

Seasonal Movements of Juvenile and Adult Herring, *Clupea harengus* L., Tagged Along the Maine Coast

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Abstract

Juvenile and adult herring tagged along the Maine coast in 1976-78 exhibited migration patterns which varied with season and region in which they were tagged. Some of the herring tagged as summer-feeding juveniles in southwestern Maine overwintered in the region of Massachusetts Bay, whereas juveniles tagged at the same time in eastern Maine had a greater tendency to overwinter in eastern Maine. Many of the herring tagged as summer-feeding adults in eastern Maine also overwintered in Massachusetts Bay. Recoveries from these tagging of adults one year after release were generally distributed over many regions, whereas returns from tagging of juveniles were distributed among fewer regions. Recoveries from tagging of juveniles on the southwest and central coast of Maine one year after release were frequently from more easterly regions but recoveries from adults and juveniles tagged in eastern Maine were frequently from the same general area. Herring tagged as overwintering juveniles in eastern and western Maine remain in close proximity to the area where they were tagged throughout the following summer. The occurrence of a relatively large percentage of prespawning and postspawning adult herring in eastern Maine supports the belief that this area is an important spawning ground. The extremes in movement of herring reported in this study are from Point Judith, Rhode Island, to Sydney Bight, Nova Scotia.

Introduction

Several previous tagging studies on the movements of juvenile and adult herring have been conducted in the Gulf of Maine. A joint study by the United States Bureau of Commercial Fisheries and the Fisheries Research Board of Canada (McKenzie and Skud, 1958; McKenzie and Tibbo, 1961) resulted in the release of 137,469 tagged juvenile herring in Passamaquoddy Bay and other sites during 1957-58. These taggings were hampered by poor retention of the celluloid operculum tags, high handling mortality, and non-reporting of tags (Sindermann, MS 1979). Watson (1963) tagged 8,300 juvenile herring along the Maine coast during 1960. These fish were tagged with yellow PVC (polyvinylchloride) spaghetti tags (1.3 mm diameter x 50 mm length) which were sewn and looped through the anterior dorsal musculature. Limited movements and short-term recoveries were reported for both of these initial studies. Herring tagged with yellow T-bar spaghetti tags (Floy FD-68) in the Bay of Fundy at Grand Manan Island and Campobello Island, New Brunswick, and off southwest Nova Scotia (Stobo *et al.*, MS 1975; Stobo, MS 1976) resulted in recoveries in the coastal waters from Maine to Rhode Island, as the fish moved to and from their overwintering areas. The westward movement to overwintering areas indicated substantial intermixing of herring of different stocks. The results of international herring tagging studies on Jeffreys Ledge and in the Great South Channel, reported by Almeida and Burns (MS 1978) and Waring (MS 1981), also showed that adults tagged with T-bar spaghetti tags in May 1977 moved from the tagging sites to the coastal waters of Maine and the Bay of Fundy during summer and early autumn and

returned to Massachusetts and Rhode Island coastal waters in late autumn and winter.

The present study was conducted by scientists of the Maine Department of Marine Resources during 1976-78 when 57,887 adult and juvenile herring were tagged and released at 34 sites along the Maine coast. The objectives of this study were to investigate (a) long-term migration patterns of juvenile and adult herring, (b) the extent of their movement to Canadian and Massachusetts waters, and (c) the occurrence in other geographical areas (fisheries) of adults tagged in Maine coastal waters.

Materials and Methods

Tagging procedures

The procedures used in locating, holding and marking herring were similar for all taggings. Information on the location of stop seine, purse seine and weir catches was obtained from herring processing facilities. Tagging personnel were stationed on board purse seiners so that they were on site when a school of fish was captured. Herring were dipped from the seine pocket, placed in large fiberglass tanks located on deck, tagged and released directly from these tanks. Fish were removed from stop seine and weir catches by submerging the floats of the pursuing net and allowing the fish to swim into the holding pocket or, more commonly, by bailing them into the holding pocket with dipnets. The holding pocket was 3.7 m diameter and 2.4 m deep. Herring used in all tagging operations were obtained prior to being concentrated tightly within the pursuing net. The holding pocket containing fish was

towed as far away from the fishing activity as practical and positioned next to the anchored tagging boat. Herring were dipped from the holding pocket and held within the partially submerged dipnet while tagging was performed. The 4-m Boston Whaler used in all stop-seine and weir tagging operations was ideally suited for the purpose; it was very stable and maneuverable, and its low sides enabled the tagging crew to kneel in close proximity to the holding net while tagging. Most of the fish tagged had little or no scale loss. The inverse relationship between scale loss and tag return rate is well known (Jensen, 1955).

