OCCURRENCE OF SILVER HAKE, *MERLUCCIUS BILINEARIS*, EGGS AND LARVAE ALONG THE MIDDLE ATLANTIC CONTINENTAL SHELF DURING 1966

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ABSTRACT

During an ichthyoplankton survey over the continental shelf between Martha's Vineyard, Mass. and Cape Lookout, N.C., from December 1965 to December 1966, 3,241 eggs and 11,032 larvae of the silver hake, *Merluccius bilinearis*, were collected. Eggs were collected from May until November, with a peak in June. Most of the eggs (77%) were collected south of Martha's Vineyard, Mass. The southernmost occurrence of eggs was off North Carolina in November. Larvae were collected from May until December, with a peak in September. Larvae were most abundant on the shelf between Hudson Canyon and Martha's Vineyard. The evidence suggests that most of the eggs and larvae collected on the survey had been spawned near the northeastern edge of the survey area and drifted southwesterly. There is also evidence of a size-related, diel, vertical migration by the postlarvae.

In December 1965, the Sandy Hook Marine Laboratory began a 1-yr ichthyoplankton survey of the continental shelf between Martha's Vineyard, Mass. and Cape Lookout, N.C. The survey was designed to delimit the spawning times and locations of marine game fishes, define dispersal patterns of larvae, and form the first phase in a study to determine what species depend on an estuarine environment during some phase of their early life history. We placed emphasis on no one species and began the survey with no preconceived notions on either the geographical extent or the seasonality of spawning of any species. This report on the eggs and larvae of silver hake, *Merluccius bilinearis* (Mitchill), represents one of a series resulting from that survey.

The silver hake is an important sport and commercial species widely distributed over the continental shelf of eastern North America from the Gulf of St. Lawrence (McKenzie and Scott, 1956) southward to South Carolina, with centers of abundance between Nova Scotia and New York (Bigelow and Schroeder, 1953). Silver hake are found in both shoal and deep water within a wide temperature range, usually over bottoms of sand or sand-silt mixtures (Fritz, 1965). When winter cooling occurs on the shelf, silver hake migrate to warmer waters on the continental edge and slope.

Silver hake in the western North Atlantic consist of two morphologically separable and nonmingling populations (Conover, Fritz, and Vieira, 1961) roughly separated by the 41°30′N meridian (Nichy, 1969). Hence, the Gulf of Maine and northern edge of Georges Bank contain one population, while the southern slopes of Georges Bank and continental shelf south and west of Cape Cod contain the other. This report concerns the eggs and larvae produced by the latter population.

Spawning in the Gulf of Maine extends from June to October, with a peak in July and August (Bigelow and Schroeder, 1953). Kuntz and Radcliffe (1917) described the embryological and larval development of silver hake and suggested that "the spawning period for this species is a protracted one and not all the eggs mature at one time." Sauskan and Serebryakov (1968), in a study of the gonads of silver hake from Georges Bank and the Nova Scotian shelf, showed: 1) larger females mature and spawn earlier than smaller ones; 2) vitellogenesis is asynchronous, and individual fish spawn in three portions within a season; 3) the initial spawning of an individual female accounts for half the total seasonal production of oocytes.

Silver hake eggs and larvae have been collected from Halifax, Nova Scotia to Cape May, N.J. (Bigelow and Schroeder, 1953). Eggs and larvae

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have been reported in local plankton collections as follows: off Nova Scotia (Dannevig, 1919); over Georges Bank (Marak and Colton, 1961); in Block Island Sound (Merriman and Sclar, 1952). Sauskan and Serebryakov (1968) discussed the distribution of silver hake eggs and larvae but limited their sampling and discussion to areas east of our 1966 sampling area.

MATERIALS AND METHODS

We conducted eight cruises aboard the RV *Dolphin* from December 1965 to December 1966. On each cruise, we sampled 92 stations arranged on 14 transects between Martha's Vineyard, Mass. and Cape Lookout, N.C. (Figure 1). The station arrangement allowed us to sample from nearshore to the 183-m (100-fathom) contour along each transect. We scheduled cruises to occur at 6-wk intervals, and the average cruise occupied 17 days. We sampled four transects from Martha's Vineyard to New Jersey on a supplemental cruise in September 1966. Dates and sampling sequences and locations of collecting stations listed to the nearest 0.8 km (0.5 nautical mile) are contained in Clark et al. (1969).

We used loran, radar and, where possible, visible ranges to position the *Dolphin* on station. Routine work on station involved the use of a bathythermograph to obtain temperature profiles, a stem thermometer to measure surface temperatures, and a Beckman[2] RS-5 portable salinometer to obtain salinities and temperatures from the surface to the maximum plankton sampling depth. In water deeper than the length of the salinometer cable, we used Frautschy water bottles and measured the salinities of these samples with a hydrometer kit. Temperature and salinity profiles resulting from the survey are found in Clark et al. (1969).

We chose the Gulf V high-speed plankton sampler (Arnold, 1959) to overcome many of the problems inherent in sampling ichthyoplankton. It samples at 5 knots, thus allowing capture of organisms capable of avoiding slower nets. Its large mouth opening provides large quantities of eggs and larvae per tow and, hence, samples with high reliability for comparative purposes. Flow-through characterisitcs of the net prevent extensive damage to larvae. Finally, the Gulf V is ruggedly built and requires a minimum of shipboard

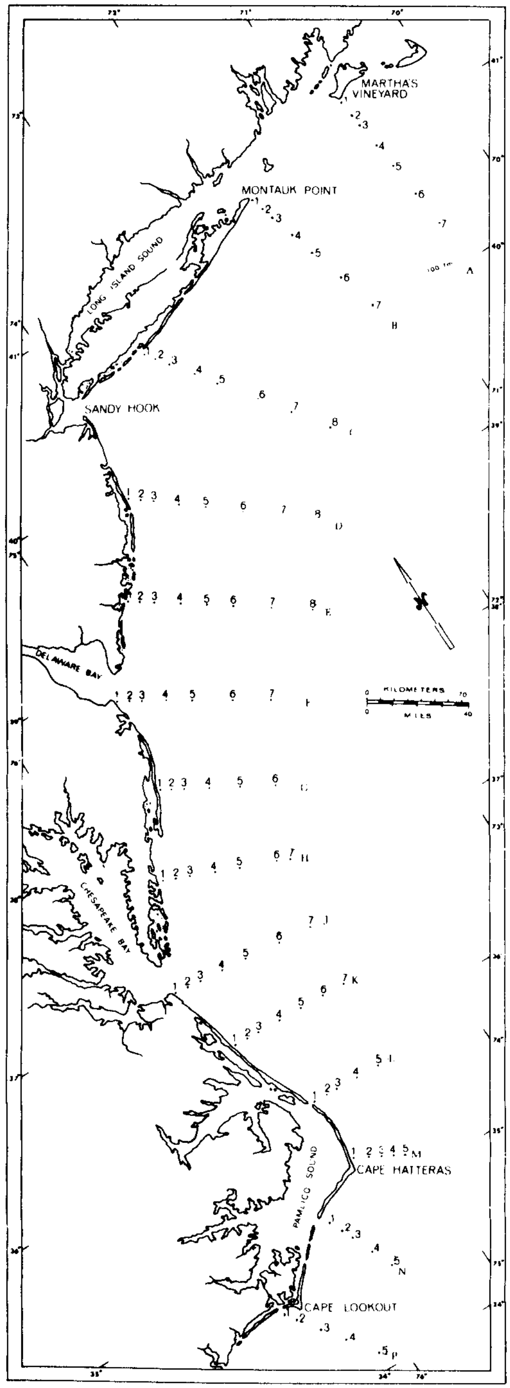

FIGURE 1.—RV *Dolphin* survey, December 1965 to December 1966. Location of transects and collecting stations.

maintenance. Our sampler (Figure 2) consists of a conical net of 0.33-mm (0.013-inch) Monel wire with 12 meshes/cm (30 meshes/inch) and an

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

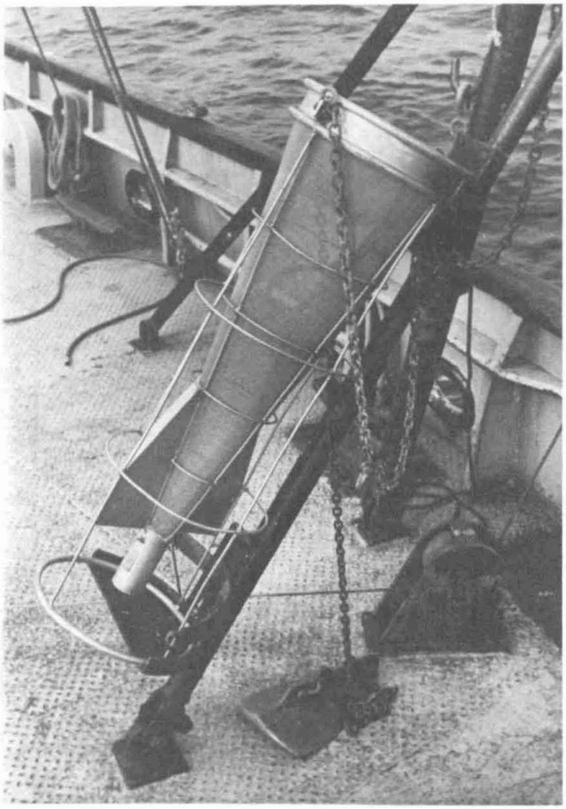

FIGURE 2.—Gulf V high-speed plankton sampler with depressor.

aperture size of 0.52 mm (0.02 inch). Other dimensions are as described by Arnold (1959).

Our method of towing two samplers consecutively was described in detail in Clark et al. (1969), Richards and Kendall (1973), and Smith (1973). Figure 3 illustrates schematically our towing methods over various depths of water. As illustrated in Figure 3, the step-oblique method sometimes resulted in unequal sampling intensity at certain depths under a unit of surface area. Therefore, to diagram the horizontal distribution on maps, I combined the catch of the two nets and adjusted them as shown in Table 1.

The catches of the two nets presented separately provide added useful information. This is especially true in view of 1) observed differences in numbers and length-frequencies between the catches of the two nets, and 2) the presence of a thermocline within the stratum sampled by the deep net. In Appendix Table 1, I tabulated the catch of the deep net as observed. However, the deep net was not equipped with a closing device and was subject to contamination in the upper 15 m during setting out and hauling back procedures. Therefore, for study of vertical distribution, I adjusted the deep net catch after assuming that it sampled the upper zone for 3 min.

Tows are labeled "D" (day), "N" (night), or "C" (crepuscular, i.e. within 1 h of sunrise or sunset) in Appendix Table 1.

After each tow, we washed the samplers down, removed the cups, and preserved the samples in buffered 5% Formalin. The samples were returned to the laboratory where all ichthyoplankton was removed and larvae divided into family groups. Gadids and merlucciids were then identified to species. Eggs were initially grouped according to their diameters. Early silver hake eggs are indistinguishable from the eggs of many other species of marine fishes. Common characteristics include: outside diameter of about 1.0 mm, presence of a single oil globule, narrow perivitelline space, and 4:1 ratio of egg diameter to oil globule diameter. Consequently, specific identifications were limited to eggs in advanced stages of development. I based identifications of late stage *M. bilinearis* eggs on published descriptions (Kuntz and Radcliffe, 1917; Sauskan and Serebryakov, 1968) and on my own rearing experiments with artifically fertilized eggs. The purpose of my experiment was to determine whether pigment was present on the yolk. It was terminated before hatching occurred. Prolarval offshore hake, *M. albidus*, were identified following the descriptions by Marak (1967) and removed from the *M. bilinearis*

TABLE 1.—Method used to combine the catches of shallow and deep samplers.

