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Migrations of Greenland Halibut, *Reinhardtius hippoglossoides*, in the Northwest Atlantic from Tagging in the Labrador-Newfoundland Region*

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Abstract

Migratory patterns of Greenland halibut in the Northwest Atlantic were investigated by two tagging experiments in 1969 and 1971 using longlines to capture the fish and three experiments in 1979-80 using otter trawls. Of nearly 24,400 tags applied, only 1.3% have been recovered to the end of 1983, the low recovery rate being attributed partly to the low level of offshore fishing activity and partly to high tagging mortality of fish caught in otter trawls. Results of the White Bay experiment in 1969 showed some movement of Greenland halibut from the tagging area to offshore deepwater areas of Labrador and Davis Strait, although many of the recaptures were in the general area of tagging. However, the Trinity Bay and Fortune Bay experiments in 1971 and 1979 respectively indicated little movements from the tagging sites. The Funk Island Bank experiments in 1979 and 1980 indicated substantial movement to coastal waters of northeastern Newfoundland in summer, but tags were also recovered both south and north of the tagging areas, the most northerly of the latter from the northern edge of Hamilton Bank. From tagging experiments off Labrador in 1980, the few returns indicated eastward movement to the deepwater areas of the continental slope, with one recapture from deep water off the northern tip of Labrador.

Introduction

Greenland halibut are distributed in the Northwest Atlantic from Arctic waters southward to the Scotian Shelf (Templeman, 1973) and constitute a significant component of the groundfish resource in the region, particularly off West Greenland (Smidt, 1969) and eastern Newfoundland (Bowering, 1983) and in the Gulf of St. Lawrence (Bowering, 1982), where the combined nominal catches in the three areas peaked at 63,000 (metric) tons in 1979. Spawning occurs in the deep warm water of Davis Strait (Jensen, 1935; Smidt, 1969) at a latitude of about 67° N. The eggs and small larvae drift northward in the West Greenland Current, and those which become engulfed by the Arctic Current drift southward along the coasts of Baffin Island, Labrador and eastern Newfoundland, colonizing the continental banks and slopes along the way (Templeman, 1973). Upon approaching maturation, these fish are believed to move into deep water and migrate northward to the spawning area in Davis Strait (Atkinson *et al.*, 1982). This pattern of movement implies that Greenland halibut constitute a continuous stock throughout the range of the species in the Northwest Atlantic, although there is evidence that some spawning occurs in the Gulf of St. Lawrence (Bowering, 1980).

Although there is no published information on migratory patterns of Greenland halibut in the Northwest Atlantic, several independent studies in recent years have been directed toward stock differentiation. Templeman (1970), from an analysis of meristic characters of Greenland halibut in samples from West Greenland to the southern Grand Bank and northern Gulf of St. Lawrence, concluded that vertebral averages were not particularly useful for separating stocks in the Northwest Atlantic except possibly the Gulf of St. Lawrence population. This peculiarity in vertebral averages for the Gulf of St. Lawrence stock was noted by Tremblay and Axelsen (1981). Fairbairn (1981), from electrophoretic analysis of tissue samples, concluded that Greenland halibut in the Northwest Atlantic constitute a single genetically-homogeneous stock. She noted that the resident population in the Gulf of St. Lawrence is not completely isolated because of its genetic similarity to the Labrador-eastern Newfoundland population. Khan *et al.* (1982), from a study of the prevalence of trypanosome and piroplasm infections as biological tags, concluded that Greenland halibut in the region from Davis Strait to the northern Grand Bank form a single stock but that separate stocks exist in the Gulf of St. Lawrence and Fortune Bay, Newfoundland. Dey (1982) found significant differences between areas in biochemical analysis of samples of Greenland halibut from the Gulf of St. Lawrence and eastern Newfoundland and inferred that the two areas contained separate stocks.

In this paper, the results of tagging experiments in Newfoundland coastal waters and in offshore areas of Labrador and eastern Newfoundland are used to illustrate migratory patterns of Greenland halibut in the region relevant to stock identification.

* Based on a paper presented at the NAFO Special Session on "Stock Discrimination in Marine Fishes and Invertebrates of the Northwest Atlantic", held at the Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada, during 8-10 September 1982.

