, anecdotal reports and information on incidental catches in fishing gear. These sources provide general information but are hampered by difficulties in obtaining adequate sighting effort. Satellite telemetry is now providing detailed information needed to delineate movements and habitat use. Between 1991 and 1993, the movements and diving behaviour of 14 hooded seals were followed as they migrated from the breeding grounds in the Gulf of St. Lawrence to the moulting grounds off the southeastern coast of Greenland. The experimental deployment of 2 transmitters on harp seals captured in the Gulf in 1992 showed that this technology is transferable to the smaller species. We know that harp and hooded seals are capable of diving to depths greater than 400 m and 1000 m respectively.

The movements of a single harp seal, captured in northern Labrador in October 1993, indicates that seals can range over large areas of the northern Gulf and continental shelf off Newfoundland within a season. Twelve adult hooded seals were captured at the whelping concentration off the coast of Newfoundland in March 1994. Following breeding, the majority of the seals moved southward toward the Flemish Cap and southern Grand Banks areas, suggesting that hooded seals may spend considerable time in Canadian waters. The impact of these seals on fish stocks in the area is unknown. The transmitters will continue to provide information on the movements and diving behaviour of these animals until the moult in late June or early July.

The diet of harp seals from 1990 - 1993 was determined through the reconstruction of stomach contents. Significant annual, seasonal and geographical variations were seen. Arctic cod (*Boreogadus saida*), capelin and Atlantic herring were important prey for inshore harp seals in all years. The proportion of Atlantic cod and redfish varied greatly among years. Samples collected from the northern Grand Banks indicate that capelin may be more important for harp seals in offshore areas than inshore. The majority of fish eaten were between 10 and 20 cm in length. Less than 1% of the Atlantic cod taken were greater than 40 cm. The results of samples collected 1990 - 92 are summarized in Lawson et al. (1993).

Greenland halibut was the most important prey of hooded seals collect in nearshore waters of Newfoundland (Ross 1992). Redfish, Arctic cod, and Atlantic herring were also important prey species. A small sample of hooded seals (n=9) from offshore waters suggest that Atlantic cod and witch flounder may be important prey during the winter. A series of collections have been made in the past year which will increase our understanding of feeding of harp and hooded seals in offshore areas.

A harp seal consumption model, incorporating all of the current data, is being developed by the regional Multispecies Working Group. Preliminary estimates of annual cod consumption should be available within next year. New data will be incorporated into the model as they become available, allowing us to refine our estimates of fish consumption.

2.5.2 Discussion

Harp seal stomach contents indicate that Arctic cod is more important than capelin in inshore diet and that pups eat less invertebrates than previously thought. However, in the offshore samples collected in January, capelin is dominant in the diet. Length measurements of fish consumed suggest that prerecruits in the size range 10-20 cm predominate. Preferred size ranges vary from species to species - for example harp seals consume smaller capelin than they do herring. Hooded seals consume larger prey than do harp seals, commonly fish in the 20-30 cm size range. The

relative importance of hooded and harp seals is important to consider. Although harp seals are 5 times more abundant than hooded seals in the region, hooded seals grow to a larger size. In certain areas, for example on the Flemish Cap, hooded seals could be having an impact on some fish stocks, although this has not yet been examined.

Based on the analysis of stomach contents, output from the population model and analyses of energy requirements, an estimate of harp seal consumption by prey type should be available by the end of the year. This work is being coordinated within the regional Multispecies Working Group. Analyses of impacts of marine mammals on fish stocks require careful consideration of the various sources of uncertainty and assumptions used. Analysis of the potential impact of consumption of juvenile cod by harp seals on the recovery of Div. 2J3KL cod has not yet been undertaken.

3. Stock assessments

3.1 Div. 2J3KL cod

3.1.1 Stock status summary - C.A. Bishop, E.F. Murphy, D.E. Stansbury and M.B. Davis, WP#37

Summary

Although it was not possible to precisely determine the stock size in 1993, the research survey data available suggest that there has been a further stock decline. Low numbers of older cod in the offshore surveys indicate that the spawning stock is also lower. The sizes of incoming year classes continue to be low. Re-evaluation of estimates of the most recent "good" year classes (1986, 1987) now indicate that they may have been below average. Until there is evidence of the presence of a significant number of young cod which then survive to maturity, stock recovery will not occur.

The Fishery

Prior to the 1950s, landings from this stock generally ranged between 200,000 t and 300,000 t. With the increased effort by foreign fleets, catches increased in the late 1950s and early 1960s and peaked at just over 800,000 t in 1968. Catches then declined to 139,000 in 1978 but increased thereafter, mostly as a result of increased catches by the Canadian offshore fleet. Severe reductions in stock size led to reduced TACs and eventually a moratorium on commercial fishing in mid 1992 which was extended to all types of fishing effective January 1, 1994. The total catch for the "recreational," foreign (outside 200 miles) and by-catch fisheries in 1993 has been estimated at about 11,000 t, although the reliability of this is unknown.

Analysis

The main data sources used in assessing this stock are estimates of catch at age from the fisheries and estimates of population numbers at age from annual research vessel surveys. The catch in 1993 was mainly from a recreational or food fishery and could only be roughly estimated. Research vessel surveys are conducted during fall in Divs. 2J3KL and spring in Div. 3L. Survey estimates of biomass and abundance have declined sharply in recent years, with the 1993 values extremely

low and no cod caught older than age 9. The survey age structure has changed in recent years with younger (age 4) cod predominating as opposed to ages 5 to 6 in the 1980s.

Hydroacoustic surveys in 1993 also suggested a continuing decline in numbers as well as some distributional changes to deeper water and toward the Nose of the Grand Bank in Div. 3L.

Although stock size and fishing mortality could not be estimated, analyses incorporating the extremely low RV abundance estimate for 1993 suggest that total mortalities in recent years have been very high and most likely in excess of 1.0 for the fully recruited age groups. Total mortality appears to have declined between 1992 and 1993 because of the fishery closure, but still appears to be higher than can be explained by the estimated catch. Thus the total estimated catch for 1993 of about 11,000 t seems to have been too low to account for the continuing decline in the RV estimates. Three alternative possibilities exist: a) the survey results are real which implies that factors other than fishing must be responsible for the observed declines, b) year effects in recent surveys are hampering calibration of SPA, or c) the 1993 catch has been underestimated. It is not possible to determine which of these is correct. Furthermore, it is also possible that the recreational fishery in 1993 took fish predominantly originating from supposed inshore stocks. The areas where these fish would occur are not covered during the fall surveys, and no information exists concerning possible trends in inshore 'stock' abundance.

Prognosis

The 2J3KL cod stock abundance increased from the mid 1970s to the mid 1980s but has since declined. There is little doubt that the stock decline observed in recent years has continued in 1993 and that the stock is at a dangerously low level.

Survey data including estimates of spawning stock size indicate that the low recruitment levels estimated for recent years will persist. Stock recovery cannot begin until there is production and survival of significant numbers of new recruits.

Stock status summary sheet for Div. 2J3KL Cod

Year	1987	1988	1989	1990	1991	1992	1993	1994	Min. ¹	Med. ¹	Max. ¹
F _{0.1} Catch '000t	246	293	125	121	100						
Advised TAC '000t	266	293	125	174	100						
TAC '000t	256	266	235	199	190	120	2	0			
Reported catches '000t	235	269	253	219	171 ³	44 ³	11 ³		11	270	810
Unreported catches					N/A						
Estimated discards					N/A						
Total catches	235	269	253	219	171 ³	44 ³	11 ³				
Total biomass '000t											
Spawning biomass											
Mean - F ()											

¹ For 1962-1993² June 1992 - lowest possible³ Preliminary

Catches: A moratorium on commercial fishing was imposed on the Canadian fishery in July 1992 and subsequently by the European Union on its fleet. Estimated catches by the recreational, foreign (outside 200 miles) and by-catch fisheries in 1993 totalled approximately 11,000 t. The moratorium was extended to include the recreational fishery effective in January 1994.

Data and Assessment: The principal index of abundance is a fall offshore research vessel survey series. From 1978 to 1990, the catch per tow averaged about 50 cod with the 1990 catch per tow equal to the average. This declined to 33 fish per tow in 1991. The decline was more pronounced for fish age 6 and older. Despite the severe reduction in fishing activity as a result of the moratorium, the catches decreased further during the 1992 and 1993 surveys to 9 and 2 fish per tow respectively.

Fishing Mortality: Although stock size and fishing mortality could not be estimated, analyses incorporating the extremely low RV abundance estimate for 1993 suggest that total mortalities in recent years have been very high and most likely in excess of 1.0 for the fully recruited age groups. The continued drastic decline in survey abundance occurred in the virtual absence of an offshore fishery and with a low 'recreational' fishery.

Recruitment: The 1986 and 1987 year-classes were originally estimated to be strong but subsequent analyses resulted in downward revisions of the estimates such that they now appear to have been below average. Survey data would suggest that year-classes since that time are weak. Spawning stock biomass remains low, and based on previous analyses strong recruitment is not anticipated.

Environmental Factors: Temperatures recorded at Station 27 during the 1990s have been anomalously low when compared with the mean for years since 1946. However, temperatures during the 1990s may be close to the average in the longer term perspective going back to the 1800s.

Multispecies Considerations: Capelin abundance estimates from offshore acoustic surveys have been very low since 1990 although inshore indices suggest 1993 abundance at or above average levels. The biomass of some other very lightly exploited groundfish stocks in this area have also decreased markedly since the 1980s. The harp seal herd appears to be increasing although their impact on cod as a predator or competitor has not been quantified. During the period when many groundfish species have declined to very low levels, the northern shrimp resource, particularly in the southern 2J and 3K areas, has increased. The snow crab population off eastern Newfoundland has also increased in recent years as evidenced by increasing catch rates with relatively stable effort although the improved recruitment occurred prior to the decline in the cod stock.

State of the Stock: The stock is in a very depressed state, probably at an all-time low.

Forecast for 1995: Current data suggest further stock declines. No fisheries should be considered until there is evidence of adequate recovery.

Long-term Prospects: Before the expansion of the fishery in the 1960s, catches were generally in the 200,000 t to 300,000 t range. During the 1960s, good recruitment along with exploitation rates ranging from 25% to 50% saw catches averaging about 580,000 t. Given the current depressed state of the stock which continues to decline, the low current spawning stock biomass and the apparent low recruitment levels of recent years, stock recovery in terms of total and spawning stock biomass is not possible in the next 5-7 years. Stock recovery cannot begin until there is production and survival of significant numbers of new recruits.

Special Comment: Total mortality appears to have declined between 1992 and 1993 because of the fishery closure, but the total estimated catch for 1993 of about 11,000 t seems to have been too low to account for the continuing decline in the RV estimates. Three alternative possibilities exist: a) the survey results are real which implies that factors other than fishing must be responsible for the observed declines, b) year effects in recent surveys are hampering calibration of SPA, or c) the 1993 catch has been underestimated. It is not possible to determine which of these is correct. It is possible that the recreational fishery in 1993 took fish predominantly originating from supposed inshore stocks. The areas where these fish would occur are not covered during the fall surveys, and no information exists concerning possible trends in inshore 'stock' abundance.

3.1.2 Technical basis

3.1.2.1 Available data

Nominal catches - C.A. Bishop, E.F. Murphy, D.E. Stansbury and M.B. Davis, WP#11

Nominal catches for this stock increased during the late 1950s and early 1960s and peaked at just over 800,000 t in 1968 (Fig. 3.1). Catches rapidly declined thereafter and were at a low of 139,000 t in 1978. From 1980 to 1992 catches ranged from 219,000 to 270,000 t, but declined to 150,000 t in 1991 and further to 44,000 t in 1992.

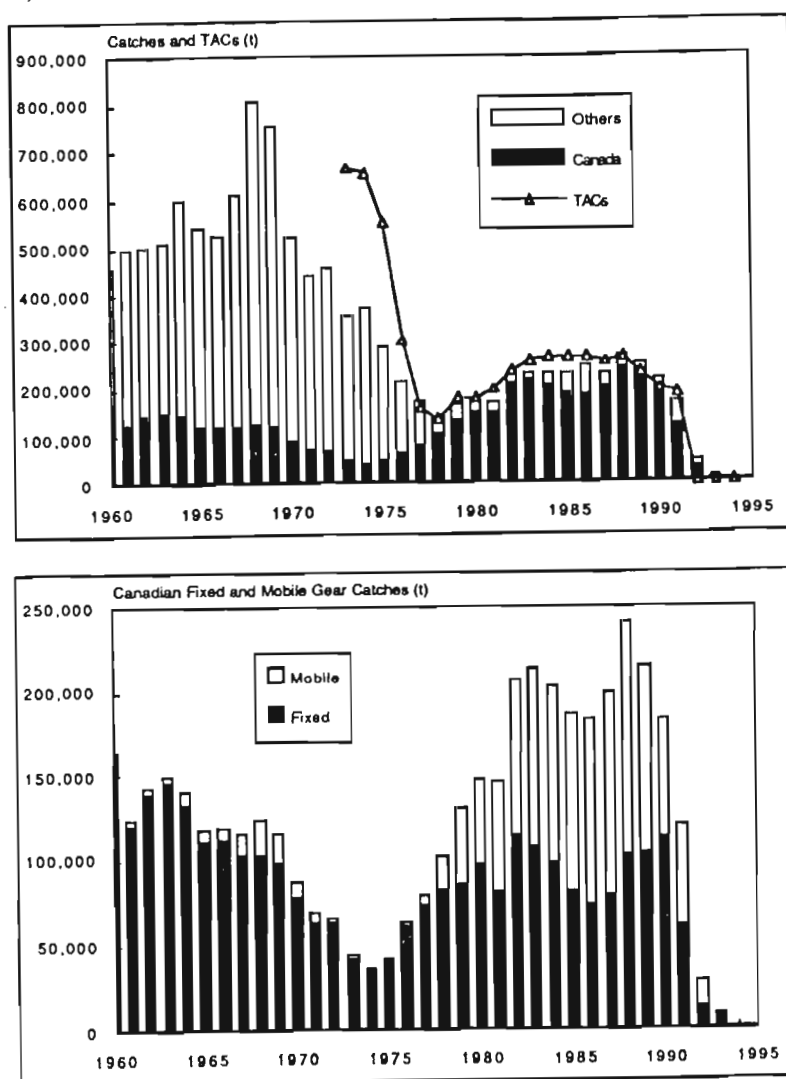


Fig. 3.1. Time series of annual catches by Canada and other sources together with the TAC for the period 1960-94, and by Canada for fixed and mobile gear.

In the same period Canadian catches peaked at 242,000 t in 1988 but subsequently declined to 29,000 t in 1992. The commercial fishery on this stock was closed in mid 1992. At the end of 1993 the recreational fishery was closed. It was estimated that during 1993 this fishery took about 9,000 t of cod. Most of this catch was taken by handline in Div.3L, and mainly during the Sept. – Oct. period. Canadian Surveillance has also estimated that about 2,500 t of cod were obtained by foreign fleets (mainly Spain) on or east of the Nose of the Grand Bank in Div. 3L.

Commercial catch rates - C.A. Bishop, E.F. Murphy, D.E. Stansbury and M.B. Davis, WP#11

Prior to the 1993 assessment of this stock, commercial otter trawl catch and effort data were used in calibration of SPA. The resulting analyses had indicated that the patterns, or year effects, in the residuals were persistent and sufficient to preclude their use as an abundance index. In any case, this information was not available for 1993 as there was no directed fishery. Adequate catch and effort data from inshore fixed gear fisheries are not obtainable from DFO statistics.

Catch at age - C.A. Bishop, E.F. Murphy, D.E. Stansbury and M.B. Davis, WP#11

The total catch and consequently total removals at age in 1993 were only roughly estimated. Sampling was available to adequately estimate age and length compositions of the catch from the recreational fishery. A limited amount of data (length frequency only) was provided for the foreign “by-catch” fishery in the regulatory area. Catch at age for the latter was obtained using the Canadian Spring 3L RV age length key. Canadian catches were mainly of ages 4 and 5.

Condition Factors

Condition factors as measured by body and liver weights relative to length fluctuated without apparent trend from 1977 until 1989 after which they declined through 1992 in divisions 2J and 3K (Taggart et al. 1994). These declines were most pronounced in Div. 2J. In Div. 3L on the other hand, there has been an upward trend in recent years. Data were not yet available for 1993.

Research trawl survey data - C.A. Bishop, E.F. Murphy, D.E. Stansbury and M.B. Davis, WP#11

Research vessel surveys have been conducted by Canada during fall in divisions 2J, 3K and 3L since 1977 1978 and 1981 respectively. Since their inception, the surveys in divisions 2J and 3K have experienced difficulties in specific areas with respect to the accuracy of nautical charts regarding recorded depths. These charts had formed the basis for stratification charts. The availability of accurate charts in the late 1980s resolved some of these problems but necessitated some adjustment to the original stratification scheme, particularly in Div. 2J. The revised stratification schemes were first used during the 1993 fall surveys. Some difficulties were encountered in comparisons with previous strata although the total area covered was only slightly different than that of the original stratified area.

Survey estimates of biomass and abundance have declined sharply in recent years with the 1993

values being extremely low (Fig. 3.2). Similarly the 1993 spring survey conducted in Div. 3L indicated that biomass and abundance in this division are by far the lowest in the time series.

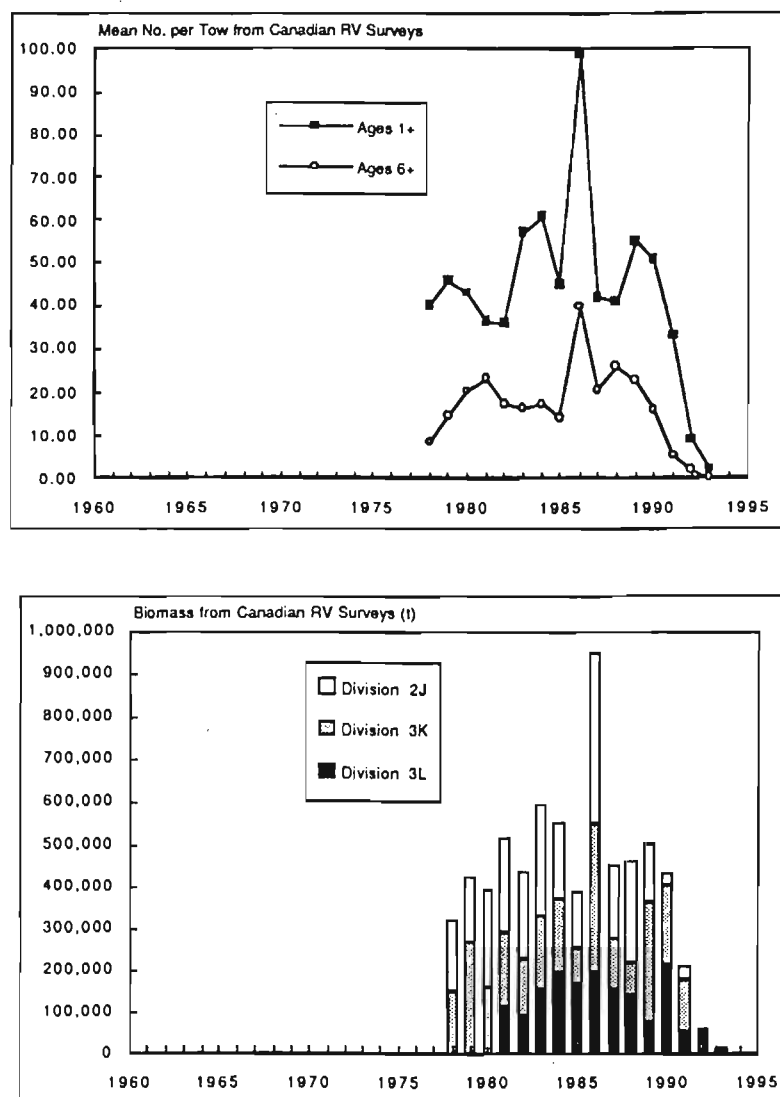


Fig. 3.2. Estimated of annual abundance and biomass from Canadian fall RV trawl surveys from 1978 to 1993. Abundance estimates are divided into ages 1+ and 6+ components and the biomass estimates into the contribution from each of the three Divisions.

The survey catches at age in 1993 were mainly from ages 3 and 4 although, as indicated, total abundance was very low. No cod were caught at ages older than 9 years. Average weights at age from the 1993 surveys, although represented by small samples, were not

substantially different from those observed in the 1992 survey. Recent average weights for all divisions were substantially lower than those observed in the early 1980s (Fig. 3.3).

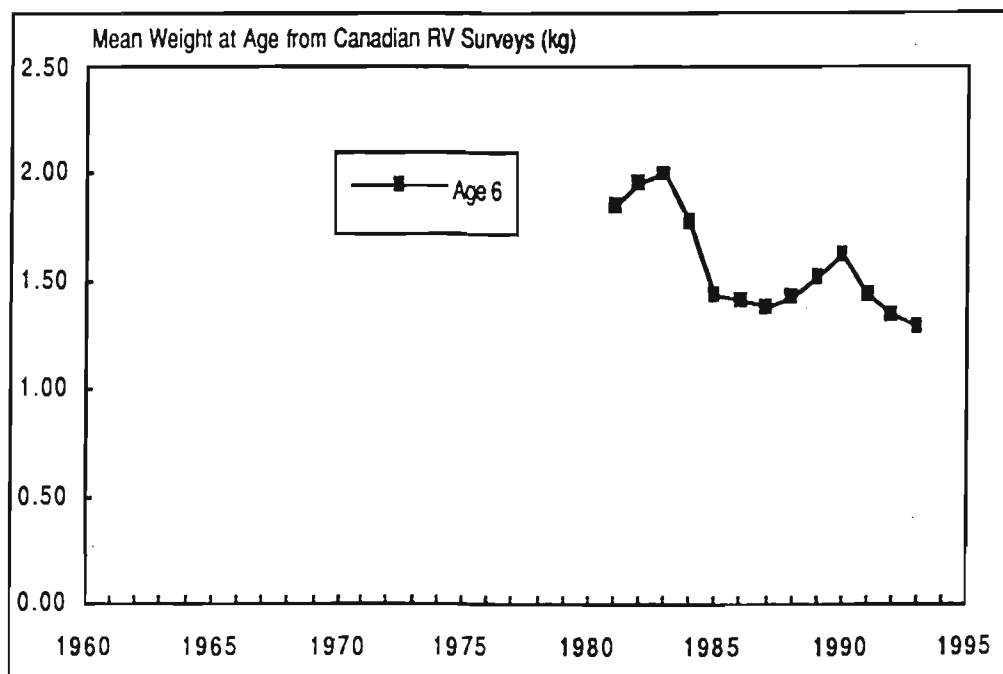


Fig. 3.3. Mean weight at age for age 6 cod in Canadian RV surveys for the period 1981-93.

The distribution of cod catches during the fall surveys from 1981 to 1993 indicated a fairly typical pattern from 1981 to 1988. Catches were spread over the entire survey area and most large catches were in shallower water. Commencing in 1989 fewer cod were found near the coast, particularly in Div. 2J. During 1990 and 1991 most cod were found on the seaward slopes of the offshore banks and in 1992 and 1993 there were virtually none in divisions 2J and 3K and very low abundance in Div. 3L, particularly in 1993. The only cod located during 1992 and 1993 were in the northern part of Div. 3L bordering with Div. 3K.

In divisions 2J and 3K, abundance generally increased at depths greater than 400 m since 1987 although, total abundance was constant or declining (Fig. 3.4).

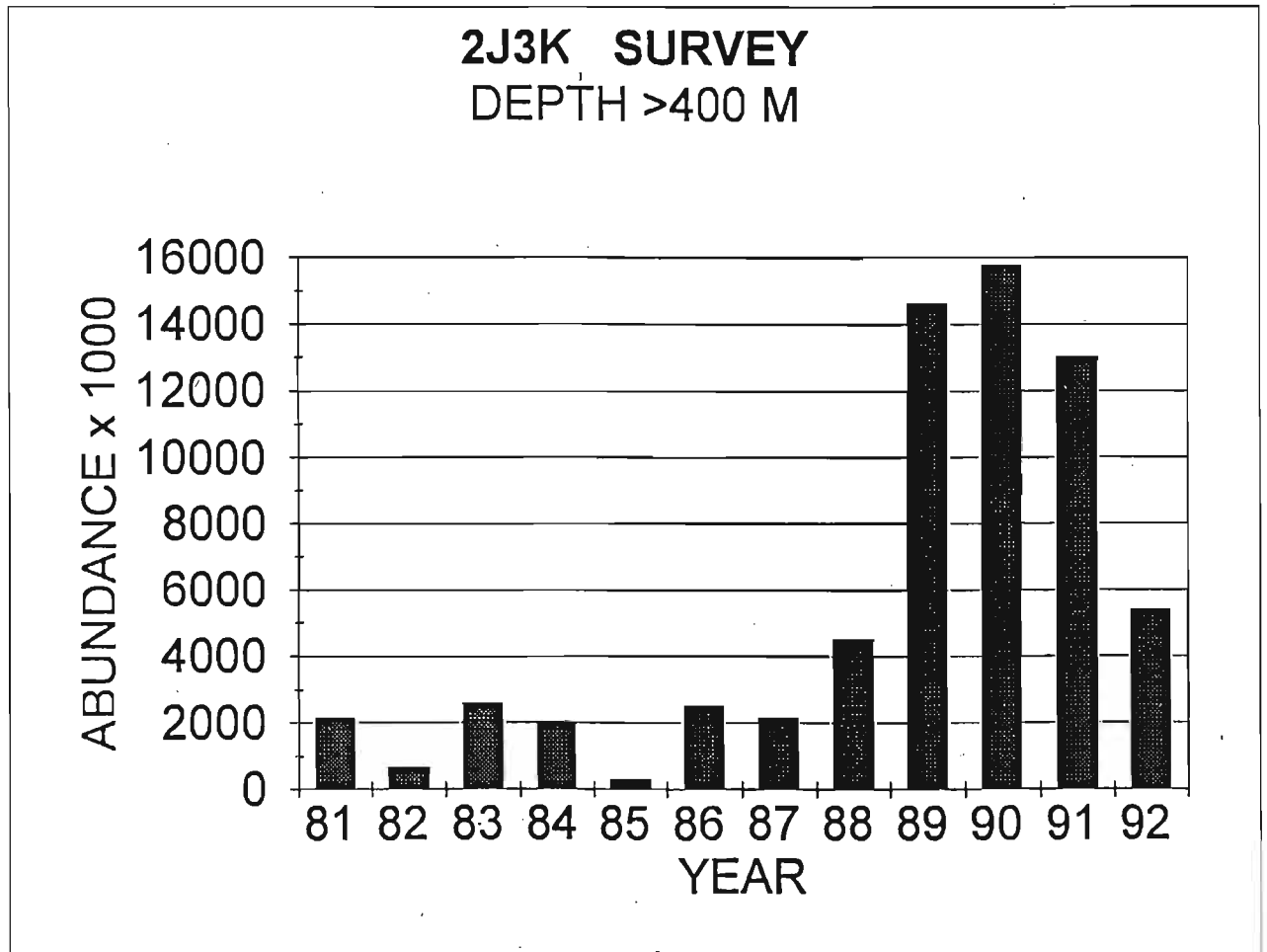


Fig. 3.4. Abundance of cod at depths greater than 400m in Canadian fall RV surveys from 1981 to 1992.

