Northwest Atlantic Fisheries Organization

Serial No. N432

NAFO SCR Doc. 81/IX/126

THIRD ANNUAL MEETING - SEPTEMBER 1981

Oceanographic and Atlantic Herring Life History Distributions of Interest in Relation to the Herring Stock Problem in the Georges Bank, Gulf of Maine and Bay of Fundy Area

by

M. Sinclair and T. D. Iles

Marine Fish Division, Bedford Institute of Oceanography,
Dartmouth, Nova Scotia, Canada

INTRODUCTION

From a comparative study of Atlantic herring population biology on each side of the North Atlantic an hypothesis (Sinclair and Iles, 1981a) has been put forward to account for the existence of herring stocks (their multiplicity, range in absolute abundance and location of spawning areas). It is proposed that the existence of a geographically fixed, or stable, larval retention area is a pre-requisite for the maintenance of a discrete stock. The physical size of the specific larval retention areas determine the mean abundance of the individual stocks. In this paper much of the empirical data from the Georges Bank - Gulf of Maine - Bay of Fundy area, in support of the hypothesis, is brought together. The empirical data focused upon includes spawning locations and larval distributional areas, as well as in general terms the physical oceanographic characteristics of these areas. This has been attempted to aid in planning research efforts on the stock problem in this area. It is the opinion of the authors that research and management problems associated with Georges Bank herring population biology (and the associated international Georges Bank herring larval program), cannot be fruitfully resolved unless they are considered within the overall framework of the herring stock complex in NAFO SA 4, 5, and 6.

S-W. NOVA SCOTIA HERRING

It is well recognized that there is between stocks mixing during various phases of the annual migration of adult herring as well as

within the juvenile nursery areas. Thus in the following description of distributional areas for the S-W. Nova Scotia stock, it is not assumed in all cases that only S-W. Nova Scotia spawned fish are within the distributional area. Most of the information on juvenile and adult distributions comes from various components of the 4WX herring fishery, which are summarized in Sinclair and Iles (1981b).

At least part of the stock overwinters in the Chedabucto Bay area between December and March (Stobo 1974). Between March and mid-June there is essentially no fishery on this stock; the migratory route has not been described. In that up to 500,000 tonnes may have been migrating during years of high stock abundance it is unlikely that a coastal route is being taken. If migration were to occur close to shore, it is probable that a near-shore fishery would have developed on this part of the annual migration, which is not the case. From mid-June to the beginning of August the stock is concentrated during the feeding part of its migration off S-W. Nova Scotia in close proximity to a predicted tidally-induced front (Fig. 1). The between year variability in the location of summer feeding (as estimated from purse-seine log record catch information) is surprisingly limited. In early August pre-spawning aggregations form inshore of the summer feeding area (Fig. 1). It is at this time that a drift-gill net fishery begins each year. Fat levels decline (Fig. 2), and "red feed" incidence is rare indicating that feeding has stopped or been reduced during this phase of the annual migration. Spawning occurs during a relatively restricted period, from mid-August to mid-September (Fig. 3). The location of major spawning sites in relation to the stratification parameter (Garrett et al., 1978) are shown in Fig. 4. All the spawning sites (as well as the pre-spawning aggregation area) are areas of strong vertical mixing of the water column where no summer thermocline develops ($S < 1.9$). Subsequent to spawning the adults leave the area presumably migrating back to the overwintering area(s). Again there is no fishery during this migration, at least on that part of the stock which migrates to the Chedabucto Bay area.

A standard autumn and spring herring larval survey have been run since 1972 for this spawning component. The station positions for the survey are indicated in Fig. 5 and details of the methodology given

in Sinclair et al., 1979. The distributions for many of the cruises are described for this meeting in Iles and Sinclair (1981). The mean distribution for the years 1972 to 1976 is shown in Fig. 6. The larvae from this spawning component are retained with the Bay of Fundy. The spring distribution seven months after spawning is very similar to that shown in Fig. 6 (Stobo and Iles, 1973, and Iles and Sinclair, 1981, this meeting). There is good evidence for a discontinuity in larval abundance between the S-W. Nova Scotia stock and larval aggregations presumed to be associated with the Grand Manan and Scotts Bay stocks (see Fig. 6 and Iles and Sinclair, 1981, this meeting).

The importance of the concept of larval retention for this stock, and a physical mechanism to explain it, were first described by Iles (1975). Residual bottom water drift from S-W. Nova Scotia into the Bay of Fundy, has been inferred by both Lauzier (1967), Fig. 7, and Iles (1975). The empirical observations are consistent with theoretical models (Garrett and Loucks, 1976, and Garrett et al., 1978, Fig. 8). In well mixed water columns (the shaded areas in Fig. 8) there is no density gradient in the water column such that wind-driven up welling may be facilitated (as well as on-shore transport of bottom water, Fig. 7).

SCOTTS BAY HERRING

In recent years (1977 to 1980) there has been a well defined fishery on spawning herring in mid-July at the head of the Bay of Fundy in the vicinity of Scotts Bay. The fishery has been well sampled with the age composition being similar to the S-W. Nova Scotia spawning fishery (Table 1). Nevertheless, there are indications that this spawning group deserves "stock status".

Spawning occurs at least a month before the peak spawning time of the S-W. Nova Scotia herring. Recently hatched larvae were observed during the 1979 August larval survey (Fig. 9) in the area of spawning. Also a discontinuity in the larval population at the head of the Bay of Fundy is observable in many of the distributional maps (Iles and Sinclair, 1981, this meeting). Finally, there is a well described tidal residual gyre in the larval distributional area (Fig. 10,

personnal communication, D. Greenberg, Bedford Institute of Oceanography) which may aid the larval population to maintain its integrity. As is the case for S-W. Nova Scotia herring, the location of spawning and of the subsequent larval distribution is within a tidally well mixed area (Fig. 11). Distributional information at other phases of the life history and parts of the annual adult migration are not known.

GRAND MANAN STOCK

Huntsman (1953) brought much of the information together on adult herring in the Grand Manan - Passamaquoddy Bay region. His interpretation of the collapse (late 1870's) of the adult summer herring fishery south of Grand Manan and the adult winter herring fishery to the east and north of Grand Manan (coincident with continued healthy juvenile herring fisheries within Passamaquoddy Bay) is perhaps doubtful, but the accumulated data permits an alternate interpretation. There are several parallels between this "stock" and that off S-W. Nova Scotia.

Summer feeding and an associated fishery occured in the vicinity of a predicted tidally induced front (Fig. 12 and Fig. 8). Spawning occured inshore to the south of the island in late summer (the exact timing and locations are not provided, perhaps since fishing on spawning herring was illegal). The overwintering adult distributions appear to have been less concentrated (Fig. 12). Even though the spawning population off Grand Manan is very small compared to that reported during the last century, some inferences can be drawn concerning the larval distributional (or "retention") area (Fig. 6, and Iles and Sinclair, 1981, this meeting). It appears to coincide with a tidally induced gyre
predicted by D. Greenberg (Fig. 13) and described by Hachey (1952), Fig. 14. As the case for both the S-W. Nova Scotia and Scotts Bay "stocks", the spawning locations and larval distributional areas are co-incident with tidally induced features. It is probable that the intensive "summer feeding" and "overwintering" fisheries on the Grand Manan "stock" provide one of the first examples of recruitment overfishing on Atlantic herring (the stock having "collapsed" prior to 1880).

GEORGES BANK HERRING

There are several comprehensive articles on Georges Bank herring and its fishery (Anthony and Waring, 1980, Lough et al., 1980a, B). Here only some comparative observations will be made relative to the above "stocks". Some aspects of the seasonal distribution of Georges Bank herring can be inferred from the Russian Fishing Atlas. During 1961/62 there was a directed fishery for herring using drift-gill nets from Russian offshore trawlers. In figure 15 changes in the location of this fishery have been redrawn from the Atlas. There are two points of interest. First, as is the case for the S-W. Nova Scotia stock and the Grand Manan stock (historically) summer feeding occurs in the close vicinity of predicted tidally induced fronts (for Georges Bank herring along the northern edge of the Bank), Fig. 15 and Fig. 8. Secondly, during spawning (October) the fishery broke up into two components, one on Georges Bank proper, the other on Nantucket Shoals. This division of the fishery into two locations, beginning at the timing of spawning, coincides with the discontinuity in the larval distributions in these areas (Fig. 16) and with the discontinuity in the stratification parameter distributions (Fig. 8). The results of a simulation model by D. Greenberg (personnal communication) indicate the existence of two tidal residual gyres (Fig. 17) over respectively Georges Bank and Nantucket Shoals. It is critical that these physical features are present during the winter months (when the larvae are present) not just during the summer months when the horizontal temperature gradients are established (Loder 1981).

Thus there is some evidence (from the location of spawning, larval distributions and physical oceanographic features) to suggest that there are two biological stocks in the Georges Bank - Nantucket Shoals area.

OTHER SPAWNING COMPONENTS ASSOCIATED WITH ESTUARIES

Historically there was a well described spring spawning component (May), or stock, in Oak Bay well up on one side of the St. Croix estuary (Fig. 12). Nothing is known about either the larval distribution area or distributions at other phases of the life cycle (it is inferred that this stock overwintered in Passamaquoddy Bay). In that this component or stock collapsed at the same time as the Grand Manan

Stock, it is probable that there was intermixture during summer feeding and overwintering.

