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Report of the 4Vn Cod Working Group on the Scientific Value of a 4Vn Cod (May-Oct) Stock Assessment

by

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[1]This series documents the scientific basis for the evaluation of fisheries resources in Atlantic Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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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

At the May 1994 meeting of the Regional Advisory Process Committee, questions were raised concerning the scientific value of a 4Vn cod (May-October) stock assessment. The questions were based on ongoing difficulties in producing an internally consistent stock assessment, raising the possibility that the currently-defined 4Vn (May-Oct) subdivision does not represent the home range of a unit stock. Accordingly, the 4Vn Cod Working Group was struck in July 1994 to review available information concerning the extent of stock mixing in and around 4Vn, the utility of the summer RV survey in 4Vn as an index of abundance, the relevance and utility of the current stock assessment unit, and potential alternatives to the current assessment unit.

The evidence in support of the presence of a persistent spawning component of cod in 4Vn was compelling. Cod tagged in 4Vn in summer were most often recovered in 4Vn. In addition, observations of spawning fish and ichthyoplankton collections suggested annual spawning in the Sydney Bight each May or June. Analyses of RV length at age, fish-otolith allometry, vertebral counts, year-class strength, RV age coefficients, and parasite loads all resulted in significant differences between 4Vn and adjacent stocks, although the differences could also be attributed to age-structured mixing among 4T, 4Vn and 4Vs. Indeed, while there was little doubt of a resident stock in 4Vn, there was equally little doubt that it mixed to varying degrees with the 4T and 4Vs stocks at all times of the year. Tagging studies and analyses of fleet movement both suggested that the winter migration of 4T cod was largely restricted to the outer reaches of 4Vn, along the Laurentian Channel. However, incursions of 4Vs cod were not so restricted. A pattern common to most analyses of 4Vn cod was one of 4T-like characteristics in young (ages 1-3) cod, becoming more and more similar to 4Vs cod at older ages, consistent with an influx of 4Vs cod into 4Vn through time. This pattern was particularly evident in the length at age and fish-otolith allometry trajectories. Linear models of RV data indicated that 4Vn was depauperate in young fish relative to the number later recorded in 4Vn for any given cohort. Such results might be expected of a stock which was augmented by adults from a neighbouring stock, and was consistent with the migration of some 4VsW cohorts into 4Vn as adults.

Based on the extent of stock mixing within and outside of 4Vn, and in light of the difficulties in past stock assessments of 4Vn cod, the current 4Vn cod (May-Oct) stock assessment unit appears to have limited utility and relevance. The dispersal rate of cod across the 4Vn boundary appears to be too great to permit an assessment unit as small as 4Vn. In addition, the current RV survey design allocates few sets to 4Vn, and shows poor internal consistency in tracking year-classes. While survey precision could be increased by increasing the number of sets, the result could well be a more precise measure of abundance of cod of differing stock origins. The Working Group noted that the resident 4Vn cod stock is but one of a number of coastal cod stocks, of which only 4Vn is assessed separately. Thus the rationale for assessing 4Vn cod separately was unclear, although there appeared to be some justification based on traditional fishing patterns for continuing to manage the stock as a distinct management unit.

Modifications to the geographic or temporal boundaries of the 4Vn cod assessment unit appear

unlikely to provide significant benefits. If the degree of stock mixing in and around 4Vn does indeed increase with age, the stock provides a moving target for assessments, and one that is difficult to address with fixed boundaries. Given that the association between 4Vn and 4Vs at the adult stage appeared to be stronger than that between 4Vn and 4T, there may be some advantage to assessing 4Vn as part of 4VsW, or of developing assessment models which incorporate immigration/emigration. Alternatively, there may be an advantage in developing an assessment unit based only on stock origin. Such an assessment would require the means to identify the stock origin of individual fish based on otolith, genetic or other markers, and then assign and pro-rate both commercial and RV catches to their original stock, irrespective of location of capture. While unusual for groundfish fisheries, such an assessment could take advantage of standard assessment protocols without the confounding effects of stock mixing. The Working Group recommends that these and other options be evaluated in the near future, before the cod fishery is re-opened.

RÉSUMÉ

Lors de la réunion de mai 1994 du Comité régional du processus consultatif, certaines questions ont été posées quant à la valeur scientifique de l'évaluation du stock de morue de 4Vn (mai-octobre). Les questions se fondaient sur les difficultés que pose la production d'une évaluation cohérente, ce qui pourrait signaler que la subdivision 4Vn (mai-octobre) actuellement définie ne représente pas le domaine vital d'un stock donné. En conséquence, le Groupe de travail sur la morue de 4Vn a été chargé en 1994 d'examiner l'information disponible sur l'importance du mélange des stocks dans 4Vn et aux alentours et de se prononcer sur l'utilité de le relevé scientifique estival dans 4Vn comme indice de l'abondance, sur la pertinence et l'utilité de l'unité actuelle d'évaluation, et enfin sur les possibilités de solutions de remplacement.

Les preuves confirmant la présence d'une composante reproductrice permanente dans 4Vn étaient convaincantes. Les morues étiquetées en été dans 4Vn étaient le plus souvent récupérées dans la même subdivision. De plus, les observations des géniteurs et les collectes d'ichtyoplancton montrent qu'il semble y avoir ponte dans le Sydney Bight chaque année en mai ou juin. Les analyses des données de NR sur la longueur selon l'âge, l'allométrie poisson-otolithe, le nombre de vertèbres, l'effectif des classes d'âge, les coefficients de l'âge obtenus par NR et des charges en parasites faisaient apparaître dans tous les cas des différences significatives entre le stock de 4Vn et les stocks adjacents; les différences pouvaient toutefois être aussi attribuées à un mélange structuré par âge entre 4T, 4Vn et 4Vs. En fait, si l'existence d'un stock résident dans 4Vn ne suscite guère de doute, il est tout aussi évident que ce stock se mélange à des degrés divers à ceux de 4T et de 4Vs tout au long de l'année. Des travaux de marquage et des analyses du déplacement de la flottille font apparaître que la migration hivernale de la morue de 4T se limite essentiellement à la bordure de 4Vn, le long du chenal Laurentien. Par contre, les incursions de morues de 4Vs n'étaient pas restreintes de la même façon. La plupart des analyses de la morue de 4Vn faisaient apparaître un schéma similaire, avec des caractéristiques semblables à celles de 4T chez les jeunes (âges 1-3), puis un rapprochement de celles de 4Vs par la suite, ce qui correspondrait à un afflux de morues de 4Vs dans 4Vn au fil du temps. Ce schéma était

particulièrement évident dans les courbes de la longueur selon l'âge et de l'allométrie poisson-otolithe. Les modèles linéaires des données de NR indiquaient que 4Vn était pauvre en jeunes poissons par rapport aux effectifs observés par la suite pour une cohorte donnée. Ce sont des résultats qu'on peut attendre d'un stock qui s'enrichit d'adultes provenant d'un stock voisin, et ils concordent avec l'hypothèse d'une migration de certaines cohortes de 4VsW dans 4Vn au stade adulte.

Étant donné l'ampleur du mélange de stocks dans 4Vn et aux alentours, et vu les difficultés qu'ont posées dans le passé les évaluations de la morue de 4Vn, l'unité actuelle d'évaluation du stock de morues de 4Vn (mai-octobre) ne semble avoir qu'une utilité et une pertinence limitées. Le taux de dispersion des morues qui traversent la limite de 4Vn semble trop élevé pour justifier l'existence d'une unité d'évaluation aussi petite. De plus, la conception actuelle des relevés de NR n'alloue qu'un petit nombre de traits à 4Vn, et ne révèle qu'une faible cohérence interne pour le pistage des classes d'âge. Il serait possible d'accroître la précision des relevés en augmentant le nombre de traits, mais le résultat pourrait être tout simplement une mesure plus précise de l'abondance de morues provenant de stocks différents. Le Groupe de travail a noté que le stock résident de morues de 4Vn n'est que l'un des nombreux stocks côtiers, et c'est le seul à faire l'objet d'une évaluation distincte. La justification d'une telle évaluation distincte n'est donc pas claire, même si les schémas traditionnels de la pêche semblent dans une certaine mesure justifier que l'on continue à gérer ce stock comme une unité distincte de gestion.

La modification des limites géographiques ou temporelles de l'unité d'évaluation de la morue de 4Vn ne semble pas devoir présenter des avantages significatifs. Si le degré de mélange des stocks dans 4Vn et aux alentours augmente bien avec l'âge, le stock constitue une cible mouvante pour les évaluations, et il est difficile à étudier dans des limites fixes. Étant donné que l'association entre 4Vn et 4Vs au stade adulte semble plus forte que celle entre 4Vn et 4T, il pourrait être intéressant d'évaluer 4Vn dans le cadre de 4VsW, ou d'élaborer des modèles d'évaluation qui intègrent l'immigration et l'émigration. Il pourrait aussi par ailleurs être avantageux de définir une unité d'évaluation fondée uniquement sur l'origine du stock. Il faudrait pour cela avoir les moyens d'identifier l'origine des poissons pris individuellement en se servant des otolithes, de facteurs génétiques ou d'autres marqueurs, puis d'attribuer au prorata les prises commerciales et les captures de NR à leur stock d'origine, quel que soit le lieu de capture. Si cette méthode semble inusitée dans les pêches du poisson de fond, elle pourrait tirer profit des protocoles standard d'évaluation sans souffrir des effets perturbants du mélange des stocks. Le Groupe de travail recommande d'évaluer ces options parmi d'autres dans un proche avenir, avant de rouvrir la pêche de la morue.

Introduction

During the May 1994 meeting of the Regional Advisory Process Committee, questions were raised concerning the scientific value of a 4Vn cod (May-December) stock assessment. While the assessment period was recently adjusted to May-October to better account for the migration of 4T cod through 4Vn, there remains the possibility that the currently defined 4Vn subdivision does not represent the home range of a unit stock. This possibility was highlighted by ongoing difficulties in producing an internally consistent stock assessment, and in the apparent absence of a coherent signal of cod abundance in the summer RV survey. Accordingly, the Committee recommended striking a working group to study this issue in 1994/95 using available information (Appendix 1).

The objectives of the 4Vn Cod Working Group were as follows:

1. Review and document the historical context of the current stock boundaries.
2. Review available information concerning stock mixing in 4Vn by season and location.
3. Review available information concerning the presence of 4Vn resident cod in other assessment units throughout the year.
4. Assess the utility of the summer RV survey in 4Vn as an index of stock abundance.
5. In light of the above, through RAP, assess the relevance and utility of the current 4Vn cod (May-October) stock assessment unit.
6. Determine if an alternate assessment unit would be more useful in assessing the abundance of cod in and around Cape Breton. Consider modifications to either the geographic extent or the time period covered.
7. Where necessary, recommend to line management research programs to address unresolved issues.

Implicit in the above is the assumption that there is indeed a resident cod stock in 4Vn. This assumption was explicitly tested by the Working Group.

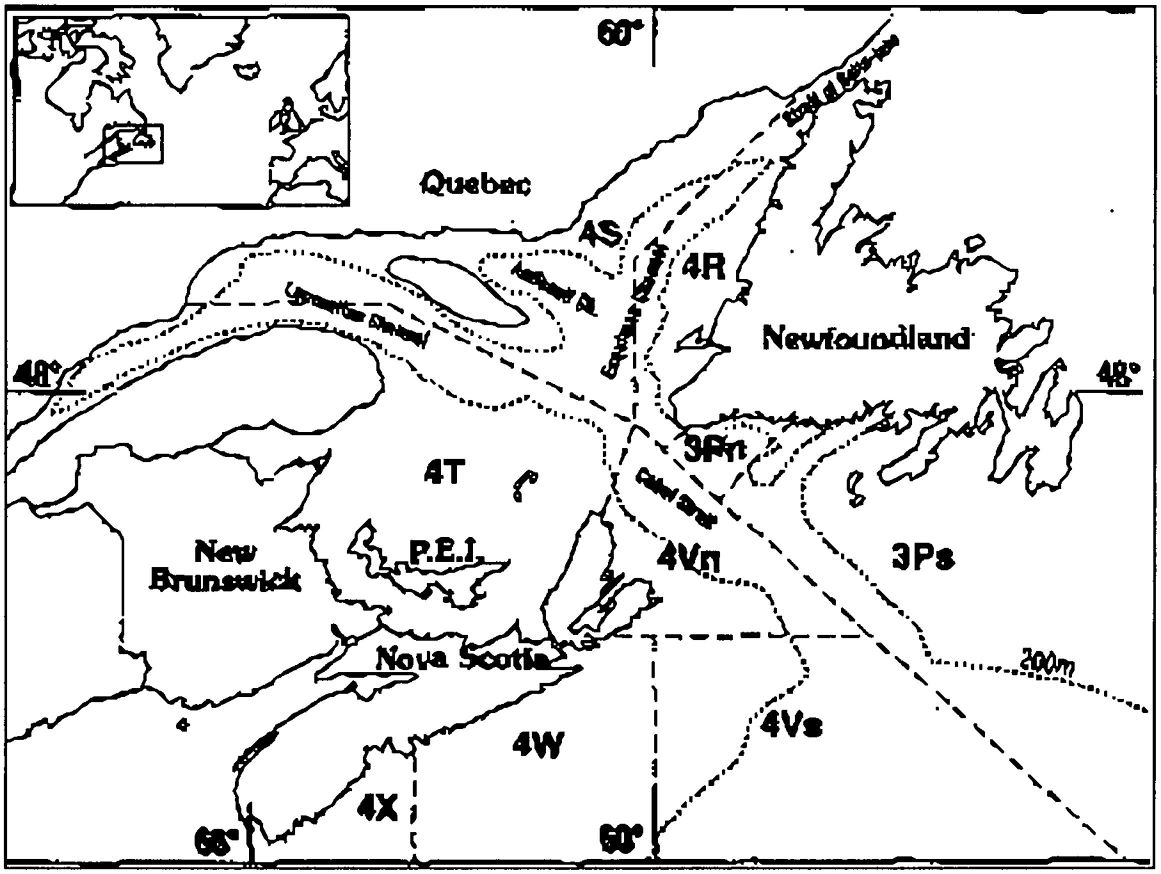
Members of the Working Group worked between Nov 1994 and March 1995 in carrying out analyses of published and unpublished data, and in preparing working papers. In addition, three meetings were spent in planning and reviewing the analyses, while a 4th meeting was spent in synthesizing the various studies and in discussing the implications of the findings.

In summarizing the findings of the Working Group, this report draws upon both the highlights of 11 working papers and the ensuing discussion to address each of the terms of reference. The relevant text of the working papers is appended (Appendix 2).

Background

NAFO Subdivision 4Vn, off of the northern tip of Nova Scotia (Fig. 1), has long been known to lie on the annual migration route of cod in the southern Gulf of St. Lawrence (4T). 4T cod are known to migrate out of the southern Gulf each fall, returning to the Gulf each spring. A large portion of the 4T stock overwinters within 4Vn each year, where it is is thought to mix with the resident cod stock during a time of significant fishing pressure. An unknown amount of stock mixing occurs during the summer months. Given its geographic location between the large 4T and 4VsW cod stocks, 4Vn is widely viewed as a mixing ground for both cod and other species (D'Amours et al. 1994).

Fig. 1. Map of the Gulf of St. Lawrence and approaches, showing NAFO divisions and the 200-m bathymetric contour.



While 4Vn has traditionally supported a local, primarily fixed gear fishery (Lambert and Wilson 1994), the area is also the site of a more intensive fishery during the winter. Summer (May-Dec) cod catches in 4Vn have always been considerably smaller than those of its larger neighbours (Table 1). The discrepancy in size of catches and fishing effort among the three stocks is a source of concern for both biologists and fishery managers: with any significant degree of stock mixing, a small 4Vn resident cod stock can be subjected to undue fishing pressure as a product of routine fishing on its larger neighbours. Indeed, its very existence as a stock could be jeopardized, thus explaining some of the rationale for the formation of this Working Group.

Table 1. Summary of recent landings and TACs for 4T, 4Vn (May-Dec) and 4VsW cod ('000t).

	4T Cod		4Vn Cod		4VsW Cod	
Year	Landings	TAC	Landings	TAC	Landings	TAC
1970	64	-	10	-	57	-
1971	56	-	11	-	53	-
1972	65	-	9	-	62	-
1973	51	-	6	-	54	61
1974	49	63	6	10	44	60
1975	42	50	4	10	33	60
1976	33	30	6	10	24	30
1977	22	15	8	4	10	7
1978	38	38	6	4	25	7
1979	56	46	6	3	40	30
1980	55	54	10	5	49	45
1981	65	53	13	10	54	50
1982	58	60	12	14	56	56
1983	61	62	9	14	52	64
1984	59	67	10	14	53	55
1985	61	67	12	12	57	55
1986	69	60	12	12	52	48
1987	55	45	11	9	46	44
1988	56	54	9	8	38	38
1989	57	54	8	8	37	35
1990	58	53	5	8	34	35
1991	49	48	5	10	33	35
1992	41	43	5	10	30	35
1993	5	13	1	2	3	11

Objective: Review and document the historical context of the current stock boundaries

Control of exploitation level for Northwest Atlantic fisheries was established by ICNAF through introduction of a comprehensive system of Total Allowable Catches (TACs) in the 1972-74 period. Agreement was reached at the June 1972 meeting of ICNAF to establish TAC regulation for cod in Div. 4VsW in 1973. In January 1974, TACs were established for cod in Div. 4T + Subdiv. 4Vn (January-April), and for cod in Subdiv. 4Vn (May-December).

Canada introduced fisheries closure lines in 1971 which brought Gulf of St. Lawrence fisheries under domestic jurisdiction. Phase-out agreements were negotiated with all foreign nations with traditional fisheries in the Gulf during 1971 and 1972. Canada was reluctant to propose regulation of stocks in ICNAF for which it was in the process of establishing a domestic jurisdictional claim. A proposal was put forward to ICNAF in June 1972 to regulate cod fishing in Div. 4Vn (only) but this was rejected because it controlled fishing on only part of the southern Gulf stock. (The closure line included only a small part of Subdiv. 4Vn, north of a line from Money Point, Cape Breton Island, to St. Paul Island, in the Gulf of St. Lawrence.) By January of 1974 Canada had secured international recognition of its jurisdictional claim but was faced with a continued foreign presence in the Gulf until 1976 by most parties (1986 by France) and an indefinite period of foreign fishing of Gulf cod stocks in adjacent international waters. At this juncture, international regulation of cod fishing for an area which included Gulf waters was the most practical action.

The first stock assessment for eastern Scotian Shelf cod (Halliday 1972a) adopted Div. 4VsW as the assessment unit. Although it was recognized that there was a complex of stocks within these divisions, considerable mixing was thought to take place among stocks at the adult stage, and possibly also during the pelagic egg and larval stages. Therefore it was considered most practical to treat the complex as a single unit. This decision was based on the evidence available in the review of cod stock structure by Templeman (1962) and the results of winter tagging in Div. 4VW presented by Martin and Jean (1964).

The first analysis of the dynamics of southern Gulf of St. Lawrence cod was that of Paloheimo and Kohler (1968). They included fishery catch data from Subdiv. 4Vn in the first quarter of the year with those from Div. 4T (all year) to estimate removals from the stock, based on the tagging results of McCracken (1959) and Martin and Jean (1964) describing its seasonal migration. The first assessment for this stock presented to ICNAF (Halliday 1972b) followed Paloheimo and Kohler but included January-April Subdiv. 4Vn data in the analysis. The ICNAF Standing Committee on Research and Statistics (STACRES) report (ICNAF Redbook 1972 Part 1) explained that the stocks involved in Div. 4TVn cod fisheries were the Div. 4T stock, which migrates eastward into Subdiv. 4Vn in December-January and moves back to Div. 4T in April-May, and inshore stocks in Subdiv. 4Vn. Stock structure in Div. 4TVn was further discussed at the January 1974 ICNAF Commission meeting at which the TAC regulation was decided (Halliday 1974; ICNAF Redbook 1974). At this meeting, it was pointed out that at least three stocks spend part or all of the year in Sydney Bight (Subdiv. 4Vn). The large southern Gulf of St. Lawrence stock was known to move out of the

Magdalen Shallows to deeper water along the western slope of the Laurentian Channel around December. The centre of overwintering concentration was believed to be in Subdiv. 4Vn, although it extended into Div. 4T as far north as Bird Rocks and as far south as Subdiv. 4Vs. Movement back into the Gulf occurred in April-May. The eastern Scotian Shelf cod showed some movement to the north in spring and summer, and Banquereau (Subdiv. 4Vs) cod in particular were known to move as far as Sydney Bight and even into the southernmost part of the Gulf of St. Lawrence. Coastal Nova Scotia has a complex of inshore stocks which mix very little with each other or with the larger offshore stocks. Thus, in winter the bulk of the cod in Subdiv. 4Vn were thought to belong to the southern Gulf of St. Lawrence stock. In summer, the northern fringes of the eastern Scotian Shelf stock complex were believed to move into Subdiv. 4Vn and, along with the sedentary coastal stocks, support the summer fishery. These conclusions were largely based on the tagging results of Martin and Jean (1964), McCracken (1957, 1959) and McKenzie (1956) and on the stock structure review of Templeman (1962). It was assumed that the coastal fixed gear fishery, which occurred close to shore on rough grounds of about 20-40 fm depth, was dependent on resident coastal stocks whereas the mobile trawl fishery, which occurred on more offshore grounds, was supported by summer immigrants from Subdiv. 4Vs. This allowed estimates to be produced of the effects of fishing on both coastal and offshore stocks, and comment to be made on their level of exploitation as a basis for TAC regulation. There was, however, no firm supporting evidence for such assumptions; they were hypotheses, the implications of which were investigated for illustrative purposes.

In the early 1970s ICNAF was introducing a radically new approach to management by bringing stocks throughout the Northwest Atlantic under TAC controls, and was necessarily painting with a broad brush. The decision in 1972 to establish the eastern Scotian Shelf cod management unit of Div. 4VsW ignored the seasonal overlaps in distribution with cod from Div. 4TVn. Although it was known that Div. 4T cod migrated as far south as Subdiv. 4Vs the evidence was that the main overwintering concentration remained in Subdiv. 4Vn. Furthermore, there was no strong evidence that a large proportion of Subdiv. 4Vs fish moved into Div. 4TVn in summer. In contrast, there was no room for doubt that the interconnection between cod in Div. 4T and Subdiv. 4Vn had to be recognized in the management system. The preference of the ICNAF Commission was simply to manage these as one regulatory unit but scientists argued for Subdiv. 4Vn in May-December to be treated as a separate unit to protect the interests of coastal stocks and of the inshore fishermen in Sydney Bight who depended on them (ICNAF Redbook 1974). Similar arguments were concurrently being made for separate management of inshore and offshore cod stocks in Div. 4X, which appeared to be discrete. It was recognized that the migration of cod out of the Magdalen Shallows to the edge of the Laurentian Channel occurred "about December" (Halliday 1974) and that the management unit for the southern Gulf of St. Lawrence stock probably would best include Subdiv. 4Vn in the December-April, rather than the January-April period. However, Canadian management authorities judged that this departure from calendar year quota periods would create difficulties in ICNAF which might prejudice acceptance of TAC management for these stocks, and, even if accepted, could create problems in accounting of catches against quotas (Halliday, pers. comm.). Thus, the decision to propose a temporal division of Subdiv. 4Vn of January-April and May-December was influenced by political circumstances and administrative practicalities.

Objective: Review evidence in support of the existence of a resident 4Vn cod stock

Numerous disparate studies support the suggestion of a resident cod stock in 4Vn. Since genetic studies of 4Vn cod have not yet been done (but see Research Recommendations), Ihssen et al.'s (1981) definition of a stock as an "intra-specific group of randomly mating individuals with temporal or spatial integrity" could not be formally applied. Nevertheless, the evidence in support of the presence of a small but persistent spawning component was compelling, as summarized below.

Tagging

As discussed in Stobo and Fowler (Appendix 2), cod tagged in winter in 4Vn tended to be recovered most often in 4T (Fig. 9), clearly highlighting the migration of 4T fish into and through the 4Vn region in winter. However, cod tagged in 4Vn in summer were most often recovered in 4Vn at later times, irrespective of season (Figs. 8, 11, 12, 13). The same general pattern was observed whether or not the tag recoveries were weighted by catch numbers. Such a pattern is consistent with the presence of a small resident stock in 4Vn which is overwhelmed numerically by an influx of 4T migrants in winter.

Spawners and Recruits

If there is a resident stock in 4Vn, there must also be a resident spawning component as a supply of recruits. In an analysis of the RV data time series, Mohn (Appendix 2) reported the virtual absence of female cod in spawning condition (stages 4-5) in spring or fall surveys of 4Vn (Fig. 1.1 and 3.1). However, summer RV surveys demonstrated that there was a clear aggregation of spawning females in the Sydney Bight region (Fig. 2.1). These observations are consistent with the presence of the "Gutter" fishery in May and June of each year (Lambert and Wilson, Appendix 2), wherein spawning fish aggregations are targeted by mobile gear (Fig. 5 and 6). The presence of a spawning component in 4Vn is also consistent with ichthyoplankton collections made from the 1950's onward which have documented concentrations of early-stage cod eggs in Sydney Bight in May and June (Fig. 1-4). Interpretation of juvenile cod distributions was more problematic, in that standard RV groundfish surveys have captured few juveniles in 4Vn relative to other areas (Appendix 2: Lambert and Wilson, Fig. 7-9, 12-13; Frank et al. 1994 - Fig. 3; Hanson - Fig. 3). Inshore surveys of 4Vn caught proportionately more small fish than did the standard summer groundfish surveys (Lambert and Wilson, Fig. 16-17), but there was no basis for comparison with other inshore areas.

Biological Indicators

A suite of additional analyses all provided results which were consistent with the presence of a 4Vn resident stock, but which could also be interpreted in other ways. After analyzing length at age in RV surveys, Sinclair and Fanning (Appendix 2) noted that the size of 4Vn cod differed significantly, but was intermediate to, that of 4T and 4Vs cod (Fig. 2). Campana (Appendix 2) noted a similar phenomenon with respect to fish-otolith allometry, wherein the weights of 4Vn otoliths for any given fish length were significantly different from, but intermediate to, those of 4T and 4Vs fish (Fig. 3). In an analysis of vertebral counts from cod collected on the 1994 RV summer survey, Frank (Appendix 2) also noted significant differences between 4Vs and 4Vn cod, at least for one year-class (Fig. 2-3). Estimates of year-class strength based on linear models of RV data showed some general synchrony among 4T, 4Vn and 4Vs, but with significant differences for 4Vn for some time periods (Sinclair, Appendix 2, Fig. 5-6; Fanning, Appendix 2, Fig. 4). Age effects in 4Vn also differed significantly from, but were intermediate to, those from 4T and 4VsW (Sinclair, Fig. 2; Fanning, Fig. 3). Finally, parasite loads have been observed to differ significantly between cod from 4Vn and 4T (McClelland and Marcogliese 1994). All of the above studies indicate that 4Vn cod as a group are significantly different than the 4T or 4VsW stocks; however, the causes of the heterogeneity can be attributed to a number of different hypotheses, only one of which is the presence of a resident 4Vn stock.

Objective: Review available information concerning stock mixing in 4Vn by season and location

The evidence in support of cod stock mixing within 4Vn boundaries during the winter (Nov-Apr) was essentially incontrovertible, and has long been recognized; 4Vn lies on the winter migration route of 4T cod. However, there was also strong evidence for stock mixing during other seasons of the year, and by other stocks. In addition, young 4Vn cod appear to share many of the same characteristics of 4T cod at ages 1-3, but become much more similar to 4Vs cod at ages 7+, suggesting a gradual and continual influx from other areas, particularly 4Vs. There was also some evidence of stock-specific heterogeneous distribution within the 4Vn boundaries. A summary follows.

Tagging

Cod tagged in 4T were recovered almost exclusively in 4Vn and western 4Vs during the winter months, particularly along the edge of the Laurentian Channel (Stobo and Fowler, Fig. 16, 18, 20, 25, 29). However, the number of 4Vn recaptures from the same tagging studies was relatively low in summer months (Fig. 17, 19, 22, 27, 31). In general, cod tagged in eastern 4T were more likely to be recovered in 4Vn in summer (Fig. 31) than were cod tagged in western 4T (Fig. 17).

Relatively few recaptures of 4W-tagged fish were made in 4Vn at any time of year (Stobo and Fowler, Fig. 2). However, the number of recaptures of 4Vs-tagged fish was considerably larger, both in winter (Fig. 5) and in summer (Fig. 6). Interestingly, 4Vs recaptures in 4Vn appeared to be somewhat more likely to be made in inshore waters than were 4Vn recaptures of cod tagged in western 4T.

Distribution of Fishing Effort

Maps of the monthly distribution of the mobile gear fleet clearly highlighted the annual migration of 4T cod into and through 4Vn each winter. Fleet movement, which presumably paralleled that of the migrating fish, exited 4T and entered 4Vn in Oct-Nov of each year, re-entering 4Vn the following Apr-May (Sinclair, Appendix 2, Fig. 1). The over-wintering fleet distribution spanned 4Vn and part of 4Vs, in both cases along the edge of the Laurentian Channel.

Biological Indicators

Of the remaining studies, all were highly suggestive of stock mixing within 4Vn, although none provided conclusive evidence of its existence. The pattern common to most of the studies was one of 4T-like characteristics in young (ages 1-3) 4Vn cod, becoming more and more similar to 4Vs at older (7+) ages. This pattern was evident in both the length at age trajectories (Sinclair and Fanning, Appendix 2) and the fish-otolith allometry trajectories (Campana, Appendix 2), suggesting an influx (either continuous or sporadic) of 4Vs cod into 4Vn through time. Linear models of RV catch at age data by both Sinclair (Appendix 2) and Fanning (Appendix 2) indicated that cohorts of 4Vn fish were depauperate in young fish relative to the number of older fish from the same cohort which were later observed. Comparison of year-class coefficients across areas suggested that at least one year-class was strong in 4W until age 3, appeared in 4Vs at age 4, and subsequently appeared in 4Vn at age 5 (Fanning, Appendix 2). If such age-structured migration patterns were common to other year-classes as well, it could account for the increase in the numbers of each 4Vn cohort with age. Analyses of cohort-specific vertebral counts generally showed correspondence between 4Vn and 4Vs, with some exceptions (Frank, Appendix 2).

While the above studies all suggest that 4Vs is a source of at least some adult cod to 4Vn, the source of young 4Vn cod is less clear. Given the evidence of spawning in the area (Mohn, Appendix 2; Lambert and Wilson, Appendix 2), some proportion of 4Vn recruits must originate from the resident stock. However, calculations based on current speeds and egg development rates indicate that drift of eggs and larvae from the Magdalen Island spawning site in 4T is also possible. There was no evidence one way or the other to indicate whether such an influx actually occurs. Nor were analyses of year-class strength particularly helpful in this regard. Despite some general synchrony in year-class strengths among 4T, 4Vn and 4VsW, year-class effects were weak in 4Vn through at least age 3 (Sinclair, Appendix 2). The 4Vn year-class effects became stronger at ages 4-6, once again suggesting continued dilution or migration into the 4Vn cod stock through time.

Objective: Review available information concerning the presence of 4Vn resident cod in other assessment units throughout the year

In the absence of genetic, otolith or other types of markers to identify specific stock components, only tagging data could be used to address this objective. These data indicated that significant numbers of cod tagged in 4Vn in summer were subsequently recaptured in other areas (Stobo and Fowler, Appendix 2). 4VsW was particularly well represented in winter recaptures (Fig. 11), consistent with a winter migration parallel to that of 4T cod. However, considerable numbers of recaptures were also made in summer in 4VsW (Fig. 8, 12). A few recaptures were also made on the other side of the Laurentian Channel in 3Ps and 3O, with even fewer from 4RS (Fig. 8, 12).

On a more general note, the Working Group recognized that 4Vn is a small geographic area. Given the dispersal rates noted in cod throughout the Atlantic, it is possible that significant numbers of 4Vn resident cod exit 4Vn each year due simply to dispersal processes across a relatively large perimeter:area ratio. Given the larger population sizes of the adjacent cod stocks, such an effect would be cumulative, and therefore would become increasingly noticeable with time for any given cohort.

Objective: Assess the utility of the summer RV survey in 4Vn as an index of stock abundance

In general, the summer RV survey of 4Vn appears to provide a poor index of stock abundance. The Working Group identified three sources of error and imprecision that contribute to this problem:

1) Because of the small area, the survey design allocates few sets to the 4Vn area; in many years, the total number of sets is around 12, which is too few to provide high precision. In an analysis of RV survey efficiency, Smith (1991) noted that relative efficiency due to stratum and set allocation effects was no worse in 4Vn than in other Scotia-Fundy cod stocks. However, the CVs around the abundance estimates in 4Vn were higher than in the other stocks. An increase in the number of sets per stratum would improve the precision of the abundance estimates. The question then becomes: which stock(s) are being measured?

2) Past stock assessments of 4Vn cod have reported that year-classes were poorly tracked in the summer RV survey catch at age. Sinclair's analysis (Appendix 2, Fig. 1) supports this suggestion by showing that the internal consistency of the survey is lower in 4Vn than elsewhere. Indeed, there was no significant year-class effect in 4Vn for ages 1-3.

3) The age coefficients estimated from linear models of RV catch at age data by both Fanning (Appendix 2) and Sinclair (Appendix 2) indicate that the summer RV survey collects relatively few young fish in 4Vn. These results could indicate either that most of the young fish are unavailable to the survey gear in 4Vn, or that a significant proportion of the adult fish found in 4Vn are not of 4Vn origin, or both.

Objective: In light of the above, through RAP, assess the relevance and utility of the current 4Vn cod (May-October) stock assessment unit

The current 4Vn cod stock assessment unit has had limited utility and relevance, as evidenced by the lack of confidence usually given the assessments of this stock by the CAFSAC Groundfish Subcommittee. The following concluding statement from the section of Subcommittee Report 92/13 dealing with 4Vn cod is representative of the Subcommittee report of most years: "Given the lack of coherence among the various sources of information and the degree of uncertainty, there is no scientific foundation to recommend a change in advice." The findings of this Working Group make considerable progress in explaining the poor quality of past assessment advice. However, these explanations do not change the fact that the current assessment unit has significant problems for which solutions have not been identified.

The Working Group noted that the resident 4Vn cod stock is but one of a number of coastal cod stocks in the northwest Atlantic. However, it is the only coastal stock with a discrete assessment unit. There is no question that there is a persistent spawning component in 4Vn. However, there are also multiple spawning components in 4T (Shediac Valley and Magdalen Islands), 4VsW (inshore, offshore, spring and fall), and 4X (inshore complex and Browns Bank), each of which is assessed as a stock complex. Thus the time has come to reconsider the rationale for treating 4Vn cod differently from these other stocks. That being said, there is a very clear rationale based on social and economic considerations for providing a distinct management unit for resident 4Vn cod. Nevertheless, a separate management unit does not necessarily require a separate assessment unit.

Objective: Determine if an alternate assessment unit would be more useful in assessing the abundance of cod in and around Cape Breton. Consider modifications to either the geographic extent or the time period covered

Modifications to the geographic or temporal boundaries of the 4Vn cod assessment unit were discussed by the Working Group. In the absence of additional research, the Working Group could not recommend an improved winter boundary between 4T, 4Vn and 4VsW cod, although 4T cod appear to restrict themselves more to the shelf edge than do the other two stocks. A more significant problem appeared to be the extent of stock mixing between 4Vn and other stocks at other times of the year, both within 4Vn and elsewhere. At all times of the year, stock mixing within and around 4Vn is present, and probably varies on a year to year basis. Some of this mixing is associated with the "edge effect" of a small geographic area, which necessarily involves greater two-way dispersion across boundaries than would a larger area. Moreover, some of the stock mixing appears to occur on an age-structured basis, whereby 4T may be more likely to provide additional recruits to 4Vn, while 4VsW may be a more likely source of additional adults. If confirmed, this form of mixing creates a moving target for assessments, and one that is difficult to address by adjusting fixed boundaries.

The Working Group considered various options for alternate assessment areas, including the incorporation of 4Vn cod (May-Oct) into the 4VsW stock assessment unit. The rationale for amalgamating the 4Vn and 4VsW stocks was linked with the perceived association between the two stocks, which appeared to be stronger than that between 4Vn and 4T. However, the advantages to carrying out such a stock aggregation were not clear. While both benefits and drawbacks to amalgamating the assessment units were discussed, there was no information tabled upon which to base a decision. However, spatially-variable assessment models may hold some promise. Given the current stock status in both 4Vn and 4VsW, it was recommended that no change be made until more information is available.

While modifications to the fixed boundaries of 4Vn may not be advantageous, there may be some potential in developing an assessment unit based on stock origin. If it were possible to identify the stock origin of individual fish based on genetic, otolith or other markers, it would then be possible to assign and pro-rate both commercial and RV catches to their original stock, irrespective of location of capture. Such stock-assigned data could then be treated using standard assessment protocols, without the confounding effect of stock mixing. It is not currently possible to identify individual cod collected in 4Vn as to their stock origin. However, such identifications are feasible in principle (see next section).

Objective: Where necessary, recommend to line management research programs to address unresolved issues

The Working Group identified several changes in standard operating procedure, as well as research items, which could make significant improvements to our ability to assess the 4Vn resident cod stock. These are listed below in no particular order of feasibility and cost:

1. Allocate more sets to the summer RV survey in 4Vn.
2. Weigh all otoliths prior to embedding for potential use in fish-otolith allometric analyses.
3. Given their importance in discriminating among the 4T, 4Vn and 4VsW cod stocks based on age, allometric and elemental characteristics, enhance the collection of otoliths from both commercial and RV sources. Significant numbers from each survey or sample should be left intact and unembedded for future elemental and genetic analyses.
4. Examine survey efficiency implications of combining 4Vn with 4Vs.
5. Develop SPA with capabilities for handling spatially-heterogeneous stock distributions.
6. Determine the stock origin of adult cod. The most promising approaches include the use of DNA gene probes and otolith elemental fingerprints, both of which have been used to successfully discriminate among cod stocks. A proposal to use both forms of analyses, along with others, in carrying out a high-resolution study of cod stock structure in the Gulf of St. Lawrence has been submitted to DFO in Ottawa for consideration as to high-priority science funding.

Management Considerations

The Working Group was not specifically asked to comment on the management of 4Vn cod. Nevertheless, in the course of its deliberations, the Working Group identified a number of management measures which would have clear benefits in conserving the resident 4Vn cod stock in the face of fishing pressure on the adjacent, larger cod stocks.

1. Close the "Gutter" fishery on spawning cod in the Sydney Bight each May-June. These fish constitute what may be the major spawning component in 4Vn, and are unlikely to be able to withstand continued, intensive fishing effort by an efficient mobile gear fleet.
2. Continue to manage 4Vn cod (May-Oct) separately from either 4T or 4VsW to restrict effort on the local resident stock and in recognition of the social and economic concerns of the local fishing community.
3. Restrict winter (Nov-Apr) fishing in 4Vn to the offshore region, adjacent to the Laurentian Channel, in order to minimize the by-catch of resident 4Vn cod by fleets targeting the winter migration of 4T cod.

References

Halliday, R.G. 1972a. A yield assessment of the eastern Scotian Shelf cod stock complex. ICNAF Res. Bull. 9: 117-124.

Halliday, R.G. 1972b. The fishery on the Southern Gulf of St. Lawrence cod stock, 1960-70. ICNAF Res. Bull. 9: 51-64.

Halliday, R.G. 1974. The cod stocks of the Southern Gulf of St. Lawrence and Sydney Bight (Div. 4TVn). ICNAF Res. Doc. 74/24, Ser. No. 3171, 16p.

Ihssen, P. E., H.E. Booke, J.M. Casselman, J.M. McGlade, N.R. Payne and F.M. Utter. 1981. Stock identification: materials and methods. Can. J. Fish. Aquat. Sci. 38:1838-1855.

Koutitonsky, V. G. and G.L. Bugden. 1991. The physical oceanography of the Gulf of St. Lawrence: a review with emphasis on the synoptic variability of the motion. Can. Spec. Publ. Fish. Aquat. Sci. 113:57-90.

Lambert, T.C. and S. Wilson. 1994. Update on the status of 4Vn cod: 1992-1993. DFO Atl. Fish. Res. Doc. 94/46.

Martin, W.R. and Y. Jean. 1964. Winter cod taggings off Cape Breton and on offshore Nova Scotia banks, 1959-62. J. Fish. Res. Bd. Canada, 21: 215-238.

McClelland, G. and D.J. Marcogliese. 1994. Larval anisakine nematodes as biological indicators of cod (Gadus morhua) populations in the southern Gulf of St. Lawrence and on the Breton

Shelf, Canada. Bull. Scand. Soc. Parasitol. 4:97-116.

McCracken, F.D. 1957. Results of cod tagging off eastern Nova Scotia. Fish. Res. Bd. Canada, Atl. Prog. Rept. 67: 6-13.

McCracken, F.D. 1959. Cod tagging off northern New Brunswick in 1955 and 1956. Fish. Res. Bd. Canada, Atl. Prog. Rept. 72: 8-19.

McKenzie, R.A. 1956. Atlantic cod tagging off the southern Canadian mainland. Fish. Res. Bd. Canada, Bull. 105, 93p.

Page, F.H. and K.T. Frank. 1989. Spawning time and egg stage duration in northwest Atlantic haddock (Melanogrammus aeglefinus) stocks with emphasis on Georges and Browns Bank. Can. J. Fish. Aquat. Sci. 46 (Suppl. 1):68-81.

Paloheimo, J.E. and A.C. Kohler. 1968. Analysis of the Southern Gulf of St. Lawrence cod population. J. Fish. Res. Bd. Canada, 25: 555-578.

Smith, S.J. 1991. Assessing the efficiency of the groundfish survey design for the Scotian Shelf summer trawl surveys -- 1980-1990. CAFSAC Res. Doc. 91/39.

