NOAA Technical Report NMFS SSRF-691

Seasonal Distributions of Larval Flatfishes (Pleuronectiformes) on the Continental Shelf Between Cape Cod, Massachusetts, and Cape Lookout, North Carolina, 1965-66

W. G. SMITH, J. D. SIBUNKA, and A. WELLS

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UNITED STATES DEPARTMENT OF COMMERCE
Rogers C. B. Morton, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Robert M. White, Administrator

National Marine Fisheries Service
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ABSTRACT

Larval flatfishes, representing 4 families, 17 genera, and 15 species, were identified from collections taken during a 1-yr survey designed to locate spawning grounds and trace dispersion of fish eggs and larvae on the continental shelf. Most flatfishes began spawning in the spring, a time of marked seasonal temperature change. The seasonal distribution of larvae indicated that: 1) bothids had longer spawning seasons than pleuronectids; 2) pleuronectids spawned largely in the northern half of the survey area during the spring; 3) most bothids spawned in the southern half, beginning in spring and continuing through early fall; 4) although cynoglossids spawned incidentally off North Carolina, most of their larvae were transported into the survey area from spawning grounds south of Cape Lookout; 5) the few representatives of the family Soleidae originated south of Cape Lookout; 6) spawning that began in the spring proceeded from south to north as the season progressed, but spawning that began in the fall proceeded from north to south, suggesting that the onset of spawning is triggered by spring warming and fall cooling; 7) most species spawned within a relatively narrow range of temperature; 8) salinity had no apparent influence on spawning.

INTRODUCTION

Recruitment is a major factor determining the size of heavily exploited fish populations such as those found along our eastern seaboard. Unfortunately, we lack the needed scientific information about the life histories of most coastal fishes to relate numbers of adults to numbers of young and, in turn, relate numbers of young to the sequence of biological and environmental events that lead to a successful year class. The sound management policies that seem so essential during this period of increased foreign and domestic fishing pressure will follow the enormously important task of understanding life histories in their entirety; not just that part dealing with adults but with all stages of development.

In 1965, biologists at Sandy Hook began a 2-yr survey of young fishes on the continental shelf between southern New England and Florida. The first year we sampled from Cape Cod, Mass., to Cape Lookout, N.C.; the second year from New River, N.C., to Palm Beach, Fla. We planned initially to determine spawning areas and trace the distributional patters of eggs and larvae after spawning, with a view toward assessing the importance of the estuarine zone as a nursery ground for juvenile fishes. In this paper, we discuss the seasonal distribution and relative abundance of flatfish larvae, belonging to 17 genera and 15 species, collected during the year of sampling along the Middle Atlantic Bight, i.e., that portion of the continental shelf between Cape Cod, Mass., and Cape Hatteras, N.C. To assess the contribution of ichthyoplankton to the Middle Atlantic Bight from waters south of Cape Hatteras, we sampled to Cape Lookout.

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The Middle Atlantic Bight, hereafter referred to as the bight, is inhabited by an arctic-boreal group of flatfishes, largely pleuronectids, whose center of abundance lies north of Cape Cod; and a warm-temperate group, mostly bothids, that range southward to Florida and, for some species, into the Gulf of Mexico, the Caribbean Sea, and the South Atlantic Ocean (Topp and Hoff 1972). Some of the pleuronectids escape unsuitably warm inshore water in the bight by moving offshore to cool deep water in summer. Conversely, many of the bothids favor the warm inshore water in summer and some move offshore in winter, where bottom temperatures are warmer than those inshore. Despite their seasonal movements, members of both groups possess the temperature tolerance characteristic of most coastal fishes found at temperate latitudes.

METHODS

We conducted nine cruises during the survey, sampling at 92 stations situated along 14 transects (Fig. 1). The sequence of sampling varied, depending largely on existing weather conditions. With the exception of the September cruise, which was twice delayed and subsequently rescheduled after sampling the four northernmost transects, nearly all cruises were completed. Rough weather precluded our sampling along transects A and B on the first cruise in December, and at six stations on the second cruise in January (Table 1).

Sampling procedures, equipment, hydrographic data, and laboratory procedures are described by Clark et al. (1969). Two Gulf V nets (Arnold 1959) were towed for 30 min in a step oblique pattern to collect plankton. Net 1 fished for 5 min each at six 3-m depth intervals from the surface to 15 m; the other, net 2, at six intervals from 18 to 33 m. At depths less than 33 m, we decreased the number of towing depth

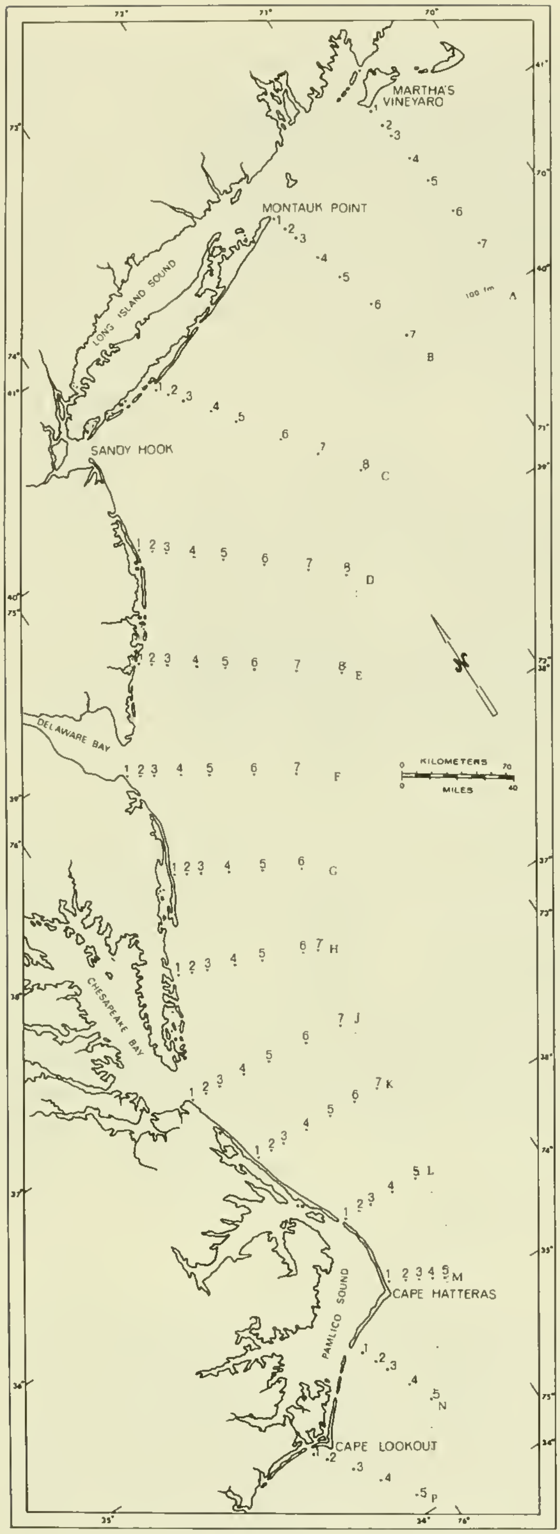


Figure 1.—Transects (lettered) and collecting stations (numbered) of 1965-66 plankton survey between Cape Cod and Cape Lookout.

intervals and increased the towing time at each interval for net 2. The tow profile for net 1 was similarly adjusted in depths less than 15 m (Smith 1973).

Because of variations in the towing time at 3-m depth intervals between inshore and offshore stations, it was necessary to standardize tows to obtain measures of relative abundance. 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. We adjusted the catches to equalize sampling effort at all depth intervals when either net was limited to sampling at less than six intervals. For example, when a net fished at only three intervals during the 30-min tow, the catch was halved. When two intervals were fished, it was reduced by two-thirds. We combined the adjusted catches of nets 1 and 2 at stations where both nets fished simultaneously. All catches discussed are adjusted.

If more than 100 larvae of a species were caught at a station, we usually measured a subsample of 25 randomly selected specimens to the nearest 0.1 mm and adjusted the number measured to coincide with the total catch, which we recorded in size increments of 1.0 mm.

In spite of the possibility of year-to-year variations in the onset, duration, and success of spawning, data collected during the two calendar years of the survey were combined and treated as a single complete spawning season for each species. For example, we discuss results of fall and winter spawning by beginning with the October and November 1966 catches, and continue with results of December 1965, January 1966, etc. We determined monthly shifts in spawning grounds and the duration of spawning by plotting the distribution of larvae by size categories, provided larvae occurred in sufficient numbers to merit such analyses. Figures showing the distribution of larvae by cruise include damaged larvae that could not be measured, but tables and, of course, those figures depicting the distribution of larvae by size categories do not. Thus, the number of larvae in the tables and the figures showing the distribution of larvae by size do not always correspond with the figures showing the distribution of all larvae collected on a cruise. If we caught only a few larvae of a species, a figure showing their distribution for that cruise may not be included. These larvae are, however, included in the composite figure, or that figure showing the combined catch for all cruises on which we caught larvae of a particular species. Thus, the composite figure for a species may show larval occurrences that are not evident on other figures.

Because larvae hatch and metamorphose at sizes that are intraspecifically similar but interspecifically different, the size categories vary between species. We assumed that the spawning grounds for each species were represented by the area encompassing stations where we caught small larvae. The spawning season included months when small larvae occurred in our samples.

ENVIRONMENTAL INFLUENCES ON THE DISTRIBUTION OF FISHES

Both water temperature and salinity undergo pronounced seasonal changes within the bight, due mostly to changes in weather and runoff from the numerous adjacent estuaries. Water temperatures increase rapidly during the spring. Warming begins inshore along the southern end of the bight, and progresses northward and seaward as cold winter winds give way to warm spring and summer breezes (Norcross and Harrison 1967). A seasonal thermocline develops throughout most of the bight by summer, and the water column remains thermally stratified until fall. A unique cell of cold

Table 1.--Cruise schedule and sequence of sampling transects during R. V. *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	No. of stations
D-65-4	Dec. 3-15, 1965	C to P	80
D-66-1	Jan. 25-26, 1966	B, A-1 and -2	86
	Feb. 2-9, 1966	C to P	
D-66-3	Apr. 6-9, 1966	A to D	92
	Apr. 13-16, 1966	E-1 and -2, F to J-7 to -3	
	Apr. 19-21, 1966	J-1 and -2 to P	
	Apr. 22, 1966	E-8 to -3	
D-66-5	May 12-25, 1966	A to P	92
D-66-7	June 17-20, 1966	A to D	92
	June 22-25, 1966	L to P	
	June 25-29, 1966	K to E	
D-66-10	Aug. 5-10, 1966	A to F	92
	Aug. 21-26, 1966	G to P	
D-66-11	Sept. 13-14, 1966	A and B (except B-3)	30
	Sept. 17-18, 1966	B-3, C and D	
D-66-12	Sept. 28-Oct. 6, 1966	M, N, L to F, E-1 to -3, D-1 to -3	92
	Oct. 11-15, 1966	E-4 to -8, F-8 to -4, C to A	
	Oct. 20, 1966	P	
D-66-14	Nov. 9-14, 1966	E to J (except F-7, E-8)	92
	Nov. 15-19, 1966	P to K, F-7, E-8	
	Dec. 1-4, 1966	D to A	

water forms below the thermocline from New York to as far south as Virginia (Bigelow 1933; Ketchum and Corwin 1964). The cell's pronounced effect on the distribution and movements of several summer spawning fishes is reflected in the patterns of their egg and larval distributions. Late summer and fall storms usually break down the thermal stratification, and water temperatures cool rapidly thereafter. By winter, the water column is isothermal, except near the outer edge of the shelf where temperatures are usually warmer near the bottom than at the surface.

Salinity throughout the bight seldom reaches 35‰, and it is usually less than 30‰ at the mouths of the major estuaries. Whereas water temperatures often seem related to the spawning habits of some species, we were unable to relate our salinity observations to spawning or the distribution of flatfish larvae.

Circulation within the bight has been studied largely by the release and return of drift devices such as bottles and seabed drifters. Nontidal drift is generally west to southwest but it changes seasonally, and surface and subsurface currents sometimes flow in opposite directions (Bumpus and Lauzier 1965; Norcross and Stanley 1967). Wind and runoff are the external forces most responsible for nontidal water movement in the bight. The intrusion of high salinity ocean water into the bight is poorly understood, but it probably occurs through exchange of shelf and slope water along the outer edge of the shelf (Bumpus 1973). Much of the coastal water turns seaward near Cape Hatteras and becomes entrained in the Gulf Stream (Norcross and Harrison 1967).

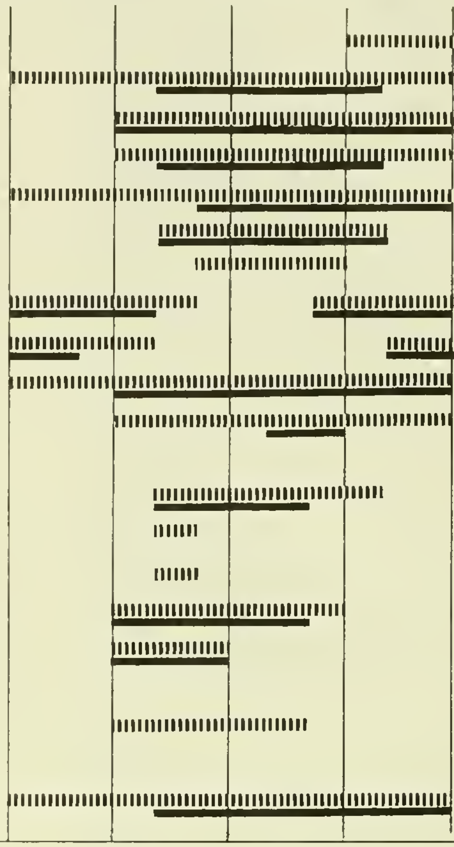
The Gulf Stream passes within 22 km of Cape Hatteras. As the stream meanders northward, it acts as a transport vehicle for larvae spawned throughout the warm-temperate and tropical waters of the western North Atlantic. Thus, it is difficult to predict the origin of larval fishes caught off the North Carolina capes. Many of the larvae we caught off North Carolina, and some caught as far north as New York, probably originated somewhere off our southeast coast and were subsequently transported northward by the stream.

The literature falls far short of providing the information needed to describe adequately how environmental factors influence spawning, and the subsequent distribution of eggs and larvae in the bight. Although our survey was not designed to permit such detailed analyses, some of the distributional patterns of larvae can be related to circulation trends; and the onset, extent, and duration of spawning often can be associated with rather narrow ranges of temperature. These associations are noted throughout the text.

Table 2.--The seasonal occurrence of flatfish larvae (IIIII) collected during 1965-66 plankton survey between Cape Cod and Cape Lookout. Solid line (▬) represents duration of spawning within the survey area, based on the occurrence of small larvae. Larvae were presumed to be present during months not sampled (*) if they were caught during preceding and subsequent months.

Family	Scientific and Common Name
Bothidae	
	Ancylopsetta quadrocellata ocellated flounder
	Bothus spp.
	Citharichthys arctifrons Gulf Stream flounder
	Cyclopsetta fimbriata spotfin flounder
	Etropus microstomus smallmouth flounder
	Hippoglossina oblonga fourspot flounder
	Monolene sessilicauda deepwater flounder
	Paralichthys dentatus summer flounder
	Paralichthys spp.
	Scophthalmus aquosus windowpane
	Syacium papillosum dusky flounder
Pleuronectidae	
	Glyptocephalus cynoglossus witch flounder
	Hippoglossus hippoglossus Atlantic halibut
	Hippoglossoides platessoides American plaice
	Limanda ferruginea yellowtail flounder
	Pseudopleuronectes americanus winter flounder
Soleidae	
	Gymnachirus melas naked sole
Cynoglossidae	
	Symphurus spp.

Months of Occurrence: J F M* A M J J* A S O N D



RESULTS AND DISCUSSION

Most of the pelagic fishes in the Middle Atlantic Bight are seasonal migrants, and many of those that spawn there do so during their spring immigration into the bight or fall emigration out. Because migrations through the bight are closely tied to water temperatures, spawning is usually localized and intense at its onset, but shifts seasonally and increases in areal extent as the migrations advance. In the spring when waters are warming, spawning generally proceeds northward and often begins south of the bight. In the fall when coastal waters are cooling, spawning proceeds southward and for some fishes begins north or east of the bight.

Although flatfishes move seasonally within the bight, they do not migrate long distances and most are considered residents of the bight. Despite the limited movements of adult flatfishes, their seasonal spawning patterns resemble those of migratory pelagic fishes such as Atlantic mackerel, *Scomber scombrus*, and Atlantic menhaden, *Brevoortia tyrannus*, by proceeding northward in the spring and southward in the fall. Thus, it seems that the onset of spawning by fishes that are migratory, as well as those that are not, is closely tied to temperature in the bight.

The survey area does not encompass the entire range for any of the species discussed here. We assume, however, that larvae represented spawning that occurred within the bight if they were collected in significant numbers on several cruises. Although the young of several flatfishes utilize estuaries as nursery grounds, those that survive will return to the offshore waters of the bight and eventually will be recruited into the spawning stock(s). From a biological standpoint, fishes so limited in their movements make excellent subjects for both study and management.

The occurrence of pelagic larval stages is usually more protracted than the actual spawning season, but we used the presence of larvae presumed to have been recently hatched to estimate the approximate duration of spawning. Our collections of larvae indicate that the pleuronectids have short spawning seasons characteristic of fishes found in water with seasonally variable temperatures, and the bothids have extended spawning seasons characteristic of warm-water fishes that are adapted to less severe seasonal changes (Table 2). Some of the bothids represented in our collections apparently spawned throughout the year, but,

Table 3.--The seasonal distribution of ocellated flounder, Ancylopsetta quadrocellata, larvae by size. Numbers are adjusted to standardize sampling effort.

Larval length (mm)	66-12 Sept.-Oct.	66-14 Nov.-Dec.	65-4 Dec.	Total
	Number of larvae			
2.1-3.0	1		1	2
3.1-4.0	2	3	4	9
4.1-5.0	3	5	4	12
5.1-6.0	4	3	2	9
6.1-7.0	2	1		3
7.1-8.0		2		2
8.1-9.0		2		2
Total	12	16	11	39

with the possible exception of the Gulf Stream flounder, *Citharichthys arctifrons*, not in the bight. All of the soleid larvae and most of the cynoglossid larvae in our collections originated south of the survey area.

I. Family Bothidae—Lefteye Flounders

Ancylopsetta quadrocellata Gill, ocellated flounder.—Ocellated flounder range from North Carolina to Florida and into the Gulf of Mexico (Gutherz 1967). The larvae have not been described. We based larval identifications on a combination of marginal fin ray and vertebral counts taken from late-stage larvae collected on this survey and one that followed in 1967-68 between North Carolina and Florida. Characteristic pigment patterns allowed us to identify specimens that lacked the adult numbers of meristic elements.

Because we sampled only the extreme northern end of the ocellated flounder's range, larvae seldom appeared in our collections. During the three cruises between October and December, we caught 39 larvae (Table 3), all at stations south of Cape Hatteras. Most were caught off Cape Lookout and may represent spawning that occurred south of the survey area (Fig. 2).

Bothus spp.—Our collections contain at least two species of *Bothus* larvae. Based on fin ray and vertebral counts from x-ray photographs of 21 specimens >12 mm, we identified six *B. ocellatus* (Agassiz). The remaining 15 could not be identified positively. Insufficient ossification prevented identification of specimens <12 mm beyond the generic level, so all the larvae are treated as *Bothus* spp. Kyle (1913) described development of advanced larval stages of the genus *Bothus*, but larvae of the different species have not been described.

Jutare (1962) concluded, from gonadal studies, that *B. ocellatus* spawned almost year-round. Her larval collections indicated a major spawning peak in July and a minor peak in December. Larvae occurred year-round in our samples, mostly in that part of the survey area in or near the Gulf Stream off North Carolina. We noted peaks in their abundance in May and November, but, because of the unknown distributional influences of the stream, we do not know whether such peaks represent the time of actual spawning peaks.

We judge that larvae collected in February represented the "beginning" of spawning because of their small numbers and limited size range (Table 4). We caught one larva near the outer edge of the shelf between Cape Hatteras and Chesapeake Bay, the rest between the North Carolina capes. The catch in April increased slightly, both in numbers and size range, but the distribution of larvae remained limited to the outer half of the shelf between capes Lookout and Hatteras, as it was in January.

The distribution of larvae in May was unchanged from that in April, but the catch increased sharply, owing largely to a concentration of larvae between the capes (Fig. 3). If the larvae caught thus far were transported into the survey area by the Gulf Stream, the increased number of small larvae caught in May suggests that spawning had moved northward since the previous cruise in April (Table 4). There was little change in either the distribution of larvae or the center of larval abundance from May to June (Fig. 4).

The catch dropped sharply by August (Table 4). The areal extent of larval distribution remained much the same as before, except that the young fish were closer to shore than on previous cruises. An 11-mm larva caught at the most seaward station off southern New England represented the northernmost occurrence of the survey (Fig. 5).

The catch increased in October, perhaps reflecting peak spawning by one of the species represented in our collections (Table 4). The pattern of distribution changed somewhat from that of earlier cruises by extending northward along the outer banks to Virginia. The center of abundance, however, remained along the edge of the shelf between capes Hatteras and Lookout (Fig. 6).

We caught more larvae in November than in any other month (Table 4). The distribution of larvae was similar to results of cruises before September, when the young fish were confined to that part of the survey area south of Cape Hatteras. The major concentration occurred near the edge of the shelf (Fig 7).

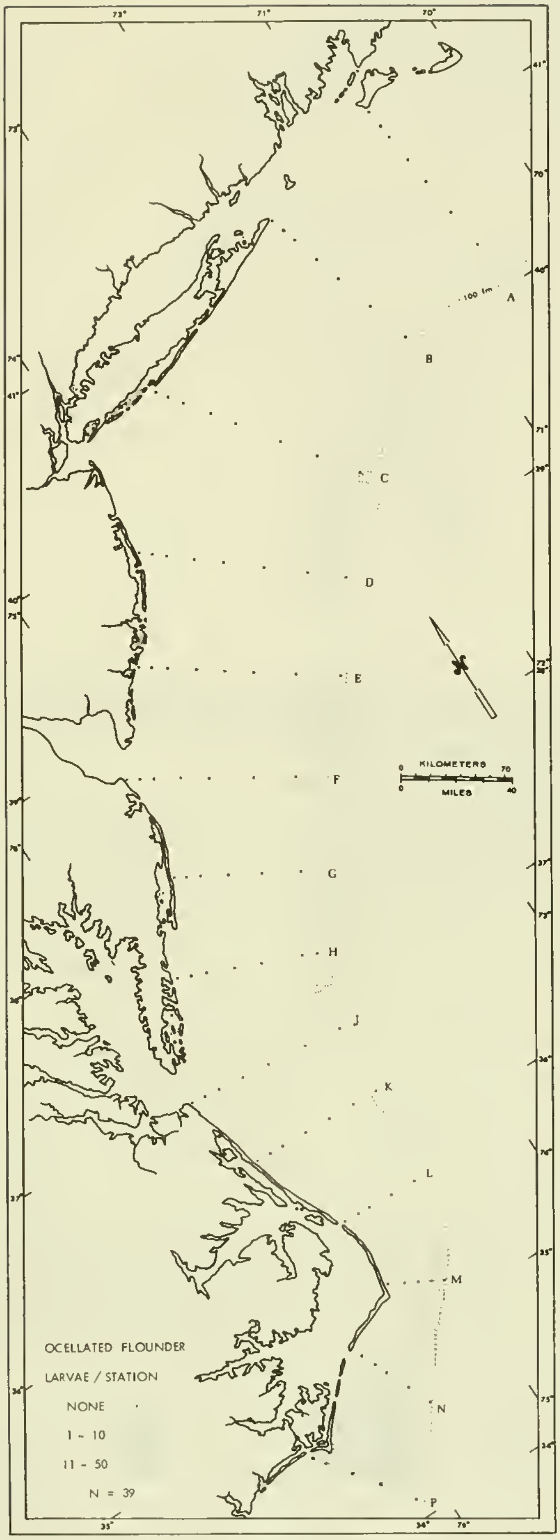


Figure 2.—Distribution and relative abundance of ocellated flounder, *Ancylopsetta quadrocellata*, larvae collected during 1965-66 survey.

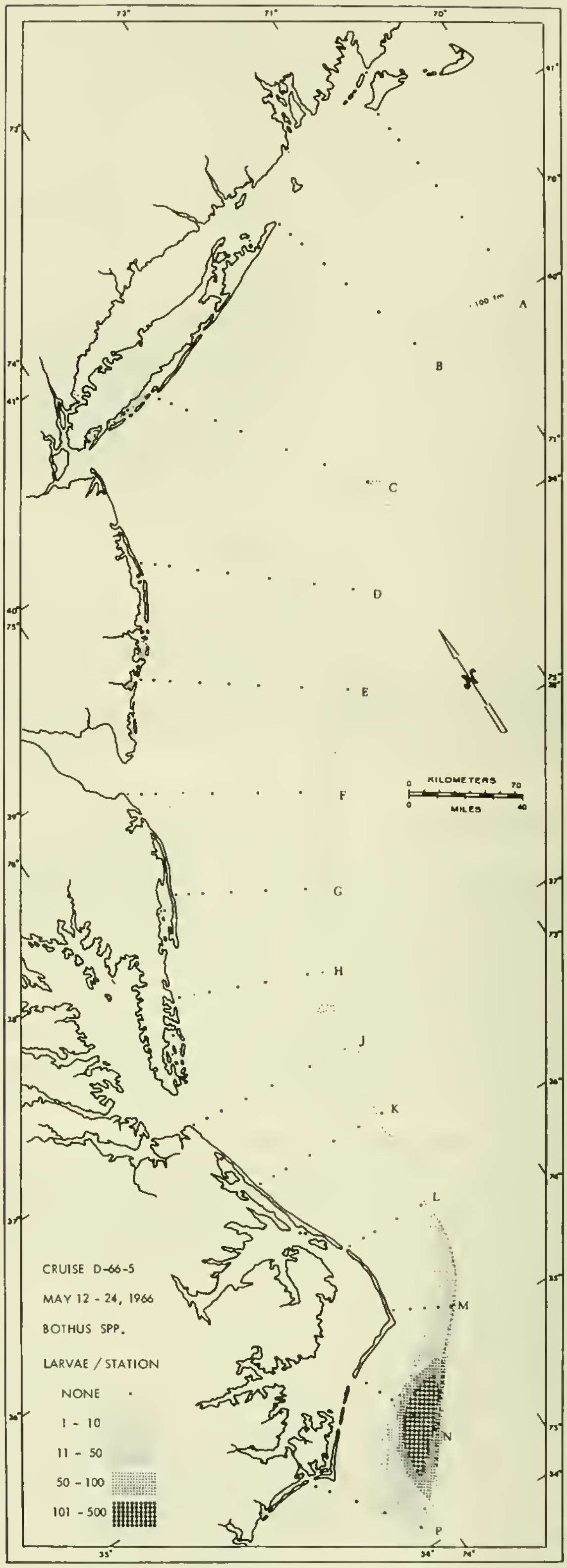


Figure 3.—May 1966. Distribution and relative abundance of *Bothus* spp. larvae.

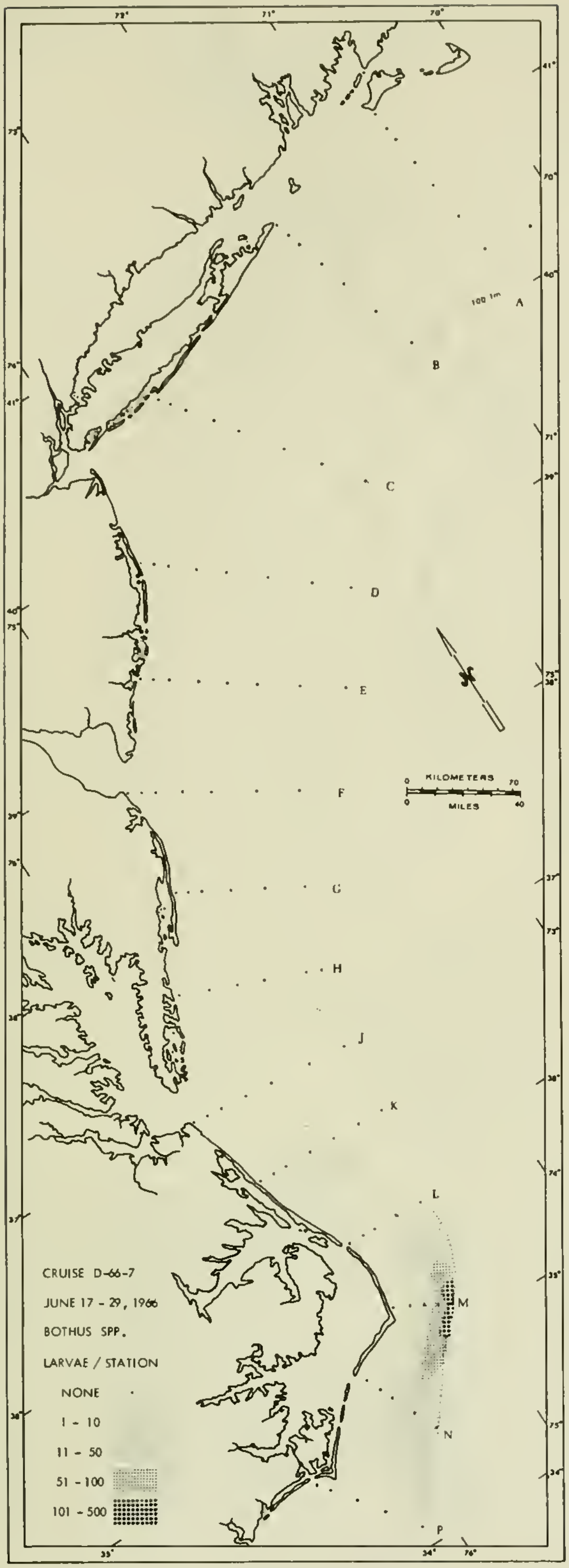


Figure 4.—June 1966. Distribution and relative abundance of *Bothus* spp. larvae.

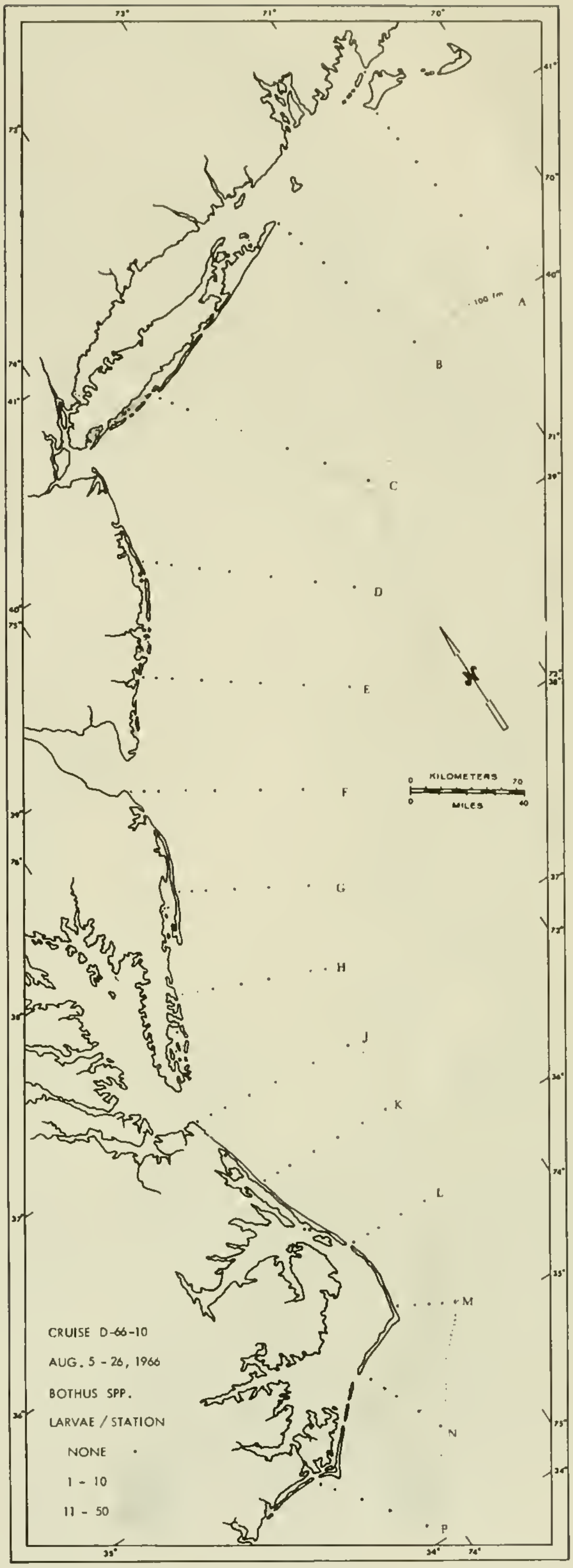


Figure 5.—August 1966. Distribution and relative abundance of *Bothus* spp. larvae.

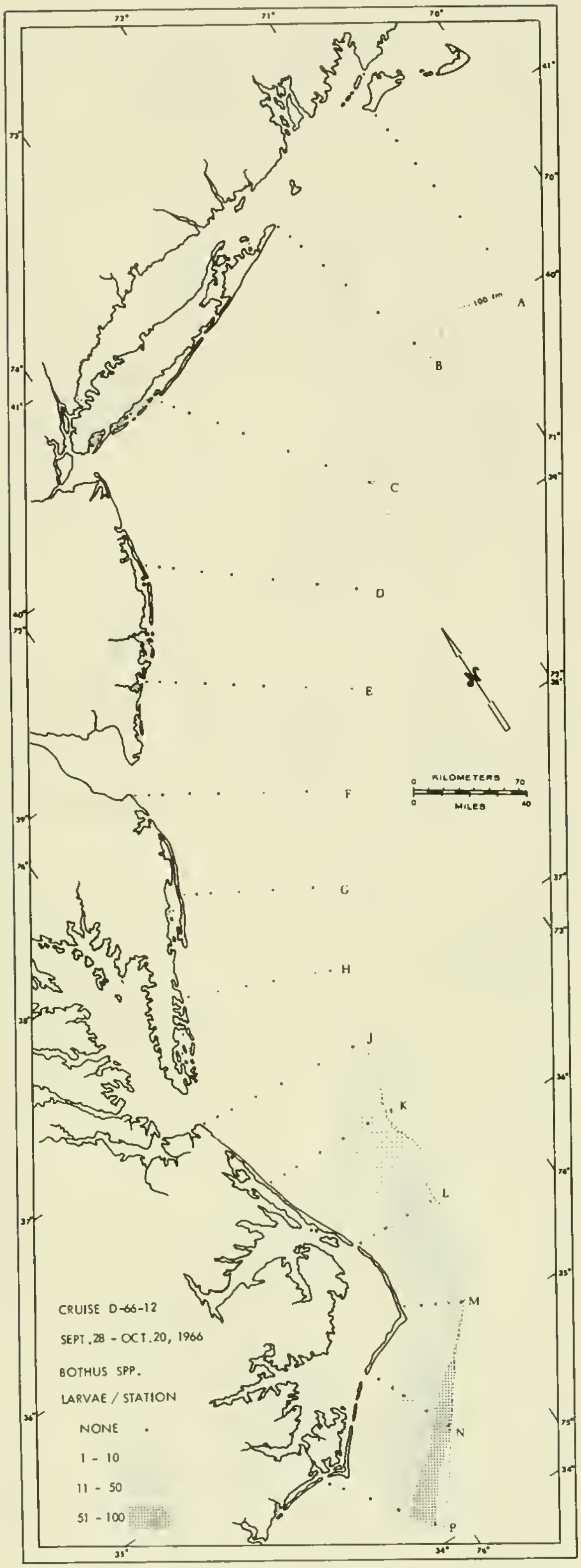


Figure 6.—September to October 1966. Distribution and relative abundance of *Bothus* spp. larvae.

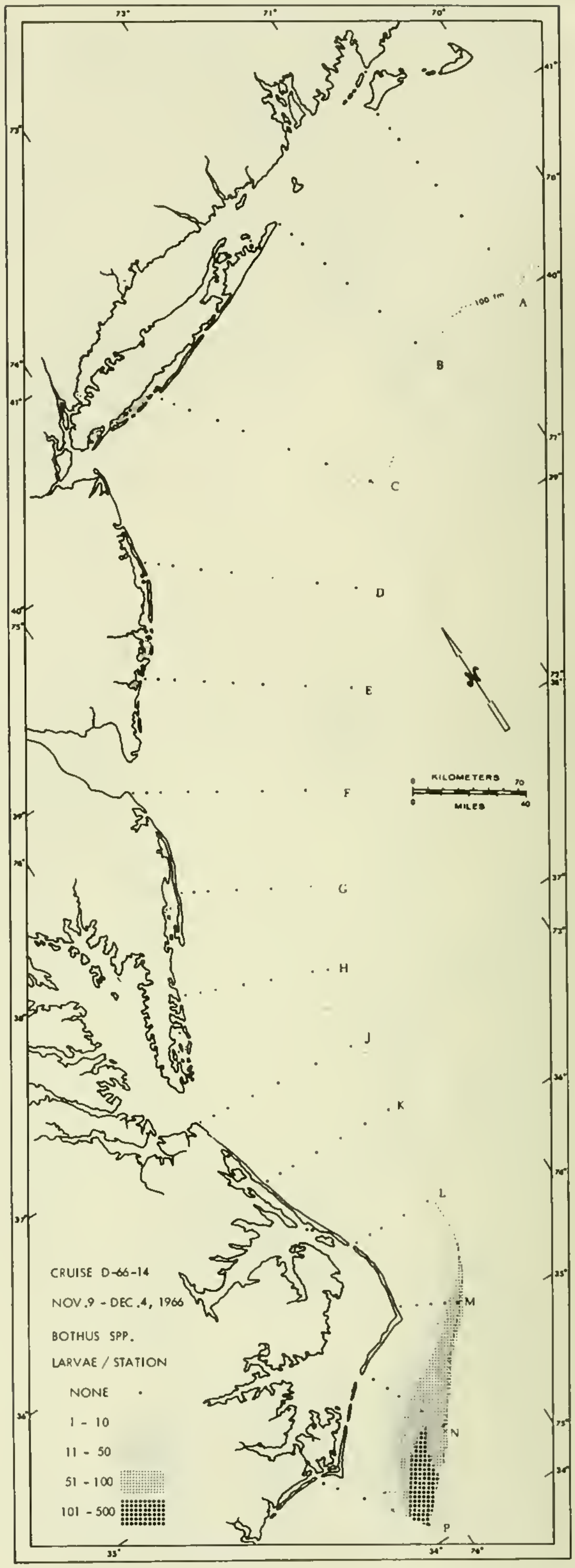


Figure 7.—November to December 1966. Distribution and relative abundance of *Bothus* spp. larvae.

Table 4.--The seasonal distribution of Bothus spp. larvae by size. Numbers are adjusted to standardize sampling effort.

Larval length (mm)	Cruise and date									
	66-1 Jan.-Feb.	66-3 Apr.	66-5 May	66-7 June	66-10 Aug.	66-11 Sept.	66-12 Sept.-Oct.	66-14 Nov.-Dec.	65-4 Dec.	Total
	Number of larvae									
2.1- 3.0		3	31	9	4		16	12	10	85
3.1- 4.0	1	12	78	40	9		34	55	28	257
4.1- 5.0	2	5	122	81	17		58	119	30	434
5.1- 6.0	1	3	66	48	8		57	65	27	275
6.1- 7.0	1	4	29	33	1		34	39	6	147
7.1- 8.0	4	2	9	27	3		23	18	5	91
8.1- 9.0	1	1	4	7	3		16	9	2	43
9.1-10.0			2	6	4		6	19	4	41
10.1-11.0		1	2	4	1		2	9		19
11.1-12.0		2	1	1	2		4		2	12
12.1-13.0					1		3	3		7
13.1-14.0			1	2				1	1	5
14.1-15.0			1				4			5
15.1-16.0		1				1				2
16.1-17.0					1					1
17.1-18.0				1	1				2	4
18.1-19.0									1	1
19.1-20.0		1							1	2
20.1-21.0										
21.1-22.0								1		1
Total	10	35	346	259	55	1	257	350	119	1,432

The catch declined in December. The distribution of larvae was restricted to the southern end of the survey area, except for five larvae (7.9 to 10.6 mm) that we caught near the edge of the shelf off New Jersey (Fig. 8).

