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Distribution of Eggs and Larvae of Atlantic Menhaden, *Brevoortia tyrannus*, Along the Atlantic Coast of the United States

Mayo H. Judy and Robert M. Lewis

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U.S. DEPARTMENT OF COMMERCE
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741. [illegible] Amphipoda (Crustacea) in the Middle Atlant[ic] [illegible] Roland L. Wigley, Richard D. Brodeur, a[nd] [illegible] 1980, [illegible] 46 p., 26 figs., 52 tables.

742. [illegible] Ocean Weather Station V, northwestern Pacific Ocea[n] [illegible] By D. M. [illegible] and G. R. Seckel. October 1980, 18 figs., 4 tables.

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746. Distribution of gammaridean Amphipoda (Crustacea) on Georges Bank, [by] John J. Dickinson and Roland L. Wigley. June 1981, iii + 25 p., 16 figs., 1 table.

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752. Movements of tagged summer flounder, *Paralichthys dentatus*, off south[ern] New England, by F. E. Lux and F. E. Nichy. December 1981, iii + 16 p., 13 figs., [illegible] tables.

753. Factors influencing ocean catches of salmon, *Oncorhynchus* spp., off Wa[sh]ington and Vancouver Island, by R. A. Low, Jr. and S. B. Mathews. January 19[82], iv + 12 p., 6 figs., 7 tables.

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John V. Byrne, Administrator
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William G. Gordon, Assistant Administrator for Fisheries

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Distribution of Eggs and Larvae of Atlantic Menhaden, *Brevoortia tyrannus*, Along the Atlantic Coast of the United States[1]

MAYO H. JUDY and ROBERT M. LEWIS[2]

ABSTRACT

Atlantic menhaden, *Brevoortia tyrannus*, eggs and/or larvae were collected during 52 of 77 ocean cruises by 12 vessels from 1953 to 1975. The combined cruises extended from the Antilles Current southeast of Florida to Cape Cod, Mass. Eggs and/or larvae were present in samples from Cape Canaveral, Fla., to Martha's Vineyard, Mass. Eggs were found at several locations off the coast from October to February and they occurred in the upper water column (10 m or less in depth). The largest batch of eggs were caught in December off North Carolina. Larvae were found at numerous locations off the coast and catch by gear indicated that they appear to be most concentrated in the upper portion of the water column. Larvae were caught each month except September. They were more concentrated in the South Atlantic Bight than north of Cape Hatteras, N.C. Most larvae were taken between 20 and 75 km from shore and the two largest catches occurred in December and March off North Carolina. The cruise data show that the seasonal distribution and abundance of eggs and larvae coincide with the seasonal distribution of adults.

INTRODUCTION

Information on abundance and distribution of eggs and larvae is important in understanding the life history of any species but is often difficult and expensive to obtain. For pelagic species this data is particularly difficult to acquire, since large areas of the ocean must be systematically sampled, and sampling requires detailed planning, large vessels, sophisticated gear, adequate funding, and trained personnel to sort, catalog, and examine material after it is collected. It is not surprising, therefore, that only fragmentary information is available on early life histories of many pelagic species important to man.

One such species is the commercially valuable Atlantic menhaden, *Brevoortia tyrannus,* which ranges along the east coast of the United States from central Florida to the Gulf of Maine. Seasonal movements and distribution of adult menhaden have been well documented (June and Reintjes 1959; June and Nicholson 1964; Nicholson 1971, 1972; Dryfoos et al. 1973). Menhaden make extensive seasonal movements along the coast and are known to spawn in the open ocean as well as in sounds and bays in the northern part of their range. Larvae eventually are transported to estuaries, where they metamorphose. Prior to 1953, collections were made almost exclusively in sounds, bays, and inlets.

Since 1953 a number of cruises have been designed specifically to collect pelagic fish eggs and larvae, including menhaden, in the open ocean. Vessels from state, federal, and academic research institutions, as well as vessels of the U.S. Coast Guard and the National Aeronautics and Space Administration, have been used. The results of many of these cruises, particularly those aspects pertaining to menhaden, have not been published.

Results of a series of cruises from three studies, however, have been published. Reintjes (1961) reported on material collected during nine cruises of the MV *Theodore N. Gill* from February 1953 to December 1954 between Cape Hatteras, N.C., and Cape Canaveral, Fla. Massmann et al. (1962) reported on the occurrence of menhaden eggs and larvae collected at a series of stations from the mouth of Chesapeake Bay to 74 km offshore by the RV *Pathfinder* from December 1959 to December 1960. Kendall and Reintjes (1975) discussed the occurrence and distribution of menhaden eggs and larvae collected during eight cruises of the RV *Dolphin* from December 1965 to December 1966 between Martha's Vineyard, Mass., and Cape Lookout, N.C. The area between Cape Hatteras and Cape Lookout had previously been sampled during earlier cruises of the *Gill.*

In this report we include some published data from the *Gill* and *Dolphin* cruises, as well as unpublished information on menhaden eggs and larvae from samples taken during 60 ocean cruises by 11 vessels from 1964 through 1975, including 18 monthly cruises in Onslow Bay, N.C., by a small National Marine Fisheries Service research vessel, the *Onslow Bay.* Some cruises were designed to survey broad areas for the occurrence of all pelagic eggs and larvae, others were designed specifically to determine the abundance and distribution of menhaden eggs and larvae. Several types of sampling gear and a variety of mesh sizes were used. Personnel of the Beaufort Laboratory sorted and examined material collected by the *Onslow Bay* and by the *Dolphin* on cruises D1-74, D1-75, and D4-75. Material from other cruises was sorted and examined at other east coast laboratories. Much effort and time were spent separating eggs and larvae from the large amounts of extraneous material. Many samples probably were not searched for menhaden eggs, since the original objectives of some cruises were not directly related to menhaden. A total of 670 samples taken with the 0.333 mm mesh bongo net was used for other studies and was not searched for eggs and larvae.

Our objectives were to record the number of menhaden eggs and larvae collected during each cruise or series of cruises; summarize significant aspects of each cruise, such as date, geographic loca-

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tion, type of gear, number of stations and samples; and briefly discuss our findings in relation to conclusions drawn by other investigators.

RESULTS AND DISCUSSION

Temporal and Geographical Collections of Eggs

Due to limited information on eggs we did not plot egg data by cruise on separate figures as we did for larvae. Distribution and abundance of Atlantic menhaden eggs along the Atlantic coast are shown in Table 1 for the following nine cruises from which eggs were reported: MV *Theodore N. Gill* (1, 5, and 9), RV *Dolphin* (D-66-12, D-66-14, and D-66-15), RV *Advance II* (3 and 4), and RV *Eastward* (E-42-69).

Atlantic menhaden eggs have been found at some location off the east coast every month except March. Reintjes (1961) reported that during the *Gill* cruises in 1953-54, eggs were collected off Cape Lookout, N.C., in December and February, off Cape Fear, N.C., in February, and in the vicinity of Cape Canaveral and Jupiter Inlet, Fla., in January and February. (In Florida, eggs or larvae could be either Atlantic menhaden or yellowfin menhaden, *B. smithi.*) Kendall and Reintjes (1975) reported that during the *Dolphin* cruises in 1965-66, eggs were collected at widely scattered locations from Long Island, N.Y., to Delaware Bay in October, and just north of the entrance to Chesapeake Bay in November. Other investigators (Wheatland 1956; Richards 1959; Herman 1963; Matthiessen[3]) have reported eggs from New York and New England waters from April to October.

[3]Matthiessen, G. C., Rome Point Investigations, Quarterly Progress Reports for June-August 1972; September-November 1972; July 3-August 29, 1973; September-November 1973. Mimeo Rep. Marine Research, Inc., East Wareham, Mass.

The incubation period of eggs is only 36 to 48 h (Kuntz and Radcliffe 1918), so eggs from a particular spawning are unlikely to become widely dispersed before they hatch. As a result, there are likely to be a few places where eggs are heavily concentrated and vast areas where there are few or no eggs. Random or systematic sampling, therefore, will produce many collections with no eggs and a few collections with a large number of eggs. During the November-February period in the South Atlantic, when menhaden eggs are most likely to be present, Reintjes (1961) found eggs at 12 of 267 stations, with only three of those stations containing more than 100 eggs. Of 1,088 samples collected from Martha's Vineyard, Mass., to Cape Lookout, N.C., reported by Kendall and Reintjes (1975), only 6 contained eggs. From other cruise data, eggs were identified in samples at 50 of 1,542 stations off North Carolina and South Carolina in November, December, and January when menhaden would be expected to spawn. The largest number of eggs from a series of tows in the same area was about 500,000, taken in December 40 km southeast of New River Inlet, N.C., from a patch of eggs estimated to have been about 9 km in diameter (*Dolphin* cruise 66-15). Estimates of egg abundance, however, are undoubtedly low because many cruises were concerned only with larvae, and eggs were not sorted and identified from the samples.

Generally eggs were near the surface. None were found in samples from oblique tows. In all instances they were taken by surface tows or tows 10 m or less in depth, supporting the conclusion by Reintjes (1969) that Atlantic menhaden eggs are buoyant in ocean waters.

Temporal and Geographical Collections of Larvae

Larval data for each cruise are shown in Table 2. Cruise area, station locations, and larval distribution and abundance for selected cruises are shown in Figures 1 to 11, Appendix I. Menhaden larvae were taken more frequently and over wider areas

Table 1.—Distribution and abundance of Atlantic menhaden eggs along the Atlantic coast are shown for the following nine cruises from which eggs were reported: MV *Theodore N. Gill* (1, 5, and 9); RV *Dolphin* (D-66-12, D-66-14, and D-66-15); RV *Advance II* (3 and 4); and RV *Eastward* (E-42-69).

Vessel	Cruise no.	No. stations: By cruise	No. stations: With eggs	Month	No. eggs	Location	Distance from shore (km)
RV *Dolphin*	66-12	92	5	Oct.	2,000+	Northeast end of Long Island, N.Y., to east of Delaware Bay.	14-82
	66-14	92	1	Nov.	<100	Northeast Cape Charles, Va.	24
RV *Eastward*	E-42-69	22	13	Nov.	1,627	East-northeast Cape Lookout, N.C.	15-77
MV *Gill*	9	67	1	Dec.	47	South Cape Lookout, N.C.	30
RV *Dolphin*	66-15	85	30	Dec.	500,000+	Southeast New River Inlet, N.C.	26-134
RV *Advance II*	3	81	4	Dec.	14	Southeast Cape Fear, N.C.	48-72
	4	91	2	Jan.	77	Southeast Cape Fear, N.C.	120-140
MV *Gill*	5	66	1	Jan.	4	North of Jupiter Inlet, Fla.	14
			3	Feb.	33	South of Cape Lookout and east of Cape Fear, N.C.	29-62
			3	Feb.	2,025	Vicinity Cape Canaveral, Fla.	34-96
	1	52	3	Feb.	659	Vicinity Jupiter Inlet, Fla.	5-25

than eggs. Overall, larvae occurred in 15% of all samples taken, although frequency of capture was considerably greater during periods and in areas of menhaden spawning activity. Reintjes (1961) found larvae at 20% of the 252 stations sampled between November and April south of Cape Hatteras. Kendall and Reintjes (1975) reported them at 20% of 638 stations sampled between December 1965 and December 1966 north of Cape Hatteras. Of the additional cruise data that we examined, larvae were present at 27% of the 1,567 stations sampled during a time when spawning would be expected. Because of the patchy distribution of menhaden larvae, most positive samples contained few larvae, while a few accounted for the majority. For example, six samples (Table 3, Density Category < 1000 larvae) (0.6% of positive samples or 0.1% of total samples) accounted for 33,965 (63%) of the larvae, while 664 samples (Table 3, Density Category 1-10 larvae) (73%) accounted for only 2,226 (4%) of the larvae.