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

APPENDIX 1

Approved Terms of Reference of the 4Vn Cod Working Group

Background

During the May 1994 meeting of the Regional Advisory Process Committee, questions were raised concerning the scientific value of a 4Vn cod (May–December) stock assessment. While the assessment period was recently adjusted to May–October to better account for the migration of 4T cod through 4Vn, there remains the possibility that the currently-defined 4Vn subdivision does not represent the home range of a unit cod stock. This possibility was highlighted by ongoing difficulties in producing an internally-consistent stock assessment, and in the apparent absence of a coherent signal of cod abundance in the summer RV survey. The Committee recommended striking of a working group to study this issue in 1994/95 using available information.

Objectives

The working group is to:

1. Review and document the historical context of the current stock boundaries.
2. Review available information concerning stock mixing in 4Vn by season and location.
3. Review available information concerning the presence of 4Vn resident cod in other assessment units throughout the year.
4. Assess the utility of the summer RV survey in 4Vn as an index of stock abundance.
5. In light of the above, through the RAP, assess the relevance and utility of the current 4Vn cod (May–October) stock assessment unit.
6. Determine if an alternate assessment unit would be more useful in assessing the abundance of cod in and around Cape Breton. Consider modifications to either the geographic extent or the time period covered.
7. Where necessary, recommend to line management research programs to address unresolved issues. This input will be useful for the upcoming "OPEN III" initiative.

Membership

The participation is to be from both MFD and GFC (Moncton). While there is in principle no restriction of staff participating, the core group should consist of at least the following:

S. Campana (chair)
R. Halliday
T. Lambert
R. Mohn

The chair is to solicit the participation of other relevant staff as and when required. W. Stobo for instance could be approached regarding the tagging data base.

Schedule

The Working Group is to conduct its activities during the rest of 1994/95, in time for tabling of a report at the spring 1995 RAP.

It is expected that the working group would consult on an ongoing basis with staff, holding meetings as required.

APPENDIX 2

The following working papers, presented here in alphabetical order, comprise those discussed by the 4Vn Cod Working Group. In many instances, the individual working papers were of sufficient import that they were later re-drafted for submission as DFO Research Documents or Technical Reports. To avoid repetition, only the salient figures and an abstract of the latter documents have been extracted for presentation here. In the interim, the full text of those working papers is available from the authors.

USE OF OTOLITHS IN DIFFERENTIATING AMONG 4T, 4Vn AND 4Vs COD

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The physical and chemical characteristics of fish otoliths make them particularly useful for studies of stock discrimination. The utility of otoliths is largely based on their inorganic nature: unlike bone, otolith material is metabolically inert, and thus unlikely to be resorbed or altered after deposition (Campana and Neilson 1985). As a result, otolith growth is conservative relative to body growth, and thus relatively insensitive to the short-term processes such as starvation which can distort or modify other body parts. This conservative growth process lends itself to several potential and realized stock discrimination capabilities, two of which are applicable to 4Vn cod: otolith elemental fingerprints and otolith allometry.

The physical and chemical oceanography of the 4Vn area makes it a likely candidate for stock discrimination based on otolith elemental fingerprints. Trace elements incorporated into the growing surface of the fish otolith are derived primarily from the surrounding water, as modified by temperature, thus reflecting the physical and elemental composition of the ambient environment. Since otoliths grow continuously throughout the life of the fish and otolith material is not resorbed after deposition, fish populations growing up in different water masses produce otoliths of different elemental composition (Campana and Gagné 1994), despite any periodic inter-mixing. Since the oceanography of the Sydney Bight region differs from that of both the southern Gulf and the eastern Scotian Shelf, the elemental fingerprints of any 4Vn resident cod should also be characteristic.

The otolith elemental fingerprints of cod from western 4T differed significantly from those of 4Vs (Fig. 1), despite the samples having been matched for size of fish and date of collection (Campana et al. 1995). The 4Vs fingerprints did not differ significantly between years of collection along the stock discrimination (first principle component) axis. Thus the fingerprints were relatively stable through time within a stock. However, the sample from the western coast of Cape Breton (eastern 4T) did differ significantly from that of both western 4T and 4Vs. Unfortunately, a corresponding sample from 4Vn was not available for comparison with the eastern 4T sample. Such a comparison might have indicated that eastern 4T cod were distinct from those of 4Vn. On the other hand, if cod from eastern 4T and 4Vn actually form a single aggregation, the elemental fingerprint results would indicate that the group is environmentally distinct from that of both the main 4T (western Gulf) and 4Vs stocks. Therefore the elemental fingerprints of cod in this region are logical candidates for future research.

It is well documented that slow-growing fish produce heavier otoliths than do fast-growing fish of the same body length (Templeman and Squires 1956; Campana 1990). Thus it is reasonable to expect the relationship between otolith weight and fish length in a region to reflect the average difference in growth rate which characterizes the cod stocks of 4T, 4Vn and 4Vs. Of course, these relationships would not be expected to show the spatial or temporal stability of an elemental fingerprint. Nevertheless, growth rate differences form the current basis for separating mixed catches of 4T and 4Vs cod in the 4Vs winter fishery (Hanson and Nielsen 1992).

To determine the potential of otolith allometry for stock discrimination, samples of 4T, 4Vs and 4Vn cod otoliths from various locations and months of 1992 were compared with ANCOVA to determine if there were consistent differences within and among the stocks. Comparisons among four independent samples of the southern Gulf showed no significant differences between east and west, and only a small (albeit significant) difference between June and July collections. A similar comparison among July, August and October samples in 4Vs showed no significant differences among months. Thus the otolith allometric relationship appeared to be reasonably stable within stocks. However, when all of the above data was compared between stocks, the 4Vs and 4T samples differed significantly (Fig. 2), indicating a stock-specific relationship through much of 1992.

Otolith samples from 4Vn cod in 1992 were not available to this analysis. To determine if a comparison to 1993 4Vn samples might be justified, July 1992 and August 1993 samples in 4Vs were compared and tested for inter-year differences. The differences were not significant. Assuming similar inter-year stability in 4Vn, July and August 1993 samples from 4Vn were compared with the 1992 samples from 4T and 4Vs described previously. The differences in allometry among all three stock areas were highly significant, with the allometric relationship for 4Vn lying between that of 4T and 4Vs, but closer to the latter (Fig. 3).

The analysis described above does not provide definitive evidence of a unique 4Vn cod stock, since the various samples could not be precisely matched by year. However, the relative stability of the stock-specific allometric relationship through time suggested that further research is justified. If successful, stock-specific allometric relationships might prove to be a cost-effective approach to determining the stock composition of samples from the 4Vs winter fishery.

References

CAMPANA, S. E. 1990. How reliable are growth backcalculations based on otoliths? Can. J. Fish. Aquat. Sci. 47:2219-2227.

CAMPANA, S. E. and J.A. GAGNE. 1994. Cod stock discrimination using ICPMS elemental assays of otoliths. In: D.H. Secor, J.M. Dean and S.E. Campana [ed]. Recent Developments in Fish Otolith Research. University of South Carolina Press. Columbia, SC. In press.

CAMPANA, S. E. and J.D. NEILSON. 1985. Microstructure of fish otoliths. Can. J. Fish. Aquat. Sci. 42:1014-1032.

CAMPANA, S. E., J.A. GAGNE and J.W. McLAREN. 1995. Elemental fingerprinting of fish otoliths using ID-ICPMS. Mar. Ecol. Prog. Ser. In press.

TEMPLEMAN, W. and H.J. SQUIRES. 1956. Relationship of otolith lengths and weights in the haddock Melanogrammus aeglefinus (L.) to the rate of growth of the fish. J. Fish. Res. Bd. Canada 13:467-487.

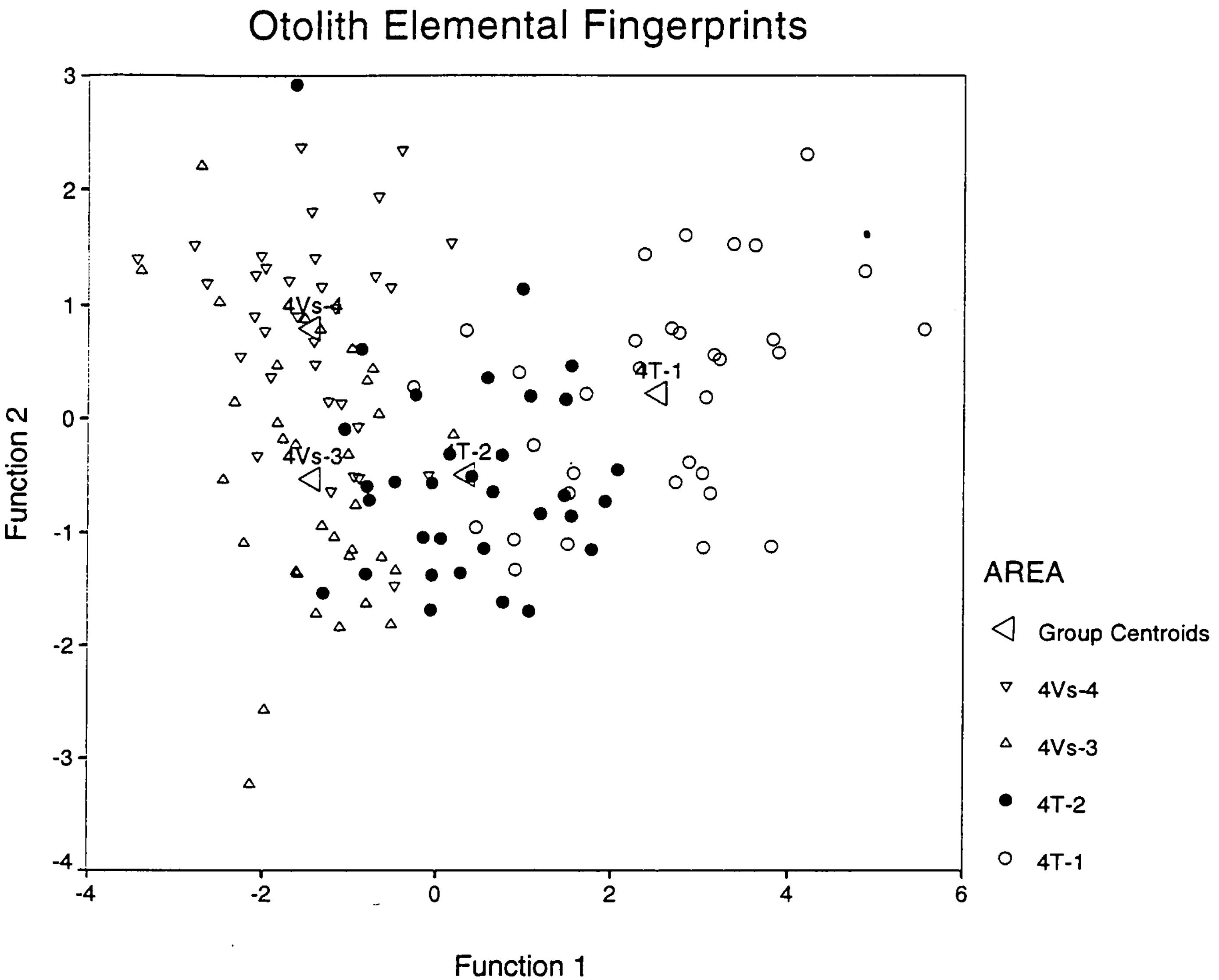


Fig. 8. Discrimination of 4T cod (4T-1 = west; 4T-2 = east) from 4Vs cod (4Vs - 3 = 1993; 4Vs-4 = 1992) using otolith elemental fingerprints.

Fig. 2

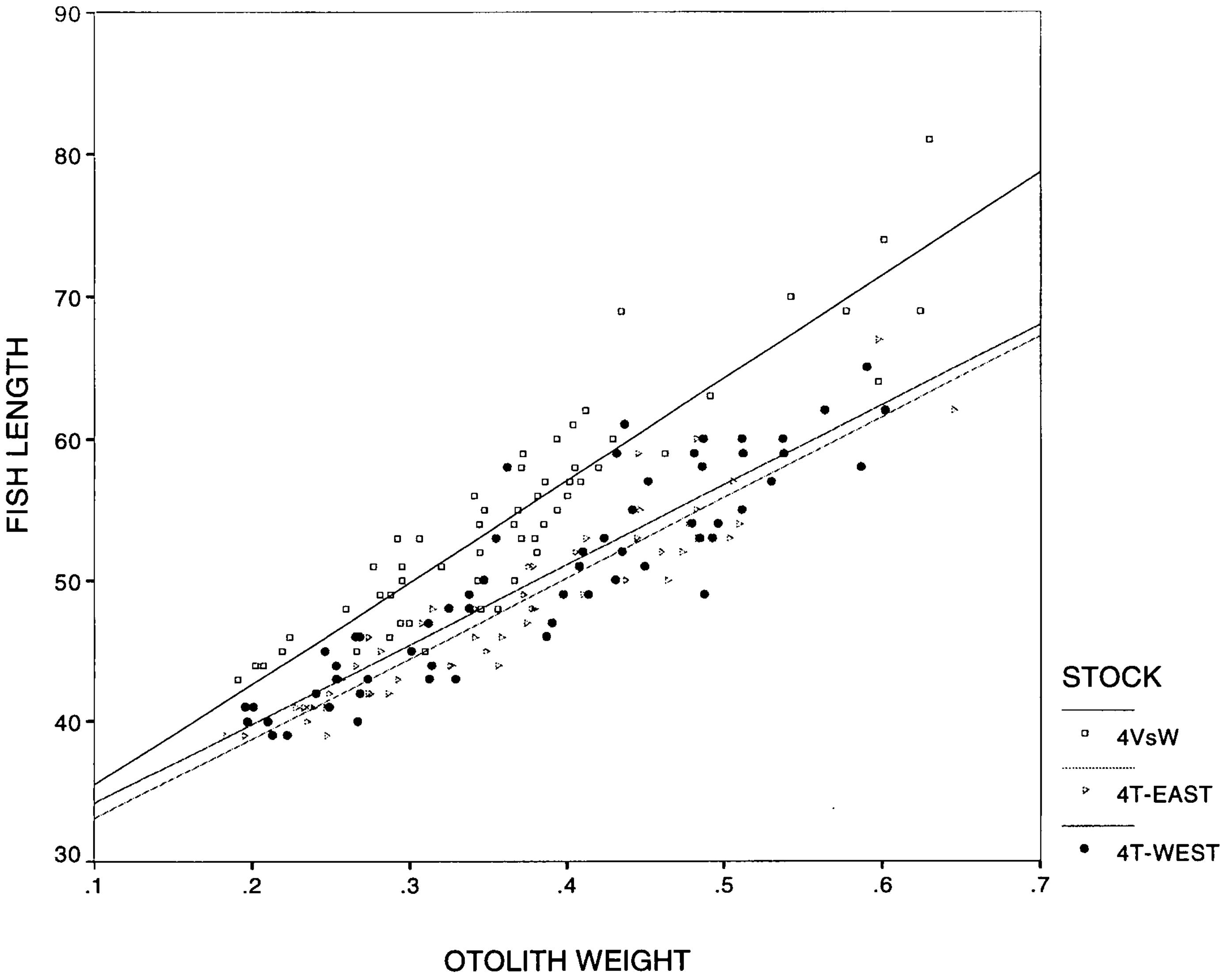
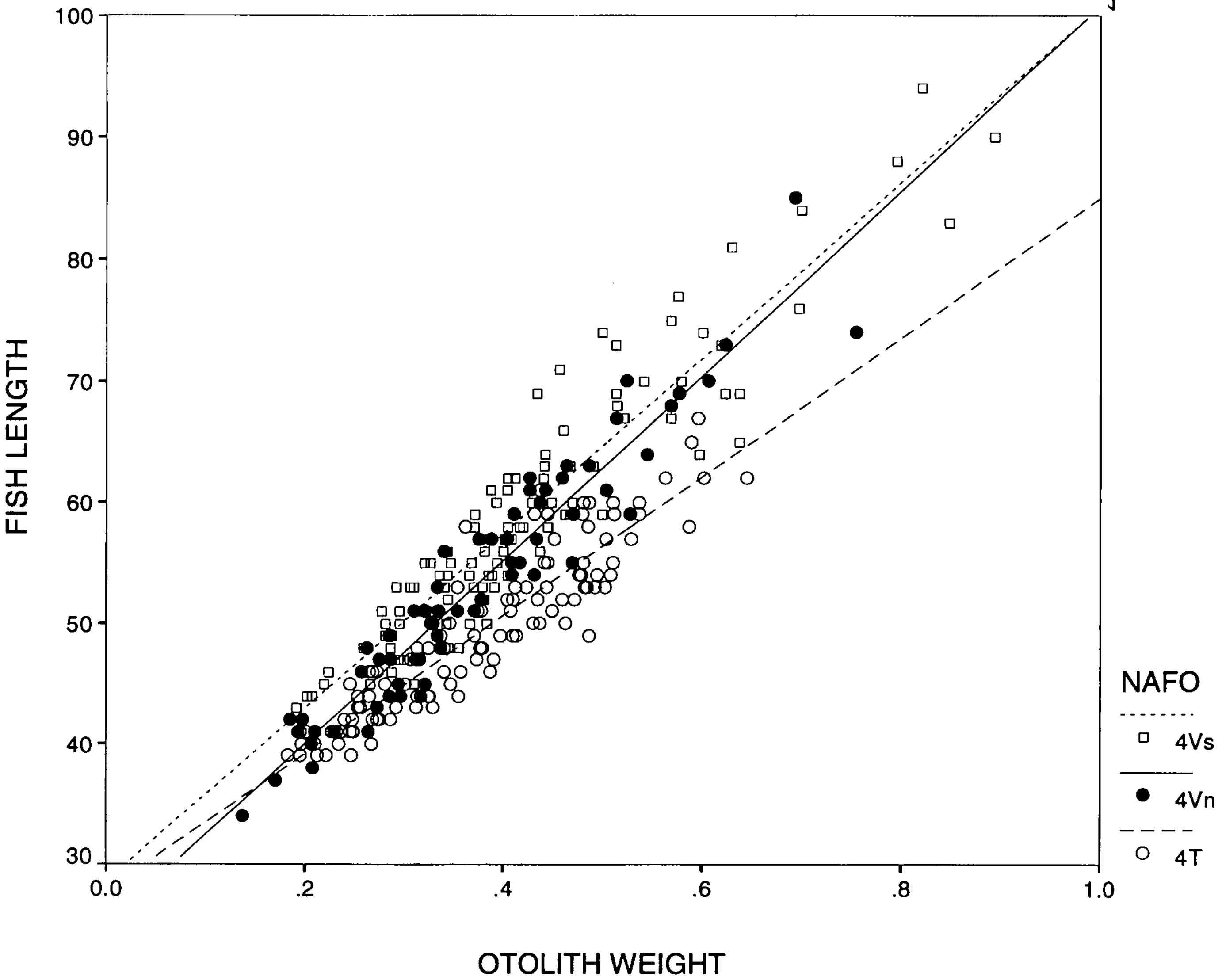

90
80
70
60
50
40
30
FISH LENGTH
.1
.2
.3
.4
.5
.6
.7
OTOLITH WEIGHT
STOCK
4VsW
4T-EAST
4T-WEST

Fig. 3



FISH LENGTH
100
90
80
70
60
50
40
30
0.0
.2
.4
.6
.8
1.0
OTOLITH WEIGHT
NAFO
4Vs
4Vn
4T

Linear models of cod surveys in 4T and 4VW.

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Introduction

Groundfish surveys are growing in importance as resource assessment tools as various fisheries are closed or reduced to minimal levels as the amount of information about stock status available when in the fishery is closed is essentially limited to surveys. In addition, there are relatively long time series available, in excess of 20 years, for both the Scotian Shelf and the Gulf of St. Lawrence in which highly consistent methodology and gear were utilized. In cases where changes were unavoidable there were significant efforts undertaken to estimate the impact on the time series of survey results.

This paper will examine the survey data for cod from five areas, NAFO (sub)divisions 4W, 4Vs, 4Vn, and NAFO division 4T split into eastern and western components based on survey strata boundaries. The individual catches of cod are analysed in a separable model including year, stratum, age and yearclass within each of the five areas. Consistencies in estimated coefficients are considered in terms of stock area affiliations, in particular 4Vn.

Methods

Data

These data were collected during the summer (July) Scotian shelf groundfish surveys from 1971 to 1993 and the fall (September) southern Gulf of St. Lawrence groundfish surveys from 1971 to 1993. During these surveys different survey vessels have been used at different times and conversions factors have been applied based on comparative fishing experiments at the time changes occurred (Table 1). The standard survey data processing was used for each area to produce the standardized (for vessel and distance towed) numbers caught at age in each set. Ages were assigned from annual age length keys compiled from data for each area separately. Because the survey design was not being explicitly incorporated into the analysis and because the sampling rates are not strictly proportional to stratum area the numbers caught at age were weighted by the stratum size divided by the number of sets in the stratum. This yields values that are the contributions to the total population numbers at age from each set and which implicitly incorporates the stratum sizes. To ensure consistent and comparable results in each area the data ranges to be included were restricted to ages 2-9, years 1971-93, and yearclasses 1962-91. In particular the yearclasses were restricted to a range in which all the relevant ages appeared.

Analysis

The basic approach to the analyses was to utilize multiplicative models of survey population numbers at age with explanatory such as for stratum, year, age, yearclass, vessel and area by log transforming the response variable. Zero-valued responses were treated as missing which has little impact on the predicted values, since only non-zero responses contribute to the population numbers and the observed zeros are still included in the weights i.e. in the number of sets in the stratum. Explanatory variables were treated as factors i.e. categorical variables for which the first category is assumed by convention to be zero, and interaction effects were explored. Models were fitted as a General Linear Model using the General ANOVA procedure in SPSS for Windows and SPSS for UNIX. Problem size limitations due to computer capabilities were a constraint which limited the development of all-inclusive models.

The 4Vs data was used for model selection amongst the factors year, stratum, age, yearclass, vessel, and the interactions stratum*age and stratum*yearclass. Residuals in all analyses were assumed to be i.i.d. Normal and examination of residual plots and normal probability plots was used to assess this. When several of the better models had been identified they were compared between areas. The results of individual models were compared between areas by plotting the coefficients for each factor level and by plotting predicted means for years. The predicted means were graphically compared to the corresponding survey population numbers (log-transformed) as well. The log-transformed model results were not re-transformed to the linear scale but were compared to log-transformed survey results because of the biases that are introduced when re-transforming from a non-linear scale.

The vessel effect was tested for 4Vn, 4Vs and 4W by using unconverted data, i.e. no conversion factors were applied, and including a vessel term in the model.

Results

A model including a vessel effect was tested in areas 4Vn, 4Vs, 4W and in all three areas the vessel term was highly significant but was highly correlated with the year effect. As a result it introduced a severe 'step' into the pattern of coefficients for years which was then offset by exceptionally large vessel coefficients (Table 2). This was deemed an unlikely model for survey numbers and vessel effects were not used analysed further.

All the main effect terms were highly significant ($p<.0001$) in all combinations however the two interaction terms examined were either non-significant or only marginally significant ($.05>p>.01$)

in all cases. The instances of significant effects associated with the interaction terms were limited to cases where a small number of the individual parameter estimates for the interaction effects were significant. In all cases the interactions were much less significant than the corresponding main effects and so were not included in the final model. The ANOVA tables from the final model for each area are given in Table 3. The parameter estimates from each of the five areas for the factors year, stratum, age and yearclass are plotted in Figures 1-4 respectively.

Predicted values from the final model for each area are summarized as means by year and means by yearclass and the means by year are compared directly to the stratified analysis results for areas 4Vn, 4Vs and 4W by rescaling the predicted means to be equal to the observed mean in 1971.

Discussion

The impact of treating the zero-valued responses as missing was minimal with respect to the predicted values, since only non-zero responses contribute to the population numbers and the observed zeros are still included in the weights i.e. in the number of sets in the stratum. This does reduce the variance since the zeros are the lower extreme of the observations in all cases. It can be considered a conditional analysis i.e. an analysis of the factors influencing the log abundance of cod given that there were cod in the catch.

The combination of year, age and yearclasses creates a difficulty when defining the factor ranges to be analysed. If all available data are included it results in yearclasses which only appear at one age i.e. the oldest age in the first year or the youngest age in the final year. In this case the initial and terminal yearclasses will be difficult to estimate. Although it is possible, and possibly desirable, to utilize some of the partially represented yearclasses i.e those not present at all ages, these analyses utilized only those fully represented given the age and year ranges selected. This ensures that all yearclass estimates are based on equal numbers of ages however years will have variable numbers of yearclasses contributing to the estimates. A future analysis may explore the most appropriate means of balancing the year and yearclass estimation problem.

Examination of the year effects (Figure 1) shows the the very tight match of 4Tw and 4Te from about 1980 onward is much weaker for the earlier years. Also, from about 1981 onwards 4Vn is closely related to 4Te and from the late 80's onward, to 4Vs.

The stratum effects (Figure 2) have been estimated primarily as nuisance parameters in this analysis although these effects could be compared to allocation, variance and efficiency statistics from survey design based methods. It should be noted that all the most negative stratum effects are for edge strata along the deep water areas.

The age effects (Figure 3) are best interpreted as relative partial recruitment to the survey gear. Again, as with the year effects, 4Tw and 4Te are the two most similar and 4Vn, while different, is closer to them than 4Vs or 4W. The curves for 4Vs and 4W have little similarity however the differences would be consistent with a generally higher proportion of young fish in 4W.

In all cases for the yearclass effects (Figure 4) the final yearclass is not estimable. The greatest range is shown by 4Tw and 4Vs and while there is a general agreement in all five areas in the yearclass sizes there is no noticable consistency between any pairs of areas.

The predicted means over years (Figure 5) show a reasonable consistency between 4Tw and 4Te, particularly from 1980 onward, as expected from the year effects. Because of the log transformed scale the series look much less noisy than is usually case when looking at untransformed survey data. The predicted means over yearclasses (Figure 6) show the most parallelism between 4Tw and 4Te however 4Vs and 4W are also closely related and 4Vn is generally closer to 4Vs than anything else. Both these figures must be interpreted bearing in mind that the standards for estimation are different in each area an so direct comparisons of magnitude are meaningless, only trends can be compared.

To make comparisons of magnitude the predicted values must be rescaled to the standards which they were based on. This is done for 4Vn, 4Vs and 4W (Figure 7) and compared with the log transformed stratified population numbers estimated directly from the individual surveys.

The predicted means for the year and yearclass effects are of particular interest because they represent two key population parameters of interest.

Table 1. Survey data sources and areas used in analyses.

Area	Survey	Years	Vessel	Conversion Factor	Notes
4T west	Gulf strata 415-429	1971-85	E.E.Prince		-Daytime only -Yankee trawl
		1985-91	Lady Hammond	Equation	Depth dependent w.r.t. EEP
		1992-94	Alfred Needler	Equation	Depth dependent w.r.t. EEP&LH
4T east	Gulf strata 431-439	As 4T west	As 4T west	As 4T west	
4Vn	Scotian Shelf strata 440-441	1970-81	A.T.Cameron		-Side trawler -Yankee trawl
		1982,1991	Lady Hammond	1.0	w.r.t ATC
		1983-90 1992-93	Alfred Needler	0.8 0.8	w.r.t ATC w.r.t. LH
4Vs	Scotian Shelf strata 443-452	As 4Vn	As 4Vn	As 4Vn	
4W	Scotian Shelf strata 453-466	As 4Vn	As 4Vn	As 4Vn	

Table 2. Vessel effect coefficients

Vessel	4Vn	4Vs	4W
ATC	1.879394	1.128059	1.180651
LH	-0.97731	-0.32885	-0.69257
AN	-0.90209	-0.7992	-0.48808

Table 3. Analysis of variance tables for each area.

A.) 4Tw - Southern Gulf of St. Lawrence (west)

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	13573.25	6479	2.09		
YEAR	1236.71	22	56.21	26.83	.000
STRATUM	3324.25	14	237.45	113.34	.000
AGE	2315.80	7	330.83	157.92	.000
YRCLASS	1411.67	14	100.83	48.13	.000
(Model)	12994.96	57	227.98	108.82	.000
(Total)	26568.20	6536	4.06		

R-Squared = .489
Adjusted R-Squared = .485
Redundancies in Design Matrix

Column	Effect
59	YRCLASS

B.) 4Te - Southern Gulf of St. Lawrence (east)

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	6384.10	3063	2.08		
YEAR	721.60	22	32.80	15.74	.000
STRATUM	2409.74	8	301.22	144.52	.000
AGE	589.56	7	84.22	40.41	.000
YRCLASS	424.72	14	30.34	14.56	.000
(Model)	5799.83	51	113.72	54.56	.000
(Total)	12183.94	3114	3.91		

R-Squared = .476
Adjusted R-Squared = .467
Redundancies in Design Matrix

Column	Effect
53	YRCLASS

C.) 4Vn - Scotian Shelf - Sydney Bight

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	1492.82	811	1.84		
YEAR	137.81	22	6.26	3.40	.000
STRATUM	264.22	2	132.11	71.77	.000
AGE	146.99	7	21.00	11.41	.000
YRCLASS	83.69	14	5.98	3.25	.000
(Model)	752.97	45	16.73	9.09	.000
(Total)	2245.79	856	2.62		

R-Squared = .335
Adjusted R-Squared = .298
Redundancies in Design Matrix
Column Effect
47 YRCLASS

D.) 4Vs - Scotian Shelf - Banquereau

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	6018.17	2486	2.42		
YEAR	278.13	21	13.24	5.47	.000
STRATUM	2824.57	9	313.84	129.64	.000
AGE	182.07	7	26.01	10.74	.000
YRCLASS	230.80	14	16.49	6.81	.000
(Model)	4036.09	51	79.14	32.69	.000
(Total)	10054.27	2537	3.96		

R-Squared = .401
Adjusted R-Squared = .389
Redundancies in Design Matrix
Column Effect
54 YRCLASS

E.) 4W - Scotian Shelf - Sable Island

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	7732.83	3015	2.56		
YEAR	264.53	22	12.02	4.69	.000
STRATUM	1545.90	13	118.92	46.36	.000
AGE	1111.66	7	158.81	61.92	.000
YRCLASS	308.07	14	22.01	8.58	.000
(Model)	4440.53	56	79.30	30.92	.000
(Total)	12173.37	3071	3.96		

R-Squared = .365
Adjusted R-Squared = .353
Redundancies in Design Matrix
Column Effect

58 YRCLASS

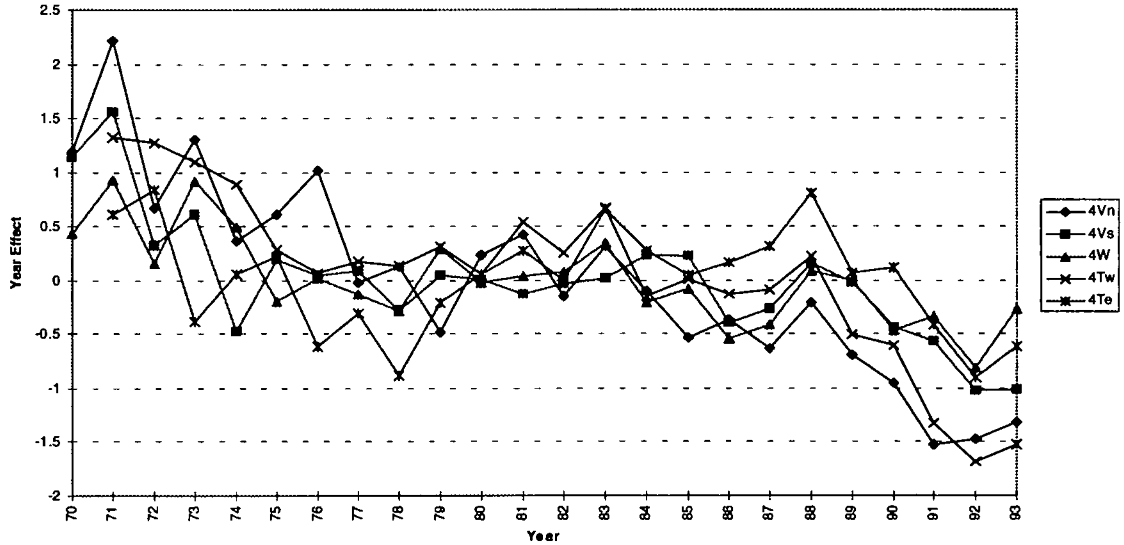

Figure 1. Year effects (coefficients) from independent analyses of each area.

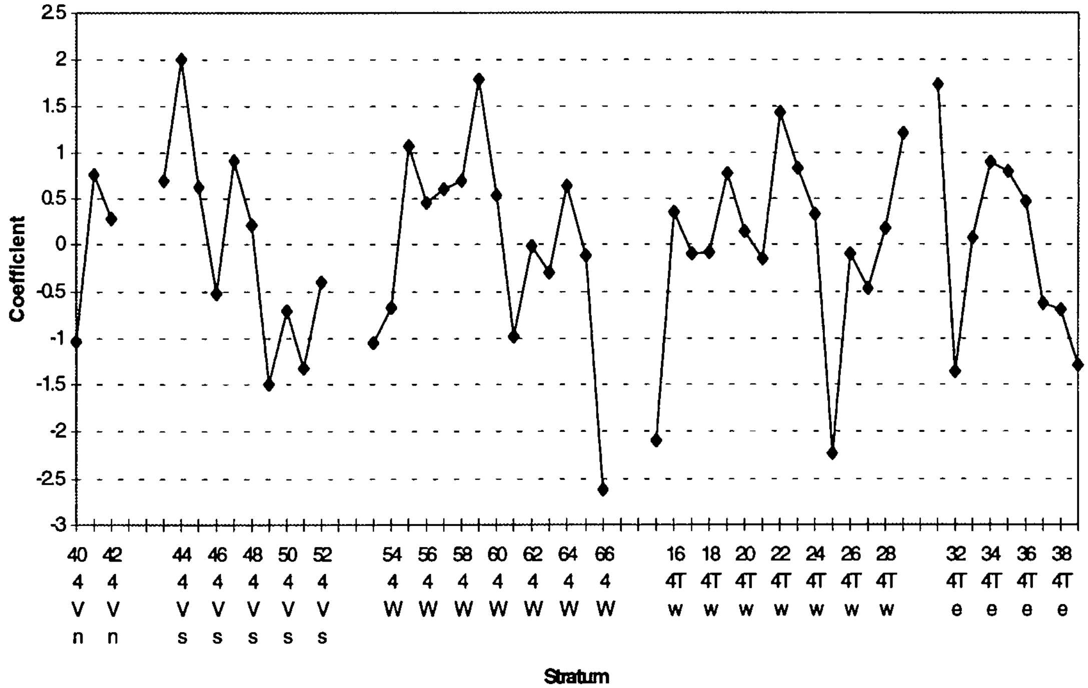

Figure 2. Stratum effects (coefficients) from independent analyses of each area.

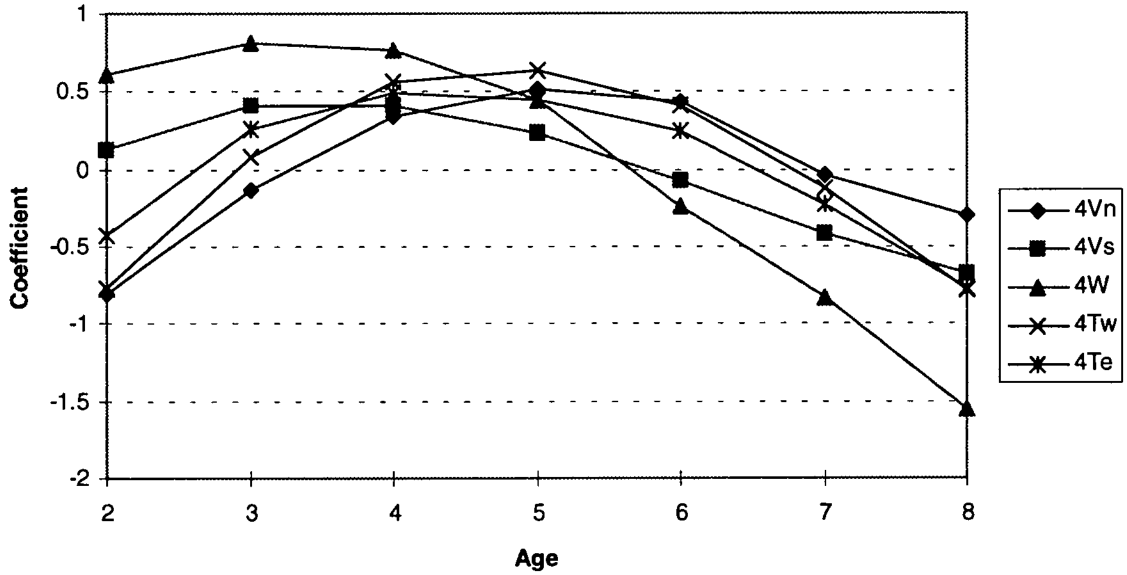

Figure 3. Age effects (coefficients) from independent analyses of each area.

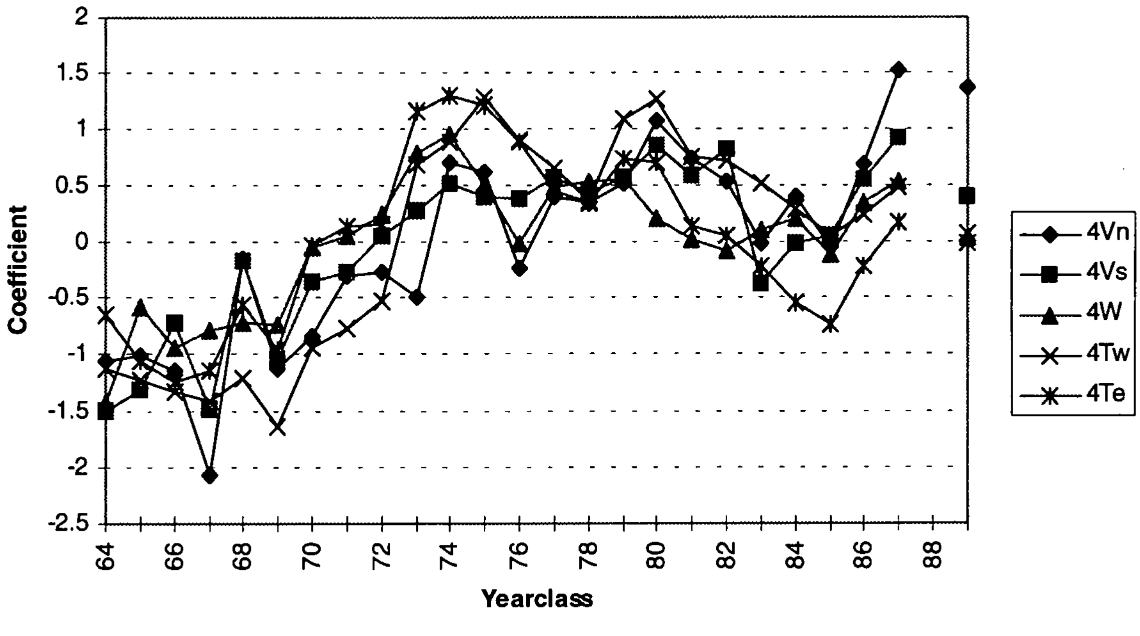

Figure 4. Yearclass effects (coefficients) from independent analyses of each area.

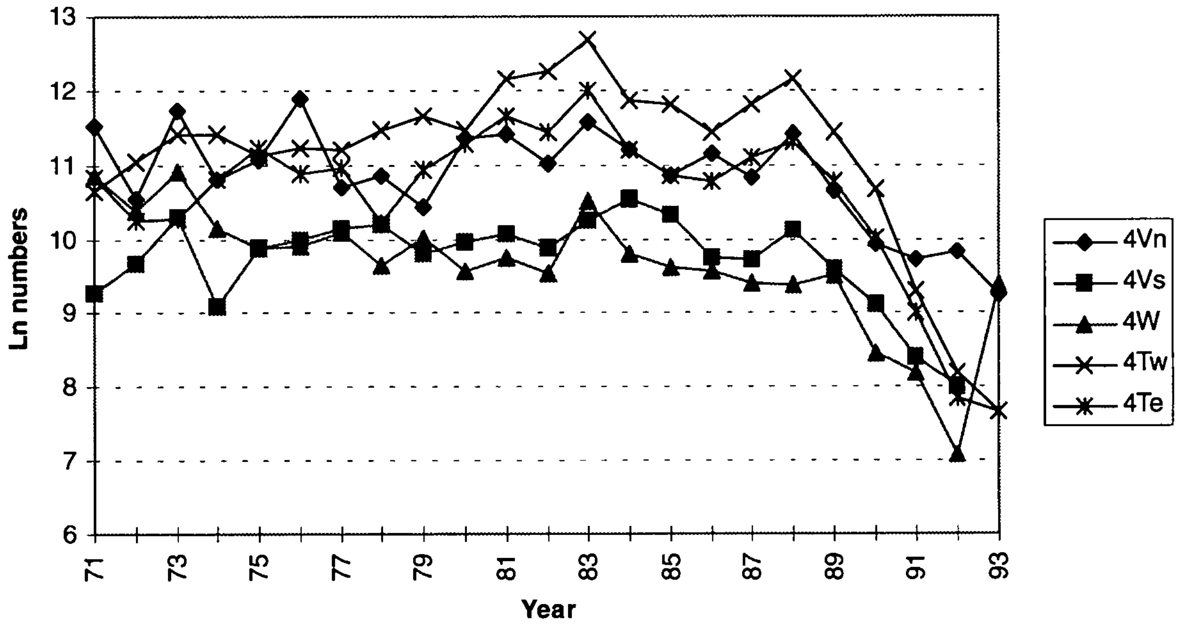

Figure 5. Predicted log population numbers from independent analyses for each area.

