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Tagging Studies on Scotian Shelf Herring

by

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Introduction

Tagging herring in the NAFO area was first successfully attempted in 1970 in the Gulf of St. Lawrence (NAFO Subdivision 4T) using internal magnetic tags. Attempts to elucidate herring movements and stock relationships on the Scotian Shelf - Georges Bank - Gulf of Maine areas first begin in November, 1973, using a T-bar anchor tag (Figure 1).

The 1973 study, and several additional experiments in 1974, were concentrated on the herring populations in the Bay of Fundy being exploited by Canadian purse seine and fixed gear fisheries. The potential value of tagging studies in elucidating herring movements, and assisting in the definition of management areas by demonstrating stock relationships, was quickly demonstrated by the information obtained from subsequent tag recoveries. In 1975, based on the tagging information, two management units were altered substantially: one existing management area (ICNAF Subdivision 4VWa) was split so that Subdivision 4V would be managed as a discrete area, and the remaining portion (4Wa) was combined with another existing management area (ICNAF Subdivision 4WXb) to create the Subdivision 4WX management area. Subsequent to this early work considerable additional effort has been directed to herring tagging by a number of countries. Canada alone has tagged about 400,000 herring between 1973 and 1981 and in the NAFO area well over 500,000 have been tagged in total by Canada, USA, and USSR.

The value of herring tagging is often disputed for a variety of reasons, including the fact that recovery information often does not

indicate consistent patterns of movement, and it has not been well documented that herring are capable of homing. The purpose of this paper is to address the problems associated with the logistics of herring tagging studies and their subsequent interpretation, as well as to provide evidence of homing.

Results and Discussion

The Fisheries

The tagging studies which are being considered in this paper are associated with major herring fisheries on the Scotian Shelf. A short description of the fisheries is provided in order to understand the complexity of stock interrelationships in the area.

The NAFO Subdivision 4WX herring fishery consists of 7 components (Figure 2) which are prosecuted by various gears in all seasons of the year.

The New Brunswick weir and purse seine fisheries and the Grand Manan purse seine fishery primarily prosecute summer feeding and overwintering aggregations of juveniles, and to a much lesser extent, adults. The southwest Nova Scotia components of the fishery (weir, gillnets, purse seine) prosecute summer feeding, pre-spawning aggregations, and fall spawning herring; the gillnet fishery concentrates on the spawning adults. The Chedabucto Bay purse seine fishery prosecutes overwintering fish, a mixture of juveniles and adults. In addition there are a variety of fixed gear fisheries along the Nova Scotia coast between Chedabucto Bay and Cape Sable Island, as well as a small purse seine fishery on summer spawning herring at the head of the Bay of Fundy.

The NAFO Subdivision 4Vn purse seine fishery, the last one of interest in this paper, prosecutes overwintering herring in the Sydney Bight area. These aggregations are almost exclusively adult fish. As well there is a much smaller inshore fixed gear fishery in summer.

Logistics of the Tagging Studies

The tagging studies on the Scotian Shelf were intended to address the interrelationships of the stocks associated with the above fisheries. In 1974, almost 24,000 herring were tagged off southwest Nova Scotia in August. It was originally intended to tag spawning fish, but only

pre-spawning aggregations could be found (the gonads of the sampled herring were at the maturity stage "ripe", but not "running". The subsequent recoveries of tags (Figure 3) indicated that while the majority of tags were recovered in the environs of the Bay of Fundy, almost an equal proportion of the tagged fish moved east and west to overwinter. In August-September, 1977, the experiment was repeated, except that on this occasion the majority of the herring tagged were in the sexual maturity stage "ripe and running". A total of 54,266 fish were tagged. The subsequent recoveries from this tagging study (Figure 4) indicated a somewhat different picture of movement. Again, the majority of tags were recovered in the environs of the Bay of Fundy. However on this occasion a much larger proportion of the tagged fish moved east than west, to overwinter.

In comparison (Table 1a), in the 1974 study, 14.0% and 15.5% of the tag recoveries were made in NAFO Subareas 5-6 and Subdivision 4RVW respectively, while in the 1977 study the comparable percentages were 6.0% and 40.9%. When the recoveries made in the Bay of Fundy environs (4X) were excluded (Table 1b), the differences between the results is further emphasized. The recoveries in Subareas 5-6 were 47.4% from the 1974 study, but only 12.8% from the 1977 study.

The differing results of the two studies, in conjunction with the information on stage of sexual maturity, has led to the hypothesis that during the feeding and pre-spawning period, the Bay of Fundy has a large admixture of Gulf of Maine and Scotian Shelf stocks. As the fish near the "ripe and running" sexual maturity stage they begin to segregate. The Gulf of Maine herring move westward towards their spawning grounds. The Subdivision 4WX herring stay in the southwest Nova Scotia area to spawn, and subsequently move eastward to overwinter. The fact that a proportion of the fish tagged in 1977 still moved westward may mean that Gulf of Maine fish were still in the area at time of spawning for southwest Nova Scotia fish and further illustrates the complexity of the stock interrelationships.

Another example of the complexity of the stock interrelationships are the results of 3 tagging studies conducted in Sydney Bight on overwintering, adult herring. The distributions of recoveries for the 3 years are shown in Figures 5, 6, 7, and summarized in Tables 2a and 2b. In

the 3 successive years of the tagging study, the fishery moved progressively northward; thus so did the tagging operations. In 1977, the fishery was concentrated close inshore with the majority of the catch being taken in the southern area. In 1978, the majority of the catch was taken further offshore and more to the southwest of the Subdivision 4Vn area. In 1979/80, the fishery was concentrated even further to the north and northwest.

The distribution of tag recoveries exhibit a similar movement, with an increasing proportion of tags being recovered to the north and northwest. The majority of recoveries from the 1978 and 1979/80 tagging studies were made in the area of tagging, 4Vn. It is interesting, however, that a greater proportion of tags from the 1977 study were recovered southwest of 4Vn than in 4Vn; a large proportion of these being taken in the Chedabucto Bay fishery of the same winter. These data do indicate a large movement of inshore fish to the southwest during winter. Nevertheless, the proportion of the total tag recoveries taken to the southwest, decreases from 80% in 1977 to only 5.8% in 1979/80 while the proportion taken to the north and northwest increases from 2.5% to 10.0%. Excluding the numbers of tags recovered in Subdivision 4Vn, the change is from 97.0% to 36.7% and 3.0% to 63.4% for the southwest verses north/northwest respectively.

In this case, the differing results of the 3 studies, along with detailed knowledge of relatively small scale changes in the geographic distribution of the fishery, has led to the hypothesis that the Subdivision 4Vn area is an overwintering area for several stocks. It is now believed that some proportion of stocks of herring from NAFO Subdivisions 4T, 4V, and 4WX overwinter and intermix in the Subdivision 4Vn area; those in the northern part largely belong to Subdivision 4T, those in the southern part largely belong to Subdivision 4WX stocks, and the Subdivision 4Vn "local" stocks mix throughout. The consequence of this complexity has resulted in a biological recommendation to close the overwntering fishery in Subdivison 4Vn, thus restricting exploitation of these stocks to their summer distributions.

The examples presented above of the results of tagging studies of the southwest Nova Scotia stock complex and the Sydney Bight complex illustrate the necessity for detailed knowledge of the fisheries and biological status of the fish. Tagging studies must be replicated and the results

interpreted in the light of such knowledge.

