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Overview of Atlantic cod (Gadus morhua) stock structure  
in NAFO Subdivision 3Ps inferred from tagging studies

by

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### Abstract

Since the 1930's an extensive series of tagging experiments, involving over 54,000 fish, have been conducted on cod stocks inhabiting various areas off the south coast of Newfoundland. Recaptures of over 13,000 of these cod, primarily by commercial fishermen, has shown that stock structure and migration patterns within this area are extremely complex. Interpretation of the recapture data indicate that attempts to estimate stock size within 3Ps are complicated by a seasonal influx of cod from adjacent managements units, notable the western Gulf stock (3Pn4R) from the west during winter, and possible southern Grand Banks (3LNO) from the south and east during fall. Migration of offshore components of the stock to inshore areas during spring and summer, as well as the possible existence of inshore components that remain outside the survey areas throughout the year, have also complicated the assessment of stock biomass. Tagging studies suggest that several components contribute to commercial catches in 3Ps; these include cod from the western Gulf, Burgeo Bank, southern St. Pierre Bank, southern Grand Banks, and the inshore Avalon-Burin stock complex. The origins of the cod that have contributed to the high catch rates observed during the Sentinel Survey in the last four months of 1995 are not known. Further tagging studies, particularly in Placentia Bay where coverage has been poor, could help elucidate the origins of these fish.

### Résumé

Depuis les années 30, une série complète d'expériences d'étiquetage portant sur 54 000 poissons ont été menées sur les stocks de morue peuplant divers secteurs de la côte sud de Terre-Neuve. La capture une deuxième fois de plus de 13 000 de ces morues, principalement par des pêcheurs commerciaux, a démontré que la structure des stocks et les régimes migratoires dans cette région sont extrêmement complexes. L'interprétation des données de deuxième capture indique que les tentatives d'estimation de la taille des stocks de 3Ps sont compliquées par un apport saisonnier de morue des unités de gestion adjacentes, en particulier le stock de l'ouest du golfe (3Pn4R) qui arrive de l'ouest en hiver, et peut-être le stock du sud des Grands Bancs (3LNO) qui arrive du sud et de l'est en automne. La migration de composantes hauturières du stock vers les eaux côtières au printemps et en été, ainsi que l'existence possible de composantes côtières qui restent à l'extérieur des zones des relevés pendant toute l'année, viennent compliquer davantage l'évaluation de la biomasse du stock. Des études d'étiquetage portent à croire que plusieurs composantes alimentent la pêche commerciale dans 3Ps : morue de l'ouest du golfe, du banc Burgeo, du sud du banc Saint-Pierre, du sud des Grands Bancs et du complexe côtier du stock Avalon-Burin. On ne connaît pas l'origine de la morue qui a contribué aux taux élevés de capture observés lors de la pêche de contrôle effectuée au cours des quatre derniers mois de 1995. D'autres études d'étiquetage pourraient aider à éclaircir l'origine de ces poissons, en particulier dans le cas de la baie de Plaisance où la couverture a été pauvre jusqu'à maintenant.

## Introduction

Management of fish stocks ideally assumes that single or fixed numbers of populations occur in each area, and these do not migrate or intermingle with populations from other areas. However, among cod populations research and commercial fishing practices indicate that extensive migrations and intermixing of cod occurs, particularly among populations off the south coast of Newfoundland and adjacent areas. Since management is based largely on estimates of the biomass and age composition of the stocks within a management unit, ideally seasonal migration patterns, locations of mixing areas, and the extent of mixing should all be known on an annual basis. Otherwise, estimates of biomass and population numbers can be strongly influenced by annual variability in the degree of mixing of stocks that originate from different management units.

The south coast of Newfoundland, excluding the most westerly portion, comprises two management units (3Pn and 3Ps), and stock structure within this broad area is complex and relationships between cod populations within and adjacent to it are not fully understood. However, extensive research employing various stock discrimination techniques such as meristics (Templeman 1981), parasites (Templeman 1963; Templeman et al. 1976; Bratley et al. 1990), fishery statistics and general biology (Pinhorn 1969), and tagging (summarized by Taggart et al. 1996) have provided useful information on stock structure and migration patterns among cod within this area. No detailed genetic analyses of cod stocks off southern Newfoundland has been conducted, but DFO scientists at BIO (S. Campana and colleagues) have recently begun studies to identify the cod stocks of the approaches to the Gulf of St. Lawrence through a combination of otolith elemental analysis, genetics, and meristics; sampling for this study was recently completed (April 1996) but results are not yet available.

The present paper summarizes current knowledge of cod stock structure within 3Ps based largely on tagging studies, but drawing on other sources of information where appropriate.

## Tagging studies

Since the 1930's, approximately 55 tagging experiments have been conducted involving cod from the south coast of Newfoundland and adjacent areas (Table 1). These studies were initiated during 1933-37 (Thompson 1943), 1947-48, 1954-55, 1962-1965 (Templeman and Fleming 1962; Templeman 1974, 1979), and during 1980-89 (Lear 1984, 1988). A detailed summary of all of the post-1954 tagging experiments conducted by DFO in Newfoundland Region up to June 1993, together with a comprehensive bibliography, was recently compiled by Taggart et al. (1995). In addition, over 1000 cod caught in Placentia Bay during the 1996 Sentinel Survey have also been tagged and released and further tagging during the summer and fall of 1996 is planned.

In total, 54,044 cod have been tagged and released during the experiments summarized in Table 1. Of these, 13,942 (25.8%) have been recovered with information on date and location of capture. Several tagging experiments have been conducted in each of the past six decades, but there has been no tagging of cod off the south coast during recent years (since 1989) due in part to the moratorium. Note that although tagging experiments have been initiated in all seasons, most involved tagging of cod during September-October, March, and June-August. There have been relatively few tagging experiments conducted in winter (November-February), or spring (April-May) and most of these have involved offshore taggings.

Tagging experiments relevant to 3Ps have been reasonably well spread out, with studies covering most of the areas where cod are known to aggregate and support commercial fisheries. Maps are provided showing the positions of the DFO statistical fishing unit areas (Fig. 1) which are listed for

each tagging experiment in column 4 of Table 1. The positions of major bays and fishing banks within 3Pn-3Ps are also shown (Fig. 2).

There have been nine tagging experiments involving inshore cod from the eastern and southern Avalon Peninsula which is in NAFO Division 3L (10, 11, 12, 28, 29, 30, 34, 37, and 50 in Table 1). Similarly, St. Pierre Bank has been reasonably well covered with 8 experiments (nos. 3, 4, 9, 24, 44, 45, 46, 48), as has Fortune Bay with 7 experiments (nos. 1, 2, 36, 52-55), Burgeo Bank with 5 experiments (nos. 8, 23, 39, 43, 47), 3PN with 4 experiments (nos. 20, 22, 40, 42), and the northern and western Gulf of St. Lawrence with 13 tagging experiments (nos. 13-15, 17, 18, 25-27, 31-33, 38, 41). Some areas have been poorly covered, notably Placentia Bay with only three experiments (nos. 6, 35, 51), Green Bank with only one experiment (no. 49), and offshore areas of adjacent management units 3L, 3N, and 3O with only one experiment each (nos. 7, 16, and 5, respectively). The large number of experiments listed in Table 1 that involve tagging of cod outside 3Ps but subsequently had >5% of recaptures within 3Ps (29 of 55 experiments) clearly demonstrates the extent to which cod from adjacent management units contribute to the fishery in 3Ps. There have also been several tagging experiments involving cod from 2GH, 3K, 3L, and 3M that did not result in significant recaptures within 3Ps; details of these experiments are summarized elsewhere (Thompson 1943; Templeman and Fleming 1962; Templeman 1974, 1979; Taggart et al. 1996).