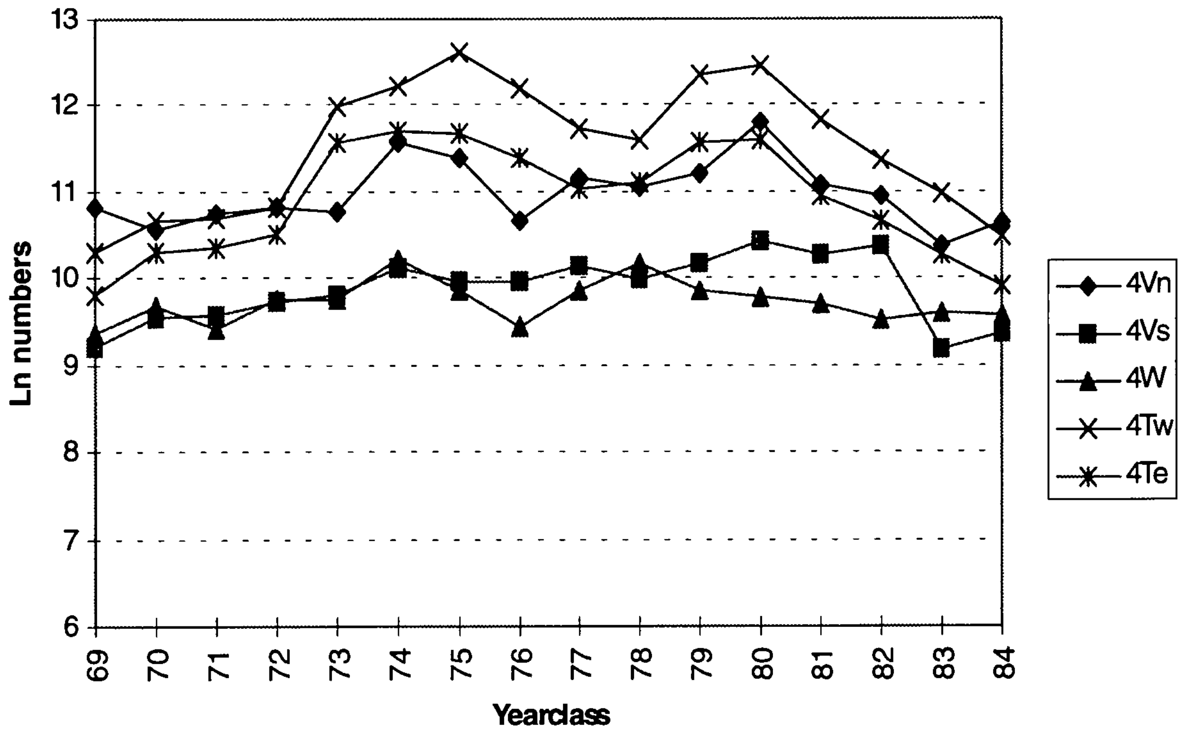

Figure 6. Predicted log yearclass size from independent analyses of each area.

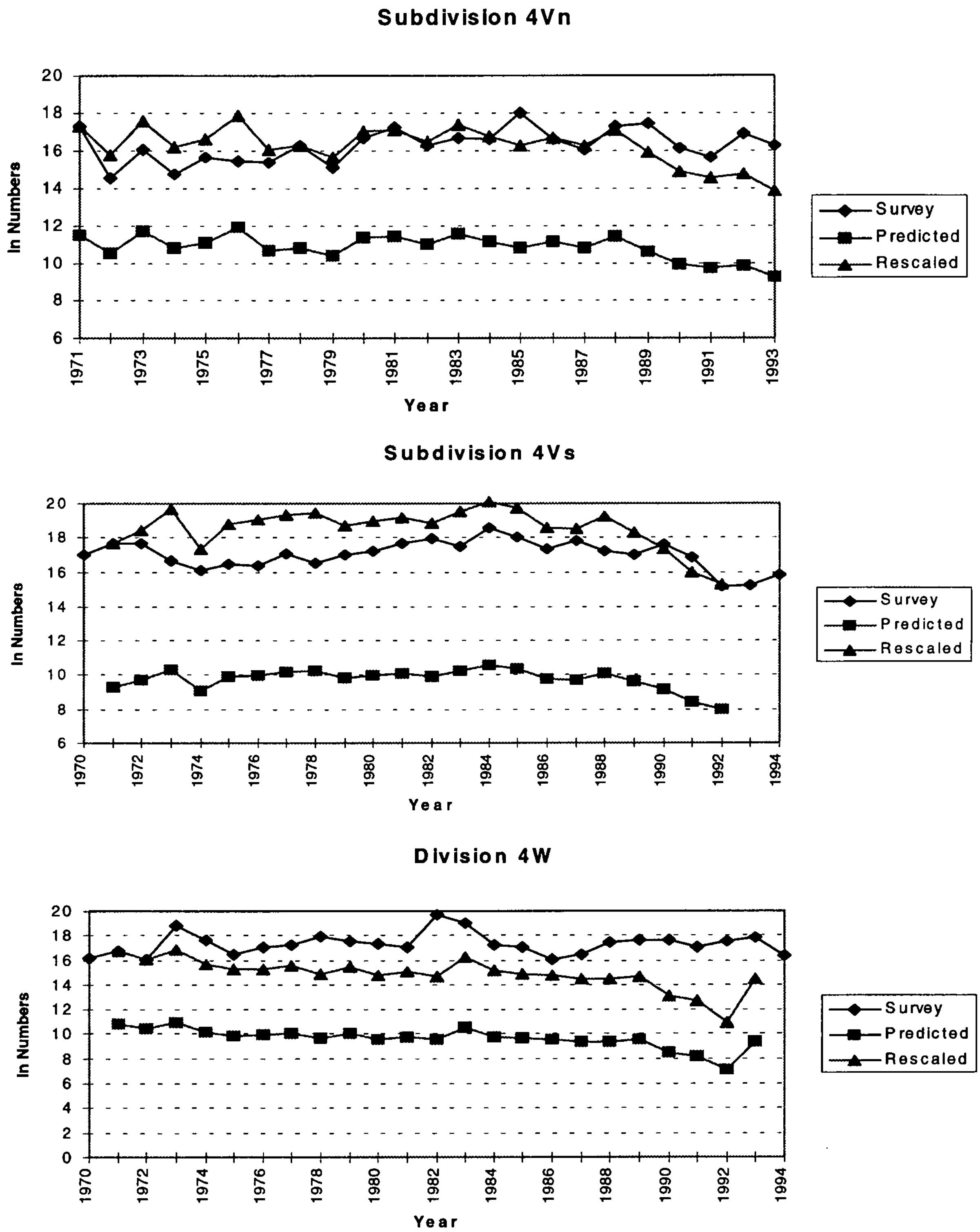

Figure 7. Predicted and observed (rescaled) log population numbers.

Analysis of meristic variation in cod populations from the Scotian Shelf: preliminary results from the 1994 summer research vessel survey

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Introduction

Recent collections of cod from the Scotian Shelf during the July 1994 research vessel survey were processed for vertebral counts. The resulting data were examined for differences in total vertebrae between the three cod management units recognized on the Scotian Shelf. Vertebral numbers within a population can be quite variable and this variation arises from both genetic and environmental influences. The vertebral number is fixed early in development (pre-juvenile) and many studies have shown that water temperatures and vertebral count are inversely correlated for the species examined. Consequently, most of the within population variation in vertebral counts is due to environmental variability acting on individual cohorts. Therefore, vertebral counts were evaluated on both a stock (age-aggregated) and yearclass (age-specific) basis.

Because vertebral count variation is partly genetic and partly environmental in origin we have made abdominal and caudal vertebral counts on each fish. The abdominal counts were expected to be less variable than the cadual counts and possibly more related to the genetic component of stock origin. The caudal vertebrae are involved in the mechanics of swimming by lateral undulations and as such it may be influenced by selective forces acting during different life history stages and therefore may be more indicative of environmental variation. These data (abdominal and caudal vertebrae and derived ratios) will be the focus of future analyses.

Materials and Methods

About 1200 cod carcasses were retained during the July 1994 groundfish survey of the Scotian Shelf. Processing of this material was achieved by boiling each carcass to remove the flesh and making direct counts of the vertebrae including the urostylar half vertebrae. This procedure resulted in the completion of about 20 fish/day and all of the fish were processed (n=1107) by the end of December 1994. Most of the fish have associated detailed information such as age, sex, weight, length, and maturity. These same fish have served as a source of tissue for the genetic assessment by the Marine Gene Probe Laboratory, Dalhousie University. For the analysis presented here only the aged material is examined (n=894). Therefore the age-aggregated analyses should be considered preliminary at this time.

Results

Total vertebral counts of cod, based on collections made during the July 1994 survey, ranged from 51 to 56 with modal counts split between 53 and 54 vertebrae (Figure 1). Mean vertebral counts differed significantly among the three cod management units and the differences were consistent with the water temperature regime in each region: mean vertebral counts were highest in Div. 4Vn (53.82) where it is generally coldest, lowest in Div. 4X (53.44) where it is warmest and intemediate in Div. 4VsW (53.65). This result was supported by a two-way analysis of variance with management unit and age as the main effects (Table 1). In this analysis both the age and stock*age interaction term were significant. This result warranted an examination of variation of vertebral counts on an age or yearclass specific basis both within and among the three management units.

Table 1. Two-way analysis of variance of vertebral counts of cod from the July 1994 research vessel survey of the Scotian Shelf. The main effects were management unit (3 levels) and age (9 levels: ages 0-8).

Source	Sum of Squares	df	Mean Square	F
Stock	16.591	2	8.29	10.22***
Age	28.640	8	3.58	4.41***
Stock*Age	14.314	10	1.43	1.76*
Error	689.139	849	0.81	
Total	748.685	869		

The mean and 95% confidence interval of vertebral count by age were calculated for each cod management unit. In general, the Div. 4X age-specific mean vertebral count was consistently lower for each yearclass compared to the other two management units (Figure 2). The age-specific mean vertebral counts were similar between Div. 4VsW and Div. 4Vn for most yearclasses except the 1990 yearclass (equivalent to age 4). Some other features of interest in this comparison is that the variation in total vertebral counts at age is generally higher and the modal count greater in Div. 4Vn than Div. 4VsW (Figure 3). This could be a result of greater mixing of cod of different origin in Div. 4Vn. This and other possible interpretations cannot be ruled out until cod samples from Div. 4T have been processed for vertebral counts.

Figure 1

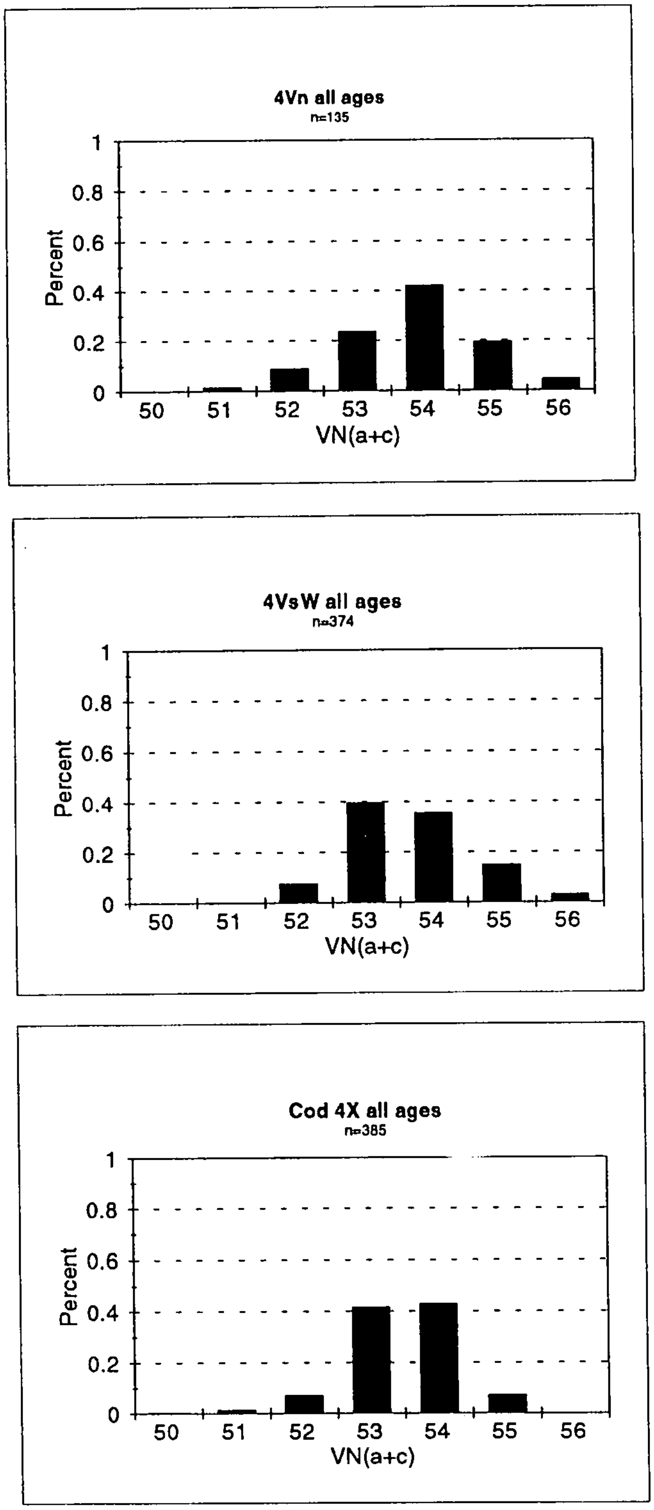
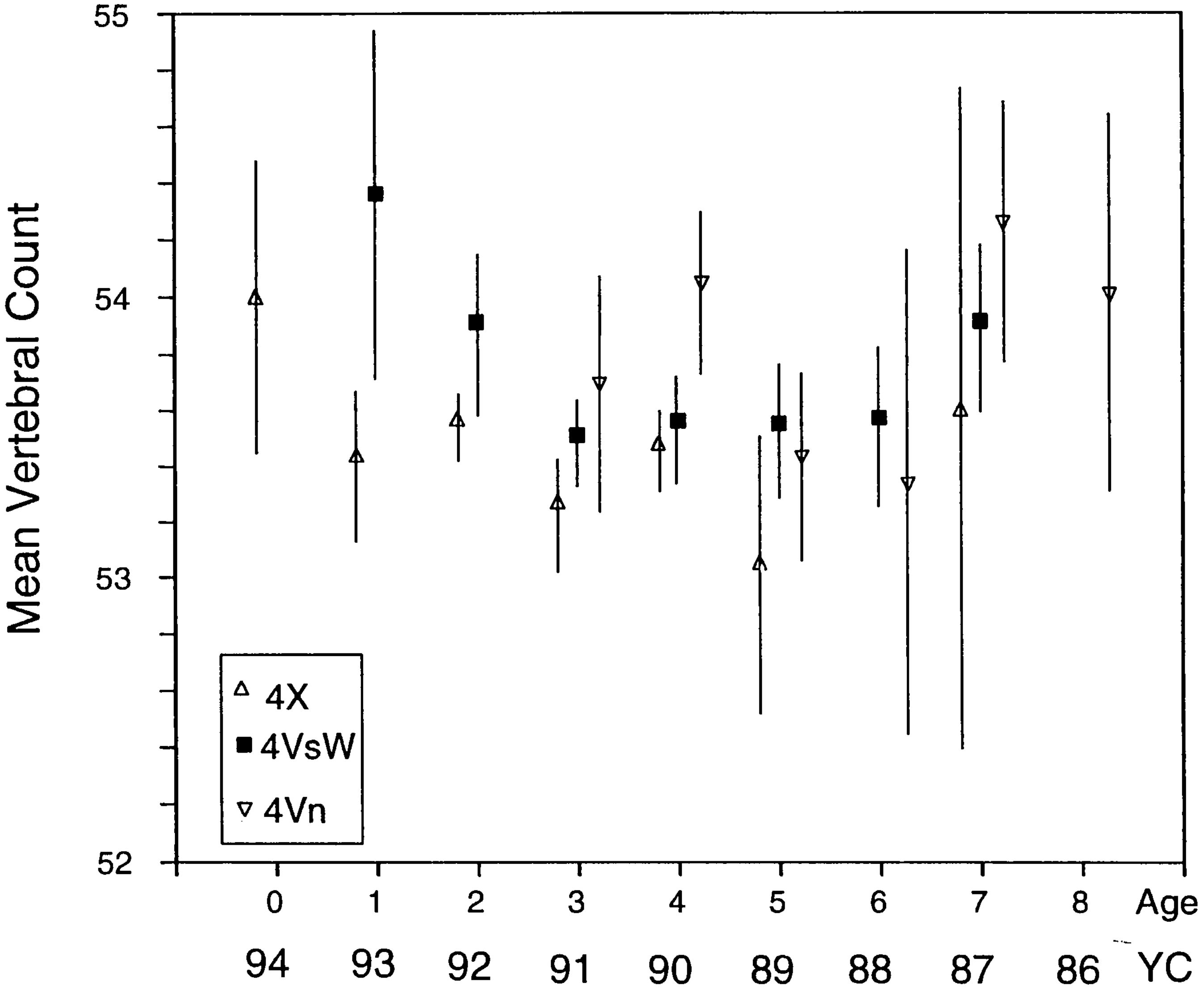
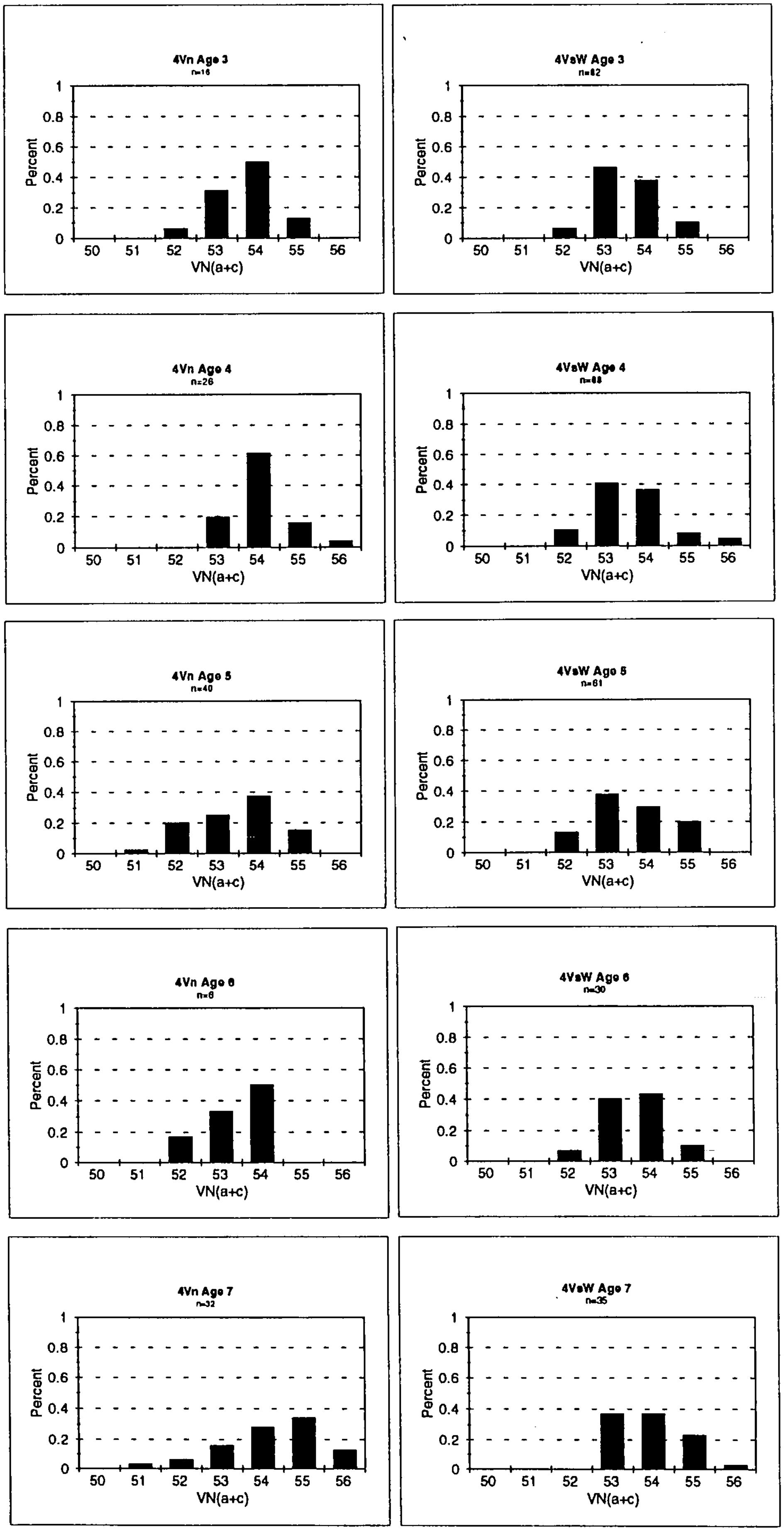

4Vn all ages
n=135
Percent
VN(a+c)
4VsW all ages
n=374
Percent
VN(a+c)
Cod 4X all ages
n=385
Percent
VN(a+c)

Figure 2



Mean Vertebral Count
55
54
53
52
4X
4VsW
4Vn
0
1
2
3
4
5
6
7
8
Age
94
93
92
91
90
89
88
87
86
YC

Figure 3


4Vn Age 3
n=16
4VsW Age 3
4Vn Age 4
n=26
4VsW Age 4
4Vn Age 5
n=40
4VsW Age 5
n=61
4Vn Age 6
n=6
4VsW Age 6
n=30
4Vn Age 7
4VsW Age 7
Percent
VN(a+c)
0
0.2
0.4
0.6
0.8
1
50
51
52
53
54
55
56

ICES mar. Sci. Symp., 198: 110–120. 1994

Possible causes of recent trends and fluctuations in Scotian Shelf/Gulf of Maine cod stocks

Kenneth T. Frank, Kenneth F. Drinkwater, and Fredrick H. Page

Frank, K. T., Drinkwater, K. F., and Page, F. H. 1994. Possible causes of recent trends and fluctuations in Scotian Shelf/Gulf of Maine cod stocks. – ICES mar. Sci. Symp., 198: 110–120.

Three major cod stocks are generally recognized in the Scotian Shelf/Gulf of Maine region: one each on the eastern and western Scotian Shelf (ESS and WSS) and Georges Bank (GB). Spring spawning is common to all stocks with peak egg concentrations occurring on offshore banks during January/February (GB cod), March/April (WSS cod), and April/May (ESS cod). Fall spawning, an event quite exceptional among cod stocks, also occurred during November/December in ESS cod at locations identical to those in spring. During the past two decades landings averaged about 50 000 t in ESS cod, 22 000 t in WSS cod, and 17 000 t in GB cod. Annual fishing mortality rates (F) have, on average, ranged from 0.51 to 0.61, with an increase since the mid-1980s in ESS cod. Recent fishing mortalities in ESS and GB cod have been substantially in excess of their long-term mean and have contributed to declines of spawning-stock biomasses (SSB) to near-historic low levels. In ESS cod, strong year classes were produced during the 1970s coincident with low SSB with a reversal of this situation occurring in the 1980s. Prior to the mid-1980s there existed a strong inverse correlation between ESS cod recruitment and St Lawrence River discharge (RIVSUM) and it disappeared with the addition of recruitment data from the 1980s, when year-class survival per unit of SSB was quite low and when environmental variability was well within the range of historical observations. This recent sequence of events on the eastern Scotian Shelf coincided with a change in spawning pattern to fall only, resulting from either a disappearance of the spring-spawning component or a switch to autumn spawning.

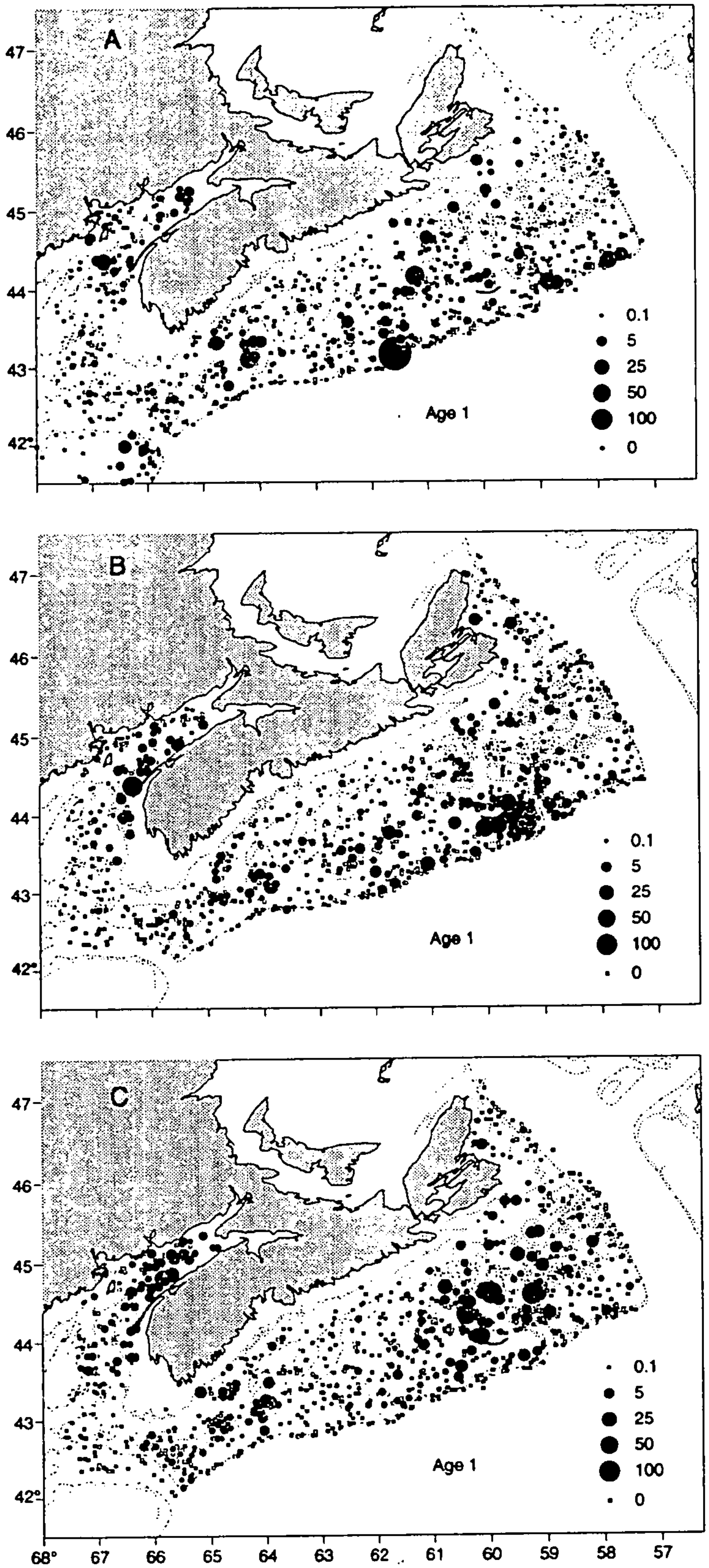


Figure 3. Distribution of juvenile cod (age 1 numbers/standard tow) from trawl surveys conducted during (A) spring (February–April), (B) summer (July), and (C) fall (October–December), 1979–1984, in the region of the Scotian Shelf. Note: summer and fall surveys did not include Georges Bank.

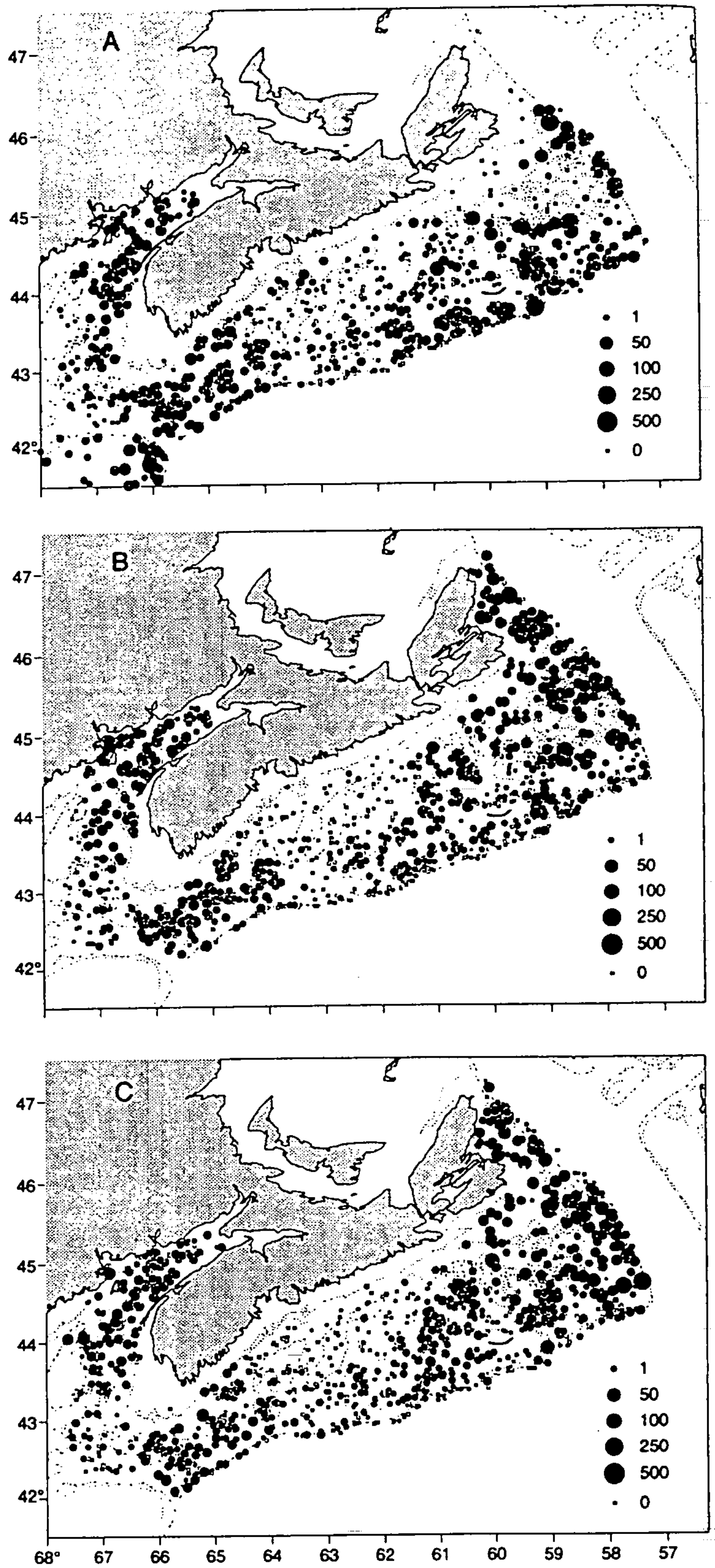


Figure 4. Distribution of adult cod (numbers/standard tow) from trawl surveys conducted during (A) spring (February–April), (B) summer (July), and (C) fall (October–December), 1979–1984, in the Scotian Shelf/Gulf of Maine region. In NAFO Division 4X and 5Z, age 3+ numbers are shown and in Division 4VW, age 6+ numbers are shown. Note: summer and fall surveys did not include Georges Bank.

Seasonal distribution of juvenile Atlantic cod in the southern Gulf of St. Lawrence

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Seasonal changes in the geographic distribution of juvenile (ages 1 to 4) Atlantic cod (*Gadus morhua* L.) were determined from research surveys conducted seasonally in the southern Gulf of St. Lawrence during 1986/87, 1990/91, and 1994. From late June to early October, juvenile cod were most abundant in shallow water (< 50 m deep) at the west end of Prince Edward Island and near the Magdalen Islands. All age-groups had left the relatively shallow summer and early autumn habitat for the edge of the Laurentian Channel (> 100 m deep) by late November. Age 1 and 2 cod were only found along the Laurentian Channel west of Cape Breton during January whereas some age 3 and 4 fish had migrated southeast of Cape Breton as far as Misaine Bank. No cod were present in the shallow waters (<80 m deep) of the southwestern Gulf during April 1991 due, in part, to later than average ice-melt. Large numbers of all age-classes were present in most of the southeastern Gulf by mid-May. Summer distribtions were similar to those observed during early autumn except that the fish were in shallower water.

The full text of this document has been submitted for primary publication. In the interim, copies of the complete working paper are available from the author.

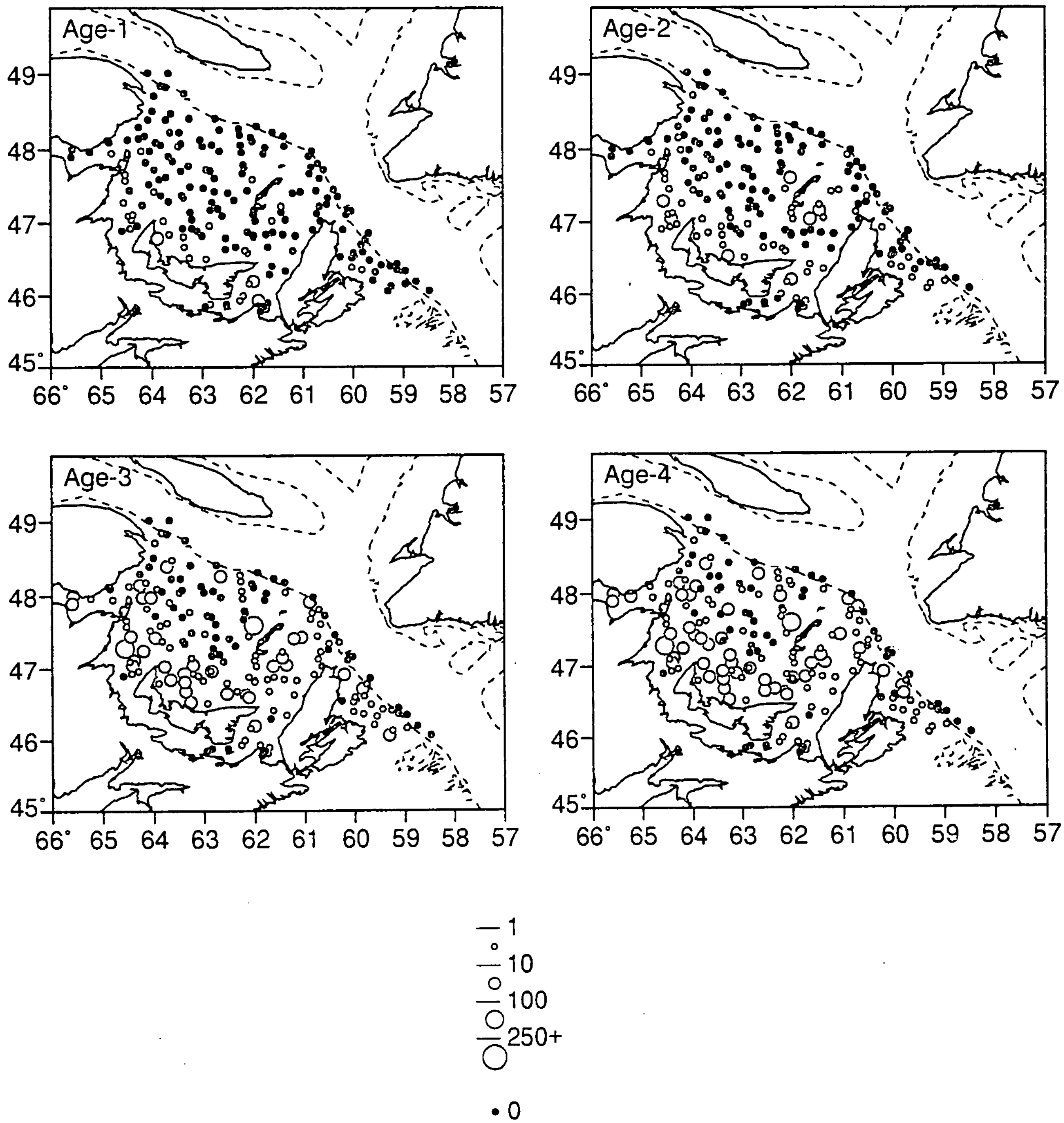

Figure 3. Early autumn 1994 distribution of juvenile Atlantic cod in the southern Gulf of St. Lawrence and Sydney Bight. The dashed line represents the 200 m contour.

SPAWNING & NURSERY AREAS
4VN COD

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SYNOPSIS OF 4VN COD ANNUAL CYCLE

Cod enter the 'Gutter' area off Cape Smokey to the west of Sydney Bight from deeper water to the north beginning usually in late April. The cod concentrate here for about a two-month period while spawning. It is at this time they are heavily exploited by the dragger fleet. When spawning is complete the fish disperse in an easterly direction across Smokey Bank towards Scaterie Bank. It is not clear just how the cod are distributed during the summer but it appears a few may move as far as 4Vs. Accumulated returns of all cod tagged in 4Vn during late summer - early fall showed nearly 75% were recaptured in 4Vn. The next common area for returns (about 10%) was 4Vs.

In the late autumn the cod begin a relatively short offshore migration to deeper water. During the winter they are joined by overwintering cod from 4T. The distribution of these cod during the winter is not known; however, the pattern of tag returns indicate the 4Vn cod are separate from an eastern 4T component, but possibly mixed with, or in close proximity to the western 4T component.

SPAWNING

Overview

Ichthyoplankton surveys were run on a semi-routine basis in the Gulf of St. Lawrence from 1958 to 1975. Ten cruises occurred between 1958 and 1962, two of which sampled in Sydney Bight (Kennedy & Powles 1964). Between 1965 and 1975 about 30 egg and larval surveys were run in the Gulf, five of which extended into Sydney Bight (Kohler et al 1974(a), 1974(b), 1975, 1976, 1977). Whereas the earliest group of cruises concentrated on sampling the south western Gulf in the Chaleur - Gaspé region, the cruises run during the late 60's and into the early 70's had comprehensive coverage of the entire southern Gulf. These surveys found cod eggs consistently in the same locations. During the spring (May -June) concentrations were found in 1) the area from the Shediac valley to the Gaspé, 2) the region between the Magdalen Islands and the west coast of Cape Breton and 3) western Sydney Bight. Cod eggs at lower concentrations were also found to the west of the Magdalen Islands. The later set of data were summarised by

Lett (1980) (Fig 1). In the autumn (October - November) cod eggs were found intermittently at much lower concentrations in area 1) and area 3).

Later, the survey of the Scotian Shelf Ichthyoplankton Program (SSIP) at the northerly extent of its range covered Sydney Bight from 1979 to 1981 (Gagné & O'Boyle 1984, Brander & Hurley 1992). The findings in Sydney Bight were consistent with the earlier surveys; high numbers of eggs during May - June with a few in October (Fig 2)

Recently (1991 and 1992) Lambert & Wilson (unpublished data) surveyed the western part of Sydney Bight and found concentrations of cod eggs supporting findings of earlier studies (Figs 3 & 4).

Sydney Bight

It has been suggested that eggs found off Cape Smokey in Sydney Bight may have drifted there from the Gulf of St. Lawrence. This is not likely. Brander & Hurley addressed this problem and concluded that cod eggs would not drift far from their point of spawning. They reckoned that at a residual current velocity of 2 cm/sec, a cod egg from the time of spawning to the point of hatching would drift 35 km. Under the same conditions the majority of eggs ('unidentified'- stages 1 to 3 of four stages) in the samples they considered would have drifted a mere 12 km. Most of the cod eggs collected by Lambert & Wilson, particularly the May cruise, were at development stage 1 (of three stages) and could be expected to have drifted about 10 km under the same hydrographic conditions. Even at as high a residual drift as 10 cm/sec the eggs could not have moved the 135 to 200 km between their location and Gulf cod spawning grounds to the west. Furthermore, current patterns in the region probably would not permit a direct line of drift between the two areas in question.

The fishing industry is well aware that cod spawn in the same area where eggs have been located by various ichthyoplankton surveys over the years. The mobile fleet sector concentrates its efforts in the so-called 'Gutter' area off Cape Smokey where fishermen know cod spawn. The fleet fishes on these concentrations of cod for at least two months in the spring (Figs 5 & 6). Samples of the catch from two of these boats in 1991 (May 18) and 1992 (May 21) show that most cod were in 'ripe and running' (spawning) condition (Table 1). In addition, plots of the

Table 1. Maturity composition of cod from the 'Gutter', Sydney Bight in May.

YEAR	**PERCENTAGE OF TOTAL**				**SAMPLE SIZE**
	RIPE	***SPAWNING***	***SPENT***	***OTHER***	
1991	3	34	23	39	64
1992	2	98	0	0	60

distribution by maturity stage of cod from the DFO July groundfish survey reveal a concentration of ripe and spawning fish in Sydney Bight (Mohn, draft this WG). Thus there is no doubt that cod spawn in Sydney Bight. Commercial vessels exploit the concentrations of spawning fish and four different surveys over the past 35 years have documented the presence of eggs at the same time in the same locality.

JUVENILE COD

Overview

Juvenile cod appear to settle close to the area where they were spawned and thereafter, do not move far from their nursery area for at least the first two years of their life. The areas of concentration of age 1 cod are more or less coincident with the identified spawning areas for cod; Shediac Valley - Chaleur Bay, eastern Prince Edward Island - Western Cape Breton, to the west of the Magdalen Islands and western Sydney Bight.

Gulf of St. Lawrence

The distribution of cod by age (1-8) was described for 1971 to 1981 by Tremblay & Sinclair (1985). Discrete centres corresponding to the areas named above can be seen at age from age 1 to about 3 (Figs 7, 8 & 9). Thereafter, as the cod age the distributions become more diffuse (Fig 10). Since 1981 groundfish surveys in the Gulf show much the same pattern (Chouinard et al 1991); discrete concentrations of young (ages 1 to 3) cod were located in the Shediac Valley and off the Magdalen Islands (Fig 11). Aggregations of young cod were also found in the Bay of Chaleur and off eastern PEI; however, these young fish were mixed in with older fish. Recent surveys specifically targeting juvenile cod support early findings (Jean 1962) that very young cod do not move far from the nursery ground and gradually take part in adult migrations to an increasing extent as they grow older (Hansen?).

Sydney Bight

Groundfish research survey.

