Canadian Atlantic Fisheries
Scientific Advisory Committee

Comité scientifique consultatif des
pêches canadiennes dans l'Atlantique

CAFSAC Research Document 87/ 3

CSCPCA Document de recherche 87/ 3

Proportions of Atlantic Cod (*Gadus morhua*) of the 2J3KL stock components taken by the Inshore Fishery as estimated by offshore tagging

by

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ABSTRACT

Results of tagging experiments were used to estimate the proportions of cod on various offshore banks in late winter that were harvested by the inshore fisheries of Newfoundland and Labrador. Five different tag types were used. T-bar tags were returned at significantly lower rates than were Peterson discs, danglers and double tags; all of which were returned at similar rates.

The banks differed significantly in the proportion of fish offshore in late winter that were harvested inshore during the following summer. The inshore exploitation rate was highest on fish tagged in late winter on the Funk Island Bank; lower for fish from Belle Isle Bank, lower yet for fish from Hamilton Bank, and lowest for fish from the North Cape of the Grand Bank. Aside from 1981, a year in which catches were low in the inshore fishery, there was only one significant difference among years for the inshore exploitation rates of fish from each bank. Rates differed among years for fish tagged on the North Cape of the Grand Bank, but in all years rates were lower than for any other bank.

The distribution of offshore biomass among NAFO Div. 2J, 3K and 3L was stable for 1981-83, but changed substantially in 1984-85, with a substantial proportional increase in Div. 3L, at the expense of Div. 2J and 3K. From the distribution of offshore biomass in 1981-83, and tagging information on inshore migration patterns and exploitation rates the inshore fishery harvested approximately 8% of the biomass of the stock. The redistribution of biomass among the banks in 1984 and 1985 would have reduced this to 7%, if migration factors and inshore effort did not change. Hence the distribution of offshore biomass may influence success rate of the inshore fishery.

RESUME

Les résultats d'expériences de marquage ont été utilisés pour estimer les proportions de morues provenant des divers bancs du large (fin de l'hiver) qui étaient capturées par la pêche côtière de Terre-Neuve et du Labrador. Cinq types de marques ont été utilisées. La proportion des marques retournées étaient significativement plus faible pour les marques en T que pour les autres types de marques (disques de Peterson, "danglers" et marques doubles) qui, elles, présentaient des taux de retour semblables.

Les bancs variaient de façon statistiquement significative en ce qui a trait à la proportion de poissons au large en fin d'hiver qui étaient récoltés près de la côte au cours de l'été suivant. Le taux d'exploitation du poisson marqué en fin d'hiver décroissait dans l'ordre suivant : banc Funk Island, banc Belle Isle, banc Hamilton et North Cape du Grand Banc. Sauf pour 1981, année au cours de laquelle les prises de la pêche côtière ont été faibles, il n'y a eu qu'une seule différence statistiquement significative entre les années pour les taux d'exploitation par la pêche côtière des poissons de chaque banc. Les taux ont différé au cours des années dans le cas du poisson marqué sur le North Cape du Grand Banc, mais pour toutes les années, les taux ont été plus faibles que pour tout autre banc.

La répartition de la biomasse au large entre les divisions 2J, 3K et 3L de l'OPANO a été stable pendant 1981-1983, mais elle a changé substantiellement en 1984-1985, alors qu'on a enregistré une augmentation proportionnelle substantielle dans la division 3L, aux dépens des divisions 2J et 3K. A partir de la répartition de la biomasse au large en 1981-1983, et des renseignements obtenus par marquage sur les habitudes de migration au large et sur les taux d'exploitation, la pêche côtière a récolté environ 8 % de la biomasse du stock. La redistribution de la biomasse entre les bancs en 1984-1985 aurait réduit cette proportion à 7 %, si les facteurs de migrations et les efforts de pêche côtière étaient demeurés inchangés. Ainsi, la répartition de la biomasse au large peut influer sur le taux de succès de la pêche côtière.

INTRODUCTION

With the inception of the 200 mile fisheries zone and the emphasis on rebuilding the northern cod (NAFO Div. 2J3KL) in part for the benefit of the inshore fishery, the question has been raised as to what proportion of the offshore stock is harvested by the inshore fishery in a given year. In an attempt to answer this question a tagging program was initiated in 1978.

The cod of NAFO Div. 2J, 3K, and 3L are managed as one large stock complex (Templeman 1962) on the basis of studies of morphology and migration from tagging. However, there may be a number of sub-stocks which contribute to this great stock complex (Templeman 1962). There was also some evidence of homing of coastally tagged cod to or near the tagging area, indicating that portions of the stock complex return to their own local areas during the feeding season (Templeman 1974, 1979).

From the results of tagging of 25,000 cod from prespawning and overwintering concentrations in NAFO Div. 2J, 3K, and 3L during February-March 1978-81, Lear (1984) presented evidence of a consistent annual pattern of migration to inshore waters during summer and to offshore areas during winter for each group of cod tagged along the outer continental shelf. The Hamilton Bank component evidently contributes to the southern Labrador and northeast Newfoundland coastal fisheries, mainly from Notre Dame Bay northward. The Belle Isle Bank component migrates during summer mainly to southern Labrador, Strait of Belle Isle entrance and northeastern Newfoundland as far south as Notre Dame Bay. The pattern of movement is similar to that of the Hamilton Bank component except for a greater proportion in the Strait of Belle Isle. Cod on the northern and northeastern slopes of Funk Island Bank migrate during summer to eastern and southeastern Newfoundland, with smaller proportions going to southern Labrador and the Strait of Belle Isle than from the taggings on Belle Isle Bank. Cod from the southwestern slope of Funk Island Bank contribute mainly to the summer inshore fishery of Notre Dame Bay and Bonavista Bay and in a smaller degree to the fishery in Trinity Bay, Conception Bay and the eastern part of the Avalon Peninsula. Cod which overwinter on northern Grand Bank migrate southwards across the bank to the Virgin Rocks and to the eastern slope of the bank. This component contributes mainly to the inshore fishery from Trinity Bay southward to St. Mary's Bay, with little effect on the fishery north of Cape Bonavista.