Homing in Herring

As mentioned above, little documentation exists to entrench the idea that herring undertake definite migration patterns (ie. are capable of homing). Results of tagging studies, as those shown above, upon simplistic interpretation could indicate random movement. However, such an interpretation does not correlate well with the existence of discrete spawning beds and highly discrete and predictable fisheries, of a fairly stable magnitude, over long time periods.

In an attempt to address the issue of homing, the recovery results of the 1974 and 1977 tagging studies in southwest Nova Scotia and those in 1977 and 1978 in Chedabucto Bay are summarized. The geographic distributions of the recoveries are presented for each successive summer (June-October period) and winter (November to March period) after release. The results from the southwest Nova Scotia studies are given in Figures 8 and 9 and Table 3a. As can be seen from the distribution of summer recoveries (Figure 8), the majority of recoveries in successive summers following release are in the Bay of Fundy environs which is the feeding and pre-spawning area for the southwest Nova Scotia fish. In the 1st summer after release, 94.0% of the recoveries were made in the Bay of Fundy environs and 78.8% were made in the area of release, off southwest Nova Scotia (Table 3a). In subsequent summers between 70% and 100% of the recoveries were made in the Bay of Fundy environs with 29% to 50% being made in the area of release, off southwest Nova Scotia. The winter recoveries show a consistent pattern of movement year after year with the greatest proportion of recoveries (71-86%) being made in the Chedabucto Bay area. Considering that the 1974 tagging study off southwest Nova Scotia was on a pre-spawning aggregation of Gulf of Maine and southwest Nova Scotia stocks, the tendency for the tagged fish to also return to the summer feeding area appears quite strong.

The recoveries of fish tagged off Chedabucto Bay during the winter fishery in 1977 and 1978 (Figures 10 and 11) again indicate a tendency for herring to maintain a consistent migration pattern from year to year. During the 1st and 2nd winters after tagging, over 93% of the recoveries were made off eastern Nova Scotia, with over 58% being taken in the area of release (Table 3b). The summer distributions indicate a consistent major

movement (over 85% of all recoveries) into the Bay of Fundy area during the 2 successive summers (Table 3b). There is only a very limited movement into the Gulf of Maine area.

The data presented above suggest that between 70-100% ($\bar{X}$ = 88.9%) of the fish off southwest Nova Scotia in summer will return to the Bay of Fundy environs in successive years and that between 71-86% ($\bar{X}$ 78.6%) of these fish overwinter in the Chedabucto Bay area. The results from the tagging studies off Chedabucto Bay suggest that between 85-90% ($\bar{X}$ = 87.5%) of these fish use the Bay of Fundy area as a feeding and spawning area. These results suggest that homing does occur in herring and that they do maintain a consistent migratory pattern.

Table 1a. Comparison of recovery rates by NAFO Subareas/Subdivisions from the 1974 and 1977 southwest Nova Scotia tagging studies. Recovery numbers exclude those made within 2 weeks of release; percentages given in parentheses.

Year	Number Tagged	Recoveries by Region			
		Total	SA 5-6	4X	4RVW
1974	23938	393 (1.6)	55 (14.0)	277 (70.5)	61 (15.5)
1977	54266	750 (1.4)	45 (6.0)	398 (53.1)	307 (40.9)

Table 1b. Comparison of recovery rates from the 1974 and 1977 southwest Nova Scotia tagging studies considering only recoveries made outside of NAFO Subdivision 4X.

Year	Recoveries Outside NAFO Subdivision 4X		
	Total	SA 5-6	4RVW
1974	116	55 (47.4%)	61 (52.6%)
1977	352	45 (12.8%)	307 (87.2%)

Table 2a. Comparison of recovery rates by NAFO Subdivision from the tagging studies in Sydney Bight 1977-1980. Recovery numbers exclude those made within 2 weeks of release; percentages given in parentheses.

Year	Number Tagged	Recoveries by Region			
		Total	4WX	4Vn	4RT
1977	3082	120 (3.9)	96 (80.0)	21 (17.5)	3 (2.5)
1978	3994	147 (3.7)	25 (17.0)	106 (72.1)	16 (10.9)
1979/80	10585	451 (4.3)	26 (5.8)	380 (84.3)	45 (10.0)

Table 2b. Comparison of recovery rates from the Sydney Bight tagging studies, 1977-1980, considering only recoveries made outside of NAFO Subdivision 4Vn.

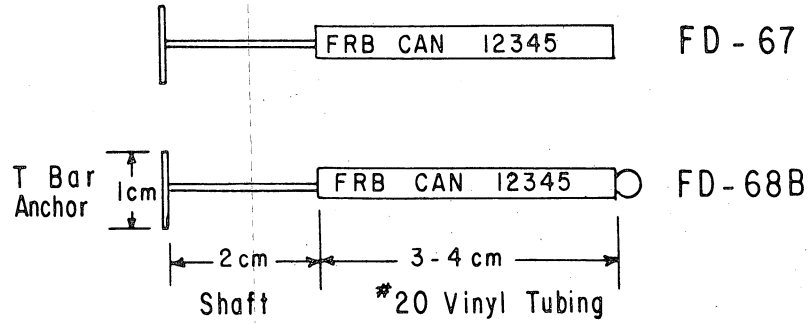
Year	Recoveries Outside NAFO Subdivision 4Vn		
	Total	4WX	4RT
1977	99	96 (97.0%)	3 (3.0%)
1978	41	25 (61.0%)	16 (39.0%)
1979/80	71	26 (36.7%)	45 (63.4%)

Table 3a. Comparison of distribution of recoveries by NAFO Subdivision, from the 1974 and 1977 southwest Nova Scotia tagging studies for each summer (June-October) and winter (November-March) after release. Percentages given in parentheses. The percentage of total recoveries recovered in the area of tagging also given in parentheses.

Season of Recovery	Recoveries by Region			
	Total	SA 5-6	4X	4RVW
1st Summer	401	13 (3.2)	377 (94.0(78.8))	11 (2.7)
2nd Summer	51	13 (25.0)	36 (70.6(41.2))	2 (3.9)
3rd Summer	22	2 (9.1)	20 (90.9(54.6))	0
4th-7th Summer	7	0	7(100.0(28.6))	0
1st Winter	363	44 (12.1)	12 (3.3(0))	307 (84.6)
2nd Winter	42	7 (16.7)	5 (11.9(0))	30 (71.4)
3rd Winter	11	0	3 (27.3(0))	8 (72.7)
4th-7th Winter	7	0	1 (14.3(0))	6 (85.7)

Table 3b. Comparison of distribution of recoveries by NAFO Subdivision from the 1977 and 1978 tagging studies off the Chedabucto Bay area (NAFO Subdivision 4W) for each summer (June-October) and winter (November-March) after release. Percentages are given in parentheses.

Season of Recovery	Recoveries by Region				
	Total	SA 5-6	4X	4W	4RTV
1st Winter	57	3 (5.3)	1 (1.2)	38 (66.7)	15 (26.3)
2nd Winter	12	0	0	7 (58.3)	5 (41.7)
1st Summer	135	4 (3.0)	121 (89.6)	5 (3.7)	5 (3.7)
2nd Summer	34	1 (2.9)	29 (85.3)	4 (11.8)	0
3rd Summer	1	0	0	1 (100.0)	0



Two types of anchor tags currently being used to tag herring.