Of 60 cruises on which we report, 2 were in the Antilles Current southeast of Florida, 41 were between Florida and Cape Hatteras, 9 were between Florida and Chesapeake Bay, 1 was between Florida and Massachusetts, and 7 were between Cape Hatteras and Massachusetts (Table 2). Although larvae have been reported north of Martha's Vineyard, Mass., (Marak and Colton 1961; Herman 1963; Matthiessen footnote 3) we will discuss the seasonal distribution of larvae only in the area between Martha's Vineyard and Florida, since we found no larvae north of Martha's Vineyard or from the Antilles Current. We arbitrarily divided the area into two parts, one extending from Cape Hatteras to Martha's Vineyard and the other from Florida to Cape Hatteras.

North of Cape Hatteras, where sampling was irregular, larvae were taken throughout most of the year but not necessarily in every month (Table 3). Larval catch per sample was much less than for south of Cape Hatteras, ranging from 0.006 in March to 9.8 in October with a mean of 3.4. The *Dolphin* (Kendall and Reintjes 1975), which took samples each month except March and July, caught larvae in each of the other months, except January and September, when only 14 and 25 samples, respectively, were taken. Other investigators (Perlmutter 1939; Wheatland 1956; Richards 1959; Herman 1963) have reported larvae north of Long Island from May to October.

South of Cape Hatteras, approximately 63% of the samples were collected from November to April, the period when all larvae were caught. Larval catch per sample ranged from 0.2 in April to 44.4 in December with a mean of 11.5. The four most productive months were from December to March (Table 3). From May to October, 1,493 samples were taken, but they contained no larvae (Table 3). Larvae collected off Cape Canaveral in November, a time when no other larvae were caught south of about Cape Romain, S.C., probably were yellowfin menhaden, which are known to spawn in the area at that time (Hildebrand 1948; June 1958; Reintjes 1960). The *Gill* (Reintjes 1961) took samples each month except September but caught larvae only during November, December, February, and March, the most productive month being December, when approximately 22,000 larvae were caught in one Gulf V sample. The *Dolphin* (Kendall and Reintjes 1975) took samples each month except January, March, and July but caught larvae only during November, December, February, and April, December again being the most productive month. Larvae caught in December were predominately very small (4-6 mm) and were taken in the Cape Hatteras-Cape Lookout area, indicating that spawning was just beginning in the northern portion of the South Atlantic Bight.

Most larvae were taken between 20 and 75 km from shore. In this zone 2,660 samples (43%) accounted for 40,832 larvae (76%). Less than 20 km from shore 1,052 samples (17%) accounted for 2,811 larvae (5%). Between 76 and 130 km, 1,546 samples (25%) contained 3,997 larvae (7%); between 131 and 185 km, 619 samples (10%) contained 5,085 larvae (10%); and between 186 and 402 km, 309 samples (5%) contained 661 larvae (0.01%). Because larvae in samples from the Newport River were not included in this breakout the total numbers do not agree with those in Table 3.

There were considerable differences in the numbers of larvae caught by the bongo and neuston nets, the bongo nets averaging 2.5 larvae/sample and the neuston nets 25.4. Each oblique bongo sample required about 20 min at 1.5 kn (approximately 250 m^3 strained) and each surface neuston sample required about 10 min at 5 kn (approximately 1,500 m^3 strained). We compared catches, without standardizing gear, only for cruises where both samplers were used and when one or both caught larvae. Each bongo net was considered one sample. Each gear exhibits some bias in that large larvae may avoid the slowly towed bongo nets and small larvae are extruded through the larger mesh of the faster towed neuston net. However, the overall results support observations of earlier authors that menhaden larvae appear to be most concentrated in the upper portions of the water column (Kendall and Reintjes 1975; Nelson et al. 1977).

TEMPORAL AND GEOGRAPHIC NORMS OF SPAWNING

The cruise data that we examined show a seasonal and geographic distribution of menhaden larvae (Figs. 12 to 15 Appendix I) similar to that inferred from other cruise data by previous investigators, and therefore support the conclusions drawn by Kendall and Reintjes (1975) and Higham and Nicholson (1964) that the seasonal distribution and abundance of eggs and larvae coincides with the seasonal distribution of adults. South of Cape Hatteras, menhaden of spawning age generally have moved north by late April and do not return again until late October or November. Larvae also are absent during this period, except for a few found in April (Table 3). North of Cape Hatteras, where menhaden of spawning age are found at some place in nearly every month of the year, larvae also have been reported in nearly every month, although spawning in late fall and winter is mainly restricted to the area south of Delaware Bay. The broad seasonal and geographic occurrences of eggs and larvae indicate that spawning probably takes place over a wide range of temperature.

In October, November, and December, significant numbers of larvae were taken along much of the east coast, when menhaden were moving southward (Fig. 12, Appendix I). Larvae were first taken offshore of Long Island in October and were not found north of New Jersey after that month. As spawners moved progressively down the coast, larvae appeared over the entire shelf area from New Jersey to Cape Hatteras. They were not found south of Cape Hatteras before November but extended as far south as Cape Romain by December.

During January, February, and March, larvae were concentrated in the South Atlantic Bight although a few occurred as far north as New Jersey in February (Fig. 13, Appendix I). Distribution appeared continuous from North Carolina to Florida and offshore to the inner edge of the Gulf Stream.

In April, May, and June during the spring northward migration, larvae appeared progressively later up the coast as older fish moved north (Fig. 14, Appendix I). By May larvae were found only from

Table 2.—Number of stations, number of plankton samples, and number of Atlantic menhaden larvae by month and cruise along the Atlantic coast of the United States and north of the Greater and Lesser Antilles 1953-75. (N, north of Cape Hatteras, N.C., S, south of Cape Hatteras, N.C.). See Appendix I for general summary of cruise da ta and data source.

Vessel	Year	Cruise number	Gear	Location	Number of stations, samples, and larvae by month and cruise													
							Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
MV *Theodore N. Gill*	1953	1-4	Gulf III Gulf IA Half Meter	Jupiter Inlet, Fla., to Cape Hatteras, N.C.	Stations	S	0	32	20	35	52	0	35	40	0	57	15	0	286
					Samples			32	20	35	52		35	40		57	15		286
					Larvae			24	10	0	0		0	0		0	0		34
	1954	5-9	Same	Same	Stations	S	6	60	0	17	0	25	44	0	76	0	41	26	295
					Samples		6	60		17		25	44		76		41	26	295
					Larvae		0	2,154		0		0	0		0		51	22,054	24,259
RV *Dolphin*	1965	4	Gulf V	Martha's Vineyard, Mass., to Cape Lookout, N.C.	Stations	N												71	71
						S												7	7
					Samples	N												115	115
						S												10	10
					Larvae	N												402	402
						S												512	512
	1966	1,3, 5, 7, 10, 12, 14	Same	Same	Stations	N	9	67	0	82	82	83	0	82	12	70	52	28	567
						S	0	10	0	10	10	10	0	10	5	5	10	3	73
					Samples	N	14	99		125	129	129		128	25	108	74	38	869
						S	0	13		15	15	13		14	7	7	15	4	103
					Larvae	N	0	33		16	3	14		8	0	5,420	286	4	5,784
						S	0	272		18	0	0		0	0	0	18	0	308
RV *Eastward*	1964	Date only	Clark-Bumpus	Off North Carolina Cape Lookout to Oregon Inlet	Stations	S											21	14	35
					Samples												84	56	140
					Larvae												4	1	5
	1965	Date only	Same	Same	Stations	S	14	14	14	14									56
					Samples		56	56	56	56									224
					Larvae		6	12	175	0									193
RV *Dolphin*	1966	15	Gulf V	Cape Lookout, N.C., to Cape Romain, S.C.	Stations	S												85	85
					Samples													157	157
					Larvae													29	29
RV *Albatross IV*	1967	1	Six different samplers	Off North Carolina northeast of Cape Fear	Stations	S	13												13
					Samples		30												30
					Larvae		769												769
RV *Eastward*	1967	7	Gulf V	Off North Carolina Oregon Inlet, Ocracoke Inlet and Cape Lookout	Stations	S		10											10
					Samples			10											10
					Larvae			117											117
RV *Dolphin*	1967	4, 8, 16	Gulf V	New River Inlet, N.C., to Palm Beach, Fla.	Stations	S					80		74	6		80			240
					Samples						110		102	8		111			331
					Larvae						0		0	0		0			0
	1968	1	Same	Same	Stations	S	45	35											80
					Samples		61	50											111
					Larvae		274	155											429
RV *Albatross IV*	1968	3, 17	Bongo	Nantucket Island, Mass., to Cape Hatteras, N.C.	Stations	N			85							106			191
					Samples				170							212			382
					Larvae				0							211			211

RV *Advance II*	1968	3	Gulf V	Off North Carolina between Cape Fear and Cape Lookout	Stations	S										81	81
					Samples											81	81
					Larvae											21	21
	1969	4	Gulf V and 30 cm fabric net	Between Cape Fear, N.C., and Cape Romain, S.C.	Stations	S	91										91
					Samples		91										91
					Larvae		466										466
USCG Cutter *Chilula*	1969	Date only	0.5 m cloth nets	Cape Hatteras, N.C., to Charleston, S.C.	Stations	S		32									32
					Samples			32									32
					Larvae			250									250
NASA *Range Recoverer*	1969	Date only	Same	Same	Stations	S		26									26
					Samples			26									26
					Larvae			99									99
RV *Albatross IV*	1969	2,11	Bongo	Nantucket Island, Mass., to Cape Hatteras, N.C.	Stations	N			62					90			152
					Samples				124					180			304
					Larvae				0					58			58
RV *Eastward*	1969	42	Gulf V	Onslow Bay and Raleigh Bay, N.C. Area of Cape Lookout	Stations	S									22		22
					Samples										22		22
					Larvae										97		97
RV *Undaunted*	1970	Date only	Gulf V	Off North Carolina between Cape Lookout and Cape Fear	Stations	S										15	15
					Samples											15	15
					Larvae											10	10
	1971	Date only	Gulf V and Bongo	Cape Lookout, N.C., to Cape Fear, N.C., and Cape Fear to Savannah, Ga.	Stations	S	39	19	12								70
					Samples		51	67	30								148
					Larvae		85	4,916	315								5,316
RV *Albatross IV*	1972	6 (Part I and Part II)	Bongo and Neuston	Lat. 18°00 'N in the Caribbean to lat. 30°00 'N off Florida	Stations	S				37	43						80
					Samples					55	65						120
					Larvae					0	0						0
RV *Delaware II*	1972	19	Bongo and Neuston	Lat. 42°00 'N off Massachusetts to lat. 29°20 'N off Florida	Stations	N				82	9						91
						S				0	56						56
					Samples	N				164	18						182
						S				0	112						112
					Larvae	N				2	0						2
						S				0	0						0
RV *Onslow Bay*	1972	Date only	Bongo	Onslow Bay, N.C. off Beaufort, N.C.	Stations	S								12	16	16	44
					Samples									24	32	32	88
					Larvae									0	19	29	48
RV *Albatross IV*	1973	2 (Part I)	Bongo and Neuston	Lat. 20°00 'N in the Greater Antilles to lat. 30°00 'N off Florida	Stations	S	30	16									46
					Samples		60	32									92
					Larvae		0	0									0
	1973	2 (Part II)	Same	Lat. 30°30 'N off Florida to lat. 37°00 'N off Chesapeake Bay	Stations	N		15									15
						S		27									27
					Samples	N		30									30
						S		54									54
					Larvae	N		0									0
						S		3									3

