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Report of the Working Group on Oceanographic Effects on Stock Migration and Mixing - reviewed by the Fisheries Oceanography Committee (FOC)

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[1]La présente série documente les bases scientifiques des évaluations des ressources halieutiques sur la côte atlantique du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

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ABSTRACT

In 1993 the Fisheries Oceanography Committee (FOC) established a Working Group to investigate oceanographic effects on stock migration and mixing. The investigation of the Working Group was to bear on the distribution of groundfish, particularly cod and redfish, in the area of Cabot Strait. This document summarizes the contents of analyses presented to the Working Group, their subsequent critical review by the FOC, and the collective discussion by the Committee in the context of the terms of reference given to the Working Group. A total of twenty working papers were reviewed documenting i) recent and past patterns in the winter distributions of cod and redfish (and other species) in Divs. 3Pn, 4R, 4S, 3Ps, 4T, 4Vn, 4Vs, and 4W using survey and commerical fisheries data, and tagging data, ii) the application of methods to discriminate mixed populations and iii) changes in ocean climate conditions in the Cabot Strait area. During the course of the review by the FOC it became apparent that some of the recent observations on variations in stock distribution were not new but had been described in varying detail in the past. The Working Group in many instances was able to better demonstrate the existence of stock mixing than in the past based on combining surveys from different regions and countries, the use of computer animation and graphics of positioned catch and effort data, and initiation of a new winter survey in the Cabot Strait area during January 1994. Interpretation of fish distribution patterns and their variability using physical oceanographic data remains a challenge, although advances have been made in terms of characterizing associations between water mass types and fish concentrations that may ultimately lead to better understanding of stock mixing and migration patterns. Specific instances where the management unit and stock distribution (principally during winter months) do not agree are highlighted and discussed. This includes 4TVn cod, Unit 1 and 2 redfish, 4RS witch, 4T hake, 3Pn4Rs cod and 3Ps cod.

RÉSUMÉ

En 1993, on a créé un Groupe de travail sur les effets océanographiques sur la migration et le mélange des stocks dans le but d'expliquer les variations dans la distribution et la migration des stocks dans le détroit de Cabot et le golfe du Saint-Laurent, en particulier durant la pêche hivernale de la morue et du sébaste. Le présent document résume les analyses présentées, les critiques qu'elles ont suscitées au sein du Fisheries Oceanographic Committee (FOC) et les discussions de ce dernier sur le mandat du groupe. Vingt documents de travail ont été examinés. Ils portaient sur i) les tendances anciennes et récentes de la distribution de la morue et du sébaste (ainsi que d'autres espèces) durant l'hiver dans les divisions 3Pn, 4R, 4S, 3Ps, 4T, 4Vn, 4Vs et 4W, tendances fondées sur les relevés de recherche, les données de la pêche commerciale, et les résultats d'opérations d'étiquetage; ii) l'application de méthodes permettant de différencier les composantes des populations mixtes et iii) les changements survenus dans les conditions climatiques de l'océan dans la région du détroit de Cabot. Au cours de l'évaluation réalisée par le FOC, il est apparu que certains des changements récents de la distribution des stocks n'étaient pas nouveaux, et qu'ils avaient fait l'objet de descriptions antérieures plus ou moins détaillées. Dans bien des cas, le groupe de travail a pu démontrer de façon plus probante l'existence d'un mélange des stocks, en se fondant sur une combinaison de relevés de recherche de différentes régions et pays, en utilisant des techniques d'animation et de représentation graphique des données sur les prises et l'effort assistées par ordinateur, et en entreprenant un nouveau relevé de recherche hivernal dans le détroit de Cabot, en janvier 1994. L'interprétation des tendances de la distribution du poisson et de leur variabilité à partir de données océanographiques reste problématique; on a cependant réalisé certains progrès à cet égard, ayant dégagé des associations entre les types de masse d'eau et les concentrations de poisson, qui pourront ultimement nous aider à mieux comprendre le mélange des stocks et les régimes de migration. Il est question également ici des cas précis où l'unité de gestion et la distribution du stock ne correspondent pas (en particulier durant l'hiver), notamment pour ce qui est de la morue de 4TVn, du sébaste des unités 1 et 2, de la plie de 4RS, du merlu argenté de 4T, de la morue de 3Pn4Rs et de celle de 3Ps.

INTRODUCTION

The Fisheries Oceanography Committee (FOC) met in Dartmouth, N.S. at the Bedford Institute of Oceanography on 23-25 March 1994 to review scientific information associated with the Working Group on Oceanographic Effects on Stock Migration and Mixing. The Working Group was established to provide explanations for the current stock delimitation problems of some groundfish species in the Cabot Strait at the entrance to the Gulf of St. Lawrence (**Figure 1**). The problems were reported as unexpected changes in the distribution of cod and redfish in the Gulf of St. Lawrence, particularly during the winter, which had been occurring in the recent past. Winter research vessel surveys have shown that cod in Subdiv. 3Ps and 3Pn4RS are distributed in deeper water and beyond the boundaries of the survey (or stock) area. The southern Gulf cod stock (Div. 4T and Vn (Jan.-Apr.)), which normally undertakes a winter migration out of the Gulf, had apparently extended its migration range further south resulting in mixing with Div. 4VsW cod on the eastern Scotian Shelf. Recent commercial fishing patterns appeared to reflect these winter distributions of cod with fishing effort increasing along the edges of the Laurentian Channel. These changes in cod distribution appeared to be rooted in ocean climate variability in the Gulf of St. Lawrence. However, this claim could not be supported or rejected because there had been no systematic evaluation of the relationship between cod distribution and environmental variability in the Gulf cod stocks. The Working Group, under the joint chairmanship of Denis D'Amours (BSB, IML) and Gary Bugden (PCS, BIO), was given the following terms of reference:

1. Using survey and commercial fisheries data, document recent changes in cod and redfish distributions in Divs. 3Pn, 4R, 4S, 3Ps, 4T, 4Vn, 4Vs, and 4W giving particular emphasis to the winter months.

2. Compare and examine spatial analyses of catch rates from survey and observer data in relation to stock management units.

3. Extend historical time series estimates of 2) as far as possible and examine in relation to physical oceanographic observations of hydrographic conditions, circulation patterns and areal extent of sea ice.

4. Explore and test potential indices of stock distribution and/or mixing, whether biological or physically based, using the historical data series.

5. Review and test methods to discriminate individuals from mixed populations.

6. The time table for completing the terms of reference should be

no later than March 1994. The WG report will be reviewed by the Fisheries Oceanography Committee.

REVIEW OF WORKING PAPERS

A total of twenty working papers, divided according to the terms of reference, were reviewed by the Committee. These papers are produced for the purposes of the meeting only and are not citable. Interested readers should contact authors for details of the contents of the working papers. A list of attendees in provided in Appendix 1.

Ten working papers were presented that dealt with terms of reference #1, #2, and #3. They presented information from research vessel surveys and commercial fisheries in order to document changes in fish distribution in relation to stock management units, and some hydrographic conditions were considered in the analyses as well. The working paper (WP) number, title and author are as follows:

(**1**) WP 94/28 Notes concerning the origin of cod on Burgeo Bank. A. Fréchet

(**2**) WP 94/20 Cartographie des rendements de morues capturées lors des missions d'hiver des instituts de recherche canadiens et francais dans les divisions 3P, 4RST4Vn. C. Rollet, A. Fréchet, J-C. Brethes, et A. Battaglia.

(**3**) WP 94/38 The distribution of cod catches from winter-spring RV surveys in subdivisions 3Ps-3Pn along with length and age comparisons from contiguous strata. C.A. Bishop and E.F. Murphy.

(**4**) WP 94/36 Review of cod migration pattern in 3Ps based on published literature and NWAFC cod tagging database. C. Taggart.

(**5**) WP 94/22 Seasonal components in technological interactions in Gulf of St. Lawrence shrimp and groundfish fisheries. A.Sinclair.

(**6**) WP 94/37 The autumn migration of 4T cod as seen by the 4Vn test Fishery. T. Lambert.

(**7**) WP 94/24 Timing of commercial fisheries based on the movement of cod into and out of the Gulf of St. Lawrence, 1986-1993. A. Sinclair and L. Currie.

(**8**) WP 94/21 Distribution of groundfish during the winter 1994 Cabot Strait survey. G. Chouinard.

(**9**) WP 94/29 Distribution of redfish in the Gulf of St. Lawrence and in the Laurentian Channel based on the RV surveys and commercial catch rates. B. Morin, D. Power, and P. Gagnon.

(**10**) WP 94/27 Distribution of witch and white hake in the Gulf of St. Lawrence in relation to management units. R. Morin and T. Hurlbut.

Five working papers were reviewed that dealt with terms of reference #5 - examine methods to discriminate individuals from mixed populations. These included:

(**11**) WP 94/31 Use of otolith elemental fingerprints for differentiating among stocks of Atlantic cod (Gadus morhua). S.E. Campana, S.R. Thorrold, A.J. Fowler, J.A. Gagné, and C.M. Jones.

(**12**) WP 94/40 Potential for use of nuclear DNA gene probes in elucidating stock/population structure in cod and application to individuals from mixed populations. C.T. Taggart.

(**13**) WP 94/25 Correspondence analysis of length frequencies from 4T, 4Vn and 4Vs. G. Nielsen and A. Sinclair.

(**14**) WP 94/26 Can 4T and 4Vn cod be separated from commercial catches based on length-frequency analyses? M. Hanson.

(**15**) WP 94/39 Parasites as indicators of Gulf of St. Lawrence fish stocks. G. McClelland et al.

Five working papers were reviewed that dealt with terms of reference #3 and #4. Physical environmental conditions influencing the Cabot Strait area were examined and discussed in relation to patterns of stock distribution in the following working papers:

(**16**) WP 94/32 The interannual variability of ice conditions in the vicinity of Cabot Strait. K.F. Drinkwater and G. Bugden.

(**17**) WP 94/33 Variability in the position of the shelf/slope front near the mouth of the Laurentian Channel. K.F. Drinkwater and G. Bugden.

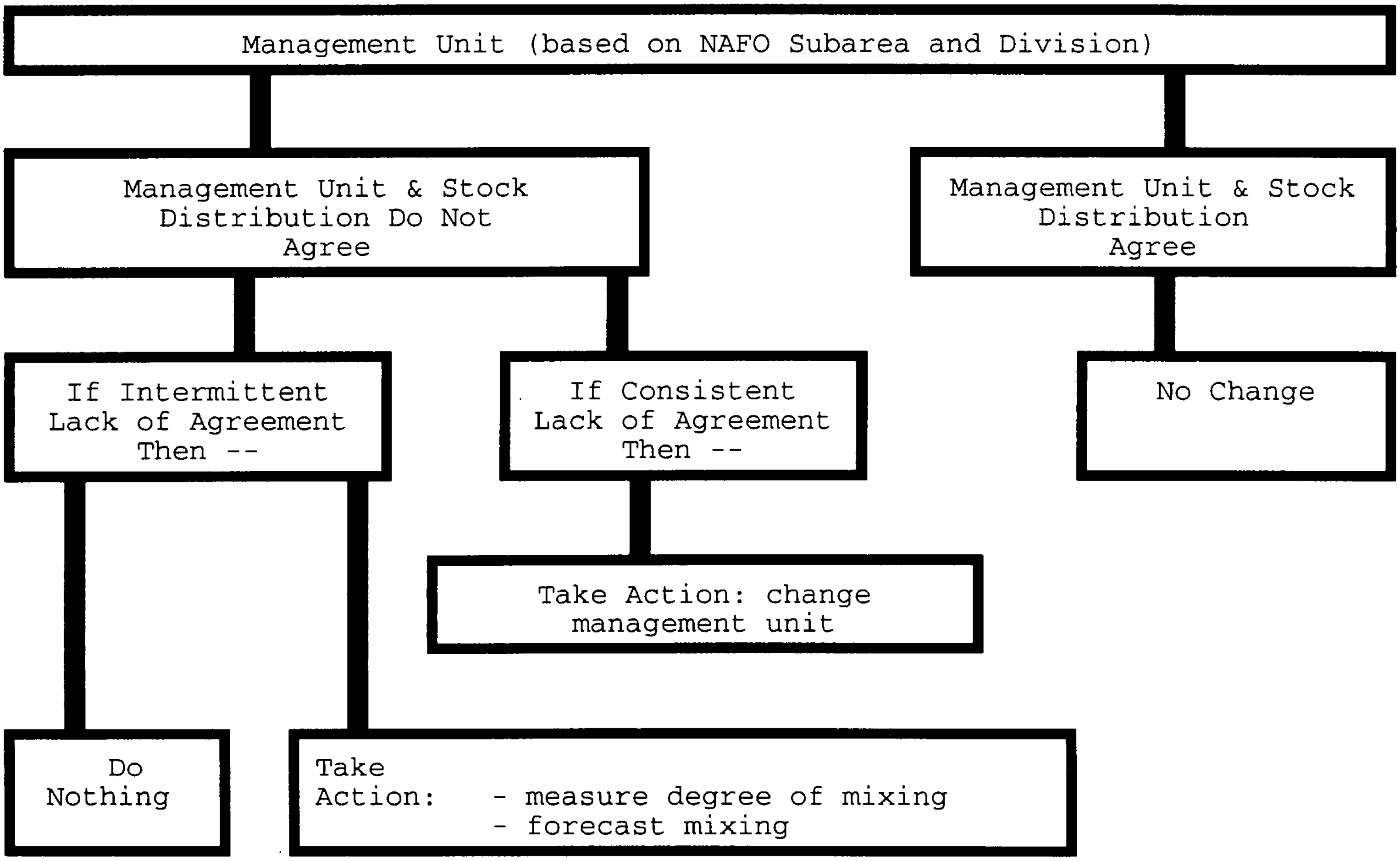
(**18**) WP 94/45 Oceanographic conditions at the entrance to the Gulf of St. Lawrence. G. Bugden, B. Petrie and K.F. Drinkwater.

(**19**) WP 94/42 Tagging results in relation to environmental conditions. W. Stobo and G. Bugden.

(**20**) WP 94/46 Variations in dissolved oxygen and nutrient distributions in the Laurentian Channel. G. Bugden and D. D'Amours.

OPENING REMARKS

At the start of the meeting one of the Chairs of the Working Group (D'Amours) presented his view of the goals of the meeting in the form of the following framework:



The Chair of the Working Group (D'Amours) suggested that for each stock examined, determining whether or not the management unit (**Figure 2**) and stock distribution agreed would first be evaluated. Lack of agreement would then be characterized according to whether it was a consistent pattern seen from year to year or whether it was an intermittent or variable lack of agreement. Suggestions for dealing with such situations would be provided.

WORKING PAPER SUMMARIES

(**1** and **2**) WP 94/20,28: Influx of Gulf cod (3Pn, 4RS) on Burgeo Bank (3Ps). A. Frechet, C. Rollet, J-C. Brethes and A. Battaglia.

An overview of published literature concerning the origin of cod on Burgeo Bank (based on commercial fishing, tagging, growth, parasites, etc.) was presented. Northern Gulf cod (3Pn4RS) have, in the past, routinely been found in 3Ps. Cod overwintering on Burgeo Bank (northwestern 3Ps) showed greater affinity with the northern Gulf cod than with the remainder of 3Ps. Composite maps of winter research vessel (RV) surveys in Quebec, Newfoundland and St. Pierre and Miquelon regions (between 1978 and 1994) were presented. They showed variable concentrations of northern Gulf cod on Burgeo Bank and the adjoining slope area to the southwest (the degree of mixing was not known). Since 1987 an increasing proportion of 3Pn4RS cod were found in deeper waters (> 200 fa) in January (**Figure 3**). The relative abundance of cod in 3Pn has also increased with over 90% of the 3Pn4RS survey catch now originating from a few strata along the southern boundary of 3Pn. With the declining abundance of both cod stocks, catchability (higher concentrations in restricted areas) and movements of fish may have increased.

The Burgeo Bank aggregation was most apparent after 1986 and this coincided with a reduction of cod concentrations in 4R. Recent low recruitment of northern Gulf cod might explain this apparent change in distribution because small cod typically overwintered in the northern Gulf. The Committee recommended an age-disaggregated, spatial analysis of the winter RV survey data in this region to address this possibility. Earlier and longer ice cover in Cabot Strait are other possible causes of the more extensive movements of cod into 3Ps.

Inter-annual variability in the movement of northern Gulf cod into 3Ps during winter may bias the estimates of cod biomass derived from the January RV surveys in 3Pn4RS and the February RV surveys in 3Ps. Also, when cod originating from the northern Gulf are captured on Burgeo Bank and assigned to 3Ps, they experience a higher level of total fishing mortality than would be apparent from the northern Gulf cod stock assessment. Some possible remedies to these problems include avoid conducting winter surveys when the potential for stock mixing is high and prevent any fishery in 3Psa and 3Psd (**Figure 2**) during the first few months of the year. RV surveys could also be conducted simultaneously in the winter months over the entire area with application of several discrimination techniques to characterize the identity of the resident 3Ps stock. It was noted that in 1993 DFO-St. John's reinstated an April RV survey of 3P.

Logbook data from the Newfoundland region (i.e. position data for landings in 3P) were not available for this and other analyses presented during the review.

(**3**) WP 94/38: The distribution of cod catches from winter-spring RV surveys in subdivisions 3Ps-3Pn along with length and age comparisons from contiguous strata. C.A.Bishop and E.F. Murphy.

A review of documentation relative to the intermixing of cod stocks near the 3Pn-3Ps boundary indicated that cod migrate out of the nothern Gulf of St. Lawrence (4RS) to overwinter in southern 4R and 3Pn. The migration sometimes extends into the Burgeo Bank (3Ps) area. The extent of the latter migration is annually variable and difficult to quantify.

Research vessel surveys have been conducted in Div. 3P during winter-spring for most years since 1979. Distribution plots indicated a general pattern with largest concentrations in the areas of Burgeo Bank and adjacent slope waters, and the southeast portion of 3Ps (**Figure 4**). This pattern was less pronounced in 1983 when the survey occurred later in the year (April-May). Current interpretations of distribution patterns may be influenced by the relatively low stock sizes.

Comparisons of annual length frequency distributions for cod from 3Pn and Burgeo Bank using the Kolmogorov-Smirnov test for paired frequency distributions indicated that they were all significantly different. The difference was less well defined in some years (1986 and 1993-April) when mixing apparently obliterated the size differences. Fish length was greater on Burgeo Bank than in 3Pn for all surveys except that in April 1993 when 3Pn cod were larger.

