THE DISTRIBUTION OF SUMMER FLOUNDER, *PARALICHTHYS DENTATUS*, EGGS AND LARVAE ON THE CONTINENTAL SHELF BETWEEN CAPE COD AND CAPE LOOKOUT, 1965-66

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ABSTRACT

Eggs and larvae of summer flounder, *Paralichthys dentatus*, were collected with Gulf V plankton nets between Cape Cod, Mass., and Cape Lookout, N.C., during a 1-year survey of continental shelf waters. The most productive spawning grounds were located off New York and New Jersey. Spawning began in northern parts of the survey area, progressed southward with the season, and ended off Cape Lookout. We collected eggs north of Chesapeake Bay from September to December and south of the Bay from November to February, and larvae north of Chesapeake Bay from September to February and south of the Bay from November to May. Most spawning occurred at temperatures between 12° and 19°C, but the pelagic eggs were caught at mean temperatures from 9.1° to 22.9°C, and the larvae from 0° to 23.1°C.

Fishery scientists generally agree that the shallow, protected waters of bays, rivers, and sounds along our eastern seaboard provide essential habitat for many marine fishes. The occurrence of juvenile fishes in estuaries has led biologists to conclude that a major role of the estuarine zone is its function as a sanctuary or nursery ground for young fishes, many of which are spawned at sea. In 1965, the Sandy Hook Laboratory at Highlands, N.J., began a study to elucidate the degree of estuarine dependence of young fishes by studying their distributions from egg through juvenile stages. Impetus for the study resulted from the accelerated degradation of the estuarine zone and a concurrent decline in some of our most valuable coastal fishery yields.

We began our program with a 1-year survey of the continental shelf between Cape Cod, Mass., and Cape Lookout, N.C., to determine the duration of spawning, define the areas of spawning, and trace the dispersal of pelagic eggs and larvae of all marine sport fishes that we caught. This report describes the offshore distribution of eggs and larvae of the summer flounder, *Paralichthys dentatus*, a highly prized catch for both sport and commercial fishermen.

The life history of summer flounder is understood only in broad outline. The geographic range of the species encompasses estuarine and continental shelf waters from Maine to Florida (Gutherz, 1967). Within this range, the species' population structure remains to be determined. Migratory habits of summer flounder in the Middle Atlantic Bight have been outlined from seasonal changes in the location of commercial and sport catches. From the returns of tagged fish, Poole (1962) and Murawski (1970) added support to the general concept that yearly movements of summer flounder are not extensive. The adults migrate shoreward in spring from wintering grounds near the edge of the continental shelf. They summer in shallow coastal waters and adjacent estuaries and, in the fall, again move offshore. Both Poole and Murawski noted the strong tendency of adult fish to return in subsequent years to the area where they had been tagged. Shortly after the adults begin their fall migration, they begin to spawn, presumably on or near the bottom. Eggs and early larval stages have been found only at sea, and young-of-the-year juveniles only in or near the mouths of estuaries.

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Because young-of-the-year have not been captured at sea, biologists have presumed they cannot survive there and, at an early stage of development, must seek an estuarine habitat. This presumption has been challenged, but not systematically tested.

THE CRUISE SCHEDULE

Eight cruises were completed from December 1965 through December 1966. During each cruise, we planned to sample at 92 stations situated along 14 transects. Transects originated as nearshore as water depths would allow the RV *Dolphin* to enter, and extended seaward to depths near or beyond the 183-m depth contour (Figure 1).

The sequence for sampling transects varied, depending primarily on weather (Table 1). On our first cruise in December, inclement weather forced us to omit the two northernmost transects. We sampled at four additional stations

TABLE 1.—Cruise schedule, sequence of sampling transects, and number of stations occupied during RV *Dolphin* ichthyoplankton survey, 1965-66. Sampling interruptions in excess of 48 hr are shown, whether or not the sampling sequence was affected.

Cruise	Sampling dates	Transect or station sampling sequence	Number of stations
D-65-4	3-15 Dec. 1965	C to P	80
D-66-1	25-26 Jan. 1966	B, A-1 and -2	86
	2- 9 Feb. 1966	C to P	
D-66-3	6- 9 Apr. 1966	A to D	92
	13-16 Apr. 1966	E-1 and -2, F to J-7 to -3	
	19-21 Apr. 1966	J-1 and -2 to P	
	22 Apr. 1966	E-8 to -3	
D-66-5	12-25 May 1966	A to P	92
D-66-7	17-20 June 1966	A to D	92
	22-25 June 1966	L to P	
	25-29 June 1966	K to E	
D-66-10	5-10 Aug. 1966	A to F	92
	21-26 Aug. 1966	G to P	
D-66-11	13-14 Sept. 1966	A and B (except B-3)	30
	17-18 Sept. 1966	B-3, C and D	
D-66-12	28 Sept.-6 Oct. 1966	M, N, L to F, E-1 to -3, D-1 to -3	92
	11-15 Oct. 1966	E-4 to -8, F-8 to -4, C to A	
	20 Oct. 1966	P	
D-66-14	9-14 Nov. 1966	E to J (except F-7, E-8)	92
	15-19 Nov. 1966	P to K, F-7, E-8	
	1- 4 Dec. 1966	D to A	

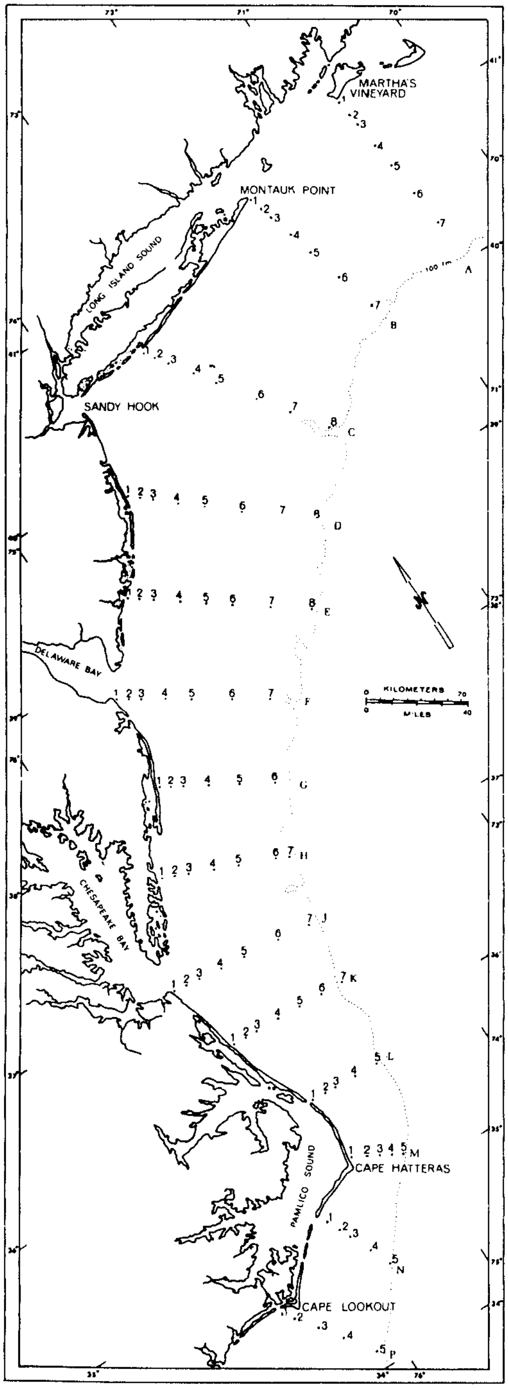

FIGURE 1.—Transects and collecting stations of plankton survey conducted from December 1965 through December 1966.

(designated transect X) off the outer banks of North Carolina. On our second cruise, inclement weather forced us to omit four stations on the northernmost transect, and an outflow of ice from Delaware Bay prevented sampling at the inboard station off Cape Henlopen. We occupied all stations during cruises in April, May, June, and August. In September, adverse weather resulted in a 2-day interruption shortly after we began sampling, and gear problems required a second unscheduled port call soon thereafter. Because of these delays, we rescheduled the cruise after completing only the four northern transects. Although bad weather also interrupted the final two cruises, we occupied all stations.

SAMPLING METHODS

We used Gulf V high speed nets (Arnold, 1959) to collect plankton. These had 0.33-mm Monel[2] wire netting with 12 meshes/cm and a mesh aperture of 0.52 mm.

To assure reaching below the thermocline, or that part of the water column encompassing most pelagic eggs and larvae, we sampled to a maximum depth of 33 m, using two Gulf V nets. One net, hereafter referred to as net no. 1, fished at 3-m depth intervals from surface to 15 m; the other, net no. 2, fished at 3-m depth intervals from 18 to 33 m. We sampled at each depth interval for 5 min. Tows lasted 30 min. In depths less than 33 m, we altered the sampling pattern of net no. 2 by decreasing the number of sampling depth intervals and increasing the towing time at each interval to 10 or to 15 min. Sampling depths for net no. 1 were similarly adjusted in depths less than 15 m (Figure 2). The RV *Dolphin* usually traversed 4.6 km/tow, traveling at a constant engine speed. We preserved plankton samples in 5% buffered Formalin.

Catch per standard tow was used as a measure of relative abundance for eggs and larvae. A standard tow consisted of one or both nets fishing for 5 min at each of the six depth intervals within its vertical sampling range (see Figure 2). The catches were adjusted to equalize sampling effort at all depth levels when either net was limited to sampling at less than six intervals. For example, when only three intervals were sampled during the 30-min tow, the catch was halved. When two intervals were fished, it was reduced by two-thirds. The adjusted catch of net no. 2 was added to that of net no. 1 at stations where both nets fished simultaneously. All catches of eggs and larvae discussed herein are adjusted.

We recorded vertical temperature and salinity data at each station (Clark et al., 1969). Surface temperature was measured with a stem thermometer, subsurface temperature with a mechanical bathythermograph, and salinity with an induction salinometer. Salinity data were recorded at 5-m depth intervals to a maximum depth of 40 m.

Fish eggs and larvae were separated from the plankton collections by microscopically examining aliquots of a sample placed in a gridded Petri dish. Methods employed to check sorting accuracy and measured plankton volumes are described by Clark et al. (1969).