Throughout the survey, the center of larval abundance occurred along the outer edge of the shelf between capes Hatteras and Lookout (Fig. 9). This consistency in the distribution of *Bothus* larvae led us to believe that most were transported into the survey area by the Gulf Stream. Because the duration of the pelagic larval life varies according to external conditions (Kyle 1913), we cannot speculate as to where or when the larvae originated. Colton (1961) attributed the occurrence of *B. ocellatus* larvae on Georges Bank to an influx of Gulf Stream water. This is a logical explanation for the occurrence of larvae in the northern part of our survey area.

Citharichthys arctifrons Goode, Gulf Stream flounder.—Gulf Stream flounder are common in the bight, where they prefer deeper water and range farther north than smallmouth flounder, *Etropus microstomus*, which they closely resemble. They occur most frequently in depths >40 m, whereas smallmouth flounder generally inhabit depths <40 m (Gutherz 1967; Richardson and Joseph 1973). The reported range of Gulf Stream flounder extends from Georges Bank to Charleston, S.C. (Bigelow and Schroeder 1953), and southward along both coasts of Florida, and Yucatan, Mexico (Gutherz 1967). The larvae were described by Richardson and Joseph (1973).

The occurrence of larvae in collections from all but the late January-early February cruise suggested that Gulf Stream flounder have a prolonged spawning season in the bight. Although they might spawn year-round, our collections indicate that spawning began in late spring, peaked during the summer, and declined sharply by fall.

In June, we caught 13 larvae at three stations: two off Virginia and one off North Carolina. All were caught nearshore over depths shallower than those where adults usually occur. With two exceptions, the larvae were <3.1 mm and presumed to represent the onset of the 1966 spawning season in the bight (Table 5).

Spawning evidently reached its peak in July, since we caught the greatest number of larvae in August when their distribution was continuous from southern New England to

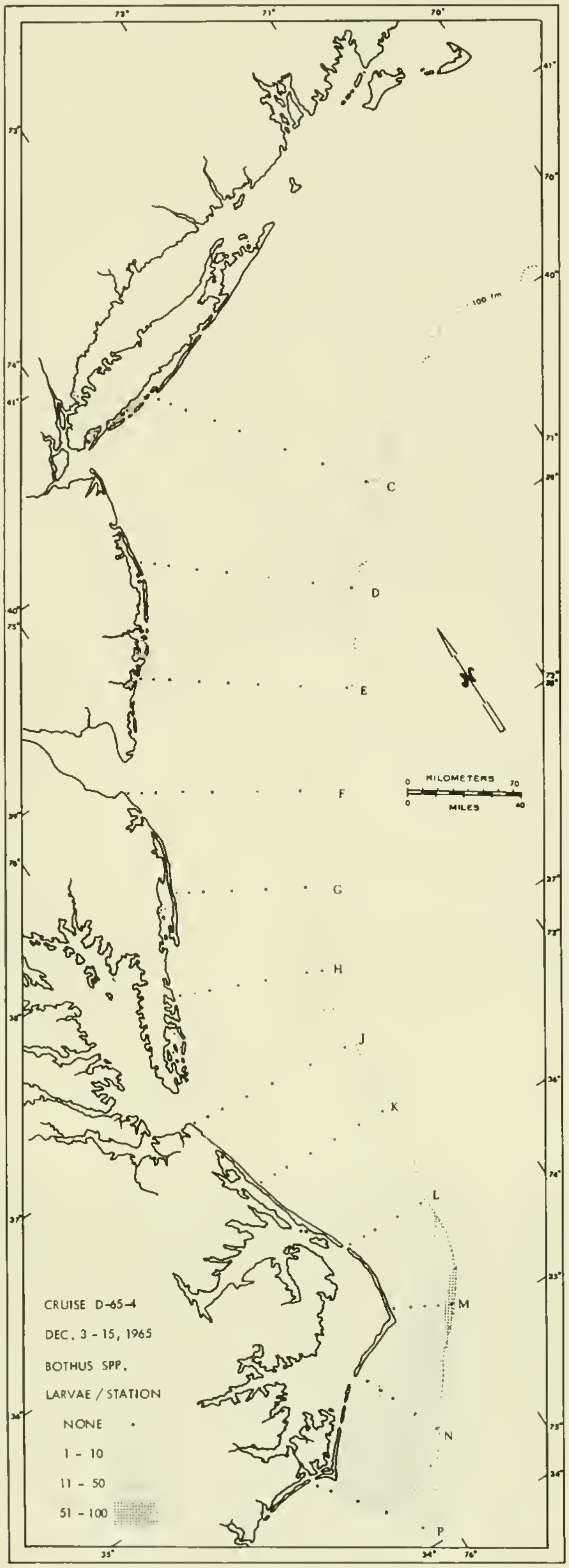


Figure 8.—December 1965. Distribution and relative abundance of *Bothus* spp. larvae.

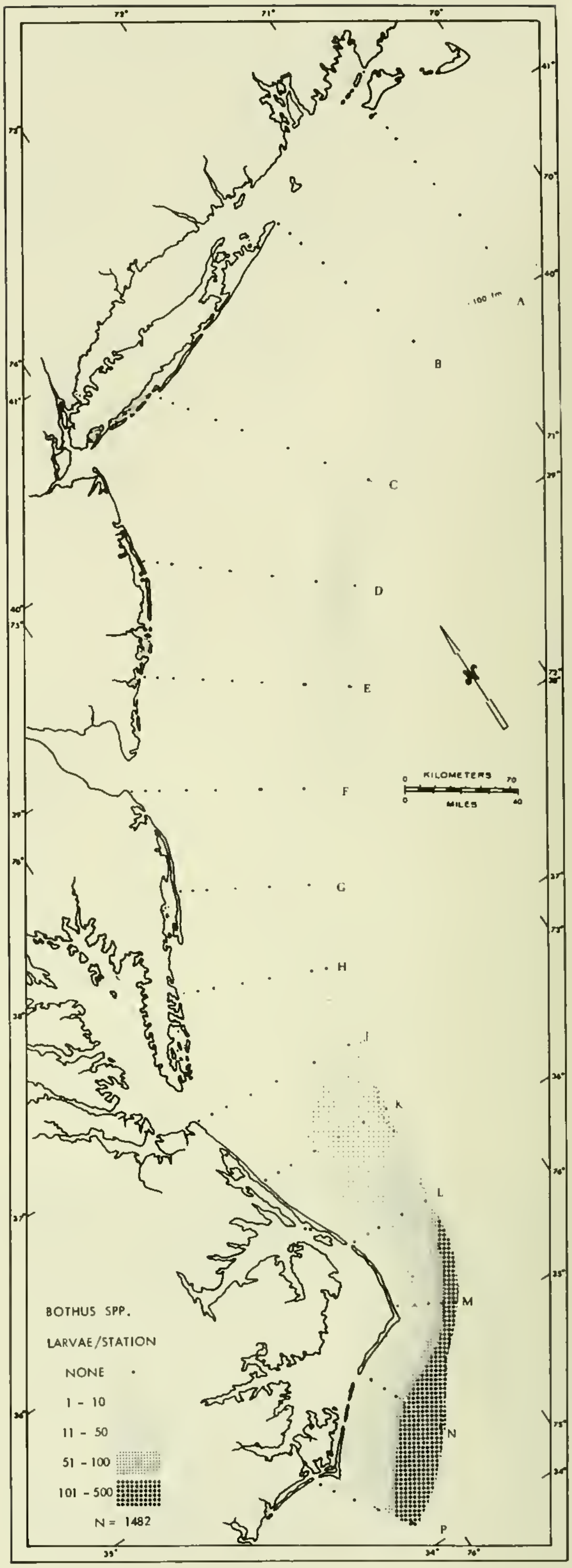


Figure 9.—Distribution and relative abundance of *Bothus* spp. larvae collected during 1965-66 survey.

Table 5.--The seasonal distribution of Gulf Stream flounder, *Citharichthys arctifrons*, larvae by size. Numbers are adjusted to standardize sampling effort. Larvae < 4.1 mm represented recent spawning.

Larval length (mm)	66-7 June	66-10 Aug.	66-11 Sept.	66-12 Sept.-Oct.	66-14 Nov.-Dec.	65-4 Dec.	66-3 Apr.	66-5 May	Total
	Cruise and date								
	Number of larvae								
1.1- 2.0	2	19							21
2.1- 3.0	9	169	13	13			1		205
3.1- 4.0		481	324	236	3	1	4	1	1,050
4.1- 5.0		629	693	518	10		6		1,856
5.1- 6.0		1,034	630	527	22	3	4		2,220
6.1- 7.0		946	487	1,018	71	7	3		2,532
7.1- 8.0		375	216	452	41	7	4		1,095
8.1- 9.0	1	234	144	260	31	9	1	2	682
9.1-10.0	1	77	112	275	24	3			492
10.1-11.0		44	74	116	12	2		1	249
11.1-12.0		63	28	68	13	2	3		177
12.1-13.0		36	36	37	7		1		117
13.1-14.0		25	30	39	3		1		98
14.1-15.0		19	38	30	6				93
15.1-16.0		2	1	13	2				18
16.1-17.0				1	2				3
17.1-18.0				2					2
Total	13	4,153	2,826	3,605	247	34	28	4	10,910

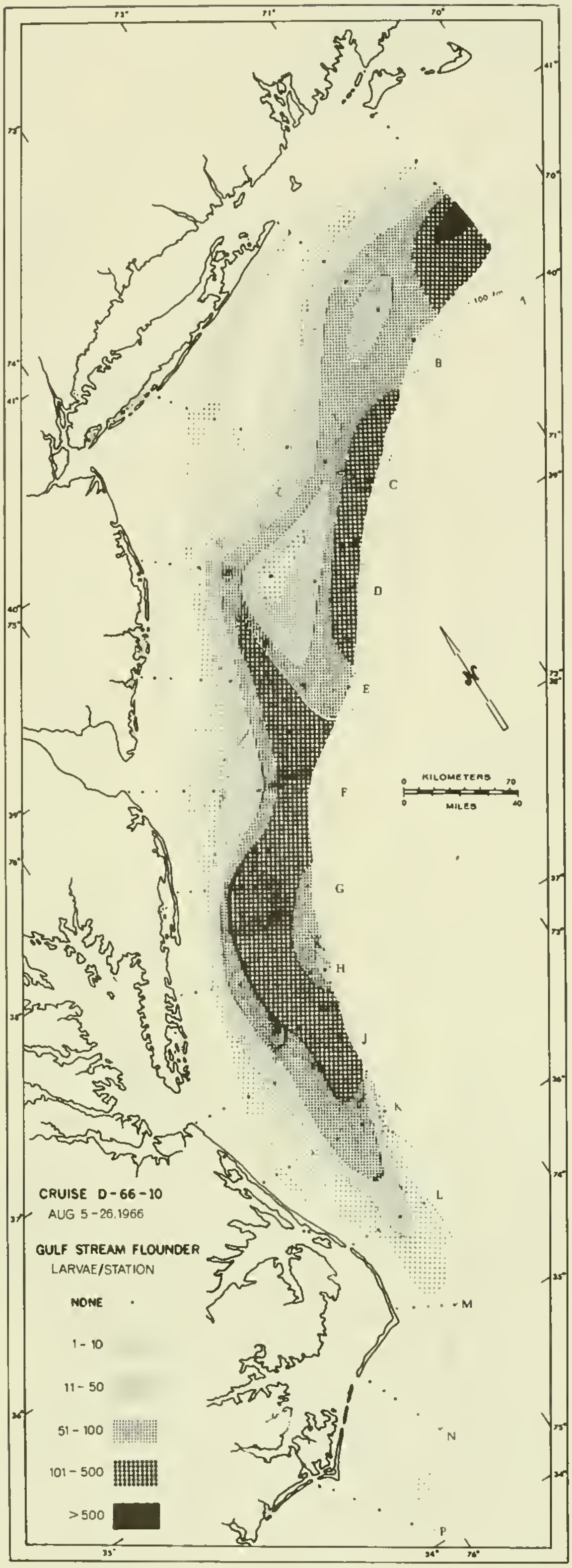
Cape Hatteras. Although we caught larvae over depths as shoal as 20 m, the center of abundance extended along the outer half of the shelf between southern New England and Chesapeake Bay over depths of 30 to 175 m. Based on the distribution of larvae <4 mm, the most recent spawning was centered off New Jersey, but the distribution of larvae 4 to 8 mm indicated that heavy spawning had taken place as far north and east as Cape Cod in July (Fig. 10). Although the distribution of larvae overlapped the boundaries of the cold bottom water off Long Island and New Jersey, the major concentrations of recently spawned larvae, those <4 mm, were generally outside the periphery of the coldest water. Nonetheless, if concentrations of small larvae are indicative of nearby spawning, the Gulf Stream flounder spawns in colder water than any other member of the family that spawns in the bight. Despite this flounder's tolerance of cold water, our data indicate that spawning began in the southern part of the bight and progressed northward, a trend that we associate with spring warming.

During the abbreviated September cruise, larvae were caught throughout the area sampled. They were abundant over a wide part of the shelf, but the major concentration occurred south of Long Island over bottom temperatures between 6° and 8°C (Fig. 11). Larvae were more abundant in the part of the survey area which we sampled in September than in August, but, based on the relative numbers of small larvae taken along the same transects on the two cruises, we concluded that spawning had peaked in July or, at the latest, early August (Table 5).

We caught larvae in October from southern New England to Oregon Inlet, N.C. The center of abundance extended along the seaward half of the shelf between Long Island and Chesapeake Bay over depths of 35 to 120 m and bottom temperatures between 7° and 11°C (Fig. 12). Although a small patch of larvae <4 mm was situated east of Delaware Bay, the overall distribution by size indicated that the height of the spawning season had passed (Table 5).

The catch dropped off sharply in November, and no concentrations were evident. The near absence of larvae <4 mm substantiated the sharp decline in spawning noted in October (Table 5). The distribution of larvae receded to Long Island at the northern end of the survey area and in outline closely resembled that of the area of major abundance found on the previous cruise (Fig. 13). This suggests that circulation had little effect on the transport of larvae. The catch declined further in December (Fig. 14). None occurred in late January or early February.

Although larvae were absent from our January collections, we caught intermediate-sized specimens off Long Island and southern New England, and both large and small specimens off North Carolina, in April and May (Table 5). Despite the absence of larvae from our winter collections,



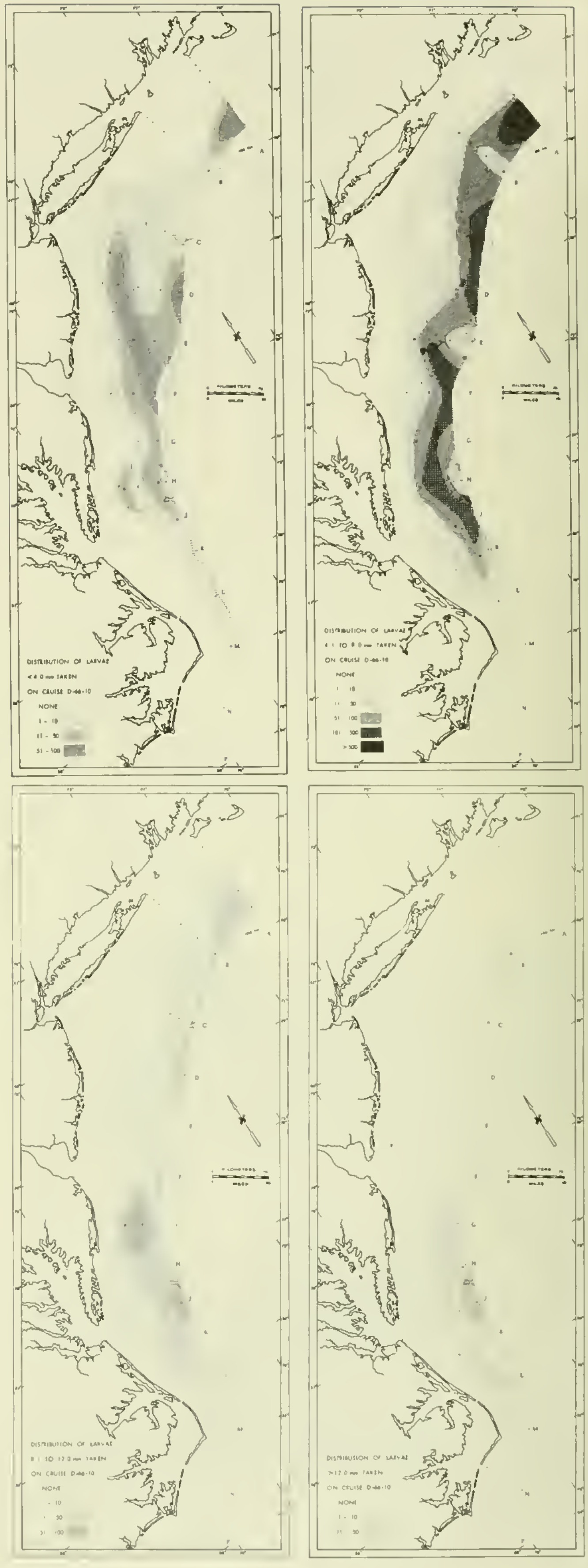
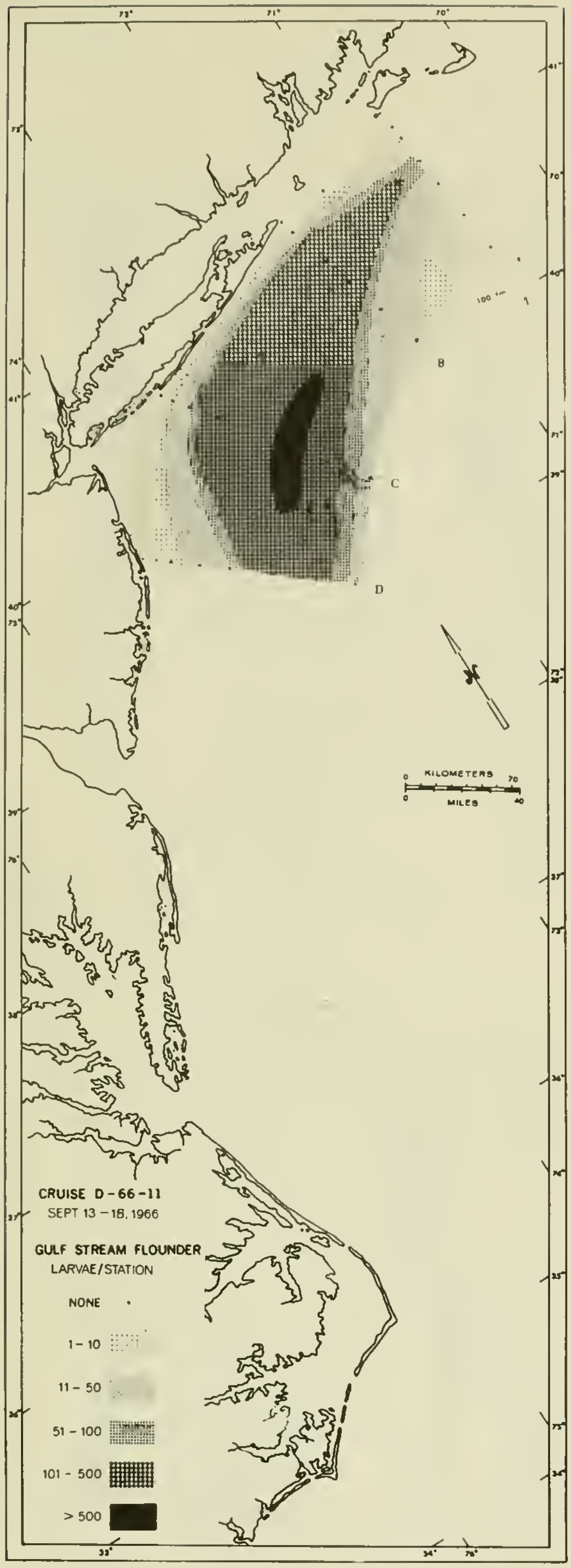


Figure 10.—August 1966. Distribution and relative abundance of Gulf Stream flounder, *Citharichthys arctifrons*, larvae (left) and (right) their distribution and relative abundance by size groups. Top ≤4.0 mm, 4.1 to 8.0 mm; bottom 8.1 to 12.0 mm, > 12.0 mm.



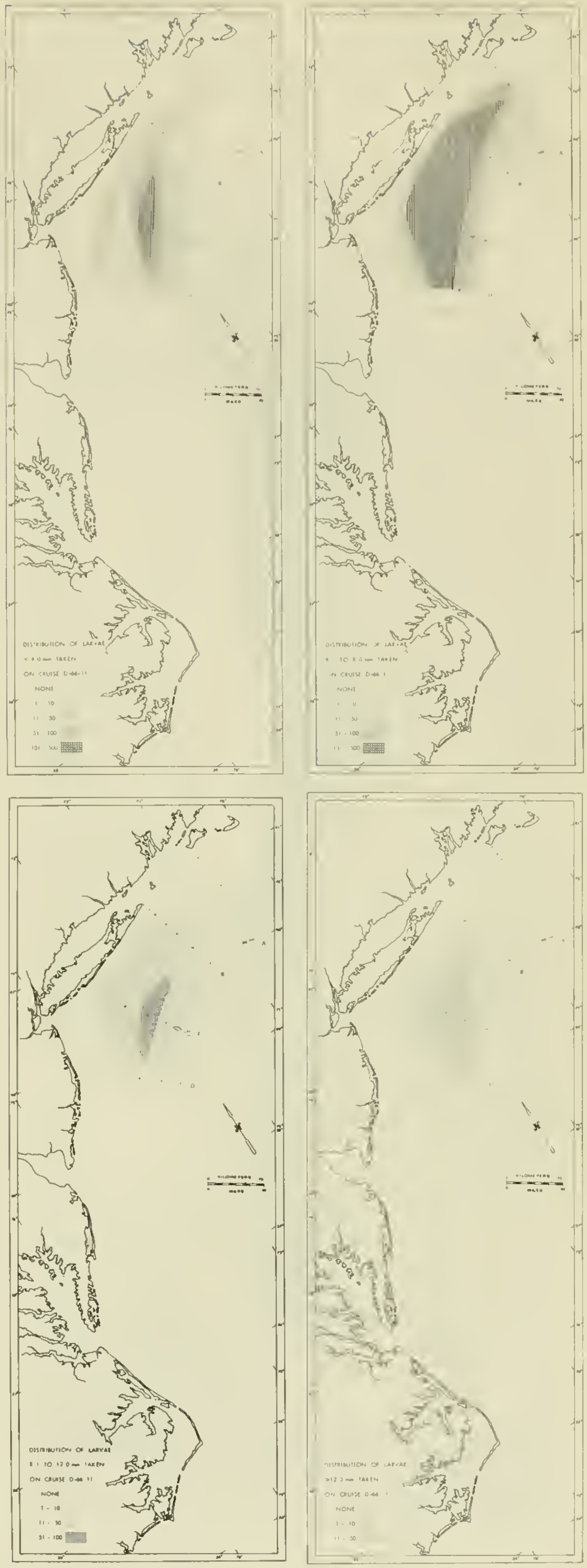
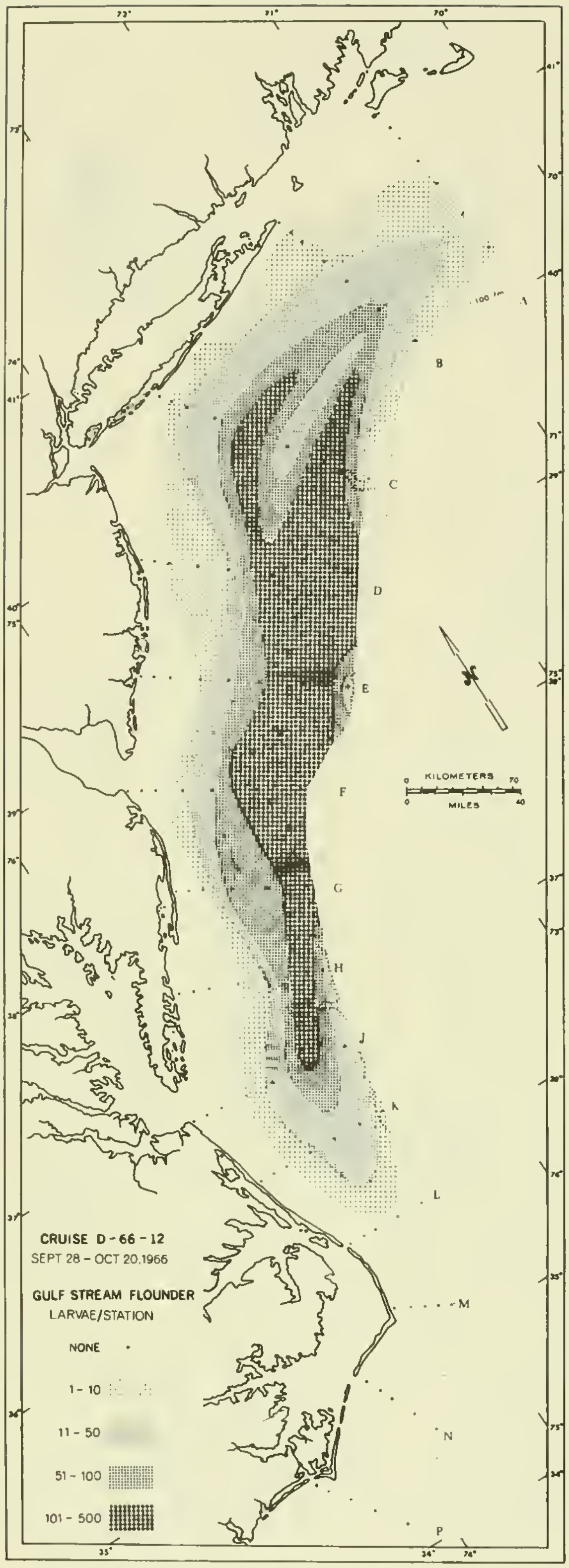


Figure 11.—September 1966. Distribution and relative abundance of Gulf Stream flounder, *Citharichthys arctifrons*, larvae (left) and (right) their distribution and relative abundance by size groups. Top ≤4.0 mm, 4.1 to 8.0 mm; bottom 8.1 to 12.0 mm, >12.0 mm.



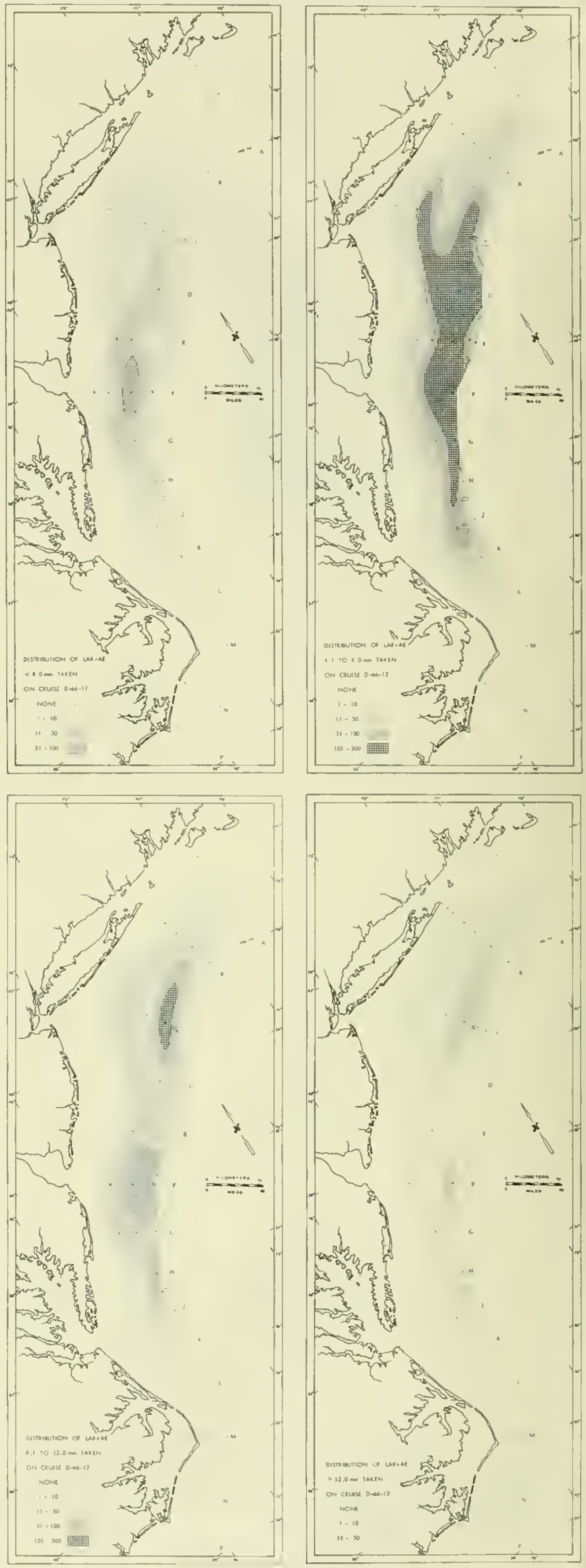


Figure 12.—September to October 1966. Distribution and relative abundance of Gulf Stream flounder, *Citharichthys arctifrons*, larvae (left) and (right) their distribution and relative abundance by size groups. Top ≤4.0 mm, 4.1 to 8.0 mm; bottom 8.1 to 12.0 mm, >12.0 mm.

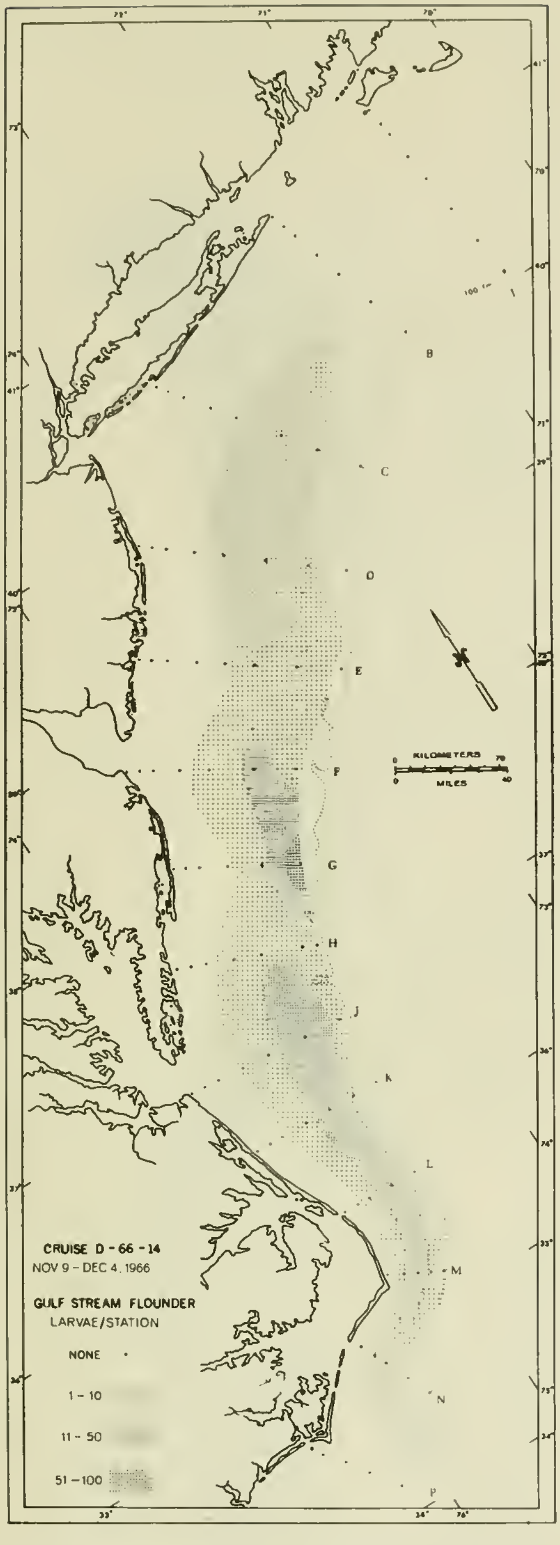


Figure 13.—November to December 1966. Distribution and relative abundance of Gulf Stream flounder, *Citharichthys arctifrons*, larvae.

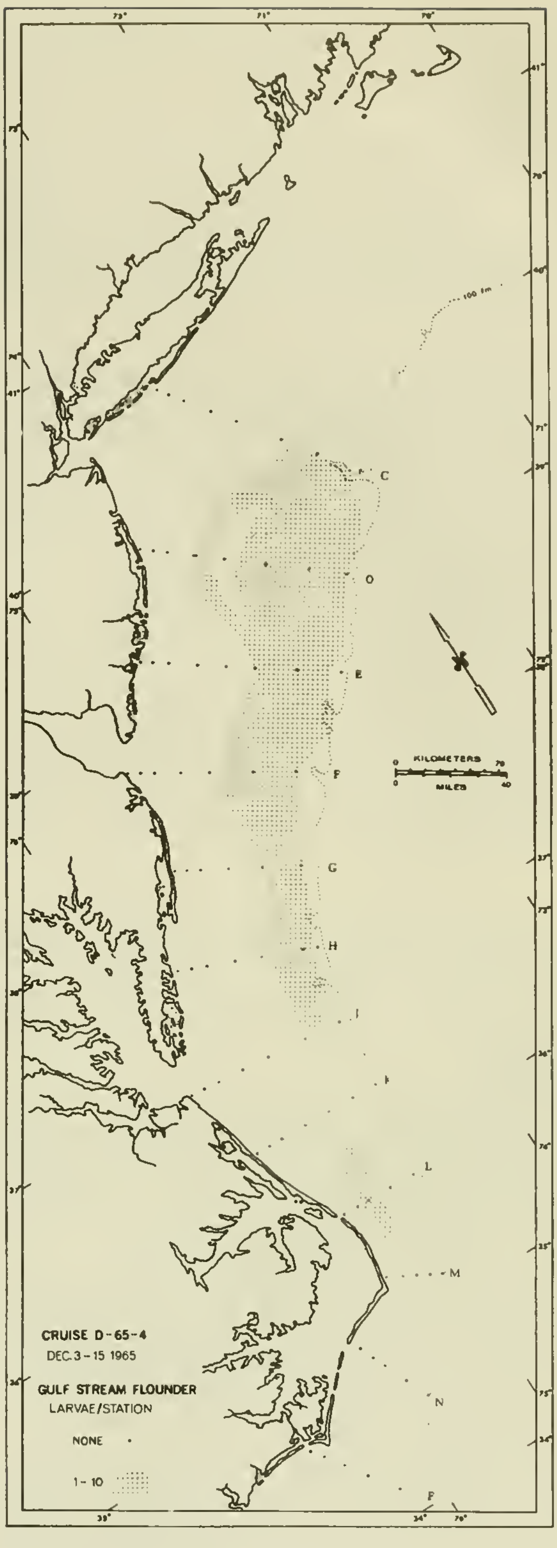


Figure 14.—December 1965. Distribution and relative abundance of Gulf Stream flounder, *Citharichthys arctifrons*, larvae.

their occurrence and extensive size range during early spring cruises suggest that spawning may occur sporadically throughout the year. Richardson and Joseph (1973) reached the same conclusion after examining ovaries of adult Gulf Stream flounder.

We caught larvae throughout the survey area during the spawning season, largely along the outer half of the shelf, i.e., at depths where the adults seem to be most abundant (Fig. 15). Although the distributional patterns of summer and fall catches showed no apparent influence of coastal circulation, the lack of larvae >12 mm off southern New England suggests transport from there southward.

Cyclopsetta fimbriata (Goode and Bean), spotfin flounder. —This warm-water bothid ranges from North Carolina to the Gulf of Mexico and along the Caribbean coasts of Central and South America. Spawning takes place off the west coast of Florida in late spring (Topp and Hoff 1972), but Gutherz (1971), who described the larvae, reported a longer spawning season off our southeast Atlantic coast. His data indicate that spawning begins in April, peaks in June and again in September, and continues to October.

The southern end of our survey area and the northern end of the spotfin flounder's range overlapped between capes Lookout and Hatteras. Although the number of larvae in our collections is small (Table 6), the seasonality of their occurrence agrees closely with that of Gutherz (1971). We caught larvae from April to December, mostly at stations on the seaward half of the shelf where depths exceeded 25 m (Fig. 16). Most of these larvae probably originated south of the survey area and were subsequently transported north by the Gulf Stream.

Etropus microstomus (Gill), smallmouth flounder.— Smallmouth flounder range from New England to Florida (Parr 1931) and into the Gulf of Mexico (Gutherz 1967). Gutherz reported their northern limit as North Carolina, but these small bothid flounders are common in the Middle Atlantic Bight. The larvae are described by Richardson and Joseph (1973).

Spawning might occur throughout the year south of the survey area, because we caught larvae the year-round in the southern part of the survey area. In the bight, however, spawning probably did not begin until June, after which it peaked during summer and early fall. Richardson and Joseph (1973) reported similar results from a series of monthly collections made off Chesapeake Bay.

We considered larvae collected in April between capes Lookout and Hatteras to represent the onset of the 1966 spawning season. Judging from their size and numbers, we assumed they originated somewhere south of Cape Lookout and were transported into the survey area (Table 7). The distribution, sizes, and numbers of larvae collected in May resembled those of April.

The distribution of larvae in June extended northward to Maryland. Although a center of abundance was not evident, most larvae, and most recently hatched larvae, occurred over depths of 15 to 35 m between the eastern shore of Virginia and Cape Hatteras over bottom temperatures of 13° to 17°C. Most of the larvae collected in June were <4 mm and presumably represented recent spawning (Table 7). The northward progression of spring spawning was apparent within the June collections, when larvae <4 mm occurred farther north than those >4 mm. The seaward movement of water off North Carolina would account for the

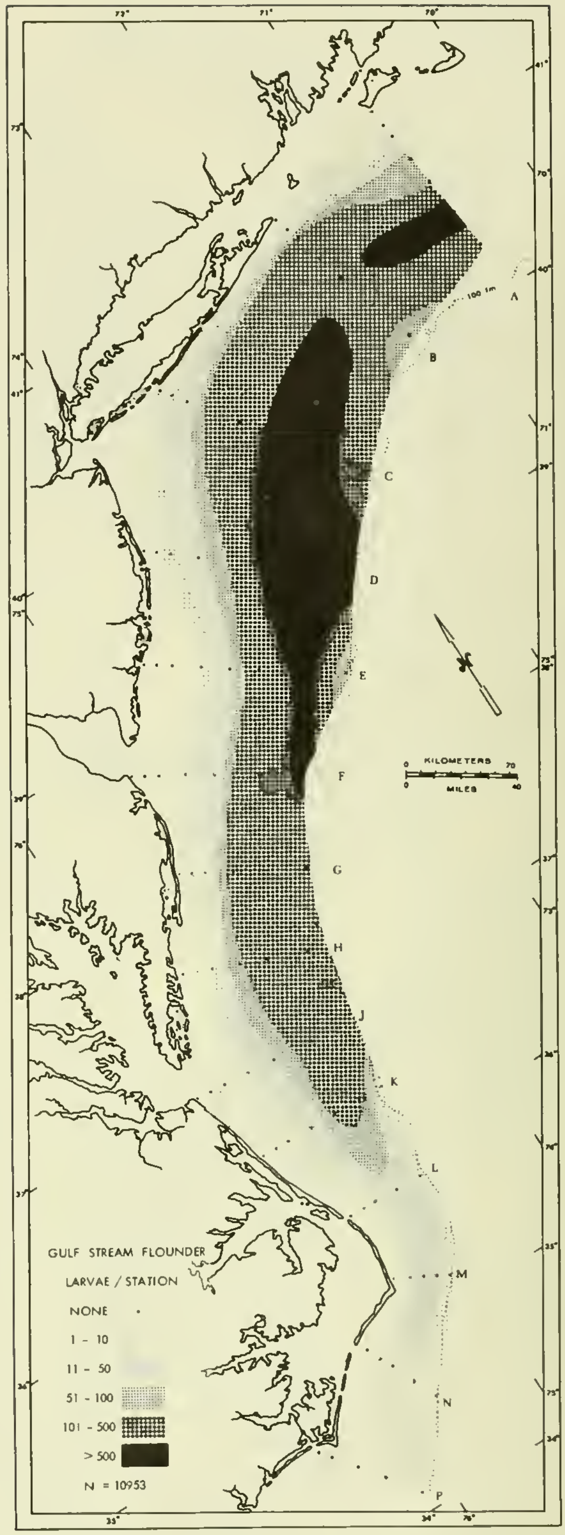


Figure 15.—Distribution and relative abundance of Gulf Stream flounder, *Citharichthys arctifrons*, larvae collected during 1965-66 survey.