Shallow net		Deep net		
Number of steps	Minutes per step	Number of steps	Minutes per step	Total station catch formula
2	15	0	0	⅓ shallow
3	10	0	0	½ shallow
6	5	0	0	Total shallow
6	5	2	15	Total shallow + ⅓ deep
6	5	3	10	Total shallow + ½ deep
6	5	6	5	Total shallow + total deep

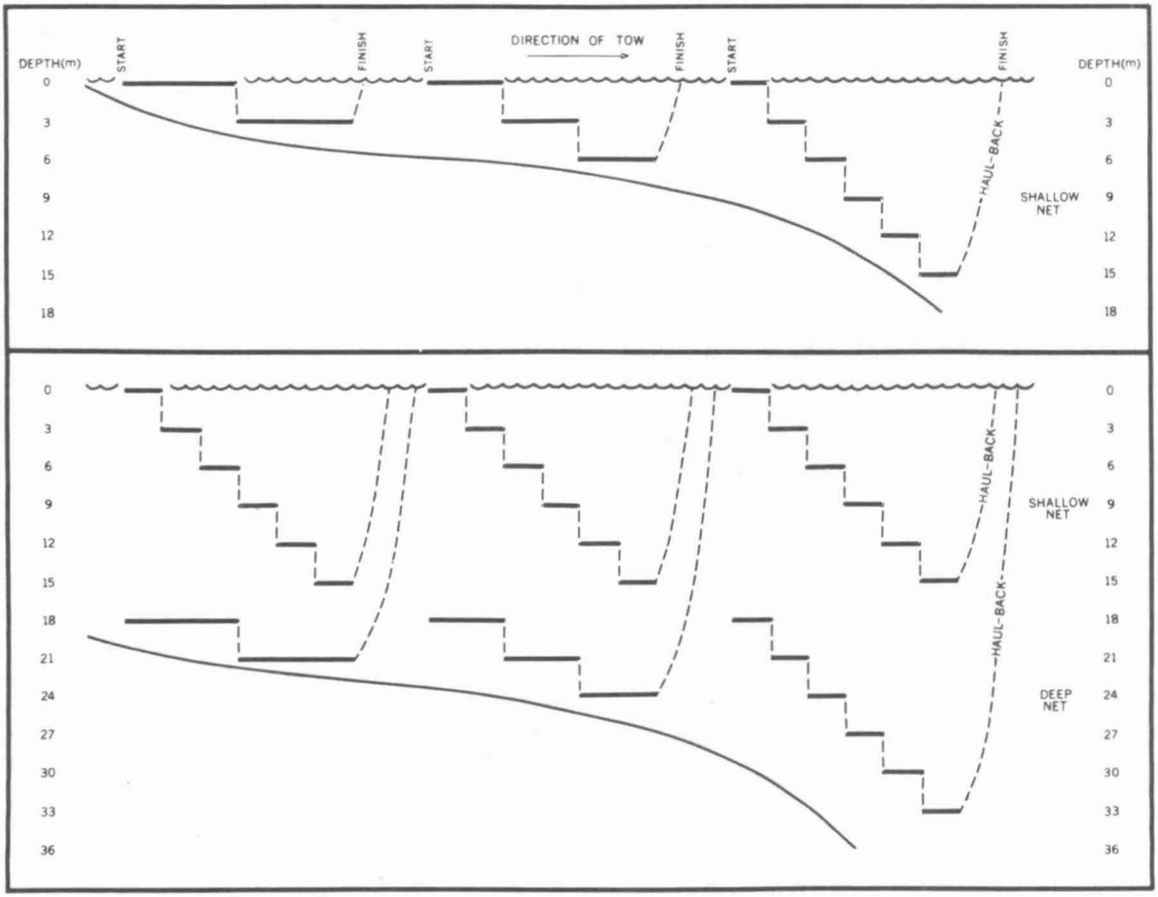

FIGURE 3.—Six sampling methods for ½-h plankton tows over different water depths.

collection. I also removed several postlarvae recognized as *Merluccius* sp. but which I presume are *M. albidus*, the postlarvae of which are undescribed.

We measured all specimens, except mutilated ones, from the tip of the snout to the tip of the notochord or urostyle with an ocular micrometer or point-to-point dial calipers. Measurements are expressed as millimeters notochord length (mm NL) and recorded to the nearest 0.1 mm. Because preservation resulted in shrinkage of specimens, the recorded size of some larvae is smaller than the reported hatching length of 2.8 mm (Kuntz and Radcliffe, 1917).

RESULTS

Egg and larval distributions are shown in Appendix Table 1 and Figures 4 through 8. A map is not shown for the one egg and one larva caught off the Virginia coast on May 20 and 22, respectively.

Distribution of Eggs

Eggs identified as silver hake for this report are in stages III and IV of development, when the embryo encompasses at least 75% of the yolk and the tail tip is separated from the yolk surface. Fine pigment is present on the part of the yolk surface lying under the snout of the embryo. This is not shown by Kuntz and Radcliffe (1917).

We collected 3,241 silver hake eggs from May through November 1966, with a peak in June. The temporal distribution of eggs changed geographically. Spawning began earlier in the northeastern end of our survey area and progressively later to the south. Table 2 demonstrates this trend for four transect groups. According to Sauskan and Serebryakov (1968), about half the total seasonal

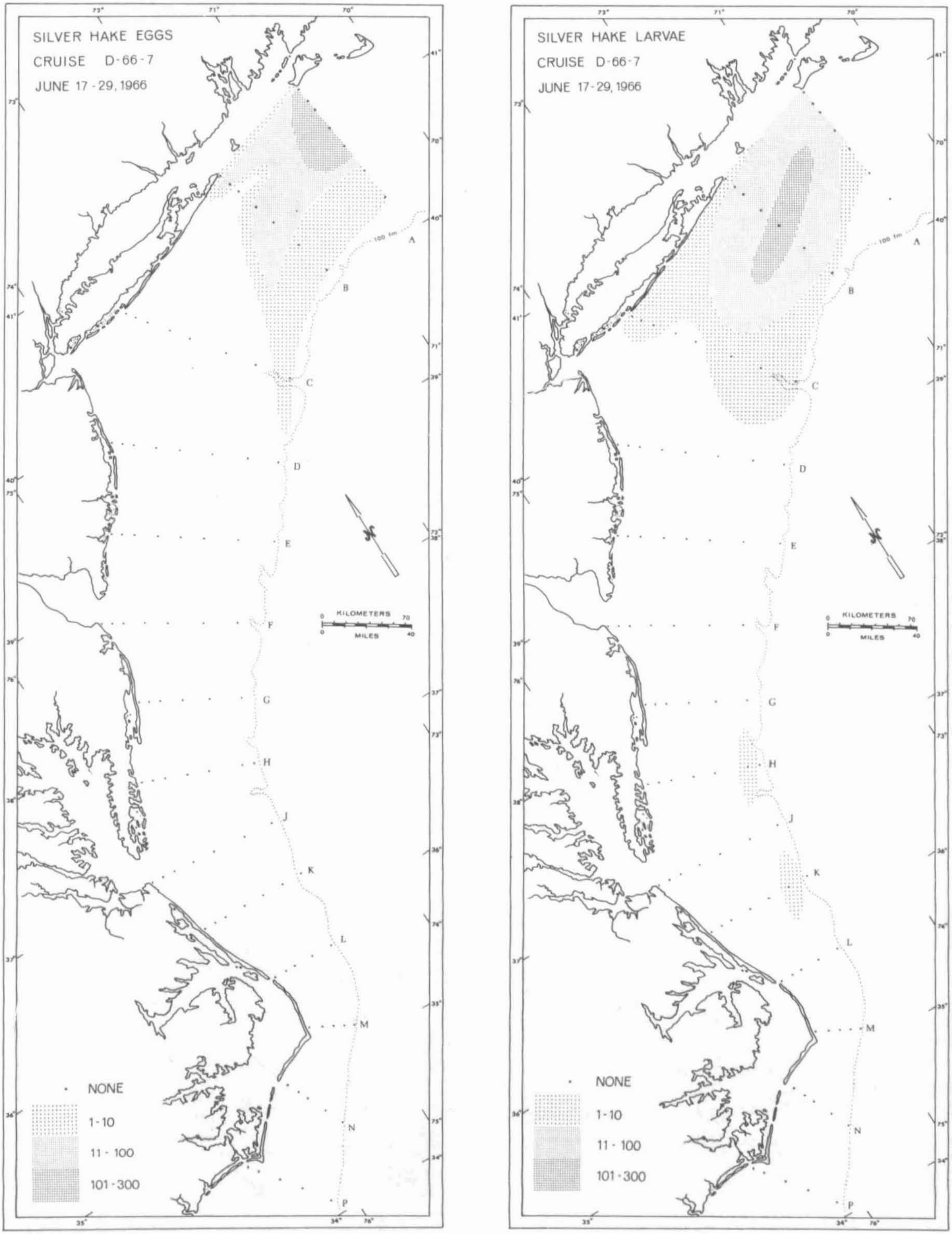

FIGURE 4.—Occurrence of silver hake eggs and larvae, June 1966.

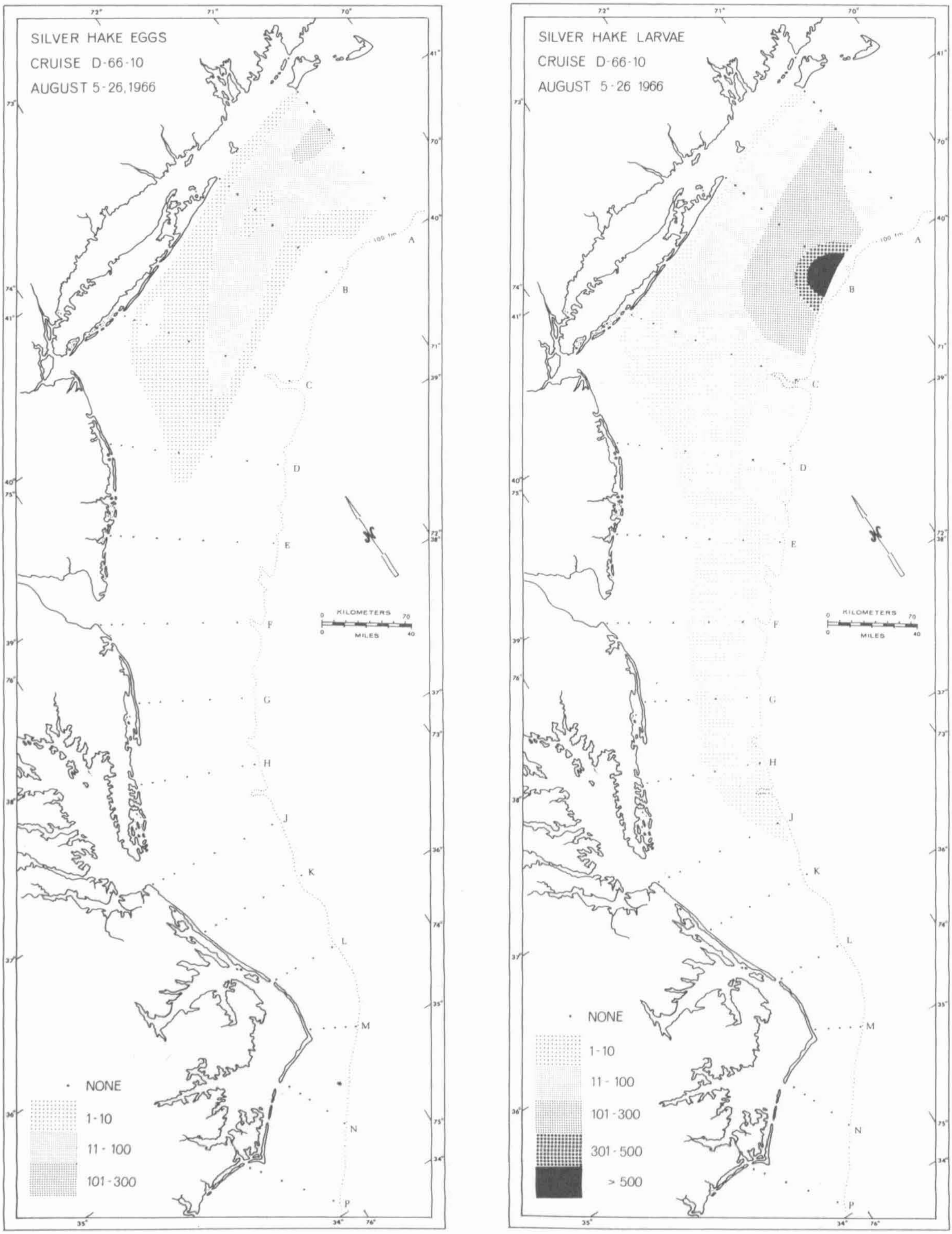

FIGURE 5.—Occurrence of silver hake eggs and larvae, August 1966.