The concern has been raised that the concentration of offshore winter fishing effort in any one division might generate differential fishing mortality between stock components and this could result in local overexploitation. This is not a straight forward problem, however, because not only do the various overwintering and spawning components contribute in different degrees to the inshore fishery of the various regions of Newfoundland and Labrador but these regions may well vary in the type and level of inshore fishing effort relative to the size of their inshore substocks.

The purpose of this paper is first to provide estimates of the proportions of these various components of the offshore cod stock complex in NAFO Div. 2J3KL which are harvested inshore during May to December. The proportions of the biomass of each division are then combined to provide an overall proportion of the total stock harvested annually by the inshore fishery. The change in the patterns of offshore distribution during 1984 and 1985 are also examined to estimate the effects of this change in offshore distribution of biomass on the proportions harvested inshore.

MATERIALS AND METHODS

During February-March 1978-83 about 38,000 adult cod (45 cm and larger) (Table 1) were tagged using a variety of tag types (Table 2) from the pre-spawning concentrations on Hamilton Bank, Belle Isle Bank, Funk Island Bank and the northern slopes of the Grand Bank (Fig. 1).

The cod tagged in 2J3KL were obtained by an Engel High Rise Otter trawl. The net was not lined with a fine mesh liner except during the 1978 tagging. The sets were generally short (10-30 minute duration), depending on the concentration of cod as indicated from the echo sounder. The net was taken back very slowly (8-10 m/minute) to allow the cod to acclimate to the changing pressure somewhat and to prevent drowning from crowding in the codend. Only fish classed in excellent condition were tagged. Any fish showing signs of bruising, scale loss, injuries to fins or gills, bleeding and "pop-eye" condition were routinely culled out during the tagging procedures. Any fish with distended swim bladders were culled out rather than attempt to squeeze the gas out of the swim bladder. The cod were held in holding tanks filled with running sea water, dipped out with dipnets, tagged, placed in recovery tanks filled with running sea water until they fully recovered and actively swam in the tank. They were released through the rock hatch at the level of the water line of the ship. Thus the cod were placed, not dropped, into the sea.

The number of tagged cod offshore on May 1 was used as a basis for the calculation of the inshore proportion harvested during May 1-December 31 of the tagging year.

Using Pope's (1972) cohort approximation for the catch equation i.e.: assuming that the offshore fishery recovers tagged fish at an instant in time exactly half way between the time that the fish are released and May 1, an estimate of the number of tagged cod remaining on May 1 is given by:

$$T_0 = (T\ p_s \exp[-Mt_0/2] - R_0/p_r) \exp[-Mt_0/2]$$

where

T = number of tags applied

p_s = proportion of tagged cod which survive tagging and handling

R_0 = recoveries from offshore fishery between date of tagging and May 1

p_r = proportion of recaptured tags reported

M = natural mortality rate

t_o = time between release of tagged fish and May 1
Estimating the number of tagged fish harvested by the inshore fishery from

$$H_I = R_I/p_r$$

where R_I = recoveries from inshore, the proportion of cod offshore on May 1 which is harvested by the inshore fishery can be estimated by

$$P_I = H_I/T_o$$

It should be noted that these estimates are slightly biased due to the occurrence of ratios of random variables in the expressions.

Assuming that variables are uncorrelated and that M is known without error, approximate variances can be found using the delta method (Seber 1973).

$$\mathrm{Var}(T_o = (\exp[-Mt_o/2])^2 \; ((T \exp[-Mt_o/2])^2 \; \mathrm{Var}\,(p_s) +$$

$$(R_o/p_r)^2(\mathrm{Var}(R_o)/R_o{}^2 + \mathrm{Var}(p_r)/p_r{}^2))$$

$$\mathrm{Var}\,(H_I) = (R_I/p_r)^2 \; (\mathrm{Var}(R_I)/(R_I{}^2 + \mathrm{Var}(p_r)/p_r{}^2)$$

$$\mathrm{Var}\,(p_I) = (H_I/T_o)^2 \; (\mathrm{Var}(H_I)/H_I{}^2 + \mathrm{Var}(T_o)/T_o{}^2)$$

The standard error of the proportion of cod offshore harvested by the subsequent inshore fishery is found by taking the square root of Var (p_I). Although it is reasonable to expect that the number of inshore and offshore recoveries are not significantly correlated with the reporting rate it is probable that the number of tagged fish harvested by the inshore fishery is postively correlated with the number of tagged fish offshore. Consequently the estimated standard error will be conservative i.e., the calculated value will be an overestimate.

The mean and variance for the proportions p_s and p_r were calculated using formulas for cluster sampling (Cochrane 1977, p. 66).

$$p = \sum a_i/\sum m_i$$

$$\mathrm{Var}(p) = \sum a_i{}^2 - 2p\sum a_i m_i + p^2\sum m_i^2/\bar{m}^2 n(n-1)$$

where a_i = number of units falling into a class in cluster i

m_i = number of units in cluster i

n = number of clusters

Mark-recapture experiments have been modeled using the hypergeometric and binomial distributions (Seber 1973). For large sample sizes and small recovery proportions the Poisson distribution can be used as an approximation, giving an estimate of the variance of R

$$Var(R) = R$$

RESULTS

IMMEDIATE MORTALITY DUE TO TAGGING AND HANDLING

During the tagging cruises in 1978-81, representative samples of cod were held in tanks onboard the research vessel to estimate the immediate mortality arising from handling and tagging. The cod were placed in recovery tanks and treated in the same way as cod which were to be tagged and released. In each tank 10 controls (untagged cod) and 10 tagged cod were placed. The temperatures of the tanks were monitored and the flow of water to the tanks was regulated to keep the temperature in the tanks as close as possible to that in which the cod were living on the bottom (2-3°C).