Juvenile and adult herring were tagged with Floy FD-67 yellow T-bar spaghetti tags, which were constructed from sections of labelled PVC tubing (2 mm diameter x 32-38 mm long) connected to nylon monofilaments (20-25 mm long) with a T-bar at the distal end. Tags were attached to the fish by means of Floy FDM-68 tagging guns equipped with stainless steel needles (1.9-2.2 mm outside diameter), which were inserted through the anterior dorsal musculature diagonally between the interneural bones near the base of

the dorsal fin. Dell (1968) described the use of these guns for tagging fish. Each tagger was responsible for dipping, holding and tagging his own fish.

An attempt was made to tag herring at as many different locations as possible in Maine (Fig. 1) because little information was available on movements along the entire coast. The large number (9) of taggings in the Boothbay Harbor region occurred because of the close proximity of the Fishery Research Laboratory. Tags and information on recoveries were obtained from herring processing facilities in Massachusetts, Maine, New Brunswick and Nova Scotia. The initial reward of \$1.00 per tag in 1976 and 1977 was increased to \$3.00 in 1978. There is no evidence that the increased reward in 1978 had an effect upon the subsequent return rate of tags. Only recoveries with complete information (tag number, date and location of capture) are considered in this paper.

A sample of herring was collected during each tagging experiment and analyzed for length and age. Information on sex and maturity stage were usually