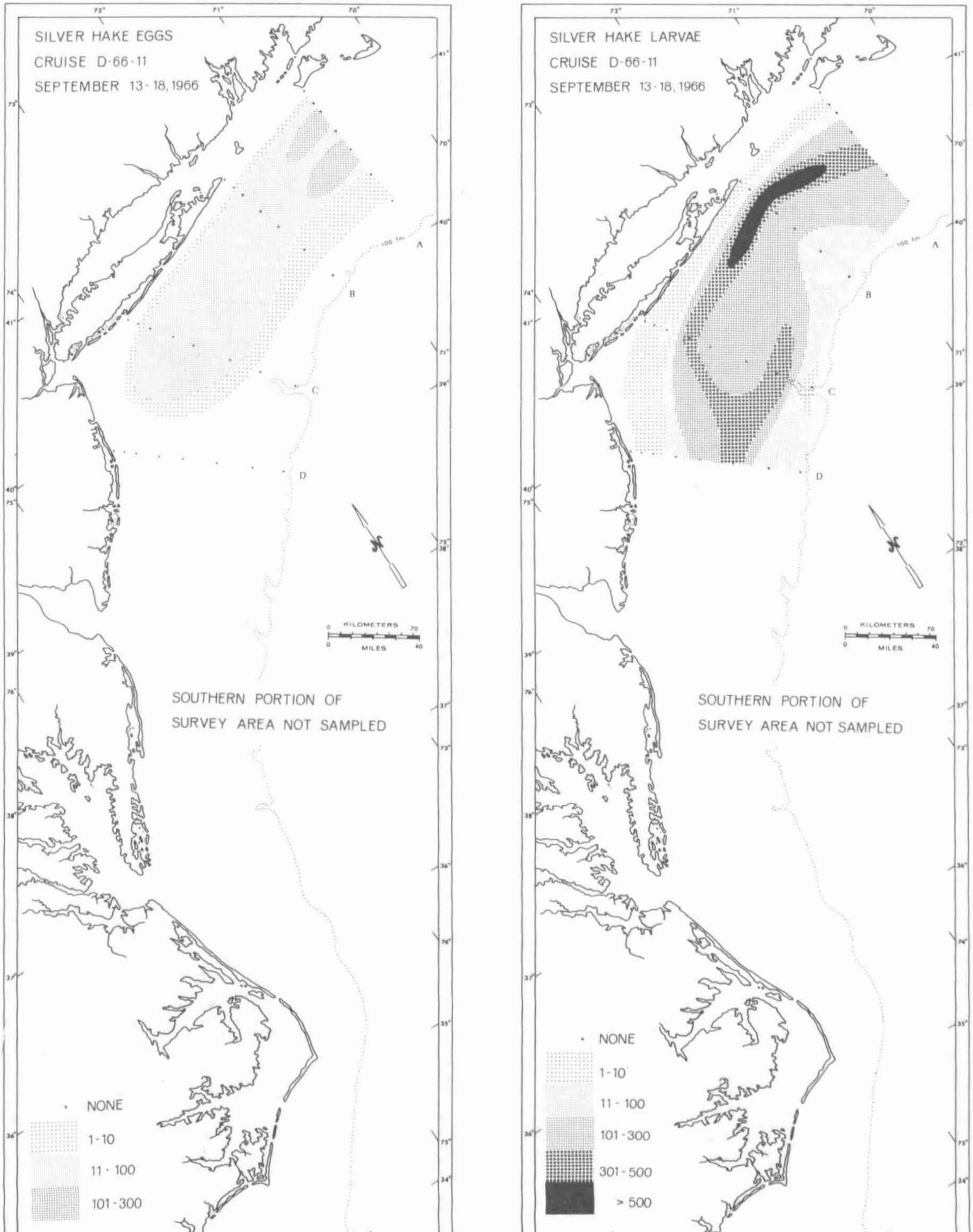

FIGURE 6.—Occurrence of silver hake eggs and larvae, September 1966.

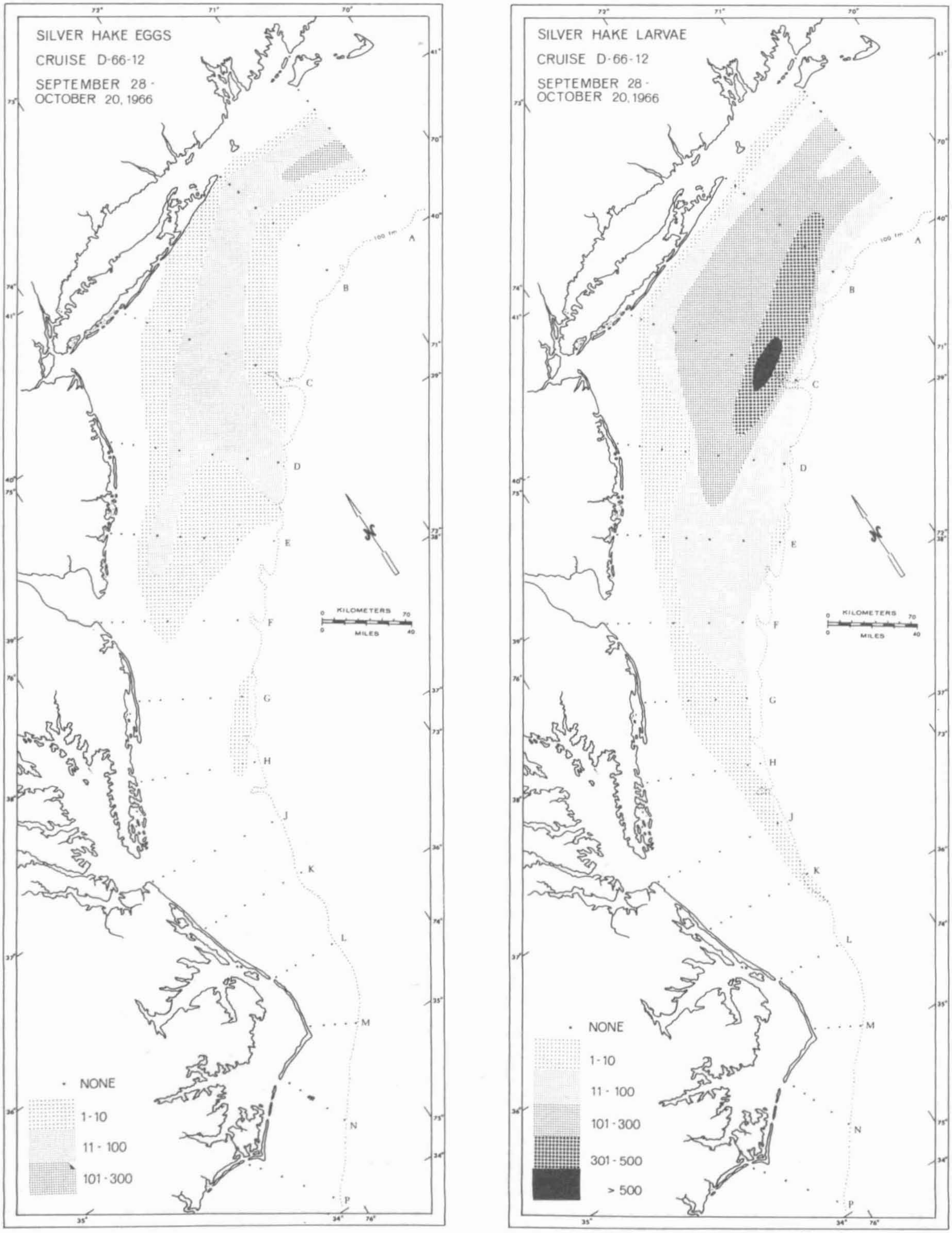

FIGURE 7.—Occurrence of silver hake eggs and larvae, September-October 1966.

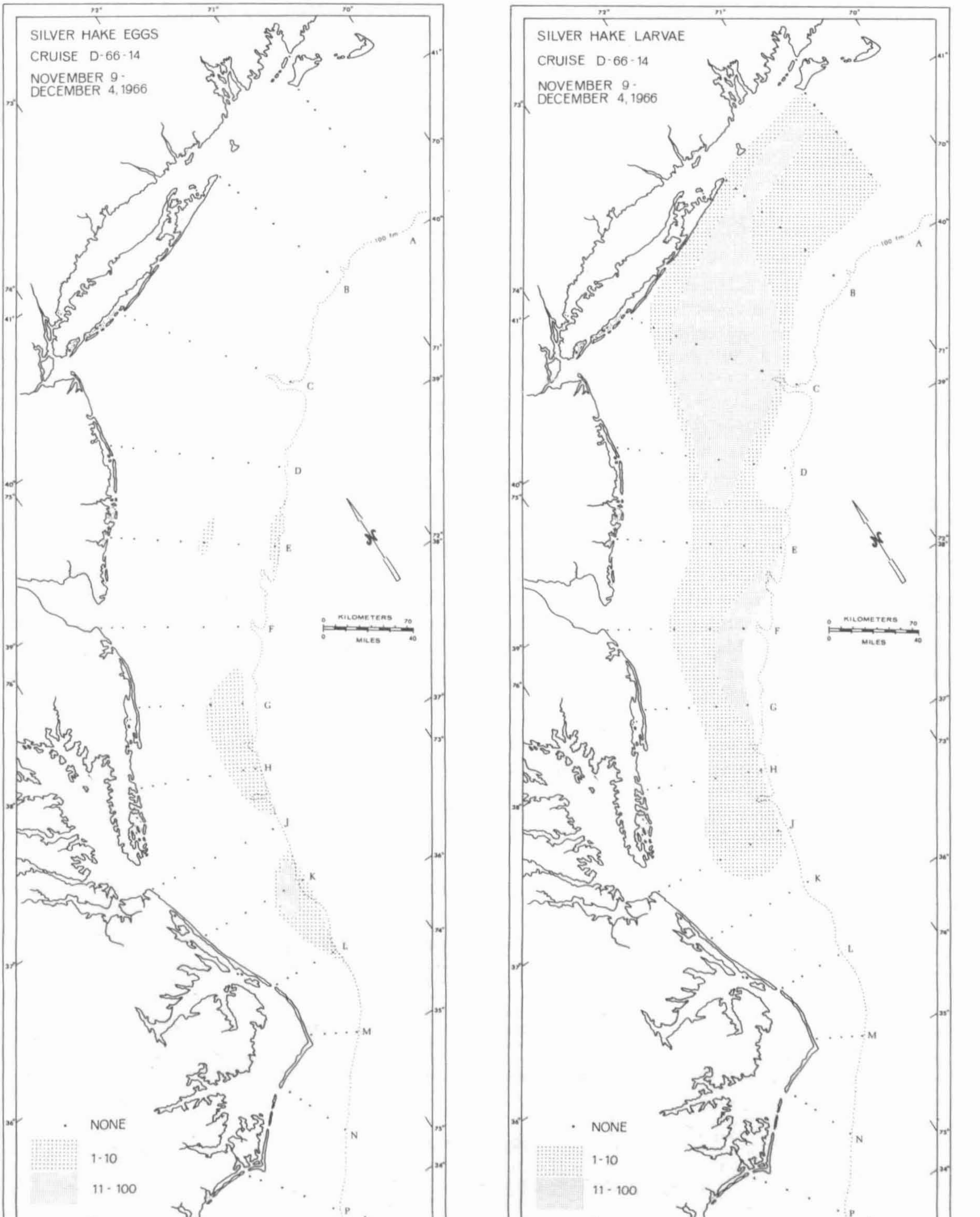

FIGURE 8.—Occurrence of silver hake eggs and larvae, November-December 1966.