Graham (1972) and Graham et al., (1972) have described the retention of larvae within the estuaries along the coast of Maine. The precise location of spawning has not been described since, with the exception of Jeffry's Ledge component, there is not a fishery on spawning populations of the Gulf of Maine Stock complex. The major locations can however be inferred from yolk sac larval concentrations. The common feature for these spawning populations is the retention of the larval populations within the Gulf of Maine estuaries. It is a moot point whether these spawning components constitute a single biological "stock" (as has been concluded for Norwegian spring spawning herring) or a number of distinct stocks associated with specific estuarine larval retention areas. Detailed information on the location and timing of spawning for the Gulf of Maine complex would aid in this respect.

DISCUSSION

Much of the information presented here is inferred from various herring fisheries in the area of interest. Nevertheless, there do seem to be some common features that stand out. There are discontinuities in larval distributions derived from the various late summer to autumn spawning populations that have been described. In each case there is a geographically fixed physical feature (whether it is a tidally induced or estuarine) that may be involved in maintaining the discreteness of the larval populations. It is interpreted that spawning locations for the various biological stocks are defined in relation to these larval retention areas. Another repetitive feature is the association between summer feeding herring distributions (where the stocks can be intermixed) and the location of tidally induced temperature fronts.

REFERENCES

Anthony, V. and G. Waring. 1980. Dynamics of the Georges Bank herring fishery. Symposium on the Biological Basis of Pelogic Fish Stock Management. Aberbeen.

Garrett, D.J.R. and R.J. Loucks. 1976. Upwelling along the Yarmouth shore of Nova Scotia. J. Fish. Res. Board Can. 33, 116.

Garrett, C.J.R., J.R. Keely, and D.A. Greenberg. 1978. Tidal mixing versus thermal stratification in the Bay of Fundy and Gulf of Maine. Atmosphere - Ocean 16, 403.

Graham, J.J. 1972. Retention of larval herring within the Sheepscot estuary of Maine. Fish. Bull., U.S. 70, 299-305.

Graham, J.J., S.B. Chenoweth and C.W. Davis. 1972. Abundance, distribution, movements and lengths of larval herring along the western coast of Maine. Fish. Bull., U.S. 70, 307-321.

Hachey, H.B. 1952. The general hydrography of the waters of the Bay of Fundy. Fish. Res. Board Can. Man. Rep. No. 455.

Huntsman, A.G. 1953. Movements and decline of large Quoddy herring. J. Fish. Res. Board Can. 10, 2-47.

Iles, T.D. 1975. The movement of seabed drifters and surface drift bottles from the spawning area of the "Nova Scotia" herring stock and the herring larval transport-retention hypothesis. ICNAF Comm. Mtg. No. C: 37, 17 p.

Iles, T.D. and M. Sinclair. 1981. Bay of Fundy herring larval distributions. NAFO, this meeting.

Loder, J.W. 1980. Secondary tidal effects in tidally energetic shallow seas with application to the Gulf of Maine. Ph.D. thesis, Dalhousie University, Nova Scotia, Canada.

Lough, R.G., and G.R. Golz. 1979. A description of the sampling methods, and larval herring data report for surveys conducted from 1968-1978 in the Georges Bank and Gulf of Maine areas. NMFS Northeast Fisheries Centre Lab. Ref. Doc. 79-60.

Lough, R.G., G.R. Bolz, M.D. Grosslein and D.C. Potter. 1979. Abendance and survival of sea herring (*Clupea harengus L.*) larvae in relation to environmental factors, spawning stock size, and recruitment for the Georges Bank area, 1968-1977 seasons. ICNAF Res. Doc. 79/VI/112, 47 pp.

Sinclair, M. and T.D. Iles. 1981a. The stock structure of Atlantic herring in relation to tidally induced temperature fronts. ICES C.M. 1981/H: 46.

Sinclair, M. and T.D. Iles. 1981b. Assessment of the 1980 4WX herring fishery. CAFSAC Res. Doc. 81/10.

Sinclair, M., J. Black, T.D. Iles and W. Stobo. 1979. Preliminary analysis of the use of Bay of Fundy larval survey data in 4WX herring assessments. CAFSAC Res. Doc. 79/44.

Stobo, W.T. 1974. The Canadian 4VWa fishery: analysis of the 1973-74 catch, and the distribution of fishing activity and catch per unit of effort from 1971-74. ICNAF Res. Doc. 74/95.

Stobo, W.T. and T.D. Iles. 1973. Larval herring distributions in the Bay of Fundy. ICNAF Res. Doc. 73/93.

Table 1. Comparison of Numbers-at-age from the Scots Bay and Southwestern Nova Scotia Purse Seine Fisheries ($x10^{-3}$)

	AGE											
	1	2	3	4	5	6	7	8	9	10	11+	Total
1980												
Scots Bay	0	24	866	7,463	678	187	550	452	222	878	183	11,503
% of Total	0	0.2	7.5	64.9	5.9	1.6	4.8	3.9	1.9	7.6	1.6	
S.W.N.S.	978	311	30,129	349,567	19,298	1,733	1,410	941	321	1,267	245	406,200
% of Total	.2	.1	7.4	86.1	4.8	.4	.3	.2	.1	.3	.1	
1978												
Scots Bay	0	4	72	298	4,370	3,556	1,596	6,300	429	103	113	16,841
% of Total	0	<.1	.4	1.8	25.9	21.1	9.5	37.4	2.5	.6	.7	
S.W.N.S.	0	13,390	14,246	5,009	50,687	35,445	15,353	60,635	5,126	1,125	580	201,596
% of Total	0	6.6	7.1	2.4	25.1	17.6	7.6	30.1	2.5	.6	.3	

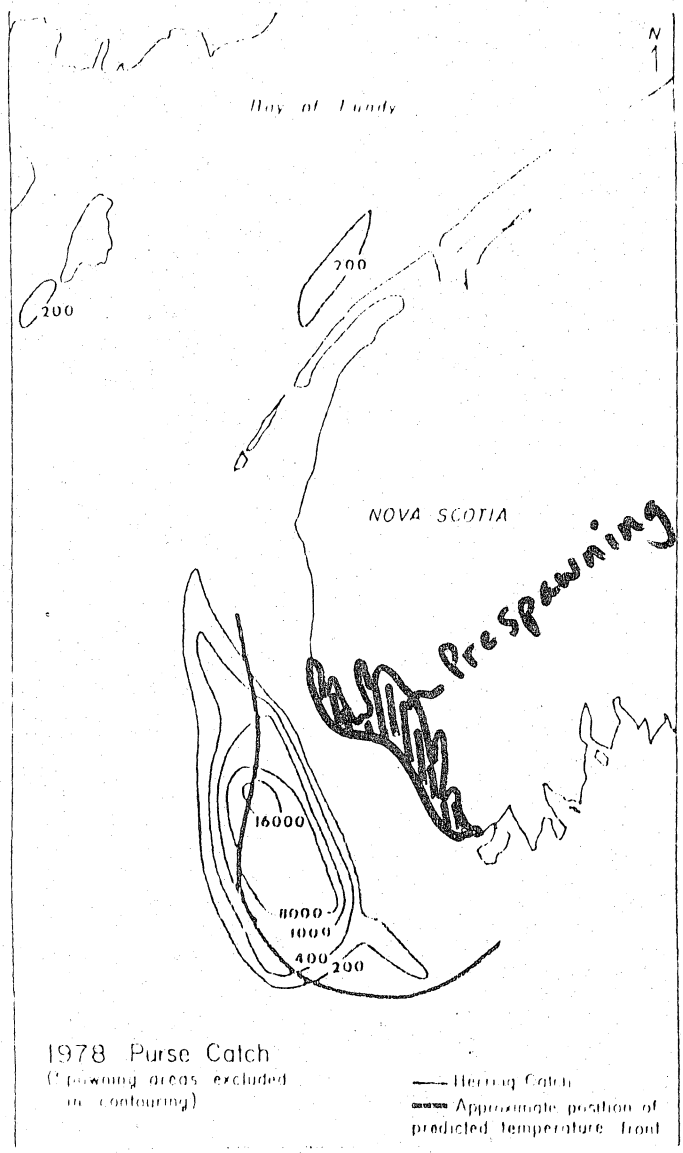

Figure 1. Location of purse-seine fishery on summer feeding herring in relation to the critical value of the stratification parameter.