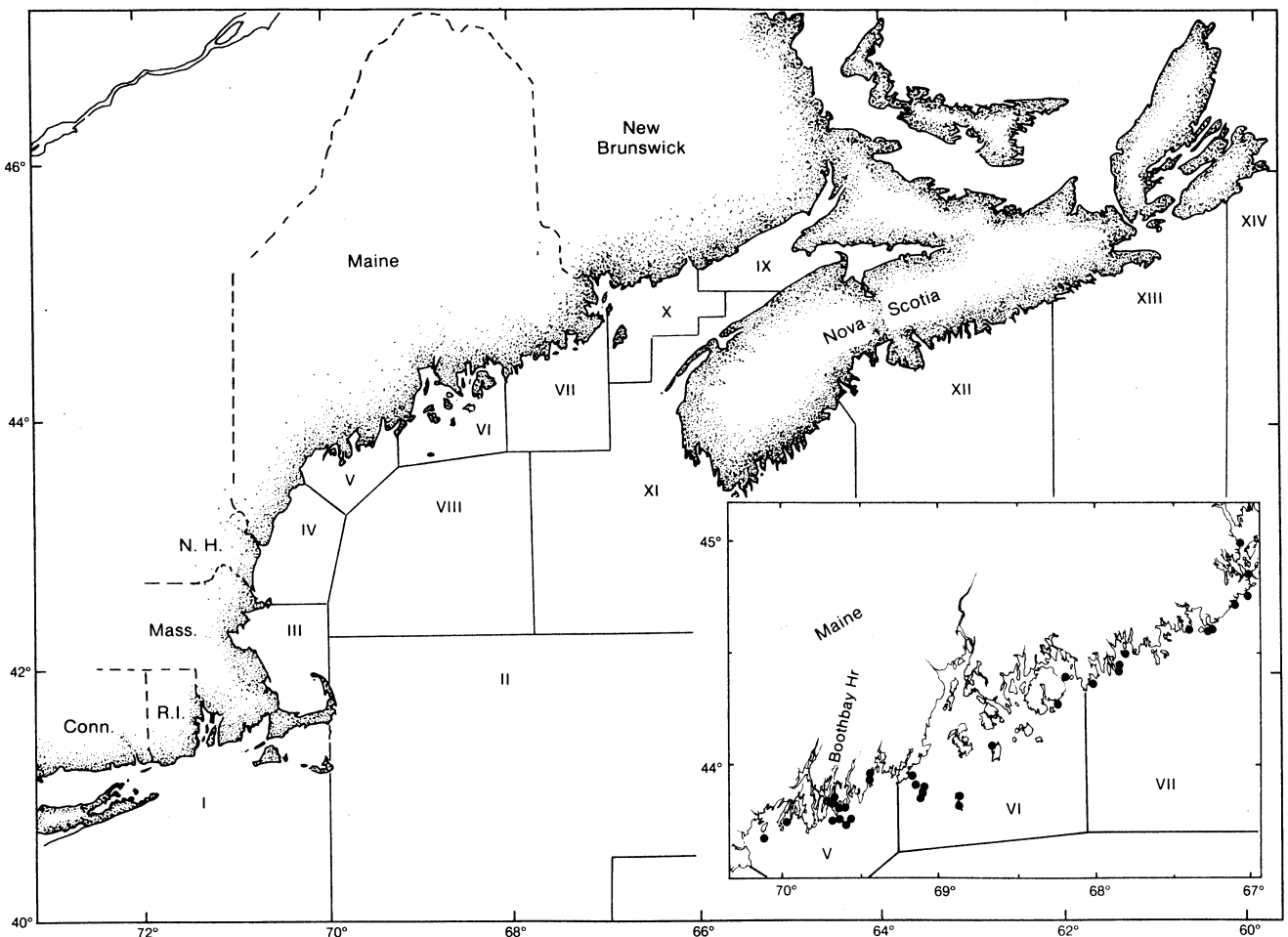


Fig. 1. Tagging locations (inset) and regions (I-XIV) established for the analysis of data on tag recoveries off the Atlantic coasts of southern Canada and northeastern United States.

collected only for fish >23 cm total length. The criteria for distinguishing the stages of sexual maturity were those for the 8 stages listed by Boyar (1968).

Analysis of tagging data

To facilitate analysis of the tag release and recovery data, the area from Cape Cod to eastern Nova Scotia was divided into 14 regions designated by roman numerals in Fig. 1. These regions were agreed upon by scientists of the U. S. National Marine Fisheries Service, Woods Hole, Mass. (regions I–VIII) and the Canadian Department of Fisheries and Oceans, Dartmouth, Nova Scotia (regions IX–XIV), for mutual convenience in the discussion of herring movements throughout the area.

Each tagging experiment was assigned to one of the following seasonal behavior categories: overwintering (concentrations of fish with limited movement during winter), spring migrating (fish which were moving from overwintering to summer-feeding areas), summer feeding (concentrations of fish with limited movement during summer), spawning (ripe and running fish in maturity stage 6), and autumn migrating (fish which were moving from summer-feeding to overwintering areas). Tag recovery data for each category and year were summarized by calendar quarter and region.

Tagged groups of fish were categorized as juveniles, adults or mixed fish on the basis of length frequency samples taken at each tagging site. Groups were considered juveniles if 85% or more were <23 cm long and adults if 85% or more were \geq 23 cm. Groups which did not fit into these categories were considered mixed.

The numbers of tag recoveries are presented as total recoveries (from the day of release) and effective recoveries (from the 15th day after release). Recaptures during the first 14 days were not considered 'effective' recoveries because the tagged fish were released in close proximity to commercial fishing operations where they were quickly vulnerable to recapture by the gear. Stobo *et al.* (MS 1975) and Stobo (MS 1982) also allowed 14 days for the tagged herring to become dispersed within the exploited populations. Winters (1977), on the other hand, reported immediate diffusion of tagged herring within the exploited populations of southwestern Newfoundland.