TABLE 2.—Monthly distributions of silver hake eggs arranged by transect-groups. Monthly peak abundance for each group indicated by bold type. ns = not sampled.

Transect groups	Numbers of eggs collected						
	May	June	Aug.	Sept.	Oct.	Nov.-Dec.	Total
AB	0	**1,362**	415	617	454	0	2,848
C	0	5	26	**108**	48	0	187
DEF	0	0	6	0	**141**	9	156
GHJKL	1	1	0	ns	3	**45**	50
Total	1	1,368	447	725	646	54	3,241

production of eggs is released in a first batch, and the second half is divided between second and third batches. Our egg collections on the shelf south of Montauk Point and Martha's Vineyard (transects A and B in Table 2) are consistent with their conclusion. We collected 1,362 eggs in June, the remainder during August (415), September (617), and October (454).

The silver hake eggs collected during our 1966 cruises originated principally over Nantucket Shoals and on the continental shelf south of Martha's Vineyard. We collected 88% of the eggs on the two northernmost transects, 77% on the Martha's Vineyard transect alone. Sauskan and Serebryakov (1968) found concentrations south of Martha's Vineyard in May, on the southern slopes of Georges Bank in June. Thus, this area probably is an important silver hake spawning center. Small, distinct spawning groups are also located near Hudson Canyon, on the deeper parts of the shelf off New Jersey, and further south off Delaware, Maryland, and Virginia. The small numbers of eggs collected in the latter areas probably reflect the small numbers of adults occurring there.

Silver hake eggs are found in as wide a range of temperatures as the adults. The relation between numbers of eggs collected and surface temperatures is shown in Table 3. This may be misleading however, for we observed egg concentrations in a particular geographic area (south of Martha's Vineyard and Montauk Point) and these concentrations were apparently independent of prevailing surface temperatures which ranged from 13.5° to 21.7°C. It is not known how near the bottom silver hake spawn, nor in what range of temperatures. Assuming they spawn near the bottom, the wide temperature range of egg occurrences might be due to a wide range of temperatures in the spawning areas or might simply be the result of extreme temperature ranges in surface waters over the spawning areas, in which case the ascending eggs demonstrate a wide temperature tolerance.

Distribution of Larvae

Larval distributions are shown in Appendix Table 1 and Figures 4 through 8. We collected 11,032 silver hake larvae from May to December 1966, 91% during August, September, and October (Table 4). We captured no postlarvae larger

TABLE 3.—Abundance of silver hake eggs relative to observed surface temperatures.

Surface temperature (°C)	Number of tows which collected:				Total number of tows
	1-10 eggs	11-100 eggs	101-200 eggs	200+ eggs	
10.0-10.9	1				1
11.0-11.9	1				1
13.0-13.9	5			1	6
14.0-14.9	16	6	3	3	28
15.0-15.9	14	6	1		21
16.0-16.9	13	2			15
17.0-17.9	9	3	3		15
18.0-18.9	3	4	1		8
19.0-19.9	4	4			8
20.0-20.9	6	5			11
21.0-21.9	7	2			9
22.0-22.9	1				1
Total tows	80	32	8	4	124

TABLE 4.—Numbers of silver hake larvae collected during six cruises in 1966.

May	June	Aug.	Sept.	Oct.	Nov.-Dec.	Total
2	585	2,989	3,875	3,175	406	11,032

than 18.0 mm NL until the August cruise (Figure 9). Since the spawning season probably began in early June, and since 18.0 mm approximates the size at which silver hake postlarvae begin to live near the bottom, the length of pelagic life is apparently about 2 mo.

Within our 1966 sampling area, larvae were most densely concentrated between Nantucket Shoals and Hudson Canyon. Progressing southward, we found larvae increasingly restricted to the offshore part of the shelf. Distribution varied according to the size of larvae. Generally, we found smaller larvae inshore and near the surface, and larger larvae offshore and deeper. Smaller larvae were also more numerous in the northeastern part of the survey area than the southwestern. Tables 5 through 7 illustrate this trend for the August, September, and October cruises. These differences in distribution by size are partly a result of a southwesterly drift during growth, partly a preference by larger larvae for deeper water.

Silver hake larvae in 1966 were distributed in areas where surface temperatures ranged from 8.6° to 25.8°C. Since silver hake larvae are not necessarily surface-dwelling animals, the mean observed temperatures within the depths sampled by the two Gulf V nets may be more significant. Table 8 shows the number of tows containing larvae (arranged by volume of catch) relative to these temperatures. The total number of tows, regardless of the presence of silver hake, is in-

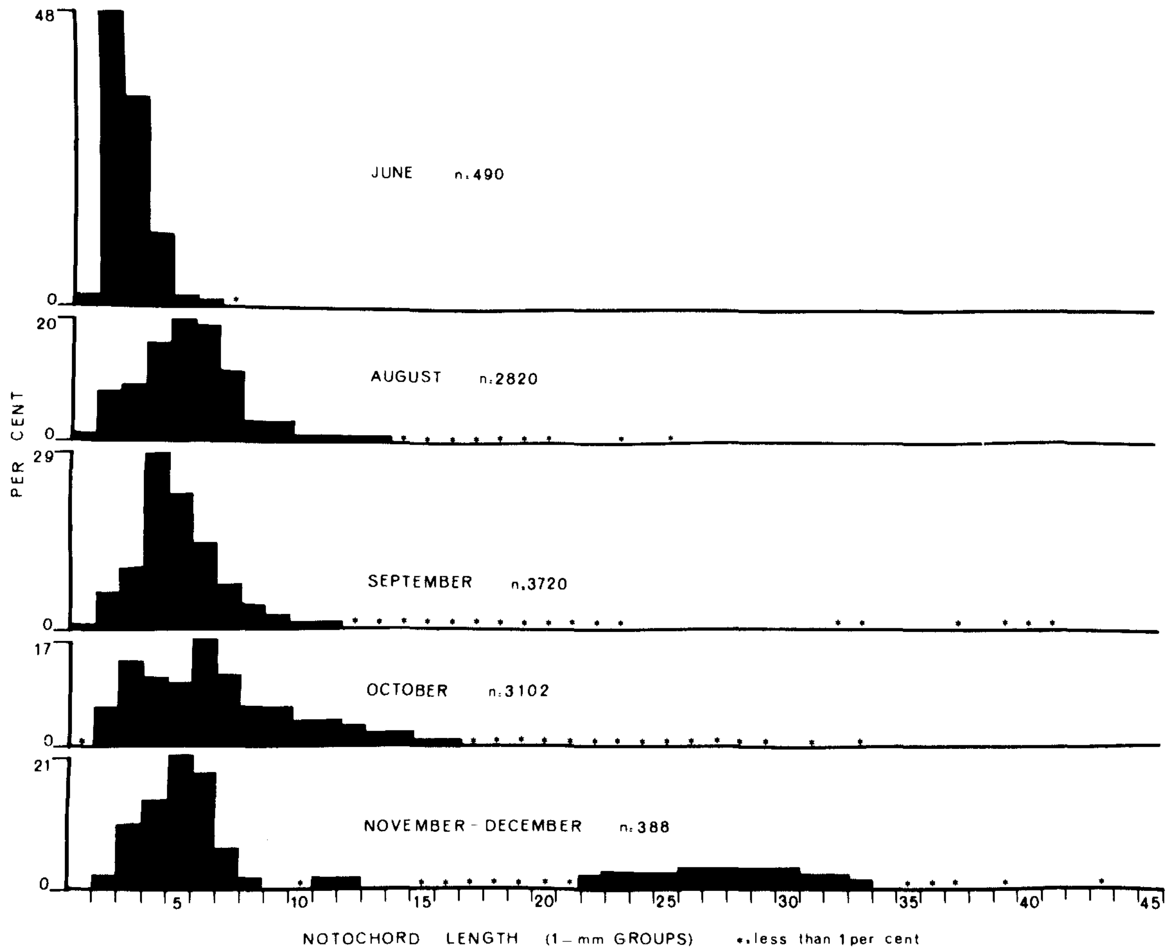

FIGURE 9.—Length-frequency distributions of silver hake larvae during five cruises, 1966.

TABLE 5.—Mean lengths (mm NL) of silver hake larvae collected during *Dolphin* cruise D-66-10 (August 1966), arranged by transect, net 1 (0-15 m) or net 2 (18-33 m), and station.

Transect	Net	Station 1	2	3	4	5	6	7	8	Mean length	*N*
A	1	3.2	2.8	4.0	3.1	5.0	4.0	3.6		3.8	598
	2			5.8	5.1	5.3	5.8	4.2		5.6	658
B	1	2.6	3.8	2.0	3.9	4.1	5.4	6.6		5.4	413
	2		3.6	3.3	5.5	6.2	6.8	8.5		7.8	1,037
C	1	2.1		3.2	3.6		3.2		4.9	3.5	54
	2				4.7	3.5		5.3	5.4	5.3	98
D	1					3.8	5.8	6.0	3.6	5.6	33
	2					3.2		12.2	10.2	10.3	71
E	1						5.3	3.3		4.0	3
	2						6.0	5.5		5.7	8
F	1						6.0	7.5		7.3	8
	2						7.0			7.0	2
G	1					3.6				3.6	1
	2										
H	1					14.8				14.8	1
	2					14.5		15.1		15.0	3
J	1										
	2							5.7		5.7	1
Mean length		3.0	3.2	4.2	3.6	5.1	5.6	7.9	7.4	6.1	
N		18	67	82	357	472	853	987	153		2,989

TABLE 6.—Mean lengths (mm NL) of silver hake larvae collected during *Dolphin* cruise D-66-11 (September, 1966), arranged by transect, net 1 (0-15 m) or net 2 (18-33 m), and station.

Transect	Net	Station 1	2	3	4	5	6	7	8	Mean length	*N*
A	1		3.0	3.6	4.2	4.5	5.8	5.0		4.7	478
	2		3.0	3.9	3.8	4.8	5.9	5.2		4.9	529
B	1	2.7	2.8	4.2	3.5	5.6	7.0	11.6		4.8	79
	2			5.6	4.9	4.1	6.6	12.0		5.7	921
C	1	3.0	2.7		4.4	3.0		12.3	8.2	7.2	29
	2				4.2	6.9	5.6	8.5	9.7	6.4	1,011
D	1		3.6	2.8	3.4	3.8	6.0	8.8		4.5	62
	2				2.8	4.9	5.5	7.0	9.1	5.8	620
Mean length		2.8	2.9	5.4	4.3	5.0	5.7	7.9	9.1	5.6	
N		14	22	615	730	799	840	650	59		3,729

cluded in the table to demonstrate the possibility that the temperature relationship is simply an artifact created by our cruise schedule. The probability of collecting these temperature-tolerant larvae at any temperature increases as sampling at that temperature increases.

Our maximum sampling depth was below the thermocline on all stations where we captured larval silver hake. Larvae apparently were more concentrated near the thermocline than near the surface during the summer months. Table 9 compares the percentage of the total catch contributed by the deep net (which sampled near the thermocline) during each cruise with observed surface temperatures and indicates that during August and September, when surface temperatures were highest, silver hake larvae were distributed more deeply where temperatures were lower.

Our cruise schedule and sampling sequence resulted in many consecutive stations being sampled during the same light regime. Thus, opportunities for comparing the diel differences in the captures of silver hake larvae are limited.