The proportion of cod which died as a result of tagging and handling varied between tag types and years but generally averaged around 10-15% with an overall average of 13% (Table 3). The 30% mortality from the Petersen disc tags for 1978 is partly due to the stormy conditions while the fish were in the tank and the necessity of having to cover the tank with a small meshed liner. The liner meshes entangled in the Petersen tags and held the cod at the surface of the tank where they died as a result of exhaustion from struggling against the netting. This was corrected in subsequent years by holding the cod in larger tanks with a spillway at the top of the tank constructed of wooden strips with small spaces to allow the water to overflow without losing the fish. The overall estimate of survival, p_s=0.87, was applied to the number of cod tagged.

NATURAL MORTALITY BETWEEN THE TIME OF TAGGING AND MAY 1

Pinhorn (1975) estimated that the natural mortality for the Div. 2J3KL cod stock ranged from 0.16 to 0.21 with a mean value of 0.18. The annual natural mortality rate for this analysis is assumed to be about 0.20. Although it is possible that natural mortality varies over the year, information is not available on a finer scale. Therefore the annual mortality rate was assumed to be distributed evenly across the year and specifically, across the interval from tagging until commencement of the inshore fishery.

The numbers of tagged cod caught in the offshore area up to May 1 were obtained from reported tag recaptures from the offshore fleet during this period. These offshore recaptures are accounted for when estimating inshore harvesting rates.

RATE OF REPORTING OF RECAPTURED TAGS

On the basis of questionnaires mailed to all licenced fishermen (including fishermen who do not fish directly for cod) at Bonavista and LaScie, as well as personal interviews conducted on Fogo Island during 1980, estimated reporting rates for recaptured tags ranged from 63 to 78% (Table 4). The overall estimate indicated that about 72% of recaptured cod tags were reported. Bowen (1979) obtained a reporting rate of 75% on the northeast Newfoundland coast for harp seal tags recaptured during the 1979 hunt. For the 1980 hunt the reporting rate was estimated at 80% (Bowen and Sergeant 1980). The overall estimated report rate, p_r=0.72, was applied to the reported tag returns.

INSHORE HARVESTING RATES

The results of the analysis of tag returns indicate that harvesting rates were variable among experiments. There are indications that certain areas such as Funk Island Bank showed consistently higher rates than some other areas, for example, the North Cape of the Grand Bank (Table 5). This general pattern was present in data from all lengths combined, and for intermediate-sized fish of 50-79 cm. Details of these patterns were hard to see, however, due to the distribution of experiments over the 6 years, and the differences in return rate for different tag types. Therefore, the percentages in Table 5 were analyzed by a factorial ANOVA, using SAS proc GLM. The percentages were transformed with the square root transformation prior to the ANOVA. The unbalanced design (not all areas were tagged in all years) means that interpretation of some effects is difficult. However, preliminary models fitted to the data indicated that the interactions of area and year with type of tag were insignificant (Table 6). Therefore models without the tagtype interactions were fitted to inshore harvest rates from all data, and data from 50-79cm fish.

The results indicated that there were no systematic differences among years for either data set; F values were insignificant and SNK range tests indicated that all year means constituted a homogeneous set, using Type IV estimates of error terms. (For a discussion of types of sums square terms, see SAS 1985).

The final model fit to both data sets contained terms for area, an area by year interaction, and type of tag. Both main effects were highly significant, and the interaction was marginally significant as well (Table 7).

From the parameter estimates in the models, it was determined that the significant interaction was due to the differences between 1980 and 1983 in harvesting rate of fish tagged on the northern portion of the Grand Bank (Table 8). Both values were lower than any other harvest rates but in the 1980 values were at least twice those of 1983 (for all fish; 1.18 to 3.67 vs. .33 to .99, depending on type of tag: for 50-79 cm fish 0.17 to 3.77 vs 0.0 to 0.42).

For type of tag, range tests indicated that Petersen discs, danglers and double tags were returned at similar rates, and significantly more frequently than orange T-bar and yellow T-bar tags, which also had similar return rates (Table 9). The lower values for orange T-bars and yellow T-bars tags were expected. These tags are smaller and more likely to be either lost from the fish or overlooked by the fishermen. Therefore rates of harvesting estimated from these tags will underestimate true harvesting rates. The statistical similarity of the three other tag types suggests harvesting rates estimated from these data are realistic.

The SNK range test of the 5 areas indicated that harvesting rates by the inshore fishery for fish tagged on Funk Island Bank, Belle Isle Bank, and east of Cape Bonavista did not differ from each other. The harvesting rate from the northeast portion of Funk Island Bank during 1981 was significantly lower than from the same area of the bank during 1979, 1980, 1982, and 1983. The harvesting rate from southwestern Funk Island Bank during 1981 was similar to that of the northeast in the above years. The harvesting rate for fish tagged on Hamilton Bank was significantly lower than those from Belle Isle Bank, Funk Island Bank and east of Cape Bonavista. The rate for the northern Grand Bank was significantly lower than that for Hamilton Bank. The pattern was present for both all data, and data from fish of the 50-79 cm length range (Table 10).

The lack of significant differences in harvesting rates among years required additional exploration, because the results of the type IV sum-squares suggested some difference may have been present, although none was found with the *a posteriori* tests. The very unbalanced design weakened the search for interannual variation. Therefore, the analysis was redesigned, with each of the 13 experiments as individual levels of a single factor. A model with two terms, experiment and type of tag, was fitted to these data sets. In these analyses the design is balanced, and Type III sum squares are appropriate for evaluating effects.

For data from all tagging and from fish 50-79 cm, both terms of the model were significant (Table 11). The high r^2 values for these models indicate that the relative rate of return of different types of tags did not change greatly from experiment to experiment. For both data sets, the differences among tag types were the same as reported in the previous analyses: T bar tags were returned significantly less frequently than were other types of tags.