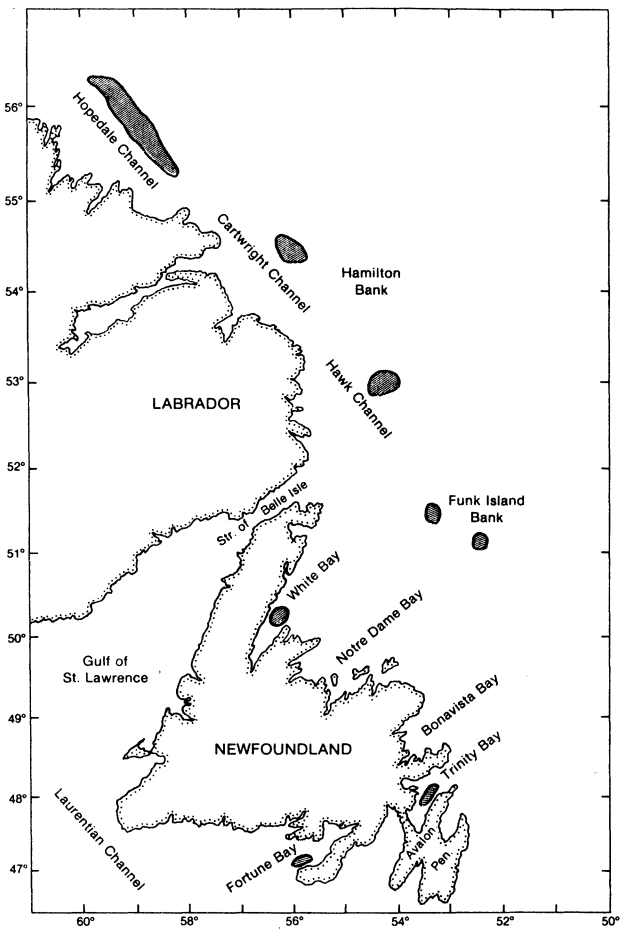

Fig. 1. Map of the Labrador-Newfoundland region showing the general areas of tagging (shaded).

Materials and Methods

Tagging of Greenland halibut in coastal waters was conducted in White Bay in 1969, Trinity Bay in 1971 and Fortune Bay in 1979, and offshore tagging was carried out on Funk Island Bank in 1979 and 1980 and in three channels off Labrador in 1980 (Fig. 1). Fish for tagging in White Bay and Trinity Bay were obtained by longlines set on bottom in 300–350 m and retrieved on the same day (maximum fishing time of 4 hr per set). In Fortune Bay and the offshore areas, fish were obtained by bottom otter trawls towed in 350–450 m for 10–30 min, depending on the abundance of fish in the area. The trawl was retrieved at a slower speed than usual to avoid damage to the fish from abrupt changes in pressure and temperature. Once aboard the vessels, the live Greenland halibut were quickly placed in tanks with continuously running seawater. Fish greater than 35 cm (fork length), which appeared to be in good condition with little or no scale loss, were tagged and placed in separate tanks where they were observed for approximately 30 min. Those in active condition were released, and those whose survival was considered doubtful were discarded after removal of the tags.

The fish were tagged with Petersen-type discs (1 cm diameter and 1 mm thick) which were attached with stainless steel wire (0.32 mm diameter) through the musculature near the head about 2–4 cm below the dorsal fin. The wire was inserted through the body with a hypodermic needle, and the discs (numbered tag on one side of the fish and blank on the other) were attached loosely, with 0.5–1.0 cm space between disc and body to allow for future growth.

To enhance the return of information on recaptured fish, about 20,000 fishermen were informed of the purpose and importance of the tagging experiments by letter and poster, which showed the location of the tag on the fish and requested information on where, when and how the fish was recaptured. A reward of $5.00 (Canadian) was offered for each tag returned prior to 1980. To further entice the return of tags, the 1980 experiments provided for a reward of $20.00 for each tag returned.

Distances from the tagging areas to recapture locations, where noted in this paper, are nautical miles (1 naut. mile = 1° lat. = 1.15 statute miles = 1.85 km).

Results

From a total of 1,656 tags applied to Greenland halibut in the three inshore areas, there were 203 reported recaptures (12.3%) to the end of 1983, most of which occurred in the first 2 years after the year of tagging (Table 1). From 22,733 tags applied to Greenland halibut in the offshore areas, there were only 117 returns (0.5%) to the end of 1983.