Larvae on which the caudal rays had not formed were measured from the tip of the snout to the tip of the notochord. More developed specimens were measured from the tip of the snout to the base of the median caudal rays. Specimens larger than 9 mm were considered postlarvae because they were laterally flattened. Marginal fin ray counts fell within the adult range and migration of the right eye was underway on specimens over 10 mm.

THE SEASONAL DISTRIBUTION OF EGGS

We sampled during parts of two different spawning seasons, for our survey started too late in 1965 and ended too early in 1966 to determine the beginning of the one season or the end of the other. In spite of the possibility of year-to-year variations in the onset and duration of spawning, data for the 2 years were combined and treated as a single complete season.

Although the summer flounder's spawning

[2] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

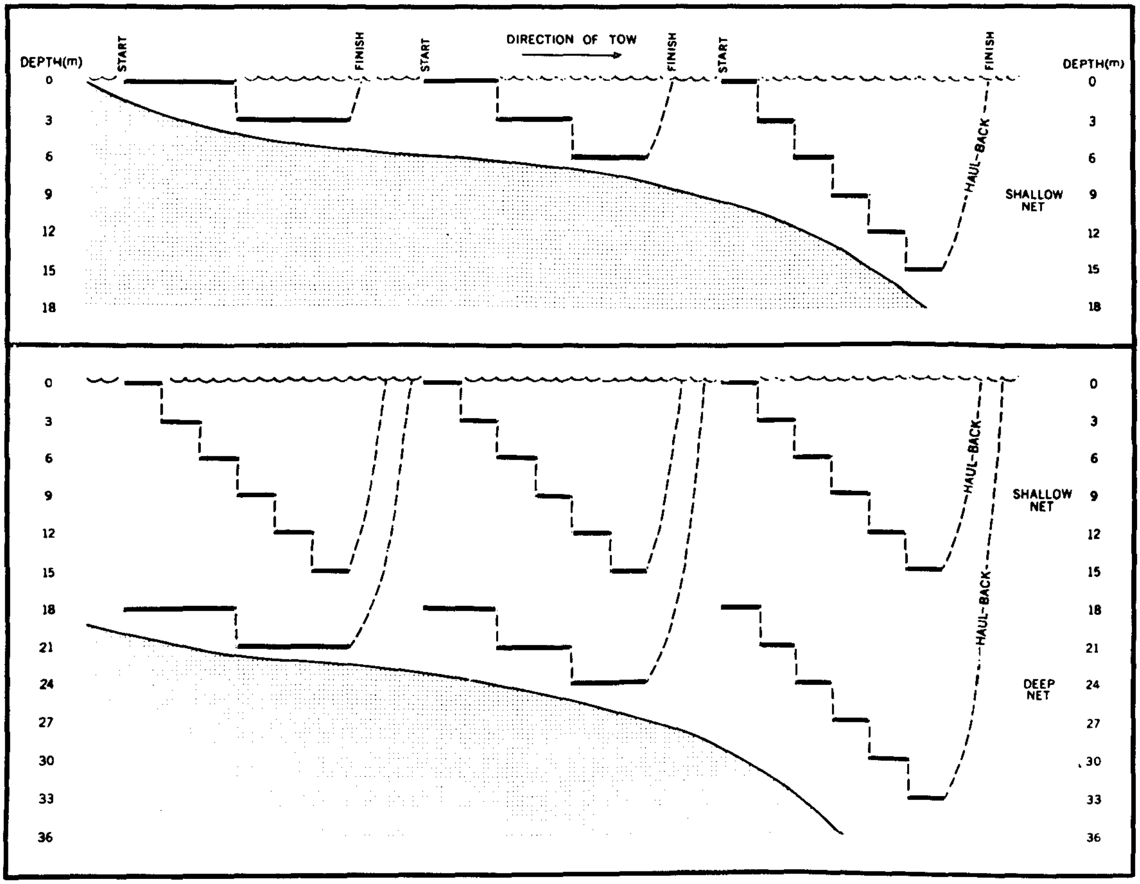

FIGURE 2.—Vertical sampling profiles for 30-min tows with Gulf V nets. The number of sampling depths in the step-oblique pattern was determined by depth of water. Sampling profiles on the right side of the figure were considered standard tows.

season usually peaks in the fall along the Middle Atlantic Bight, data are lacking on the duration of the season. Herman (1963) reported the earliest seasonal occurrence of young from larvae captured in Narragansett Bay, R.I., in July 1957. He concluded that spawning had commenced during the summer. Gravid females taken as late as mid-April off Nantucket Island led Bigelow and Schroeder (1953:267-270) to conclude that spawning occurred through spring. During our survey, it appears that some spawning may have lingered into early spring in waters off North Carolina, but not as far north as New England. Nor can I find other data to substantiate that spawning normally begins as early as July or ends as late as April off southern New England.

After studying gonads from fishes landed by the winter trawl fishery, Eldridge (1962) concluded that most spawning off the Virginia Capes occurred in November. Eldridge's findings agree closely with those of Murawski (1965), who observed a sharp rise in maturation of gonads in fish caught off New Jersey during the first half of October and running ripe females from late September through early November. Our results generally agree with these authors. In 1966, spawning evidently began in the northern part of the Middle Atlantic Bight in early September, progressed southward with the season, and ended in February off Cape Lookout. The season reached its peak in October north of Chesapeake Bay and in November south of the Bay.

We first caught eggs in mid-September. Most of these were 9 to 19 km off western Long Island where depths were 22 to 31 m (Figure 3). Because this September cruise was cancelled after sampling only the four northernmost transects, the data do not show the full distribution of eggs within the area we normally surveyed. Results of the following cruise, however, suggest that spawning in the first half of September was limited to the area between southern New England and New Jersey.

All eggs caught in October were at stations north of Chesapeake Bay, most of them off New Jersey and Delaware. Stations 22 to 61 km offshore over depths of 20 to 48 m accounted for 96% of the catch. No eggs were caught south of Chesapeake Bay (Figure 4).

In November, the area of spawning had moved southward, for concentrations of eggs were now 65 km east of Assateague Island, Md., and 9 to 19 km off the outer banks of North Carolina. Ten days elapsed from the time we started sampling off Atlantic City until we were able to sample the four northern transects. During that period, spawning apparently ended off New York and southern New England, for we caught only one egg in that sector (Figure 5). Considering the substantial number of larvae taken on the four northern transects, it seems probable that the distribution of eggs at the outset of the cruise in November extended further north than shown in Figure 5, perhaps as far as Martha's Vineyard or beyond.

By December (1965), spawning within most of the survey area had ended, for we found eggs only at stations in the southern portion (Figure 6). The following cruise in late January and early February proved even less productive. We caught four eggs at the most southerly station off Cape Lookout. Eggs were absent from samples taken on cruises in April, May, June, and August.

VERTICAL DISTRIBUTION OF EGGS

Our sampling program was not designed to study the vertical distribution of eggs and larvae. The patterns of distribution, however, suggest that summer flounder eggs drift largely within the shallow depths sampled by net no. 1. At stations where both nets fished, net no. 1 caught 75% of the eggs and net no. 2 probably caught some of the remaining 25% in the upper levels during setting and retrieval. This tendency of summer flounder eggs to float near the surface was observed during a rearing experiment set up to obtain early larval stages. All artificially fertilized eggs floated in water collected from just beneath the surface, or in the least dense part of the water column, at the site where gravid adults presumably would have spawned soon thereafter. By floating near or at the surface, the eggs were available to our nets for only a part of the 30-min tow. A short incubation period, 72 to 75 hr after fertilization at an average water temperature of 17.5°C (Smith and Fahay, 1970), may also affect the availability of eggs by limiting their dispersion away from the spawning site. Thus, the buoyancy of eggs and their relatively short incubation period probably account for our nets catching fewer eggs than larvae.

THE SEASONAL DISTRIBUTION OF LARVAE

Judging from the changes in the number of eggs in our samples, summer flounder spawned north of Chesapeake Bay from September to December and south of the Bay from November to February. As expected, larvae were taken at the same time as the eggs, and also over a longer period. We caught larvae in the northern half of the survey area from September to February, and in the southern half from November to May.

Larvae as well as eggs of the 1966 brood appeared first in our collections of mid-September, when we sampled only the four northernmost transects (Figure 3). The small number and size of larvae collected then, the more widespread distribution of eggs than larvae, and the absence of both in June and August all indicate that spawning had recently started, probably during the first week of September. The October cruise produced the largest catch of summer flounder larvae of the survey. All larvae were caught north of Chesapeake Bay, some as far as 111 km offshore, but most from 22 to 83 km offshore over depths of 31 to 57 m. Although the distribution of larvae was continuous, distinct concentrations occurred off Martha's Vineyard, off Long Island and northern New Jersey, and off Delaware Bay (Figure 4). By November, the distribution of larvae had spread throughout the survey area, apparently with a center of concentration 56 km off New Jersey, where water depths ranged from 22 to 53 m (Figure 5).

In December (1965), we found concentrations of larvae off New Jersey and North Carolina. The area of greatest abundance was 37 to 83 km off the New Jersey coast, at about the same location where we found larvae most abundant during the November (1966) cruise (Figure 6). By the end of January, the number of larvae and the area of their distribution had diminished, most of them being south of Cape Hatteras (Figure 7). In April, we found larvae only in the southern extreme of the survey area (Figure 8). In May, we caught seven larvae which probably represented remnants of late spawning off the outer banks of North Carolina, since we found no more during the next two cruises.

The seasonal progression of spawning from north to south, evident from the distribution of eggs and larvae, was further substantiated by the progressively smaller larvae that were caught as we sampled southward on late fall and winter cruises. In September, the newly spawned larvae were confined to a small area off western Long Island and northern New Jersey. By October, larvae were distributed over almost the entire northern half of the survey area. In November, when they were spread throughout the survey area, those south of Delaware Bay were smaller than those north of the Bay. In December (1965), larvae generally were largest north of Delaware Bay, and progressively smaller at more southerly stations, the smallest occurring south of Cape Hatteras. Those south of Cape Hatteras in February were small and newly hatched, while most of those to the north had started to metamorphose. By April, when larvae were found only south of Cape Hatteras, most had started to metamorphose (Appendix Table 1).