Age distribution of cod from research vessel data over the last decade - C.T. Taggart, WP#19

Autumn research vessel survey total catch at age (ages 1 to 23) data, and average number per tow at age (ages 1-23) weighted by survey stratum area using STRAP, data were used to examine the age distribution of 2J and 2J3KL cod. The age structure of the 2J cod survey population has collapsed from a relatively wide age distribution (20+) in 1982 to a relatively narrow (7+) age distribution in 1992. This represents a loss of the majority of the spawning-aged fish. The average, modal and median ages of the 2J3KL cod stock have cycled between ~age-5 and ~age-6 over the last decade or so, but has recently (1990s) decreased to ~age-4 with a corresponding decrease in the width of the age distribution (maximum age-8 in 1992). This parallels a decrease in the total numbers of fish estimated for the stock.

Acoustic surveys - C.A. Bishop, E.F. Murphy, D.E. Stansbury and M.B. Davis, WP#11

Winter hydroacoustic surveys conducted since 1987 found large concentrations of cod in southern Div. 2J and northern Div. 3K at depths ranging from 300 to 500 m from 1987 to 1989, with concentrations occurring further south each year. In the 1990 survey, commercial concentrations of cod were found still further south in Div. 3K and mainly at 550 m, about 150 m deeper than in previous years. Over the period 1991–93 the surveys indicated substantial declines in cod densities, particularly in 1993. Significant concentrations were encountered outside the primary survey area in 1993 at depths approximately 930 m on the Nose of the Grand Bank. There was no comparable survey in 1994.

Spring studies have been conducted during the 1990–93 period on the distribution and movements of cod in divisions 3K and 3L when cod are concentrated in this area for spawning and prior to their migration to inshore areas. From 1990–1992, cod were highly aggregated in the basin south of Funk Island Bank (termed the "Bonavista Channel"). In 1993 a large aggregation did not occur in this area. The distributions observed suggest that cod had moved along the slope further to the southeast in the winter of 1992/93. The aggregation located in the latter area was only 20–25 miles from an area of concentration located during the winter 1993 acoustic survey.

Cod were concentrated at similar temperatures and salinities in spring of all years. Cod were also aggregated along the northern edge of the Grand Bank in 1991, 1992 and 1993, (no sampling was conducted there in 1990). Fish were located at depths of less than 400 m in 1991. In 1992 fish were located up to and likely deeper than average acoustic enumeration limits (ca. 600 m). In 1993 fish were located at depths between 350 and 500 m.

The densities within the aggregations in the spring surveys remained relatively stable in the 4 years studied. However, the volume of the aggregations declined sharply from 1990 to 1991, less so from 1991 to 1992, then sharply again from 1992 to 1993. The overall estimates of abundance declined dramatically from 1990 to 1991, then slightly from 1991 to 1992. Abundance estimates in 1993 were less than half those measured in 1992.

Acoustic survey data for 1993 - G.A. Rose, WP#10

An acoustic survey using 2 vessels (Gadus Atlantica 231 and Petrel V 93-2) was conducted from the Nose of the Grand Bank (47°06'N, 47°18'W) to the outer reaches of the Funk Island Bank (50°45'N, 50°30'W), from June 8-30, 1993 (divisions 3L and 3K) (Fig. 3.5a). The survey grid consisted of parallel transects spaced 10 n miles apart and covered waters within the depth range 200-900 m. (a total of approximately 3,480 km of transects). There were three deviations from this general design: (i) in areas characterized by temperatures and salinities previously identified as holding the bulk of the cod in this region at this time of year (from 1990-1992 data), transect spacing was reduced to 5 n. miles, (ii) storm conditions reduced the precision of the spacing on several occasions, and (iii) secondary adaptive grids were conducted on 3 occasions when aggregations of cod were located on the large grid (several hundred kms of additional transects). Adaptive grid results were not included in present estimates. Thirty-four fishing sets were made as directed by acoustic indications of target density, size, and species.

Dual beam echosounders were used on both vessels. On the Gadus an EK400 sounder (49 kHz) with the deep tow system enabled integration measurements (20 Log R amplification) to be made to 750-800 m (300 m tow depth + 450-500 m acoustic range). Depths from 800-900 m could be

surveyed only qualitatively (no cod were identified there). Single target mensuration is limited with this system to 525 m at 300 m tow depth because of the restricted TVG properties of the EK400. On the Petrel V a Biosonics 102 sounder (38 kHz) was used with a 40 m tow depth (this combination and the quieter conditions of this vessel relative to the *Gadus* allows integration and single target mensuration (20 and 40 Log R amplification) of small cod to a maximum of 550 m). Signal processing on both vessels was done using Biosonics ESP technology with data channelled directly to optical storage drives. Both vessels and their respective hardware and software were calibrated in two ways: (i) Sounder outputs and receiving sensitivities were calibrated against standard spheres (copper 49 kHz; tungsten carbide 38 kHz). (ii) An intervessel calibration comparing *in situ* target strength measures was conducted over an aggregation of capelin on the north Cape of the Grand Bank. In this exercise, vessels ran similar transects at a distance of approximately 0.5 miles apart with the following vessel just off the leading vessel's stern. Each vessel took a turn at leading and following. The results of the target strength comparison of the two vessel indicated that differences in frequency, vessel, and hardware brand had no significant effect on results.

Data analysis included simultaneous integration and target strength estimation. Integration was done simultaneously from the transducer down in 20 m strata and from the bottom up in 1 m strata (to 10 m off bottom). Report length was 1 km (except for adaptive grids). The bottom up strata were used in a back stepping algorithm to find the first inflection point in the echo signal (nearest bottom) and any signal below this was subtracted from the top down strata (used for the integration). This procedure has been found to reduce the noise in integrator signals near bottom and to give less variable results than commercial integrators. Signal "bins" were classified as to taxa by combining information from three sources: (i) set results, (ii) echogram interpretations, and (iii) signal patterns (Rose and Leggett 1988). Integration then was done by taxa (cod, capelin, deep-water species, pelagic scatterers (euphausiids, myctophid fishes)). Total abundance estimates were derived by expanding mean transect densities over the area half way to adjacent transects.

The largest sources of uncertainty in the acoustic abundance estimates are thought to be the target strength applied to the acoustic integration and the proportions of the stock area covered by the surveys in each year. Standard procedures have been based on average trawl samples and average length-TS relationships. This procedure assumes no trawl selectivity or fish size segregation. Recent data suggest both assumptions are violated. Hence, *in situ* target strengths have been analyzed from the adaptive surveys conducted. Preliminary results suggest strong interaction between target strength and likely trawl selectivity (e.g. smaller TS fish are undersampled in trawl). A preliminary estimate of 1993 mean TS (*in situ*) is -36 dB. Research to better estimate and apply TS values continues.

A total of 59 transects ranging in length from 9 to 198 km were used to estimate fish numbers. Cod were located in 3 regions: (i) 4-8 year-olds on the Nose and North Cape of the Grand Bank; (ii) 3-4 year olds in the Bonavista Basin; and (iii) 2-3 year olds (some 4s) in the Notre Dame Channel (Fig. 3.5b). The estimate of cod numbers is 80 million (based on -36 db mean TS). Thirty bottom and 4 mid-water sets were completed (Fig. 3.5c). The single large set was made on the aggregation located on the Nose of the Grand Bank (12,622 fish). Set data were used to aid acoustic interpretations.

Several findings are noteworthy: (i) acoustic densities in the post-spawning migratory aggregation in 1993 did not differ from those in 1990-1992 (Bishop et al. 1993) assuming equal TS values (aggregation size declined); (ii) total minimal numbers were <0.5 those estimated in 1992 (again assuming equal TS); and (iii) distributions changed remarkably between June 1992 and June 1993

(Fig. 3.5b,d). Distributions reported here suggest that fish moved along the North Cape further to the southeast in the winter of 1992/3 (the location of the aggregation in the spring was 20-25 n. miles shoreward from where cod were located in February 1993 by the *Gadus* acoustic surveys after surveillance reported foreign vessels fishing cod).

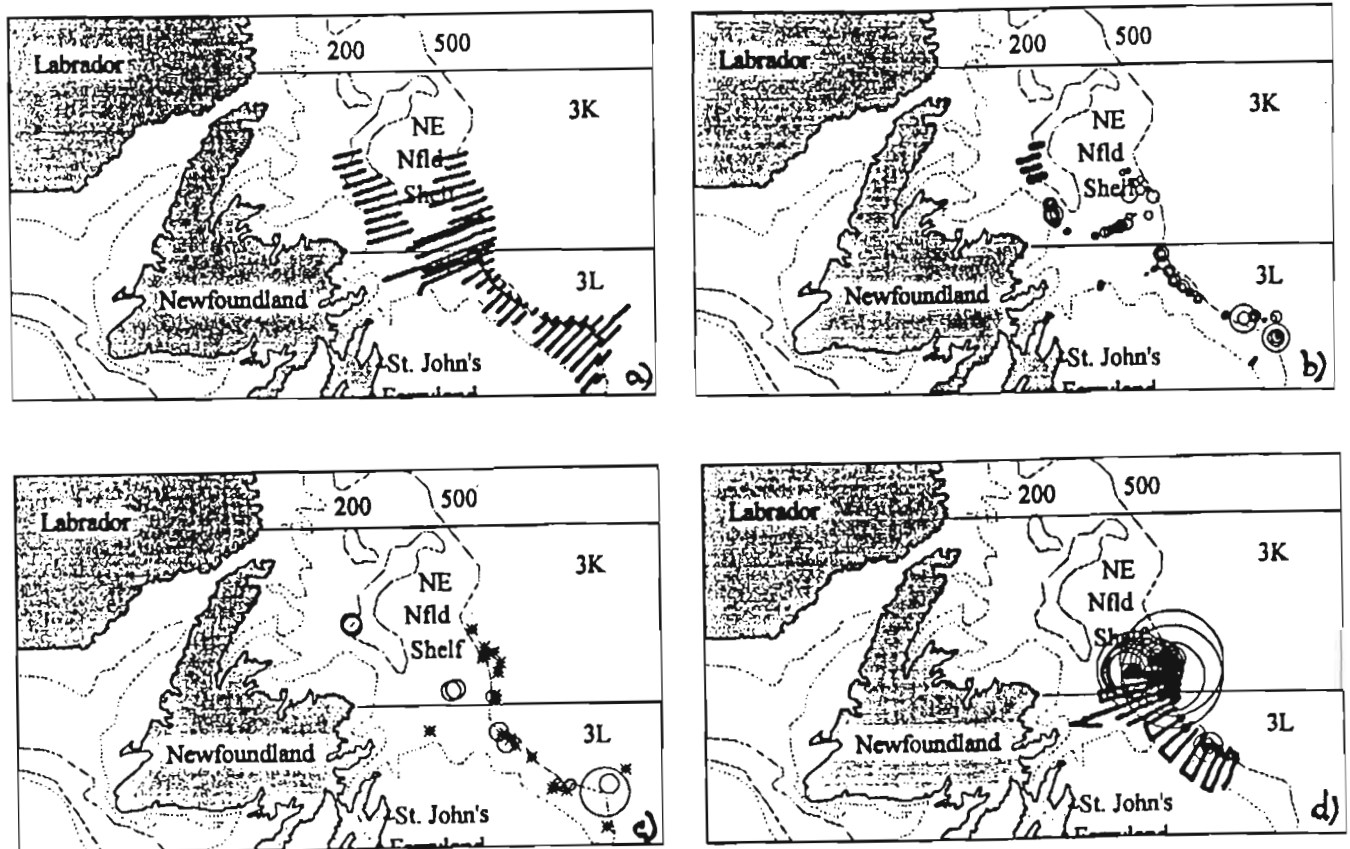


Fig. 3.5. a) Survey transects data points from 2 vessel grid run in June 1993 and used in minimal numbers estimation; b) distribution of cod from acoustic records collected in transects identified in a), densities range from 0.00001 to 0.3 fish/square metre; c) numbers of cod caught in bottom trawls directed by acoustic data interpretations, stars are 0, largest symbol = 12,500 fish; d) distribution of cod from similar survey in June 1992 (note that area covered is only part of area covered in 1993, values range from 0.00001 to 6 fish/square metre).

O-group and juvenile studies - J. Anderson, E. Dalley and D. Methven, WP#15, WP#16, WP#17, WP#18

The predominantly inshore distributions sampled for pelagic (0-group) juvenile cod during 1991-93 differed significantly from the offshore distribution observed in 1981. The different distributions are consistent with what we would expect based on historic and recent spawning distributions, and modelled drift of cod eggs and larvae. Compared to the numbers sampled and the broad offshore distribution in 1981, it would appear that significantly fewer pelagic cod occurred in recent years, 1991-93.

The distribution of 0-group cod at beaches along the coast in the nearshore environment in 1992-93 was remarkably similar to the historic distribution sampled in the early 1960s. Similarly, abundances of cod aged 0-2 years were not different, although values in 1992-93 tended to rank towards the lower range. The persistence of 0-group cod within the nearshore environment indicates this is a preferred habitat. However, this persistence contrasts with observations that there has been a significant southward shift in spawning and significantly lower recruitment during the 1990s.

The discrepancy between the distributions of pelagic 0-group cod and that of 0-group cod in the beach environment could be explained by a persistence of inshore spawning in the bays along the NE coast of Newfoundland. Inshore spawning has occurred historically within the bays (Templeman 1981, Hutchings et al. 1994). If there has not been a southward contraction of inshore spawning, as has occurred offshore (deYoung and Rose 1994), then we would not observe a contraction in the distribution of 0-group cod in the beach environment, whereas we would observe a significant shift in the distribution of pelagic juveniles offshore. Alternatively, it has been hypothesized that the nearshore beach environment is a highly preferred, albeit limited, habitat of juvenile cod. In this case, it can be argued that the beach environment is always saturated by 0-group and 1-group juvenile cod regardless of cohort abundance or spawning distributions. In either case, the nearshore beach environment would not be sensitive to year-class strength variations, as observed.

The distributions of cod aged 1-3 years observed during the demersal surveys in 1992-93 is consistent with the historical description: age 1 cod predominate inshore while age 3 cod are more predominant offshore. Because directed sampling previously has not been carried out inshore a direct comparison to historical data is not possible. The recent observations emphasize that cod < 3 years of age occur predominantly shoreward of the fall RV survey boundary. As such, we might expect the RV survey to systematically underestimate the abundance of young cod, but particularly at small cohort sizes where most juvenile cod (< 3 years) are found shoreward of the survey boundary.

Catch rates of 0-group cod were higher in 1993 than 1992, as measured in both the beach seine surveys and the demersal juvenile cod surveys. This contrasts with results of the pelagic juvenile cod surveys which indicated that catch rates in 1992 were higher. Catch rates were slightly higher for 1-group fish in 1992 in both the beach seine and demersal surveys, indicating that the 1992 year-class may be larger than that of 1991. This result agrees with estimates from the pelagic juvenile survey, which indicated the 1991 year-class to be less than either 1992 or 1993. Overall catch rates from Japanese Pelagic traps were 20% higher in 1993 than 1992, but data are not yet available to evaluate the relative catch rates of age groups in the traps in 1993.

Preliminary predictions of year-class size from the different data sources has been qualitatively summarized in Table 3.1. There is agreement between the By-catch and RV2+3 years estimates that the combined 1989-90 year-classes will be at historically low levels. However, there is disagreement between the By-catch and RV2+3 indices for the combined 1990-91 year-classes, which are ranked as "medium" and "lowest" for the available time series, respectively. Year-class size in 1991 appears to be very low, based on the beach seine, the pelagic 0-group, demersal juvenile and RV2+3 indices. However, the 1992 year-class appears to be a moderately good one, based on the beach seine, pelagic 0-group and demersal juvenile indices. The 1993 year-class would appear to be relatively low, based on the beach seine and demersal juvenile indices, and the historic comparison to 1981 for the pelagic 0-group survey.

Table 3.1. Preliminary classification of relative year-class strength based on different data sources and compared for different time series, as available. "By-catch" refers to juvenile cod ages 2 and 3 years caught in capelin trap nets; "RV2+3" refers to the mean catch rate of cod ages 2 and 3 years from the fall RV surveys; "VPA Age 3" refers to estimates available from the 1994 assessment; "Beach Seine" refers to the Flemming Beach Seine Surveys; "Pelagic 0-Group" refers to the pelagic 0-group surveys carried out in 1981 and 1991-93; "Demersal" refers to juvenile cod surveys carried out in 1992 and 1993.

Year-Class	By-Catch (1981-93)	RV2+3 (1981-93)	Beach Seine (1959-64, 1992-93)		Pelagic 0-Group (1981 & (1991-93) 1991-93)		Demersal (1992-93) (1992-93)	
			Age 0	Age 1			Age 0	Age 1
1989-90	lowest	very low	N/A	N/A	N/A	N/A	N/A	N/A
1990-91	medium	lowest	N/A	N/A	N/A	N/A	N/A	N/A
1991	N/A	N/A	N/A	lowest	lowest	lowest	N/A	lower
1992	N/A	N/A	low	med.	low	highest	lower	higher
1993	N/A	N/A	med.	N/A	low	medium	higher	N/A

Cod by-catch in capelin traps - G. Winters and B. Nakashima, WP#14, WP#28

Since 1981 catch and by-catch statistics have been collected by a voluntary logbook program involving nearly 200 fishers prosecuting the capelin fishery in Div. 3KL. An analysis of cod by-catches in the capelin trap fishery for the period 1981-93 indicated that mean annual by-catches fluctuated from 38 kg/trap haul in 1982 to 6 kg/trap haul in 1990 (mean by-catch = 20 kg/trap haul). Cod by-catch levels were, on average, much higher in 3L than in 3K with Bonavista Bay and Trinity Bay having the highest by-catch levels. Previous studies (Stevenson et al. 1984) have shown that the majority of this cod by-catch consists of juveniles at ages 2 and 3. A statistically

significant relationship was demonstrated between mean annual by-catch levels and mean cod recruitment as estimated by the 1993 ADAPT. Based on this relationship, the 1993 mean by-catch level of cod (23 kg/trap haul) suggests that recruitment of 2J3KL cod in the early 1990s was close to the average level (approximately 200 million fish) estimated for the year-classes produced in the 1980s (Fig. 3.6).

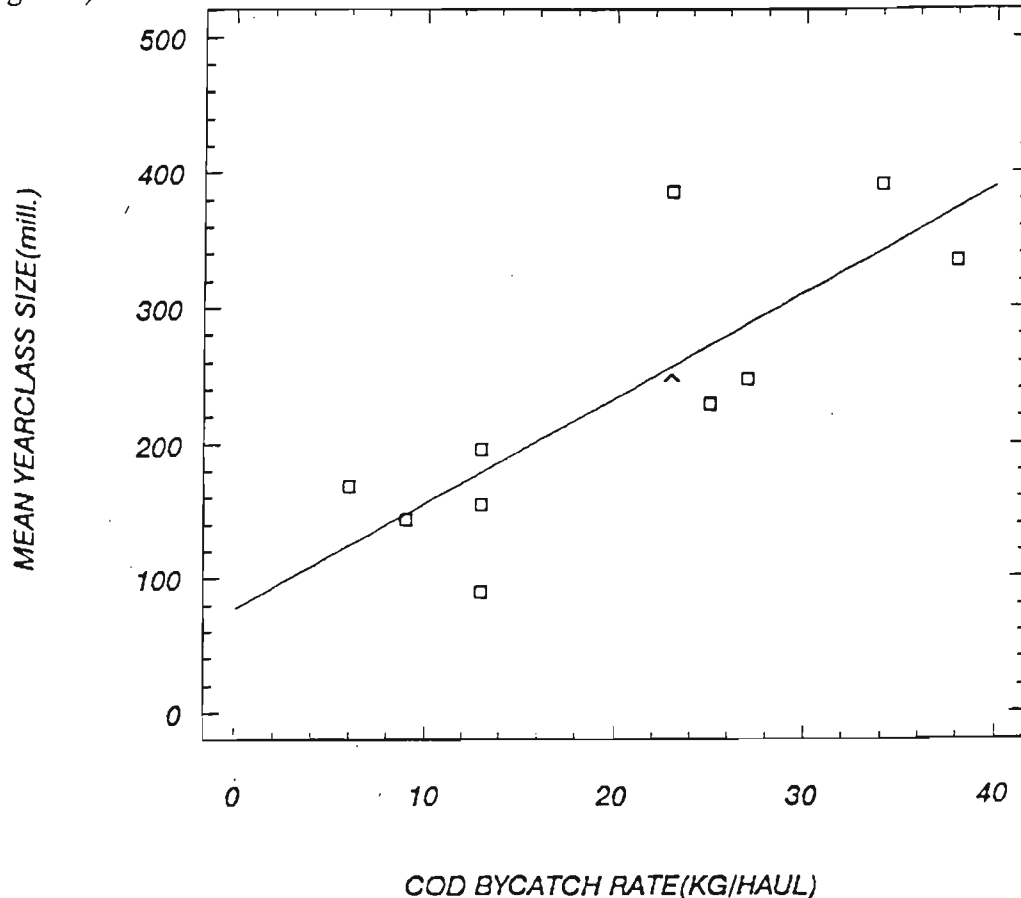


Fig. 3.6. Relationship between mean annual by-catch levels of cod in capelin traps and mean cod recruitment as estimated by the 1993 ADAPT-VPA. The 1993 mean by-catch level of cod (23 kg/trap haul) for 1993 is denoted as ^. The 1981 data point was considered an outlier and is omitted from the plot.

Food and feeding- G.Lilly, WP#9

Capelin was the major prey of cod in the offshore area of Div. 2J3K during the falls of most years in the period 1978–1989. During the recent decline in cod abundance and reduction in cod distribution, there was also a severe decline in capelin biomass as estimated from offshore Canadian and Russian acoustic surveys, with the Canadian series showing a very abrupt drop between 1989 and 1990. Nevertheless, many cod had a relatively high content of capelin in their stomachs in 1990–1992, in part because the capelin changed their distribution and occupied the general area where the remaining cod were concentrated. A preliminary analysis of the average quantity of food in cod stomachs by divisions (2J, 3K, 3L) revealed a decline only in Div. 2J (on Hamilton Bank in 1990 and in the whole division in 1991 and 1992, Fig. 3.7).

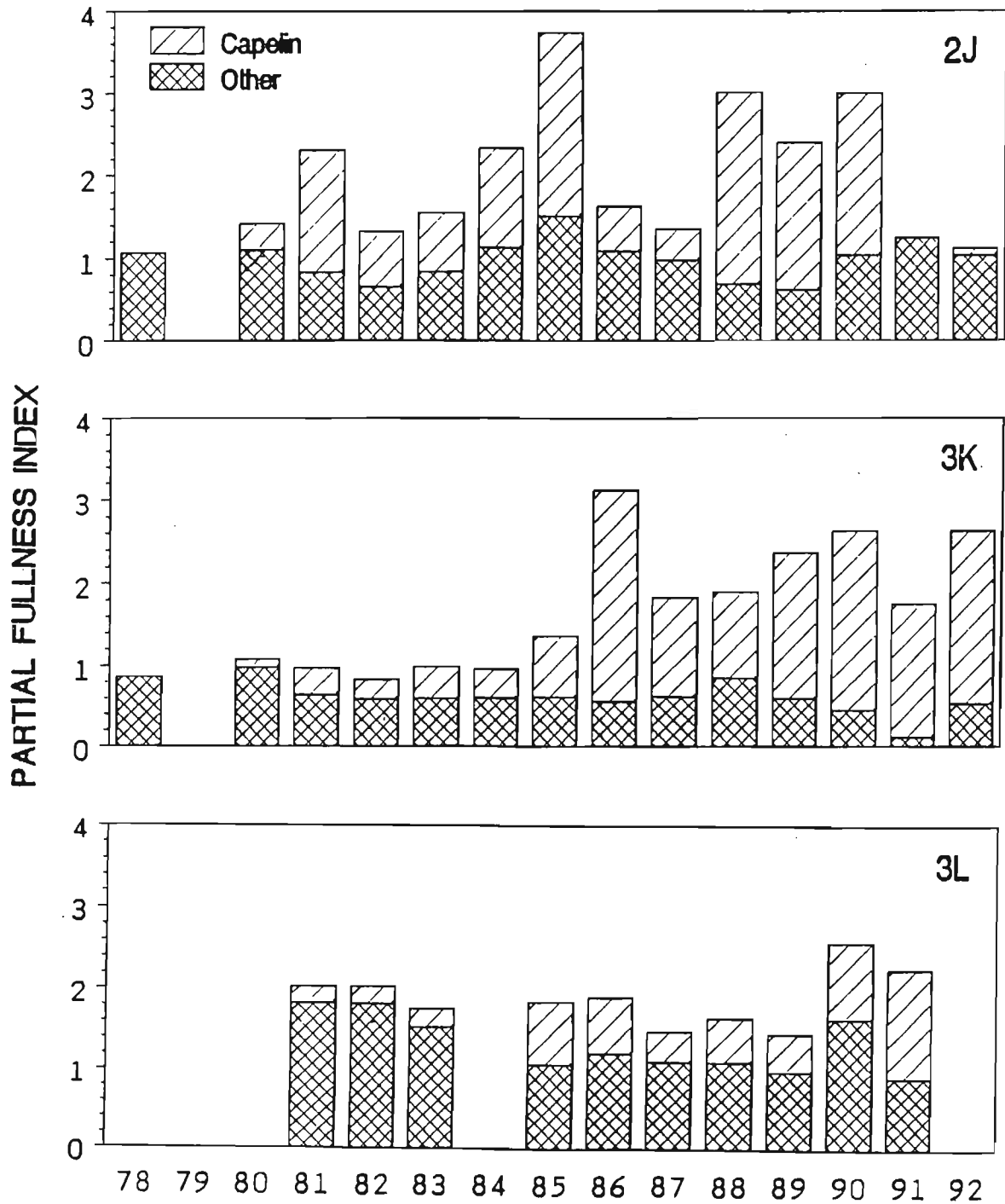


Fig. 3.7. Mean stomach fullness by Division and year. The total fullness index is divided into partial fullness indices for capelin and all other prey combined (from Lilly 1993).

3.1.2.2 Estimation of stock parameters

Analysis of recruitment and total mortality from research vessel surveys - R.A. Myers, WP#13

Recruitment indices and total mortality were estimated using all available research surveys for Div. 2J3KL cod. It was concluded that (i) recruitment was low in the last few years; and (ii) total mortality in the last few years was very high, i.e. greater than 1.0. There is a very good correspondence between the total mortality estimated from ADAPT and total mortality from the research surveys.

Estimation of population size and fishing mortality from standard ADAPT - C.A. Bishop, E.F. Murphy, D.E. Stansbury and M.B. Davis, WP#11

A formulation of ADAPT incorporating Canadian research vessel data was used to estimate stock size. The model formulation was the same as that used previously. A flat topped partial recruitment pattern was assumed as input along with full recruitment as an unweighted average over ages 7 to 9. The pattern of residuals showed strong year effects reflecting the large interannual variation in the RV index. Residuals for 1993 were all strongly negative while those for 1989 to 1992 were all positive. It was considered that the results from ADAPT were too imprecise and did not adequately represent stock abundance. Consequently it was not possible to provide an estimate of the size of the current stock biomass.