TABLE 7.—Mean lengths (mm NL) of silver hake larvae collected during *Dolphin* cruise D-66-12 (October, 1966), arranged by transect, net 1 (0-15 m) or net 2 (18-33 m), and station.

Transect	Net	Station 1	2	3	4	5	6	7	8	Mean length	*N*
A	1	3.4	4.2	4.7	3.5	3.1	5.5	9.9		3.8	143
	2		4.1	4.9	3.5	3.0	4.7	13.5		4.7	554
B	1		2.8	3.3	5.8	9.6	10.2	11.2		9.7	77
	2		5.5	4.4	6.4	7.5	10.8	9.6		8.7	699
C	1		8.7	7.1	5.8	5.0	7.6	13.5	19.8	8.3	157
	2			5.6	6.7	6.0	7.8	9.9	12.8	8.6	825
D	1	2.7		7.1		6.2	6.2	4.2	2.9	5.6	172
	2				15.0	6.1	6.9	5.6	4.5	6.3	212
E	1				2.8	6.4	6.6	8.0	3.5	6.4	67
	2					5.1	8.5	10.0	3.0	8.7	87
F	1					5.6	6.5	4.7		6.3	70
	2					3.7	7.0	6.3		6.4	27
G	1				5.4					5.4	1
	2					4.6	7.4			5.5	3
H	1										
	2						15.0			15.0	1
J	1										
	2							22.5		22.5	1
K	1							11.0		11.0	1
	2										
Mean length		3.2	4.5	5.1	4.8	6.2	7.7	9.6	4.8	7.3	
N		3	53	84	560	536	1,001	816	44		3,097

TABLE 8.—Abundance of silver hake larvae relative to mean temperature within the sampling depths of individual Gulf V nets.

Temperature (°C) within samplers' depth range	Number of tows which collected: 1-10 larvae	11-100 larvae	101-300 larvae	301-500 larvae	500+ larvae	Number of tows Containing silver hake	Total
6.0-6.9	5	2				7	9
7.0-7.9	3					3	12
8.0-8.9	4	2		1		7	18
9.0-9.9	17	2				19	34
10.0-10.9	9	8	2			19	32
11.0-11.9	5	5				10	17
12.0-12.9	4	6	3	2		15	22
13.0-13.9	14	7	3	1		25	48
14.0-14.9	22	14	8		2	46	75
15.0-15.9	8	8	2	1		19	38
16.0-16.9	12	6	1			19	36
17.0-17.9	12	5	2			19	44
18.0-18.9	4	6				10	33
19.0-19.9	1	5	4			10	39
20.0-20.9	8	3	1			12	23
21.0-21.9	6	1	1			8	25
22.0-22.9	6					6	29
23.0-23.9	1					1	14
24.0-24.9	1					1	20
25.0-25.9						0	11
26.0-26.9						0	6
Total tows	142	80	27	5	2	256	

Although day and night tows were equally productive (Table 10), differences exist when larval size is considered. Most of the smallest larvae were taken during the day, while most larger larvae and postlarvae were taken from dusk to dawn (Figure 10).

There are several possible explanations for the higher incidence of larger larvae and postlarvae

TABLE 9.—Contribution of deep net to total catch of larvae on stations where both nets were used, compared to weighted mean surface temperature.

Cruise	Month	Percent caught in deep net	Weighted mean surface temperature (°C)	Total number caught in both nets
D-66- 5	May	0	14.4	1
D-66- 7	June	34	14.5	408
D-66-10	Aug.	62	20.6	2,940
D-66-11	Sept.	82	19.9	3,836
D-66-12	Oct.	78	15.5	3,164
D-66-14	Nov.-Dec.	52	11.7	398

TABLE 10.—Diel differences in captures of silver hake larvae, cruises D-66-7 (June) through D-66-14 (November-December).

Light regime	Number of tows: Total	Number of tows: Containing silver hake	Number of larvae	Weighted mean length (mm NL)	Average catch: Total tows	Average catch: Tows containing silver hake
Dawn	62	21	810	5.4	13.1	38.6
Day	265	112	4,741	5.3	17.9	42.3
Dusk	48	18	1,255	5.7	26.1	69.7
Night	240	104	4,226	7.8	17.6	40.6

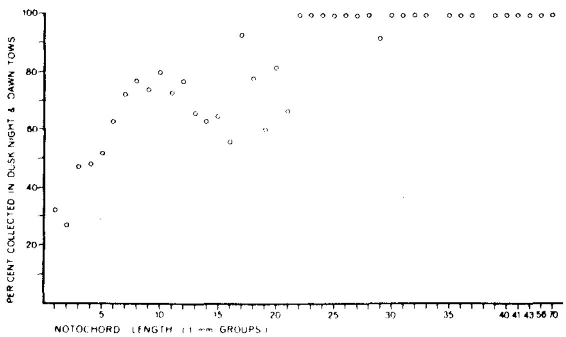

FIGURE 10.—Percentage of silver hake larvae collected in nonday tows per 1-mm size groups.

in night tows, the most generally accepted being that larvae avoid the approaching sampler during daylight in response to visual warning. The difference cannot be attributed to vibration of the towing cable or inefficient filtration by the sampler because these factors are equal during all light regimes. Undersampling of larger larvae of other species during daylight has been well documented (Silliman, 1943; Bridger, 1956; Ahlstrom, 1959; Colton, 1965). These authors, however, noted diel differences resulting from tows made at 1 knot. Miller, Colton, and Marak (1963) towed a high-speed plankton sampler at 7 knots and found no significant differences in the day and night catches of haddock larvae and pelagic juveniles. Ryland (1963) concluded that a towing speed of 5 knots (257.4 cm/s) was sufficient to prevent net avoidance by plaice larvae up to 20.0 mm whose maximum "darting velocity" he found to be 20 cm/s. If, by towing at 5 knots, we were able to overcome net avoidance by larger larvae, then the presence of larger larvae in night tows only must reflect some form of diel activity or vertical migration. Kelly and Barker (1961) found a significant difference in depth distribution with growth of young redfish, the larger juveniles occurring in deeper layers. A similar difference plus a diel change in depth distribution is observed with silver hake when the light regime, capture depth (net 1 vs. net 2), and mean larval length are combined (Figure 11). The largest larvae were captured in the deep net during the night, the smallest larvae in the shallow net during the day. In both nets, night tows contained larger larvae than day tows, and in both light regimes the deep net contained larger larvae than the shallow net. Evidently, with growth, silver hake larvae seek deeper water, perhaps in response to increasing negative phototropism, perhaps simply approximating the adult habitat.

During the summer of 1970, we made two cruises to investigate the size at which silver hake larvae first occur on or near bottom. On 12 stations northeast and southwest of Hudson Canyon, we made reciprocal tows with Gulf V samplers and an otter trawl (39-foot headrope) fitted with a ¼-inch mesh cover bag and separate cod end. Length frequencies of the Gulf V catches, compared with those of the otter trawl (Figure 12), indicate that silver hake first become available to bottom

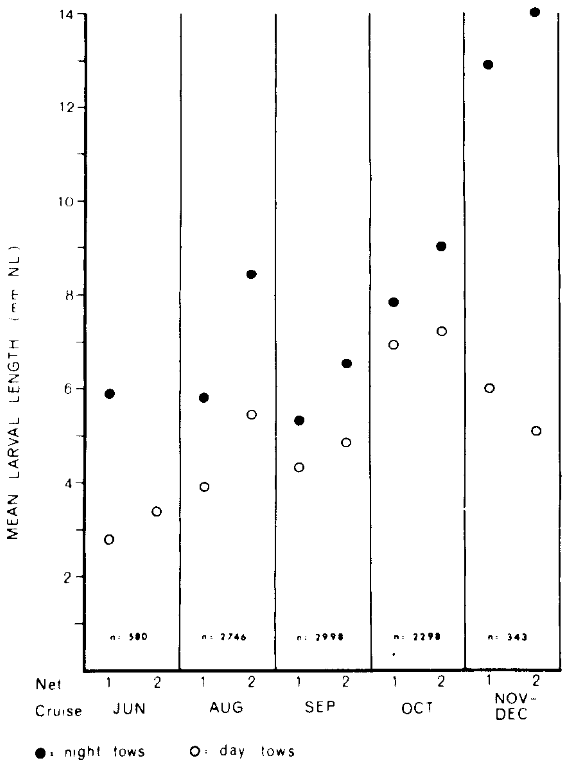

FIGURE 11.—Comparisons of silver hake mean larval size, light condition, and depth of capture. Net 1 sampled to a maximum of 15 m; net 2 to a maximum of 33 m.

sampling gear at about 17.0 to 20.0 mm NL. This figure is somewhat smaller than that indicated by Nichy (1969), whose smallest specimens taken by otter trawl were about 50 mm.

During 1966, all postlarvae larger than 21.0 mm NL (except one) were captured at night, and most of those were taken in the deep net, which sampled above, within, and below the thermocline, if one was present. Postlarvae larger than 21.0 mm NL were taken in the shallow net only when the thermocline was weak or nonexistent. All this suggests that silver hake postlarvae seek the bottom at about 17.0 to 20.0 mm NL and migrate vertically at night, ascending at least to the thermocline depth or, in the absence of a thermocline, to levels nearer the surface.

DISCUSSION

The area encompassing the southern slope of Georges Bank, Great South Channel, Nantucket Shoals, and the shelf south of Martha's Vineyard is evidently an important spawning center for silver hake. Unfortunately, neither the *Dolphin* survey nor the Soviet surveys (Sauskan and Serebryakov, 1968) sampled this area extensively enough to determine all the possible drift patterns of eggs and larvae. The 70°40'W meridian approximates the eastern limit of the *Dolphin* survey and the western limit of the sampling reported by Sauskan and Serebryakov.

Within this wide area, eggs should be expected to drift in several different directions, depending on the location of spawning and on long-term prevailing winds. One component of the westerly current on the shelf south of Martha's Vineyard and Nantucket Island originates on the southern slope of Georges Bank where it forms the southern part of a rotational eddy (Bigelow, 1927; Klimenkov and Pakhorukov, 1963; Bumpus and Chase, 1965; Bumpus and Lauzier, 1965; Harrison et al., 1967). Eggs spawned on Georges Bank may 1) drift with the eddy, develop, and recruit back to Georges Bank, or 2) drift west and south of Martha's Vineyard where we consistently found concentrations. Walford (1938) described similar patterns for haddock larvae spawned on Georges Bank. A third possibility may result in the loss of the brood. Colton (1959) reported that silver hake larvae spawned on Georges Bank were killed when a southerly drift carried them off the bank and into warm slope water (the rate of warming exceeding the larvae's rate of acclimation). Presumably, in addition to the perils of warming waters, silver hake larvae carried off Georges Bank into the slope water or Gulf Stream would be carried to the east and, unable to find suitable depths in which to begin the demersal stage, would perish.