THE RELATION OF SPAWNING TO WATER TEMPERATURES

Spawning occurred principally within a temperature range of 7°C during the year of our survey. Over the whole season, we caught 77% of the eggs where bottom temperatures were between 12° and 19°C. This percentage would probably be higher if some dispersion by coastal circulation were taken into account. Miller (1952)[3] found surface water drifting from 6 to 37 km/day within the survey area. A minimal drift of 9 km daily would be sufficient to place the origin of 98% of the eggs we caught in bottom waters between 12° and 19°C. There was no evidence that salinity had any effect on the distribution of eggs or larvae.

At the beginning of the season, in September, the summer thermocline remained intact. Water temperatures at the surface and bottom differed by as much as 14.6°C. The greatest concentration of eggs was located off Long Island, shoreward of the cold mass of bottom water that persists during the summer months from New York to as far south as Chesapeake Bay (Bigelow, 1933). Where eggs were most abundant at the surface, bottom temperatures were between 18° and 19°C (Figure 9). The few eggs caught seaward of the cold bottom water might have been spawned by a group of fish that either had migrated from northerly waters around the outer edge of the cold bottom water or by a group that remained in deep water throughout the year. By October, the thermocline was less pronounced than in September, and most of the eggs occurred over bottom temperatures between 13° and 17°C (Figure 9). As in September, the seaward distribution of eggs appeared restricted by the cold mass of bottom water which remained intact off Long Island and New Jersey. It seems certain, therefore, that the inshore edge of the cold water delimited the seaward extent of the fall migration of spawning fish.

[3] Miller, A. R. 1952. A pattern of surface coastal circulation inferred from surface salinity-temperature data and drift bottle recoveries. Woods Hole Oceanogr. Inst. Ref. No. 52-58, 14 p. (Unpubl. manuscr.)

By so doing, the mass of cold water may play a major role in the success or failure of spawning off the Middle Atlantic States, depending on the time when it becomes mixed with surrounding water by late summer and fall storms.

By November, water was mixed and temperatures uniform from surface to bottom, except at those stations on the seaward end of transects. Eggs occurred in greatest numbers off northern Virginia, over 11.7°C bottom water, and off the outer banks of North Carolina, where the bottom temperature was 15.0°C. The northern limit of the principal area of distribution was along the transect off Great Egg Inlet, N.J., where we started the cruise. At that time, bottom temperatures exceeded 12°C (Figure 10). By the time we began sampling the four northernmost transects (see Table 1), bottom temperatures had fallen below 12°C and spawning had practically ended in the northern part of the survey area. It continued in the southern part, where in December (1965) we caught eggs over bottom temperatures of 12° to 19°C (Figure 10). By late January, bottom temperatures were less than 12°C at all but five stations, and we caught eggs only at the most southerly one, where the bottom temperature was 17.8°C.

Presuming that spawing occurs on the bottom, it is limited to a narrow temperature range. The eggs, however, which subsequently rise, are evidently more temperature tolerant than their spawning parents, for we found them at water temperatures as cold as 9.1°C and as warm as 22.9°C, though mostly from 13.0° to 17.9°C. Judging from the hatching time for artificially fertilized eggs, reported by Smith and Fahay (1970), those taken offshore in 9.1°C water required about 142 hr to hatch; those taken at 22.9°C, only 56 hr. Most of the eggs collected during the survey would have hatched 74 to 94 hr after fertilization. Although larvae occurred over a still wider mean temperature range than eggs (0° to 23.1°C), they were most abundant at mean temperatures of 9.0° to 17.9°C (Appendix Table 2). Other workers also have captured young summer flounder over a wide range of both temperature and salinity. Williams and Deubler (1968) caught postlarvae in Pamlico Sound water ranging in temperature from 2° to 22°C and in salinity 0.02 to 35.0‰. Tagatz and Dudley (1961) caught young of 11 to 180 mm in length at temperatures between 9.4° and 31.2°C and salinities between 8.7 and 37.0‰, and Deubler and White (1962) kept post larvae for 33 days in water with a salinity of 40‰.

GEOGRAPHICAL SPAWNING AREAS AND SPAWNING POPULATIONS

Although summer flounder occur occasionally as far north as Maine and as far south as Florida, fishing records indicate that they are most abundant from Cape Cod to Cape Lookout. Thus, it is doubtful that much spawning occurred north or east of our northernmost transect. The most important spawning grounds within the survey area were off New York and New Jersey. We caught the greatest numbers of eggs within 46 km of shore. Larvae were most abundant 22 to 83 km offshore. In some instances, we caught the young stages at our most seaward stations, but, considering the known offshore range of adults, it is unlikely that significant numbers of eggs or larvae occurred beyond our outermost stations. The numbers of eggs and larvae were relatively low off Virginia, increased off the outer banks of North Carolina, and declined off Cape Lookout (Appendix Table 3). Cape Lookout, however, should not be considered the southern limit of spawning, for we caught larvae as far south as Daytona Beach, Fla., in January 1968. Plankton collections south of Cape Lookout in 1953, 1954, and 1967[4] contained summer flounder larvae (Figure 11). More sampling is needed to assess the importance of spawning grounds south of Cape Lookout.

Although research on summer flounder has been sporadic and limited in geographic scope, there is mounting evidence that separate spawning populations exist. The occurrence of distinct areas of egg and larvae abundance at different times of the spawning season; the tag returns of Poole (1962) and Murawski (1970), indicating a general inshore-offshore

[4] Unpublished data on file at Middle Atlantic Coastal Fisheries Center, National Marine Fisheries Service, Highlands, N.J. 07732.

movement and a strong tendency of fish to return in subsequent summers to the same area; the short time between departure from the inshore summering grounds and the onset of spawning, which would limit prespawning movement; and, finally, the differences in gill raker and anal ray counts between summer flounder collected at Chesapeake Bay and at Beaufort, N.C. (Ginsburg, 1952) strongly suggest the likelihood of different populations. Judging from our survey in 1965-66, one segment of the species appeared to spawn principally north of Delaware Bay, a second from Virginia to Cape Hatteras, and a third south of Cape Hatteras. The biological evidence is supported by commercial landings. The catch from ports between Maryland and Massachusetts declined by 66% from 1960 through 1967. During the same period, Virginia landings fluctuated but a decline was not evident. In North Carolina, landings increased. If effort remained relatively constant along the coast, it is unlikely that such trends would have occurred if the various coastal fisheries depended on one population.

LARVAL MOVEMENTS

The net transport of water along the Middle Atlantic Bight is generally southerly to southwesterly in the fall (Bumpus and Lauzier, 1965; Norcross and Stanley, 1967). Although pelagic eggs and early larval stages drift in sea currents, it appears that the summer flounder larvae we collected had not drifted far from the spawning areas. Larvae of all stages of development caught off New York and New Jersey, and off North Carolina, were taken in the general vicinity of the eggs (Figures 12 to 16). Although there is no evidence to relate the movement of young summer flounder to known current patterns, early juvenile stages have been captured only in estuaries, suggesting that the young fish are estuarine dependent. Their tolerance to wide ranging temperatures and salinities further suggests that they are physiologically adapted to utilize the estuarine zone for nursery grounds. Judging from our collections and the size of specimens collected at inlets along the coast, the shoreward migration begins after the young fish metamorphose and become capable swimmers.

Most of the postlarvae in our collections were caught at night. Of the 114 specimens larger than 9 mm, 91 (80%) were taken after dark. Additional sampling with modified collecting gear should confirm whether the significantly greater nighttime catch resulted from net avoidance during the day or from diel movements of the metamorphosing young fish. Arnold (1969) noted that metamorphosing postlarvae of the European plaice, *Pleuronectes platessa*, may go quickly to the bottom when not actively swimming. Pearcy (1962) made a similar observation on winter flounder, *Pseudopleuronectes americanus*, considering both the small and large larvae to be partially benthic animals. If postlarval summer flounder behave similarly to the above postlarval flatfishes, then perhaps day-night differences in the catch may reflect periods of low and high activity rather than net avoidance. In this case, the postlarvae would be largely unavailable to our nets when not swimming, which they might do mostly at night. If, on the other hand, the difference between day and night catches reflects net avoidance, towing speeds in excess of 9.3 km/hr are required to adequately sample postlarval summer flounder when using nets with a mouth opening comparable to a Gulf V.

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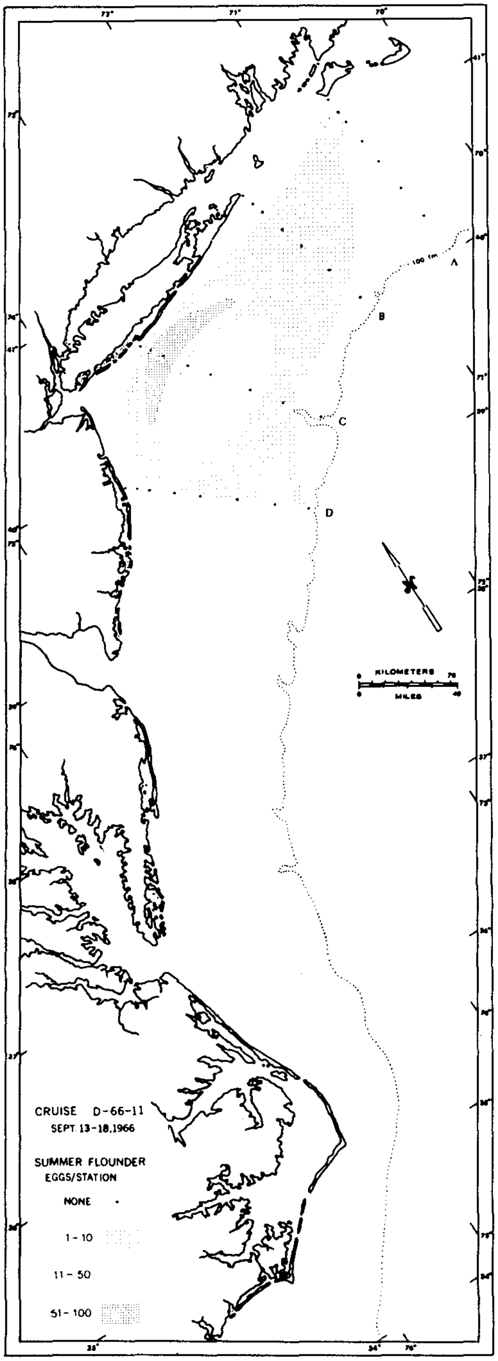