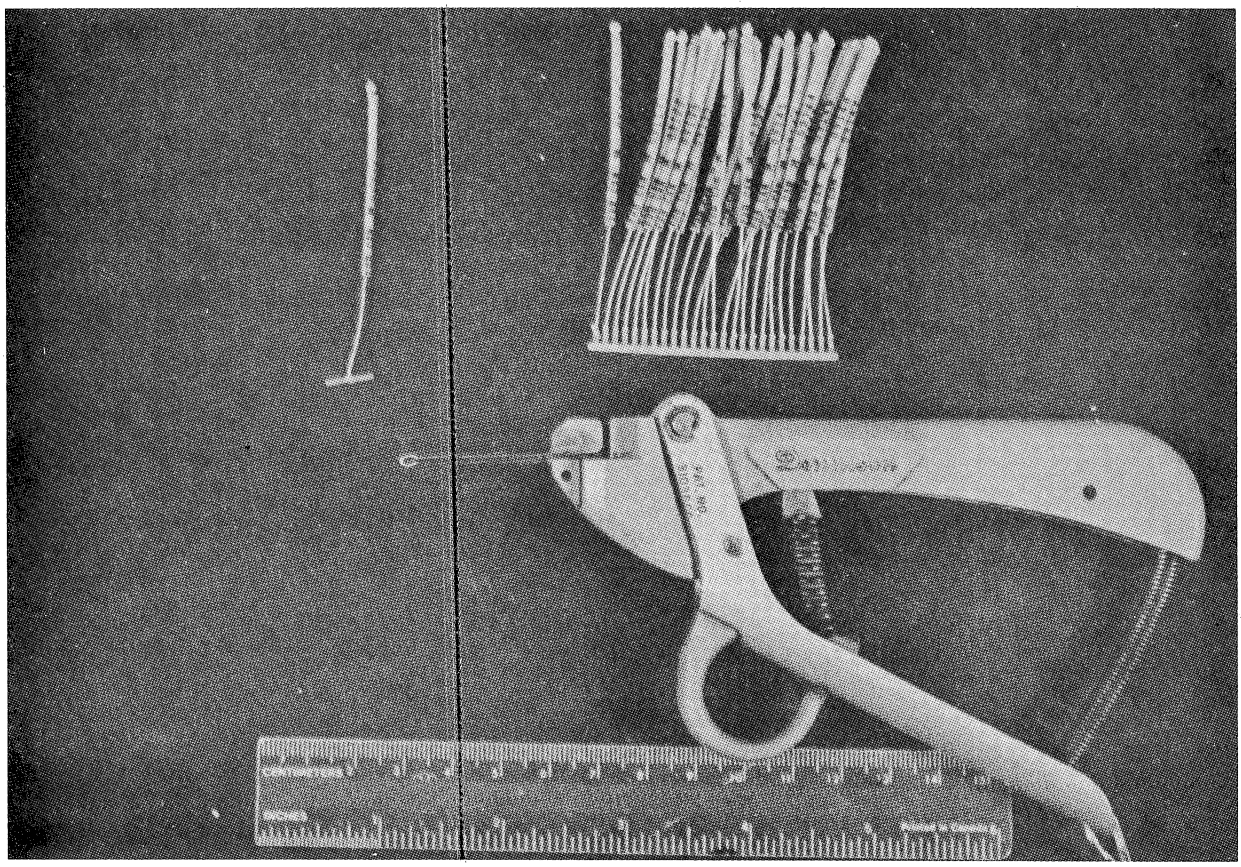


Fig. 1. Tagging gun and cartridge of FD-68B tags. A single tag is also shown. The cartridge fits into the gun just posterior to the hollow slotted needle

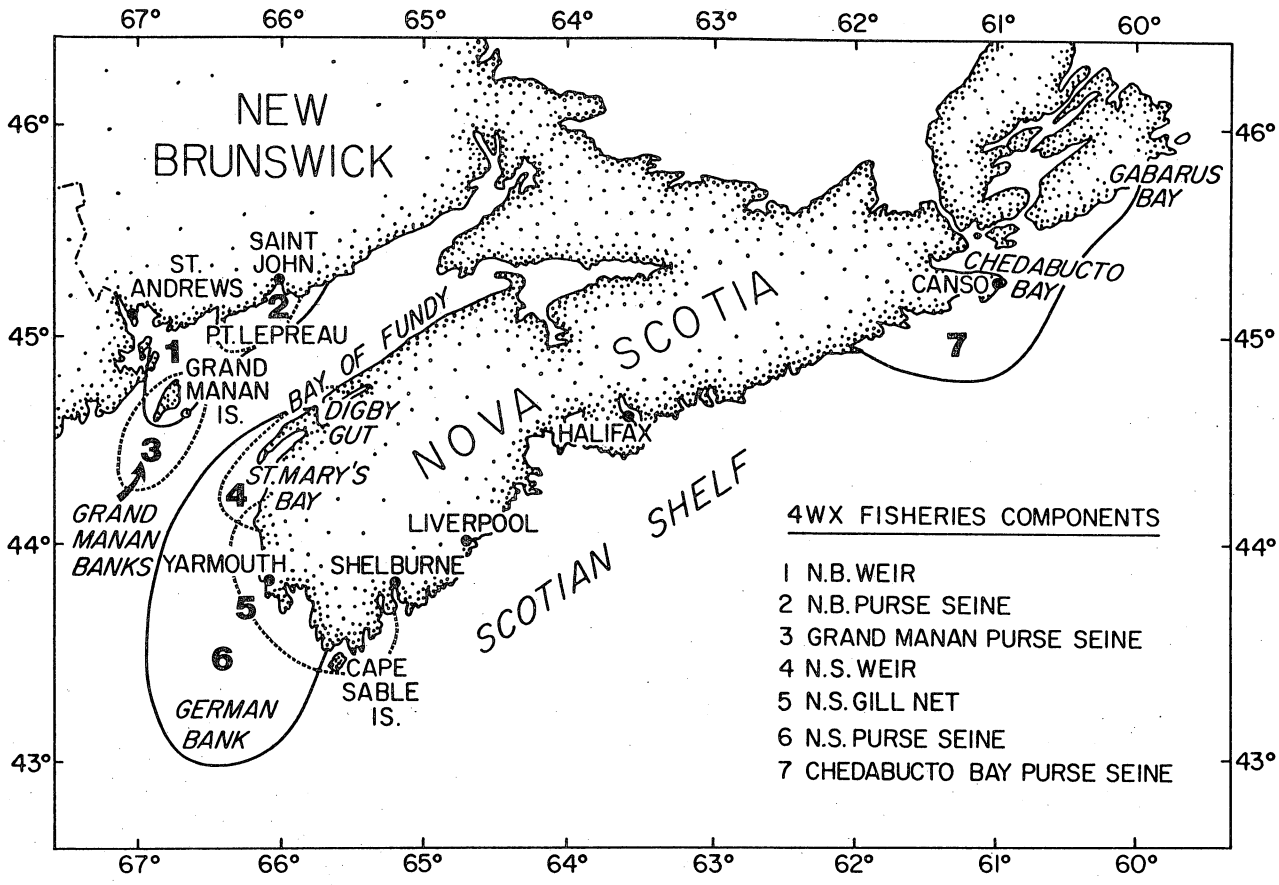


Figure 2. Map showing the geographic locations of herring fisheries associated with the southwest Nova Scotia herring stock complex.