Table 6.--The seasonal distribution of spotfin flounder, Cyclopsetta fimbriata, larvae by size. Numbers are adjusted to standardize sampling effort.

Larval length (mm)	66-3 Apr.	66-5 May	66-7 June	66-10 Aug.	66-12 Sept.-Oct.	66-14 Nov.-Dec.	65-4 Dec.	Total
	Number of larvae							
2.1- 3.0			1					1
3.1- 4.0		3	2		3			8
4.1- 5.0	1	3	2		6	1		13
5.1- 6.0		1		2	4	1		8
6.1- 7.0		4	1	1	2	1	1	10
7.1- 8.0			1	2	2			5
8.1- 9.0					1	1		2
9.1-10.0					1			1
10.1-11.0			1					1
Total	1	11	8	5	19	4	1	49

Table 7.--The seasonal distribution of smallmouth flounder, Etropus microstomus, larvae by size. Numbers are adjusted to standardize sampling effort. Larvae <4.1 mm represented recent spawning.

Larval length (mm)	66-3 Apr.	66-5 May	66-7 June	66-10 Aug.	66-11 Sept.	66-12 Sept.-Oct.	66-14 Nov.-Dec.	65-4 Dec.	66-1 Jan.-Feb.	Total
	Number of larvae									
1.1- 2.0			5			1				6
2.1- 3.0		4	47	80		30	26	50		237
3.1- 4.0	3	4	52	362		112	107	153	19	812
4.1- 5.0	1	2	19	415	2	128	81	131	23	802
5.1- 6.0	3	2	7	237	5	82	75	42	15	468
6.1- 7.0	1	2	2	184	1	60	30	26	3	309
7.1- 8.0	1	1		62	2	40	28	18	4	156
8.1- 9.0	1	3		120		36	38	19	1	218
9.1-10.0				74	2	10	18	22	2	128
10.1-11.0	1			38		4	10	2		55
11.1-12.0	1			22	1	17	9	1		51
12.1-13.0				3						3
13.1-14.0										
14.1-15.0										
Total	12	18	132	1,597	13	520	422	464	67	3,245

occurrence of larvae at the more offshore stations near Cape Hatteras, as water depths there exceeded the normal depth range of adult smallmouth flounder (Fig. 17).

Inasmuch as we made our largest catches of larvae late in August, it seems likely that spawning peaked sometime between early July and the middle of August. Larval

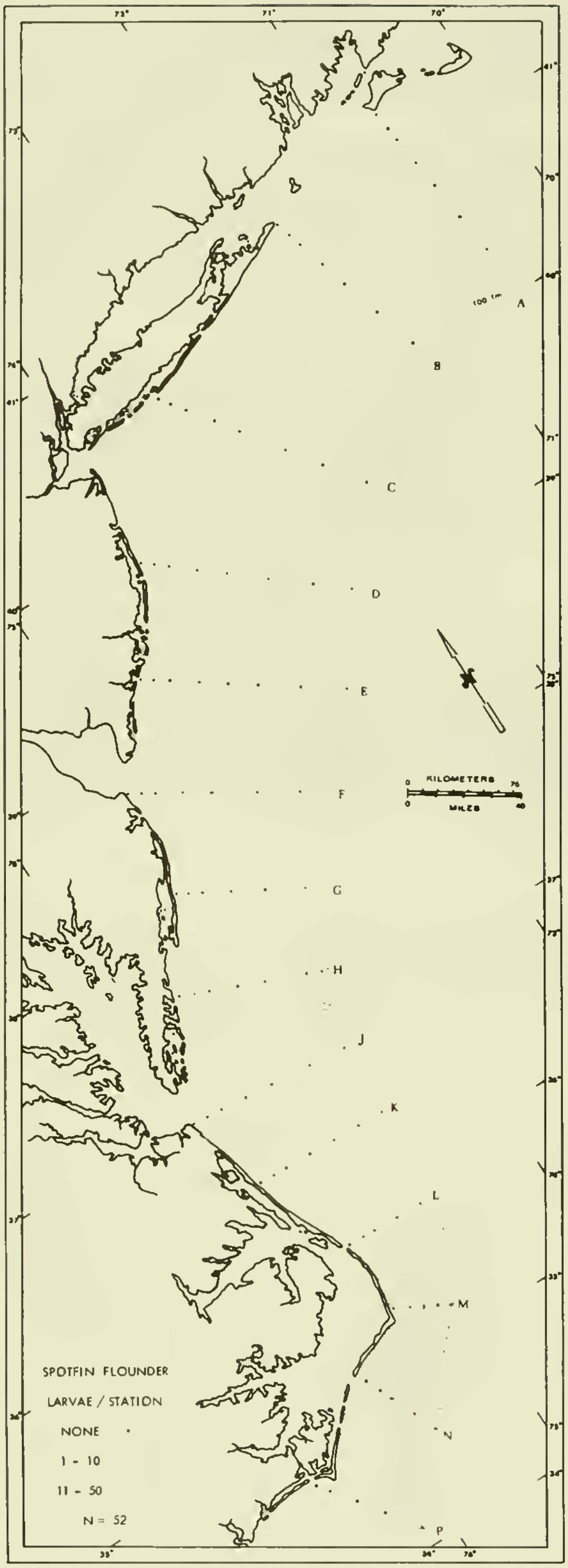


Figure 16.—Distribution and relative abundance of spotfin flounder, *Cyclopsetta fimbriata*, larvae collected during 1965-66 survey.

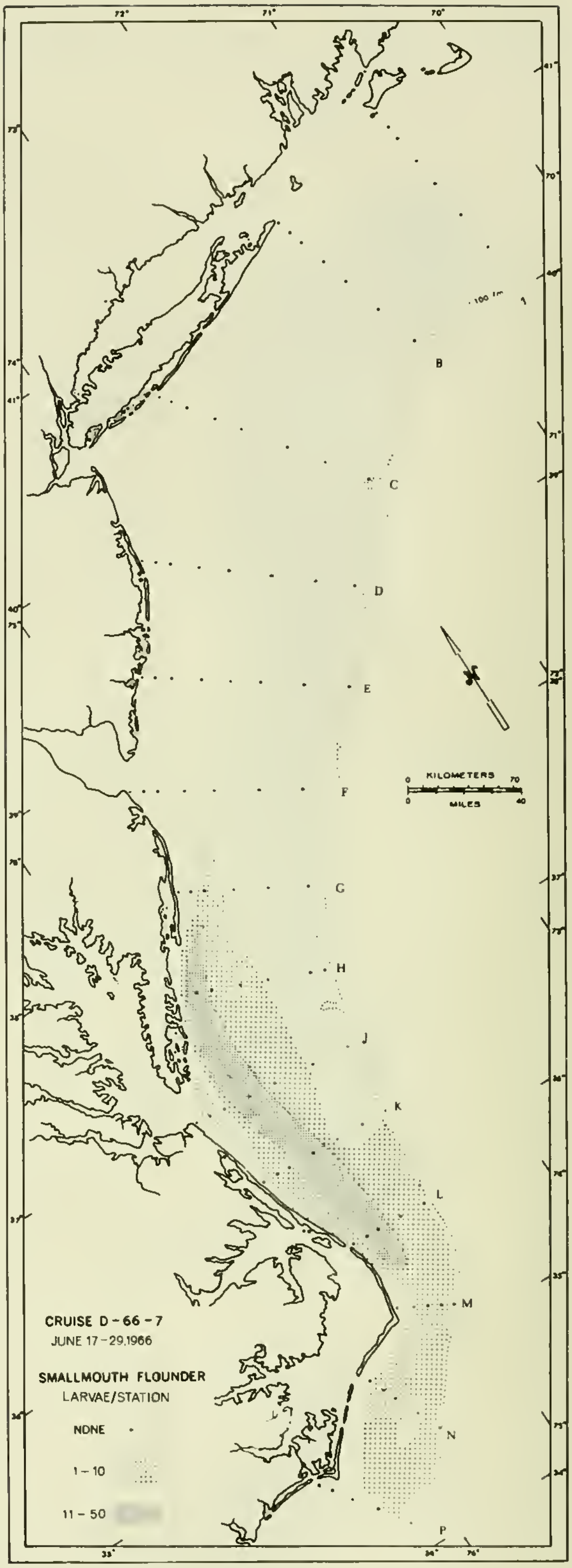


Figure 17.—June 1966. Distribution and relative abundance of smallmouth flounder, *Etropus microstomus*, larvae.

distribution was continuous from North Carolina to New York, with a large concentration centered off Chesapeake Bay, where depths ranged between 15 and 45 m, and a smaller one off Oregon Inlet, N.C., over depths of about 35 m. Bottom temperatures were 8° to 13°C below the larger of the two concentrations and 16°C below the smaller. Recent spawning had been most concentrated east of Chesapeake Bay at a depth of 30 m. If spawning reached peak proportions between the first part of July and the middle of August, it must have been largely confined to the southern half of the bight, inasmuch as both recently hatched larvae and those >4 mm were most abundant off Virginia and North Carolina (Fig. 18).

In September, when we sampled only the four northern transects, we caught 13 larvae off Long Island and northern New Jersey, none of which represented recent spawning.

We caught larvae along the entire survey area in October, except at the northernmost transect off southern New England. The center of abundance, much smaller than that of August, occurred off the outer banks of North Carolina over a depth of 35 m and a bottom temperature of 16°C. Recent spawning apparently had occurred as far north as the eastern end of Long Island, but we caught most of the larvae >6 mm between Maryland and North Carolina, a pattern similar to that found in August. Spawning was light north of Delaware Bay (Fig. 19).

The distribution of larvae in November extended from Montauk Point to Cape Lookout but it was interrupted off New Jersey, where the cruise started. Recently hatched larvae were most abundant between capes Hatteras and Lookout, south of observations made in October. Since larvae <4 mm occurred at only two stations north of Cape Hatteras, we concluded that spawning had ended in the bight. Water depths of 35 to 340 m and the catch location led us to conclude that most larvae caught south of Cape Hatteras were transported into the survey area by the Gulf Stream. We caught some intermediate-sized larvae (4 to 8 mm) off Long Island and northern New Jersey, but advanced larval stages (8 to 12 mm) occurred only as far north as Maryland (Fig. 20).

Only one larva was taken north of North Carolina in December (1965). Most larvae were taken south of Cape Hatteras, the center of their distribution being between capes Hatteras and Lookout over depths of 45 to 150 m (Fig. 21). We concluded that these, like those caught in November, were transported into the survey area. Although fewer in number, their distribution in January was similar to that in December (Fig. 22).

Smallmouth flounder have an extended spawning season which progresses northward in the spring and southward in the fall. Although this small bothid is reported from as far north as New England (Parr 1931), it appears from our collections that the bight marks its northern limit of spawning. We caught larvae from the eastern end of Long Island to Cape Lookout, but spawning was most concentrated from Virginia to North Carolina. No larvae occurred as far north and east as the transect off southern New England. The absence of advanced larval stages off New York suggests that spawning there was largely unsuccessful, or that the small larvae we caught there were subsequently transported southward by currents. Although smallmouth flounder and Gulf Stream flounder spawn at the same time of year, their respective larval distributions substantiate the smallmouth's preference for shallow water (see Gutherz 1967; Richardson and Joseph 1973) and the more northern range of Gulf Stream flounder (see Figs. 23 and 15).

Hippoglossina oblonga (Mitchill), fourspot flounder.—Fourspot flounder inhabit shelf waters as far north as Georges Bank. Although their range extends southward to Florida (Gutherz 1967), trawl records at this laboratory, and our larval collections as far south as Palm Beach, Fla., indicate that they are rare south of Cape Hatteras. The Middle Atlantic Bight encompasses that section of the shelf where fourspot flounder occur in greatest numbers. Their center of abundance lies between southern New England and Delaware Bay, where they reportedly spawn from May to mid-July (Bigelow and Schroeder 1953). The larvae were described by Leonard (1971).

Fourspot flounder had the shortest spawning season of the bothid flounders that spawn in the bight, perhaps a consequence of their more northerly distribution. The season, however, was longer than reported by Bigelow and Schroeder (1953). We caught larvae from May through October, and it appeared from their size that spawning lingered into fall (Table 8).

In June, larvae were scattered along the inner half of the shelf from the outer banks of North Carolina to Delaware, except off North Carolina where they probably were carried seaward by currents (Fig. 24). Most of the larvae were small, <4 mm, none >8 mm. Their size, limited geographic distribution, and the fact that only one was taken during the May cruise suggested that the spawning season was just beginning.

Although we did not sample during July, it appears likely that spawning was maximal then. By August, larvae were distributed from North Carolina to southern New England. There were two centers of abundance: one midway out on the shelf off New Jersey over depths of 30 to 40 m, the other on the outer part of the shelf off southern New England over depths of 60 to 80 m. A lesser concentration occurred east of Chesapeake Bay near the edge of the shelf. Most larvae comprising the two major centers of abundance were small and presumably had been spawned nearby. Bottom temperatures near the two concentrations, 8.6° and 9.0°C, respectively, were lower than those observed where we caught larvae in June but warmer than in May, when we first caught young fourspot flounder. Although larvae 4 to 8 mm had a distribution similar to that of the smaller size group, larvae 8 to 12 mm were caught mostly between New Jersey and North Carolina, reflecting the earlier spawning evident in our spring catches (Fig. 25). We caught three larvae >12 mm off Virginia.

When we sampled only the four northernmost transects in mid-September, larvae were most abundant off New Jersey and Long Island, but concentrations were not as great as those found on the previous cruise (Fig. 26). Recently spawned larvae were most numerous off Long Island over depths of 55 to 75 m and bottom temperatures between 7.9° and 8.5°C. Most of the larvae were 4 to 8 mm.

The distribution of larvae in October extended from eastern Long Island to Chesapeake Bay. A single concentration reached from southern New Jersey to Maryland over depths between 25 and 55 m. Recently hatched larvae, those <4 mm, predominated at the center of abundance over 6.2°C bottom water. Those 4 to 8 mm were scattered throughout the area of occurrence (Fig. 27). The reduced catch and receding areal extent of larval occurrence in October indicated that spawning had peaked during the summer. The absence of larvae on the following cruise confirmed the October results.

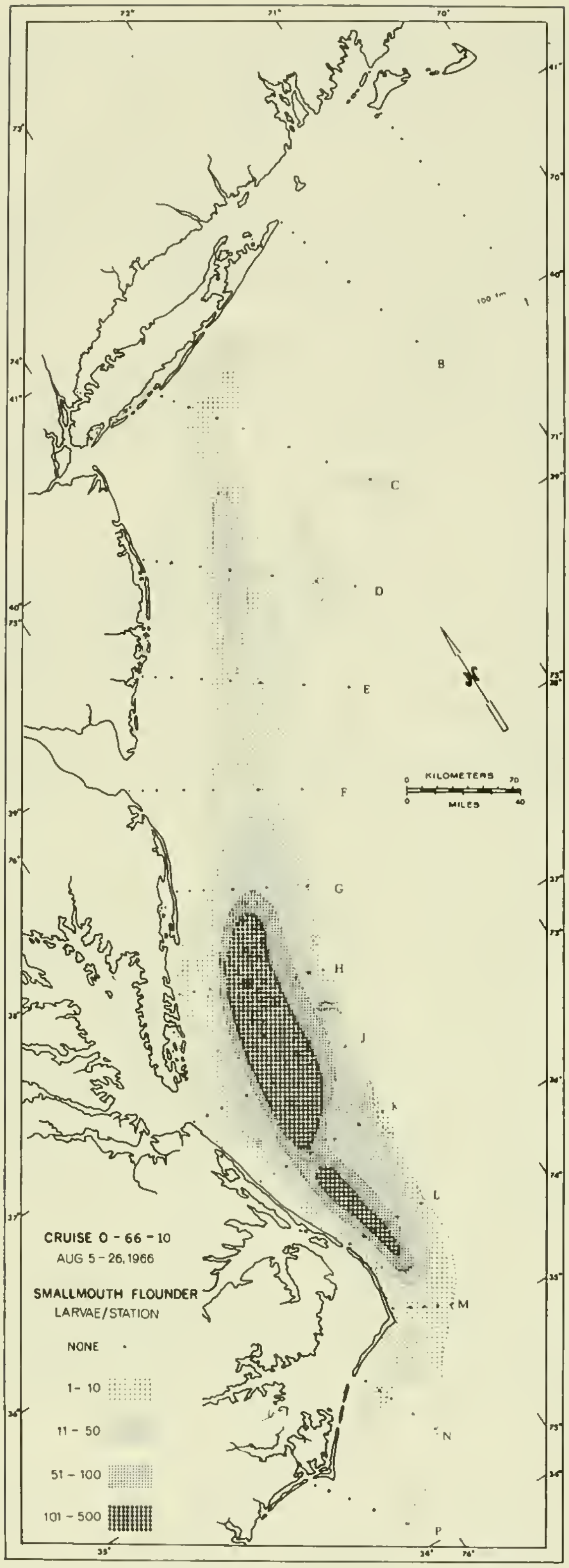


Figure 18.—August 1966. Distribution and relative abundance of smallmouth flounder, *Etropus microstomus*, larvae (left) and (right) their distribution and relative abundance by size groups. Top ≤4.0 mm, 4.1 to 6.0 mm; bottom 6.1 to 8.0 mm, 8.1 to 12.0 mm.

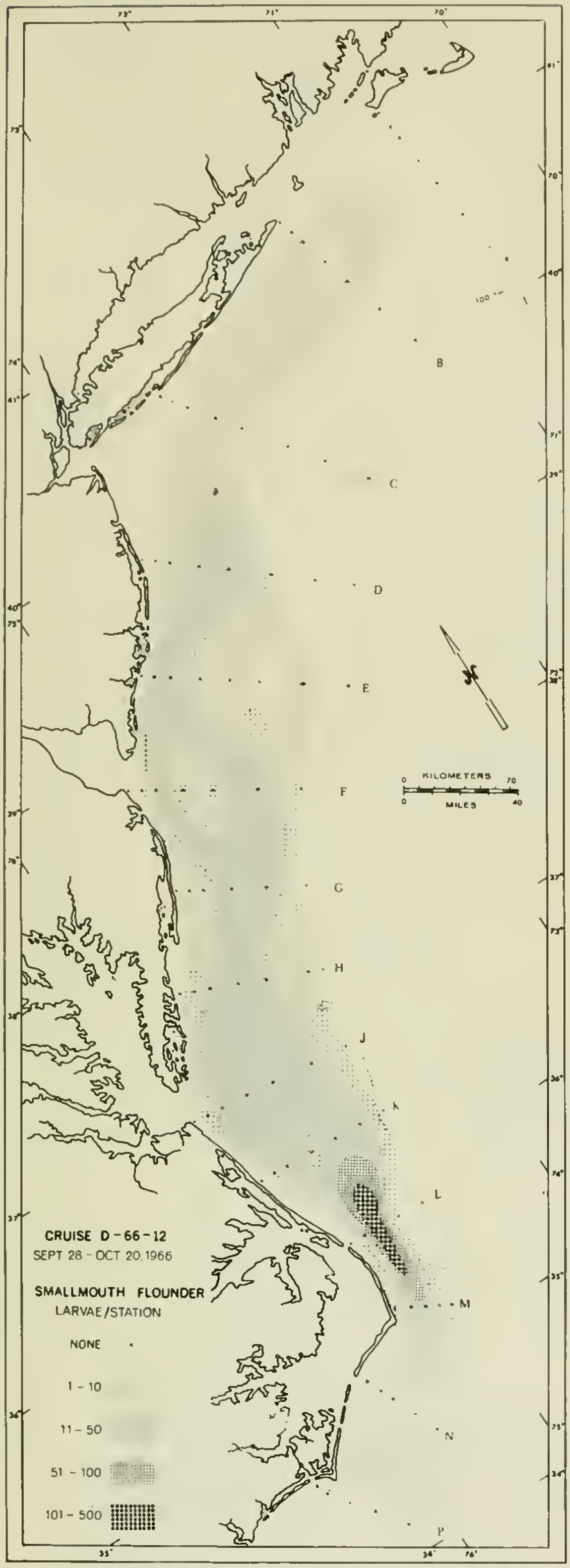


Figure 19.—September to October 1966. Distribution and relative abundance of smallmouth flounder, *Etropus microstomus*, larvae (left) and (right) their distribution and relative abundance by size groups. Top ≤4.0 mm, 4.1 to 6.0 mm; bottom 6.1 to 8.0 mm, 8.1 to 12.0 mm.

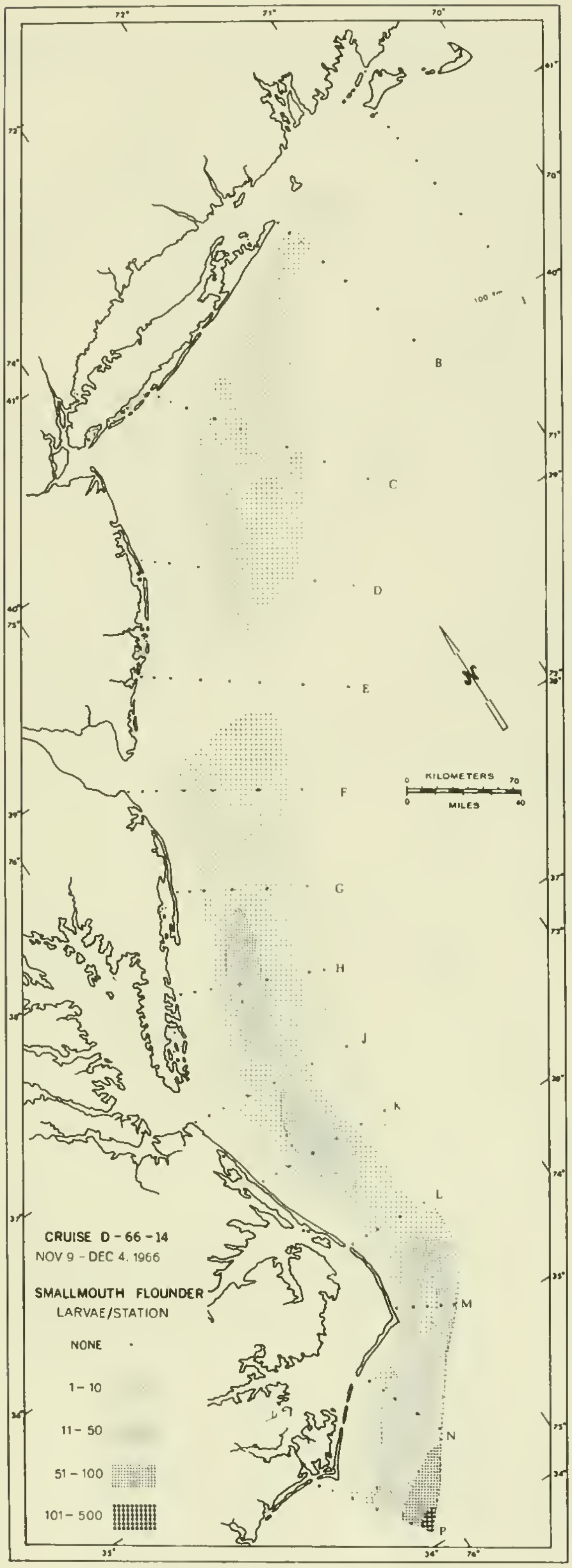


Figure 20.—November to December 1966. Distribution and relative abundance of smallmouth flounder, ***Etropus microstomus***, larvae (left) and (right) their distribution and relative abundance by size groups. Top ≤4.0 mm, 4.1 to 6.0 mm; bottom 6.1 to 8.0 mm, 8.1 to 12.0 mm.

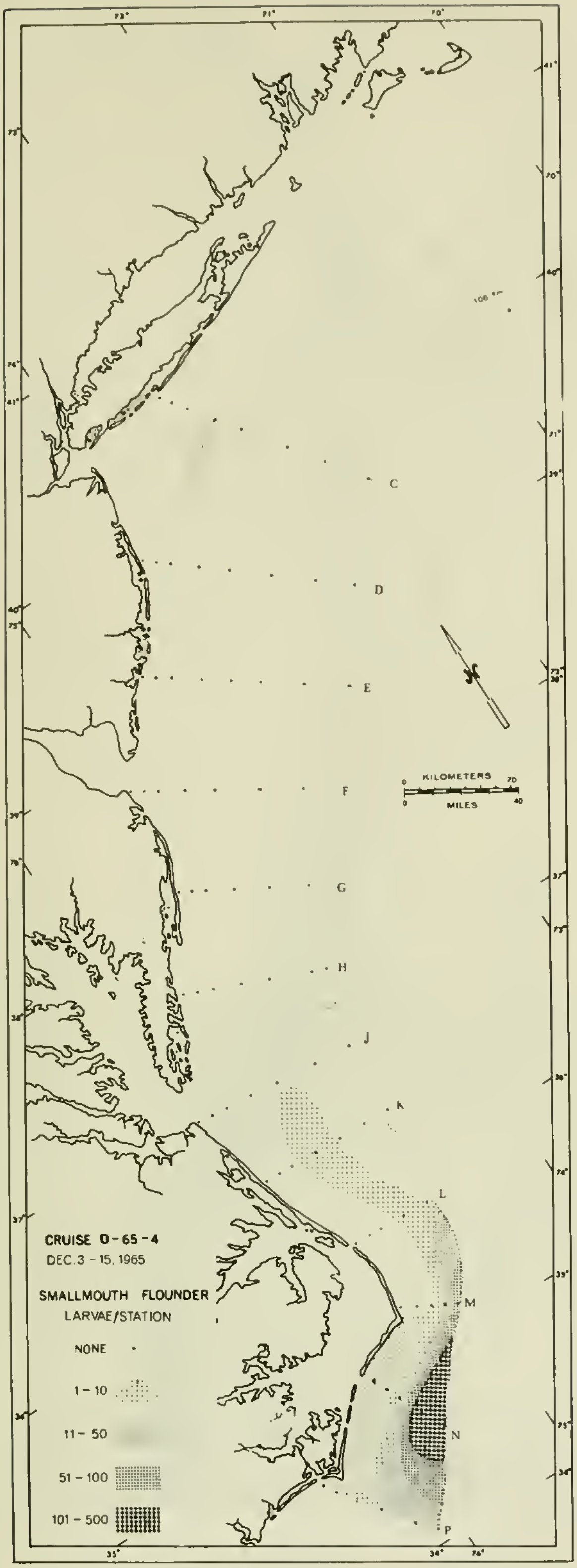


Figure 21.—December 1965. Distribution and relative abundance of smallmouth flounder, *Etropus microstomus*, larvae (left) and (right) their distribution and relative abundance by size groups. Top ≤4.0 mm, 4.1 to 6.0 mm; bottom 6.1 to 8.0 mm, 8.1 to 12.0 mm.

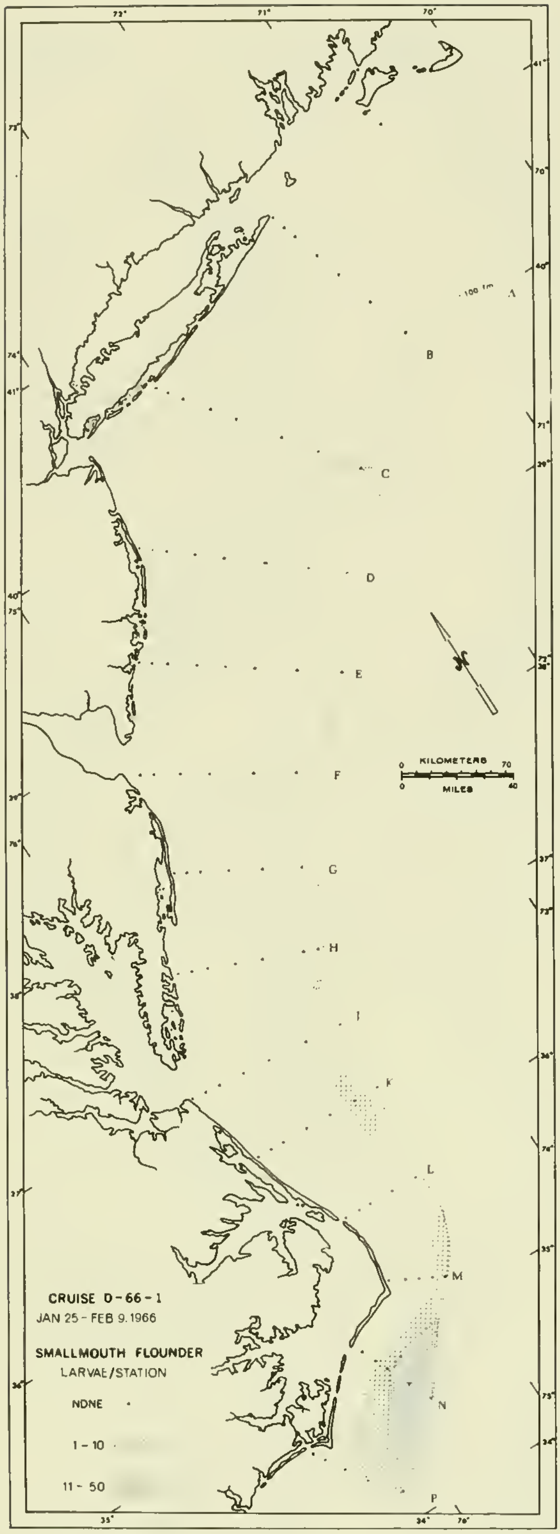


Figure 22.—January to February 1966. Distribution and relative abundance of smallmouth flounder, *Etropus microstomus*, larvae.

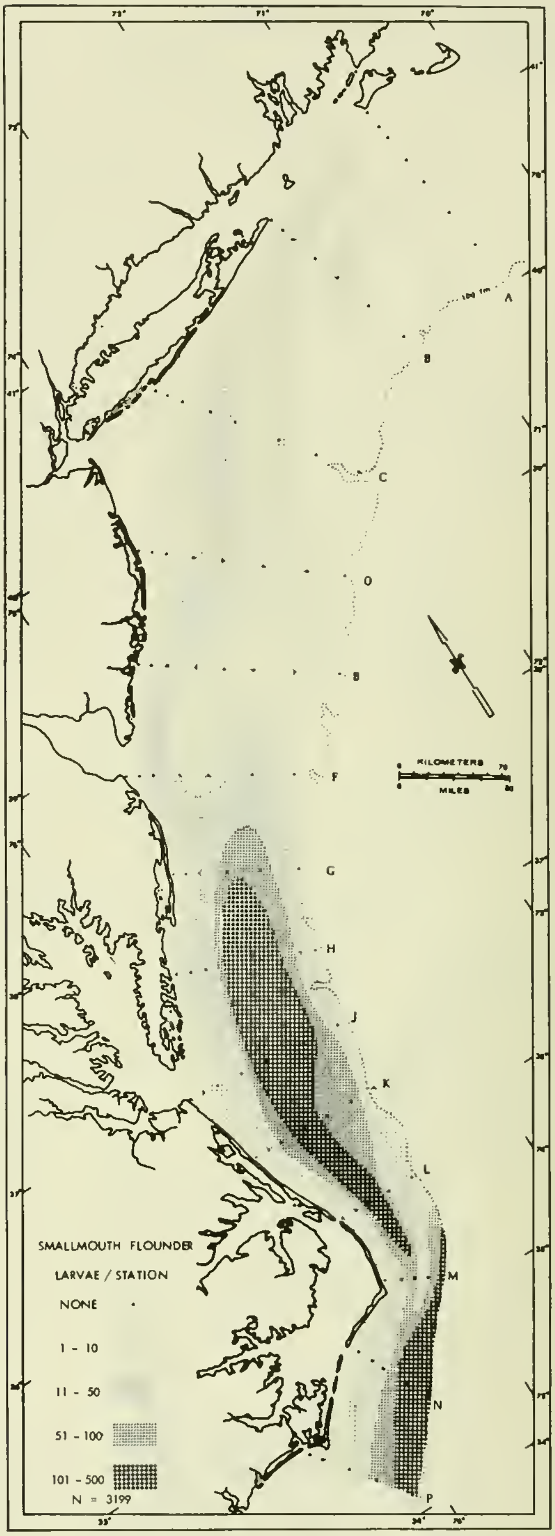


Figure 23.—Distribution and relative abundance of smallmouth flounder, *Etropus microstomus*, larvae collected during 1965-66 survey.

Table 8.--The seasonal distribution of fourspot flounder, Hippoglossina oblonga, larvae by size. Numbers are adjusted to standardize sampling effort. Larvae < 4.1 mm represented recent spawning.

Larval length (mm)	66-5 May	66-7 June	66-10 Aug.	66-11 Sept.	66-12 Sept.-Oct.	Total
	Number of larvae					
1.1- 2.0			2			2
2.1- 3.0	1	19	208	29	45	302
3.1- 4.0		22	413	113	185	733
4.1- 5.0		15	349	183	121	668
5.1- 6.0		3	229	125	71	428
6.1- 7.0		4	120	48	56	228
7.1- 8.0			41	3	24	68
8.1- 9.0			14	1	9	24
9.1-10.0			5		1	6
10.1-11.0			4		2	6
11.1-12.0			4			4
12.1-13.0			1			1
13.1-14.0			1			1
14.1-15.0			1			1
Total	1	63	1,392	502	514	2,472

The seasonal distribution of fourspot flounder larvae characterized that of most spring spawners by advancing from south to north as water temperatures increased. Additional evidence of the influence of temperature was apparent in the seaward shift in spawning as the season progressed and offshore waters warmed. Although spawning began nearshore off Virginia and North Carolina, the distribution of all fourspot flounder larvae indicated that most spawning took place along the northern half of the bight at temperatures between 6.2° and 9.0°C and in depths between 35 and 80 m (Fig. 28). The area and depths of major larval concentrations correspond with the reported depth distribution and center of abundance for adults (Bigelow and Schroeder 1953). We seldom caught larvae >8 mm, probably because they were unavailable to our gear. Because we caught metamorphosing specimens of other flatfish larvae that occurred regularly in our collections, we attribute the scarcity of fourspot flounder >8 mm to a change from a pelagic to a largely demersal life at about 8 mm, although metamorphosis is not complete at 12 mm (Leonard 1971).

Monolene sessilicauda Goode, deepwater flounder.— Deepwater flounder range from New England to Florida and into the Gulf of Mexico (Gutherz 1967). Our identification of the larvae is based on the description of larvae from the eastern Gulf of Mexico (Futch 1971), the reported distribution of adults by Gutherz (1967), and on fin ray counts from our largest specimen.

We caught only six larvae: one (7.0 mm) in April off Hatteras Inlet, three (7.1, 8.6, 10.1 mm) in June off Cape Hatteras, and one each (11.8 and 19.3 mm) in August and September off New Jersey. All six were caught near the edge of the shelf. Because of their size and infrequent occurrence, we concluded that the larvae had originated outside the survey area.

Paralichthys dentatus (Linnaeus), summer flounder.— Summer flounder range from Maine to Florida (Gutherz 1967), but they are not common north of Cape Cod or south of South Carolina. Their geographic distribution resembles that of windowpane, *Scophthalmus aquosus*, and fourspot flounder, mentioned previously, in that the center of abundance lies within the bight, and they must be considered more of a temperate latitude species than most bothids. Because of the importance of summer flounder to both commercial and sport fishermen in the bight, data on eggs and larvae collected during the survey were previously published (Smith 1973). The distribution of summer flounder larvae is presented in this paper to provide a comprehensive report, which includes all identified flatfish larvae collected during the survey. Summer flounder larvae were described by Smith and Fahay (1970).

Spawning began in late summer and continued to midwinter. There was a pronounced southerly shift in spawning and distribution of larvae as the season progressed. North of Chesapeake Bay, spawning occurred from September to December; south of the bay, from

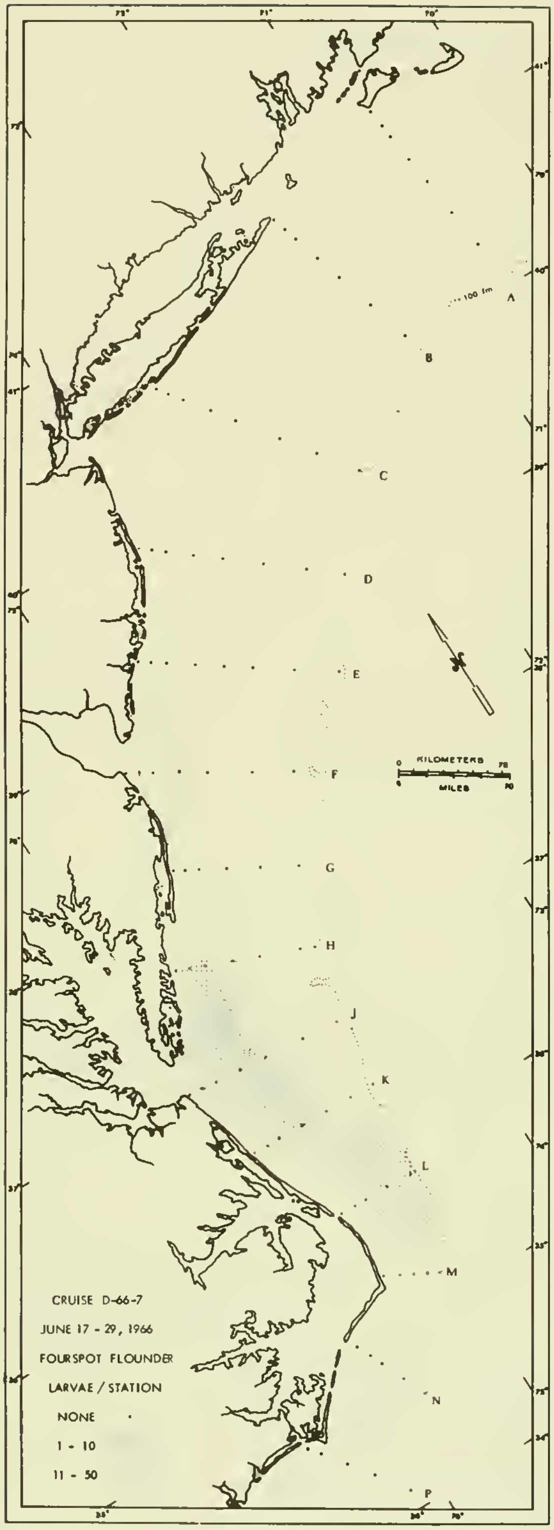


Figure 24.—June 1966. Distribution and relative abundance of fourspot flounder, *Hippoglossina oblonga*, larvae.

November to February. Although most spawning occurred at temperatures between 12° and 19°C, both eggs and larvae seemed to withstand a much wider range of temperature.

Larvae were collected first off Long Island and northern New Jersey during the abbreviated cruise in September. Their small size and restricted distribution indicated that spawning had recently started, probably during the first week in September (Table 9).

We made our largest catch of larvae in October, although spawning occurred only in the northern half of the survey area. The distribution of both eggs and larvae seemed to be restricted to nearshore waters by the cold cell of bottom water that stretched from Long Island to Maryland. Within this restricted area, the distribution of larvae was continuous from southern New England to Virginia, with concentrations off Martha's Vineyard, off Long Island and northern New Jersey, and off Delaware Bay. Spawning was most intense off New Jersey at depths of 20 to 48 m (Smith 1973). Larvae <4 mm were abundant off New Jersey over 16.8°C bottom water and off Delaware Bay over 6.8°C bottom water, where they had apparently drifted from spawning grounds nearer shore. Eggs were abundant at the adjacent inshore station over bottom temperatures of 14°C but absent from the location off Delaware Bay, where the small larvae were concentrated (Smith 1973). The distributions of larvae in size groups of 4.1 to 6.0 mm and 6.1 to 8.0 mm extended from Cape Cod to northern Virginia. Larvae >8 mm were caught off Long Island and southern New England, which substantiates earlier spawning there than in more southern parts of the bight (Fig. 29).