The modal ages in survey population estimates for 3Pn and Burgeo Bank did not correspond for most years. Values for both February and April surveys in 1993 were similar although there appeared to be a preponderance of younger cod on Burgeo Bank in February and in 3Pn in April.

(**4**) WP 94/36: Review of cod migration patterns in 3P based on published literature and NWAFC cod tagging data base. C.T. Taggart

There are approximately 21 tagging experiments in the historical DFO cod tagging data base that are of use in a quantitative analysis of migration patterns and "population" origin in the vicinity of the 3Ps region in general and Placentia Bay in particular. There are serious interpretive limitations to these data related to the original goals of the tagging, the location, numbers of animals tagged, time of tagging, reporting, and the seasonal nature of offshore vs inshore fishing effort.

Preliminary large-scale comparative analysis of historical data along the nearshore regions of the south coast of Newfoundland during the periods 1954-1963 and 1980-1989 showed little evidence of change in migratory patterns (**Figure 5**). The dominant recapture periods were between May and August during both periods (likely reflecting inshore fishing effort), but with increased proportions in the 1980-89 period during the winter (Nov.- Feb.) that likely reflect relative changes in offshore and inshore fishing effort or tag reporting relative to the 1954-63 period.

Measures of distance (euclidean) travelled by tagged fish are remarkably similar between periods and show >70% returned from within 60 miles of the marking location. In both periods there is a clear exponential decay in the proportion returned as a function of distance travelled and return distances rarely exceeded 300 miles. Relative to marking locations, the largest and similar proportions (26-32%) of tags were returned from the NE quadrant during both periods, though in the latter period (1980-89) a lower proportion was returned from the NW (14% vs 25%) and SW (6% vs 12%) quadrants, while a greater proportion (23% vs 11%) was returned from the SE quadrant. This may also reflect changes in fishing effort or tag reporting on the southern Grand Bank (SE) in the 1980-89 period relative to the 1954-63 period.

Comparative analysis of similar data on cod tagged offshore (St. Pierre/Green Bank region) during 1963 and 1986 also revealed little evidence of change in migratory patterns (**Figure 6**). However, where the dominant recapture periods were more uniform across months in the 1986 period and showed the largest proportions returned during the March to June period (9%-14%), the 1963 data showed the largest recapture period to be July, May, February and April (17%, 13%, 10%, 10% respectively). Again, the simplest explanation of the pattern is a change in effort or tag reporting in the 1960's relative to the 1980's. Relative to marking locations, there were marginally more tags returned from the NE and NW quadrant in the 1963 period relative to 1986 when marginally more tags were returned from the SE and SW quadrants. This may also reflect a relative increase in effort or reporting on the southern Grand Bank (SE) in the 1980-89 period relative to the 1954-63 period.

A qualitative analysis of the remaining data indicated the following: 1) the majority of cod tagged in September within Placentia Bay are returned in diminishing numbers from Placentia Bay, St. Mary's Bay, along the east coast of the Avalon, on the Grand Bank, St. Pierre Bank, and to the NE offshore Banks; 2) the majority of cod tagged in March on Burgeo Bank tend to be recaptured (over ~ 3-yr period) westward along the south and west coast. Fewer cod, though significant in number, are captured along the western side of Placentia Bay and along the NE coast and to the Grand Bank and offshore; 3) cod tagged in February on northern St. Pierre Bank tend to be recaptured (over ~3-yr period) eastward along the south coast, including Placentia Bay, as well as on St. Pierre Bank. Relatively few are captured west of St. Pierre Bank. 4) cod tagged in March on Green Bank (southern St. Pierre Bank) tend to be recaptured in the vicinity and eastward on the Grand Bank and northeastward and tag returns from Placentia were rare; 5) the majority of cod tagged in summer at the entrance to Fortune Bay tend to be captured in the vicinity as well as on the western side of Placentia Bay. Relatively few are captured on St. Pierre Bank and on the Grand Bank; 6) cod tagged on the eastern side of Placentia Bay are generally captured in the vicinity, though some are captured on the Grand Bank; and 7) no tags from juvenile cod tagged in St. Mary's Bay were returned from Placentia Bay. In general, the qualitative interpretation of these data is that there appears to be a flux of cod, (seasonal nature not determined at this time) from regions west of Placentia Bay (from Burgeo and northern St. Pierre Bank and Fortune Bay) into Placentia Bay. There also appears to be a flux of fish from the eastern entrance of Placentia Bay into Placentia Bay, as well as along the coast and bays to the east and northeast. There is limited evidence that fish tagged in either the southern St. Pierre Bank region or north and east of the Avalon enter Placentia Bay.

The offshore tagging (St. Pierre/Green Bank area) showed a greater distance of returns and movement to the east and southeast. This appears to be a fundamental difference between the inshore and offshore tagging, showing a linkage between offshore 3Ps and 3NO (**Figures 5** and **6**).

These kinds of evidence, along with some meristic information led Templeman (1974) to conclude that the majority of fish in the Placentia region were part of what he called the Burin-Avalon "stock", which he considered as an "inshore" stock, extending from the outer coast of the Avalon to Fortune Bay, though showing considerable migration and overlap with the Burgeo "stock".

(**5**) WP 94/22: Seasonal components in technological interactions in Gulf of St. Lawrence shrimp and groundfish fisheries. A. Sinclair.

Commercial fisheries by mobile gears (otter trawls, midwater trawls, and seines) for groundfish and shrimp in the Gulf of St. Lawrence were defined on a fine spatial and temporal scale based on catch composition of 15 species. Catch compositions were calculated by gear, 10' rectangles of latitude and longitude, and month and grouped using cluster analysis. Separate analyses of three consecutive years indicated a high degree of stability in fishery catch composition. However, the fisheries showed considerable seasonal variations in location which corresponded to the migrations of the dominant species. An animated display of the monthly maps of fishery distribution was used to visualize the movements of the fisheries.

The distribution of cod catches indicates that some modification of the current management unit definitions may be necessary. In the 4TVn area during 1990-92 the winter migration out of 4T began in November and was well advanced in December. There was a continuous distribution of catches from the southern portion of

4Vn well into 4Vs in January. There was very little catch in 4Vn during February and March when catches were high in the northern portions of 4Vs. The distribution of catches in May and June indicates that the return migration to 4T may have been ongoing during these months (**Figure 7**). The catch distribution in 3Pn4RS and 3Ps suggests that northern Gulf cod moved into northern 3Ps during February and March (**Figure 7**). If this is the case, it is possible that the research vessel surveys for the 3Pn4RS stock, which are conducted in January, and that for 3Ps cod, which has been conducted in February, may be biased. A large proportion of the 3Ps research survey abundance estimates come from the strata in this area.

The distribution of redfish catches did not entirely correspond with the current Unit 1 (Gulf: 4RST + 3Pn(Jan.-May) + 4Vn(Jan.-May) and Unit 2 (Laurentian Channel: 3Pn(June-Dec.) + 4Vn(June-Dec.) + 3Ps4VsWfgj) management unit definitions. Catches straddled the management unit boundary in Nov. and Dec. (in 4R-3Pn) as well as in Jun. to Aug. (in 4TV) Large catches were made along the 3Ps-3Pn border in Jan.-Apr. and in some months there were large catches in northern 3Ps (**Figure 8**). One can only speculate on the extent of redfish distribution into northern 3Ps in Jan.-Apr. because Newfoundland Region landings data are not available by geographic position and many of the Gulf based vessels that catch redfish in 3Pn in winter do not have redfish quotas in 3Ps. (Note: the possibility that Unit 2 redfish may be moving into 3Pn was not considered). One must also consider the possible effect of the management system on the distribution of both real and reported catches. A related concern was raised by the Committee because of lack of consideration of fishing effort in the reported analyses. The analysis presented in this working paper appeared in NAFO SCR Doc. 93/121.

(**6**) WP 94/37: The autumn migration of 4T cod as seen by the 4Vn test fishery. T.C. Lambert.

A "test" fishery for cod was carried out off eastern Cape Breton by six inshore longliners during a six-week period between October 15 and November 30, 1993. Approximately 73 kt of cod were taken. Initial catch rates were moderate, then rose to a peak near the middle of November before falling rapidly to very low levels by the end of the fishery. Length frequency data showed an increase in average size at the beginning of the fishery with a steady downward trend in size after about the second week. This trend was particularly evident in the extreme west of the fishing zone.

The pattern in length frequencies, together with trends in landings, seem to indicate the movement of Gulf of St. Lawrence cod (which, at any given age, are smaller than Eastern Scotian Shelf cod) into the Sydney Bight area. Calculated from the progression of modes in catch and length frequency, the estimated rate of migration was around twelve n.m. (21 km) a day. The first Gulf cod apparently arrived around October 29, with the bulk of migrating fish arriving about November 5.

Logbook records from 1987 to 1992 for an inshore longliner operating in the White Point Bank - St Pauls Island region show patterns of catch rates in November that are very similar to those of the "test" fishery (**Figure 9**). In addition, the proportion of large cod in the longliner catch diminished rapidly during November in all years, and by December catches were comprised of all small fish. This information along with "test" fishery data seem to indicate that the timing of the late autumn phase, at least of the Gulf cod migration, varies by less than two weeks.

(**7**) WP 94/24: Timing of commercial fisheries based on the movement of cod into and out of the Gulf of St. Lawrence, 1986-93. A. Sinclair and L. Currie.

The timing of the spring and fall fisheries at the entrance of the Gulf of St. Lawrence provided useful information to determine the occurrence of the migration of southern Gulf cod through the area. The fisheries are relatively short, 1-3 weeks between when 25% and 75% of the catch is taken, and the dates of peak catch correspond to the dates when 50% of the catch is realized (**Figure 10**). The timing of the 4Tfg and 4Vn fisheries also indicates movement through the area.

During the period 1986-90, the 4Tfg spring fisheries were about half over by May 1, indicating that a substantial portion of the southern Gulf stock was still in 4Vn in early May. In 1991 and 1992, the spring fisheries were delayed by late retreat of ice (**Figure 11**) and there were large catches of southern Gulf cod made in 4Vn during May of these years. The fall fisheries in 4Tfg occurred almost entirely during the month of November and there was no trend in the timing of these fisheries. Mobile gear catches increased in 4Vn in mid-November of all three years examined and the magnitude of the increases in catches indicated that these were almost all southern Gulf fish.

These results regarding the fall fishery indicate that the majority of November catches in 4Vn are from the southern Gulf stock. The spring fishery catch distribution suggests that a significant portion of the May catches in 4Vn are also of southern Gulf origin, particularly in 1991-92.

(**8**) WP 94/21: Distribution of groundfish during the winter 1994 Cabot Strait survey. G.A. Chouinard.

A groundfish survey was conducted in Cabot Strait (4T and 4Vsb) area from January 13-25, 1994. Seventy-two standard groundfish sets extending from 4S in the north to 4Vsb in the south were taken. Distribution of catches for 6 species (cod, redfish, white hake, A. plaice, witch flounder and Greenland halibut) of groundfish and herring were presented along with information from the Quebec Region winter survey in the northern Gulf conducted at the same time. For cod, two sets yielded more than a tonne but the remainder of the catches were less than 100 kg. Highest concentrations of cod were found along the 183 m depth contour in 4Vn (**Figure 12**). No large concentrations were detected in the middle of the Laurentian Channel or in shallow waters (<150 m) in 4Vn. Length distribution on a set by set basis for cod indicate some gradient in size; larger fish were found in the south and smaller cod in the north. Redfish catches tended to be highest in the southern section of the survey area (**Figure 13**), however, when the entire Cabot Strait is examined, the concentrations in 3Pn and 3Ps appear to be larger. Distribution according to depth for herring, cod, white hake and redfish shows that these species had relatively distinct preferred depths. The 25 and 75 percentile of cumulative catches were between 150 and 200 m for herring, 200 to 250 m for cod, 250 to 400 for white hake and >400 for redfish. Herring were found in waters less than 5°C while redfish and the flatfish species were found in waters slightly above 5°C. The largest catch of cod was made at the highest bottom temperature observed (7.5°C). Distribution of many of the groundfish species appear to be continuous between area 4T and 4Vn in winter and the migration in 4Vn appears to be widespread across species. For white hake, witch flounder, and to some extent Greenland halibut, the current management units do not appear to account for the winter distribution.

(**9**) WP 94/29: Distribution of redfish in the Gulf of St. Lawrence and in the Laurentian Channel based on RV surveys and commercial fishery catch rates. B. Morin, D. Power and P. Gagnon.

The analysis of the 4RST3Pn and 3P winter surveys from 1978 to 1993 has shown that redfish were more concentrated in the Cabot Strait area in January-February principally since 1990 and are now overlapping the 3Pn and 3Ps border (**Figure 14**). The location of highest commercial catch rates agreed well with the survey data. However, the Gulf of St. Lawrence redfish have been found in 3Pn as early as November for the last 3 years which does not coincide with the present management units (ie. 3Pn and 4Vn are still considered as Laurentian Channel redfish or Unit 2 redfish).

It also appears from the RV surveys and commercial fishery CPUE that the mixing of Units 1 and 2 redfish occurs in 3Pn and 3Ps in winter. In May, Unit 1 redfish move northward into the Gulf and Unit 2 redfish move further southward in the Laurentian Channel.

Length frequency analysis of these fish may assist in resolving the population structure of the two stocks. The distribution and the migration of the two main species of redfish (Sebastes mentella and S. fasciatus) in the Gulf of St. Lawrence are believed to be different and further investigation to describe the impact on the redfish fishery is required.

It is also necessary to emphasize the need for Newfoundland catch and effort positional data in order to obtain a more complete description of the distribution of redfish catches and CPUE in Gulf of St. Lawrence and the Laurentian Channel area. It was also noted that if distributional changes are to be inferred from commercial data, one must consider the effects of changes in regulations and associated harvesting strategies.

(**10**) 94/27: Distribution of witch and white hake in the Gulf of St. Lawrence in relation to management units. R. Morin, T. Hurlbut.

White hake are presently managed within 4T and the management unit for witch flounder is 4RS in the Gulf of St. Lawrence. The 4R, 4S and 4T divisions are contiguous with the axes of the Laurentian and Esquiman channels. Analysis of summer groundfish survey data indicated that white hake in the northern Gulf prefer depths of about 200 to 300 m. In winter, hake move to deeper channel waters where their maximum abundance is recorded at depths of 350 to 450 m. Distribution maps of combined Gulf surveys (Gulf and Quebec regions of DFO) indicate that hake concentrate during summer in the region of Northumberland Strait, off northern and western Cape Breton, and on the southern slope of the Laurentian Channel. In winter, hake are distributed in the eastern part of the Laurentian Channel uniformly across the 4RST boundaries and outside the Gulf into 3Pn and 4Vn (**Figure 15**).

Analysis of witch data from the summer surveys of 4RS indicate depth preferences of approximately 210 to 310 m. In winter, witch abundance increases with depth as they seek the deepest channel waters of the eastern Gulf. Maps of the winter distribution of witch suggest that the Gulf distribution is continuous with their presence in 3Pn and 4Vn (**Figure 16**). These results were not consistent with previous studies that differentiated 4RS and 3Pn witch on the basis of genetic and meristic characters. In general, this study confirms previous investigations that suggest management units for white hake (4T) and witch flounder (4RS) do not fully account for their seasonal distributions.

(**11**) WP 94/31: Use of otolith elemental fingerprints for differentiating among stocks of Atlantic cod (Gadus morhua). Steven E. Campana, Simon R. Thorrold and Anthony J. Fowler, Jacques A. Gagné, Cynthia M. Jones.

Trace element incorporation into the fish otolith is known to vary among samples collected at different sites. If otolith elemental composition (the elemental "fingerprint") reflects, in some way, the characteristics of the ambient water, the elemental fingerprint of the otolith could serve as a natural marker of fish populations which have inhabited different sites. By corollary, the elemental fingerprint of the otolith nucleus would serve as a marker of the hatch site.

To illustrate the approach, Atlantic cod (Gadus morhua) otoliths were collected from several spawning grounds in the northwest Atlantic and tested for differences in elemental and isotopic composition using a variety of techniques. Assays of dissolved whole otoliths using Inductively Coupled Plasma Mass Spectroscopy (ICPMS) revealed significant differences in the concentrations of 34 isotopes (representing 27 elements) among sites (**Figure 17**). The analytical sensitivity of the ICPMS reached the parts-per-billion level.

A laser-based version of the same instrument also revealed significant inter-site differences when used to assay the isotopic concentrations present in the otolith nucleus. The sensitivity of the laser ablation system exceeded that of electron microprobe by 2-4 orders of magnitude, but with much less precision than that attainable with solution-based ICPMS.

Preliminary experiments demonstrated a significant response of otolith composition to the physical and chemical environment. While the mechanism underlying trace element incorporation into otoliths is still unclear, otolith elemental fingerprinting has the potential to become an effective and accurate means of stock identification.

The laser-based system has good potential, since it can be used for both stock ID and reconstructing migratory history; however, it is still very much in the development stage. By contrast, the solution-based assays are far more established, and are now being applied to stock ID problems.

(**12**) WP 94/40: Potential for use of nuclear DNA gene probes in elucidating stock/population structure in cod and application to individuals from mixed populations. C.T. Taggart.

Techniques that may allow the genetic identification of cod populations have been applied to the evaluation of stock structure of Northern cod in the 2J3KL cod management unit. Heterogeneity among loci of 4 populations sampled offshore in January 1992 (presumed pre-spawning aggregations) ranging from Hamilton Bank in the north to the northern Grand Bank in the south is significant ($p<0.05$) in 2 of 11 cDNA loci and in 2 of 5 micro- satellite loci. Heterozygosity among the cDNA loci ranges from 0.126 to 0.593 (averaging 0.321) and is extremely high among the micro-satellite loci, ranging from 0.732 to 0.906 (averaging 0.836). Genetic distances, determined by applying both Rogers and Nie's Unbiased index to allelic patterns derived from the two very different techniques, are similar in discriminating among the populations and conform with published genetic groupings, and are consistent with studies on population distribution.

cDNA analysis of inshore and offshore Northern cod populations, sampled in the spring and fall of 1992 (presumed mixed migrants) reveal limited genetic differences, with one exception that may be consistent with the existence of relatively isolated inshore or "bay" populations, and highlights the importance of sampling spawning aggregations for population related studies on migratory species. Other factors, such as sample size limitations and differential selection among year classes, may be contributing to the observed genetic heterogeneity among the sample populations, and therefore these results should be considered preliminary.