Incidences of small cod occurring in groundfish survey trawls can be found in Figs 12 & 13. It is immediately apparent that the number of young cod occurring in 4Vn is much lower than the numbers for the Gulf. Of 356 sets taken in 4Vn over 25 years, only 92 had cod <26 cm in length. Part of the reason for this is probably the timing of the two surveys. The Gulf survey occurs in September and the Scotian Shelf survey in July. At this age and during the late summer, young cod are growing rapidly; thus more age 1 cod would be vulnerable to the trawl gear in September than in July purely due to size difference. This effect can be seen in Chouinard et al (1991). The difference in catch of cod <30 cm between a survey in July and another in September is marked (Figs 14 & 15). It would appear at least twice as many juveniles were taken during the latter cruise. Probably the main reason for the low number of young cod occurring in 4Vn July groundfish surveys is that this survey appears not to sample the area preferred by juvenile cod. In only one year out of the 25-year time series were there substantial numbers of age 1 cod caught (Table 2). In 1984 the one year-old cod were caught in the south-west region of Sydney Bight.

Table 2. Mean number per tow of age 1 cod from July research survey.

1970	0	1976	0	1982	0	1988	0.61
1971	0	1977	0	1983	0	1989	0
1972	0	1978	0	1984	2.83	1990	0
1973	0	1979	0	1985	0	1991	0.27
1974	0	1980	0	1986	0	1992	0
1975	0	1981	0.33	1987	0	1993	0

Recent inshore juvenile cod surveys near Bird Islands in this area revealed concentrations of one and two year-old cod. Of the 356 sets taken by groundfish surveys in Sydney Bight, only about four or five of the sets could be considered to be in this area frequented by juvenile cod. The month effect noted above in Figs 14 & 15 can also be seen here. Two surveys were made in 1984, summer and autumn. . In July, the mean number of small cod per set taken in this area was 22. Purely by chance, a September cruise had a set in almost the same location; this time, 106 cod less than 26 cm were taken. Other concentrations of small cod, less than 26 cm long but older than age 1, were found on the north-west and south-east edges of Smokey Bank and further east in the area of St. Anne's and Scaterie Banks.

Inshore survey.

Inshore surveys were run in the western half of Sydney Bight from 1991 to 1994. Concentrations of small cod were found consistently near the Bird Islands to the south of the survey region. The average size of cod here was about 15 cm, with the smallest being 7 cm (probably 0-group). These surveys showed that the size of cod increased in both a northerly and easterly direction away from the Bird Island area (Figs 16 & 17). In the spring cod of about 30 cm and over (probably three to four year-old fish) were mixed in with the smaller cod; whereas in the autumn, larger cod were absent from these areas, except for the furthest north ('Gutter" stations). It is possible that some smaller Gulf cod which do not migrate as far have not yet begun the return trip by May.

Comparison of 4T and 4Vn distributions.

Recently, continuous surveys run by the Gulf region through both 4T and 4Vn, and also surveys run almost concurrently by Scotia Fundy and Gulf region in 4Vn and eastern 4T, respectively, have allowed a direct comparison of cod distributions in the two regions. Except for during the overwintering period when stocks are mixed, the distribution of young cod appear discontinuous (Figs 18 - 21). It is probable the high concentrations of three and four year-old cod distributed along the western shore of Cape Breton have recently left 4Vn. Fig 22 shows the results of a September 1994 survey run through both 4T and 4Vn. There is little continuity of distribution in ages one and two; whereas, there appears to be no break in the distribution of cod older than two.

SUMMARY

The evidence from ichthyoplankton surveys and information on distribution of juvenile cod from groundfish surveys indicates the presence of at least three distinct spawning groups with the possibility of a fourth. Home ranges to the west and east of the southern Gulf of St. Lawrence and within Sydney Bight appear quite separate. Evidence is less strong, but highly suggestive of a fourth spawning component off the Magdalen Islands. Whereas these groups of cod seem well segregated during the first two years of life they become more dispersed as they grow older and begin to intermingle during at least part of the year. This mixing is particularly obvious in the winter when 4T cod migrate out of the Gulf into 4Vn.

REFERENCES

Brander, K. and P.C.F. Hurley. 1992. Distribution of early-stage Atlantic cod (*Gadus morhua)*, haddock (*Melanogrammus aeglefinus),* and witch flounder (*Glyptocephalus cynoglossus)* eggs on the Scotian Shelf: a reappraisal of evidence on the coupling of cod spawning and plankton production.

Chouinard, G.A., Hanson, J.M. and G.A. Nielsen. 1991. Definition of juvenile areas for the 4T-Vn (January-April) cod stock. CAFSAC Res.Doc. 91/6.

Gagné, J.A. and R.N. O'Boyle. 1984. The timing of cod spawning of the Scotian Shelf. *In* The propagation of cod *Gadus morhua* L. Edited by Dahl, E., Danielssen, D.S., Moksness, E. and P. Solemdal. Inst. Mar. Res. Flødevigen Biol. Station, Arendal, Norway.

Jean, Y. 1963. Distribution of cod along the western slope of the Laurentian Channel in April 1962. Fish. Res. Bd. Can., Biol. Sta. St. Andrews Ann. Rept. & Invest. Summaries 1962-1963. C-9, 3p.

Kennedy, V.S. and P. M. Powles. 1964. Plankton collections from the western Gulf of St. Lawrence and central Nova Scotian Banks, 1958 to 1962. Fish. Res. Bd. Can. MS. Rept. #799.

Kohler, A.C., Faber, D. J. and N. J. McFarlane. 1974a. Eggs, larvae and juveniles of fishes from plankton collected in the Gulf of St. Lawrence during 1965, 1966 and 1967. Fish. Res. Bd. Can. MS Rept.285, 164p.

Kohler, A.C., Faber, D. J. and N. J. McFarlane. 1974b. Eggs, larvae and juveniles of fishes from plankton collected in the Gulf of St. Lawrence during 1968. Fish. & Mar. Serv. Res. Dev. Tech. Rept.490, 105p.

Kohler, A.C., Faber, D. J. and N. J. McFarlane. 1975. Eggs, larvae and juveniles of fishes from plankton collected in the Gulf of St. Lawrence during 1969. Fish. & Mar. Serv. Res. Dev. Tech. Rept.521, 154p.

Kohler, A.C., Faber, D. J. and N. J. McFarlane. 1976. Eggs, larvae and juveniles of fishes from plankton collected in the Gulf of St. Lawrence during 1970 to 1971. Fish. & Mar. Serv. Res. Dev. Tech. Rept.645, 139p.

Kohler, A.C., Faber, D. J. and N. J. McFarlane. 1977. Eggs, larvae and juveniles of fishes from plankton collected in the Gulf of St. Lawrence during 1972 to 1975. Fish. & Mar. Serv. Res. Dev. Tech. Rept. 747, 180p.

Lett, P.F. 1980. A comparitive study of the recruitment mechanisms of cod and mackerel, their intraction, and its implication for dual stock assessment. Can. Tech. Rept. Fish. Aquat. Sci. #988.

Tremblay, M.J. and M. Sinclair. 1985. Gulf of St. Lawrence cod: Age-specific geographic distributions and environmental occurrences from 1971 to 1981. Can. Tech. Rept. Fish. Aquat. Sci. #1387, 43p.

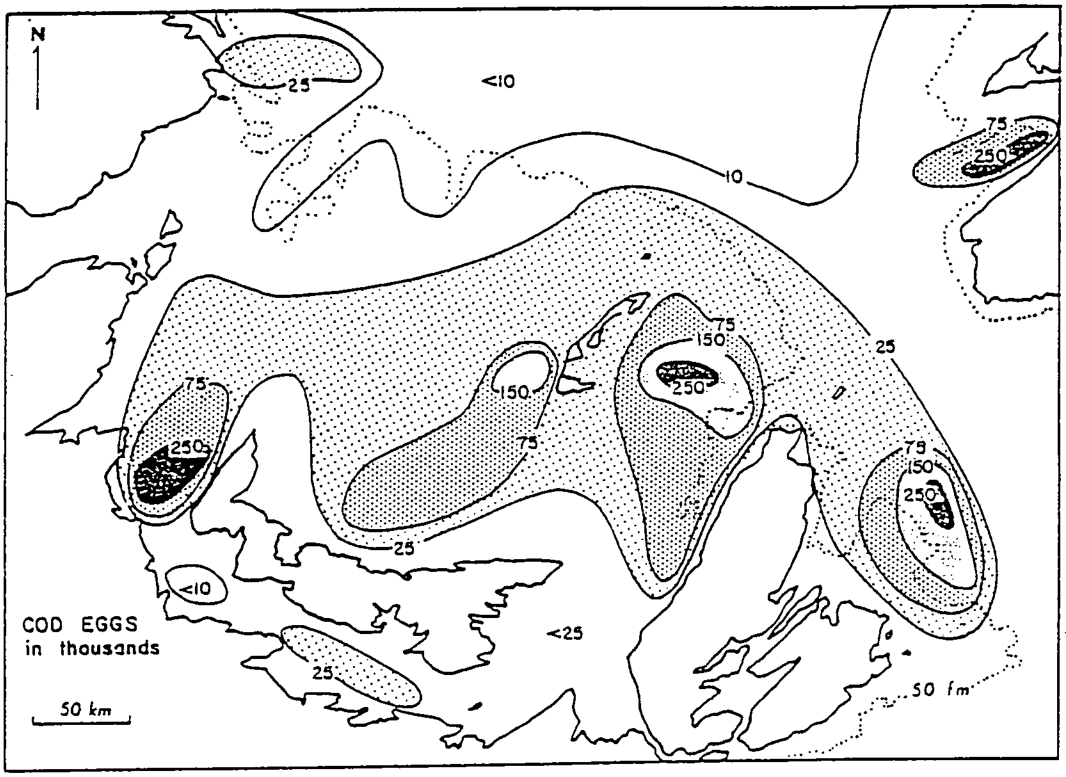


FIG 1 Average distribution of cod eggs in the Gulf of St. Lawrence during the peak spawning period. Units are thousands of eggs per 10^5 m^{-3} water. From Lett 1980.

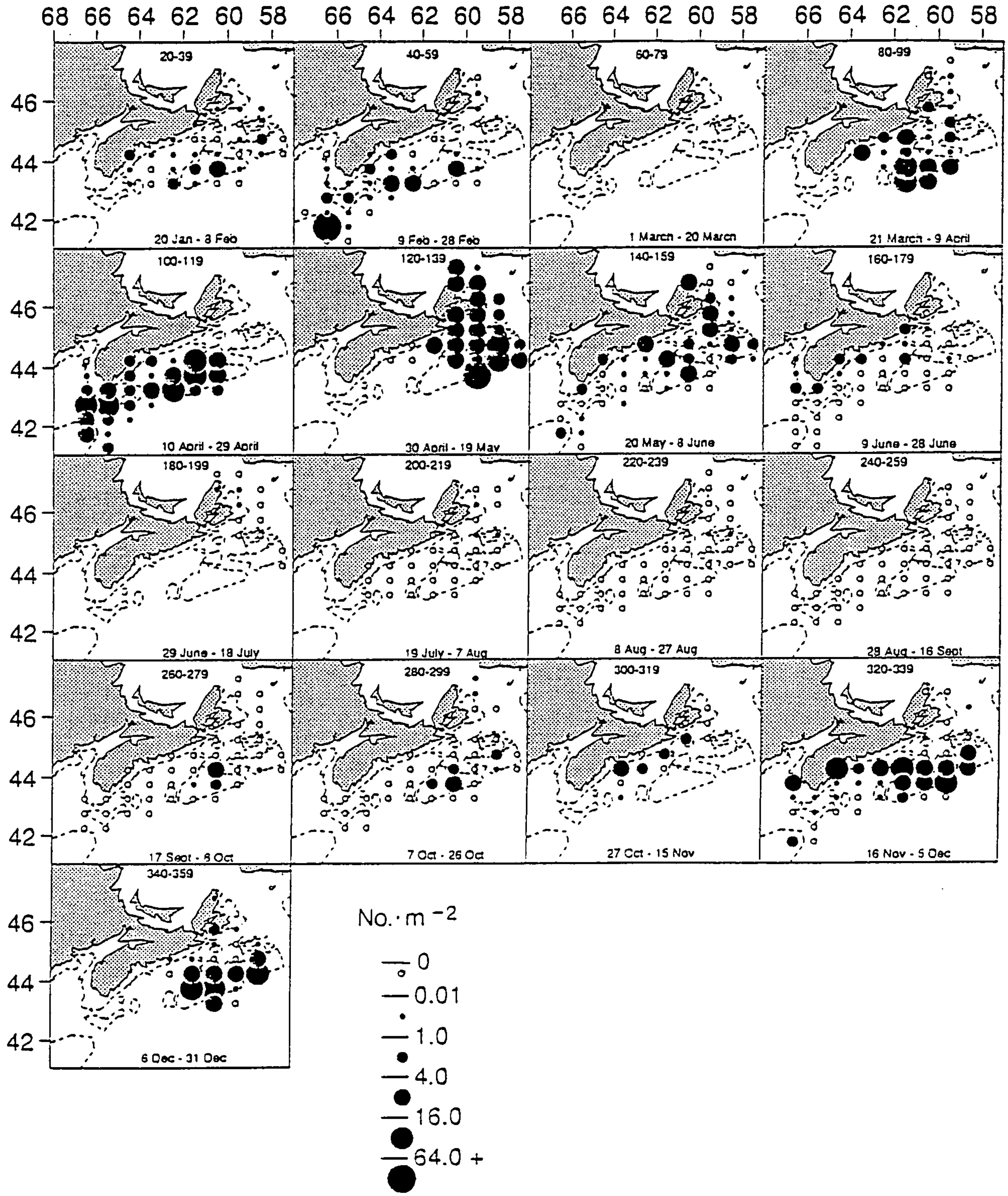
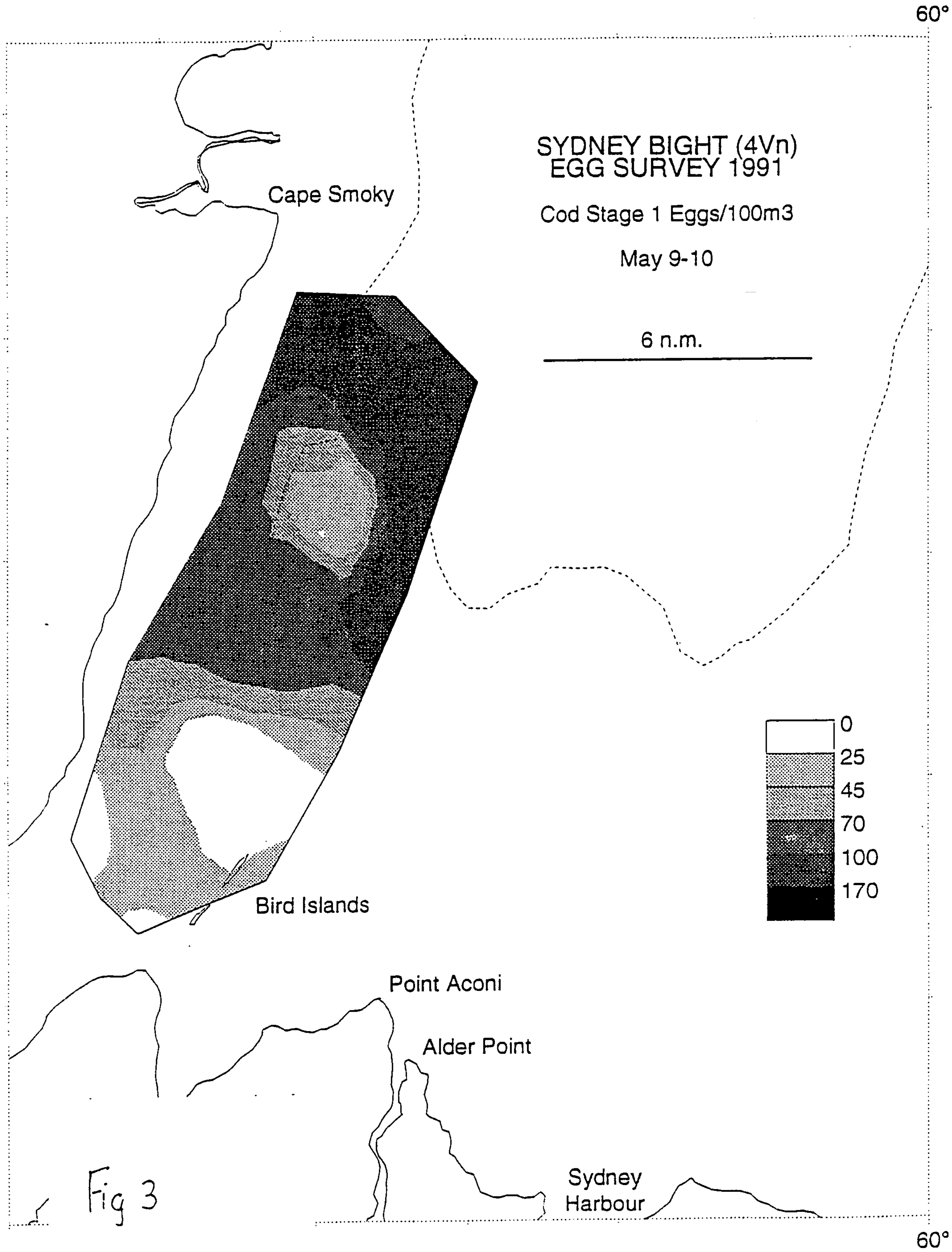


FIG 2 Distribution of stage 1–3 cod eggs. Data handled as for haddock. FROM BRANDER + HURLEY



60°
SYDNEY BIGHT (4Vn)
EGG SURVEY 1991
Cod Stage 1 Eggs/100m3
May 9-10
6 n.m.
Cape Smoky
0
25
45
70
100
170
Bird Islands
Point Aconi
Alder Point
Sydney
Harbour
60°

Fig 3

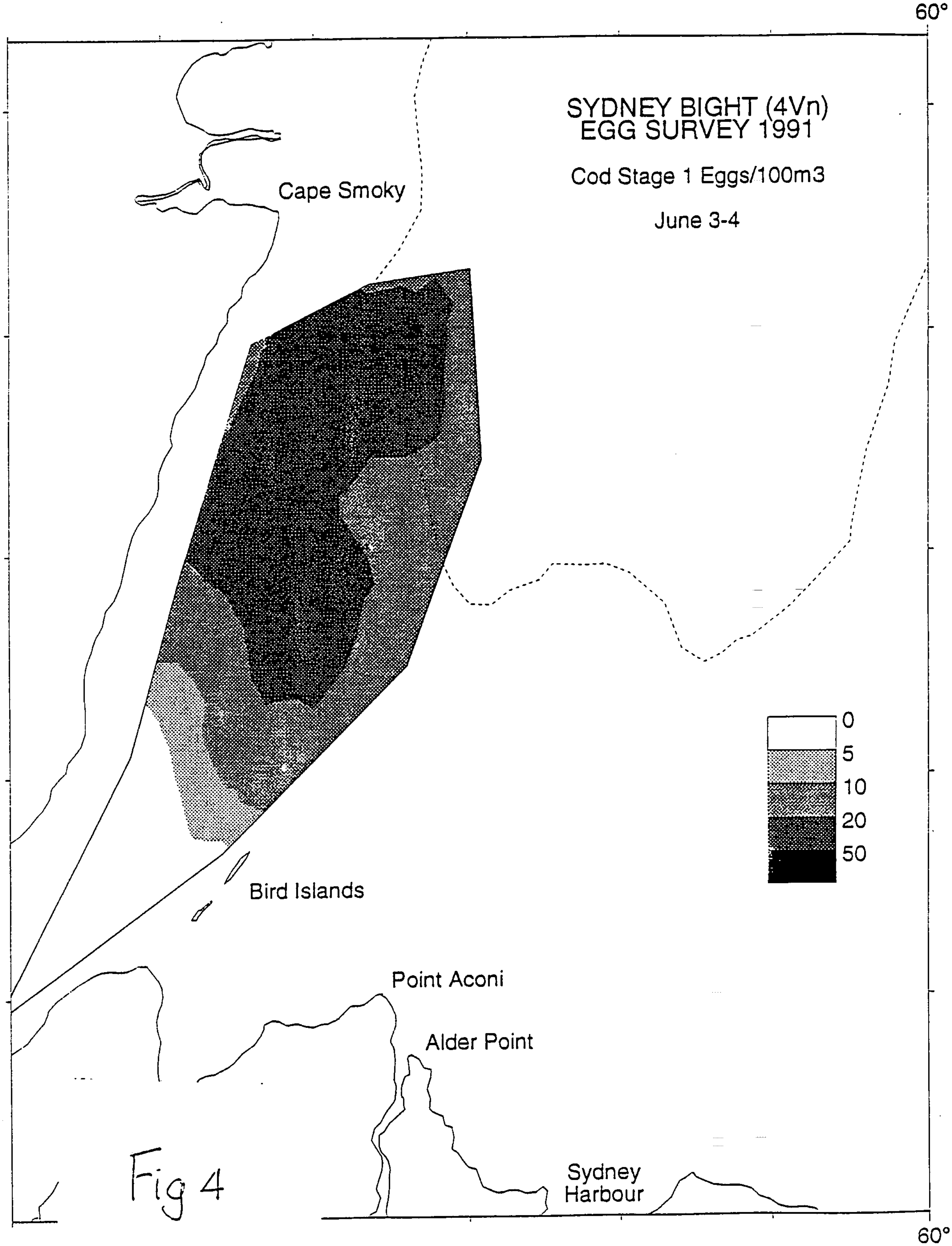

60°
SYDNEY BIGHT (4Vn)
EGG SURVEY 1991
Cod Stage 1 Eggs/100m3
June 3-4
Cape Smoky
0
5
10
20
50
Bird Islands
Point Aconi
Alder Point
Sydney
Harbour
60°

Fig 4


May 1991
48
47
46
45°
61°
60
59
58
57
Fig 5

June 1991

Tremblay + Sinclair

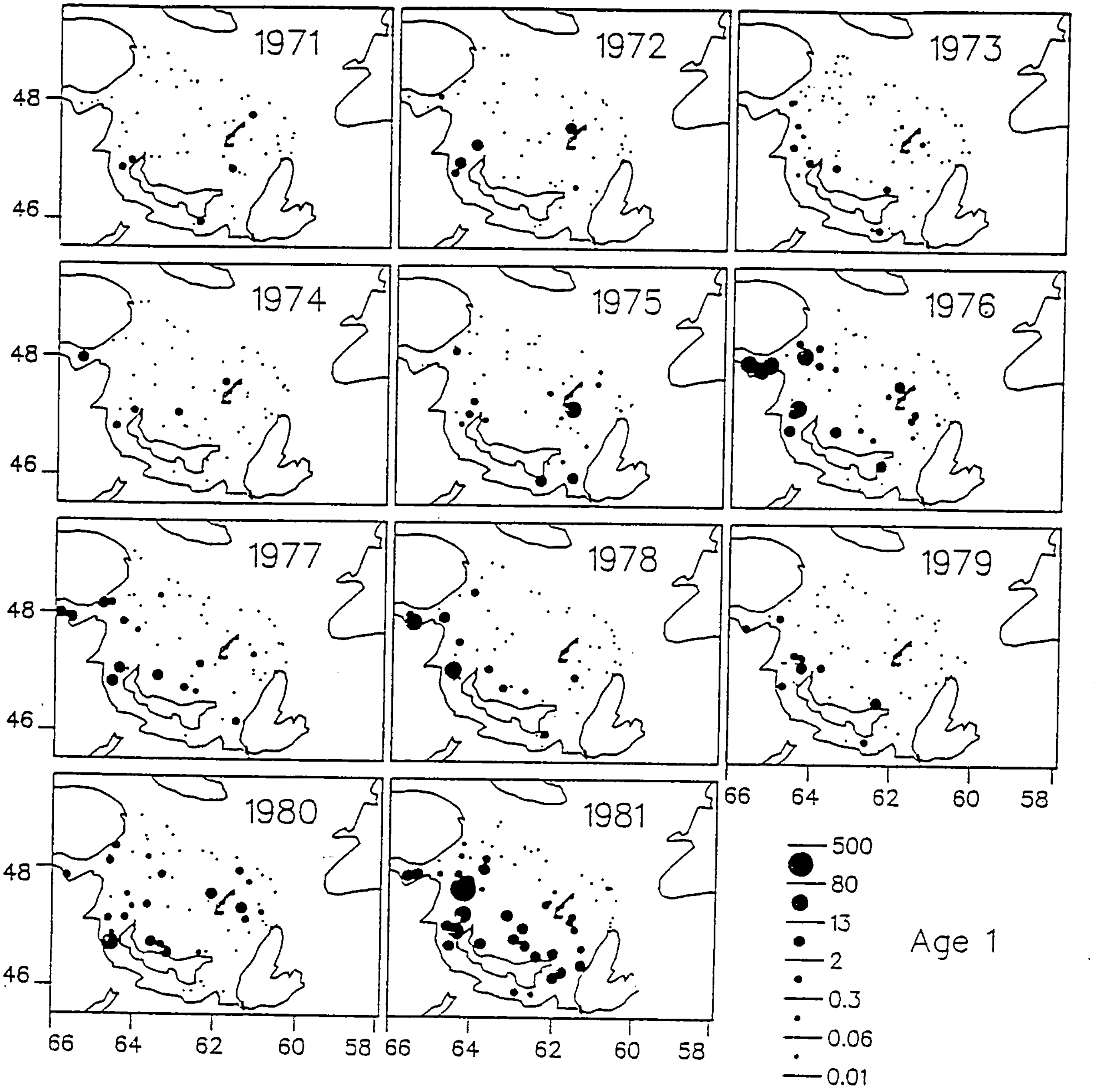


Fig. 7 The distribution of age 1 cod (number per standard tow), 1971 to 1981. Smallest dots on map are not indicated in legend and represent stations where no age 1's were found.

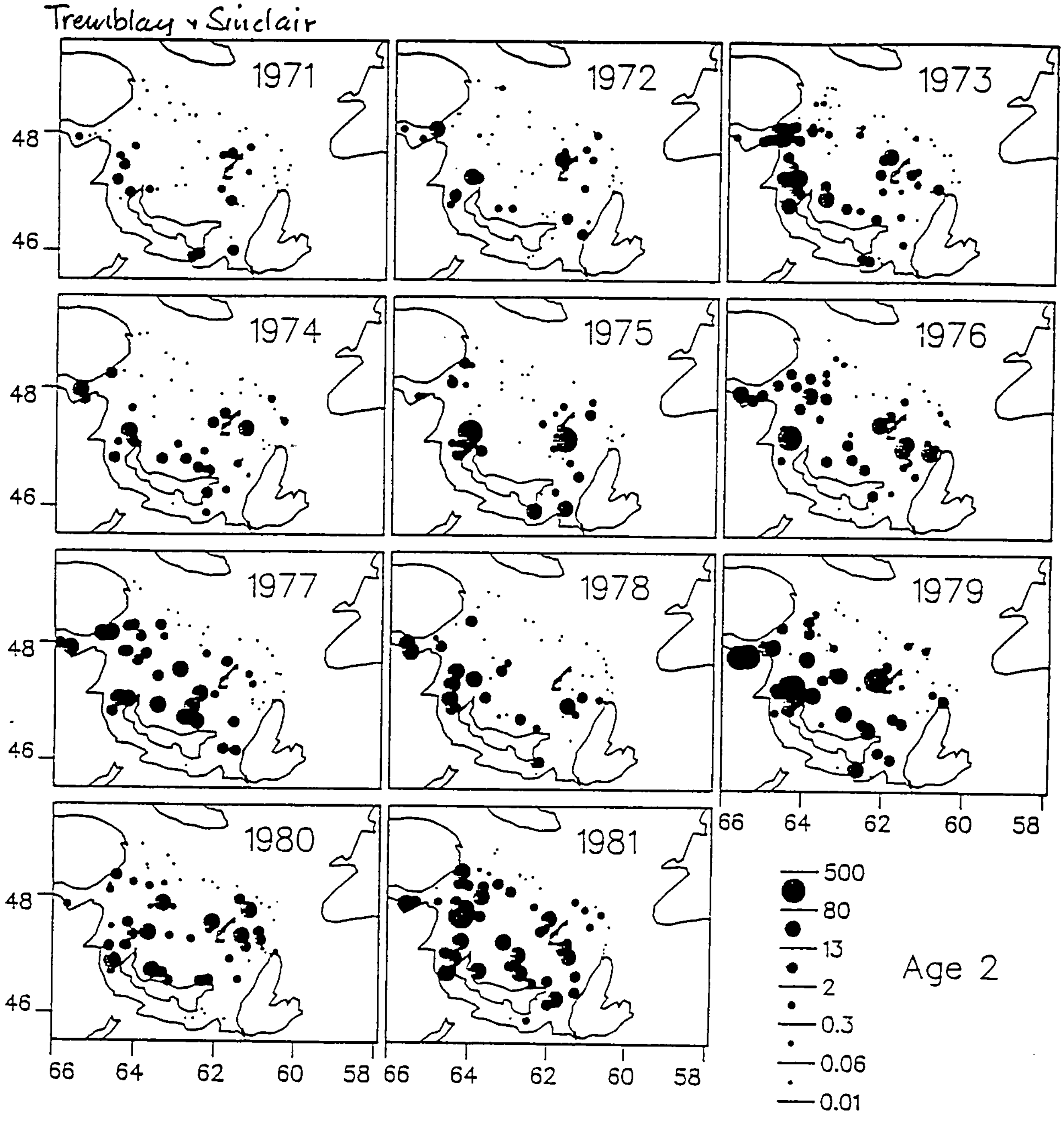


Fig. 8. The distribution of age 2 cod (number per standard tow)

Tremblay + Sinclair

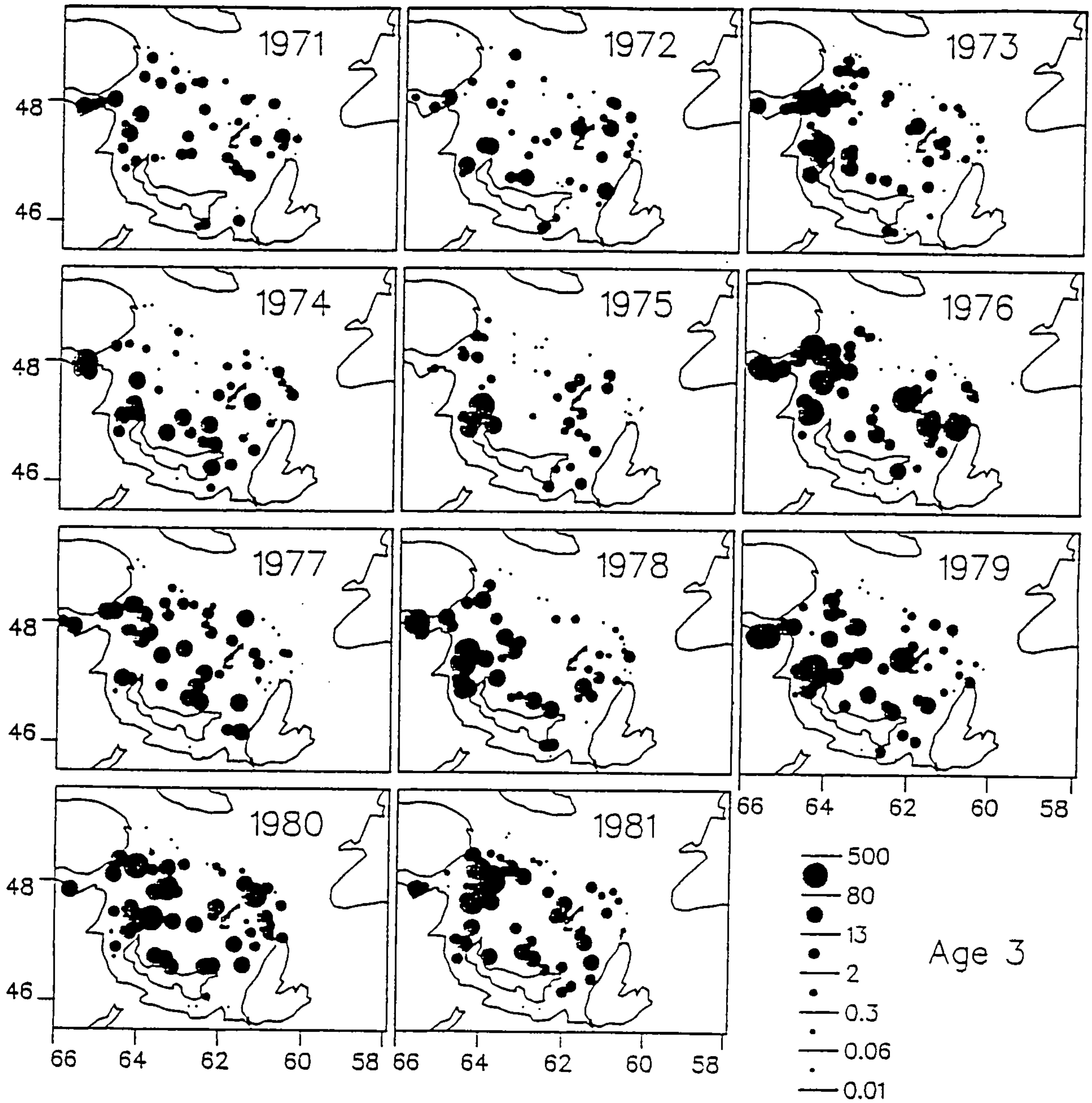


Fig. 9. The distribution of age 3 cod (number per standard tow).

Tremblay + Sinclair

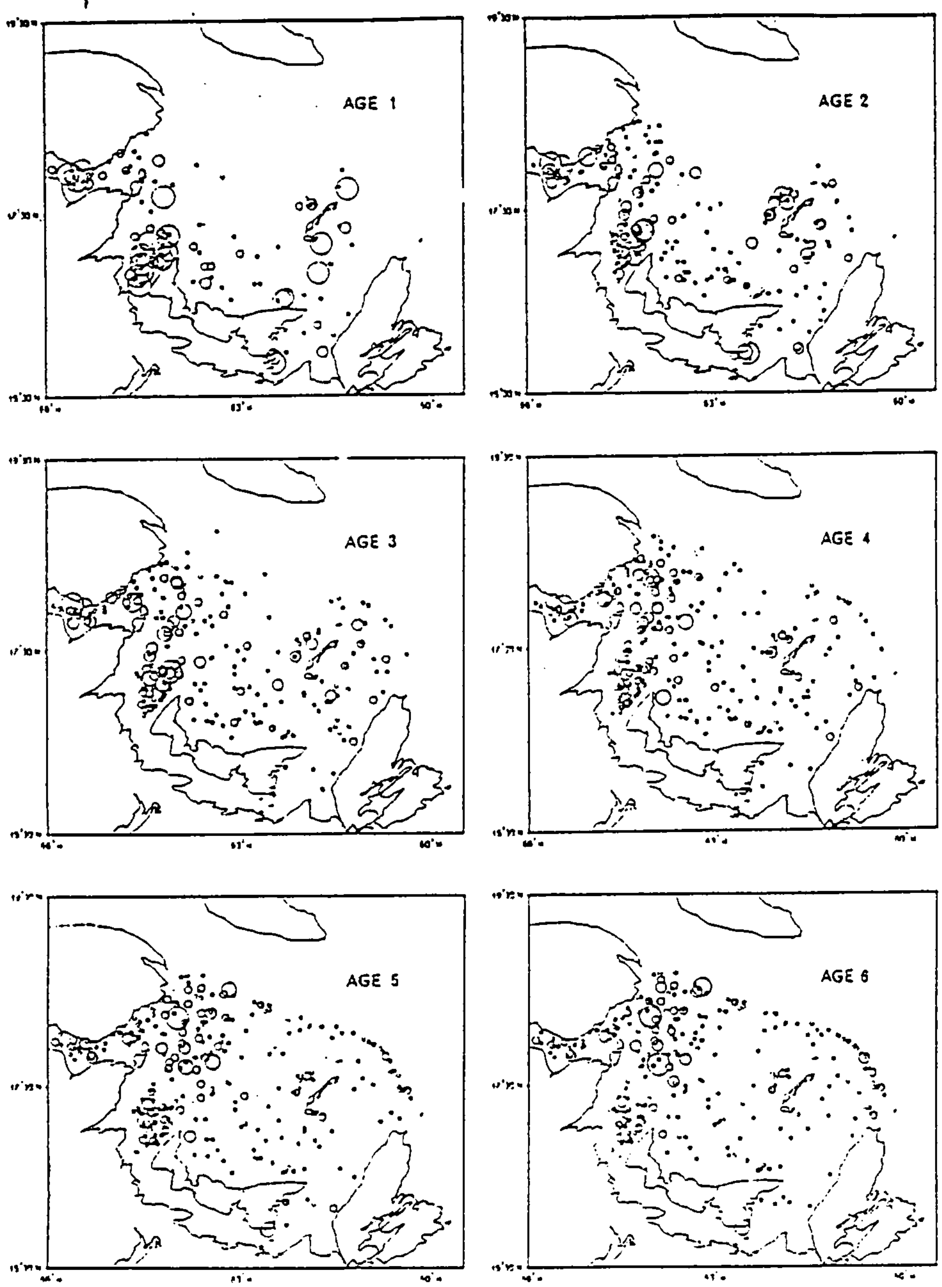


Fig. 10 Composite plots of geographic distribution for each age from 1971 to 1981 standardized by year. For each of the 11 years the percentage of the annual total number occurring at each station was determined. Beginning with the smallest, symbols are as follows: 1-5%, >5-10%, >10-15%, >15-20%, >20-25% and >25%.

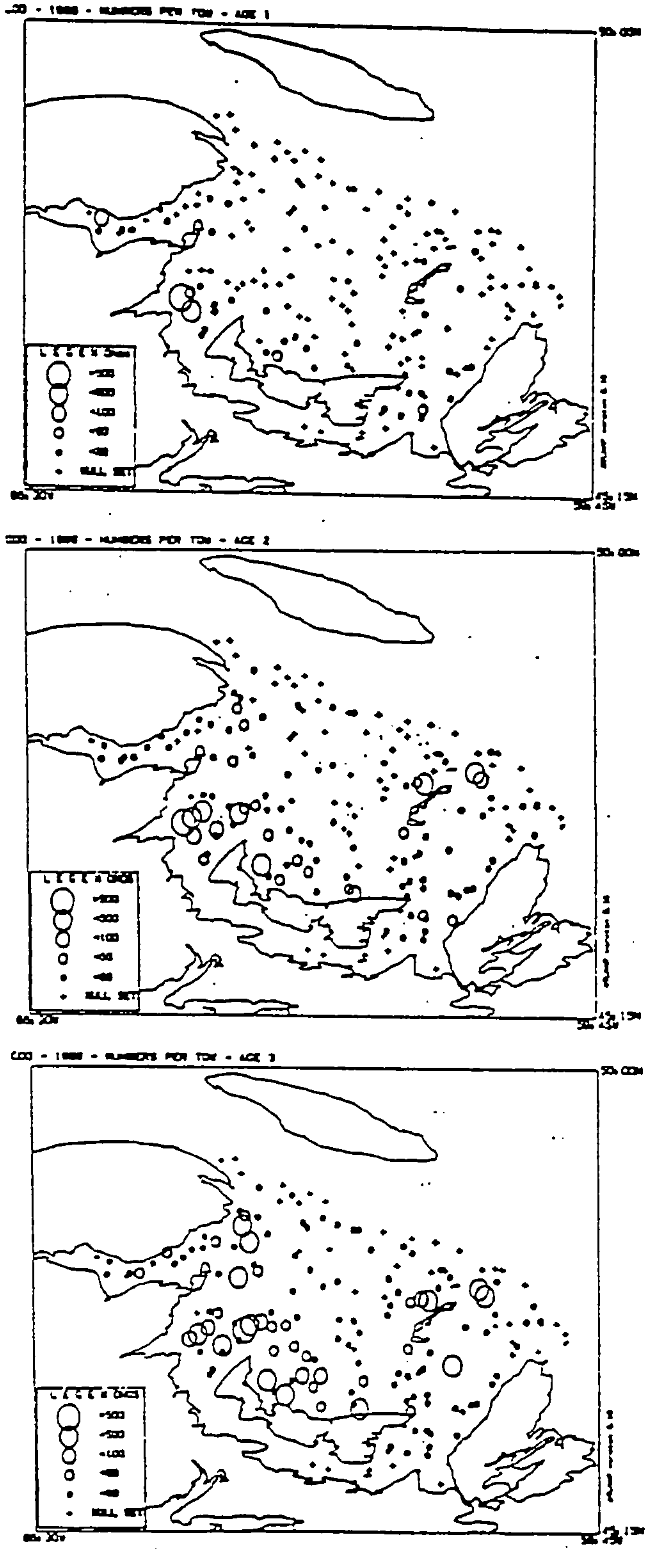


Figure .11. Numbers per tow for cod of ages 1 to 3 observed in the 1989 groundfish survey in the southern Gulf of St. Lawrence (Source: Chouinard et al. 1990).