From mid-November through early December, larvae occurred throughout the survey area. Based on the distribution of eggs, spawning was centered off Maryland and northern Virginia and off the outer banks of North Carolina (Smith 1973), but larvae of all four size groups were most abundant off Long Island and New Jersey. The center of abundance consisted mostly of larvae 4.1 to 6.0 mm long. It was located off New Jersey over a bottom temperature of 10.5°C and a depth of 45 m (Fig. 30).

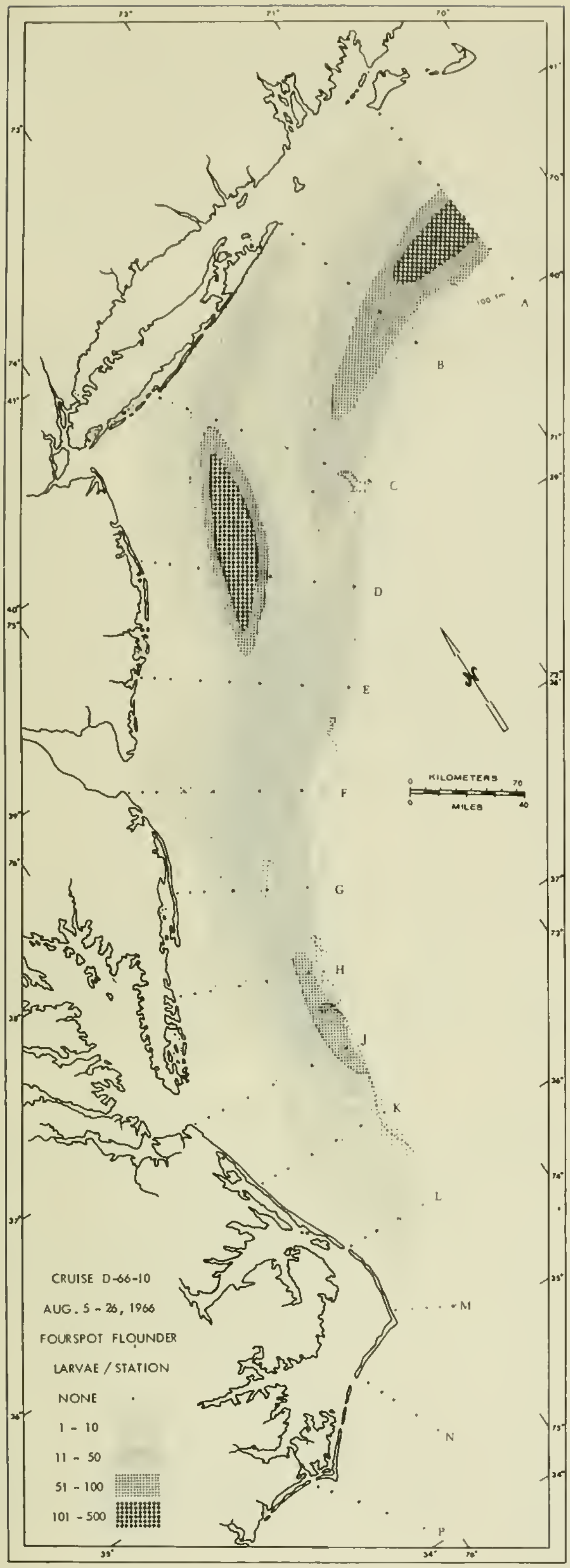
Although in December (1965) we caught larvae throughout the area sampled, the distribution of eggs was limited to waters off North Carolina (Smith 1973). Most newly hatched larvae were caught off North Carolina, but representatives of the larger size categories were most abundant off New Jersey (Fig. 31).

By January, the number of larvae diminished, and, with the exception of a few, their distribution was limited to the area south of Cape Hatteras (Fig. 32). We caught four eggs, the last of the season, at the seaward station off Cape Lookout.

In April, we caught larvae only in the extreme southern part of the survey area (Fig. 33). Most were >8 mm and had started to metamorphose (Table 9). In May, we caught seven larvae off North Carolina, which we assume represented remnants of late spawning. None were caught on the following cruises in June and August.

Larvae occurred throughout the survey area during the course of the spawning season. Their distribution shifted southward as the season progressed. The most important spawning grounds were off New York and New Jersey in early fall and, to a lesser extent, off North Carolina in late fall (Fig. 34).

Although spawning takes place at sea, young-of-the-year are found in estuaries (Smith 1973). Because the juveniles



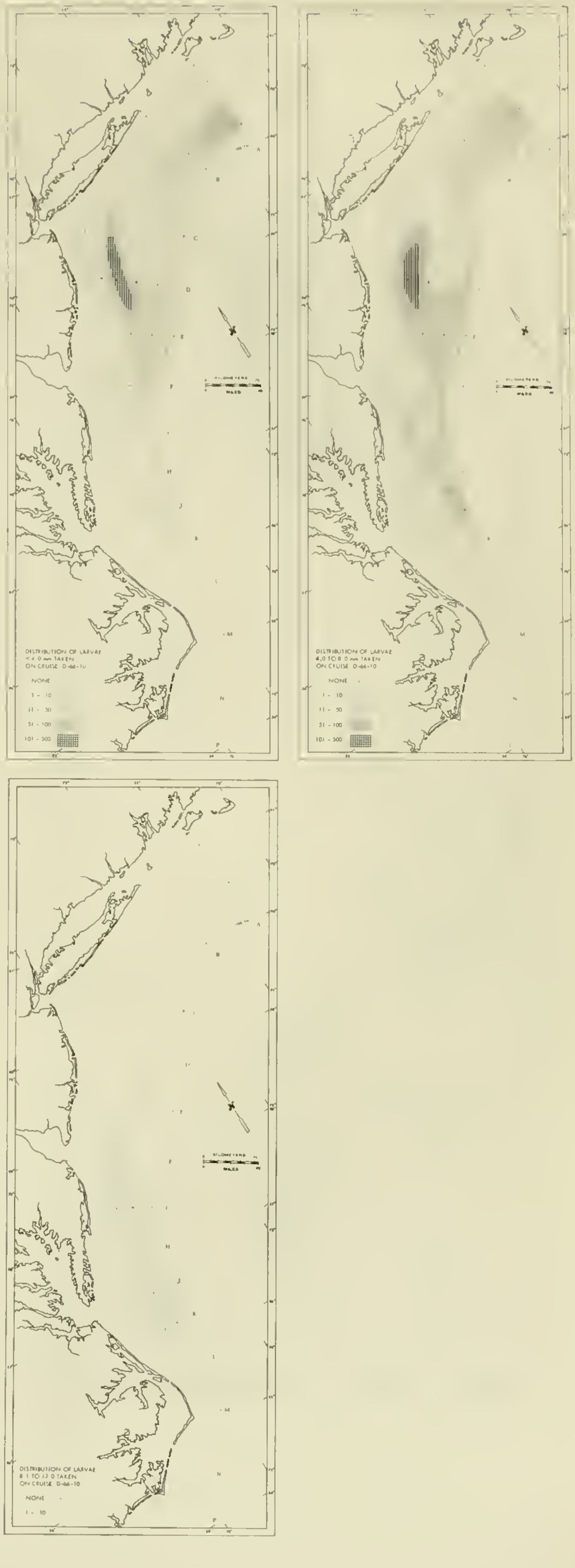


Figure 25.—August 1966. Distribution and relative abundance of fourspot flounder, *Hippoglossina oblonga*, larvae (left) and (right) their distribution and relative abundance by size groups. Top <4.0 mm, 4.0 to 8.0 mm; bottom 8.1 to 12.0 mm.

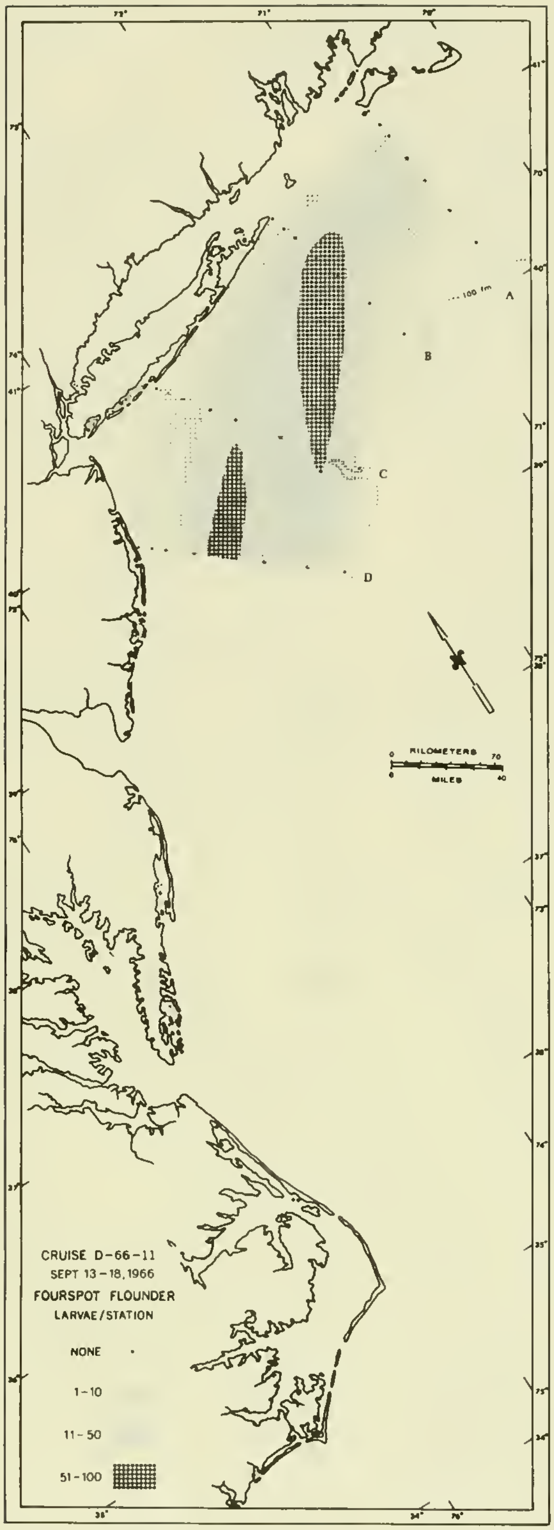


Figure 26.—September 1966. Distribution and relative abundance of fourspot flounder, *Hippoglossina oblonga*, larvae.

are found only in estuaries, summer flounder are considered estuarine dependent. Their tolerance to a wide range of both temperature and salinity indicates that they are physiologically adapted to withstand the extreme variations in temperature and salinity characteristic of our estuaries of temperate latitude. Young have been collected from waters that ranged in temperature between 2° and 31.2°C and salinity from 0.02 to 37‰ (Tagatz and Dudley 1961; Williams and Deubler 1968). Deubler and White (1962) kept young summer flounder in water with a salinity of 40‰.

Paralichthys **spp.**—Four species of *Paralichthys* occur along our eastern seaboard. We have discussed the distribution of *P. dentatus* larvae which we caught throughout the survey area. Of the other three, *P. lethostigma* Jordan and Gilbert and *P. albigutta* Jordan and Gilbert occur regularly, *P. squamilentus* Jordan and Gilbert rarely, as far north as North Carolina. Their larvae have not been described. Using a combination of fin ray and vertebral counts, we identified advanced larval stages of *P. lethostigma* and *P. albigutta* in our collections. Small larvae without the full complement of ossified parts could not be identified beyond the generic level, so we treated the entire lot as *Paralichthys* spp. Although we did not recognize larvae of *P. squamilentus*, it probably spawns as far north as the Carolinas. Juveniles have been collected in estuaries of both North and South Carolina (Rothschild and Deubler 1960; Bearden 1971).

All four species spawn in fall and early winter. We caught *P. dentatus* larvae, mostly north of Cape Hatteras, from September to May. South of the cape, larvae of *Paralichthys* spp. occurred from November into April. Spawning apparently peaked in late November or early December, as we made our largest catch of larvae in mid-December (Table 10). Larvae were not abundant at any of the stations south of Cape Hatteras, but most of those that we collected were on the outer half of the shelf. Some of the larvae probably represented local spawning, while others were transported into the survey area from spawning grounds to the south (Fig. 35).

Scophthalmus aquosus **(Mitchill), windowpane.**—Windowpane range from Maine to Florida (Gutherz 1967), but their distribution north of Cape Cod is restricted to isolated locations (Bigelow and Schroeder 1953). The Middle Atlantic Bight is the area where windowpane occur in greatest numbers. Trawl records at this laboratory indicate that the bulk of the population inhabits coastal waters from southern New England to Chesapeake Bay. Larval stages were described by Moore (1947), Bigelow and Schroeder (1953), and Colton and Marak (1969).

North of Cape Cod, spawning occurs in spring and summer (Bigelow and Schroeder 1953). Perlmutter (1939) reported that the spawning season is similar in Long Island Sound, with maximum egg production from late May to mid-June. Wheatland (1956), however, reported a split spawning season in Long Island Sound in 1952 and 1953. She collected eggs and larvae from late April through July and from mid-September through late October and early November.

Our catches indicate that, while spawning continued throughout most of the year, it was not a year-round event anywhere in the survey area, but shifted seasonally. Spawning began in April south of Chesapeake Bay, reached its peak in May, and ended by June. It advanced northward to New Jersey and New York during the summer but did not

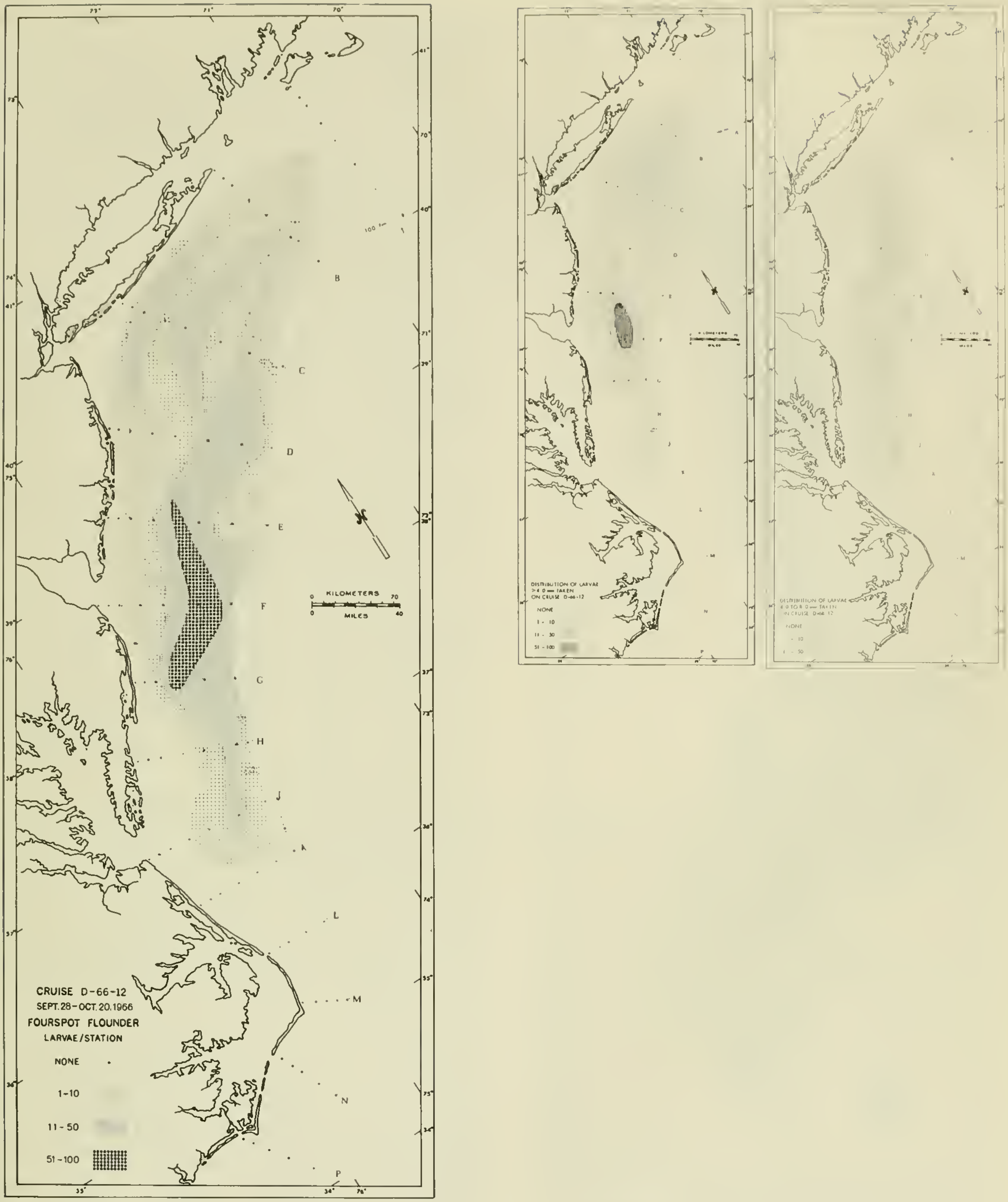


Figure 27.—September to October 1966. Distribution and relative abundance of fourspot flounder, *Hippoglossina oblonga*, larvae (left) and (right) their distribution and relative abundance by size groups. Top <4.0 mm, 4.0 to 8.0 mm.

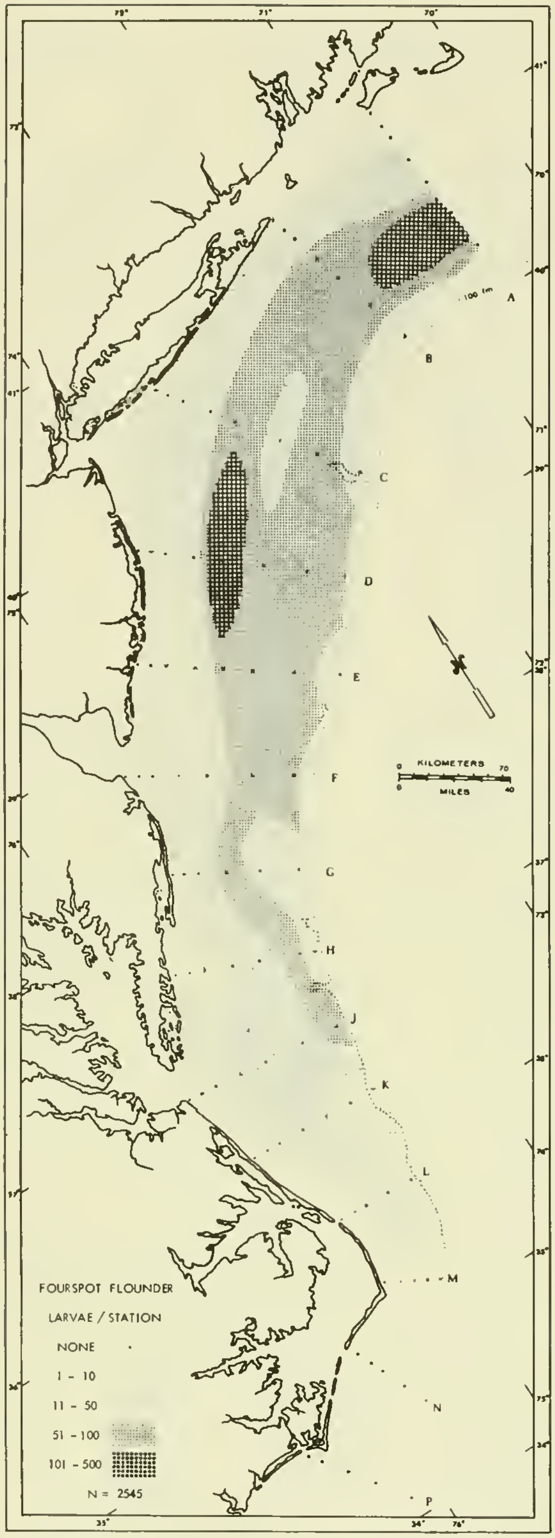


Figure 28.—Distribution and relative abundance of fourspot flounder, *Hippoglossina oblonga*, larvae collected during 1965-66 survey.

peak until fall; and, at that time, it recommenced off Virginia and North Carolina.

Larvae first appeared in April, when we caught newly hatched specimens at a few nearshore stations off Virginia and North Carolina over bottom temperatures of 8° to 13°C. In May, their distribution extended northward to New Jersey, with concentrations off Virginia and North Carolina. Most larvae were small; only eight were >6 mm (Table 11). Bottom temperatures at the two areas of maximum abundance ranged from 9° to 12°C. There was a seaward sweep in the distribution of larvae off North Carolina that probably resulted from coastal circulation (Fig. 36).

Spawning was light in June, but some newly hatched larvae were collected in the northern half of the survey area (Table 11). With few exceptions, larvae were restricted to the nearshore area over bottom temperatures between 9° and 14°C. The cold mass of bottom water off Long Island and New Jersey apparently restricted either the seaward distribution of adults or the offshore limits of spawning. Spawning ceased in the southern half of the bight in June, perhaps because the 16° to 17°C bottom temperatures that prevailed there were too warm (Fig. 37).

In August, spawning was again light and restricted to waters off Long Island and southern New England, shoreward of the cold cell (Fig. 38). The distribution of larvae in September was similar to that in August, but some spawning evidently took place off New Jersey in water deeper than that noted during the June cruise (Fig. 39).

Spawning peaked in the northern part of the survey area in October. We caught specimens at all but the seaward stations on transects between Maryland and southern New England, mostly over depths of 20 to 40 m. A large center of abundance, consisting of small larvae, extended from Delaware Bay to Long Island, where bottom temperatures were between 9° and 16°C (Fig. 40). Despite the most seaward occurrence to date, the distribution of larvae resembled the June and August results, in that the offshore edge of their center of abundance was closely alined with the inshore edge of the cold cell.

On the following cruise in November and early December, the distribution of larvae was continuous from eastern Long Island to North Carolina, but the center of abundance, consisting mostly of small larvae, remained off New Jersey over bottom temperatures between 10° and 12°C. Although spawning was light in comparison with what we had observed in May, it evidently recommenced off North Carolina, where we caught larvae <4 mm for the first time since the spring cruises (Fig. 41). Bottom temperatures dropped since the previous cruise to 14°C, where the recently hatched larvae occurred off the outer banks of North Carolina.

We made the biggest catch in December (1965), when the distribution of larvae was continuous from Long Island, the northernmost transect on the cruise, to Cape Lookout (Table 11). Based on the distribution of larvae <4 mm, recent spawning activity remained centered off New Jersey over bottom temperatures between 8° and 10°C, but spawning occurred along the entire survey area (Fig. 42). The distribution of specimens >6 mm was restricted to waters between Maryland and Long Island, suggesting that spawning recommenced south of Chesapeake Bay during the late fall of 1965, as it did in 1966.

Spawning apparently ended abruptly. By late January, when bottom temperatures dropped to less than 4°C along the inner half of the shelf, where spawning occurred earlier, we caught only five larvae.

Table 9.--The seasonal distribution of summer flounder, Paralichthys dentatus, larvae by size. Numbers are adjusted to standardize sampling effort. Larvae < 4.1 mm represented recent spawning.

Larval length (mm)	Cruise and date							Total
	66-11 Sept.	66-12 Sept.-Oct.	66-14 Nov.-Dec.	65-4 Dec.	66-1 Jan.-Feb.	66-3 Apr.	66-5 May	
	Number of larvae							
2.1- 3.0	1	36	8	11				56
3.1- 4.0	9	430	70	140	11	3		663
4.1- 5.0	4	320	126	146	10	1		607
5.1- 6.0	1	200	94	162	4	3		464
6.1- 7.0		124	53	168	4	3	1	353
7.1- 8.0		34	39	94	2	4		173
8.1- 9.0		9	30	50	10	13	1	113
9.1-10.0			12	22	8	7	2	51
10.1-11.0		1	19	12	4	4		40
11.1-12.0			6	5	1	1	2	15
12.1-13.0			2	2	1		1	6
13.1-14.0				2				2
Total	15	1,154	459	814	55	39	7	2,543

Table 10.--The seasonal distribution of Paralichthys spp. larvae by size (excluding P. dentatus). Numbers are adjusted to standardize sampling effort.

Larval length (mm)	Cruise and date				Total
	66-14 Nov.-Dec.	65-4 Dec.	66-1 Jan.-Feb.	66-3 Apr.	
	Number of larvae				
2.1- 3.0		6	1		7
3.1- 4.0	2	19	1		22
4.1- 5.0		13	5	3	21
5.1- 6.0		18	1		19
6.1- 7.0	1	9			10
7.1- 8.0		2	1	1	4
8.1- 9.0		1		1	2
9.1-10.0		1			1
Total	3	69	9	5	86

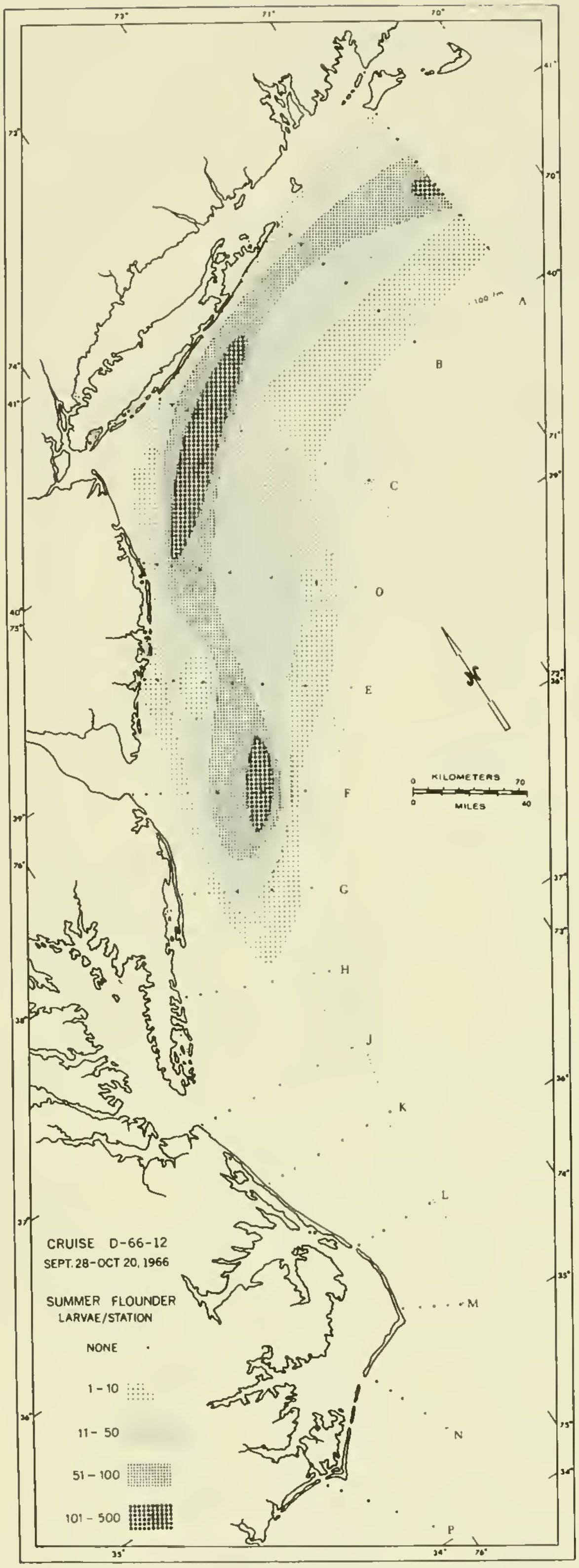


Figure 29.—September to October 1966. Distribution and relative abundance of summer flounder, *Paralichthys dentatus*, larvae (left) and (right) their distribution and relative abundance by size groups. Top ≤4.0 mm, 4.1 to 6.0 mm; bottom 6.1 to 8.0 mm, >8.0 mm.

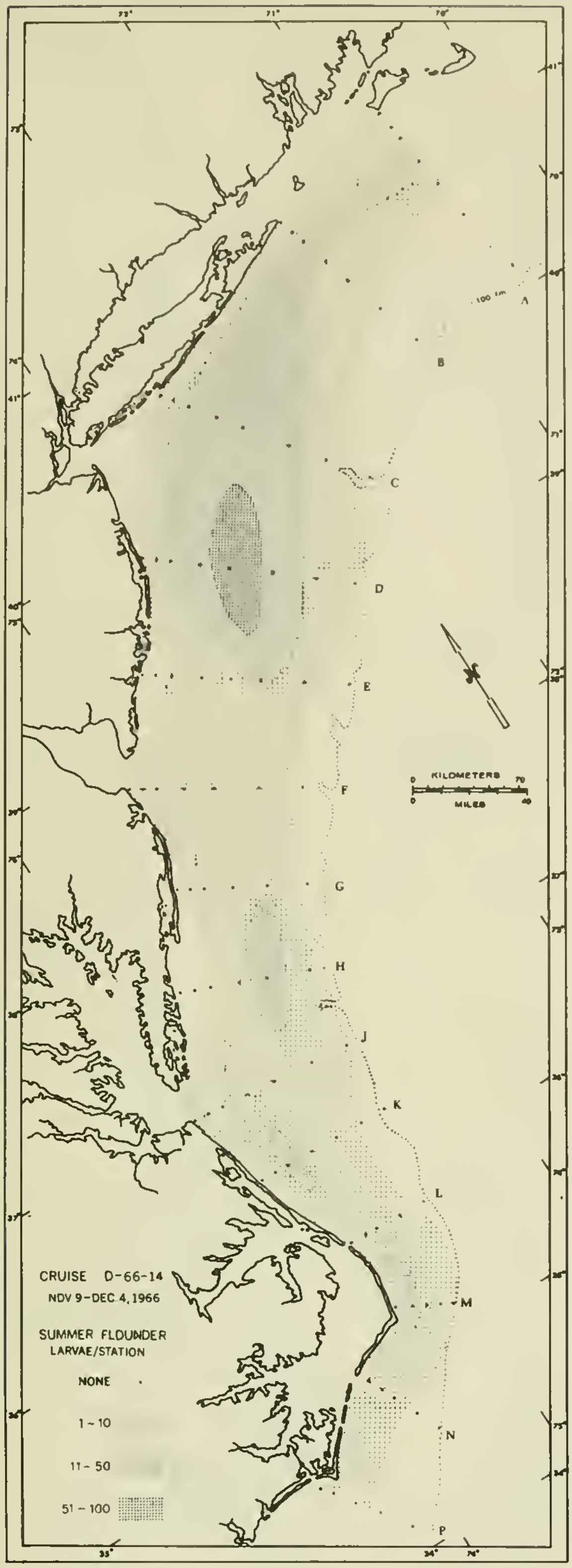


Figure 30.—November to December 1966. Distribution and relative abundance of summer flounder, *Paralichthys dentatus*, larvae (left) and (right) their distribution and relative abundance by size groups. Top ≤4.0 mm, 4.1 to 6.0 mm; bottom 6.1 to 8.0 mm, >8.0 mm.

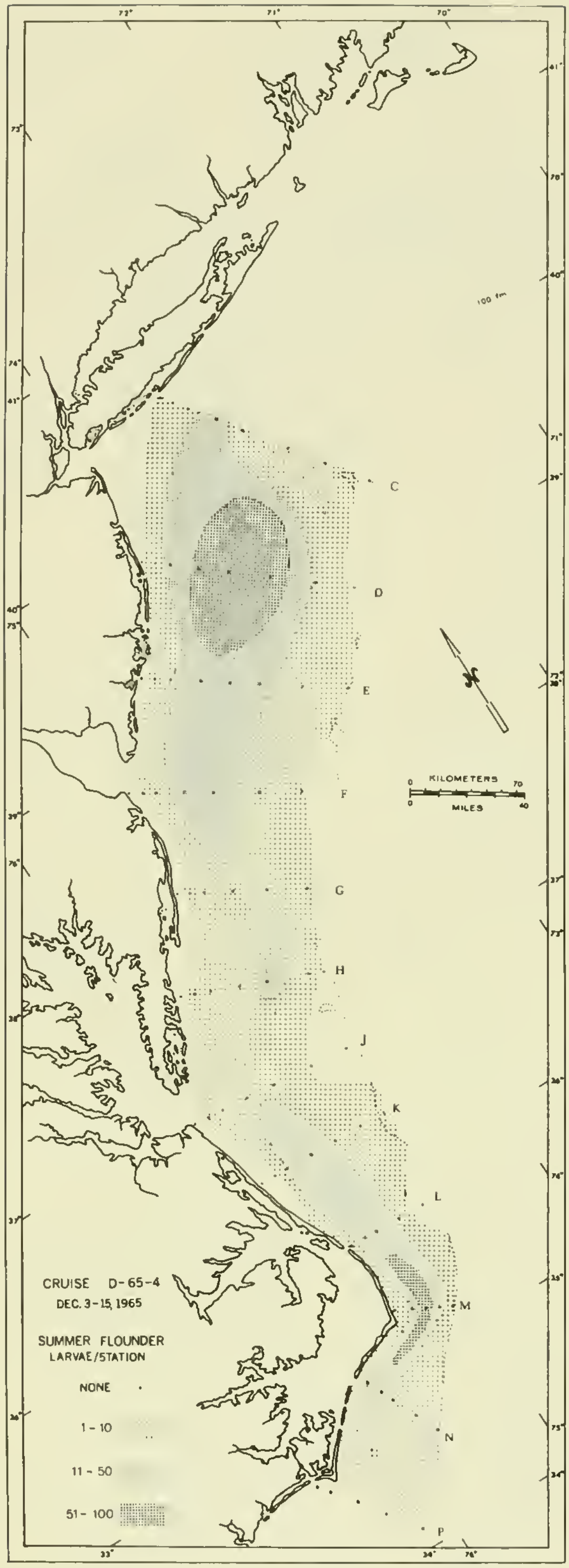


Figure 31.—December 1965. Distribution and relative abundance of summer flounder, *Paralichthys dentatus*, larvae (left) and (right) their distribution and relative abundance by size groups. Top ≤4.0 mm, 4.1 to 6.0 mm; bottom 6.1 to 8.0 mm, >8.0 mm.

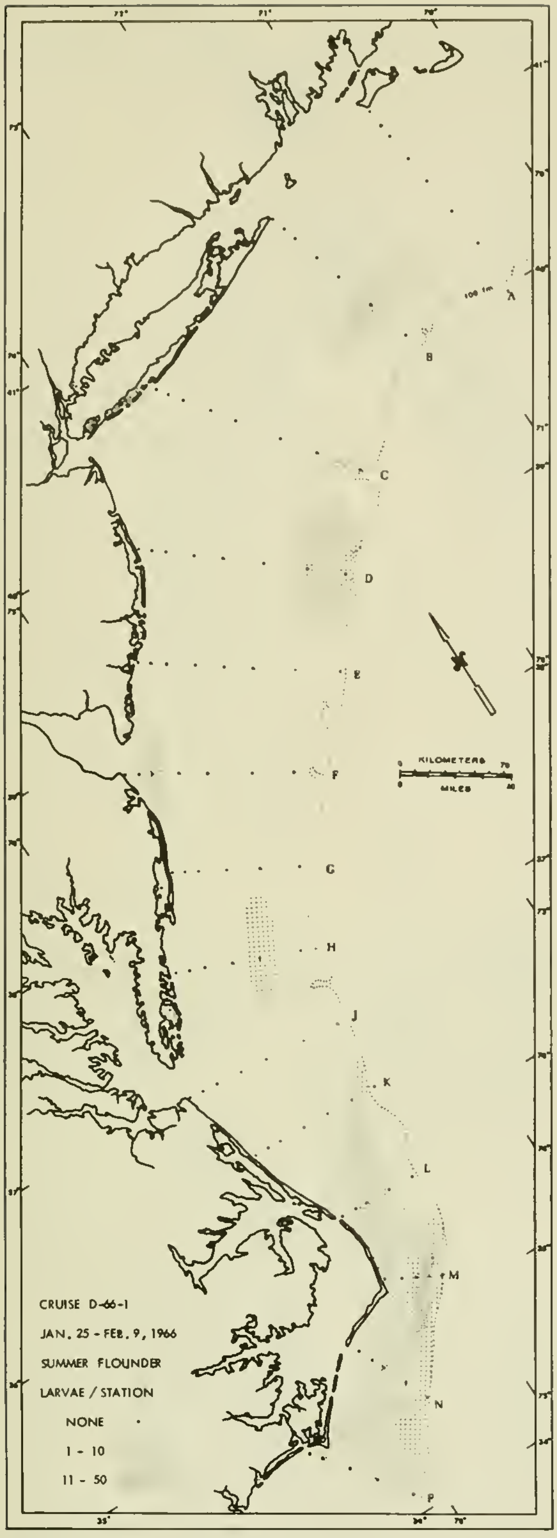


Figure 32.—January to February 1966. Distribution and relative abundance of summer flounder, *Paralichthys dentatus*, larvae.

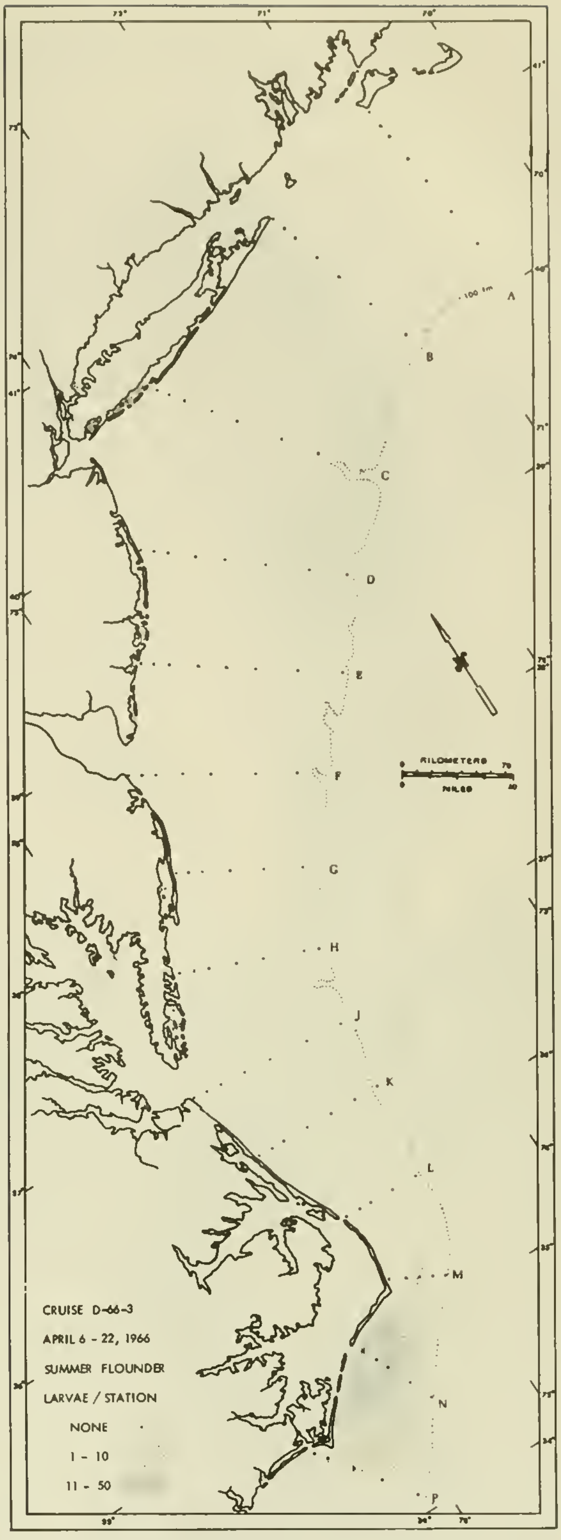


Figure 33.—April 1966. Distribution and relative abundance of summer flounder, *Paralichthys dentatus*, larvae.