Inshore tagging experiments

White Bay, 1969. From 238 Greenland halibut tagged in October–November 1969, there were 41 reported recaptures (17.2%) during 1969–76, 26 of which occurred in 1970 and 1971 (Table 1). Almost half of the recaptures occurred in the White Bay area near the tagging sites (Fig. 2). Others were taken eastward in deepwater areas of Notre Dame Bay and Funk Island Deep, mainly during winter fishing operations. The most southerly recapture from this tagging occurred 230 miles distant at the entrance to Trinity Bay about 2 years after release. There were three recaptures near the edge of the continental shelf off Labrador, one 230 miles northeast of the tagging site at a latitude of 52° N in April 1972, another about 250 miles northeastward at a latitude of 53° 20′N in March 1971, and the third about

TABLE 1. Summary of information on recaptures of Greenland halibut tagged in the Labrador-Newfoundland region in 1969, 1971 and 1979–80.

Tagging location (Number tagged)	Time of tagging	Gear used	Year of recapture	Recaptures No.	Recaptures %
White Bay (238)	Oct–Nov 1969	LL	1969	1	0.4
			1970	19	8.0
			1971	13	5.5
			1972	6	2.5
			1974	1	0.4
			1976	1	0.4
Trinity Bay (410)	Oct–Nov 1971	LL	1972	62	15.1
			1973	68	16.6
			1974	14	3.4
			1975	1	0.2
			(NK)	2	0.5
Fortune Bay (1,008)	Sep–Oct 1979	OT	1980	9	0.9
			1981	4	0.4
			1982	2	0.2
			1983	—	—
Funk Island Bank (2,976)	Apr 1979	OT	1979	23	0.77
			1980	15	0.50
			1981	11	0.37
			1983	1	0.03
Funk Island Bank (10,594)	Jun–Jul 1980	OT	1980	5	0.05
			1981	2	0.02
			1982	3	0.03
			1983	—	—
			(NK)	1	0.01
Labrador Channels (9,163)	Sep–Oct 1980	OT	1980	1	0.01
			1981	12	0.13
			1982	42	0.46
			1983	1	0.01

370 miles northward off Nain at 56°23'N, 57°37'W in the spring of 1974. The longest migrations from the White Bay tagging in 1969 were evident from the recapture of two tagged Greenland halibut in Davis Strait (Fig. 2, inset), one about 850 miles from the tagging area in July 1971 (less than 2 years after release), and the other about 780 miles distant in October 1976.

Trinity Bay, 1971. From 410 Greenland halibut tagged in October–November 1971, there were 145 recaptures (35%) during 1972–75, most of which occurred in the first 2 years after tagging (Table 1). Additionally, two tags were recently reported with no recapture information except that they were taken in Trinity Bay. Most of the recaptures from this experiment occurred within 50 miles of the tagging area, and the three most distant recaptures off Cape Bonavista were less than 100 miles from the tagging site (Fig. 3).

Fortune Bay, 1979. From 1,008 Greenland halibut tagged in September–October 1979, there were only 15 reported recaptures (1.5%) during 1980–83 (Table 1), all within 15 miles of the tagging area (Fig. 4).

Offshore tagging experiments

Funk Island Bank, 1979 and 1980. Nearly 3,000 Greenland halibut were tagged in April 1979, from which there were only 50 reported recaptures (1.7%) during 1979–83, nearly half of them in the year of tagging and the remainder (except one) in the ensuing 2 years (Table 1). More than 10,000 tags were applied during June–July 1980, from which there were only 11 recaptures (0.1%), 10 during 1980–83 and 1 with unknown year of capture. In addition, 5 tags were retrieved at processing plants on shore with no information on recapture locations, 1 from the 1979 tagging and 4 from the 1980 tagging.

Most of the recaptures from the 1979 experiment occurred in the gillnet fishery during summer in White Bay, Notre Dame Bay and Funk Island areas and, to a lesser extent, off Bonavista Bay (Fig. 5). There were five recaptures northwest of the tagging area, the most distant off Labrador (54°38'N, 56°21'W) in July 1981. Only 3 of 11 recaptures from the 1980 experiment occurred in the summer gillnet fishery, in contrast to returns from the 1979 taggings, and the remainder were taken in the spring otter-trawl fishery. The most northerly recapture from this tagging occurred in Hawke Channel about 60 miles north of the tagging area (Fig. 5), and the most southerly recapture is based on the recovery of a tag from the stomach of a cod, which was caught east of the Avalon Peninsula (47°15'N, 52°05'W).