Previous studies suggest that there are at least five stocks or stock complexes that contribute to the commercial fishery in various regions of 3Ps. These are as follows:

#### 1. Northern Gulf stock (4R-3Pn cod)

There is evidence based on the timing of landings, biological information (see Pinhorn 1969) and tagging (see Table 1) that the winter fishery off the southwest coast of Newfoundland (3Pn) largely prosecutes migrant fish that spend their summer in the northern Gulf of St. Lawrence (4RS). These fish migrate southward along the west coast of Newfoundland during late fall and overwinter off the southwest coast before migrating back into their spawning and summer feeding grounds off western Newfoundland during early spring. For example, Templeman (1974, 1979) found that many cod tagged during summer and fall in the northern and western Gulf were subsequently recaptured during winter around the southwest coast of Newfoundland in 3Pn (see Fig. 3). Mogueudet (1994) reported similar findings for cod tagged in the western Gulf during 1975 and 1976. Conversely, many cod tagged in 3Pn during winter were subsequently recaptured during the summer in the western and northern Gulf; only a small proportion of returns come from within 3Pn or from more westerly areas (i.e. 3Ps) during summer (Fig. 4.). However, in some years the winter distribution of these migrant fish appears to have extended further west resulting in (i) a considerable portion of the biomass being found in much deeper water than usual, often outside the area normally covered by RV surveys, and (ii) the fish have migrated onto areas such as Burgeo Bank, which is in the adjacent management unit (i.e. 3Ps), thereby complicating attempts to assess the stocks in each unit. In the winter of 1986 over 3000 cod were tagged on Burgeo Bank and many of these were subsequently recaptured in the Gulf indicating that in the winter of 1986 a portion of the 4R-3Pn stock had migrated into 3Ps (Fig. 5). In recent years (1994 onwards), the timing of the 3Ps survey has been delayed until April and additional deep-water strata have been added to the surveyed area. These measures were designed to ensure that cod in deeper water are included in the assessment of 3Ps whereas migrant 4R-3Pn fish are not. The appearance of overwintering fish in the deep water strata of 3Pn and 3Ps was still evident when the April 1995 survey was conducted.

## 2. Burgeo Bank Stock

A separate stock of cod is thought to exist on Burgeo Bank, since spawning concentrations have been observed on Burgeo Bank and the adjacent southwesterly slope after 4R-3Pn cod have migrated back to their spawning and feeding areas off western Newfoundland. According to Pinhorn (1969) peak spawning for Burgeo Bank cod occurs in May, with possibly some spawning in April and June; he also reported that cod on Burgeo Bank were historically larger, matured later, and grew faster than those found in 3Pn. Results from the five tagging studies conducted on Burgeo Bank (see Table 1), all conducted in winter or early spring and several decades apart, suggest that this stock disperses widely along the south coast during late spring, summer, and fall and contributes mainly to inshore fisheries in Fortune Bay, Burin Peninsula, and Placentia Bay (Fig. 5). Some of the tagged fish were also caught in 4R, but as described above it is possible that tagging was conducted while some 4R fish were overwintering on Burgeo Bank.

## 3. Southern St. Pierre Bank

Aggregations of cod have consistently been observed on the Laurentian Channel off the southern end of St. Pierre Bank, as well as adjacent to Halibut Channel, and off southern Green Bank (Fig. 2). These have often been encountered during research vessel surveys and have in the past supported an offshore winter fishery. Tagging of cod in these areas, conducted during the 1930's, 1940's and in 1986 (see Table 1) reveals a complex pattern of migrations with subtle differences in the geographic distribution of tag returns. A portion of the fish tagged toward the Laurentian Channel side of southern St. Pierre Bank appears to migrate northeastward and contributes to the summer inshore fishery in Placentia Bay and the southern Avalon (Fig. 6). Fish tagged on the southeastern slope of St. Pierre Bank appeared to migrate toward 3NO and the central Grand Bank, with some returns from inshore areas of the southern Avalon, but few returns from Placentia Bay or other inshore areas of 3Ps (Fig. 7). Similarly, cod tagged off southern Green Bank appeared to move mostly eastward and were recaptured mainly during summer fisheries in 3NO and southern 3L, although a few tags were recovered from inshore areas on the south coast and off the southern Avalon (Fig. 8). These findings suggests that only a small proportion of the cod that overwinter offshore in the southernmost reaches of St. Pierre Bank and adjacent to Halibut Channel contribute to the inshore fishery on the more easterly side of the south coast, including Placentia Bay and the southern Avalon in 3L. Tagging of inshore cod at various locations along the eastern side of the south coast support these conclusions; some inshore taggings have resulted in a small number of winter recoveries from southern St. Pierre Bank and adjacent areas (Fig. 9).

## 4. Avalon-Burin stock complex

Cod that spawn on the northern parts of St. Pierre Bank appear to undergo seasonal migratory patterns distinct from those that overwinter and spawn in offshore areas near the southern part of St. Pierre Bank. According to Templeman (1962, cited in Pinhorn 1969) peak spawning time for the northern St. Pierre Bank fish is late May and early June. The northerly St. Pierre Bank fish appear to remain on St. Pierre Bank or migrate northward toward the inshore and disperse widely across the south coast during late spring, summer and fall, contributing to the inshore fisheries as far east as the Avalon Peninsula (Fig. 10). Similarly, tagging of coastal cod of the Burin Peninsula (Fig. 9), the Avalon Peninsula, and from the northwestern slope of the Grand Bank (see Taggart et al. 1995) suggests that these mix all along the central and eastern regions of the south coast during the late spring, summer, and fall. These collectively form a group which Templeman (1974) referred to as the Avalon-Burin stock complex, although he also included southern St. Pierre Bank fish as part of this stock. Other

components of this group include the local stocks of St. Mary's Bay and Placentia Bay; the existence of local stocks remains a contentious issue although spawning cod have been observed in these bays during the Sentinel Survey and in previous years (see Hutchings et al. 1990). Unfortunately, much of the information from recaptures is on too broad a scale (30 nm) to provide much insight into the migration patterns and precise overwintering areas of local stocks. Further delineation of this stock complex is clearly needed.

## 5. 3LNO cod

There have been too few tagging experiments to determine whether offshore cod that overwinter in 3NO or southern 3L contribute to any great extent to the fisheries in 3Ps; the experiments that involved tagging of cod from these areas were conducted prior to 1956 and had a low percentage of tags returned (Fig. 6). However, some of these cod were recaptured in Placentia Bay and there has been some speculation that the fish which migrate up the eastern side of Placentia Bay during fall may originate from this area. Cod from 3NO are characterized by high growth rates and low parasite burdens and further analysis of samples from these fish should be conducted to investigate this possibility.

### Current situation

Our recent RV surveys indicate that the portion of the stock surveyed by our vessels is not in good shape with a relatively low spawning stock biomass. However, these findings appear to contrast with reports from the Sentinel Survey which indicate good catches of large fish in many communities along the south coast. These contrasting findings raise the issue of which stock components are presently being exploited by the Sentinel Survey. Tagging data indicate that cod from overwintering aggregations such as those on Burgeo Bank and St. Pierre Bank are quantified by RV surveys. A portion of these cod subsequently migrate inshore and contribute to inshore spring, summer, and fall fisheries along the south coast. However, there may be other inshore stocks that reside outside the surveyed area throughout the year that also contribute to inshore fisheries but whose biomass remains unknown. It appears that the most likely source of these fish is the Avalon-Burin stock complex, which includes the local stocks of St. Mary's Bay and Placentia Bay whose migration patterns and spawning and overwintering areas are poorly known. Similarly, the origin of the fish that contribute to the fishery on the east side of Placentia Bay during fall remains unknown although, as described above, there is speculation that these fish migrate shoreward from 3NO or possible southern 3L. More detailed tagging studies on inshore stocks is clearly needed to investigate these possibilities. Comparison of inshore catch rates over time in conjunction with knowledge of migration patterns could provide an alternative source of information on the status of these inshore components of the stock complex.