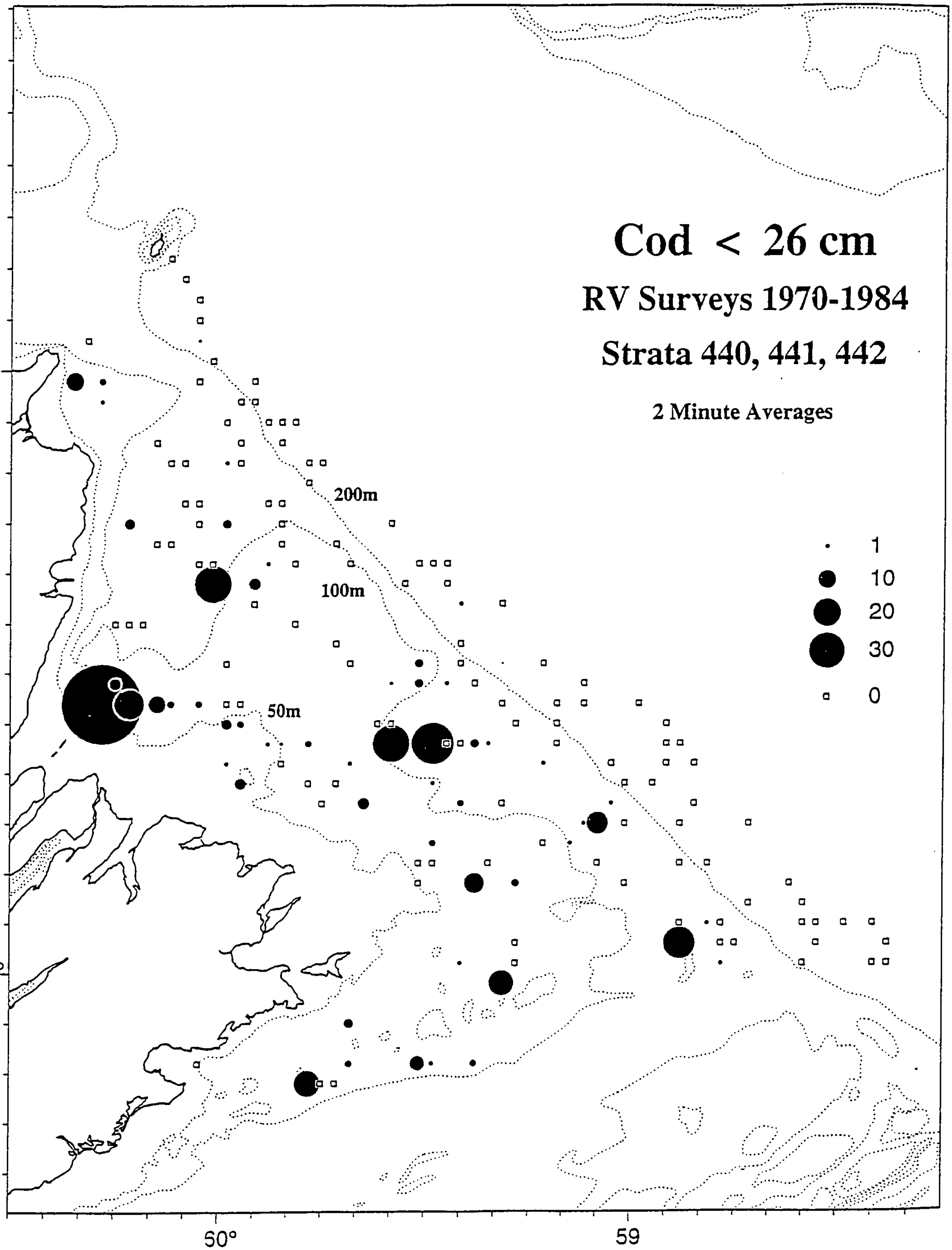

Cod < 26 cm
RV Surveys 1970-1984
Strata 440, 441, 442
2 Minute Averages
1
10
20
30
0
200m
100m
50m
47
46°
50°
59

Fig 12

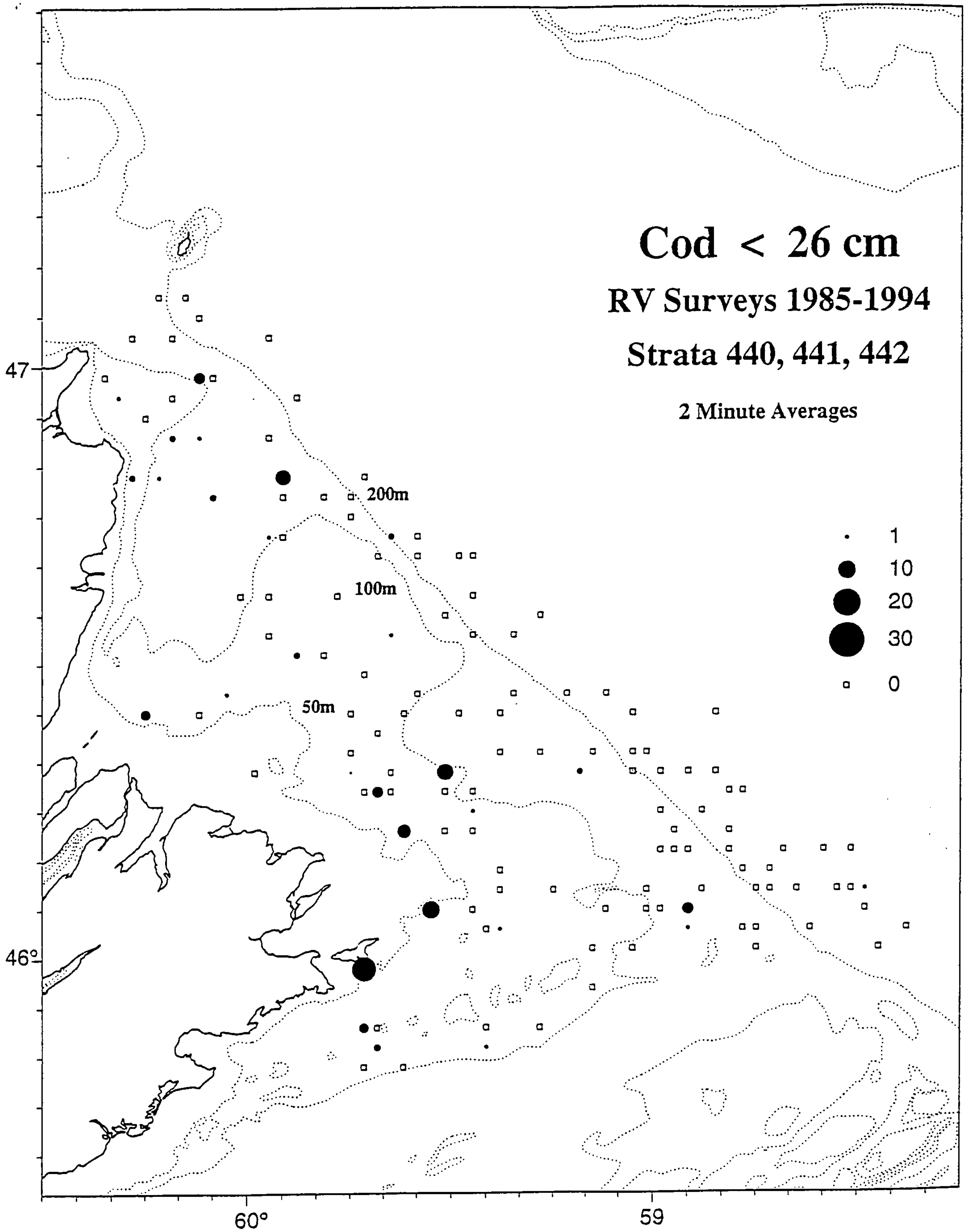

Cod < 26 cm
RV Surveys 1985-1994
Strata 440, 441, 442
2 Minute Averages
200m
100m
50m
1
10
20
30
0
47
46º
60°
59

Fig 13

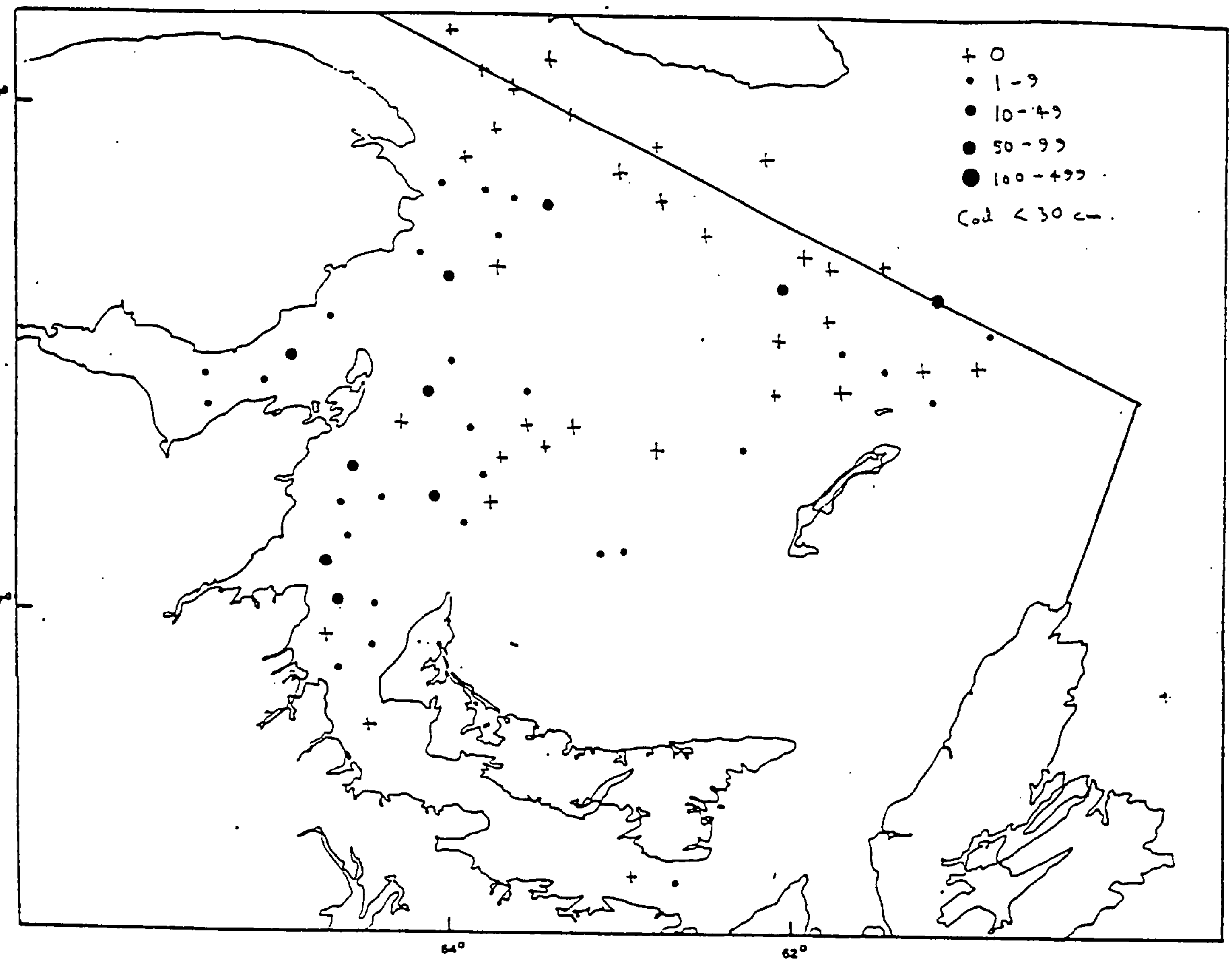


Figure 14. Distribution and abundance (numbers/tow) of cod < 30 cm during seasonal survey conducted in July 1990. From Chouinard et al.

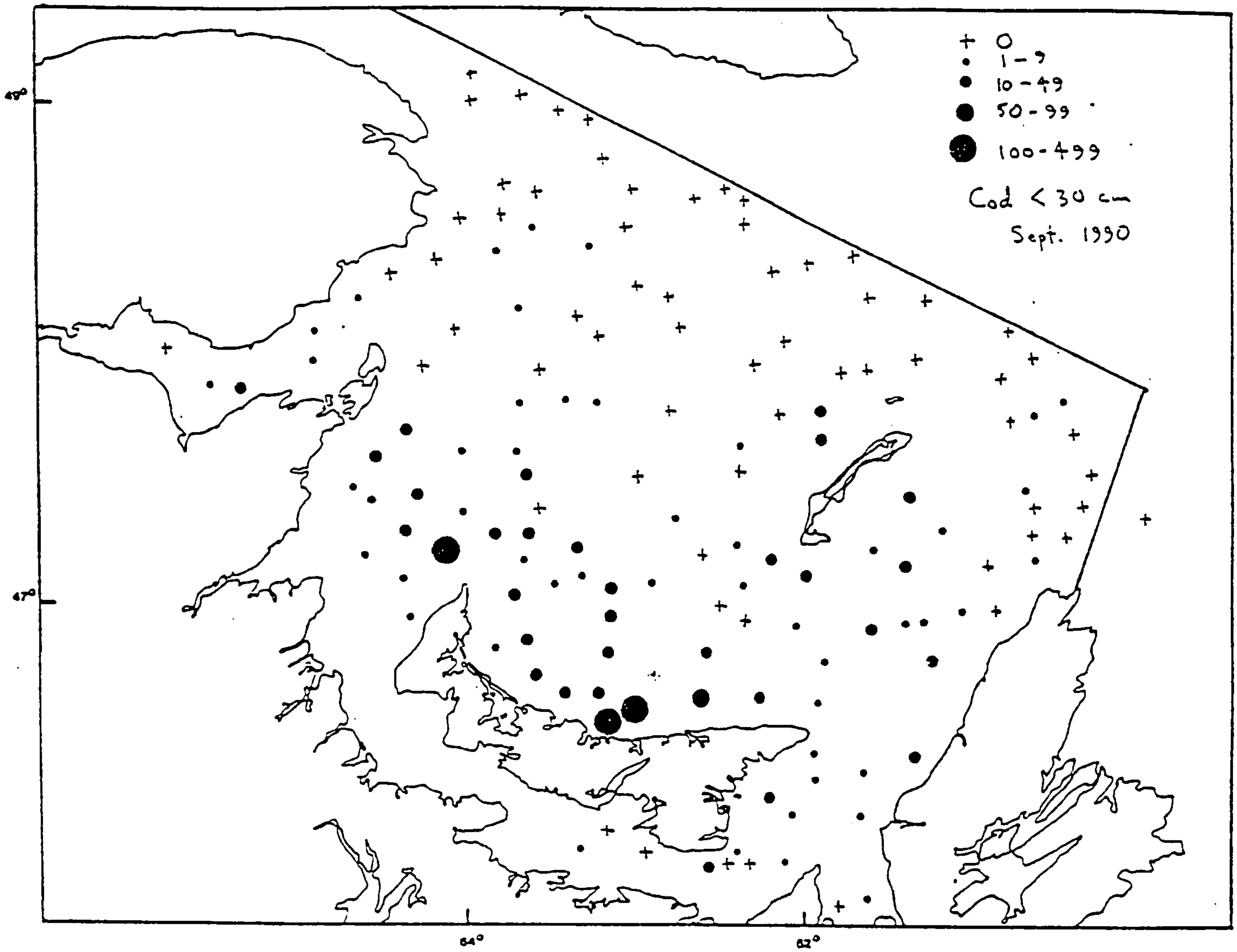


Figure . 15. Distribution and abundance (numbers/tow) of cod < 30 cm during annual groundfish survey conducted in September 1990. From Chouinard et al

4VN COD

LENGTH FREQUENCY – INSHORE SURVEY

SPRING

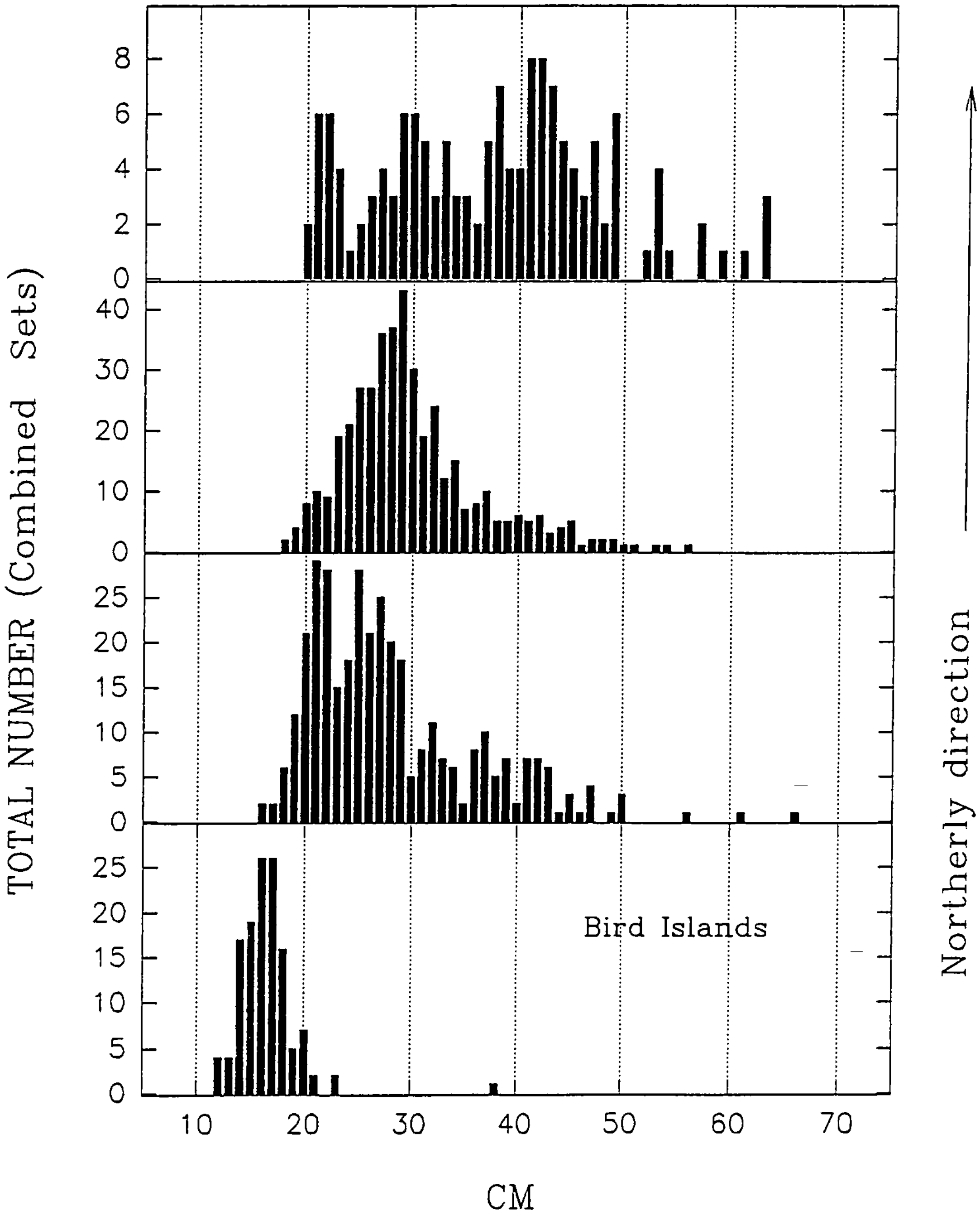


FIG 16

4VN COD

LENGTH FREQUENCY - INSHORE SURVEY
AUTUMN

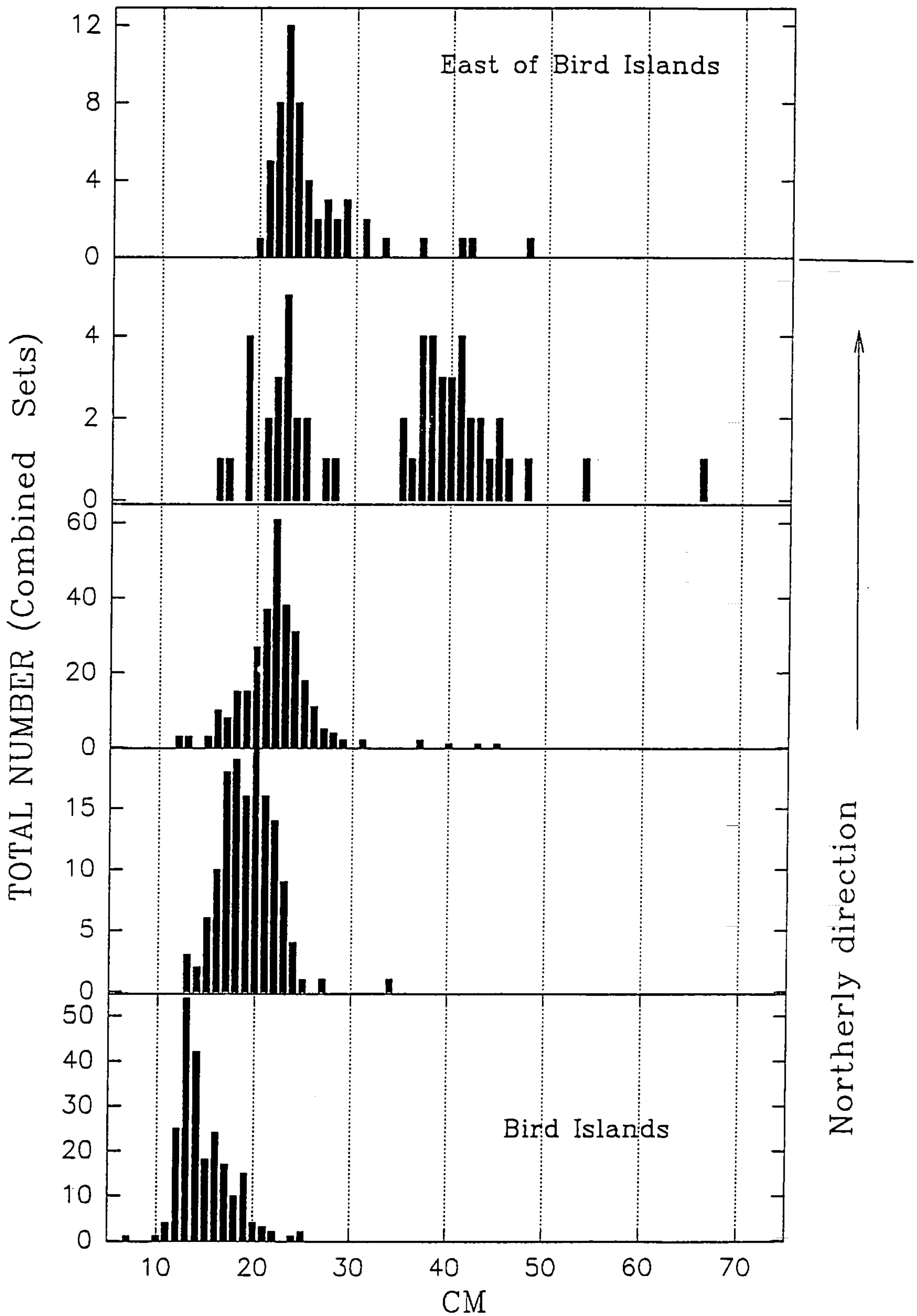


FIG 17

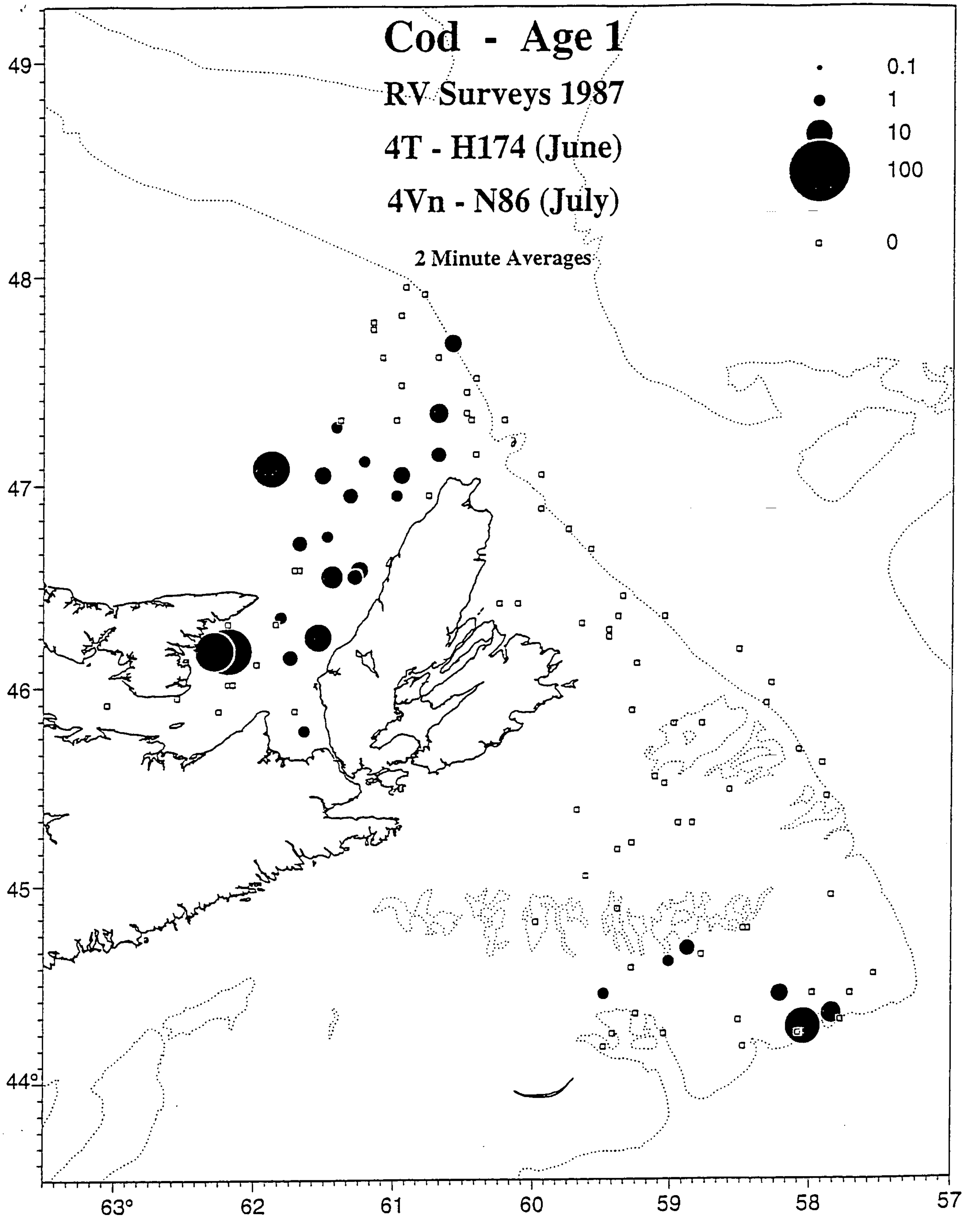
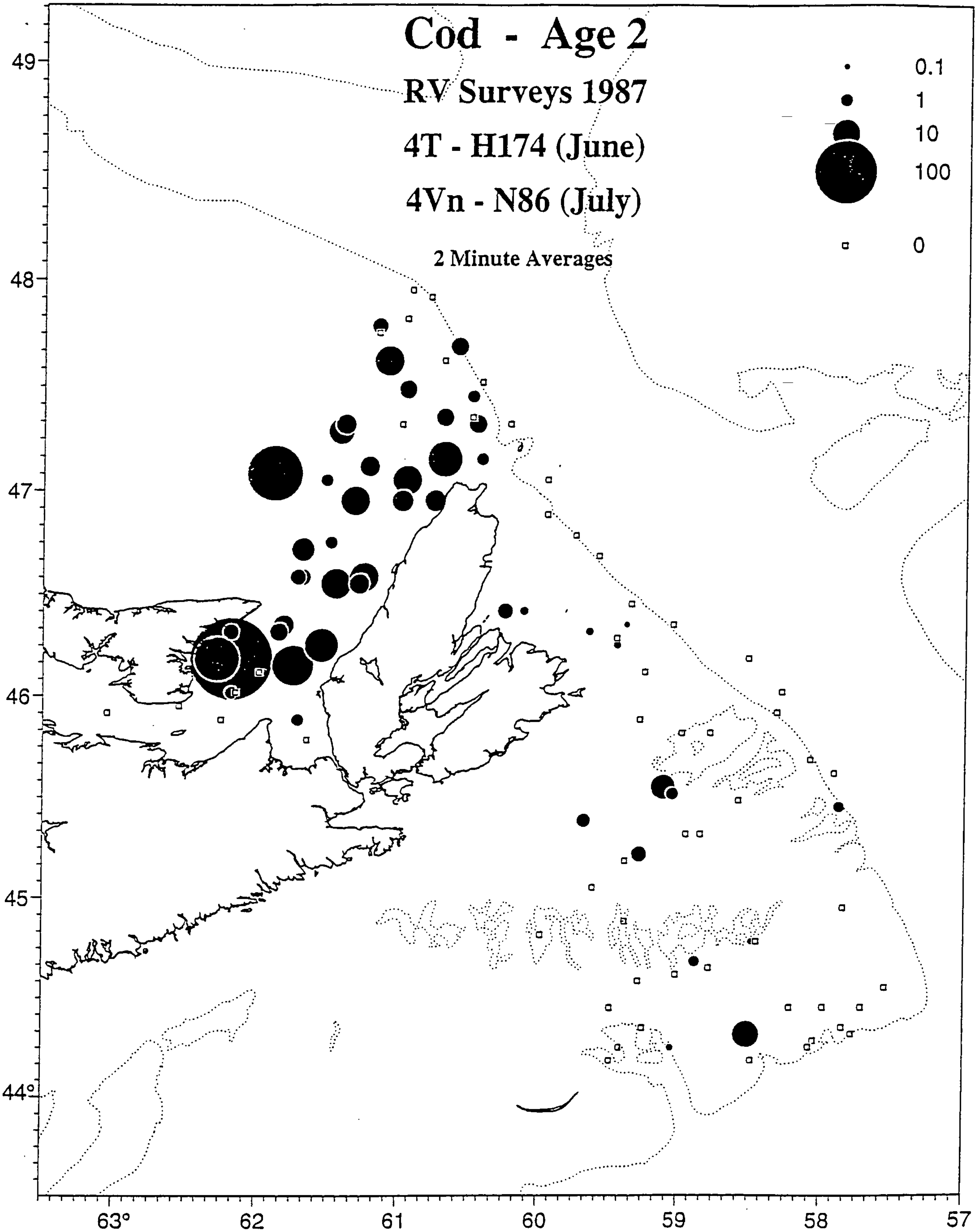
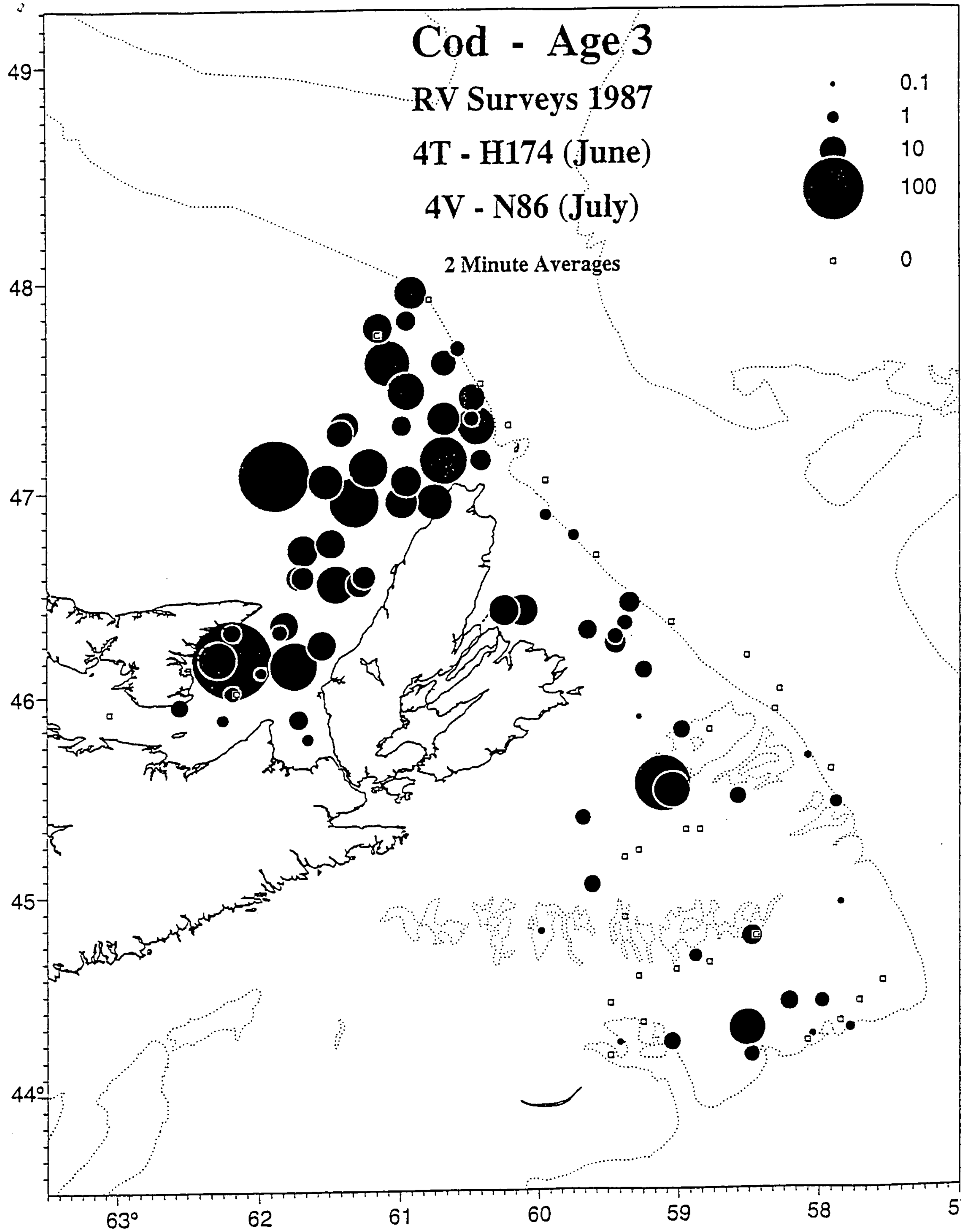

Cod - Age 1
RV Surveys 1987
4T - H174 (June)
4Vn - N86 (July)
2 Minute Averages
0.1
1
10
100
0
49
48
47
46
45
44°
63°
62
61
60
59
58
57

Fig 18



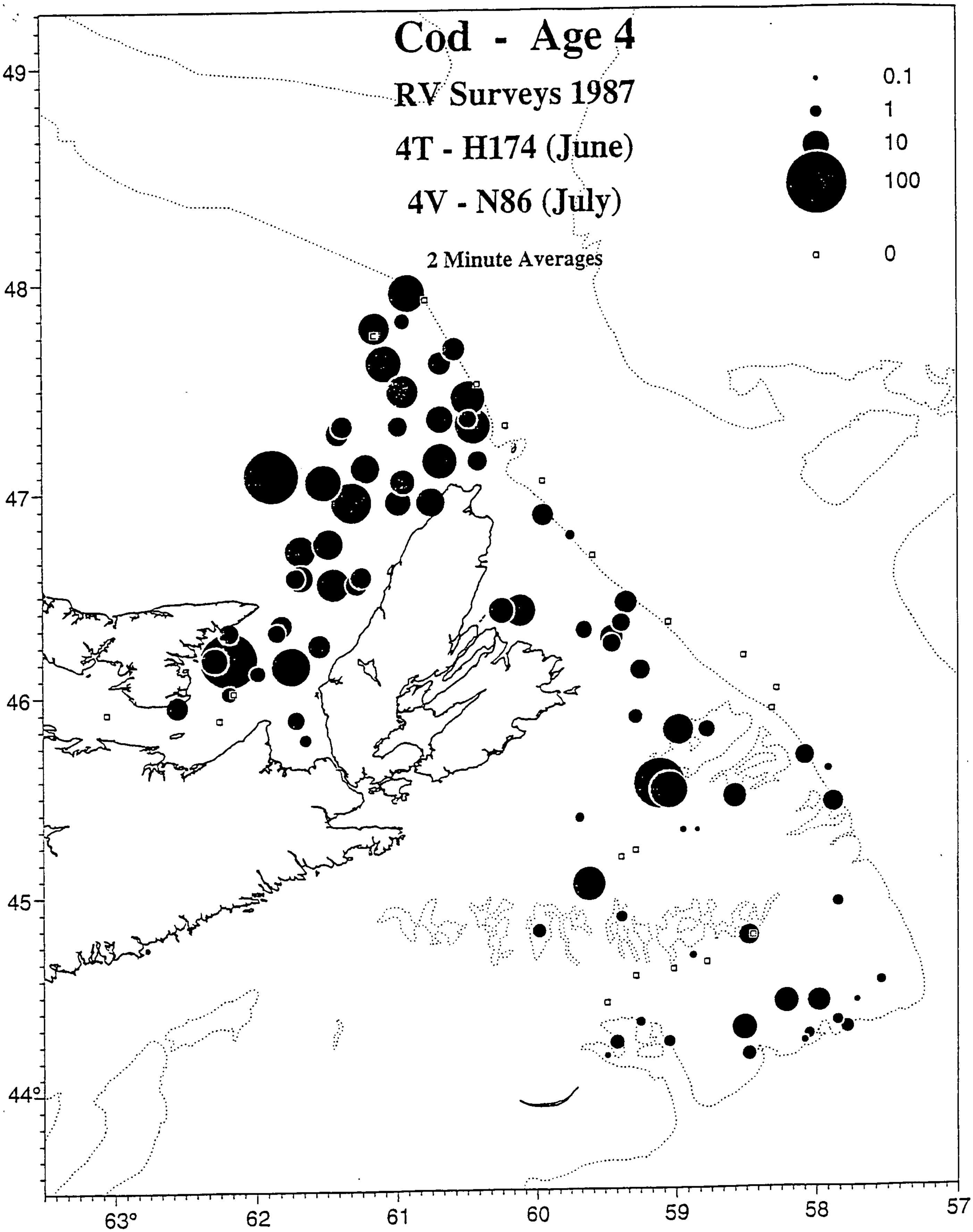
Cod - Age 2
RV Surveys 1987
4T - H174 (June)
4Vn - N86 (July)
2 Minute Averages
0.1
1
10
100
0
49
48
47
46
45
44°
63°
62
61
60
59
58
57

Fig 19



Cod - Age 3
RV Surveys 1987
4T - H174 (June)
4V - N86 (July)
2 Minute Averages
0.1
1
10
100
0
49
48
47
46
45
44°
63°
62
61
60
59
58
57

Fig 20



Cod - Age 4
RV Surveys 1987
4T - H174 (June)
4V - N86 (July)
2 Minute Averages
0.1
1
10
100
0
49
48
47
46
45
44°
63°
62
61
60
59
58
57

Fig 21

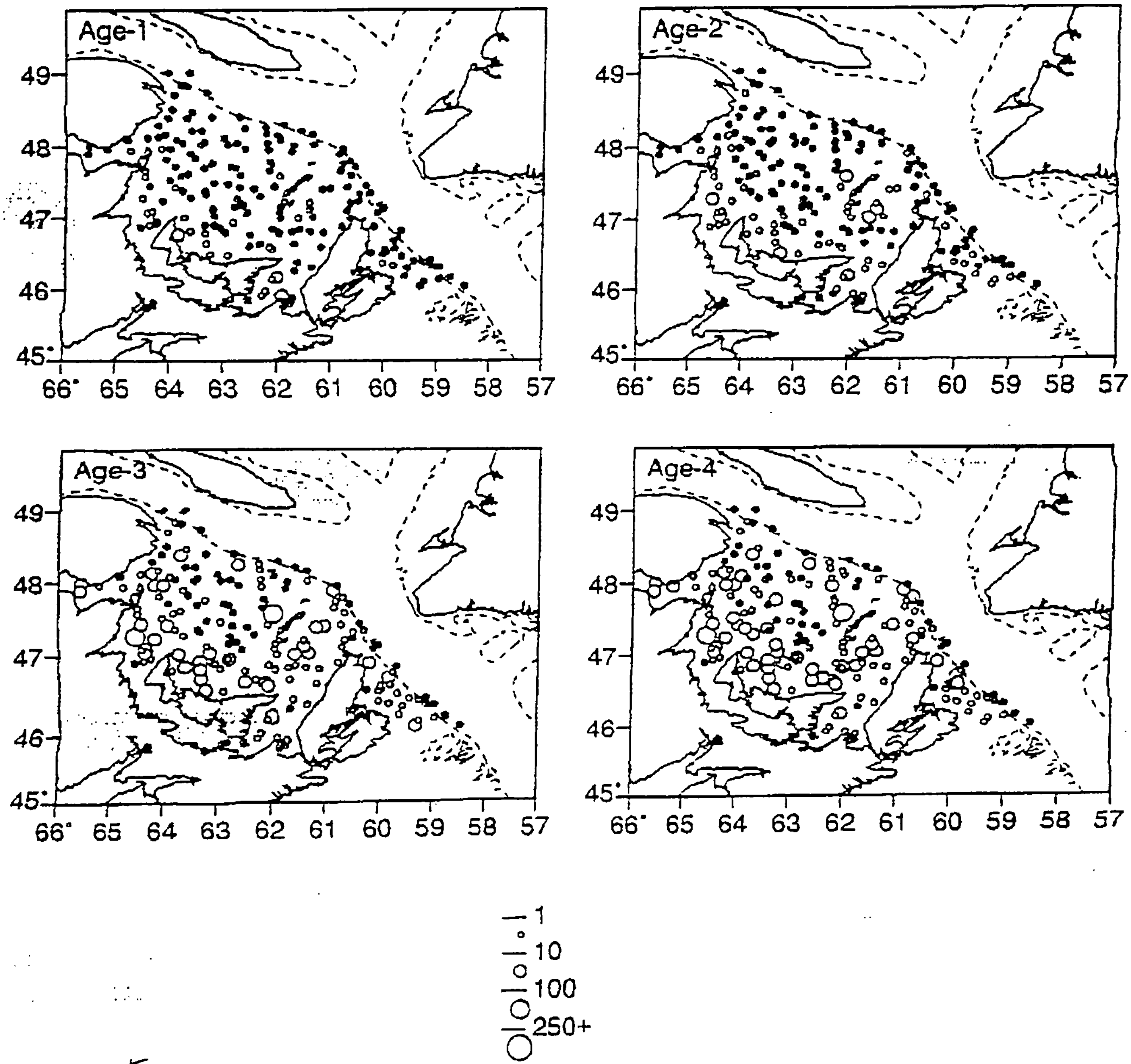


Fig 22

From Hansen

Geographical distributions of 4VW cod aggregated by maturity stage from spring, summer and fall research surveys.

R. Mohn. Marine Fish Division, BIO/DFO, P.O. Box 1006, Canada, B2Y 4A2

Maturity stages from approximately 35 thousand cod have been compiled in the research survey series, spring, summer and fall. The Spring survey from 79 to 94 (except 1985), summer 1970-94 and Fall survey ran from 1978 to 1984. The following table summarizes the occurrences from those cod for which the maturity is recorded.