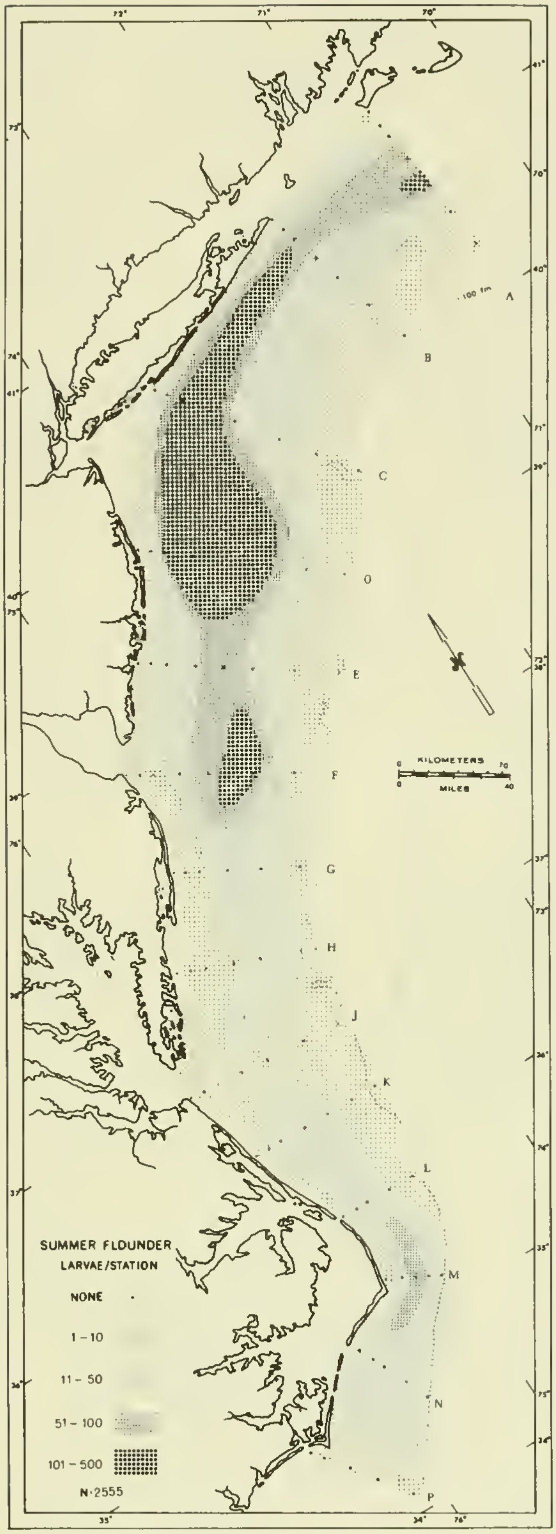


Figure 34.—Distribution and relative abundance of summer flounder, *Paralichthys dentatus*, larvae collected during 1965-66 survey.

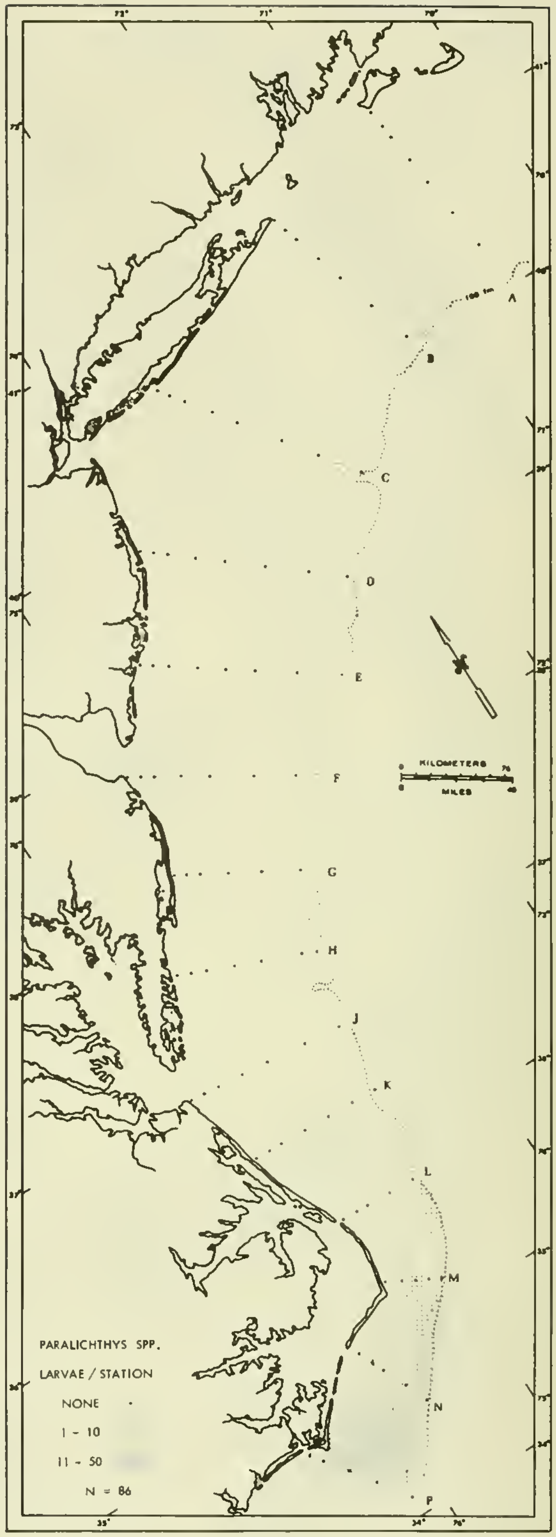


Figure 35.—Distribution and relative abundance of *Paralichthys* spp. larvae collected during 1965-66 survey (excluding *P. dentatus*).

Table 11.--The seasonal distribution of windowpane, Scophthalmus aquosus, larvae by size. Numbers are adjusted to standardize sampling effort. Larvae < 4.1 mm represented recent spawning.

Larval length (mm)	Cruise and date									
	66-3 Apr.	66-5 May	66-7 June	66-10 Aug.	66-11 Sept.	66-12 Sept.-Oct.	66-14 Nov.-Dec.	65-4 Dec.	66-1 Jan.-Feb.	Total
	Number of larvae									
2.1- 3.0	1	342	43	28	23	353	104	104		998
3.1- 4.0	10	331	25	48	19	798	266	668	1	2,166
4.1- 5.0		141	5	28	8	301	256	983		1,722
5.1- 6.0		41	5	4	2	115	150	376	1	694
6.1- 7.0		8	1	4		52	70	56		191
7.1- 8.0			1	1		5	18	10	1	36
8.1- 9.0			1			3	4	1	1	10
9.1-10.0						1	3	1	1	6
10.1-11.0								1		1
11.1-12.0							3	1		4
12.1-13.0										
13.1-14.0										
14.1-15.0								1		1
Total	11	863	81	113	52	1,628	874	2,202	5	5,829

The range of windowpane is somewhat similar to that of fourspot flounder. Although both are most abundant in the northern half of the bight, they are found at different depths. Gutherz (1967) reported windowpane most abundant in depths <46 m; fourspot flounder in depths > 37 m. This is borne out by our larval catches. Windowpane larvae were most abundant off New Jersey over depths between 20 and 40 (Fig. 43); fourspot flounder larvae off New Jersey in 40 m and off southern New England in 70 m (Fig. 28).

Both Wheatland (1956) and Perlmutter (1939) caught windowpane eggs and larvae in Long Island Sound as early as April. We caught larvae off Virginia and North Carolina in April, but not as far north as New York until June. Our results indicate a split spawning season off Virginia and North Carolina, but, contrary to Wheatland's findings in Long Island Sound, not in coastal waters off New York.

Wheatland (1956) doubted that water temperature played a major role in the interruption of spawning in Long Island Sound. Assuming that spawning takes place on the bottom, we see a correlation between water temperatures taken in conjunction with her study (Riley 1956) and the hatching temperatures of 10.0° to 21.1°C reported by Bigelow and Schroeder (1953). During Wheatland's survey of the sound, spawning began in the spring when the average bottom temperature was 7°C and stopped in the summer when it exceeded 20°C. It recommenced in late summer or early fall, soon after the average bottom temperature dropped below 20°C (see Riley 1956). Thus, the upper limits of temperature cited by Bigelow and Schroeder (1953) agree with temperature data collected during the Long Island Sound study. Furthermore, our data suggest that spawning is closely tied to temperature. We caught 98% of the recently spawned windowpane larvae, i.e., those <4.1 mm, over bottom temperatures between 6° and 17°C; 70% over temperatures between 8.5° and 13.5°C, a range of 5°. Spawning was interrupted during the summer off Virginia and North Carolina when bottom temperatures exceeded 15°C, and began again in the fall when they dropped to 14°C. Because bottom temperatures off Long Island during our survey were cooler than those recorded by Riley (1956) during Wheatland's work in the sound, we concluded that spawning was not interrupted by excessively warm water off Long Island during our survey, as it was during Wheatland's (1956) study.

Syacium papillosum (Linnaeus), dusky flounder.—Dusky flounder are common in shelf waters off our southeast Atlantic coast, and range into the Gulf of Mexico, the Caribbean Sea, and southward to Brazil. Larval stages were described by Futch and Hoff (1971).

With the exception of one specimen, the distribution of larvae during our survey did not extend north of North Carolina, which conforms with the northernmost range of adults (Gutherz 1967). Throughout the season, we made our biggest catches at stations near the outer edge of the shelf in that area often transected by the meandering Gulf Stream.

The April collections represented the onset of spawning, which probably had occurred south of Cape Lookout. We caught only four larvae: three of them 36 km off Cape Hatteras over a depth of 55 m, the other at our most seaward station off Cape Lookout where the depth was 145 m. Dusky flounder occur at depths from 11 to 384 m, but

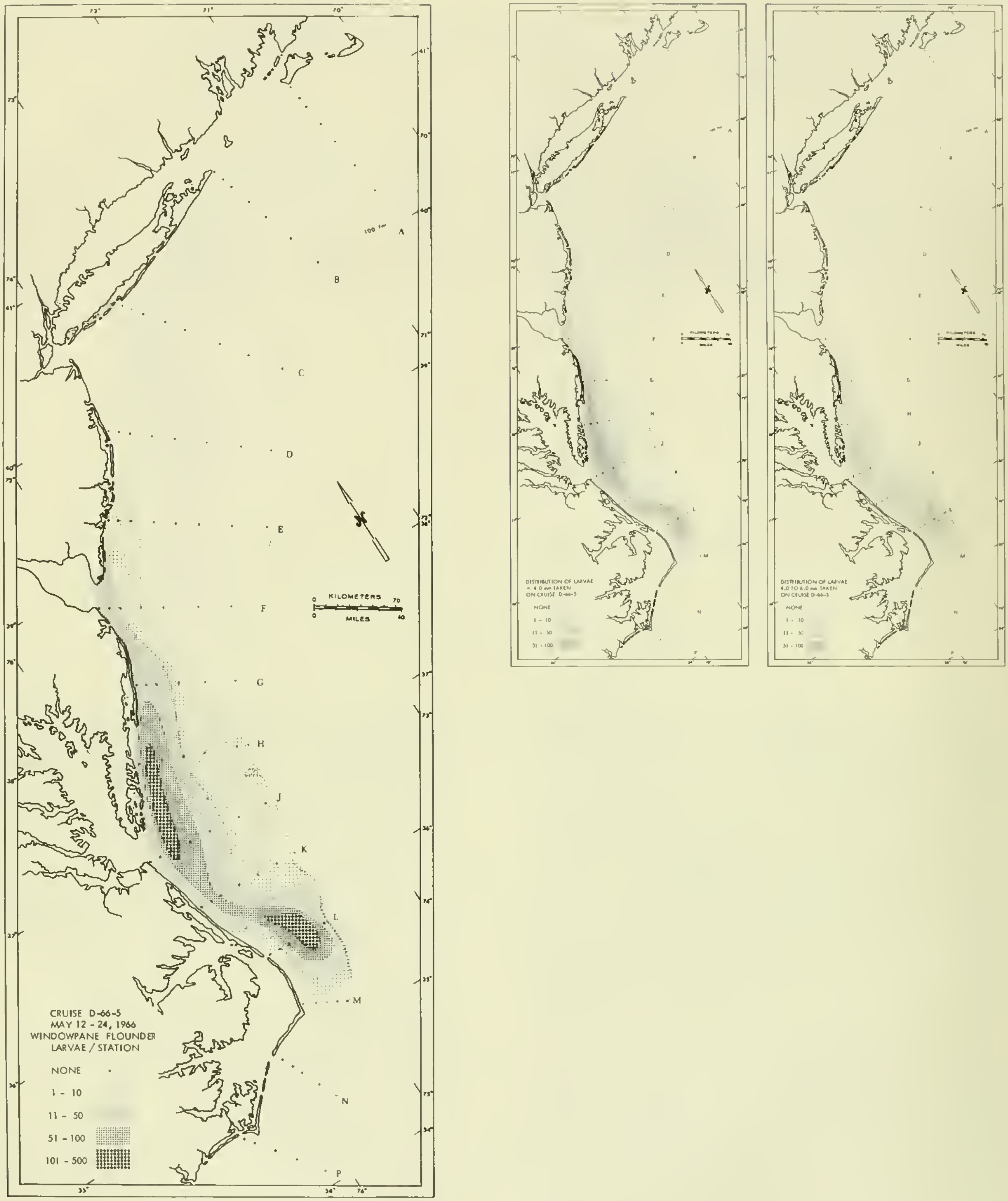


Figure 36.—May 1966. Distribution and relative abundance of windowpane, *Scophthalmus aquosus*, larvae (left) and (right) their distribution and relative abundance by size groups. Top < 4.0 mm, 4.0 to 6.0 mm.

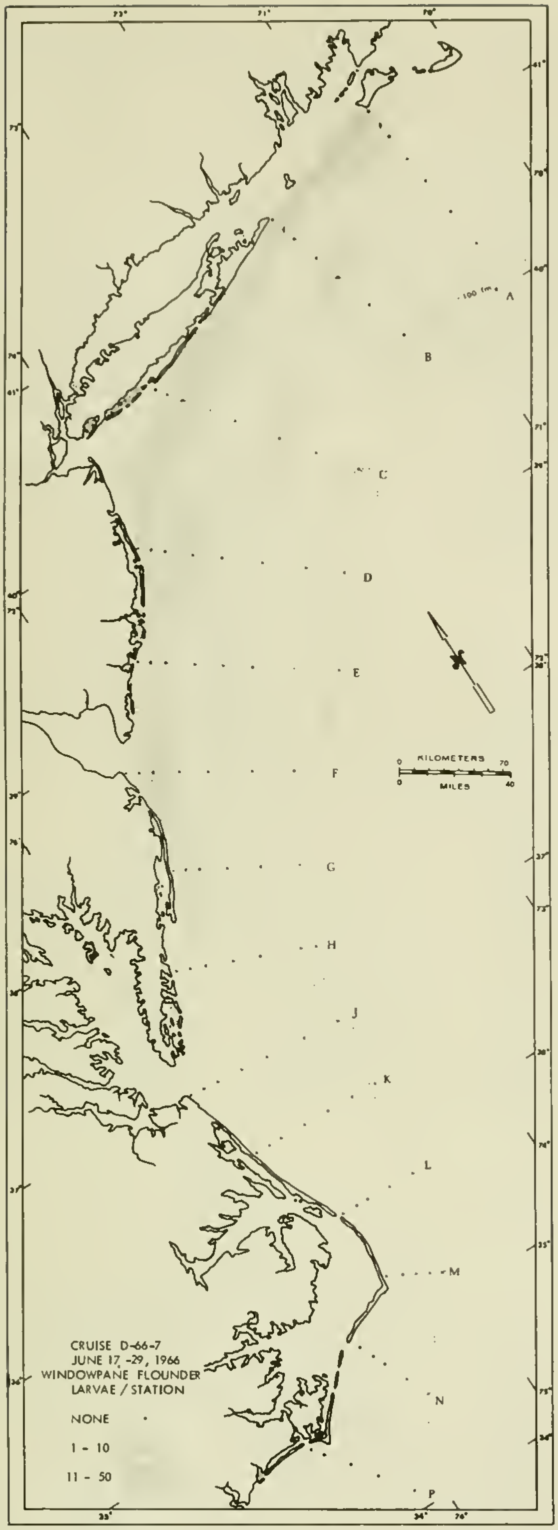


Figure 37.—June 1966. Distribution and relative abundance of windowpane, *Scophthalmus aquosus*, larvae.

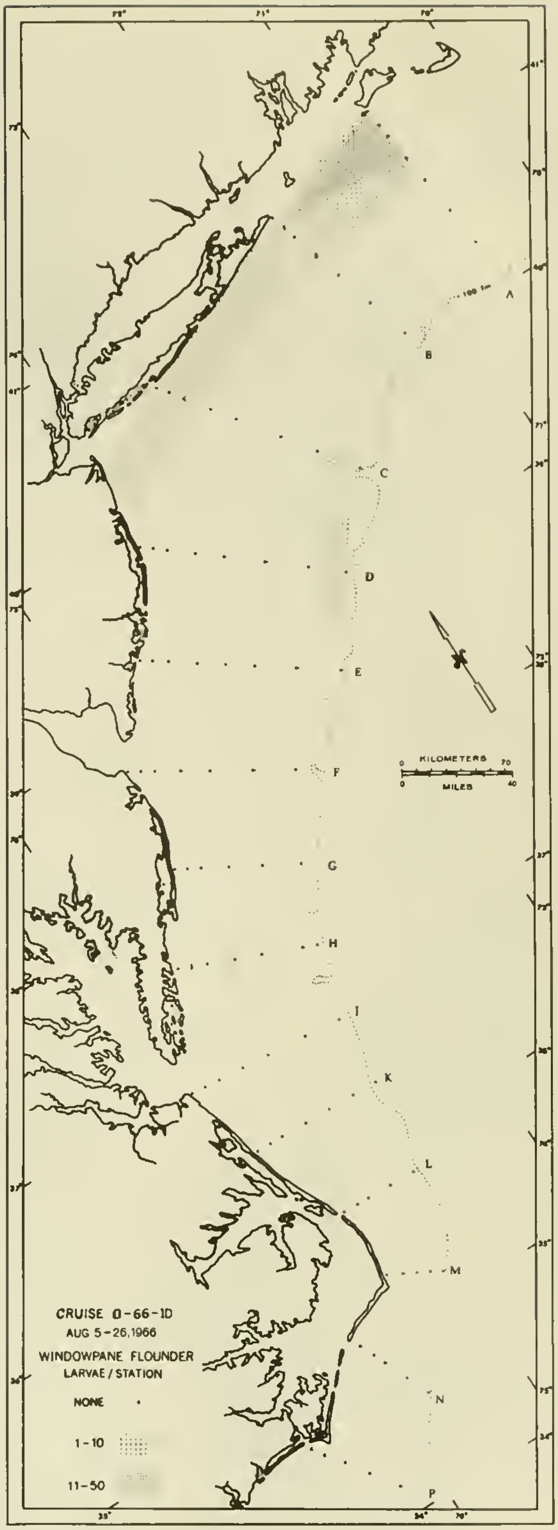


Figure 38.—August 1966. Distribution and relative abundance of windowpane, *Scophthalmus aquosus*, larvae.

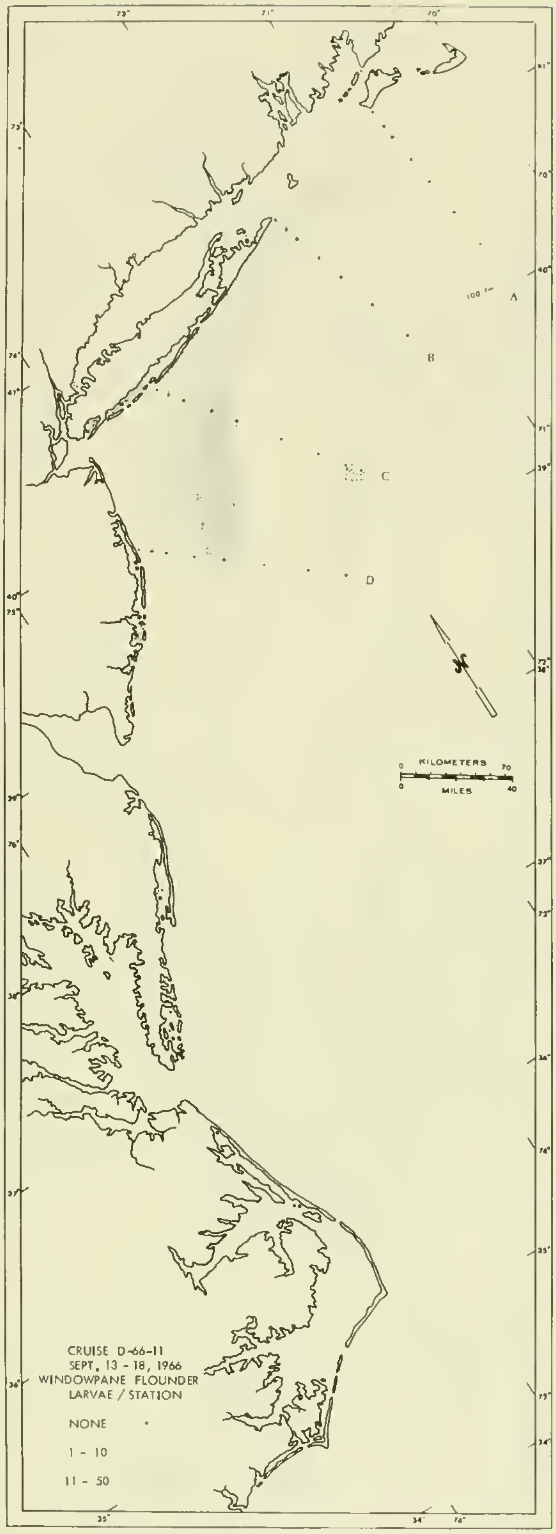


Figure 39.—September 1966. Distribution and relative abundance of windowpane, *Scophthalmus aquosus*, larvae.

they are rare at depths >92 m (Bullis and Thompson 1965). Fraser (1971) found members of the genus *Syacium* in the Straits of Florida at depths from 2 to 140 m, and questioned records from depths exceeding 182 m. Surface isotherms suggest that both stations where we caught larvae in April were within the influence of the Gulf Stream, and, judging from their size and number, we concluded that the larvae had been transported into the survey area (Table 12).

In May, larvae were confined largely to the southern end of the survey area. They were most concentrated between capes Hatteras and Lookout over a depth of 50 m (Fig. 44). Their size range and numbers indicated that spawning intensity had increased since the April cruise (Table 12). As on the previous cruise in April, their distribution seemed restricted to the Gulf Stream or its edge. The shoreward limit of their occurrence closely followed the 20°C surface isotherm.

The catch in June decreased, but the distribution remained essentially the same as in May (Fig. 45). Larvae were most abundant along the outer edge of the shelf off Cape Hatteras, an area where the depth is probably too great for spawning and the Gulf Stream too swift to permit the larvae to remain near the center of spawning. It is improbable that they represented local spawning.

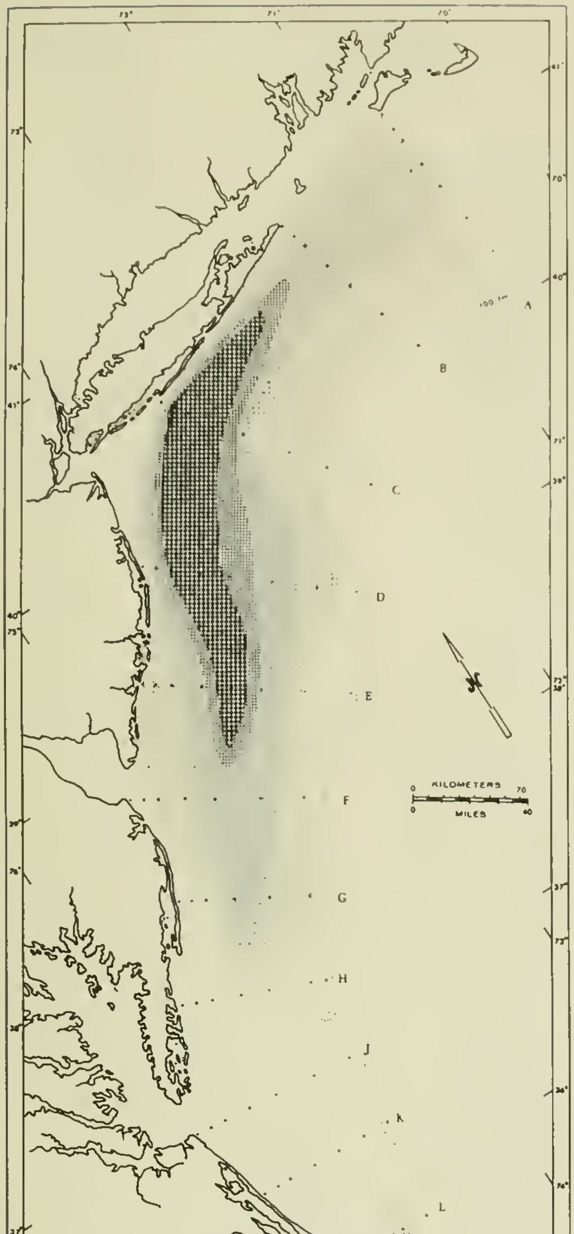
Larvae were most abundant nearshore between capes Hatteras and Lookout in August. These had probably been spawned locally. Although for the first time their distribution extended into the survey area north of Cape Hatteras (Fig. 46), the catch decreased slightly, probably because there was little or no influx from the south such as had been evident during the earlier cruises.

We made our biggest catch in late September (Table 12). The distribution of larvae extended northward to Virginia, well shoreward of the Gulf Stream. The center of abundance occurred at seaward stations between capes Hatteras and Lookout, and probably represented spawning that had occurred south of the survey area (Fig. 47).

Spawning dropped off sharply by November. We caught fewer larvae than in September, and, with one exception, their distribution had receded to that part of the survey area between the North Carolina capes. The exception, a single specimen captured off northern Virginia, represented the northernmost occurrence of this species in our survey (Fig. 48).

We caught only six larvae in December (1965), all at stations near the outer edge of the shelf south of Cape Hatteras. None were taken on the following cruise in January and February. Judging from the size of the larvae (Table 12), and their absence on the following cruise, we presumed that spawning had ended sometime in November or, at the latest, early December. Since many of the larvae we caught had been transported into the survey area by the Gulf Stream, it is possible that our catches in December reflected the end of spawning along the entire east coast.

Like most warmwater fishes, dusky flounder have a protracted spawning season. We caught larvae over a 9-mo period, mostly off the North Carolina coast between capes Hatteras and Lookout (Fig. 49). The spawning season in this area is not very different from that noted for dusky flounder in the Gulf of Mexico (Topp and Hoff 1972) and Tampa Bay, Fla. (Moe and Martin 1965). They postulated, from gonadal observations, that spawning occurred from February to November, peaking in May and June. Our collections indicate that spawning lasts from April to October or November. Larvae were most abundant from May through September, and these months probably represent the height of the



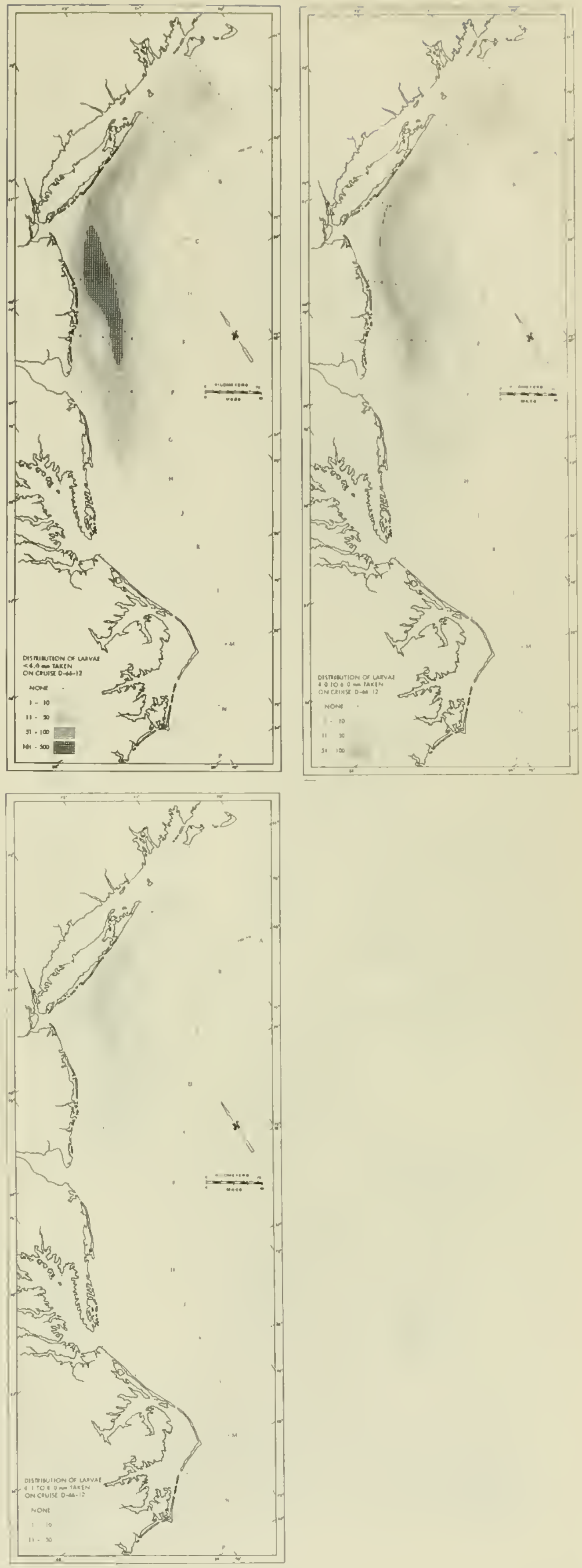


Figure 40.—September to October 1966. Distribution and relative abundance of windowpane, *Scophthalmus aquosus*, larvae (left) and (right) their distribution and relative abundance by size groups. Top <4.0 mm, 4.0 to 6.0 mm; bottom 6.1 to 8.0 mm.

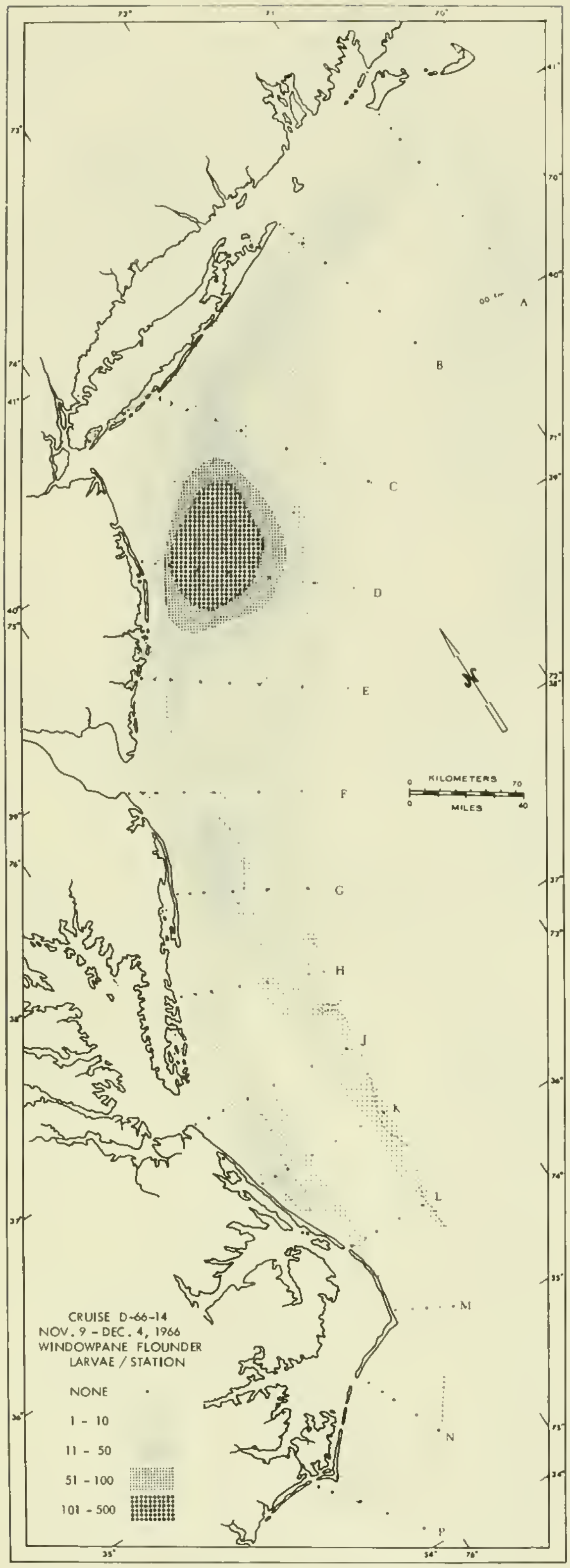
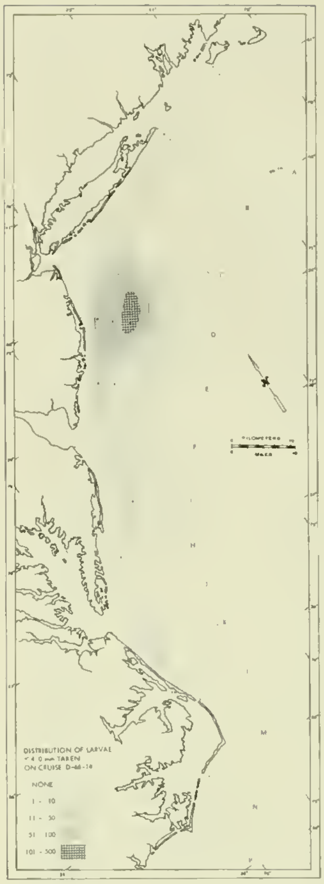
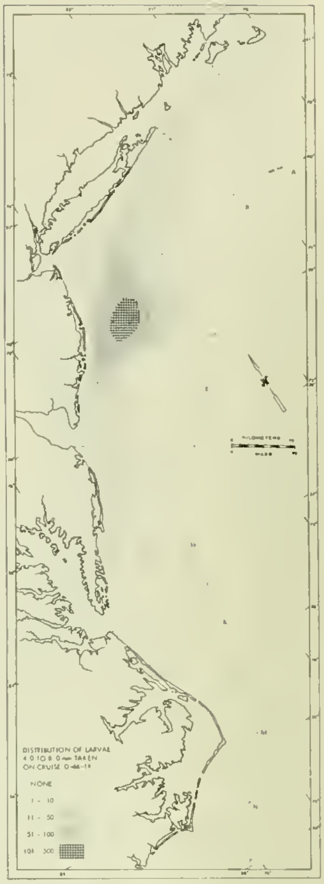
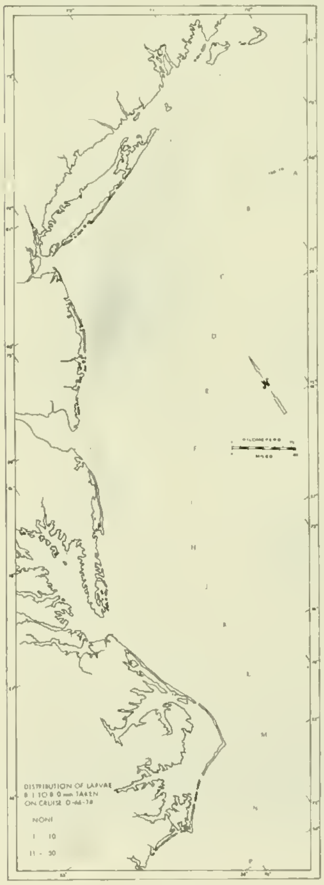
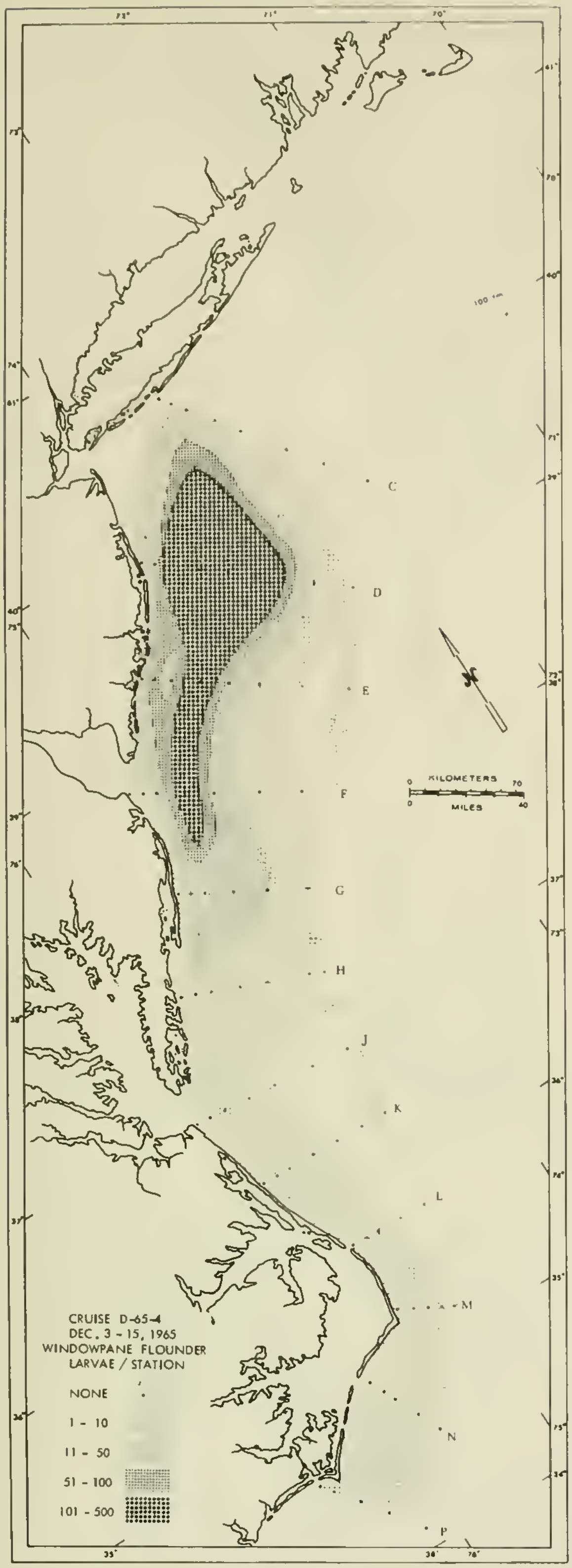


Figure 41.—November to December 1966. Distribution and relative abundance of windowpane, *Scophthalmus aquosus*, larvae (left) and (right) their distribution and relative abundance by size groups. Top <4.0 mm, 4.0 to 6.0 mm; bottom 6.1 to 8.0 mm.









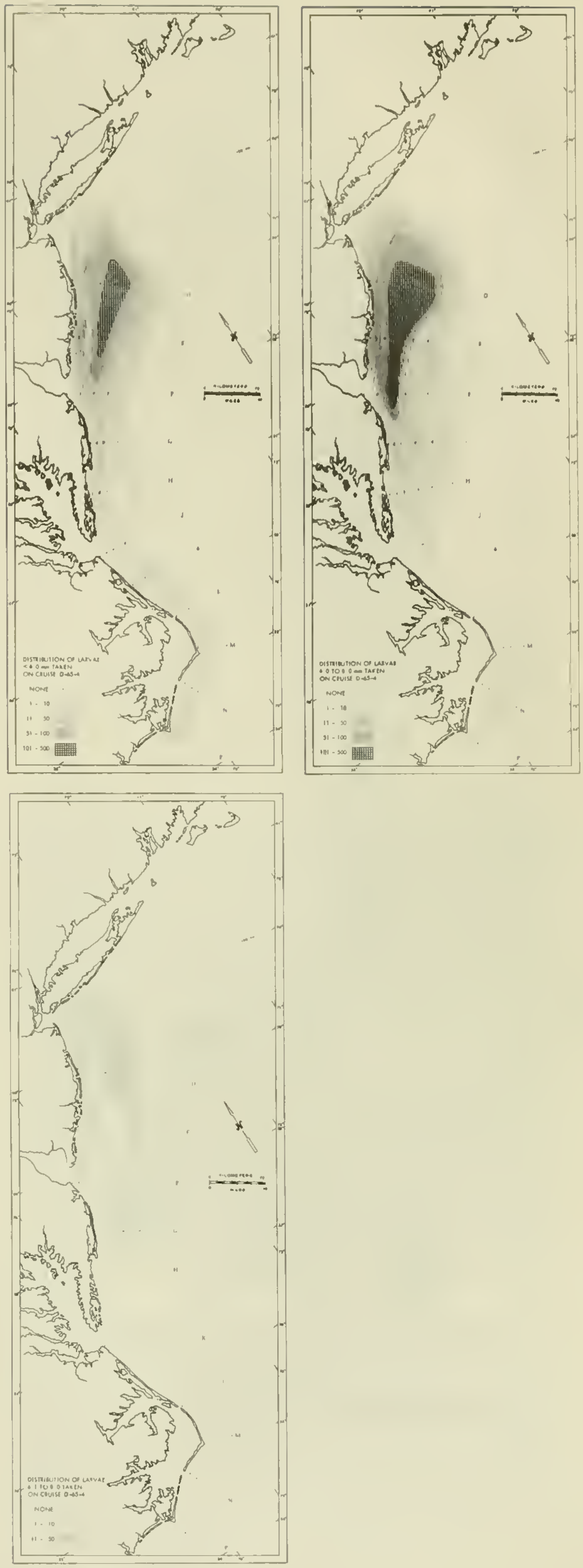


Figure 42.—December 1965. Distribution and relative abundance of windowpane, *Scophthalmus aquosus*, larvae (left) and (right) their distribution and relative abundance by size groups. Top <4.0 mm, 4.0 to 6.0 mm; bottom 6.1 to 8.0 mm.