### Acknowledgements

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## References

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**Table 1. Chronological summary of tagging experiments involving cod (*Gadus morhua*) from NAFO subdivision 3Ps (i.e. cod were tagged in 3Ps, or >5% of those tagged elsewhere were recovered within 3Ps).**

	Year	Months	DFO Stat. Area <sup>1</sup>	Location	Number Tagged	Total recaptured (all areas)		Ref.
						No.	(%)	
1	34	July	3PSb	Fortune	486	122	25.1	1
2	35	Jun.-July	3PSb	Fortune	1413	205	14.5	1
3	35	July	3PSg	Central St. Pierre Bank	647	40	6.2	1
4	47	June	3PSg	S. St. Pierre Bank	115	4	3.5	2
5	47	May	3Od	SW Grand Bank	80	4	5.0	2
6	48	June-July	3PSc	Corbin/Burin, Plac. Bay	804	321	39.9	2
7	48	June	3Ls	NW Grand Bank	216	7	3.2	2
8	54	May-June	3PSa	Burgeo Bank	1361	418	30.7	3
9	54	May-June	3PSe	Central St. Pierre Bank	1362	362	26.6	3
10	54	Oct.	3Lq	Cape Pine	1364	397	29.1	3
11	54	Oct.	3Lq	Cape St. Mary's	1356	448	33.0	3
12	54	Nov.	3Lj	Cape Ballard Bank	2728	819	30.0	3
13	55	July	4Ra	Forteau	1124	285	25.4	3
14	55	Sept.	4Ra	Port Aux Choix	1122	290	25.8	3
15	55	Sept.-Oct.	4Ra	Flowers Cove	1122	240	21.4	3
16	55	Sept.	3Nc	S.E. Shoal	496	64	12.9	3
17	62	Sept.-Oct.	4Ra	Center Bank	768	333	43.4	4
18	62	Oct.	4Sv	Cape Whittle Bank	768	166	21.6	4
19	63	Jan.	3PSh	Western Gully	736	140	19.0	4
20	63	March	3PN	Port Aux Basques	1536	585	32.1	4
21	63	Mar.-Apr.	3PSa	Penguin Islands	1152	557	48.4	4
22	63	Mar.	3PN	Off Rose Blanche	768	295	38.4	4
23	63	Mar.-Apr.	3PSa	Burgeo Bank	1152	511	44.4	4
24	63	May	3PSe	Central St. Pierre Bank	1152	345	29.9	4
25	63	Sept.	4Sx	Baie Johan Beetz, PQ	384	102	26.6	4
26	63	Sept.	4Sw	La Tabatiere, PQ	1152	382	33.2	4
27	63	Sept.-Oct.	4Sw	St. Pauls, PQ	1152	463	40.2	4
28	63	Oct.	3Lj	Off Fermuse	1152	620	53.8	4
29	63	Oct.	3Lj	Ballard Bank	1152	561	48.7	4
30	63	Nov.-Dec.	3Lq	Cape Pine	1152	569	49.4	4
31	64	Aug.-Sept.	4Ra	Port aux Choix	768	331	43.1	4
32	64	Sept.-Oct.	4Sy	Harve St. Pierre, PQ	384	105	27.3	4
33	64	Oct.	4Sz	Seven Islands, PQ	1152	396	34.4	4
34	65	Sept.	3Lq	Off Point Lance	1152	566	49.1	4
35	65	Sept.-Oct.	3PSc	Mortier Bank	384	202	52.6	4
36	65	Oct.-Nov.	3PSb	Off Fortune	384	166	43.2	4
37	65	Nov.-Dec.	3Lj	Off Cape Spear	1152	515	44.7	4
38	75	Feb.	4Rc	E. Gulf of St. Lawrence	465	30	6.5	5
39	75	Feb.	3Ps	Burgeo Bank	199	5	2.5	5
40	75	Feb.	3PN	Rose Blanche Bank	206	14	6.8	5

Cont'd.-



Table 1. Cont'd.

Year	Months	DFO Stat. Area <sup>1</sup>	Location	Number Tagged	Total recaptured (all areas)		Ref.	
					No.	(%)		
41	76	Jan.	4Rb	NE. Gulf of St. Lawrence	1496	203	13.6	5
42	76	Mar.	3PN	Rose Blanche Bank	1462	152	10.4	5
43	76	Mar.	3Ps	Burgeo Bank	35	1	2.9	5
44	80	Feb.	3PSb	NW. St. Pierre Bank	2173	204	9.4	6
45	80	Oct.	3Ps	W. St. Pierre Bank	958	45	4.7	5
46	82	Oct.	3Ps	W. St. Pierre Bank	1492	65	4.4	5
47	86	Mar.	3PSa	Burgeo Bank	3190	372	11.7	6
48	86	Mar.	3PSh	S.St.Pierre Bank	1923	70	3.6	6
49	86	Mar.	3PSh	S.Green Bank	1341	105	7.8	6
50	86	Sept.-Oct.	3Lq	Pt. Lance, St. Mary's Bay	1438	292	20.3	7
51	86	Sept.	3PSc	St. Bride's, P. Bay	160	37	23.1	7
52	88	Aug.-Sept.	3PSb,3PSc	Dantzic Pt. Fortune Bay	698	148	21.3	7
53	88	Aug.-Sept.	3PSb	Brunette Is., Fortune Bay	421	90	21.4	7
54	88	Aug.-Sept.	3PSb	Brunette Bk, Fortune Bay	122	10	8.2	7
55	89	Aug.-Sept.	3PSb,3PSc	Dantzic Pt., Fortune Bay	917	163	17.8	7
Totals					54,044	13,942	25.8	

<sup>1</sup>See Fig. 1.

- Refs:
1. Thompson (1943).
  2. Templeman and Fleming (1962).
  3. Templeman (1974).
  4. Templeman (1979).
  5. Moguedet (1994).
  6. Lear (MS 1984, MS 1988).
  7. H. Lear and C. A. Bishop unpubl., summarized in Taggart et al. (1995).