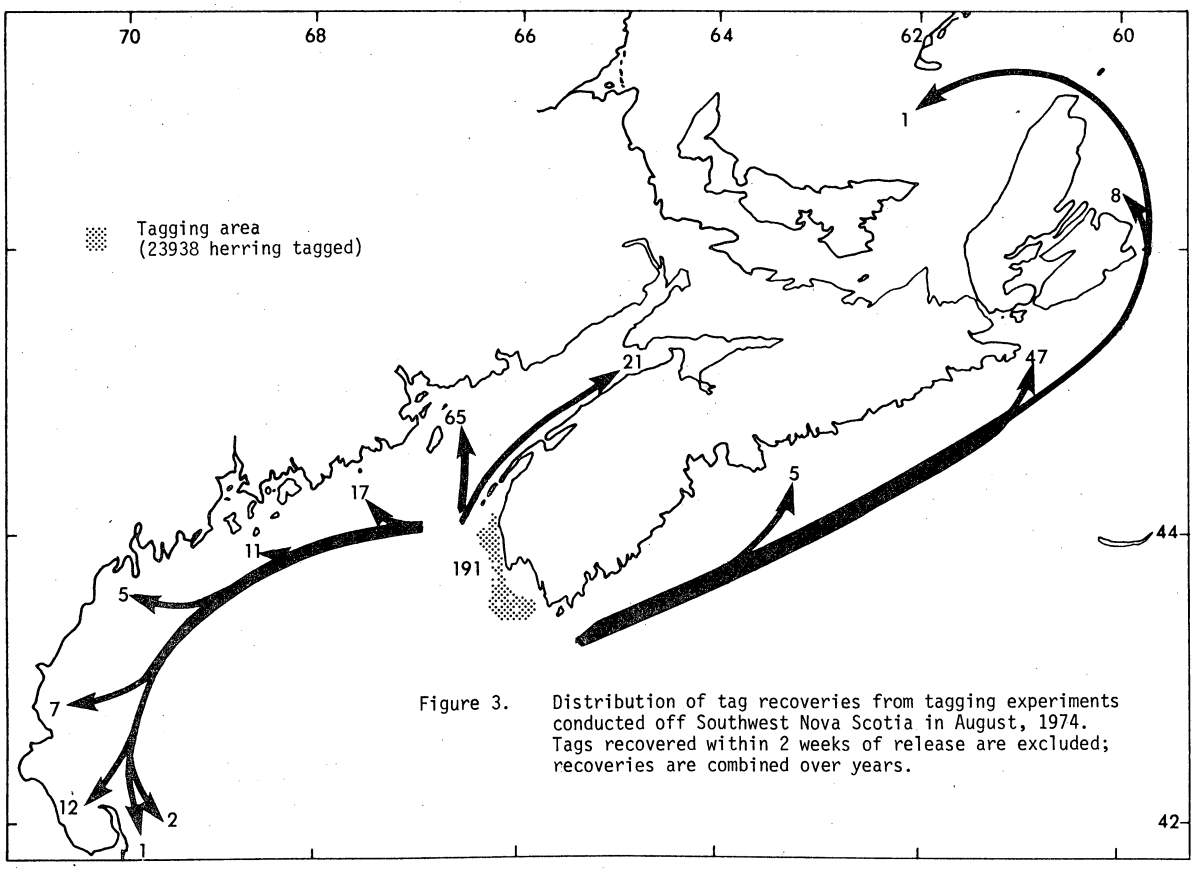


Figure 3. Distribution of tag recoveries from tagging experiments conducted off Southwest Nova Scotia in August, 1974. Tags recovered within 2 weeks of release are excluded; recoveries are combined over years.

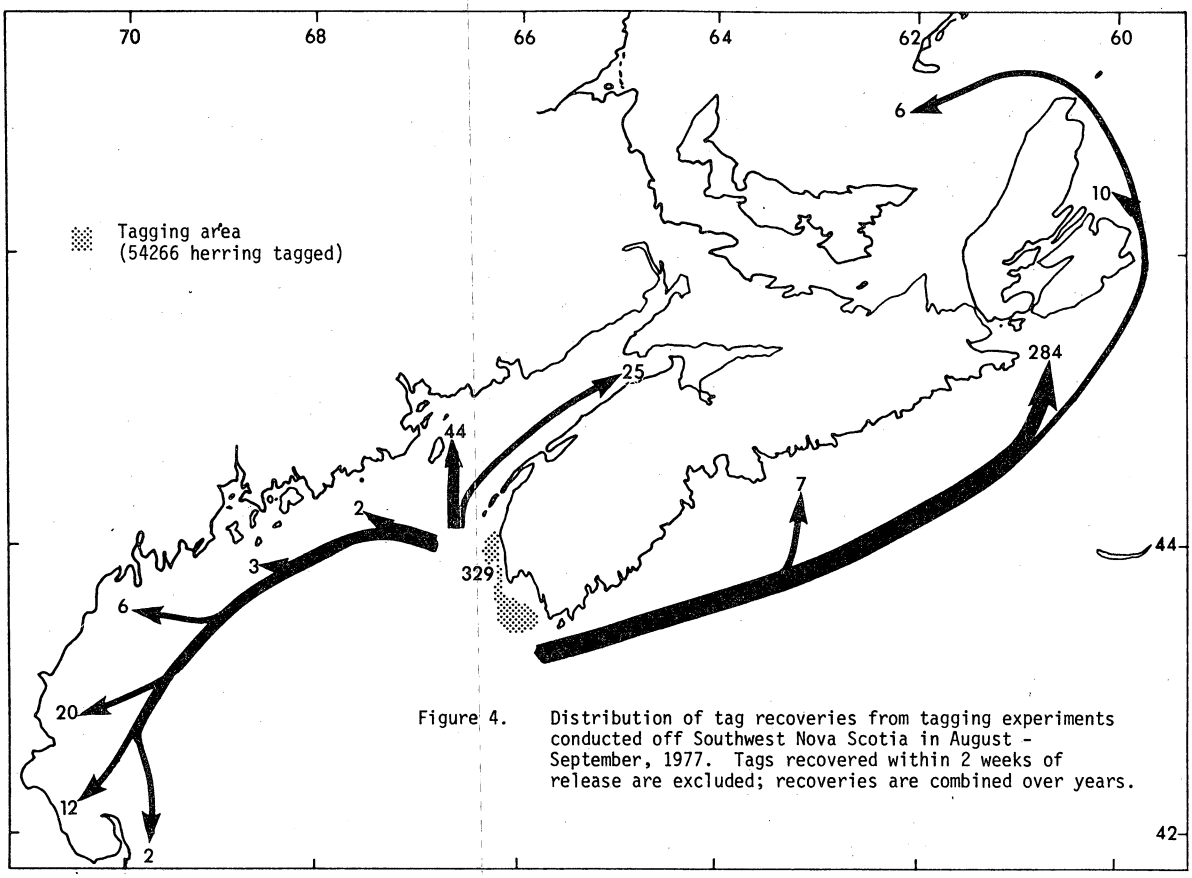


Figure 4. Distribution of tag recoveries from tagging experiments conducted off Southwest Nova Scotia in August - September, 1977. Tags recovered within 2 weeks of release are excluded; recoveries are combined over years.

