

Discrimination of the Stock Complex of Atlantic Cod (*Gadus morhua*) off Southern Labrador and Eastern Newfoundland, as Inferred from Tagging Studies

W. H. Lear

Fisheries Research Branch, Department of Fisheries and Oceans
Northwest Atlantic Fisheries Centre, P. O. Box 5667
St. John's, Newfoundland, Canada A1C 5X1

Abstract

During February-March 1978-81, about 25,000 Atlantic cod (≥ 45 cm) were tagged from the prespawning concentrations on Hamilton Bank, Belle Isle Bank, Funk Island Bank and northern Grand Bank. There is evidence of a consistent annual pattern of migration to inshore waters during summer and to offshore areas during winter for each group of cod tagged along the outer continental shelf. The Hamilton Bank component evidently contributes to the southern Labrador and northeast Newfoundland coastal fisheries mainly from Notre Dame Bay northward. The Belle Isle Bank component migrates during summer mainly to southern Labrador, Strait of Belle Isle entrance and northeastern Newfoundland as far south as Notre Dame Bay. The pattern of movement is similar to that of the Hamilton Bank component except for a greater proportion in the Strait of Belle Isle. Cod on the northern and northeastern slopes of Funk Island Bank migrate during summer to eastern and southeastern Newfoundland, with smaller proportions going to southern Labrador and the Strait of Belle Isle than from the taggings on Belle Isle Bank. Cod from the southwestern slope of Funk Island Bank contribute mainly to the summer inshore fishery of Notre Dame Bay and Bonavista Bay and in a smaller degree to the fishery in Trinity Bay, Conception Bay and the eastern part of the Avalon Peninsula. Cod which overwinter on northern Grand Bank migrate southwards across the bank to the Virgin Rocks and to the eastern slope of the bank. This component contributes mainly to the inshore fishery from Trinity Bay southward to St. Mary's Bay, with little effect on the fishery north of Cape Bonavista.

The evidence from tagging on winter concentrations is that each component contributes to the inshore fishery in specific, although wide, overlapping areas. Excessive exploitation of any one component of the stock complex could have adverse effects on the inshore fishery in the areas frequented by the summer migrants. It is desirable, therefore that the offshore fishery in winter should be managed so that the inshore fishery in summer and autumn would not be affected detrimentally by excessive exploitation of a particular component of the stock complex in Div. 2J, 3K and 3L.

Introduction

The cod populations off southern Labrador and eastern Newfoundland have been managed as a single stock complex since the implementation of total allowable catches in 1973 (ICNAF, 1972). There is a cline from north to south in such biological parameters as growth (May *et al.*, 1965), fecundity (May, 1967), vertebral numbers (Templeman, 1981), and age and size at maturity (Fleming, 1960). At the same time, however, tagging studies have confirmed that there is clear indication of localization of tag recoveries in coastal waters of Labrador and Newfoundland from cod tagged at specific inshore and offshore localities (Templeman, 1979).

May (MS 1966) hypothesized that the cod stock complex was composed of at least three major groups, the distributions of which overlap in summer and tend to be separate in winter. These are as follows:

1. The "Labrador-Newfoundland" stock, which spawns mainly on Hamilton Bank and possibly to a small extent on the Northeast Newfoundland Shelf and is distributed in summer along the coasts of Labrador and northeastern Newfoundland.

2. The "Northeast Newfoundland" stock, which spawns mainly on Hamilton Bank but also on the Northeast Newfoundland Shelf. Its distribution in summer extends only along northeastern and eastern Newfoundland. Alternately, two stocks may be involved, one spawning on Hamilton Bank and the other on the Northeast Newfoundland Shelf.
3. "East Newfoundland" stock which spawns on the northern Grand Bank and is distributed in summer mainly along eastern Newfoundland but may extend to northeastern Newfoundland.

Templeman (1962, 1966, 1974, 1979, 1981) and May (MS 1966) suggested that there is some evidence of smaller local stocks which are associated with shelf areas such as those off Baccalieu Island, Cape Bonavista, Fogo Island, Cape St. John, and Grey Islands to St. Anthony. Templeman (1979), from the results of taggings in 1962-66, reported that there was considerable homing of local populations of cod to original inshore tagging locations along the coast from Avalon Peninsula to northern Labrador. Either the fish remained in those coastal areas throughout the year or they actually "homed" to the areas to which they had

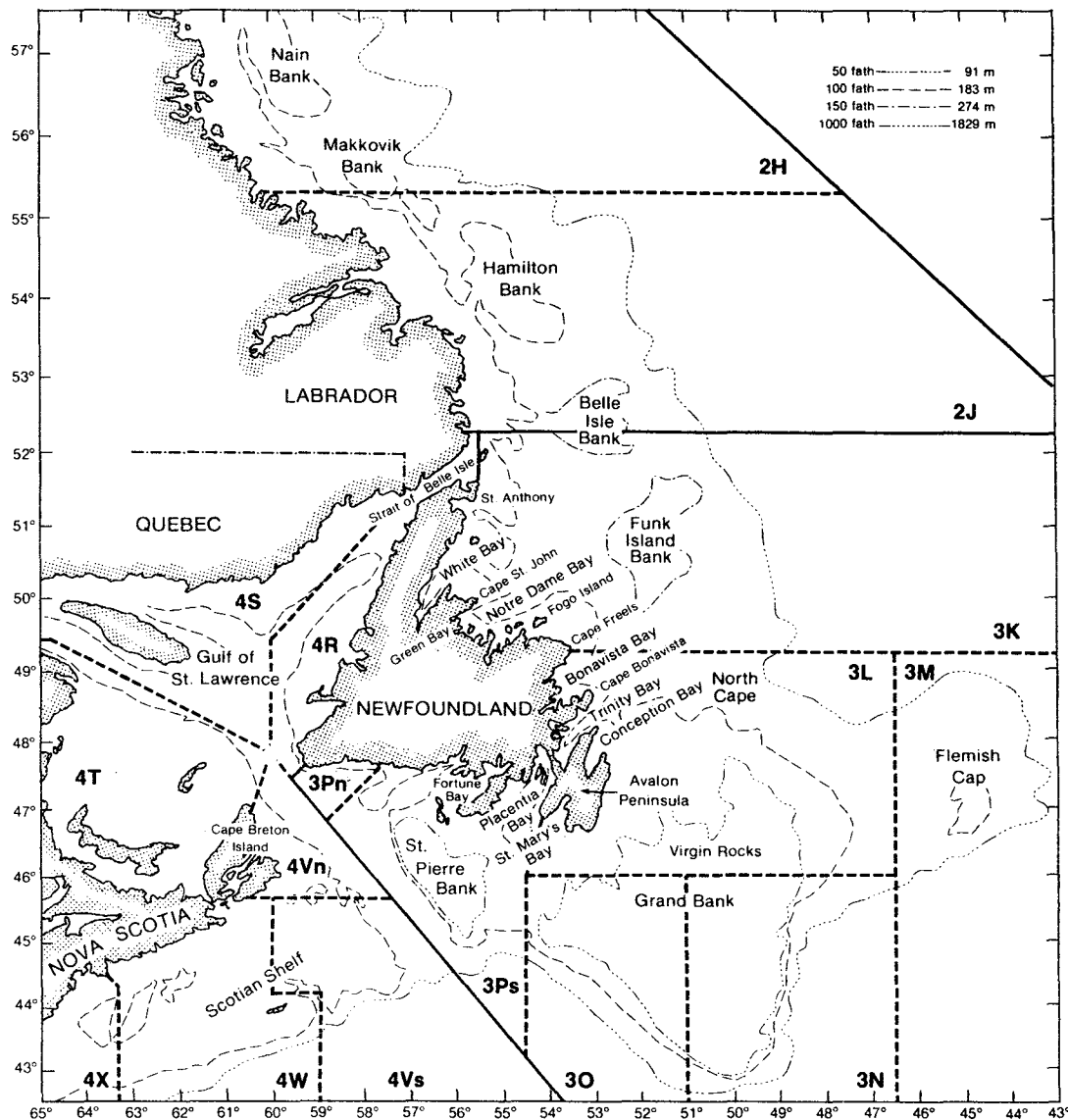


Fig. 1. Map showing the NAFO divisions and place names mentioned in the text.

drifted as larvae and in which they had spent the first years of their life as juveniles. The purpose of this paper is to reexamine migration patterns and stock relationships of cod off southern Labrador and eastern Newfoundland (Fig. 1) on the basis of recaptures of adults which were tagged offshore in areas of overwintering concentrations. May's (MS 1966) classification of the "stock complex" is discussed in the light of these more recent tagging studies.

Materials and Methods

During February–March of 1978–81, about 25,000 cod (≥ 45 cm) were tagged off southern Labrador (Div. 2J) and eastern Newfoundland (Div. 3K and 3L), using Petersen disc, spaghetti T-bar and dangler tags (Table

1). The tag types were applied to cod in equal batches (50), so that any bias due to variation in tag loss among the different types would be equally distributed throughout all experiments. The taggings were conducted in winter on prespawning concentrations of cod on Hamilton Bank in 1981, Belle Isle Bank in 1978, Funk Island Bank in 1978–81, and northern Grand Bank in 1980.