Table 2.—*Continued.*

Vessel	Year	Cruise number	Gear	Location			Number of stations, samples, and larvae by month and cruise												
							Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
	1973	3 (Part III)	Same	Lat. 30°30 'N off Long Island, N.Y., to lat. 36°30 ' off Chesapeake Bay	Stations	N			18										18
					Samples				36										36
					Larvae				2										2
RV *Wieczno*	1973	1	Bongo and Neuston	Lat. 41°00 'N off Long Island, N.Y., to lat. 37°30 'N off Chesapeake Bay	Stations	N		54	4										58
					Samples			108	8										116
					Larvae			656	0										656
RV *Dolphin*	1973	2	Bongo and Neuston	Lat. 28°00 'N off Florida to lat. 34°00 'N off North Carolina	Stations	S		20	47										67
					Samples			40	94										134
					Larvae			663	6,903										7,566
	1973	3	Bongo and Neuston	Lat. 31°00 'N off Brunswick, Ga., to lat. 34°00 'N off Cape Lookout, N.C.	Stations	S					43								43
					Samples						86								86
					Larvae						0								0
	1973	4	Neuston	Off Charleston, S.C.	Stations	S							128						128
					Samples								128						128
					Larvae								0						0
	1973	5	Bongo and Neuston	Cape Fear, N.C., to Cape Canaveral, Fla.	Stations	S										11	30		41
					Samples											24	45		69
					Larvae											0	0		0
RV *Atlantic Twin*	1973	3	Bongo and Neuston	Block Island, R.I., to Cape Hatteras, N.C.	Stations	N										41	20		61
					Samples											82	40		122
					Larvae											49	56		105
RV *Onslow Bay*	1973	Date only	Bongo	Onslow Bay, N.C. off Beaufort, N.C.	Stations	S	16	16	16		16	16	16	16	16	7	13	9	157
					Samples		32	32	32		32	32	32	32	32	14	26	18	314
					Larvae		73	85	75		0	0	0	0	0	0	16	15	264
RV *Dolphin*	1974	1	Bongo and Neuston	Onslow Bay, N.C. Cape Fear to Cape Lookout	Stations	S	33												33
					Samples		99												99
					Larvae		1,550												1,550
	1974	2	Same	Cape Hatteras, N.C., to Cape Canaveral, Fla.	Stations	S				51	4								55
					Samples					89	8								97
					Larvae					34	0								34
	1974	3	Same	Cape Fear, N.C., to Cape Canaveral, Fla.	Stations	S								36	2				38
					Samples									72	4				76
					Larvae									0	0				0
RV *Onslow Bay*	1974	Date only	Bongo	Onslow Bay, N.C. off Beaufort, N.C.	Stations	S	13	10	11	10									44
					Samples		26	20	22	20									88
					Larvae		176	10	5	3									194
RV *Dolphin*	1975	1, 4	Bongo and Neuston	Onslow Bay, N.C. Cape Fear to Cape Lookout	Stations	S	31											35	66
					Samples		93											105	198
					Larvae		3,542											47	3,589

Table 3.—Number of stations, number of samples, number of samples with Atlantic menhaden larvae (by density category), number of larvae each month for all years combined 1953-75, and number of larvae per sample, north and south of Cape Hatteras, N.C.

Area and month	Total no. stations	Total no. samples	Density category: 1-10 larvae		11-100 larvae		101-1,000 larvae		>1,000 larvae		No samples with larvae	No. larvae	No. larvae per total no. samples
			No. samples	No. larvae	No. samples	No. larvae	No. samples	No. larvae	No. samples	No. larvae			
North Cape Hatteras													
Jan.	9	14	0	0	0	0	0	0	0	0	0	0	0.00
Feb.	136	237	18	43	2	26	1	628	0	0	21	697	2.94
Mar.	168	338	2	2	0	0	0	0	0	0	2	2	0.01
Apr.	82	125	3	4	1	12	0	0	0	0	4	16	0.13
May	82	129	3	3	0	0	0	0	0	0	3	3	0.02
June	83	129	2	3	1	11	0	0	0	0	3	14	0.11
July	82	164	2	2	0	0	0	0	0	0	2	2	0.01
Aug.	82	146	5	7	0	0	0	0	0	0	5	7	0.05
Sept.	12	25	0	0	0	0	0	0	0	0	0	0	0.00
Oct.	307	582	88	290	28	772	6	2,123	1	2,553	123	5,738	9.86
Nov.	72	114	30	80	5	263	0	0	0	0	35	343	3.01
Dec.	99	154	29	72	3	154	1	181	0	0	33	407	2.64
Total	1,214	2,157	182	506	40	1,238	8	2,932	1	2,553	231	7,229	3.35
South Cape Hatteras													
Jan.	301	617	185	824	80	2,118	13	4,007	0	0	278	6,949	11.26
Feb.	253	476	116	373	44	1,629	10	3,601	2	2,859	172	8,462	17.78
Mar.	178	382	66	227	30	887	2	206	2	6,553	100	7,873	20.61
Apr.	142	243	21	55	0	0	0	0	0	0	21	55	0.23
May	205	308	0	0	0	0	0	0	0	0	0	0	0.00
June	51	76	0	0	0	0	0	0	0	0	0	0	0.00
July	297	401	0	0	0	0	0	0	0	0	0	0	0.00
Aug.	235	420	0	0	0	0	0	0	0	0	0	0	0.00
Sept.	23	49	0	0	0	0	0	0	0	0	0	0	0.00
Oct.	162	239	0	0	0	0	0	0	0	0	0	0	0.00
Nov.	182	306	32	81	5	124	0	0	0	0	37	205	0.67
Dec.	287	512	62	160	6	187	2	378	1	22,000	71	22,725	44.38
Total	2,316	4,029	482	1,720	165	4,945	27	8,192	5	31,412	679	46,269	11.48
Grand total	3,530	6,186	664	2,226	205	6,183	35	11,124	6	33,965	910	53,498	8.65

about Cape Hatteras to the mouth of Chesapeake Bay, and by June only off New Jersey and Delaware. Although only a few larvae were taken north of Long Island, where only limited sampling was done, other investigators (Perlmutter 1939; Wheatland 1956; Richards 1959) have reported larvae in Long Island Sound from April through September, with a peak usually occurring in June.

From July to September there is no evidence of spawning south of Cape Hatteras, and north of Cape Hatteras spawning appears to be limited and confined to coastal waters from northern New Jersey northward. The few larvae reported were all from this area (Fig. 15, Appendix I). From cruise data that we examined no samples were taken from Long Island Sound or Narragansett Bay, and no larvae were reported north of Cape Cod where only eight samples were taken. Other investigators (Marak and Colton 1961; Herman 1963) however, have reported larvae from these areas during summer. During this season few menhaden of spawning age are found south of Long Island.

A large sample of larvae taken 400 km east of Chesapeake Bay in February indicates either that some menhaden spawn in warm waters near the Gulf Stream or that larvae spawned farther south have become entrained in Gulf Stream waters. In either case these larvae do not appear to have much chance of reaching the estuaries, which they must do in order to metamorphose and survive.

CONCLUSIONS

From about December to March most spawning age fish concentrate in offshore waters south of Cape Hatteras, N.C. Maximum numbers probably spawn during this period. As fish begin moving north in late March, spawning continues, but at a decreasing rate. By May most of the spawning is restricted to coastal areas north of Cape Hatteras. By about June, when fish are stratified by age and size along the coast, spawning has reached a minimum. From about June to September, when nearly all menhaden of spawning age are north of Long Island, N.Y., spawning continues at a low level. As large numbers again begin to mature sexually in October, spawning increases in ocean waters from about Long Island to Virginia as the population migrates south along the coast. By December most of the fish are south of Cape Hatteras. Spawning north of there decreases while increasing to a maximum off the Carolinas.

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APPENDIX I

Cruise area, station locations, and Atlantic menhaden larval distribution and abundance for selected cruises—Figures 1-11. Seasonal and geographic distribution of Atlantic menhaden larvae (all cruises combined)—Figures 12-15.

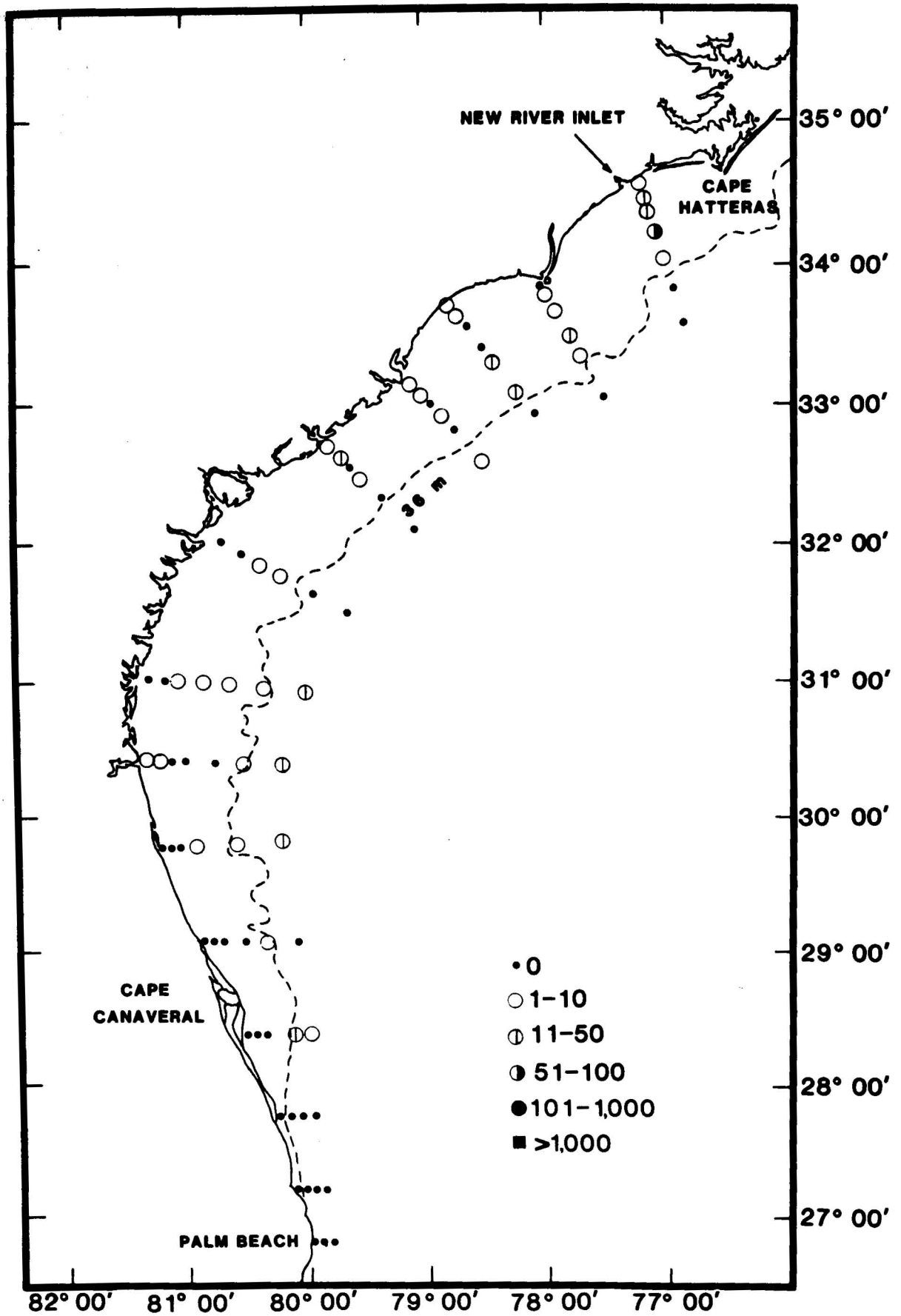

Figure 1.—RV *Dolphin* cruises D-68-1, January and February 1968. Number of Atlantic menhaden larvae by category and station locations.