ADAPT estimates using a correlated error model - R.A. Myers and N.G. Cadigan, WP#12

The correlated error model produced a much improved fit to the research vessel surveys than the model that assumed independent errors. The correlated error model produced lower estimates of abundance, e.g. the number of ages 3-12 fish in 1993 went down from 82 million to only 27 million. The fishing mortality estimated in the last two years is generally higher in the correlated error model. The fishing mortality in the in 1993 appears to be high in all models, considering that the fishery was shut down. In all models, with or without correlated errors, there are extraordinary patterns in the unstandardized residuals. There is generally a change in the sign of the residuals after 1988. This pattern may mean that one or more of the assumptions of the ADAPT model is badly wrong.

3.1.2.3 Assessment results

Fishing Mortality and Stock Abundance - C.A. Bishop, E.F. Murphy, D.E. Stansbury and M.B. Davis, WP#11

Research vessel survey results imply that stock abundance has declined to less than 1/10 of that in the mid 1980s and that the decline persisted from 1992 to 1993 in spite of a moratorium on commercial fishing. It also suggests that the size of 1986 and 1987 year-classes, which were originally considered to be above average size, may have been well below average, particularly that for 1987. As well, the size of year-classes since that time (1988-90) are also well below average.

Although stock size and fishing mortality could not be estimated, analyses incorporating the extremely low RV abundance estimate for 1993 suggest that total mortalities in recent years have been very high and most likely in excess of 1.0 for the fully recruited age groups. Although total mortality appears to have declined between 1992 and 1993 because of the fishery closure, the total estimated catch for 1993 of about 11,000 t seems to have been too low to account for the continuing decline in the RV estimates. Three alternative possibilities exist: a) the survey results are real which implies that factors other than fishing must be responsible for the observed declines, b) year effects in recent surveys are hampering calibration of SPA, or c) the 1993 catch has been underestimated. It is not possible to determine which of these is correct. It is possible that the recreational fishery in 1993 took fish predominantly originating from supposed inshore stocks. The areas where these fish would occur are not covered during the fall surveys, and no information exists concerning possible trends in inshore "stock" abundance.

Recruitment - C.A. Bishop, E.F. Murphy, D.E. Stansbury and M.B. Davis, WP#11

The results from autumn and spring surveys did indicate that the abundance of young cod remains low and consequently recruitment from recent year classes can be expected to remain low. Based on the relationship between cod by-catch in capelin traps and year class size (Fig. 3.6), the prediction from the 1992 by-catch data is the lowest mean year-class size yet observed (1989-90 year classes) while in 1993 the by-catch data predicts moderately good mean year-class size (1990-91 year classes). This relationship requires further validation.

3.1.2.4 Discussion

Food and feeding

Cod growth rates are dependent on temperature and the quantity and energetic content of the available food. The fact that the Div. 2J3KL cod stock is slow growing compared to other cod stocks makes it more vulnerable to fishing mortality. A decrease in the growth rate of cod due to food shortages and/or cold water temperatures could lead to a change (reduction) in catchability with age. Stomach fullness of cod in fall surveys provide some indication of the availability of food at that time. The freshness of food in some stomachs collected in Div. 3N0 in recent years suggests that net feeding may be occurring. This should be considered during any analysis of stomach fullness indices.

A comparison of 1993 with previous years suggests that it is only in Div. 2J that cod seem to be particularly suffering from food shortages, as indicated by both stomach fullness and condition factor. An analysis on the condition of cod between years from the fall survey data is being conducted. Overall, cod condition appears to be deteriorating and is relatively poorer in Div. 2J than in Div. 3K or 3L. Condition factors are defined as: $K_f = \text{gutted weight(grams)/length}^3$ and $K_l = \text{liver weight (grams)/length}^3$. Gutted weights are used to avoid variation resulting from different feeding intensities (Bishop and Baird 1993). On an annual basis, cod condition appears poorest in the second quarter of the calendar year and highest in the late fourth quarter-early first quarter (i.e.) winter of the year. Examination of the condition factors from the fall surveys would assess fish at a time when they should be approaching their highest condition.

Of interest is the observation that large aggregations of cod appear to have lower stomach

fullness indices than individual cod or cod in small groups. The apparent increasing aggregation of cod in the surveys in recent years is consistent with less intensive feeding by cod.

Temperature and food supply could have an interactive effect on weight at age - a more southerly distribution of cod would allow a faster growth rate provided adequate food were available compared to cod further north subject to the same feeding conditions. Analysis of the stomach fullness index in relation to weight at age taking into account latitude would be of interest.

Application of the Kalman filter approach (W.G. Warren, Department of Fisheries and Oceans, St John's, in prep.) to the weight at age data is potentially promising as a way of detecting any pattern(s) and providing forecasts based on this pattern and should be explored in future assessments.

The pattern of change in average stomach contents is similar to the pattern observed in cod condition. In both series a decline in the 1990s was found only in Div. 2J. The stomach content and condition factor data should be presented each year to assist in the interpretation of changes in cod growth and condition.

Acoustic survey data

June acoustic studies of cod have the potential of providing an estimate of minimum population size. The highly aggregated pattern of distribution of cod in recent years decreases the probability of hitting an aggregation using standard statistical designs. An argument can be advanced for obtaining a good estimate of an aggregation when one is located, but the problem remains of how many aggregations there are out there, and therefore the uncertainty in the estimate of population size is not reduced. The possibility of using a standard statistical design together with a measurement of the actual size of all aggregations that are encountered could be considered (Thomson 1992).

In the future there may be the possibility of incorporating acoustic estimates into sequential population analyses. For example, the June acoustic estimate could provide a minimum estimate of population size. In future surveys an attempt should be made to integrate acoustic and trawl approaches over the whole survey area. Regardless of the problems which are inherent to either approach, the information from one could be used by the other complementarily, but the methodology requires further investigation.

Changes in spatial patterns of abundance

A plot of RV estimates of biomass at depths greater than 400m for the period 1981 to 1992 (Fig. 3.4) provides strong evidence of an offshore displacement of fish after 1988. There is little evidence from beach seine catches of juveniles of a longshore decrease in range with the decline of northern cod, from a comparison with data collected in the late 1950s and early 1960s. One interpretation of this is that the inshore habitat is prime habitat that fills up first, and so is not sensitive to population declines, unless these are very severe. If this hypothesis is true, then the information from a monitoring programme which targets 0-group and juvenile cod could also be misleading. Analyses in Bishop et al. (1993) suggest a southward shift in distribution.

Impact of gillnets, Japanese traps and capelin traps on the increase in fishing mortality

The impact of gillnets, particularly in the Virgin Rocks fishery, has not been assessed. It is not possible to get an idea of amount of gear put into use from sales because of poor records, suppliers coming and going, cottage industries making nets, etc. (Henry Lear, pers. comm.). Ghost nets are suggested to have a continuing detrimental effect on remaining fish. The fishing characteristics of lost gill nets have often been debated with some arguing that the nets continue to fish indefinitely, filling up with fish, sinking to the bottom and then rising to fish again once the catch has rotted. Others argue that once the nets have loaded and sunk, they roll up or otherwise tangle up and cease to fish. An hypothesis that increased gillnetting activity is largely to blame for the increase in total mortality from the late 1980s onwards is at variance with the observation that total mortality increased in both the age groups vulnerable to gillnets and those that are not. In addition to fishing mortality caused by gillnets, the impact of Japanese cod traps and capelin traps should also be considered.

Cod by-catch data from capelin traps is very noisy and there are gaps in the years of coverage because of closures in the capelin fishery. There has never been systematic sampling of this by-catch. The possibility of using the cod by-catch as an additional source of samples should be considered.

Analysis of RV catch-at-age data

Analysis of recruitment and mortality from RV surveys for cod is useful but care must be taken regarding shifts outside the survey area and how this might influence the interpretation of apparent mortality rates. The general observation was made that the age distribution had not changed much up to about 1989 after which the age structure became greatly truncated towards younger fish.

Bay spawning versus offshore spawning

The relative importance of bay spawning to offshore spawning is not known. Cod eggs are sampled inshore in the bays, indicating bay spawning. The strong southward flowing inshore branch of the Labrador Current influences the longshore distribution of larvae spawned in the vicinity. With weak flows further onto the shelf, it seems likely that larvae spawned on the shelf will remain in the vicinity of where they were spawned. However, drifter work suggests that eggs spawned on the Hamilton Bank will come inshore. It is possible that the catches of juveniles in beach seine are, at least in part, of fish from "bay stocks". There is no apparent north-south variation in the length frequency distribution of juveniles in beach seine samples to suggest that substantial longshore migration from spawning sites is taking place. In interpreting beach seine results it is important to note that sampling is carried out at night. Juvenile cod tend to migrate into shallow water at night and move further offshore during the day. Two main concentrations of juveniles appear to exist offshore, one off southern Labrador and another over the northern Grand Banks. Juvenile cod are not frequently sampled offshore in the winter RV surveys. Two explanations exist: fish are predominantly off the bottom or are inshore.

Pre-recruit index

With the moratorium in place on the commercial fishery, an important piece of information with respect to present assessments is the strength of the incoming year classes, although these are generally expected to be weak because of the reduced spawner biomass. Beach seining shows no evidence of any good year classes coming in. Pre-recruit studies of the 1991 year class as 0s and 1s suggest that it is almost non-existent. Offshore sampling suggests that the abundance of 0-Group cod in the 1990s is equivalent to what was there in the early sixties, but if this is marginal habitat for spawning compared with the inshore, then these data are not informative. A problem with obtaining an 0-Group index is that a migration takes place from pelagic to demersal habitats. Surveys during the settling period using either pelagic or bottom gear will be unreliable. Sampling of the demersal habitat some time after settling is completed may be most appropriate, given the limitations of pelagic sampling. The fact that the beach seine data appear to be coherent suggest that an estimate from the data might provide an index of year class strength - although if the inshore is prime habitat, this index will not be sensitive to changes in population size. Current 0-group and pre-recruit studies were not designed as statistical surveys, but rather to develop the methodology on which such surveys could be based. Thus, although these studies provide basic information, such as geographic distribution, they cannot be used as a pre-recruit index of abundance at this stage.

The cod by-catch data from capelin traps (WP#28) suggests a statistical relationship with year-class size during the period 1981-91. Based on this relationship, the prediction from the 1992 by-catch data is the lowest mean year-class size yet observed (1989-90 year classes) while in 1993 the by-catch data predicts moderately good mean year-class size (1990-91 year classes). There is also a statistical relationship between the by-catch data and the mean catch rate of 2 and 3 year old cod in the fall RV survey during the period 1981-92. However, this relationship appears to break down in 1993 when the by-catch data indicate a stronger combined year-class for the 1990-91 cohorts than that estimated from the RV survey. This comparison indicates a possible shift in distribution of juvenile, cod ages 2 and 3, to the inshore area in 1993. However, the demersal juvenile cod surveys carried out in 1992 and 1993 indicated no significant change in distribution between years. The difference between these two indices in 1993 remains unresolved.

Comparison of ADAPT estimates from independent and correlated error models

A comparative analysis was made on calibrating the VPA by using ADAPT with independent error structure (traditionally used) and ADAPT using correlated error structure (WP#12). It was indicated that for both methods there were very large year effects especially in the most recent years which introduces considerable bias in population estimates, particularly in the younger ages. The analyses yield different results but nevertheless, given the assumptions, both models estimate total mortality at a very high level in 1993, potentially at 1.0 or greater, and the stock size at an extremely low level. It was noted that both methods suffered from severe lack of fit based on the residual patterns. This may be indicative of a problem with some of the basic assumptions of the models which could not be resolved at this time.

It was recommended that in order to evaluate the merits of the correlated error method more fully, a portion of the catch at age matrix should be selected where there is more confidence in the validity of the data.

New stratification scheme for groundfish surveys

Some concerns were raised about the new stratification schemes for divisions 2J and 3K (WP#11) in that it was difficult to do direct comparisons between previous years and 1993 onward for revised strata. It was noted that it would be difficult to re-stratify the old data because set positions in the old data were moved to accommodate the appropriate depth range even if it did not appear so on the charts. While the overall biomass and abundance may change to some degree the mean catch per depth zone would be the same.

Assessment results

Results in WP#12 were similar to that presented in WP#11 - the stock at an extremely low level although it cannot be estimated precisely because of the residual pattern in recent years which suggests serious violations of the basic assumptions of the model. It was further noted that, based on SPA, the dramatic decline in stock size appeared to begin in 1989. All information indicates that the stock is at a dangerously low level. There is no indication that recruitment has improved. Spawner stock biomass continues to decline despite the closure of the commercial fishery and stock size is likely lower than last year.

3.1.2.5 Prognosis

Although it was not possible to provide an adequate determination of absolute stock size, it is possible to describe general trends from the data.

The divisions 2J3KL cod stock abundance increased from the mid 1970s to the mid 1980s but has since declined. There is little doubt that the stock decline observed in recent years has continued in 1993 and that the stock is at a dangerously low level. The continuing decline in the RV estimates is not consistent with the reduced fishing in 1992 and 1993, although there are indications that total mortality declined somewhat.

Survey data indicate that the low recruitment levels estimated for recent years will persist because of the current low spawning stock biomass and consequently stock recovery will not occur in the near future. Stock recovery cannot begin until there is production and survival of significant numbers of new recruits.

3.2 Subdiv. 3Ps cod

3.2.1 Stock status summary - C.A. Bishop, D.E. Stansbury, E.F. Murphy and M.B. Davis, WP#37

Summary

This stock appears to have declined in population numbers and biomass since the late 1980s. Research survey biomass continues to be low, the numbers of older (ages 6+) fish found during the surveys have declined, lengths at age are decreasing, particularly at older ages, and age at maturity for males and females is decreasing. The fishery was closed in September 1993 and will

remain closed until at least the end of 1994.

The Fishery

After extension of jurisdiction (1977) catches averaged slightly over 30,000 t until the mid 1980s when catches by France increased significantly such that total landings peaked at about 57,000 t in 1986 and 1987. Catches then declined to about 40,000 t through 1991 before dropping to 32,000 t in 1992 and only 15,000 t in 1993. In 1993, there were no catches reported by France, and the Canadian fishery was closed in September. The Canadian fishery remains closed in 1994.

Analyses

Stock assessments have relied upon results from bottom trawl research surveys conducted by Canada since 1972 and by France for the period 1978–1991. However, the possible effects of inter-annual variability in cod migrations between Subdiv. 3Ps and adjacent stock areas (3Pn4RS, 3NO) are not known. Also, there has been a tendency for both survey and commercial trawler catches to be larger in deeper water (e.g. the Laurentian Channel and Southern Halibut Channel) in recent years. It appears that changing the timing of the surveys from February to April in 1993 and 1994 may have helped resolve the problem of possible mixing in that large aggregations were not found near stock boundaries in April.

Reports from inshore fishers suggest an increase in abundance of fish in the northern end of Placentia Bay. The distribution, stock affinity and behaviour of these inshore fish are not well understood. For example, it is not known if the same fish return to the same area of the Bay every winter or if there is some cycling of fish between the offshore and inshore each winter. Although the 1994 survey coverage was extended into parts of Placentia Bay, the entire area was not surveyed because of rough bottom conditions.

Because of the identified problems with the survey data time series, coupled with difficulties in assigning a portion of the annual commercial catches in the 3Ps/3Pn boundary area in winter to the appropriate stock unit, Sequential Population Analysis was not considered appropriate for this stock at this time.

Prognosis

Despite difficulties in interpreting the available data, there are a number of trends observed in them which suggest caution should be exercised. Catch curve total mortality estimates from survey data show an increasing trend, size at age is decreasing, age at maturity is decreasing, and there appears to be a loss of older age classes in surveys in recent years.

Stock summary sheet for Subdiv. 3Ps cod

Year	1987	1988	1989	1990	1991	1992	1993	1994	Min. ¹	Med. ¹	Max. ¹
F _{0.1} Catch '000t	26-58	37	20.5	N/A	29	39					
Advised TAC '000t	26-58	37	20.5	N/A	29- 44.5	39- 44.5	20				
TAC '000t	60.6	60.6	50	45	44	44	20	0			
Reported catches '000t	57	43	39.5	41	43 ²	31.5 ²	15 ²		15	49	84
Unreported catches					N/A						
Estimated discards '000t					N/A						
Total catches	57	43	39.5	41	43 ²	31.5 ²	15 ²				
Total biomass '000t											
Spawning biomass '000t											
Mean - F (7-10)											

¹ 1959-1993² Provisional

Catches: 1993 catch was 15,000 t, approximately half of the 1992 catch. The decrease was partly due to the closure of the fishery in September 1993.

Data and Assessment: Research vessel surveys have been conducted by Canada since 1972. The April, 1994 survey was expanded to include parts of Placentia Bay and additional strata in deeper water. Results from the survey were low, consistent with low survey estimates in 1992 and 1993.

Fishing Mortality: Estimates for the most recent years are not possible because of calibration problems. SPA results for the converged portion of the time series indicate that fully recruited fishing mortalities have been greater than twice F_{0.1} since the extension of jurisdiction, and have gradually increased since that time.

Recruitment: The 1994 survey results indicate that the 1989 year-class is still relatively strong. There is no indication of strong year-classes since that time.

Environmental Factors: Since 1991, water temperatures have generally increased from the lows experienced during the mid-1980s and in 1990 but large spatial areas with negative temperature anomalies have continued into the spring of 1994, particularly on the eastern portion of St. Pierre Bank, on the continental slope areas and in Placentia Bay. Possible impacts of these changes cannot be determined.

Multispecies Considerations: There are no data available to allow for consideration of multispecies interactions for this stock.

State of the Stock: Based on RV data, the stock abundance and biomass are among the lowest values observed. It is possible that some of the cod encountered during the surveys in some years may have been migrants from 3Pn4RS or 3O, but the cod stocks in these areas are currently at low levels also.

Forecast for 1995: Based on the research survey results, it is expected that the stock will remain low in 1995. Although there are difficulties with the research vessel data, size at age is decreasing, age at maturity is decreasing and there is a loss of older age classes. These trends are commonly associated with declining fish stock abundance. The 1989 year-class appears to be relatively strong and this will begin to contribute significantly to the spawning stock biomass in 1995.

Long-term Prospects: There are no indications of good recruitment after the year-class of 1989 based on research vessel data. Additional good year-classes will be required to promote stock rebuilding.

Special Comment: There are difficulties in interpreting the time series of survey data because of possible mixing of fish from adjacent areas (3Pn4RS, 3O). Nonetheless, the results suggest that stock levels have declined somewhat in recent years. Changing the timing of the surveys from February to April in 1993 and 1994 has helped resolve the problem of possible mixing in that large aggregations were not found in the areas of the stock boundaries in April. It is important that the stock affinities of catches in the research surveys and commercial fisheries (both inshore and offshore) be clarified in order to better determine the status of this resource.

3.2.2 Technical basis

3.2.2.1 Available data

Nominal Catches - C.A. Bishop, D.E. Stansbury, E.F. Murphy and M.B. Davis, WP#37

Nominal catches were highest from 1959 to 1974 (average of 62,000 t peaking at 84,000 t in 1961). They then declined to a low of 27,000 t in 1978. Catches averaged 50,000 t from 1985–1987, mainly due to increased catches by France. The 1988–1991 catches were relatively stable at about 42,000 t.

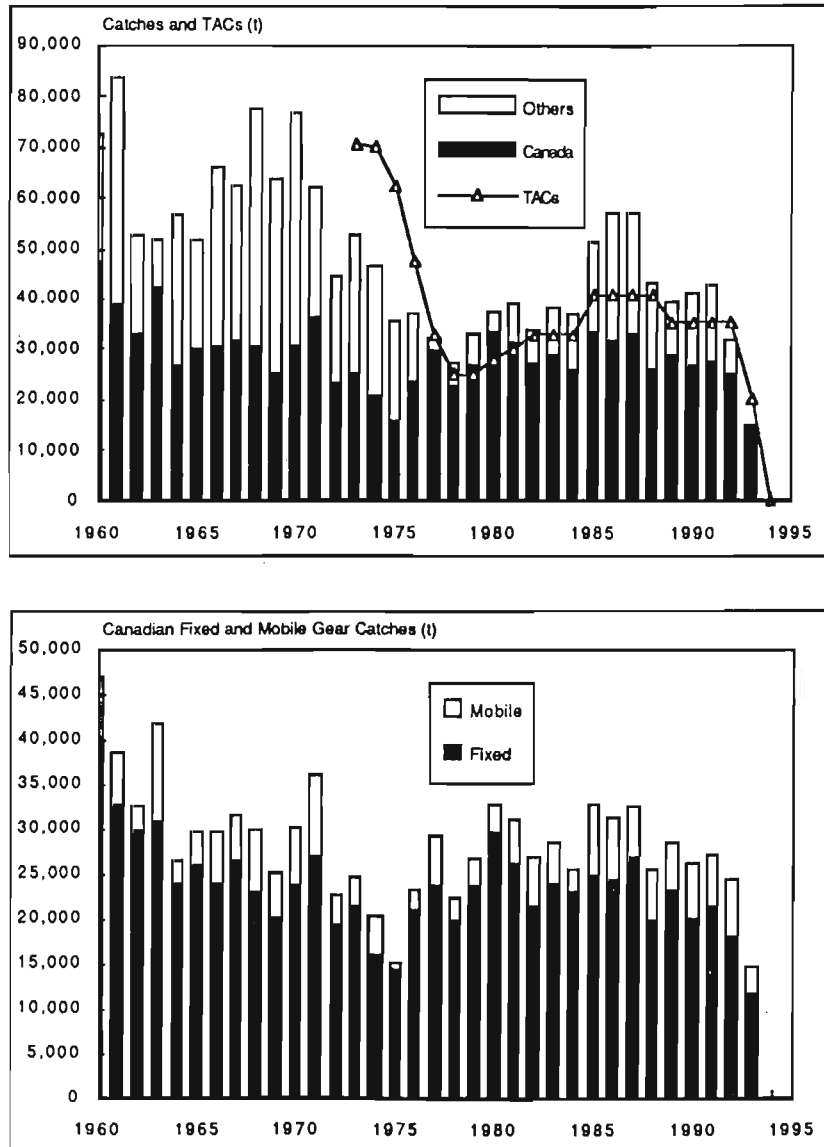


Fig. 3.8. Time series of annual catches by Canada and other sources together with the TAC for the period 1960–94, and by Canada for fixed and mobile gear.

The 1992 catch was 32,000 t reflecting a decline in French offshore and Canadian inshore landings of 8,500 t and 3,300 t respectively. The 1993 catch was approximately 15,000 t which reflects the closure of the fishery as of September 1993. The fishery is closed for 1994.

In recent years an increasing portion of the winter otter trawl catch has been taken in deeper water. This shift was not as pronounced in the 1993 winter fishery although there were catches at depths greater than those in the research vessels surveys. Again, there was no commercial winter fishery in 1994.

Catch at age and mean weights at age - C.A. Bishop, D.E. Stansbury, E.F. Murphy and M.B. Davis, WP#37

The 1993 catch at age and mean weights at age for Subdiv. 3Ps cod are based on sampling from the Canadian fishery. There was a small (40 t) inshore catch reported for St. Pierre and Miquelon but there were no sampling data available. The age distribution of catches are specific to the gear fished. Overall however, age 4 and 6 fish dominated in the combined catch for 1993. Age 4 fish dominated cod trap catches while age 6 fish were dominant in gillnet and mobile (otter trawl) gear. Longline catches which normally contribute the largest portion of the catch in 3Ps, took predominantly ages 4 and 6 in 1993. In general, weight at age and length at age declined relative to 1992 and in particular for the older ages. Mean weight for age 7 fish is plotted in Fig. 3.9.

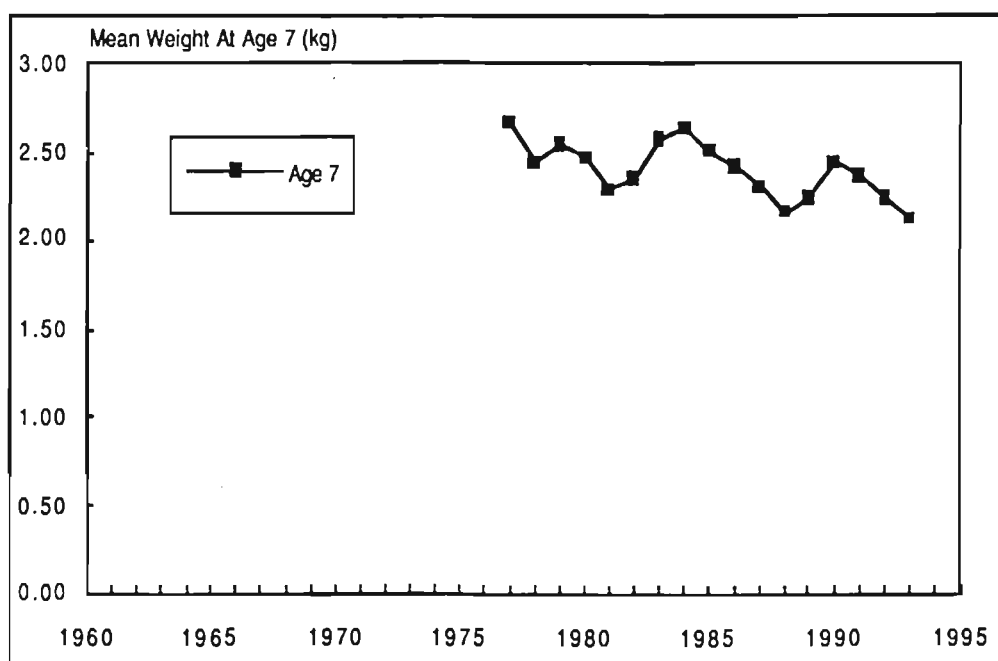


Fig. 3.9. Mean weight for age 7 cod for the period 1977-93.

Commercial catch rates - C.A. Bishop, D.E. Stansbury, E.F. Murphy and M.B. Davis, WP#37

Since technological changes within and between fleets may have a significant impact on CPUE trends, the commercial CPUE has not been used for calibration purposes. A similar situation has existed for a number of years.

Environmental Conditions - C.A. Bishop, D.E. Stansbury, E.F. Murphy and M.B. Davis, WP#37

Time series of temperature anomalies in the 3Ps area show colder periods in the mid 1970s and since the mid 1980s, similar to conditions on the continental shelf along the east coast of Newfoundland. The most recent cold period, which started about 1984, continued to the early 1990s with temperatures up to 1.0°C below average over all depths and up to 2.0°C below the warmer temperatures of the late 1970s and early 1980s in the surface layers. Since 1991, temperatures have generally increased from the lows experienced from the mid-1980s and 1990 but large spatial areas with negative temperature anomalies are continuing into the spring of 1994, particularly on the eastern portion of St. Pierre Bank, on the continental slope areas and in Placentia Bay.