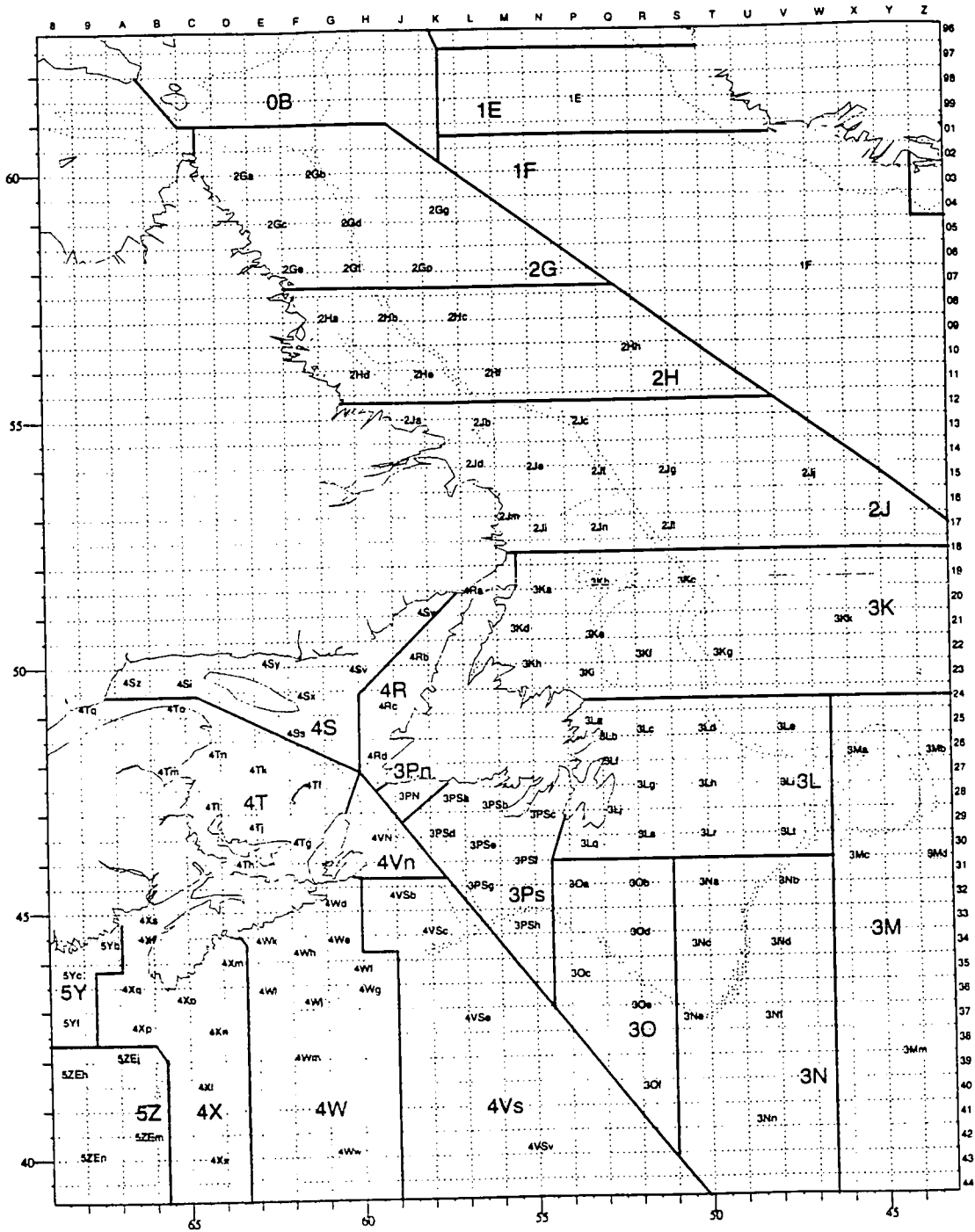


Fig. 1. Eastern Canada showing boundaries of NAFO Subdivisions and centroids of the DFO Statistical Fishing Unit Areas.

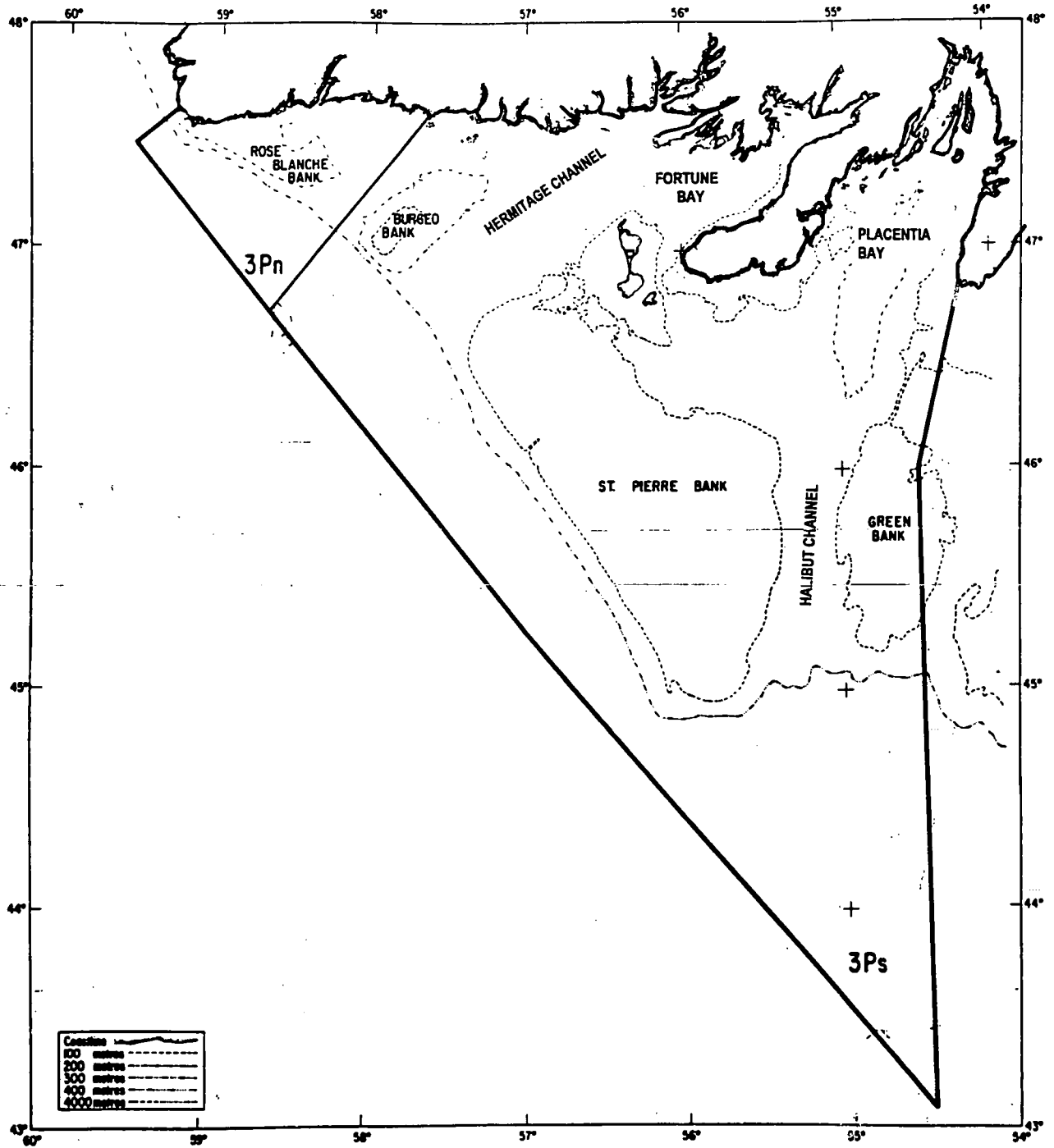


Fig. 2. Southern Newfoundland showing major bays and fishing banks in relation to boundaries of NAFO Divisions 3L, 3O, 4R, and subdivisions 3Pn and 3Ps.