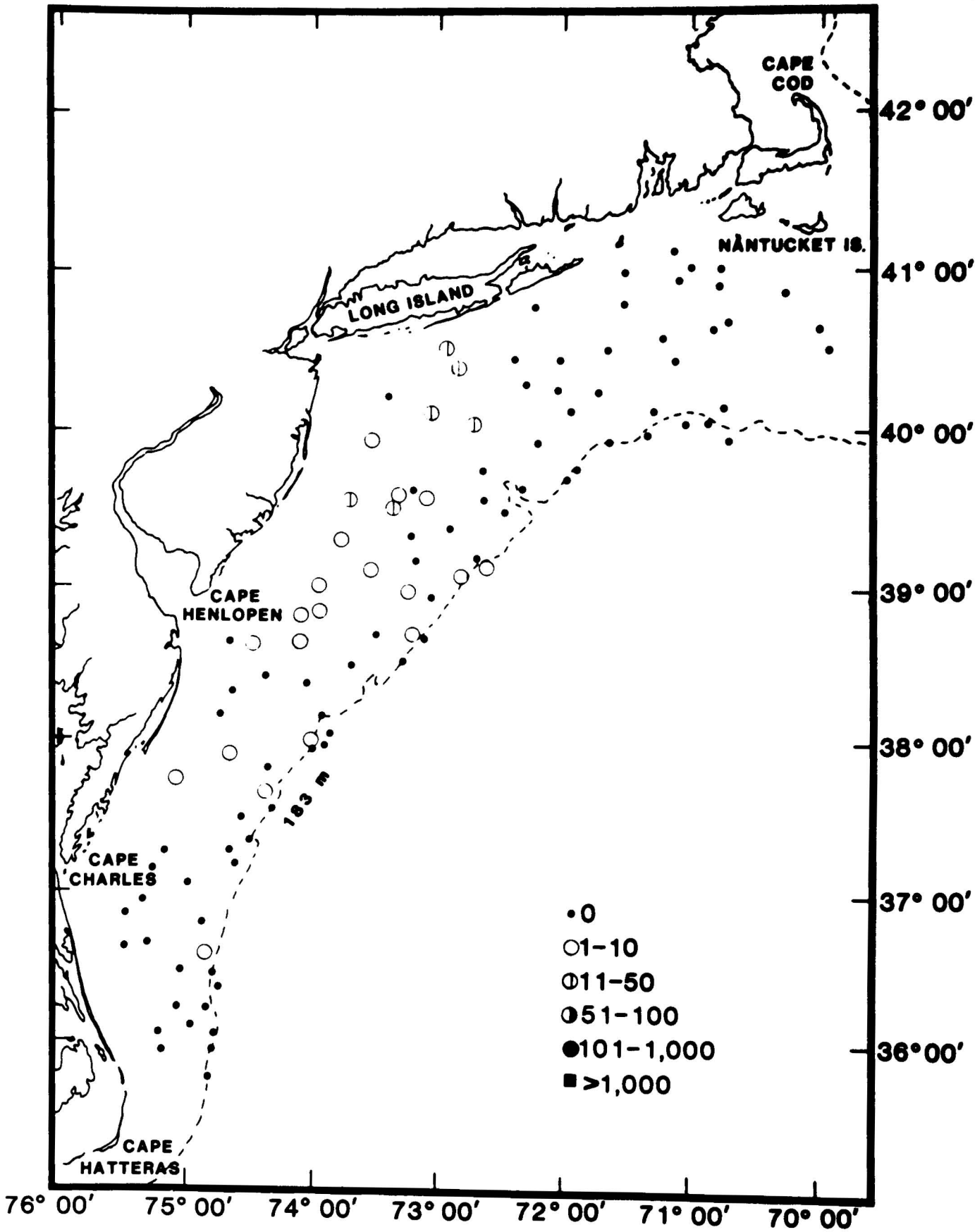

Figure 2.—RV *Albatross IV* cruise 68-17, October 1968. Number of Atlantic menhaden larvae by category and station locations.

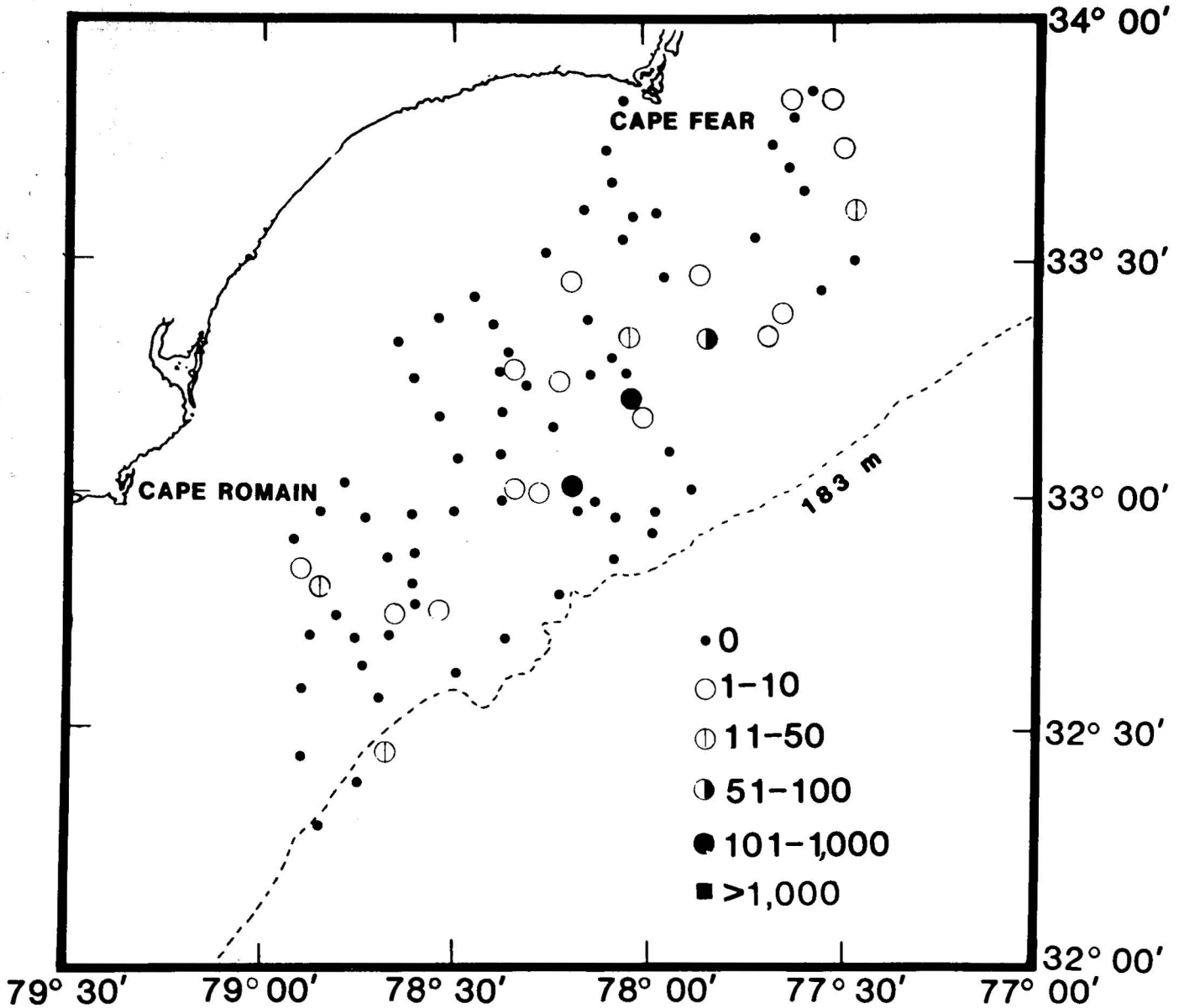

Figure 3.—RV *Advance II* cruise 4, January 1969. Number of Atlantic menhaden larvae by category and station locations.

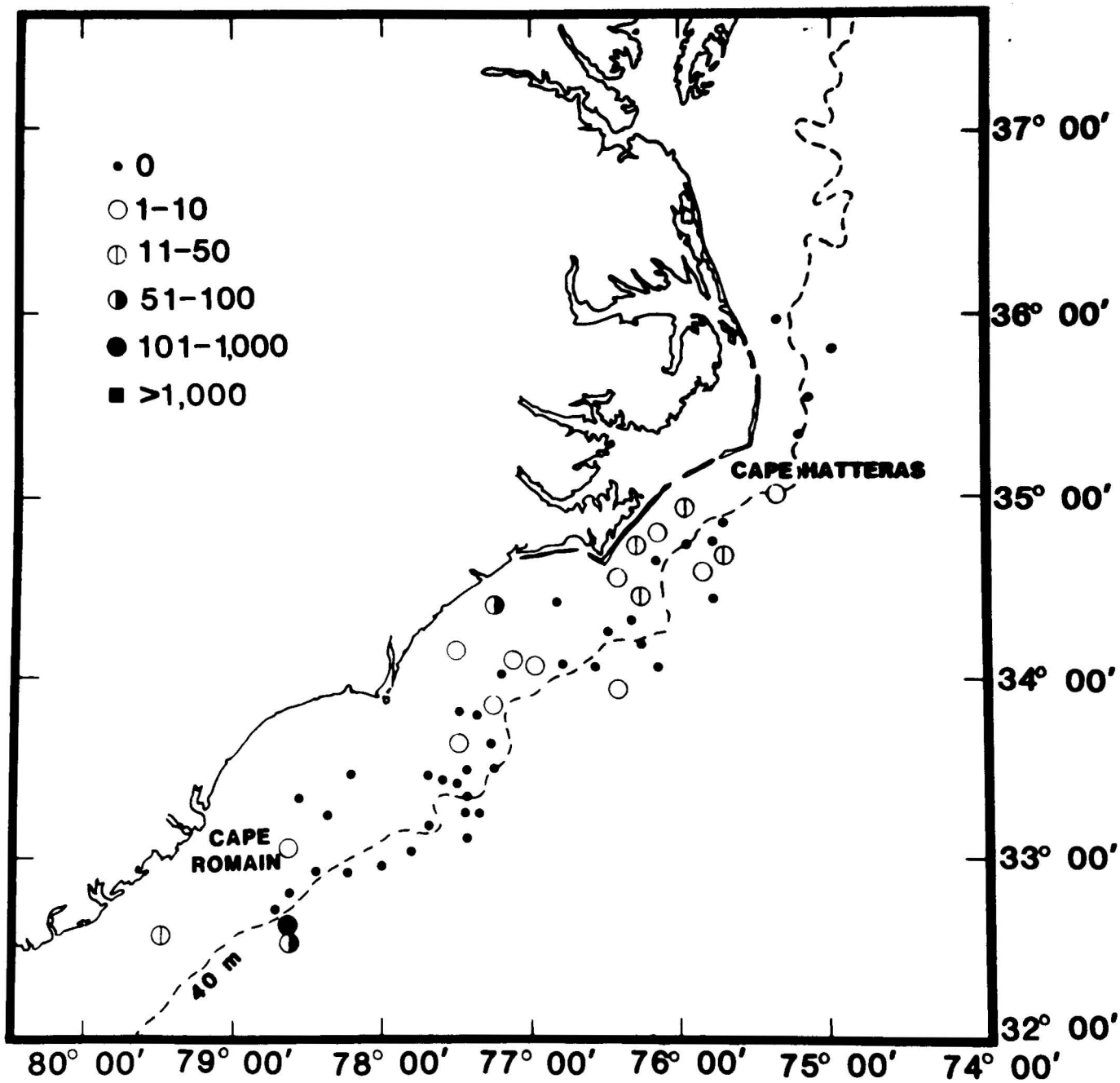

Figure 4.—USCG Cutter *Chilula* and NASA *Range Recoverer*, March 1969. Number of Atlantic menhaden larvae by category and station locations.