Research survey data - C.A. Bishop, D.E. Stansbury, E.F. Murphy and M.B. Davis, WP#37

Stratified random surveys have been conducted in Subdiv. 3Ps during winter-spring by Canada since 1972 and France for the period 1978-1992. The two survey series are similar with regard to the stratification scheme used, method of sampling and analysis of results but differ in the type of fishing gear used and the daily timing of the survey (daylight hours only for the French survey). Biomass and abundance estimates from Canadian and French surveys indicated a sharp decline in 1992 relative to previous years. The French discontinued their surveys after 1992.

Canadian estimates of abundance from 1993 and 1994 were similar to the low 1992 value although the estimate from the 1994 survey was higher than that of 1993 (Fig. 3.10). In 1994, additional strata were added in the Placentia Bay area in an effort to address fishers reports of a high abundance of fish during the winter months in this area. The 400-500 fathom depth zone in the Halibut Channel area was also surveyed for the first time. The increased abundance estimate was not however because of this increased coverage as very few fish were found in either of the newly surveyed areas.

The 1994 survey results indicate that the 1989 year-class is still relatively strong. There is no indication of subsequent strong year-classes. The numbers of older fish present in the population has been declining since 1992. The 1990 year-class appears to be of below average strength. The complete absence of age 2 cod in the 1993 survey and low numbers at age 3 in 1994 suggest that the 1990 year-class may be very weak.

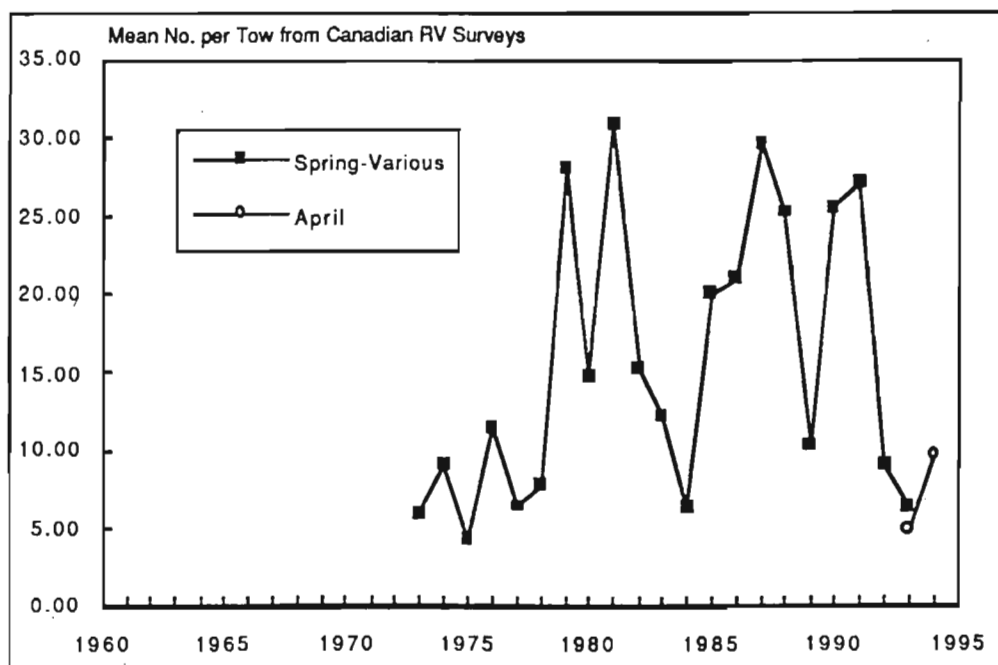


Fig. 3.10. Mean number of fish per tow for Canadian RV surveys between 1973 and 1994.

Age distribution of cod from research vessel data over the last decade - C.T. Taggart, WP#33

Research vessel survey total catch at age data (ages 1 to 21), and average number per tow at age data (ages 1-25), weighted by survey stratum area were used to examine the age distribution of 3Ps cod over the periods 1972-1993 and 1988-1993. Relative to the age distribution seen for northern cod in 2J3KL, the proportional age distribution of 3Ps cod is much wider, and relatively stable, although there are indications that some of the older age classes began to disappear from the population in recent years. The 1994 survey results indicate that the 1989 year-class is still relatively strong. There is no indication of subsequent strong year-classes. The numbers of older fish present in the population has been declining since 1992. The 1990 year-class appears to be of below average strength. The complete absence of age 2 cod in the 1993 survey and low numbers at age 3 in 1994 suggest that the 1990 year-class may be very weak.

Fishers information from Placentia Bay - M.B. Davis, P. Lundrigan and P. Ripley, WP#20

Prior to and since the closure of the Subdiv. 3Ps cod fishery in September 1993, fishers from Placentia Bay have been stating that fish abundance in their area is higher than it has been for many years. Fishers contend that DFO research vessel surveys do not adequately reflect the status of the stock(s) which they fish, the timing and contribution of these fish to their fishery or the interactions of the stocks over the year.

Researchers from DFO and the Sociology Departments of Memorial University of Newfoundland and Carleton University undertook a semi-structured interviewing process of 13 present or past chairpersons of fishers committees from Placentia Bay (Subdiv. 3Ps). The questionnaire aimed to (i) gather data which will assist in identifying if there is more than one stock complex along the south coast, (ii) identify the temporal and spatial distribution of the stock(s), (iii) provide information on fish distribution for future biological studies (eg. tagging, sampling for genetic analysis, parasite studies, etc.), and (iv) develop a network of inshore fisher contacts for future research. Charts published by the Canadian Hydrographic Service were used to allow fishers to demonstrate the temporal-spatial aspects on fish on their fishing grounds.

As anticipated, a large body of varied information was captured during the interviews. Many temporal events are unique to each community but when assembled for the entire bay describe a fall, winter and early spring fishery which catches fish apparently returning to or moving out from deep holes and channels at the north end of the Bay. A summer fishery which relies on fish moving into the Bay from across the continental shelf is also described. Fishers were unable to identify the origin of the fish which migrate into the bay for the summer fishery. Consequently, it is not possible to use fishers' knowledge from these interviews to determine how fish from 3Ps, 2J3KL or 3NO may contribute to the fishery.

Landings data for the winter and spring inshore fisheries suggest that an increase in fish availability has occurred in the past few years. However, without directly assessing changes in effort, it is difficult to determine how this may relate to changes in abundance.

Observations of fishers on the condition of fish and direction of movement were also made. Spring fish are reported to be in poor condition moving south and possibly out of the Bay whereas fall and winter fish are bigger, in better condition and moving into the Bay. It is possible that the spring observations are made on post-spawning fish dispersing around and/or out of the Bay while the fall observations are made on the same stock moving back to the spawning grounds after a season of feeding and growth.

Observations from fishers suggest that the regular groundfish survey does not temporally or spatially reach the locations where cod appear to overwinter in Placentia Bay. Some form of winter survey involving high resolution hydroacoustics might be considered to further describe the limits of the overwintering fish. Input from local fishers should be sought in the design of any survey.

3.2.2.2 Estimation of stock parameters

Sequential population estimates - C.A. Bishop, D.E. Stansbury, E.F. Murphy and M.B. Davis, WP#37

Sequential population analyses were attempted using various formulations of ADAPT, Laurec-Shepherd and Extended Survivors Analysis with RV survey data from Canada and France. Different approaches based on different assumptions (i.e. years included in the calibration, ages of full recruitment, independent vs. correlated errors) resulted in similar patterns of population abundance and resulting Fs. As observed in recent assessments, the analyses indicated patterns in the residuals i.e. generally negative in the 1980s and positive in the 1990s. Examination of the RV survey index of 3+ and ADAPT 3+ estimates show poor correlation. Some of the discrepancies in the data could possibly be explained by mixing from the neighbouring 4RS3Pn and 3NO cod stocks.

In spite of the inconsistencies apparent in the analyses, the results were considered useful as an indicator of recent trends rather than the source of absolute population parameters. The analyses indicated that population abundance has declined in recent years and that fishing mortalities have been high, maybe as high as 1.0 in 1991 and 1992 and about 0.6 in 1993.

Estimation of total mortality rate from survey data - C.T. Taggart, WP#33

The slope of the relationship between the log of the percent at age from the weighted mean catch/tow data versus age for ages 5+ (a catch curve estimate of Z) from RV data for the years 1986 to 1993 reveals an increasing trend in Z through time, suggesting an increasing trend in the loss rate from age class to age class from year to year. Such a trend is not conducive to a healthy stock.

Age at maturity - M.J. Morgan, WP#38

Estimates of annual age at 50% maturity indicate that the age at 50% maturity (Morgan and Hoenig 1993) has been declining since the mid-1980s for males and late 1980s for females (Fig. 3.11). This could be interpreted as a compensatory response elicited by declining stock size.

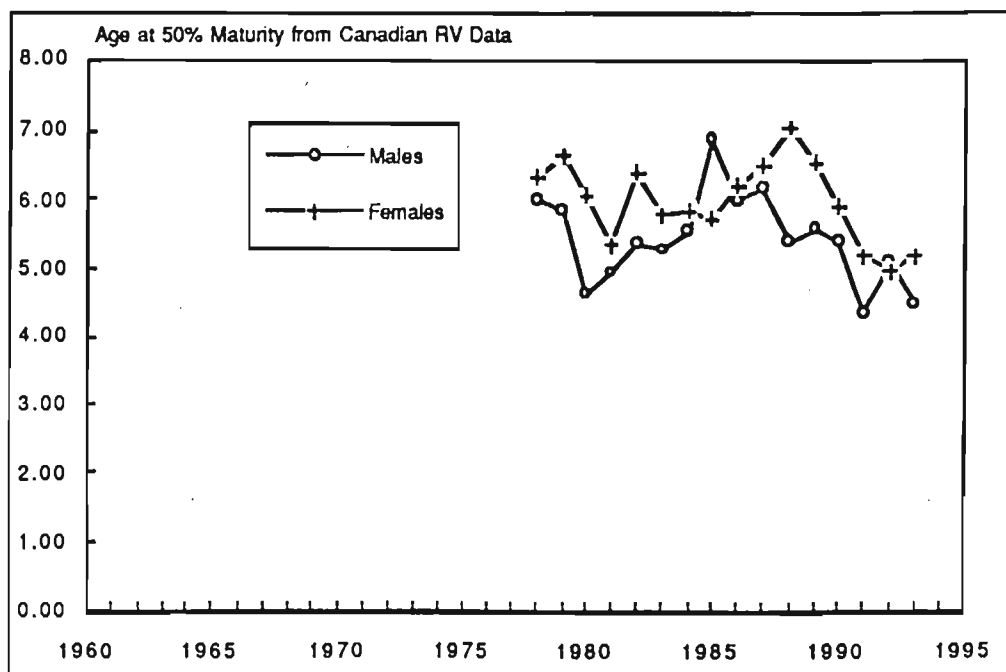


Fig. 3.11. Age at 50% maturity for female and male cod for the period 1978 to 1993.

3.2.2.3 Discussion

Information from fishers

Reports from fishers in Placentia Bay suggest that the majority of fish are caught by a small number of fishers. There is some evidence that the gillnet effort has been increasing steadily over the last decade. Trap effort may also be increasing, but is a less important component of the effort in this area and there are limited number of sites. Total inshore catches increased over the 1990 - 92 period and it is possible that total inshore effort employed in the area has doubled over the past 10 years. Fishers report that catches off Burin appear to be correlated with catches in Fortune Bay, suggesting that fish move eastward around the headland. Information from fishers indicate that fish overwinter in the bottom of Placentia Bay. The April survey has been extended as far as possible into the bay based on this information although few fish were encountered. This could have either been because the fish were further into the bay than the survey penetrated, the survey was too late and the fish had moved out, or the fishers information was erroneous.

Commercial catch at age compared to the RV data

The age composition of the commercial catch data does not immediately raise concern for this stock. The age structure in the RV data is considerably better than for 2J3KL with ages 10 up to 20 being represented. However, there are signs of a loss of the older age classes. Although this stock is clearly not in as bad a shape as the 2J3KL stock, there are a number of warning signs: (i) contraction of the age structure through the loss of older fish from the population; (ii) trend of increasingly younger age at first maturity; (iii) decline in the length at age; (iv) increasingly patchy spatial pattern of abundance. These warning signs are very similar to those observed for the Div. 2J3KL stock, although not yet as far advanced, and should not be ignored.

There is some difficulty in interpreting the survey data because of the possibility of a large year effect as a consequence of movement of fish between 3Ps and 3Pn4Rs. It is anticipated that analysis of spatial subsets of the RV data will demonstrate the same declining trend, which would argue against the possible confounding effect of migration of fish in and out of the stock area.

The only abundance indices for this stock are the Canadian and French RV indices. An additional index from trap catch rates or from an acoustic survey would be of great value in interpretation of the trends in this stock. The possibility of obtaining acoustic data on cod from the January-February herring surveys was considered, however the survey is restricted to less than 100 m and few cod are detected.

Estimates of total mortality from the RV data do not match the ADAPT results as well as those for Div. 2J3KL. The F_s from ADAPT are higher than those estimated directly from the RV data. A possible explanation may be found in the fact that the ADAPT estimates are obtained from calibration with both Canadian and French RV data, whereas WP #36 only considered the Canadian data.

Before the moratorium, the offshore commercial fishery was locating fish at depths deeper than those covered in the RV surveys. In an attempt to obtain an estimate of fish that might be outside the survey early in the year, both a February and April surveys were carried out in 1993 but only an April survey in 1994.

In interpreting catch-at-age data from the commercial fishery it is important to account for the different selectivities associated with the different gears. Patterns of total mortality from the commercial data do not match those from the RV data and this may be a result of the selectivity differences among gears.

Although several ADAPT formulations were examined, including formulations with correlated and independent error, they all indicate the same pattern of high F_s in recent years and a downward trend in population size. The correlated error model estimates population sizes for 1993 and 1994 which are about 20% lower than those for the independent error model. Common to all the ADAPT formulations is a pattern to the residuals with values for recent years being negative. This would be compatible with an increasing trend in catchability, particularly in the older age classes, with time (see WP #21), or under-reporting of the commercial catch. Because of the pattern in the residuals, the ADAPT results have to be treated with caution. The problem is further illustrated by the large amount of scatter in a plot of ADAPT estimates of 3 year olds versus survey estimates. It is also important to note that the two abundance indices used in the calibration - the French and Canadian RV data, are not closely correlated.

3.2.2.4 Prognosis

Although there are some questions concerning the reliability of the research surveys as indicators of stock abundance, their results suggest that there has been a decline in the resource for the past three years. This is consistent with declining age at maturity for both males and females, declining length at age, increased total mortality from catch curve analyses and a loss of older age groups. Similar to stocks in adjoining divisions, 3Ps cod appear to have declined since the mid-eighties. Therefore, a cautious approach should be taken with regard to management.

Despite general declines in the 3Ps cod fishery, 1993 inshore landings from the north end of Placentia Bay increased, and inshore fishers in the area report a good abundance of fish. Further study is required to determine how the fish in Placentia Bay are related to the overall stock complex because inshore fishers in other parts of 3Ps have reported declines.

3.3 Unit 2 redfish - D. Power, WP#27

3.3.1 Stock status summary

Summary

This stock is probably lower than it has been in recent years. Fishing pattern has changed in response to the implementation of this new management unit in 1993. The fishery is currently targeting the relatively good year-classes of the early 1980s. Above average recruitment to the fishery is expected within the next few years based on the relatively strong year-classes of the mid 1980s but their contribution is likely to be less than that of those of the early 1980s.

The fishery

Catches have increased steadily from about 8,000 t in 1984 to 27,000 t in 1993. Of this 1993 catch, 10,000 t was taken in 3Pn during October to December. It is likely that these catches, particularly those taken in November and December were of Unit 1 redfish that had migrated to the area earlier in 1993.

Analysis

Catch rates have been declining since 1990. Research surveys do not cover the entire stock area and therefore are not representative of year to year changes in stock size. Above average recruitment to the fishery is expected in the mid to late 1990s because of relatively strong year-classes of the mid and late 1980s. It is unlikely that their contribution will be as great as that of the early 1980s year-classes that have supported the fishery for the past 5 years.

Prognosis

This stock is probably lower than it has been in recent years and will continue to decline although this may be reversed due to growth of the relatively strong year-classes of the mid and late 1980s. Their contribution however, is likely to be less than that of the early 1980s year-classes so that the current decline in catch rates may continue but at a reduced rate.

Stock status summary sheet for Unit 2 redfish

Year	1987	1988	1989	1990	1991	1992	1993	1994	Min.	Med.	Max.
F _{0.1} Catch '000t							N/A				
Advised TAC '000t						25	25				
TAC '000t							28	25	25 ¹	26.5 ¹	28 ¹
Reported catches '000t	14	11	15	15	24 ²	17 ²	27 ²				
Unreported catches					N/A						
Estimated discards '000t					N/A						
Total catches	14	11	15	15	24 ²	17 ²	27 ²		8 ³	22 ³	58 ³
Total biomass '000t					N/A						
Spawning biomass '000t					N/A						
Mean - F ()					N/A						

¹ TAC applied to new management unit starting in 1993

² Provisional

³ From 1960-1993

Catches: Catches have ranged from 8,100 t (1984) to 58,000 t (1971). From 1960-1968 landings were at a level of 20,000 t, increased to an average of 43,000 t up to 1975 mainly due to increases by foreign fleets and subsequently declined to the lowest on record in 1984 at 8,100 t. Catches have steadily increased to the 1993 value of about 27,000 t. About 10,000 t of this was taken in October-December, and this may have been Unit 1 redfish which moved into the area earlier in 1993.

Data and Assessment: CPUE series show large increases in 1989 and again in 1990 to the highest rate observed over the time series, but have subsequently declined through to 1992. The trends over this time period are confounded with the introduction of the highly efficient midwater "turbo" trawl which distorts the historical relationships. RV survey data only cover part of the stock area and are not considered reflective of year to year changes in stock abundance.

Fishing Mortality: Not possible to estimate

Recruitment: The 1984-1985 and 1987-1988 year-classes represented about 40% of the research survey catch in 1993. Although it is not possible to precisely estimate the abundance of these year-classes it is likely that the contribution of these year-classes to the fishery in the future will be less than that of the early 1980s year-classes which the fishery currently targets.

Environmental Factors:

Multispecies Considerations:

State of the Stock: Unknown but probably lower than previous years because 1980s year-classes have been fished on for about five years. Two other above average year-classes are evident in the survey data but their sizes are likely less than that of the currently exploited early 1980s year-classes. Catch rates are declining as the year-classes of the early 1980s are fished down. Because subsequent year-classes do not appear as strong as this one, the downward trend in these rates may not be reversed.

Forecast for 1995: The 1984-1985 year-classes should start to contribute to the fishery but the impact of the of this contribution cannot be estimated.

Long-term Prospects: During the mid to late 1990s, the year-classes of the late 1980s should begin to contribute to the fishery. The magnitude of this contribution cannot be determined.

3.3.2 Technical basis

3.3.2.1. Available data

Nominal Catches

Catches have ranged from 8,100 t in 1984 to 58,000 t in 1971 (Fig. 3.12). From 1960-1968 landings were at a level of 20,000 t, increased to an average of 43,000 t up to 1975 mainly due to increases by foreign fleets and subsequently declined to the lowest on record in 1984 at 8,100 t. Catches then steadily increased to the 1993 value of about 27,000 t.

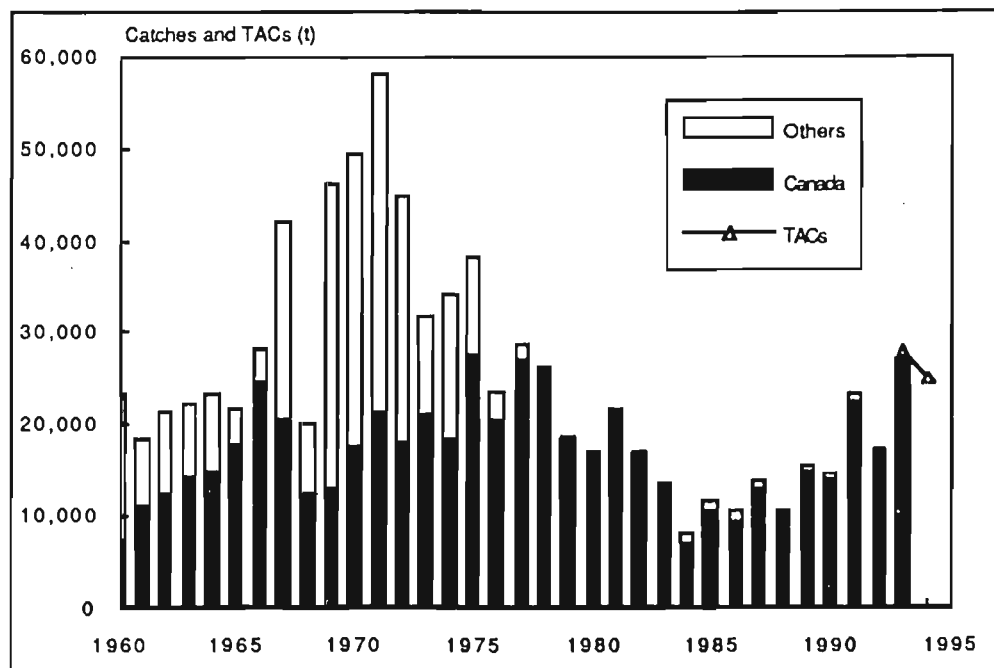


Fig. 3.12. Time series of annual catches by Canada and other sources together with the TAC for the period 1960-94.

Since declaration of the 200 mile limit in 1977, catches have been primarily by Canadian fleets. Maritimes vessels generally account for the majority of landings from subdivisions 4Vs and 4Vn while Newfoundland vessels concentrate in subdivisions 3Ps and 3Pn.

Prior to 1980 most of the catch was taken in 3Ps and 4Vs. Since then a larger proportion of the catch has been taken from 4Vn. In recent years, increases in total landings have been due to increased removals from 3Ps and 4Vn while there has been a substantial decrease in landings from 4Vs since 1991.

The 1993 fishery was quite different from that in 1992. There was a 10,000 t increase from the 1992 catch of about 17,000 t and this was almost totally accounted for by landings from 3Pn

during October to December. Based on information presented to the Fisheries Oceanography Committee in March, 1994 these catches were probably of Unit 1 redfish which moved into the area earlier in 1993.

Otter trawling is the predominant method of fishing, primarily with bottom trawls. Since 1986 there has been an increase in the proportion of catch taken with midwater trawls. There is also a proportion of the 3Ps catch taken with gillnets and longlines.

Commercial catch rates

The standardized catch rate series (t/hr) shows a steady increase from 1960 to 1966 followed by a decrease to the lowest rate on record in 1979 (Fig. 3.13). The rate increased again until 1983 to about the same magnitude of the 1960 catch rate. From 1983 to 1988 catch rates declined to about the level of the 1979 rate. Large increases occurred in 1989 and again in 1990 to the highest rate observed over the time series. The catch rate declined abruptly in 1991 and continued to decline in 1992. Preliminary data for 1993 (including only the Newfoundland fleet) suggest the mean catch rate remained at the 1992 level, but there is much higher variance associated with this estimate compared to any other year in the series. The catch rates seem to track reasonably well with the movement of what were perceived to be strong year-classes (1956-58 and early 1970s) through the fishery. Successive large increases in 1989 and 1990 can be partly attributed to the recruitment to the fishery of the relatively strong year-classes of the early 1980s. However, it is also partly due a change from side trawlers to specialized stern trawlers by the Fishery Products International fleet and the utilization of the highly efficient midwater "turbo" trawl by all fleets. Midwater gears are aggregated in the current database utilized to derive a standardized catch rate series and therefore the historical relationships cannot be put into perspective.

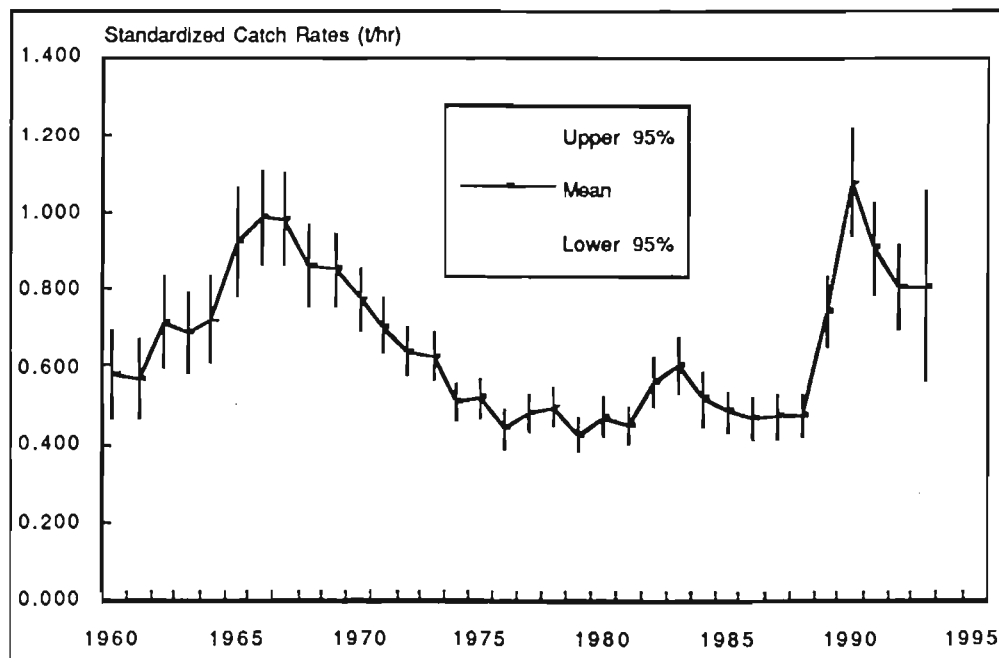


Fig. 3.13. Commerical catch rates for Unit 2 redfish for the period 1960 to 1993.

Fishers knowledge

The two major fleets involved in the fishery south of the Cabot Strait relate there are two "runs" of fish in the area based on the percentage of large sizes (characterized as greater than 25 cm standard length) in the catch. One run of about 75% large fish occurs generally in fall and winter while at other times, more notably the summer, the run generally contains about 40% large fish. These are probably related to the movements of fish from out of the Gulf of St. Lawrence into the Cabot Strait area, and possibly from 3Ps.

Windows were put in codends in the early 1990s to limit the catch but were not used as much in 1993 and have not been used at all in 1994 to date. Thus far in 1994 catch rates have been lower compared to what they were in the past few years. Trawler captains believe there is not as much fish in Unit 2 or Unit 1 as experienced previously.

By-catch restrictions of cod and other regulations are affecting the fishing pattern. The implementation in 1993 of three revised management units from the former 4RST, 3P and 4VWX units, coupled with declines in other groundfish resources also had a significant effect on the fishing patterns.