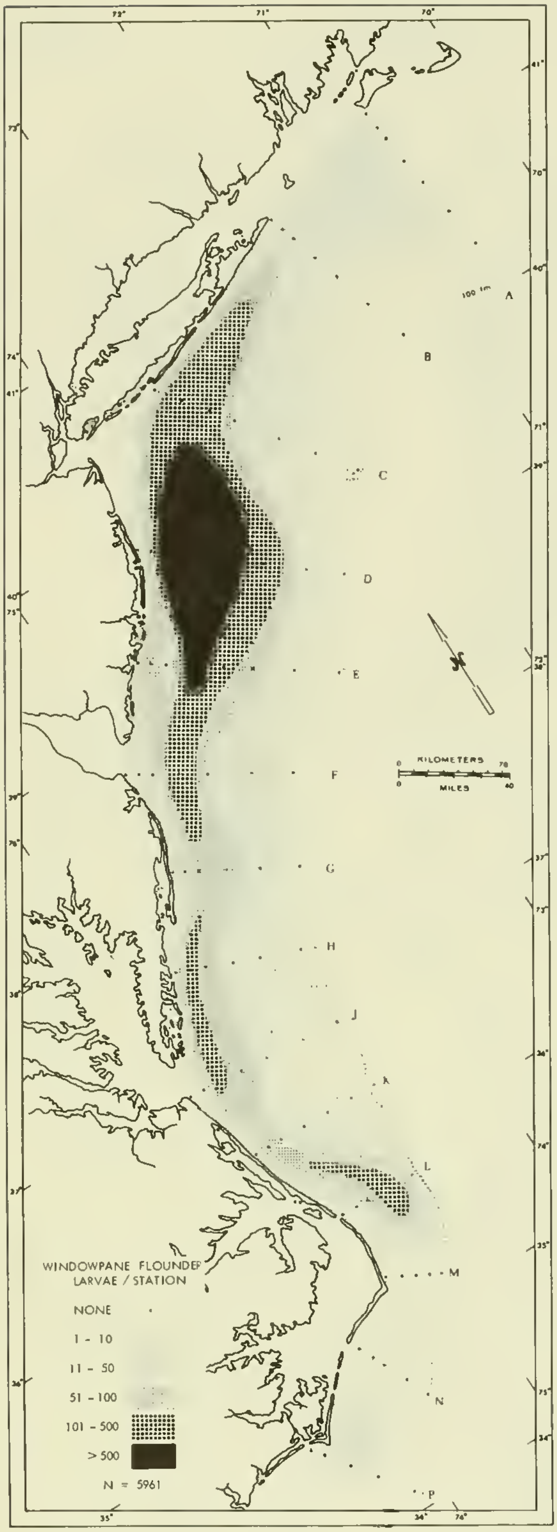


Figure 43.—Distribution and relative abundance of windowpane, *Scophthalmus aquosus*, larvae collected during 1965-66 survey.

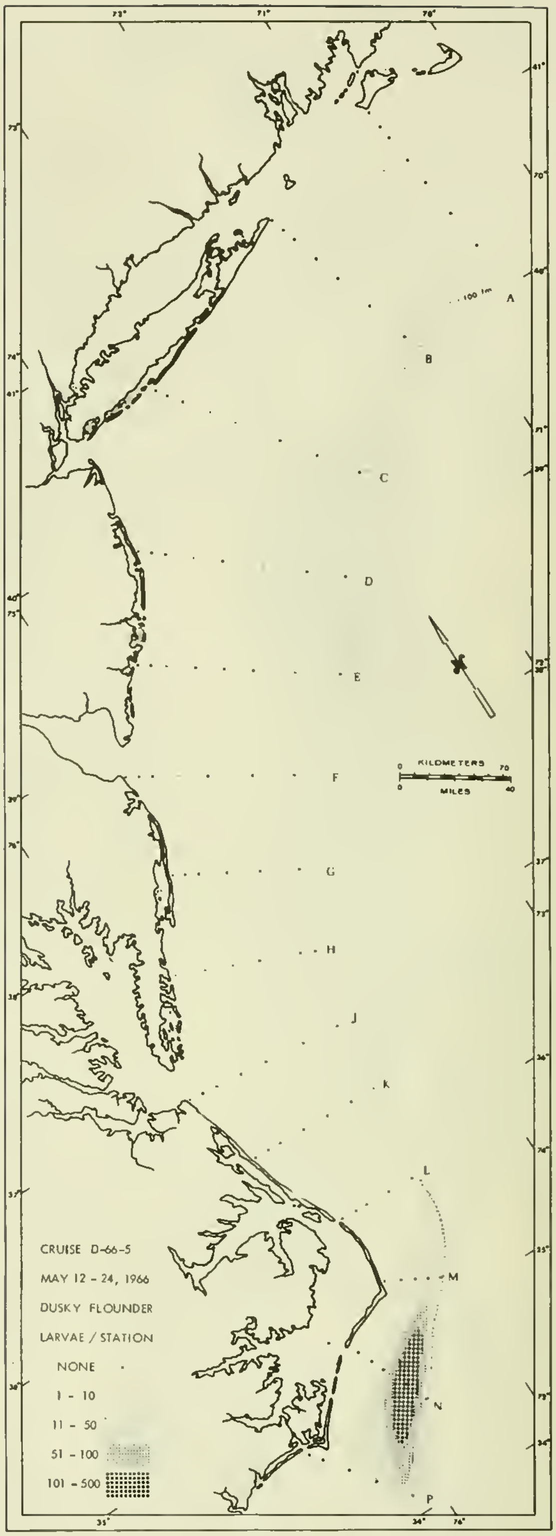


Figure 44.—May 1966. Distribution and relative abundance of dusky flounder, *Syacium papillosum*, larvae.

Table 12.--The seasonal distribution of dusky flounder, *Syacium papillosum*, larvae by size. Numbers are adjusted to standardize sampling effort.

Larval length (mm)	66-3 Apr.	66-5 May	66-7 June	66-10 Aug.	66-12 Sept.-Oct.	66-14 Nov.-Dec.	65-4 Dec.	Total
	Number of larvae							
1.1- 2.0			2	1				3
2.1- 3.0		42	41	25	70			178
3.1- 4.0	2	161	43	64	78	14	1	363
4.1- 5.0	1	94	105	111	125	14		450
5.1- 6.0		35	42	18	89	13		197
6.1- 7.0	1	13	16	14	58	5	2	109
7.1- 8.0		3	8	9	22	7		49
8.1- 9.0			2	9	12	4	1	28
9.1-10.0			4	2	11	3	1	21
10.1-11.0			2	1	5	1	1	10
11.1-12.0		1	1	2	9	3		16
12.1-13.0					2	2		4
13.1-14.0					3	2		5
Total	4	349	266	256	484	68	6	1,433

spawning season along the entire Atlantic coast.

II. Family Pleuronectidae—Righteye Flounders

Glyptocephalus cynoglossus (Linnaeus), witch flounder.—Witch flounder are deepwater pleuronectids that range from Newfoundland to North Carolina. They generally occur at depths between 90 and 330 m. Although more common north of Cape Cod than in the bight, adults are moderately plentiful off southern New England (Bigelow and Schroeder 1953), where most of the larvae were collected during our survey. Bigelow and Schroeder (1953) found no evidence of seasonal movements, but Powles and Kohler (1970) reported that adults tend to inhabit shallower depths in summer, the spawning season, than in winter in the Gulf of St. Lawrence. Spawning begins in the Gulf of Maine in the spring and continues through the summer months, reaching its peak in July and August (Bigelow and Schroeder 1953). Larvae were described by Bigelow and Schroeder (1953) and Colton and Marak (1969).

We caught larvae from April to October. In the area which we surveyed, spawning evidently peaked during May and June, earlier than in more northern waters. It apparently ended in July, since we caught no larvae in August. Although larvae of this species were only moderately abundant in our collections, they were numerous enough to indicate the duration and peak of the spawning season at the southern end of the witch flounder's range.

When we first caught larvae in April, they were scattered between North Carolina and Long Island over depths of 10 to 90 m (Fig. 50). Although some of the larvae were taken in shallower water than that normally frequented by adults, we assumed from their small size and the narrow size range that all were recently hatched. Colton and Marak (1969) reported that larvae were 3.5 to 5.6 mm at hatching, with an average length of 4.8 mm. Most of the witch flounder larvae we caught in April were <6 mm (Table 13).

Spawning advanced both northward and seaward in May. While the distribution of larvae extended the entire length of the bight, the center of abundance was located off Long Island over 75 m of water (Fig. 51). The bottom temperature at the center of abundance was 5°C. We caught a greater size range of larvae than on the previous cruise, and the number of small larvae indicated a marked increase in spawning activity (Table 13). A significant north-to-south gradation was evident in the size of larvae. Those captured off Long Island and southern New England were small and recently hatched ($\bar{x}$ = 5.6 mm). They were progressively larger from New Jersey ($\bar{x}$ = 6.5 mm) to North Carolina ($\bar{x}$ = 11.6 mm). This size difference might reflect growth during transport southward along the shelf or, alternatively, earlier spawning off North Carolina than off southern New England.

The distribution of larvae in June was continuous from southern New England to Maryland. Further south, larvae were scattered. The center of abundance occurred off eastern Long Island and southern New England, east of that in May, over 80 to 90 m of water (Fig. 52). Although the areal extent of larval distribution was less than during the previous cruise, the catch was slightly greater (Table 13). The north-to-south progression in size of larvae was again evident. Those caught off southern New England and eastern Long Island had a mean length of 6.3 mm; off

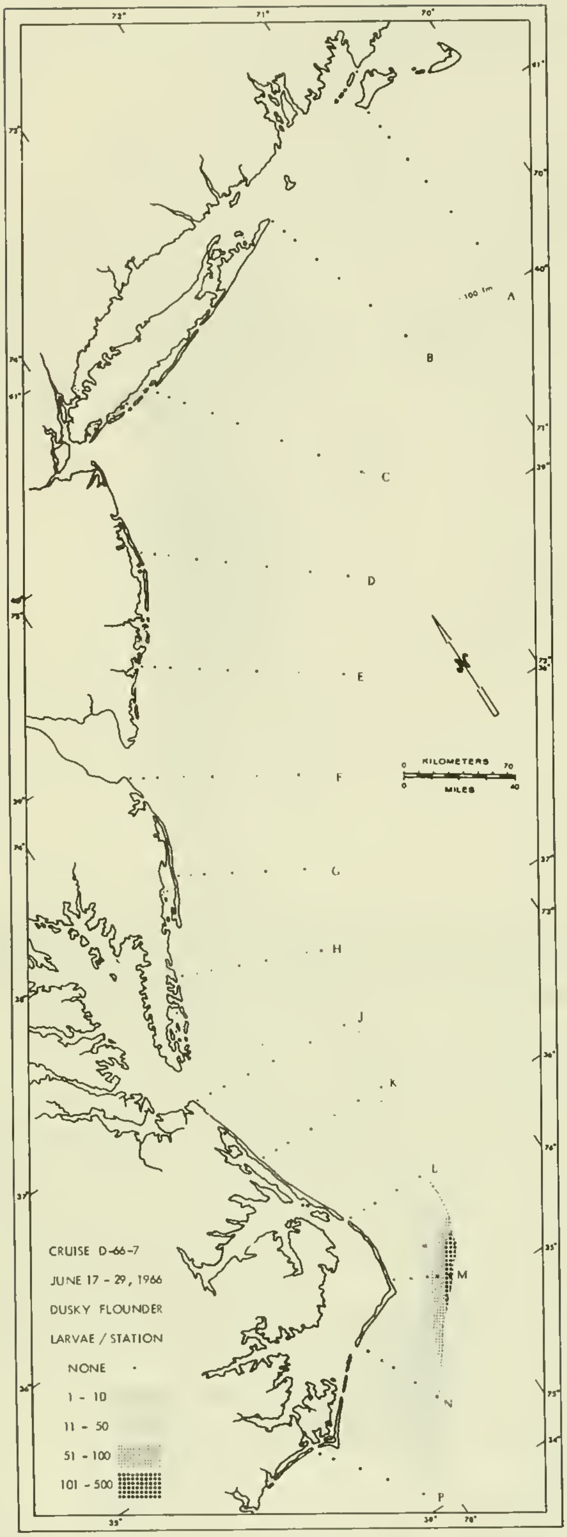


Figure 45.—June 1966. Distribution and relative abundance of dusky flounder, *Syacium papillosum*, larvae.

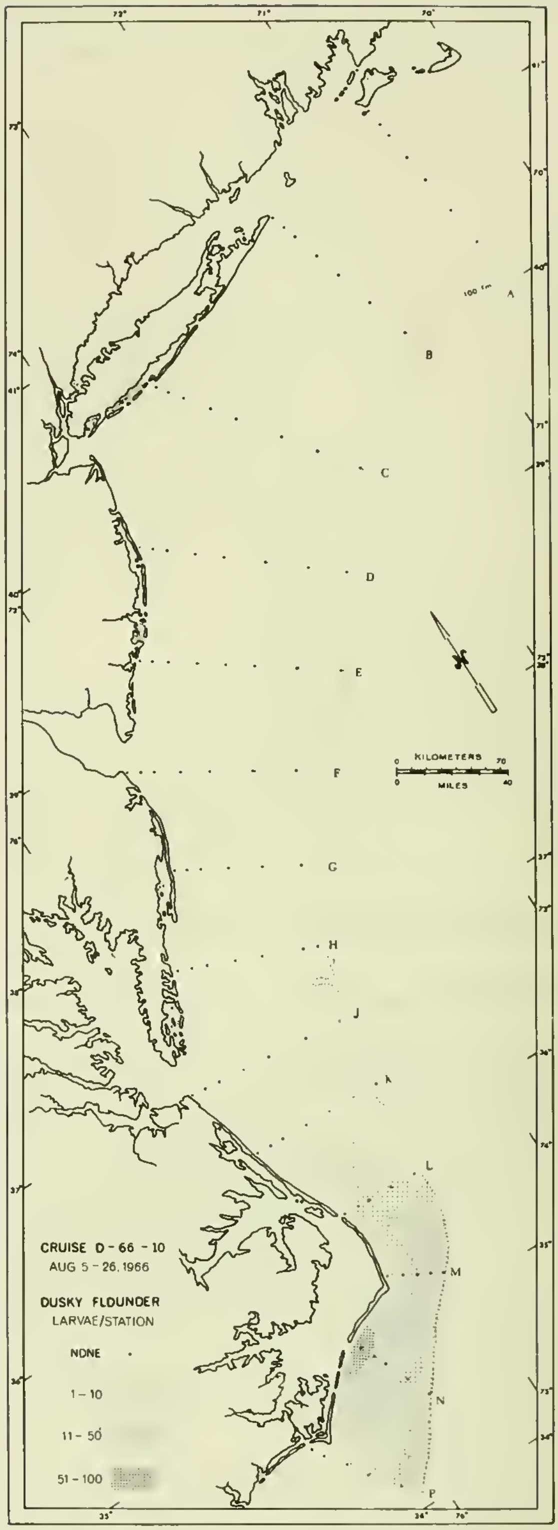


Figure 46.—August 1966. Distribution and relative abundance of dusky flounder, *Syacium papillosum*, larvae.

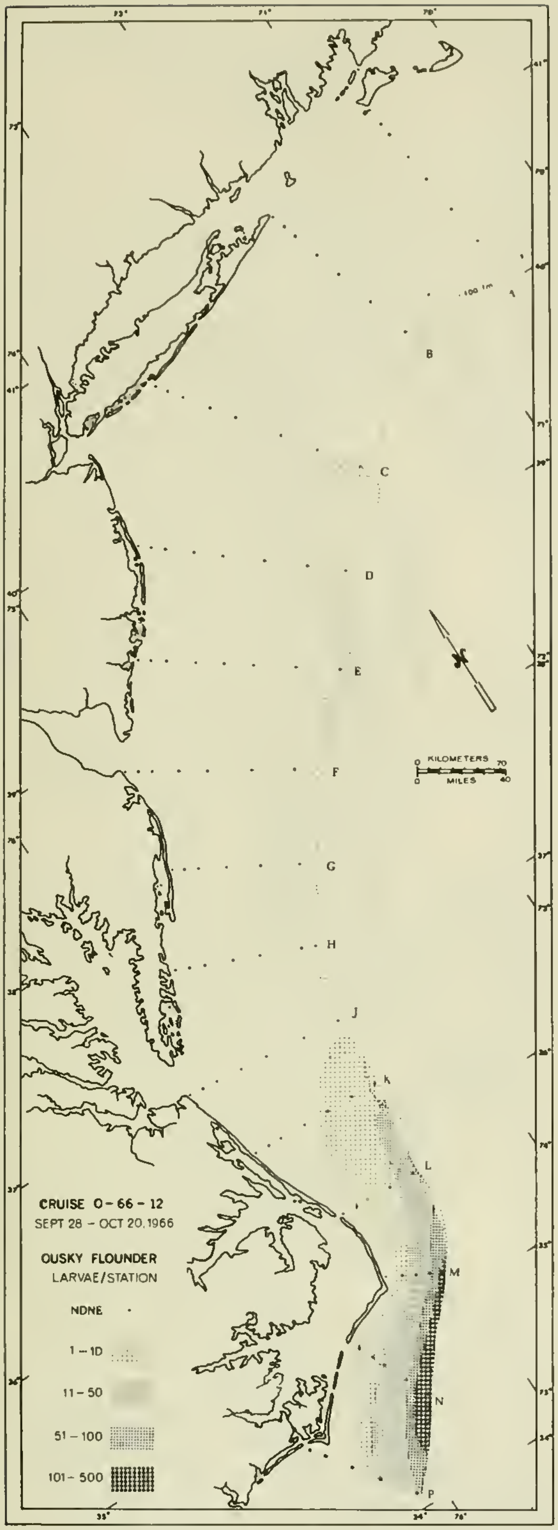


Figure 47.—September to October 1966. Distribution and relative abundance of dusky flounder, *Syacium papillosum*, larvae.

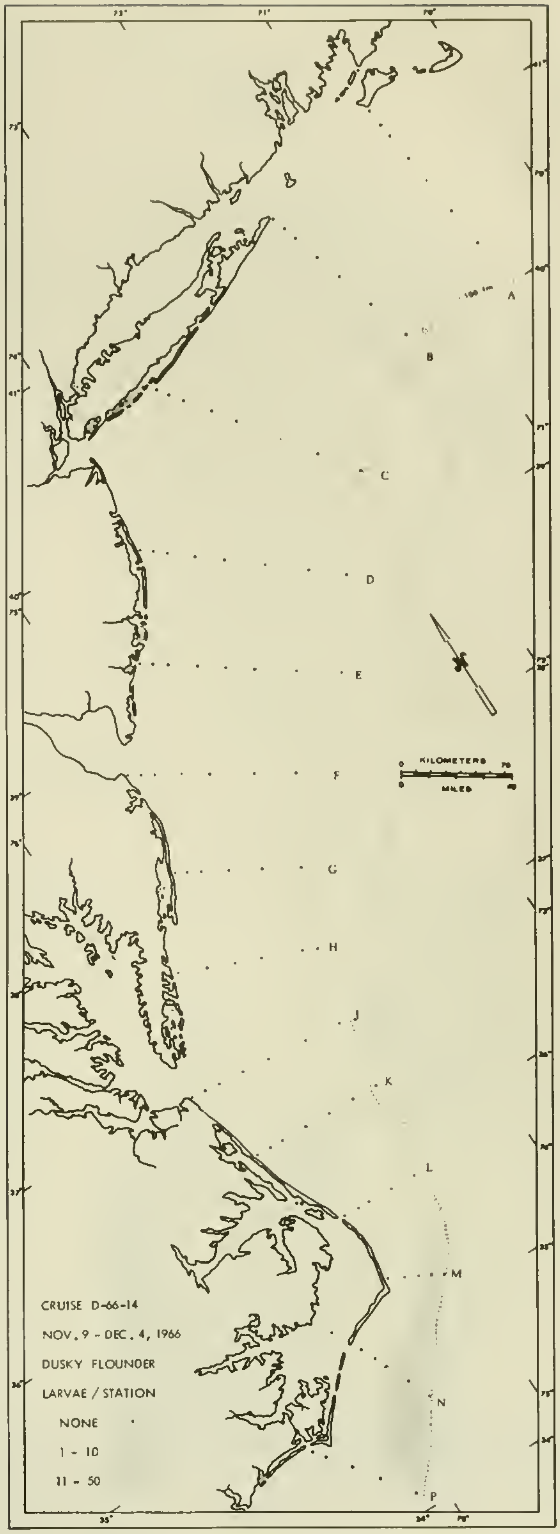


Figure 48.—November to December 1966. Distribution and relative abundance of dusky flounder, *Syacium papillosum*, larvae.

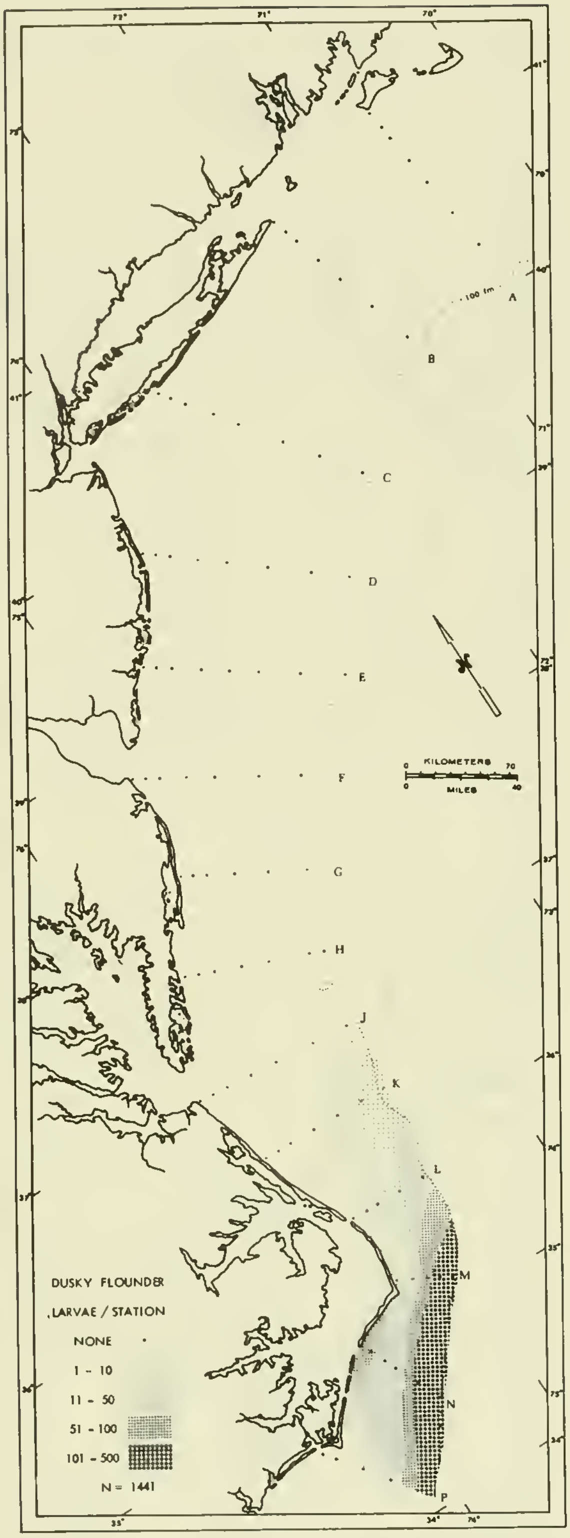


Figure 49.—Distribution and relative abundance of dusky flounder, *Syacium papillosum*, larvae collected during 1965-66 survey.

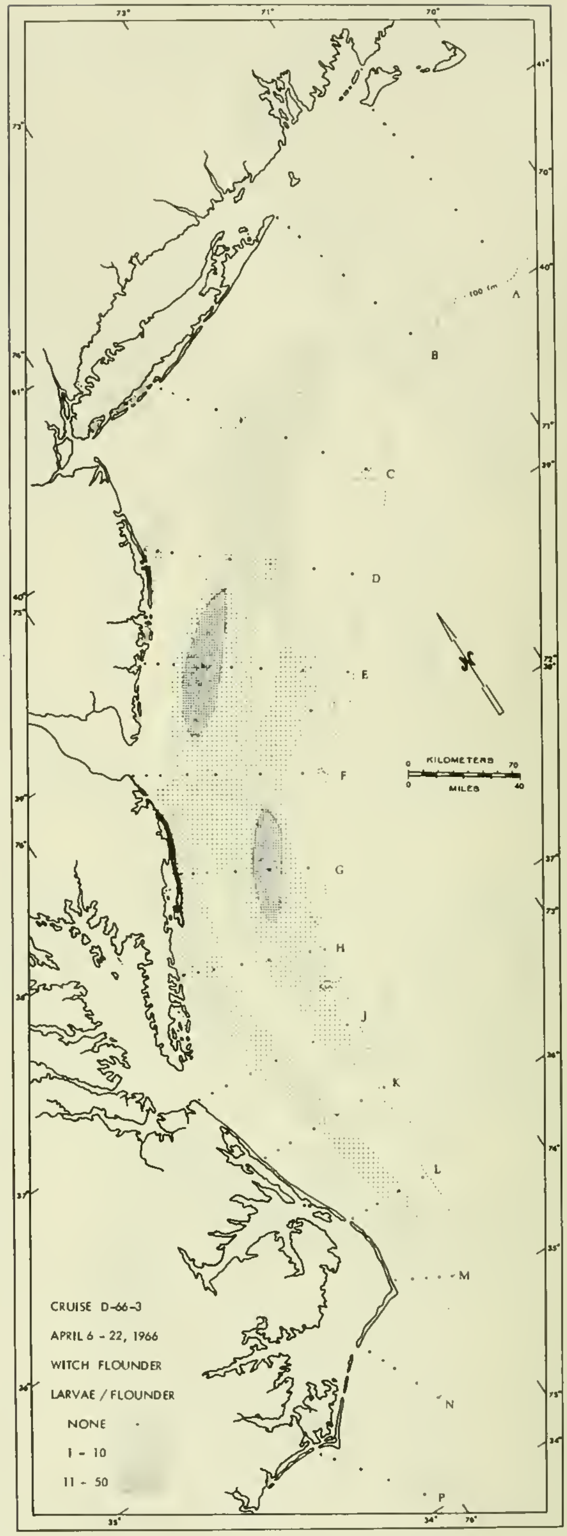


Figure 50.—April 1966. Distribution and relative abundance of witch flounder, *Glyptocephalus cynoglossus*, larvae.

Table 13.--The seasonal distribution of witch flounder, Glyptocephalus cynoglossus, larvae by size. Numbers are adjusted to standardize sampling effort.

Larval length (mm)	Cruise and date: 66-3 Apr.	66-5 May	66-7 June	66-10 Aug.	66-11 Sept.	66-12 Sept.-Oct.	Total
	Number of larvae						
3.1- 4.0		2	41	1			44
4.1- 5.0	17	106	79	4			206
5.1- 6.0	31	212	77	7	1		328
6.1- 7.0	6	74	67	5			152
7.1- 8.0	2	26	81	5			114
8.1- 9.0		11	65	6	1		83
9.1-10.0		8	27	7			42
10.1-11.0		3	21	12			36
11.1-12.0		5	6	9			20
12.1-13.0		4	5	11			20
13.1-14.0		3	4	4			11
14.1-15.0		5	5	7			17
15.1-16.0		1	3	5	1		10
16.1-17.0			2	4			6
17.1-18.0		2	5	4			11
18.1-19.0				2	2		4
19.1-20.0			3	2	1		6
20.1-21.0			1	4		1	6
21.1-22.0							
22.1-23.0		1		1		1	3
23.1-24.0			1	2			3
24.1-25.0			1	4	1		6
25.1-26.0				2			2
26.1-27.0			1	1			2
27.1-28.0				3			3
28.1-43.0			3	4	1	2	10
Total	56	463	498	116	8	4	1,145

western Long Island to Virginia 10.7 mm; and off North Carolina 28.0 mm.

Spawning had nearly ended by August. Although the distribution of larvae was continuous from New England to North Carolina, we caught far fewer than during the previous two cruises, and larvae <6 mm were taken at only two stations (Fig. 53). Compared to the previous cruise, larvae throughout the survey area increased in average size. Those caught in the northern corner of the survey area had a mean length of 10.1 mm, and from Long Island to Virginia 18.0 mm. The lone specimen caught off North Carolina was 27.1 mm long.

Cruises in September and October yielded a total of 12 larvae, which were scattered from southern New England to the outer banks of North Carolina. Only two were <15 mm, which is further evidence that spawning in the bight had run its course by August, a month when spawning is at its peak north of Cape Cod.

As with other spring-spawning flatfishes, the spawning season of witch flounder begins in the southern part of the range and subsequently progresses northward. Although we first caught larvae off Virginia and North Carolina, the most important spawning grounds in the bight were off Long Island and southern New England, the part of the survey area where other pleuronectid larvae (Fig. 54) were most abundant during our survey.

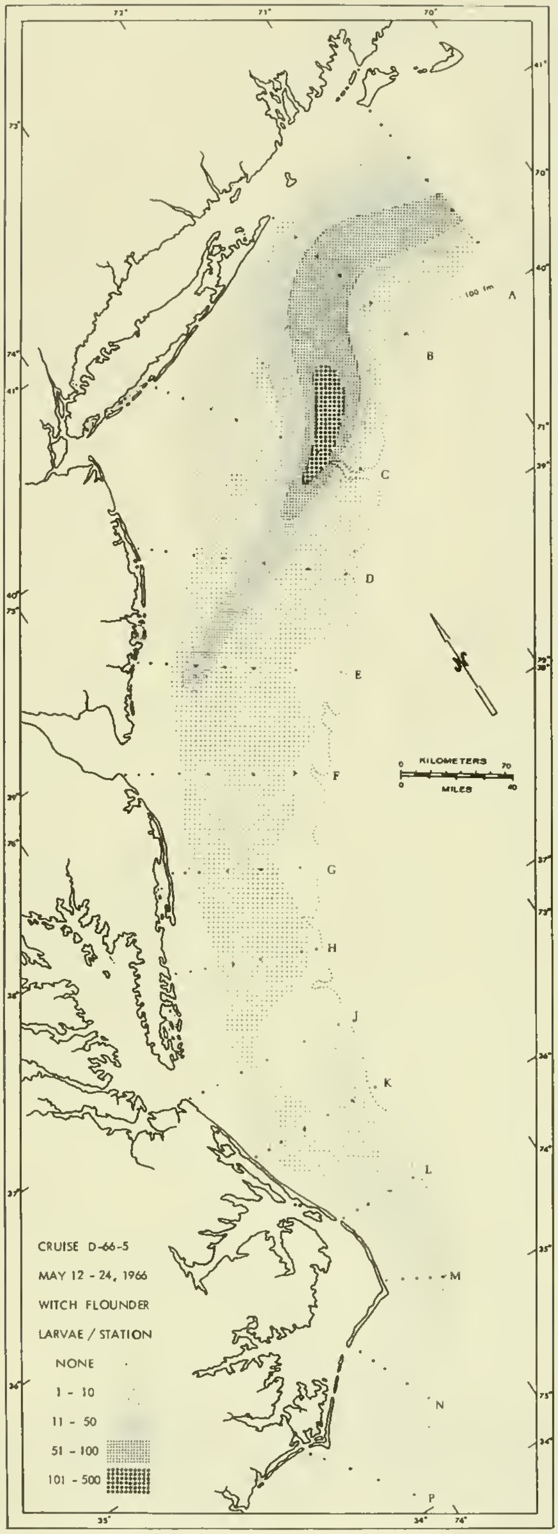


Figure 51.—May 1966. Distribution and relative abundance of witch flounder, *Glyptocephalus cynoglossus*, larvae.

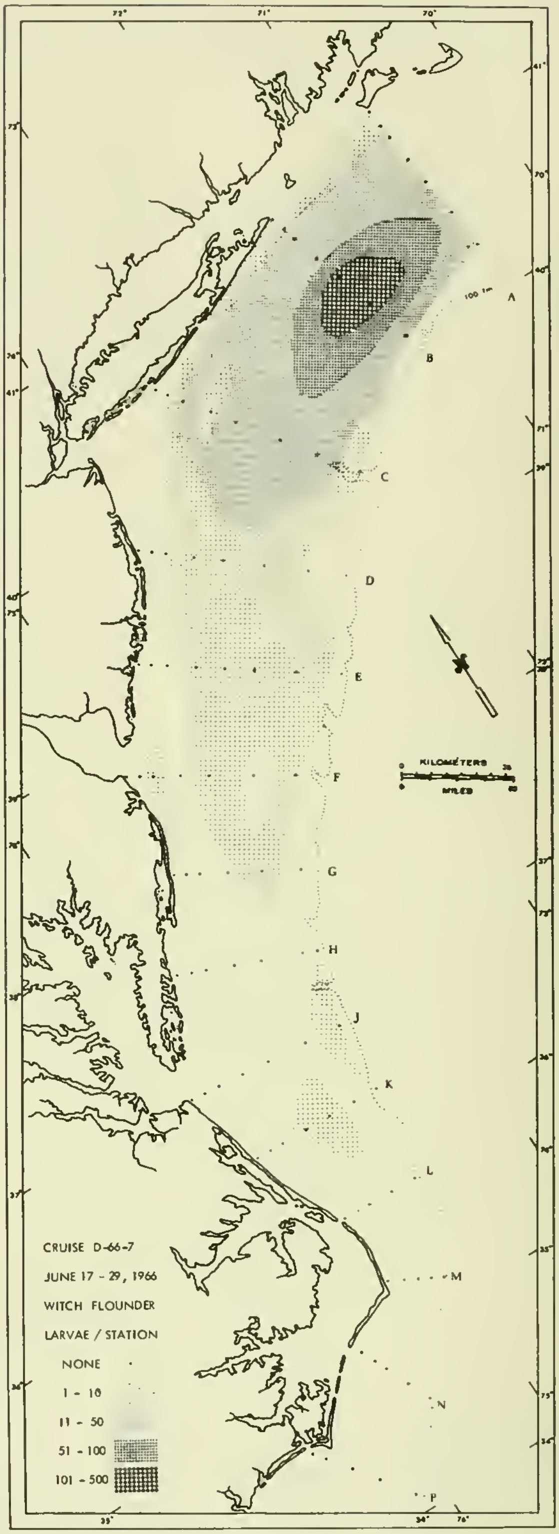


Figure 52.—June 1966. Distribution and relative abundance of witch flounder, *Glyptocephalus cynoglossus*, larvae.

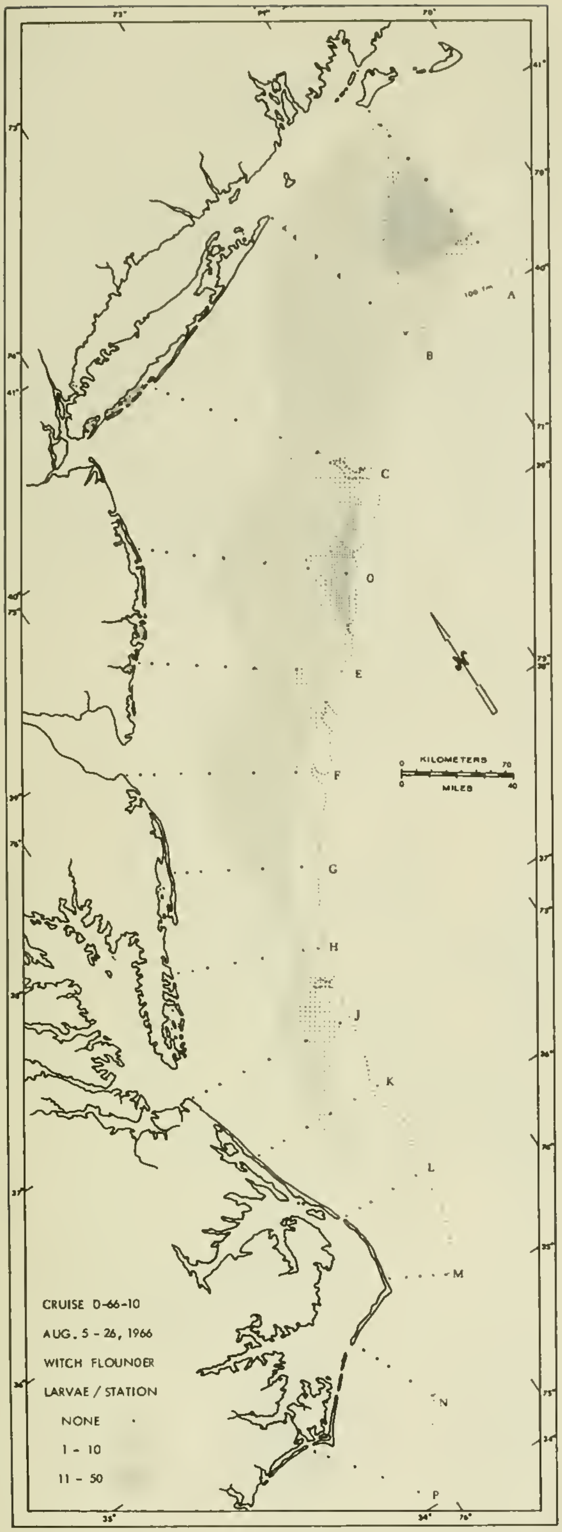


Figure 53.—August 1966. Distribution and relative abundance of witch flounder, *Glyptocephalus cynoglossus*, larvae.