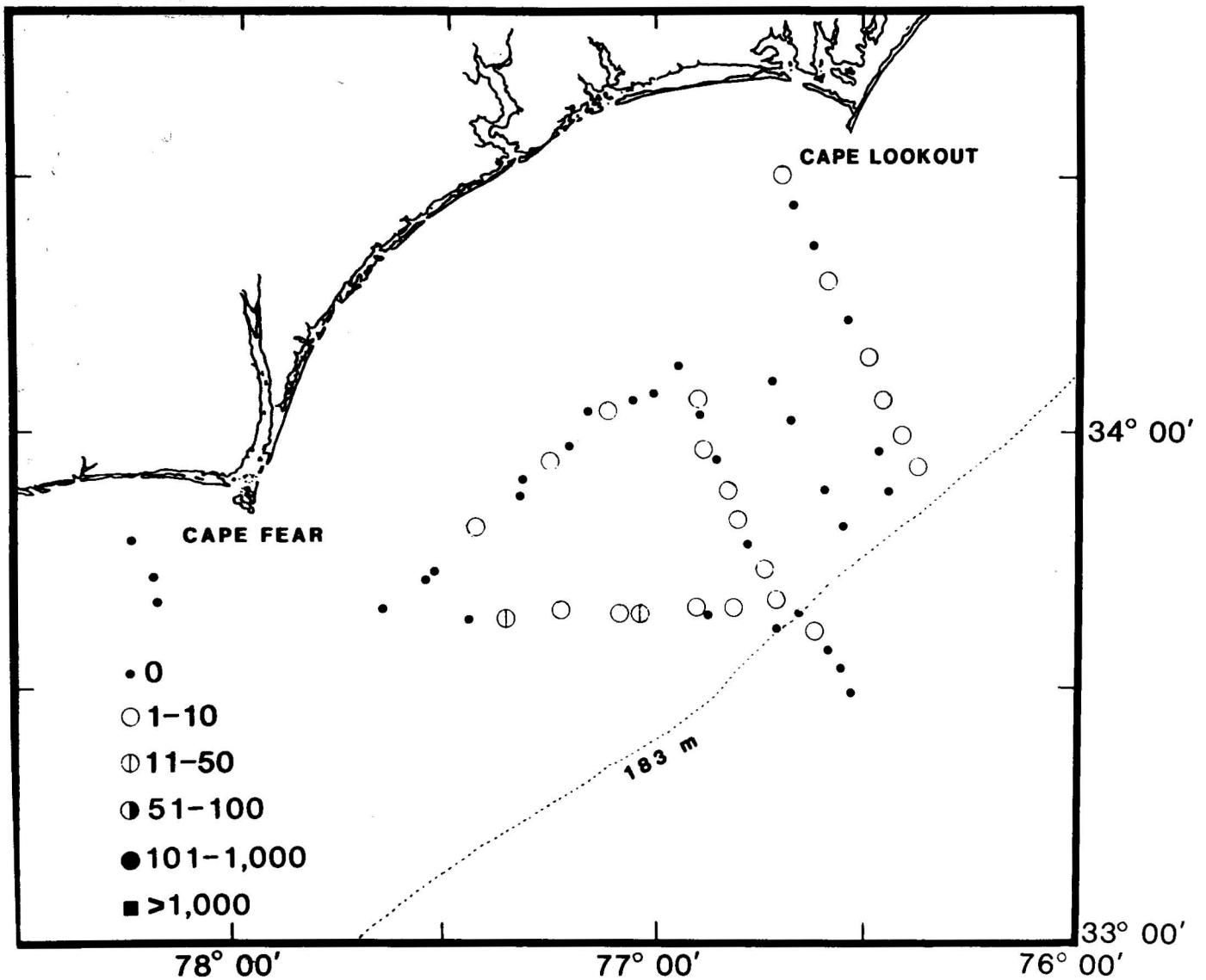

Figure 5.—RV *Undaunted* cruises, December 1970 and January 1971. Number of Atlantic menhaden larvae by category and station locations.

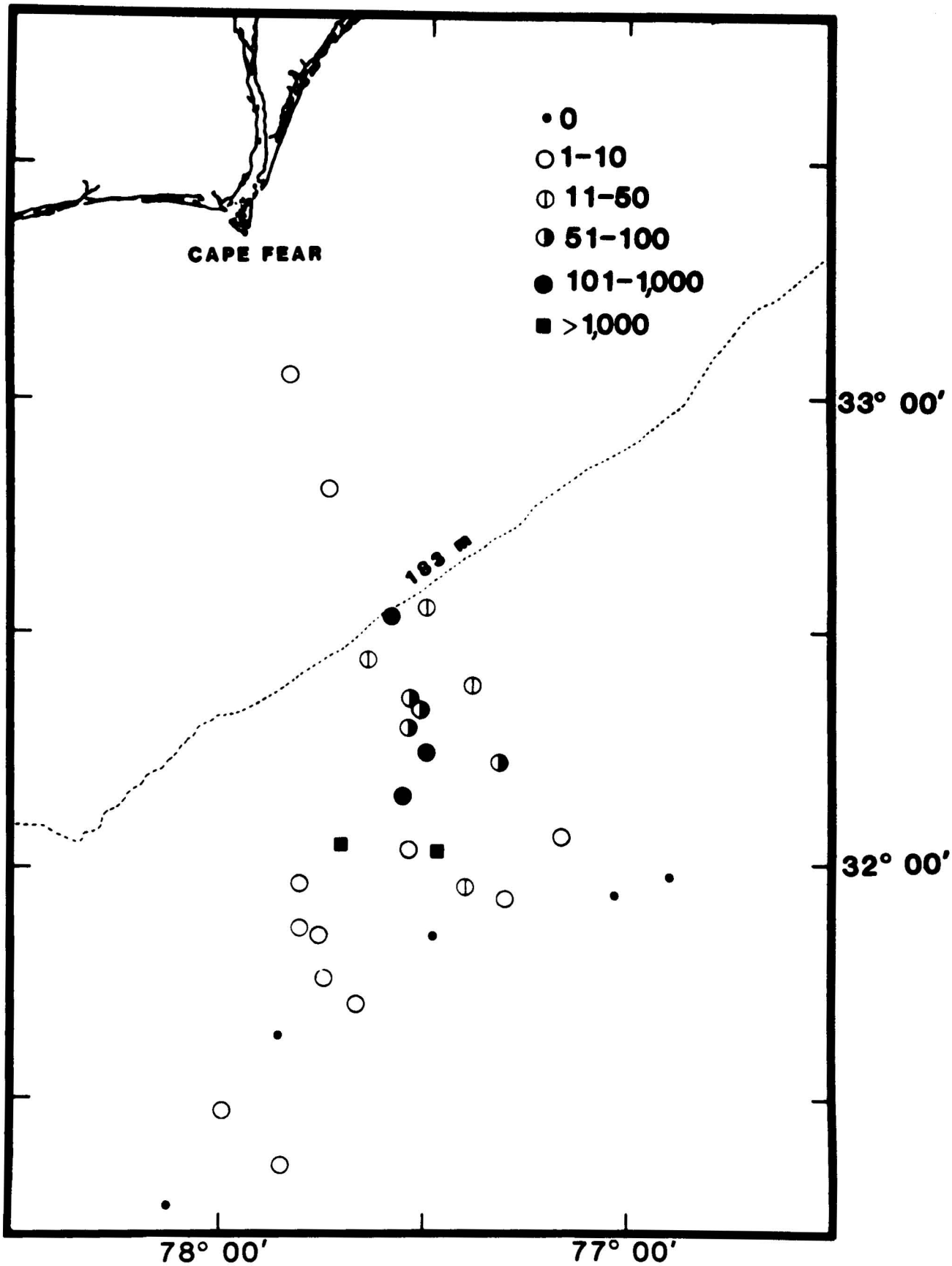

Figure 6.—RV *Undaunted* cruises, February and March 1971. Number of Atlantic menhaden larvae by category and station locations.