Research survey data

Stratified random groundfish surveys have been conducted since 1973 in Subdiv. 3Ps and consistently since 1986 in 3Pn, generally in the February to April period. The time series of abundance for Subdiv. 3Ps is shown in Fig. 3.14. These surveys commonly cover the extent of the

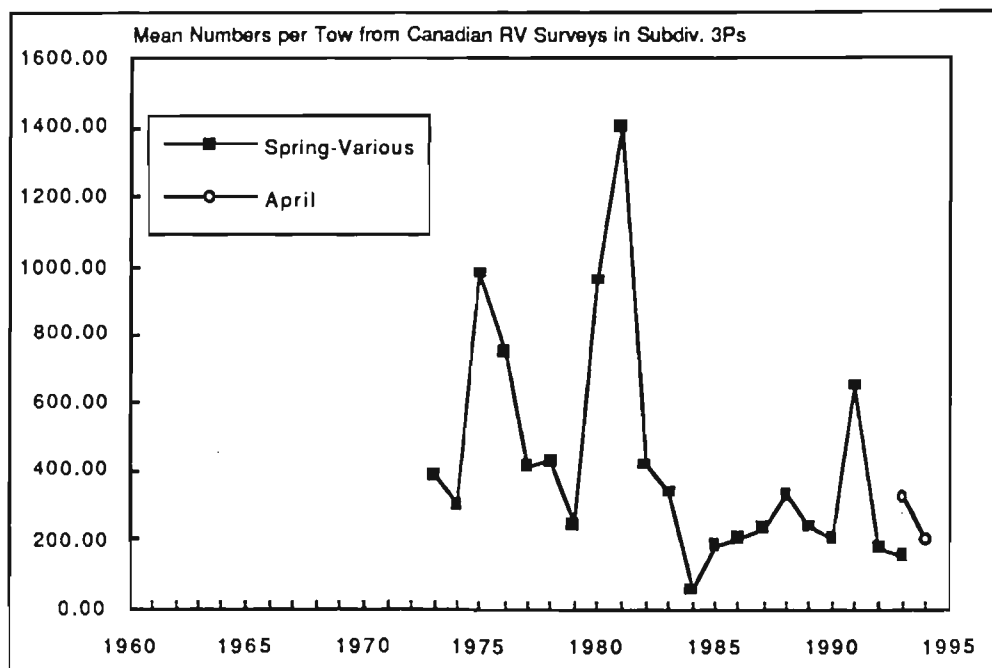


Fig. 3.14. Time series of abundance of redfish in Subdiv. 3Ps.

area of Subdiv. 3Ps to the maximum of 730 m. It is important to note that these surveys do not cover the entire stock area so that apparent trends over time may not be reflective of changes occurring throughout the entire management unit.

Two separate concentrations have been apparent throughout the recent period, one in an area encompassing the northwest corner of St. Pierre Bank that extends into 3Pn, and the second along the southern slopes of St. Pierre Bank in proximity of Div. 3O.

Length frequencies and numbers at age from the surveys reflect the relatively strong year-class(es) of the early 1980s that were first caught during the 1981 survey. These year-classes presently constitute the main component of the commercial fishery. There was also a much smaller pulse found first during the 1988 survey (perhaps the 1984-1985 year-classes), and a larger pulse observed in 1991 corresponding to the 1987-1988 year-classes. The 1984-1985 and 1987-1988 year-classes represented about 40% of the research catch in 1993. Because the surveys do not cover the entire stock area, it is not possible to estimate the abundance of these year-classes. However, it is quite evident that the early 1980s year-classes comprised a much greater proportion of the research catch than those of either 1984-85 or 1987-88.

3.3.2.2 Estimation of stock parameters

Production model

A general production model was not attempted because of the difficulties apparent in the catch rate analysis.

3.3.2.3 Discussion

This is a very difficult stock to assess. There are 2 species which can not be distinguished easily, there is a seasonal movement into and out of the area, and the RV surveys do not catch redfish well nor do they cover the entire stock area. Hydroacoustic surveys would provide a much better estimate of stock abundance. The assessment of this stock is further complicated by Newfoundland Region Statistics Branch's inability to provide the catch effort data with set by set locations or in 10 min. squares, as is done in other regions. This makes it impossible to study what may be happening at the boundary between Unit 1 and Unit 2.

CPUE in Unit 2 increased sharply in the late 1980s, but this is probably not a reflection of stock status. At that time there was an abrupt shift in fishing technology with industry moving to the more efficient Turbo midwater trawl in 1989.

There is some reason for caution regarding this stock. Since the large increase in CPUE in the late 1980s CPUE has been declining. Fishing effort has probably increased in recent years. Also, there have been some declines in the RV survey index. There is no method available for determining the size of the stock given the available data and the TAC has been based on average catch over an extended period.

3.3.2.3 Prognosis

Because of the limited database, it is not possible to provide an estimate of the size of this stock, and therefore it is not possible to estimate fishing mortalities during the past nor the possible fishing mortality generated by catching the TAC of 25,000 t in 1994. Commercial catch rates increased dramatically beginning in 1989 and peaked in 1990. Although part of this increase can be attributed to recruitment to the fishery of the relatively strong year-classes of the early 1980s, it is also partly due to a change from side trawlers to specialised stern trawlers for one fleet sector, as well as a general switch to the highly efficient midwater turbo trawl. The current data set does not allow separation of this gear from earlier midwater trawl gears, so this increase cannot be put in historical perspective. Catch rates declined in 1991, again in 1992, and according to the provisional data, were at the same level in 1993, albeit with much variability. This gives cause for concern because it is generally considered that the schooling nature of redfish is such that densities generally remain the same during declines in stock size; it is the size and number of aggregations which decrease first. Thus, catch rates based on trawling time alone may not reflect the size of the resource, and declines in catch rates based on tons per hour may lag behind real declines in the resource. A decline in the resource is not unexpected given the variable recruitment patterns observed for redfish. However, the apparent rapid decline in catch rates is unexpected and may reflect exploitation levels greater than previously believed, or what may be considered safe. Anecdotal evidence from industry supports a decline in the Unit 2 resource. Trawler captains do not believe there is as much fish in the area. Whereas a few years ago windows were being cut in the nets, these were not so prevalent in 1993 and have not been used so far in 1994. There are concerns that winter movement from Unit 1 is greater than in the past, and this may also mask possible declines in Unit 2.

Detailed survey data from the 3Ps portion of the stock area indicate biomass has fluctuated greatly, and it is not possible to determine trends in the stock from these data. It has been assumed in the past that length frequency distributions from these surveys are applicable to the entire stock area. From this it has been determined that subsequent to the good year-classes of the early 1980s there was also above average recruitment in the mid- and late-1980s, and their presence resulted in an optimistic forecast for the future of this resource. Close examination of the data however, reveals that the year-classes of the early 1980s made up a relatively greater proportion of the population than do those of the mid-1980s. It may be inferred from this that their contribution to the fishery in the future will be less than that of the early 1980s year-classes. If this is true, then rather than a future reversal of the apparent catch rate decline, it may only be temporarily halted.

Recent information examined by the Fisheries Oceanography Committee led to the conclusion that catches in Subdiv. 3Pn during November and December are most likely from Unit 1, and the management units should be changed to reflect this. The picture was not as clear for catches in October, but it may be that a substantial portion of these catches in 1993 was also of Unit 1 fish. Current fishing mortality on this resource cannot be estimated. However, with declining catch rates, maintenance of the same fishing effort on this stock will result in an increase in fishing mortality. Further, leaving the TAC for Unit 2 redfish at 25,000 t while changing the management units (and assuming the TAC will be caught) would itself result in an increase in fishing mortality of about 45% on Unit 2 fish. During the period 1981-1992, the average catch from this Unit excluding 3Pn in November and December was only about 14,000 t.

4. Stock status updates

4.1 SA 2+ Div.3K redbfish - D. Power, WP#30

4.1.1 Stock status summary

Summary

This stock is at an extremely low level of abundance. There is no evidence of any incoming recruitment.

The fishery

Catches from this stock peaked at 187,000 t in 1959 but declined to an average of 27,000 t by 1984-86. Since 1986 catches declined dramatically to the point that since 1991 there has been virtually no commercial catch taken.

Analysis

Research vessel survey data indicated that the size of this stock had declined to an extremely low level by the 1990s. Fish length compositions observed in the survey catches indicate that there has been little or no new recruitment entering the population since the early 1970s.

Prognosis

The stock is at a very low level due to poor recruitment. Should recruitment improve it would be at least 10 years before it would contribute to a fishery.

Stock summary sheet for SA 2+3K redbfish

Year	1987	1988	1989	1990	1991	1992	1993	1994	Min.	Med.	Max.
F _{0.1} Catch '000t	N/A										
Advised TAC '000t	35	35	35	35	20	20	20				
TAC '000t	35	35	35	35	20	20	20	1	1 ¹	32 ¹	35 ¹
Reported catches '000t	19	7	3.2	2.4	0.2 ²	+2	+2				
Unreported catches	N/A										
Estimated discards '000t	N/A										
Total catches	19	7	3.2	2.4	0.2 ²	+2	+2		+3	20 ³	187 ³
Total biomass '000t	N/A										
Spawning biomass '000t	N/A										
Mean - F ()	N/A										

¹ For 1973-1994

² 15t in 1992, 2t in 1993, Provisional from 1991-1993

³ From 1959 to 1993

Catches: Catches since 1960 have been as high as 130,000 t. Between 1961 and 1977 catches averaged about 28,000 t. In the early 1980s landings ranged from 14,000 t to 18,000 t then increased to between 24,000 t to 29,000 t from 1984 to 1986 in response to improved markets. Since 1986, landings have drastically declined annually such that there has been virtually no catch in recent years. These reductions have come about because of the very low catch rates, as well as persistent complaints of external parasite infestation.

Data and Assessment: Available information is not adequate for an analytical assessment. Standardized catch rates show high variability between some years but indicate a general decrease from 1984 to 1990. Limited fishing effort has occurred since 1990. RV trawl surveys in divisions 2J and 3K indicate a declining trend in both divisions since the 1980s. Trawlable biomass estimates since 1989 are exceptionally low in divisions 2J and 3K and suggests that the population is at a very low level especially when compared to estimates of the early 1980s.

Fishing Mortality: No information.

Recruitment: There has been virtually no recruitment since the year-classes of the early 1970s.

Environmental Factors: A cooling trend has been observed in the area during the 1980s, but its potential impact on this stock is unknown.

Multispecies Considerations: No information.

State of the Stock: Stock is at a very low level due to poor recruitment. The surveys in divisions 2J and 3K since 1981 indicate trawlable biomass to be at historically low levels.

Forecast for 1995: There is not expected to be any increase in the size of this resource in 1995.

Long-term Prospects: Largely unknown given the long history of recruitment failure. Should recruitment improve it would be at least 10 years before it would contribute to a fishery.

Special Comment: Given the low biomass any exploitation of this resource would be detrimental.

4.1.2 Technical basis

4.1.2.1 Available data

Nominal Catches

There has not been a persistent directed effort on this stock since 1990 when 2,400 t were taken. Catches declined to 239 t in 1991, 15 t in 1992 and only 2 t in 1993 (Fig. 4.1). The highest catch taken from this stock was 187,000 t in 1959. Between 1961 and 1979 catches averaged about 28,000 t, ranging between 17,000 t and 55,000 t. From 1980-83 catches averaged 16,000 t, increased to about 27,000 t from 1984-1986 in response to improved markets and declined steadily thereafter. The reduction since 1986 is primarily due to reduced Canadian effort coupled with a cessation of the Resource Short Plant Program effort by foreign countries (Russia and Japan) since 1987.

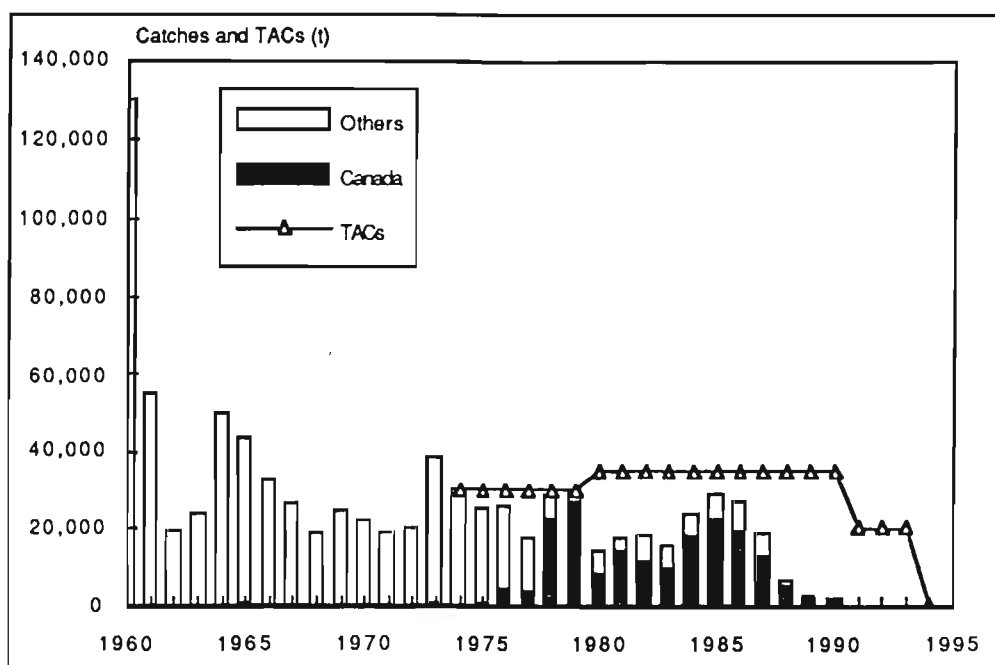


Fig. 4.1. Time series of annual catches by Canada and other sources together with the TAC for the period 1960-94.

Since the early 1980s, the fishery has been concentrated in Div. 3K which may be attributable to a variety of factors such as ice cover early in the year in divisions 2G and 2H and the prevalence of parasites in Div. 2J. Landings were generally distributed throughout the year and were predominantly taken by otter trawl.

Industry experience

A number of reasons have been cited for the substantial decline since 1986, according to Canadian sectors which had a directed fishery for this stock. First there is the continuous complaint of parasite infestation (*Sphyrion lumpi*, an external copepod which attaches itself to the flesh), particularly in Div. 2J. In addition there is a bacterial infection of the skin which is undesirable for the prime market. Also, according to veteran trawler captains, the concentrations of fish are reduced on their traditional fishing grounds and effort was redirected to other fisheries because of the low catch rates.

Research vessel surveys

Stratified random groundfish surveys have been conducted in the fall in divisions 2J and 3K since 1977. These surveys generally cover strata down to depths of 1000 m. Although there have been rather large fluctuations in density estimates between some years, there has been a general decline since the surveys began in Div. 2J and Div. 3K (Fig. 4.2). The mean numbers and weights per tow suggest the population in divisions 2J and 3K is at historically low densities. Average catch per tow has been less than 3 kg in Div. 2J and less than 5 kg in Div. 3K since 1991 compared to an average of 182 kg and 150 kg respectively from 1978-1981 surveys. Trawlable biomass estimates have averaged less than 1,800 t in Div. 2J since 1991 and less than 1,000 t in Div. 3K since 1992, compared to an average of 200,000 t in Div. 2J and 316,000 t in Div. 3K over the 1978-1981 period.

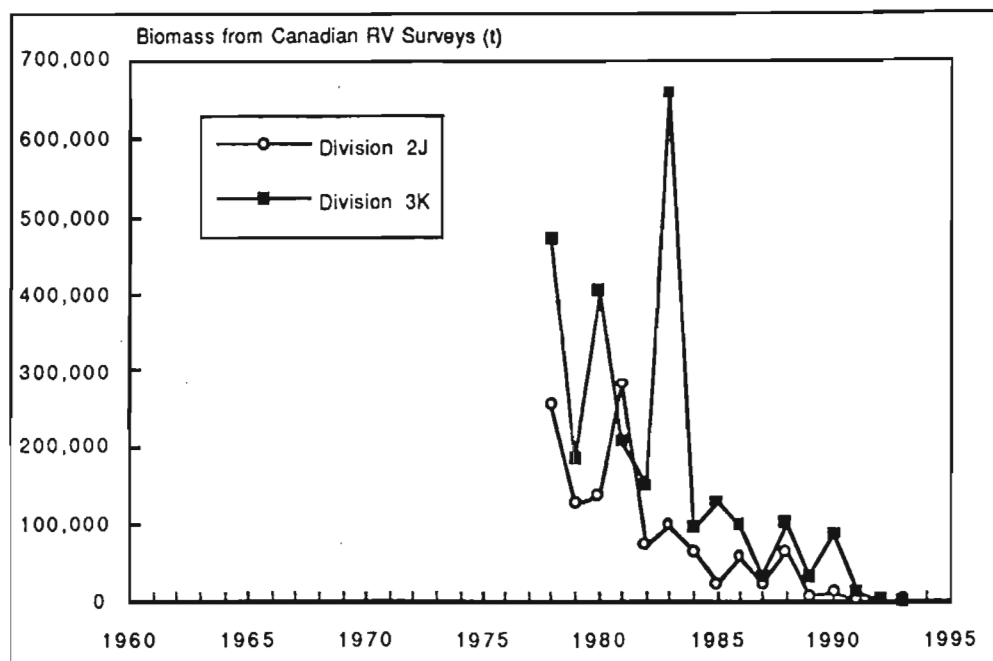


Fig. 4.2. Time series of RV estimates of redfish biomass in Divs. 2J and 3K.

Length frequencies and numbers at age from the surveys indicate that recruitment has been poor since the year-classes of the early 1970s. There was no indication from the 1993 survey that this situation has changed.

4.1.2.2 Discussion

There has been no sign of recruitment from research vessel survey data since these surveys were started in 1978. The shrimp fishery in this area has some redfish by-catch but no small fish are caught. This is another indication that there has been very little recruitment.

As with Unit 2 redfish, the stock structure is not clear. There is considerable uncertainty as to where these fish originate from.

There will be no fishery in the near future, given the current estimated stock size and the lack of recruitment. Assessment of this stock is probably not required for the next several years since very little is expected to change in the short term.

4.1.2.3 Prognosis

It is not possible to provide an estimate of the size of this stock, and therefore it is not possible to estimate fishing mortalities during the past nor the possible fishing mortality generated by catching the TAC of 1,000 t in 1994.

Trawlable biomass estimates from surveys in divisions 2J and 3K indicate the population is at a very low level. There is a considerable concern for this resource because of poor recruitment since the year-classes of the early 1970s. That recruitment has been poor is supported by the fact that shrimp fisheries in the area have no by-catch problem with small fish, yet shrimp nets generally capture small redfish (less than 15 cm) if they are in the area of the fishery.

If this stock were to experience good recruitment in the near future, it would still take about 10 years for this to start contributing to a fishery because of the relatively slow growth rate of redfish. This resource will not be able to sustain a fishery until after recruitment improves.

4.2 Div. 3O redfish - D. Power, WP#31

4.2.1 Stock status summary

Summary

Recently, more small redfish appear to be available in Div. 3O based on research vessel surveys conducted during the 1990s. However, it is unclear whether redfish in this area are resident or migrants from another area. Based on the research vessel data, the stock appears to be mostly comprised of young immature fish, although significant amounts of larger fish have been found in the past in the deeper, hard-to-fish areas of the Division.

The fishery

Since 1959 nominal catches have been in the range of 5,000 to 35,000 t. Up to 1986 catches averaged 13,000 t, increased to 27,000 t in 1987 with a further increase to 35,000 t in 1988. Catches declined to 13,000 in 1989 and were about this amount to 1992. The 1993 catch is estimated to be about 16,000 t. The fishery has primarily been conducted by foreign fleets, some of which have allocation agreements with Canada.

Analysis

Commercial catch rates suggest that the stock may have declined during the 1979-92 period. Research surveys beginning in the fall of 1992, however, indicate that there are more redfish in the area than in 1991 or the spring of 1992. Fish caught during the research surveys consist mostly of small immature fish.

Prognosis

Given the predominance of young fish in the area, any fishery, especially in depths less than 375 m, is likely to capture mainly immature fish.

Stock status summary sheet for Div. 30 redfish

Year	1987	1988	1989	1990	1991	1992	1993	1994	Min.	Med.	Max.
F _{0.1} Catch '000t	N/A										
Advised TAC '000t	20	14	14	14	14	14	14				
TAC '000t	20	14	14	14	14	14	14	10	10 ¹	16 ¹	21.9 ¹
Reported catches '000t	13	11.5	11	9	7.5 ²	12.5 ²	12.6 ²				
Unreported catches	14	23.5	2.2	5.2	0.8	1.8	3.1				
Estimated discards '000t	N/A										
Total catches	27	35	13.2	14.2	8.3 ²	14.3 ²	15.7 ²		5 ³	13.6 ³	35 ³
Total biomass '000t	N/A										
Spawning biomass '000t	N/A										
Mean - F ()	N/A										

¹ From 1974-1994² Provisional³ From 1960-1993

Catches: Since 1959 nominal catches have been in the range of 5,000 to 35,000 t. Up to 1986 catches averaged 13,000 t, increased to 27,000 t in 1987 with a further increase to 35,000 t in 1988. Catches declined to 13,000 in 1989 then remained at about this level through to 1992. The 1993 catch is estimated to be about 16,000 t. The fishery has primarily been conducted by foreign fleets, some of which have allocation agreements with Canada.

Data and Assessment: The information available is not adequate for an analytical assessment of this stock. Standardized CPUE indicates a declining trend from 1979 to 1992, however, this trend may be more indicative of a declining component of the stock in the area outside of the 200 mile limit rather than the stock as a whole. Most of the activity occurs outside the 200 mile limit given limited fishing within Canadian waters by foreign fleets, and limited Canadian interest in the resource because of the small fish size. Beginning in the fall of 1992, estimates of biomass from RV surveys have increased fairly steadily compared to 1991. The size distribution during this period of increase, nevertheless, has remained relatively stable. This apparent lack of growth is difficult to reconcile given the increase in biomass but may be related to migration to and from the area at certain size ranges.

Fishing Mortality: No information.

Recruitment: With the stability in size composition observed in recent surveys it is difficult to evaluate potential recruitment.

Environmental Factors: No information.

Multispecies Considerations: No information.

State of the Stock: RV survey indices suggest that the stock has increased beginning in the fall of 1992, however, the static size composition is difficult to interpret.

Forecast for 1995: Given the predominance of young fish in the area, a fishery especially in depths less than 375 m is likely to capture mainly immature fish.

Long-term Prospects: Unknown given the uncertainty in stock structure.

Special Comment: It should be noted that any consideration of calculating a TAC based on an average catch over some period should incorporate the revised catch figures from 1983 to 1993.

4.2.2 Technical basis

4.2.2.1 Available data

Nominal catches

Since 1959 nominal catches have been in the range of 5,000 to 35,000 t (Fig. 4.3). Up to 1986 catches averaged 13,000 t, increased to 27,000 t in 1987 with a further increase to 35,000 t in 1988. Catches declined to 13,000 in 1989 and have been about this amount through to 1992. The 1993 catch is estimated to be about 16,000 t.

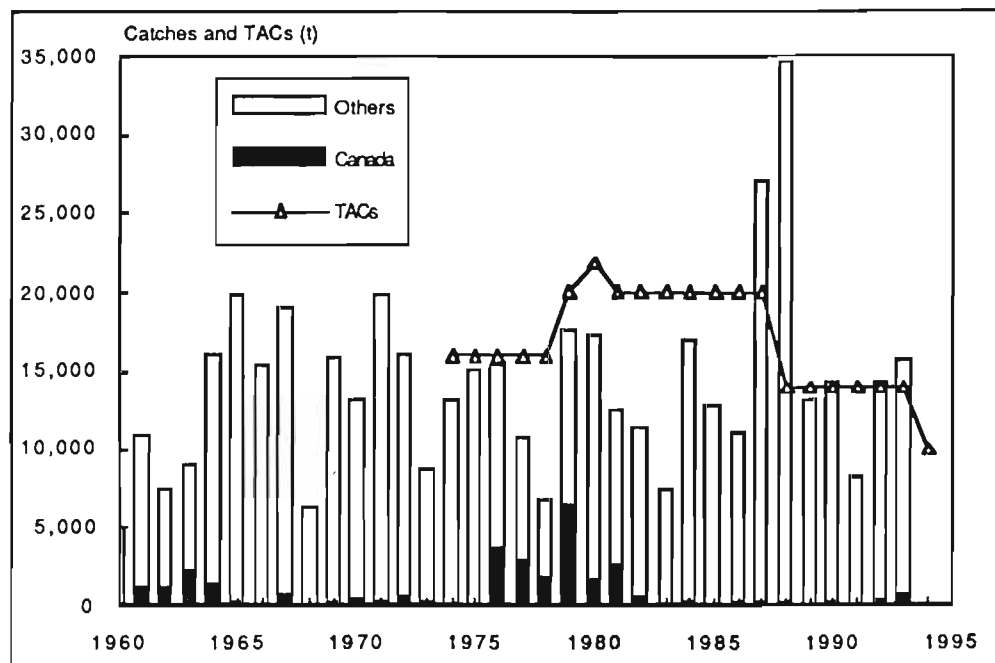


Fig. 4.3. Time series of annual catches by Canada and other sources together with the TAC for the period 1960-94.

The increased catches in 1987 and again in 1988 were due to increased activity outside 200 miles by non-contracting parties to NAFO (primarily Panama and South Korea). Prior to this assessment, Canadian surveillance estimates of catch for such countries were utilized in arriving at a total figure for the year. Further scrutiny of the surveillance estimates of catch for countries with allocations in Div. 3O revealed there were often substantial differences in the estimated catch compared to what was reported to NAFO. The differences (amount non-reported) ranged from 200 t in 1983 to 10,000 t in 1988. These estimated catches have been included for a more realistic estimate of total removals from Div. 3O for the years from 1983 onwards.

Russia has predominated in this fishery up until 1993 and generally took its share (about 50%) of the total foreign allocation, which accounted for about 2/3 of the TAC. From 1981 to 1987 the TAC was 20,000 t, lowered to 14,000 t in 1988 and remained at that amount until 1994 when it was lowered further to 10,000 t. Canada took less than 300 t in each year from 1983 to 1992. In 1993 Canada caught about 700 t.

The fishery has occurred primarily in the second and third quarters of the year since 1983. The predominant means of capture from the mid-1970s to the early 1980s was the bottom otter trawl, but since 1984 there has been an increase in the use of midwater trawls.

Industry information

There is reluctance on the part of the major Canadian offshore sector to land fish that are generally smaller than acceptable size (approximately 29 cm fork length) because there is very little to no profit in processing them. Because smaller size groups are predominant on the fishable grounds of Div. 3O, Canadian interests have historically shown little interest in a redfish fishery in this area. With declines in many other groundfish resources however, Canadian industry has shown some increased interest in 1994.

Commercial catch rates

The standardized catch rate index based on effort in hours fished shows much interannual variability from 1959 to 1978 (Fig. 4.4). In 1979 there was a dramatic increase in the catch rate. This was followed by a general decline to 1992 with the exception of 1991. Information for 1993 could not be incorporated in time for the review of this stock. There is much between year variability in estimates throughout the time series. Large fluctuations from year to year, primarily in the pre-1979 period are not reflective of the dynamics of the species. There is a declining trend apparent from 1979 to 1992. However, this trend may be more indicative of a decline in the proportion of the stock outside the 200 mile limit where most of the effort is concentrated.