Disaggregation of Male and Female fish by maturity stage

Survey	Spring		Summer		Fall	
	#	%	#	%	#	%
Immature	3223	37.0	7220	37.1	2045	25.9
R1	772	8.9	3324	17.1	1201	15.2
R2	1033	11.9	342	1.8	1252	15.9
Ripe	416	4.8	83	0.4	143	1.8
Running	175	2.0	80	0.4	77	1.0
Spent	325	3.7	443	2.3	198	2.5
Recovering	773	8.9	1836	9.4	454	5.8
Resting	1990	22.98	6108	31.4	2525	32.0
Total	8707		19436		7895	

The summer survey had very few ripe and running fish, less than 1%, the fall survey had about 3% and the spring survey almost 7%. A similar table is given below in which only females are considered.

Disaggregation of Female fish by maturity stage

Survey	Spring		Summer		Fall	
	#	%	#	%	#	%
Immature	1678	37.7	3733	37.4	1035	24.9
R1	344	7.7	1537	15.4	451	10.9
R2	473	10.6	76	0.8	583	14.0
Ripe	163	3.7	27	0.3	46	1.1
Running	31	0.7	14	0.1	26	0.6
Spent	63	1.4	95	1.0	109	2.6
Recovering	397	8.9	836	8.4	194	4.7
Resting	1298	29.2	3655	36.6	1709	41.2
Total	4447		9973		4153	

The female distribution over maturity stages is similar to the combined but there are fewer ripe and running fish in all three surveys.

The data are also displayed graphically in a set of six figures. Figure 1.1 shows the distribution of spawning (stage 4 and 5) female cod. The upper subplot shows the locations of the survey sets and shaded squares are used to show the number in squares 1/4 of a degree on a side. The lower subplot shows the proportion of females that fall into the selected maturity stage categories. The spring survey does not cover 4Vn due to ice coverage. The preponderance of spawning cod are mainly in two areas, Sable Island Bank and in the vicinity of the Gully. Figure 1.2 displays stages 2-6 which is to approximate the distributions of fish that will spawn or have just spawned. This figure shows a concentration along the Laurentian Channel that are earlier in the maturation cycle.

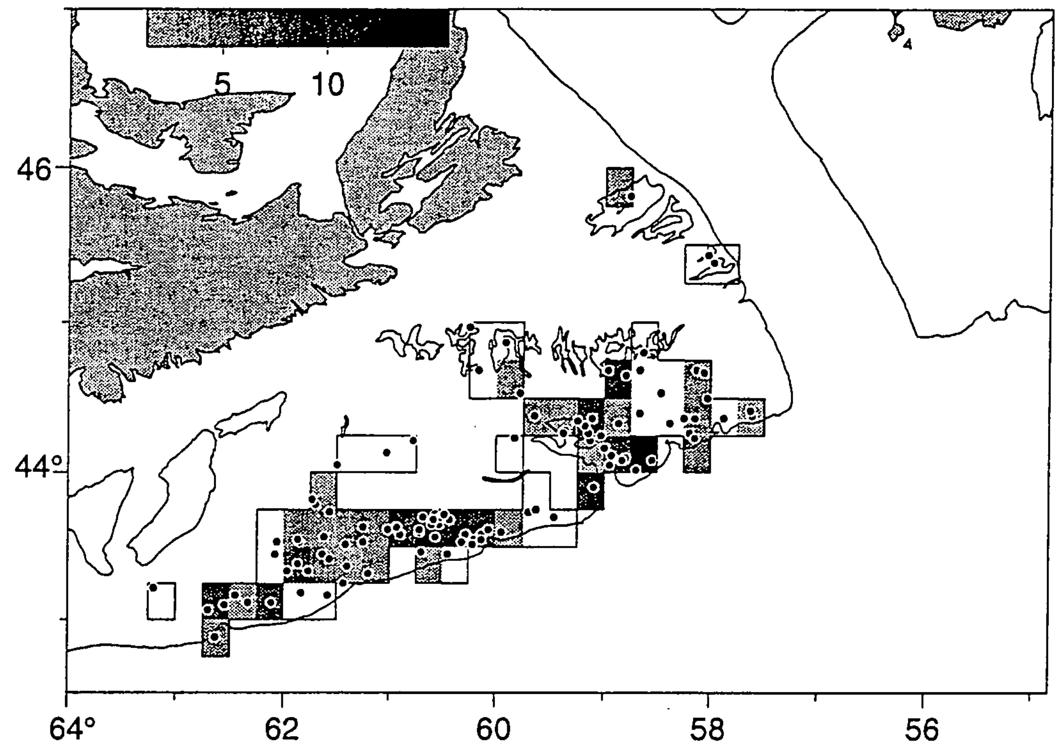
The analogous summer distributions are shown in Figure 2.1 and 2.2. As mentioned above ripe and running fish are very rare during the summer survey. Figure 2.1 however, shows a concentration in Sidney Bight. Figure 2.2 shows a scattered distribution of stages 2-6 over a large portion of 4VW without much structure.

Figure 3.1 shows the spawning fish from the Fall surveys. The aggregation on Sable Island Bank is slightly further north than in Figure 1.1. Also, there is a concentration on the tip of Banquereau not seen in 1.1.

These figures would tend to confirm the existence of a 4Vn cod stock. The summer distribution of spawning females is distinct geographically and seasonally from other spawning concentrations in 4VW. The stage 4-5 cod are fairly rare and it would be difficult to disaggregate the data much further.

The research survey data would tend to confirm the existence of a 4Vn cod stock. The summer distribution shows spawning females is distinct geographical region, Sidney Bight. As well, comparison with the spring and fall surveys suggests that this spawning of cod is seasonally distinct from other spawning concentrations in 4VW. Stage 4-5 cod are fairly rare and it would be difficult to disaggregate, either spatially or temporally, the data much further.

Figure 1.1 Cod Spring distribution stages 4-5



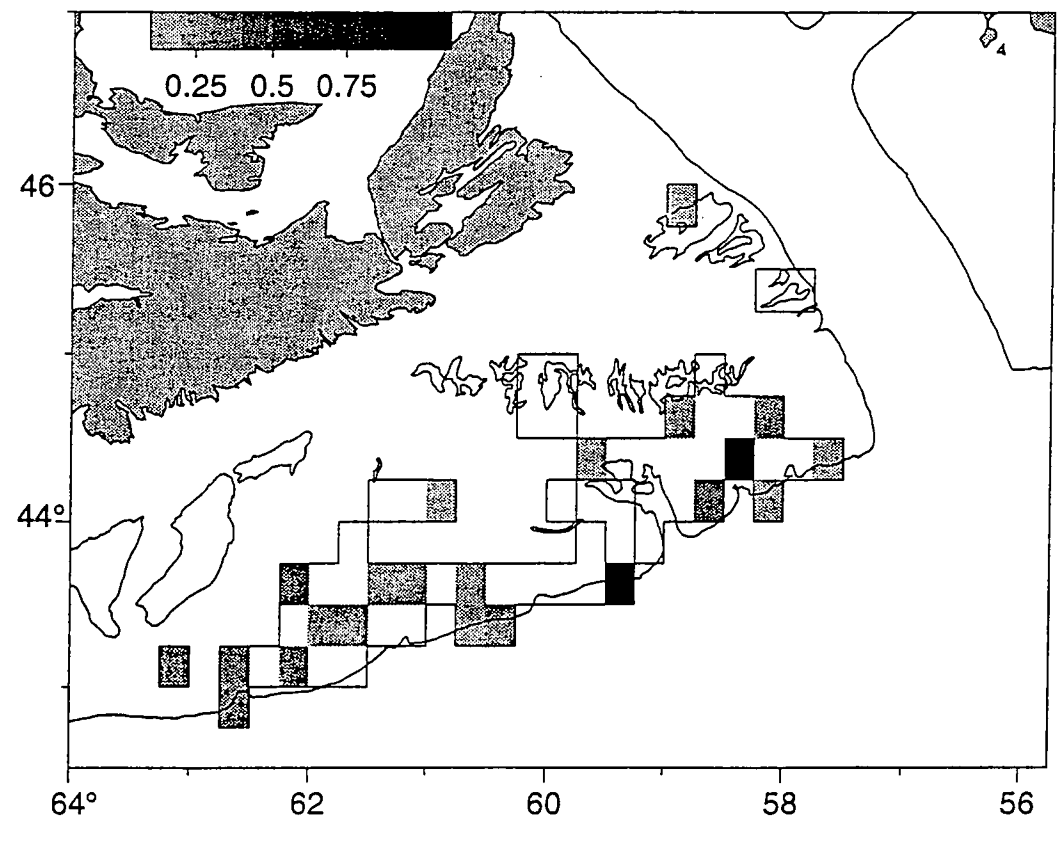


Figure 1.2 Cod Spring distribution stages 2-6

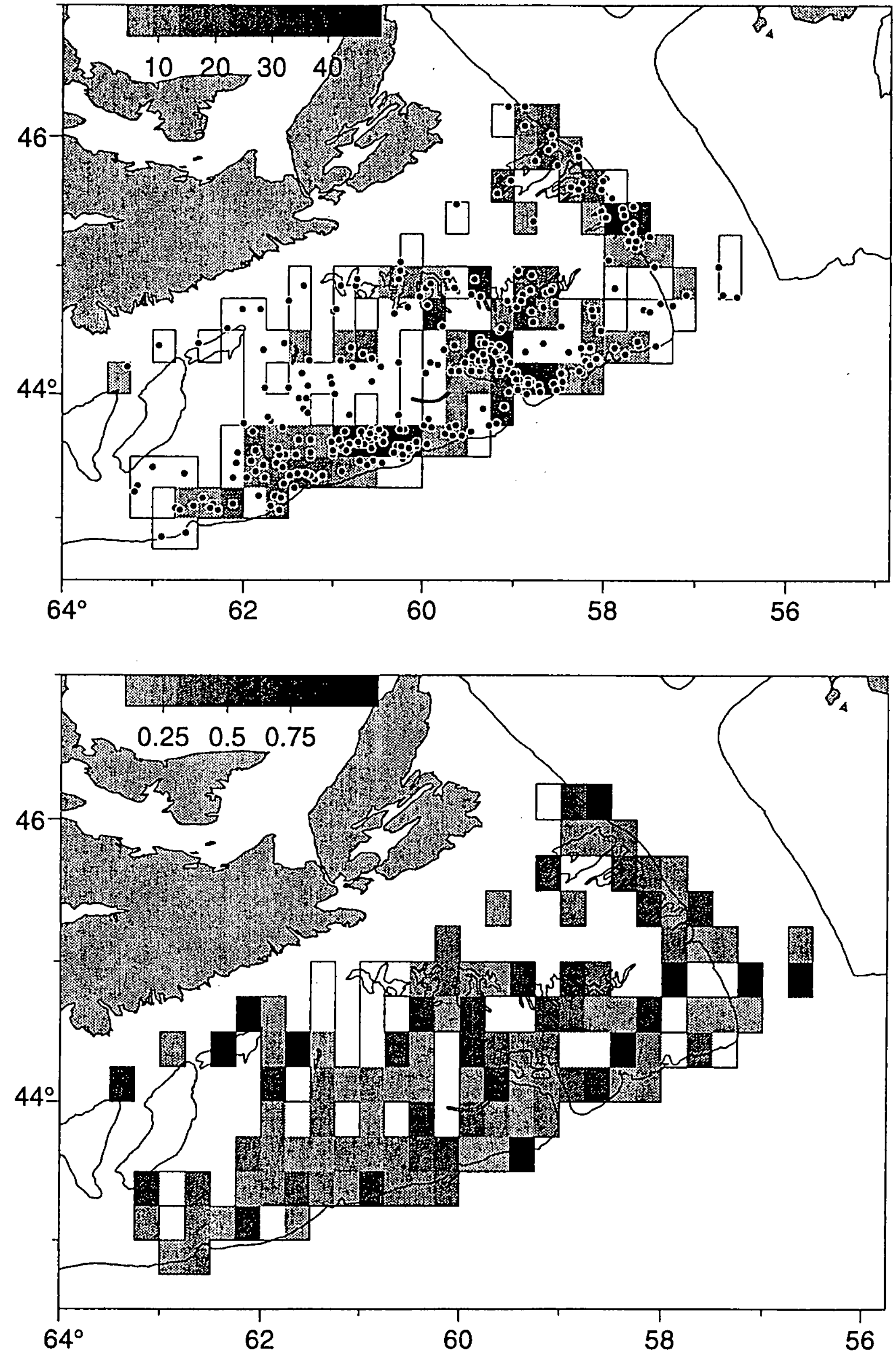


Figure 2.1 Cod Summer distribution stages 4-5.

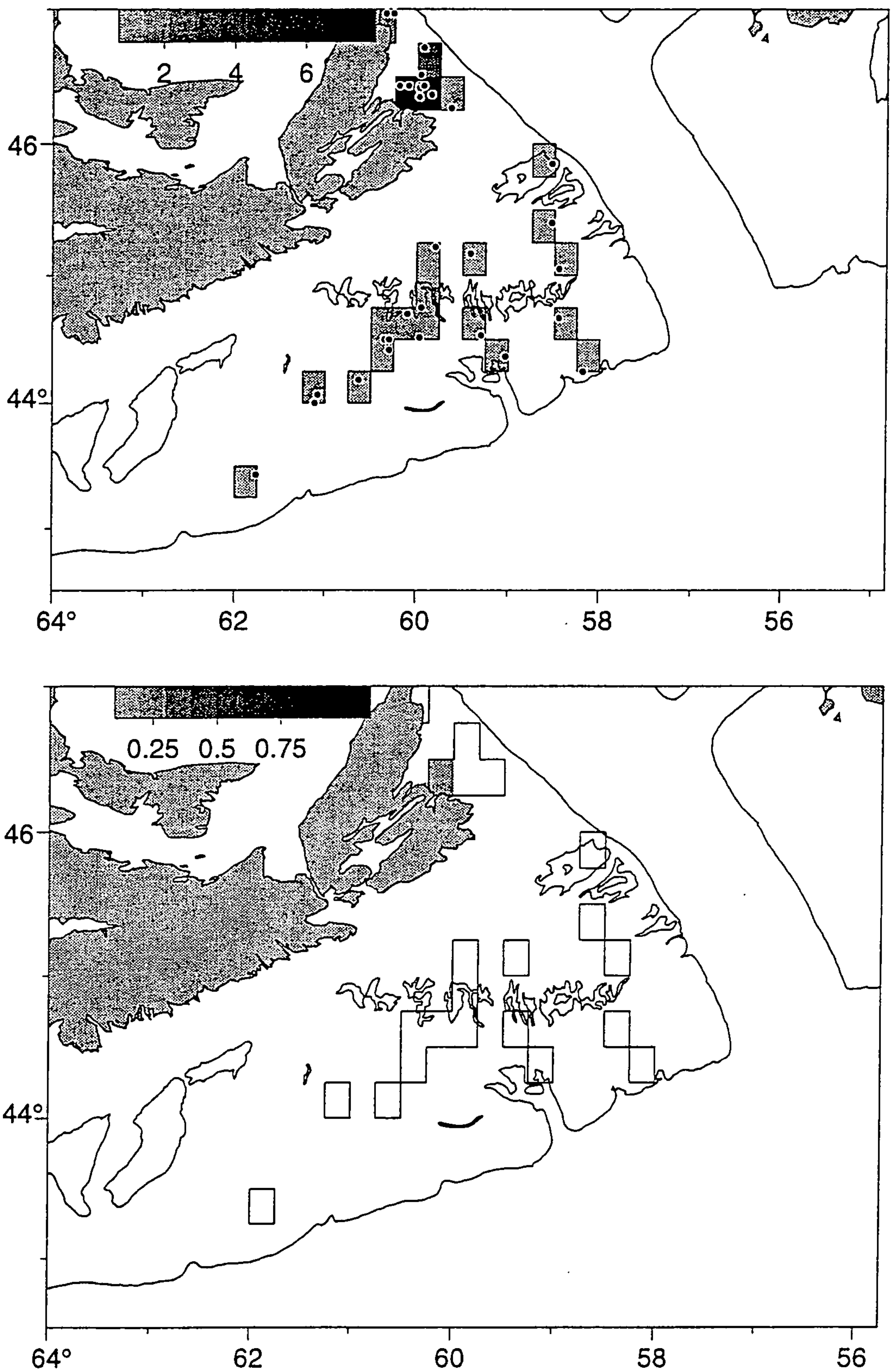


Figure 2.2 Cod Summer distribution stages 2-6

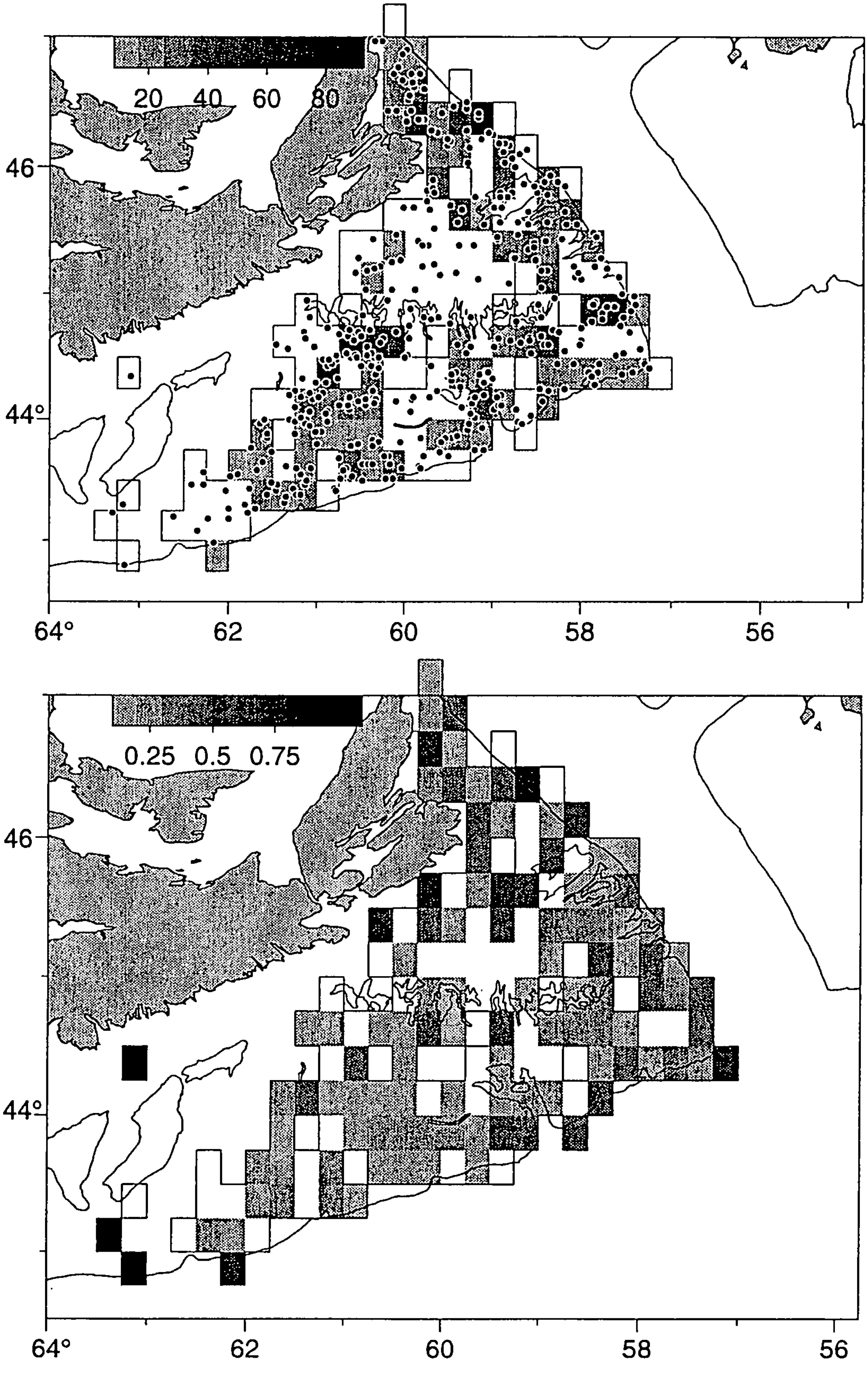


Figure 3.1 Cod Fall distribution stages 4-5

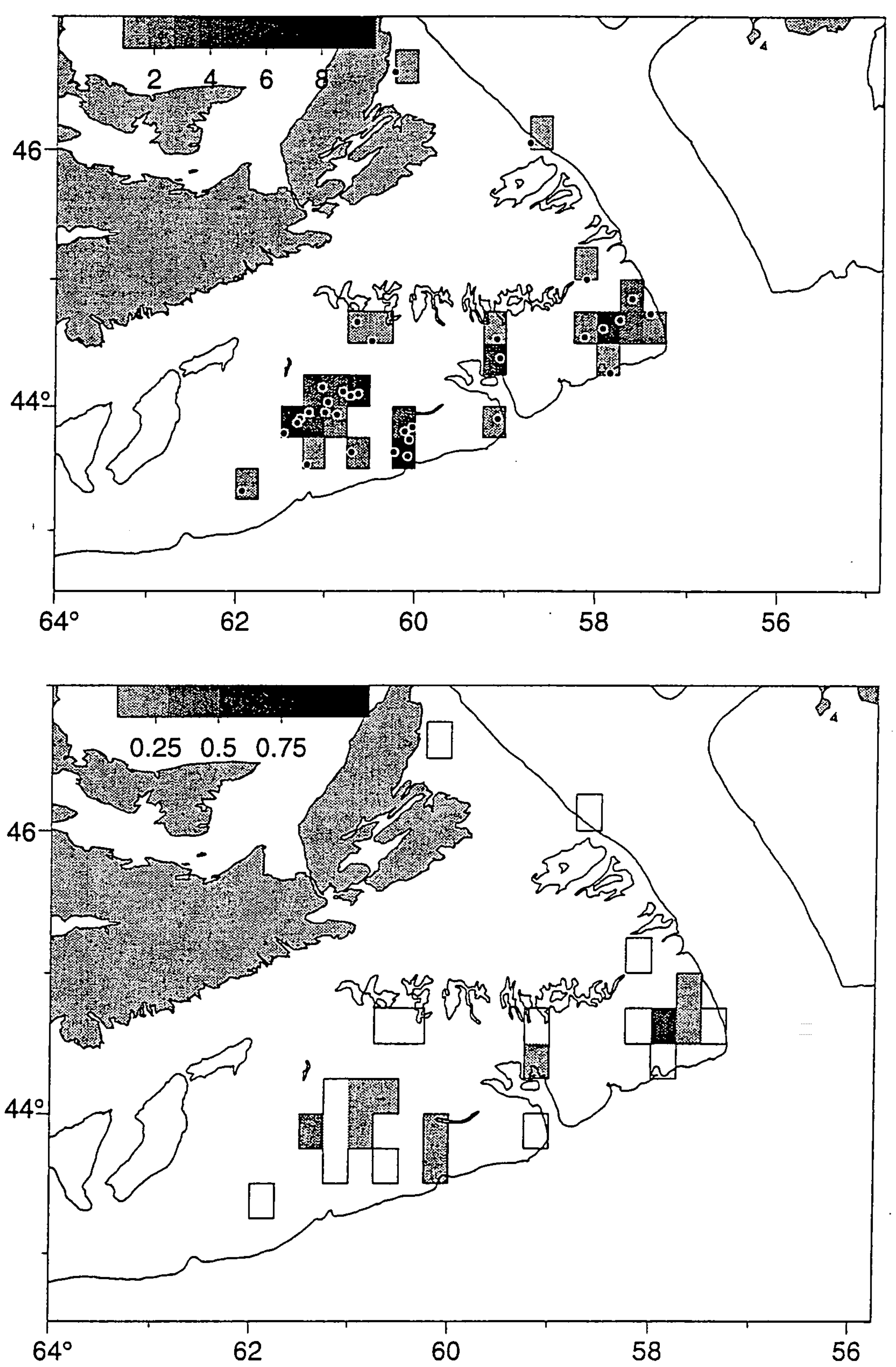
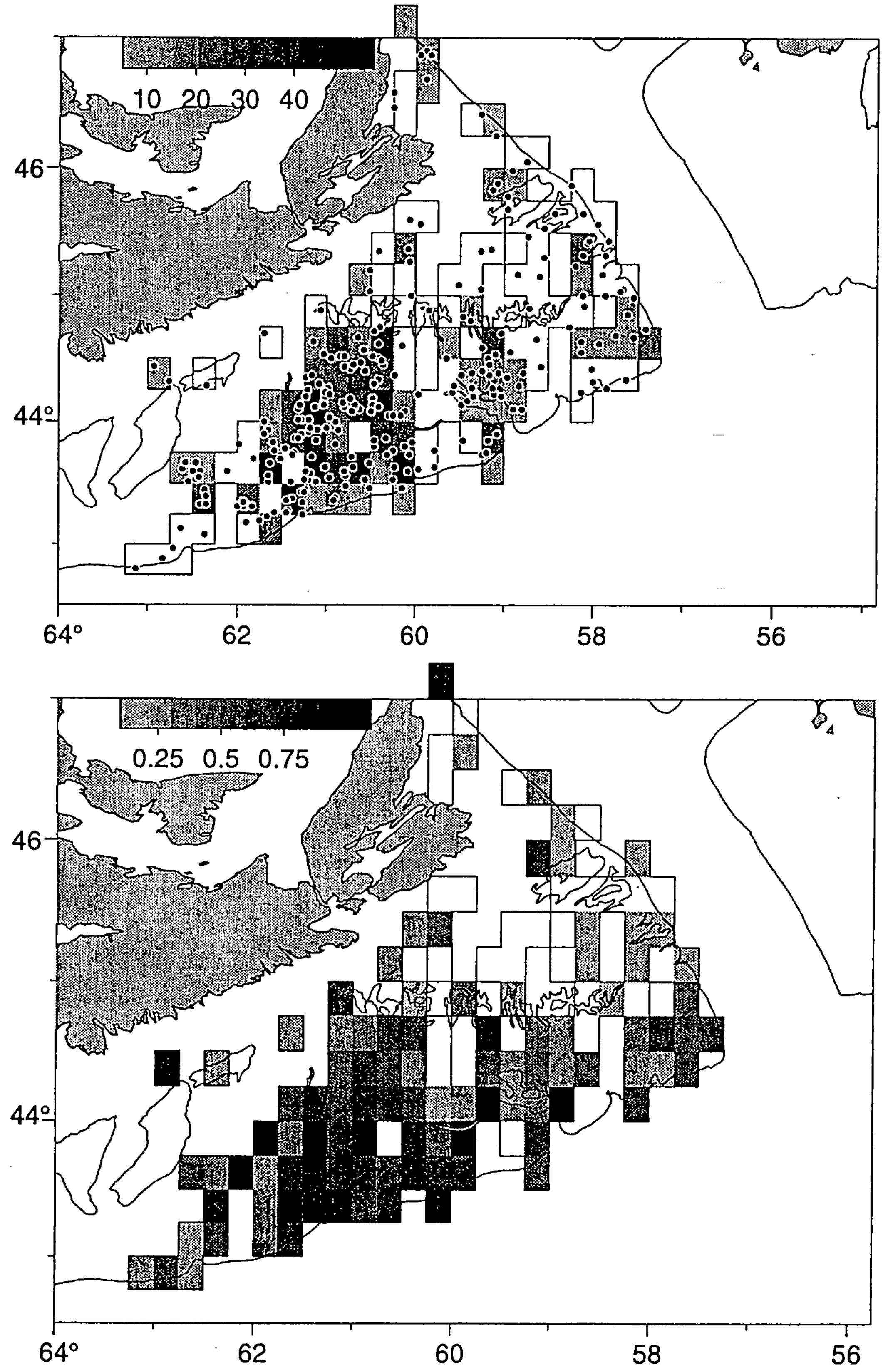


Figure 3.2 Cod Falldistribution stages 2-6



Monthly Distribution of Cabot Strait Mobile Gear Cod Fishery 1990-92 (Alan Sinclair)

The monthly distribution of the cod fishery in the Cabot Strait area was examined using commercial logbook for mobile gear vessels (otter trawls, midwater trawls, and seines). Data were obtained from the Gulf, Quebec, and Scotia Fundy ZIF data bases where the position of capture was recorded at least to 10' of latitude and longitude. Data are not available at this spatial scale from the Newfoundland region.

Reported catches were aggregated by month and 10' grid and plotted using shaded rectangles. Blank rectangles were used to indicate areas where there was some fishing effort but no cod catch. The shadings correspond to the 25^{th}, 50^{th}, 75^{th}, and 90^{th} percentiles of the non-zero catches.

Cod catches were concentrated in two main areas during January to March (Figure 1), off southwest Newfoundland in 3Pn/3Ps and along the southern edge on the Laurentain Channel in southern 4Vn and 4Vs (Misaine and Artimon Banks). Given the current understanding of stock structure it is likely that the catches off Newfoundland were predominantly of the northern Gulf of St. Lawrence stock (3Pn4RS) while the catches from the latter area are a mixture of the southern Gulf stock (4TVn), the 4Vn resident stock, and the eastern Scotian Shelf stock (4VsW). Catches declined off southwest Newfoundland in April to June as the northern gulf stock returned to the Gulf of St. Lawrence. At the same time, catches increased then declined in 4Vn and the eastern part of 4T as the southern Gulf stock undetook it's return migration. An area of high catches was noted in Sydney Bight in May and this corresponds with a spring fishery on spawning grounds. Catches on Banquereau Bank declined and the fishery became more dispersed during this period.

There were very few cod catches reported from the Newfoundland side of the Laurentian Channel in 3P and southern 4R during July to September. Cod catches in the southern Gulf, Sydney Bight, and 4Vs were dispersed. The highest catches in 4Vn came from a relatively small offshore area about mid-way along the Channel edge. In October, catches began to increase in eastern 4T, and eastern Banquereau Bank. Large catches were made in the eastern part of 4T in November and these extended into 4Vn as the southern Gulf stock began it's winter migration. At the same time, catches intensified in 4Vs around Misaine and Artimon Banks and along the Stone Fence. The redfish fishery increased in the Laurntian Channel in October - December. Cod by-catch was very low in October but this increaed in December. However, the overall cod catch on the northern side of Cabot Strait was much lower than on the southern side. From these results it appears that the winter migration of the northern Gulf cod stock was somewhat later than that of the southern Gulf stock.

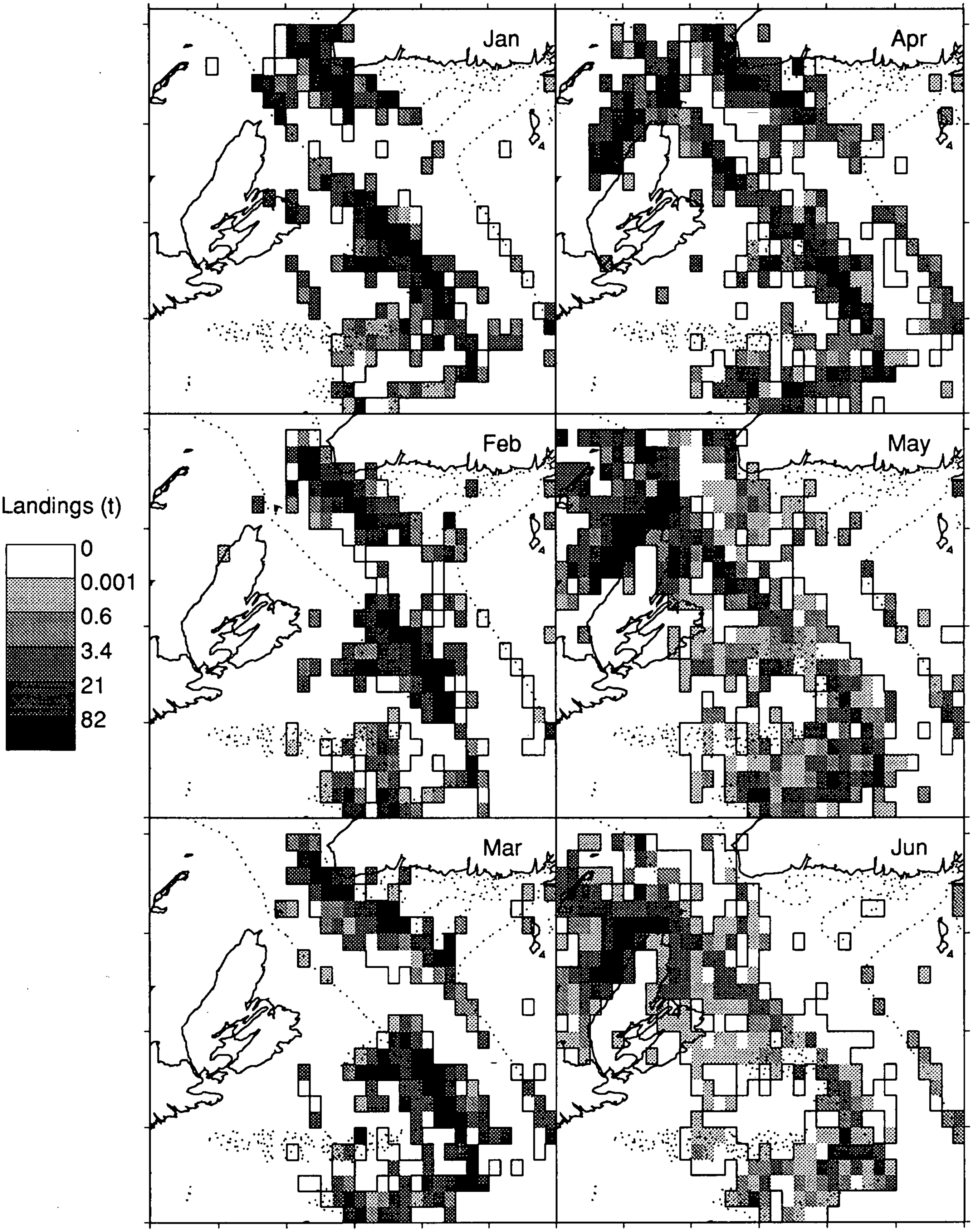


Figure 1: Monthly distribution of cod catch in the Cabot Strait 1990-92.

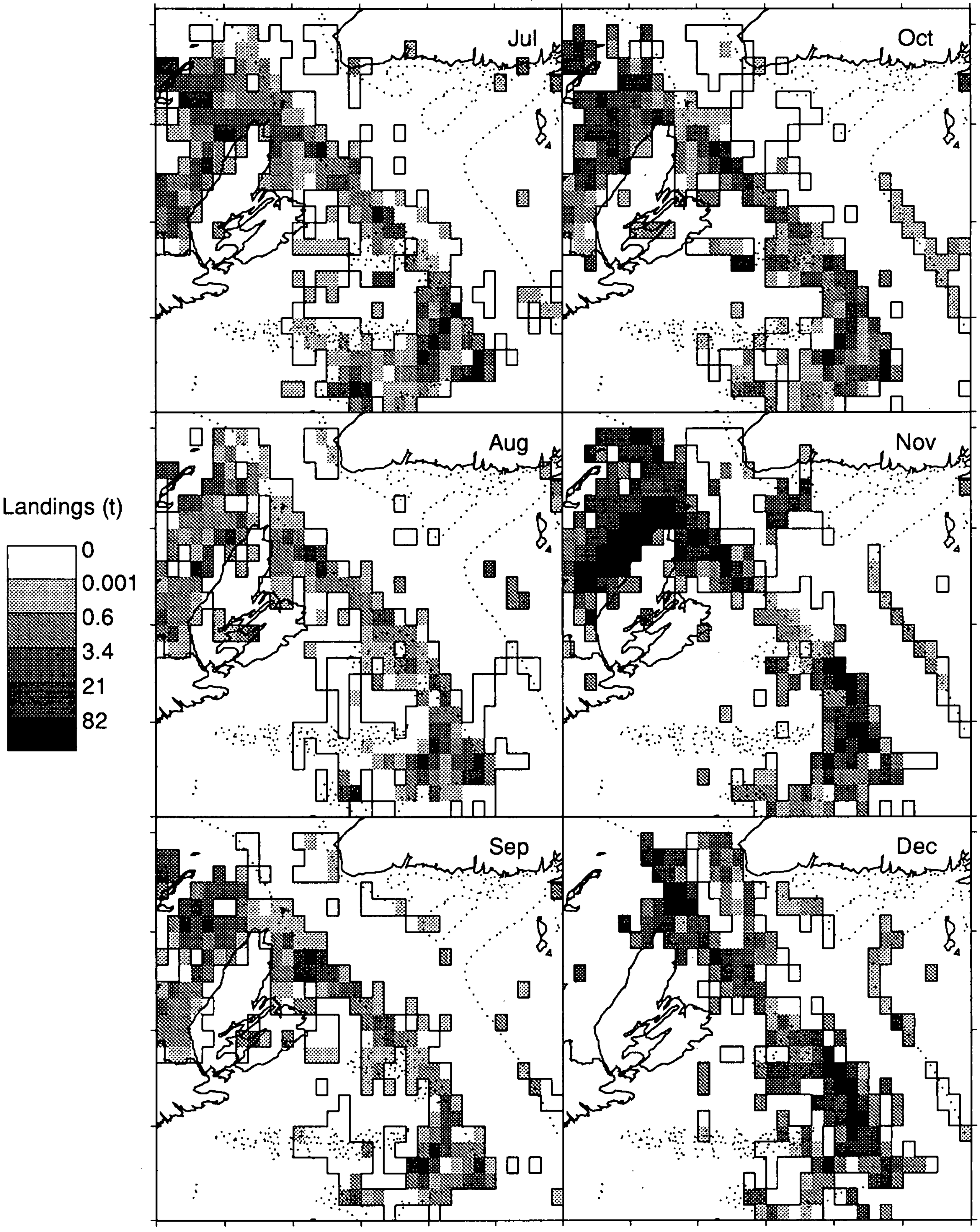


Figure 1: con't

Comparison of Research Survey Population Estimates of Cod in 4T, 4Vn, and 4Vs

Alan Sinclair
Marine and Anadromous Fish Division
Department of Fisheries and Oceans
P.O. Box 50 30
Moncton, N.B.

Research survey estimates of mean numbers per tow at age of cod in 4T, 4Vn, and 4Vs were examined to address two questions relevant to the terms of reference of the working group on 4Vn cod. The consistency of the year-class estimates among ages was examined to evaluate the utility of the survey results for providing management advice for the separate stocks if indeed these stocks exist. Secondly, the age compositions and relative year-class strengths of cod in each area were examined for evidence of stock separation.

The correlations of year-class estimates of the same cohorts at different ages was strongest for the September surveys in the eastern and western parts of 4T. The correlations were statistically significant ($p<0.05$) for ages 2-5 and ages 4-10 inclusive. The correlations were significant for ages 3-4 and 4-9 inclusive in the 4Vs summer surveys. The correlations for the 4Vn July surveys were relatively low, being significant only between ages 2 and 3, and between adjacent ages from 6-9. For the 4Vs spring surveys the correlations were significant between ages 4 and 5 and between adjacent ages from 6 to 8. This suggests that the information content of the 4Vn July and 4Vs spring surveys is relatively low and would yield highly variable assessment data when compared to the 4T and 4Vs July surveys.

There were very few young fish (age 1-3) caught in the 4Vn summer surveys. Where the modal age of the catch was 2 in 4Vs spring, 3 in 4Vs July and 4 in 4T east and west, it was age 5 in the 4Vn July survey. The lack of juvenile cod in 4Vn during summer questions the local spawning population's ability to support the abundance of adults found in the summer surveys.

Year-class trends were estimated using multiplicative analyses of the survey results. The year-class effects in analyses based on age 1-3 data were only significant for the 4T east, 4T west, and 4Vs spring data. The trends were similar for the two 4T series, but these differed from the 4Vs spring series. The year-class effects from analyses of age 4-6 data were statistically significant in all areas and were correlated among the areas with the exception of between the 4Vs spring and 4Vn summer series. Given the weak year-class signals at younger ages and the similarity in trends at older ages it is not possible to determine if there is stock separation among the areas from these analyses.

The full text of this document is being prepared for publication as a DFO Res. Doc., copies of which will be available in mid-summer.