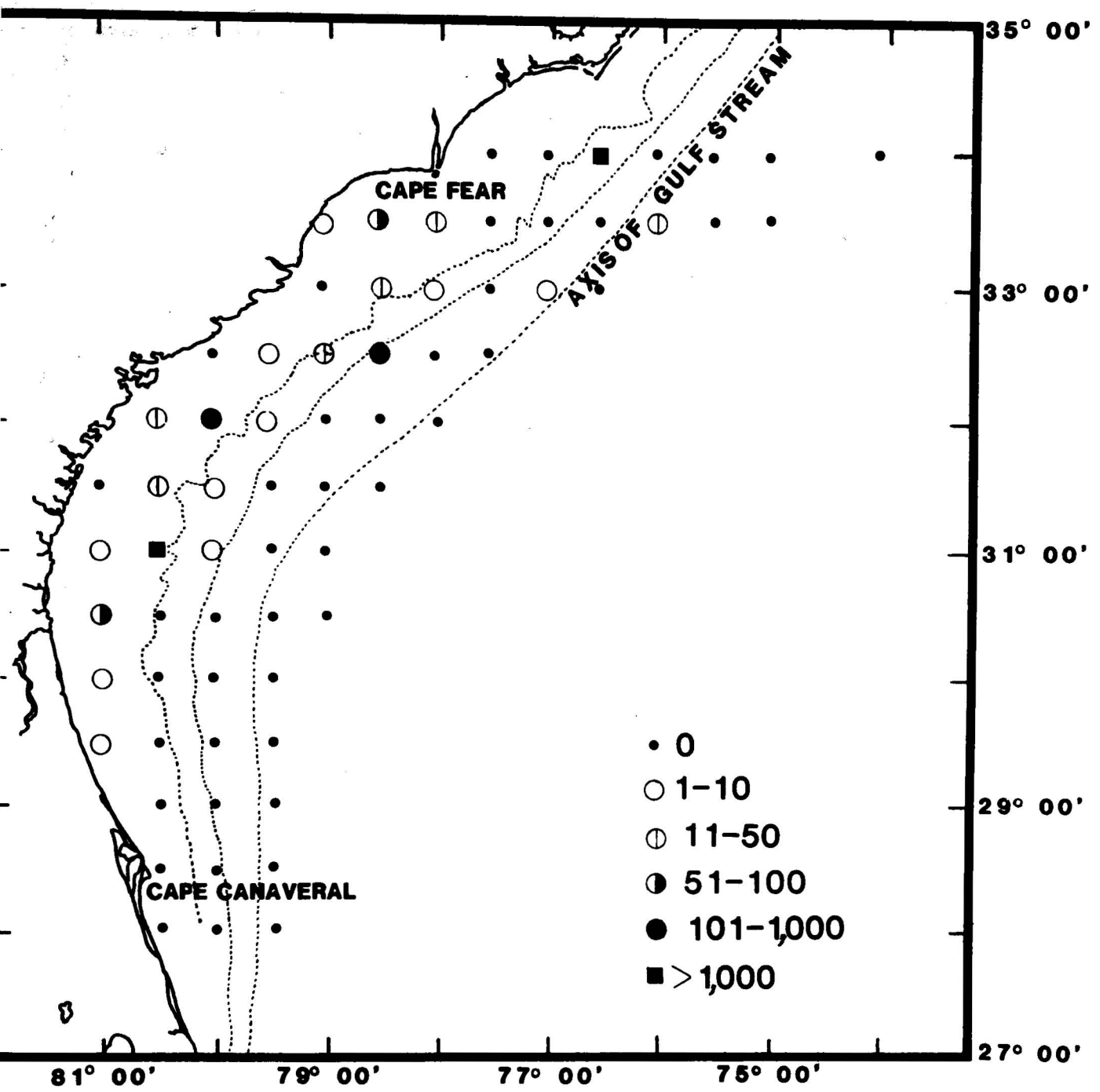

Figure 7.—RV *Dolphin* cruise D2-73, February and March 1973. Number of Atlantic menhaden larvae by category and station locations.

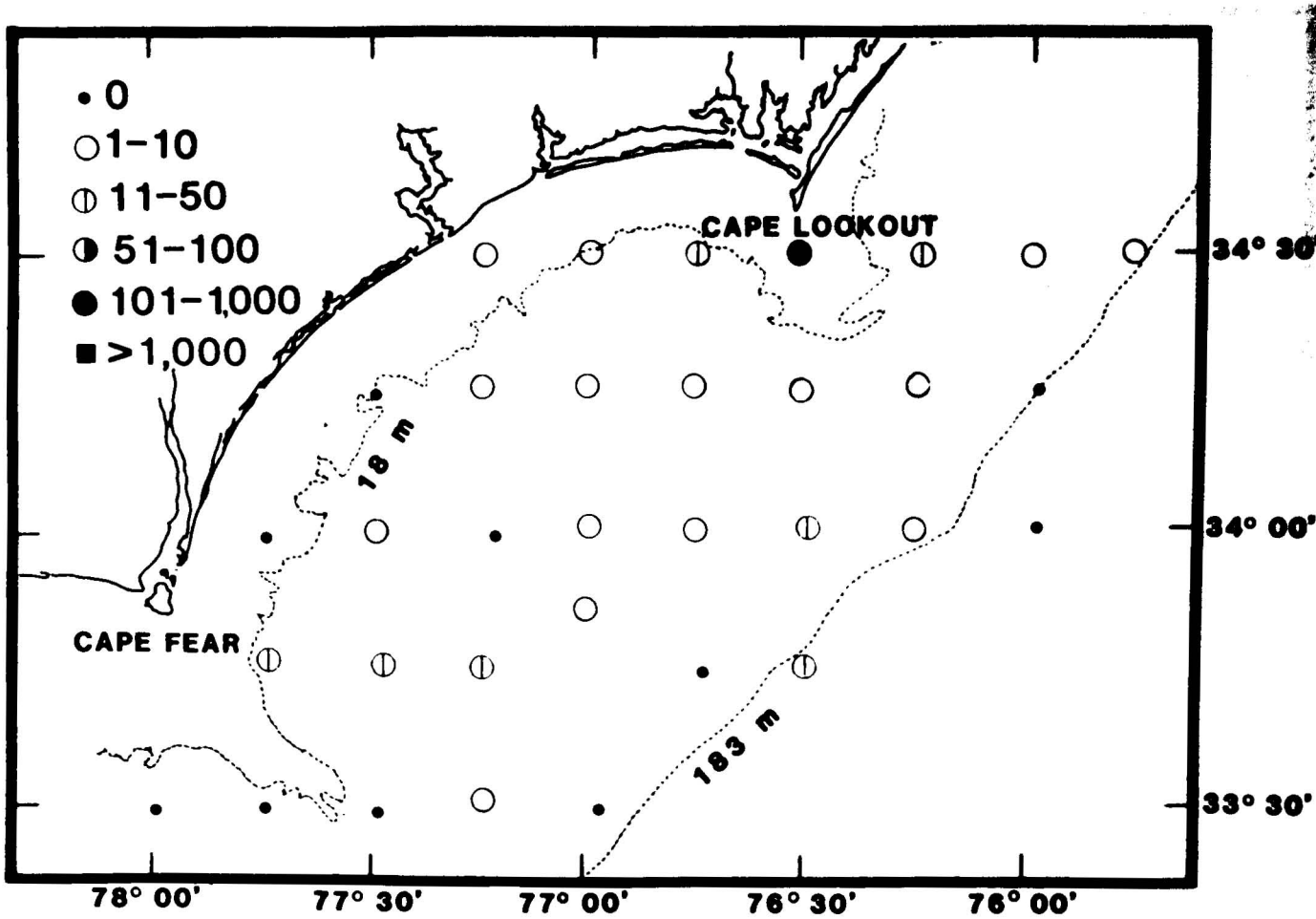

Figure 8.—RV *Dolphin* cruise D1-74, January 1974. Number of Atlantic menhaden larvae, by category and station locations, for the 60 cm bongos (0.333 and 0.505 mm mesh combined).

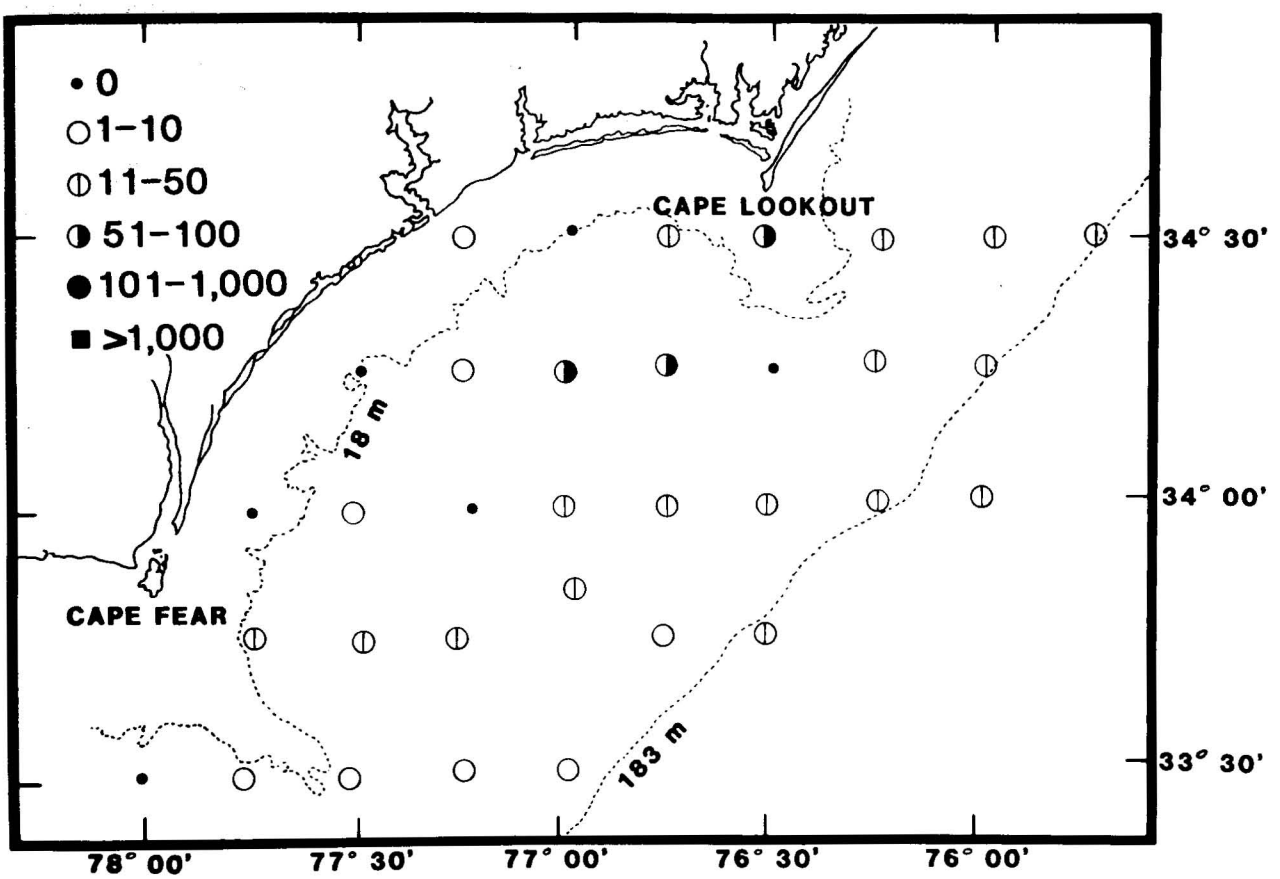

Figure 9.—RV *Dolphin* cruise D1-74, January 1974. Number of Atlantic menhaden larvae, by category and station locations, for the 1 X 2 m neuston (0.947 mm mesh).