Eggs spawned south of Martha's Vineyard drift west but probably not far before hatching, for the incubation period is only 48 h (Kuntz and Radcliffe, 1917). Unfortunately, these authors did not cite the temperature at which incubation or hatching occurred. If we assume (as did Sauskan and Serebryakov, 1968) that Kuntz and Radcliffe incubated their eggs at a maximum temperature of 20°C, then the maximum incubation period in degree-hours would be 960 ($48 \times 20 = 960$). We encountered the heaviest concentrations of eggs on the Martha's Vineyard transect when surface temperatures ranged from 13° to 22°C. Even at the minimum temperature of 13°C, incubation would occupy no more than 73.8 h ($960/13 = 73.8$). Currents between Georges Bank and Delaware

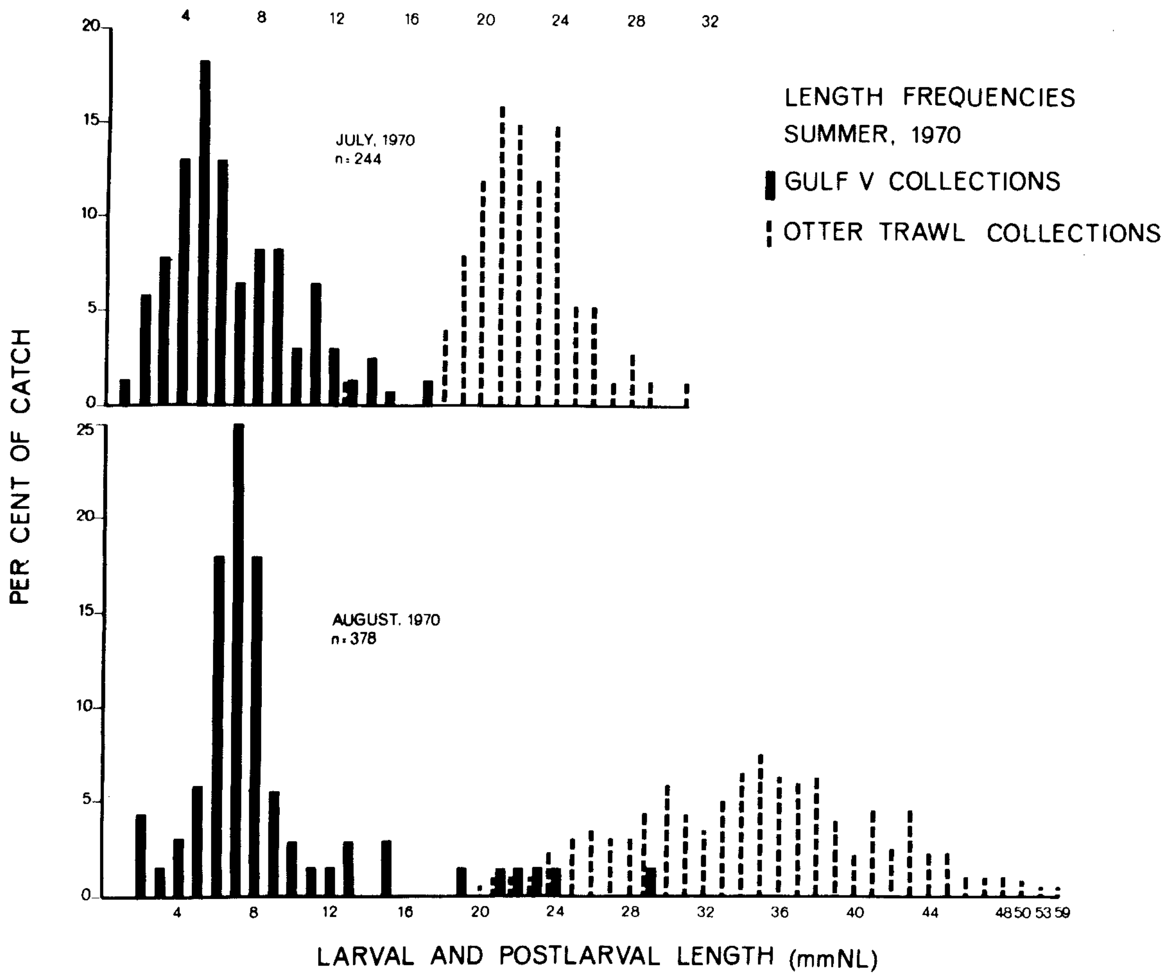

FIGURE 12.—Comparison of length frequencies of silver hake larvae and post-larvae captured in Gulf V plankton samplers near surface and otter trawl on bottom during summer cruises, 1970.

Bay flow west to southwest at average speeds of 0.93 km/h over the shelf between Nantucket Shoals and New Jersey (U.S. Navy Hydrographic Office, 1965) to 1.04 km/h over the southeast slope of Georges Bank (Sauskan and Serebryakov, 1968). Thus, the maximum distance an egg would drift from spawning to hatching is 76.8 km ($1.04 \times 73.8 = 76.8$) in the area of greatest egg abundance which we observed. This is substantiated by the fact that the center of abundance of the prolarvae is only slightly further to the southwest than that of the eggs. Also contributing to the short drift of eggs and prolarvae is the sluggish, meandering nature of currents on the shelf south of New England. During the summer of 1971, while studying vertical distribution of silver hake larvae on the shelf south of Montauk Point, we deployed a free-drifting staff buoy and sampled around it for 48 h. The course of the buoy (Figure 13) demonstrates the capriciousness of surface currents in the area, while indicating a net westerly drift.

I consider the silver hake eggs and larvae which we collected to be 1) representatives of a small brood spawned on the deeper portions of the shelf between Hudson Canyon and Cape Hatteras; 2) representatives of a brood spawned over Nantucket Shoals and the shelf south of New England; 3) survivors of a brood spawned over Georges Bank or Great South Channel.

It is during the pelagic period of development that eggs or larvae, unable to control their own movements, are most susceptible to prevailing currents, surface winds, and changing hydro-

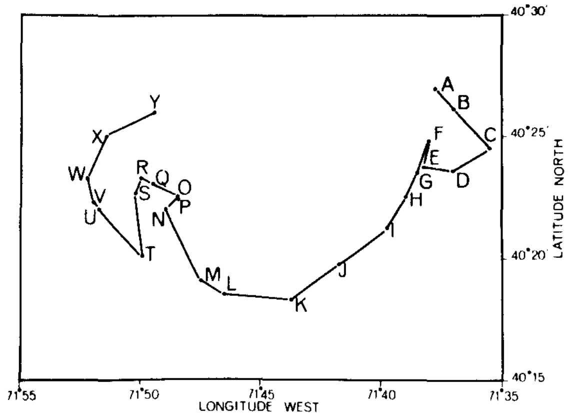

FIGURE 13.—Position of free-drifting staff buoy at 2-h intervals on the continental shelf south of Montauk Point, N.Y.

graphic conditions. The results of the *Dolphin* survey indicate several things about sampling fishes during this phase in their development. 1) One cannot hope to fully understand the early life history of any one species of fish on exploratory surveys. Such facts as gross seasonality and geographic limits of spawning might be revealed but a complete evaluation of a species' early life history can only follow a series of frequent cruises where all efforts are focused on one or a very few species. 2) Known or suspected zoogeographic barriers should be included well within the limits of a survey area, not made to coincide with the edge. 3) Sampling between the surface and levels immediately below the thermocline is inadequate when dealing with pelagic young of groundfish. A more complete and accurate picture of developing silver hake could have been drawn if the entire water column, surface to bottom, had been sampled on all stations. 4) The diel activity and vertical distribution of a postlarval fish may be directly related to the behavior of invertebrate food organisms. An analysis of the invertebrate plankton collected with the ichthyoplankton should be considered as an integral part of a survey. 5) Unless discrete-level tows are made with opening-closing nets, an exact temperature-catch relationship cannot be determined, except in vertically isothermal conditions.

I found no evidence that silver hake depend on or utilize estuaries during their early life history. Their occasional presence in estuarine areas must be considered accidental.

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APPENDIX TABLE 1.—Silver hake: station data, number of eggs, and number and length range of larvae collected during 1966.

Cruise and station	Net	Date	Start time	Depth of water (m)	Maximum tow depth (m)	Light regime[1]	Total number of eggs	Larvae			
								Total number captured	Number measured	Notochord length	
										Mean (mm)	Range (mm)
D-66-5			EDST								
B-1	1	13 V 66	2233	24-20	6	N	—	1	1	71.20	71.2
H-5	2	20 V 66	0527	24-40	24	C	1	—	—	—	—
K-5	1	22 V 66	0533	33-35	15	C	—	1	1	2.50	2.5
D-66-7			EDST								
A-1	1	17 VI 66	0927	11-27	6	D	206	81	54	2.40	1.7-2.8
A-2	1	17 VI 66	1037	29-37	15	D	242	75	55	2.28	1.8-3.2
A-3	1	17 VI 66	1137	29-48	15	D	117	49	35	2.21	1.8-2.6
A-3	2	17 VI 66	1137	29-48	24	D	209	3	3	2.10	1.9-2.3
A-4	1	17 VI 66	1322	51-53	15	D	107	3	3	3.33	3.2-3.6
A-4	2	17 VI 66	1322	51-53	33	D	158	16	15	2.43	2.0-3.1
A-5	1	17 VI 66	1703	62-62	15	D	123	4	3	2.70	2.2-3.1
A-5	2	17 VI 66	1703	62-62	33	D	79	1	1	2.80	2.8
A-6	1	17 VI 66	1919	73-75	15	C	1	—	—	—	—
A-7	1	17 VI 66	2343	117-102	15	N	1	—	—	—	—
B-1	1	18 VI 66	1732	24-24	15	D	4	3	3	2.77	2.5-3.3
B-2	1	18 VI 66	1622	46-42	15	D	16	18	16	2.61	2.0-5.3
B-2	2	18 VI 66	1622	46-42	24	D	3	—	—	—	—
B-3	1	18 VI 66	1525	53-51	15	D	—	15	15	2.95	2.1-4.4
B-3	2	18 VI 66	1525	53-51	33	D	—	4	4	2.55	2.4-2.8
B-4	1	18 VI 66	1402	62-64	15	D	20	15	14	3.34	2.8-4.1
B-4	2	18 VI 66	1402	62-64	33	D	7	6	3	3.63	2.7-5.0
B-5	1	18 VI 66	1036	77-75	15	D	1	120	116	3.33	2.4-5.7
B-5	2	18 VI 66	1036	77-75	33	D	64	62	56	3.33	2.4-4.7
B-6	1	18 VI 66	0833	86-86	15	D	—	24	24	3.93	2.7-4.6
B-6	2	18 VI 66	0833	86-86	33	D	3	60	60	3.65	2.9-4.4
B-7	1	18 VI 66	0412	88-99	15	C	—	1	1	3.10	3.1
B-7	2	18 VI 66	0412	88-99	33	C	1	—	—	—	—
C-1	1	19 VI 66	0628	20-29	15	D	—	8	2	3.60	2.7-4.5
C-2	2	19 VI 66	0733	31-31	27	D	—	1	1	2.90	2.9
C-3	1	19 VI 66	0827	35-37	15	D	—	2	2	4.15	4.1-4.2
C-6	1	19 VI 66	1531	58-58	15	D	—	1	1	5.20	5.2
C-6	2	19 VI 66	1531	58-58	33	D	—	5	5	5.74	5.1-6.3
C-7	1	19 VI 66	2043	79-77	15	C	—	4	3	6.30	5.8-6.9
C-8	1	19 VI 66	2310	112-320	15	N	4	2	2	4.90	4.7-5.1
C-8	2	19 VI 66	2310	112-320	33	N	1	—	—	—	—
H-6	1	27 VI 66	0654	79-97	15	D	—	1	1	6.30	6.3
H-7	2	27 VI 66	0758	102-214	33	D	1	—	—	—	—
K-6	1	25 VI 66	2205	42-49	15	N	—	1	1	7.80	7.8
D-66-10			EDST								
A-1	1	5 VIII 66	0502	9-22	6	C	1	14	13	3.15	2.2-5.6
A-2	1	5 VIII 66	0607	26-33	15	C	47	31	29	2.82	1.6-5.1
A-3	1	5 VIII 66	0701	33-35	15	D	73	41	34	4.02	2.2-6.2
A-3	2	5 VIII 66	0701	33-35	24	D	18	20	20	5.78	2.2-8.6
A-4	1	5 VIII 66	0840	49-55	15	D	119	217	193	3.14	1.6-5.7
A-4	2	5 VIII 66	0840	49-55	33	D	4	54	49	5.11	2.4-6.9
A-5	1	5 VIII 66	1219	58-57	15	D	6	144	141	5.03	2.7-8.1
A-5	2	5 VIII 66	1219	58-57	33	D	8	120	116	5.26	2.1-8.6
A-6	1	5 VIII 66	1441	68-71	15	D	71	144	131	4.00	2.2-6.6
A-6	2	5 VIII 66	1441	68-71	33	D	—	424	401	5.79	2.0-9.2
A-7	1	5 VIII 66	1741	102-113	15	D	5	7	5	3.58	2.3-4.3
A-7	2	5 VIII 66	1741	102-113	33	D	10	40	36	4.18	2.2-10.1
B-1	1	6 VIII 66	1349	24-16	15	D	—	2	1	2.60	2.6
B-2	1	6 VIII 66	1149	38-29	15	D	9	7	7	3.83	2.5-4.7
B-2	2	6 VIII 66	1149	38-29	21	D	1	29	22	3.58	2.1-7.1
B-3	1	6 VIII 66	1101	46-42	15	D	22	2	2	2.05	1.9-2.2
B-3	2	6 VIII 66	1101	46-42	33	D	2	10	10	3.34	2.1-6.5
B-4	1	6 VIII 66	0720	60-58	15	D	4	29	25	3.90	1.7-6.4
B-4	2	6 VIII 66	0720	60-58	33	D	—	15	15	5.53	2.9-9.2
B-5	1	6 VIII 66	0544	73-73	15	C	12	112	88	4.07	2.0-5.7
B-5	2	6 VIII 66	0544	73-73	33	C	2	85	65	6.22	2.2-13.0
B-6	1	6 VIII 66	0133	87-82	15	N	1	98	96	5.37	2.6-15.1
B-6	2	6 VIII 66	0133	87-82	33	N	—	172	149	6.81	3.0-16.7
B-7	1	5 VIII 66	2340	91-99	15	N	—	163	162	6.58	3.2-15.3
B-7	2	5 VIII 66	2340	91-99	33	N	—	726	701	8.53	3.5-25.9
C-1	1	7 VIII 66	0043	18-20	6	N	—	2	2	2.10	1.8-2.4
C-2	1	7 VIII 66	0137	27-29	15	N	1	—	—	—	—
C-3	1	7 VIII 66	0239	31-33	15	N	—	9	9	3.19	2.6-5.5
C-4	1	7 VIII 66	0413	40-40	15	N	4	41	39	3.66	1.7-6.3
C-4	2	7 VIII 66	0413	40-40	33	N	—	1	1	4.70	4.7
C-5	1	7 VIII 66	0745	48-48	15	D	2	—	—	—	—
C-5	2	7 VIII 66	0745	48-48	33	D	—	3	3	3.50	2.8-4.8