Results and Discussion

Length, age, sex and maturity

Length frequencies of juvenile and adult herring sampled during the tagging operations in different

regions, seasons and years are given in Table 1. Ranges of average lengths were 12.1–13.3 cm for overwintering juveniles, 16.0–20.8 cm for summer feeding juveniles, 21.1–21.2 cm for autumn-migrating juveniles, and 24.5–30.9 for summer-feeding adults. Most of the juveniles were 2-year-olds, whereas the adults ranged in age from 2 to 6+ years. The sex ratio of samples of summer-feeding adults was approximately 1:1, and the ratio of males to females for a single sample of summer-feeding juveniles was 1:2. Prespawning herring (maturity stage 5) were prevalent in samples from region V in 1978 (19%), region VI in 1978 (28%), and region VII in 1976 and 1977 (17 and 68%). Spent herring (stage 7) occurred in the samples from region VII in 1976 (23%). The occurrence of prespawning and spent herring in region VII supports the belief that this area is an important spawning ground. These results are somewhat consistent with the findings of Graham (1982) who reported increased abundance of larval herring in regions VII and X during coastal larval herring surveys.

Tag recovery rates

The majority of the herring tagged during 1976–78 belonged to the summer-feeding category (Table 2). Autumn-migrating and overwintering concentrations were frequently not available for tagging because of the great decline in fishing activity during autumn and winter. Spring-migrating fish and spawning adults were not encountered during the coastal tagging operations. About 70% of the tagging experiments involved juveniles which were most prevalent in the inshore fishery. The overall total and effective recovery rates were 7.4 and 4.4% respectively. The total and effective rates were 7.2 and 4.6% for juveniles and 5.0 and 4.2% for adults. The differences between the total and effective rates for juveniles and adults indicate that juveniles stay in the vicinity of the release area longer than adults. Other herring tagging studies, involving the use of T-bar spaghetti tags, had effective recovery rates of 1.1–7.3% (mean 2.8%) for Bay of Fundy experiments (Stobo, MS 1976), 1.4–1.6% for southwest Nova Scotia and 3.7–4.3% for Sidney Bight (Stobo, MS 1982). Total recovery rates for the same tag type were 2–3% for Newfoundland herring (McKone and Winters, MS 1976), 1.2% for herring tagged in Great South Channel and 2.7% for Jeffreys Ledge and Cape Ann experiments (Waring, MS 1981). These differences in recovery rates probably resulted from differences in fishing intensity and in tagging procedures.

Migration patterns

Recoveries from the tagging of summer-feeding juveniles in regions V, VI and VII (Table 3) show that some fish migrated southwesterly and overwintered in regions I, III and IV, where they were caught in the

TABLE 1. Length and age frequencies (numbers) and sex and maturity compositions (%) of juvenile and adult herring sampled during tagging operations in regions V-VII and X along the Maine coast in 1976-78.