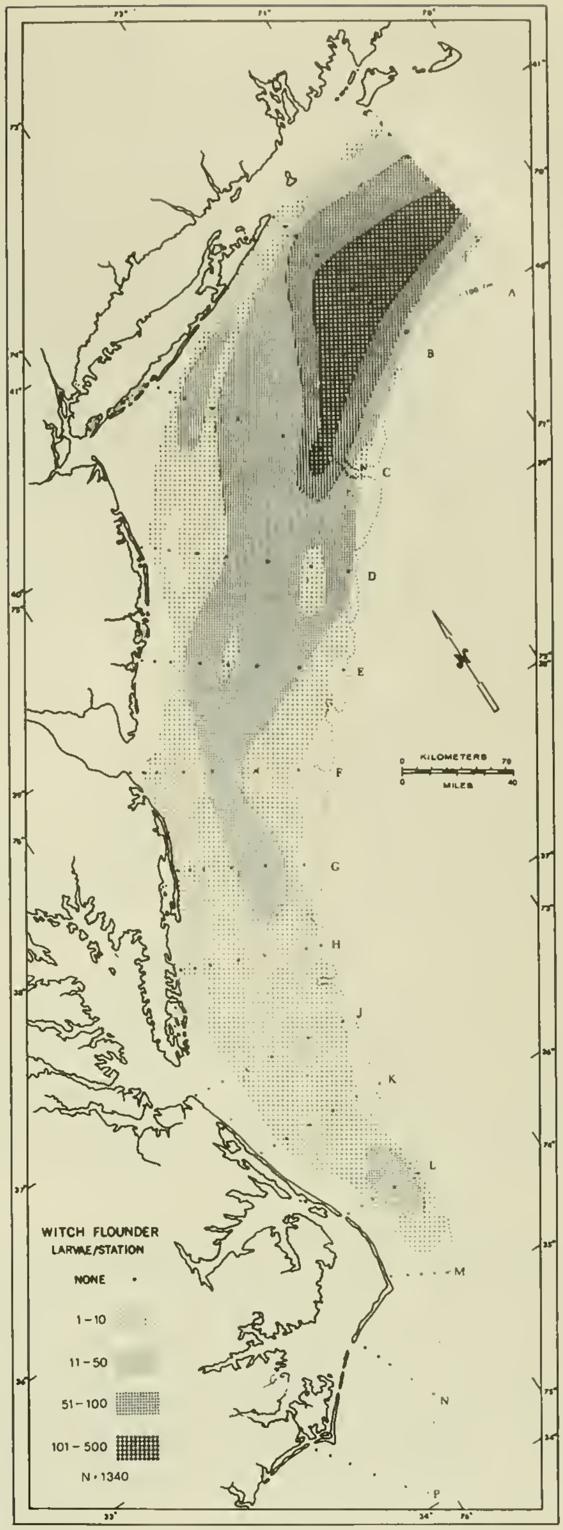


Figure 54.—Distribution and relative abundance of witch flounder, *Glyptocephalus cynoglossus*, larvae collected during 1965-66 survey.

Hippoglossus hippoglossus (Linnaeus), Atlantic halibut.—Atlantic halibut inhabit boreal and subarctic waters on both sides of the Atlantic Ocean. Although they have been caught as far south as Virginia in the western Atlantic, those taken south and west of Nantucket Shoals and the southern edge of Georges Bank are considered stragglers (Bigelow and Schroeder 1953). Larvae were described by Schmidt (1904).

Unlike most other pleuronectids, halibut have an extended spawning season. Ripe females have been reported from April through early September from Georges Bank to the Grand Banks. In the eastern Atlantic, most spawning takes place in the spring, though ripe adults have been captured as early as January (Bigelow and Schroeder 1953).

We caught only one larva, a 21.2 mm specimen, during the survey. It was taken near the Hudson Canyon at station C-7 on 14 May (Fig. 1). It probably originated somewhere on Georges Bank and was subsequently transported by coastal circulation into the bight.

Hippoglossoides platessoides (Fabricius), American plaice.—American plaice are found on both sides of the Atlantic Ocean. This arctic-boreal pleuronectid is most common from Newfoundland to Cape Cod in the western Atlantic. Martha's Vineyard marks the southern limit of its range. Spawning begins in March, peaks in May, and ends by mid-June north of Cape Cod (Bigelow and Schroeder 1953). Larvae were described by Bigelow and Schroeder (1953) and Colton and Marak (1969).

Our survey area overlapped the distribution of plaice in the vicinity of Cape Cod. Although we caught larvae during only one cruise, their occurrence in our samples conforms with both the spawning season and the southern limit of adult distribution reported by Bigelow and Schroeder (1953).

We caught 80 larvae in May at the northern end of the survey area. There were no concentrations that would suggest nearby spawning; instead, the larvae were scattered mostly south of Martha's Vineyard (Fig. 55). Their size range (5.1 to 16.4 mm), infrequent occurrence, sparseness, and the general circulation pattern off southern New England all suggest that these larvae had been spawned along the southern edge of Georges Bank and subsequently carried into the bight by currents.

Limanda ferruginea (Storer), yellowtail flounder.—Yellowtail flounder, the most economically important flatfish in the western North Atlantic, range from the Gulf of St. Lawrence to Chesapeake Bay, but they are most abundant from the western Gulf of Maine to southern New England. Spawning north of Cape Cod begins in March, peaks in May, and continues through the summer (Bigelow and Schroeder 1953). Although the center of abundance of adults lies north and east of the bight, yellowtail flounder larvae were the most abundant flatfish larvae in our collections. Larvae were described by Perlmutter (1939), Bigelow and Schroeder (1953), and Colton and Marak (1969).

Larvae first appeared in our April samples, and we assume that spawning began sometime between then and the end of the January-February cruise, probably in March. Their distribution extended from North Carolina to the eastern tip of Long Island. The greatest concentration of larvae was located 55 km off southern New Jersey over depths of 30 to 40 m, where the bottom temperature was 6.6°C. The majority of the larvae in the center of abundance

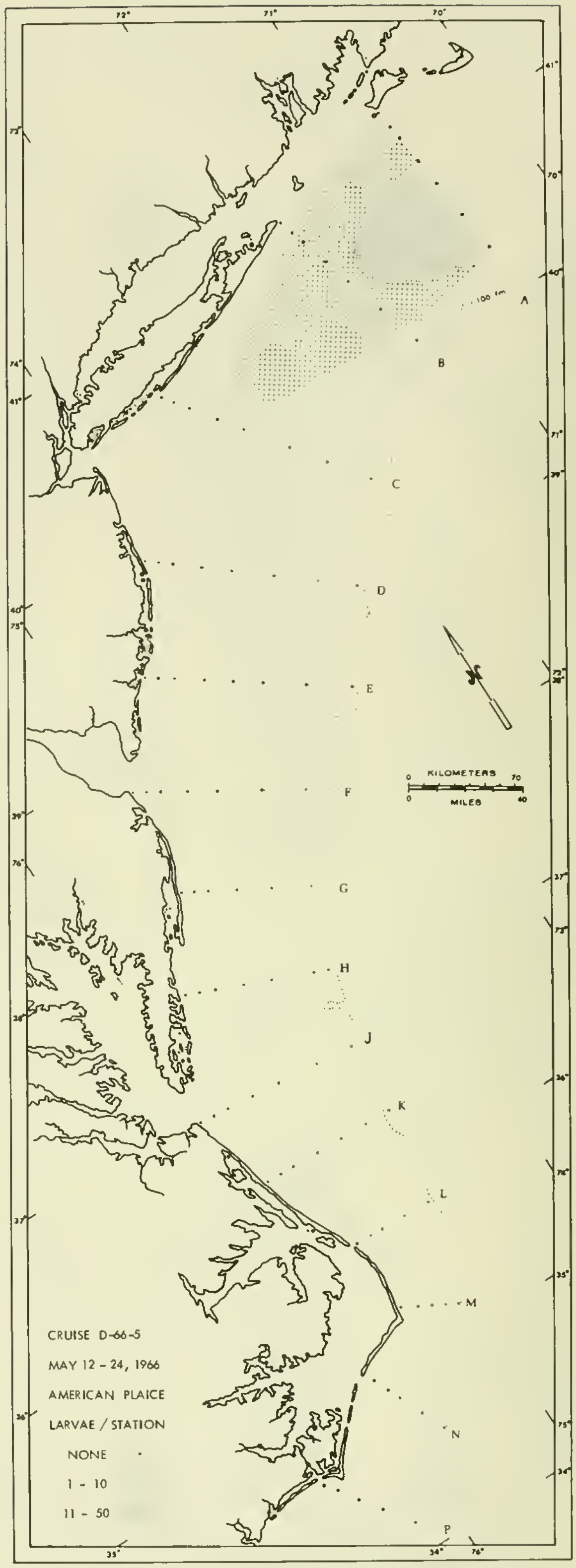


Figure 55.—May 1966. Distribution and relative abundance of American plaice, *Hippoglossoides platessoides*, larvae.

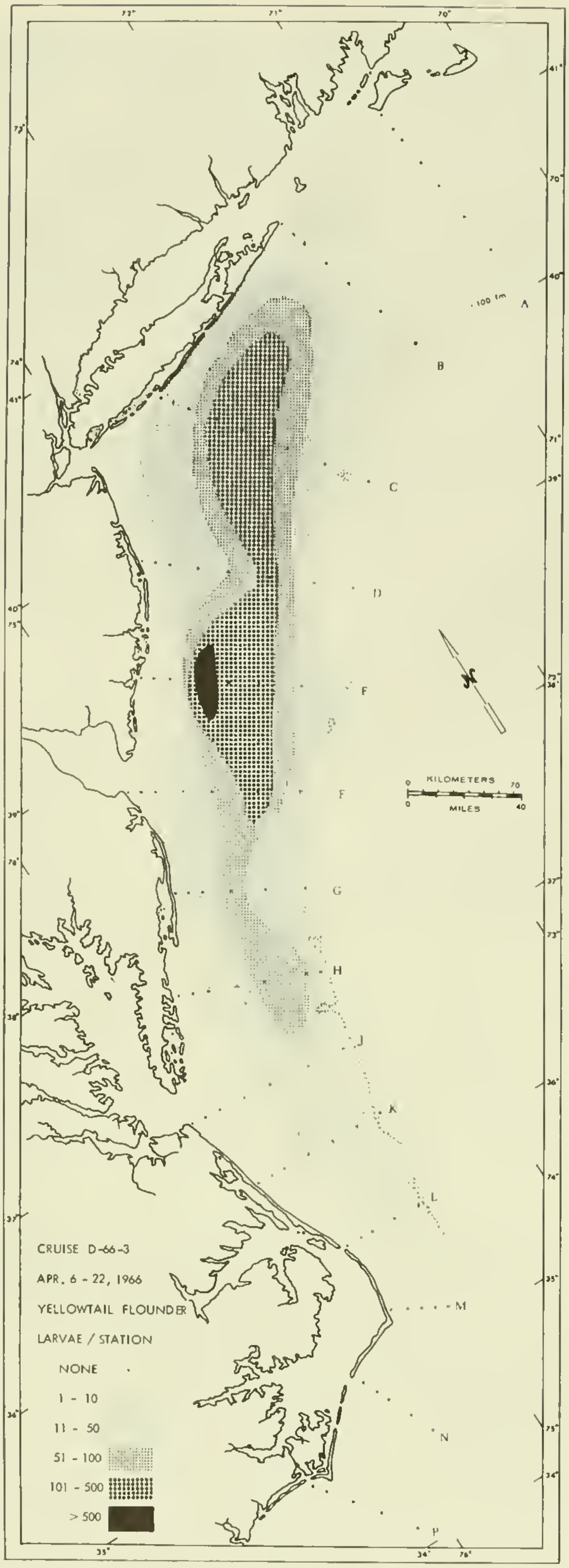
were <4 mm, and probably had been spawned nearby. Intermediate-sized larvae (4.1 to 8.0 mm) were most abundant in the same area, with lesser concentrations found off the Delmarva Peninsula and off northern New Jersey and Long Island. The presence of larvae >4.0 mm both north and south of the center of abundance suggests that spawning was not restricted to waters off the coast of southern New Jersey, but had occurred before the April cruise from North Carolina to New York. Specimens of 8 to 12 mm were taken at just three stations, two off Virginia and one off North Carolina (Fig. 56).

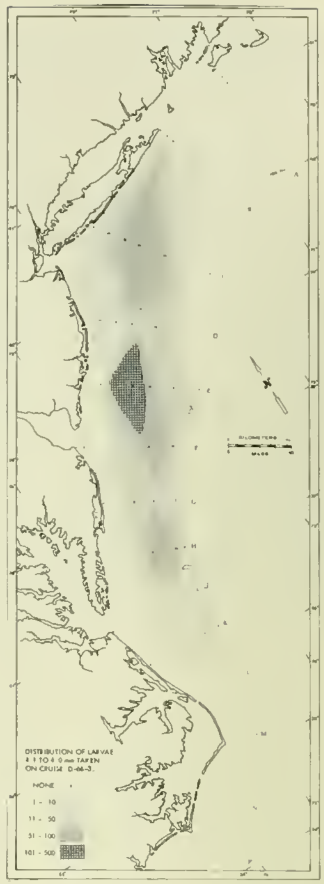
We caught larvae from Cape Hatteras to southern New England in May, finding two concentrations both larger than that found in April. The smaller of the two was located 110 km off Maryland and Delaware. The other covered the small center of abundance found off southern New Jersey in April, and extended north and east to a point 125 km southwest of Montauk Point. Based on the distribution of larvae <4 mm, recent spawning had occurred at depths of 30 to 80 m along a narrow band extending from Virginia to New Jersey, and from eastern Long Island to southern New England at depths of 55 to 75 m. Bottom temperatures off New Jersey and Virginia ranged from 6.8° to 8.7°C and off southern New England from 4.1° to 4.9°C. Intermediate-sized larvae, which made up the bulk of the catch, were abundant from Maryland to southern New England, chiefly off Delaware Bay and off the New Jersey coast. Large larvae, more numerous in May than in April, were caught in two separate areas: one off North Carolina and Virginia and the other from Delaware Bay to Long Island. Specimens >12 mm were caught only off North Carolina and Virginia (Fig. 57).

In June, the areal extent of larval distribution resembled that of May, but the major concentration had shifted to the north and east of the center of abundance of the previous cruise, and was now positioned off southern New England. The distribution of small larvae indicated that recent spawning occurred only off southern New England at depths of 45 to 75 m and bottom temperatures between 4.5° and 8.1°C. As in May, intermediate-sized larvae predominated, but their center of abundance, like that of the smaller group, had moved to the northeastern end of the bight. We caught large larvae from Long Island to North Carolina. They were most abundant midway out on the shelf south of Long Island and east of New Jersey. Unlike the two groups of

Table 14.--The seasonal distribution of yellowtail flounder, *Limanda ferruginea*, larvae by size. Numbers are adjusted to standardize sampling effort. Larvae < 4.1 mm represented recent spawning.

Larval length (mm)	Cruise and date 66-3 Apr.	66-5 May	66-7 June	66-10 Aug.	66-11 Sept.	Total
	Number of larvae					
2.1- 3.0	66	139	98			303
3.1- 4.0	1,011	1,243	1,049	1		3,304
4.1- 5.0	797	2,841	2,376	2		6,016
5.1- 6.0	203	3,053	2,341	12		5,609
6.1- 7.0	65	1,393	1,179	22	1	2,660
7.1- 8.0	17	635	583	31		1,266
8.1- 9.0	8	374	357	30	1	770
9.1-10.0		142	351	23		516
10.1-11.0		48	358	23		429
11.1-12.0	1	12	340	13		366
12.1-13.0		8	381	15	1	405
13.1-14.0		4	399	10		413
14.1-15.0			322	13	1	336
15.1-16.0			209	1		210
16.1-17.0			97	1		98
17.1-18.0			71			71
18.1-19.0			18			18
19.1-20.0			14			14
20.1-21.0			1			1
Total	2,168	9,892	10,544	197	4	22,805





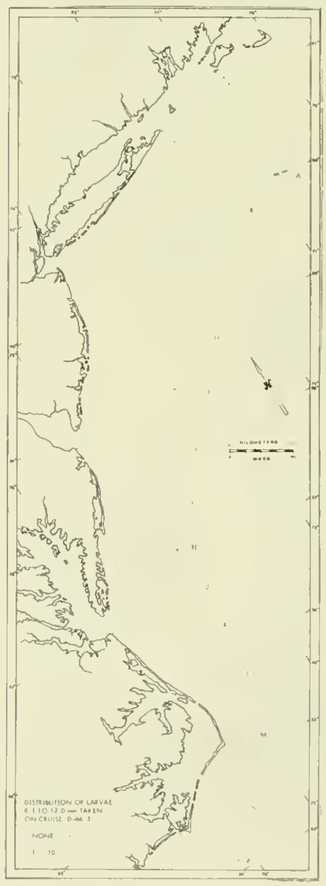
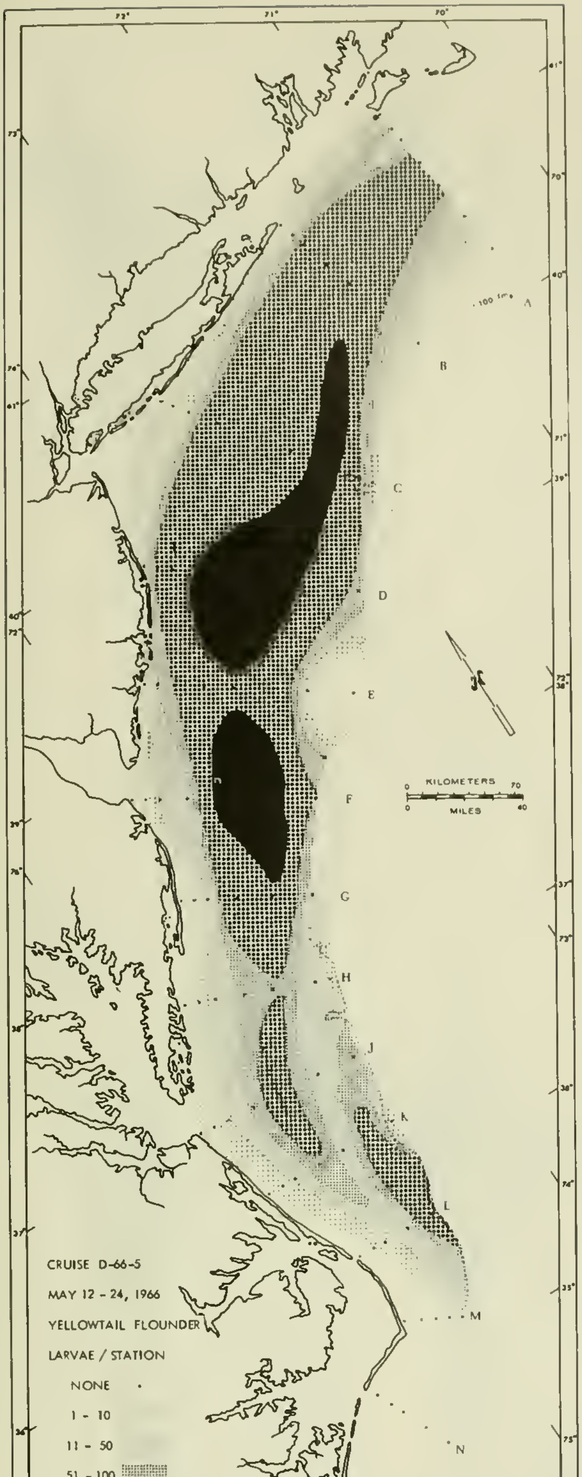


Figure 56.—April 1966. Distribution and relative abundance of yellowtail flounder, *Limanda ferruginea*, larvae (left) and (right) their distribution and relative abundance by size groups. Top 2.1 to 4.0 mm, 4.1 to 8.0 mm; bottom 8.1 to 12.0 mm.



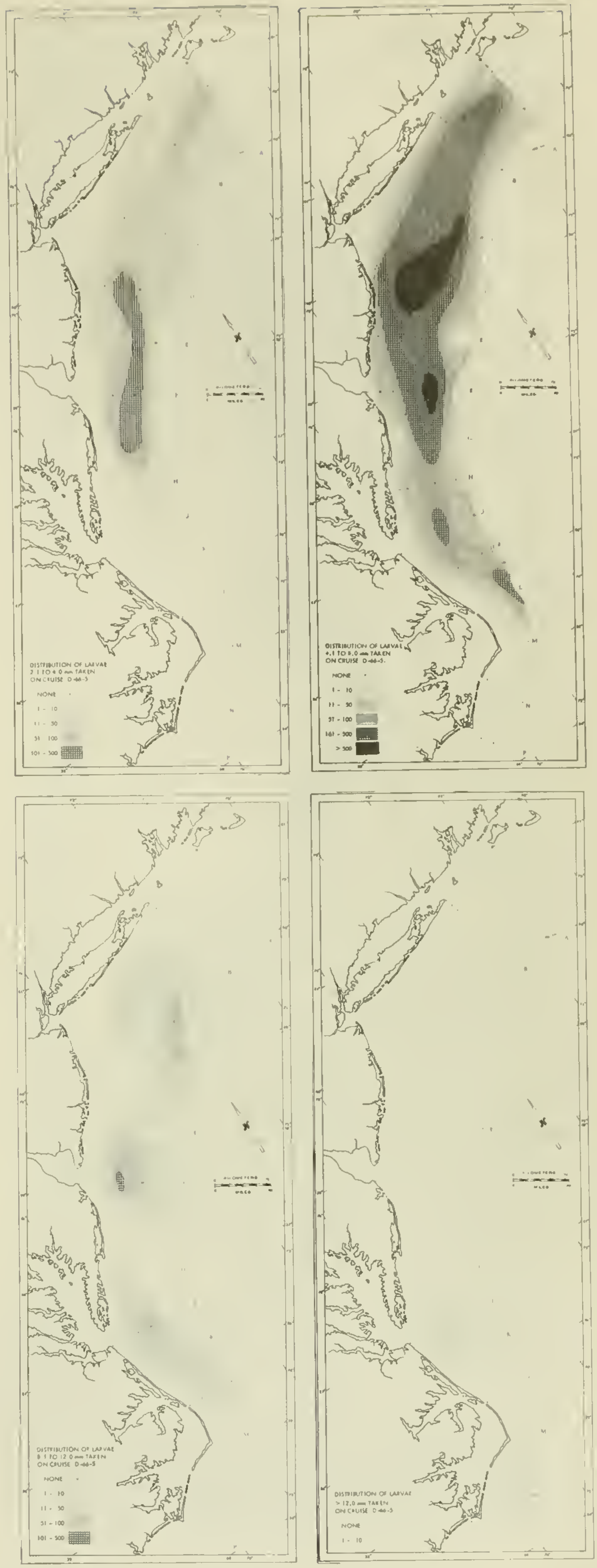
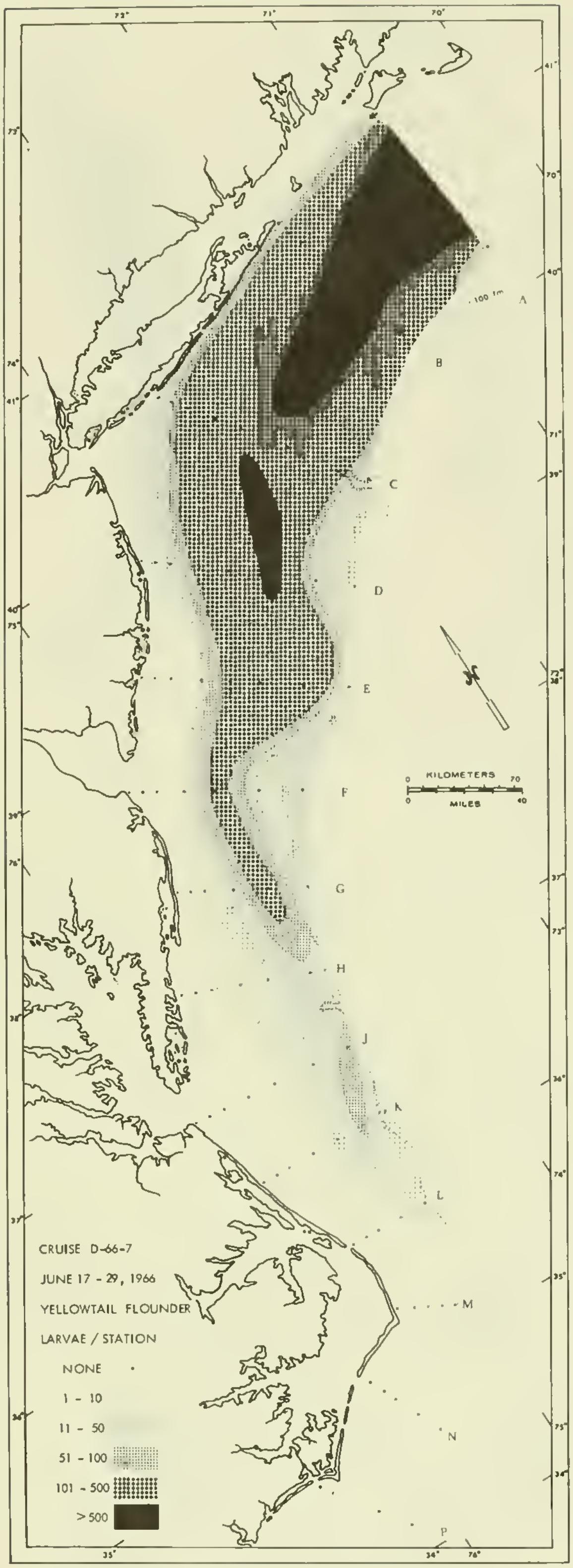


Figure 57.—May 1966. Distribution and relative abundance of yellowtail flounder, *Limanda ferrugmea*, larvae (left) and (right) their distribution and relative abundance by size groups. Top 2.1 to 4.0 mm, 4.1 to 8.0 mm; bottom 8.1 to 12.0 mm, >12.0 mm.



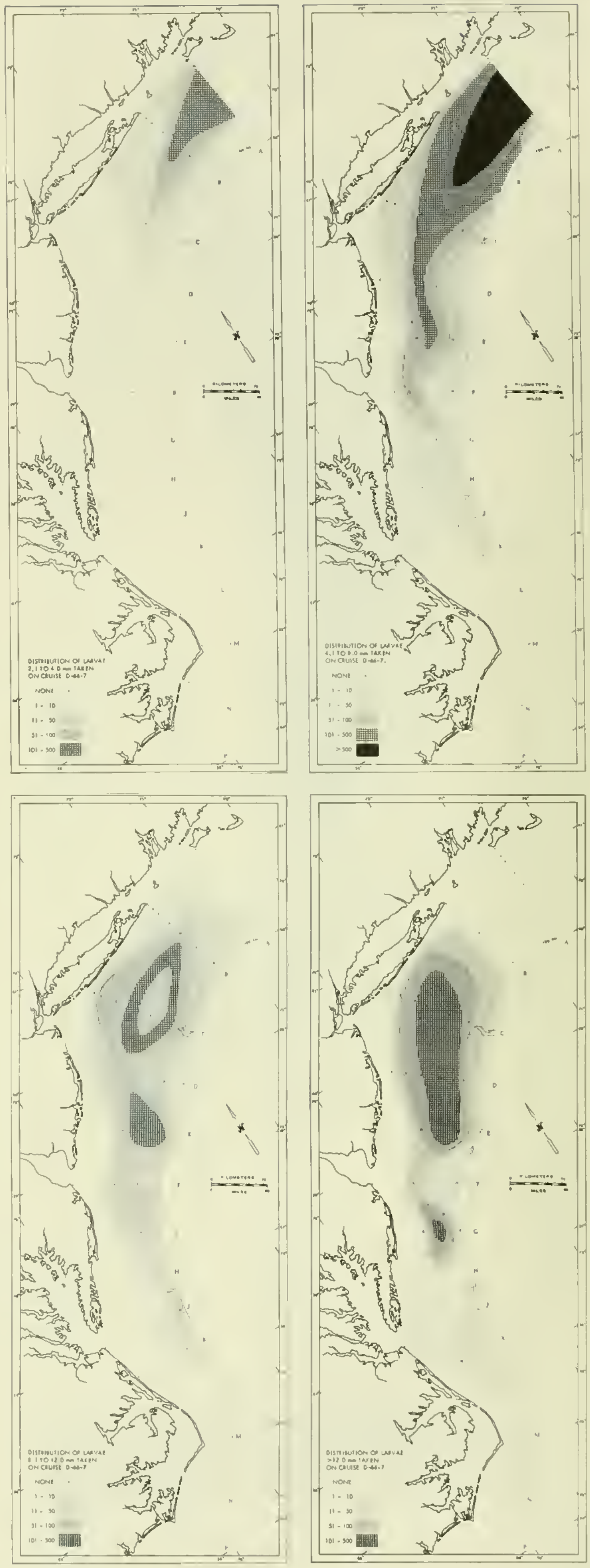


Figure 58.—June 1966. Distribution and relative abundance of yellowtail flounder, *Limanda ferruginea*, larvae (left) and (right) their distribution and relative abundance by size groups. Top 2.1 to 4.0 mm, 4.1 to 8.0 mm; bottom 8.1 to 12.0 mm, >12.0 mm.

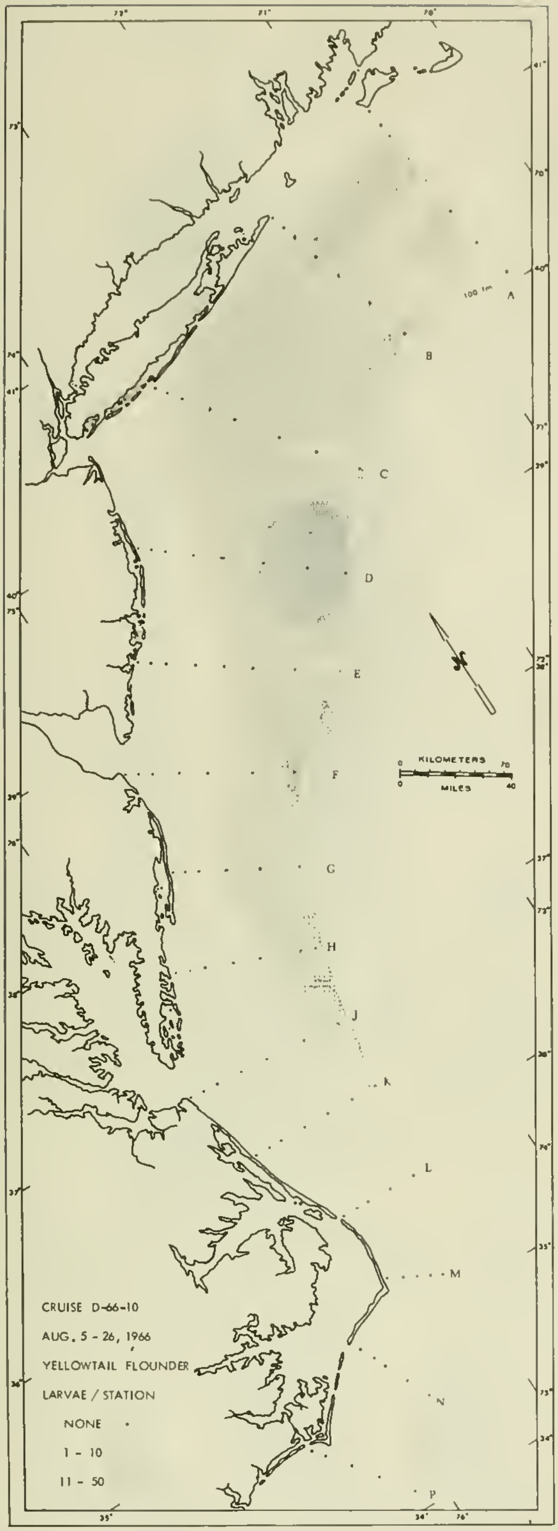


Figure 59.—August 1966. Distribution and relative abundance of yellowtail flounder, *Limanda ferruginea*, larvae.

smaller-sized larvae, no large ones occurred off southern New England. Larvae >12 mm were distributed still farther west and south than the large larvae. Their distribution extended from western Long Island to North Carolina, with the greatest abundance off Long Island and New Jersey (Fig. 58).

Spawning ended by August. We caught larvae from southern New England to Chesapeake Bay, but in far fewer numbers than in June (Fig. 59). Large larvae dominated the catch, and we caught only one small larva (Table 14). Intermediate-sized larvae were scattered from southern New England to New Jersey. We found large larvae scattered from New England to Chesapeake Bay, and larvae >12 mm mostly off New Jersey.

During the abbreviated cruise in mid-September, we caught only four larvae, the last of the season.

The distribution of all yellowtail flounder larvae was continuous from Cape Cod to Cape Hatteras. The composite figure is strongly influenced by catches in May and June, with the area of greatest abundance extending from Cape Cod to Chesapeake Bay (Fig. 60). We judged, from the distribution of small larvae, that spawning was most concentrated off New Jersey and southern New England. In contrast, larvae >12 mm were concentrated off western Long Island and New Jersey; only four were taken off southern New England. Like most flatfish, yellowtail flounder do not undertake extensive seasonal migrations. Royce et al. (1959) found, however, that adults migrate from waters off western Long Island to southern New England in the spring. Fish tagged off western Long Island in February were caught off southern New England during summer, and back near the release site in winter. Thus, some of the seasonal eastward shift in spawning, implied from the shift in concentrations of our larvae <4 mm, might be attributed to migrating adults. The near-absence of larvae >12 mm off southern New England and their presence off Long Island suggested that larvae originating off southern New England swim or are carried out of the area by currents to the area off New Jersey and Long Island. Royce et al. (1959) also found large numbers of small larvae in samples collected off southern New England in the spring of 1932, but no late-stage larvae either there or to the west. They concluded that the larvae originating off southern New England were carried north or east beyond the area covered by their data. Recently published data on circulation off southern New England, inferred from drift bottle and seabed drifter released between 1960 and 1970, support their conclusion (Bumpus 1973). Furthermore, Sette (1943) presented wind data recorded at Nantucket Shoals Light during June 1932 that could account for the transport of yellowtail flounder larvae to the north or east, as Royce et al. (1959) suggested. Such an occurrence may affect the year class that would normally replenish the yellowtail flounder off Long Island and northern New Jersey.

Royce et al. (1959) surmised from samples collected in 1929 that spawning began in early April at the latest, when bottom temperatures reached 5° to 7°C. Eggs in collections they examined occurred over a minimum bottom temperature of 4.8°C, and recently hatched larvae over bottom temperatures ranging from 4.9°C in early May to 12.3°C in late May. Most of the small specimens in our samples occurred over similar bottom temperatures. We caught 98% of those <4 mm over bottom temperatures between 4.1° and 8.9°C, which is probably commensurate with temperatures where spawning occurred.

Although we caught the most larvae in June, spawning apparently had peaked about the end of April or the beginning of May, as larvae <4 mm were most abundant during the May cruise. No larvae were caught after mid-September (Table 14). Our findings agree closely with those of Royce et al. (1959). They estimated that 90% of the yellowtail flounder landed in New Bedford, Mass., in 1943 spawned between 12 April and 26 June, with heaviest spawning from 4 May to 4 June.

Pseudopleuronectes americanus (Walbaum), winter flounder.—Winter flounder have been captured from as far north as Labrador to as far south as Georgia, but they seldom range north of Newfoundland or south of Chesapeake Bay, where they occur from the inner reaches of the littoral zone to depths of 128 m. Throughout its range, the species is evidently composed of local independent populations, perhaps the most notable being that group of exceptionally large fish found on Georges Bank (Bigelow and Schroeder 1953). Larvae were described by Sullivan (1915), Perlmutter (1939), and Bigelow and Schroeder (1953).

Winter flounder are considered one of our least migratory fish. A separate population seems to inhabit its own river system along the northern half of the Middle Atlantic Bight, where adults move but a few miles offshore to deep cool water during the summer and return to the shallow waters of their respective home bays or rivers for the winter (Perlmutter 1947). Young-of-the-year remain inshore. Spawning occurs in the estuaries during winter and early spring. Eggs are demersal. Although the larvae are pelagic, they become strongly bottom oriented even before completion of metamorphosis, which occurs at about 8 mm (Pearcy 1962).

We caught larvae during the three spring cruises mostly nearshore, but some midway out on the shelf over depths of 55 m. In April, when they were most abundant, their distribution was continuous from Cape Cod to Chesapeake Bay. There were concentrations of larvae off the northern New Jersey coast, and from Delaware Bay southward to Maryland over depths less than 20 m (Fig. 61). Both concentrations were near the mouths of estuaries, and the tide was ebbing when we sampled. Judging from the tidal phase at the time, the known spawning habits of winter flounder, and information from Pearcy (1962), who reported that currents flush 3% of the winter flounder population per day from the upper Mystic River, we assumed that most of the winter flounder larvae collected during the three spring cruises originated in estuaries and were subsequently carried seaward by currents. Using incubation times and growth rates reported by Bigelow and Schroeder (1953), we calculated that most of those caught in April had been spawned during the latter half of March (Table 15).

In May, the distribution of larvae was again continuous from Cape Cod to Chesapeake Bay, but the center of abundance occurred off southern New England, or farther north than in April (Fig. 62). Larvae occurred only off Cape Cod in June (Fig. 63). We assumed from their absence farther south that spawning had ended in the adjacent estuaries.

The characteristic south-to-north progression in spawning that we found prevalent in offshore spring spawners is apparent in our collections of winter flounder larvae. Since winter flounder populations in the bight are isolated when spawning, each having its own home river system, the northward progression of spawning that is evident in our

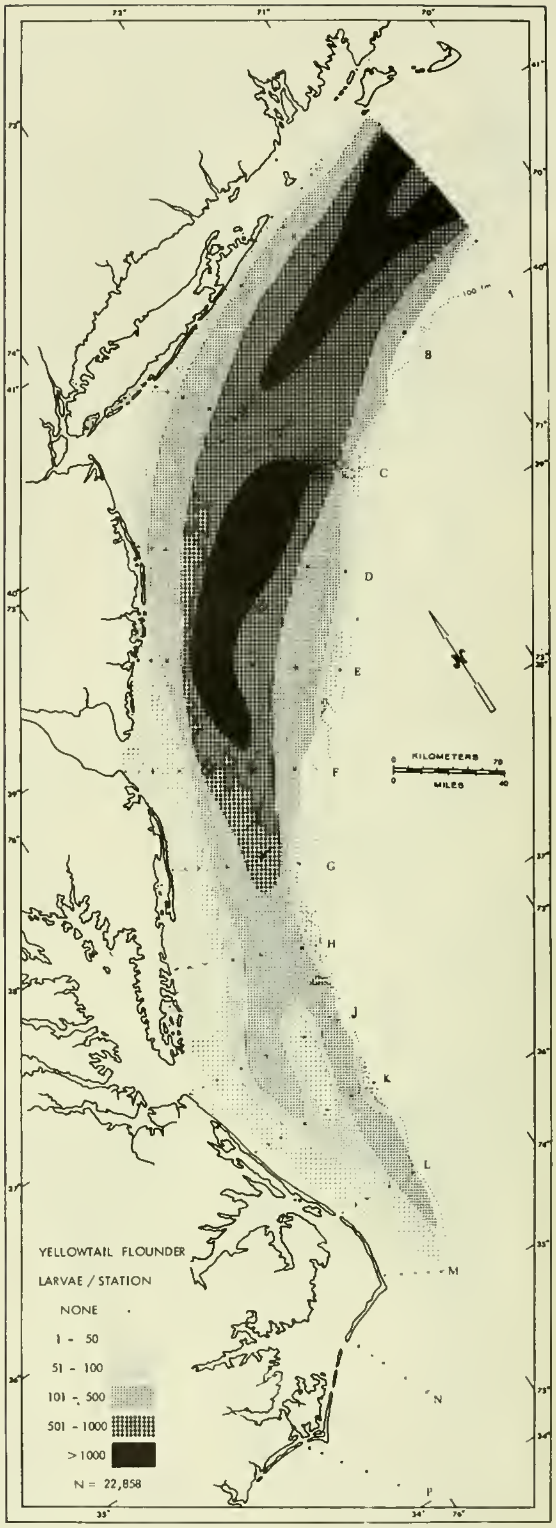


Figure 60.—Distribution and relative abundance of yellowtail flounder, *Limanda ferruginea*, larvae collected during 1965-66 survey.