# Exp. No. 6209, Tagging: Oct 23 To Oct 26, 1962, (CAPE WHITTLE BANK)

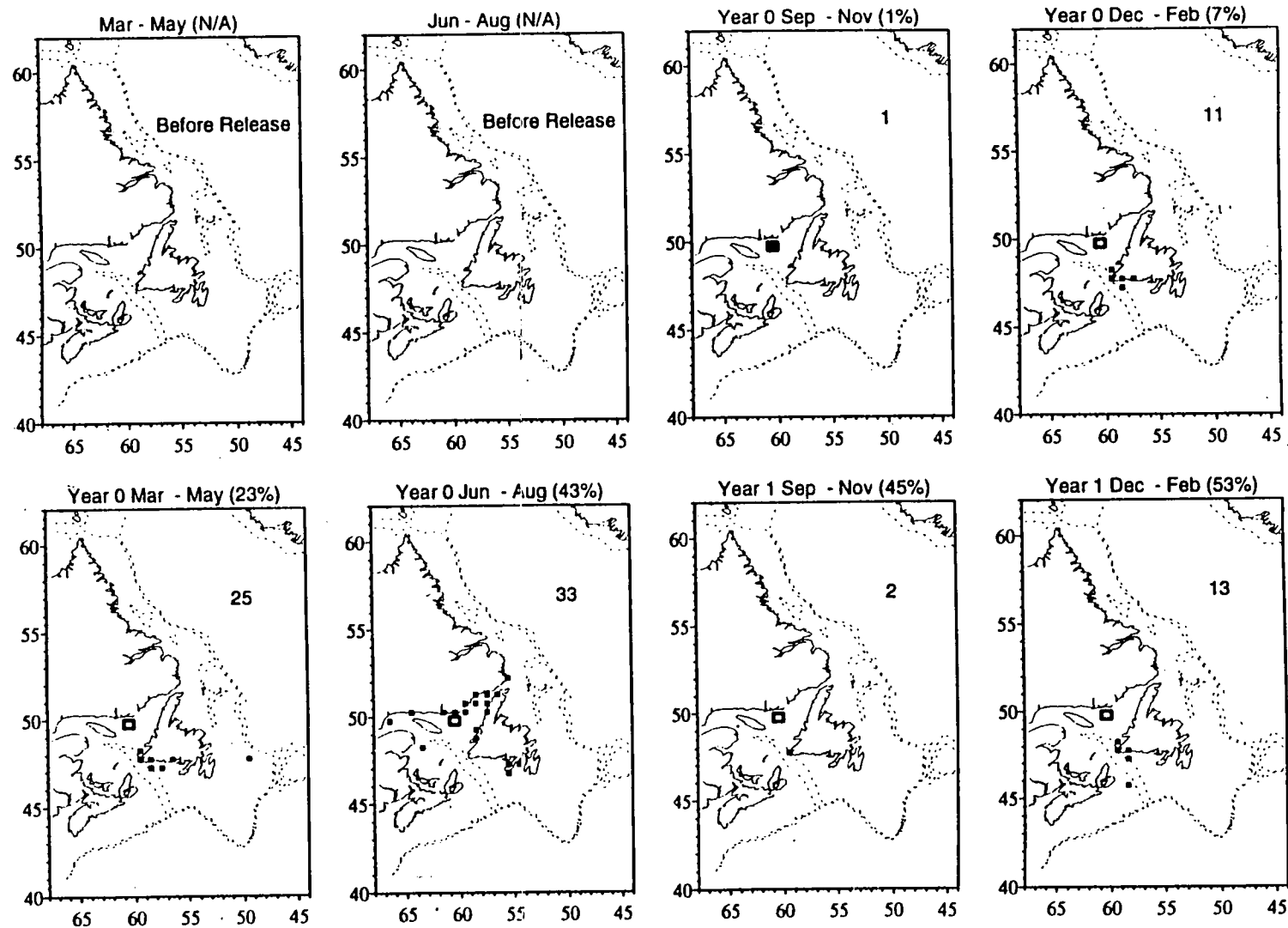


Fig. 3. (reproduced with permission from Taggart et al. 1995).

Exp. No. 6302, Tagging: Mar 14 To Mar 26, 1963, (PORT AUX BASQUES)

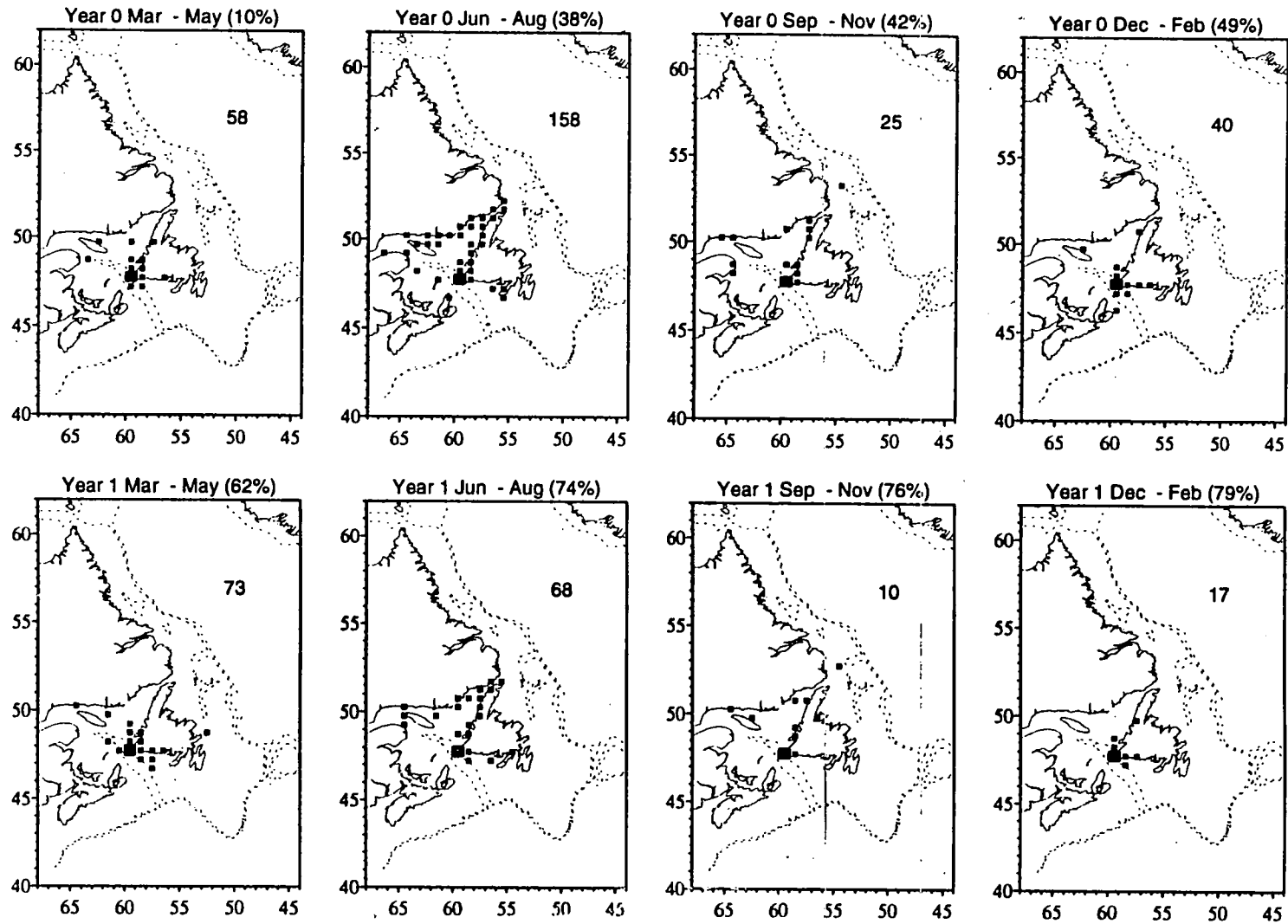


Fig. 4. (reproduced with permission from Taggart et al. 1995)