The cod were caught in an Engels high-rise otter trawl (without small-mesh codend liner except in 1978), which was towed on bottom generally for 10–20 min and occasionally for 30 min, depending on the density of cod deduced from echo-sounding. Because the concentrations of cod occurred in ice-covered areas at depths of 230–350 m, the trawl was retrieved very slowly (8–10 m/min) to allow the fish to acclimate

TABLE 1. Tag types applied to cod during tagging operations of southern Labrador and eastern Newfoundland in the winters of 1978-81.

Year	Tag type
1978-81	Yellow Petersen disc and blank (13 mm diam.) attached through the flesh posterior to first dorsal fin with soft stainless steel wire allowing 3 mm space on each side of fish.
1978	Yellow spaghetti T-bar (7 cm long) inserted at base of first dorsal fin.
1979-81	Yellow spaghetti T-bar (8.25 cm long) inserted at base of first dorsal fin. Orange spaghetti T-bar (8.25 cm long) inserted at base of first dorsal fin. Combination tag composed of yellow Petersen disc and blank (13 cm diam.) attached through the flesh at base of first dorsal fin allowing 3 mm space on each side of fish, with yellow dangle (50 x 13 mm) attached to trail along each side of fish.

to the changing pressure and to prevent suffocation from crowding in the codend. Also, the codend had to be retrieved in open water to prevent death of the cod from supercooling and eventual freezing. This occurred if, after being pulled through water where temperatures were -1.5° to -1.7°C , the cod were hauled through surface water filled with ice crystals. Similarly, the tagged cod were released in open water areas.

Tags were applied only to those cod which were classified as being in excellent condition. Any fish, with signs of bruising, scale loss, injury to fins and gills, bleeding, "pop-eye" condition, and distended swim-bladder were routinely discarded during the tagging operations. The cod were released from the codend into holding tanks with running sea water. They were retrieved individually with dipnets, measured to the nearest centimeter (fork length), examined for the gill parasite *Lernaecocera branchialis*, tagged and placed in recovery tanks filled with running sea water. When it appeared that the fish had fully recovered from the shock of being handled and tagged (swimming actively), they were released through a hatch at the

water line of the ship (i.e. they were placed, not dropped, into the sea).

Tag recoveries were grouped arbitrarily by seasonal periods, corresponding approximately to the off-shore winter fishery (January-April) and the inshore summer and autumn fishery (May-December), and, where possible, by standard unit areas within the larger NAFO divisions. Generally, the information provided by fishermen or obtained from logbook records and observer reports was sufficient to determine the approximate locations of recaptures. There were a few instances ($<5\%$ of offshore recaptures) where the tag recoveries could be assigned only to NAFO divisions, and these are not included in this analysis of the data by unit area.

The monthly nominal catches of cod by Newfoundland-Labrador fishermen in the designated unit areas, as collected and compiled by the Statistics Branch of the Department of Fisheries and Oceans, were combined for the two seasonal periods (see Appendix) and used to calculate the numbers of tags recovered by Newfoundland-Labrador fishermen per 1,000 tons of cod caught. It was not possible to include the tags recovered offshore by non-Canadian fishermen, because their catches were not available by unit areas. However, the overall distributions of tag recoveries by Canadian and non-Canadian fishermen are illustrated in the diagrams by season and unit area. The adjusted recovery rates, based on tag recoveries and catches by Newfoundland-Labrador fishermen, are considered to be representative of the overall situation, because tag recoveries by these fishermen accounted for about 56% of all tags returned during the January-April period, 90% of all tags returned during the May-December period, and 83% of all tags returned during 1978-82 (Table 2).

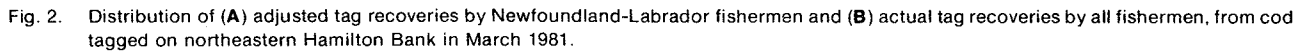
Results

Northeastern Hamilton Bank (Fig. 2)

From 3,305 cod tagged on northeastern slope of Hamilton Bank during 18-22 March 1981, there were

TABLE 2. Summary of information on cod tagging experiments off Labrador and eastern Newfoundland in February-March, 1978-81, and recoveries to the end of 1982. (Numbers in parentheses are tag recoveries by Newfoundland-Labrador fishermen.)

Tagging area	Tagging year	Tagging dates	Number tagged	No. of tag recoveries	Fig. ref.
NE Hamilton Bank	1981	18-22 Mar	3,305	290 (228)	2
Belle Isle Bank	1978	26 Feb-12 Mar	2,728	450 (366)	3
N Funk Island Bank	1978	27 Feb-10 Mar	1,725	241 (195)	4
N Funk Island Bank	1979	27 Feb-2 Mar	3,119	348 (274)	5
N Funk Island Bank	1981	25-27 Mar	3,139	284 (245)	6
E Funk Island Bank	1979	25 Feb-2 Mar	1,801	285 (232)	7
SE Funk Island Bank	1980	17-23 Mar	2,259	133 (112)	8
W Funk Island Bank	1980	24-27 Mar	2,158	362 (340)	9
SW Funk Island Bank	1981	14-17 Mar	1,195	141 (137)	10
N Cape of Grand Bank	1980	28-30 Mar	1,978	157 (110)	11



1 was reported from Placentia Bay. These movements confirm that cod which overwinter on the northeastern slope of Hamilton Bank contribute substantially to the inshore fishery of southern Labrador and northeastern Newfoundland north of Cape Freels and to a lesser degree in areas from Bonavista Bay southward. A few of these tags were recovered in the Strait of Belle Isle, indicating some intermingling with the northern Gulf of St. Lawrence stock.

During the January–April period, the highest numbers and adjusted rates of tag recoveries occurred on the southeastern slope of Hamilton Bank, adjacent

TABLE 3. Percentage distribution of adjusted tag recoveries in inshore areas of Labrador and eastern Newfoundland during the May–December periods to the end of 1982 from 11 tagging operations in offshore areas during the winters of 1978–81.

Recovery areas	Northeast Hamilton Bank (1981)	Belle Isle Bank (1978)	Northern Funk I. Bank (1978)	Northern Funk I. Bank (1979)	Northern Funk I. Bank (1981)	Eastern Funk I. Bank (1979)	Southeast Funk I. Bank (1980)	Western Funk I. Bank (1980)	Southwest Funk I. Bank (1981)	Northern Grand Bank (1980)
Labrador coast ^a	35.9	35.5	16.0	14.0	19.7	5.6	2.4	1.8	0.0	0.0
Belle Isle Strait	6.3	15.9	10.5	5.8	7.8	2.8	2.0	2.4	2.0	2.0
White Bay ^b	26.4	30.1	26.8	15.9	16.1	4.5	2.2	10.0	5.9	0.0
Notre Dame Bay ^c	9.9	9.8	15.0	13.1	12.5	10.3	12.5	25.9	36.4	1.5
Bonavista Bay	6.8	6.1	11.0	17.4	10.9	25.6	14.5	26.6	28.2	4.4
Trinity Bay	7.7	2.3	5.2	18.9	14.1	22.9	25.9	13.5	12.7	24.6
Conception Bay	2.9	0.0	11.3	4.7	6.2	15.1	5.5	13.3	8.7	21.9
Southeast Avalon	4.1	0.3	2.7	6.5	9.1	4.7	10.8	6.0	2.1	23.3
St. Mary's Bay	0.0	0.0	1.5	3.6	4.1	9.1	24.2	0.7	3.8	24.3
Tag Recoveries	146	304	156	206	169	180	93	307	128	52

^a Unit areas 201, 208 and 209 of Fig. 2.

^b Unit areas 341 and 342 of Fig. 2.

^c Unit areas 339 and 340 of Fig. 2.

to the tagging area, and around Hawke Channel (Fig. 2). It is evident that cod, which were concentrated on the northeastern slope of Hamilton Bank during tagging operations in March 1981, were located farther south along the slope of that bank during the winter of 1982. This indicates that the Hamilton Bank component of the Labrador-East Newfoundland stock complex exhibits some variability in the center of distribution, extending anywhere from the northern to the southern slopes of the bank in different years.

From inshore cod tagging at Domino in southern Labrador and Quirpon in northern Newfoundland during summer in 1962–64 (Templeman, 1979), 60–66% of the recoveries in the January–May period of subsequent years were made on Hamilton Bank and 17–24% on Belle Isle Bank, indicative of “homing” from inshore feeding grounds in summer to offshore overwintering areas. Templeman (1979) also showed that cod, which were tagged on northeastern and southeastern Hamilton Bank in April–May, returned mainly to Hamilton Bank in subsequent winters (January–May). Those results, together with these from the present study, show that the cod exhibit well-defined inshore-offshore migratory patterns typical of homing, with inshore movement for feeding in summer and offshore movement to overwinter and spawn.

