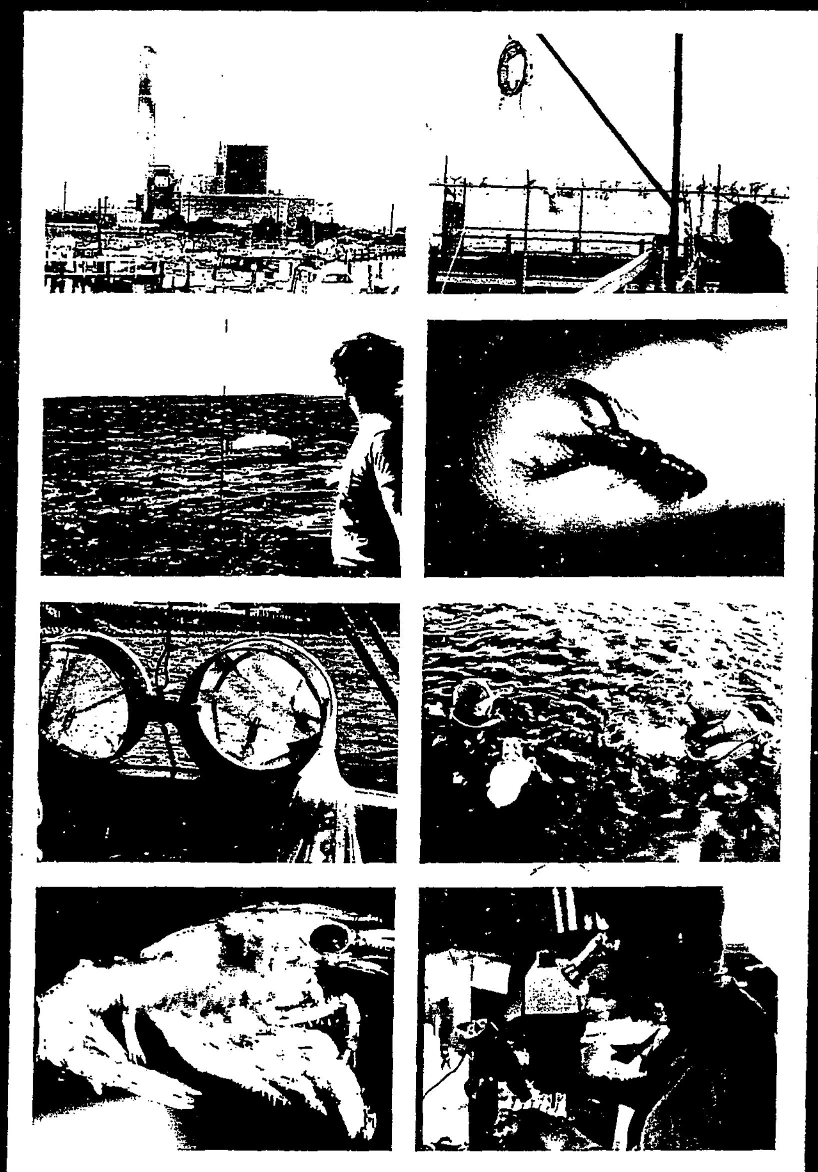
Bulk Attachment EFSB-W-55

The Effects of Power Generation on some of the Living Marine Resources of the Cape Cod Canal and Approaches

by
W. Stephen Collings, Christine Cooper-Sheehan,
Sally C. Hughes and James L. Buckley



November 1, 1981
Massachusetts Department of Fisheries, Wildlife and Recreational Vehicles
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Introduction

While ichthyoplankton surveys have been conducted in proximity to and in parts of the study area, no intensive studies have been made in Buzzards Bay. As part of the proposal to study the environmental effects of Canal Plant Units 1 and 2, a three year study of the spacio-temporal distribution of ichthyoplankton in northern Buzzards Bay, the Cape Cod Canal and southwestern Cape Cod Bay was initiated. The Administrative-Technical Committee overseeing the study felt that sufficient information existed on ichthyoplankton distribution in Cape Cod Bay, but that collections should be made in Buzzards Bay and the Cape Cod Canal during the period when the Canal was filled with Buzzards Bay water. The survey was initiated in May, 1976 and continued into March, 1979.

Methods and Materials

Seven stations were established extending from Cape Cod Bay to Cleveland Ledge in Buzzards Bay (Figure 28). Three stations were situated in Buzzards Bay, three in the Cape Cod Canal and one in Cape Cod Bay. The project proposal and contract called for a sampling regime of 18 sampling trips per year, 1 per month from October through March and 2 per month from April through September. Sampling was initiated on May 20, 1976 and continued with the following exceptions until March 13, 1979. No samples were collected in August, 1976 (equipment failure), January and February, 1977 and February, 1979 (severe ice conditions). However, extra samples were taken in October, 1976 and 1977 and in June, 1978 to further delineate finfish spawning activities.

Forty-nine sampling trips were made during daylight hours. A Station 7 (Cape Cod Bay) sample was lost on June 20, 1977 when the net hung up on a submerged object and the tow cable parted. Four other bottles were broken during rough weather sampling. A total of 680 samples was collected and analyzed.

Sampling gear design followed the basic MARMAP (Marine Resources Monitoring Assessment and Prediction Program) 61 cm fiberglass bongo arrangement (Jossi et al. 1975) (Figure 29). General Oceanics Model A 5300-BF bongo frames and A 5100 JR cod end rings were used. The frames were weighted with the standard MARMAP 45 kg lead ball and chain. The nets were General Oceanics Model 5360-505 and the bongo frames were fitted with General Oceanics Model 2030 MKII flowmeters equipped with S 2030 R standard range rotors. Flowmeters were calibrated twice yearly in the National Marine Fisheries Service calibration tank at Woods Hole. Flowmeter readings were used to calculate the volume of water strained.

All ichthyoplankton sampling was conducted from the Division's 50 foot vessel R/V F.C. WILBOUR. The boat was equipped with a hydraulic winch, stern gantry, washdown system, Datamarine Model S-100 DMII digital depth readout, Furuno white line depth recorder, Decca Super 101 radar and Datamarine Corinthian series Model S-100-KII digital ship speed indicator. Oblique tows were made from the stern and the depth of the net was read from a precalculated wire angle/line out/depth table. Net depth was initially monitored with a Hydro Products 904-S remote sensing temperature depth system attached to the net frame. Continual equipment malfunctions necessitated the discontinuance of this technique and the utilization of a different technique. Tow cable angles averaged approximately 60 degrees but ranged from 45 to 70 degrees. The line out was determined from calibrated markings on the tow cable. When the

Plate 7. Ichthyoplankton sampling gear including 61 cm bongo nets, flowmeters and 505 mm nets.

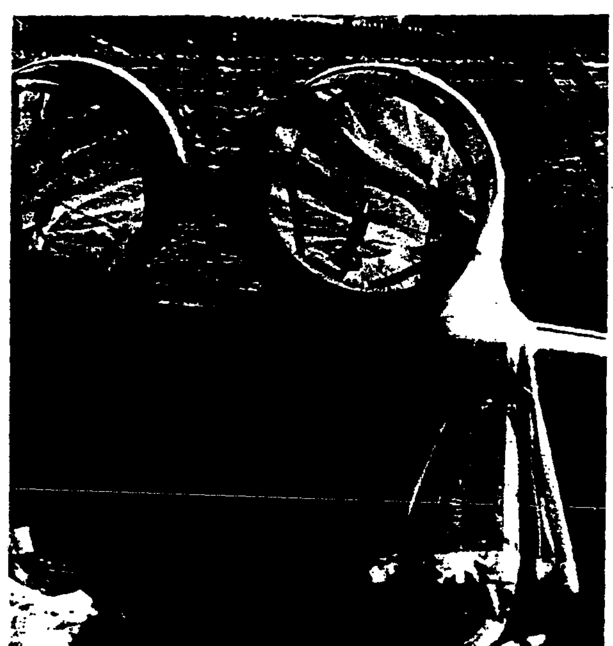


Figure 28. Ichthyoplankton station locations.