A secondary advancement in this research stems from recently developed procedures for probing DNA (through PCR amplification) in small amounts from cellular tissue found on dried scale and otolith samples from cod preserved and catalogued by DFO-St. John's extending back to 1946. These archived tissues should enable us to estimate gene-frequency profiles and temporal stability of populations that cannot be sampled in any other way. Work is now underway to assess both the contemporary and historical population structure of northern cod in conjunction with the historical tagging data analysis.

(**13**) WP 94/25: Correspondence analysis of length frequencies of cod samples from 4T, 4Vn, AND 4Vs. G. Nielsen and A. Sinclair.

Length frequency samples collected from cod catches in 4T, 4Vn, and 4Vs were analyzed with correspondence analysis. Data collected in the Gulf and Scotia Fundy region commercial sampling programmes in 1988-1990 and observer programmes in 1991 and 1992 were used. Samples from 4T were well separated from samples from 4Vs by their scores on the first two components of the explanatory axes in the fall period of all 5 years examined. 4Vn samples overlapped those of both other areas, indicating some samples taken from 4Vn may have been a mixture of 4T and 4Vs fish. Analysis of January and February length frequencies show that some fish caught in both 4Vn and 4Vs in these months may have been of 4T fish. The analysis supports the notion that 4T fish migrate into 4Vn in the fall and then into 4Vs, returning to 4T in the spring. It appears that correspondence analysis can be of use in studying stock mixing, and investigation into refining its use may be beneficial.

(**14**) WP 94/26: Can 4T and 4Vn cod be separated from commercial catches in Sydney Bight based on length-frequency analysis? M. Hanson.

Because Atlantic cod caught during July research surveys in Sydney Bight were much larger at age than those caught during September research surveys in the southern Gulf (**Figure 18**), length-frequency data from the commercial fishery could be used to separate the catch-at-age of the two stocks during periods of stock mixing - provided that suitable sampling (numbers of age-determinations and length-frequencies) had been done during the period of mixing and when the stocks were thought to be separate.

Too few data were available to permit separation of catches of cod in Sydney Bight into stocks of origin on a monthly basis, therefore, the data were grouped by season. The winter fishery (January through April) in Sydney Bight is prosecuted principally by otter trawlers and analyses for data from 1986 to 1991 confirmed that these landings were composed almost entirely of fish of southern Gulf of St. Lawrence origin. Only limited data were available for fixed gear and mobile gear landings from Sydney Bight during spring (May-June), nevertheless, moderate numbers of southern Gulf cod could be identified in these catches. Although few data were available for the fixed and mobile gear landings in Sydney Bight for the autumn period (October-December), large numbers of southern Gulf cod were identified in the landings. These results are consistent with the patterns of fishing effort in both the southern Gulf and Sydney Bight from October to May, i.e., the autumn migration of cod out of the southern Gulf of St. Lawrence begins in late October and is largely completed by the end of November and the spring migration back into the southern Gulf usually begins in April but can be delayed until June during years of late ice-melt in the southern Gulf.

(**15**) WP 94/39: Parasites as indicators of Gulf of St. Lawrence fish stocks. G. McClelland, D.J. Marcogliese and J.R Arthur.

Parasites have been widely used as indicators of fish populations, including North Atlantic cod (<u>Gadus morhua</u>) stocks. An earlier 1980-81 survey of larval sealworm (<u>Pseudoterranova decipiens</u>) and related species of parasitic nematode (<u>Anisakis simplex</u> and <u>Contracaecum osculatum</u>) in southern Gulf of St. Lawrence (4T) and Breton Shelf (4Vn) cod revealed that inshore fish were infected with significantly greater numbers of sealworm larvae than offshore fish and that abundances of <u>A. simplex</u> and <u>C. osculatum</u> larvae were significantly greater in migrant 4T cod than they were in local 4Vn cod (**Figure 19**). Reanalysis of these data employing multivariate procedures showed that while spring samples of cod from the southeastern Gulf differed from other 4T samples in regard to <u>P. decipiens</u> and/or <u>C. osculatum</u> levels, all three species of nematodes were uniformly prevalent and abundant in summer and fall samples from the southwestern Gulf, Bradelle Bank and St. Paul's Island.

Samples from the 4Vn winter cod fishery were consistent with cod sampled in 4Vn in late spring and summer in respect to nematode levels but had significantly lower levels of A. simplex and C. osculatum than migrant 4T cod. This would seem to indicate that the winter samples were primarily local 4Vn fish.

Along with larvae of the spiny-headed worm, Corynosoma strumosum and the parasitic flatworm, Otosistomum sp., larval sealworm, A. simplex and Contracaecinea have also been shown in other studies to be able to delineate Greenland halibut stocks from the Gulf of St.Lawrence, the Saguenay Fiord, Hamilton Bank and the Cumberland Sound. In this instance, the geographic origins of individual fish were identified with almost 100% certainty by nonparametric discriminant analysis of parasite levels. It is unlikely, however, that larval anisakines (sealworm and related species) would be useful indicators in discriminating northern Gulf (4RS) from southern Newfoundland (3P) groundfish stocks. A complete inventory of groundfish parasites from these latter areas may be necessary in order to identify suitable natural tags.

(**16**) WP 94/32: On the interannual variability of ice conditions in the vicinity of Cabot Strait. K.F. Drinkwater and G.L. Bugden.

Interannual variability in ice cover may be one factor that might result in fluctuations in the seaward extend of the migration of fish from the Gulf of St. Lawrence. For example, more ice may lead to an extended outward migration of cod and hence greater mixing with adjacent stocks along southern Newfoundland and the eastern Scotian Shelf. Although quantitative estimates of the degree of stock mixing are unavailable, an analysis of the ice statistics was undertaken.

First the long-term (1962-87) median, maximum and minimum positions of the ice edge in Cabot Strait and on the Scotian Shelf were presented. Ice normally covers the Gulf of St. Lawrence by late February with the exception of the area around the southwest tip of Newfoundland. Ice also normally occupies Sydney Bight and extends out onto the eastern Scotian Shelf during February and March. In heavy ice years the entire eastern Scotian Shelf may be ice covered and extend southward along the coast as far as Halifax in late February or March.

The interannual variability in ice conditions was described in terms of the time of first ice, time of last ice and ice duration at three sites, one in western Cabot Strait, one off Scateri Island in eastern Cape Breton and the other near Burgeo Bank off southern Newfoundland (**Figure 20**). Ice usually lasts two to three months in Cabot Strait and off Scateri Island but less than a month off southern Newfoundland. At the later site, ice was observed in only half of the number of years when data were available (1960-1993). In the last 2 years, the ice has generally appeared earlier and left later than average at all three locations. Similar ice conditions were observed in the early 1970s but contrast with the light ice years in the early 1980s.

An empirical model was developed based upon monthly mean air temperatures and northwest wind stresses which accurately predicted the presence of first ice and the duration of ice for the Cabot Strait area. Ice conditions off Scateri Island were also modeled using temperatures and wind but with slightly less predictive ability than in Cabot Strait.

(**17**) WP 94/33: Variability in the position of the shelf/slope front near the mouth of the Laurentian Channel. K.F. Drinkwater and G.L. Bugden.

It has been suggested that the degree of mixing of fish stocks may be influenced by changing temperature conditions. The longest time series of temperatures in the area is for the deep (200-300 m) waters in Cabot Strait. Previous studies have shown that interannual changes in temperature in this layer are due to varying proportions of the constituent water masses and that the position of the boundary between the shelf waters and the offshore slope waters mirrored the changes in Cabot Strait temperatures. When the front was closer inshore the temperatures were warmer. A 2.5 year lag occurs between the frontal boundary positions and the temperatures, which is the time it takes for any temperature events occurring at the mouth of the Laurentian Channel to reach Cabot Strait. Due to this lag, monitoring the front was believed to provide an early indication of temperature conditions in the Strait. In the present study, the relationship between the shelf/slope front and deep temperatures in Cabot Strait was tested with an additional 7 years of data.

The shelf/slope front undergoes a seasonal shift off the mouth of the Laurentian Channel of approximately 40 km from offshore in winter to onshore in late summer and early autumn. The low-frequency variability of the front shows an onshore movement in the early 1980s from a minimum in the late-1970s. The front reached its maximum onshore position in 1984. The front retreated to near its long-term mean location after 1984 and remained there for several years. In 1993 the front again moved onshore. The temperature pattern in Cabot Strait in recent years has been one of above normal temperatures with a decline in the late 1980s to a strong negative anomaly that bottomed out in 1991. Since that time, deep temperatures have returned to warmer-than-normal conditions. This pattern does not match the recent positional changes in the shelf/slope front (**Figure 21**) and thus it does not appear that the frontal positions can be used to predict bottom temperatures in Cabot Strait as had been suggested from earlier studies.

(**18**) WP 94/45: Temperature distributions at the entrance to the Gulf of St. Lawrence. G. Bugden, B. Petrie, and K. Drinkwater.

The temperature distribution at the entrance to the Gulf of St. Lawrence is characterized by relatively sharp horizontal and vertical gradients and variations on widely varying time scales. These characteristics make it difficult, with limited sampling, to document all of the various changes which may be occurring. By choosing appropriate areas and types of analysis, some recent changes at relatively long time scales (7-10 y) have been documented, even with modest temporal and spatial coverage.

(**19**) WP 94/42: Gulf of St. Lawrence cod tagging results related to environmental conditions. G. Bugden and W.T. Stobo.

The waters of the Laurentian Channel below about 200 m were significantly colder prior to about 1970 than in the 1980's (**Figure 22**). Differences in the returns of tags from cod tagged in the Southern Gulf during these two periods were sought. Because of the extensive annual migration of the cod and potential differences in the behaviour of Eastern and Western Gulf stocks an attempt was made to separate the eastern and western releases and to compare only results from fish released during the same seasons. Preliminary results showed no striking differences in the distribution of recoveries between releases before after 1970, except that the return rate of tags was higher before 1970. This might indicate high mortality in recent years.

(**20**) WP 94/46: Distributions of dissolved oxygen in the Laurentian Channel. G. Bugden and D. D'Amours.

Dissolved oxygen is relatively difficult to measure properly and oxygen sensors fitted to CTD's must be regularly calibrated by comparison to field titrations if acceptable results are to be obtained. Titrations require special skills and equipment if they are to be reliable.

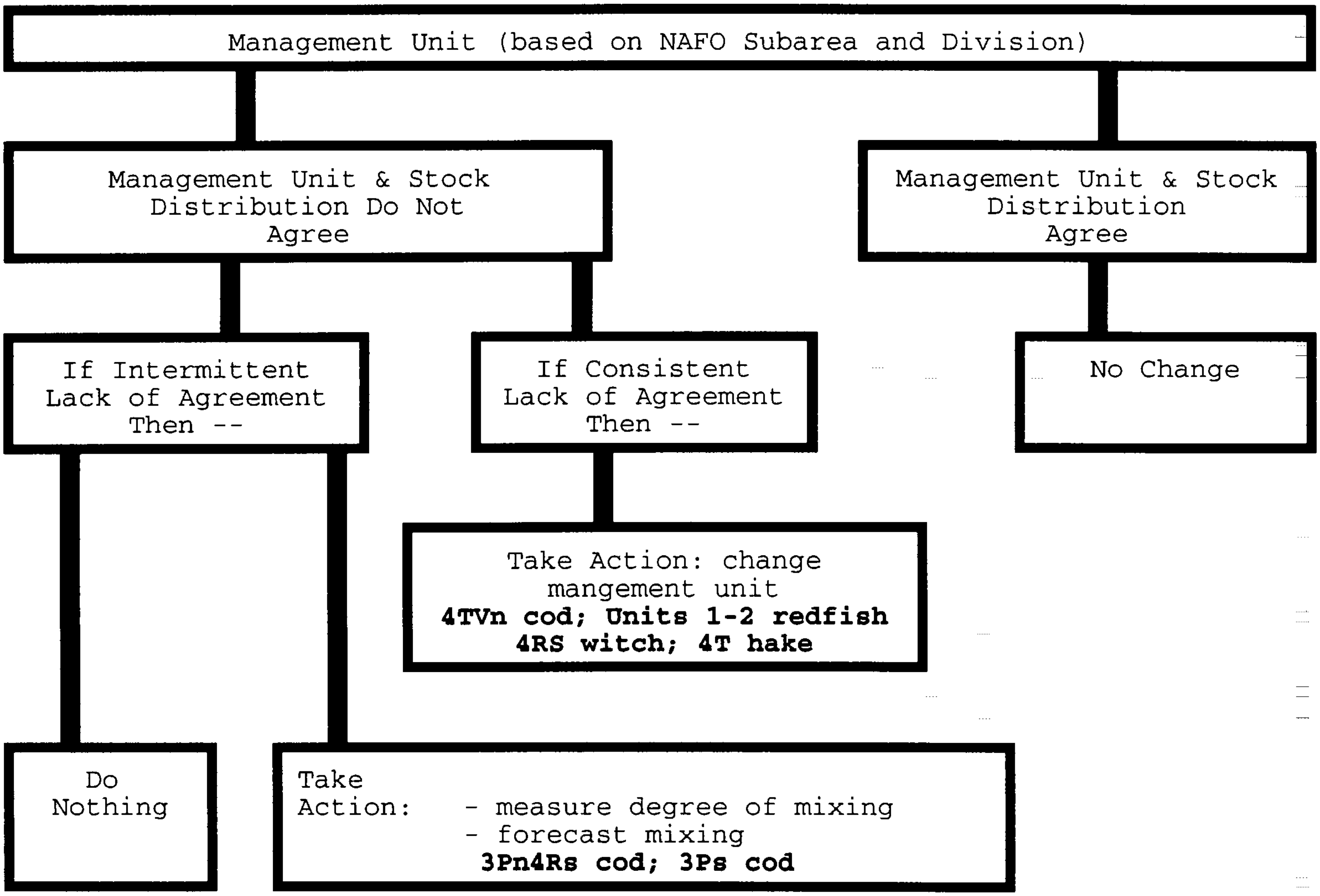
DISCUSSION and CONCLUSIONS

The terms of reference given to the Working Group on the Oceanographic Effects on Stock Migration and Mixing have generally been met although not all possible analyses have been conducted nor was all relevant material/approaches reviewed. For example, appropriate position data were not available for landings in the Newfoundland region, age-structured spatial analysis of survey catch rates was not evaluated, and inter-comparisons of stock identification techniques from simple (morphometric/meristic) to complex (parasites, genetics, otolith element composition) were not made. It was also apparent that some of the recent observations on variations in stock distribution are not new but have been described in varying detail in the past. The current fish distribution problems appear, in part, to be due to the fact that there are simply fewer fish everywhere - a situation that now requires a more exact accounting of the limited quantities of fish available to each fishery. The working group in many instances better demonstrated the existence of stock mixing than in the past based on combining surveys from different regions and countries, the use of computer animation and graphics of positioned catch and effort data, and initiation of a new winter survey in the Cabot Strait area during January 1994. Interpretation of fish distribution patterns and their variability using physical oceanographic data remains a challenge, although advances have been made in terms of characterizing associations between water mass types and fish concentrations that may ultimately lead to better understanding of stock mixing and migration patterns. This work is hampered by a lack of time series of the extent of stock mixing.

For 4TVn cod, Unit 1 and 2 redfish, 4RS witch, 4T hake, 3Pn4Rs cod and 3Ps cod, their winter distribution pattern did not fully agree with the management unit definition. The combination of survey catch information from different surveys conducted at the same time proved to be particularly useful in examining potential stock overlap. This should be encouraged and expanded to all available surveys. Using a combination of different methods (e.g. fishery distribution, RV surveys, length frequency (correspondence) analysis, etc.) gives more discriminating power when trying to resolve these issues (e.g 4TVn cod).

It appeared that for 4TVn cod, Units 1-2 redfish, 4RS witch, and 4T hake, there has been a consistent lack of agreement between the management unit and winter distributions. This is in contrast to the situation for 3Pn4RS cod and 3Ps cod, where the lack of agreement between the management unit and stock distribution has been more variable (or intermittent) over the recent past. If one follows the decision framework suggested by the Working Group Chairmen then, for 4TVn cod, Unit 1-2 redfish, 4RS witch and 4T hake, consideration should be given to changing the management unit defintion (in time or space). For instance, cod catches in 4TVn (Jan.-Apr.) may be more appropriately considered as 4TVn (Nov.-May) based on the material reviewed by FOC, although the timing of the return migration of Gulf cod from 4Vn during the spring is variable and depends on ice conditions in the eastern Gulf. The outward migration of 4T cod into 4Vn occurred quite regularly each year, however, and was corroborated by fishing patterns of mobile and fixed gear catches and the 1993 "test" fishery in 4Vn. The northern Gulf - 3Ps winter mixing has been documented repeatedly in the past based on the analysis of tagging data, morphometrics, meristics, parasites, etc., although the mixture has never been quantified. The recent occurrence of northern Gulf cod in 3Ps does appear to be related to heavy ice conditions in the northern Gulf.

Following the Working Group Chairmen's framework the following summary is provided:



3Pn 4RS and 3Ps cod stocks

Cod which inhabit the waters of the south and west coasts of Newfoundland are managed separately as 2 stocks: 3Pn4RS and 3Ps. Reviews (WP 94/28 and WP 94/38) of literature indicated that the occurrence of 3Pn4RS cod in 3Ps is not a recent event; composite maps from regional RV surveys (WP 94/20) suggested a highly variable influx of Gulf cod onto Burgeo Bank and adjacent slope waters. Analysis of commercial catches also indicated that the fishery for northern Gulf cod (3Pn4RS) moved into 3Ps during February and March (WP 94/22). Comparisons of annual cod length frequencies from 3Pn and Burgeo Bank indicated that they were significantly different but variable; the modal ages in survey population estimates for 3Pn and Burgeo Bank did not correspond for most years (WP 94/38). There appear to be two cod components in Div. 3P: a southern component near Halibut Channel, having higher affinities with 3O, and a component around Burgeo Bank, having more affinities with 3Pn (WP 94/38); this is consistent with the preliminary analysis of 3P cod tagging data suggesting two stock components: an inshore component with ties to 3Pn and an offshore component more related to 3NO (WP 94/36). Since 1987, the proportion of cod in deeper water has increased. This could indicate a migration of the fish into deeper water; however, this increased proportion of fish in deeper water could also be due to a decrease in cod biomass in shallower water or to a reduction in recruitment Age-disaggregation of the survey data would be useful to help resolve year-class effects on apparent depth distribution changes. The depth distribution of cod may also be linked to the ice-regime (first and last presence of ice and ice duration) in the area of Cabot Strait.