Belle Isle Bank (Fig. 3)

From 2,728 cod tagged on Belle Isle Bank during 26 February–12 March 1978, there were 351 tag recoveries during the five ensuing May–December periods, of which 329 were reported by Newfoundland–Labrador fishermen. The adjusted tag recoveries in coastal waters were distributed from Labrador southward along eastern Newfoundland to the Avalon Peninsula with the highest rates in the region from southern Labrador to White Bay (Fig. 3A). About 90% of these adjusted recoveries occurred north of Cape Freels (Table 3). Although nearly three times as many tags

were recovered in the Strait of Belle Isle and southern Labrador areas (86 and 83) as in the St. Anthony area (31) (Fig. 3B), the adjusted recovery rate for the Strait of Belle Isle was about 35% of the rate for southern Labrador and 50% of the rate for the St. Anthony area. The pattern of tag recoveries along the coast indicates clearly that this group of cod, which overwinters on the shelf and slopes of Belle Isle Bank, migrates mainly to southern Labrador, Strait of Belle Isle and northeastern Newfoundland as far south as Notre Dame Bay, and confirms Templeman's (1979) results from tagging on Belle Isle Bank in September 1962. There is evidence of migration northward along the Labrador coast in summer, and a few tags were recovered south of Cape Freels. Also, 1 tag was recovered on Flemish Cap, 1 off southwestern Newfoundland and 1 off Cape Breton on the Scotian Shelf.

During the January–April period, tag recoveries were mainly from the tagging site and adjacent areas (Fig. 3) indicating a high degree of homing in 4 successive years to the overwintering areas where they were tagged. There was some evidence of movement of this group of cod northward along the seaward slope of Hamilton Bank. These may be cod which had spawned on the slopes of Hamilton Bank and had migrated to the neighbouring Belle Isle Bank before being tagged there. Movement of these Belle Isle Bank cod southward to the Grand Bank was negligible. During the winter period, single recaptures occurred on Flemish Cap, off Cape Breton on the Scotian Shelf, and off southwestern Nova Scotia.

Northern Funk Island Bank (Fig. 4–6)

Three tagging experiments were conducted on the northern slope of this bank, which is adjacent to Belle Isle Bank (Fig. 1), during the winters (February–March) of 1978, 1979 and 1981. These experiments involved the tagging of 7,983 cod, from which 873 recaptures (714 by Newfoundland–Labrador fishermen) were

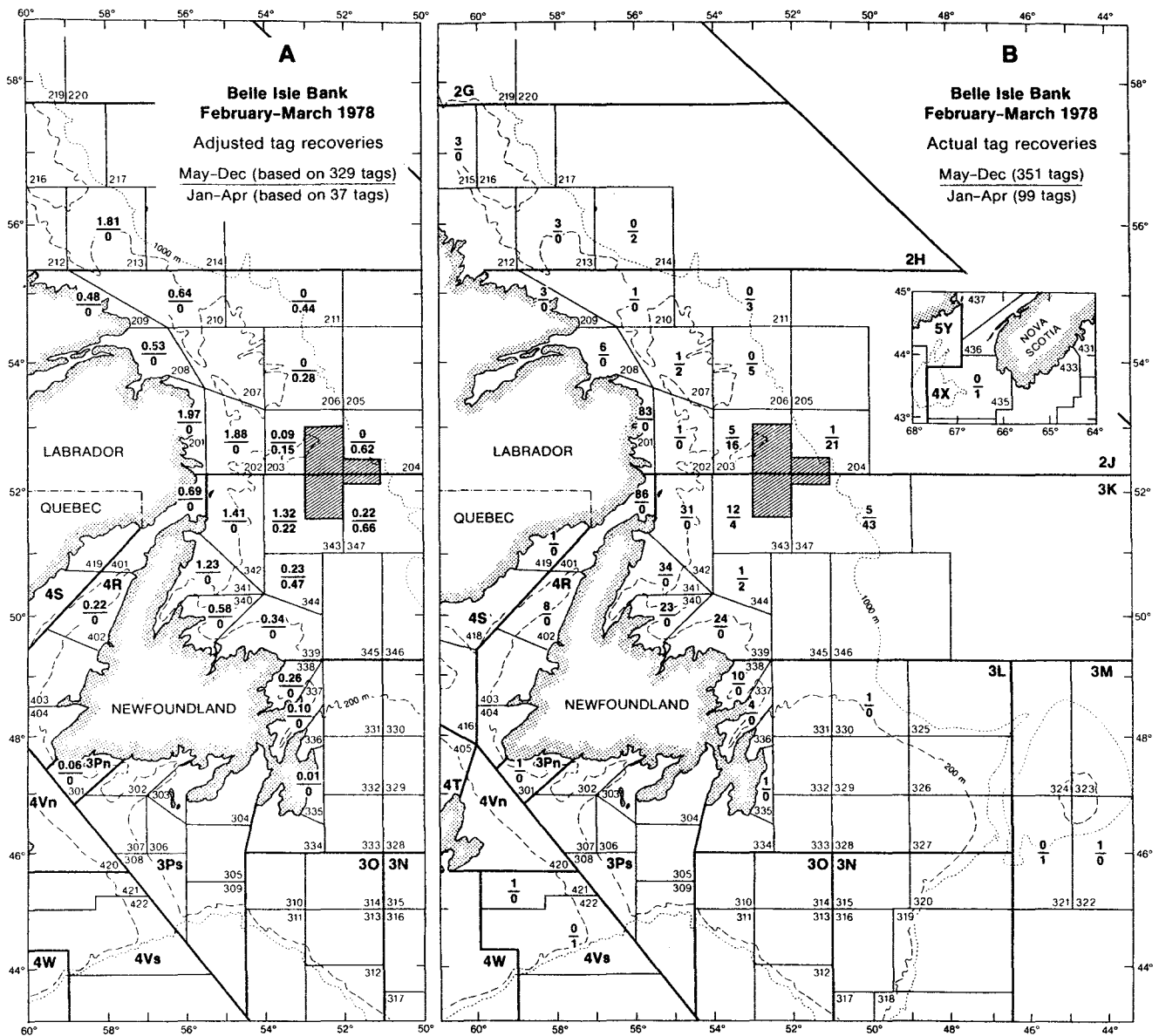


Fig. 3. Distribution of (A) adjusted tag recoveries by Newfoundland-Labrador fishermen and (B) actual tag recoveries by all fishermen, from cod tagged on Belle Isle Bank in February-March 1978.

reported during the period from May in the tagging year to December 1982.

From 1,725 cod tagged on the northern slope of Funk Island Bank during 27 February-10 March 1978, there were 181 tag recoveries during the five ensuing May-December periods, of which 168 were reported by Newfoundland-Labrador fishermen (Fig. 4). The inshore recovery rates (adjusted) were highest for the St. Anthony and White Bay areas and about one-third lower for the southern Labrador and Notre Dame Bay areas (Fig. 4A). The recovery rate for the Strait of Belle Isle was about 60% of the rate for southern Labrador and 40% of that for the St. Anthony area. From this northern Funk Island Bank tagging, the relative recov-

ery rates of tags in the Labrador, Strait of Belle Isle and White Bay areas were consistently lower than those from the Belle Isle Bank tagging experiment (Table 3), particularly so for Labrador coastal waters, and there was greater dispersion of tag recoveries southward to the Avalon Peninsula. Except for the recoveries from the Strait of Belle Isle, the only tags returned from areas outside Div. 2J, 3K and 3L were 3 from the fishery off central Labrador and single recoveries from Placentia Bay and northeastern Scotian Shelf (Fig. 4B).

From 3,119 cod tagged on the northern slope of Funk Island Bank during 27 February-2 March 1979, there were 248 recoveries in the four ensuing May-December periods, of which 223 were reported by