	Overwintering juveniles			Summer feeding juveniles						Autumn-migrating juveniles		Summer feeding adults				
	V		X	V		VI		VII		V		V		VI		VII
	77	77	78	76	77	78	76	78	76	77	78	76	77	78	76	78
A. Length (cm) frequencies																
9	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
10	1	9	16	—	—	—	1	—	—	—	—	—	—	—	—	—
11	12	22	36	—	7	—	—	—	1	—	—	—	—	—	—	—
12	27	27	24	—	30	—	—	—	—	—	—	—	—	—	—	—
13	34	21	19	—	66	—	—	—	—	11	—	—	—	—	—	—
14	15	15	2	—	57	—	1	—	4	45	—	—	—	—	—	—
15	8	5	1	1	55	1	5	6	8	53	1	—	—	—	—	—
16	2	—	1	—	60	5	22	12	30	37	6	—	1	—	—	—
17	1	1	—	—	70	10	67	13	18	29	6	1	2	—	2	—
18	—	—	—	—	57	22	70	12	17	13	9	2	8	—	—	—
19	—	—	—	4	32	39	92	5	14	8	13	6	17	—	—	—
20	—	—	—	19	30	25	93	1	3	3	10	30	17	1	—	1
21	—	—	—	18	19	19	25	1	—	1	5	35	24	—	4	—
22	—	—	—	3	5	16	11	—	—	—	—	14	17	—	5	—
23	—	—	—	1	5	7	6	—	—	—	—	5	8	—	14	2
24	—	—	—	—	4	1	4	—	1	—	—	3	4	1	10	—
25	—	—	—	—	3	1	—	—	—	—	—	1	1	3	19	10
26	—	—	—	—	—	3	—	—	1	—	—	—	1	5	13	38
27	—	—	—	—	—	1	—	—	2	—	—	—	—	14	2	36
28	—	—	—	—	—	—	—	—	1	—	—	—	—	12	—	32
29	—	—	—	—	—	—	—	—	—	—	—	—	—	12	1	7
30	—	—	—	—	—	—	—	—	—	—	—	—	—	13	—	1
31	—	—	—	—	—	—	—	—	—	—	—	—	—	36	—	4
32	—	—	—	—	—	—	—	—	—	—	—	—	—	24	—	—
33	—	—	—	—	—	—	—	—	—	—	—	—	—	14	—	—
34	—	—	—	—	—	—	—	—	—	—	—	—	—	10	—	—
35	—	—	—	—	—	—	—	—	—	—	—	—	—	3	—	—
36	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—
37	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—
Total	100	100	100	46	500	150	397	50	100	200	50	97	100	150	70	131
Mean	13.3	12.8	12.1	20.8	16.6	20.3	19.2	17.5	17.8	16.0	18.9	21.2	21.1	30.9	24.5	27.3
B. Age (years) frequencies																
1	—	50	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	50	—	50	11	67	15	25	14	18	29	15	20	28	—	6	—
3	—	—	—	4	8	21	4	1	—	5	—	—	2	7	62	23
4	—	—	—	—	—	4	—	—	—	—	—	—	—	4	2	4
5	—	—	—	—	—	—	—	—	—	—	—	—	—	10	—	3
6+	—	—	—	—	—	—	1	—	—	—	—	—	—	9	—	—
Total	50	50	50	15	75	40	30	15	18	34	15	20	30	30	70	30
C. Sex composition (%)																
M							33							49	46	46
F							67							51	54	54
D. Maturity stage composition (%)																
1	100	100	100	—											—	11
2	—	—	—	89											15	69
3	—	—	—	—											10	16
4	—	—	—	—											56	4
5	—	—	—	11											19	—
6	—	—	—	—											—	—
7	—	—	—	—											—	—
8	—	—	—	—											—	—

TABLE 2. Summary of tag release and recovery data for juveniles (J), adults (A) and mixed groups (M) of herring by seasonal behavior category, region and year, 1976-78.

Region	Year	Number of release sites			Total number of tagged fish			Percent total recoveries			Percent effective recoveries		
		J	A	M	J	A	M	J	A	M	J	A	M
Summer feeding													
V	1976	1	—	1	2,000	—	1,000	4.1	—	37.9	3.9	—	5.7
	1977	5	—	—	7,000	—	—	11.6	—	—	8.6	—	—
	1978	2	1	—	7,650	537	—	5.2	6.9	—	4.8	0.9	—
VI	1976	4	1	1	6,838	959	2,200	7.0	6.6	11.8	1.0	2.3	1.5
	1978	2	1	1	5,566	434	800	3.1	1.8	2.4	2.1	1.2	1.3
VII	1976	1	3	—	1,000	6,997	—	7.7	3.6	—	5.6	3.4	—
	1977	2	1	—	3,000	2,796	—	16.2	8.0	—	1.2	7.8	—
	1978	1	—	—	513	—	—	2.9	—	—	0.4	—	—
Autumn migrations													
V	1976	1	—	—	1,900	—	—	5.3	—	—	5.3	—	—
	1977	1	—	—	1,197	—	—	16.7	—	—	16.7	—	—
VI	1977	—	—	1	—	—	800	—	—	9.6	—	—	9.6
Overwintering													
V	1977	1	—	—	1,000	—	—	1.5	—	—	1.5	—	—
X	1977	1	—	—	2,200	—	—	5.1	—	—	4.6	—	—
	1978	1	—	—	1,500	—	—	2.1	—	—	0.4	—	—
Totals		23	7	4	41,364	11,723	4,800	7.2	5.0	15.3	4.6	4.2	3.7
Overall totals			34			57,887			7.4			4.4	