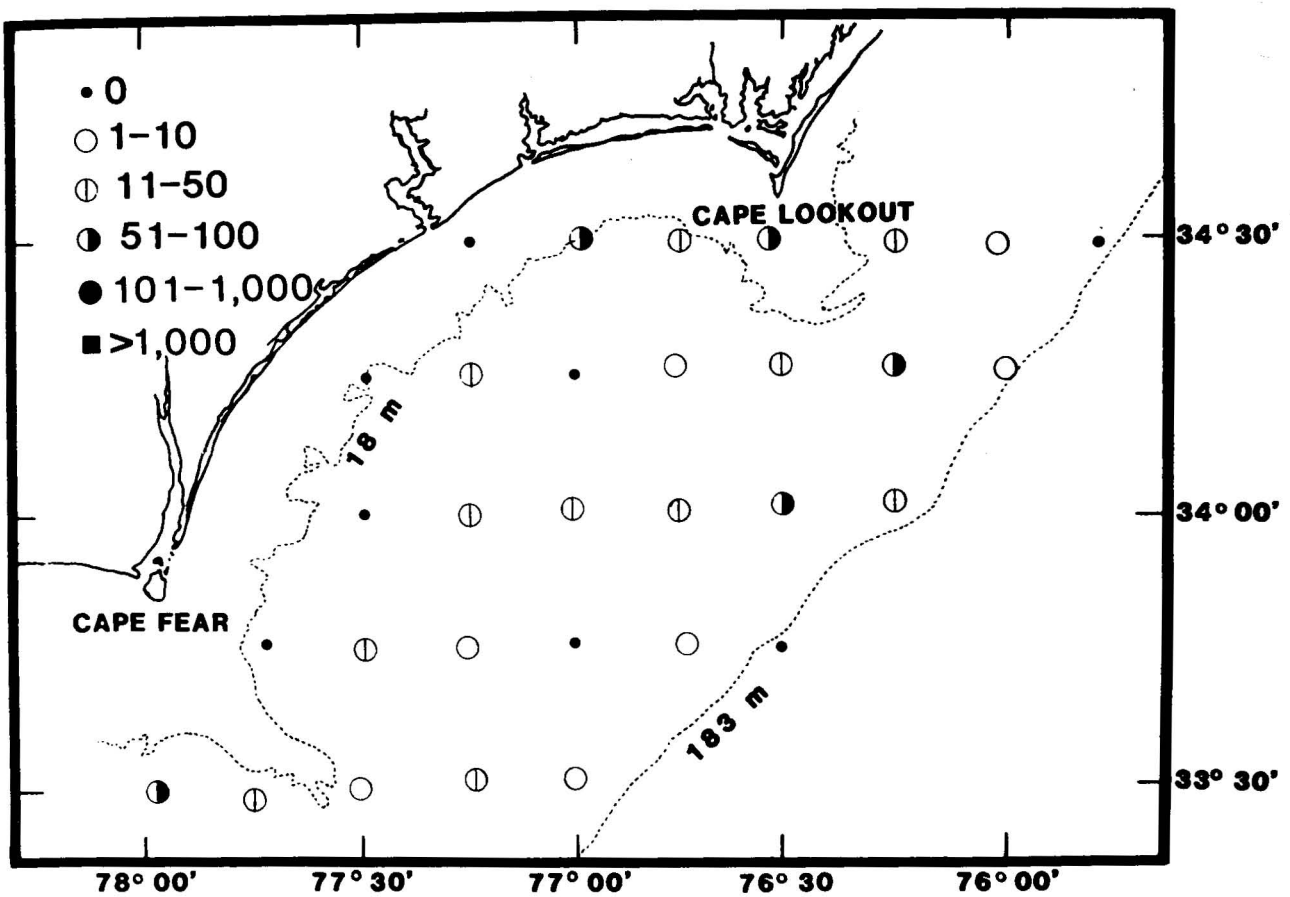

Figure 10.—RV *Dolphin* cruise D1-75, January 1975. Number of Atlantic menhaden larvae, by category and station locations, for the 60 mm bongos (0.333 and 0.505 mm mes combined).

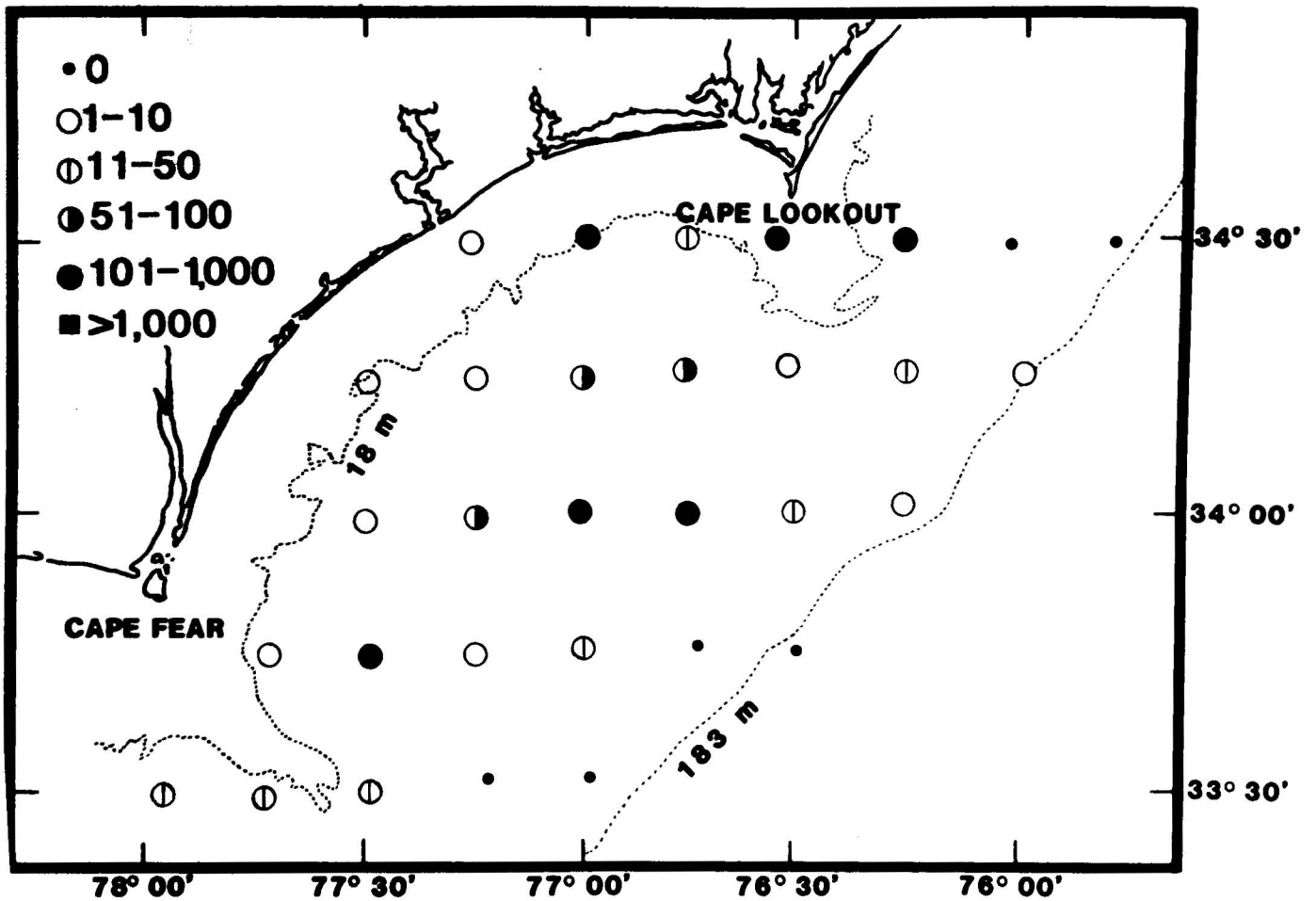

Figure 11.—RV *Dolphin* cruise D1-75, January 1975. Number of Atlantic menhaden larvae, by category and station locations, for the 1 X 2 m neuston (0.947 mm mesh).

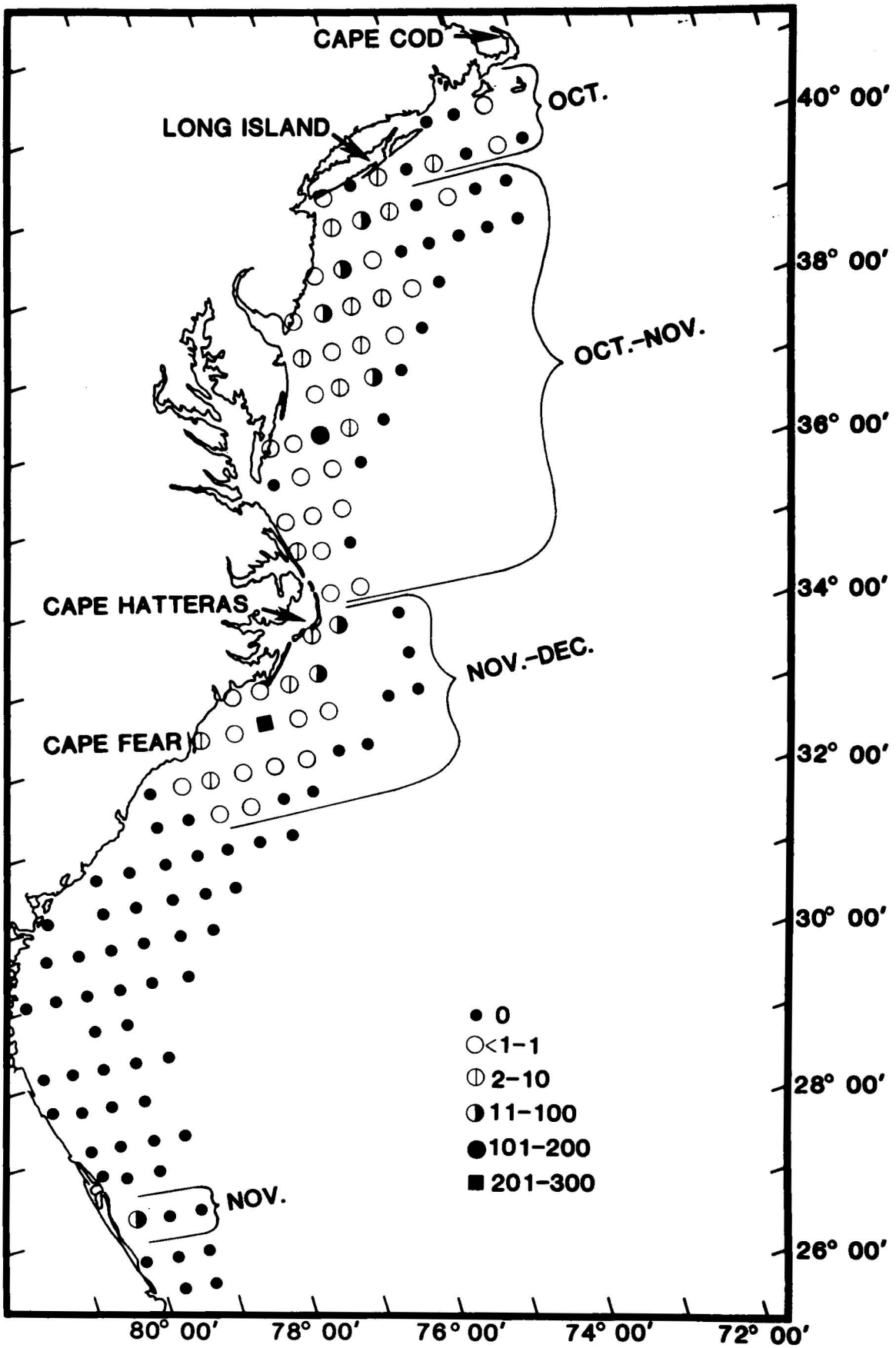

Figure 12.—Mean number of Atlantic menhaden larvae, by category, shown by symbols representing areas of 15′00″ latitude and 15′00″ longitude, October - December, 1953-75.