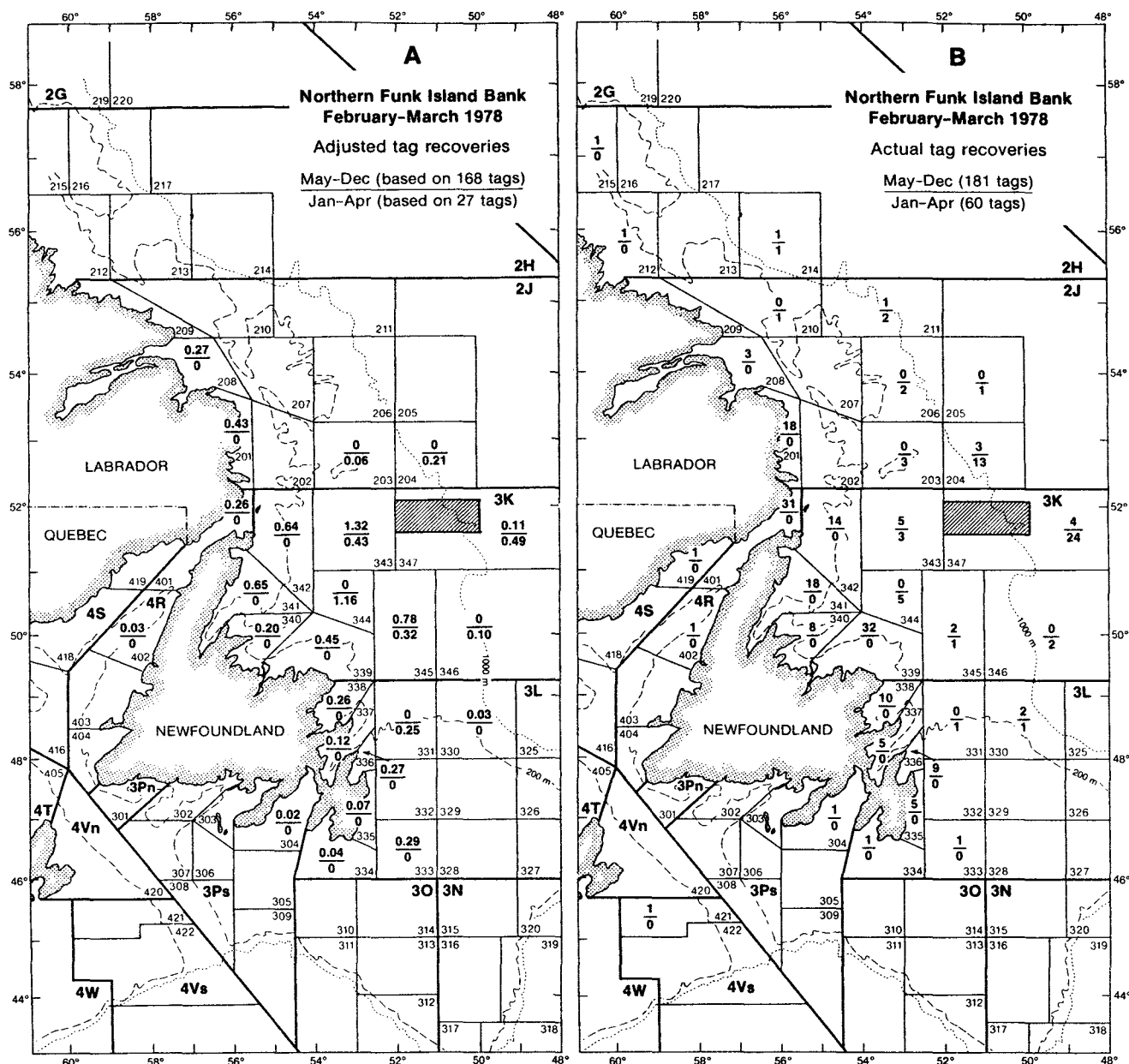


Fig. 4. Distribution of (A) adjusted tag recoveries by Newfoundland-Labrador fishermen and (B) actual tag recoveries by all fishermen, from cod tagged on northern Funk Island Bank in February-March 1978.

Newfoundland-Labrador fishermen (Fig. 5). The adjusted recovery rates were relatively high (0.54–0.79) in coastal areas from southern Labrador to Conception Bay (Fig. 5A). The results from this experiment indicated a more southerly distribution of adjusted tag recoveries than the 1978 tagging (Table 3), with the combined percentages being almost equal for the areas north and south of Cape Freels, compared with a ratio of 68:32 for the 1978 tagging in this area and 91:9 for the 1978 tagging on Belle Isle Bank. Also, there were substantially fewer recoveries in the Strait of Belle Isle (6%) from this northern Funk Island Bank tagging than from the 1978 tagging on Belle Isle Bank

(16%). Except for the recoveries in the Strait of Belle Isle, the only tags recovered in areas outside of Div. 2J, 3K and 3L during May–December were 2 off western Newfoundland, 1 in Placentia Bay and 1 off central Labrador (Fig. 5B).

From 3,139 cod tagged on the northern slope of Funk Island Bank during 25–27 March 1981, there were 216 tag recoveries during the two ensuing May–December periods, of which 193 were reported by Newfoundland-Labrador fishermen (Fig. 6). The highest adjusted recovery rates in coastal waters were for the southern Labrador and St. Anthony areas (1.23–1.60),

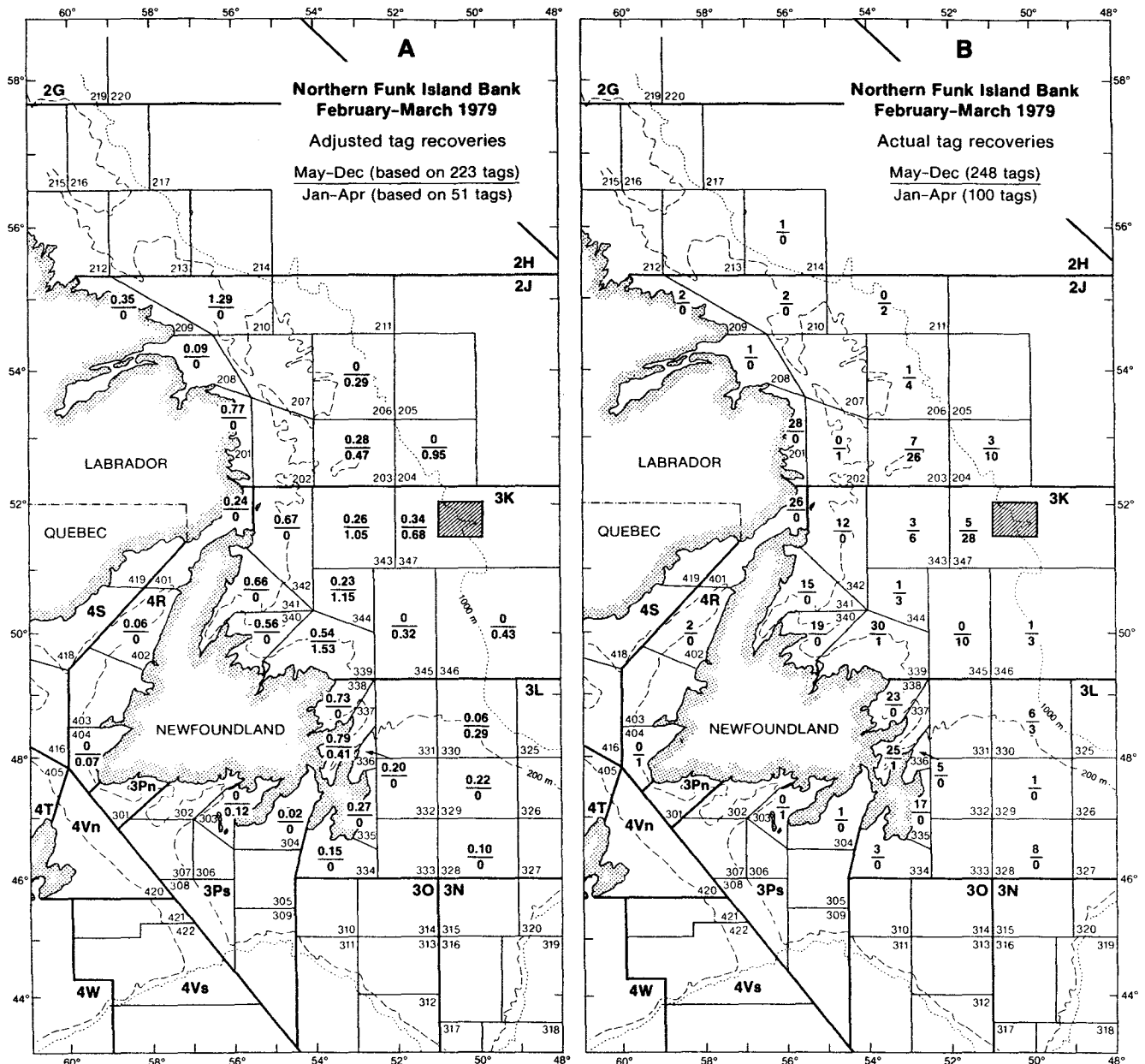


Fig. 5. Distribution of (A) adjusted tag recoveries by Newfoundland-Labrador fishermen and (B) actual tag recoveries by all fishermen, from cod tagged on northern Funk Island Bank in February-March 1979.

with somewhat lower values for the eastern Newfoundland areas (0.66–0.85) (Fig. 6A). The rates were quite high in some offshore areas, but these are based on few tag returns and very low catches. The relative proportions of adjusted recoveries from coastal waters were similar to those from the 1979 tagging (Table 3), with slightly more than half (56%) from the region north of Cape Freels in 1981, compared with 68% from the 1978 tagging. The offshore recoveries were mainly on the northern and central areas of the Grand Bank and on the Northeast Newfoundland Shelf (Fig. 6B). Except for those from the Strait of Belle Isle, the only recoveries outside Div. 2J, 3K and 3L were 2 off central Labrador, 3 in the northern Gulf of St. Lawrence and 1 on the southwestern slope of Grand Bank.

The May-December results from the three taggings on the northern slope of Funk Island Bank confirm that this component of the stock complex contributes substantially to the inshore fishery from southern Labrador southward to the Avalon Peninsula, in contrast to the relatively smaller contributions to the fishery south of Cape Freels from the Hamilton Bank and Belle Isle Bank taggings. These results are similar to those reported by Templeman (1979) from the tagging of 384 cod on northern Funk Island Bank in May 1964.