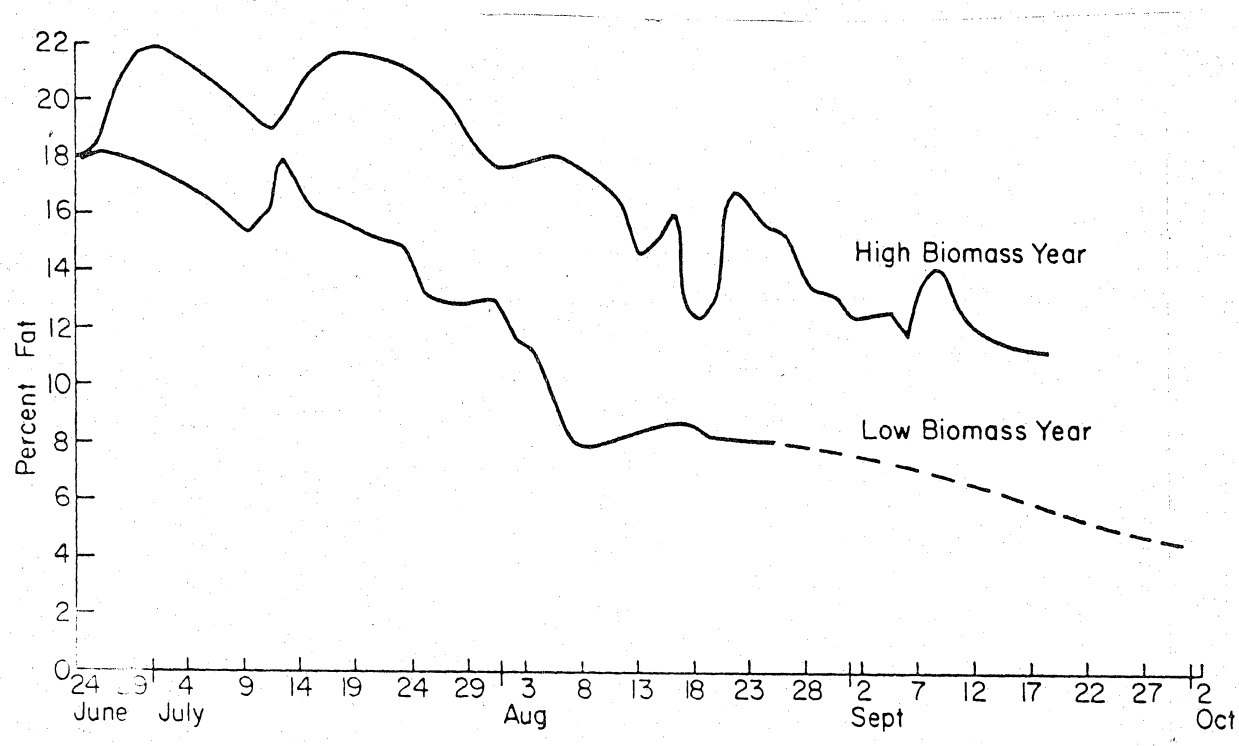

Fig. 2. Distribution of percent body fat for herring sampled off S. W. Nova Scotia.

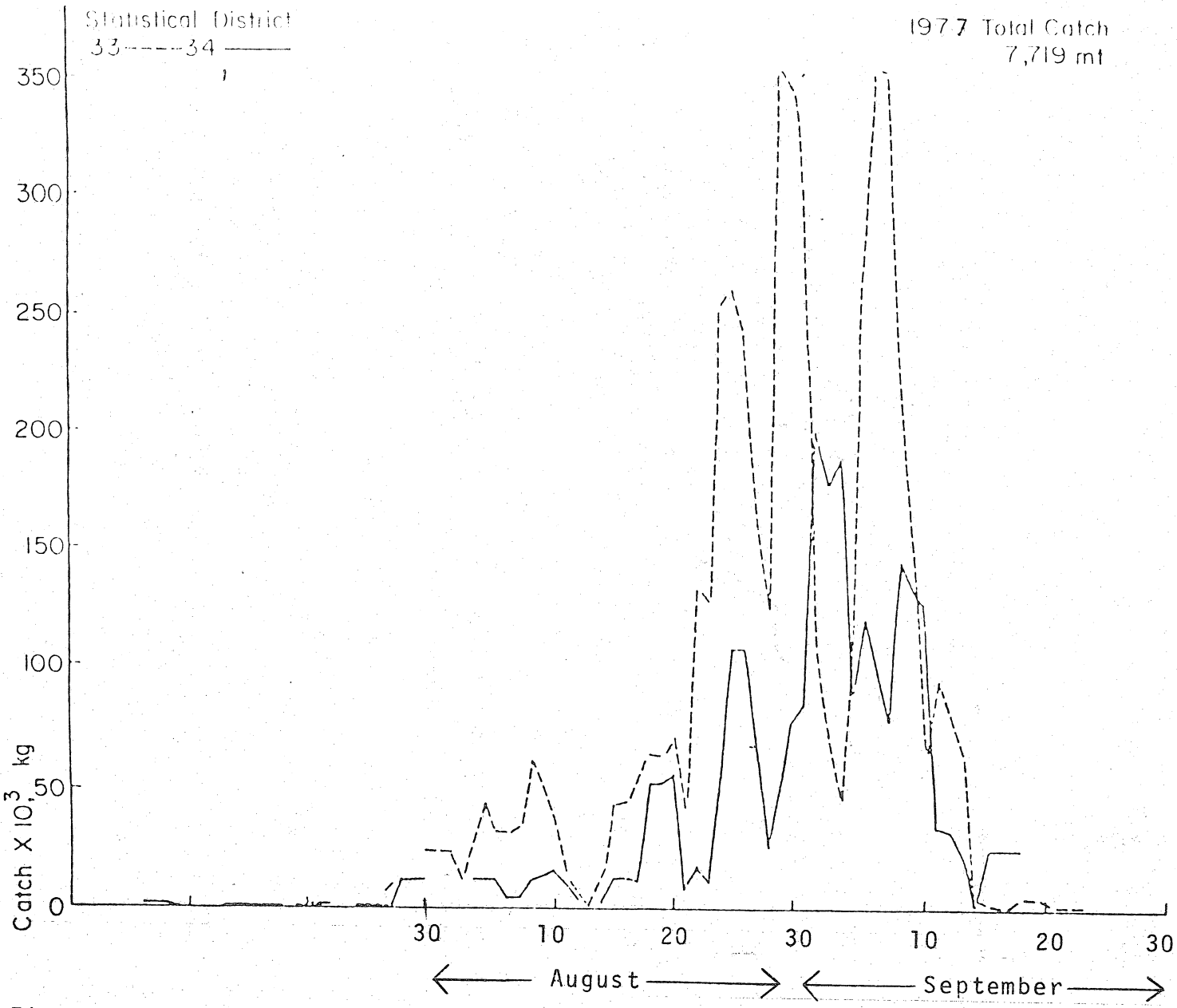

Fig. 3. Distribution of the drift gill net catch on pre-spawning and spawning aggregations.

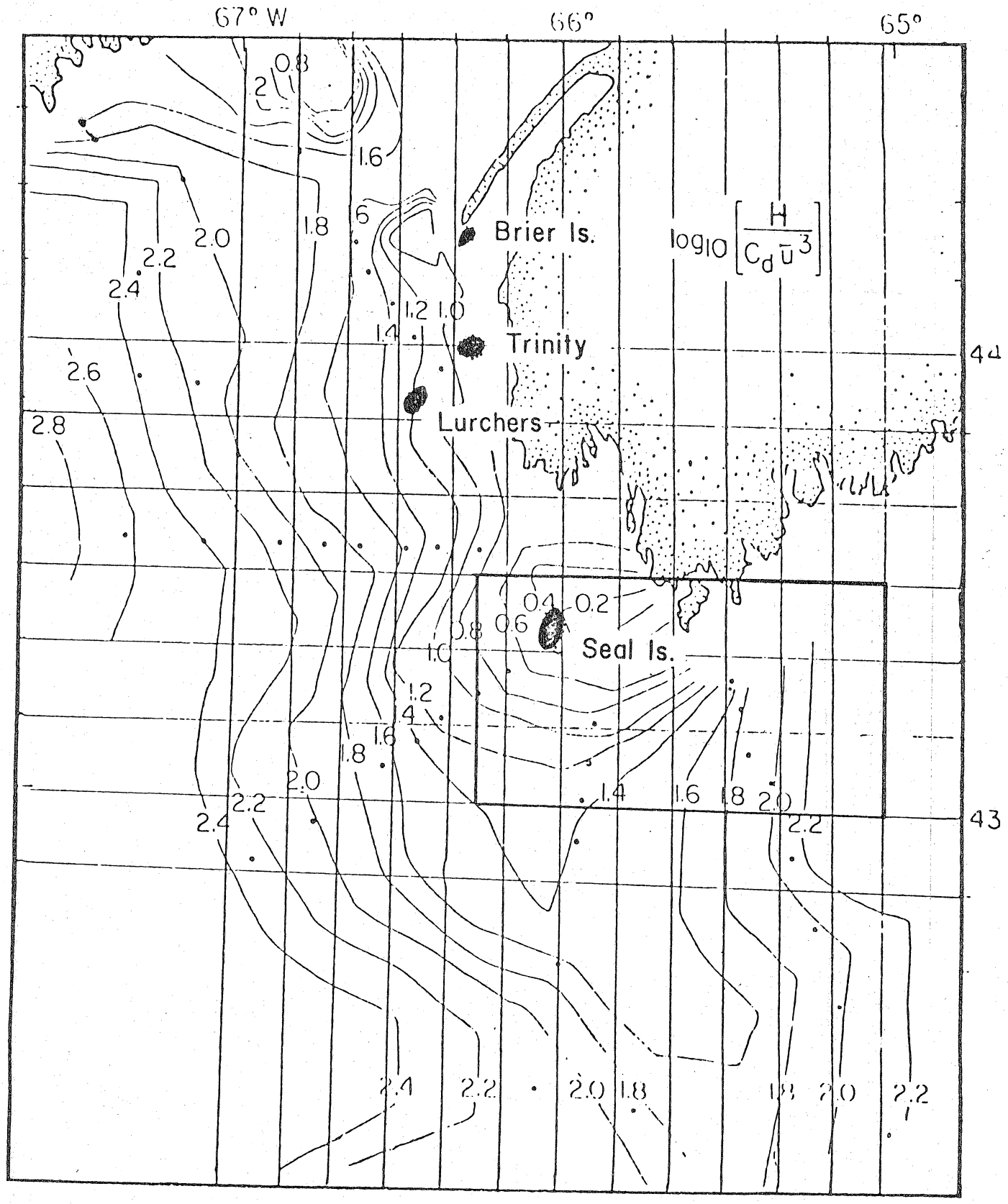

Figure 4. Location of herring spawning sites in relation to the distribution of the stratification parameter (Garrett et al., 1978).