SNK tests of the 13 experiments supported the interpretation that there was no systematic interannual variation in harvesting rate; rather, there were systematic differences in rates of harvesting fish tagged on different banks. The details differ slightly between estimates from all fish, and estimates from only fish between 50-79 cm (Table 12).

In both cases all the experiments on Funk Island Bank form one homogeneous unit except Experiment 7, (Northeast Funk Island Bank in 1981). Fish in that experiment were harvested at a lower rate than in other experiments on Funk Island Bank and is possibly a reflection of reduced inshore migration from this area in this year. However the estimates from fish tagged in 1981 on Southwest Funk Island Bank, which is located nearer to the east coast of Newfoundland than is Northeast Funk Island Bank, were the same as those from all other experiments on Funk Island Bank in other years. Although there are no statistically significant differences among the other 5 experiments on Funk Island Bank, there is a tendency for the estimated harvesting rate to go up each year, particularly in the data from all taggings. Regression analysis of this trend alone was significant ($F = 17.95$, $P < 0.01$, $r^2 = 0.67$), but the analysis is *a posteriori*, and should be interpreted with great caution.

There are fewer experiments from the other banks. Nonetheless, the two experiments from Belle Isle Bank do not differ, nor do the two experiments from Hamilton Bank. The data from east of Cape Bonavista lie intermediate between those of Funk Island Bank and Belle Isle Bank. The two experiments on the northern Grand Bank provided estimates of inshore harvesting significantly lower than those of any other experiments. As was found in the factorial analyses, the data from the two experiments on the northern Grand Bank were significantly different. This difference is also likely due to differences in areas where tagging was conducted. Experiment 40 involved tagging well out on the northeast slope, whereas the tagging for Experiment 14 was conducted further west, on the north cape of the bank.

EFFECTS OF DISTRIBUTION OF OFFSHORE BIOMASS ON INSHORE FISHERY

Baird and Bowering (1986) provide a breakdown of the northern cod biomass in the fall among the three NAFO Divisions. This partition was quite stable for the early portion of their series (1981-83) corresponding to the latter period of tagging. During this time, on average, the total biomass was distributed with 42% in 2J, 30% in 3K and 28% in 3L.

The tagging results from the Petersen disc type tags are used here to estimate the average rate of exploitation by Division during 1978-83.

Tagging experiments in Hamilton Bank were used to estimate the average rate of exploitation of the 2J portion of the stock by the inshore fishery at 7.08%. Experiments on Belle Isle Bank and Funk Island Bank (except the 1981 experiment on Northeast Funk Island Bank; where the estimated exploitation rate (8.94%) differed significantly from the other Funk Island Bank experiments) estimated an average inshore exploitation rate of 13.37% for 3K. The two experiments on the northern portion of Grand Bank estimated an average exploitation rate of 2.33% for the northern portion of Division 3L.

The proportional exploitation rates for each division can be combined with the distribution of biomass among the divisions, to provide estimates of the proportion of the total stock harvested yearly from each division by the inshore fishery (Table 13). From these estimates the inshore fishery harvests about 8% of the stock yearly. Because the stock breakdown appeared stable over the period 1981-83, (Baird and Bowering, Table 7) and the inshore proportional exploitation rates were not significantly different among years for any bank (except 1981 for northern Funk Island Bank) (Tables 6 and 7), these estimates should be stable over that period as well. This estimate of inshore harvesting rate is only slightly lower than that expected from total stock biomass and inshore landings (Lear et al. 1986). This is consistent with use of conservative estimates for rates of tag-induced mortality and non-reporting of tags when estimating harvesting rate from tagging results.

In 1984 and 1985, the distribution of cod biomass among the three divisions differed from that in earlier years. Tagging data from these years are not available. However, assuming the distribution of inshore fishing effort remained as it was in the period from 1978 to 1983, changes in the proportion of the total northern cod stock harvested from each division can be estimated as they were for the 1981-83 period.

The proportions of the 2J3KL stock that are harvested in Div. 2J and 3K both decrease, reflecting the decrease in portion of the stock in the regions. Although the value for Div. 3L increases, because of the low rate of harvesting 3L by the inshore fishery, the increase does not compensate for the losses in the other divisions. The total portion of the northern cod stock harvested by the inshore fishery decreases from 8% to 7% of the total stock.

DISCUSSION

The proportions of cod harvested inshore in the year of tagging, estimated from results of tagging on the spawning and pre-spawning concentrations of the Div. 2J3KL cod stock complex, are highly variable. The northern component from the Belle Isle and Funk Island banks contribute more to the inshore fishery at present (9-19%) than does the northern Grand Bank component (1-4%).

Recaptures in the tagging year from cod tagged offshore during April-May 1964 and 1966 (Templeman 1979) were analyzed using the same basic assumptions as those used for the 1978-83 taggings. Results of these analyses indicated that the proportions harvested inshore in those earlier years were lower than those estimated from the 1978-83 taggings. The proportions harvested inshore during May-December of the tagging year for several of the tagging experiments are as follows: northeast and southeast Hamilton Bank (6.8% harvested inshore ± 0.8% standard error), south side of Hawke Channel (4.8±1.0) Funk Island Bank (7.9±1.9) and for north cape of the Grand Bank (2.7±0.6). This is probably a reflection of a lower inshore exploitation rate in those earlier years than during the 1978-83 period. Pinhorn (1984) also reported that the inshore fishery harvested a lower proportion of cod which survived the offshore fishery during the 1961-74 period then during 1975-76. All evidence indicates that the proportion of cod harvested by the inshore fishery decreases both north and south of Funk Island Bank. The changes could arise from differences in migration of the stock components or differences in inshore effort among regions. We suspect there is a lower inshore migration factor for the northern Grand Bank cod than that from cod of the Funk Island Bank and surrounding areas. The lower exploitation rates for Hamilton Bank may indicate lower effort rather than less migration.