There was no doubt about the presence of 3Pn4RS cod on Burgeo Bank and the Committee discussed three possibilities to overcome the problems of mixing on the estimates of stock abundance and management. These were: 1) eliminate fishing during winter in 3P, 2) combine winter RV surveys in order to partition cod into appropriate stocks, and 3) conduct RV surveys at other times of the year in the Gulf and off southern Newfoundland. Variations of the second and third option have already been implemented to some extent, while the first option needs broader evaluation than FOC can provide.

4T4Vn COD

The timing of the spring and fall fisheries at the entrance of the Gulf of St. Lawrence was evaluated based on commercial catches (WP 94/24). In spring 1986-90, the 4Tfg spring fisheries were about half over by May 1, indicating that a substantial portion of the Southern Gulf stock was still in 4Vn early in May. The fall fisheries in 4Tfg occurred almost entirely during November. The results from the fall fishery indicate that all November catches should be included as part of the southern Gulf stock. The timing of the fall cod fishery is quite predictable (8 d range from 1986-92); the timing of the spring fishery is less predictable, and has been late in recent years due to recent extensive ice-cover in the area in spring (WP 94/24). There was a continuous distribution of catches from the southern portion of 4Vn well into 4Vs in January, with little catch in 4Vn during February and March, when catches were high in the northern portion of 4Vs.

Data from Gulf and Quebec Region winter surveys in 1994 support the notion of 2 areas of concentration of cod in Cabot Strait (3Pn-4Vn)(WP94/21). The length distribution for cod in southern Cabot Strait is consistent with that from the southern Gulf in the summer. With the recent shift in distribution towards deeper water for 3Pn4RS cod in winter, it is noted that catches made in 4Vn close to the 3Pn-4Vn line in the Laurentian Channel may be of 3Pn4RS origin. This was particularly apparent when the catches of winter surveys are combined onto one map.

Catch rates of cod in a test fishery in Sidney Bight were fair in mid-October, then rose to a peak in middle November before falling to low levels at the end of November; length frequency information showed an increase in average size at the beginning of the fishery, with a downward trend after the second week. These observations are interpreted as evidence of movement of 4T cod into Sidney Bight area in early November (WP 94/37). These observations from the test fishery are consistent with logbook catch records from a fisherman in the Sidney Bight area. With data on length per area and time of peak catch per area, the migration speed of cod was estimated at about 21 km per day.

Correspondence analysis of cod length frequencies from 4T, 4Vn and 4Vs is consistent with the migration pattern described above (WP 94/25).

For now, it may be appropriate to change the management unit period from December to November for Gulf cod. The relation of the cod in 4Vn during May-October with the adjacent 4VsW and 4T stocks needs to be further investigated. Although the return migration in April-May from 4Vn to 4T was more variable than the fall event, it would be warranted to monitor the situation as there may be significant overlap in May in certain years and particularly recently.

Redfish Unit 1 (Gulf: 4RST + 3Pn(Jan.-May) + 4Vn(Jan.-May)) and Unit 2 (Laurentian Channel: 3Pn(June-Dec.) + 4Vn(June-Dec.) + 3Ps4VsWfgj)

The analysis of the 4RST, 3Pn and 3P winter surveys show that redfish are concentrated in the area of Cabot Strait in January-February, especially since 1986-87, and to a greater extent since 1990, and overlap the 3Pn and 3Ps border (WP 94/29).

From the commercial catches from 1990, the general temporal evolution reveals higher catches south of 4R, in 3Pn and northern 3Ps from November to April, and a gradual shift to the Gulf of St. Lawrence and the west side of the Laurentian Channel (4Vn and 4Vs boundary) from May to October. Gulf of St. Lawrence (Unit 1) redfish were found in 3Pn as early as November for the last 3 years, at a time when redfish from 3Pn and 4Vn are considered as fish from Unit 2. For redfish in Unit 1, there were also some indications of overlap in northern 3Ps during winter. The unavailability of logbook data with positional information from the Newfoundland region and the fact that a portion of the fleet (Gulf based vessels) has limited access to that area, made it difficult to arrive at a definite conclusion.

Consideration should be given to advancing the management unit period (from January to November) for the inclusion of 3Pn and 4Vn fish to Unit 1. The mixing of fish from the 2 units is apparently important in 3Pn and 3Ps boundary area in winter until May, when the 2 Units segregate. There were also some indications of Unit 1 redfish remaining in 3Pn in the summer. This appeared to be recent and may be linked to oceanographic conditions. It was concluded that further information both on the timing of migration in and out of the Gulf of St. Lawrence and on distribution in northern 3Ps would likely help in resolving the redfish management units.

Witch and White Hake

Analysis of groundfish survey data indicated that white hake (4T) and witch (4RS) extend their winter distributions beyond their management unit definition (WP 94/27). Catches of witch and hake inside the Gulf of St. Lawrence in January were low (WP 94/21), which is consistent with a migration out of the Gulf into the Sidney Bight area and beyond. It was noted that for witch, a previous study indicated that witch found in 3Pn in winter are genetically different from those found inside the Gulf of St. Lawrence. For white hake, there appears to be two components in 4T in summer (a deep-water and a shallow Northumberland Strait group). Both of these components likely migrate to Cabot Strait in winter. In addition, concentrations from the northern Gulf also likely migrate to the Cabot Strait in winter.

Oceanographic variability and changes in fish distribution

The functional relationships between fish distribution and environmental conditions are generally not well understood. Further, to test for any such relationships, both the distribution and environmental conditions must be expressed quantitatively. The lack of quantitative indices of interannual stock mixing and changes in fish distribution has in part hampered extensive examination for environmental relationships. Distributional studies are most often presented as a time series of plots showing changes in fish abundance as a function of location. For statistical analysis abundance changes must be reported as a scalar if they are to be related to any change in the oceanographic environment. It must also be recognized that our existing time series of ocean variables, as well as their temporal and spatial scales (see WP 94/45), were not necessarily chosen to specifically examine fish migration and distribution patterns.

One environmental variable which appears to explain the date of the return migration of cod into the Gulf is the timing of the disappearance of sea ice (WP 94/32). A project scheduled to begin during spring 1994 will digitize ice data seaward of Cabot Strait including conditions on Sydney Bight, Burgeo Bank and on the eastern Scotian Shelf. The data cover the time period from 1960 to present. These, together with the ice data from the Gulf, should be analyzed further in relation to changes in fish distribution, especially for those apparent distributional changes in 3Pn4RS (earlier and quicker fall migration of cod into deep water; WP 94/20) and the spring migration of cod into 4Tfg (WP 994/21).

A previous study had suggested that the deep (200-300 m) water temperatures in Cabot Strait could be predicted 2-3 years into the future from knowing the surface position of the shelf/slope front. Using 7 years of additional data, this relationship could not be confirmed and the frontal position is no longer consider a good predictor of Cabot Strait temperatures (WP 94/33).

Other Issues

Tagging

The tagging information (WP 94/36, 94/42) showed little difference in the release-recovery patterns between the 1980s and pre-1970s. The only exception was in the percent recovered which was significantly higher in the earlier years. Further studies are suggested to determine whether this was related to differences in fishing practices, reluctance to return tags in recent years or reflects changes in mortality.

Stock Discrimination Techniques

Papers were presented on four stock discrimation techniques. These included otolith elemental composition (WP 94/31), genetics (WP 94/40), length-frequency analyses (WP 94/25; WP 94/26) and parasites (WP 94/39). The first two methods are relatively new but offer high discriminatory powers and continued analysis is encouraged. The length-frequency and parasite analyses showed certain discrimatory powers for the stocks under consideration and some combination should be continued to monitor stock mixing.

Commercial Logbook Data

Finally, FOC noted that a substantial effort was made to combine research vessel survey and commercial fishery data from the four Atlantic regions to investigate the question on fish distribution in the Laurentian Channel area. However, the lack of commercial logbook position data from the Newfoundland region was considered a serious detriment to the analysis and it needs to be rectified. In addition, several new techniques were used to analyze these data. This improved spatial and temporal resolution of the data has undoubtedly contributed to a better perception of reality. In order to continue to monitor and better understand fish distributions in this and other areas it is imperative that inter-regional data exchange and calibration continues, and that appropriate data continue to be collected. This is particularly relevant to commercial logbook data.

Appendix 1. List of attendees for the 23-25 March 1994 of Fisheries Oceanography Committee.

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5	K. Zwanenburg	MFD, BIO	(902) 426-3310
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7	G. Nielsen	MAFD, Gulf	(506) 851-2035
8	G. Chouinard	MAFD, Gulf	(506) 851-6220
9	K. Drinkwater	PCS, BIO	(902) 426-2650
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11	J.M. Hanson	MAFD, Gulf	(506) 851-2047
12	C. Bishop	DFO, St. John's	(709) 722-2053
13	W.R. Bowering	DFO, St. John's	(709) 772-2054
14	D. Rivard	DFO, Ottawa	(613) 990-0281
15	B. Atkinson	DFO, St. John's	(709) 772-2052
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18	G.M. Fowler	MFD, BIO	(902) 426-9646
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22	D. Gilbert	DFO, Mont Joli	(418) 775-0570
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32	G. McClelland	MFD, HFRL	(902) 426-2593
33	R. Branton	MFD, BIO	(902) 426-3537

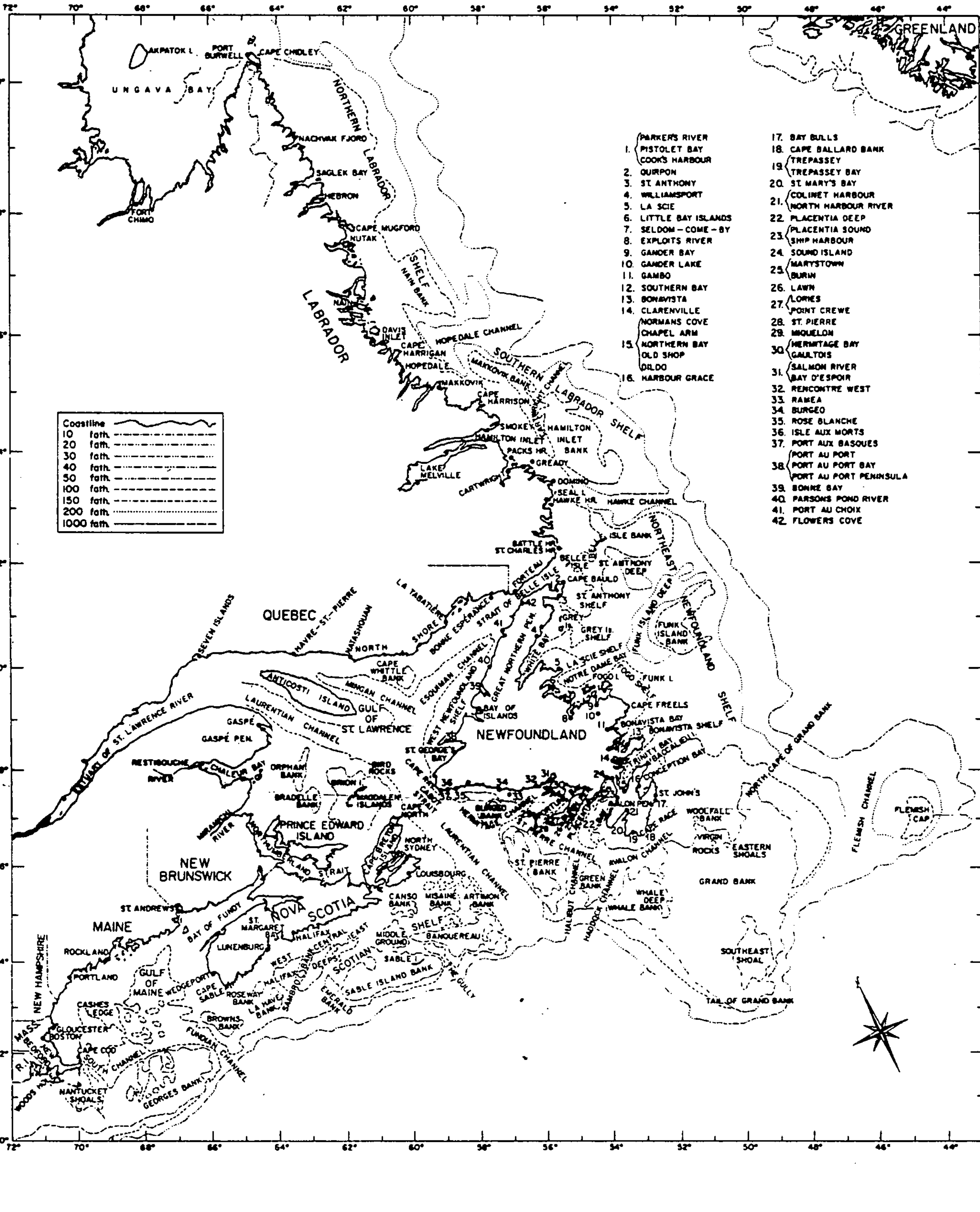


Fig.1. Map showing place names referred to in the report.

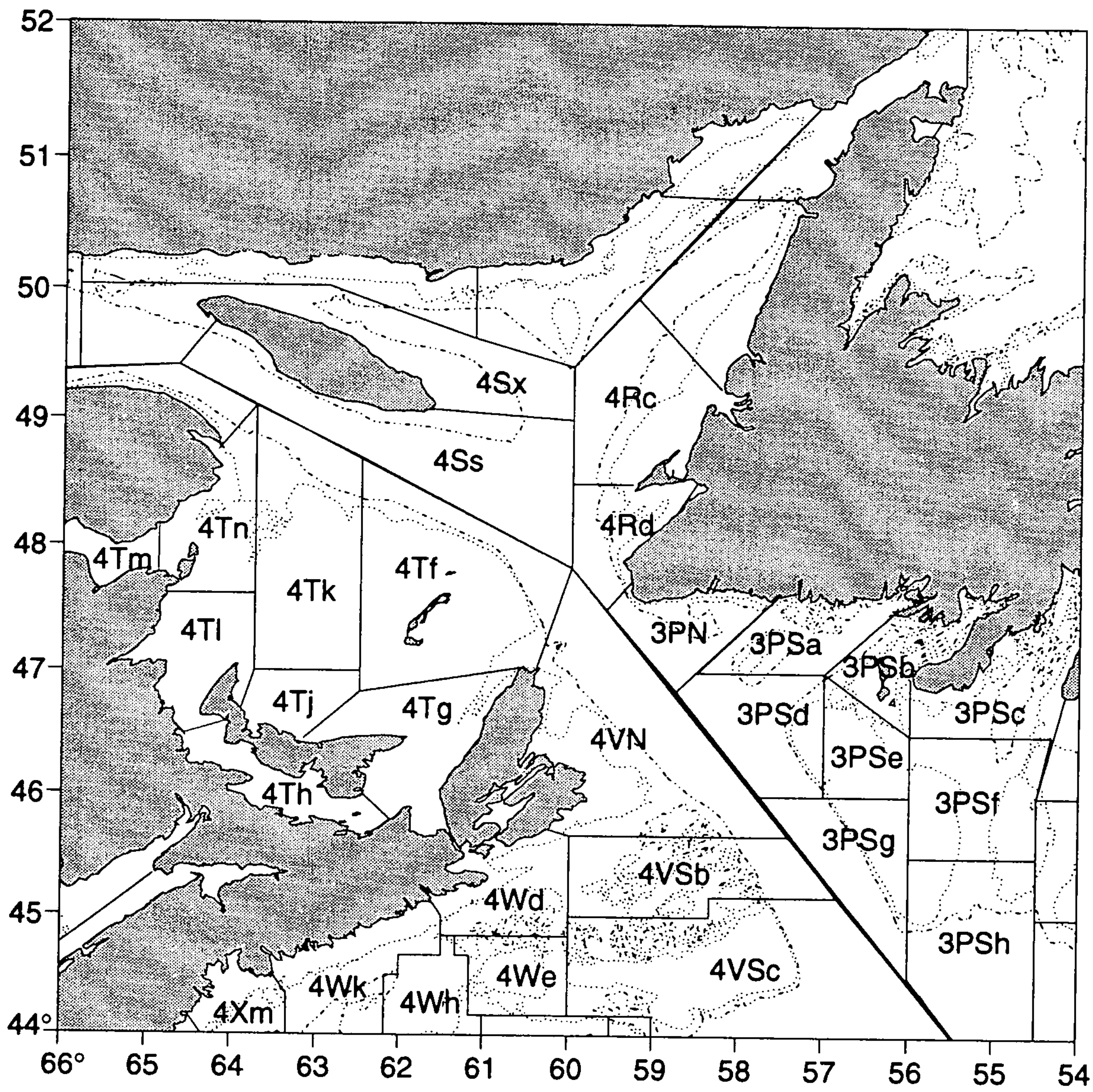


Fig. 2. Map showing NAFO Divisions and Subdivisions as well as statistical areas in the Gulf of St. Lawrence, southern Newfoundland, and eastern Scotian Shelf regions.