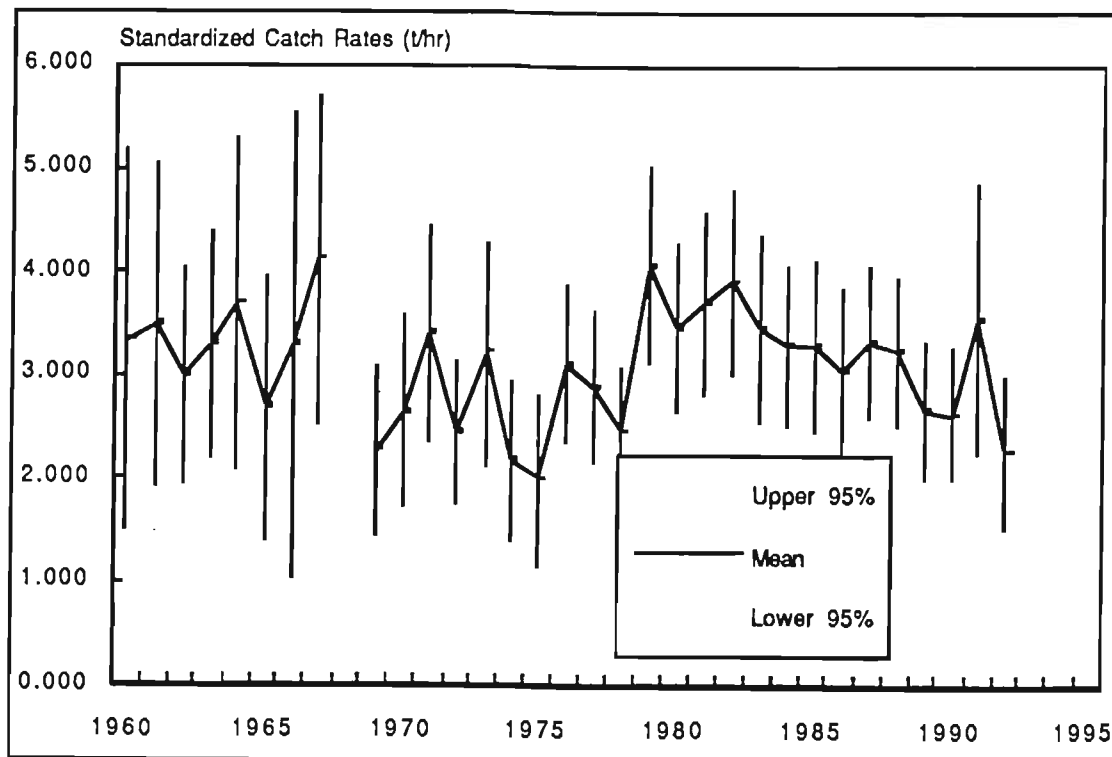


Fig. 4.4. Commercial catch rates for the Div. 30 redfish fishery over the period 1960 to 1992.

Research vessel surveys

Stratified random groundfish surveys have been conducted in the spring and fall in Div. 30 since 1991 (Fig. 4.5), where the planned coverage included depths of 730 m. Prior to this all surveys only covered strata down to 375 m. There was also a summer survey conducted in 1993 covering depths to 730 m. From 1991 spring through 1992 spring average trawlable biomass estimated from these surveys was about 10,000 t. From the 1992 fall survey there was an increase in the trawlable biomass in the area to 26,000 t. The average of the three 1993 surveys was 44,000 t and a preliminary estimate of the biomass in the 1994 spring survey was 72,000 t. Stratum by stratum estimates indicate that the increases occurred over a great deal of the area, particularly in strata greater than 375 m, although 43,000 t of the 1994 estimate came from two large sets (> 2,000 kg) occurring in a narrow stratum along the slope.

Length frequencies from the 1991 spring survey indicated modes at 11 cm and 20 cm corresponding to the 1988 and 1984 year-classes respectively. These modes were seen to progress in the surveys that followed, up to the 1992 fall survey when the modes were at 17 cm and 22 cm. The length distributions from each of the three 1993 surveys showed identical modes with no

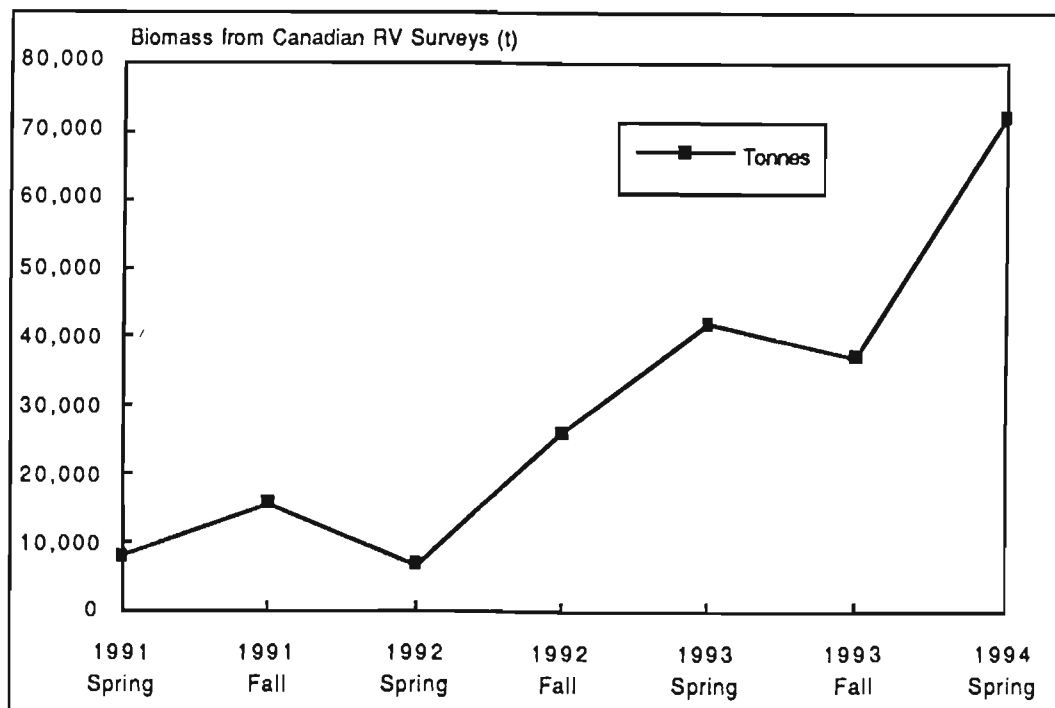


Fig. 4.5. Time series of Canadian RV survey biomass estimates for the period 1991 to 1994.

apparent signs of growth. It is unknown how this might relate to the increase in estimated biomass over the same period, although migration to and from the area at certain sizes is a possibility that should be explored. It is also apparent that a relatively low proportion of the estimates are accounted for by fish greater than 30 cm in any of the surveys since 1991.

4.2.2.2 Discussion

The research vessel survey in recent years has shown large increases in the abundance of redfish in this area. However, the same length classes are seen in each year with no progression of the fish to larger size. The absence of larger fish is a concern both in terms of stock structure and stock status. Apparent lack of growth makes the interpretation of increases in survey abundance difficult at this time.

There are large gaps in knowledge about all of the redfish stocks. Coherent analyses of all the stocks is required if there is to be any hope of learning enough about these stocks to adequately assess them. A workshop on redfish would certainly be useful.

4.2.2.3 Prognosis

It is not possible to estimate the size of this stock. Consequently it is not possible to determine fishing mortalities during the past nor the possible fishing mortality generated by catching the TAC

of 10,000 t in 1994.

The CPUE index indicates a general decline from 1979 to 1992, however, this may be more representative of the area of Div. 3O outside 200 miles, rather than the entire stock area. The survey information from recent years indicates a substantial increase in the biomass beginning in the fall of 1992, although this increase is difficult to interpret because the length distribution data suggest an apparent lack of growth. The absence of larger fish (>30 cm) is a concern in terms of stock status and stock structure, although more information on fish distribution in deeper, generally untrawlable areas is required.

The length at which half the population is sexually mature (L50) is 18.2 cm fork length for males and 27.7 cm fork length for females (Ni and Sandeman, 1984). Given that generally the shallower the depth fished the smaller the size composition, caution is warranted that a greater proportion of immature females may be captured if fishing is concentrated in shallower water (less than 375 m).

The current TAC of 10,000 t was recommended as a precautionary measure based on average catches in recent years. This is no longer valid when consideration is given to the revised catch figures from 1983 to 1993.

4.3 SA 2 + Div. 3K American plaice - W.B. Brodie, WP#29

4.3.1 Stock status summary

Summary

This stock is at its lowest level in at least 17 years. The numbers of older fish in the population have declined and there is no evidence of increased numbers of young fish.

The Fishery

Catches from this stock were at their highest in the early 1970s but have declined in recent years to their lowest observed levels in 1992 and 1993. Only a by-catch TAC exists for 1994.

Analysis

Research vessel surveys have shown that this stock has declined by 95 percent from the early 1980s to the present. The numbers of fish at all ages has been decreasing. It is very unlikely that fishing alone can account for the magnitude of the decline in this stock since the early 1980s.

Prognosis

This stock is at a very low level and any fishing would be detrimental to its recovery. There does not appear to be any prospect of the stock rebuilding in the short to medium term.

Stock summary sheet for SA 2+3K American plaice

Year	1987	1988	1989	1990	1991	1992	1993	1994	Min. ¹	Med. ¹	Max. ¹
F _{0.1} Catch '000t	N/A								0.1	3.5	12.7
Advised TAC '000t	10	10	10	10	10	10	5				
TAC '000t	10	10	10	10	10	10	5	0.5			
Reported catches '000t	1.1	1	4.2	1.8	.5 ²	.1 ²	.1 ²				
Unreported catches	N/A										
Estimated discards '000t	N/A										
Total catches	1.1	1	4.2	1.8	.5 ²	.1 ²	.1 ²				
Total biomass '000t	N/A								.		
Spawning biomass '000t	N/A										
Mean - F ()	N/A										

¹For 1963-1993²Preliminary statistics

Catches: Catches have been declining since 1989 and in 1992 and 1993 were about 100 t each year. Catches have been less than 1900 t in 9 of the past 11 years.

Data and Assessment: Research vessel surveys indicate sharp declines in biomass in all divisions since the mid 1980s. The biomass estimates for divisions 2J and 3K were about 5,500 t in both 1992 and 1993, compared to an average of over 105,000 t from 1980-84.

Fishing Mortality: Total mortality is likely to have been very high to have caused such rapid declines in abundance. Fishing mortality from reported catches cannot explain these decreases. Misreporting of catches and migration are thought to be unlikely causes.

Recruitment: Research vessel survey data indicate a decline in recent years.

Environmental Factors: Anomalously low water temperatures since the mid 1980s may have had an effect on distribution and abundance through some unknown mechanism. From 1989 onward, RV surveys showed a very low proportion of biomass in the shallower areas of divisions 2J and 3K compared to the earlier period.

Multispecies Considerations: There are strong negative correlations between shrimp CPUE and the biomass estimates of American plaice and other groundfish in the fall RV surveys in divisions 2J and 3K. This is unlikely to be a simple predator-prey relationship and may be indicative of a more complex process.

State of the Stock: Stock size is the lowest observed in at least 17 years. There are no indications of recruitment necessary to rebuild the stock. It is very unlikely that fishing mortality has contributed substantially to the recent declines in biomass. Causes of the decline are not known.

Forecast for 1995: Given the very low biomass, any commercial fishery on this stock would be detrimental.

Long-term Prospects: Unknown, but a recovery of the fishery is unlikely before at least 10 years, given recent recruitment estimates and the age structure required to support a fishery.

4.3.2 Technical basis

4.3.2.1 Available data

Catches

Catches increased steadily throughout the 1960s, peaking at 12,686 t in 1970 (Fig. 4.6). After the declaration of the 200 mile limit in 1977, foreign catches were greatly reduced, with the total catch from the stock exceeding 2,000 t on only two occasions after 1981. Catches in 1992 and 1993 were only 104 and 79 t respectively and are by far the lowest in the time series, due in part to the moratorium on the northern cod fishery. In most years, a large percentage of the catch has come from Div. 3K, with recent exceptions of 1989 and 1990 when a directed fishery occurred in the fall in Div. 2J. Catches from divisions 2GH combined have not exceeded 125 t in any year since 1972.

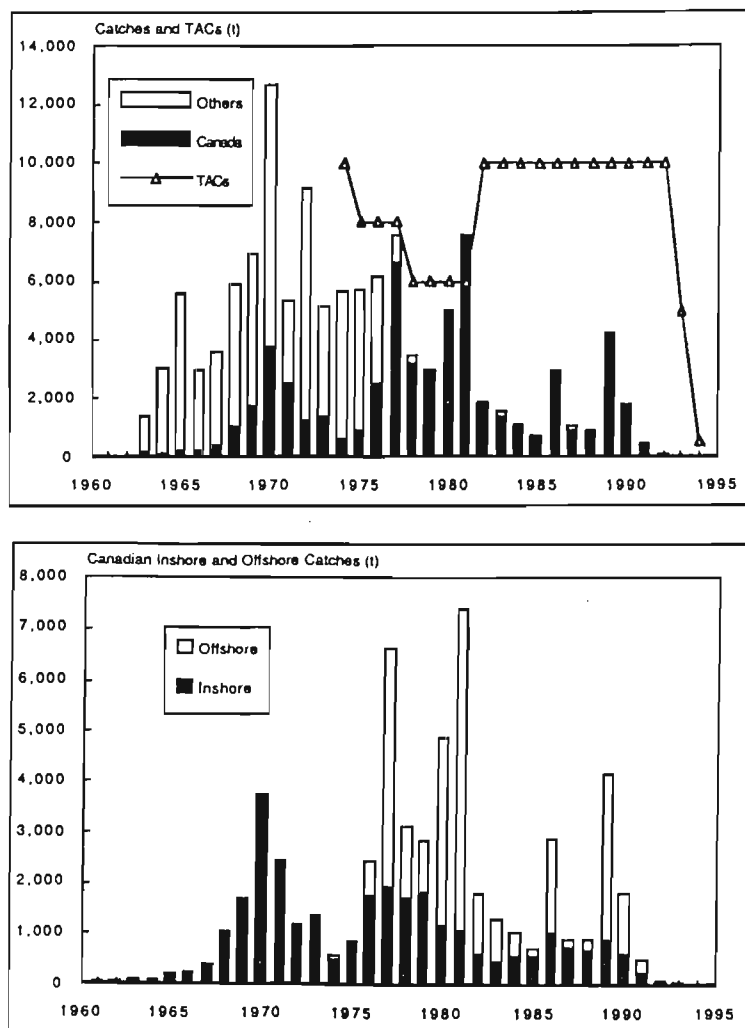


Fig. 4.6. Time series of annual catches of American plaice in SA 2+3K by Canada and other sources together with the TAC for the period 1960-94 and by Canada broken down into inshore and offshore catches.

In most years prior to 1991, the inshore catch ranged between 500 and 2,000 t, while the offshore catch has fluctuated more widely. By-catch of American plaice from the shrimp fisheries in SA 2 + Div. 3K averaged about 200 t per year since 1980 and was mostly discarded. There is no directed catch allowed from this stock in 1994 and by-catches are limited to 500 t.

Catch at age and mean weights at age

Catch-at-age data for this stock are available for the period 1984-90, based on samples from the Canadian fisheries. For many years prior to 1984, and for 1991 to 1993, sampling data are either non-existent or inadequate to calculate catch at age. In most years, ages 9-12 comprise the bulk of the commercial fishery, and there was a declining trend in the catch numbers of older individuals up to 1990 (Brodie et al. 1993). As well, the mean weights at age increased at all ages in both 1989 and 1990.

Catch rates

CPUE data are available from Canadian offshore otter trawlers for the period 1976-92. However, in only 2 of the past 11 years has the directed catch exceeded 500 t, and in many years it was negligible. Therefore these data cannot be used as an index of abundance for this stock since by-catch rates are not considered to be representative of stock abundance.

Research vessel surveys

Stratified random surveys have been conducted in divisions 2G, 2H, 2J, and 3K since the late 1970s, although not annually in Div. 2GH. The biomass index in Div. 2G was relatively low in all surveys, although coverage was poor in most years except 1987 and 1988. In divisions 2G and 2H, the biomass declined substantially from the late 1970s to the late 1980s (Brodie et al. 1993).

In Div. 2J, where survey coverage has been virtually complete since 1981, the biomass index has declined drastically from estimates of about 90,000 t in 1982-83 to only 2,400 and 2,100 t in 1992 and 1993 respectively (Fig. 4.7). Div. 3K shows a similar pattern, with the biomass declining from a range of 25,000 to 40,000 t between 1979 and 1987 to only 3,100 and 3,400 t in the 2 most recent surveys

Shifts in the depth distribution of the biomass to deeper water occurred during 1986-89 in both divisions (shown for Div. 2J in Fig. 4.8), and were followed by rapid declines to very low levels.

There has been a gradual reduction in the numbers of older fish caught in the surveys, consistent with the commercial fishery data. Virtually all cohorts declined at very high rates from 1990 to 1992. There has also been decreased recruitment in recent years (Brodie et al. 1993). Age-specific data from the 1993 survey are not available at this time.

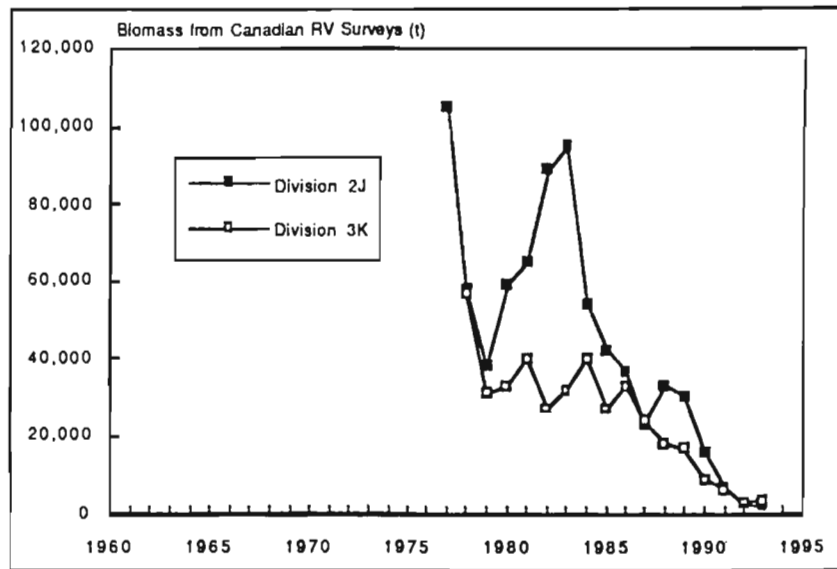


Fig. 4.7. Time series of Canadian RV survey estimates of American plaice biomass in Div. 2J3K for the period 1977 to 1993.

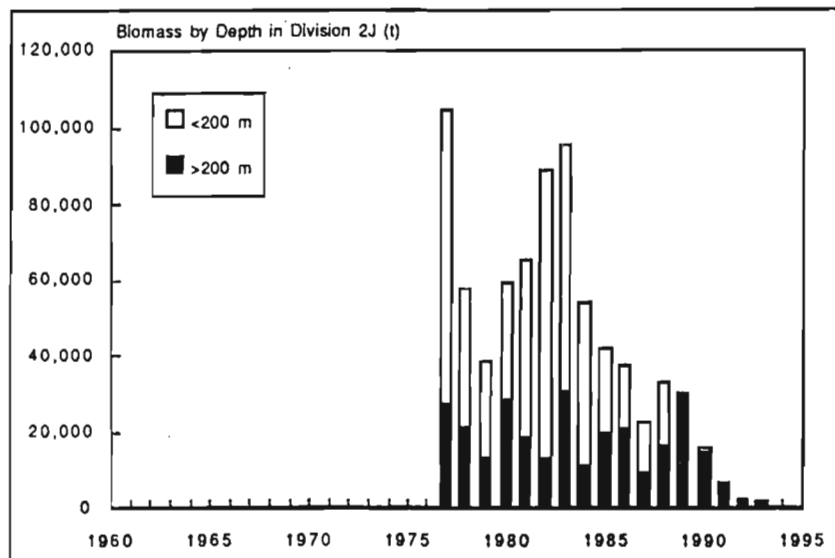


Fig. 4.8. Change in the depth distribution of American plaice biomass in Div. 2J over the period 1977 to 1993.

Environmental factors:

Anomalously low water temperatures since the mid 1980s may have had an effect on distribution and abundance through some unknown mechanism. From 1989 onward, RV surveys showed a very low proportion of biomass in the shallower areas of Divs. 2J and 3K compared to the earlier period (for Div. 2J see Fig. 4.8).

Multispecies interactions

There are strong negative correlations between shrimp CPUE and the biomass estimates of American plaice and other groundfish in the fall RV surveys in Divs 2J and 3K (see Fig. 2.4). This is unlikely to be a simple predator-prey relationship and may be indicative of a more complex process.

4.3.3 Estimation of stock parameters

Analysis of recruitment and total mortality from research vessel surveys - R.A. Myers, WP#34

Recruitment indices and total mortality were estimated using all available research surveys for 2J, 3K and 3L. It was concluded that recruitment was low during the last few years, and that total mortality in the last few years has been high.

4.3.4 Assessment results

Research vessel surveys have shown that this stock has declined by 95 percent from the early 1980s to the present. The numbers of fish at all ages has been decreasing. It is very unlikely that fishing alone can account for the magnitude of the decline in this stock since the early 1980s. This stock was at a very low level by the end of 1993. Causes of the decline are not known. There are no indications of recruitment necessary to rebuild the stock. Stock size is the lowest observed in at least 17 years. That fishing mortality has been low can be inferred from an examination of the ratio of reported catches to RV estimated biomass (Fig. 4.9).

4.3.5 Discussion

Recruitment indices and total mortality were estimated using all available research surveys for American plaice and yellowtail flounder. It was concluded that (1) recruitment for American plaice in 2J and 3K is very low, and (2) total mortality appears to be large (greater than 1) and increasing for 2J, and 3K American plaice. Fishing mortality from reported catches cannot explain these decreases. Misreporting of catches and migration out of the stock area are thought to be unlikely causes. Research vessel surveys indicate a decline in recruitment in recent years.

Faced with the current low level of abundance, no evidence of significant recruitment and high and increasing mortality over recent years, recovery of this resource is unlikely within the next decade. The sharp decrease in abundance since the early 1980s occurred when catch levels were low suggesting that the commercial fishery did not cause the decline in the stock, unless there is some

unknown source of fishing mortality. Alternatively, there has been an increase in there natural mortality (M) in recent years to levels well beyond 0.2, the source of which is unknown, and/or emigration.

Any commercial fishery would be detrimental to the resource under current conditions and the fishery should be closed in 1995.

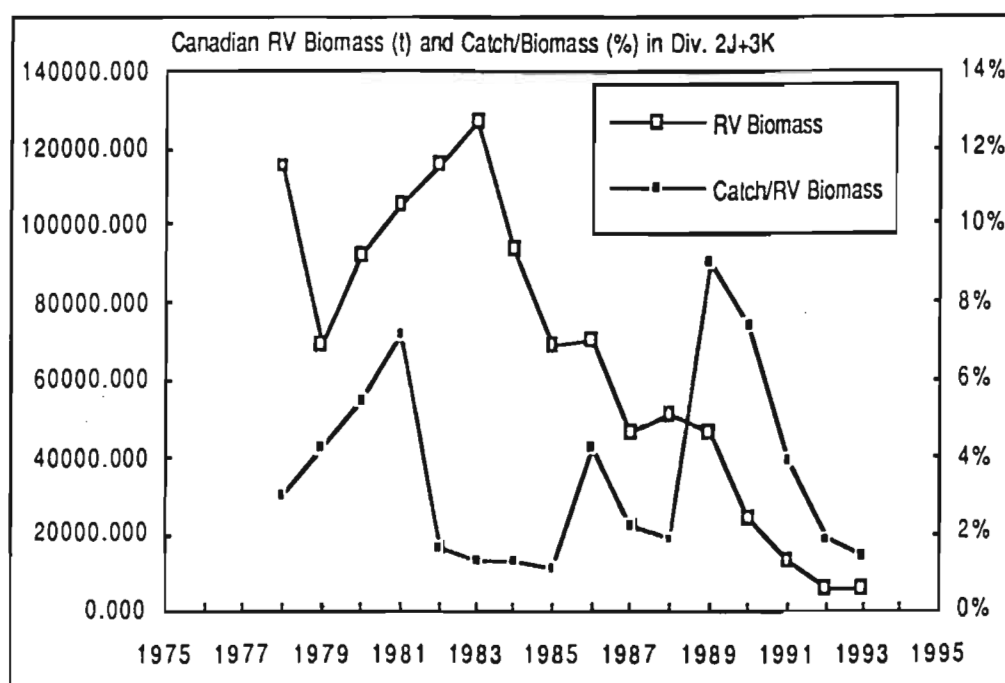


Fig. 4.9. Relationship between catch and biomass for the SA 2+3K American plaice stock over the period 1978 to 1993.

4.3.5 Prognosis

It is clear from the RV survey data that this stock had declined to an extremely low level in 1992-1993. Catches in the commercial fishery, even before the moratorium on northern cod in 1992, had been decreasing and the catch in 1991 of 500 t was then the lowest in about 30 years. With the stock size estimated from surveys in the early to mid 1980s, and the relatively low catches in the commercial fishery since then, it is evident that the low levels of prevailing fishing mortality cannot explain the magnitude of the declines in stock size which have occurred.

Given the current stock size estimates from surveys, there can be no optimism in the short or medium term. Even with negligible catches, the stock size continued its sharp decline from 1991 to 1992 and remained at this very low level in 1993. The prospects for rebuilding in the longer term are unknown, although "a recovery of the fishery is unlikely before at least 10 years" (FRCC, unpublished report, Nov. 1993). The current TAC of 500 t is based on by-catch only, with no provision for a directed fishery. Any fishery on this stock would be detrimental to the resource.

4.4 Subdiv. 3Ps American plaice - W.B. Brodie and M.J. Morgan, WP#22

4.4.1. Stock status summary

Summary

This stock is at its lowest level in at least 15 years. The number of older fish in the population has declined and there is no indication of increased numbers of young fish. The fishery was closed in late 1993 and remains closed in 1994 except for a small by-catch TAC.

The fishery

The peak catches for this stock were in the 1968 to 1973 period. Catches and catch rates have declined in recent years to their lowest observed levels. In 1993 only 751 t were caught before the fishery was closed in September. The catch is mainly made up of fish ages 8 to 12.

Analysis

Research vessel surveys have shown that the stock has been declining since the mid 1980s and is now at a very low level. The numbers of fish at all ages have been decreasing. The fish, both male and female, have been maturing at a younger age.

Prognosis

This stock is at a very low level and any fishing would be detrimental to its recovery. There does not appear to be any prospect for stock rebuilding in the short to intermediate term.