The figures for the 1978-83 tagging experiments and those of Templeman (1979) may be underestimated to some degree, if the 13% tagging mortality rate is low. In a much longer experiment, Khan et al. (1981) found that about 52% of captive Atlantic cod died from fin rot. However, the cod in that experiment were held for about 2 weeks in tanks at sea, kept in port without water circulation, brought ashore, trucked to the laboratory and again put into tanks. Therefore, the mortality rates in Khan et al. (1981) are much higher than we expect tag related mortality to be.

The lack of differences among the years 1979-80 and 1982-83 for Funk Island Bank may be surprising, but is consistently supported by the analyses. Although there is a significant relationship of exploitation rates with year, 2 standard error bars around the 1979 and 1983 estimates still overlap. The lower inshore harvesting rate in 1981 for northern Funk Island Bank fish is reflected in the fishery failure in that year. Data from 1985 and 1986 would be particularly valuable but are not available. If the increasing trend possibly present in these data were supported, it would likely indicate systematically increasing inshore effort, systematically declining stock, or both factors. In this light the estimates of recent inshore harvesting rates of over 15% are high and continued increases would be cause for some concern. The results certainly do not support the conjecture that there were great variations during 1978-83 in the proportions of the stock migrating inshore, except for 1981.

The redistribution of northern cod among the three divisions appears to influence inshore landings. Without changing harvesting rates inshore, or total stock biomass, the apparent shift in proportion of cod to Div. 3L from 2J and 3K could have reduced total inshore landings 12%. The stock did not stay constant over that period, however, nor have we any data indicating that inshore fishing effort was distributed in the same way and remained at the same levels after 1983. The possible 12% decline in inshore landings, due to the changes in distribution of biomass among the three divisions should be taken as one more factor to be considered, not as a final explanation for the lower inshore catches in 1985 and 1986. It indicates that management of the offshore stock should consider the distribution of the biomass among the divisions, as well as the overall level of biomass.

REFERENCES

Baird, J. W., and W. R. Bowering. 1986. Biomass estimates for cod and Greenland halibut beyond the Canadian 200-mile economic zone in NAFO Division 2J+3KL. NAFO SCR Doc. 86/51. Ser. No. N 1168, 6 p.

Bowen, W.D. 1979. A mark recapture experiment to determine harp seal pup production on the Front, 1979. NAFO SCR Doc. 79/XI/4, Ser. No. N015, 12 p.

Bowen, W.D., and D.E. Sergeant. 1980. Estimates of harp seal pup production from mark recapture estimates. NAFO SCR Doc. 80/XI/162, Ser. No. N249, 14 p.

Cochrane, W.G. 1977. Sampling Techniques. Third Edition. John Wiley and Sons. Toronto. 428 p.

Khan, R.A., J. Campbell, and W.H. Lear. 1981. Mortality in captive Atlantic cod (<u>Gadus morhua</u>) associated with fin rot disease. J. of Wildlife Diseases. <u>Vol. 17</u>, No. 4, 521-527.

Lear, W.H. 1984. Discrimination of the cod stock complex of Atlantic cod (<u>Gadus morhua</u>) off southern Labrador and eastern Newfoundland as inferred from tagging studies. J. Northw. Atl. Fish. Sci. Vol. 5: 143-159.

Lear, W. H., J. W. Baird, J. C. Rice, J. E. Carscadden, G. R. Lilly, and S. A. Akenhead. 1986. An examination of factors affecting catch in the inshore cod fishery of Labrador and eastern Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. 1469: iv + 71 p.

Pinhorn, A.T. 1975. Estimates of natural mortality for the cod stock complex in ICNAF Div. 2J, 3K, and 3L. ICNAF Res. Bull. No. 11: 31-36.

1984. Inshore exploitation of Atlantic cod, Gadus morhua in Labrador and eastern Newfoundland waters. J. Northw. Atl. Fish. Sci. 5: 79-84.

Pope, J.G. 1972. An investigation of the Accuracy of Virtual Population Analysis Using Cohort analysis. ICNAF Res. Bull. 9: 65-74.

Templeman, W. 1962. Divisions of cod stocks in the Northwest Atlantic. ICNAF Redbook 1962, Part III: 79-123.

1974. Migrations and intermingling of Atlantic cod (Gadus morhua) of the Newfoundland area. J. Fish. Res. Bd. Canada, 31: 1073-1092.

1979. Migration and intermingling of stocks of Atlantic cod (Gadus morhua) of the Newfoundland and adjacent areas from tagging in 1962-66. ICNAF Res. Bull. No. 14: 5-50.

SAS 1985. SAS users guide: statistics version, 5th edition, Cary, N.C. SAS Institute Inc. (956 p.)

Seber, G.A.F. 1973. The Estimation of Animal Abundance. Griffin, London. 506 p.

Table I. Numbers of cod tagged by 3cm length group in various areas during February-March, 1978-83

Fork length (cm)	Experiment number(year)												
	1 (1978)	7 (1979)	13 (1980)	14 (1980)	19 (1981)	20 (1981)	22 (1981)	28 (1982)	30 (1982)	31 (1982)	40 (1983)	41 (1983)	42 (1983)
37							1	3					
40		1						3					
43	11	5	1					10					
46	277	295	80	54	28	3	72	44	21	31	43	42	117
49	702	653	221	170	60	61	195	80	43	82	141	102	288
52	999	838	421	281	106	217	388	97	114	126	287	211	418
55	860	882	606	406	148	475	540	174	213	199	339	317	445
58	517	804	714	342	213	640	505	228	386	235	231	304	430
61	312	584	673	261	170	631	449	224	497	313	141	279	376
64	207	358	540	169	172	504	346	198	473	316	116	240	286
67	195	218	448	124	96	348	225	160	393	320	72	184	240
70	133	131	308	63	72	191	137	98	286	293	92	125	157
73	93	83	212	26	47	101	108	55	204	204	98	77	110
76	45	58	147	29	28	50	63	33	112	129	82	59	80
79	36	37	133	16	16	34	34	20	73	64	100	24	67
82	34	25	96	11	15	16	24	10	38	36	74	12	31
85	13	10	80	12	2	16	11	5	41	15	64	6	29
88	5	13	68	9	6	3	12	3	27	13	44	5	21
91	2	3	69	8	6	5	8	1	17	2	27	1	18
94	8	2	44	5		3	10	1	10	3	10	4	13
97		1	40	2	3	4	6		17	1	7	1	6
100	1	3	34		1	2	3		8		5	2	2
103			14	3	1		1	2	7	1	6		6
106		1	8	1	2	1		1	6		1		1
109			8	1				1	3		2		
112		1	2	1			1					1	
115			1		1				1				
118			2					1			1		
121			1		1								
124			2		1						1		
127													
130													
133													
136			1										
No length	5	2	2						2				
	4455	5008	4977	1994	1195	3305	3139	1452	2992	2383	1984	1996	3142