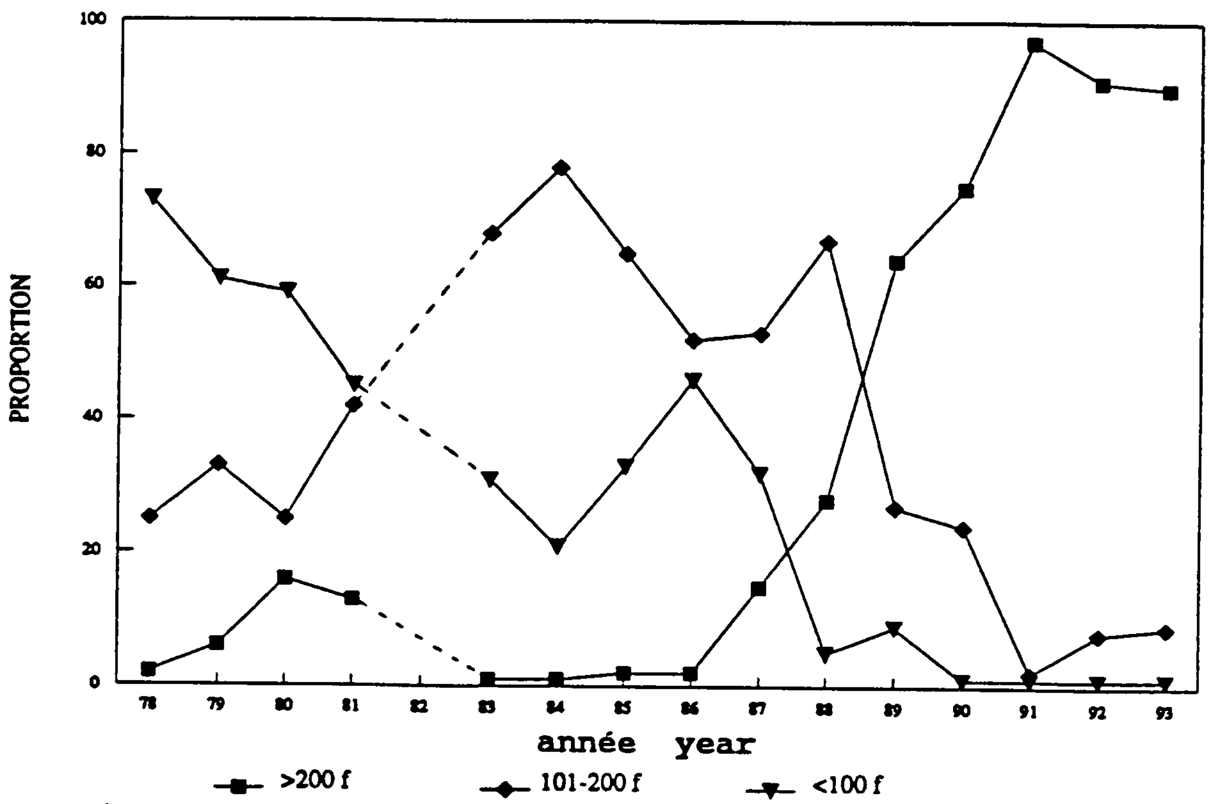


Fig. 3. Percent cod biomass by depth during the winter groundfish surveys in 3Pn4RS (from WP 94/20).

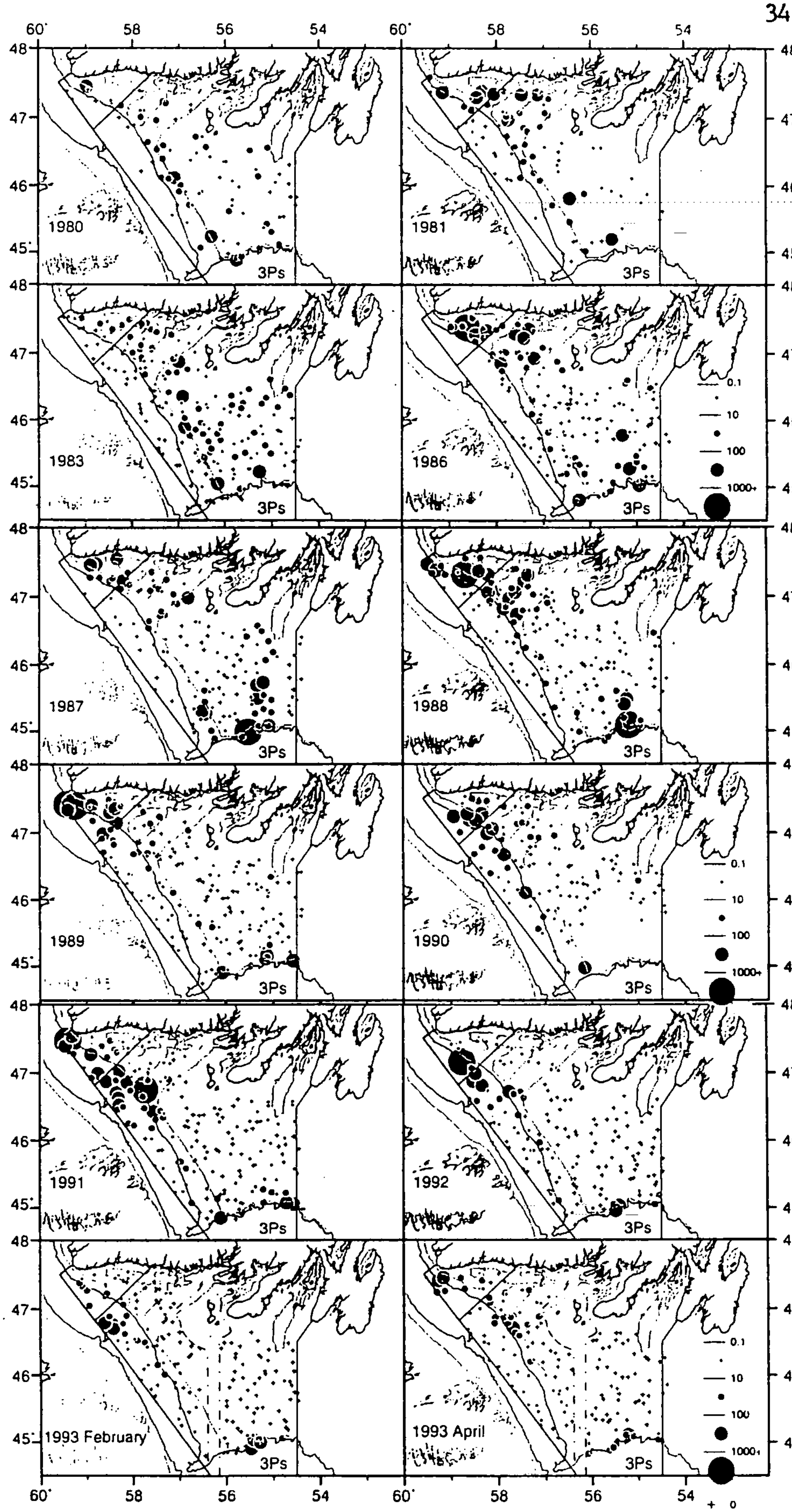


Fig. 4. Cod distribution (numbers per standard tow) from Canandian winter-spring surveys in 3P. Surveys were conducted during March in 1980-81, April-May 1983, March in 1986, February-March in 1987, and February in 1988-93. An additional survey was conducted in April 1993 (from WP 94/38).

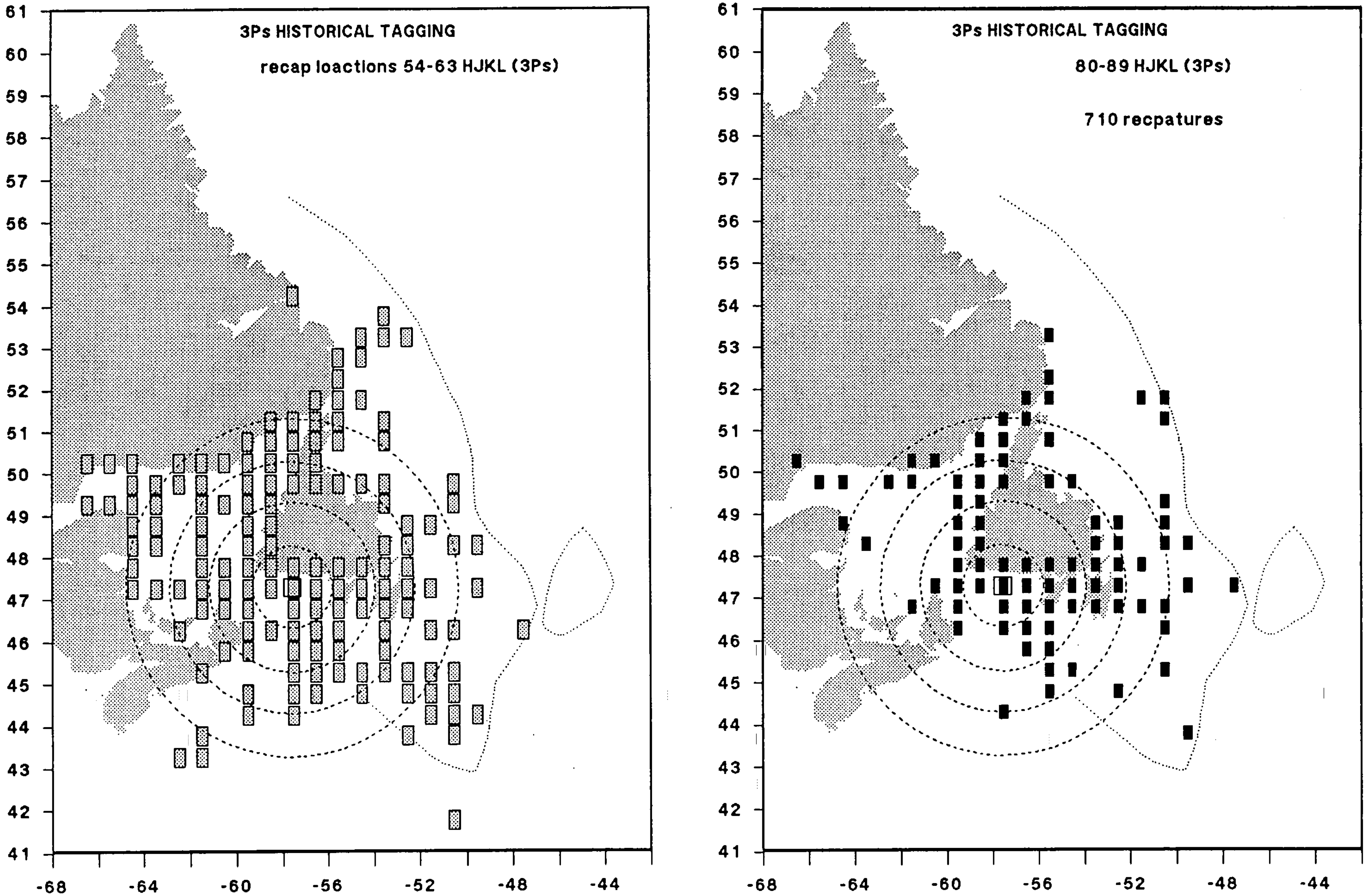


Fig. 5. Chart showing the geographic distribution of tag return sites (resolved on a 30 nm grid) for a combination of tagging studies conducted along the nearshore and bays of coastal southern Newfoundland during period 1954 to 1963 (left panel) and during the period 1980 to 1989 (right panel). The centre of the "bulls-eye" represents the centroid of all the coastal release locations and each successive ring from the centre denotes a 60 nm increment. Note that the number of tags returned from each highlighted grid point decreases exponentially from the centre (from WP 94/36).

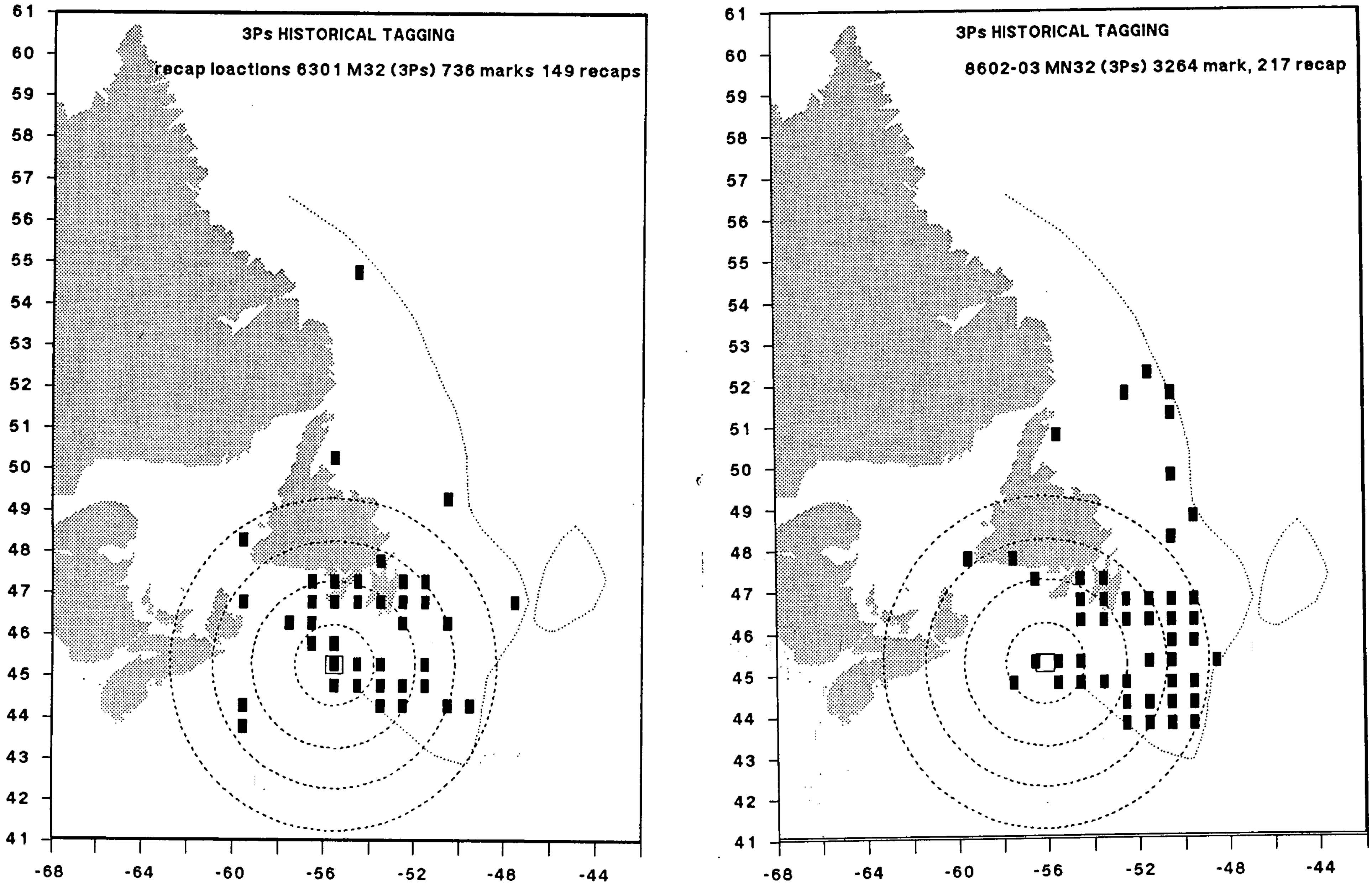


Fig. 6. Chart showing the geographic distribution of tag return sites (resolved on a 30 nm grid) for a combination of tagging studies conducted offshore (St. Pierre Bank/Green Bank region) of southern Newfoundland during 1963 (left panel) and during 1986 (right panel). The centre of the "bulls-eye" represents the centroid of all the offhsore release locations and each successive ring from the centre denotes a 60 nm increment. Note that the number of tags returned from each highlighted grid point decreases exponentially from the centre (from WP 94/36).

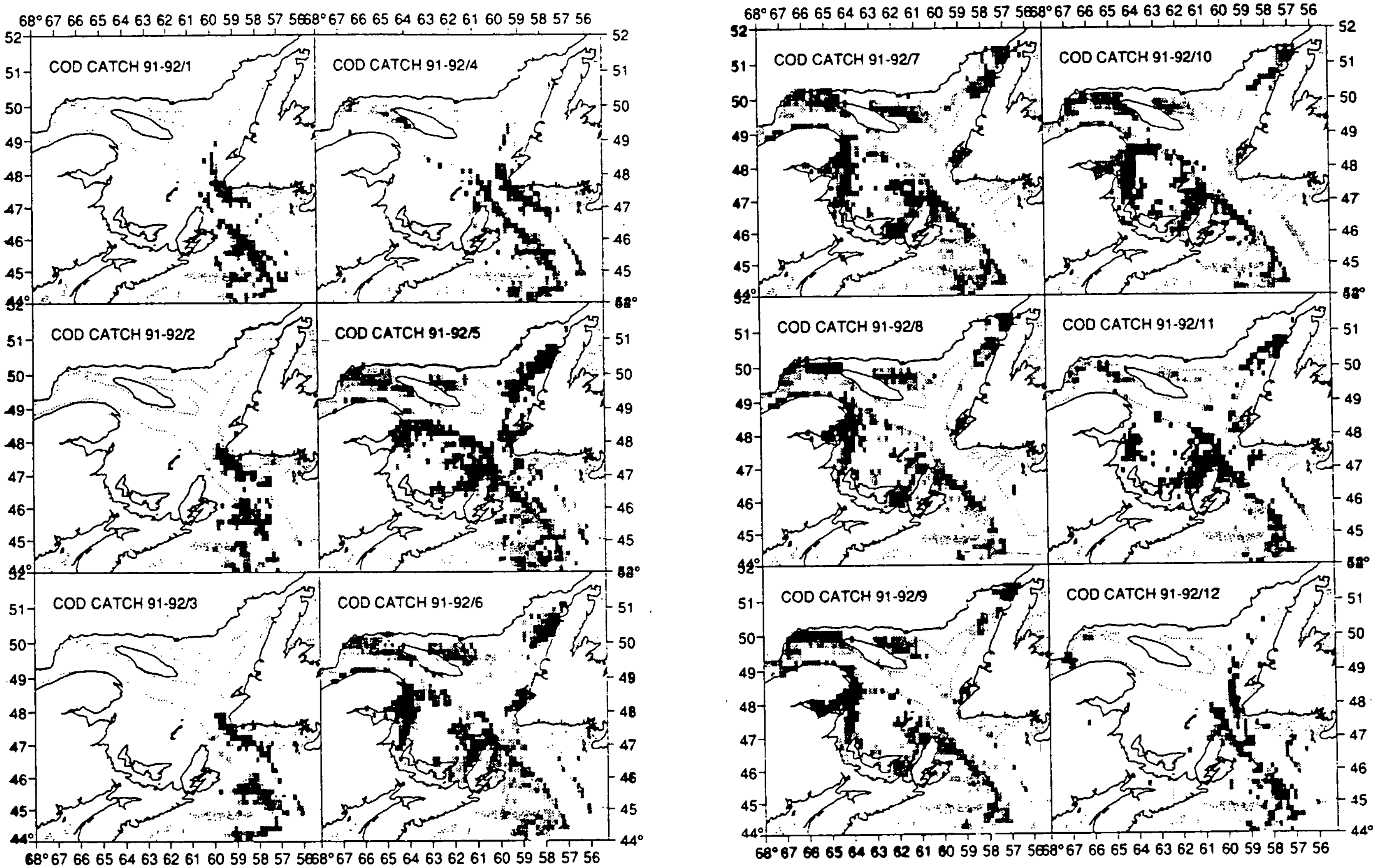


Fig. 7. Cod catches from 1991-92 combined for mobile gear groundfish fisheries aggregated by 10' grids, month and year. Shading intervals are 0.5, 10, 50, and 100 t. Catch data were obtained from Gulf, Quebec, and Scotia-Fundy regional statistics DFO branches (from WP 94/22).