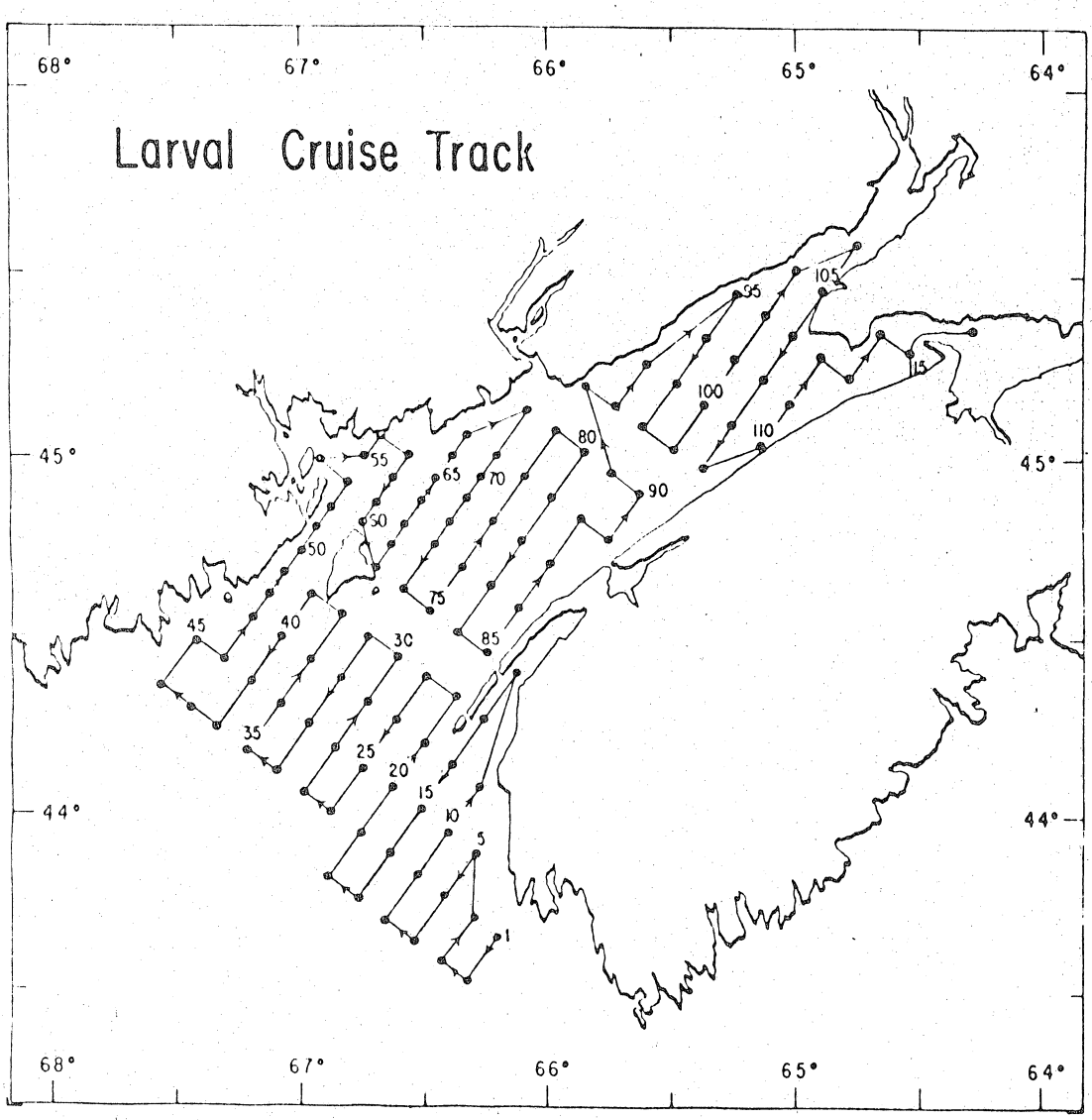

Fig. 5. The larval sampling stations in the Bay of Fundy are presented along with the proposed cruise track. Selected station numbers are also given for reference.

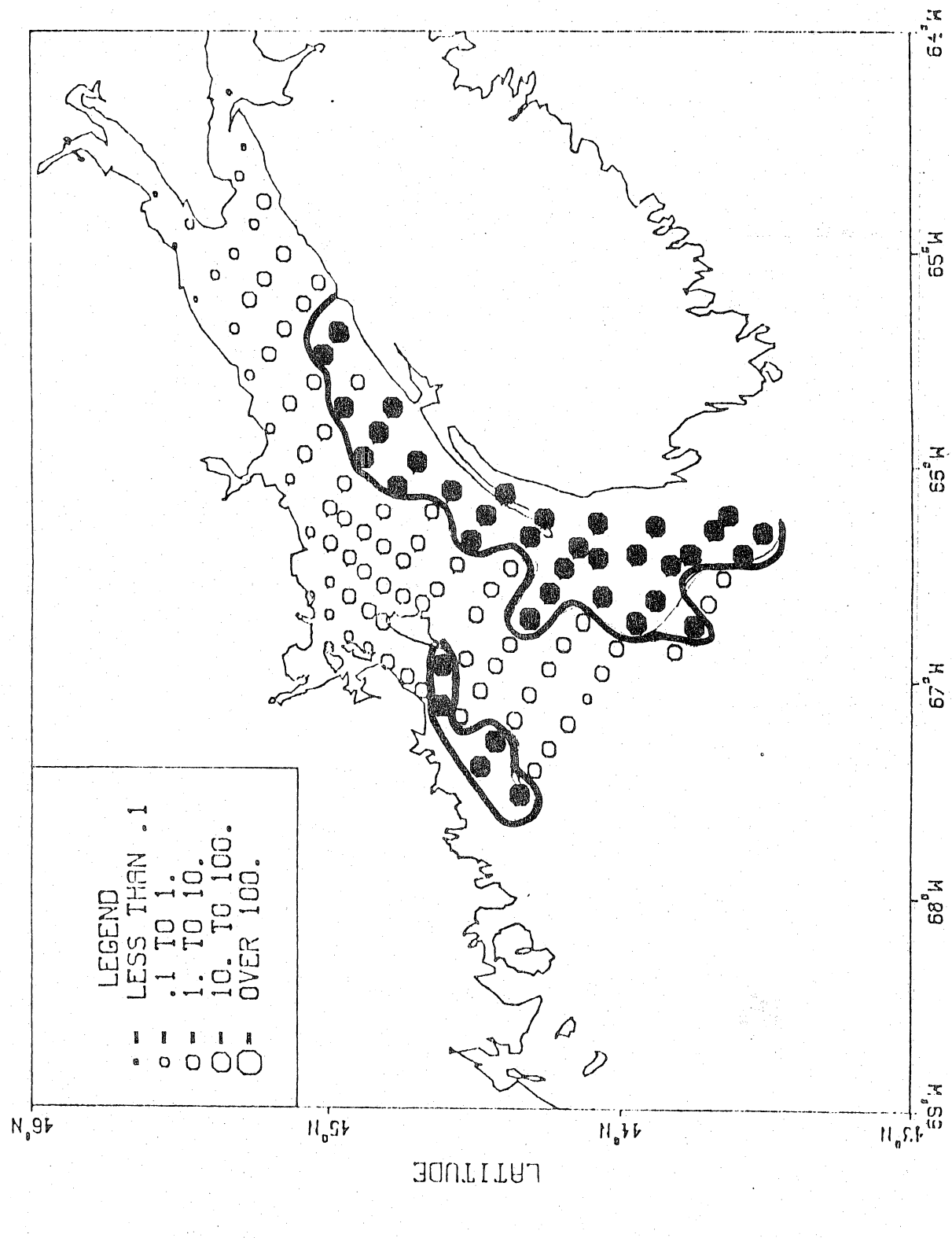
BAY OF FUNDY LARVAL HERRING
505 BONGO NUMBERS PER METER SQUARED
MEAN OF 1972 TO 1976
LEGEND
LESS THAN .1
.1 TO 1.
1. TO 10.
10. TO 100.
OVER 100.
46°N
45°N
44°N
43°N
LATITUDE
69°W
68°W
67°W
66°W
65°W
LONGITUDE

Figure 6.