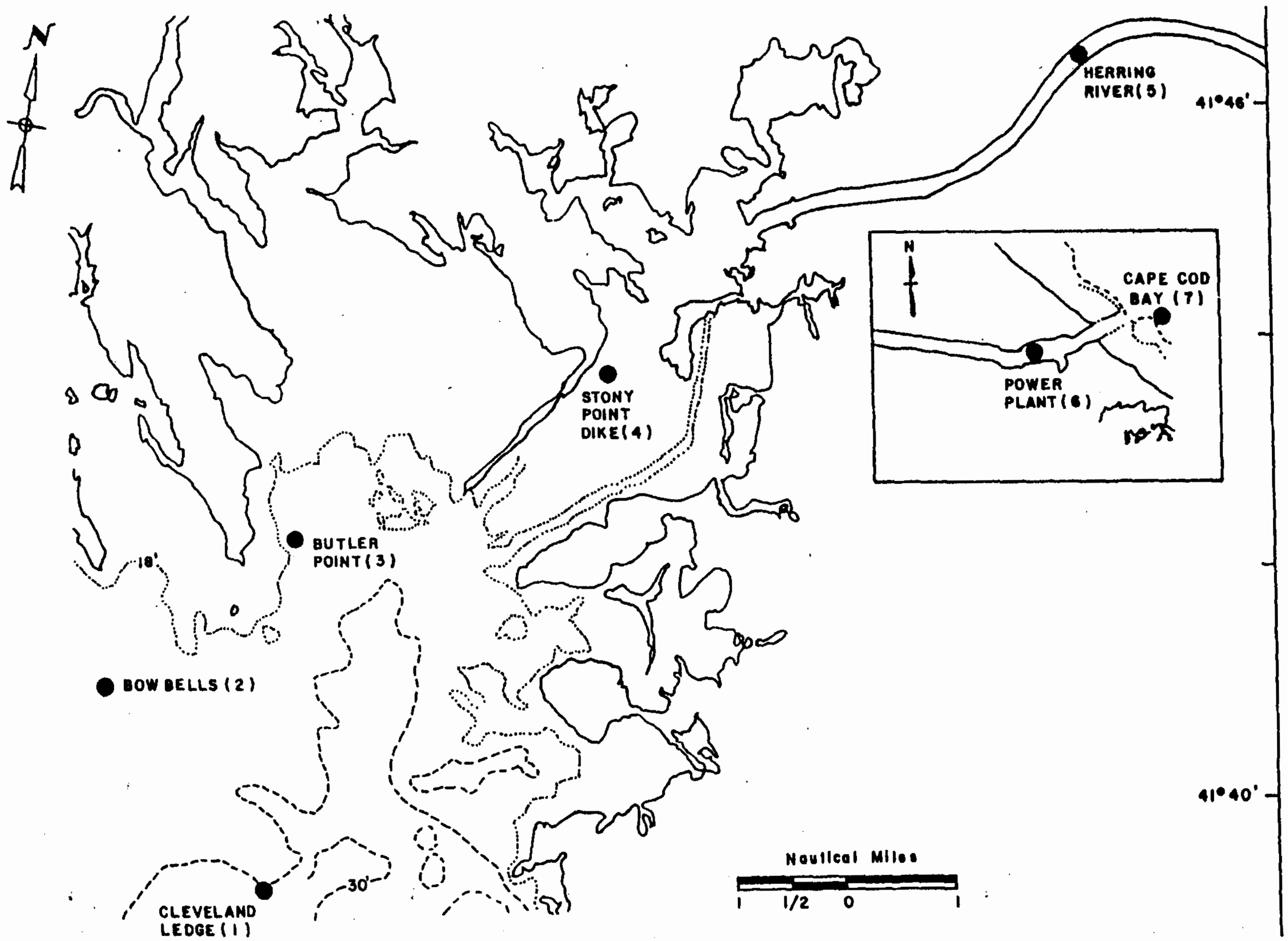
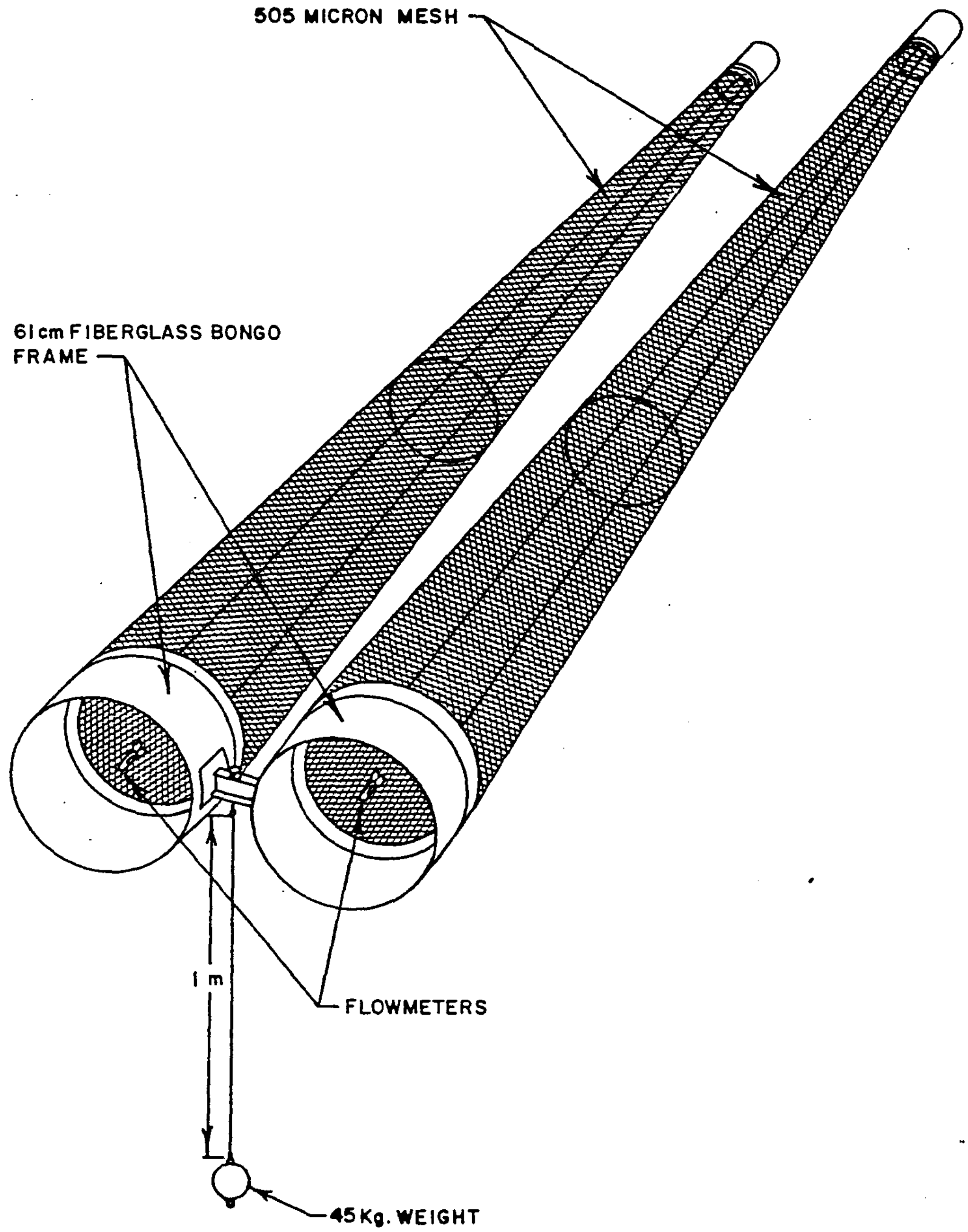


Figure 29. Schematic of ichthyoplankton sampling gear.



net weight was 1 to 2 meters from the bottom, the net was retrieved. Boat speed was maintained between 2 and 3 knots. Tow duration was approximately 5 minutes to assure that the minimum water volume strained was 100 m^3 per side of the net. There was no significant difference ($t = 0.0232$, $df = 93$, $P > 0.05$) between the volumes calculated for each side of the net in a subsample of volumes taken from March to July, 1977.

Nets were washed down and the samples carefully rinsed into the glass collecting jars on the cod ends. The jars were removed from the nets, capped, labeled and the contents preserved by adding 50 mls of formalin buffered with sodium borate ($Na_2B_4O_7 \cdot 10H_2O$) creating a 5% preservative solution.

After each tow, salinity was measured with an electrodeless induction salinometer, a refractometer or hydrometer. Surface and bottom water temperatures were measured with a marine hydrographic thermometer. Air temperatures, percent cloud cover, wind direction and force, station depth, sea state and Secchi disc readings were also taken at each station.

Each sample was removed to the laboratory where all fish eggs and larvae were identified, staged (by developmental stage) and enumerated. Many samples, because of high densities, were split into aliquots using a Marine Research plankton splitter. The densities of eggs and larvae (#/100 m^3) for each tow were used as the measure of relative abundance between stations.

Major references used in egg identification were Bigelow and Schroeder (1953), Colton and Marak (1969), Hildebrand and Cable (1930, 1938), Fritzsche (1978), Hardy (1978a and 1978b), Johnson (1978), Jones et al. (1978), Martin and Drewry (1978), Kuntz and Radcliffe (1917), Lippson and Moran (1974), Mansueti and Hardy (1967), Perlmutter (1939a and b), Richards (1959), Scotton et al. (1973), U.S. Department of Interior (1978), Wang and Kernahan (1979), Welsh and Breder (1923), and Wheatland (1956). Taxonomic classification follows that of the American Fisheries Society (1970) with the exception of the fourspot flounder, *Hippoglossina oblonga*. Based on pigmentation patterns, we have placed this species in the genus *Hippoglossina* rather than *Paralichthys* (Leonard 1971). Positive species identification of the early developmental stages of many eggs was difficult due to similar egg characteristics and overlapping spawning times. Differentiation between these species was unreliable; hence, they were placed into groups. Larvae were more readily identified.

An estimate of the proportion of each species comprising a major egg grouping can be obtained by examining the proportions of different larvae within an egg grouping. Care should be taken with this estimate however, since larvae of different species exhibit different natural mortality, developmental rates, and behavioral patterns. This could have a pronounced effect on their availability to the net.

Eggs were separated into three developmental stages and larvae into two according to the following criteria:

EGGS		LARVAE	
Stage	Characteristics	Stage	Characteristics
I	early cleavage through blastula, dead or unfertilized	I	yolk sac (prolarvae)
II	gastrula through tail bud	II	yolk sac absorbed (postlarvae)
III	tail free through late embryo		

To insure that Buzzards Bay water was sampled off the power plant, collections were made at high slack water. This period is approximately 45 minutes prior to and 15 minutes after the predicted time of the turn of the tide toward the west.