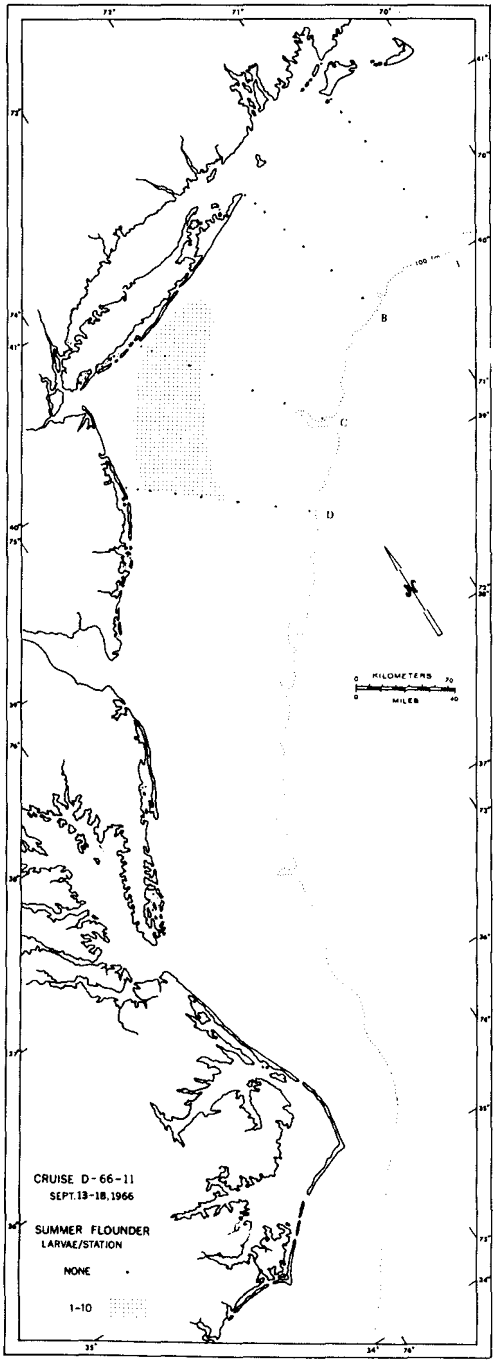
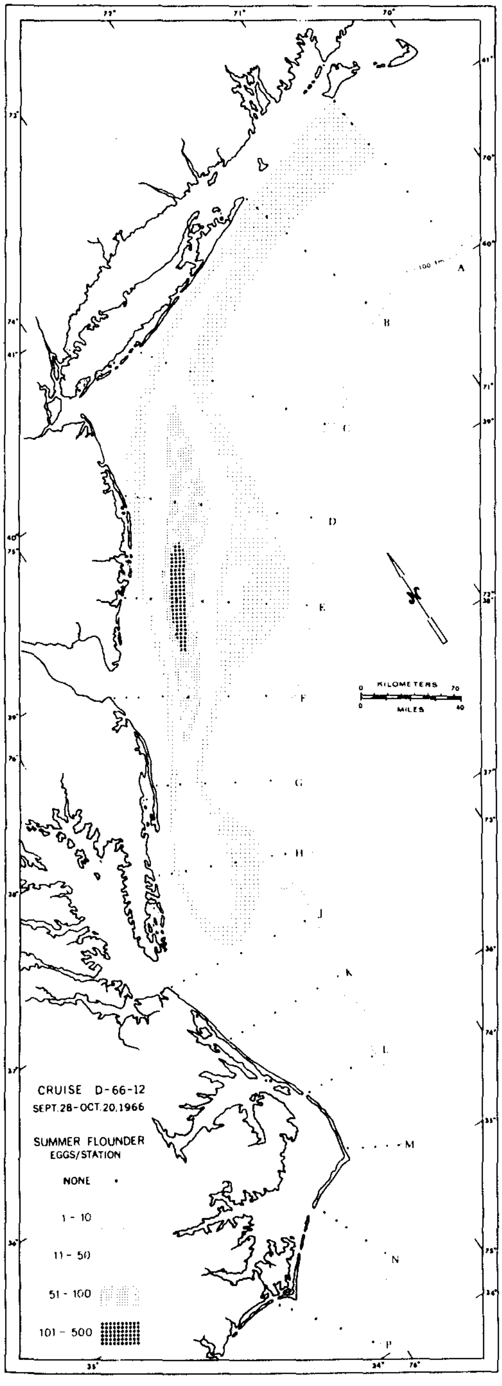


FIGURE 3.—Distribution and relative abundance (adjusted) of summer flounder eggs (left) and larvae (right) from Cruise D-66-11.



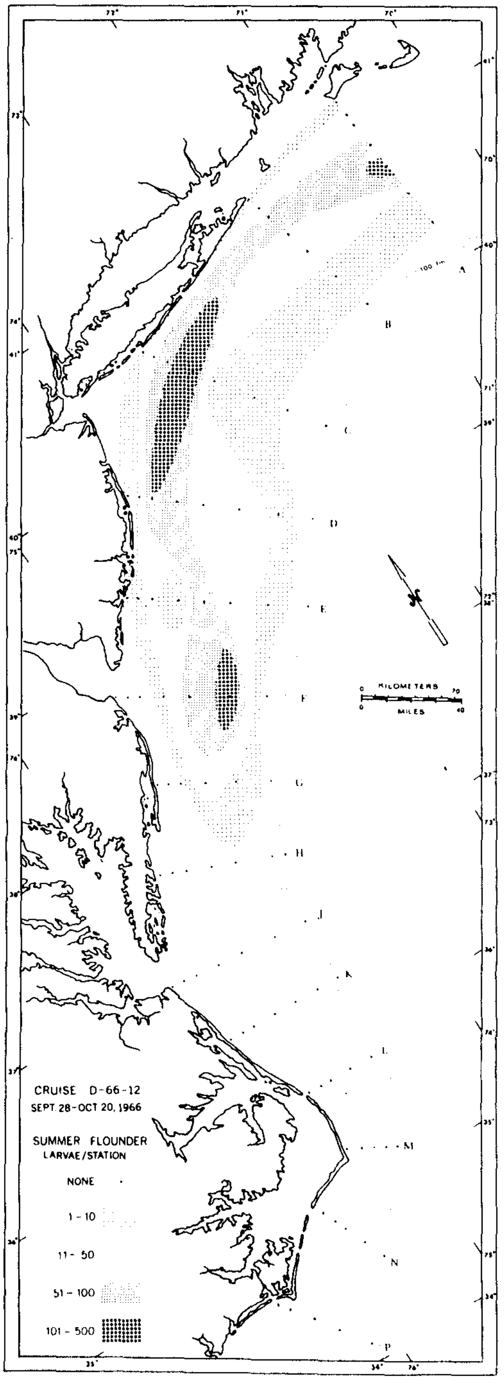


FIGURE 4.—Distribution and relative abundance (adjusted) of summer flounder eggs (left) and larvae (right) from Cruise D-66-12.

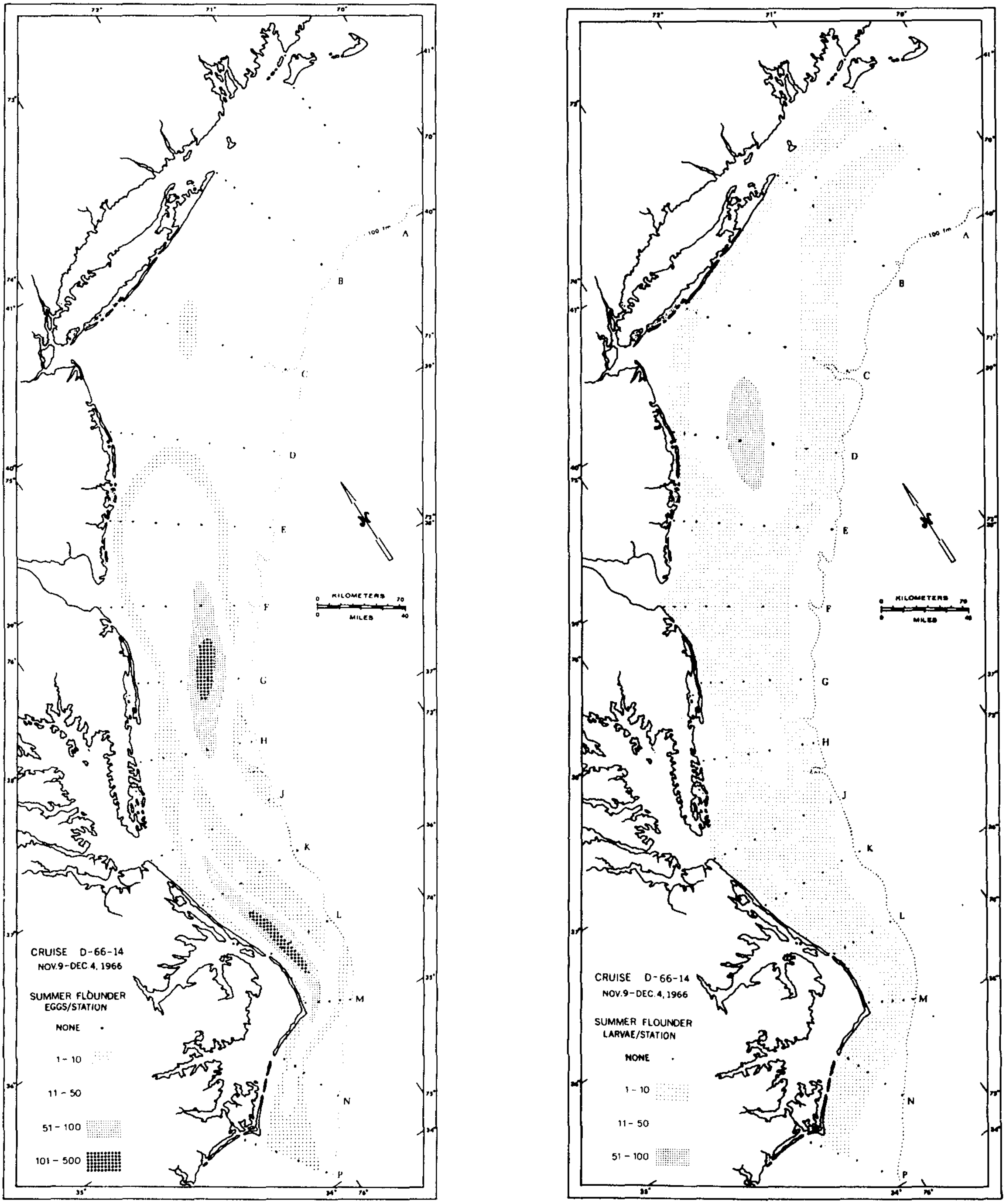


FIGURE 5.—Distribution and relative abundance (adjusted) of summer flounder eggs (left) and larvae (right) from Cruise D-66-14.