APPENDIX TABLE 1.—Continued.

Cruise and station	Net	Date	Start time	Depth of water (m)	Maximum tow depth (m)	Light regime[1]	Total number of eggs	Larvae			
								Total number captured	Number measured	Notochord length	
										Mean (mm)	Range (mm)
D-66-10—Continued			EDST								
C-6	1	7 VIII 66	1005	55-55	15	D	19	1	1	3.20	3.2
C-7	2	7 VIII 66	1406	70-60	33	D	—	7	6	5.30	4.5-6.0
C-8	1	7 VIII 66	1630	108-210	15	D	—	1	1	4.90	4.9
C-8	2	7 VIII 66	1630	108-210	33	D	—	87	73	5.39	3.3-7.3
D-5	1	8 VIII 66	0615	40-33	15	D	6	4	4	3.75	2.4-7.1
D-5	2	8 VIII 66	0615	40-33	24	D	—	1	1	3.20	3.2
D-6	1	8 VIII 66	0422	48-54	15	N	—	7	6	5.77	4.5-6.5
D-7	1	8 VIII 66	0018	77-75	15	N	—	21	20	5.95	4.5-13.5
D-7	2	8 VIII 66	0018	77-75	33	N	—	6	6	12.25	6.4-17.6
D-8	1	7 VIII 66	2221	110-126	15	N	—	1	1	3.60	3.6
D-8	2	7 VIII 66	2221	110-126	33	N	—	64	61	10.21	6.0-19.9
E-6	1	9 VIII 66	1306	44-42	15	D	—	1	1	5.30	5.3
E-6	2	9 VIII 66	1306	44-42	33	D	—	3	3	5.97	5.8-6.2
E-7	1	9 VIII 66	1505	64-64	15	D	—	2	2	3.30	2.9-3.7
E-7	2	9 VIII 66	1505	64-64	33	D	—	5	5	5.54	4.2-7.2
F-6	1	9 VIII 66	2306	55-53	15	N	—	1	1	6.00	6.0
F-6	2	9 VIII 66	2306	55-53	33	N	—	2	2	7.05	6.9-7.2
F-7	1	9 VIII 66	2118	77-71	15	N	—	7	7	7.50	5.5-10.1
G-5	1	21 VIII 66	1355	51-48	15	D	—	1	1	3.60	3.6
H-5	1	22 VIII 66	0239	37-44	15	N	—	1	1	14.80	14.8
H-5	2	22 VIII 66	0239	37-44	24	N	—	1	1	14.50	14.5
H-7	2	21 VIII 66	2130	95-163	33	N	—	2	2	15.10	15.0-15.2
J-7	2	23 VIII 66	0717	86-119	33	C	—	1	1	5.70	5.7
D-66-11			EDST								
A-2	1	13 IX 66	1133	29-31	15	D	15	2	2	2.95	2.6-3.3
A-2	2	13 IX 66	1133	29-31	24	D	7	9	7	3.03	2.6-3.7
A-3	1	13 IX 66	1243	38-42	15	D	190	13	12	3.65	2.5-4.8
A-3	2	13 IX 66	1243	38-42	24	D	23	9	8	3.86	2.8-4.6
A-4	1	13 IX 66	1415	46-53	15	D	7	136	131	4.17	2.2-6.2
A-4	2	13 IX 66	1415	46-53	33	D	22	91	86	3.78	2.3-6.5
A-5	1	13 IX 66	1816	60-60	15	C	112	197	187	4.49	1.8-6.7
A-5	2	13 IX 66	1816	60-60	33	C	116	201	198	4.77	1.8-7.5
A-6	1	13 IX 66	2030	68-68	15	N	—	86	83	5.82	2.7-11.9
A-6	2	13 IX 66	2030	68-68	33	N	9	131	123	5.86	4.1-11.5
A-7	1	14 IX 66	0104	113-112	12	N	—	81	63	5.00	3.7-20.0
A-7	2	14 IX 66	0104	113-112	30	N	—	113	107	5.24	2.9-21.0
B-1	1	14 IX 66	2304	26-26	6	N	—	13	10	2.70	2.4-3.2
B-2	1	14 IX 66	0025	33-35	15	N	—	13	9	2.76	2.4-3.1
B-3	1	17 IX 66	0033	49-51	15	N	36	38	32	4.18	2.3-9.4
B-3	2	17 IX 66	0033	49-51	33	N	19	567	558	5.60	2.4-17.3
B-4	1	14 IX 66	1743	60-66	15	C	9	12	12	3.50	2.3-5.8
B-4	2	14 IX 66	1743	60-66	33	C	3	178	178	4.86	2.4-13.0
B-5	1	14 IX 66	1359	73-71	15	D	22	2	2	5.60	4.8-6.4
B-5	2	14 IX 66	1359	73-71	33	D	23	103	96	4.14	2.0-11.0
B-6	1	14 IX 66	1004	80-84	15	D	4	12	4	7.05	4.9-8.8
B-6	2	14 IX 66	1004	80-84	33	D	—	39	38	6.57	5.1-7.8
B-7	1	14 IX 66	0457	95-93	15	C	—	10	10	11.65	6.7-40.0
B-7	2	14 IX 66	0457	95-93	33	C	—	53	51	12.05	6.5-41.1
C-1	1	17 IX 66	0850	18-16	9	D	—	4	4	3.05	2.7-3.7
C-2	1	17 IX 66	0758	29-26	15	D	—	5	3	2.73	2.6-2.8
C-3	1	17 IX 66	0707	38-29	15	C	56	—	—	—	—
C-4	1	17 IX 66	1640	40-42	15	D	8	1	1	4.40	4.4
C-4	2	17 IX 66	1640	40-42	33	D	4	312	300	4.20	2.3-10.3
C-5	1	17 IX 66	1835	49-47	15	C	16	8	7	3.04	2.5-4.5
C-5	2	17 IX 66	1835	49-47	33	C	1	157	157	6.92	2.8-11.9
C-6	2	17 IX 66	2033	57-57	33	N	23	208	207	5.61	2.1-19.5
C-7	1	17 IX 66	2247	71-77	15	N	—	13	12	12.32	3.1-22.5
C-7	2	17 IX 66	2247	71-77	33	N	—	351	345	8.49	3.1-32.8
C-8	1	18 IX 66	0049	110-519	15	N	—	2	2	8.25	7.9-8.6
C-8	2	18 IX 66	0049	110-519	33	N	—	2	2	9.70	9.4-10.0
D-2	1	18 IX 66	1421	22-20	6	D	—	1	1	3.60	3.6
D-3	1	18 IX 66	1326	20-26	15	D	—	6	5	2.80	2.2-4.0
D-4	1	18 IX 66	1159	33-27	15	D	—	12	11	3.39	2.6-4.2
D-4	2	18 IX 66	1159	33-27	24	D	—	11	11	2.78	2.2-4.2
D-5	1	18 IX 66	1043	35-35	15	D	—	25	22	3.82	2.6-5.9
D-5	2	18 IX 66	1043	35-35	33	D	—	136	130	4.93	2.6-11.2
D-6	1	18 IX 66	0843	55-53	15	D	—	22	22	5.99	4.1-8.8
D-6	2	18 IX 66	0843	55-53	33	D	—	372	363	5.48	3.1-12.2
D-7	1	18 IX 66	0624	73-70	15	C	—	1	1	8.80	8.8
D-7	2	18 IX 66	0624	73-70	33	C	—	61	61	6.96	3.5-10.2
D-8	2	18 IX 66	0424	121-115	33	N	—	56	55	9.14	6.5-12.7

APPENDIX TABLE 1.—Continued.