Results

Forty-seven finfish species were separated from the 680 bongo samples collected (Table 27). Totals of 1,158,422 eggs and 167,118 larvae were collected. Twenty-eight species were represented by eggs and larvae, 17 by larval and/or juvenile stages and two by eggs alone. Northern kingfish (*Menticirrhus saxatilis*) larvae were collected during entrainment sampling, but no larvae were found in bongo samples. For those species for which both eggs and larvae were collected, four have demersal eggs and 24 have pelagic eggs. Of those species represented by larvae and/or juvenile stages, 10 have demersal eggs, 6 have egg characteristics which are not reported in the literature and one, northern pipefish (*Syngnathus fuscus*), is viviparous. The two species represented by eggs alone, northern

Table 27. Ichthyoplankton Species Checklist May, 1976 - March, 1979*

Taxon	Common Name
Ammodytidae - sand lances	
Ammodytes spp.	sand lance E/L
Agonidae - poachers	
Aspidophoroides monopterygius	alligatorfish L
Atherinidae - silversides	
Menidia menidia	Atlantic silversides L
Bothidae - lefteye flounders	
Etropus microstomus	smallmouth flounder E/L
Hippoglossina oblonga	fourspot flounder E/L
Paralichthys dentatus	summer flounder E
Scophthalmus aquosus	windowpane E/L/J
Clupeidae - herrings	
Brevoortia tyrannus	Atlantic menhaden E/L
Clupea harengus harengus	Atlantic herring L
Cryptancanthodidae - wrymouths	
Cryptacanthodes maculatus	wrymouth L
Cottidae - sculpins	
Myoxocephalus spp.	sculpin E/L
Hemitripterus americanus	sea raven L
Cyclopteridae - lumpfishes and snailfishes	
Liparis atlanticus	seasnail L
Liparis liparis	striped seasnail L
Cyclopterus lumpus	lumpfish J
Engraulidae - anchovies	
Anchoa spp.	anchovy E/L
Gadidae - codfishes	
Brosme brosme	cusk (E)/L
Enchelyopus cimbrius	fourbeard rockling E/L/J
Gadus morhua	Atlantic cod E/L
Merluccius bilinearis	silver hake E/L
Pollachius virens	pollock E/L
Urophycis chuss	red hake E/L/J
Microgadus tomcod	Atlantic tomcod L
Melanogrammus aeglefinus	haddock E/L
Gobiidae - gobies	
Gobiosoma bosci	naked goby L

* E - Egg positively identified
(E) - Egg grouped in general category
L - Larvae positively identified
J - Juvenile positively identified

Table 27. (Continued)

Taxon	Common Name
Labridae - wrasses	
Tautoga onitis	tautog E/L
Tautogolabrus adspersus	cunner E/L/J
Lophiidae - goosefishes	
Lophius americanus	goosefish E/L
Ophidiidae - cusk-eels and brotulas	
Rissola marginata	striped cusk-eel L
Pholidae - gunnels	
Pholis gunnellus	rock gunnel L
Pleuronectidae - righteye flounders	
Hippoglossoides plattessoides	American plaice E/L
Glyptocephalus cynoglossus	witch flounder E/L
Limanda ferruginea	yellowtail flounder E/L
Pseudopleuronectes americanus	winter flounder E/L
Sciaenidae - drums	
Cynoscion regalis	weakfish (E)/L
Menticirrhus saxatilus	northern kingfish E
Scombridae - mackerels	
Scomber scombrus	Atlantic mackerel E/L
Serranidae - sea basses	
Centropristis striata	black sea bass E/L
Soleidae - soles	
Trinectes maculatus	hogchoker E/L
Sparidae - porgies	
Stenotomus chrysops	scup E/L/J
Stichaeidae - pricklebacks	
Ulvaria subbifurcata	radiated shanny L
Lumpenus lumpretaeformis	snakeblenny L
Leptoclinus maculatus	daubed shanny L
Stromateidae - butterfishes	
Peprilus triacanthus	butterfish E/L/J
Syngnathidae - pipefishes	
Syngnathus fuscus	northern pipefish J
Tetraodontidae - puffers	
Sphoeroides maculatus	northern puffer L/J
Triglidae - searobins	
Prionotus spp.	searobin E/L

* E - Egg positively identified
(E) - Egg grouped in general category
L - Larvae positively identified
J - Juvenile positively identified

kingfish and summer flounder *(Paralichthys dentatus)*, have pelagic eggs.

Those species represented by pelagic eggs account for 99.9% of the total eggs collected with the bongo nets. Six egg groups accounted for 95.9% of the eggs collected (Table 28). These major egg groups were cunner-tautog-yellowtail flounder (Labridae-*Limanda*), scup-weakfish-silver hake (*Stenotomus-Cynoscion-Merluccius*), anchovies (*Anchoa* spp.), Atlantic menhaden (*Brevoortia tyrannus*), windowpane-fourspot flounder- black sea bass-summer flounder (*Scophthalmus-Hippoglossina Centropristis-Paralichthys*) and fourbeard rockling-red hake-butterfish (*Enchelyopus-Urophycis-Peprilus*).

Larvae of finfish having demersal eggs accounted for 25.3% of the total larvae collected. Six species were responsible for 95.2% of all the larvae collected. Those species were cunner (*Tautogolabrus adspersus*), sand lance (*Ammodytes* spp.), anchovy, tautog (*Tautoga onitis*), scup (*Stenotomus chrysops*) and menhaden (Table 29).

Eggs and larvae were collected in the study area during every calendar month (Appendices A-H). The only station at which eggs and larvae were found in every collection was Station 7 (Appendix H). Larvae were collected on every sampling trip at Station 6, while eggs were not collected on two occasions (October 25, 1977 and October 16, 1978) (Appendix G).

Egg densities peaked during the summer of each year (Figures 30-37) with the greatest densities occurring at Station 2 (19,405.45 eggs/100 m^3) on May 20, 1976 (Figure 32), Station 6 (31,968.53 eggs/100 m^3) on June 20, 1977 (Figure 36) and Station 2 (25,378.54 eggs/100 m^3) on June 20, 1978 (Figure 32). The egg groups comprising 94% of the eggs collected at Station 2 on May 20, 1976 were *B. tyrannus* (20%), *Stenotomus-Cynoscion-Merluccius* (20%) and Labridae-*Limanda* (54%). A major proportion (99%) of the Station 6 sample collected on June 20, 1977 was made up of Labridae-*Limanda* eggs. *Anchoa* spp. (30%) and Labridae-*Limanda* (45%) eggs comprised 75% of the sample collected from Station 2 on June 20, 1978.

Larval densities peaked in June in all three years with maximum densities of 6,305.47, 2,710.58 and 5,172.55 larvae/100 m^3 being collected at Station 2 on June 23, 1976, June 20, 1977 and June 27, 1978. The two species that accounted for a large proportion of the collected larvae were *T. adspersus* (cunner) and *T. onitis* (tautog). Cunner comprised 79%, 59% and 79% of the total larval catch in maximum density samples in 1976, 1977 and 1978. Tautog larvae (while not as abundant as cunner larvae) represented 18%, 9% and 13% of the total larval catch in these maximum density samples.

Station 2 had both the largest number and greatest density of eggs collected (Table 30). Collections at this station contained 25.7% (Table 28) of all eggs collected and the average density was 2,910.1 eggs/100 m^3 (Table 30). Cunner-tautog-yellowtail flounder eggs comprised 45.0% of the eggs collected at Station 2 (Tables 28 and 31). Station 2 also ranked first in number of larvae collected (Table 32). Larvae collected at this station represented 30.2% of the total larval catch and were collected at an average density of 482.6 larvae/100 m^3 (Tables 30 and 32). Cunner and tautog larvae made up 75.4% of the total larval catch at Station 2. The other two Buzzards Bay stations, Cleveland Ledge (1) and Butler Point (3) ranked third and sixth in the total number of eggs collected. Cleveland Ledge ranked second in average density of eggs (2,607.8/100 m^3) while Butler Point ranked fifth in average egg density (1,253.9/100 m^3). The Cleveland Ledge and Butler Point stations ranked second and third in both total number of larvae collected and average density of larvae. The power plant station (6) ranked second in total eggs collected and third in average egg density (2,214.1 eggs/100 m^3). Eggs from the cunner-tautog-yellowtail flounder grouping accounted for 96.4% of the total eggs collected at Station 6. Station 6 ranked sixth in total larvae collected and average larval density. Sand lance larvae comprised 45.1% of the larvae collected at the power plant station. The Cape Cod Bay station, located off the eastern end of the Cape Cod Canal, ranked last in number and average density of eggs and larvae collected.

Differences in species composition were evident in the three areas under study. The ichthyoplankton population of Cape Cod Bay was quite different from that of the Cape Cod Canal and Buzzards Bay. The number of codfishes-witch flounder eggs collected at the one Cape Cod Bay station (1,119 eggs) far exceeds the number collected at the other six stations (510 eggs). The same relationship was apparent in the numbers of Gadidae and witch flounder larvae collected. The distribution of menhaden eggs and larvae is opposite with the vast majority of eggs and larvae collected in Buzzards Bay rather than at the Cape Cod Canal and Cape Cod Bay stations. Density circles (Figures 38-80) for each major species group are representative of actual calculated densities. Density circles shown in the key for each figure can be utilized to obtain visual estimates of actual densities. Eggs and larvae were collected in water ranging in temperature from -0.5 to 29.5C (Appendices I and J).

Labridae-*Limanda*

cunner-tautog-yellowtail flounder

The tautog spawning season extends from

Table 28. Distribution and percent contribution of eggs collected by station and species, May 20, 1976 - March 13, 1979.

Species	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Totals
Cunner-tautog- -yellowtail flounder	63,214 30.2%	134,013 45.0%	38,920 41.9%	52,102 76.0%	138,554 93.6%	231,467 96.4%	75,133 73.9%	733,403 63.3%
Scup-weakfish -silver hake	98,826 47.2%	83,538 28.1%	29,854 32.1%	6,385 9.3%	1,137 0.8%	920 0.4%	676 0.7%	221,336 19.1%
Anchovies	19,747 9.4%	37,250 12.5%	12,351 13.3%	4,996 7.3%	3,429 2.3%	3,077 1.3%	266 0.3%	81,116 7.0%
Atlantic menhaden	5,324 2.5%	22,338 7.5%	1,220 1.3%	83 0.1%	169 0.1%	191 0.1%	170 0.2%	29,495 2.5%
Windowpane -fourspot flounder -black sea bass	7,328 3.5%	7,626 2.6%	3,206 3.4%	994 1.4%	470 0.3%	333 0.1%	3,130 3.1%	23,087 2.0%
Fourbeard rockling-red hake-butterfish	3,877 1.9%	1,731 0.6%	915 1.0%	971 1.4%	1,680 1.1%	1,849 0.8%	12,053 11.9%	23,076 2.0%
Searobins	5,778 2.8%	9,580 3.2%	4,343 4.7%	1,241 1.8%	600 0.4%	482 0.2%	114 0.1%	22,138 1.9%
Atlantic mackerel-cusk	4,449 2.1%	785 0.3%	563 0.6%	873 1.3%	1,435 1.0%	1,022 0.4%	8,333 8.2%	17,460 1.5%
Northern kingfish-hogchoker	459 0.2%	593 0.2%	1,303 1.4%	639 0.9%	150 0.1%	124 0.1%	18 *	3,286 0.3%

Table 28. (Continued)