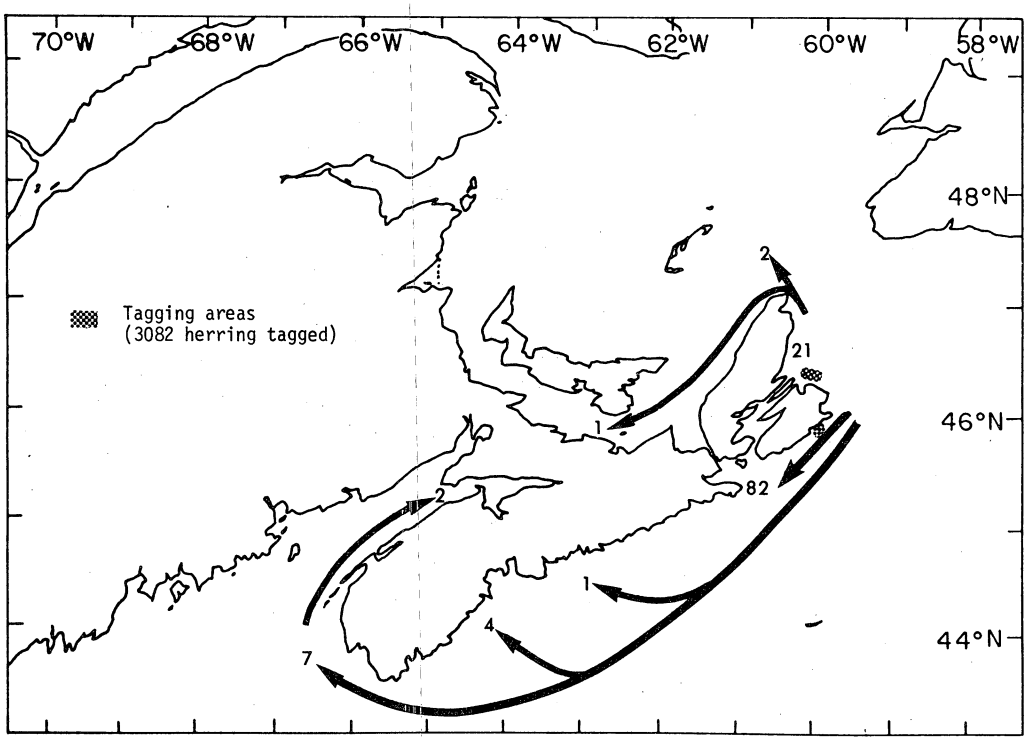


Figure 5. Distribution of tag recoveries from tagging experiments conducted in Sydney Bight in November - December, 1977. Tags recovered within 2 weeks of release are excluded; recoveries are combined over years.

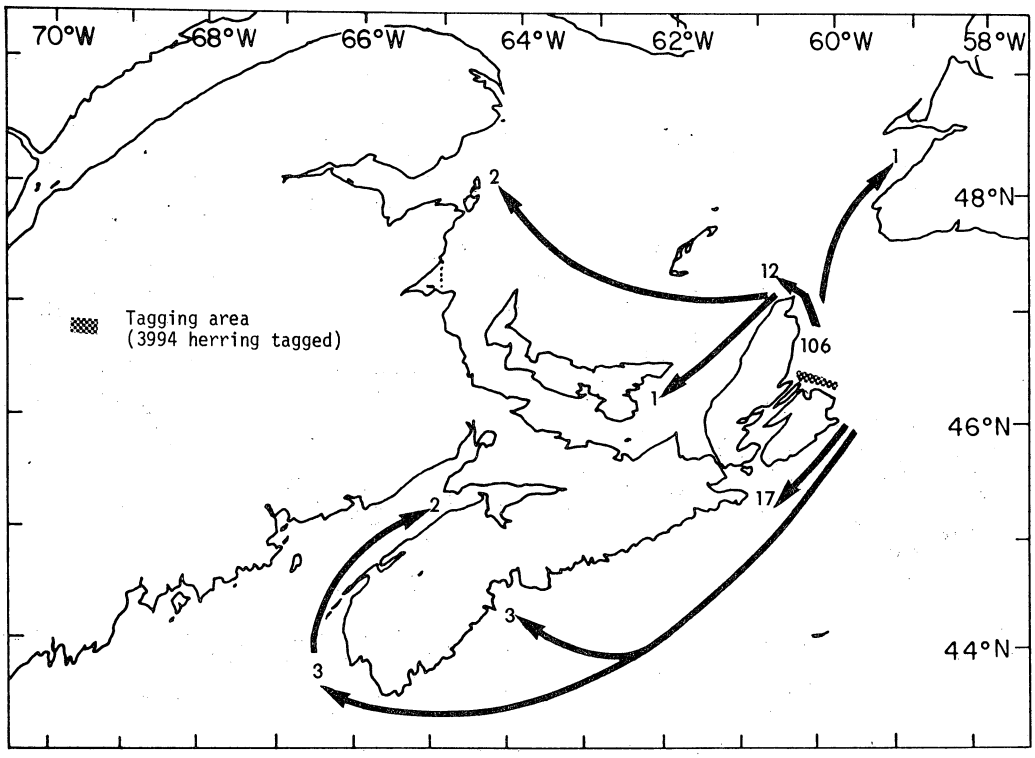


Figure 6. Distribution of tag recoveries from tagging experiments conducted in Sydney Bight in November, 1978. Tags recovered within 2 weeks of release are excluded; recoveries are combined over years.

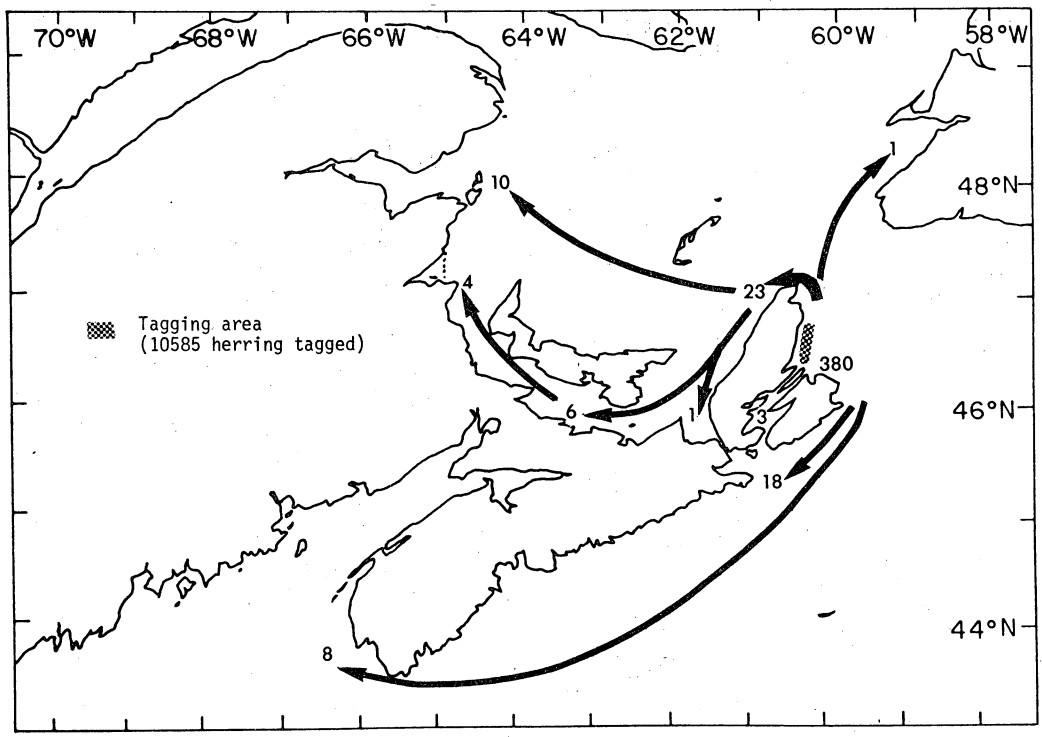


Figure 7. Distribution of tag recoveries from tagging experiments conducted in Sydney Bight in December, 1979 and January, 1980. Tags recovered within 2 weeks of release are excluded; recoveries are combined over years.