During the January-April periods in the years after tagging, the recaptures from the 1978, 1979 and 1981 experiments occurred in or near the tagging area and

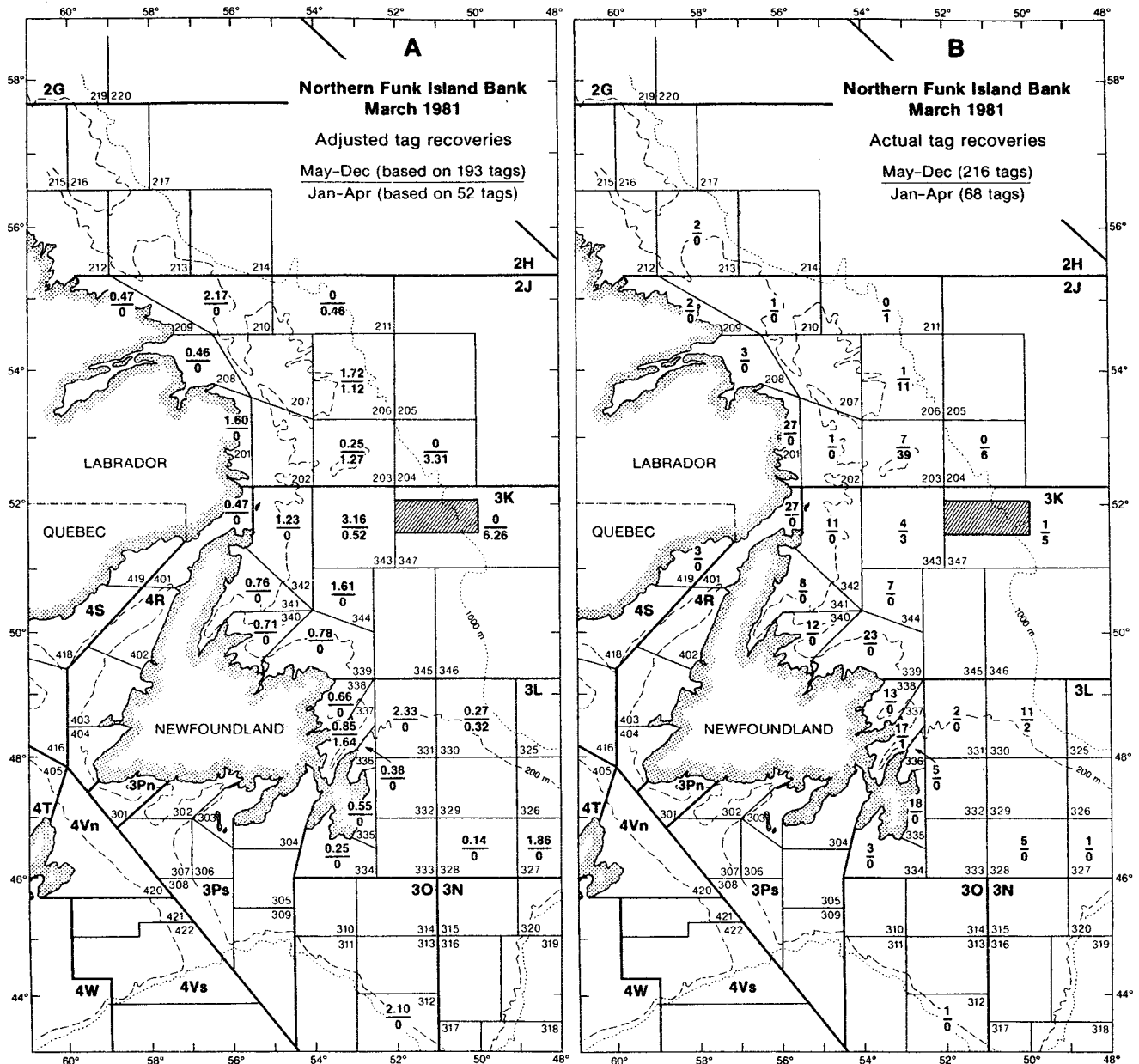


Fig. 6. Distribution of (A) adjusted tag recoveries by Newfoundland-Labrador fishermen and (B) actual tag recoveries by all fishermen, from cod tagged on northern Funk Island Bank in March 1981.

northwestward around Belle Isle Bank and Hamilton Bank. There were a few winter recoveries on the northern Grand Bank from each tagging (Fig. 4B-6B), and single tags were reported from southwestern Newfoundland and Fortune Bay (Fig. 5B).

Eastern and southeastern Funk Island Bank (Fig. 7 and 8)

From 1,801 cod tagged on the eastern slope of Funk Island Bank during 25 February–2 March 1979, there were 232 tag recoveries during the four ensuing May–December periods, of which 201 were reported by

Newfoundland-Labrador fishermen. The inshore recoveries were distributed mainly from Notre Dame Bay southward to the Avalon Peninsula, with the highest adjusted rates (1.11 and 1.01) in Bonavista Bay and Trinity Bay (Fig. 7A). The proportion of adjusted recoveries from inshore areas south of Cape Freels (77%) was substantially higher than the corresponding proportions (32–51%) from the three taggings on the northern slope of Funk Island Bank (Table 3). The relatively high recovery rates in four offshore areas of the Grand Bank (0.63–1.36) are based only on 2 or 3 tag returns from each area (Fig. 7), but there were 11 recoveries in a central Grand Bank area. In addition to

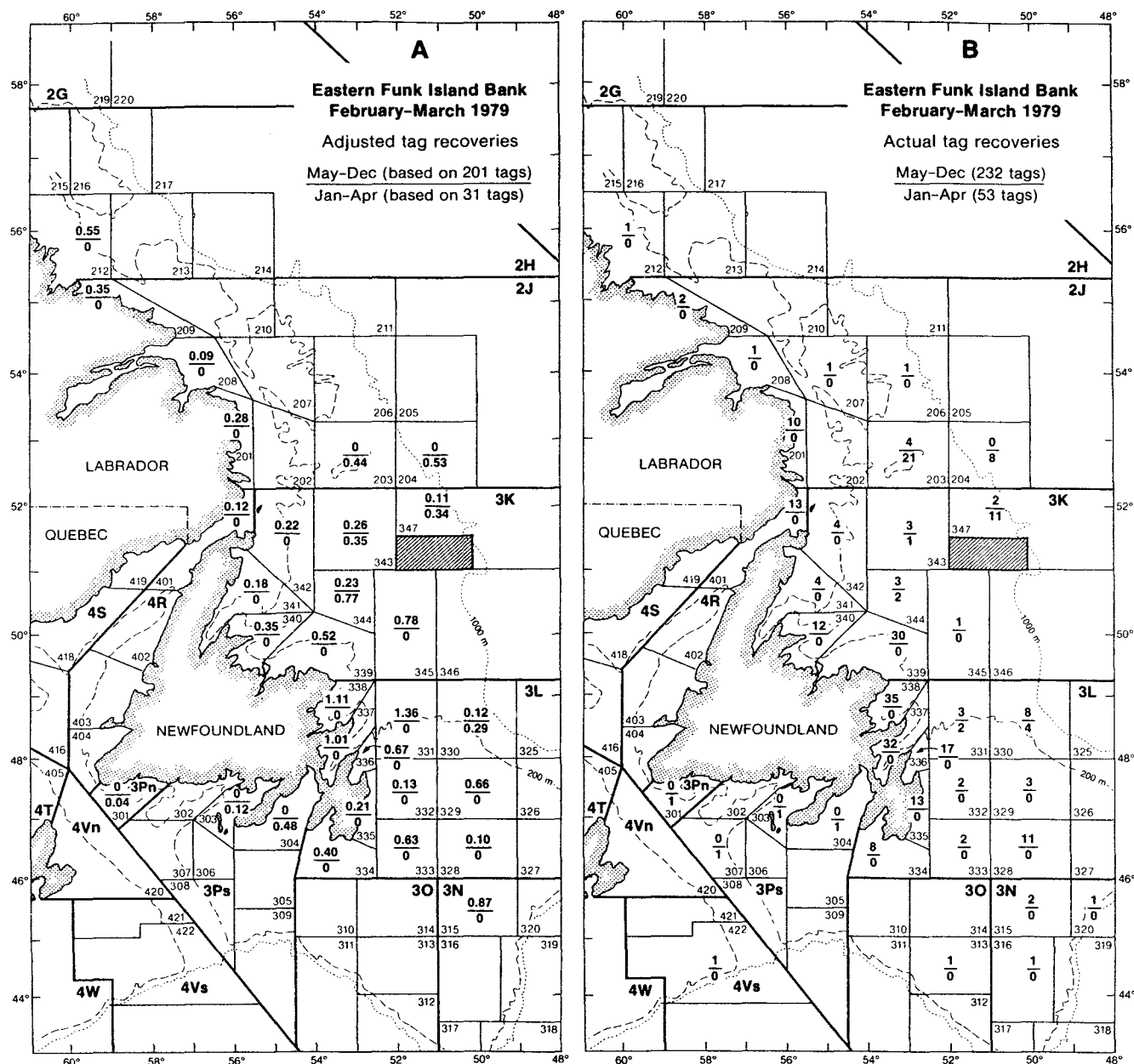


Fig. 7. Distribution of (A) adjusted tag recoveries by Newfoundland-Labrador fishermen and (B) actual tag recoveries by all fishermen, from cod tagged on eastern Funk Island Bank in February-March 1979.

some movement of cod from the tagging area to southern Labrador and the Strait of Belle Isle in summer, there were 5 recoveries on the southern Grand Bank and 1 on the northeastern Scotian Shelf.

From 2,259 cod tagged on the southeastern slope of Funk Island Bank during 17-23 March 1980, there were 125 tag recoveries in the ensuing three May-December periods, of which 106 were reported by Newfoundland-Labrador fishermen. The distribution of inshore recoveries was generally similar to that of the preceding experiment with some variation in adjusted rates from Notre Dame Bay southward to St.