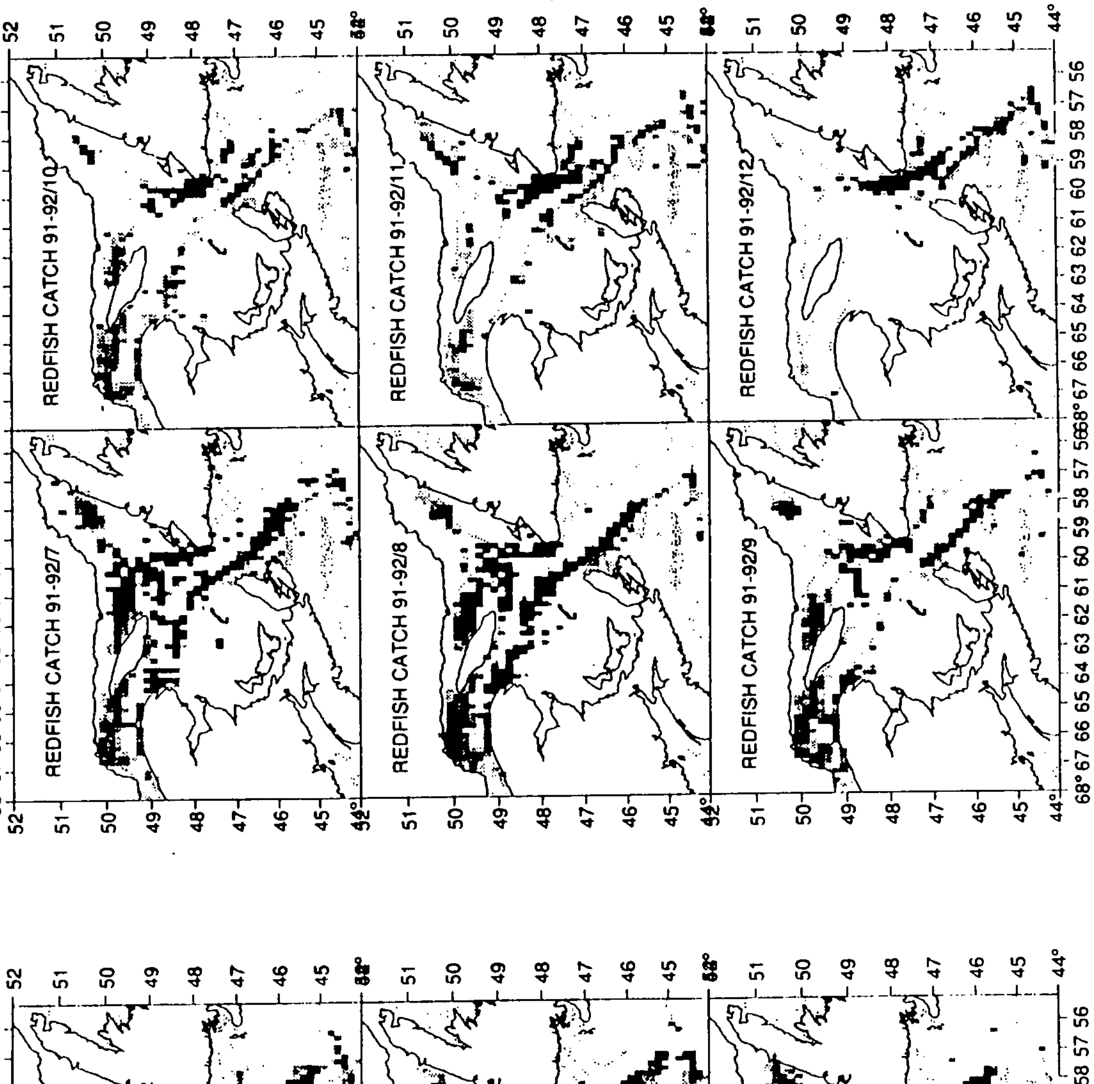


Fig. 8. Redfish catches from 1991-92 combined for mobile gear groundfish fisheries aggregated by 10' grids, month and year. Shading intervals are 0.2, 1.5, 10, and 50 t. Catch data were obtained from Gulf, Quebec, and Scotia-Fundy regional statistics DFO branches (from WP 94/22).

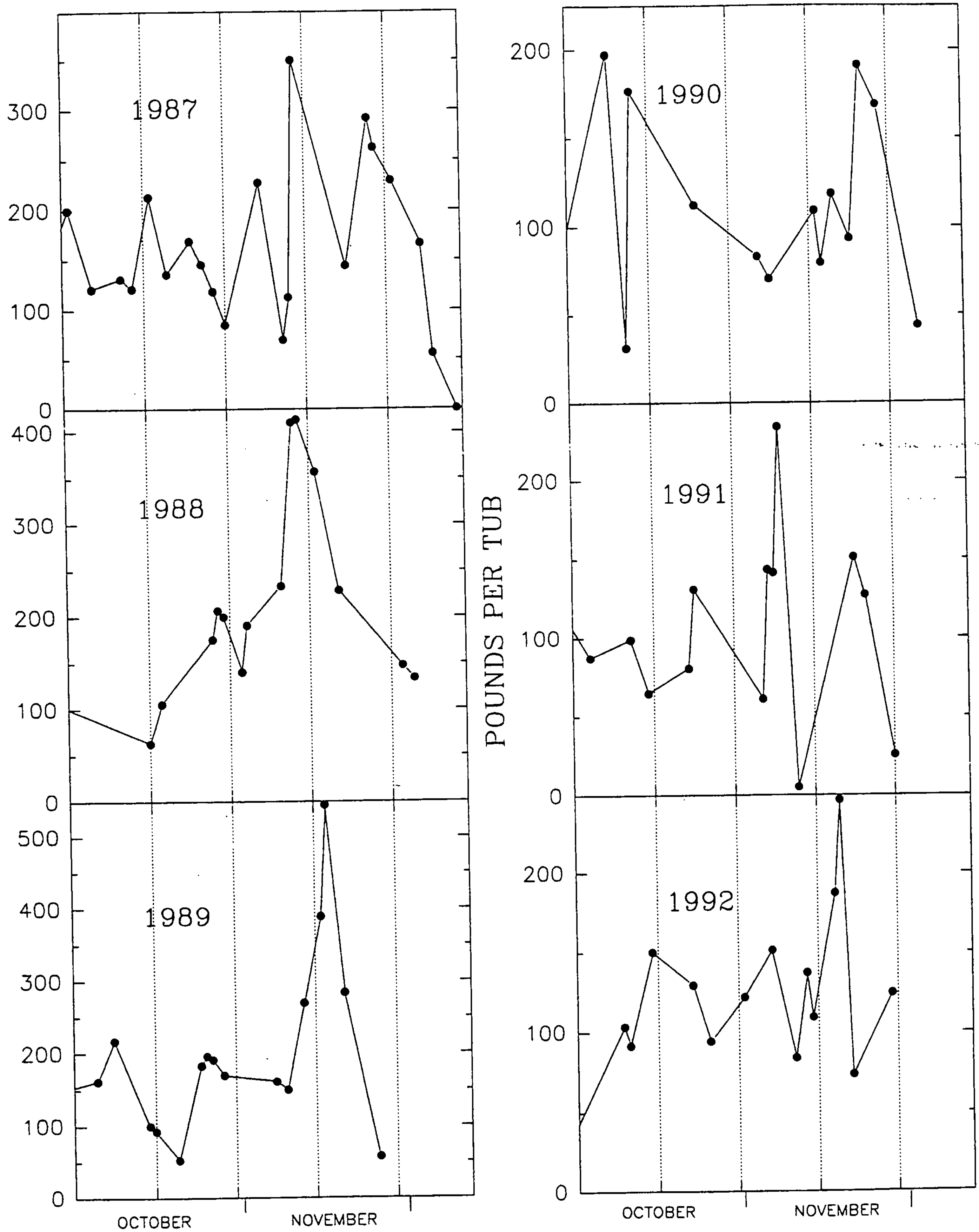


Fig. 9. Cod catch rates (pounds per tub) recorded by a fisher working the White Point Bank - St. Pauls Island areas off Cape North, Cape Breton (4Vn) during October and November 1987 to 1992 (from WP 94/37).

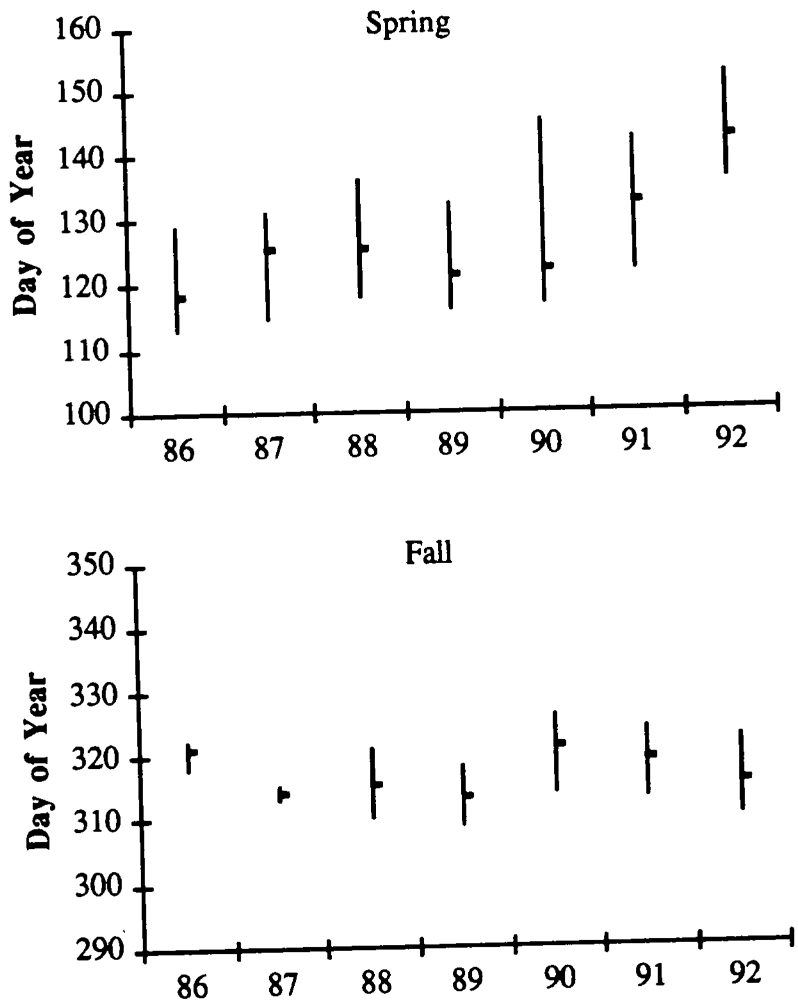


Fig. 10. Timing of spring and fall cod fisheries in unit areas 4Tfg, 1986-92. Dates correspond to when 25%, 50% and 75% of the catch was made (from WP 94/24).

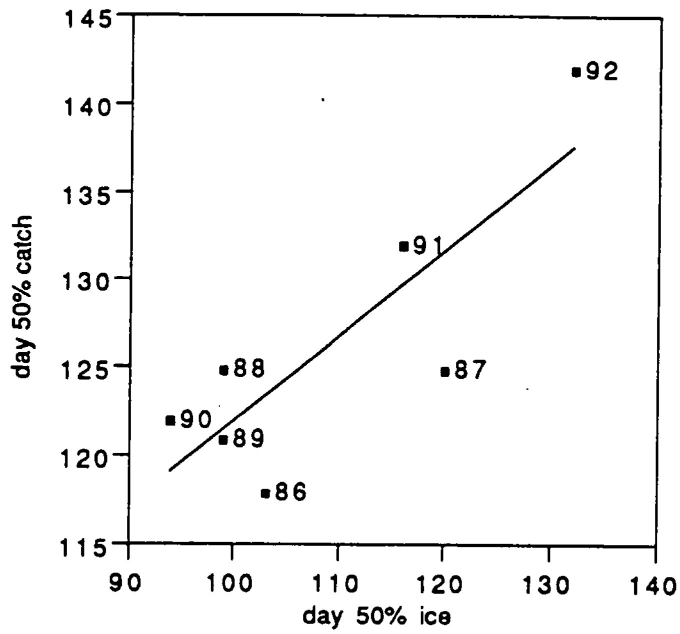


Fig. 11. Relationship between day of 50% catch and day of 50% ice out in 4Tfg, 1986-92. Ice out explains 70% ($p=0.02$) of the variability in catch (from WP 94/24).

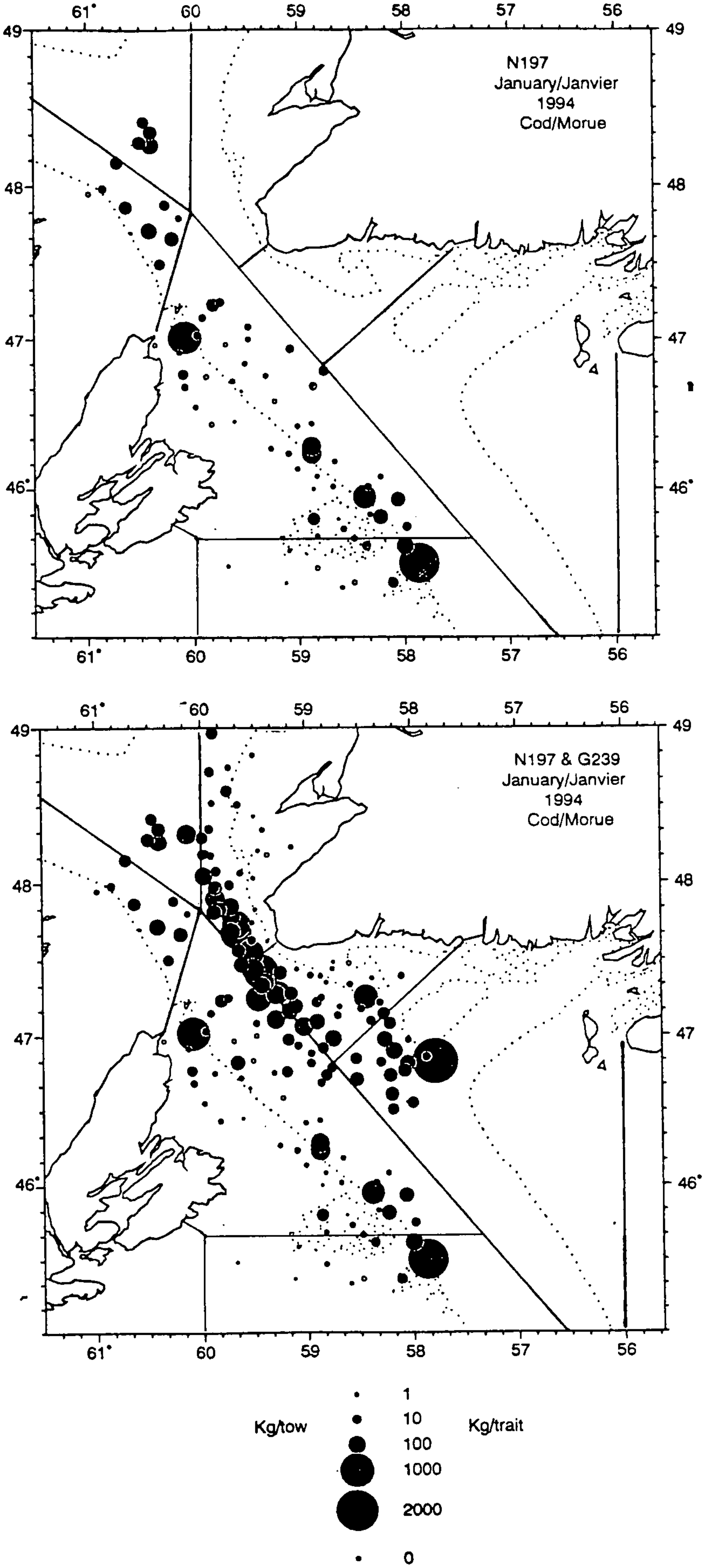


Fig. 12. Catches of cod (kg/standard tow) during the 13-25 January 1994 groundfish survey in Cabot Strait. Bottom panel combines survey results from 3Pn4RS winter survey during January 1994 that was extended into 3Ps (from WP 94/21).

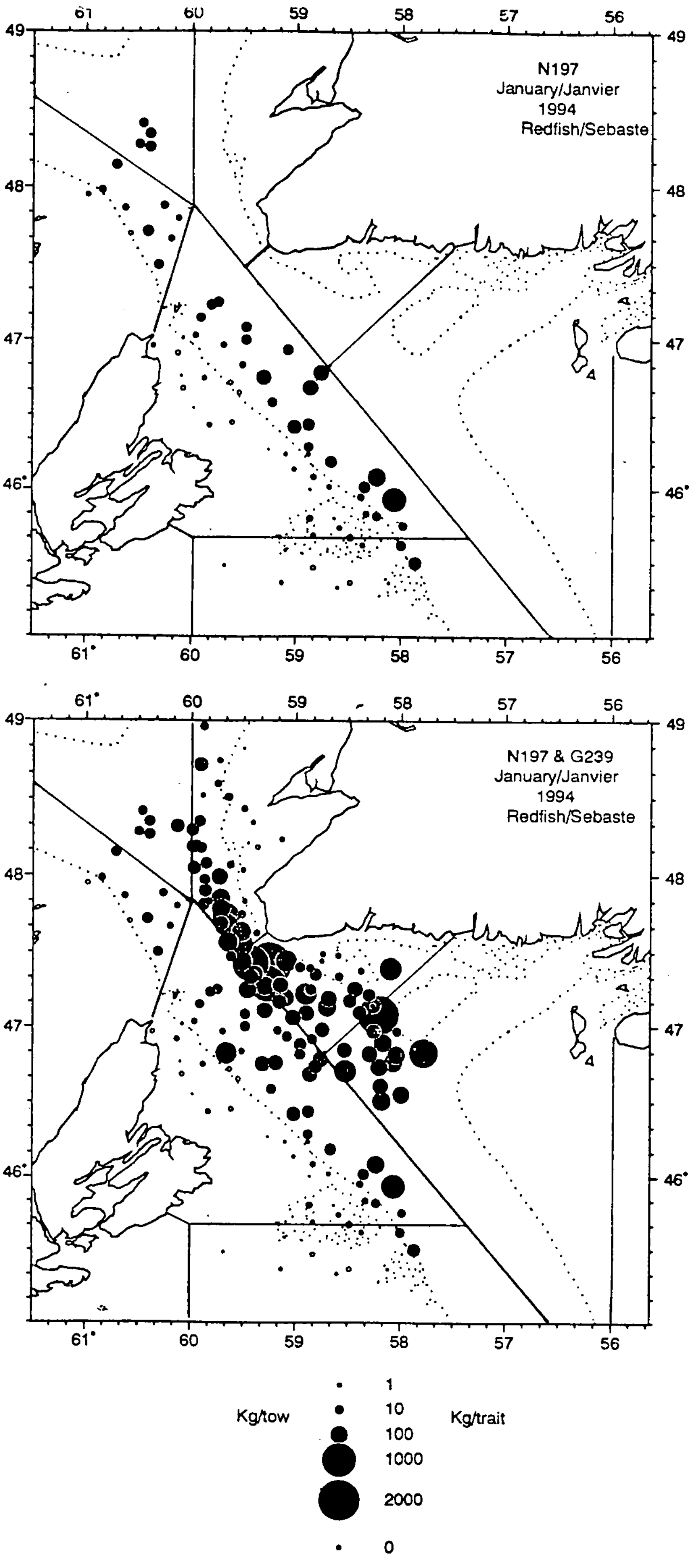


Fig. 13. Catches of redfish (kg/standard tow) during the 13-25 January 1994 groundfish survey in Cabot Strait. Bottom panel combines survey results from 3Pn4RS winter survey during January 1994 that was extended into 3Ps (from WP 94/21).