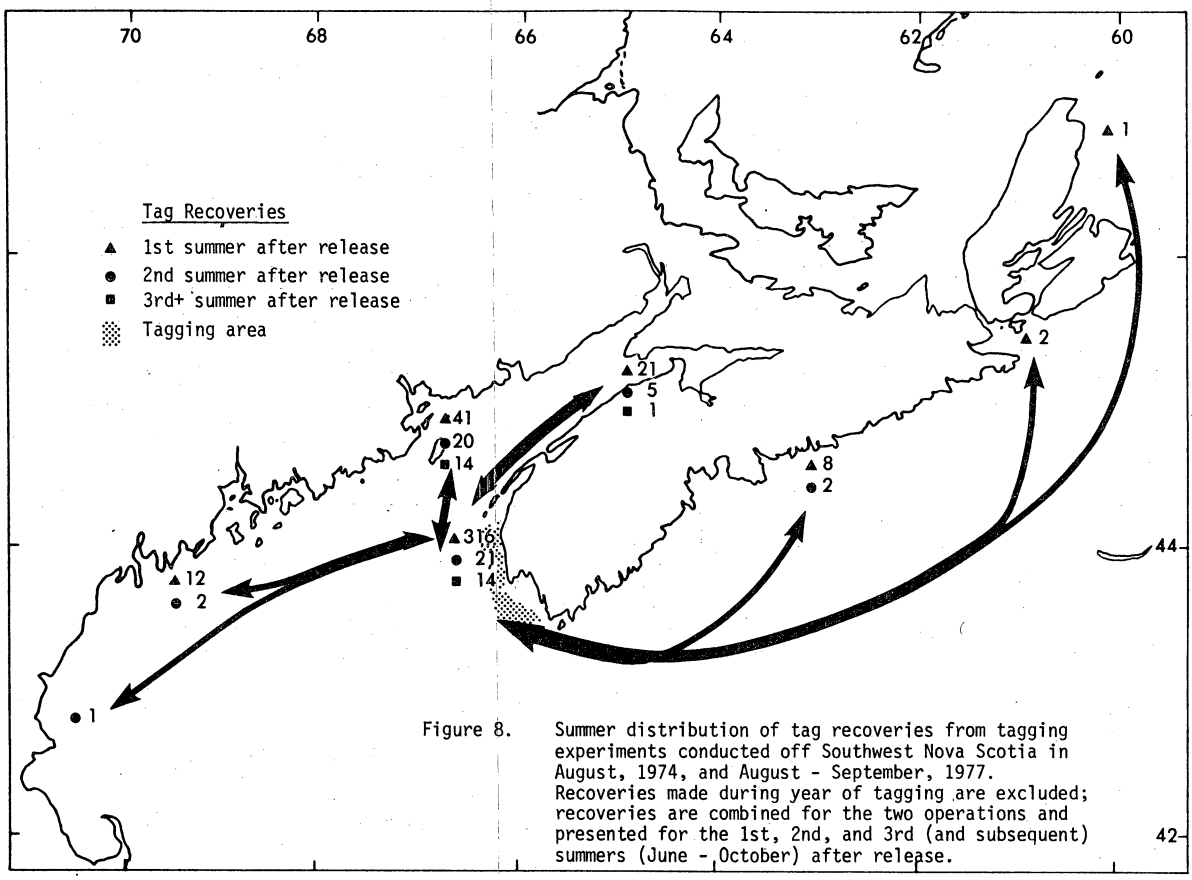


Figure 8. Summer distribution of tag recoveries from tagging experiments conducted off Southwest Nova Scotia in August, 1974, and August - September, 1977. Recoveries made during year of tagging are excluded; recoveries are combined for the two operations and presented for the 1st, 2nd, and 3rd (and subsequent) summers (June - October) after release.

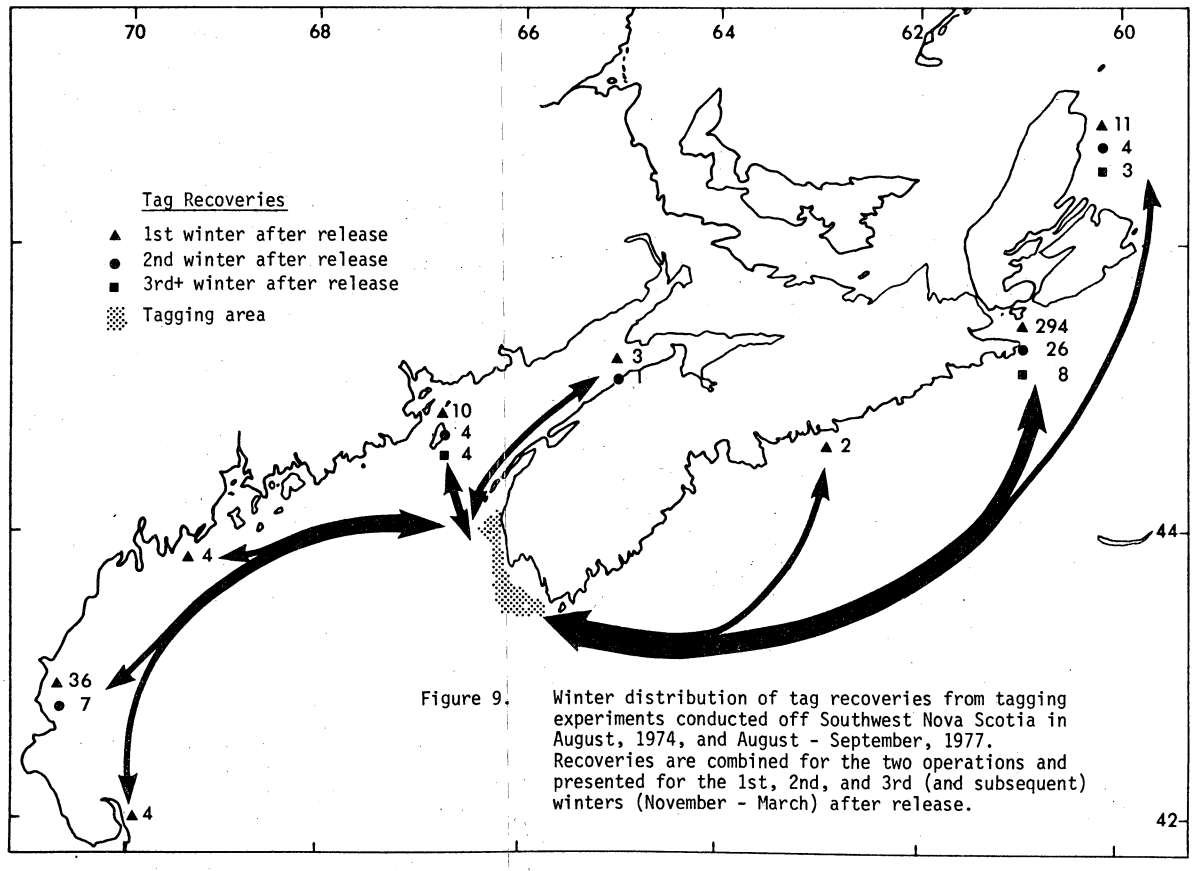


Figure 9. Winter distribution of tag recoveries from tagging experiments conducted off Southwest Nova Scotia in August, 1974, and August - September, 1977. Recoveries are combined for the two operations and presented for the 1st, 2nd, and 3rd (and subsequent) winters (November - March) after release.