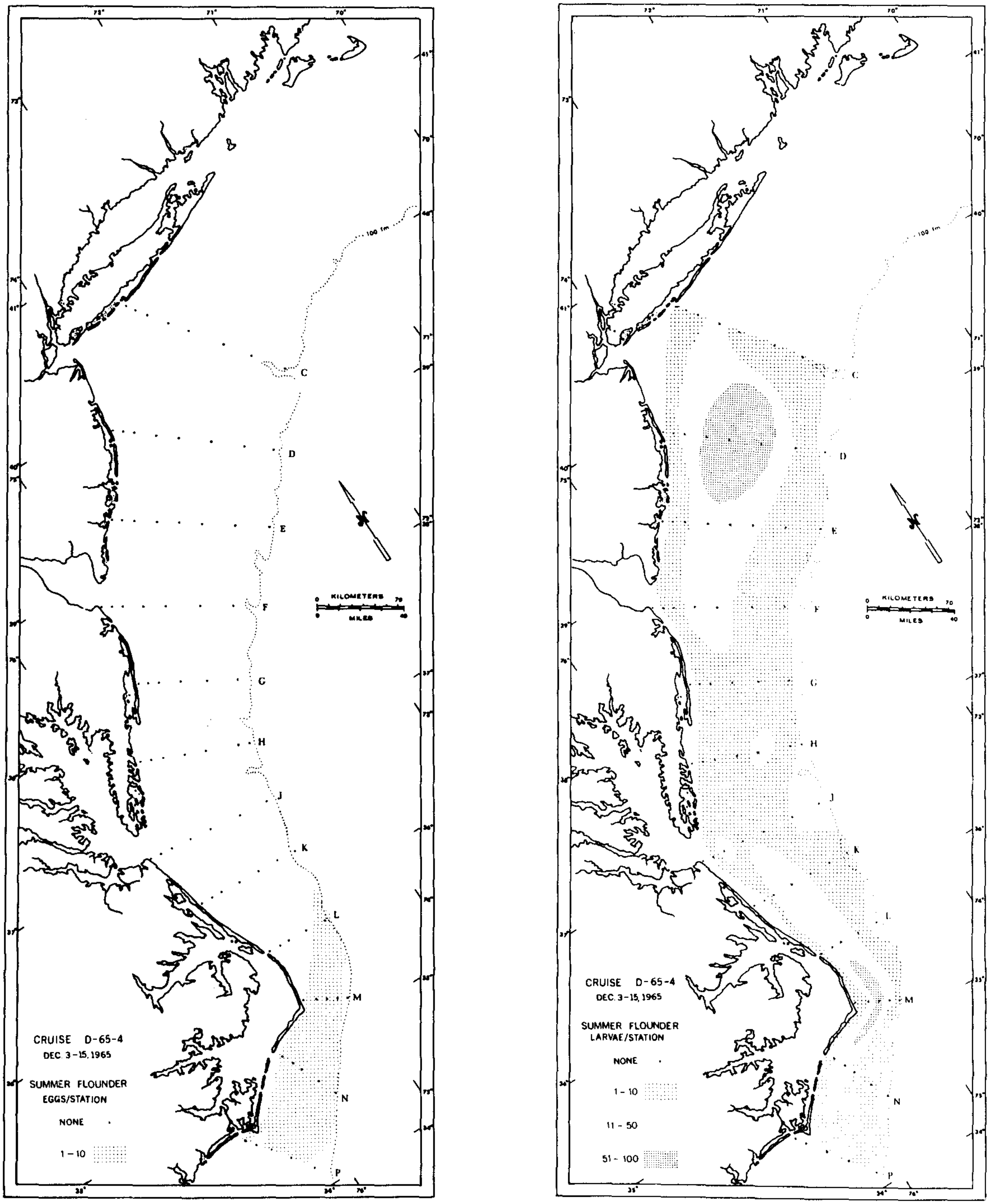


FIGURE 6.—Distribution and relative abundance (adjusted) of summer flounder eggs (left) and larvae (right) from Cruise D-65-4.

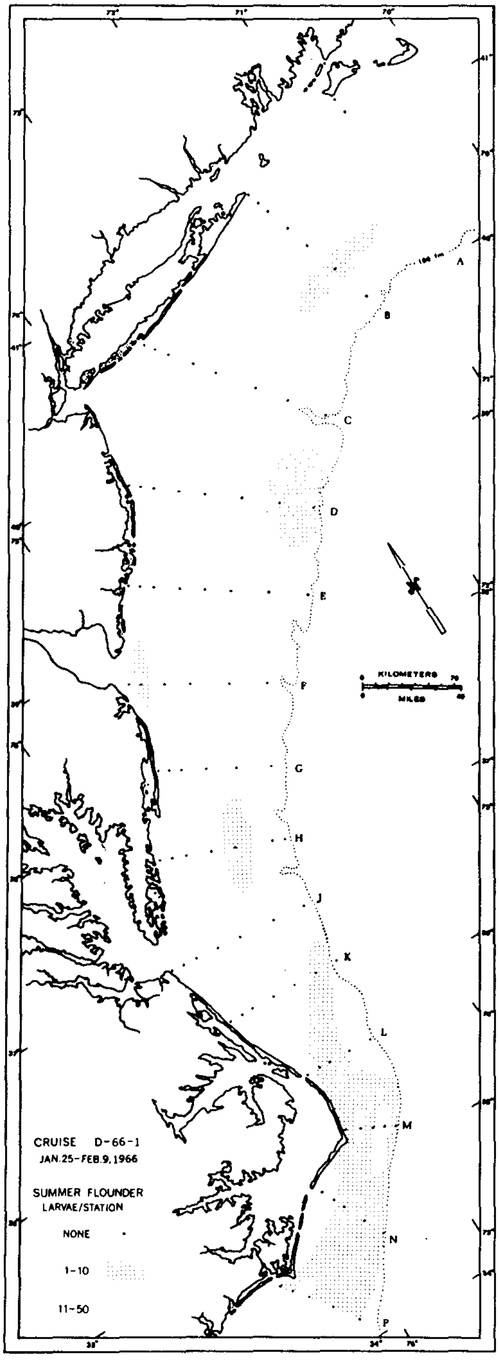


FIGURE 7.—Distribution and relative abundance (adjusted) of summer flounder larvae from Cruise D-66-1.

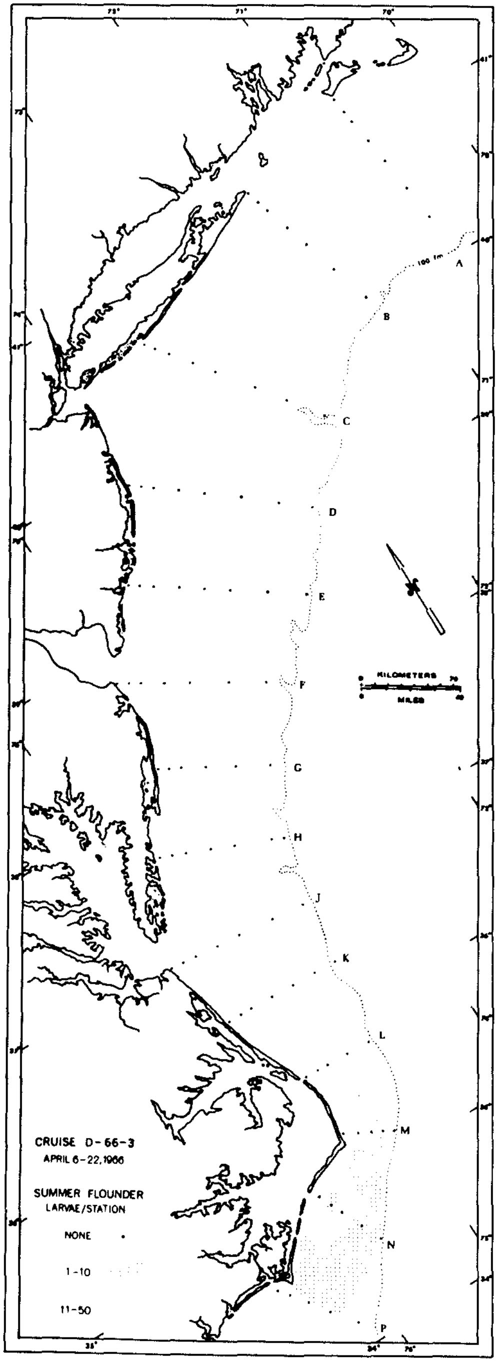


FIGURE 8.—Distribution and relative abundance (adjusted) of summer flounder larvae from Cruise D-66-3.