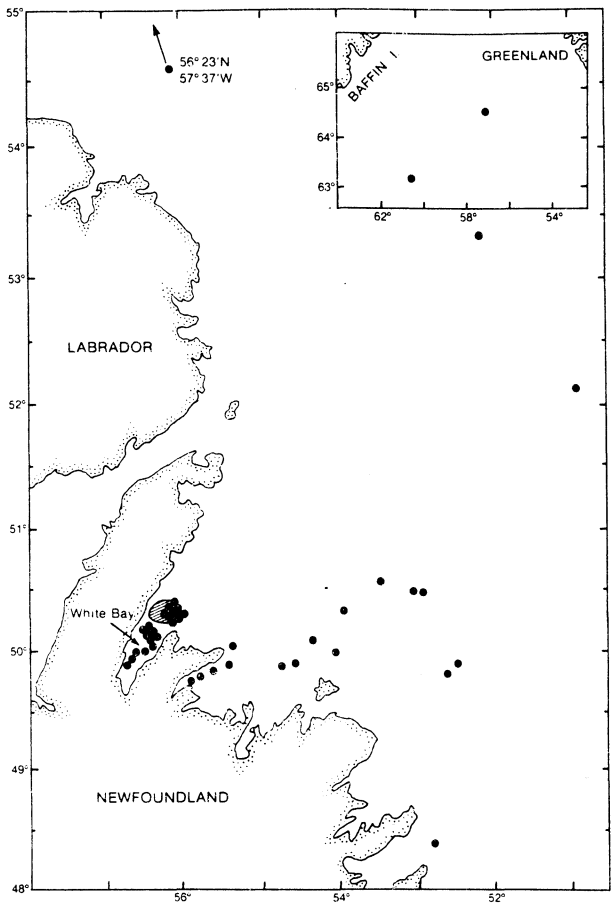

Fig. 2. Greenland halibut recaptures from tagging in White Bay, October-November 1969. (Tagging area is shaded.)

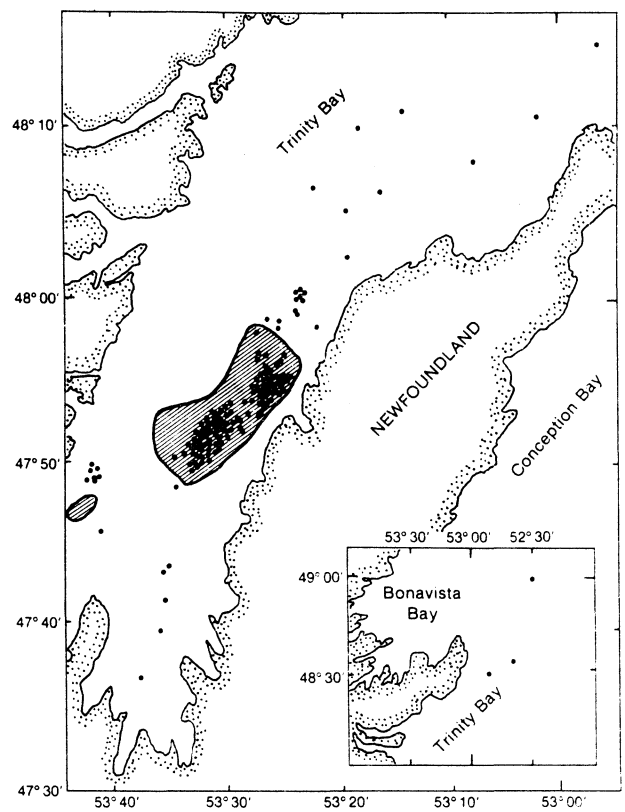

Fig. 3. Greenland halibut recaptures from tagging in Trinity Bay, October-November 1971. (Tagging areas are shaded.)