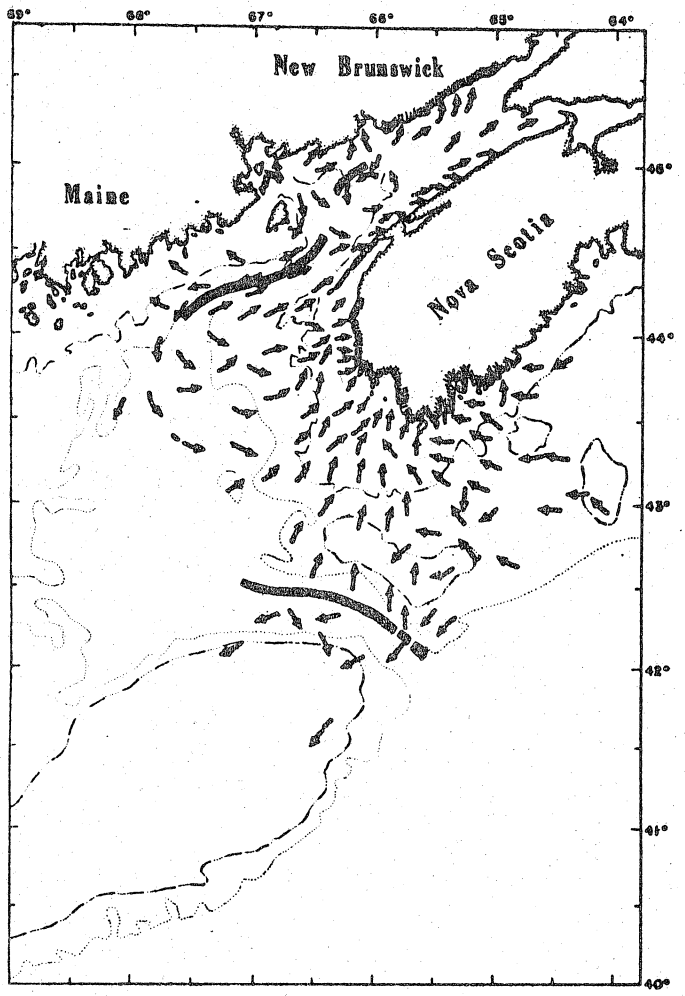

FIG. 7. Inferred residual bottom drift from SW Nova Scotia to the Bay of Fundy.

From Lauzier (1967)

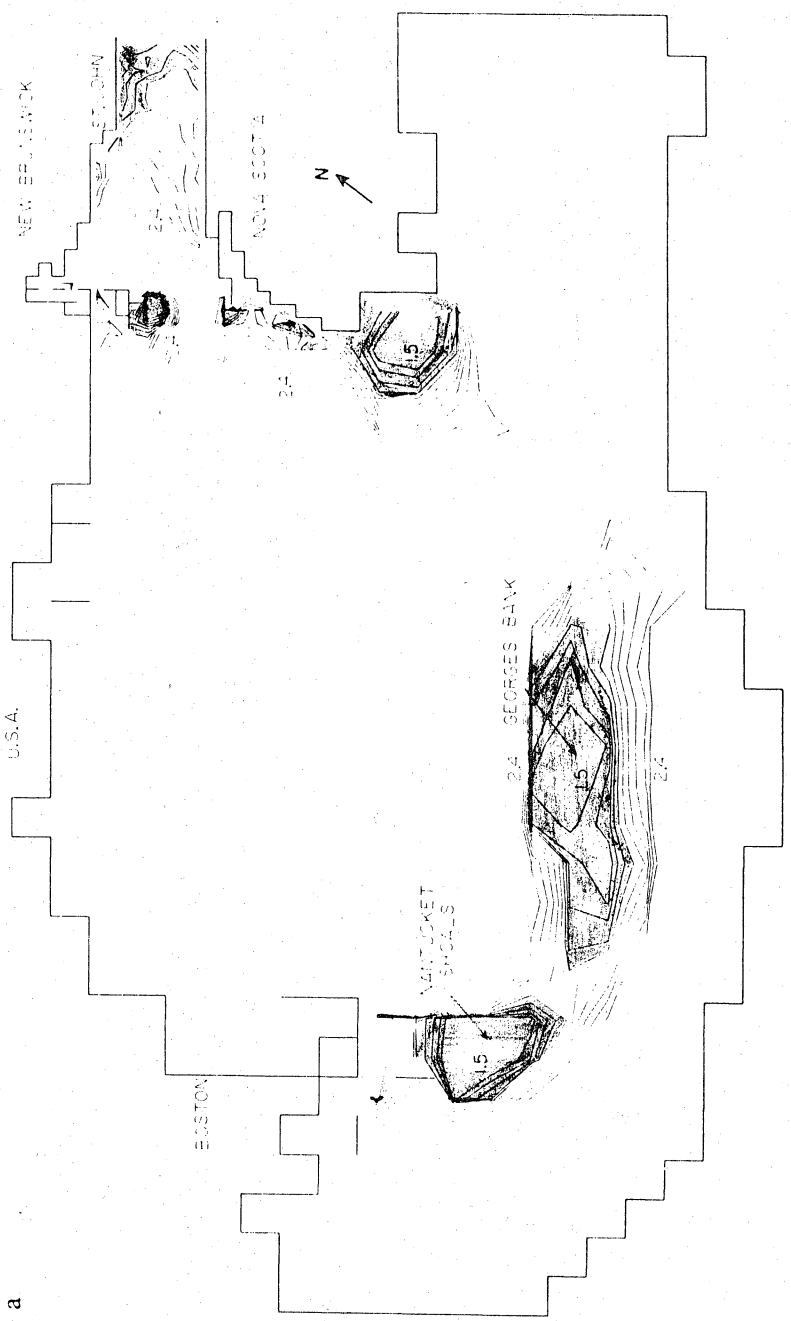

Figure 8. Distribution of the stratification parameter in the Gulf of Maine area (from Garrett et al., 1978).

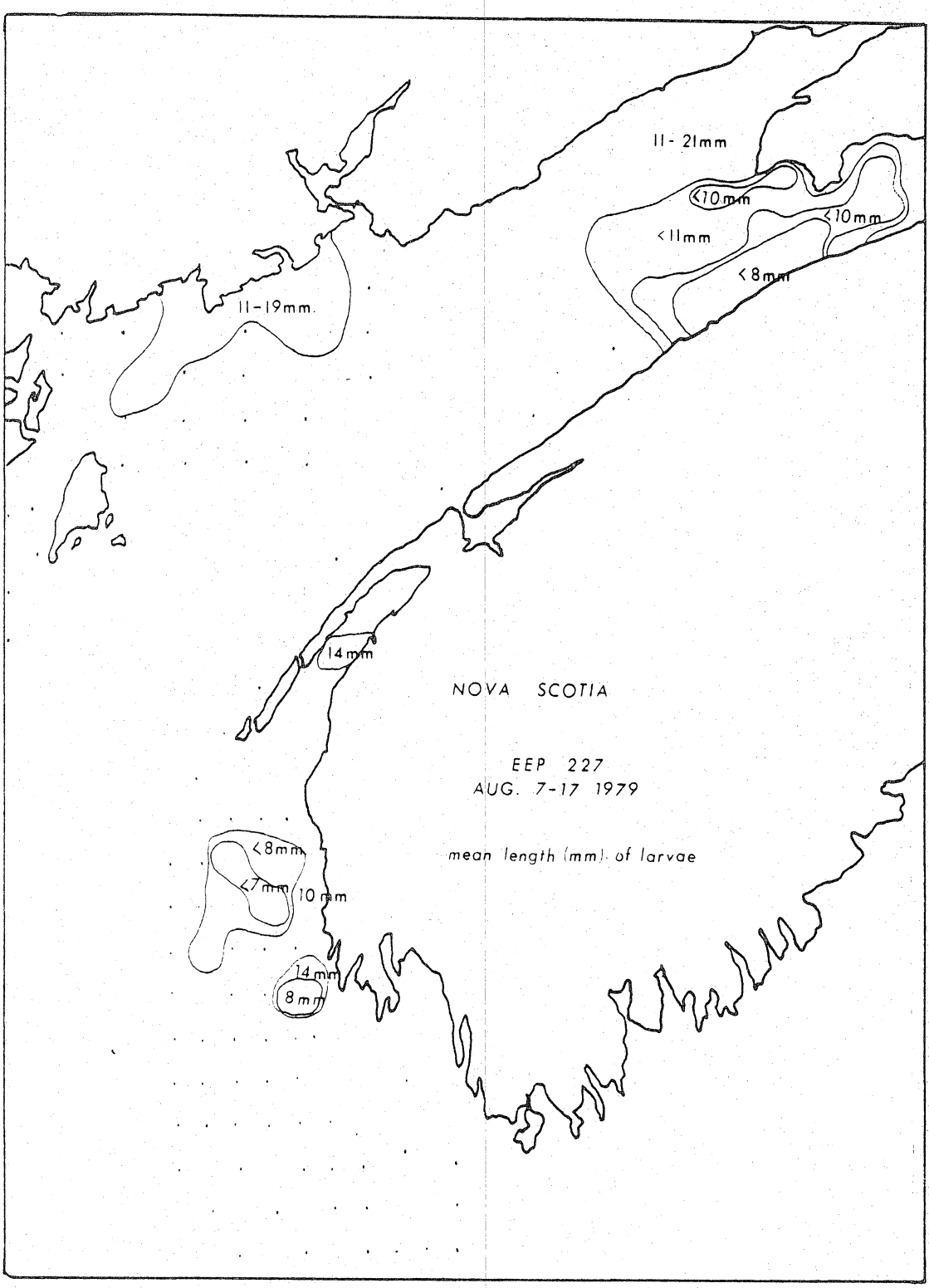

Figure 9. Distribution of mean lengths of herring larvae caught during the August 1979 survey.