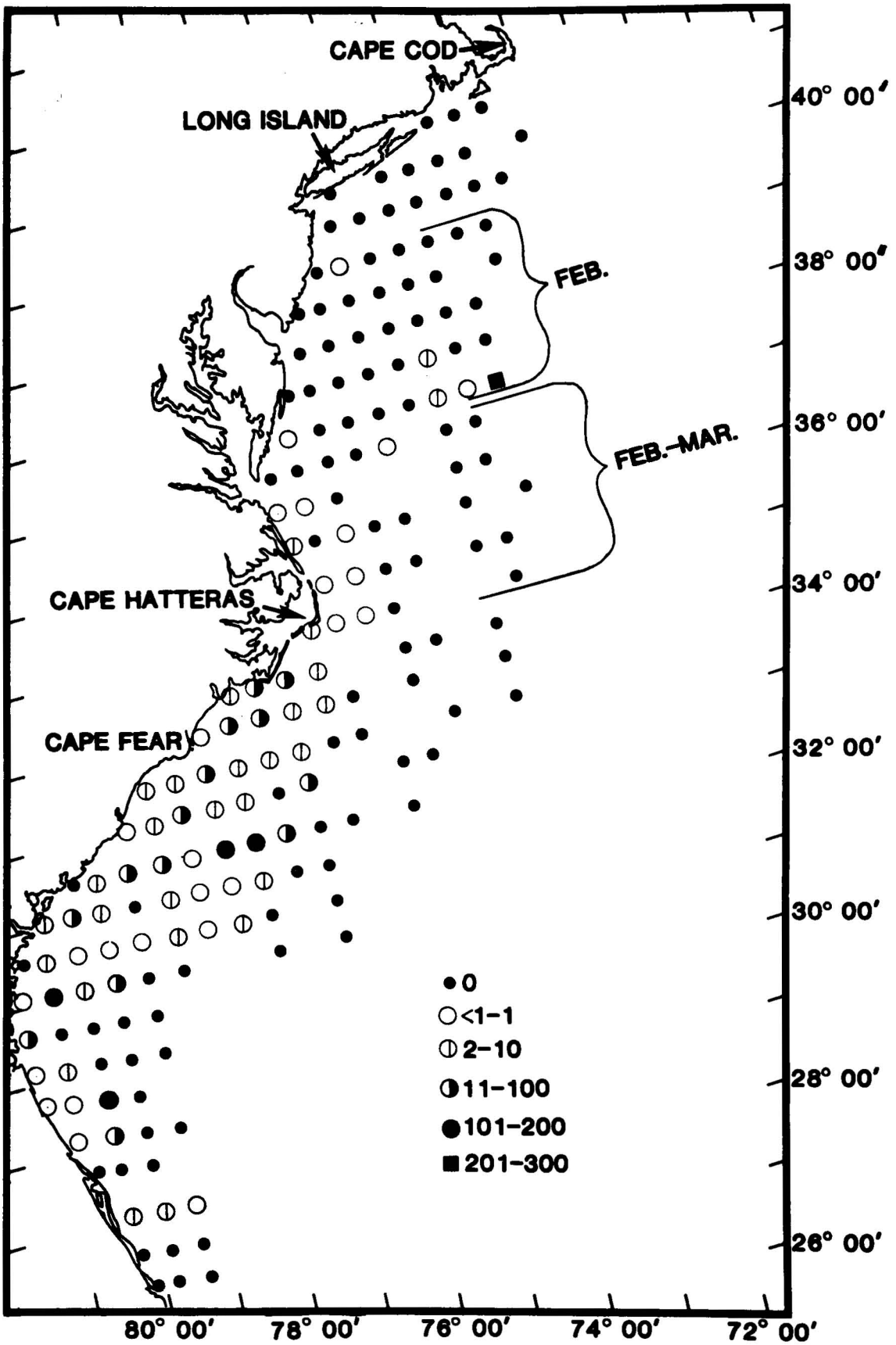

Figure 13.—Mean number of Atlantic menhaden larvae, by category, shown by symbols representing areas of 15′00″ latitude and 15′00″ longitude, January-March, 1953-75.

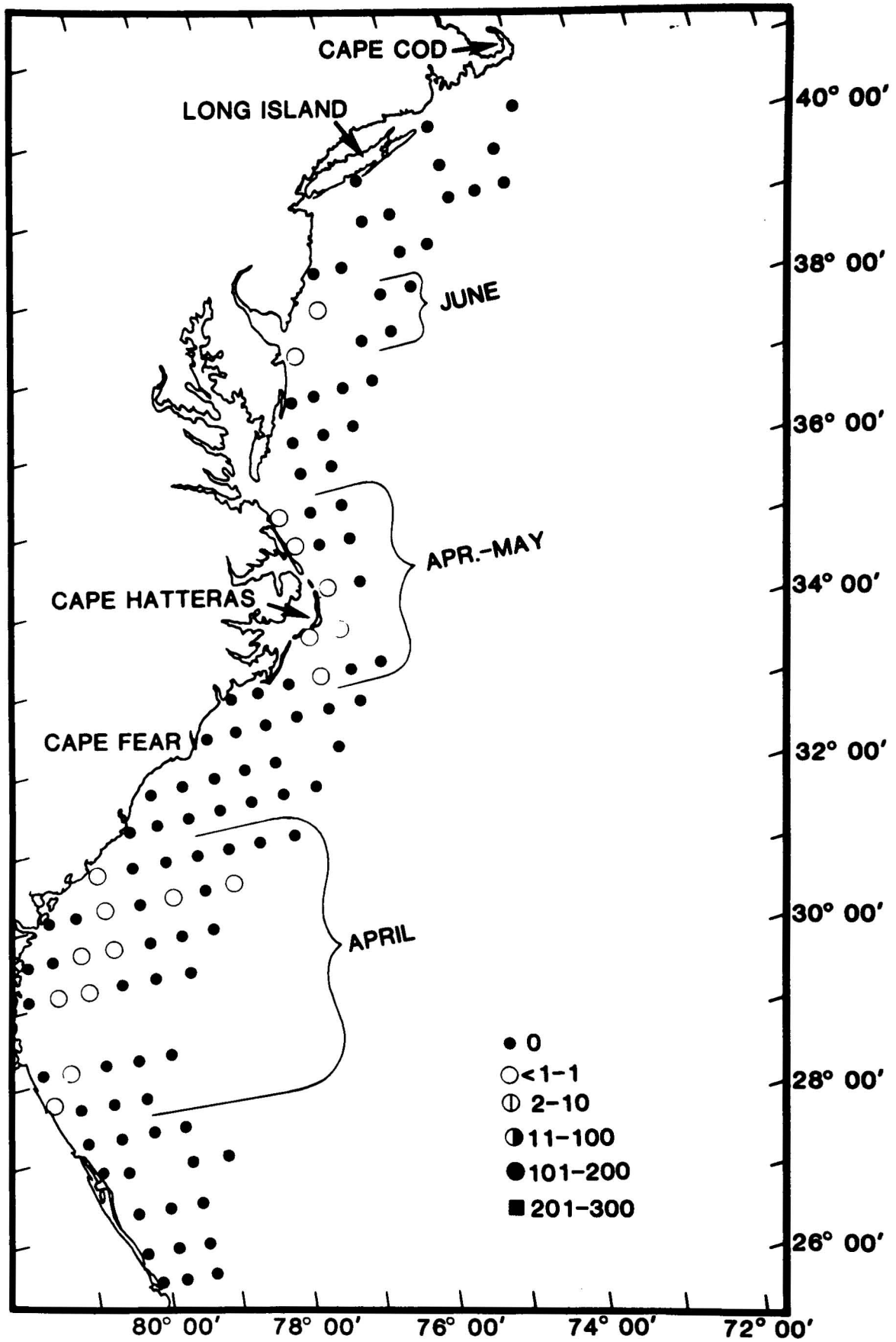

Figure 14.—Mean number of Atlantic menhaden larvae, by category, shown by symbols representing areas of 15′00″ latitude and 15′00″ longitude, April-June, 1953-75.

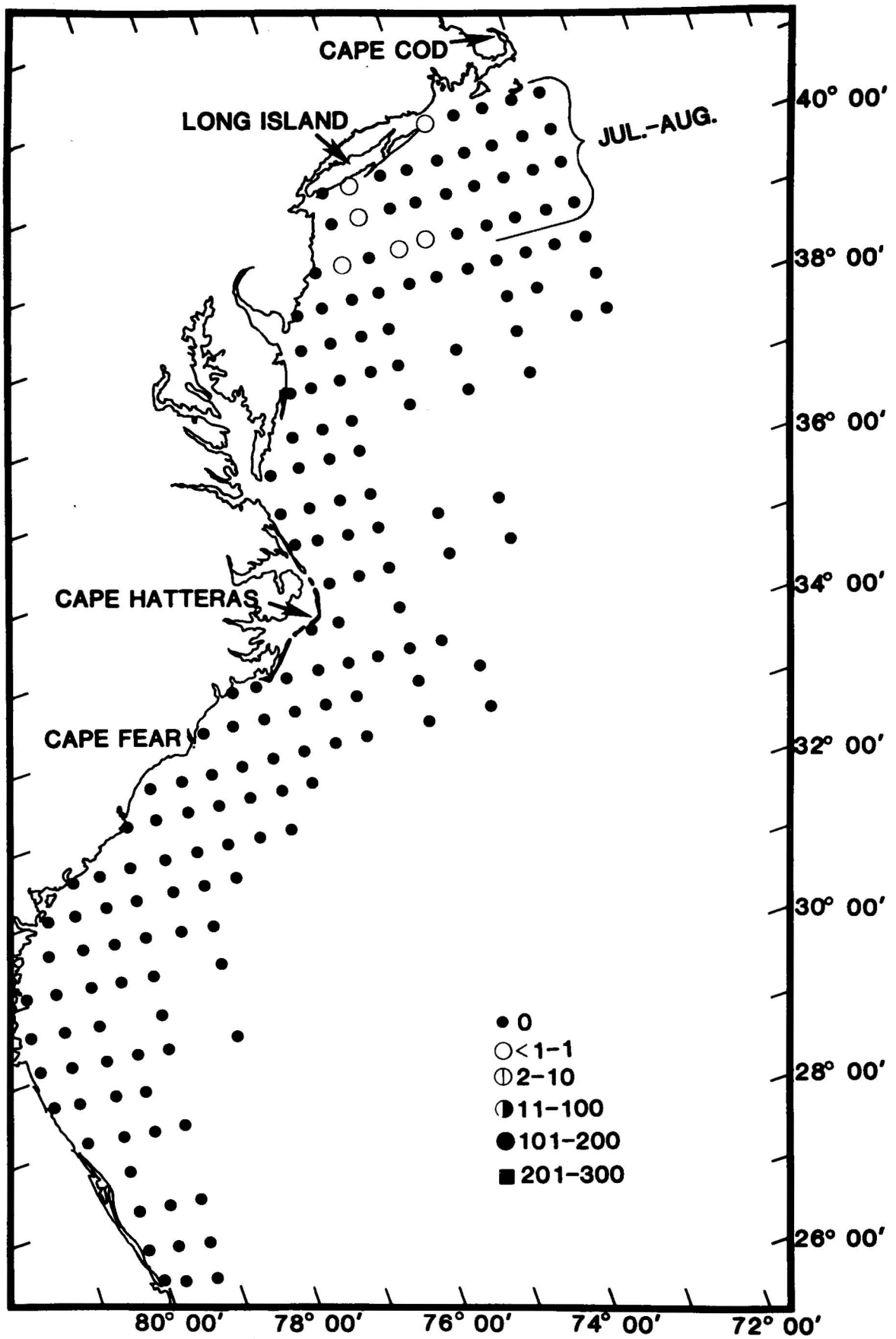

Figure 15.—Mean number of Atlantic menhaden larvae, by category, shown by symbols representing areas of 15′00″ latitude and 15′00″ longitude, July-September, 1953-75.