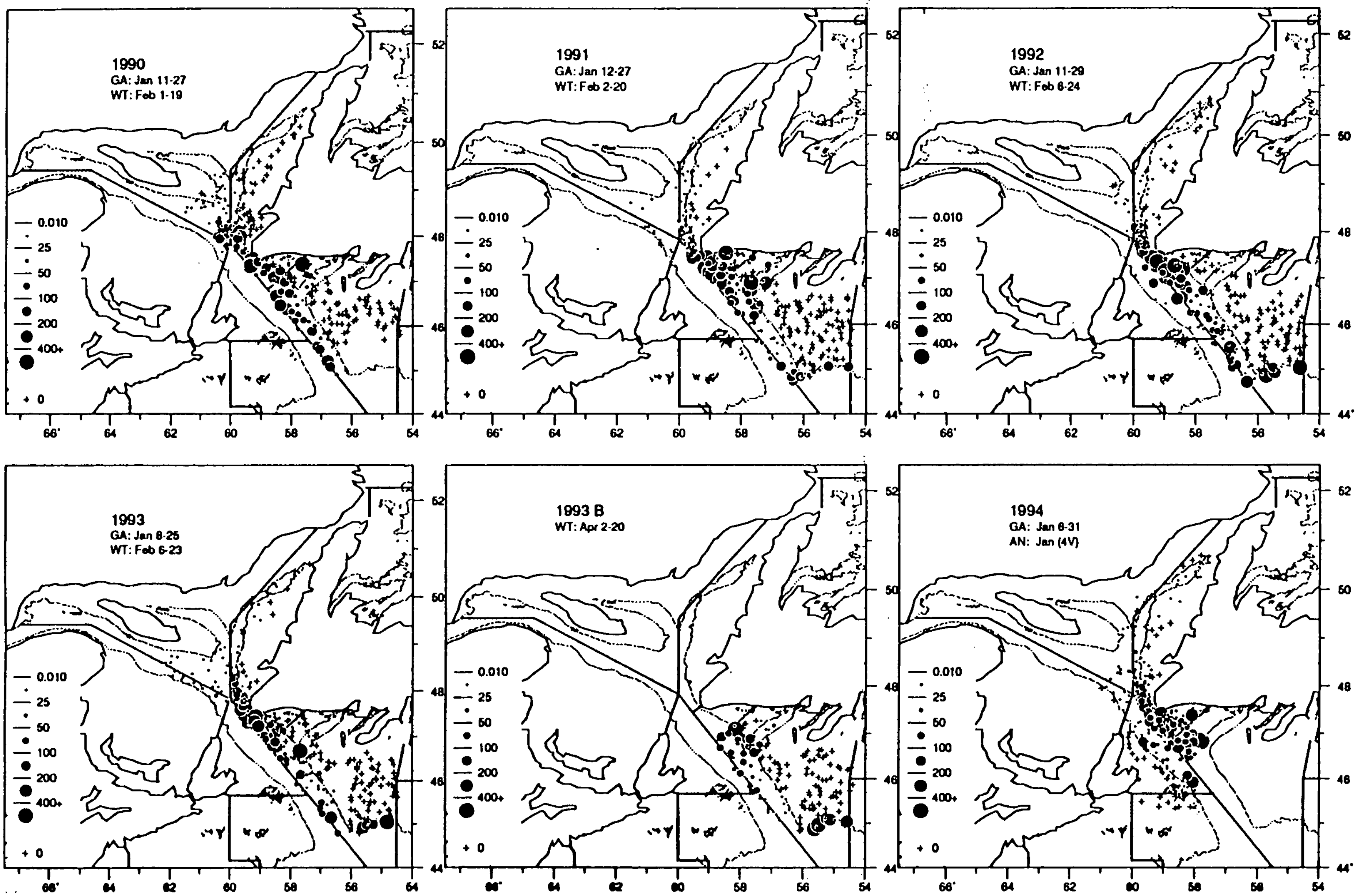


Fig. 14. Distribution of redfish catches from January (only April in 1993) RV surveys in Subdiv. 4RST3Pn from 1990 to 1994. Catches are kg per 30 minute tow. The 250 m depth contour is shown (from WP 94/29).

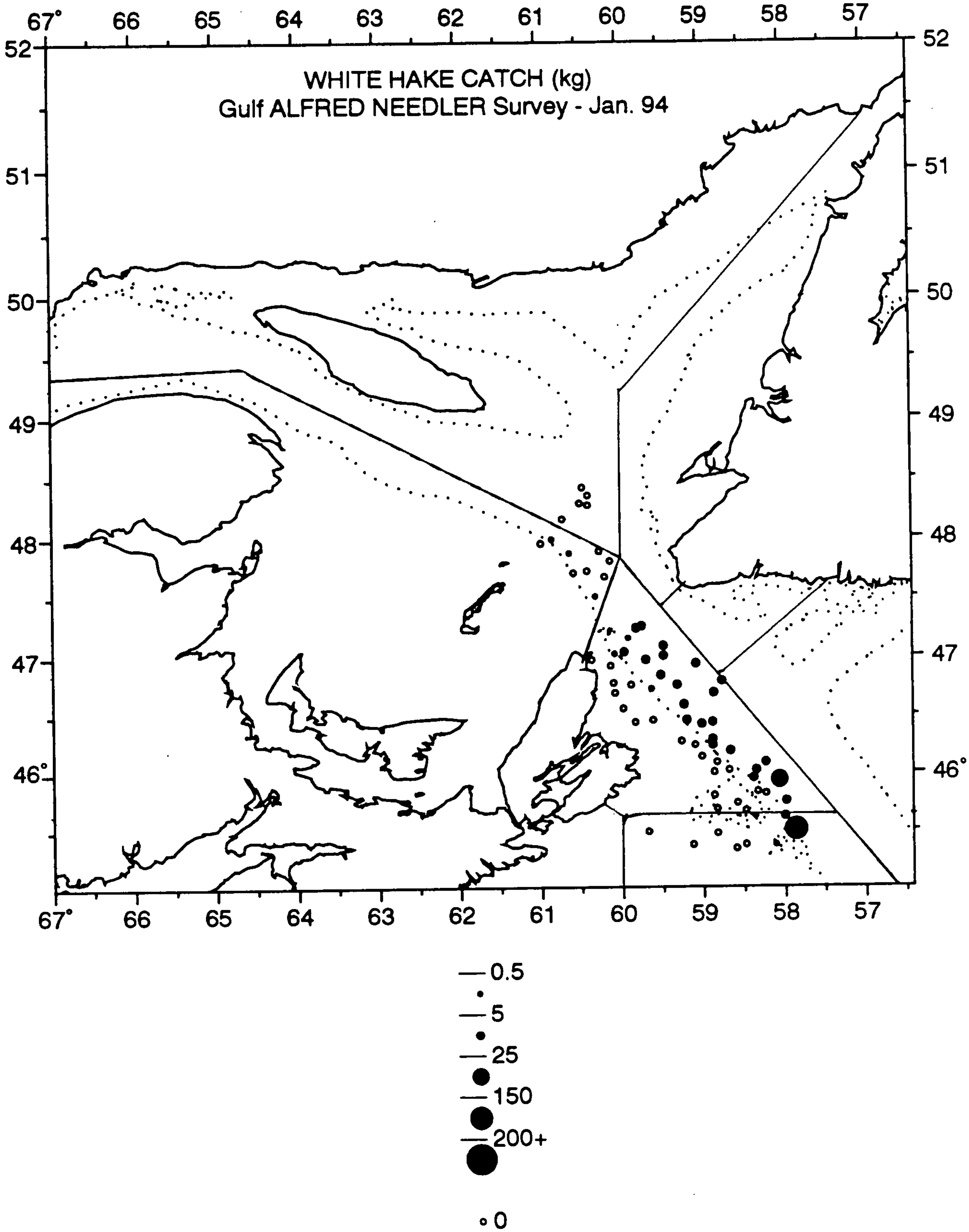


Fig. 15. Distribution of white hake collected during 13-25 January 1994 groundfish survey in Cabot Strait (from WP 94/27).

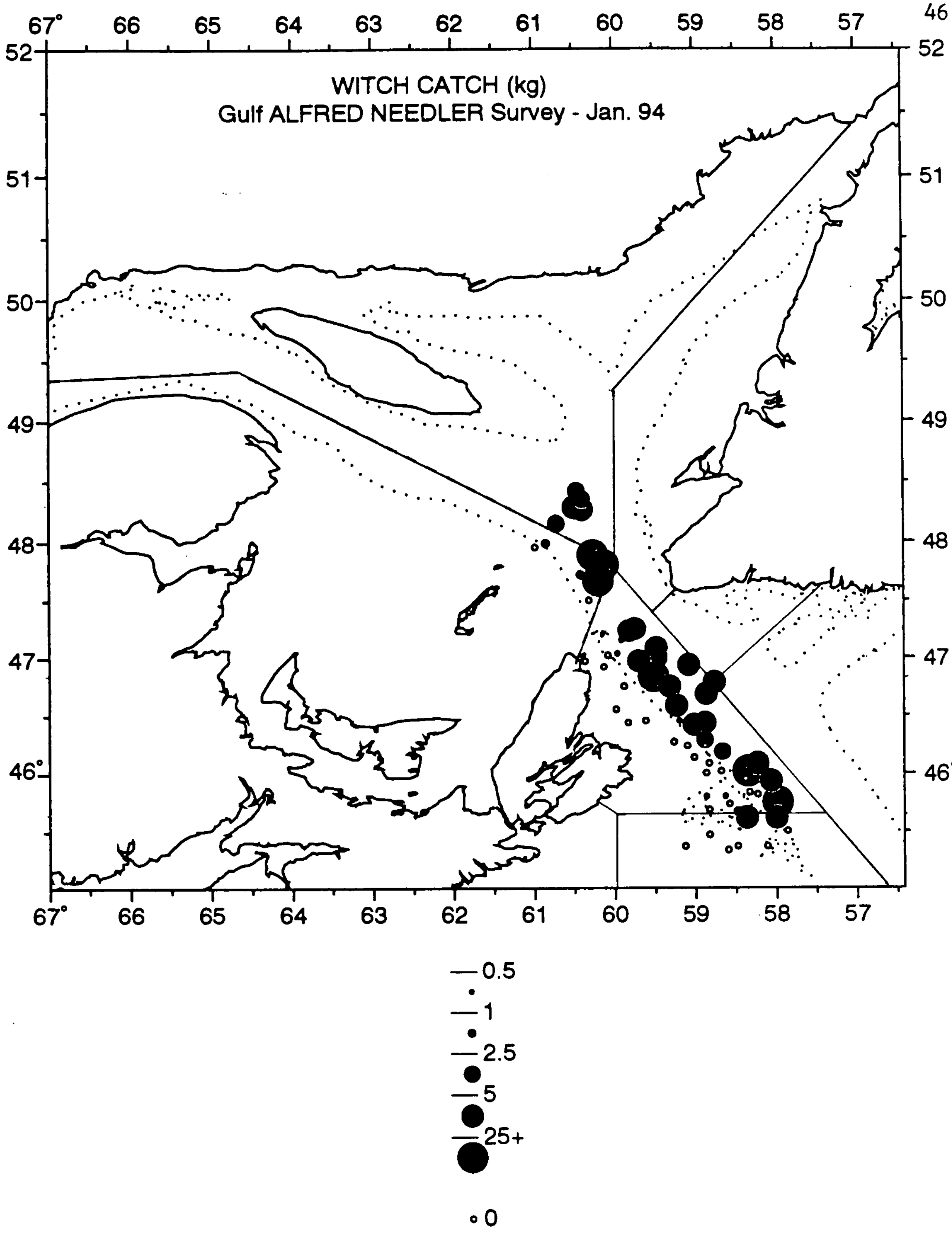


Fig. 16. Distribution of witch flounder collected during the 13-25 January 1994 groundfish survey in Cabot Strait (from WP 94/27).

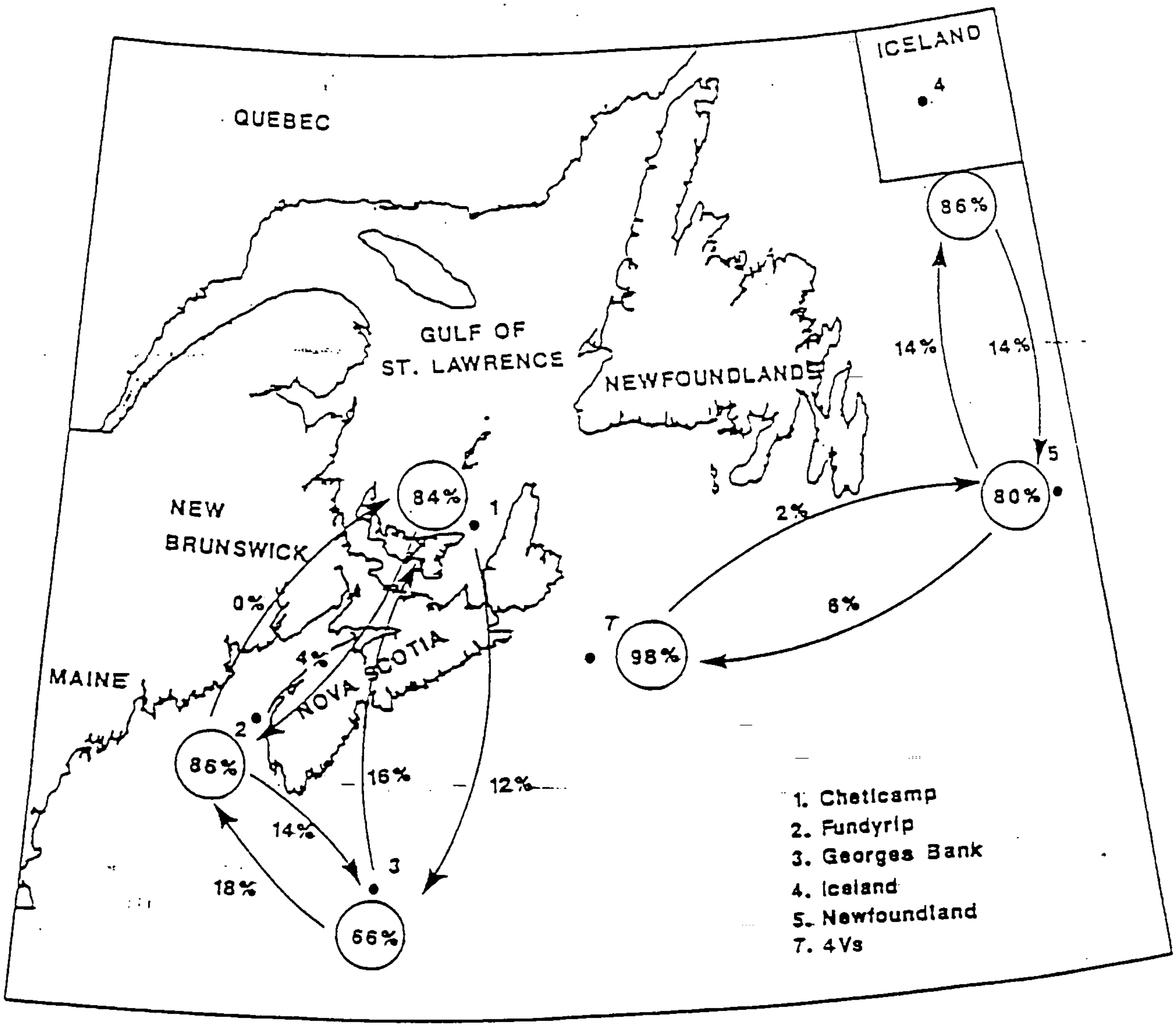


Fig. 17. Accuracy of whole otolith elemental composition analysis showing discrimination (based on proportion correctly reassigned within a stock) between cod sampling sites in the North Atlantic. Arrows show the percentage of fish misclassified to other regions (from WP 94/31).