Table 2. Descriptions of tag types applied to adult Atlantic cod during 1978-83 on the Hamilton Bank, Belle Isle Bank, Funk Island Bank, and the northern slopes of the Grand Bank.

Tag type	Description
011213	13mm diameter yellow Petersen disc and blank attached posterior to first dorsal fin by 0.32 soft stainless steel wire, 3mm space allowed on each side of fish.
601368	7 cm yellow spaghetti T-Bar tag attached through base of the first dorsal fin (used only during 1978).
611368	8.25 cm yellow spaghetti T-Bar tag attached through base of the first dorsal fin.
614368	8.25 cm orange spaghetti T-Bar attached through base of the first dorsal fin.
411213	Combination tag composed of 13mm diameter yellow Petersen disc and blank with a yellow dangler tag (5cm long by 13mm wide) attached to trail along each side of fish. The attachment is by .032 soft stainless steel wire posterior to the first dorsal fin with a spacing of 3mm allowed on each side of the fish.
Double	These were combinations of 13mm diameter yellow Petersen discs, 8.25 cm yellow or 8.25 orange spaghetti T-Bar tags attached in the area of the first and second dorsal fins. Each cod was tagged with two tags, either of the same type or two different types. The tags were attached in two positions around the first and second dorsal fins.

Table 3. Results of tagging and handling mortality of cod held in tanks onboard ships during offshore tagging experiments conducted during 1978-81.

Date	Tag Type	Duration (hr)	No. Tagged	No. Dead
February-March 1978	011213	167	10	3
	601368	139	10	0
March, 1979	011213	264	10	0
	611368 or 614368	264	10	0
March, 1980	011213	327	10	2
	611368 or 614368	327	10	1
	411213	327	10	1
March, 1981	011213	265	10	3
	611368 or 614368	212	10	2
	411213	265	10	1
1978-81			100	13

$p_s = 0.87$

Var $(p_s) = 0.0013444$.

Table 4. Results of surveys at Bonavista, Fogo, and LaScie during 1980 to determine rates of reporting of recaptured cod tags.

Area	No. of fishermen contacted	No. of responses	No. of cod tags caught	No. previously reported	% Reporting rate
Bonavista	138[a]	40	16	10	63
Fogo	66[b]	66	27	21	78
LaScie	58[a]	20	3	2	67
TOTAL	262	126	46	33	72

$p_r = 0.72$

$Var(p_r) = 0.0007667$

[a]Mailed questionnaire

[b]Personal interviews.

Table 5. Numbers of cod tagged and percentages recaptured inshore during May-December in the year of tagging with standard errors for all lengths combined and for the 50-79 cm group by tag type, experiment number, tagging locality, and year.

Expt. No.	Area	Year Tagged	Tag Type	No. Tagged	All Lengths %	All Lengths S.E.	50-79 cm %	50-79 cm S.E.
1	Belle Isle Bank	1978	011213	3525	11.36	0.98	12.53	1.14
			601368	930	3.74	0.84	4.09	0.97
7	Funk Island Bank	1979	011213	1014	9.65	1.42	9.84	1.54
			411213	991	9.09	1.38	9.29	1.48
			611368	1003	4.65	0.94	5.16	1.06
			614368	1001	6.08	1.10	5.63	1.12
			Double	999	10.32	1.46	12.04	1.83
13	Funk Island Bank	1980	011213	1242	12.36	1.47	13.31	1.64
			411213	1287	13.64	1.54	14.76	1.73
			611368	1237	5.27	0.90	5.90	1.01
			614368	1211	6.77	1.04	7.67	1.20
14	North Cape of Grand Bank	1980	011213	500	3.67	1.13	3.77	1.21
			411213	498	2.69	0.96	3.03	1.08
			611368	574	1.18	0.59	0.67	0.47
			614368	422	1.97	0.89	2.17	0.97
19	SW Funk Island Bank	1981	011213	299	17.66	3.28	19.42	3.61
			411213	310	13.92	2.84	15.36	3.14
			611368	287	4.60	1.65	5.02	1.80
			614368	299	6.66	1.96	7.30	2.15
20	NE Hamilton Bank	1981	011213	832	7.14	1.26	7.22	1.27
			411213	845	6.26	1.16	6.40	1.19
			611368	822	3.01	0.80	3.09	0.82
			614368	806	3.28	0.84	3.44	0.88
22	NE Funk Island Bank	1981	011213	849	8.94	1.41	8.96	1.46
			411213	487	7.46	1.65	7.88	1.74
			611368	905	3.11	0.77	3.25	0.83
			614368	898	2.76	0.73	2.67	0.76
28	E of Cape Bonavista	1982	011213	355	15.02	2.79	14.64	2.89
			411213	350	16.03	2.90	16.93	3.14
			611368	393	4.25	1.37	4.64	1.49
			614368	354	4.68	1.51	4.64	1.57

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Table 5 (Cont'd.)