Exp. No. 8601, Tagging: Mar 13 to Mar 17, 1986, (BURGEO BANK)

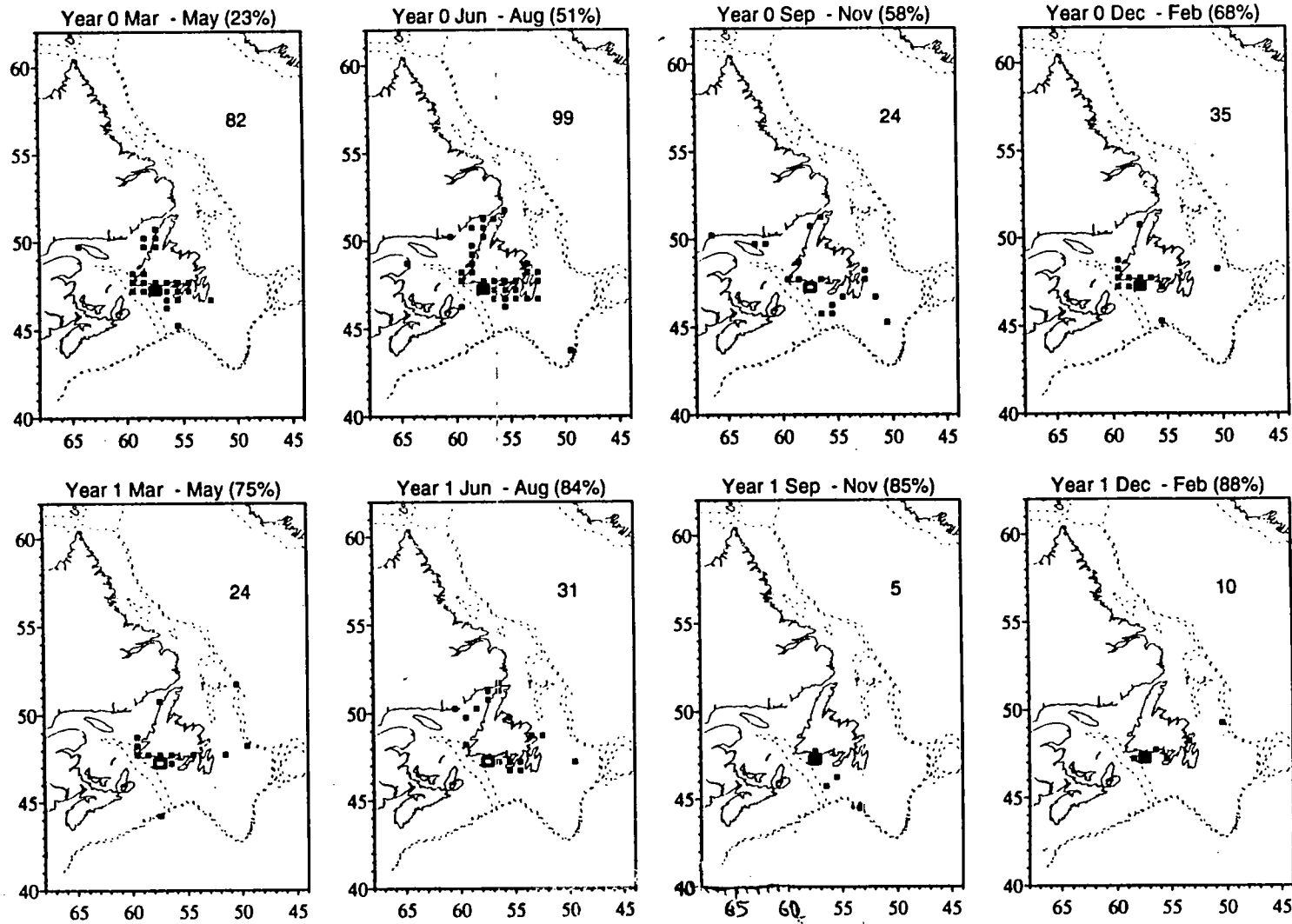


Fig. 5. (reproduced with permission from Taggart et al. 1995).

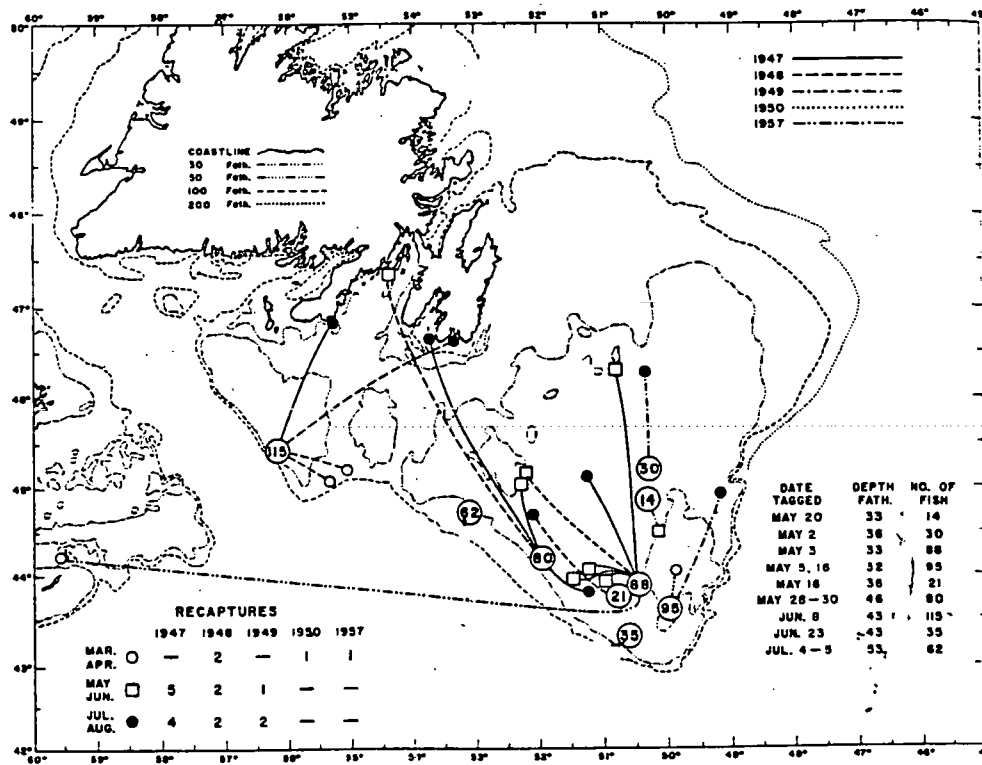


Fig 6. (From Templeman and Fleming 1962).