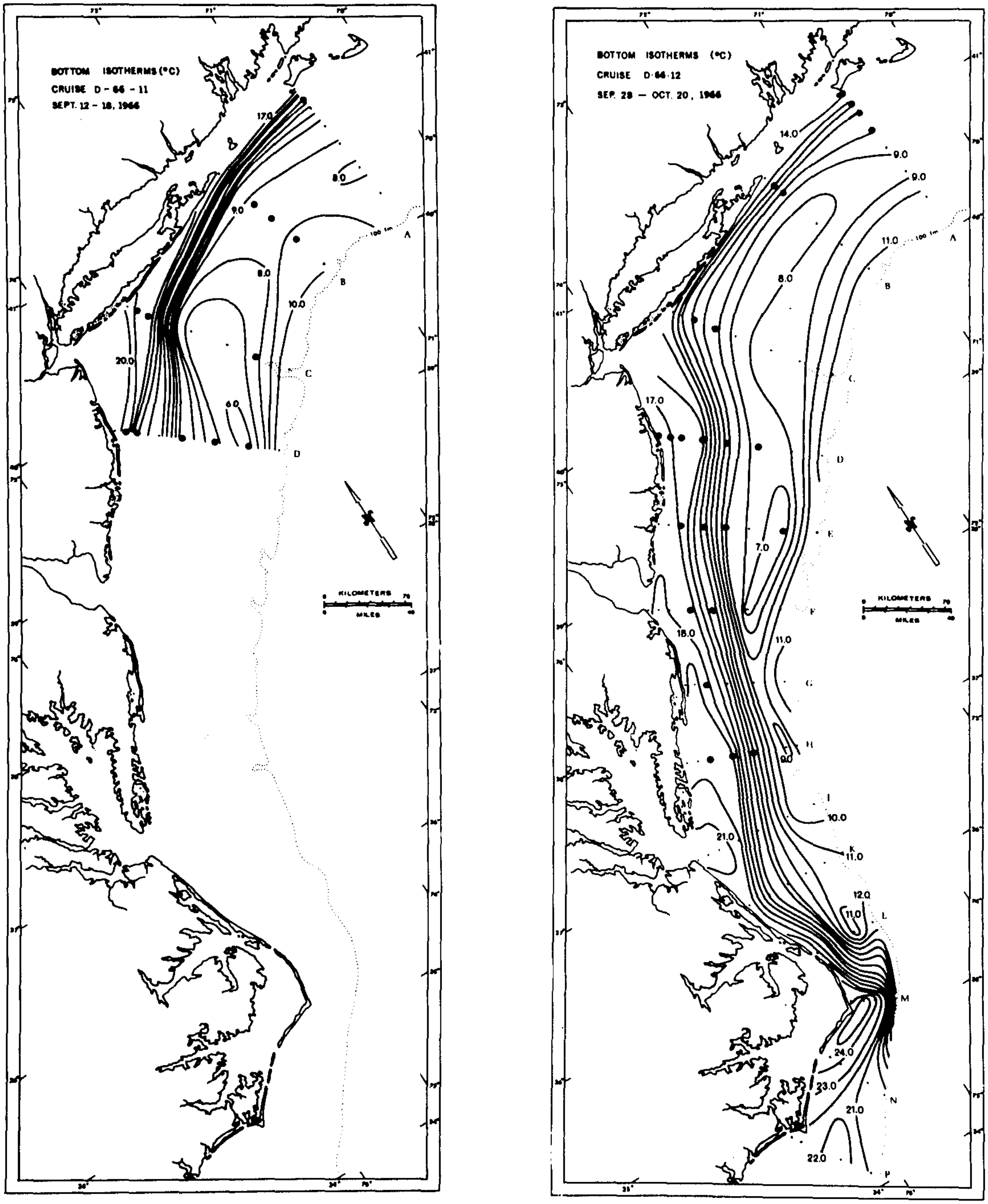


FIGURE 9.—The occurrence of pelagic eggs of summer flounder and associated bottom temperatures from Cruise D-66-11 (left) and Cruise D-66-12 (right). Eggs occurred at station positions shown by a large dot.

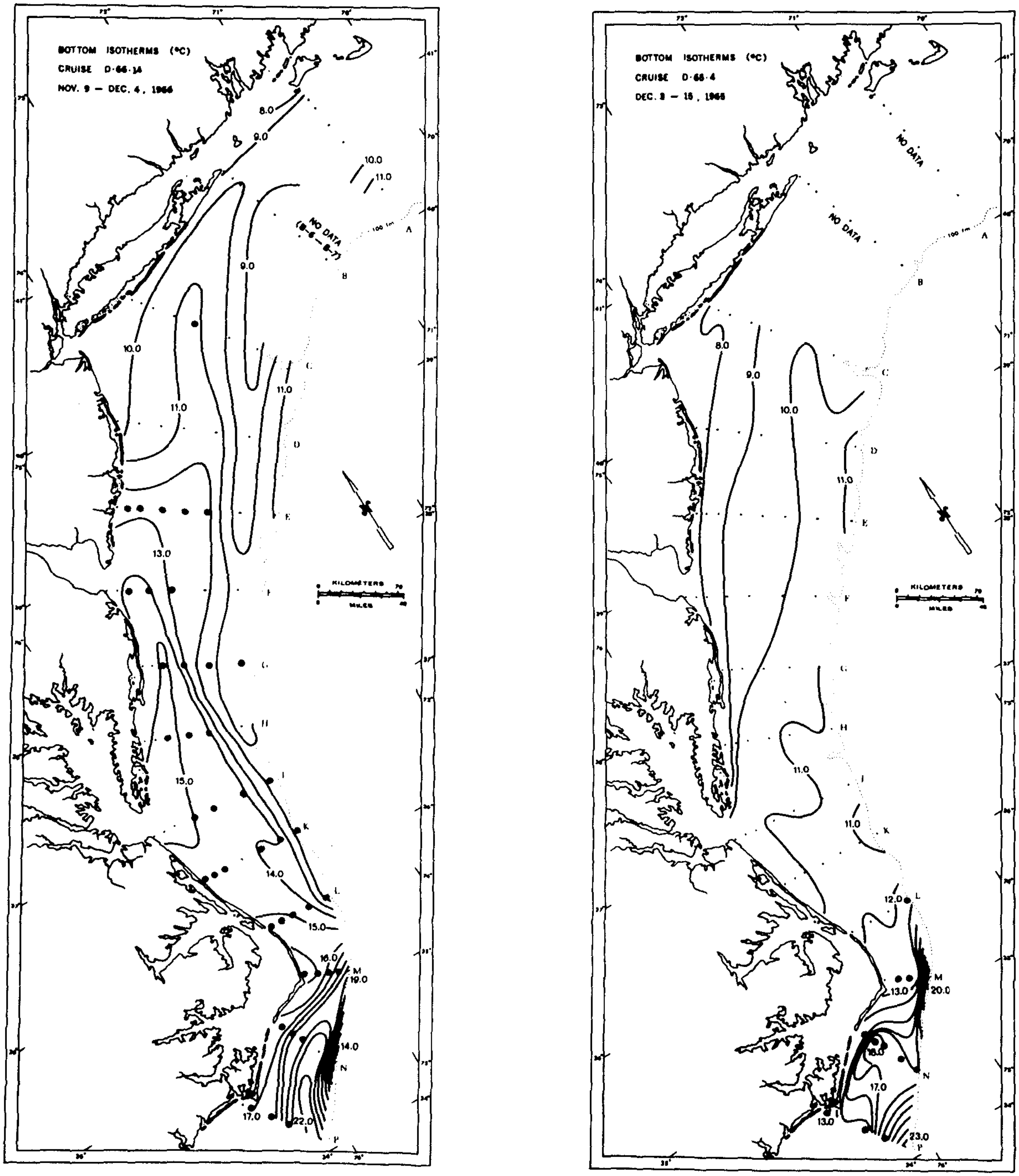


FIGURE 10.—The occurrence of pelagic eggs of summer flounder and associated bottom temperatures from Cruise D-66-14 (left) and Cruise D-65-4 (right). Eggs occurred at station positions shown by a large dot.

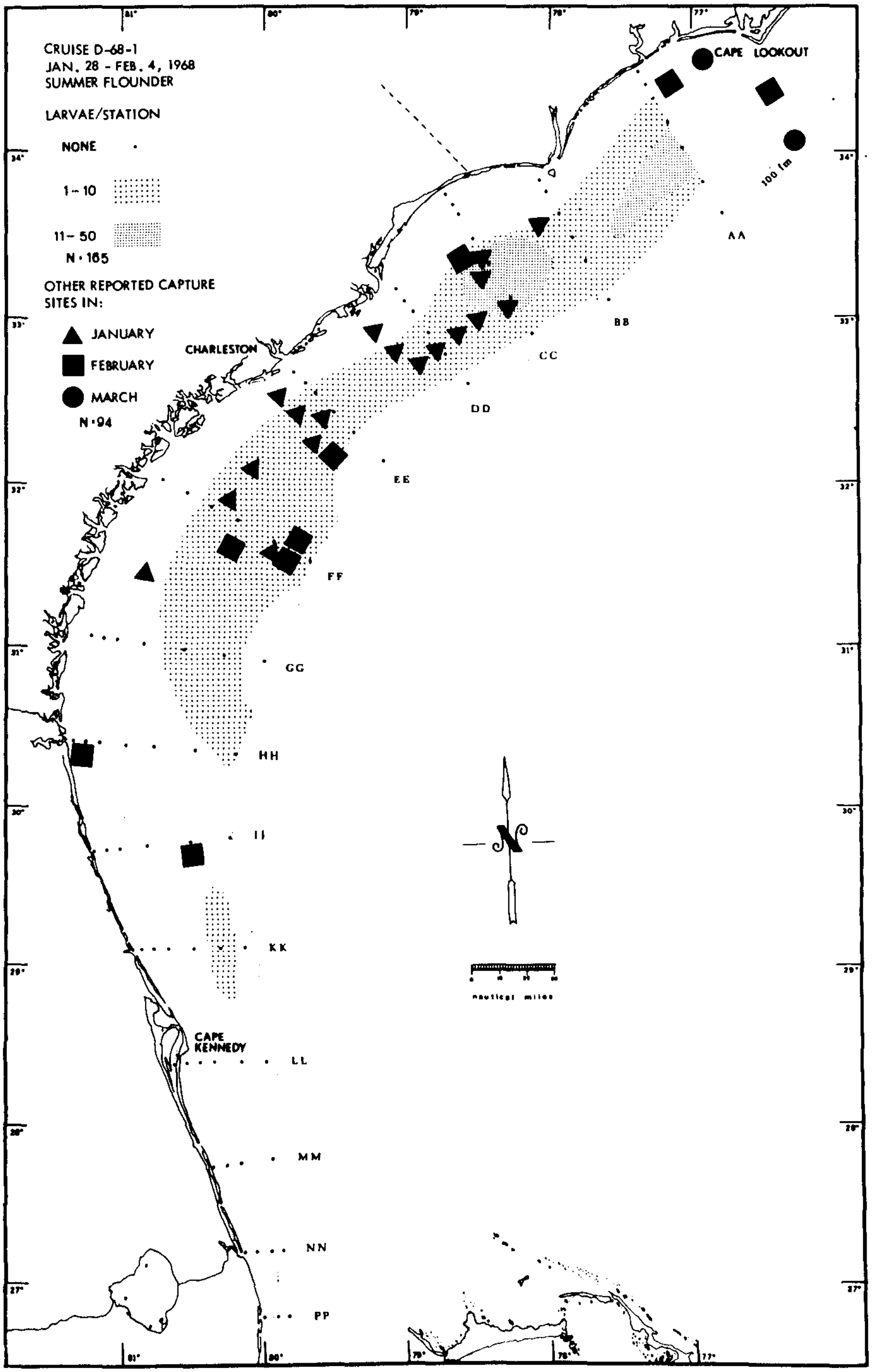


FIGURE 11.—Distribution and relative abundance of summer flounder larvae captured by RV *Dolphin* between New River, N.C., and Palm Beach, Fla., in 1968, and other reported capture sites of summer flounder larvae.