Mary's Bay (Fig. 8A). The proportion of adjusted recoveries from inshore waters south of Cape Freels was 81% (Table 3), with substantially higher proportions in the most southerly areas than were evident from the 1979 tagging on the eastern slope of Funk Island Bank. The offshore recaptures occurred mainly around the Virgin Rocks on the central Grand Bank (Fig. 8B). In addition to a few recoveries in the southern Labrador and Strait of Belle Isle areas, there were 2 in the Gulf of St. Lawrence and 2 in Placentia Bay.

In the January-April period, tag recoveries from both experiments were substantially less than those in

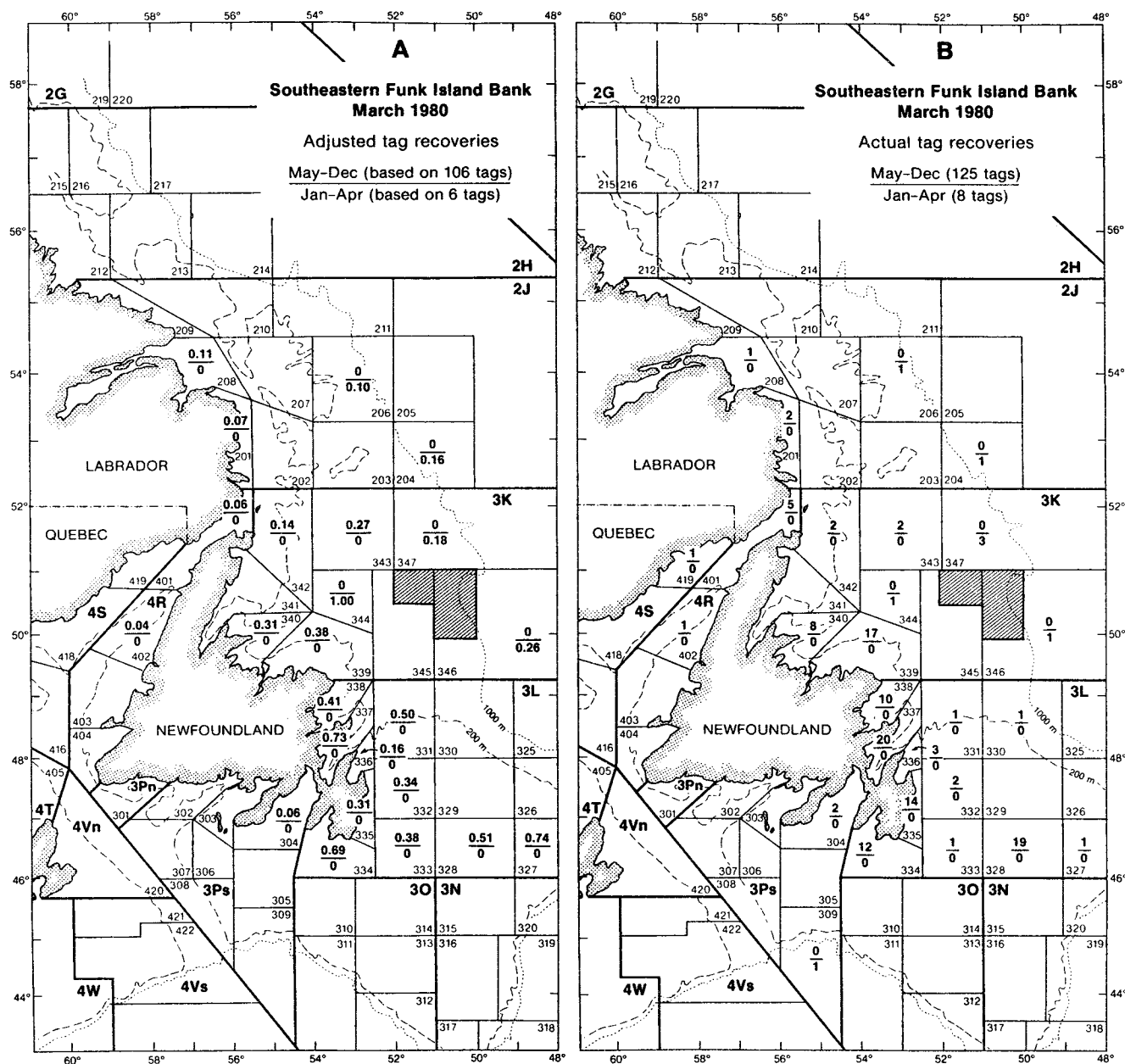


Fig. 8. Distribution of (A) adjusted tag recoveries by Newfoundland-Labrador fishermen and (B) actual tag recoveries by all fishermen, from cod tagged on southeastern Funk Island Bank in March 1980.

the May–December period (Fig. 7 and 8) and were distributed in and around the tagging area and on the northern Grand Bank. Single recoveries were reported from Hamilton Bank in the north and from southern Newfoundland areas in the south.

It is clearly evident from these tagging experiments on Funk Island Bank that migration in summer is mainly to eastern and southeastern Newfoundland from Notre Dame Bay to St. Mary's Bay, with some movement southward to northern and central Grand Bank areas.

Western and southwestern Funk Island Bank (Fig. 9 and 10)

From 2,158 cod tagged on the western slope of Funk Island Bank during 24–27 March 1980, there were 334 tag recoveries during the three ensuing May–December periods, of which 320 were reported by Newfoundland-Labrador fishermen. The inshore recoveries were distributed mainly from the Strait of Belle Isle entrance to the Avalon Peninsula, with the highest adjusted rates (2.43 and 2.06) in Notre Dame Bay and Bonavista Bay (Fig. 9A) and relatively high

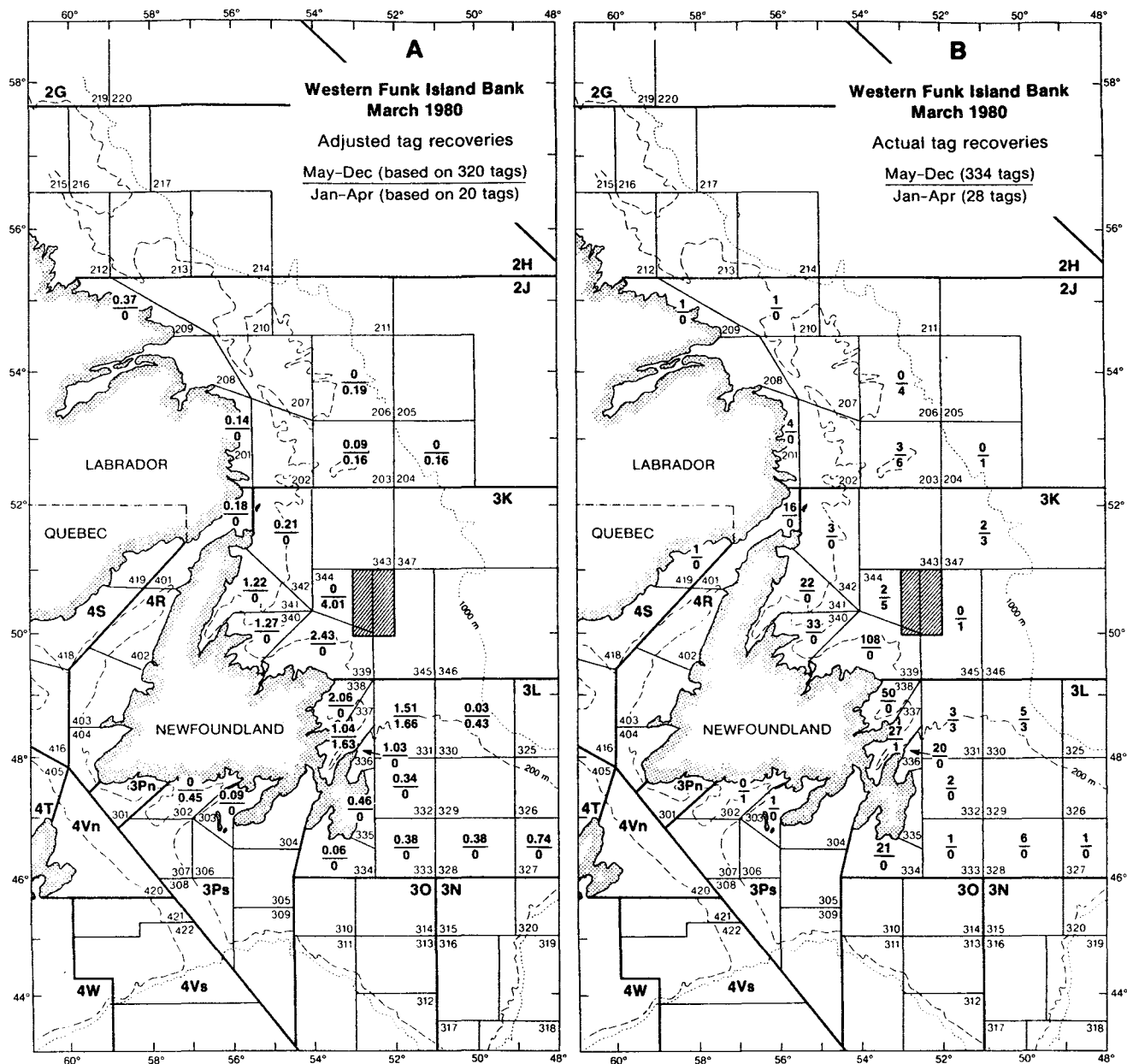
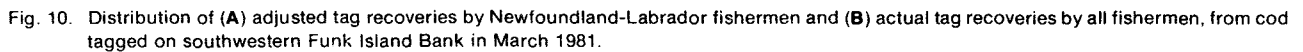


Fig. 9. Distribution of (A) adjusted tag recoveries by Newfoundland-Labrador fishermen and (B) actual tag recoveries by all fishermen, from cod tagged on western Funk Island Bank in March 1980.

rates both northward in the Green Bay and White Bay areas and southward in the Trinity Bay and Conception Bay areas. In contrast to the results from the preceding two experiments on the eastern and southeastern slopes of the bank, there was a substantial increase (to 40%) in the percentage of adjusted recoveries from the inshore region north of Cape Freels and a corresponding decrease (to 60%) from the southern inshore region (Table 3). There were several offshore recoveries on the northern and central Grand Bank, and single tags were returned from Fortune Bay and the northern Gulf of St. Lawrence (Fig. 9B).