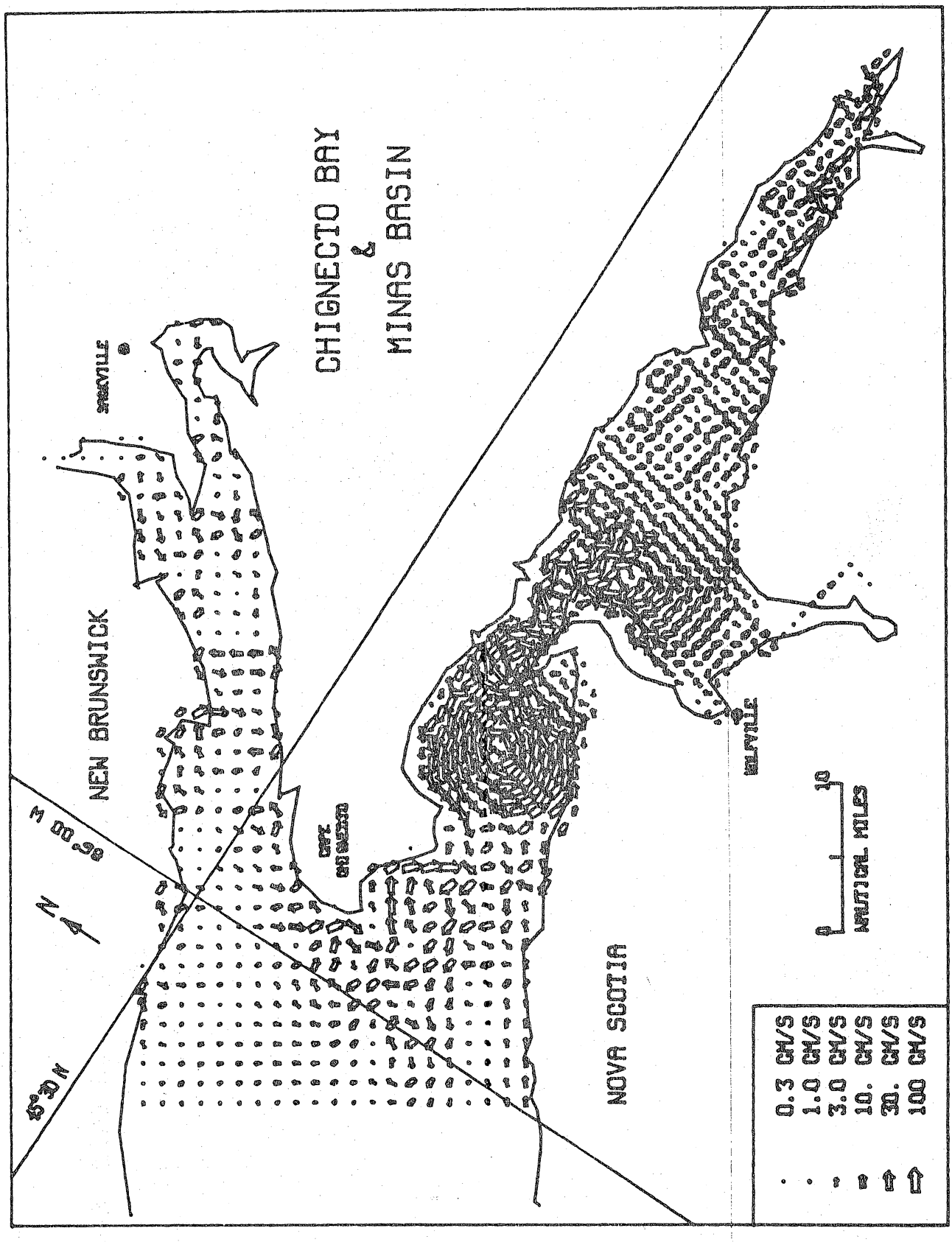

Figure 10. Tidal residual circulation estimated at the head of the Bay of Fundy from a tidal model by D. Greenberg.

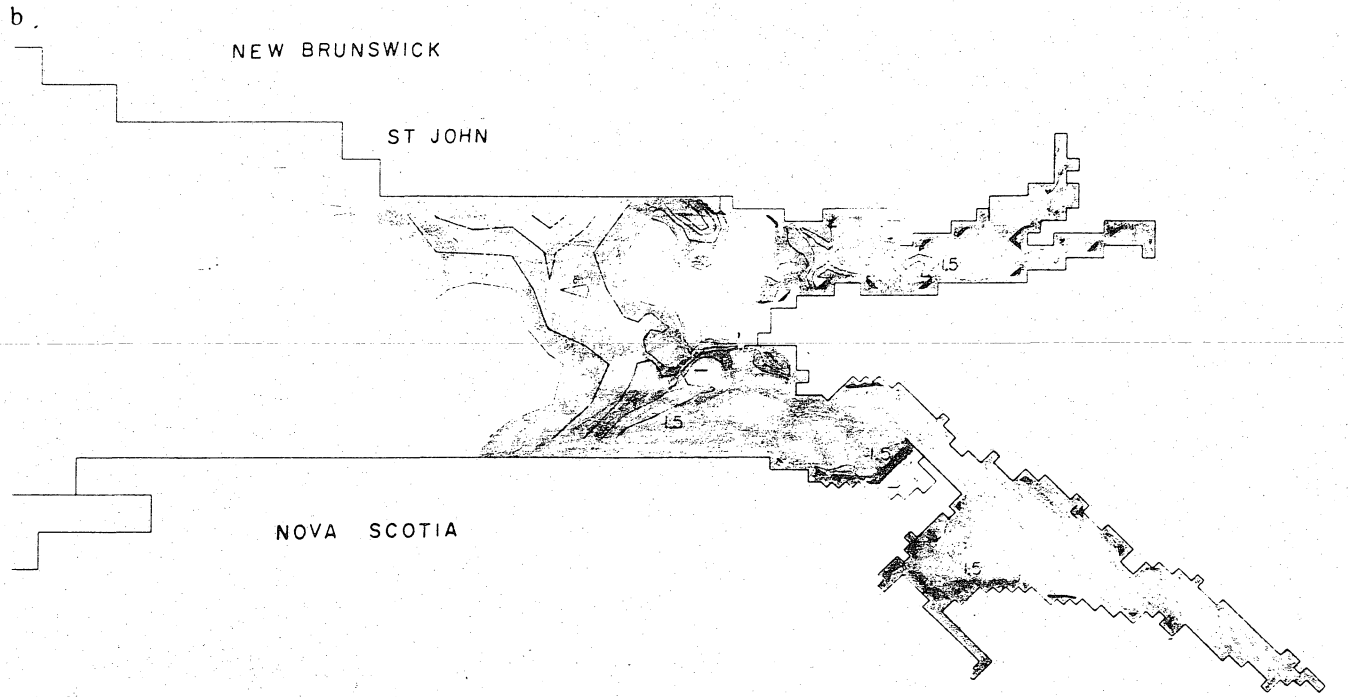

Figure 11. Distribution of the stratification parameter at the head of the Bay of Fundy (from Garrett et al., 1978).