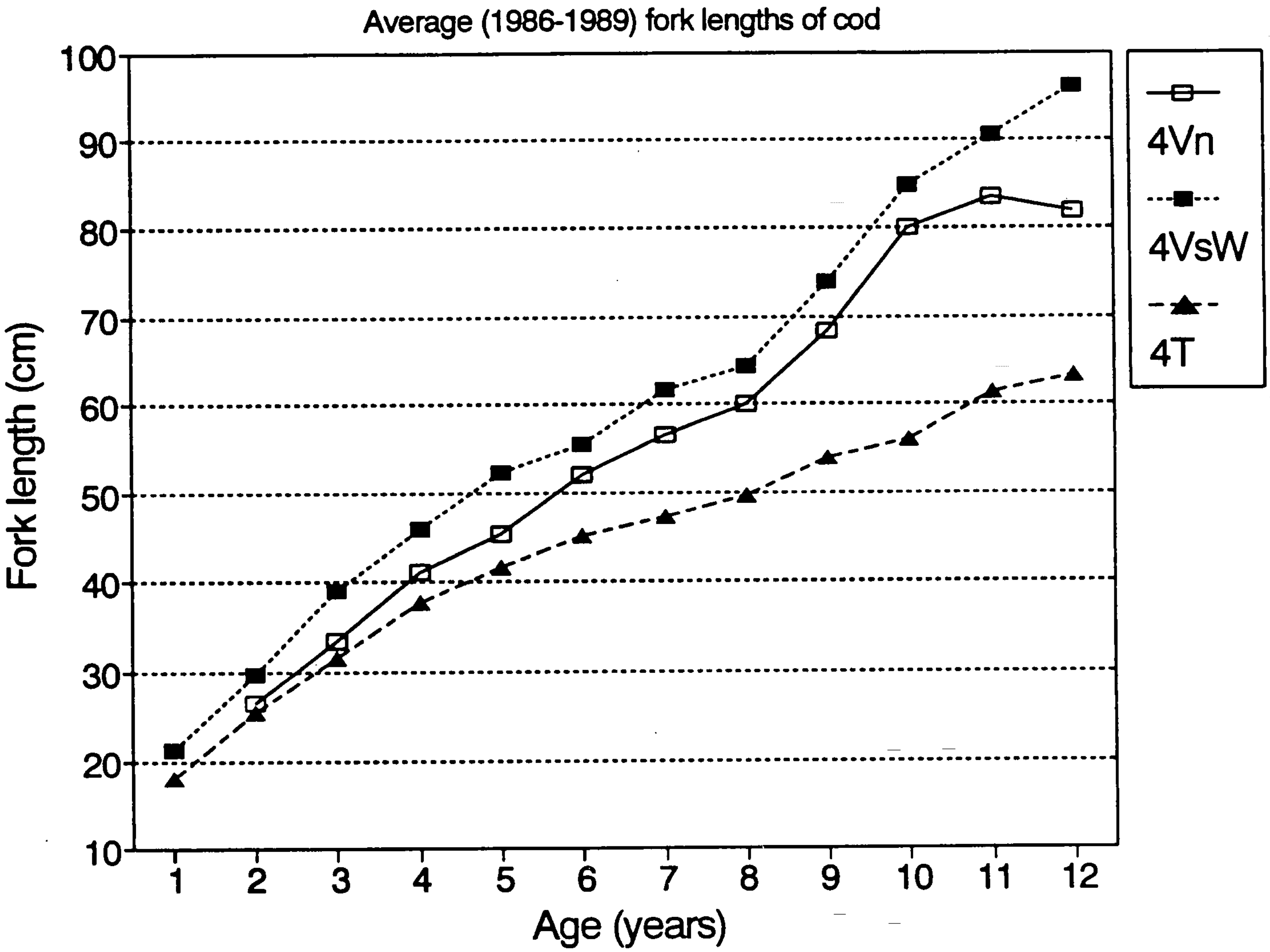


Fig. 18. Mean length at age of cod collected during July (4Vn and 4VsW) and September (4T) during 1986 to 1989 (from WP 94/26).

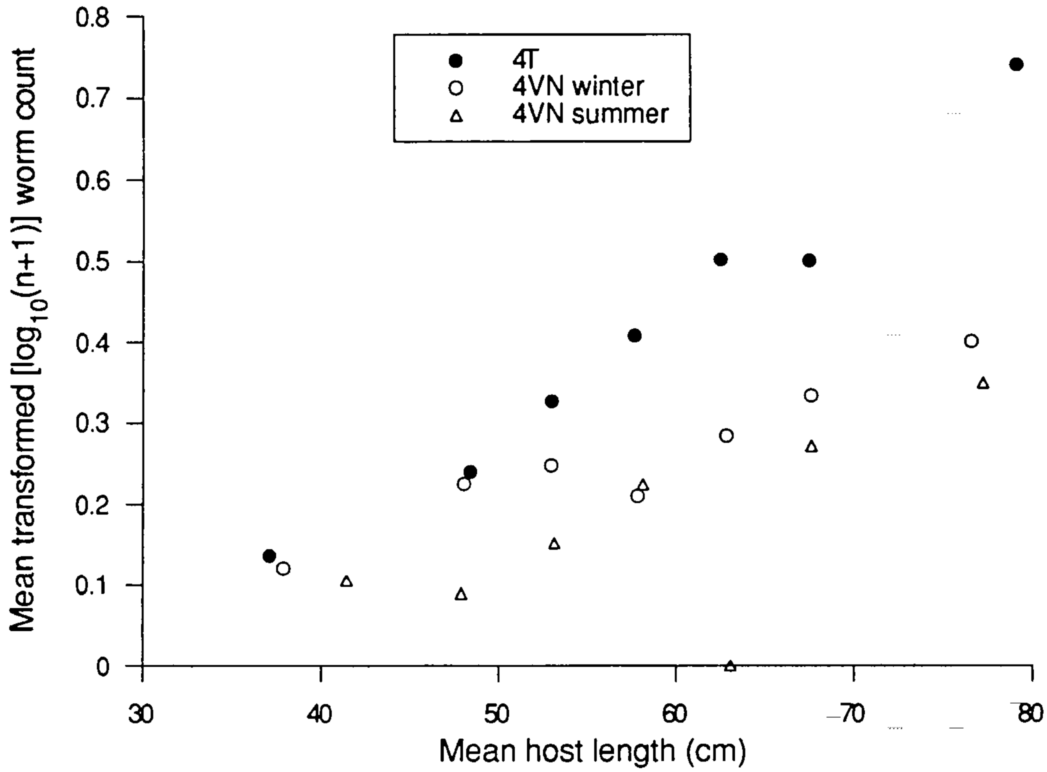


Fig. 19. Relationship between the abundance of the nematode species Anisakis simplex and host (cod) length in 5 cm length groups from samples collected in various location in 4T and 4Vn (from WP 94/39).

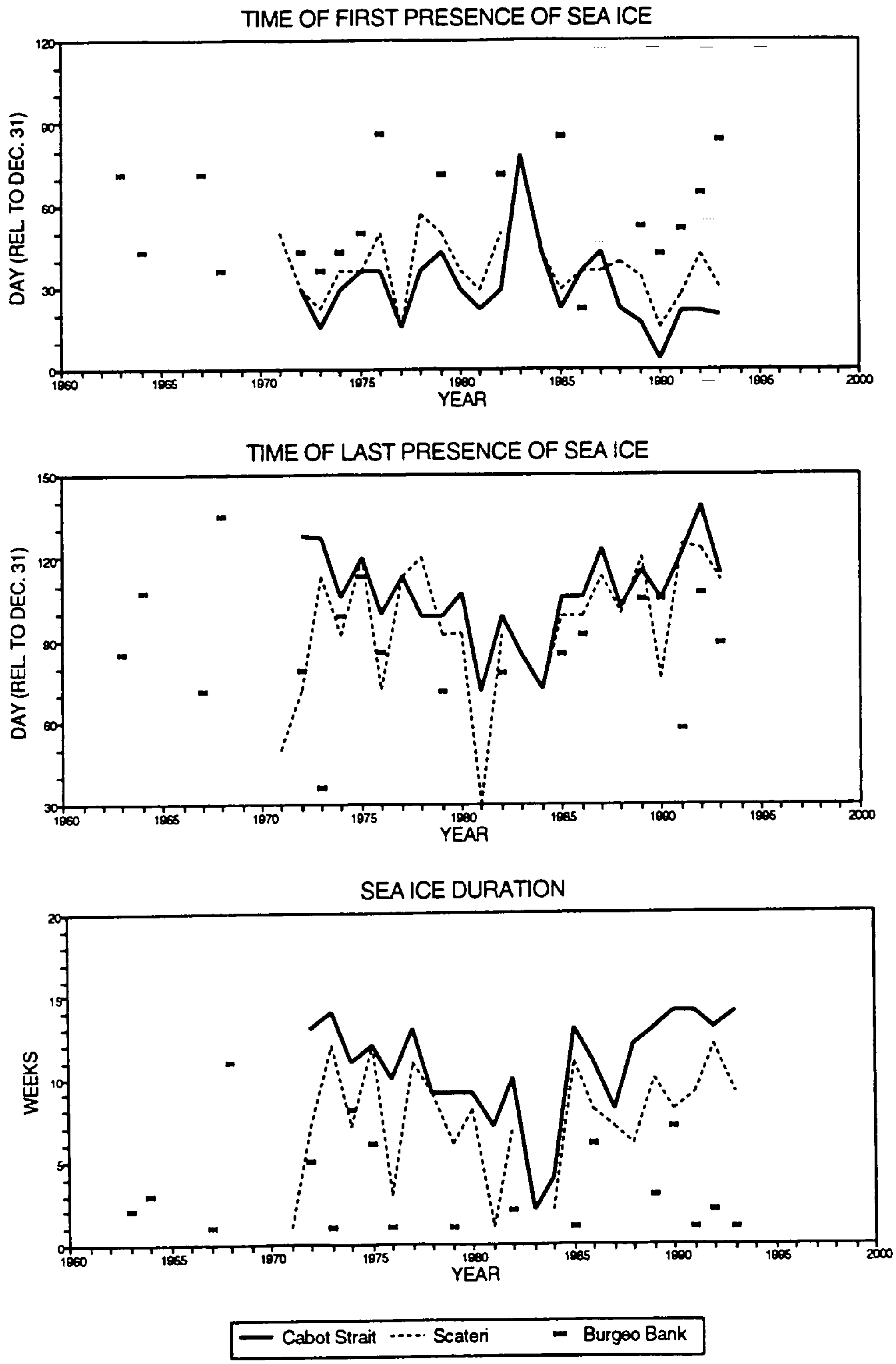
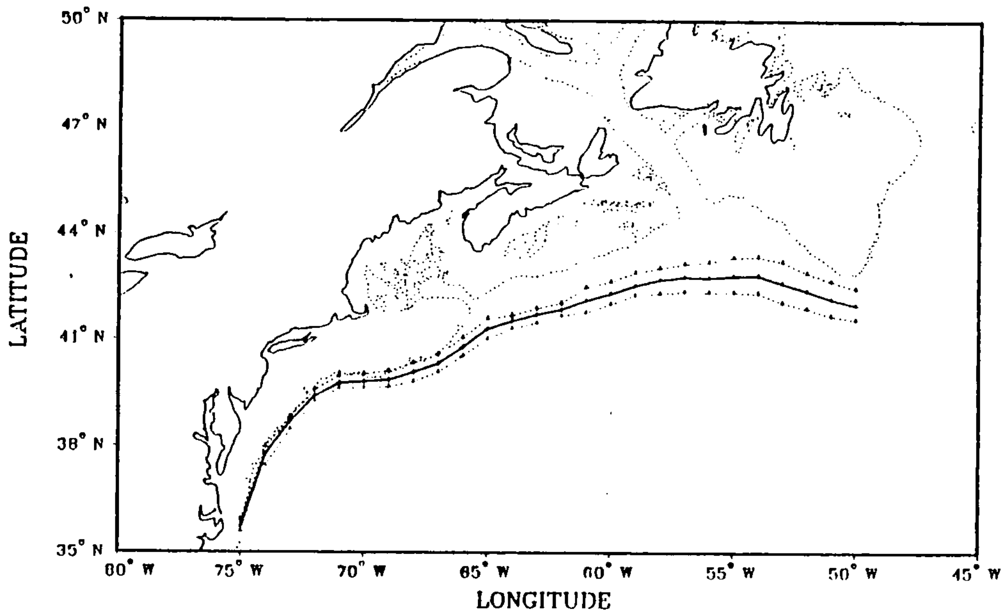


Fig. 20. Sea ice variability in the Cabot Strait, near Scateri Island, and Burgeo Bank in terms of time of first presence of ice (measured relative to Dec. 31), time of last presence of ice, and duration of ice measured in weeks (from WP 94/32).



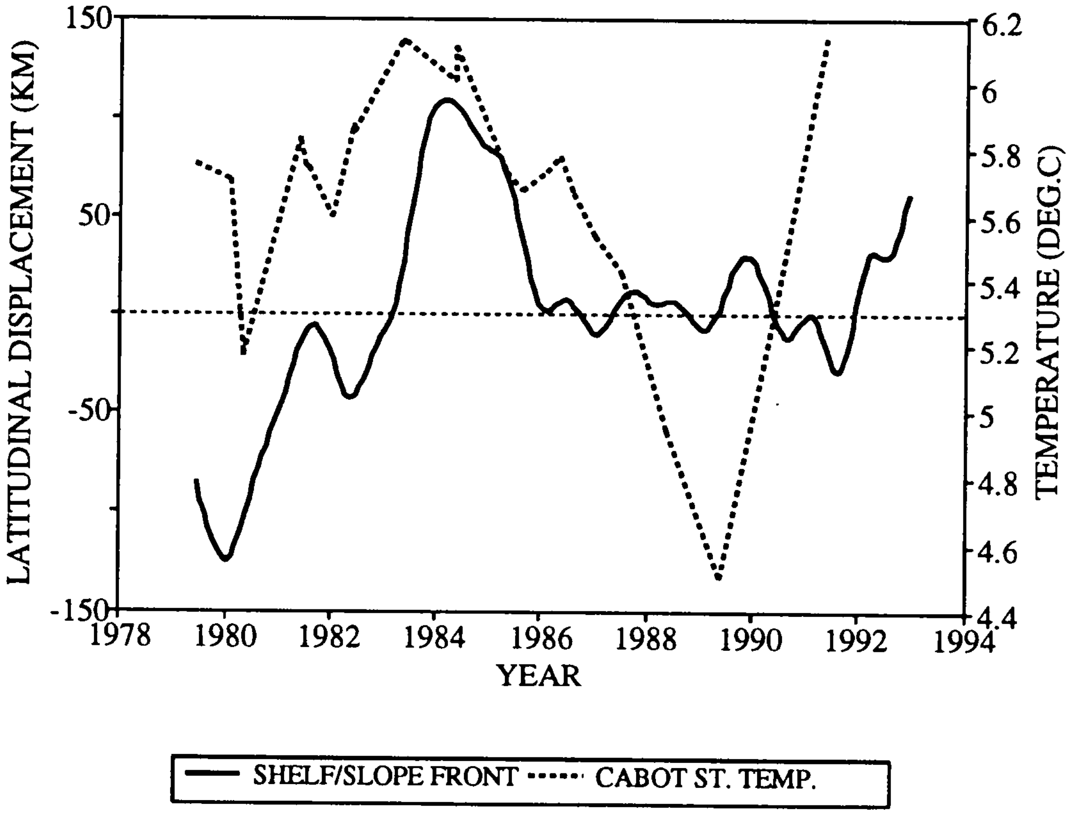


Fig. 21. a) The long-term (1973-92) mean location of the Shelf/Slope front together with the maximum and minimum monthly average. b) Variations in the position of the Shelf/Slope front and the average deep (200-300 m) temperature at Cabot Strait. Note: the temperature has been lagged by 2.5 y to account for the expected travel time from the mouth of the Laurentian Channel to Cabot Strait (from WP 94/33).

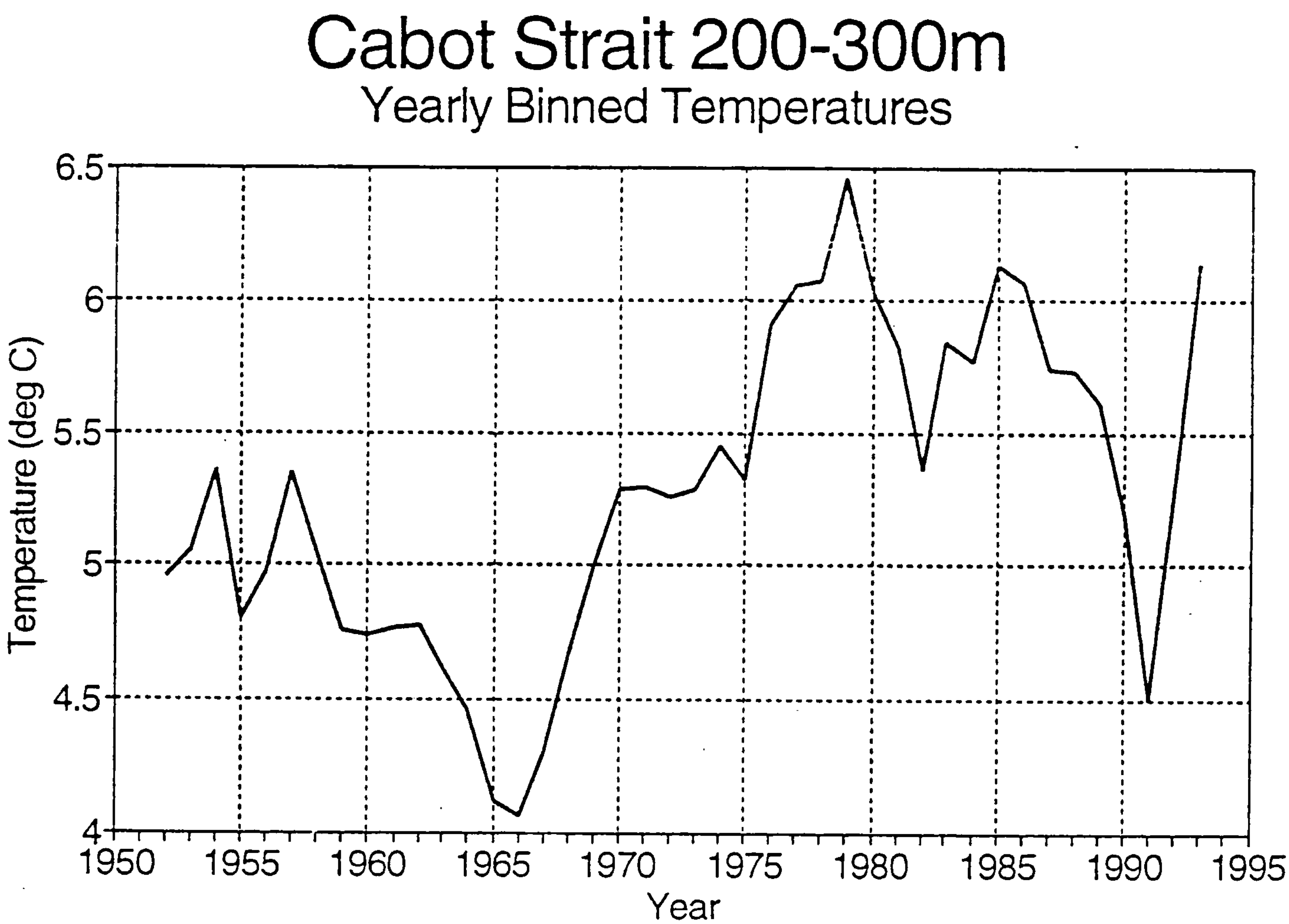


Fig. 22. Annual mean temperatures between 200-300 m in Cabot Strait from 1952 to present (from WP 94/42).