Expt. No.	Area	Year Tagged	Tag Type	No. Tagged	All Lengths %	All Lengths S.E.	50-79 cm %	50-79 cm S.E.
30	SE Hamilton Bank	1982	011213	750	7.01	1.51	7.24	1.63
			411213	744	8.21	1.62	8.34	1.70
			611368	744	1.22	0.62	1.32	0.67
			614368	754	5.11	1.25	5.26	1.33
31	N Funk Island Bank	1982	011213	596	13.09	2.05	13.54	2.16
			411213	592	19.90	2.62	18.86	2.65
			611368	599	6.65	1.41	6.46	1.43
			614368	596	6.66	1.42	7.18	1.52
40	NE Grand Bank	1983	011213	500	0.99	0.58	0.38	0.38
			411213	489	0.34	0.34	0.00	0.00
			611368	499	0.33	0.33	0.42	0.42
			614368	496	0.33	0.33	0.39	0.39
41	N Funk Island Bank	1983	011213	500	17.23	2.61	17.54	2.73
			411213	498	16.62	2.56	17.15	2.72
			611368	500	6.67	1.54	6.74	1.59
			614368	498	6.00	1.46	5.69	1.46
42	Belle Isle Bank	1983	011213	500	10.58	2.00	11.68	2.27
			411213	647	11.05	1.82	12.42	2.12
			611368	999	4.03	0.85	4.61	0.98
			614368	996	6.16	1.09	6.81	1.23

Table 6. Results of ANOVA for full model, with factors year, area, tag type, and all 2-way interactions.

	df	SS	F	P	SS	F	P
	Type III Sum Squares				Type IV Sum Squares		
	All Fish						
Model	40	45.65	5.19	.004			
Area	4	22.25	25.23	.001	18.23	20.67	>.0001
Year	5	1.37	1.24	.358	2.76	2.50	.102
Area x Year	2	1.59	3.60	.066	1.59	3.60	.066
Tag Type	4	6.66	7.56	.004	0.84	0.95	.476
Area x Tagtype	12	1.90	0.72	.710	1.90	0.72	.710
Year x Tagtype	13	1.04	0.36	.954	1.04	0.36	.954
Error	10	2.20					
$r^2=.954$							
	Only 50-79 cm Fish						
Model	40	51.73	4.12	.0104			
Area	4	21.30	21.30	.001	21.54	17.18	.0002
Year	5	1.90	1.21	.370	3.23	2.06	.154
Area x Year	2	1.62	2.58	.125	1.62	2.58	.125
Tagtype	4	6.84	5.45	.014	1.07	0.85	.525
Area x Tagtype	12	2.71	0.72	.708	2.71	0.72	.708
Year x Tagtype	13	1.11	0.27	.984	1.11	0.27	.984
Error	10	3.14					
$r^2=.943$							

df - degrees of freedom
SS - sum of squares
F - F ratio
P - probability

Table 7. Results of ANOVA for reduced model with area, tagtype, and area by year interaction. In this model Type III and Type IV Sum Squares are identical.

	df	SS	F	P
		All Fish		
Model	15	42.45	18.31	.0001
Area	4	23.74	38.40	.0001
Area x Year	7	3.15	2.91	.0166
Tagtype	4	15.88	25.68	.0001
Error	35	5.41		
r^2=.887				
		Only Fish 50-79 cm		
Model	15	47.62	15.33	.0001
Area	4	28.00	33.80	.0001
Area x Year	7	3.64	2.51	.0333
Tagtype	4	16.06	19.39	.0001
Error	35	7.25		
r^2=.868				

Table 8. Estimates of parameter values for individual levels of the area X year interaction, from reduced model. For each area, the last year of tagging in that area is taken as a baseline.

Area	Year	Parameter Estimate	t parm=0	P
		All Fish		
Belle Isle Bank	78	-0.117	-0.34	0.736
Belle Isle Bank	83	0.0	-	-
Funk Island Bank	79	-0.629	-2.26	0.030
Funk Island Bank	80	-0.288	-1.04	0.307
Funk Island Bank	81	-0.589	-2.45	0.020
Funk Island Bank	82	-0.005	-0.02	0.095
Funk Island Bank	83	0.0	-	-
Grand Bank	80	0.830	2.98	0.005
Grand Bank	83	0.0	-	-
Hamilton Bank	81	-0.395	-0.14	.888
Hamilton Bank	82	0.0	-	-
Cape Bonavista	82	-	-	-
		Only Fish 50-79 cm		
Belle Isle Bank	78	-0.088	-0.22	0.827
Belle Isle Bank	83	0.0	-	-
Funk Island Bank	79	-0.620	-1.93	0.062
Funk Island Bank	80	-0.156	-0.48	0.632
Funk Island Bank	81	-0.515	-1.85	0.073
Funk Island Bank	82	-0.168	-0.05	0.959
Funk Island Bank	83	0.0	-	-
Grand Bank	80	1.621	3.17	0.003
Grand Bank	83	0.0	-	-
Hamilton Bank	81	-0.048	-0.15	0.883
Hamilton Bank	82	0.0		
Cape Bonavista	82	-	-	-

Table 9. Results of SNK range tests for means of tag types from model fitting area, area by year, and tag type. Means sharing a bar do not differ from each other (α=0.05).

All Fish		Only Fish 50-79 cm	
Tag Type	Mean	Tag Type	Mean
Double	3.213	Double	3.470
Petersen disc	3.101	Petersen disc	3.136
Double dangler	3.052	Double dangler	3.075
Orange T-bar	2.086	Orange T-bar	2.129
Yellow T-bar	1.864	Yellow T-bar	1.891

Table 10. Results of SNK range tests for means of areas from model fitting area, area by year and tag type. Means sharing a bar do not differ from each other (α=0.05)

All Fish		Only Fish 50-79cm	
Area	Mean	Area	Mean
Cape Bonavista	3.026	Cape Bonavista	3.062
Funk Island Bank	2.975	Funk Island Bank	3.042
Belle Isle Bank	2.764	Belle Isle Bank	2.877
Hamilton Bank	2.200	Hamilton Bank	2.231
North Grand Bank	1.097	North Grand Bank	0.983

Table 11. Results of ANOVA for model with Experiments (13 levels) and tags (5 levels) as factors.