Species	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Totals
Gadidae	91	10	42	102	105	160	1,119	1,629
-witch flounder	*	*	*	0.1%	0.1%	0.1%	1.1%	0.1%
Summer flounder	247	197	184	65	42	43	107	885
-windowpane	0.1%	0.1%	0.2%	0.1%	*	*	0.1%	0.1%
Winter flounder	1	*	*	65	187	218	277	748
	*	*	*	0.1%	0.1%	0.1%	0.3%	0.1%
Sand lance	*	*	*	6	87	126	64	283
	*	*	*	*	0.1%	0.1%	0.1%	*
Unknown C	67	114	66	12	4	*	*	263
	*	*	0.1%	*	*	*	*	*
American plaice	1	6	3	17	14	20	113	174
	*	*	*	*	*	*	0.1%	*
Goosefish	*	*	*	*	*	1	34	35
	*	*	*	*	*	*	*	*
Smallmouth flounder	1	*	*	*	*	*	*	1
	*	*	*	*	*	*	*	*
Sculpins	*	*	*	*	1	*	*	1
	*	*	*	*	*	*	*	*
Unknowns	*	*	*	2	2	2	*	6
	*	*	*	*	*	*	*	*
Total eggs	209,410	297,781	92,970	68,553	148,066	240,035	101,607	1,1 58,422

Table 29. Distribution and percent contribution of larvae collected by station and species, May 20, 1976-March 13, 1979

Species	Sta.1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Totals
Cunner	22,029 60.6%	32,038 63.4%	10,173 38.4%	3,202 16.8%	4,037 27.8%	3,689 28.7%	502 6.9%	75,670 45.3%
Sand lance	3,060 8.4%	3,266 6.5%	6,516 24.6%	11,301 59.1%	6,684 46.1%	5,806 45.1%	2,799 38.5%	39,432 23.6%
Anchovies	3,991 11.0%	5,058 10.0%	5,252 19.8%	1,757 9.2%	1,338 9.2%	899 7.0%	1,028 14.1%	19,323 11.6%
Tautog	4,141 11.4%	6,074 12.0%	1,575 5.9%	1,367 7.2%	988 6.8%	977 7.6%	97 1.3%	15,219 9.1%
Scup	1,912 5.3%	2,760 5.5%	1,591 6.0%	489 2.6%	407 2.8%	385 3.0%	18 0.2%	7,562 4.5%
Atlantic menhaden	443 1.2%	661 1.3%	579 2.2%	92 0.5%	59 0.4%	39 0.3%	22 0.3%	1,895 1.1%
Atlantic mackerel	30 *	11 *	2 *	5 *	9 *	6 *	1,226 16.9%	1,289 0.8%
Sculpins	22 *	31 *	36 0.1%	187 1.0%	261 1.8%	341 2.7%	174 2.4%	1,052 0.6%
Northern pipefish	93 0.3%	116 0.2%	157 0.6%	180 0.9%	124 0.9%	99 0.8%	45 0.6%	814 0.5%
Winter flounder	37 0.1%	23 *	66 0.2%	111 0.6%	153 1.1%	112 0.9%	185 2.5%	687 0.4%
Fourbeard rockling	29 *	24 *	27 0.1%	60 0.3%	94 0.6%	146 1.1%	306 4.2%	686 0.4%

Table 29. (Continued)

Species	Sta.1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Totals
Windowpane	102 0.3%	172 0.3%	88 0.3%	77 0.4%	45 0.3%	52 0.4%	90 1.2%	626 0.4%
Rock gunnel	30 *	18 *	33 0.1%	72 0.4%	96 0.7%	78 0.6%	52 0.7%	379 0.2%
Naked goby	26 *	32 *	172 0.6%	15 *	18 0.1%	8 *	9 0.1%	280 0.2%
Black sea bass	106 0.3%	64 0.1%	33 0.1%	18 *	5 *	5 *	* *	231 0.1%
Red hake	3 *	0 *	3 *	13 *	15 0.1%	25 0.2%	159 2.2%	218 0.1%
Cod	1 *	1 *	3 *	7 *	9 *	14 0.1%	160 2.2%	195 0.1%
Butterfish	78 0.2%	64 0.1%	11 *	10 *	13 *	11 *	4 *	191 0.1%
Silversides	16 *	22 *	70 0.3%	12 *	28 0.2%	16 0.1%	6 *	170 0.1%
Hogchoker	51 0.1%	17 *	16 *	20 0.1%	13 *	25 0.2%	8 0.1%	150 *
Searobins	71 0.2%	25 *	14 *	10 *	5 *	9 *	* *	134 *
Atlantic herring	7 *	6 *	18 *	19 0.1%	25 0.2%	15 0.1%	65 0.9%	155 *
Seasnails	5 *	3 *	11 *	21 0.1%	31 0.2%	32 0.2%	48 0.7%	151 *

Table 29. (Continued)

Species	Sta.1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Totals
Witch flounder	1	1	1	10	12	14	54	93
	*	*	*	*	*	0.1%	0.7%	*
Silver hake	*	*	*	1	2	7	82	92
	*	*	*	*	*	*	1.1%	*
Yellowtail flounder	3	1	1	11	3	8	43	70
	*	*	*	*	*	*	0.6%	*
Radiated shanny	6	2	1	9	7	13	20	58
	*	*	*	*	*	0.1%	0.3%	*
Pollock	*	*	3	14	6	5	13	41
	*	*	*	*	*	*	0.2%	*
Fourspot flounder	9	14	3	2	5	3	4	40
	*	*	*	*	*	*	*	*
Weakfish	7	5	13	7	3	1	1	37
	*	*	*	*	*	*	*	*
American plaice	*	*	*	4	2	2	26	34
	*	*	*	*	*	*	0.4%	*
Striped cusk-eel	14	4	5	7	1	2	1	34
	*	*	*	*	*	*	*	*
Smallmouth flounder	16	5	2	*	2	8	*	33
	*	*	*	*	*	*	*	*
Northern puffer	7	2	8	*	3	5	2	27
	*	*	*	*	*	*	*	*
Tomcod	1	1	2	5	3	1	4	17
	*	*	*	*	*	*	*	*

Table 29. (Continued)

Species	Sta.1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Totals
Cusk	*	*	*	*	1	*	7	8
	*	*	*	*	*	*	*	*
Wrymouth	*	*	*	*	*	3	1	4
	*	*	*	*	*	*	*	*
Haddock	*	*	*	*	*	1	2	3
	*	*	*	*	*	*	*	*
Snakeblenny	*	*	1	1	*	*	1	3
	*	*	*	*	*	*	*	*
Alligatorfish	1	*	*	*	*	*	1	2
	*	*	*	*	*	*	*	*
Goosefish	*	*	*	*	*	*	1	1
	*	*	*	*	*	*	*	*
Lumpfish	1	*	*	*	*	*	*	1
	*	*	*	*	*	*	*	*
Daubed shanny	*	*	*	*	*	*	1	1
	*	*	*	*	*	*	*	*
Sea raven	1	*	*	*	*	*	*	1
	*	*	*	*	*	*	*	*
Unidentified	*	*	7	*	2	*	*	9
	*	*	*	*	*	*	*	*
Total larvae	36,350	50,521	26,493	19,116	14,509	12,862	7,267	167,118

* 0 larvae collected and/or less than 0.1%.

Figure 30. Average egg and larval densities at all stations from May 20, 1976 to March 13, 1979.

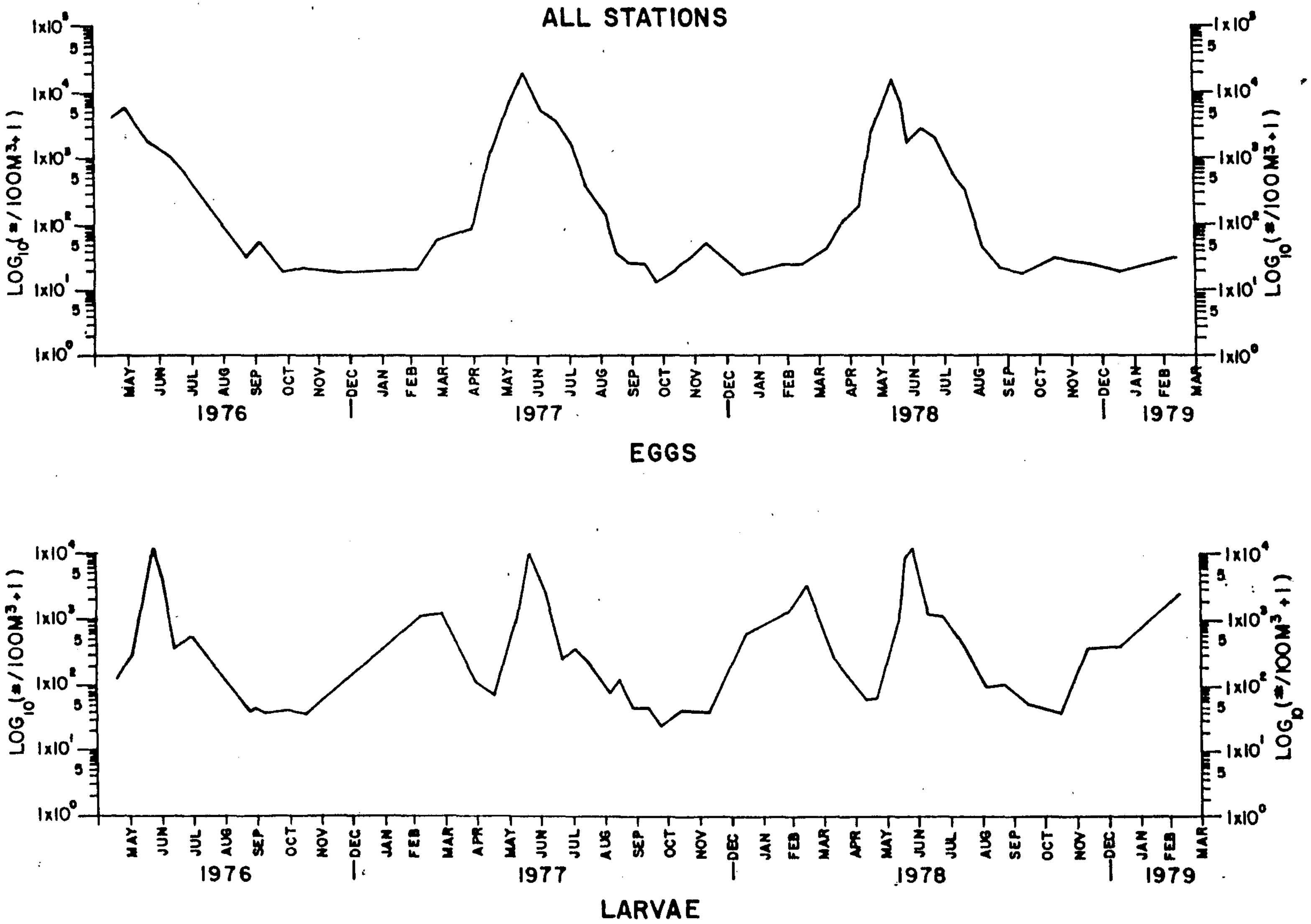


Figure 31. Average egg and larval densities at Station 1 from May 20, 1976 to March 13, 1979.