# Exp. No. 86b2 Tagging: Mar 18 To Mar 21, 1986, (S ST. PIERRE BANK)

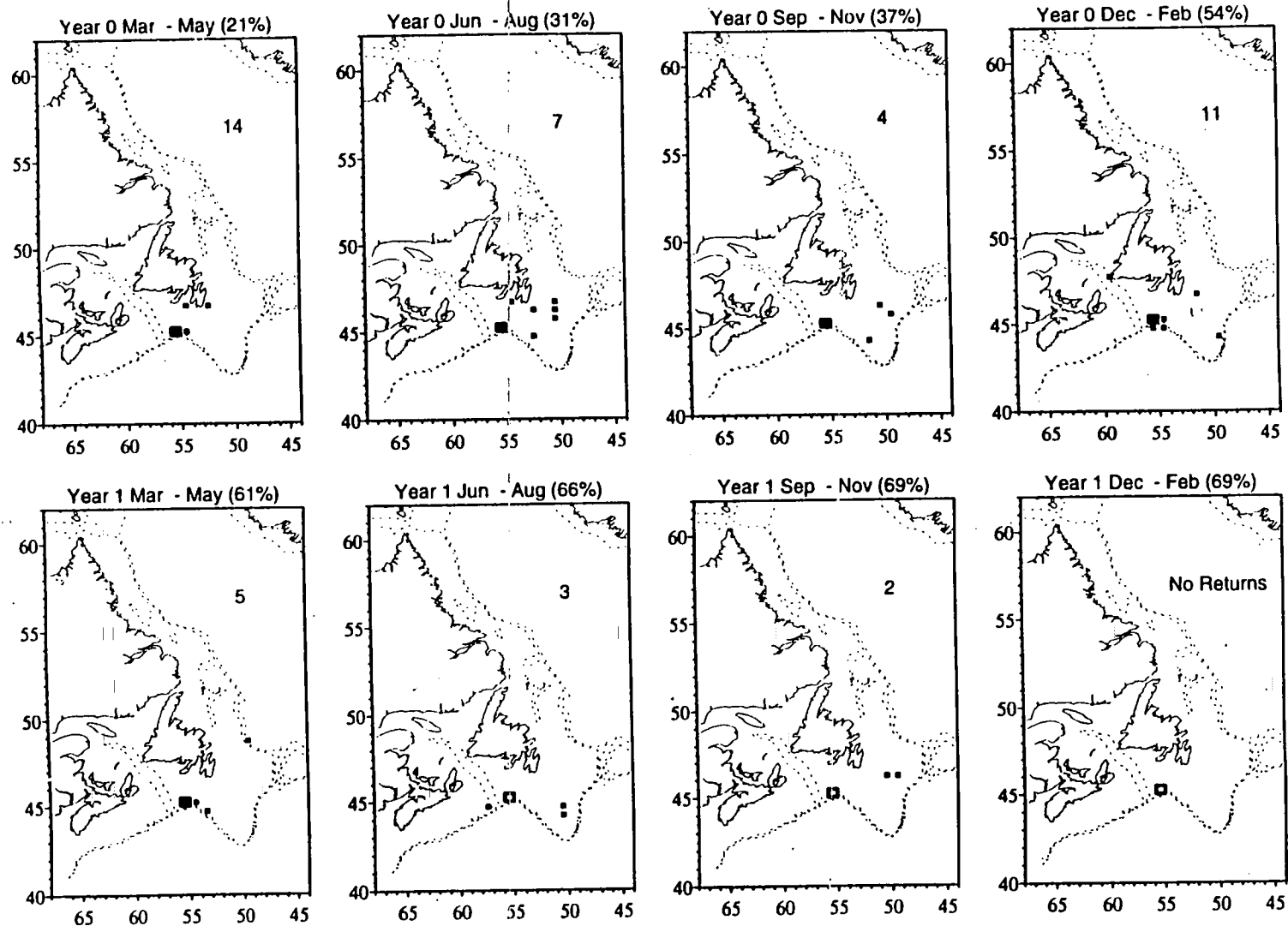


Fig. 7. (reproduced with permission from Taggart et al. 1995).



# Exp. No. 8603, Tagging: Mar 21 To Mar 23, 1986, (S GREEN BANK)

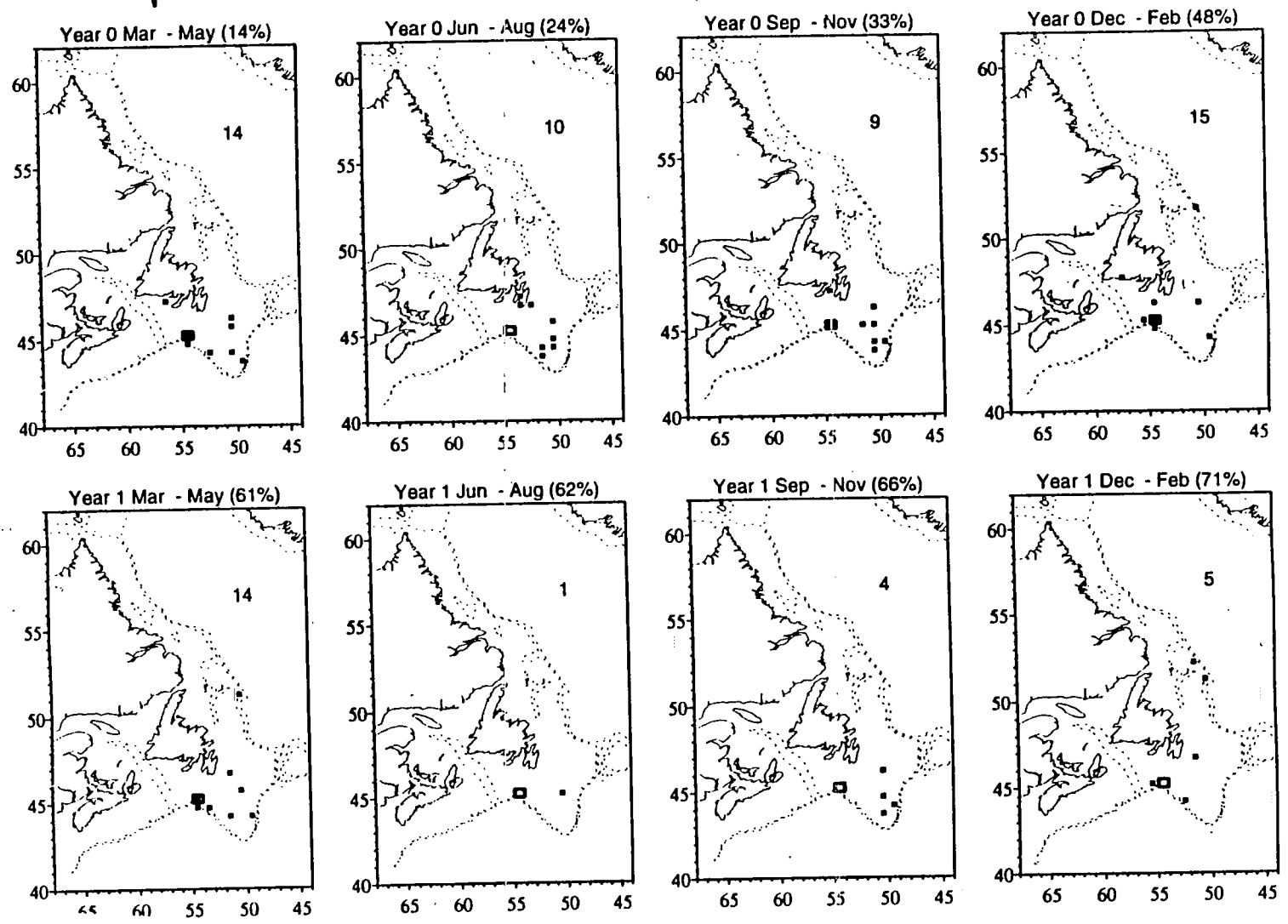


Fig. 8. (reproduced with permission from Taggart et al. 1995).