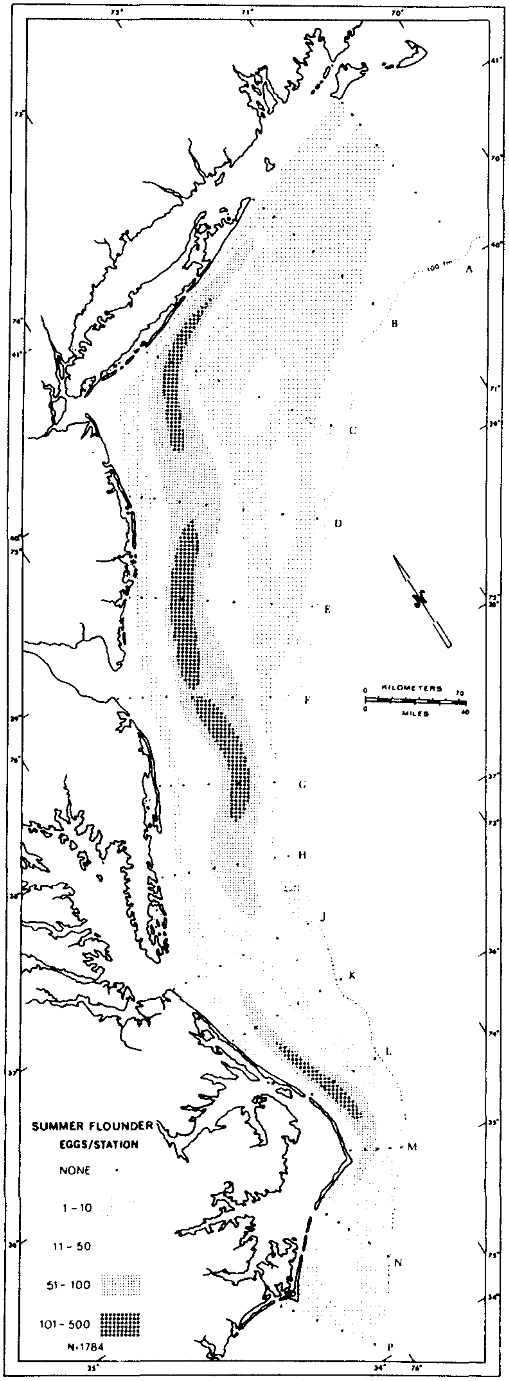


FIGURE 12.—Distribution and relative abundance (adjusted) of summer flounder eggs from 1965-66 plankton survey.

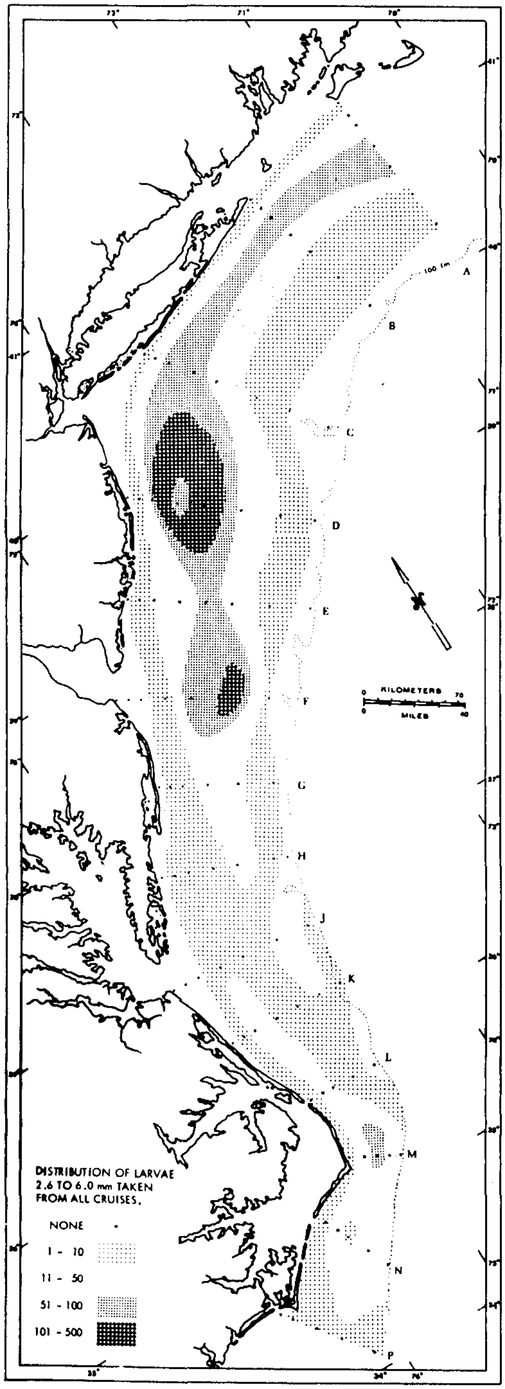


FIGURE 13.—Distribution and relative abundance (adjusted) of summer flounder larvae 2.6 to 6.0 mm from 1965-66 plankton survey.

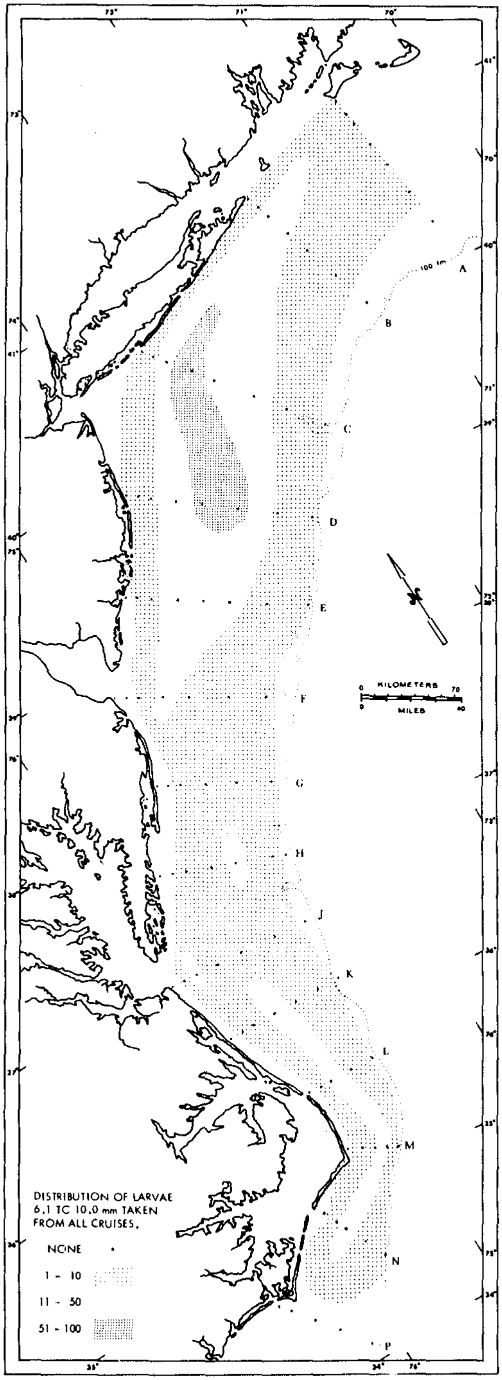


FIGURE 14.—Distribution and relative abundance (adjusted) of summer flounder larvae 6.1 to 10.0 mm from 1965-66 plankton survey.

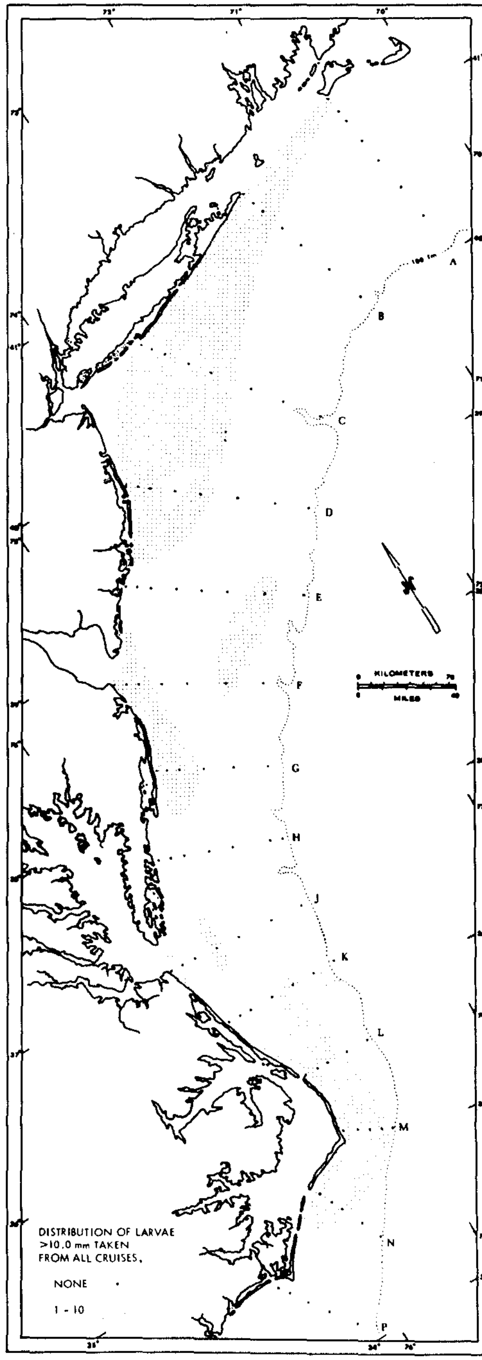


FIGURE 15.—Distribution and relative abundance (adjusted) of summer flounder larvae greater than 10.0 mm long from 1965-66 plankton survey.