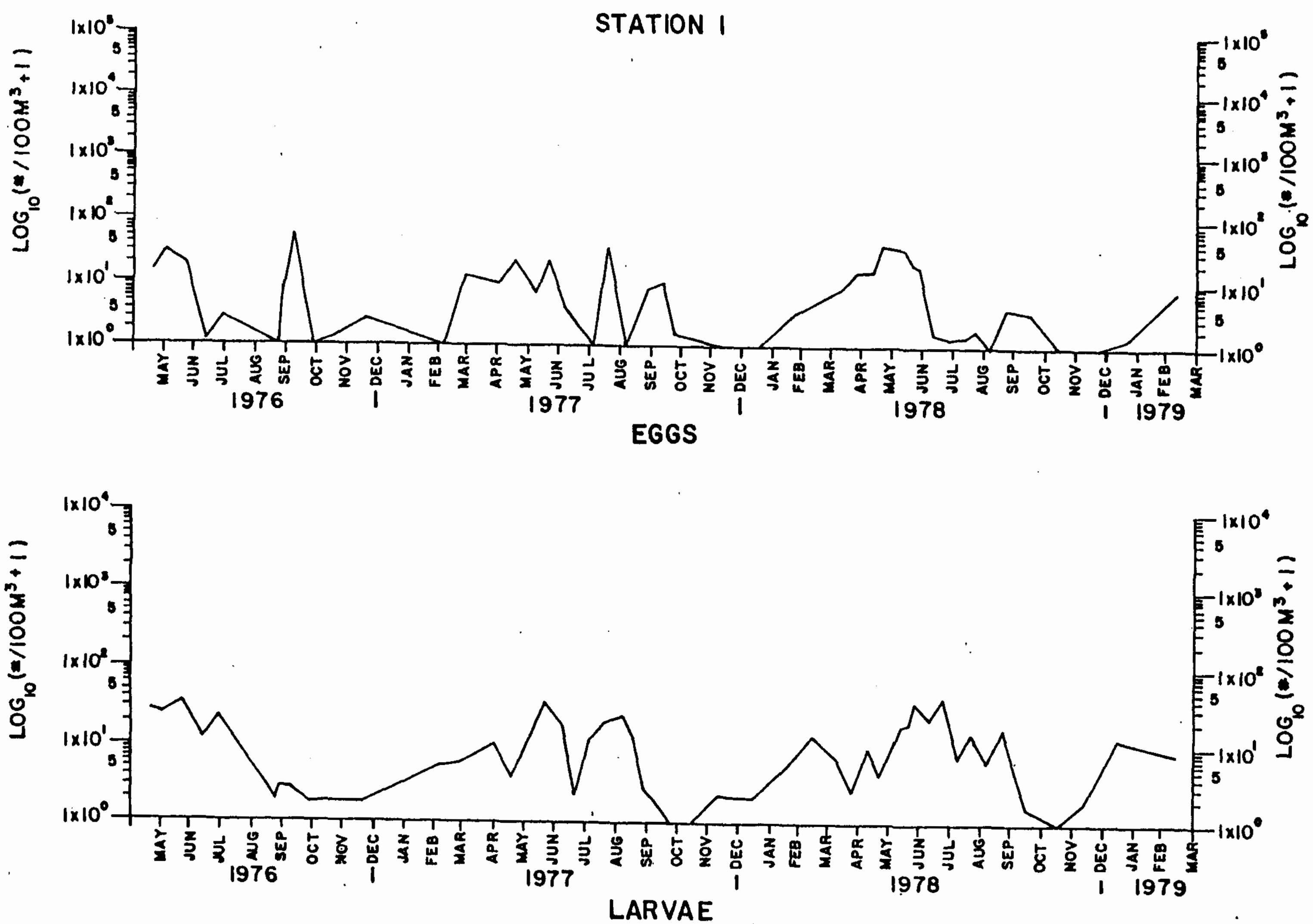


Figure 32. Average egg and larval densities at Station 2 from May 20, 1976 to March 13, 1979.

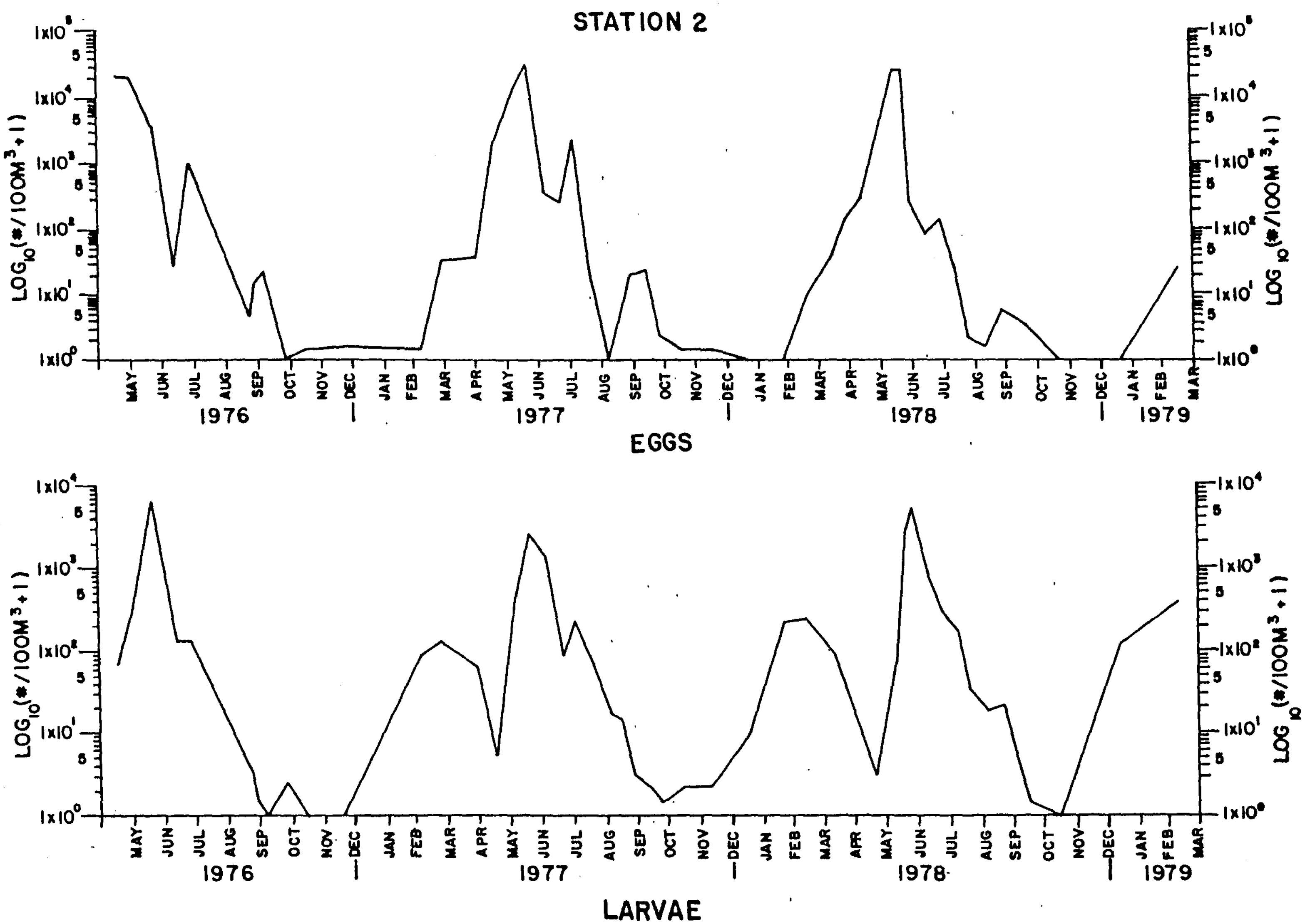


Figure 33. Average egg and larval densities at Station 3 from May 20, 1976 to March 13, 1979.