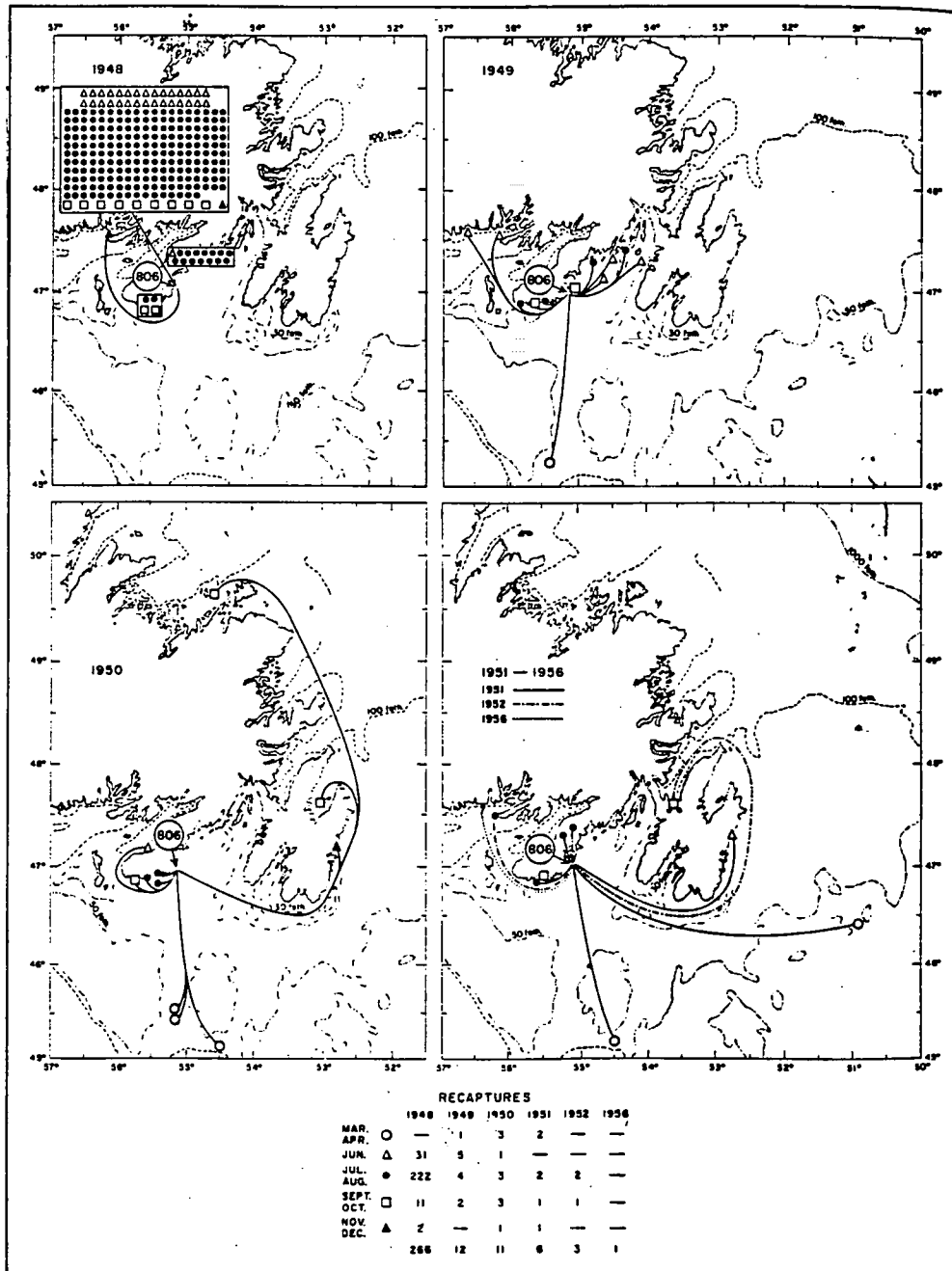


Fig 9. (From Templeman and Fleming 1962).

Exp. No. 8001, Tagging: Feb 10 To Feb 24, 1980, (NORTHERN ST. PIERRE BANK)

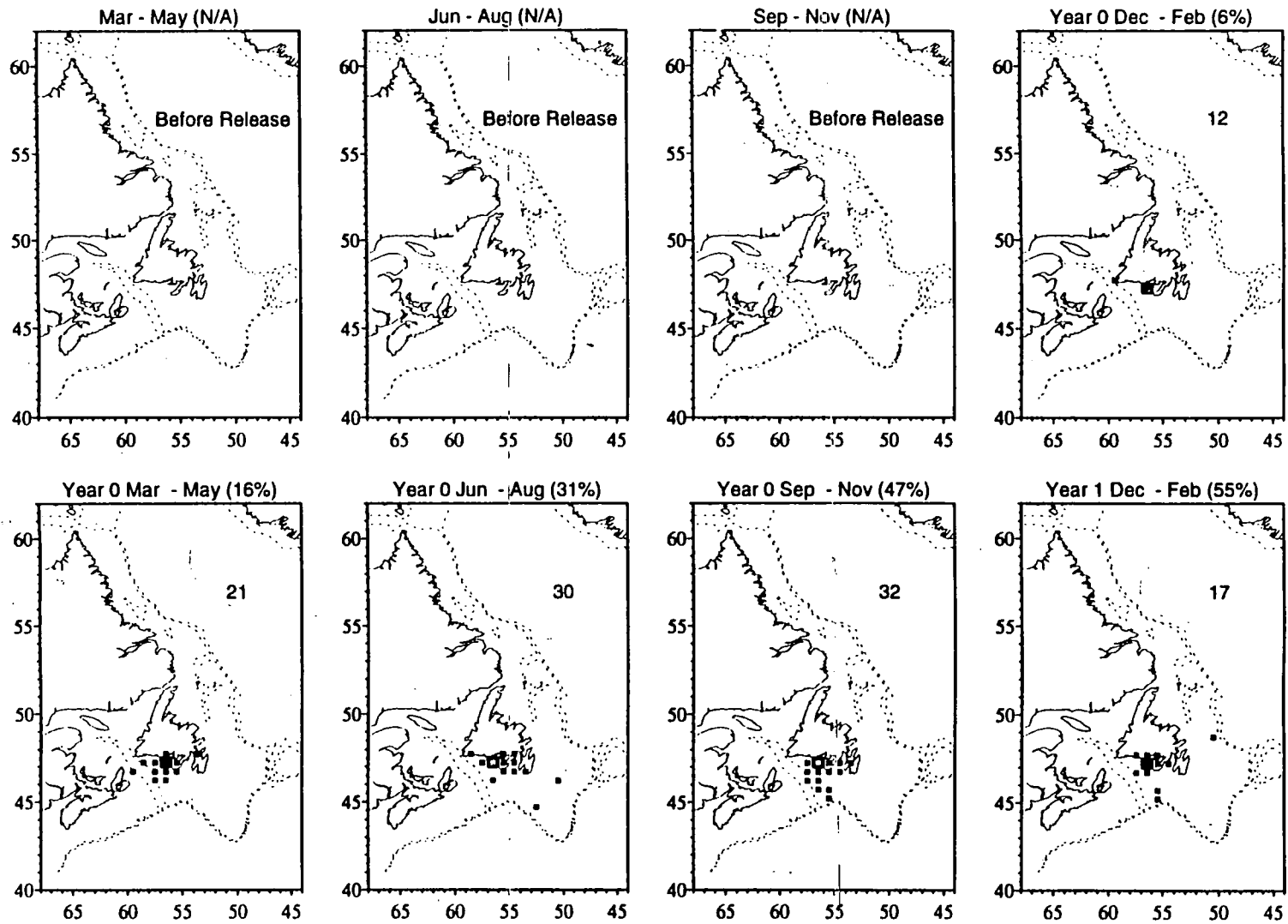


Fig. 10. (reproduced with permission from Taggart et al. 1995).