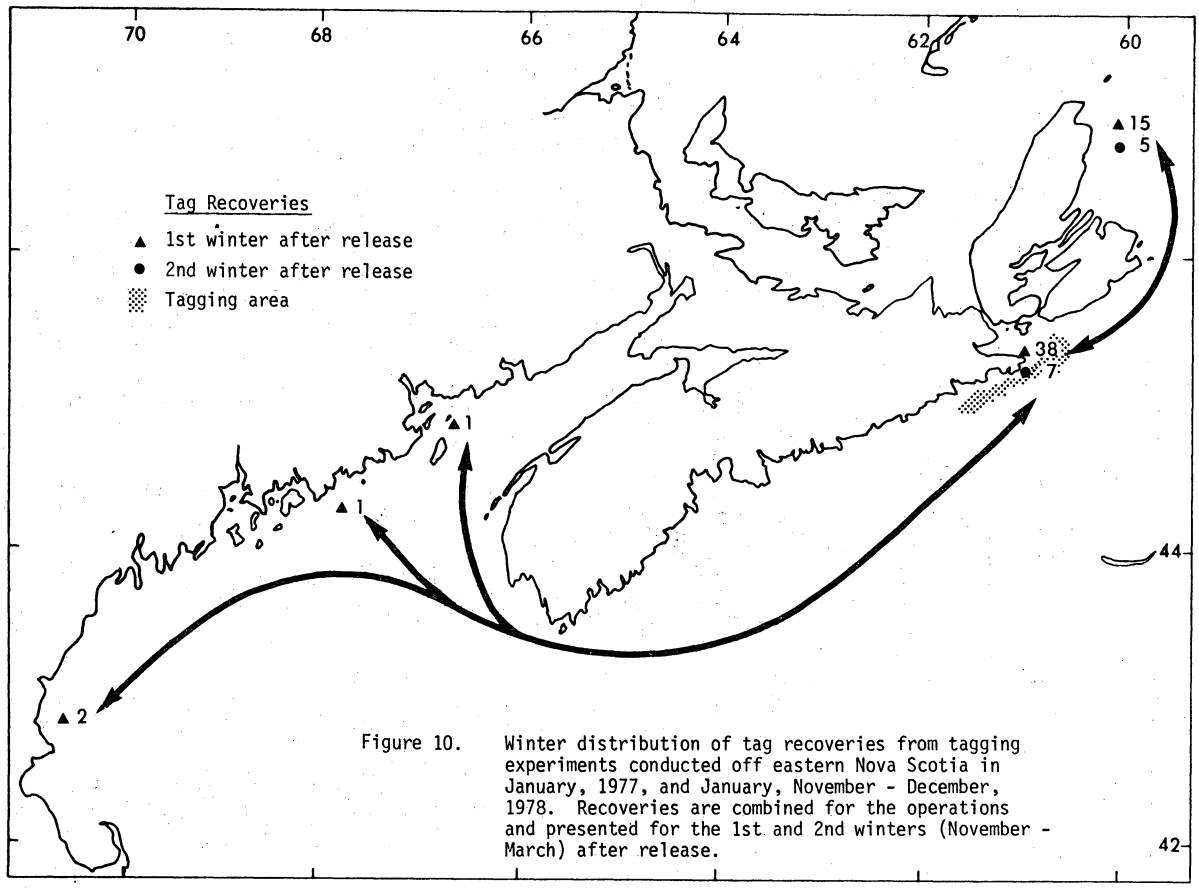


Figure 10. Winter distribution of tag recoveries from tagging experiments conducted off eastern Nova Scotia in January, 1977, and January, November - December, 1978. Recoveries are combined for the operations and presented for the 1st and 2nd winters (November - March) after release.

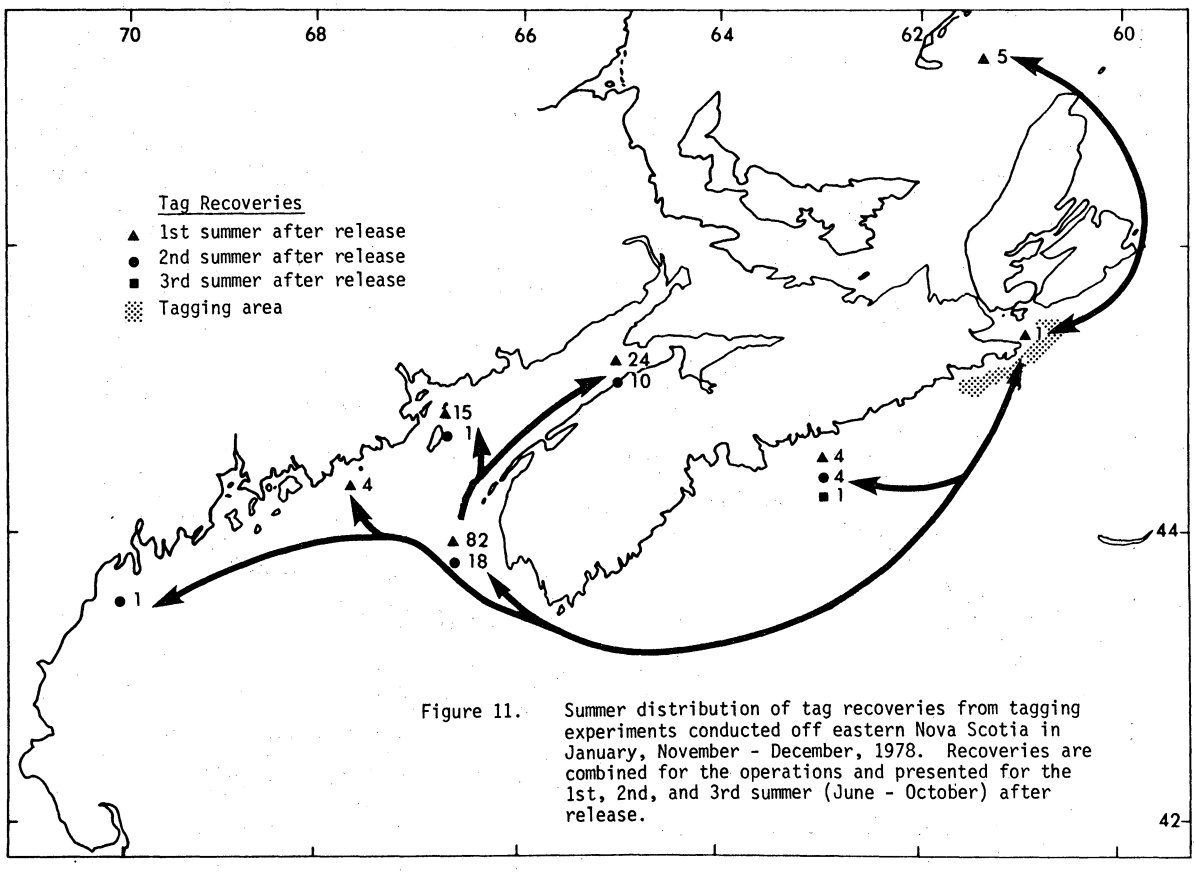


Figure 11. Summer distribution of tag recoveries from tagging experiments conducted off eastern Nova Scotia in January, November - December, 1978. Recoveries are combined for the operations and presented for the 1st, 2nd, and 3rd summer (June - October) after release.