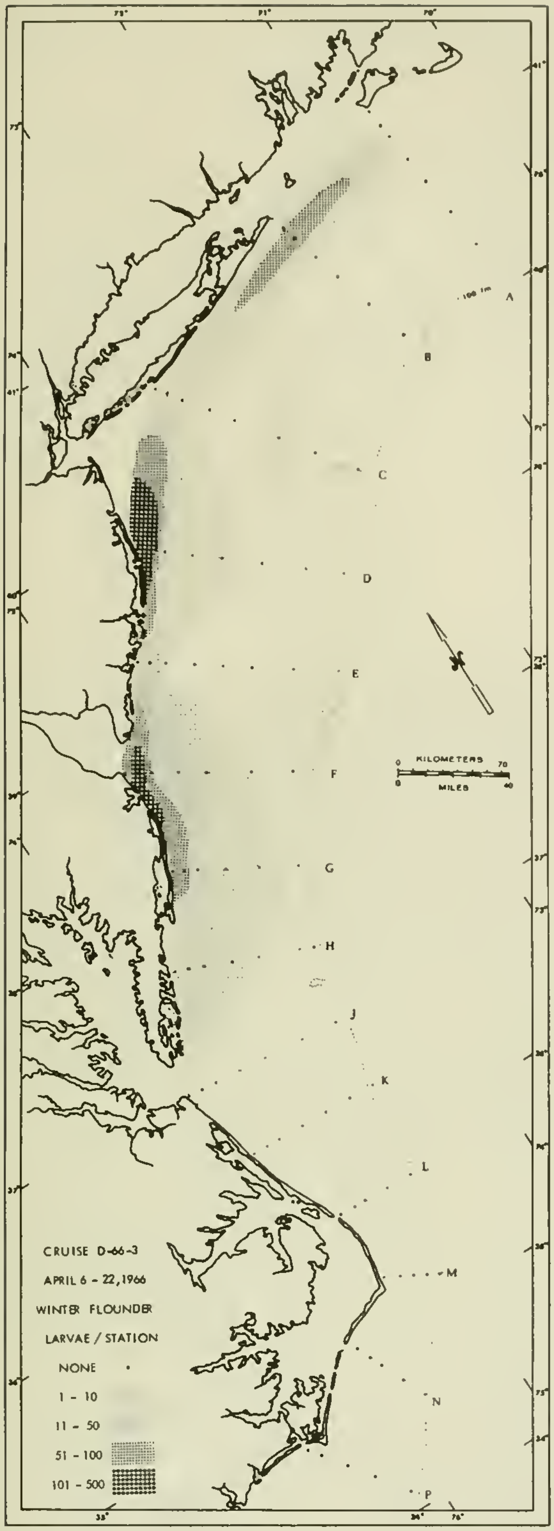


Figure 61.—April 1966. Distribution and relative abundance of winter flounder, *Pseudopleuronectes americanus*, larvae.

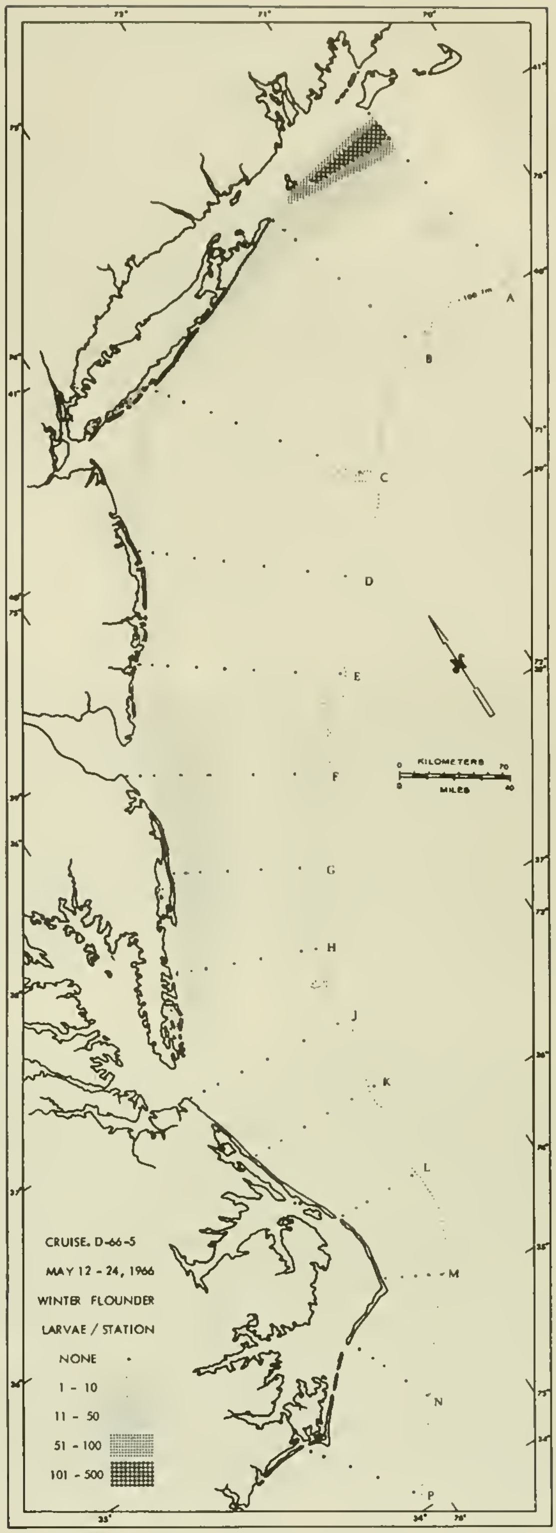


Figure 62.—May 1966. Distribution and relative abundance of winter flounder, *Pseudopleuronectes americanus*, larvae.

Table 15.--The seasonal distribution of winter flounder, Pseudopleuronectes americanus, larvae by sizes. Numbers are adjusted to standardize sampling effort.

Larval length (mm)	Cruise and date 66-3 Apr.	66-5 May	66-7 June	Total
	Number of larvae			
2.1- 3.0	15	2		17
3.1- 4.0	612	261	53	926
4.1- 5.0	313	149	120	582
5.1- 6.0	70	24	113	207
6.1- 7.0	22	70	19	111
7.1- 8.0		39	2	41
8.1- 9.0	1	22		23
9.1-10.0		3		3
Total	1,033	570	307	1,910

data strongly suggests that warming spring temperatures are a triggering mechanism for the onset of spawning. Most of the larvae caught during the three spring cruises occurred within 25 km of shore (Fig. 64). Whether or not they were flushed from nearby estuaries or spawned at sea, chances for their survival seem remote, since estuaries are apparently necessary as both spawning and nursery grounds. Our trawl records from coastal groundfish surveys support this theory. Young-of-the-year have not been collected along the oceanfront, but they are caught in the estuaries.

III. Family Soleidae—Soles

Gymnachirus melas Nichols, naked sole.—Naked sole range from Massachusetts to Florida and into the Gulf of Mexico, but only one specimen has been collected north of Cape Hatteras. They are the only member of the family found in offshore shelf waters off the eastern United States (Dawson 1964). From gonadal studies, Topp and Hoff (1972) estimated that spawning occurred from May to November off the west coast of Florida. Larvae have not been described. Larval identifications are based on morphological characters, fin ray counts, pigmentation, and the reported range of adults.

We caught 12 specimens between 3.2 and 8.2 mm. All were caught between capes Hatteras and Lookout from April through August, half of them in May. Since we caught all the larvae except one on the outer half of the shelf, they had probably been transported into our survey area by the Gulf Stream.

IV. Family Cynoglossidae

Symphurus spp., tonguefishes.—The ranges of five species of *Symphurus* extend into the survey area. None of the five are common north of Cape Hatteras, but some occur more regularly than others. *Symphurus diomedianus* (Goode and Bean) range from North Carolina to Brazil; *S. minor* Ginsburg from Nova Scotia to Florida and into the Gulf of Mexico; *S. plagiusa* (Linnaeus) from New York to the Bahamas and Greater Antilles, and into the Gulf of Mexico. *Symphurus civitatus* Ginsburg has been collected from North Carolina to Florida and the Gulf of Mexico, and *S. pusillus* (Goode and Bean) from New York and the Gulf of Mexico (Ginsburg 1951; Topp and Hoff 1972). Hildebrand and Cable (1930) described early development of a tonguefish they thought was *S. plagiusa*. Larvae of the other species have not been described.

Our collections may contain larvae of all five species, and perhaps representatives of one or more species that are not found as adults in the survey area. We could identify a few specimens of only one, *S. minor*. Because meristic characters of the others widely overlap, we could not make positive identifications beyond the generic level, so all the larvae are treated as *Symphurus* spp.

The presence of more than one species of *Symphurus* larvae in our collections, coupled with the unpredictable influence of the Gulf Stream on their distribution, makes interpretation of the data speculative. Although we caught larvae the year-round, differences in seasonal distribution as well as size and numbers of larvae make it doubtful that any one species dominated the catch on all cruises. We interpreted the catch as being represented by at least two species that have overlapping spawning seasons that together continued the year-round.

Because *S. plagiusa* is a shoal-water species limited to depths <26 m as adults (Ginsburg 1951), we concluded that most of the larvae caught from January to May at depths >40 m represented one or more of the other species. Based on their size and the pattern of distribution, larvae caught from January to April were spawned south of Cape Lookout and subsequently transported into the survey area by the Gulf Stream (Fig. 65). Some of those caught in May might also have been spawned south of our survey area, but the concentration of small larvae nearshore between capes Lookout and Hatteras might have been spawned locally (Fig. 66).

The catch declined in June. The distribution of larvae resembled that of the previous two cruises, and probably

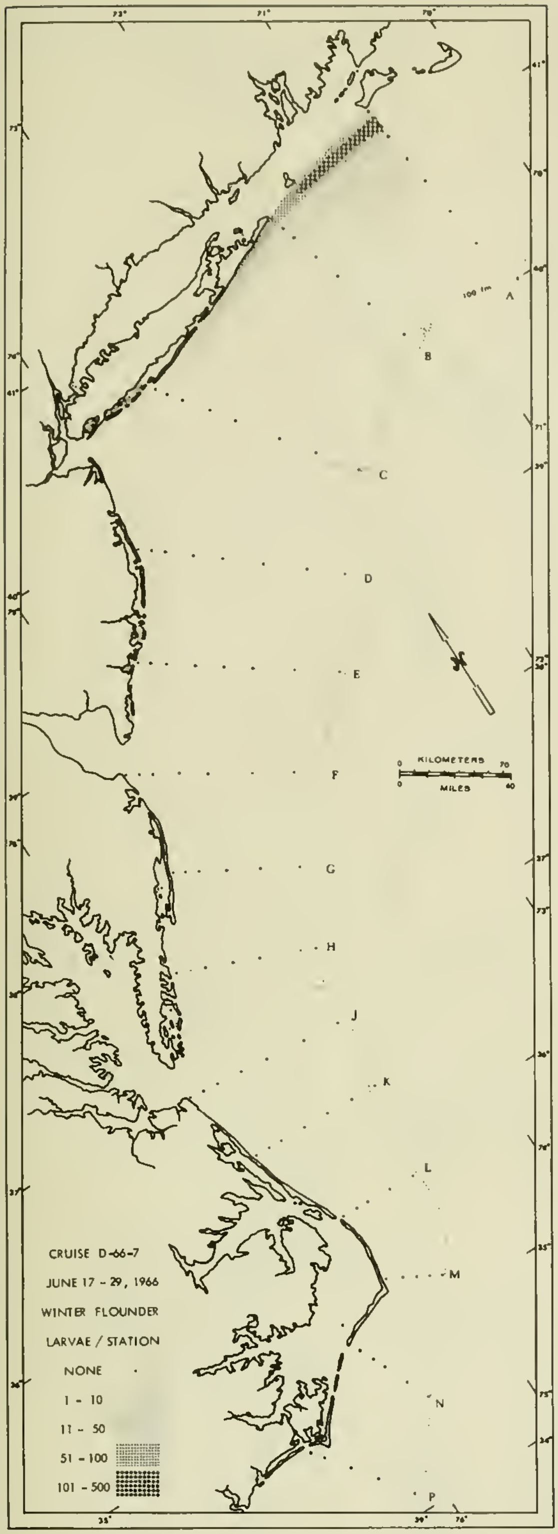


Figure 63.—June 1966. Distribution and relative abundance of winter flounder, *Pseudopleuronectes americanus*, larvae.

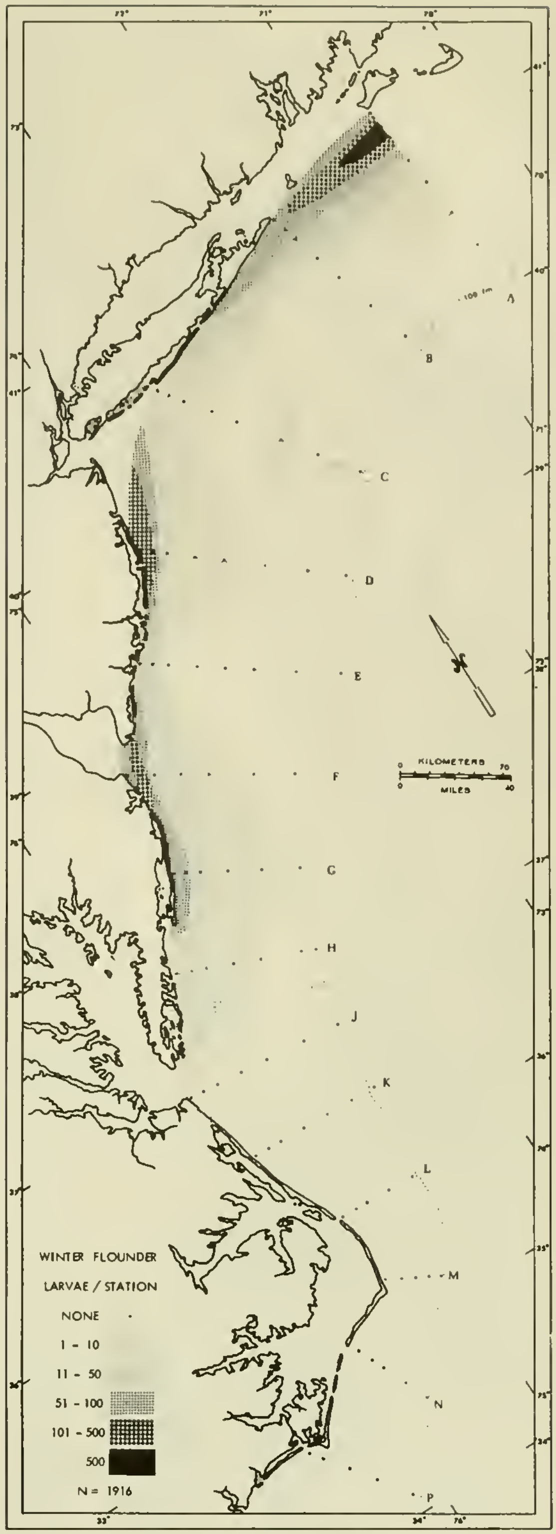


Figure 64.—Distribution and relative abundance of winter flounder, *Pseudopleuronectes americanus*, collected during 1965-66 survey.

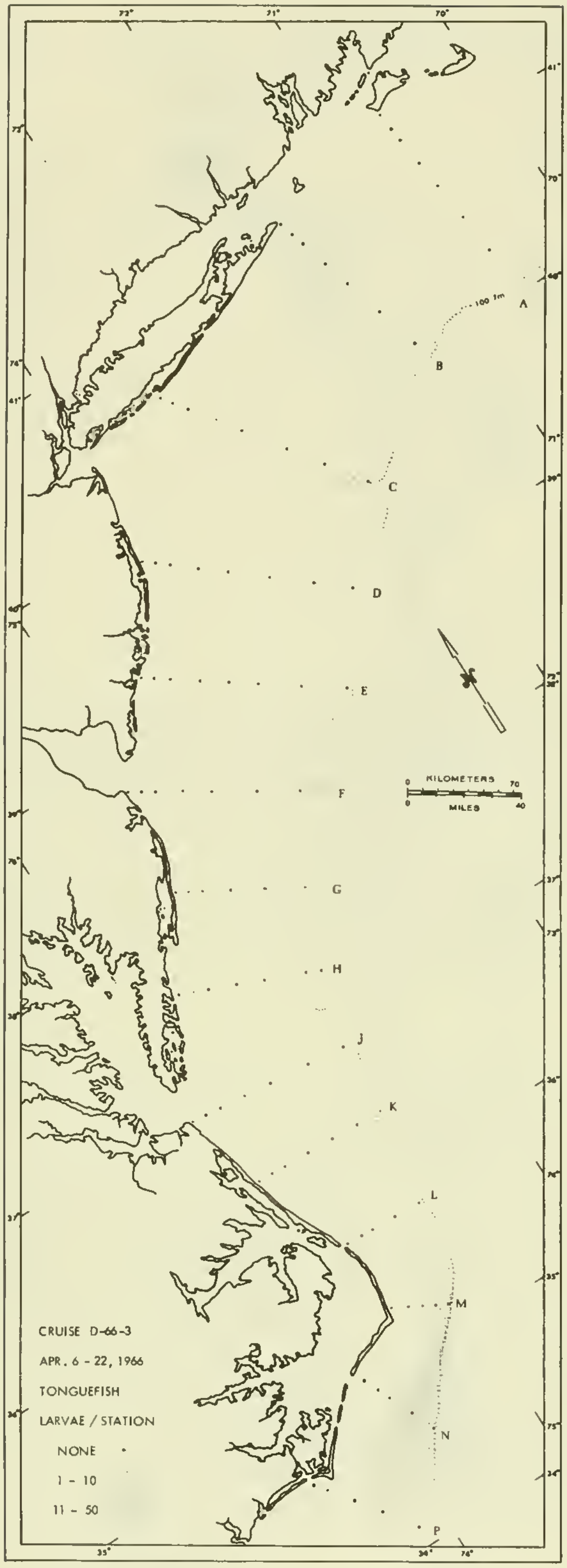


Figure 65.—April 1966. Distribution and relative abundance of *Symphurus* spp. larvae.

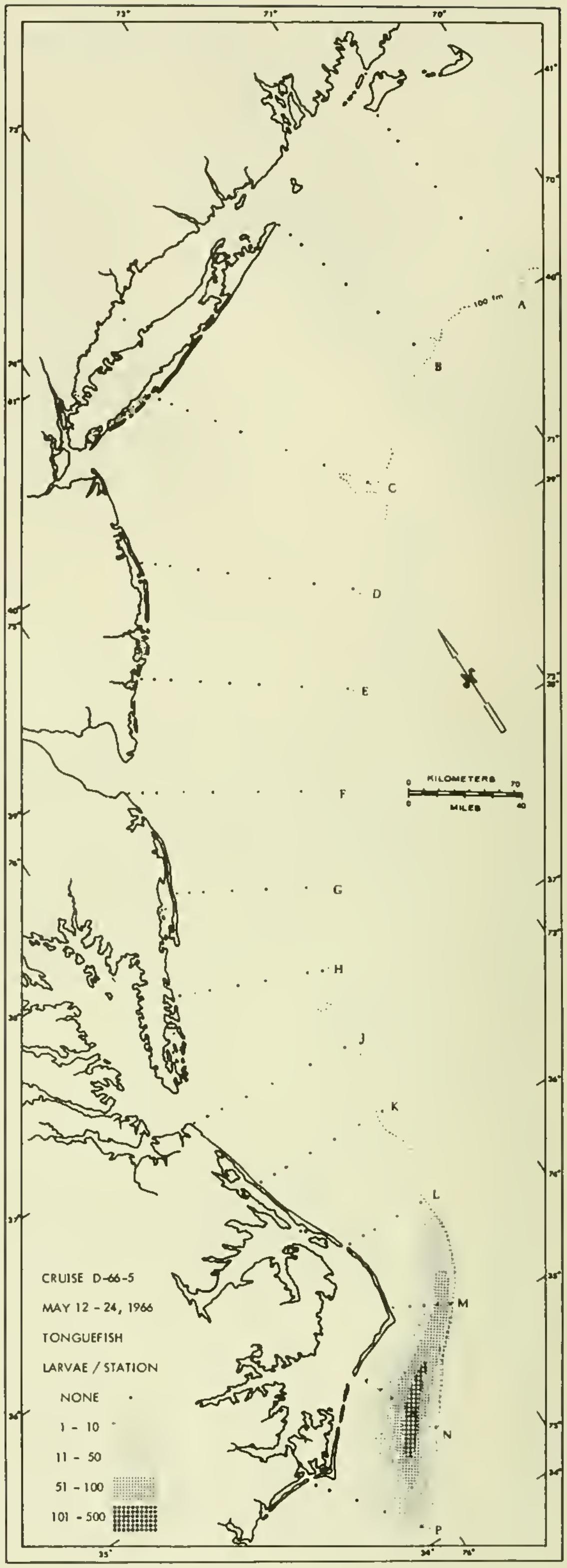


Figure 66.—May 1966. Distribution and relative abundance of *Symphurus* spp. larvae.

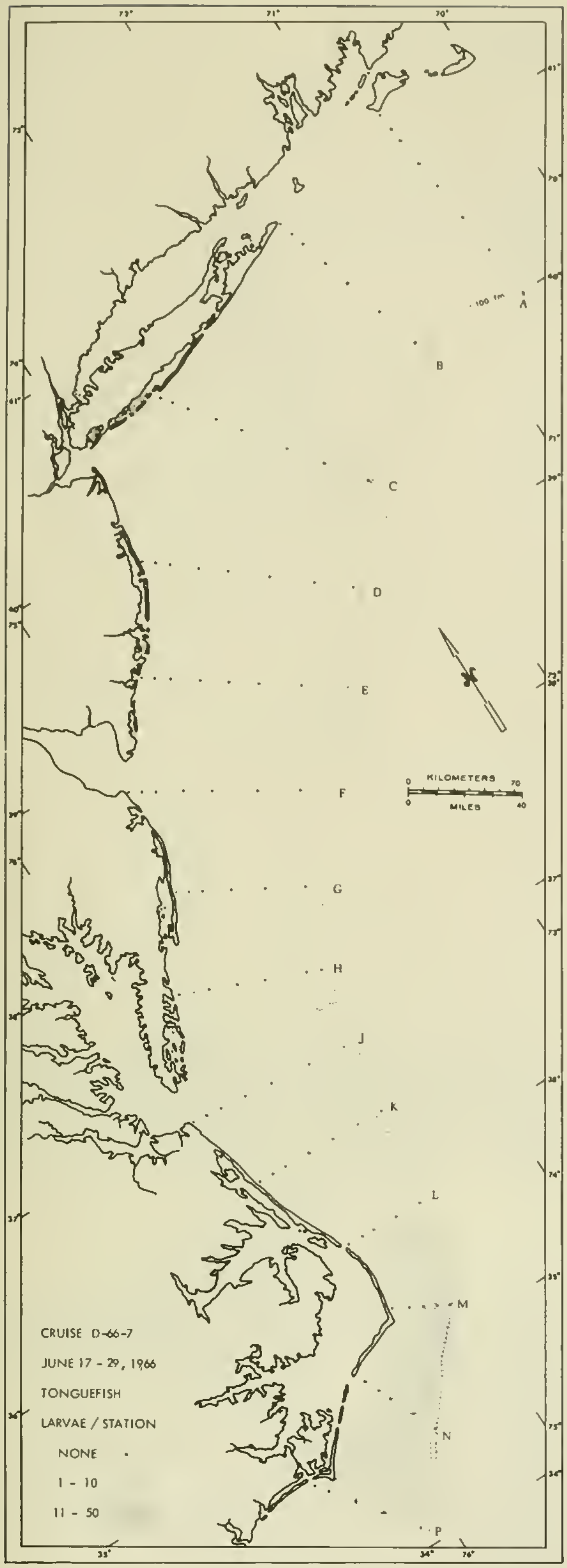


Figure 67.—June 1966. Distribution and relative abundance of *Symphurus* spp. larvae.

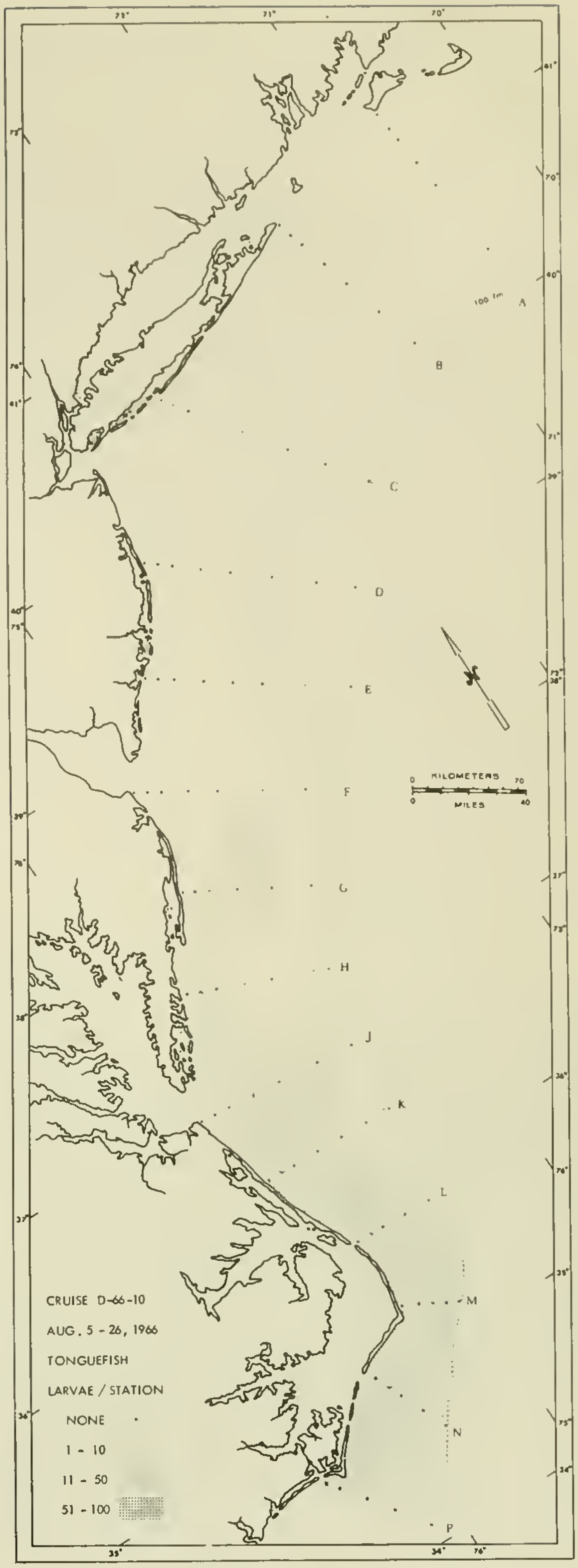


Figure 68.—August 1966. Distribution and relative abundance of *Symphurus* spp. larvae.

Table 16.--The seasonal distribution of *Symphurus* spp. larvae by size. Numbers are adjusted to standardize sampling effort.

Larval length (mm)	Cruise and date								
	66-1 Jan.-Feb.	66-3 Apr.	66-5 May	66-7 June	66-10 Aug.	66-12 Sept.-Oct.	66-14 Nov.-Dec.	65-4 Dec.	Total
	Number of larvae								
2.1- 3.0				5	33	2	4		44
3.1- 4.0			49	19	74	17	29	4	192
4.1- 5.0		3	67	9	49	21	20	7	176
5.1- 6.0	1	5	53	8	39	7	10	4	127
6.1- 7.0	5	2	28	4	16	11	7	2	75
7.1- 8.0	1	3	24	4	7	12	3	2	56
8.1- 9.0			7	1	10	9	2	2	31
9.1-10.0		2	9	3	4	5	3	3	29
10.1-11.0		3	10	2	5	2	2	1	25
11.1-12.0		3	5		2	5		1	16
12.1-13.0		2	1		1	4		2	10
13.1-14.0		1	3			4	3	1	12
14.1-15.0			2		1		2		5
15.1-16.0			1				1		2
16.1-17.0						1			1
17.1-18.0		1							1
Total	7	25	259	55	241	100	86	29	802

consisted largely of the same species that we caught earlier (Fig. 67).

The distribution of larvae changed in August. Most specimens occurred at inshore stations, and the areal extent of their distribution reached northward to Maryland (Fig. 68). These shifts in distribution and the increased catch over June (Table 16) led us to conclude that the catch consisted largely of a different species, probably *S. plagiusa*, the most commonly occurring tonguefish off North Carolina.

By October, the catch began to decline again (Table 16). Larvae were scattered, and their distribution had receded to waters south of Chesapeake Bay (Fig. 69). The catch declined further in November, and the distribution of larvae continued to recede southward. Catches were light, and most larvae occurred along the outer half of the shelf south of Cape Hatteras, an area traversed by the Gulf Stream (Fig. 70). In December (1965), we caught *Symphurus* specimens only south of Cape Hatteras (Fig. 71). Catches on the three fall cruises presumably represented a late spawning of *S. plagiusa*, and an influx of one or more of the other four species from south of Cape Lookout.

Hildebrand and Cable (1930) concluded from their larval collections that *S. plagiusa* spawned from May to October near Cape Lookout, with a peak in June. They apparently discounted the possibility of their specimens being anything but *S. plagiusa*, and may have been justified in doing so since they sampled to a maximum depth of about 21 m. Throughout the year, we caught *Symphurus* larvae from Maryland to North Carolina. Their center of abundance occurred at seaward stations over depths of 50 to 185 m between the North Carolina capes, and, with the exception of catches from August to early October, their overall distribution in the survey area appeared strongly influenced by the Gulf Stream (Fig. 72).

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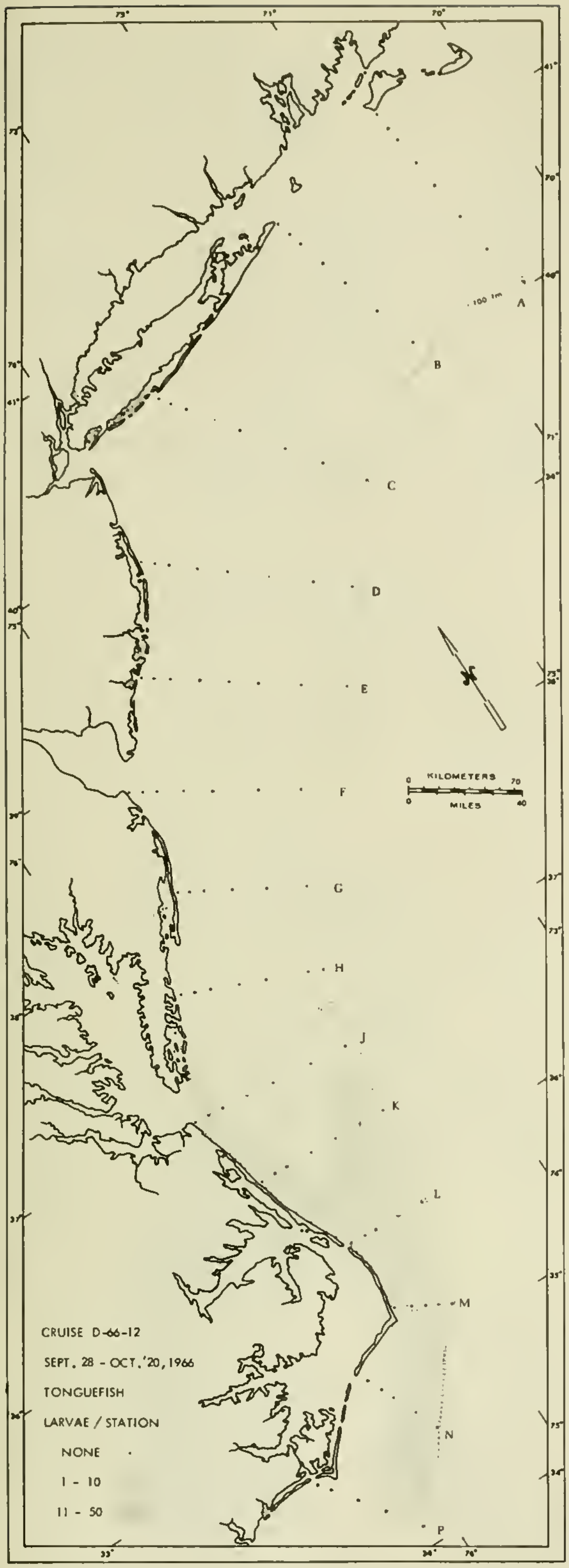

Figure 69.—September to October 1966. Distribution and relative abundance of *Symphurus* spp. larvae.

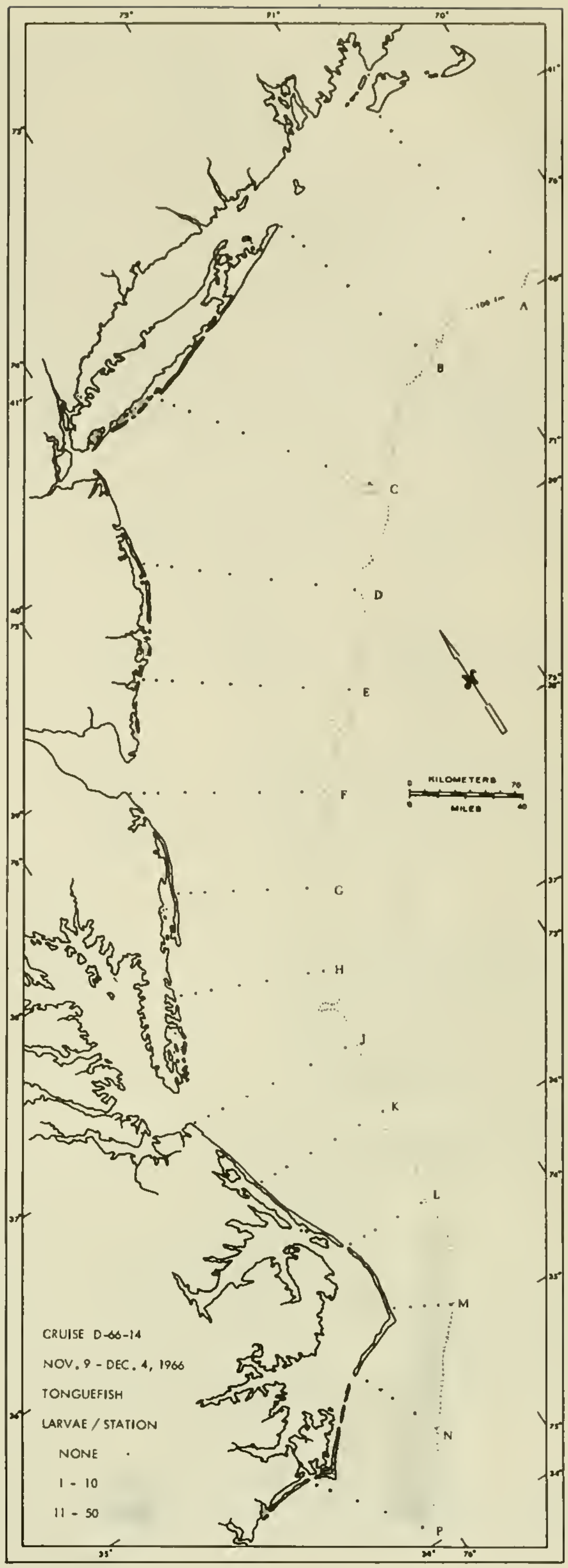

Figure 70.—November to December 1966. Distribution and relative abundance of *Symphurus* spp. larvae.

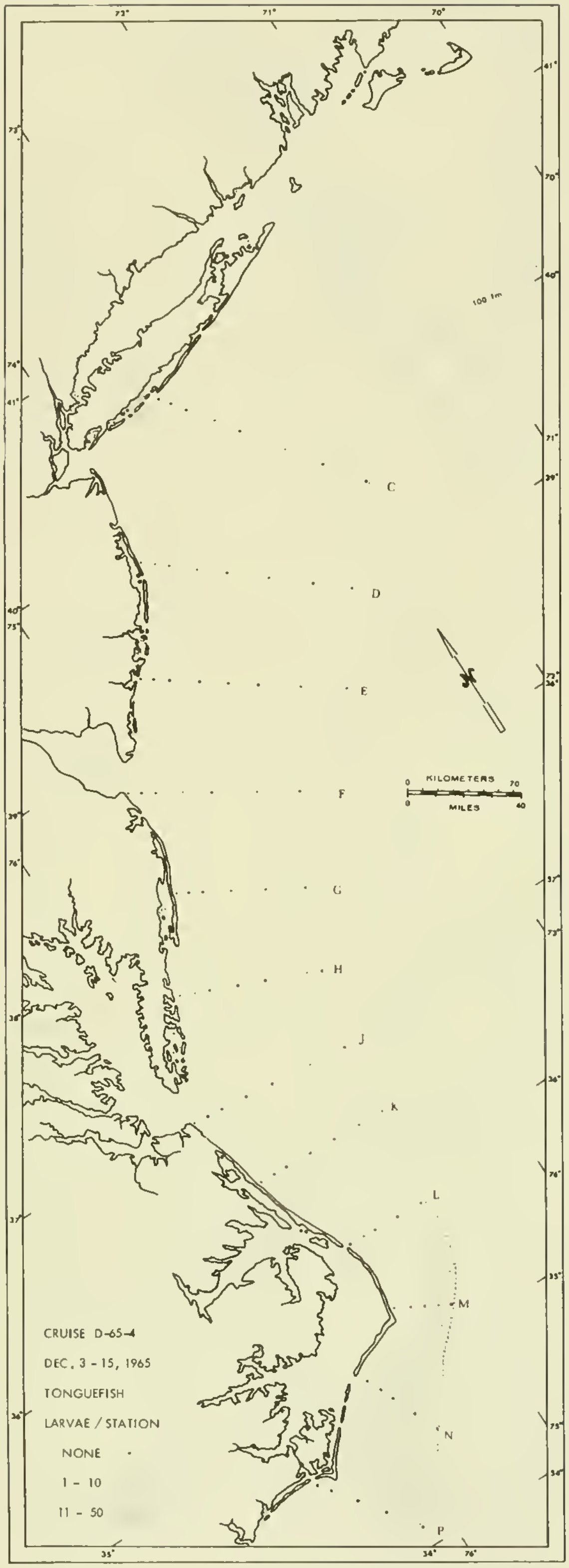

Figure 71.—December 1965. Distribution and relative abundance of *Symphurus* spp. larvae.

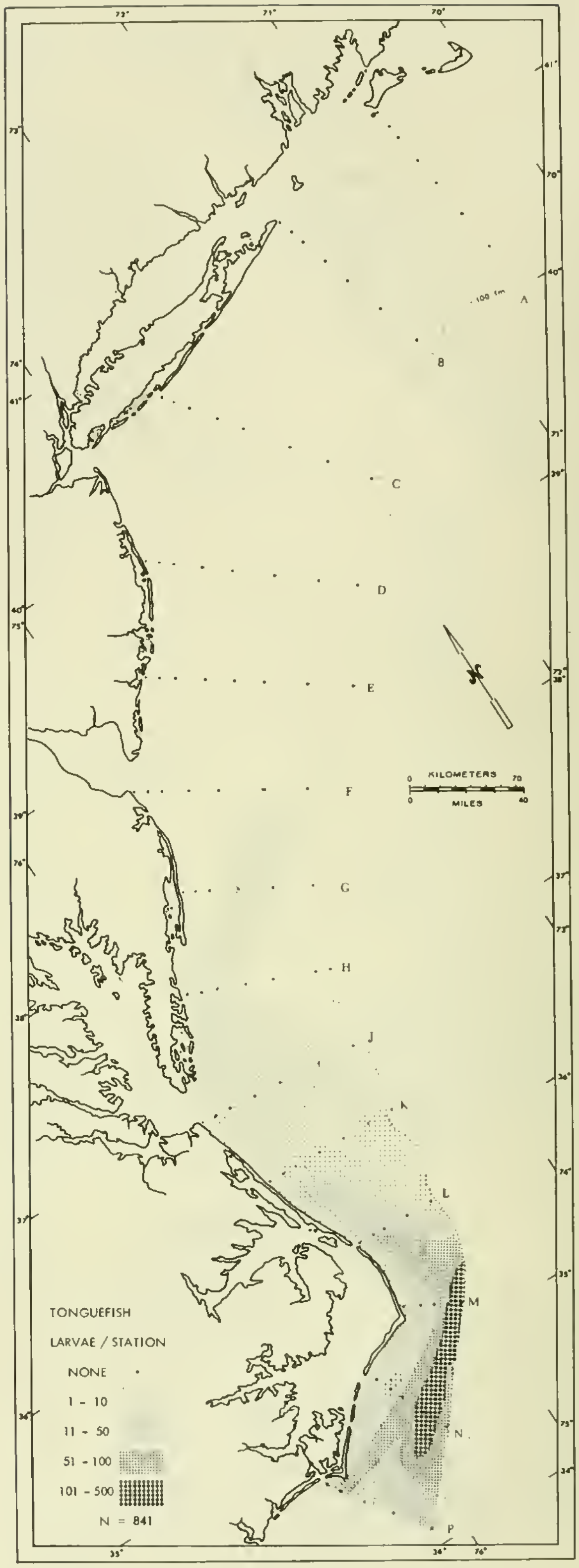

Figure 72.—Distribution and relative abundance of *Symphurus* spp. larvae collected during 1965-66 survey.

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