Stock status summary sheet for American plaice in Subdiv. 3Ps

Year	1987	1988	1989	1990	1991	1992	1993	1994	Min. ¹	Med. ¹	Max. ¹
F _{0.1} Catch '000t	N/A										
Advised TAC '000t	5	5	5	4	4	3	3				
TAC '000t	5	5	5	4	4	4	3	0.5			
Reported catches '000t	5.3	4.4	4.0	4.8	4.4 ²	2.3 ²	0.8 ²		0.8	4	14
Unreported catches	N/A										
Estimated discards '000t	N/A										
Total catches	5.3	4.4	4.0	4.8	4.4 ²	2.3 ²	0.8 ²				
Total biomass '000t	N/A										
Spawning biomass '000t	N/A										
Mean - F ()	N/A										

¹For 1963-1993²Preliminary statistics

Catches: Overall the catch in 1993 was 751 t, the lowest since the early 1960s. The catch by Canadian offshore trawlers was the lowest in the time series and the inshore catch the lowest since 1985.

Data and Assessment: The commercial catch per unit effort analyses done in 1993 showed that there has been a sharp decline since the mid-1980s. Research survey biomass estimates were relatively stable around 30,000 t in 1986-88 but have declined substantially since 1989 with 5 of the 6 surveys since then (including 1994) giving an estimated biomass at less than 7,000 t.

Fishing Mortality: Total mortality is likely very high in light of the rapid decrease in abundance. It is unlikely that reported catches are solely responsible for the observed decline in abundance, although fishing mortalities themselves are likely to have been high in recent years.

Recruitment: Surveys indicate that recruitment is very low.

Environmental Factors: There is some indication that temperatures have been low in recent years, but the possible impacts of this on the stock cannot be determined.

Multispecies Considerations: There are no data available to allow for consideration of multispecies interactions for this stock.

State of the Stock: Currently at an extremely low level coupled with low levels of recruitment.

Forecast for 1995: In the short term, there is no prospect for stock rebuilding.

Long-term Prospects: The longer term outlook is pessimistic given the low stock size and lack of recruitment. Rebuilding cannot be expected until there are indications of improved recruitment.

Special Comment: Given the current status, any commercial fishery on this stock would be detrimental.

4.4.2 Available data

Catches

Catches from this stock were highest from 1968 to 1973, exceeding 12,000 t on three occasions in this period (Fig. 4.10). Catches by foreign vessels peaked at about 8,800 t in 1968, due mainly to the USSR catch, but have not exceeded 800 t since 1973. Catches by France ranged from 540 t to 760 t from 1986-89, but declined to only 26 t in 1992. There was no French catch reported in 1993.

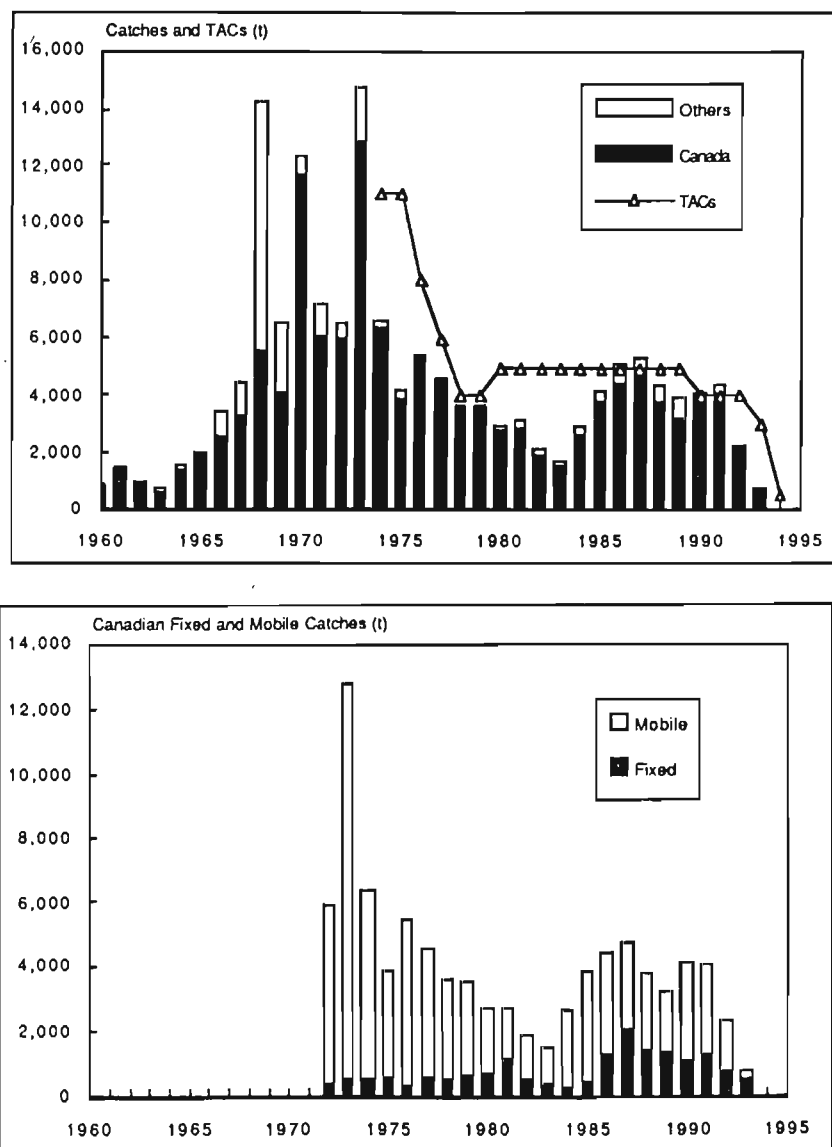


Fig. 4.10. Time series of annual catches of American plaice in Subdiv. 3Ps by Canada and other sources together with the TAC for the period 1960-94, and by Canada for fixed and mobile gear.

The Canadian inshore catch in 1993 declined to the lowest level since 1985. The catch by Canadian offshore trawlers in 1993 was by far the lowest in the time series. This fishery has a substantial directed component which has often been prosecuted in the first quarter.

Overall, the catch in 1993 was 751 t, the lowest since the early 1960s. Based on a recommendation by the FRCC the fishery was closed in September of 1993 for the remainder of that year. The TAC for 1994 was set at 500 t to allow a by-catch in other fisheries. To date in 1994 reports from industry are that approximately 40 t have been taken as a by-catch in the witch fishery. It is anticipated that there will not be much additional catch.

Catch at age and mean weights at age

In 1993 the catch was comprised mainly of fish aged 8-12 (Fig. 4.11), similar to most years (Brodie et al. 1993), although there was no sampling data from the inshore catch in 1993, which comprised 60% of the catch weight. The mean weights at age in 1993 and 1992 were lower than recent earlier values, due in part to the absence of the inshore sampling. Inshore gear tends to catch larger fish at age so that absence of sampling from this fishery would tend to result in a bias in the mean weights at age.

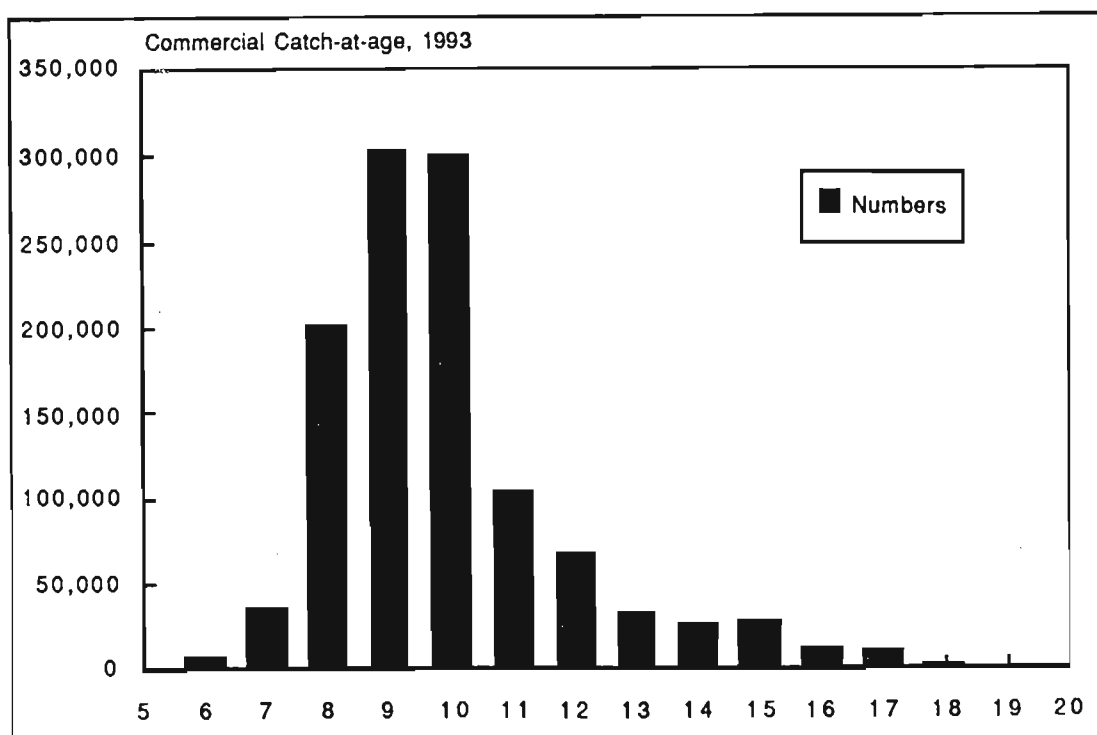


Fig. 4.11 . Commercial catch at age of American plaice in Subdiv. 3Ps in 1993.

Catch effort data

A multiplicative analysis of commercial catch rates of American plaice for the Canadian offshore trawler fleet in Subdiv. 3Ps was not updated because of very low catch and closure of the fishery in 1993. The analyses of CPUE done in 1993 (Brodie et al. 1993) showed relative stability from 1987 to 1990, at about the same level observed in 1981-83, then a sharp decline to the lowest observed levels in 1991 and 1992. Reports from the fishing industry indicated very poor catch rates in this fishery in 1993.

Research vessel survey data

Stratified random surveys have been conducted by Canada in Subdiv. 3Ps in each year from 1972 to 1994, although survey coverage was poor in many years prior to 1979. The index of stock size was relatively stable from 1986 to 1988 (biomass around 30,000 t), but 5 of the 6 surveys since 1989 have produced biomass estimates less than 7,000 t (Fig. 4.12). The two surveys completed in 1993 (February and April) and the survey in 1994 all gave biomass estimates between 2,400 and 4,600 t. The abundance of all age groups has declined and there has been a decrease in recruitment.

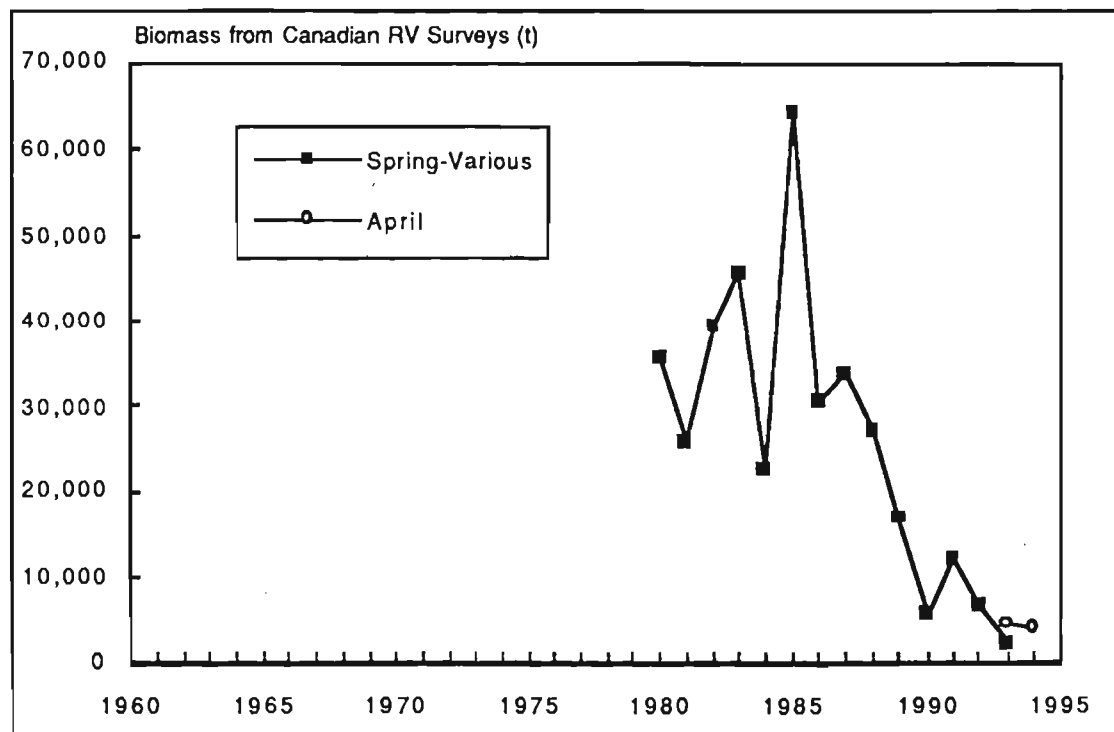


Fig. 4.12. Time series of Canadian RV survey estimates of biomass of American plaice in Subdiv. 3Ps for the period 1979 to 1994.

Data from the French RV surveys in 3Ps also show a decline in abundance through 1992 (Brodie et al. 1993). There have been no French surveys since then.

4.4.3 Estimation of stock parameters

Age at Maturity

Maturity at age was estimated from RV data for males and females in 3Ps from 1973 to 1993 (Fig. 4.13) using the method of Morgan and Hoenig (1993). From these estimates age at 50% maturity was calculated for each sex and year using probit analyses assuming a normal distribution. For both males and females there has been a dramatic decline in age at 50% maturity over the time period examined. For males, the average A_{50} from 1973 to 1982 was 6.67 years while in the 1984 to 1993 period it was 5.33 years with estimates for the last 3 years being less than 5 years. For females, the average A_{50} from 1973 to 1982 was 10.61 years while in the 1984 to 1993 period it was 8.93 years with estimates in 6 of the last 10 years being less than 9 years.

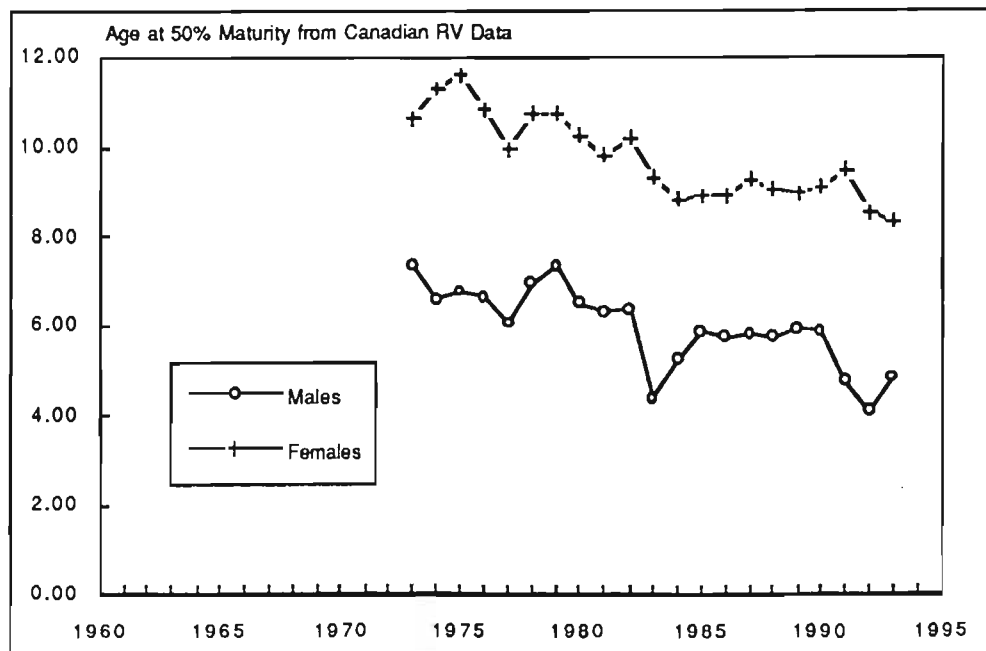


Fig. 4.13. Estimated age at 50% maturity from Canadian RV data for Subdiv. 3Ps American plaice for the period 1973 to 1993.

Sequential population analysis

Sequential population analysis was attempted in the 1989 and 1991 assessments of this stock using various formulations of ADAPT with RV survey data and CPUE at age from the Canadian trawler fleet. The results were not acceptable as the basis for the assessment, due to strong year effects in the residuals and a U-shaped pattern in the slopes of the age by age relationships. Given these

problems, along with the severe declines in the recent survey indices, and concerns with the 1993 catch at age, it was concluded that further attempts at SPA would not be useful at this time.

4.4.4 Discussion

Although there is no directed fishery for this species concern was expressed about the by-catch TAC of 500 t, which represents 10-15% of the 1994 RV biomass. This by-catch is associated mainly with the 3Ps witch flounder fishery and vessels are restricted to the 5% by-catch rule. Since this fishery is offshore and prosecuted mainly by Fisheries Products International, preliminary landing statistics for 1994 show that the 500 t by-catch level will not be reached due to cessation of fishing related to the 5% by-catch.

SPA was not applied to this species, however, an earlier attempt in 1991 showed that Fs had increased for most ages. Although the SPA estimates in 1991 were not accepted, it is believed that the fishery has contributed to the stock decline in recent years.

There was no sampling of the gillnet fishery for weights at age in 1993. This fishery generally catches larger plaice, hence the low weight-at-age in 1993 may, in part, be related to fewer samples of large fish.

Most of the commercial catch was composed of females and there has been a dramatic decline in age at 50% maturity of both males and females in recent years. It is recommended that estimates of mature female biomass be presented in future assessments.

4.4.5 Prognosis

Similar to other stocks of American plaice in the Labrador area and on the Grand Banks, 3Ps American plaice has declined markedly since the mid to late 1980s and is now well below any previously observed level. This is confirmed by all three indices (Canadian RV surveys up to 1994, French RV surveys up to 1992, and Canadian OTB CPUE (1974- 1992)), and by declines in the fishery. There has also been a gradual decline in the age of 50% maturity, a possible consequence of stock decline.

Although it has not been possible to quantify fishing mortality precisely, it has probably increased in the late 1980s and early 1990s. However, it is questionable whether catches in the range of 1,000 t to 5,000 t could be solely responsible for declines in the order of 90% from 1986-88 to the present, considering the historical catch, recruitment, and biomass levels. Regardless of the cause of the high total mortality, the outlook is very pessimistic, given the current low stock size and the lack of recruitment indicated by the surveys. In the short term, there is no immediate prospect for stock rebuilding.

4.5 Div. 2J3KL witch flounder - W.R. Bowering, WP#24

4.5.1 Summary of stock status

Summary

Both the total and spawning biomasses have been declining since the mid 1980s. Recruitment has been poor to non-existent since the mid 1980s as well. The estimated biomass in 1993 is the lowest since surveys began in 1978. What remains of the stock appears to be located in very deep water (>1000 m) near the Div. 3KL border. However, during the winter of 1993 quantities were insufficient to support a viable fishery.

The fishery

The fishery for witch flounder started in the late 1960s by large trawlers from the USSR and Poland and catches peaked at 24,000 t in 1973. After the introduction of the 200 mile limit foreign countries were gradually phased out and Canada became the only participant in the fishery. Catches declined systematically from 1973 and levelled out at about 3,000 to 4,000 t annually from 1978 to 1991. Since then catches declined dramatically with a catch in 1993 of less than 400 t. The 1994 catch is anticipated to be even less.

Analysis

The status of this stock is generally evaluated by following trends in biomass and abundance from research vessel surveys. Biomass has declined considerably from an average of about 40,000 t in the early 1980s to just 1,300 t in the fall of 1993. When the fishery began there were fish as old as 26 years in the stock whereas today none are found older than 14 years. What remains of the stock appears to be located in depths greater than 1,000 meters near the divisions 3K and 3L boundary although quantities are now insufficient to support a viable fishery.

Prognosis

This stock has reached a dangerously low level and any exploitation is ill-advised. Short term prospects for re-building are poor and in the long term are unknown.

Stock status summary sheet for Div. 2J3KL witch flounder

Year	1987	1988	1989	1990	1991	1992	1993	1994	Min. ¹	Med. ¹	Max. ¹
F _{0.1} Catch '000t	N/A										
Advised TAC '000t	4	4	4	4	4	4	4				
TAC '000t	6	5	5	4	4	4	4	1			
Reported catches '000t	4.5	4.2	4.9	4.0	4 ²	2.3 ²	0.3 ²		0.3	4	24
Unreported catches	N/A										
Estimated discards '000t	N/A										
Total catches	4.5	4.2	4.9	4.0	4 ²	2.3 ²	0.3 ²				
Total biomass '000t	N/A										
Spawning biomass '000t	N/A										
Mean - F ()	N/A										

¹For 1963-1993²Preliminary statistics

Catches: Catches fluctuated between 3,000 t and 4,500 t from 1980 to 1991. Catches in 1992 decreased to 2,300 t and further declined to less than 400 t in 1993. Catch in 1994 expected to be less than 100 t.

Data and Assessment: Commercial catch per unit of effort fluctuated widely in the late 1980s, reaching very high values in 1986 and 1989, perhaps reflecting increased concentrations of fish rather than higher stock sizes. Biomass estimates from research surveys have decreased from about 40,000-45,000 t in the early 1980s, to about 1,300 t by 1993. The geographical distribution of witch in the surveys changed suddenly after the 1985 survey. The area of distribution has gradually decreased since. The fishery in recent years has been prosecuted in depths deeper than those covered by the survey.

Fishing Mortality: No information available.

Recruitment: The decrease in biomass from the mid-1980s implies that recruitment was very small to non-existent during that period.

Environmental Factors: Harsh oceanographic conditions may have played a role in the decreased abundance of witch.

Multispecies Considerations: No information available.

State of the Stock: The stock is presently at the lowest level ever recorded. The biomass outside of the survey area is believed to be insignificant.

Forecast for 1995: No quantitative forecast possible, but the stock is not expected to increase in biomass.

Long-term Prospects: The prospects for rebuilding in the long term are unknown. Both the total and the spawning stock biomasses are far below any previous estimate in the 16 year time series and are considered to be at dangerously low levels.

Special Comment: Given the low state of this stock, any commercial fishery will be detrimental.

4.5.2 Available Data

Catches

The commercial fishery began for witch in this area in the early 1960s and increased steadily from about 1,000 t in 1963 to a peak of over 24,000 t in 1973 (Fig. 4.14). Catches declined rapidly to 2,800 t by 1980 and subsequently fluctuated between 3,000 and 4,500 t to 1991. The catch in 1992 declined to 2,300 t, the lowest since 1964, and further declined to just 342 t in 1993. Up until the late 1980s the fishery was prosecuted by Poland, USSR and Canada primarily in Div. 3K. In recent years the fishery has been mainly Canadian although significant catches were taken by EU (Portugal) in the NAFO Regulatory area of Div. 3L. For 1993, however, only 44 t was reported for the Regulatory area of Div. 3L.

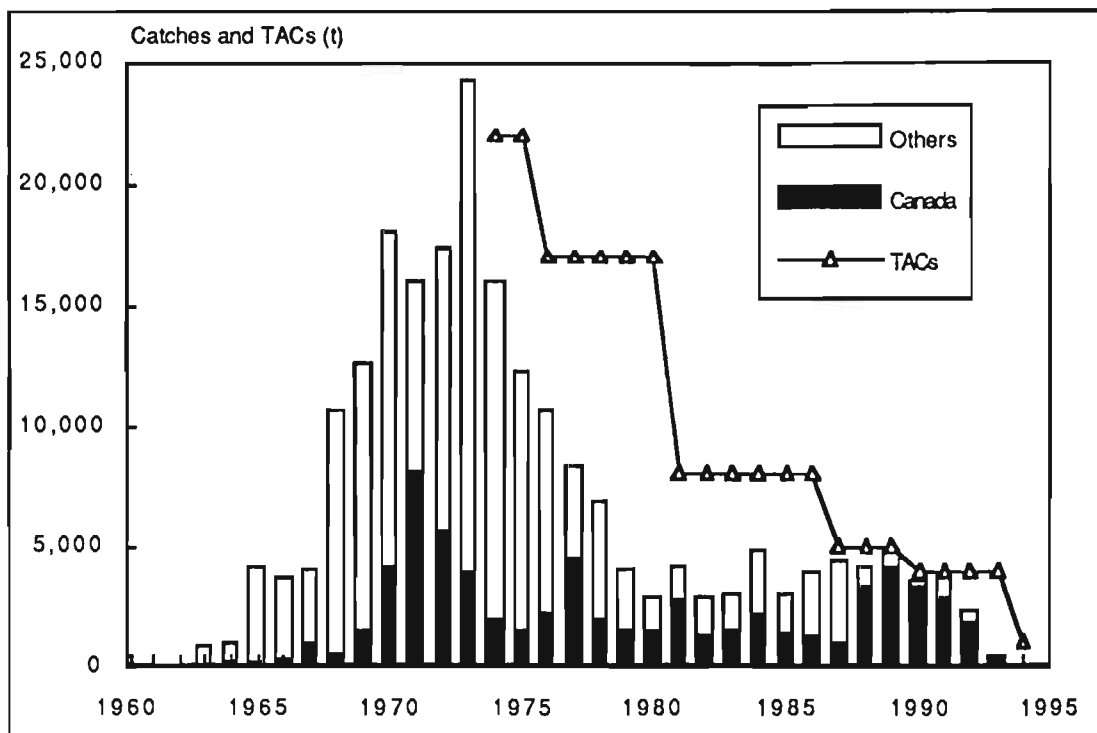


Fig. 4.14. Time series of annual catches by Canada and other sources together with the TAC for the period 1960-94.

Since 1988, the offshore Canadian fishery has been particularly successful by fishing on prespawning concentrations in the deep slopes of Div. 3K especially in depths beyond 700 m. Between 1988 and 1993, however, the area fished has become increasingly smaller and substantially deeper. Based upon information from the fishing industry the fishery during the winter of 1993 was very poor with the best catch rates occurring in depths greater than 1400 m. As

the season progressed catch rates quickly declined until they became too low for economic viability and the fishery was curtailed. Similar observations were made during the winter of 1994 only more extreme. Considering usual harvesting strategies it is likely that the nominal catch in 1994 will be even lower than that of 1993.

Catch at Age

Catch-at-age data examined in the previous assessment (Bowering et al. 1993) indicate that there has been a reduction in the number of age groups comprising the population with a maximum age of 17 in 1981 and 14 since about 1986. In the early to mid 1970s there were fish in the population up to age 26 years old. Nevertheless, the age structure has been fairly stable since about 1985. While no stock recruitment relationship for this stock has ever been investigated, fewer older fish (>14 years old) seen in recent catches probably reflects a substantial loss of spawning potential. No aging data were available for this stock for 1993 at the time of the meeting.