From 1,195 cod tagged on the southwestern slope of Funk Island Bank during 14-17 March 1981, there were 135 tag recoveries during the ensuing two May-December periods, of which 134 were reported by Newfoundland-Labrador fishermen. The inshore distribution of adjusted recaptures was approximately similar to that of the preceding experiment, with the highest rates (1.83 and 1.22) in Notre Dame Bay and Bonavista Bay (Fig. 10A) and somewhat lower rates in adjacent areas to the north and south of these bays. The relative proportions of adjusted recoveries north and south of Cape Freels (44 and 56%) were similar to



During the January–April period, there were only 28 and 6 tag recoveries from the 1980 and 1981 experiments respectively (Fig. 9 and 10). About half of these recoveries were northward of the tagging site as far as Hamilton Bank, but several occurred in the vicinity of the tagging area and southward on the northern Grand Bank. There were only 2 inshore recoveries, 1 in Trinity Bay and 1 off the south coast of Newfoundland.

From 1,978 cod tagged on the northern slope of Grand Bank during 10-30 March 1980, there were 134

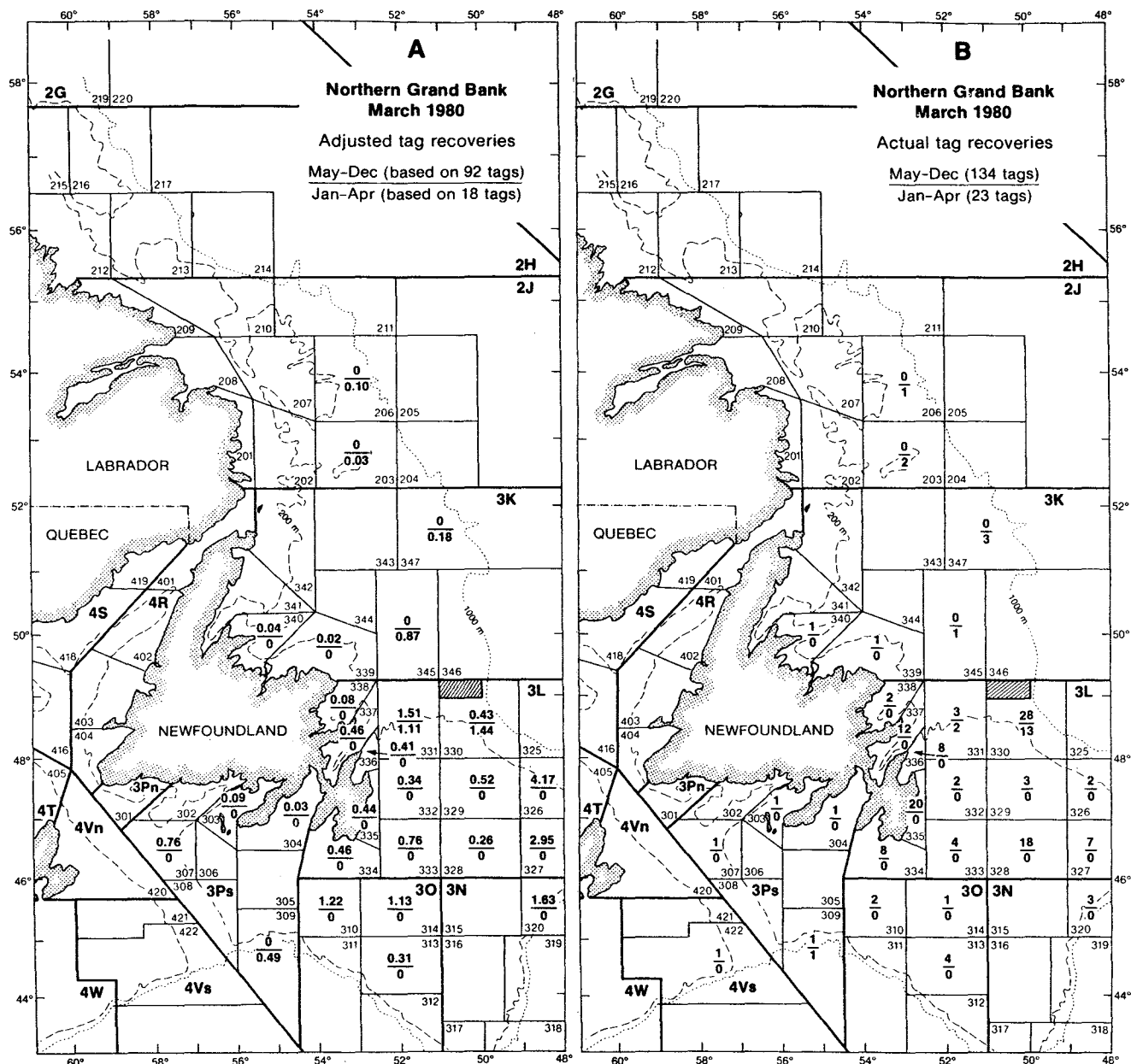


Fig. 11. Distribution of (A) adjusted tag recoveries by Newfoundland-Labrador fishermen and (B) actual tag recoveries by all fishermen, from cod tagged on the northern slope of Grand Bank in March 1980.

tag recoveries during the three ensuing May-December periods, of which 92 were reported by Newfoundland-Labrador fishermen. The inshore recoveries (adjusted) were distributed almost equally (0.41-0.46) in the region from Trinity Bay to St. Mary's Bay (Fig. 11A), with 98.5% being recovered south of Cape Freels (Table 3). However, most of the recoveries were from offshore areas on the northern half of Grand Bank and a few occurred on the southern part of the bank (Fig. 11B). During the May-December period, there were only 2 recoveries (both inshore) north of Bonavista Bay, and single recoveries were recorded from four unit areas in Div. 3P off southern Newfoundland and 1 from the Scotian Shelf.

Recoveries during the January-April periods of 1981-82 were mainly from areas around the tagging location, although there was some northward movement to the Northeast Newfoundland Shelf and Hamilton Bank (Fig. 11). There were no recoveries from coastal waters and the southern Grand Bank, but a single tag was recovered on the southern slope of St. Pierre Bank.

Discussion and Conclusions

The migratory patterns of cod, based on tagging the various spawning components of the stock com-

plex in Div. 2J, 3K and 3L, confirm that there is associated with each component a definite inshore distribution in summer-autumn and presumably a high degree of homing during winter to concentrate for spawning in or near the offshore areas where the fish were tagged. The components which overwinter on the slopes of Hamilton Bank and Belle Isle Bank contribute very significantly to the summer fishery along the coasts of Labrador and northern Newfoundland, including the Strait of Belle Isle, and insignificantly to the fishery south of Notre Dame Bay. These patterns of migration and summer distribution conform with May's (MS 1966) concept of the "Labrador-Newfoundland" cod stock. High exploitation of the overwintering concentrations in the Hamilton Bank and Belle Isle Bank areas would have adverse effects on the inshore fishery from southern Labrador to Notre Dame Bay. On the other hand, the effects of high exploitation of the concentrations on the northern part of Funk Island Bank would be distributed almost equally over a much larger area from southern Labrador to the Avalon Peninsula.

The stock component which overwinters on the eastern and southeastern slopes of Funk Island Bank contributes very substantially to the inshore fishery of eastern Newfoundland from Notre Dame Bay to St. Mary's Bay, mainly in the region south of Cape Freels. The component which overwinters on the western and southwestern slopes of the bank contributes mainly to the localized fishery in Notre Dame Bay and Bonavista Bay and less significantly to the fishery in areas north and south of these bays. Thus, the components which overwinter and spawn on the slopes of Funk Island Bank collectively form what might best be described as the "Eastern Newfoundland" stock, and the inshore fishery from Notre Dame Bay to the Avalon Peninsula would likely be sensitive to changes in the size of this stock.

The component which overwinters on the northern slope of Grand Bank migrates in summer not only to coastal waters of eastern Newfoundland south of Cape Bonavista but also southward along the eastern edge of Grand Bank, around the Virgin Rocks on the central part of the bank and to the southwestern slope. High exploitation of this stock component in offshore areas would have some effect on the inshore fishery of southeastern Newfoundland.