Cruise and station	Net	Date	Start time	Depth of water (m)	Maximum tow depth (m)	Light regime[1]	Total number of eggs	Larvae: Total number captured	Larvae: Number measured	Notochord length: Mean (mm)	Notochord length: Range (mm)
D-66-12			EDST								
A-1	1	15 X 66	0402	24-9	6	N	—	3	2	3.40	3.1-3.7
A-2	1	15 X 66	0309	31-29	15	N	—	16	15	4.21	3.2-5.8
A-2	2	15 X 66	0309	31-29	24	N	—	31	30	4.06	2.8-5.3
A-3	1	15 X 66	0209	42-37	15	N	—	8	8	4.72	2.8-6.7
A-3	2	15 X 66	0209	42-37	33	N	1	37	33	4.94	2.6-26.5
A-4	1	15 X 66	0715	48-51	15	C	31	105	102	3.47	2.3-6.9
A-4	2	15 X 66	0715	48-51	33	C	63	216	207	3.47	2.3-5.7
A-5	1	15 X 66	0843	58-60	15	D	12	6	6	3.07	2.7-3.7
A-5	2	15 X 66	0843	58-60	33	D	275	73	67	2.98	2.0-4.6
A-6	1	15 X 66	1032	68-71	15	D	1	8	8	5.51	3.1-11.5
A-6	2	15 X 66	1032	68-71	33	D	2	191	177	4.69	1.8-12.8
A-7	1	15 X 66	1226	108-115	15	D	—	2	2	9.90	3.0-16.8
A-7	2	15 X 66	1226	108-115	33	D	—	40	40	13.54	3.7-21.5
B-1	1	14 X 66	1930	7-18	6	N	2	—	—	—	—
B-2	1	14 X 66	2037	33-37	15	N	6	1	1	2.80	2.8
B-2	2	14 X 66	2037	33-37	24	N	14	4	4	5.47	3.2-6.8
B-3	1	14 X 66	2134	42-48	15	N	10	1	1	3.30	3.3
B-3	2	14 X 66	2134	42-48	33	N	19	19	19	4.39	2.2-8.8
B-4	1	14 X 66	1406	62-58	15	D	6	6	6	5.75	4.2-6.8
B-4	2	14 X 66	1406	62-58	33	D	9	145	142	6.36	2.5-18.5
B-5	1	14 X 66	1238	71-71	15	D	2	24	23	9.59	4.1-14.1
B-5	2	14 X 66	1238	71-71	33	D	1	204	200	7.51	2.7-13.8
B-6	1	14 X 66	0850	82-80	15	D	—	31	31	10.20	4.3-16.5
B-6	2	14 X 66	0850	82-80	33	D	—	276	276	10.81	2.2-21.0
B-7	1	14 X 66	0710	91-90	15	C	—	15	15	11.16	6.3-15.7
B-7	2	14 X 66	0710	91-90	33	C	—	59	58	9.63	3.5-15.0
C-2	1	13 X 66	1012	22-27	15	D	—	3	3	8.73	4.2-15.2
C-3	1	13 X 66	1105	31-31	15	D	1	5	5	7.14	3.5-13.2
C-3	2	13 X 66	1105	31-31	24	D	2	15	15	5.65	4.4-7.2
C-4	1	13 X 66	1233	37-40	15	D	—	38	38	5.77	2.6-9.2
C-4	2	13 X 66	1233	37-40	33	D	2	65	62	6.74	2.6-13.0
C-5	1	13 X 66	1555	48-46	15	D	11	34	33	4.98	2.6-7.3
C-5	2	13 X 66	1555	48-46	33	D	7	161	161	5.99	2.6-11.7
C-6	1	13 X 66	1814	55-55	15	C	1	34	34	7.64	3.1-12.2
C-6	2	13 X 66	1814	55-55	33	C	17	100	99	7.84	2.2-16.3
C-7	1	13 X 66	2147	77-70	15	N	4	45	43	13.54	3.9-29.2
C-7	2	13 X 66	2147	77-70	33	N	3	490	487	9.90	2.3-33.8
C-8	1	13 X 66	2359	198-787	15	N	—	1	1	19.80	19.8
C-8	2	13 X 66	2359	198-787	33	N	—	1	1	12.80	12.8
D-1	1	6 X 66	0224	16-20	6	N	—	1	1	2.70	2.7
D-3	1	6 X 66	0408	26-22	15	N	—	3	3	7.13	6.9-7.4
D-4	2	13 X 66	0036	31-22	24	N	2	1	1	15.00	15.0
D-5	1	12 X 66	2304	35-37	15	N	1	1	1	6.20	6.2
D-5	2	12 X 66	2304	35-37	24	N	30	4	4	6.07	4.6-8.3
D-6	1	12 X 66	1901	55-53	15	C	8	125	121	6.18	2.5-18.3
D-6	2	12 X 66	1901	55-53	33	C	3	134	130	6.94	1.6-17.7
D-7	1	12 X 66	1702	70-75	15	C	5	46	45	4.18	3.0-6.7
D-7	2	12 X 66	1702	70-75	33	C	7	42	42	5.58	3.4-8.3
D-8	1	12 X 66	1313	99-121	15	D	36	1	1	2.90	2.9
D-8	2	12 X 66	1313	99-121	33	D	9	39	35	4.50	2.8-6.7
E-4	1	11 X 66	2134	29-29	15	N	33	1	1	2.80	2.8
E-5	1	11 X 66	2310	35-35	15	N	1	21	21	6.37	2.9-20.2
E-5	2	11 X 66	2310	35-35	24	N	1	15	15	5.10	2.7-7.6
E-6	1	12 X 66	0250	44-42	15	N	3	35	34	6.64	3.1-25.0
E-6	2	12 X 66	0250	44-42	33	N	—	18	18	8.49	4.5-23.4
E-7	1	12 X 66	0452	64-66	15	N	1	7	7	7.99	4.7-14.1
E-7	2	12 X 66	0452	64-66	33	N	—	52	52	10.04	2.8-31.4
E-8	1	12 X 66	0903	157-121	15	D	—	4	4	3.52	2.8-4.4
E-8	2	12 X 66	0903	157-121	33	D	—	2	2	3.00	2.8-3.2
F-5	1	4 X 66	2251	37-33	15	N	—	2	2	5.60	4.2-7.0
F-5	2	4 X 66	2251	37-33	24	N	1	1	1	3.70	3.7
F-6	1	4 X 66	2053	53-55	15	N	—	63	62	6.54	2.9-23.3
F-6	2	4 X 66	2053	53-55	33	N	—	10	9	7.03	3.7-13.8
F-7	1	4 X 66	1652	104-79	15	D	—	6	6	4.68	3.0-7.0
F-7	2	4 X 66	1652	104-79	33	D	—	21	17	6.33	3.0-9.3
G-4	1	4 X 66	0727	29-33	15	C	—	1	1	5.40	5.4
G-5	2	4 X 66	0916	49-53	33	D	—	2	2	4.65	3.5-5.8
G-6	2	4 X 66	1309	95-75	33	D	1	1	1	7.40	7.4
H-6	1	3 X 66	0711	88-66	15	C	2	—	—	—	—
H-6	2	3 X 66	0711	88-66	33	C	—	1	1	15.00	15.0
J-7	2	3 X 66	0055	79-91	33	N	—	1	1	22.50	22.5
K-7	1	30 IX 66	1950	823-914	15	N	—	1	1	11.00	11.0

APPENDIX TABLE 1.—Continued.

Cruise and station	Net	Date	Start time	Depth of water (m)	Maximum tow depth (m)	Light regime[1]	Total number of eggs	Larvae			
								Total number captured	Number measured	Notochord length	
										Mean (mm)	Range (mm)
D-66-14			EST								
A-1	1	4 XII 66	1956	26-9	3	N	—	2	1	6.50	6.5
A-2	1	4 XII 66	1857	33-29	15	N	—	2	2	5.60	5.4-5.8
A-3	1	4 XII 66	1750	44-33	15	N	—	2	2	5.95	5.9-6.0
A-3	2	4 XII 66	1750	44-33	24	N	—	1	1	3.10	3.1
A-4	1	4 XII 66	1618	53-51	15	C	—	5	5	5.44	4.9-5.7
A-4	2	4 XII 66	1618	53-51	33	C	—	6	6	5.00	4.2-6.4
A-5	2	4 XII 66	1449	58-58	33	D	—	3	3	4.93	4.1-5.5
A-6	1	4 XII 66	1255	73-68	15	D	—	3	3	6.30	6.0-6.6
A-6	2	4 XII 66	1255	73-68	33	D	—	2	2	3.60	2.8-4.4
B-1	1	3 XII 66	1937	18-22	6	N	—	1	1	6.10	6.1
B-2	1	3 XII 66	2056	31-42	15	N	—	1	1	3.60	3.6
B-2	2	3 XII 66	2056	31-42	24	N	—	2	2	5.60	3.0-8.2
B-3	1	3 XII 66	2210	44-51	15	N	—	19	18	5.55	3.2-7.2
B-3	2	3 XII 66	2210	44-51	33	N	—	25	25	5.93	4.2-7.6
B-4	1	3 XII 66	2351	62-71	15	N	—	4	4	4.10	2.9-6.5
B-4	2	3 XII 66	2351	62-71	33	N	—	5	5	8.70	4.5-23.2
B-5	1	4 XII 66	0113	73-73	15	N	—	2	2	8.80	5.7-11.9
B-6	1	4 XII 66	0310	84-84	15	N	—	1	1	8.50	8.5
B-6	2	4 XII 66	0310	84-84	33	N	—	1	1	6.50	6.5
C-3	2	3 XII 66	1047	33-37	24	D	—	1	1	5.10	5.1
C-4	1	3 XII 66	0412	42-40	15	N	—	5	5	15.56	4.1-56.9
C-4	2	3 XII 66	0412	42-40	33	N	—	8	8	4.99	3.6-7.4
C-5	1	2 XII 66	2302	49-47	15	N	—	25	25	5.67	3.5-7.4
C-5	2	2 XII 66	2302	49-47	33	N	—	22	22	5.74	3.5-8.4
C-6	1	2 XII 66	2022	57-57	15	N	—	19	19	7.29	3.1-33.9
C-6	2	2 XII 66	2022	57-57	33	N	—	21	21	5.06	3.1-7.7
C-7	1	2 XII 66	1727	77-70	15	N	—	17	15	7.13	3.2-12.8
C-7	2	2 XII 66	1727	77-70	33	N	—	7	7	11.56	4.4-43.1
D-6	1	2 XII 66	0652	51-53	15	C	—	18	17	4.78	3.1-6.9
D-6	2	2 XII 66	0652	51-53	33	C	—	18	17	5.07	2.7-6.5
D-7	1	2 XII 66	0920	73-79	15	D	—	1	1	6.20	6.2
D-7	2	2 XII 66	0920	73-79	33	D	—	1	1	6.10	6.1
E-6	1	10 XI 66	0722	42-40	15	C	1	1	1	3.60	3.6
E-6	2	10 XI 66	0722	42-40	33	C	—	4	4	3.82	3.5-4.2
E-7	1	10 XI 66	1200	68-62	15	D	—	1	1	29.60	29.6
E-7	2	10 XI 66	1200	68-62	33	D	—	2	2	5.05	4.0-6.1
E-8	1	19 XI 66	0201	110-95	15	N	8	1	1	23.80	23.8
E-8	2	19 XI 66	0201	110-95	33	N	—	1	1	6.00	6.0
F-5	1	11 XI 66	0126	37-38	15	N	—	1	1	3.80	3.8
F-6	1	10 XI 66	2303	51-51	15	N	—	4	4	15.90	8.5-24.2
F-6	2	10 XI 66	2303	51-51	33	N	—	4	4	8.22	6.0-12.9
F-7	1	18 XI 66	2203	68-70	15	N	—	36	36	29.49	20.4-36.5
F-7	2	18 XI 66	2203	68-70	33	N	—	61	61	28.63	16.7-39.3
G-5	1	11 XI 66	2234	51-46	15	N	1	4	4	12.75	3.8-22.6
G-5	2	11 XI 66	2234	51-46	33	N	—	1	1	7.30	7.3
G-6	1	12 XI 66	0050	79-97	15	N	8	6	6	15.17	5.7-24.6
G-6	2	12 XI 66	0050	79-97	33	N	2	9	9	6.99	2.5-17.9
H-5	1	12 XI 66	0754	40-44	15	D	—	2	2	6.80	6.6-7.0
H-5	2	12 XI 66	0754	40-44	33	D	—	1	1	7.10	7.1
H-6	1	12 XI 66	0609	84-82	15	C	1	—	—	—	—
H-6	2	12 XI 66	0609	84-82	33	C	3	3	3	4.73	3.9-5.2
H-7	1	12 XI 66	0503	97-172	15	N	5	—	—	—	—
H-7	2	12 XI 66	0503	97-172	33	N	5	4	4	5.60	2.4-10.4
J-5	1	14 XI 66	1727	26-27	15	C	—	1	1	6.70	6.7
J-6	1	14 XI 66	1935	35-35	15	N	—	1	1	7.60	7.6
J-6	2	14 XI 66	1935	35-35	24	N	—	2	2	8.20	7.6-8.8
J-7	2	14 XI 66	2329	90-71	33	N	—	3	3	4.83	3.2-6.3
K-1	1	18 XI 66	0842	13-16	6	D	—	1	1	3.10	3.1
K-6	1	17 XI 66	2236	53-40	15	N	13	—	—	—	—
K-6	2	17 XI 66	2236	53-40	33	N	4	—	—	—	—
K-7	2	17 XI 66	2127	483-311	33	N	2	—	—	—	—
L-5	2	17 XI 66	1545	88-622	33	C	1	1	1	4.30	4.3
M-4	1	16 XI 66	2339	58-24	6	N	—	1	1	2.90	2.9

[1]Light regime: D = day tow; N = night tow; C = crepuscular tow (when any part of a tow occurred within 1 h of sunrise or sunset).