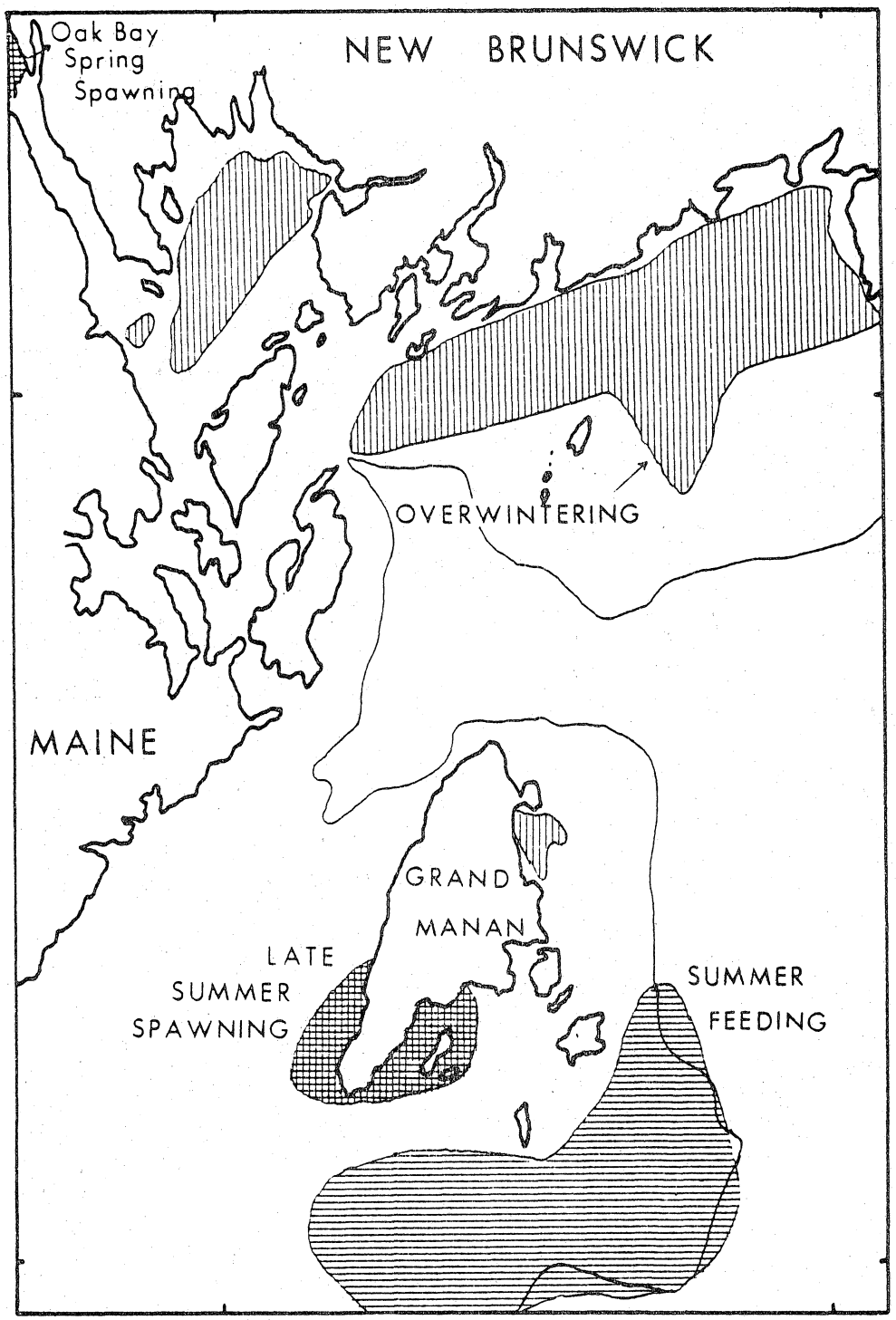

Figure 12. Distribution of various phases of the adult annual migration of Grand Manan herring (redrawn from Huntsman, 1953).

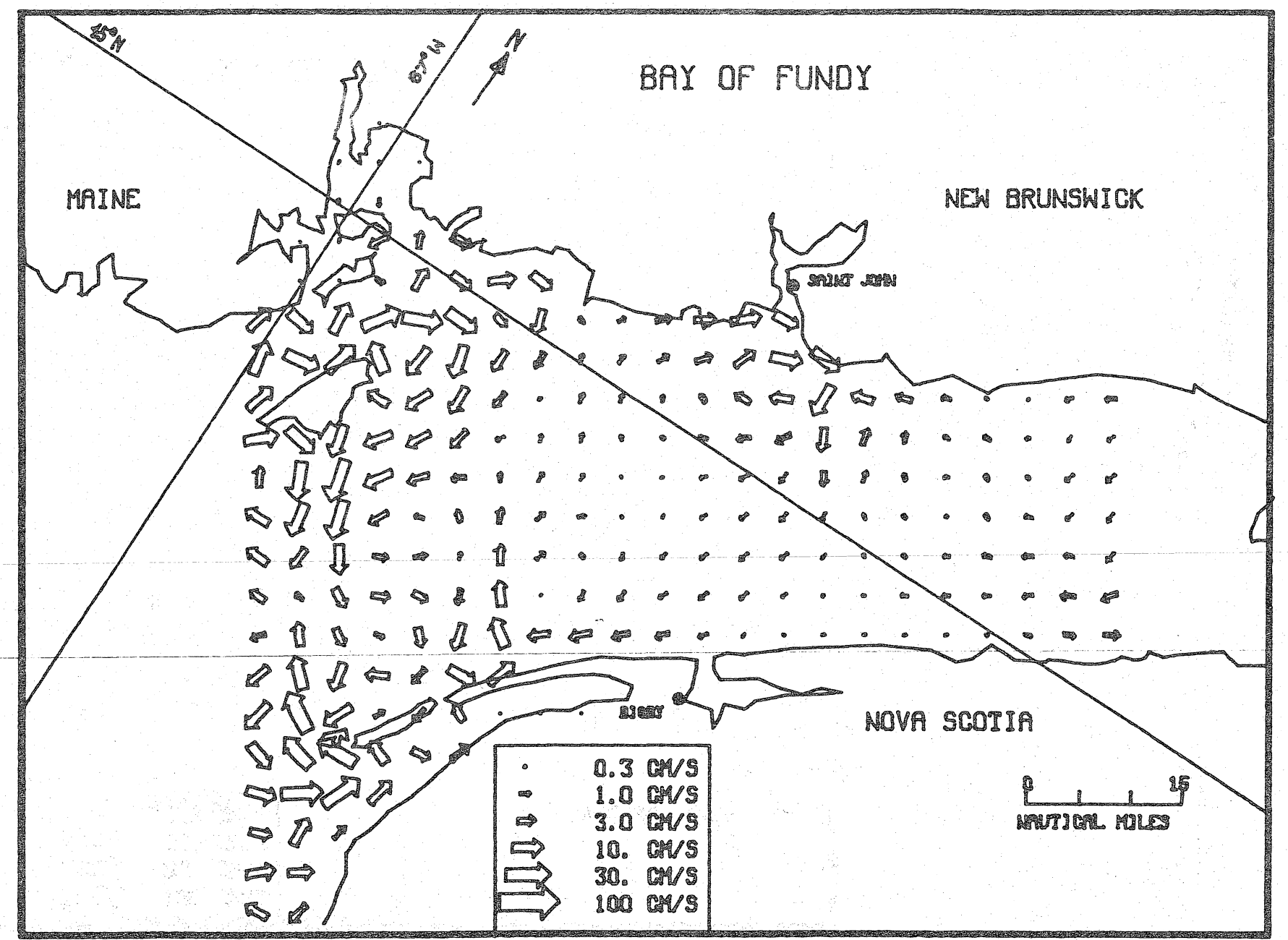

Figure 13. Tidal residual circulation at the mouth of the Bay of Fundy, estimated from a tidal model by D. Greenberg.

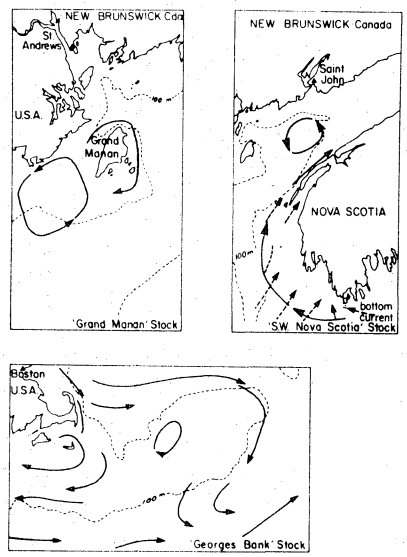

Figure 14. Residual gyre south-west of Grand Manan inferred by Hachey (1952), upper left.

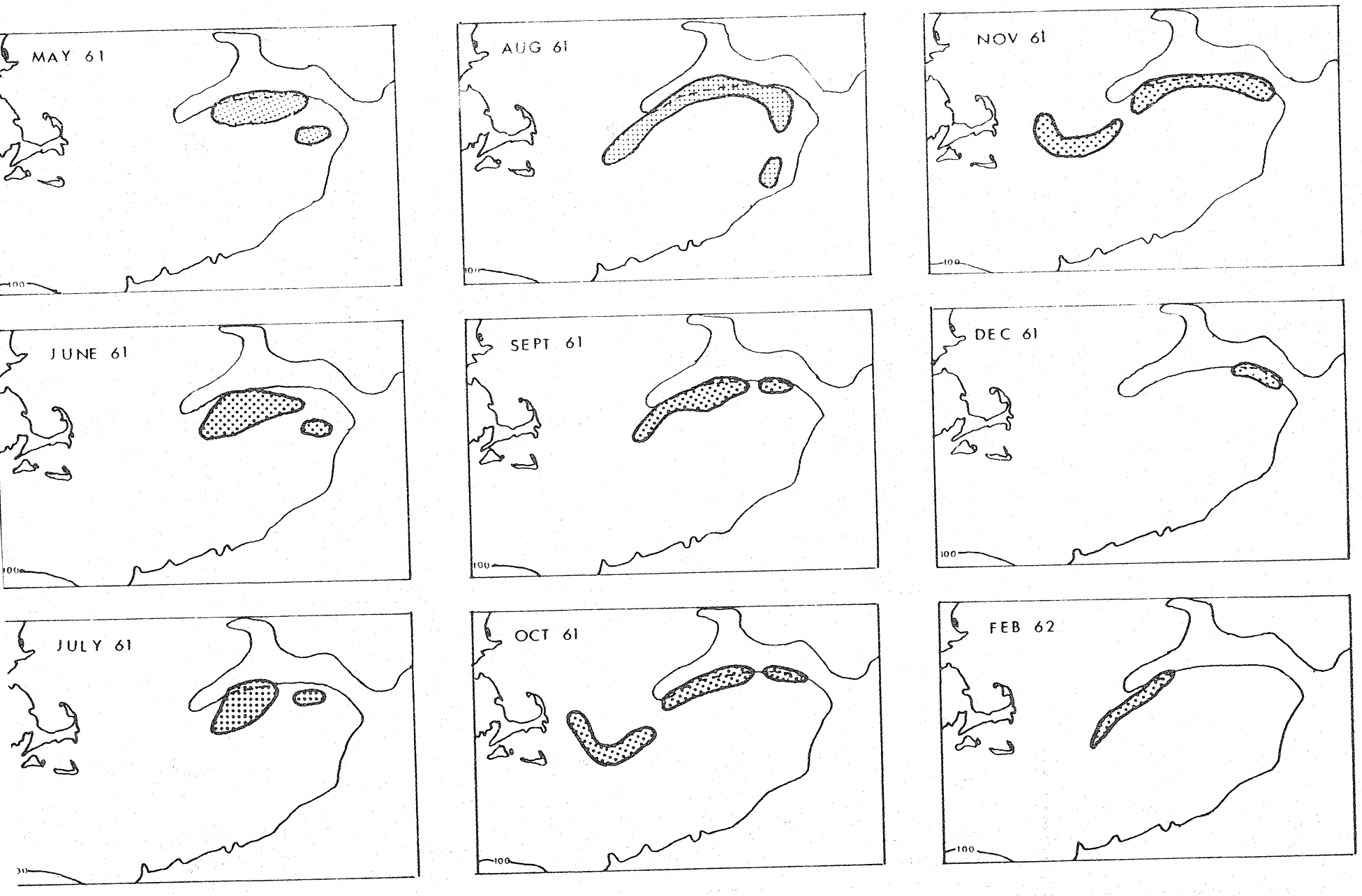

Figure 15. Location of Russian drift-gill net fishery during 1961/63.