From all of the cod tagging experiments, there is evidence of substantial inshore migration in summer and subsequent homing to specific offshore overwin-

tering and spawning areas, although with some straying. Therefore, heavy offshore exploitation of a particular component of the stock complex in winter could have concomitant adverse effects on the inshore summer fishery. The cod fishery could be poor along a particular section of the coast and successful in other areas, depending on which offshore component of the stock complex was heavily or lightly exploited. It is therefore desirable that the offshore winter fishery be regulated to prevent excessive exploitation of any one component of the stock. This could be achieved by ensuring that the allowable level of fishing effort is distributed over the entire stock complex.

Pinhorn (1984) estimated that about 5% of the Div. 2J+3KL stock of cod, which survived the winter fishery in each year of the 1961-74 period, were actually caught in the summer fishery of these years, but that the inshore exploitation increased subsequently to 17% in 1976. If these rates reflect the "average" situation, the actual rates of inshore exploitation may vary greatly from area to area, depending on the extent of migration and distribution of the various stock components.

References

- FLEMING, A. M. 1960. Age, growth and sexual maturity of cod (*Gadus morhua* L.) in the Newfoundland area, 1947-1950. *J. Fish. Res. Board Can.*, **17**: 775-809.
- ICNAF. 1972. Report of the 22nd Annual Meeting, 25 May-2 June 1974. *ICNAF Ann. Proc.*, **22**: 17-66.
- MAY, A. W. MS 1966. Biology and fishery of Atlantic cod (*Gadus morhua* L.) from Labrador. Ph.D. Thesis, McGill Univ., Montreal, 225 p.
- 1967. Fecundity of Atlantic cod. *J. Fish. Res. Board Can.*, **24**: 1531-1551.
- MAY, A. W., A. T. PINHORN, R. WELLS, and A. M. FLEMING. 1965. Cod growth and temperature in the Newfoundland area. *ICNAF Spec. Publ.*, **6**: 545-555.
- PINHORN, A. T. 1984. Inshore exploitation of Atlantic cod, *Gadus morhua*, in Labrador and eastern Newfoundland waters. *J. Northw. Atl. Fish. Sci.*, **5**: 79-84.
- TEMPLEMAN, W. 1962. Division of cod stocks in the Northwest Atlantic. *ICNAF Redbook*, 1962(III): 79-129.
- 1966. Marine resources of Newfoundland. *Bull. Fish. Res. Board Can.*, **154**, 170 p.
- 1974. Migrations and intermingling of Atlantic cod (*Gadus morhua*) stocks of the Newfoundland area. *J. Fish. Res. Board Can.*, **31**: 1073-1092.
- 1979. Migrations and intermingling of stocks of Atlantic cod, *Gadus morhua*, of the Newfoundland and adjacent areas from tagging in 1962-68. *ICNAF Res. Bull.*, **14**: 5-50.
- 1981. Vertebral numbers in Atlantic cod, *Gadus morhua*, of the Newfoundland and adjacent areas, 1947-71, and their use for delineating cod stocks. *J. Northw. Atl. Fish. Sci.*, **2**: 21-45.

Appendix

Nominal catches (metric tons) of cod by Newfoundland fishermen in designated fishing areas during January-April and May-December periods of 1978-82. (+ indicates a catch <0.5 ton.)

Unit area	ICNAF Div.	1978		1979		1980		1981		1982	
		Jan-Apr	May-Dec	Jan-Apr	May-Dec	Jan-Apr	May-Dec	Jan-Apr	May-Dec	Jan-Apr	May-Dec
201	2J	—	5,655	—	6,826	—	12,688	—	9,325	—	7,544
202	2J	—	6	—	5	—	—	147	—	946	520
203	2J	1,238	—	865	9	—	6,654	9,726	224	22,104	3,791
204	2J	2,520	—	5,002	4	3,423	—	4,572	—	1,509	40
205	2J	—	—	—	4	309	—	—	—	188	—
206	2J	199	—	58	6	—	264	1,433	3	8,899	577
207	2J	—	4	—	521	—	15	—	2	191	67
208	2J	—	492	104	1301	—	3,044	—	2,904	—	3,564
209	2J	—	486	—	813	—	634	—	986	—	3,313
210	2J	—	4	—	1,073	—	13	—	7	162	454
211	2J	—	+	77	9	—	17	—	—	2,182	+
212	2H	—	5	—	67	—	66	—	71	—	1,628
213	2H	—	16	—	14	—	—	—	3	—	521
214	2H	—	—	—	37	—	—	—	—	—	431
215	2H	—	14	—	8	—	34	—	9	—	286
216	2H	—	+	—	—	—	—	—	—	—	121
217-224	2GH	—	—	—	—	—	+	—	6	—	3
301	3Pn	460	5,811	9,896	312	8,133	16	3,552	7,643	10,935	3,783
302	3Ps	77	4,573	4,426	128	5,746	158	549	5,561	1,667	3,103
303	3Ps	62	3,848	5,195	626	7,207	263	—	6,632	1,354	3,820
304	3Ps	34	11,310	—	13,441	1,953	12,773	—	11,460	149	11,470
305	3Ps	9	241	—	272	—	726	78	1,489	31	287
306	3Ps	186	4	59	36	—	502	9	213	66	49
307	3Ps	764	148	1,190	+	1,101	746	2	444	256	129
308	3Ps	115	7	242	32	380	515	393	885	74	136
309	3Ps	309	—	134	13	—	166	1,041	—	1,015	383
310	3O	—	1,042	—	2,083	7	998	—	463	702	180
311	3O	—	513	1,771	300	—	126	—	46	388	192
312	3O	139	7	—	168	38	15	—	40	32	437
313	3O	—	316	—	91	—	107	—	1,089	112	5,198
314	3O	—	682	—	353	—	244	—	477	—	168
315	3N	—	517	—	673	—	377	—	754	—	500
316	3N	—	250	—	603	11	1,141	—	2,564	—	934
317	3N	153	—	—	75	—	130	—	61	1	42
318	3N	79	1	—	251	—	428	49	1	—	11
319	3N	688	1	—	399	—	696	—	220	—	437
320	3N	39	—	—	217	—	256	—	103	68	187
321-324	3M	1	112	—	1	—	—	—	2	—	—
325	3L	—	10	1	147	45	—	21	—	86	307
326	3L	—	116	379	74	—	239	—	132	52	109
327	3L	—	150	+	288	—	821	—	196	—	341
328	3L	—	2,225	—	2,034	—	851	—	3,597	+	3,402
329	3L	—	598	7	681	—	1,218	—	1,424	14	1,207
330	3L	1,445	8	5,434	256	—	10,532	632	12,781	6,310	9,659
331	3L	—	2,219	2,231	211	—	1,135	1,458	172	350	686
332	3L	—	441	—	2,118	—	2,194	—	1,416	1,684	2,248
333	3L	—	285	—	534	—	558	198	1,012	10	1,050
334	3L	—	8,924	7,092	2,442	2,804	5,342	—	5,880	29	6,254
335	3L	—	14,827	—	17,016	—	12,950	51	14,342	34	18,309
336	3L	—	7,541	1,310	6,018	—	6,164	—	4,965	28	8,285
337	3L	381	8,667	4,299	5,734	1,830	5,960	2	7,489	611	12,434
338	3L	—	6,261	—	7,366	3,186	4,643	3	8,875	343	10,751
339	3K	156	15,052	—	11,239	413	14,986	14	10,393	228	19,073
340	3K	—	5,687	—	8,015	—	9,127	—	6,046	31	10,762
341	3K	5	5,076	—	4,559	—	7,503	—	3,780	22	6,748
342	3K	62	4,017	—	3,533	—	5,421	—	2,924	—	6,048
343	3K	1,204	+	1,759	9	137	2,825	787	—	1,931	951
344	3K	1,208	3	1,682	23	1,614	27	—	4,112	998	236
345	3K	2,455	—	13	1,052	1,956	53	1,080	16	74	157
346	3K	321	1	2,798	10	3,210	—	1,383	—	2,464	507
347	3K	457	2	12,528	99	364	8,128	10,805	—	639	698

Appendix (continued)

Unit area	ICNAF Div.	1978		1979		1980		1981		1982	
		Jan-Apr	May-Dec	Jan-Apr	May-Dec	Jan-Apr	May-Dec	Jan-Apr	May-Dec	Jan-Apr	May-Dec
401	4R	—	16,454	—	18,930	297	30,285	—	26,196	32	31,114
402	4R	696	5,521	5,087	3,728	3,380	3,540	419	12,362	79	11,582
403	4R	4,275	2,442	2,048	2,564	2,499	869	+	2,972	173	2,860
404	4R	4,930	1,058	1,517	3,222	11,018	470	+	7,500	3,546	1,894
405	4T	80	—	1,112	1,078	85	26	924	143	3	74
406	4S	225	4	47	—	1,437	—	29	—	113	2
417	4S	—	—	—	—	—	—	—	—	—	—
418	4S	—	—	—	—	—	—	—	—	—	1
419	4S	—	—	—	—	—	—	—	307	—	16
420	4Vn	3,359	2	—	1,299	1,095	558	2	2,892	15,291	121
421	4Vs	43	65	—	90	—	902	1,107	—	1,871	22
422	4Vs	89	260	—	1,273	1,736	2,863	652	919	1,677	1,594