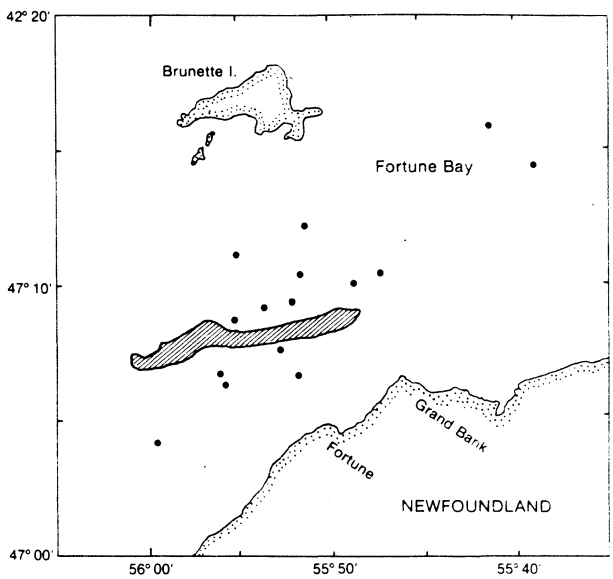

Fig. 4. Greenland halibut recaptures from tagging in Fortune Bay, September-October 1979. (Tagging area is shaded.)

Labrador Channels, 1980. More than 9,000 Greenland halibut were tagged off Labrador in September-October 1980 (4,540 in Hopedale Channel, 2,033 in Cartwright Channel, and 2,590 in Hawke Channel), from which a total of only 54 tags were returned (0.6%) during 1980-83, nearly all of them in 1981 and 1982 (Table 1). From the tagging in Hopedale Channel (Fig. 6), there were 41 recaptures of which 35 occurred in the general area of tagging and the remaining 6 recaptures were scattered along the slope of the continental shelf. The most southerly recapture occurred in 840 m at 53°07'N, 52°05'W about 340 miles from the tagging area, and the most northerly recapture was made in 643 m at 60°15'N, 60°54'W about 240 miles from the tagging area. From the tagging in Cartwright Channel, eight recaptures occurred in the tagging area and one about 60 miles northward on the continental slope. From the tagging in Hawke Channel, the only recapture was made just south of the tagging area.

Discussion

The main fishery for Greenland halibut in the Northwest Atlantic occurs off eastern Newfoundland (Div. 3K and 3L), with much less activity off Labrador. At West Greenland, the fishery occurs mainly in the fjords with little activity near the spawning grounds in Davis Strait (Smidt, 1969) or the presumed nursery grounds on Baffin Island Bank (Bowering, MS 1982).

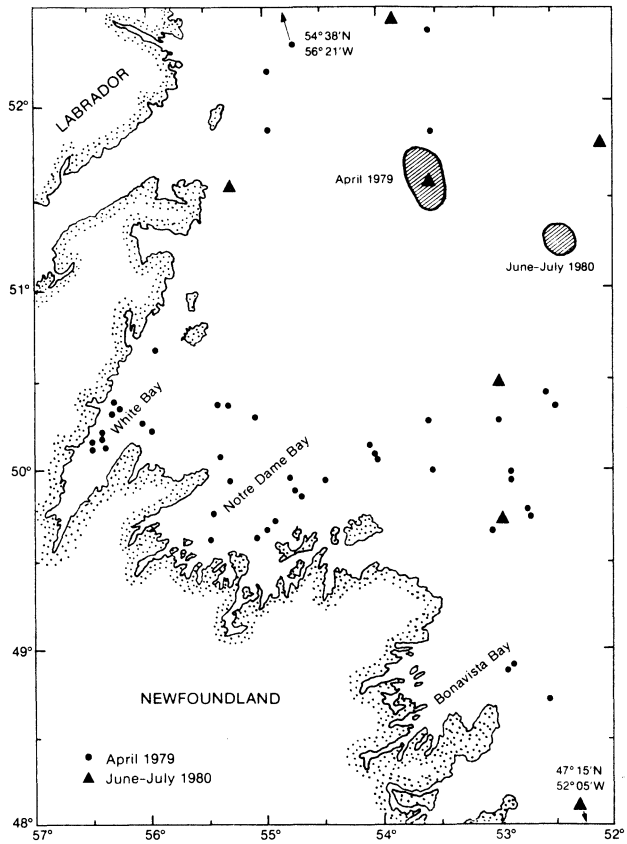

Fig. 5. Greenland halibut recaptures from tagging on Funk Island Bank, April 1979 and June-July 1980. (Tagging areas are shaded.)