APPENDIX

Table 1. Summary of tag recoveries from tagging experiments conducted off southwest Nova Scotia in August, 1974, and August-September, 1977. Recoveries combined over years.

		RECOVERIES BY REGION														
Year	No. Tagged	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1974	23938	1	2	12	7	5	11	17	-	21	65	191	5	47	8	1
1975	54266	2	-	12	20	6	3	2	-	25	44	329	7	284	10	6

Table 2. Summary of tag recoveries from tagging experiments conducted in Sydney Bight in November-December, 1977, November, 1978, and December, 1979 - January, 1980. Recoveries are combined over years.

		RECOVERIES BY REGION														
Year	No. Tagged	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1977	3082	-	-	-	-	-	-	-	-	2	-	7	5	82	21	3
1978	3994	-	-	-	-	-	-	-	-	2	-	3	3	17	106	16
1979/80	10585	-	-	-	-	-	-	-	-	-	-	8	-	18*	380*	45

* 3 tags recovered in Bras d'Or Lakes connecting areas 13 and 14 not included although fisheries information suggests the movement would be from the northern end.

Table 3. Summary of tag recoveries from tagging experiments conducted off southwest Nova Scotia in August, 1974, and August - September, 1977. The data are grouped into recoveries made during the 1st to 7th (5th-7th combined) summers and winters after release.

	RECOVERIES BY REGION														
Season of Recovery After Release	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1st Summer	-	-	-	-	6	6	1	-	21	40	316	8	2	-	1
2nd Summer	-	-	1	-	2	-	10	-	5	10	21	2	-	-	-
3rd Summer	-	-	-	-	-	-	2	-	-	8	12	-	-	-	-
4th Summer	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-
5th-7th Summer	-	-	-	-	-	-	-	-	-	2	2	-	-	-	-
1st Winter	3	1	13	23	2	2	1	-	3	9	-	2	294	10	1
2nd Winter	-	-	5	2	-	-	-	-	1	4	-	-	26	4	-
3rd Winter	-	-	-	-	-	-	-	-	-	3	-	-	5	-	-
4th Winter	-	-	-	-	-	-	-	-	-	1	-	-	2	1	-
5th-7th Winter	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-

Table 4. Summary of tag recoveries from tagging experiments conducted off eastern Nova Scotia in January, 1977, and January, November - December, 1978. The data are grouped into recoveries made during the 1st-3rd summers and winters after release.

	RECOVERIES BY REGION														
Season of Recovery After Release	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1st Winter	-	-	-	2	-	-	1	-	-	1	-	-	38	11	4
2nd Winter	-	-	-	-	-	-	-	-	-	-	-	-	7	5	-
1st Summer	-	-	-	-	-	-	4	-	24	15	82	4	1	-	5
2nd Summer	-	-	-	-	1	-	-	-	10	1	18	4	-	-	-
3rd Summer	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-

APPENDIX

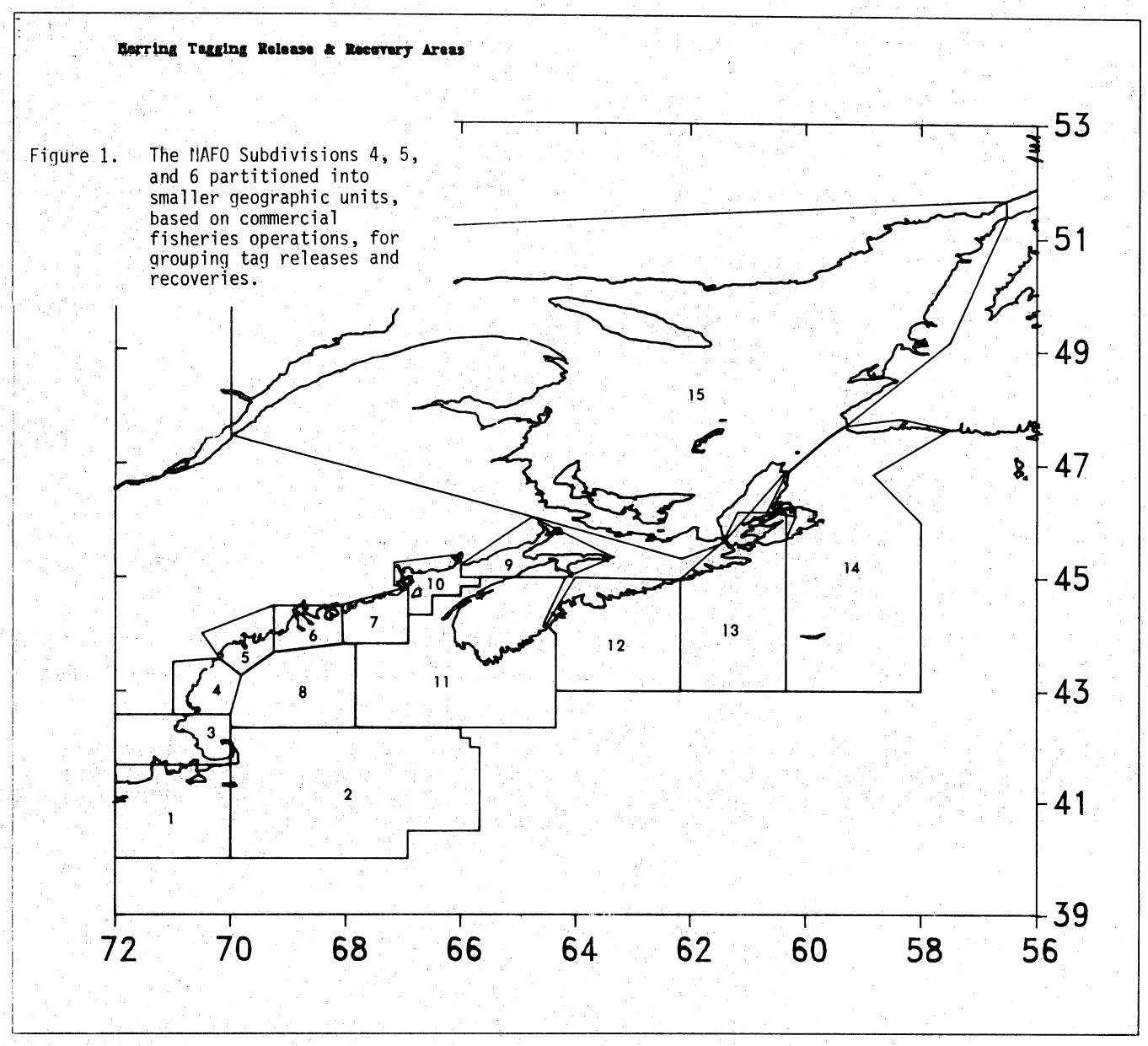


Figure 1. The NAFO Subdivisions 4, 5, and 6 partitioned into smaller geographic units, based on commercial fisheries operations, for grouping tag releases and recoveries.