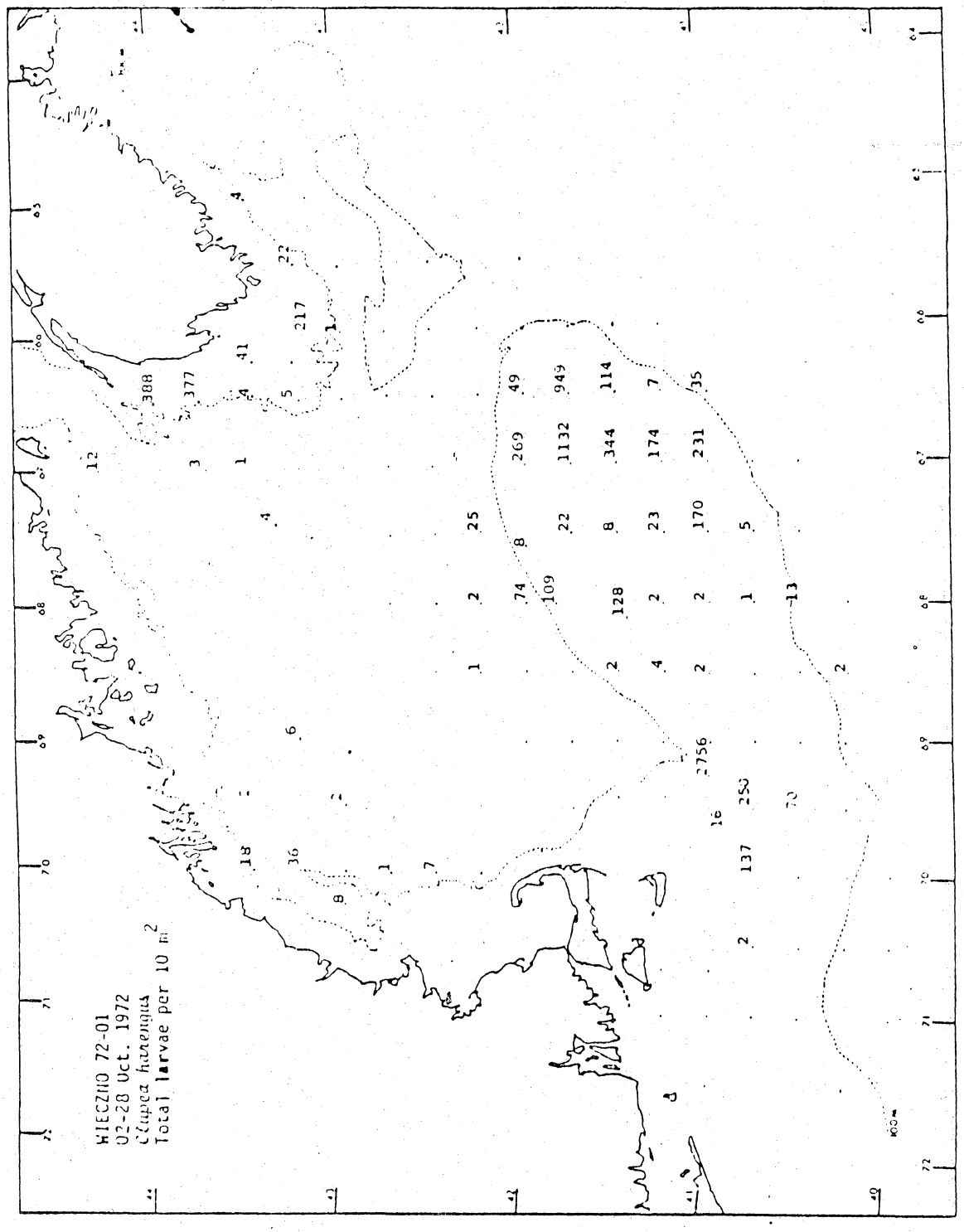

Figure 16. Representative autumn herring larval distribution in Georges Bank - Nantucket Shoals area (Fig. 48 from Laugh and Bolz, 1979).

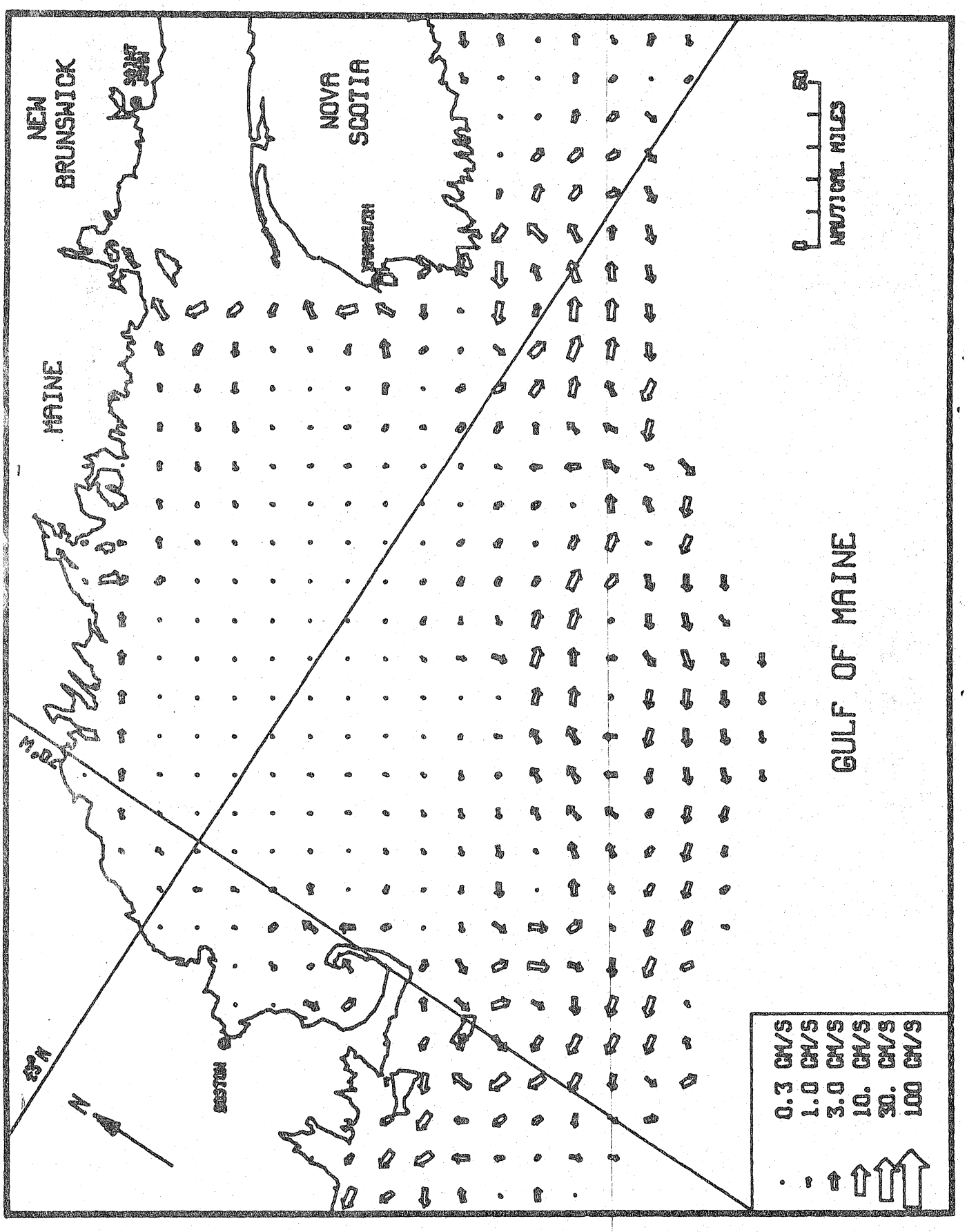

Figure 17. Tidal residual circulation in Georges Bank - Nantucket Shoals Region estimated from a tidal model by D. Greenberg.