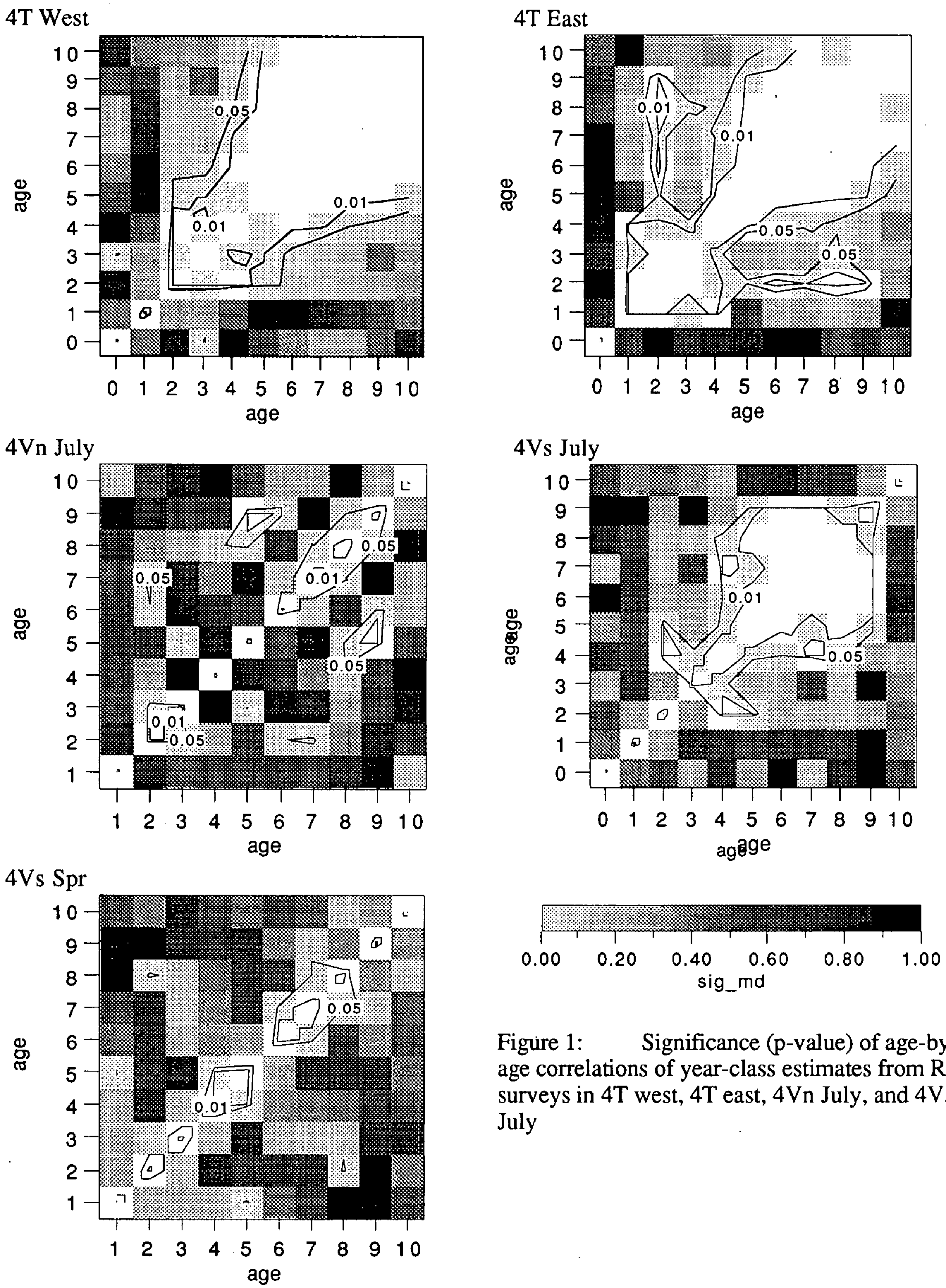


Figure 1: Significance (p-value) of age-by-age correlations of year-class estimates from RV surveys in 4T west, 4T east, 4Vn July, and 4Vs July

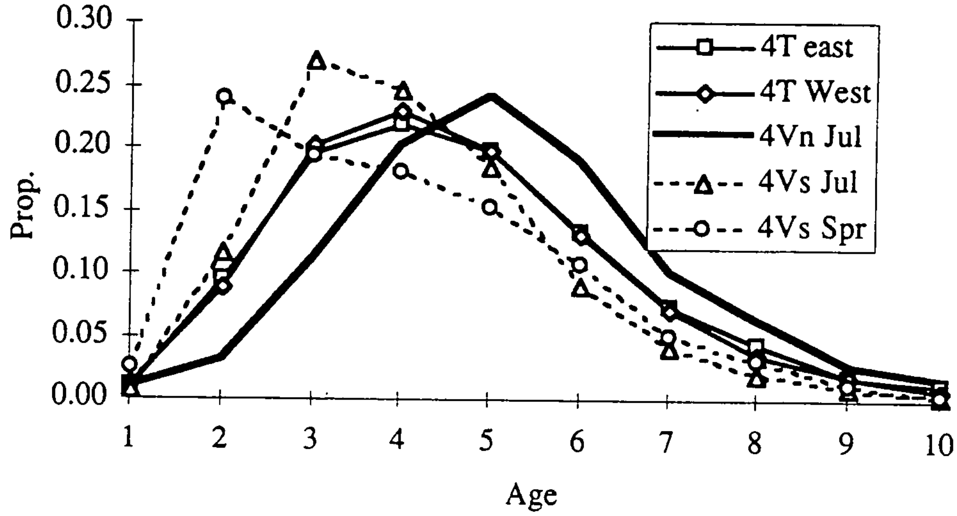


Figure 2: Estimated age effects from multiplicative analyses of research survey mean numbers per tow at age. The least square means estimates were retransformed and scaled to proportions at age.

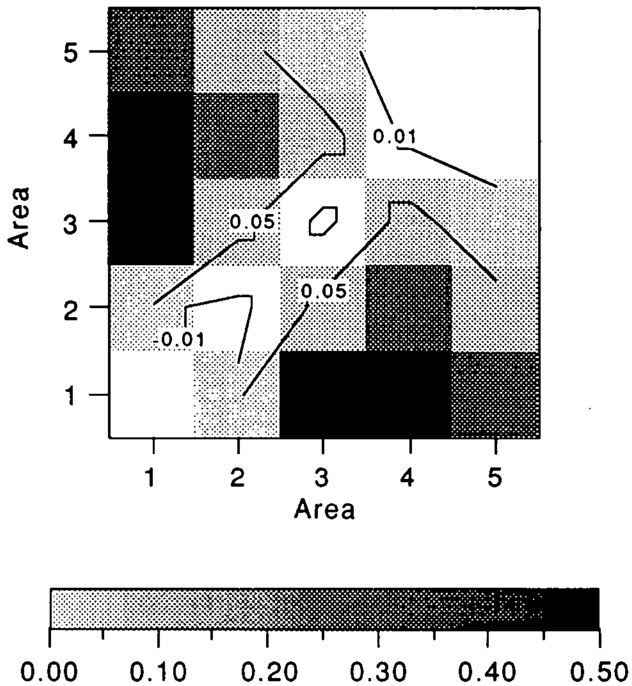


Figure 5: Significance values of correlations between age 1-3 year-class estimates from multiplicative analyses. The survey areas are coded as follows, 1 - 4T west, 2 - 4T east, 3 - 4Vn July, 4 - 4Vs July, and 5 - 4Vs Spring.

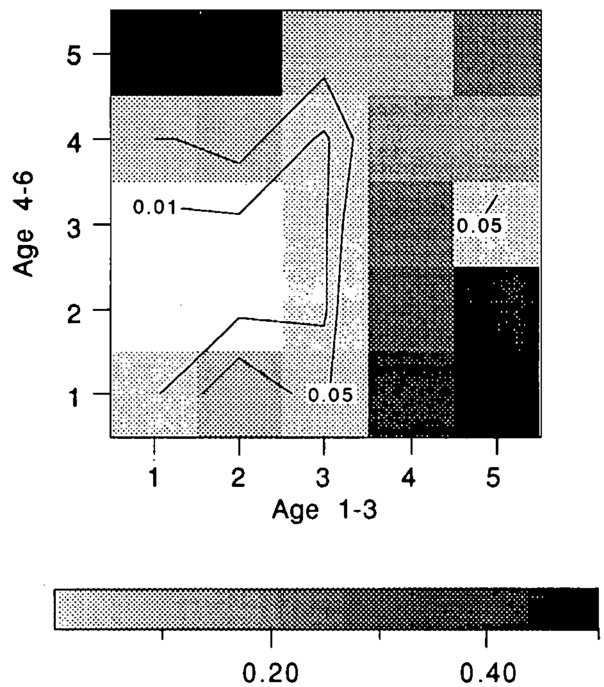


Figure 6: Significance values of correlations between age 1-3 and age 4-6 year-class estimates from multiplicative analyses. The survey areas are coded as follows, 1 - 4T west, 2 - 4T east, 3 - 4Vn July, 4 - 4Vs July, and 5 - 4Vs Spring.

Lengths at Age of Cod in 4T, 4Vn, and 4Vs

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Differences in research survey estimates of size at age of cod in the southern Gulf of St. Lawrence and eastern Scotian Shelf were examined for evidence of stock separation among the areas and within 4T. We ask two main questions, do the available data support the idea of separate 4T, 4Vn, and 4Vs stocks; and do they suggest the existence of separate stocks within 4T (east and west).

There was very little difference in size at age and growth of cod from the eastern and western Gulf of St. Lawrence. During the late 1970's and early 1980's age 6+ cod from the eastern Gulf were slightly larger at age than those from the western Gulf. However, these differences did not persist and were very small compared to differences in size at age between 4T and the other areas. During the summer months when the stocks are most likely to be spatially separated, the 4T fish were consistently the smallest at age. For ages 2 and 3, 4T and 4Vn cod were of similar size from 1983 to the present. In all years age 4+, cod in 4Vn were larger than 4T cod. 4Vs cod were consistently the largest fish.

The seasonal patterns in change in length at age in 4Vs and 4Vn were also examined. The mean lengths at older ages decreased on average between the July and November surveys in both areas. This may have been caused by the arrival of the 4T fish in 4Vn by the time the surveys were conducted. The effect was greater for the older fish, possibly because of differential migration timing, larger fish may begin their migration earlier than smaller fish. The decline in average length at older ages in 4Vs may also be the result of migration of relatively smaller 4Vn and possibly 4T fish into the area in the fall.

The results do not suggest stock segregation within the Gulf. Even if there are sub-stocks within the area, methods that rely on differences in size at age could not be used to separate them. The results are consistent with the current stock identification of 4TVn (N-A), 4Vn (M-O), and 4VsW. The differences in size at age noted here have persisted throughout the period that the groundfish abundance surveys have been conducted (1970 to the present). There is potential to use stock identification methods which rely on differences in size at age to separate southern Gulf, 4Vn, and 4Vs cod during this period.

The full analysis will be available in the DFO Atlantic Fisheries Science Res. Doc. series.

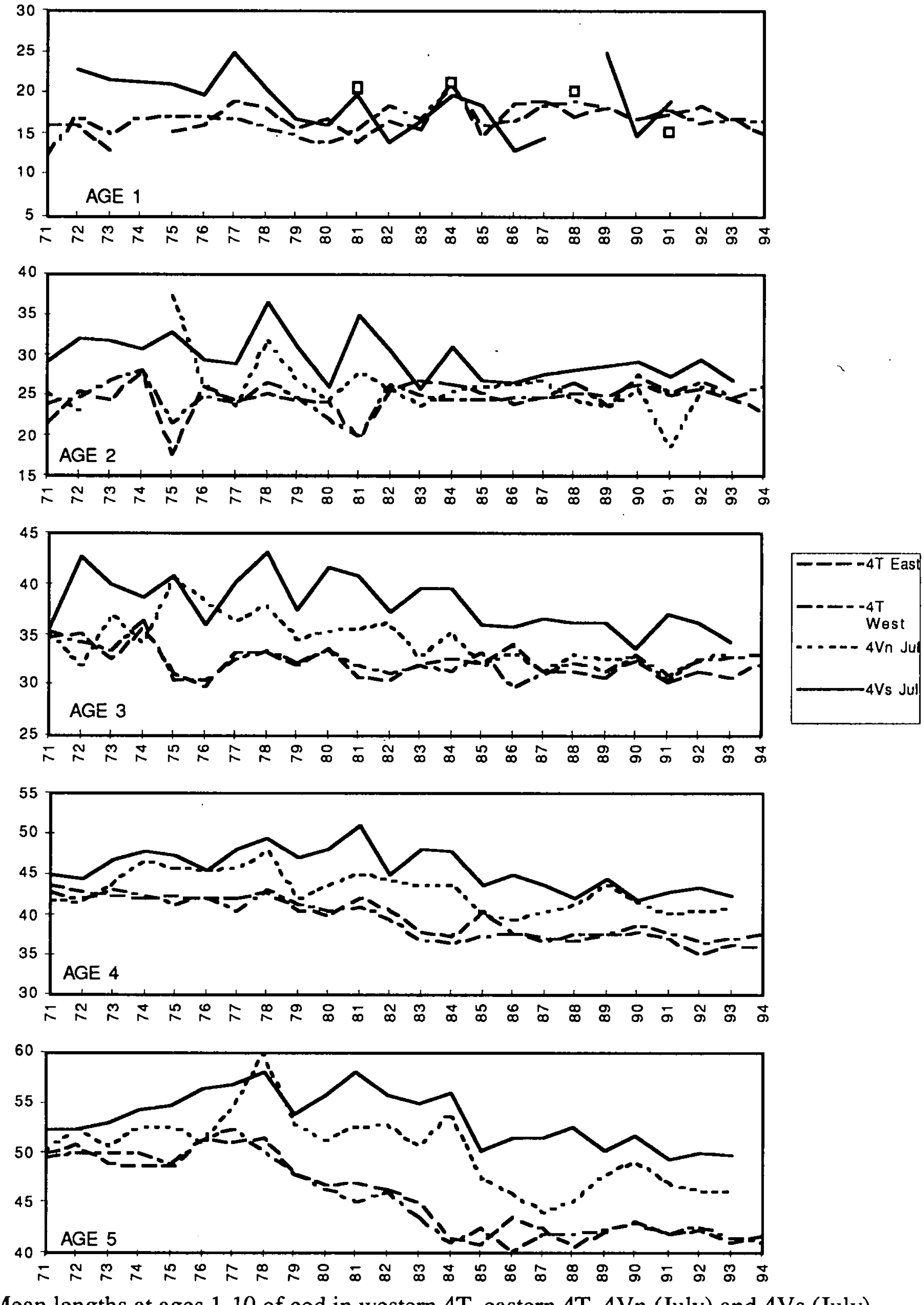

Figure 2: Mean lengths at ages 1-10 of cod in western 4T, eastern 4T, 4Vn (July) and 4Vs (July) 1971-94.

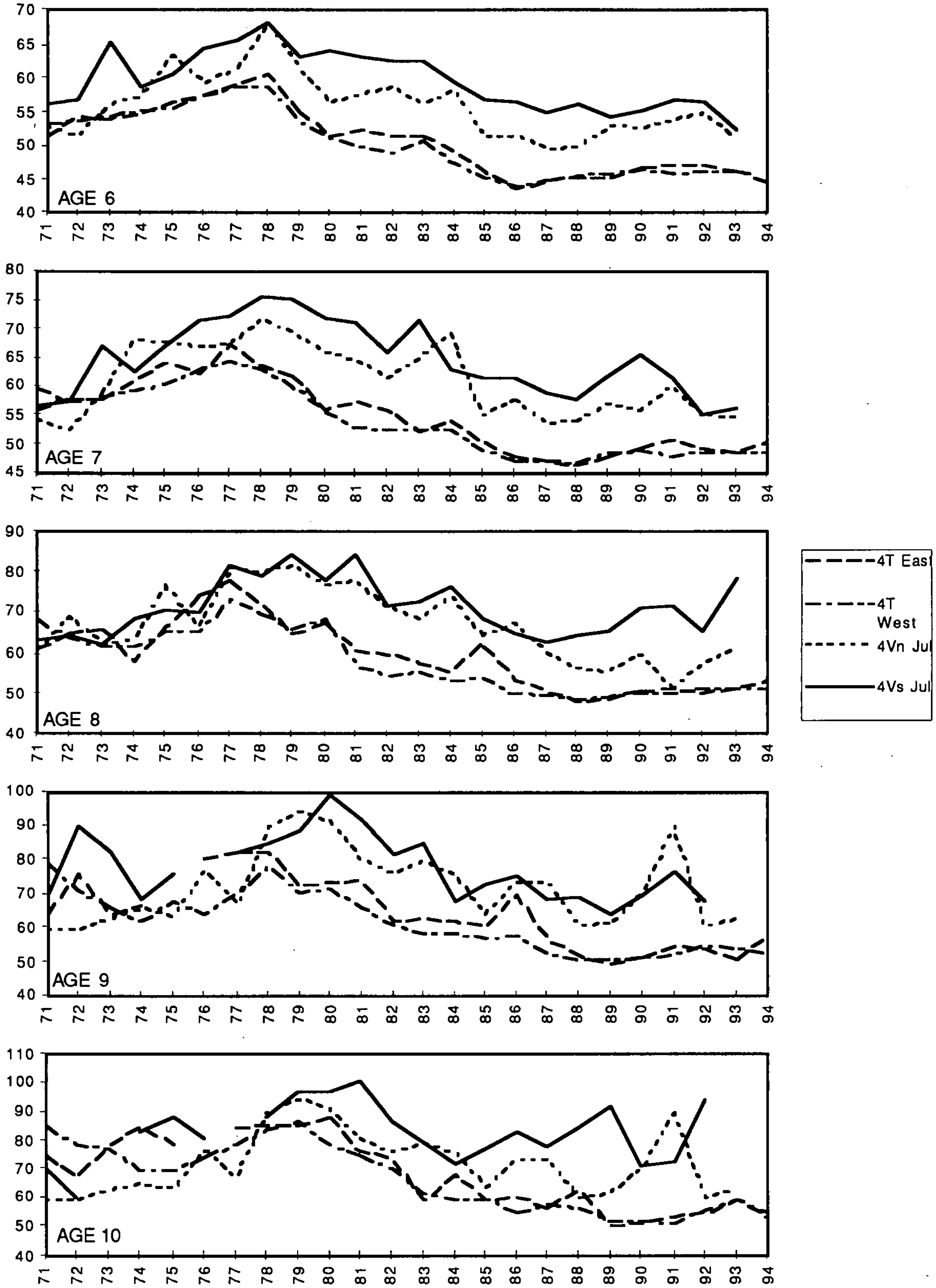

Figure 2: con't.

DISTRIBUTION AND SEASONAL MOVEMENTS OF COD IN 4TVW

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(This document is being prepared as a Technical Report and will be available for distribution in mid-summer. Draft copies can be obtained from the senior author)

SUMMARY

The Subdiv. 4Vn area has always been a major overwintering mixing area with an intensive fishery, and the management regulations have incorporated both geographic and time components in an attempt to deal with the biological complexity of the 4Vn area. The timing of seasonal movements into the 4Vn area and the vagueness of stock discreteness have, however, continued to confound management measures, and the temporal component of the management regimes for the 4TVn and summer 4Vn fisheries have changed over time

Two major initiatives occurred in groundfish tagging studies in NAFO Subarea 4, one between 1953 and 1973 and a second between 1978 and 1985; cod was the prominent groundfish species in both programs. In this analysis we examined the cod tagging studies conducted in 4TVW between 1954 and 1981. As one aspect, we weighted the recovery data by catch to adjust for differences in fishery distribution. We examined the potential change in movement patterns between the 4T, 4Vn, 4Vs and 4W areas over the time period using both raw and weighted recoveries, examined the seasonality of the movements, and partitioned the release data to examine for differences between sub-populations within the 4T and 4Vn management areas.

Conclusions

Cod in Div. 4Vn are a complex of stocks from different areas which intermix to varying degrees seasonally. Cod found inshore and nearshore in 4Vn in summer are largely a resident 'stock' present throughout the year. This 'stock' moves offshore during winter and intermixes with the Div. 4T and 4Vs complexes. However it also appears that the 4Vn 'stock' represents a small proportion of the overwintering offshore group. The 4Vn 'stock' appears to have substantial leakage to, and from, the 4T and 4Vs complexes.

Cod in 4T are a complex of at least two components, one in the western portion (centered around Chaleur Bay and Gaspé) and the other in the south eastern portion (centered around the Magdalen Islands south to St. Georges Bay). Both complexes are primarily located in Div. 4T from May to November with outward movement commencing in November, though most substantial in December, and substantial return movement occurring in April. The two components appear to have slightly different migration routes, the western group moving into the Gulf along the edge of the Laurentian Channel while the eastern group re-enters south of the Magdalen Islands. Both components overwinter primarily offshore near the shelf edge mainly in Div. 4Vn, but also extending into Div. 4Vs. There appears to be considerable leakage from this complex into the 4Vn, 4Vs and 4RS3Pn 'stocks'.

Most of the 4Vs 'stock' overwinters in the southeastern portion of 4Vs, although a relatively small portion of this 'stock' intermixes with the overwintering 4Vn and 4T 'stocks' along the shelf edge in Div. 4Vn and the northern portion of Div. 4Vs. Cod in Div. 4Vs however do appear to be closely linked with the 4Vn 'stock' with substantial mixing in the nearshore area of 4Vn during the summer.

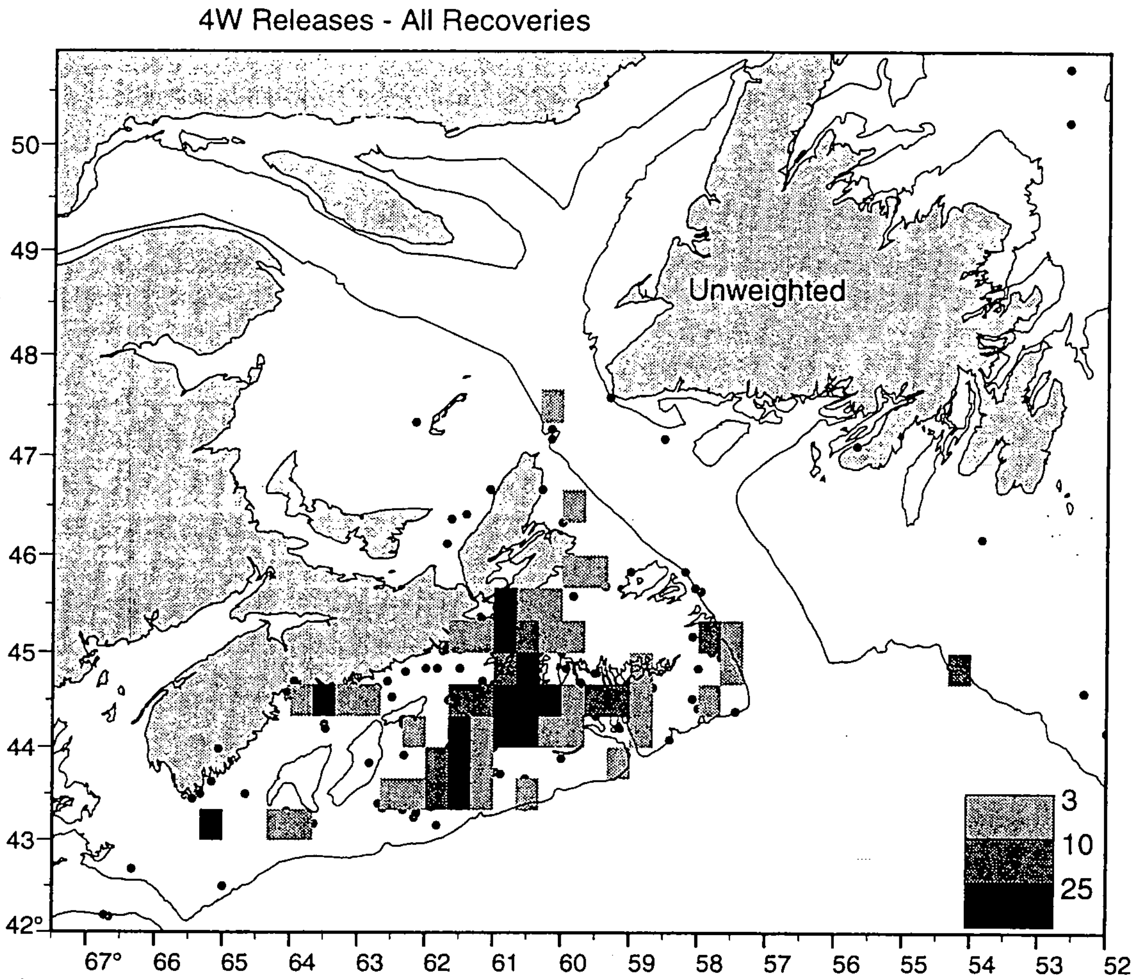


Fig. 2. Recoveries from cod tagged between 1954-81 in Div. 4W.

Fig. 5. Recoveries from cod tagged in April-May of 1979 and 1981 in Div. 4Vs.

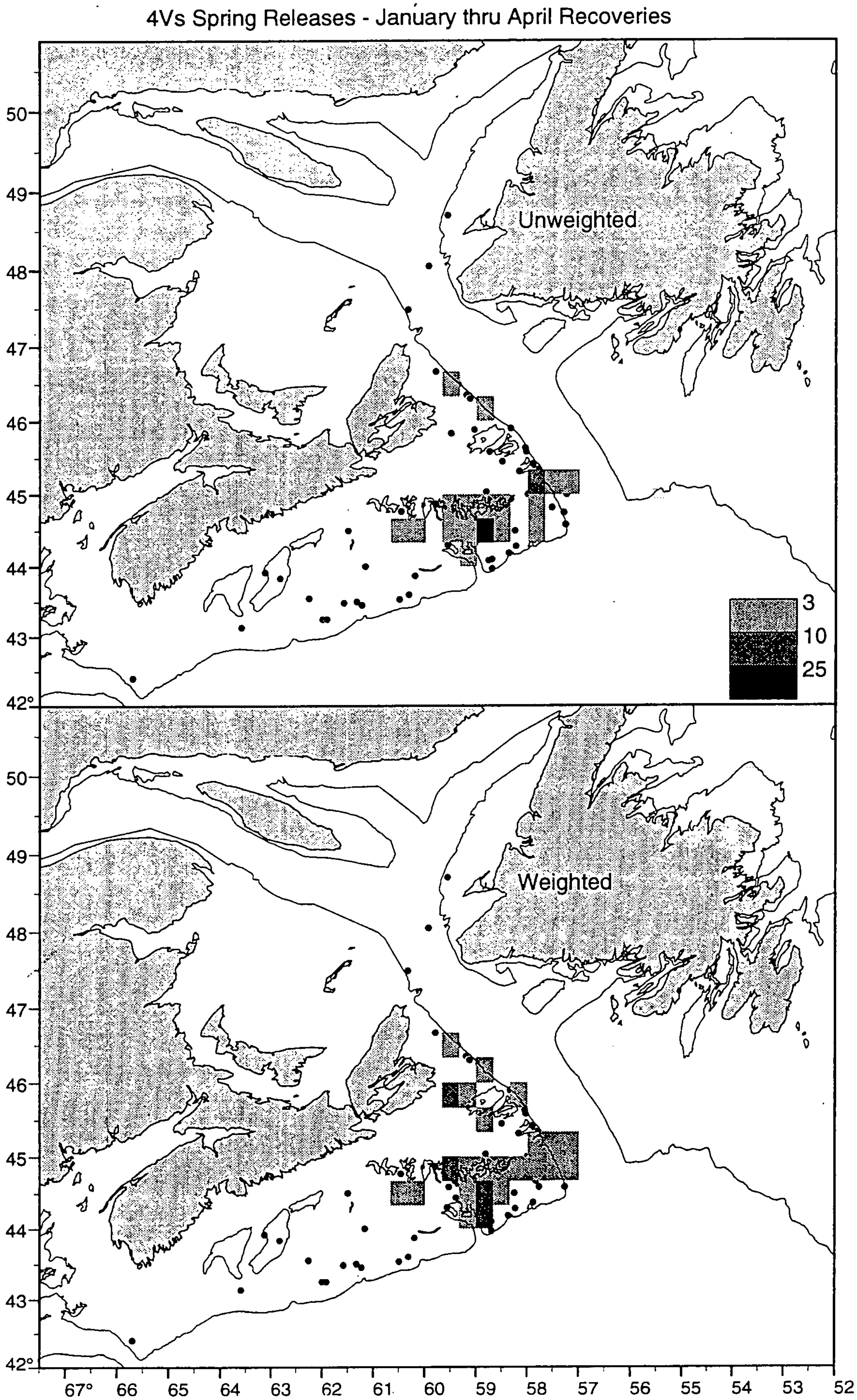
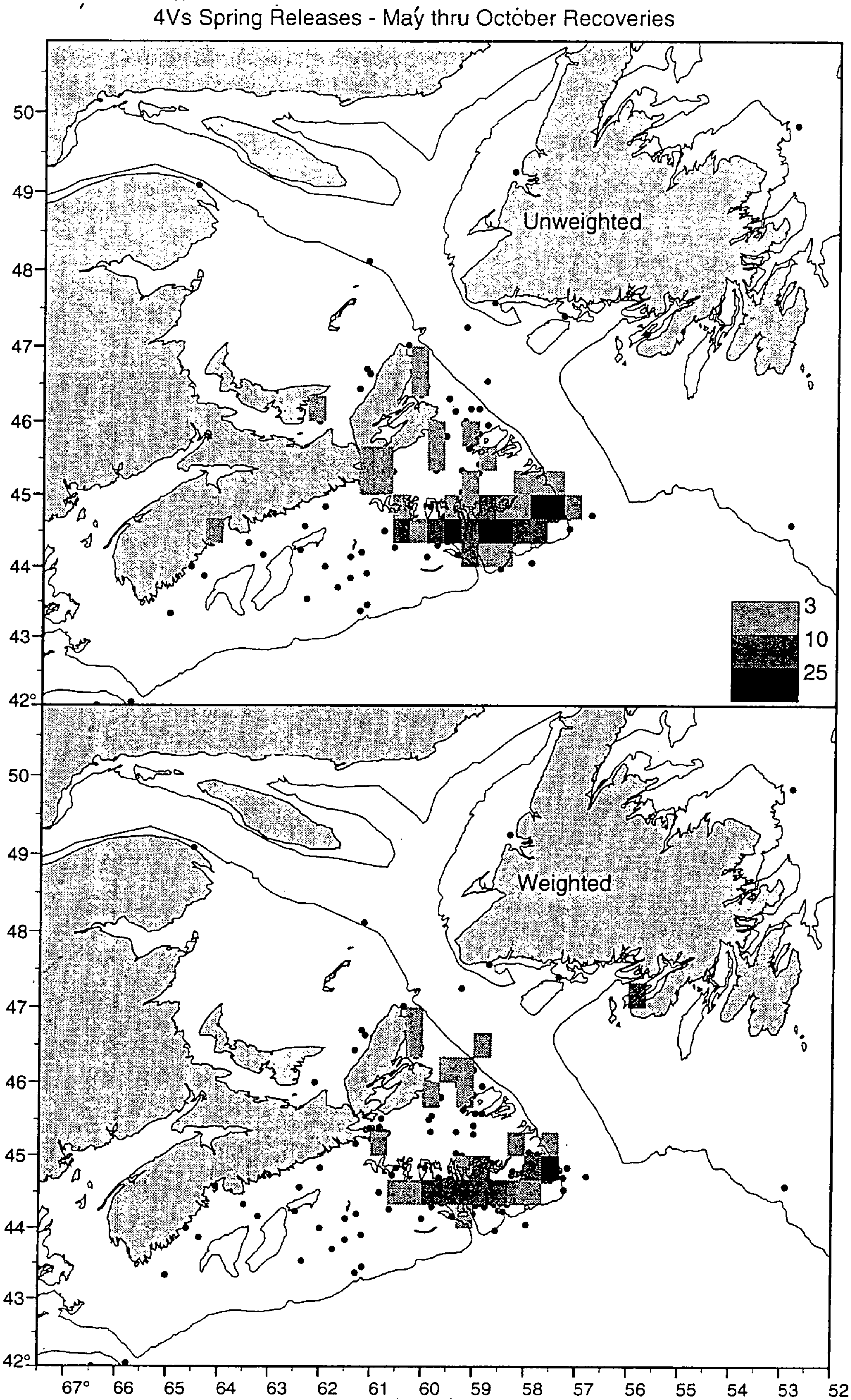


Fig. 6. Recoveries from cod tagged in April-May of 1979 and 1981 in Div. 4Vs.



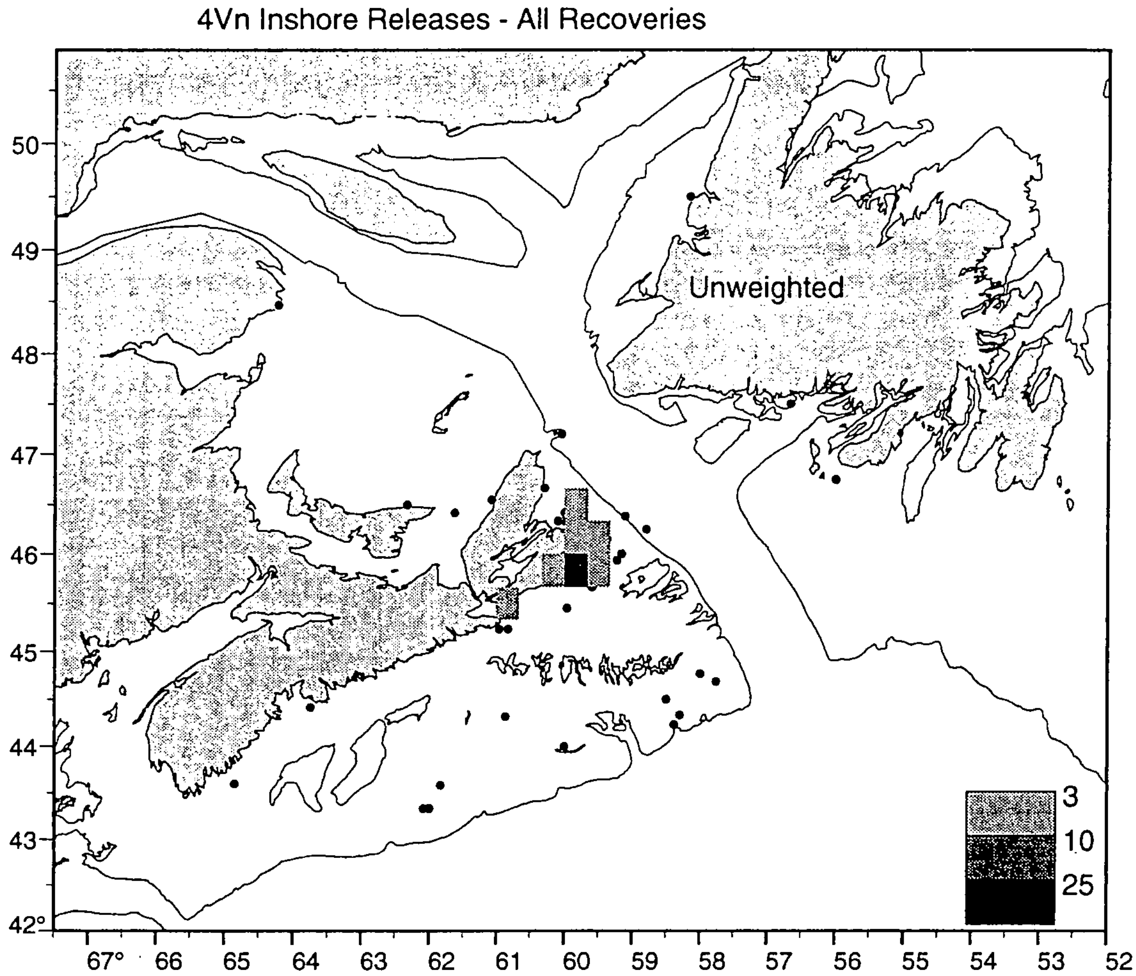


Fig. 8. Recoveries from cod tagged in June-July of 1954 in Div. 4Vn.

Fig. 9. Recoveries from cod tagged in January-April of 1960, 1962 and 1969 in Div. 4Vn.

4Vn Offshore Releases - Unweighted Recoveries

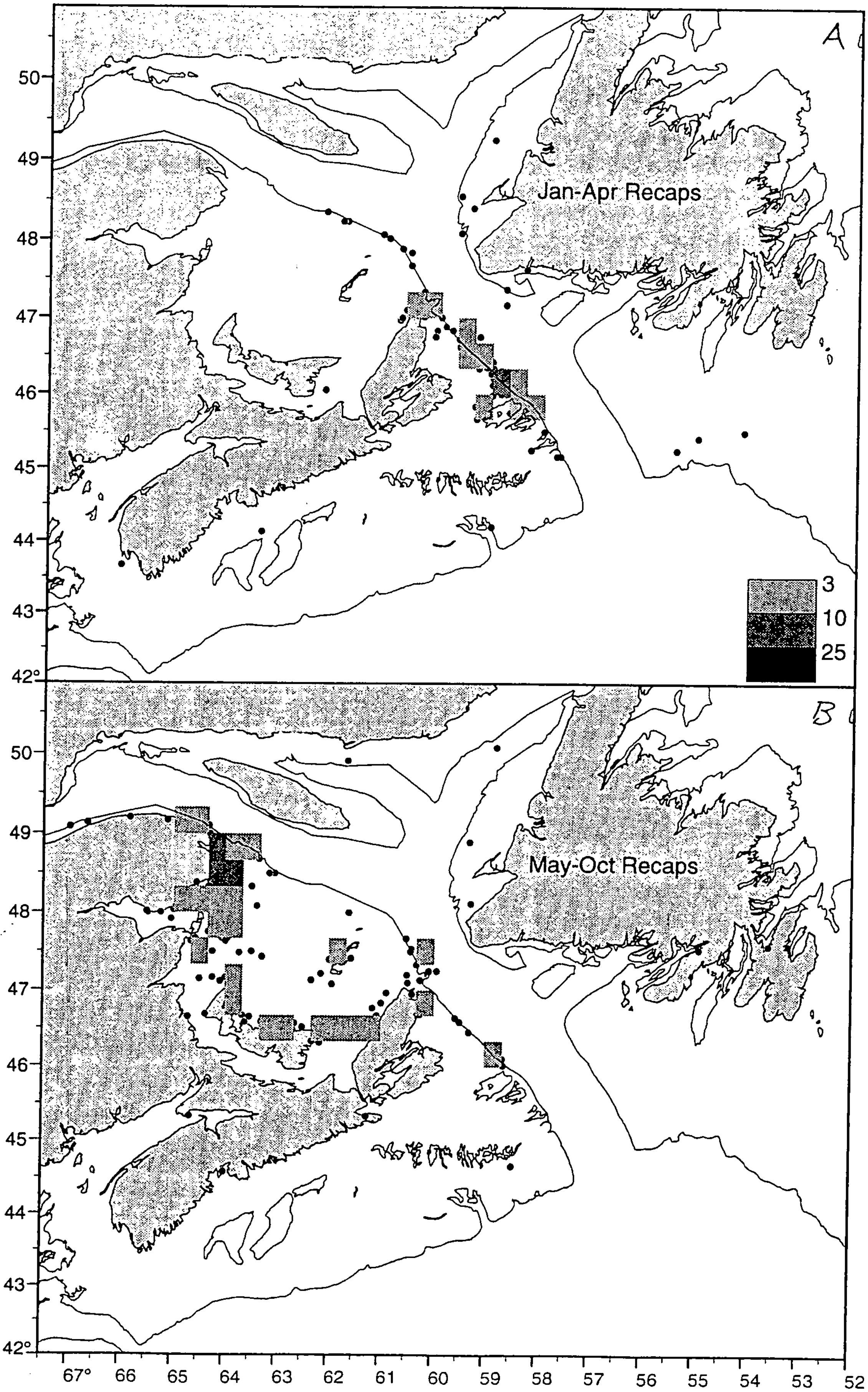


Fig. 11. Recoveries from cod tagged in September-October of 1980 in Div. 4Vn.

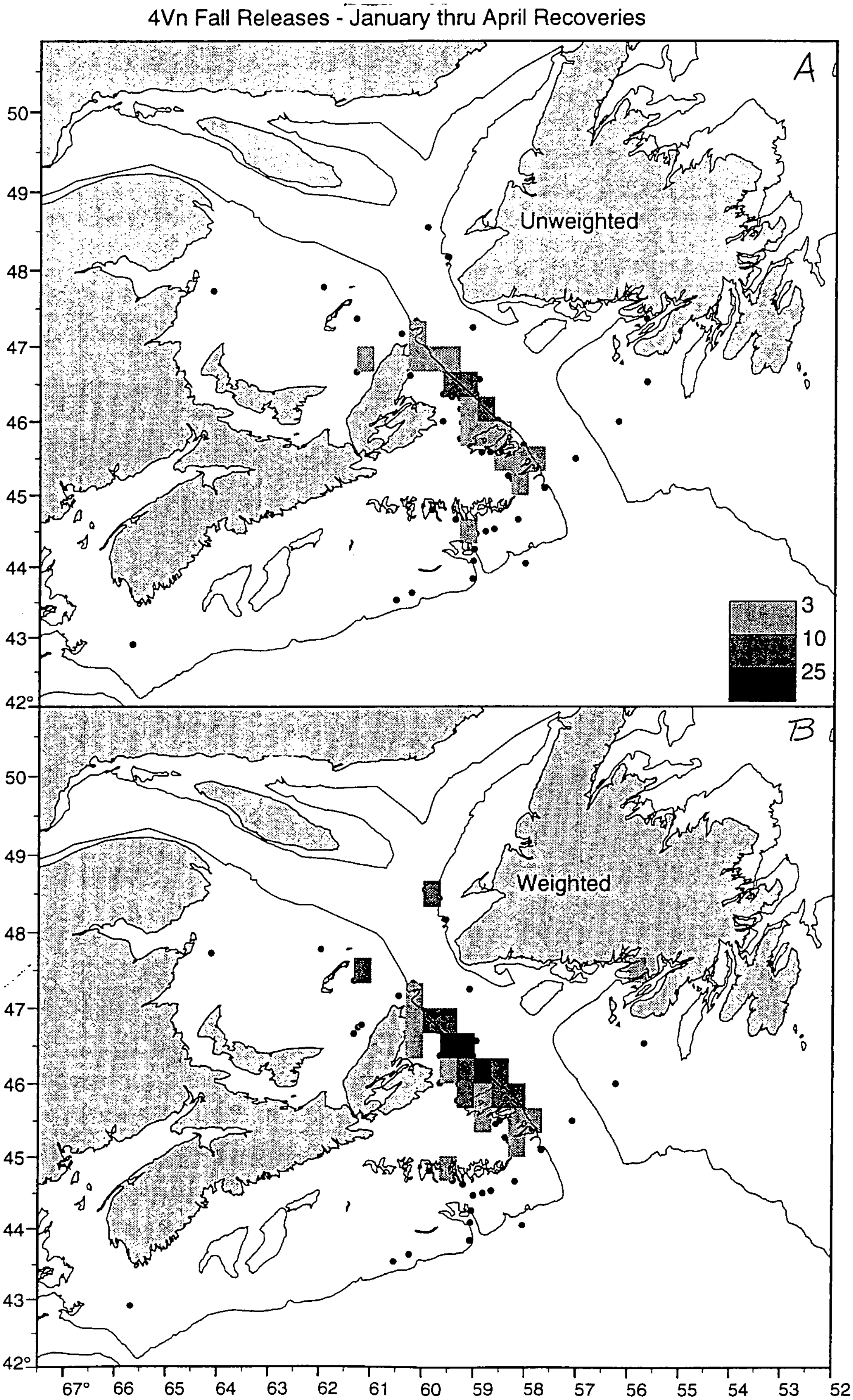


Fig. 12. Recoveries from cod tagged in September-October of 1980 in Div. 4Vn.