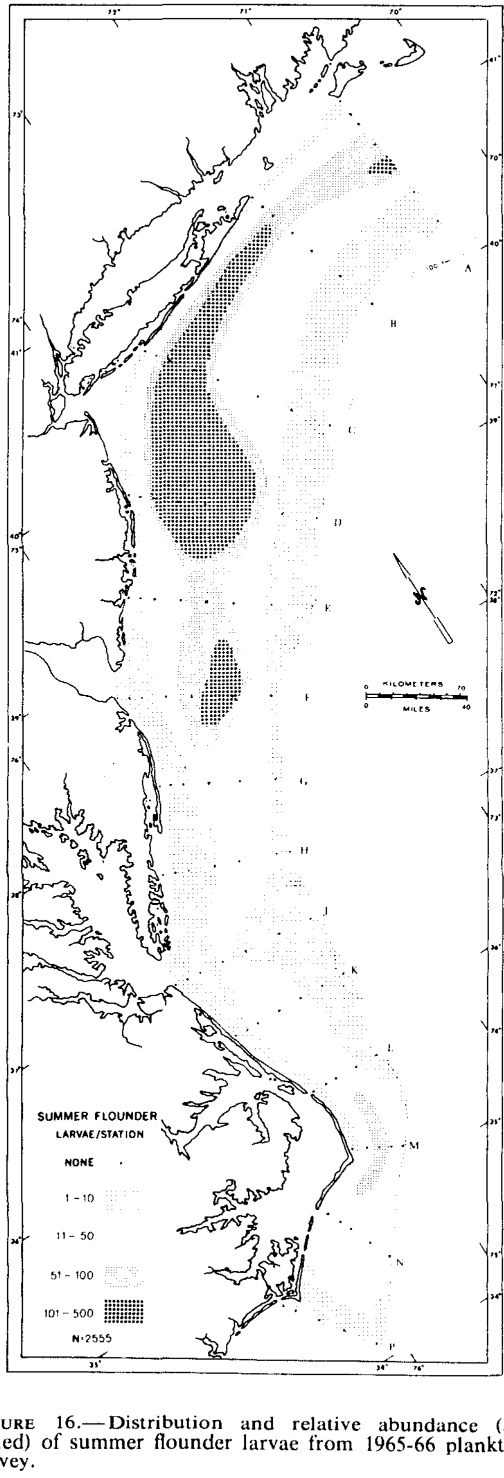


FIGURE 16.—Distribution and relative abundance (adjusted) of summer flounder larvae from 1965-66 plankton survey.

APPENDIX TABLE 1.—The length-frequency distribution of summer flounder larvae (to nearest 0.5 mm) taken on cruises from late summer to spring. Numbers are adjusted to standardize sampling effort of the two nets. Section I extended from Cape Cod to Cape Henlopen (Transects A to F); II from Cape Henlopen to Cape Hatteras (Transects G to M); and III from Cape Hatteras to Cape Lookout (Transects N and P). The survey began with the December 1965 cruise and ended with the November-December 1966 cruise.

Standard length (mm)	Cruise D-66-11 Sept. 1966				Cruise D-66-12 Oct. 1966				Cruise D-66-14 Nov.-Dec. 1966				Cruise D-65-4 Dec. 1965			
	Section				Section				Section				Section			
	I	II	III	Total	I	II	III	Total	I	II	III	Total	I	II	III	Total
2.6- 3.0	1			1	36			36	1	6	1	8		6	5	11
3.1- 3.5	5			5	148	3		151	12	17	3	32	5	30	18	53
3.6- 4.0	4			4	271	8		279	25	11	2	38	12	54	21	87
4.1- 4.5	3			3	182	10		192	42	9	1	52	19	47	13	79
4.6- 5.0	1			1	126	2		128	54	19	1	74	26	30	11	67
5.1- 5.5	1			1	112	1		113	46	9	1	56	48	23	6	77
5.6- 6.0					87			87	34	4		38	64	16	5	85
6.1- 6.5					69	1		70	20	10		30	60	30	1	91
6.6- 7.0					54			54	14	8	1	23	52	22	3	77
7.1- 7.5					18	1		19	17	8		25	34	26	2	62
7.6- 8.0					15			15	13	1		14	17	13	2	32
8.1- 8.5					7			7	17	1		18	18	11		29
8.6- 9.0					2			2	12			12	10	11		21
9.1- 9.5									9	1		10	6	7		13
9.6-10.0									2			2	2	6	1	9
10.1-10.5					1			1	7	1		8	4	3		7
10.6-11.0									6	5		11		5		5
11.1-11.5									3	2		5	2	2		4
11.6-12.0									1			1		1		1
12.1-12.5									1			1		2		2
12.6-13.0									1			1				
13.1-13.5													1	1		2
Total	15			15	1,128	26		1,154	337	112	10	459	380	346	88	814

Standard length (mm)	Cruise D-66-1 Jan.-Feb. 1966				Cruise D-66-3 Apr. 1966				Cruise D-66-5 May 1966				All cruises			
	Section				Section				Section				Section			
	I	II	III	Total	I	II	III	Total	I	II	III	Total	I	II	III	Total
2.6- 3.0													38	12	6	56
3.1- 3.5			4	4									170	50	25	245
3.6- 4.0			7	7			3	3					312	73	33	418
4.1- 4.5			5	5									246	66	19	331
4.6- 5.0			5	5			1	1					207	51	18	276
5.1- 5.5	1		3	4			1	1					208	33	11	252
5.6- 6.0							2	2					185	20	7	212
6.1- 6.5		1	2	3						1		1	149	43	3	195
6.6- 7.0			1	1			3	3					120	30	8	158
7.1- 7.5	1			1									70	35	2	107
7.6- 8.0		1		1			4	4					45	15	6	66
8.1- 8.5		2		2		1	6	7					42	15	6	63
8.6- 9.0	1	6	1	8		1	5	6		1		1	25	19	6	50
9.1- 9.5	1	4	1	6			5	5		2		2	16	14	6	36
9.6-10.0		1	1	2			2	2					4	7	4	15
10.1-10.5		3		3			3	3					12	7	3	22
10.6-11.0		1		1			1	1					6	11	1	18
11.1-11.5		1		1			1	1		2		2	5	7	1	13
11.6-12.0													1	1		2
12.1-12.5										1		1	1	3		4
12.6-13.0		1		1									1	1		2
13.1-13.5													1	1		2
Total	4	21	30	55		2	37	39		7		7	1,864	514	165	2,543

APPENDIX TABLE 2.—The relation of adjusted catch size of summer flounder eggs and larvae to mean temperature of water sampled by net no. 1 or no. 2. Only successful tows are included.

Mean temperature	Size of catch									
	1-10		11-50		51-100		101-500		Total	
	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
°C	*Number of tows*									
Less than 2.0		1								1
3.0- 3.9		4								4
4.0- 4.9		4								4
5.0- 5.9		1		1						2
7.0- 7.9		5								5
8.0- 8.9		11		4						15
9.0- 9.9	1	26		9		1			1	36
10.0-10.9		29		8						37
11.0-11.9	2	14		4		1			2	19
12.0-12.9	8	17	1	5		1			9	23
13.0-13.9	8	18	7	3	1				16	21
14.0-14.9	6	27	10	10	2	4	2		20	41
15.0-15.9	7	14	5	1	1	1			13	16
16.0-16.9	3	5	4	5					7	10
17.0-17.9	5	10	2	2	1	1	1	1	9	14
18.0-18.9	2	7	2	2					4	9
19.0-19.9	1	5			2				3	5
20.0-20.9	9	4	1	2					10	6
21.0-21.9	2	2							2	2
22.0-22.9	1	2							1	2
23.0-23.9		2								2
Total	55	208	32	56	7	9	3	1	97	274

APPENDIX TABLE 3.—The adjusted catch of summer flounder eggs and larvae, showing effort and relative densities by section and by transect. Section I extended from Cape Cod to Cape Henlopen; II from Cape Henlopen to Cape Hatteras; and III from Cape Hatteras to Cape Lookout. All stations sampled within a section where eggs or larvae occurred are included in density estimates, whether or not eggs or larvae were caught.

Section	Transect	Location	Eggs			Larvae		
			Number of		Catch per standard tow	Number of		Catch per standard tow
			Standard tow	Eggs		Standard tow	Larvae	
I	A	Martha's Vineyard, Mass.	21	21	1.0	23	224	9.7
	B	Eastern Long Island, N.Y.	21	17	0.8	28	186	6.8
	C	Western Long Island, N.Y.	24	179	7.5	40	388	9.7
	D	Barnegat Inlet, N.J.	24	187	7.8	40	637	15.9
	E	Great Egg Inlet, N.J.	16	241	15.1	32	210	6.6
	F	Cape Henlopen, Del.	14	167	11.9	27	253	9.4
Total			120	812	6.8	190	1,898	10.0
II	G	Assateague Island, Md.	18	192	10.7	30	72	2.4
	H	Eastern Shore, Va.	21	142	6.8	35	54	1.5
	J	Cape Henry, Va.	21	54	2.6	35	21	0.6
	K	Currituck Beach, N.C.	21	151	7.2	35	77	2.2
	X	Currituck Beach[1] to Oregon Inlet	4	0	0.0	4	54	13.5
	L	Oregon Inlet, N.C.	15	243	16.2	25	67	2.7
	M	Cape Hatteras, N.C.	15	126	8.4	25	151	6.0
Total			115	908	7.9	189	496	2.6
III	N	Ocracoke Inlet, N.C.	15	44	2.9	20	141	7.1
	P	Beaufort Inlet, N.C.	15	20	1.3	20	20	1.0
Total			30	64	2.1	40	161	4.0
Grand total			265	1,784	6.7	419	2,555	6.1

[1] Sampled only during December (1965) cruise.