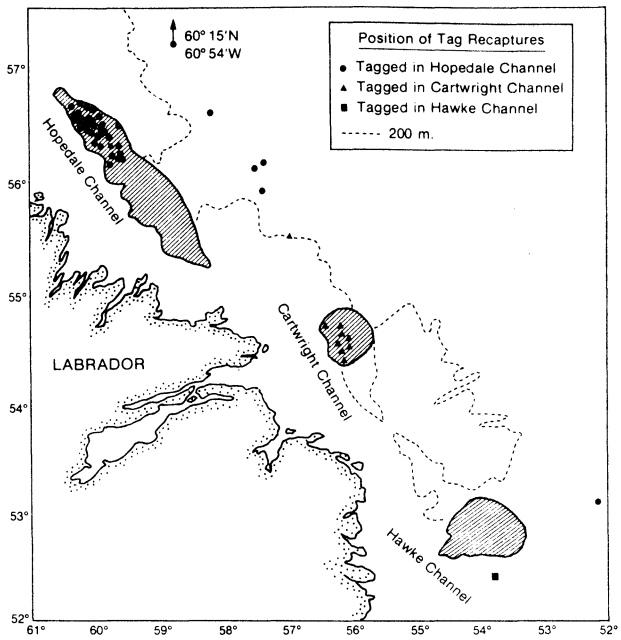

Fig. 6. Greenland halibut recaptures from tagging in three channels off Labrador, September-October 1980. (Tagging areas are shaded.)

The offshore component of the Greenland halibut fishery, which was conducted by large distant-water trawlers with the capability of fishing in depths exceeding 600 m along the continental slope, have been virtually eliminated following the extension of fisheries jurisdiction to 200 miles by the coastal states in 1977. Consequently, the low number of recaptures in the northern divisions from Labrador to West Greenland is considered to be the result of low fishery activity in deepwater areas of the continental shelf and slope.

The low level of tag returns from the Fortune Bay tagging experiment may also be due in part to low fishing activity. Danish-seining, mainly for witch flounder, American plaice and Atlantic cod, is the main deepwater fishery in this area, but these vessels are unable to fish the deepest part of the bay (about 370 m) where Greenland halibut are more likely to be found, thus reducing the probability of catching tagged fish.

Although tagging mortality is difficult to measure with any degree of accuracy, it was probably much higher in fish tagged from otter-trawl catches than from longline catches, in view of the differences in percentage recaptures. Injury to the mouth from hooks is likely to be much less severe than the loss of protective body mucous and scales which occurs during trawling operations. This differentiation in tagging mortality between gears was also observed in tagging experiments at Iceland (A. Sigurdsson, Marine Research Institute, Reykjavik, pers. comm.).

Long-distance migrations of Greenland halibut, as evidenced by those tagged in White Bay and recaptured off northern Labrador, Baffin Island and West Greenland, have occurred in other areas of the North Atlantic. A Greenland halibut tagged north of Iceland in July 1973 was recaptured 4 months later in the Barents Sea, and there were two recaptures at Faroe Islands and one at Shetland Islands from tagging off Northeast Iceland (Sigurdsson, 1979). From Greenland halibut tagged off the east coast of Iceland in January 1970, one was recaptured in the Barents Sea in August 1972 (Nizovtsev, 1974). A Greenland halibut tagged in Lichtenau Fjord, West Greenland, in June 1955 was recaptured off Vestfirdir, Iceland, in June 1959, this being the only known record of a possible connection between the Iceland and West Greenland populations (Smidt, 1969).

Investigations by Kosier (1970), Chumakov (1969) and Sigurdsson (1979) in Iceland waters have shown from tagging experiments that Greenland halibut tended to remain near the release sites during the summer until a prespawning migration westward and northwestward to Denmark Strait began in late September. After spawning in April-May, the fish migrated

eastward to their summer-feeding grounds north of Iceland. In the Northwest Atlantic, the long-distance movement of Greenland halibut from eastern Newfoundland to Davis Strait is also believed to represent a spawning migration, in view of the general consensus that the region from the northern Grand Bank to West Greenland contains a single interbreeding stock with spawning grounds in Davis Strait, as concluded and inferred from stock delineation studies of Templeman (1970), Fairbairn (1981) and Khan *et al.*, (1982). Bowering (1983) reported that, although growth patterns of Greenland halibut were similar throughout the range of the species in the Northwest Atlantic, the fish matured at progressively smaller sizes from south to north. Because the sex and maturity condition of the fish cannot be determined at the time of tagging and because the sizes at which males and females become sexually mature are markedly different, it is difficult to draw conclusions on movements of maturing fish based on size alone. However, the most northerly recapture (a 91-cm fish tagged 7 years earlier in White Bay) was undoubtedly a mature female.