	All Fish				Only 50-79 cm Fish		
	df	SS	F	P	SS	F	P
Model	16	43.99	24.17	<.0001	49.65	20.22	<.0001
Experiment*	12	27.89	20.43	<.0001	33.28	18.07	<.0001
Tag Type*	4	15.88	34.90	<.0001	16.06	26.17	<.0001
Error	34	3.87			5.23		
r^2					.905		

*Type III Sum Squares for these terms.

Table 12. Results of SNK range tests for means from model fitting experiments and tag types. Means sharing a bar do not differ significantly from each other, (α=0.05).
F=Funk Island Bank, B=Belle Isle Bank, C=Cape Bonavista, H=Hamilton Bank, G=Grand Bank. Entries are means across tag types of square root transformed proportions.

All Fish		Only 50-79 cm Fish	
Expt.	Mean	Expt.	Mean
F-83	3.32	F-83	3.33
F-82	3.31	F-81*	3.32
F-81*	3.16	F-82	3.31
F-80	3.03	F-80	3.17
C-82	3.03	C-82	3.06
B-83	2.82	B-83	2.92
F-79	2.79	F-79	2.86
B-78	2.65	B-78	2.78
F-81**	2.29	F-81**	2.31
H-82	2.22	H-82	2.26
H-81	2.18	H-81	2.21
G-80	1.51	G-80	1.49
G-83	0.68	G-83	0.47

*Southwestern portion of bank
**Northeast portion of bank.

Table 13. Exploitation rates and distribution of stock among divisions for the periods 1981-83 and 1984-85.

Division	Inshore exploitation rate	Percent of stock in division (Baird and Bowering, 86)		Proportion of stock taken by inshore fishery	
		1981-83	1984-85	1981-83	1984-85
2J	.0708	47	34	.0333	.0241
3K	.1337	31	28	.0414	.0374
3L	.0233	22	38	.0051	.0089
				.0798	.0704

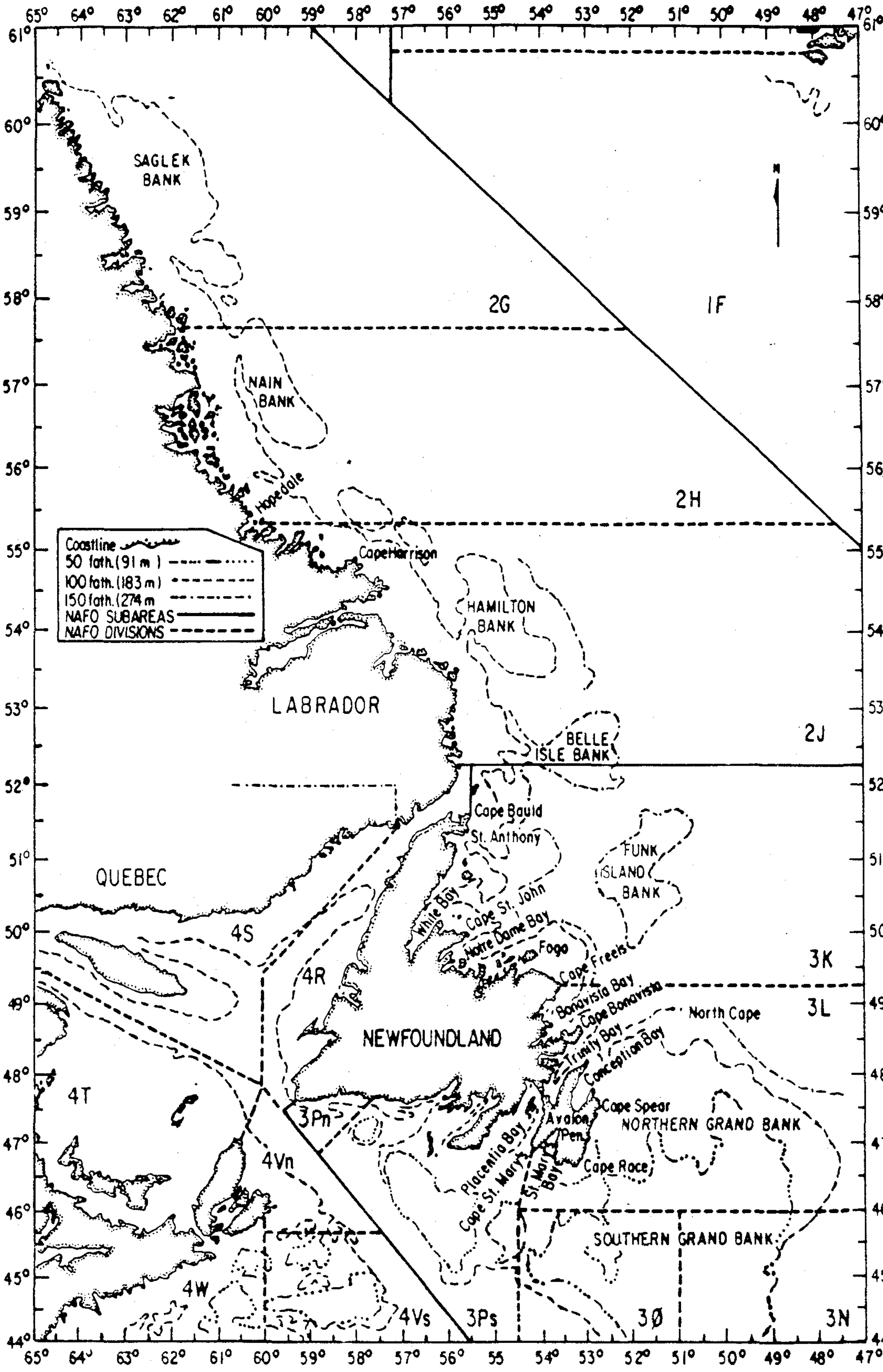

Fig. 1. Area map of Newfoundland and Labador, showing NAFO Divisions and place names mentioned in the text.