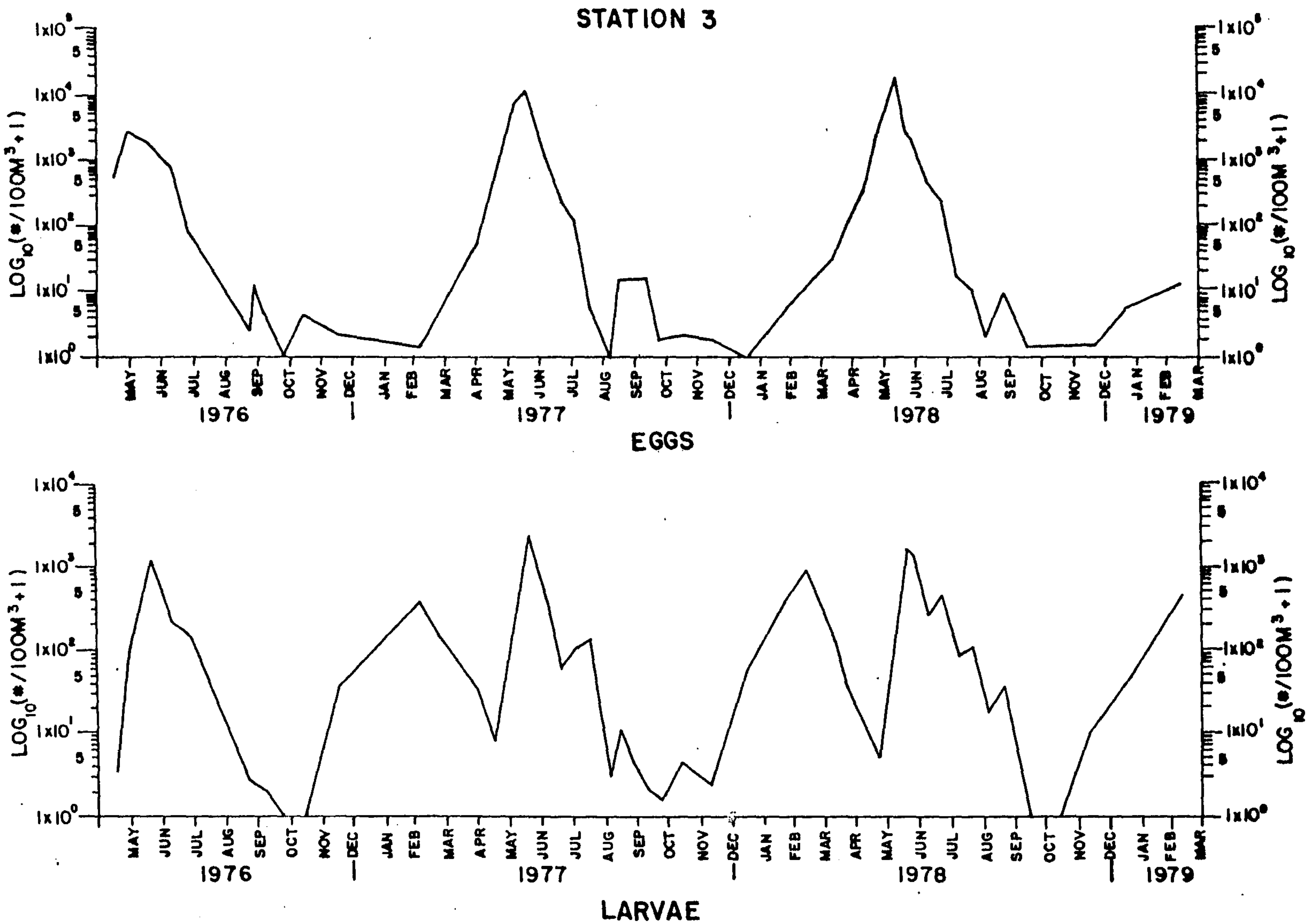


Figure 34. Average egg and larval densities at Station 4 from May 20, 1976 to March 13, 1979.

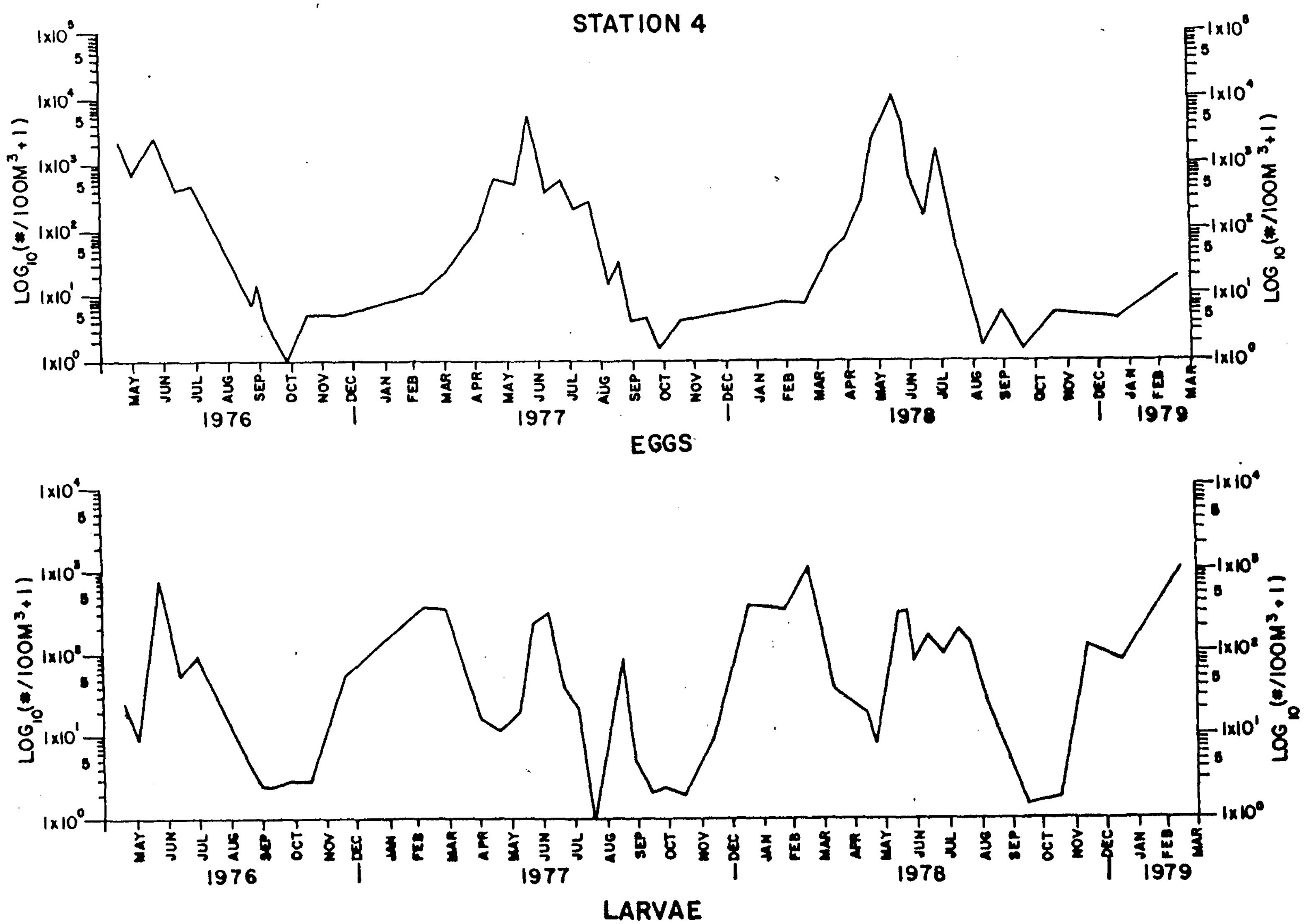


Figure 35. Average egg and larval densities at Station 5 from May 20, 1976 to March 13, 1979.

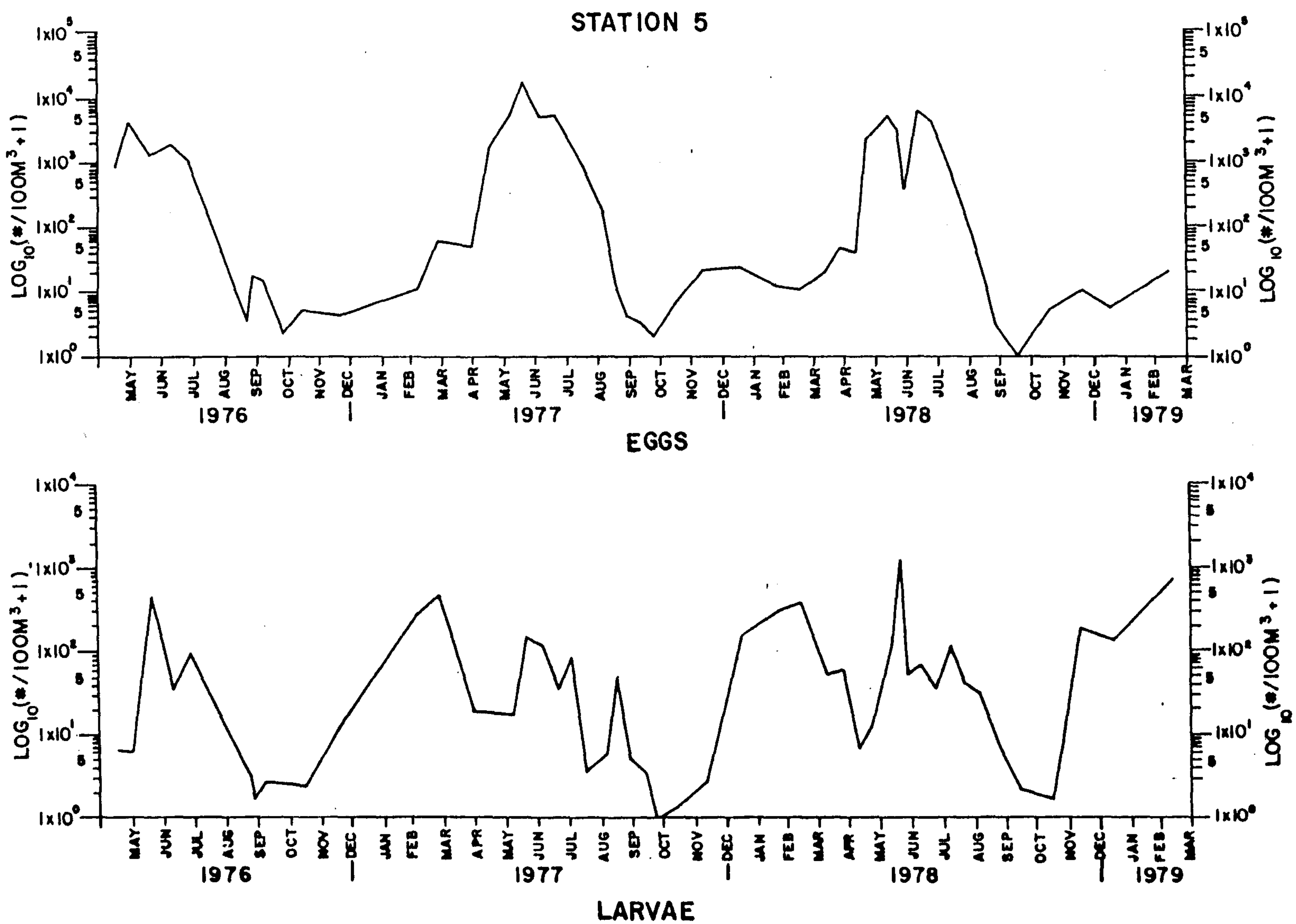


Figure 36. Average egg and larval densities at Station 6 from May 20, 1976 to March 13, 1979.