winter fisheries in Massachusetts Bay and at Point Judith, Rhode Island. Sindermann (MS 1979) observed that juveniles from New Brunswick (region X) also migrate southwesterly along the Maine coast in winter, some moving as far south as Cape Cod. Recoveries from the 1978 and, to some extent, the 1976 taggings in region V show that some juveniles spend the winter in the area where they were tagged, and the 1977 tagging shows some eastward movement in winter by the recapture of two juveniles in region X during the first quarter of 1978. Although it is well known that region X is an overwintering area, it is somewhat surprising that some juveniles tagged in region V would overwinter in region X because of the distance involved. Recoveries from the summer tagging of juveniles in regions V-VI were frequently made eastward of the tagging regions one year later during summer and autumn, indicating that these fish may eventually recruit to the spawning stocks which are shown to exist in regions VII and X. From the 1977 tagging in region VII, there were more recaptures in region X than in regions I and III. This is not surprising because of the close proximity of region VII to region X. Few recoveries were made eastward of region X.

There were few recoveries from the tagging of summer-feeding adults in region VI (Table 4), but sufficient data were obtained from the 1976 and 1977 taggings in region VII to show that many adults migrated southwestward to winter in regions I, III and IV, where

they were recaptured in the winter fisheries of Massachusetts Bay and Rhode Island. These results are consistent with the knowledge that the majority of the herring taken in Massachusetts Bay during winter are adults. The movement of adult herring to the Massachusetts Bay winter fishery has also been reported for a portion of the prespawning fish tagged off Southwest Nova Scotia (region XI) (Stobo, MS 1982). The data in Table 4 show that two adults tagged in 1977 were recaptured eastward in region X during the following winter. Also, one adult was recaptured in Sydney Bight (region XIV) in November 1977 and another in Chedabucto Bay (region XIII) in January 1978.

Several important differences are apparent from a comparison of the results in Tables 3 and 4. Recoveries during a year after the release of tagged fish are generally distributed over more regions for adults than for juveniles. It is also evident that returns from taggings of juveniles in regions V and VI, one year after release, were frequently from more easterly regions, but the same does not necessarily hold for adults and juveniles tagged in region VII. One possible explanation for this may be that juveniles tagged in regions V and VI originated from spawning in regions VII and X, emigrated from these regions and eventually returned to them upon reaching sexual maturity, whereas adults and juveniles, which were tagged in region VII, will eventually spawn in close proximity to the area of release. Some repetitive tagging of adults and juveniles in

TABLE 3. Distribution of tag recoveries by region and calendar quarter from summer-feeding juvenile herring tagged in region V, VI and VII in 1976-78. (Shaded areas indicate migration patterns.)

Tag. year	Recovery quarters	Recoveries by region from tagging in region V									Recoveries by region from tagging in region VI									Recoveries by region from tagging in region VII																																																				
		I	III	IV	V	VI	VII	X	XI	I	III	IV	V	VI	VII	X	XI	I	III	IV	V	VI	VII	X	XI																																															
1976	1976	3			8																					3			18	1	2																	3			33																					
	4				38	1																								25	7		1																			3																				
	1977	1			13		2																						3		11																					2		6																		
	2				1		11																								2																							1																		
3				1			3																							1																																										
1977	1977	2			61	4																																																																		
	3				417	16							1																																																											
	4				78	2							1	1																																																										
	1978	1			3	5	1																																																																	
	2																																																																							
3																																																																								
4																																																																								
1978	1978	3			81																																																																			
	4				7	185	14																																																																	
	1979	1			10	19	14																																																																	
	2																																																																							
	3																																																																							
	4																																																																							
	1980	1																																																																						
	2																																																																							
	3																																																																							
	4																																																																							
1981	1																																																																							
2																																																																								
3																																																																								

regions V, VI, VII and X will be required to confirm this hypothesis. Nevertheless, the results show that recoveries of tagged adults and juveniles were sufficient to follow seasonal movements over a period of 2 years and 1 year respectively.