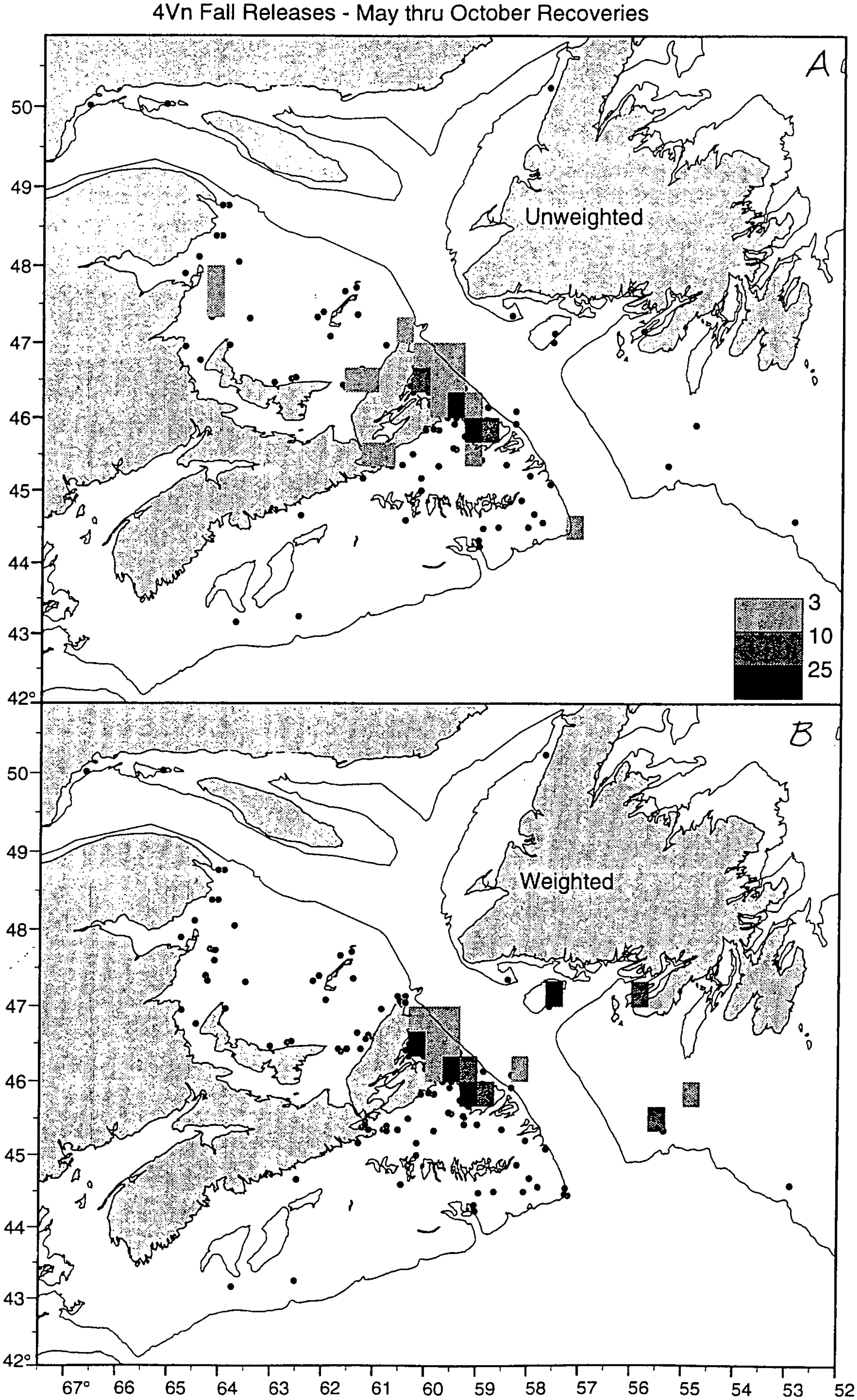


Fig. 13. Recoveries from cod tagged in September-October of 1980 in Div. 4Vn.

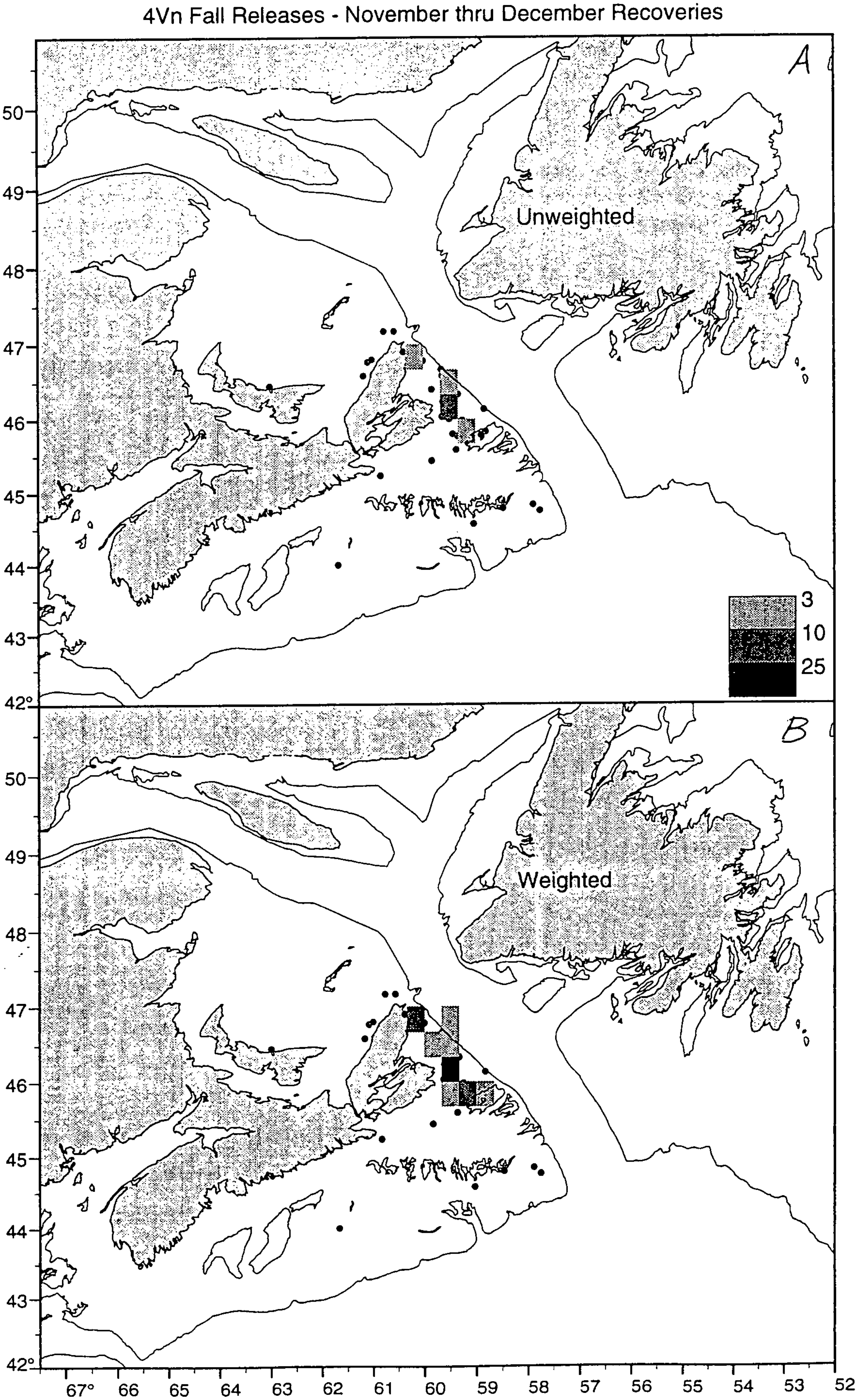


Fig. 16. Seasonal recoveries from cod tagged in the western part of Div. 4T. between 1955-58.

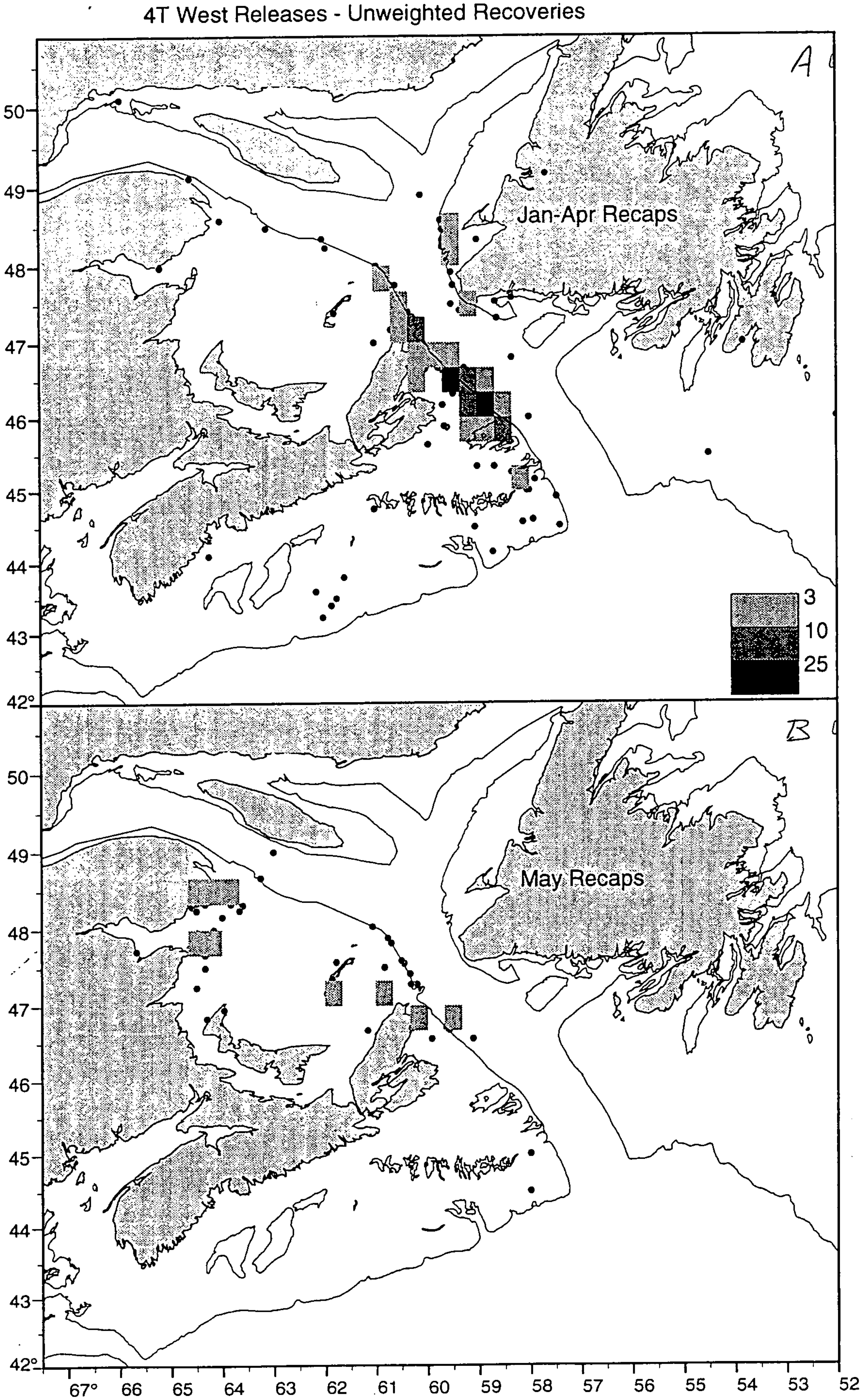


Fig. 17. Seasonal recoveries from cod tagged in the western part of Div. 4T. between 1955-58.

4T West Releases - Unweighted Recoveries

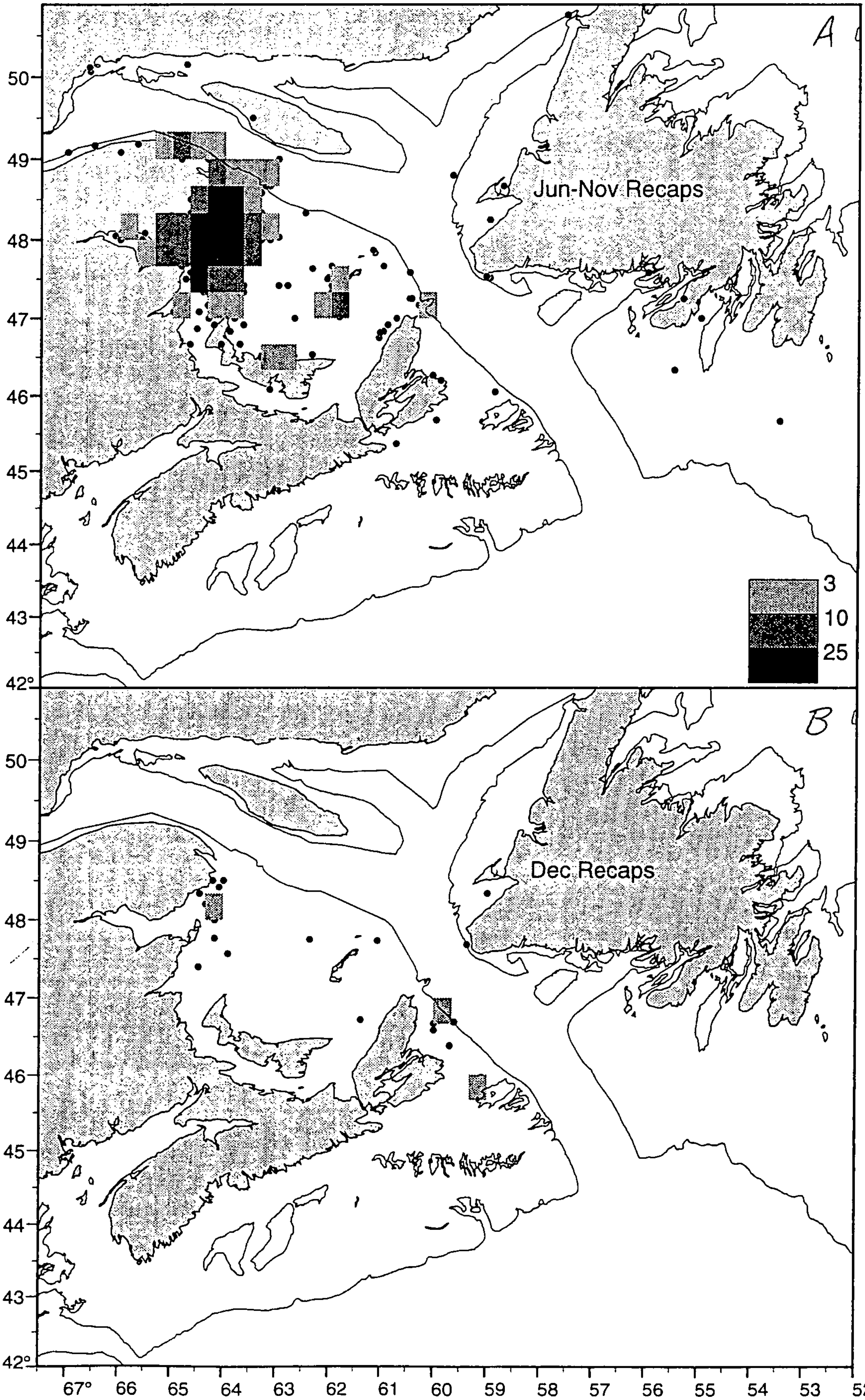


Fig. 18. Seasonal recoveries from cod tagged in the eastern part of Div. 4T. between 1956-58.

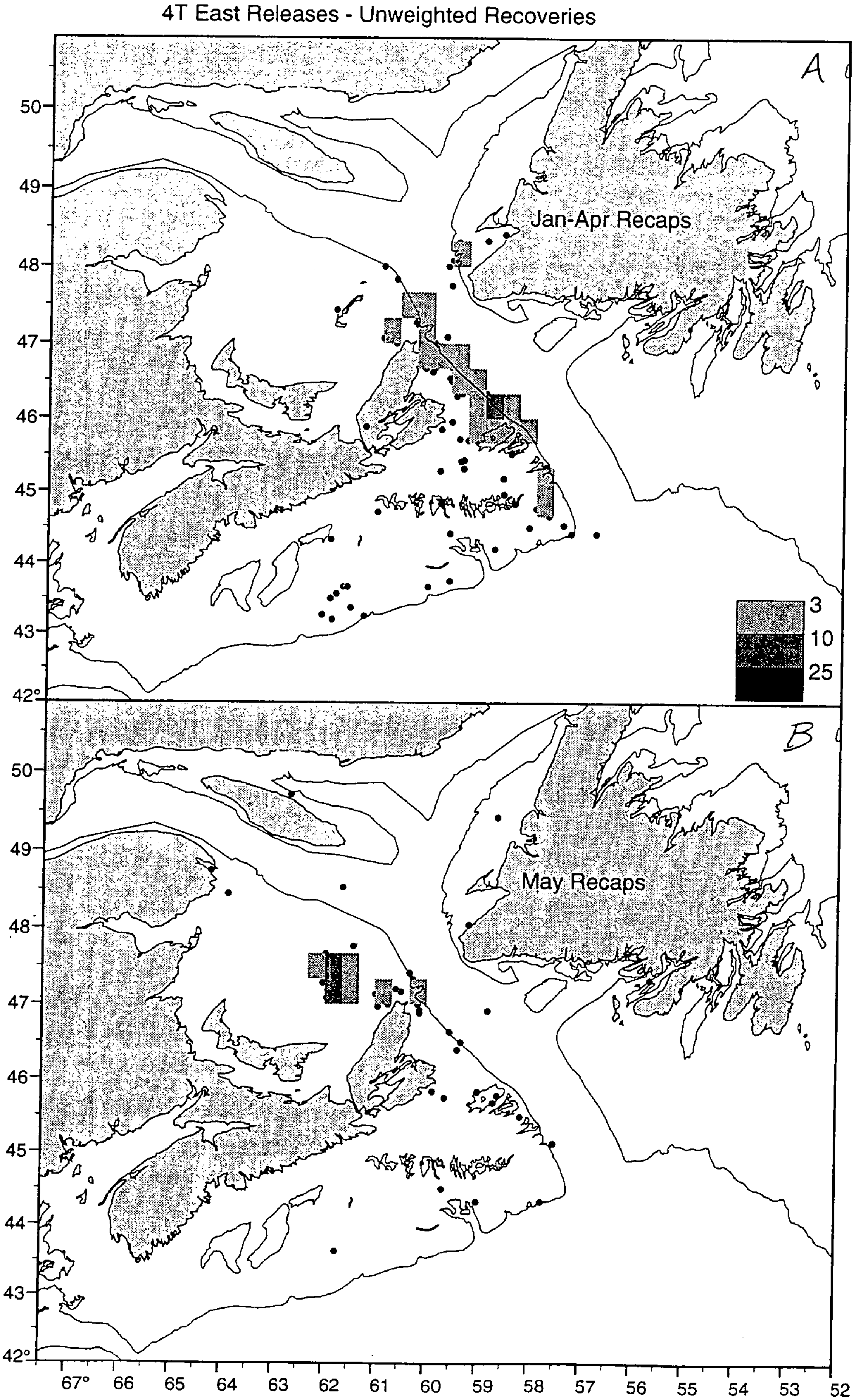


Fig. 19. Seasonal recoveries from cod tagged in the eastern part of Div. 4T. between 1956-58.

4T East Releases - Unweighted Recoveries

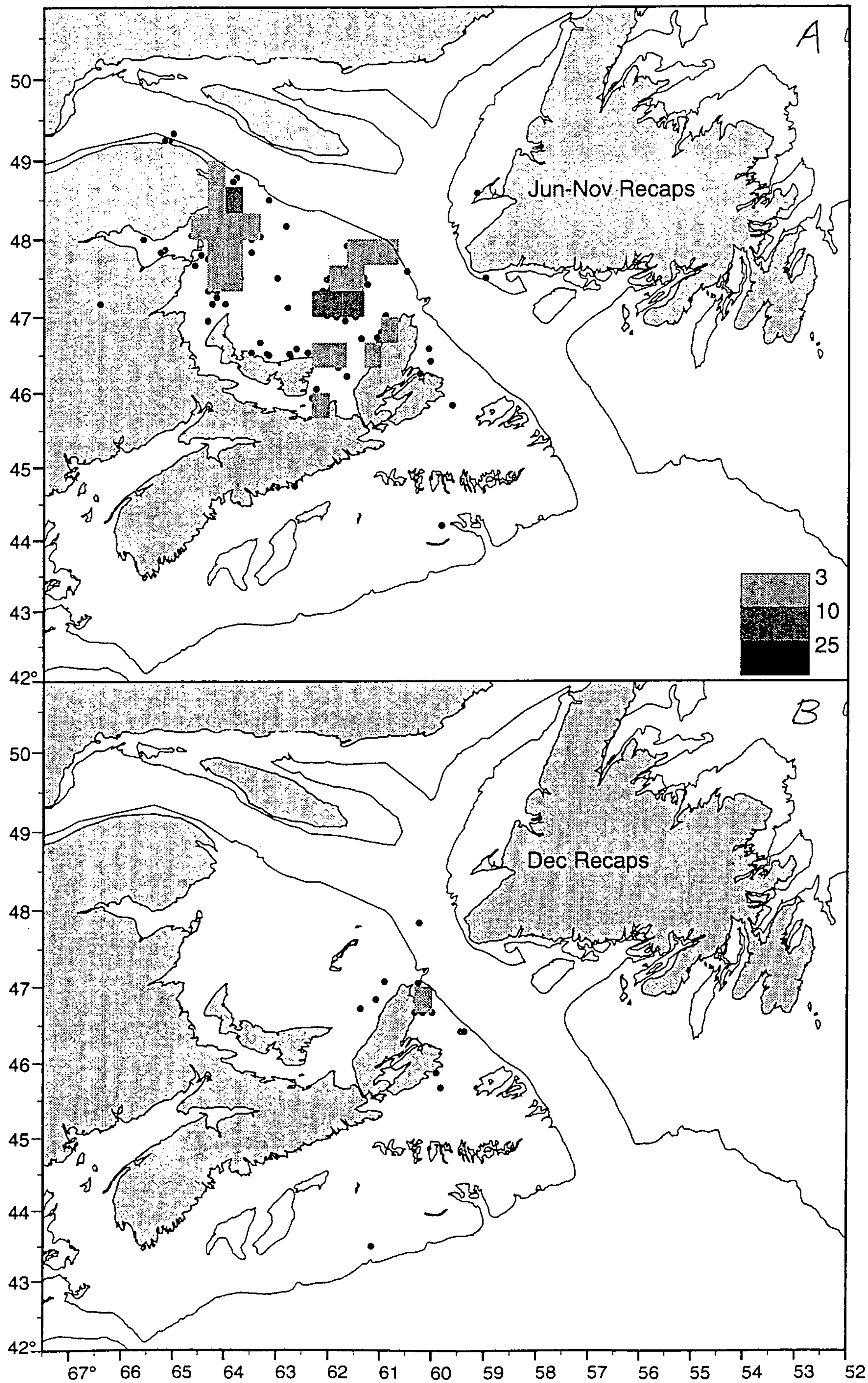


Fig. 20. Seasonal recoveries from cod tagged September, 1979, in the eastern part of Div. 4T.

4T 1979 Releases - January thru April Recoveries

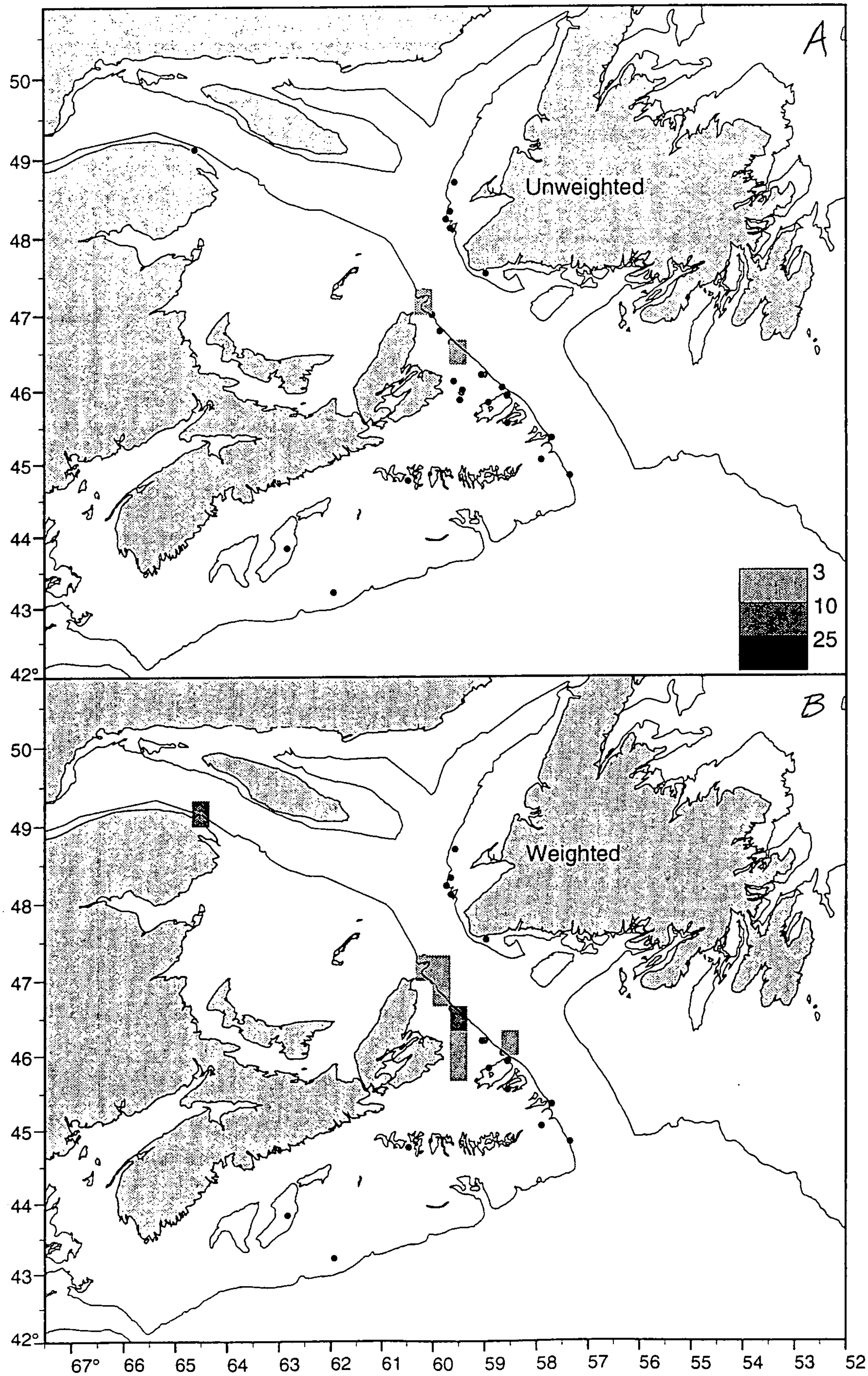


Fig. 22. Seasonal recoveries from cod tagged September, 1979, in the eastern part of Div. 4T.

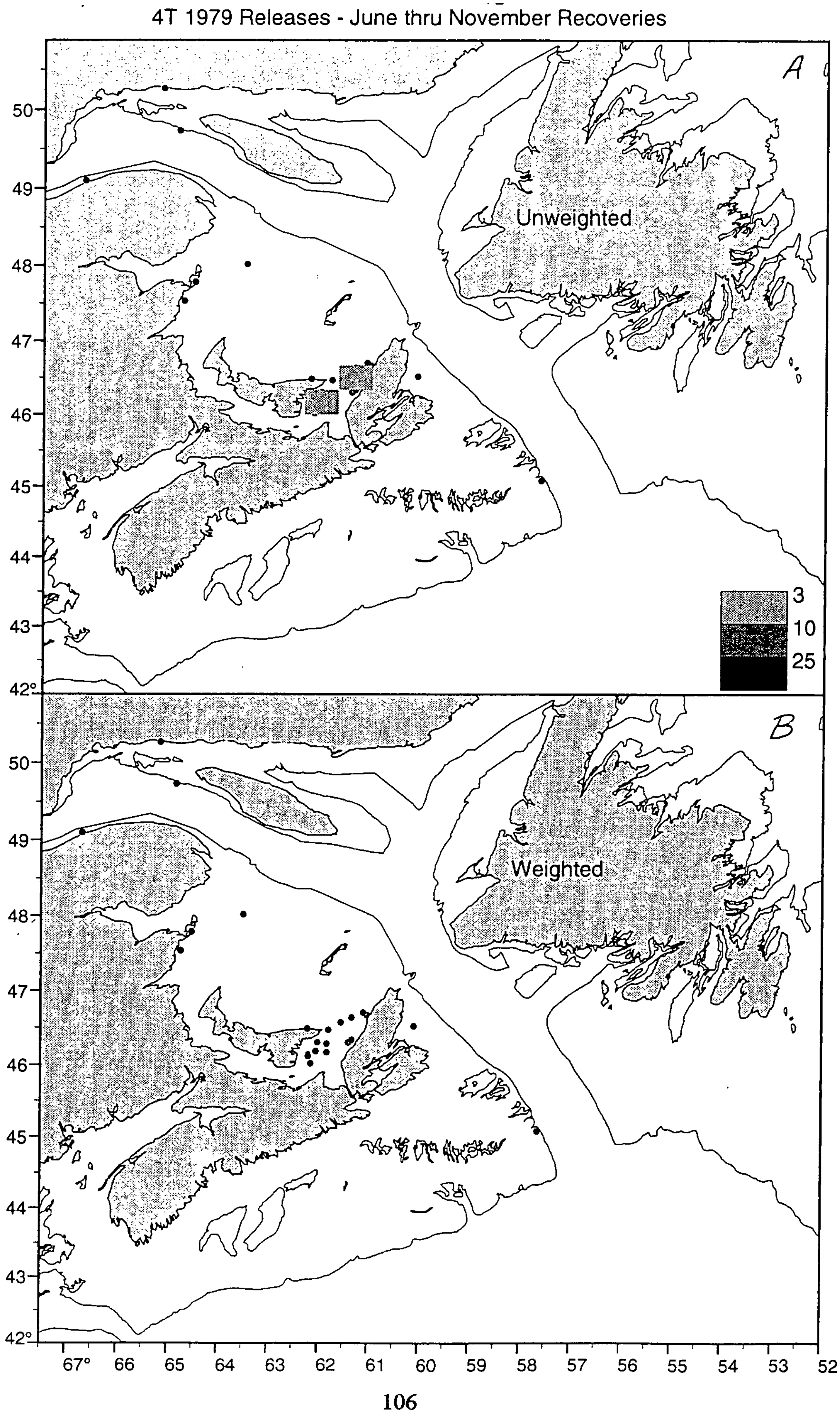


Fig. 25. Seasonal recoveries from cod tagged November-December, 1980, in the eastern part of Div. 4T.

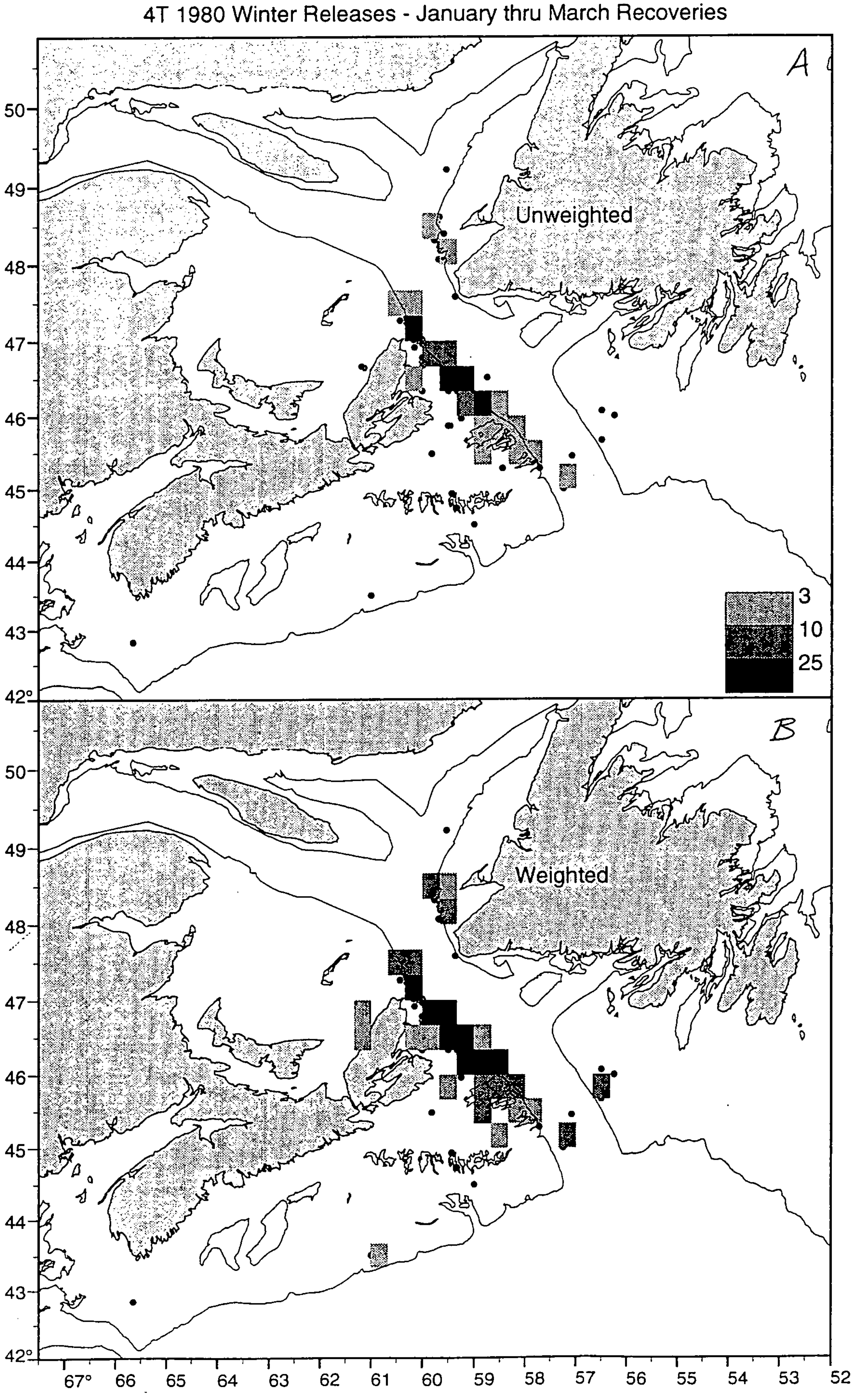


Fig. 27. Seasonal recoveries from cod tagged November-December, 1980, in the eastern part of Div. 4T.

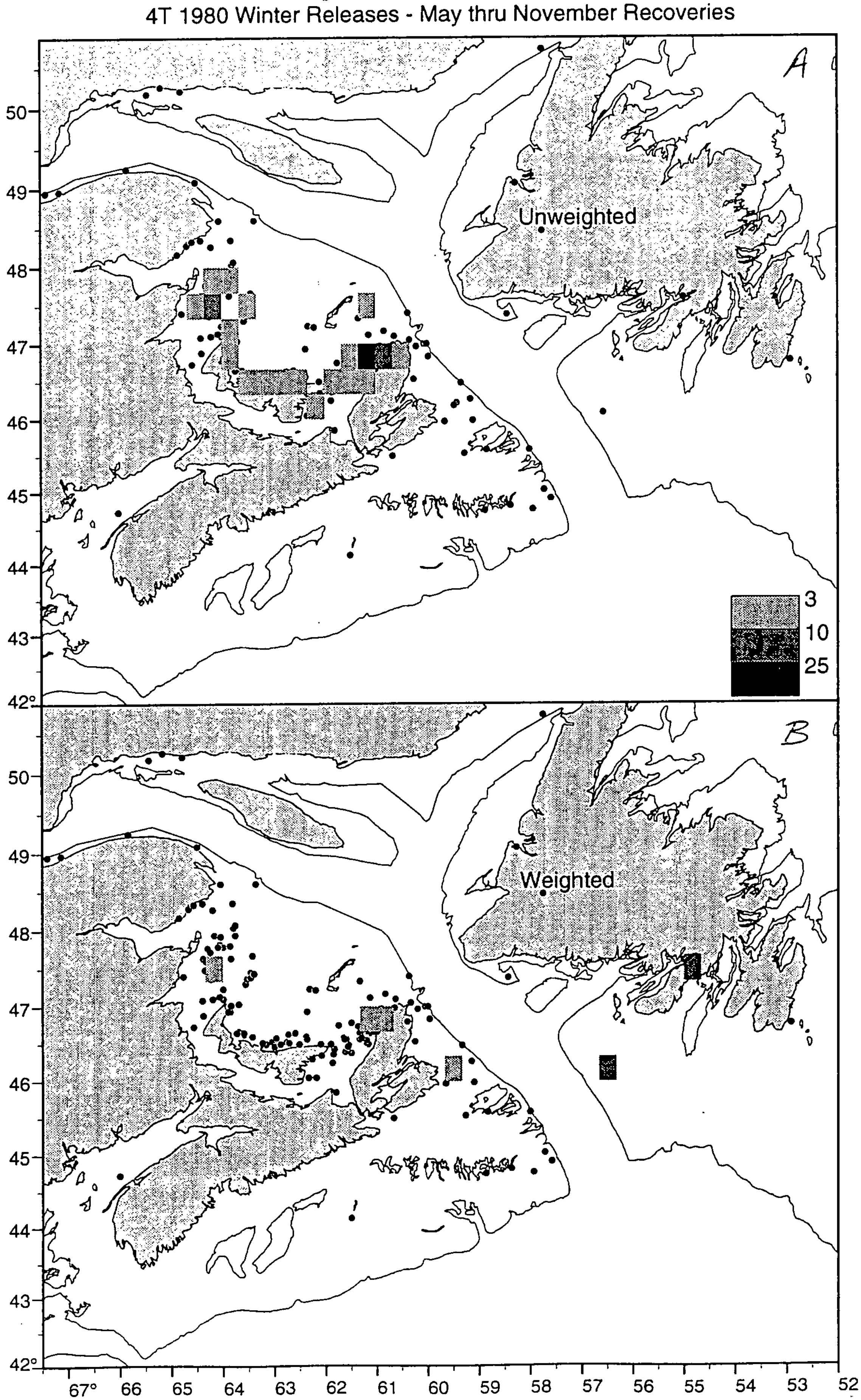


Fig. 29. Seasonal recoveries from cod tagged April-May of 1980 and 1981 in the eastern part of Div. 4T.

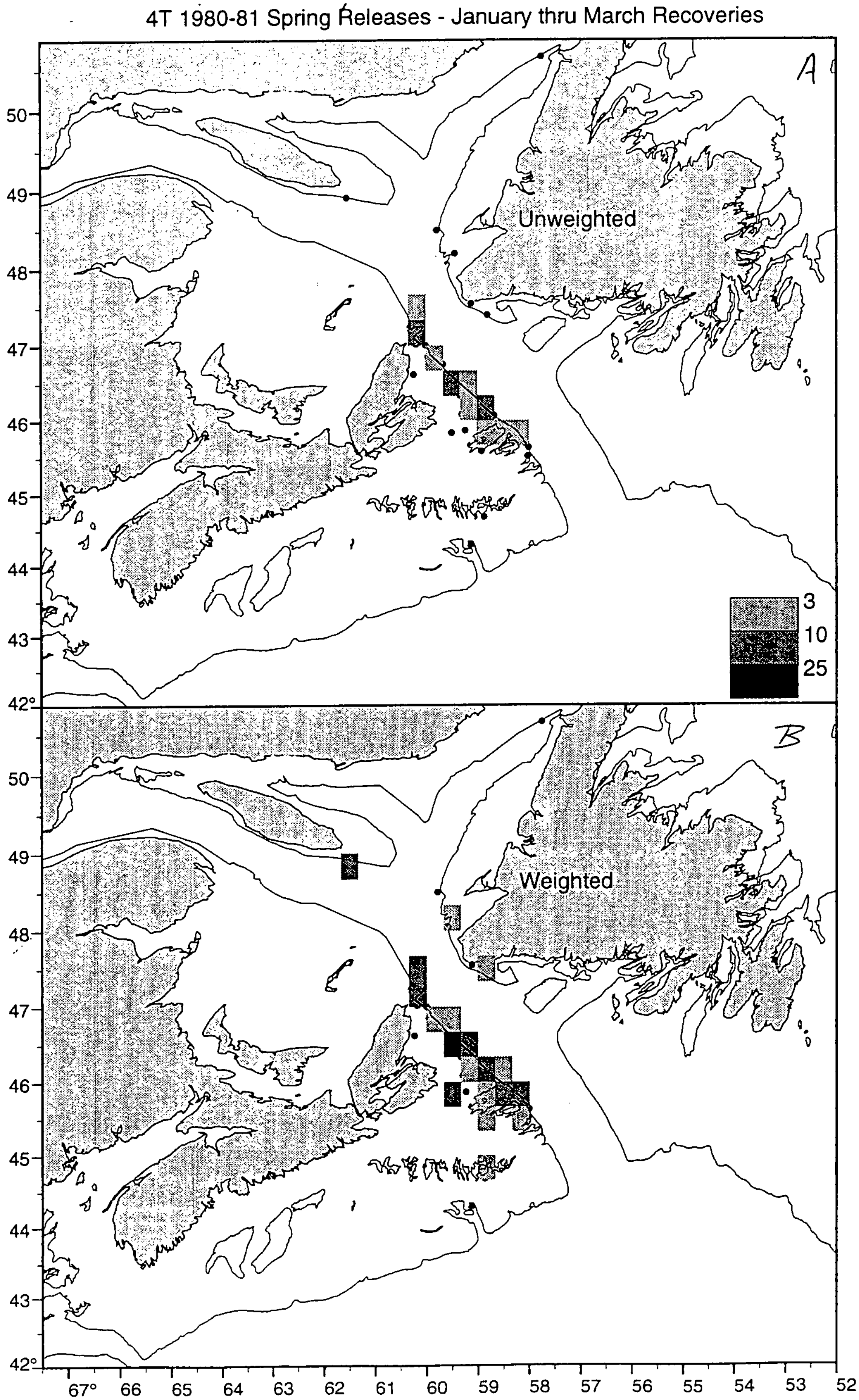


Fig. 31. Seasonal recoveries from cod tagged April-May of 1980 and 1981 in the eastern part of Div. 4T.