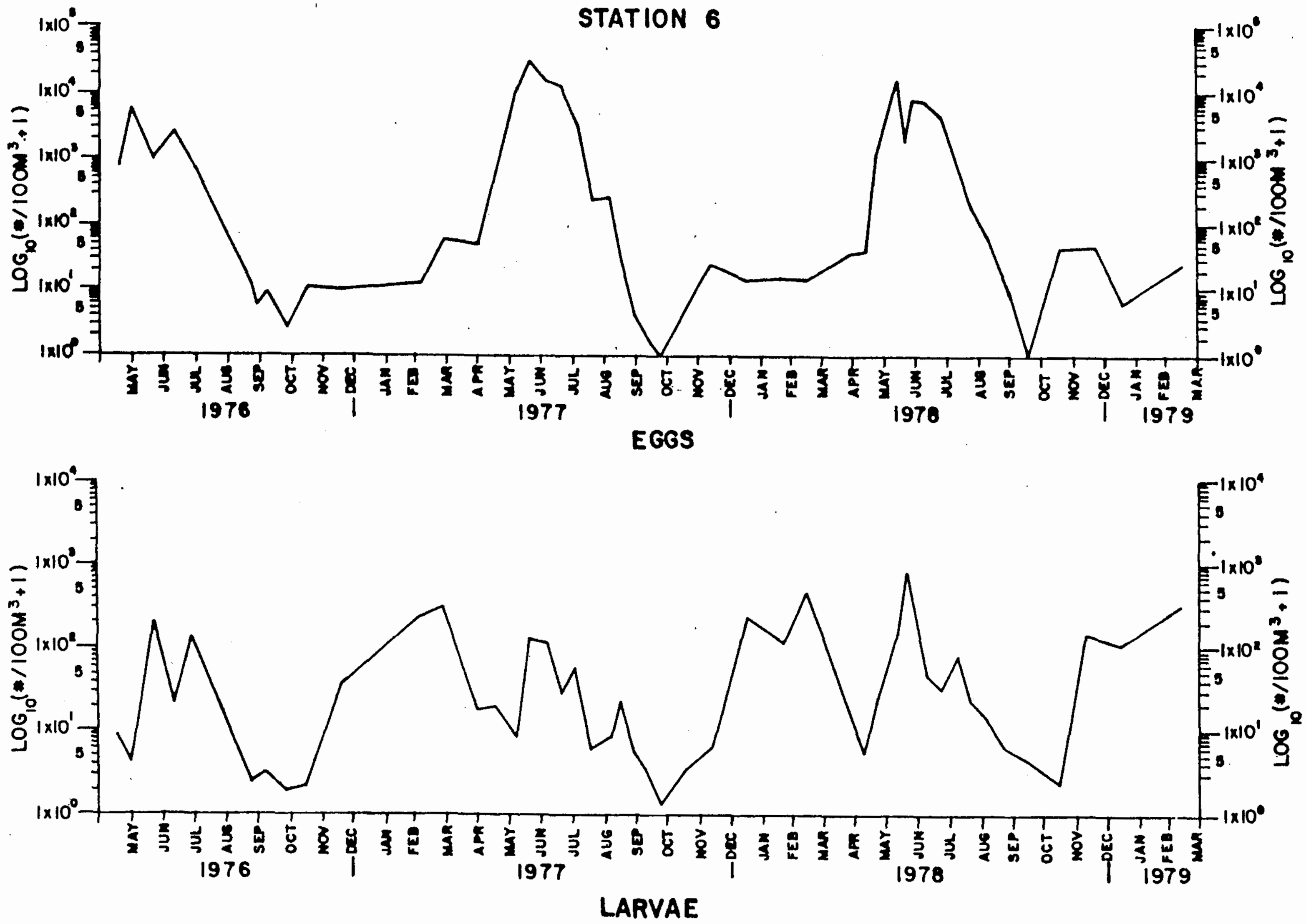


Figure 37. Average egg and larval densities at Station 7 from May 20, 1976 to March 13, 1979.

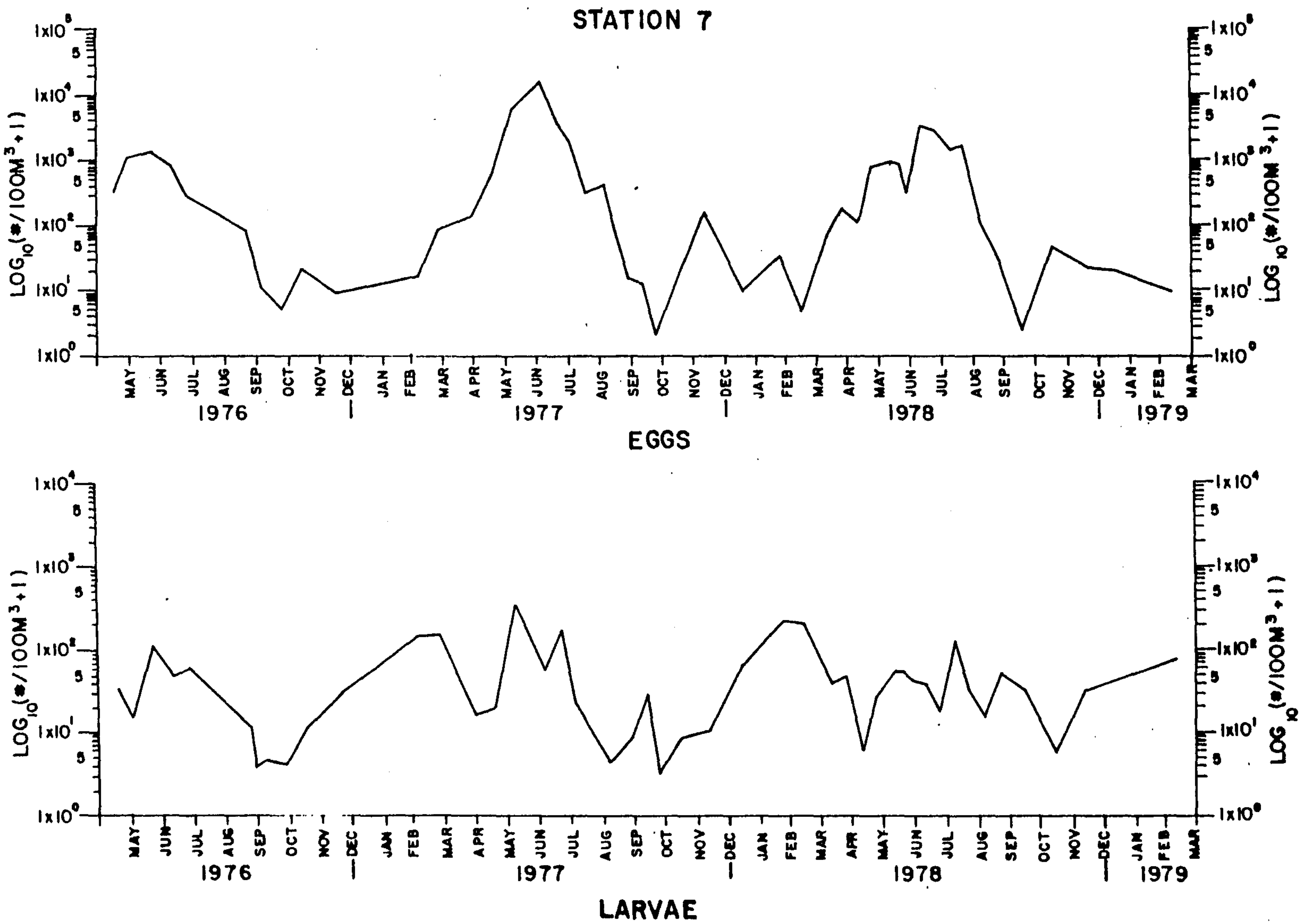


Table 30. Rank of stations by average egg and larval density (#/100m³) from May 20, 1976 through March 13, 1979.

Station (No.)	Average egg density (#/100m³)	Ranking by egg density	Average larval density (#/100m³)	Ranking by larval density
Cleveland Ledge (1)	2607.8	2	363.1	2
Bow Bells (2)	2910.1	1	482.6	1
Butler Point (3)	892.9	5	259.1	3
Stony Point Dike (4)	641.4	7	174.6	4
Herring River (5)	1253.9	4	131.2	5
Power Plant (6)	2214.1	3	113.2	6
Cape Cod Bay (7)	870.6	6	62.3	7

Table 31. Rank of stations by total number of eggs May 20, 1976 through March 13, 1979.

Station (No.)	Ranking	# of eggs	Major species contributing to total catch at station	Percentage of station total catch
Bow Bells (2)	1	297,781	Cunner-tautog-yellowtail flounder	45.0
			Scup-weakfish-silver hake	28.1
			Anchovies	12.5
			Atlantic menhaden	7.5
			Searobins	3.2
			Windowpane-fourspot flounder-black sea bass	2.6
Power Plant (6)	2	240,035	Cunner-tautog-yellowtail flounder	96.4
			Anchovies	1.3
			Fourbeard rockling-red hake-butterfish	0.8
			Atlantic mackerel-cusk	0.4

Table 31. (Continued)

Station (No.)	Ranking	# of eggs	Major species contributing to total catch at station	Percentage of station total catch
Cleveland Ledge (1)	3	209,410	Scup-weakfish-silver hake	47.2
			Cunner-tautog-yellowtail flounder	30.2
			Anchovies	9.4
			Windowpane-fourspot flounder black sea bass	3.5
			Searobins	2.8
			Atlantic menhaden	2.5
Herring River (5)	4	148,066	Cunner-tautog-yellowtail flounder	93.6
			Anchovies	2.3
			Fourbeard rockling-red hake-butterfish	1.1
			Atlantic mackerel-cusk	1.0
Cape Cod Bay (7)	5	101,607	Cunner-tautog-yellowtail flounder	73.9
			Fourbeard rockling-red hake-butterfish	11.9
			Atlantic mackerel-cusk	8.2
			Windowpane-fourspot flounder-black sea bass	3.1
Butler Point (3)	6	92,970	Cunner-tautog-yellowtail flounder	41.9
			Scup-weakfish-silver hake	32.1
			Anchovies	13.3
			Searobins	4.7
			Windowpane-fourspot flounder-black sea bass	3.4
			Northern kingfish-hogchoker	1.4
Stony Point Dike (4)	7	68,553	Cunner-tautog-yellowtail flounder	76.0
			Scup-weakfish-silver hake	9.3
			Anchovies	7.3
			Searobins	1.8
TOTAL EGGS		1,158,422	Cunner-tautog-yellowtail flounder	63.3
			Scup-weakfish-silver hake	19.1
			Anchovies	7.0
			Atlantic menhaden	2.5
			Windowpane-fourspot flounder-sea bass	2.0
			Fourbeard rockling-red hake-butterfish	1.9

Table 32. Rank of stations by total number of larvae May 20, 1976 through March 13, 1979.