Some recovery data were obtained from the tagging of autumn-migrating juveniles in region V and overwintering juveniles in regions V and X (Table 5). The data for autumn-migrating juveniles show that some moved to the southwest and overwintered in regions I and III and many overwintered in region V where they were tagged. Considering that these juveniles were moving southwestward when they were tagged and that their seasonal movement should correspond closely with the seasonal movement of juveniles tagged during summer feeding (Table 3), it is not surprising that fish tagged during fall migration appeared during the following summer in regions further to the northeast than where they were tagged. The recovery data from the tagging of overwintering juveniles in regions V and X indicate that they remained in close proximity to the tagging areas throughout the following summer. Subsequent movements are unpredictable because of the lack of long-term returns. It is

noteworthy that one juvenile tagged during November 1977 in region X was recaptured in Chedabucto Bay (region XIII) in January 1978, and another individual was recaptured in Massachusetts Bay (region III) at approximately the same time. However, the significance of single tag returns from given regions is questionable.

From the data in Tables 3 and 5, regions I, III, IV, V and X appear to contain overwintering grounds for juvenile herring. In particular, the evidence for overwintering in region V is shown by the recapture there during the winter quarter of juveniles tagged in that region during the summer-feeding period (Table 3). Also, the Maine Department of Marine Resources research vessel *Explorer* caught juvenile herring in the lower Sheepscot River (region V) during trawling operations in February 1982, and some juveniles were purse-seined from a school of herring which was located in the vicinity of Pemaquid Point-Damariscove Island (region V) during February 1983. The possibility exists that juveniles overwinter along the entire coasts of Maine, New Hampshire and Massachusetts, but tag recovery information is available only from those regions where winter fisheries presently exist.

TABLE 4. Distribution of tag recoveries by region and calendar quarter from summer-feeding adults tagged in regions VI and VII in 1976 and 1977. (Shaded areas indicate migration patterns.)

Tag. year	Recovery quarters	Recoveries by region from tagging in region IV														Recoveries by region from tagging in region VII																																
		I	III	IV	V	VI	VII	X	IX	XI	XII	XIII	XIV	I	III	IV	V	VI	VII	X	IX	XI	XII	XIII	XIV																							
1976	1976	3				14	1																																									
		4				2	1	1																								22	107	16														
	1977	1			2																								1	24	1	2																
		2																											1	3	4																2	
		3																													3	6	8	22													3	
	1978	1																																												1		
		2																																														
		3																																														
	1977	1977	3																																													
4																																																
1978		1																																														
		2																																														
		3																																														
		4																																														
1979		1																																														
		2																																														
		3																																														
		4																																														
1980		1																																														

TABLE 5. Distribution of tag recoveries by region and calendar quarter from (A) autumn-migrating juveniles tagged in region V in 1976 and 1977 and (B) overwintering juveniles tagged in regions V and X in 1977 and 1978. (Shaded areas indicate migration patterns.)

Tag. year	Recovery quarters	A. Autumn-migrating juveniles								B. Overwintering juveniles																																		
		Recoveries by region from tagging in region V								Recoveries by region from tagging in region V							Recoveries by region from tagging in region X																											
		I	III	IV	V	VI	VII	X	I	IV	IV	V	VI	VII	X	I	III	V	VI	VII	X	XI	XII	XIII	XIV																			
1976	1977	1			6	22																																						
		2					11	7																																				
		3					7	38	2	5																																		
		4						2																																				
1977	1977	1																																										
		2																																										
		3																																										
		4																																										
	1978	1																																										
		2																																										
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1980	1																																											
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1978	1978	2																																										
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Single isolated tag recoveries were often made in areas which were not characteristic of general movements. Some of these anomalous returns probably

result from reporting errors at the processing plants. In other cases, however, recoveries from distant locations, such as Chedabucto Bay and Sydney Bight,

eastern Nova Scotia, were checked and found to be quite accurate. This phenomenon of "spillage" into atypical areas is not uncommon among herring (W. T. Stobo, Marine Fish Division, Dartmouth, Canada, pers. comm.). It may occur when a portion of one stock of herring becomes mixed with a portion of another stock which is moving through a common area used in the migration of both stocks. Uncharacteristic movements may also indicate changing migration patterns, and caution should be used in attempts to categorize movements. Sindermann (MS 1979) mentioned the possibility that migration patterns of different stock components may change with changes in stock size.

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