Research vessel data

Stratified-random research vessel surveys have been conducted in the fall in divisions 2J, 3K and 3L since 1977, 1978 and 1981 respectively. For Div. 2J, biomass estimates ranged from as high as 4,100 t in 1986 to a low of less than 300 t in 1993 (Fig. 4.15). In Div. 3K, during 1979-85, there was a period of relative stability where most annual biomass estimates were over 30,000 t. Since that time estimates have declined considerably to just over 600 t in 1993, the lowest in the time series. For Div. 3L, biomass estimates varied generally between 6,000 and

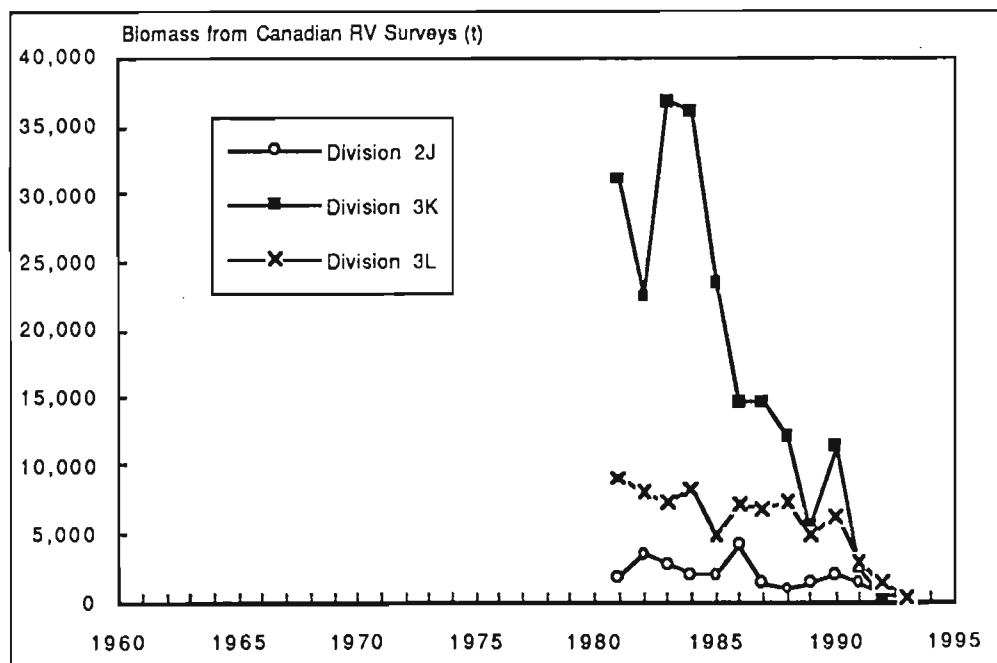


Fig. 4.15. Time series of Canadian RV survey estimates of witch flounder biomass in Div. 2J, 3K and 3L for the period 1981 to 1993.

7,000 t from 1981-88 but declined rapidly since then to a low of just under 1,500 t in 1992 and less than 400 t by 1994. For the three divisions combined there has been a very steady and systematic decline from about 1984 through 1993 with the estimate of 1,300 t in 1993 not only the lowest in the time series but not much higher than the existing TAC of 1,000 t.

Estimates of biomass by depth indicate that for all divisions in the earlier years the biomass is distributed in depths generally less than 500 m (Bowering et al. 1993). Since 1989 most witch flounder has been found in depths greater than 500 m. Based upon these observations and the knowledge that the commercial fishery operates in much deeper zones it is also evident that the depth constraints of the survey design are restrictive (maximum depth of about 1,000 m) in measuring the complete biomass of this species, more particularly in recent years. Nevertheless, a deepwater survey conducted during the summer of 1991 in divisions 3K and 3L to depths of 1,500 m did not encounter any witch flounder.

Distribution

Spatial distribution had been examined from fall survey data collected from 1978-92 in the previous assessment (Bowering et al. 1993). From the period 1978-85 the pattern of distribution is fairly consistent with the dominant division being Div. 3K. The distribution in those years is consistent with distribution patterns during the 1950s and 1960s. Between 1985 and 1986, however, there was a substantial change in the pattern coincident with a considerable reduction in biomass. Witch flounder usually found in high abundance in the deep channels on the western side of Funk Island Bank virtually disappeared. Throughout the late 1980s the area of distribution continued to shrink towards the southeast portion of Div. 3K and by 1990 it became clear that the only fish in the survey area were concentrated along the very deep slope area (Fig. 4.16). By 1992, virtually the only witch flounder caught were located in the deep slope area of the Sackville Spur (Nose of the Grand Bank) outside the Canadian 200-mile zone. These observations are consistent with those of the fishery including the winters of 1993 and 1994.

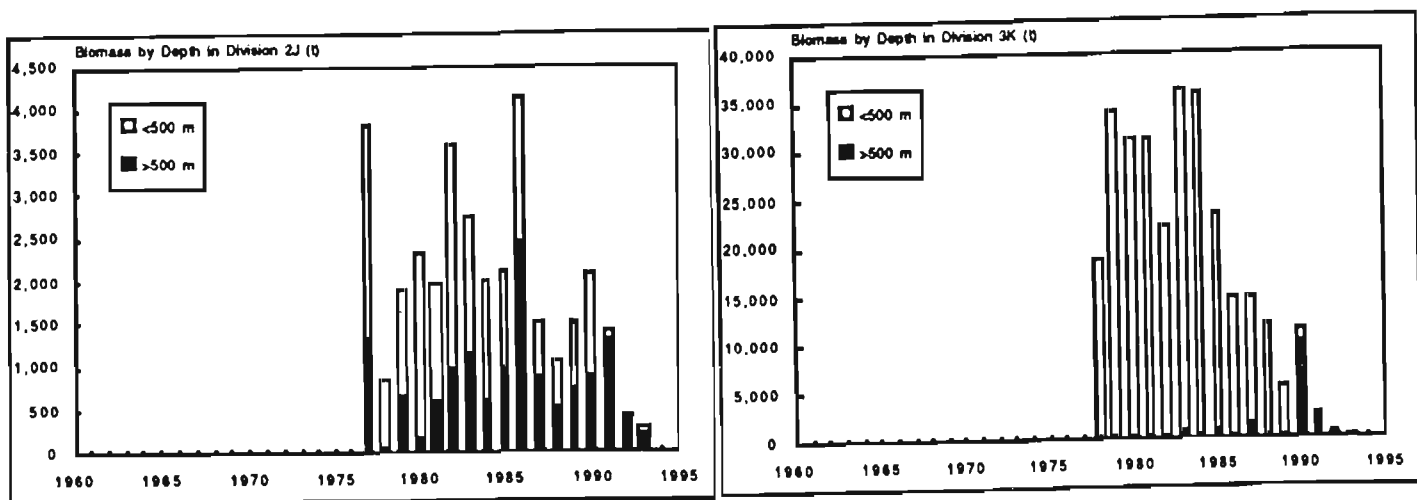


Fig. 4.16. Depth distribution of witch flounder biomass as estimated from Canadian RV surveys in Div. 2J and 3K.

4.5.3 Estimation of stock parameters

Analysis of recruitment and total mortality from research vessel surveys - R.A. Myers, WP#32

Recruitment indices and total mortality were estimated using all available research surveys for witch in 2J, 3K and 3L. It was concluded that recruitment was low during the last few years, and that total mortality in the last few years has been very high, i.e. greater than one.

4.5.4 Discussion

The data from both the assessment update and from analyses of recruitment and mortality patterns showed that this stock is at a critically low level. The steep decline in research trawl biomass estimates since the mid 1980s cannot be completely explained by fishing mortality since catches during the period of decline were low relative to earlier years. A change in distribution also has occurred since 1989 showing a shift in to deeper waters (>500 m) in a general southeast direction.

Under these extreme conditions, exploitation is not justifiable. The rationale used by FRCC to set a nominal TAC of 1000 tons in 1994 as a means to obtain some fishery data was not supported by this Review and it was agreed that the fishery should be closed in 1995.

It is clear that this stock has been reduced to levels far below anything observed in the past. It would seem also that during the 1980s, declines in biomass observed in the surveys cannot be fully explained by the removals of the commercial fishery. On the other hand, having observed the shrinking area of distribution in recent years coupled with the fact that fishing was most intense in this area upon prespawning aggregations it is probable that recent catches may have accelerated the decline over the last few of years. It may be argued that because the fishery has recently been prosecuted well beyond depths occupied by the surveys, biomass estimates may be biased downwards, at least to some degree. Nevertheless, fishing took place in a very restricted area in 1993 and was a failure as indicated by poor catch levels in comparison to the total allowable catch. In 1994, no concentrations could be found by commercial vessels to support a viable fishery, therefore, virtually no fishery was conducted.

4.5.5 Prognosis

It is difficult not to accept that this stock is at a dangerously low level. Exploitation of this stock in its present state is unjustifiable from a conservation point of view.

4.6 Subdiv. 3Ps witch flounder - W.R. Bowering, WP#23

4.6.1 Summary of stock status

Summary

Research vessel survey biomass indices have been variable during the last 16 years, however, the range of variation has generally been small suggesting some stability in the stock size. The most recent three surveys, on the other hand, have all estimated the biomass to be at the low end of the range. Catches in 1994 are expected to be low due to constraints on the by-catch of other groundfish species.

The Fishery

Until recent years the fishery for witch flounder was largely a by-catch of other groundfish offshore and part of a small mixed groundfish fishery in Fortune Bay. The catch never exceeded 5,000 t. Recently, catches have generally been taken around the TAC of 1,000 t as more directed effort has been placed on the stock due to shutdowns in other fisheries. The catch in 1994 is expected to be quite low as a result of constraints on the by-catch of American plaice and cod.

Analysis

The status of this stock is generally evaluated by following trends in biomass and abundance from research vessel surveys. In the past 16 years there has been little in the way of persistent trends in biomass. However, the most recent three surveys all estimate the biomass to be at the low end of the range of estimates for the 16 year period.

Prognosis

Although the catch is expected to be quite low for 1994 because of by-catch regulations it is unclear if catches may have been low because of low stock size. Given the recent low estimates of biomass caution is advised.

Stock status summary sheet for witch flounder in Subdiv. 3Ps

Year	1987	1988	1989	1990	1991	1992	1993	1994	Min. ¹	Med. ¹	Max. ¹
F _{0.1} Catch '000t	N/A										
Advised TAC '000t	3Max	1	1	1	1	1	1				
TAC '000t	3	1	1	1	1	1	1	1			
Reported catches '000t	1.3	.6	.9	1.0	1.1 ²	1.0 ²	1.0 ²		.4	1.0	4.8
Unreported catches				N/A							
Estimated discards '000t				N/A							
Total catches	1.3	.6	.9	1.0	1.1 ²	1.0 ²	1.0 ²				
Total biomass '000t				N/A							
Spawning biomass '000t				N/A							
Mean - F ()				N/A							

¹For 1993²Preliminary statistics

Catches: Catches have generally averaged about 1,000 t annually since 1979. The 1994 catch is not expected to exceed 200 t due to by-catch constraints.

Data and Assessment: Biomass has been estimated by research surveys since 1976. Biomass estimates were generally between 3,000 t and 6,000 t during the 1980s, with no identifiable persistent trend. Estimated biomass was about 2,000 t in February 1993, but the 1993 April survey estimate increased to about 3,000 t. A preliminary estimate for the 1994 April survey was 2000 t.

Fishing Mortality: No information available.

Recruitment: No information available, but spawning stock biomass may have declined in recent years based on reduction in older aged fish in the catches.

Environmental Factors: No links to the environment can be made at present.

Multispecies Considerations: No information available.

State of the Stock: The state of the stock is uncertain. The 1993 and 1994 survey estimates are within the range of variability during the last 10-15 years, however, all three surveys are at the low end of the range. Based on these research survey data, the stock appears to be declining but it is not clear whether this is the result of fishing mortality only.

Forecast for 1995: A quantitative forecast is not possible. However, caution is advised given recent low levels of estimated biomass.

Long-term Prospects: Long term prospects are uncertain. The 1993 fishery was considered highly successful, however, it occurred on a very densely aggregated pre-spawning concentration and may not be representative of stock abundance. The 1994 fishery was poor due to regulations restricting by-catch. It could not be determined if low stock size may have contributed to low catch.

4.6.2 Available data

Catches

The catches of witch flounder in Subdiv. 3Ps were about 1000 t annually during the 1960s (Fig. 4.17). Catches increased to over 4,000 t in 1967-69, then declined slowly to former levels in the late 1970s. During the last 10 years catches have ranged from as low as 300 t in 1983 to as high as 1,300 t in 1986. However, since 1989 the average catch has been about equal to the TAC of 1,000 t. During the 1980s the catch was primarily a by-catch in other groundfish fisheries, however, in recent years with the severe declines in major groundfish resources (flatfish species in particular) certain sectors of the fishing industry depend more on this stock.

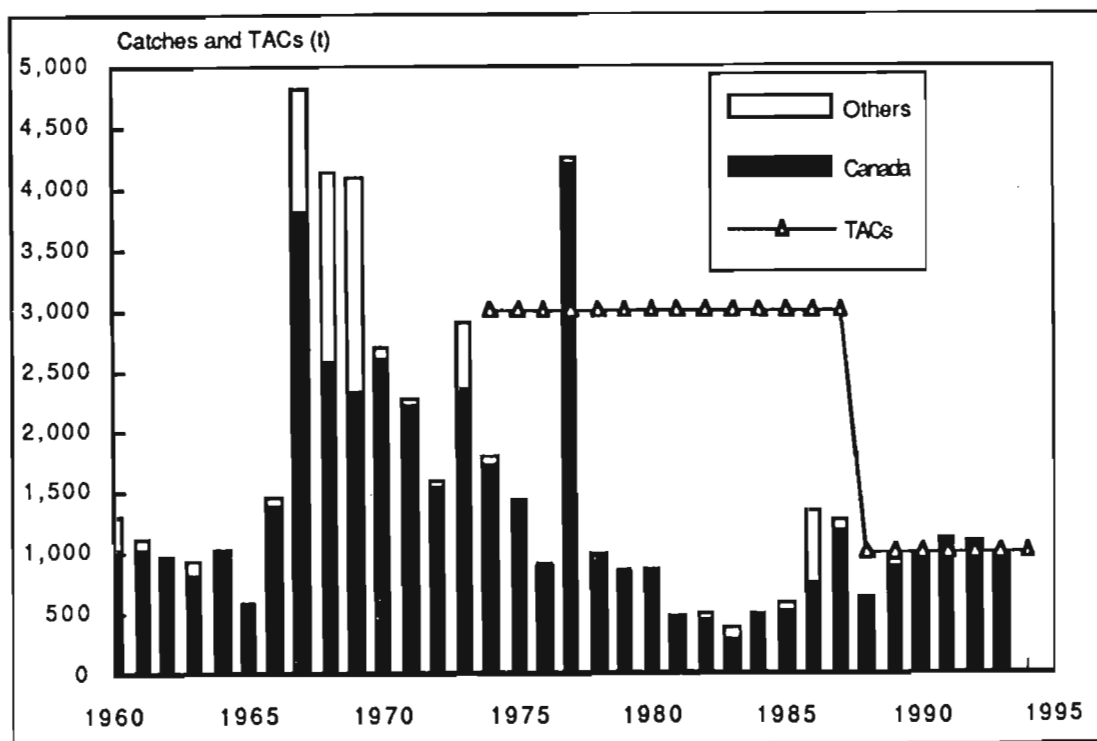


Fig. 4.17. Time series of annual catches by Canada and other sources together with the TAC for the period 1960-94.

Catches from this stock have been taken mainly by Canadian trawlers fishing offshore on St. Pierre Bank while there are some catches taken by small Scottish seiners and gillnetters fishing in Fortune Bay off the south coast of Newfoundland. Prior to the boundary settlement between Canada and France, fishermen from St. Pierre and Miquelon also caught small amounts of witch flounder on St. Pierre Bank although this no longer appears to be the case.

The fishing pattern for offshore Canadian participants during the winter of 1994 appears to have been similar to that of 1993 according to information obtained from industry representatives. Fishing was conducted at the southeastern tip of St. Pierre Bank in depths ranging from 200-900 m. As a result of the closure of the American plaice and cod fisheries in Subdiv. 3Ps for 1994

combined with a 5% by-catch constraint, the fishery for witch flounder has been seriously hampered. Catches to date are estimated to be about 110-120 t. Given usual harvesting strategies it is unlikely that the fishery will be pursued further for 1994. Therefore, the total catch for 1994 will probably be near current estimates of catch to date.

Research vessel data

Stratified random research vessel surveys have been conducted by Canada in wintertime on St. Pierre Bank since the early 1970s, however, only since about 1976 has coverage been relatively complete at least to a depth of 550 m. Biomass estimates have been highly variable over the past 15 years fluctuating between 2,000 and 6,000 t and showing little in the way of trends (Fig. 4.18). However, two surveys in 1993 (February and April) and the most recent survey in April, 1994 are all at the low end of the range. An examination of survey indices by depth zone (Bowering 1993) also indicated that during the late 1970s and early 1980s there were considerable levels of the biomass in depths less than 183 m whereas during the 1990s there were none.

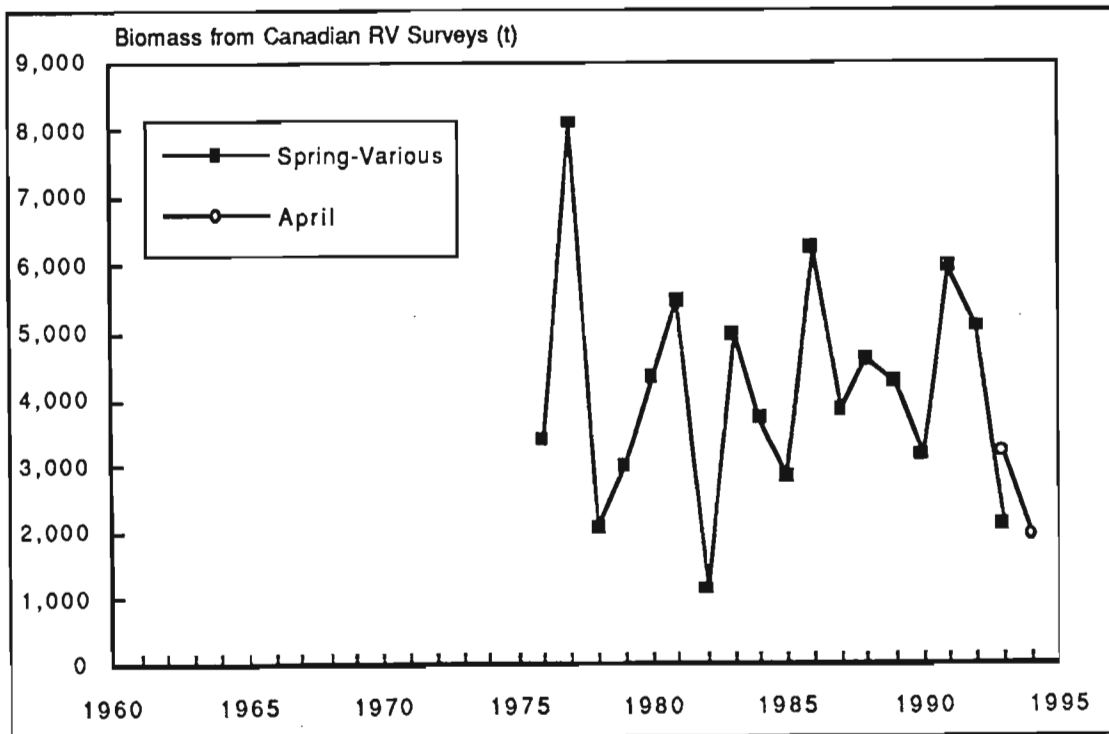


Fig. 4.18. Time series of witch flounder biomass estimates in Subdiv. 3Ps from Canadian RV surveys.

Abundance estimates at age from research vessel surveys have shown that in the mid 1970s ages ranged as high as 22 years old, however, this was reduced to a maximum of 14 years old by 1980. The age structure has remained relatively stable since that time to the present although the abundance indices have shown considerable variation on an annual basis as indicated earlier.

4.6.3 Prognosis

Given the high annual variability of the survey biomass indices it is not possible to provide a precise estimate of stock size. Considering that the 1993 survey estimates were within the range of variation coupled with the success of the 1993 winter fishery, largely outside the survey area, it was concluded in the previous assessment that there was no immediate need for concern at recent catch levels (Bowering 1993). There is little danger of this stock declining, in the short term, as a result of commercial exploitation given that the expected catch for 1994 is unlikely to exceed 200 t. However, caution is nevertheless advised considering that the three most recent biomass estimates from surveys are all at the low end of the long term range.

5. Research recommendations

1. The relationship between cod growth, cod abundance and temperature should be updated and used to forecast cod weight at age in the next assessment. This is particularly relevant for cod in Subdiv. 3Ps for which better temperature data are now available.
2. Consideration should be given to intensive acoustic studies on capelin patches to investigate alternative hypotheses regarding the failure of the offshore surveys to detect capelin in recent years, as a prerequisite to examining the potential effect of capelin abundance on cod.
3. Models for predicting year-class strength should be examined and their predictive ability compared to a prediction based on the geometric mean of past year-class strengths, traditionally used in stock projections.
4. The relationship between the abundance of age 3 cod in Div. 2J3KL from the by-catch of age 2 and 3 cod in capelin traps should be carefully examined to establish its usefulness as a predictor.
5. Capelin is a key prey species for cod and other groundfish in the region and an attempt should be made to obtain the best possible composite index of relative capelin abundance from the various alternative indices for use in multispecies analyses. In particular, effects on the capelin population of the two big declines in Northern cod abundance (1960s/early 1970s and late 1980s/1990s) should be sought.
6. Attention should be devoted to survey designs which allow an acoustic survey to be carried out simultaneously with the trawl survey for cod in Div. 2J3KL.
7. The relationships between invertebrate biomass increases and groundfish stock declines should be examined in greater detail by the Regional Multispecies Working Group and plausible explanations sought for this apparent phenomenon.
8. Preliminary estimates of harp seal consumption by prey species should be carried out by the Regional Multispecies Working Group and made available prior to the next regional review.
9. There are large gaps in knowledge about all of the redfish stocks. Coherent analyses of all the redfish stocks is required. A Zonal workshop on redfish should be considered to achieve this.
10. Research survey information for redfish from the July surveys in Div. 4VW should be incorporated into the evaluation of Unit 2 redfish in future.
11. In future assessments an attempt should be made to disaggregate the catch rate database for Unit 2 redfish into specific gear types.
12. Work should continue on analyses that pertain to further refinement of management units developed for Unit 1 and Unit 2 redfish in 1991.
13. Application of the Kalman filter approach to the weight at age data for cod should be continued and results tabled at the next Groundfish Regional Review.
14. In order to evaluate the merits of ADAPT with correlated error more fully, a portion of the catch at age matrix should be selected where there is confidence in the validity of the data, and the

correlated error and random error models applied.

15. In the next assessment of Subdiv. 3Ps American plaice estimates of mature female biomass taking into account changes maturity at age should be examined.

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- WP#2 Mertz, G. 1994. Physical oceanography overview.
- WP#3 Colbourne, E. 1994. Environmental conditions during the fall of 1993 in NAFO Divisions 2J3KL.
- WP#4 Drinkwater, K.F. 1994. Overview of environmental conditions in the Northwest Atlantic in 1993.
- WP#5 Shelton, P.A and B. Atkinson. 1994. Failure of the Div. 2J3KL cod recruitment prediction using salinity.
- WP#6 Stenson, G. and B. Sjare 1994. Current research on interactions between seals and commercial fisheries.
- WP#7 Parsons, D.G. and E.G. Dawe. Status of invertebrate stocks and ecological links.
- WP#8 Winters, G. 1994. Summary of pelagic fish stocks.
- WP#9 Lilly, G. 1994. Predation by Atlantic cod on capelin on the southern Labrador and Northeast Newfoundland shelves during a period of changing spatial distributions.
- WP#10 Rose, G.A. An acoustic survey of cod in NAFO Divisions 3L3K in June 1993.
- WP#11 Bishop, C.A., E.F. Murphy, D.E. Stansbury, and M.B. Davis. 1994 . An assessment of the Div. 2J3KL cod stock.
- WP#12 Myers, R.A. and N.G. Cadigan. 1994. Correlated error model results for 2J3KL cod in 1993.
- WP#13 Myers, R.A. 1994. Analysis of the recruitment and mortality from research vessel surveys for 2J3KL cod.
- WP#14 Winters, G. and B. Nakashima. 1994. Cod bycatch in capelin traps.
- WP#15 Anderson, J. and E. Dalley. 1994. Interannual variations in the distribution and abundance of pelagic 0-group cod in the fall, 1991-93, in 2J3KL.
- WP#16 Dalley, E. and J. Anderson. 1994. Summary of results of demersal juvenile cod surveys carried out in 1992 and 1993.
- WP#17 Dalley, E. and E. Dawe. 1994. Summary of catch rates of juvenile cod in Japanese pelagic traps at four sites along the northeastern Newfoundland coast in 1992 and 1993.
- WP#18 Methven, D. 1994. Preliminary results of the 1993 Fleming survey.

- WP#19 Taggart, C.T. 1994. Examination of age distribution of 2J3KL cod over the last decade.
- WP#20 Davis, M.B. and P. Lundrigan. 1994. A description of the stock structure (of cod) in Placentia Bay, NAFO Subdivision 3Ps.
- WP#21 Maguire, J.-J. 1994. Catchability coefficients of the research surveys for Subdivision 3Ps cod.
- WP#22 Brodie, W. and M.J. Morgan. 1994. American plaice in Subdiv. 3Ps.
- WP#23 Bowering, W.R. 1994. Technical details of the assessment of witch flounder in Subdivision 3Ps.
- WP#24 Bowering, W.R. 1994. Technical details of the assessment of witch flounder in Divisions 2J, 3KL.
- WP#25 Baird, J. and C. Bishop. 1994. Annual variation in biomass in the 2J3K RV survey at depths greater than 400m.
- WP#26 Myers, R.A. and N.G. Cadigan. 1994. Was an increase in natural mortality responsible for the collapse of the northern cod?
- WP#27 Power, D. 1994. Redfish in the Laurentian Channel (Unit 2) Management Unit 3PsVs4Wfgi and 3Pn4Vn (June to December).
- WP#28 Winters, G. 1994. Bycatch of cod in capelin traps, revisited.
- WP#29 Brodie, W. 1994. American plaice in Subarea 2+ Div. 3K.
- WP#30 Power, D. 1994. Update - redfish in Div. 2+3K.
- WP#31 Power, D. 1994. Update - redfish in Div. 3O.
- WP#32 Myers, R.A. 1994. Recruitment and total mortality estimates from RV data for witch flounder and turbot stocks.
- WP#33 Taggart, C. Age structure of Subdiv. 3Ps cod from RV data.
- WP#34 Myers, R.A. 1994. Recruitment and total mortality estimates from RV data for American plaice and yellowtail flounder.
- WP#35 Myers, R.A. and N.G. Cadigan. 1994. Correlated error model results for 3Ps cod in 1993.
- WP#36 Myers, R.A. 1994. Analysis of the recruitment and mortality from research vessel surveys for 3Ps cod.
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WP#38 Morgan, M.J. 1994. Changes in age at maturity for 3Ps cod.

WP#39 Shelton, P.A. 1994. Mutlispeices and ecosystem approaches to fisheries.

WP#40 Taggart, C. 1994. Length at age for Div. 3Ps. cod.

WP#41 Atkinson, B. 1994. Regional overview and environmental summary.

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