Jensen (1935) and Smidt (1969) reported that Greenland halibut in the fjords of West Greenland perform spawning migrations. Mature individuals migrate from the fjords to an area south of the ridge extending from Baffin Island to Greenland where they spawn at depths of 600–1,000 m. After spawning, these fish return to the West Greenland fjord where they are exploited during the summer. In contrast, the summer fishery of Greenland halibut in eastern Newfoundland and Labrador waters is based on immature fish. It is possible, therefore, that maturing Greenland halibut, which migrate from the Newfoundland-Labrador area to Davis Strait for spawning, remain in the West Greenland area. On the other hand, if the adults return southward after spawning, it is possible that they remain along the continental slope at depths beyond the capability of the otter trawls used during survey operations.

Spawning migrations of Greenland halibut may also occur in the Gulf of St. Lawrence. Data from the Newfoundland trawler fishery and research vessel surveys (Bowering, 1982) indicate that prespawning concentrations occur during the winter in the Laurentian Channel in the southeastern part of the Gulf. In summer, Greenland halibut tend to be concentrated in the western part of the Gulf and are taken as by-catch in the shrimp fishery. This westward movement is probably a feeding migration, because Greenland halibut are known to feed intensively on shrimp (Smidt, 1969; Bowering and Parsons, MS 1981).

None of the Greenland halibut tagged off eastern Newfoundland and Labrador were recaptured in the Gulf of St. Lawrence, implying little, if any, movement to the Gulf from the eastern areas. However, the biochemical studies of Fairbairn (1981) indicated that the Gulf of St. Lawrence population is not completely isolated because of its genetic similarity to the population off eastern Newfoundland and Labrador, and the peculiarities in sexual maturity ogives of Greenland halibut in the Gulf, found by Bowering (1982), were attributed to a mixture of resident fish with those from eastern areas. Recaptures of Greenland halibut within the Gulf from tagging experiments outside the Gulf would not be expected if immigration occurs as larvae or at fish sizes smaller than those which were tagged.

The Funk Island tagging experiment clearly indicates an inshore movement to deepwater bays of northeastern Newfoundland. Most of the recaptures occurred in the nearshore gillnet fishery during the summer period. This inshore movement may be a feeding migration, similar to that reported for Atlantic cod of the same area (Templeman, 1979) and for Greenland halibut at West Greenland (Jensen, 1935; Smidt, 1969). In the Newfoundland area, both species have been reported to feed heavily on capelin (Lear, MS 1970; Templeman, 1979) and follow them toward coastal waters in summer. Most of the Greenland halibut tagged in the Funk Island Bank experiment were less than 60 cm in length and few of them would have matured sufficiently to undertake the northward migration for spawning. However, any northward movement of these fish may not be detectable from tag returns, in view of the very low level of offshore fishing activity for Greenland halibut off Labrador and Baffin Island in recent years. This situation also pertains to the tagging experiments of Labrador, but scattered offshore returns indicate movement both north and south over considerable distances, with several recaptures from deepwater areas of the continental slope.

All recaptures from the Fortune Bay tagging experiment were made in the vicinity of the tagging sites, possibly indicating the existence of a resident population there, as suggested by Khan *et al.* (1982), but there is no information on spawning of Greenland halibut in the area to support that conclusion. The unfavorable environmental conditions of the Avalon Channel off southeastern Newfoundland make it unlikely that Greenland halibut move westward to Fortune Bay from the northern Grand Bank. However, there are no physical or environmental barriers to movement for spawning from Fortune Bay to the southern entrance of the Gulf of St. Lawrence by way of the Hermitage and Laurentian Channels. If Fortune Bay fish migrate to that area where the Gulf population of Greenland halibut concentrates in winter, one would expect to have recovered tagged fish if they were present.

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