Station (No.)	Ranking	# of larvae	Major species contributing to total catch at station	Percentage of station total catch
Bow Bells (2)	1	50,521	Cunner	63.4
			Tautog	12.0
			Anchovies	10.0
			Sand lance	6.5
			Scup	5.5
			Atlantic menhaden	1.3
Cleveland Ledge (1)	2	36,350	Cunner	60.6
			Tautog	11.4
			Anchovies	11.0
			Sand lance	8.4
			Scup	5.3
			Atlantic menhaden	1.2
Butler Point (3)	3	26,493	Cunner	38.4
			Sand lance	24.6
			Anchovies	19.8
			Scup	6.0
			Tautog	5.9
			Atlantic menhaden	2.2
Stony Point Dike (4)	4	19,116	Sand lance	59.1
			Cunner	16.8
			Anchovies	9.2
			Tautog	7.2
			Scup	2.6
			Sculpins	1.0

Table 32. (Continued)

Station (No.)	Ranking	# of larvae	Major species contributing to total catch at station	Percentage of station total catch
Herring River (5)	5	14,509	Sand lance	46.1
			Cunner	27.8
			Anchovies	9.2
			Tautog	6.8
			Scup	2.8
			Sculpins	1.8
Power Plant (6)	6	12,862	Sand lance	45.1
			Cunner	28.7
			Tautog	7.6
			Anchovies	7.0
			Scup	3.0
			Sculpins	2.7
Cape Cod Bay (7)	7	7,267	Sand lance	38.5
			Atlantic mackerel	16.9
			Anchovies	14.1
			Cunner	6.9
			Fourbeard rockling	4.2
			Winter flounder	2.5
			Sculpins	2.4
			Atlantic cod	2.2
			Red hake	2.2
TOTAL LARVAE		167,118	Cunner	45.2
			Sand lance	23.6
			Anchovies	11.6
			Tautog	9.1
			Scup	4.5
			Atlantic menhaden	1.1

mid-May into August and spawning occurs at temperatures between 10 and 26C (Fritzsche 1978). Cunner spawn from June into August and occasionally to mid-October. Eggs have been collected when water temperatures were between 10 and 26C. Yellowtail flounder have a prolonged spawning season from mid-March to September, peaking in April to June in New England. Water temperature during spawning is between 4.5 and 8.1C (Martin and Drewry 1978).

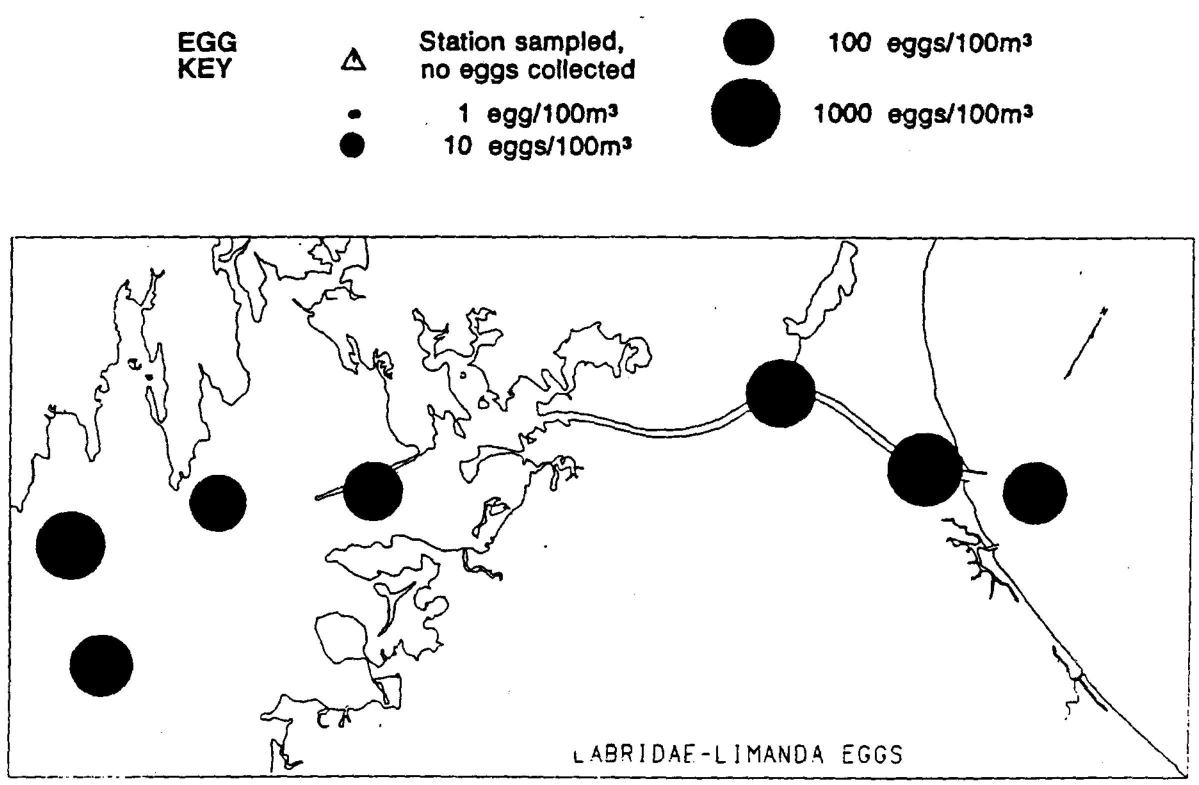
The group ranking first in abundance was Labridae-*Limanda* (cunner-tautog-yellowtail flounder). A total of 733,403 eggs was collected, representing 63.3% of all eggs collected. Eggs comprised from 30.2% of the total egg catch at Station 1 to 96.4% of the catch at Station 6 (Table 28, Figure 38). Eggs from this group ranked first at all stations except Station 1 where they ranked second.

Cunner-tautog-yellowtail flounder eggs were present in the plankton from March into September with greatest densities collected in June. The highest density recorded was 31,677.95 eggs/100 m^3 at Station 6 on June 20, 1977. On 11 occasions egg densities exceeded 10,000 eggs/100 m^3 (Appendices B-H). Based on the number of Stage III yellowtail flounder (100) and Labridae (66,062) eggs recorded, it was estimated that less than 1% of the eggs in the Labridae-*Limanda* egg grouping were yellowtail flounder eggs. Eggs from this group were collected at temperatures between 6 and 24C (± 1C).

Stage I eggs (559,507) represented 76.3% of the total Labridae-*Limanda* eggs collected while Stage II (107,734) represented 14.7% and Stage III (66,162) represented 9.0%. With only 100 yellowtail flounder third stage eggs collected, the location of principal spawning areas was difficult to define, but 84% of the Stage III yellowtail flounder eggs collected were from Station 7.

Totals of 75,670 cunner larvae, 15,219 tautog larvae and 70 yellowtail flounder larvae were collected. The percentage of yellowtail flounder larvae found in this larval grouping is less than 1%, the same ratio found for Stage III eggs.

Figure 38. Spatial distribution of cunner-tautog-yellowtail flounder (Labridae-*Limanda*) eggs, May 20, 1976 to March 13, 1979.



Cunner larvae ranked first in total abundance, and were most abundant at Stations 1, 2 and 3, but fell to second in abundance at Stations 4, 5 and 6 and were the third most abundant larvae at Station 7 (Figure 39). They were found in the plankton samples from May to September with densities peaking in June. The greatest density recorded was 4,918.16 larvae/100 m^3 at Station 2 on June 23, 1976. On 12 occasions densities exceeded 1,000 larvae/100 m^3. Larvae were collected from waters ranging in temperatures from 12 to > 24C (± 1C). Greatest larval densities were found at 20-22C (± 1C). Mean larval densities ranged from 4.30 larvae/100 m^3 at Station 7 to 283.36 larvae/100 m^3 at Station 1. Total mean larval density was 96.10 larvae/ 100 m^3.

Tautog, *T. onitis*, larvae were collected from May to September with greatest densities found in June (1,109.14 larvae/100 m^3 at Station 2 on June 23, 1976). Tautog larvae ranked fourth in total abundance contributing 9.1% of the total larvae collected. Tautog larvae ranked fourth in abundance at Stations 4, 5, 6 and 7 and third in abundance at Stations 1 and 2 (Figure 40). Tautog ranked fifth in abundance at Station 3. Almost five times as many cunner larvae were collected as tautog larvae. *T. onitis* larvae were collected at water temperatures ranging from 12 to > 24C (± 1C) with the greatest densities found between 20-22C (± 1C). Total mean larval density was 19.33 larvae/100 m^3 with mean densities ranging from 0.83 larvae/100 m^3 at Station 7 to 53.72 larvae/100 m^3 at Station 2.

A total of 70 yellowtail flounder larvae was collected with 43 collected at Station 7. Larvae represented less than 0.1% of the total larval catch. The greatest densities were collected at 14C (± 1C). Larvae were collected from April to August.

Stenotomus-Cynoscion-Merluccius

scup-weakfish-silver hake

Scup spawn in southern New England waters from May to August, activity peaking in June

Figure 39. Spatial distribution of cunner (*Tautogolabrus adspersus*) larvae. May 20, 1976 to March 13, 1979.

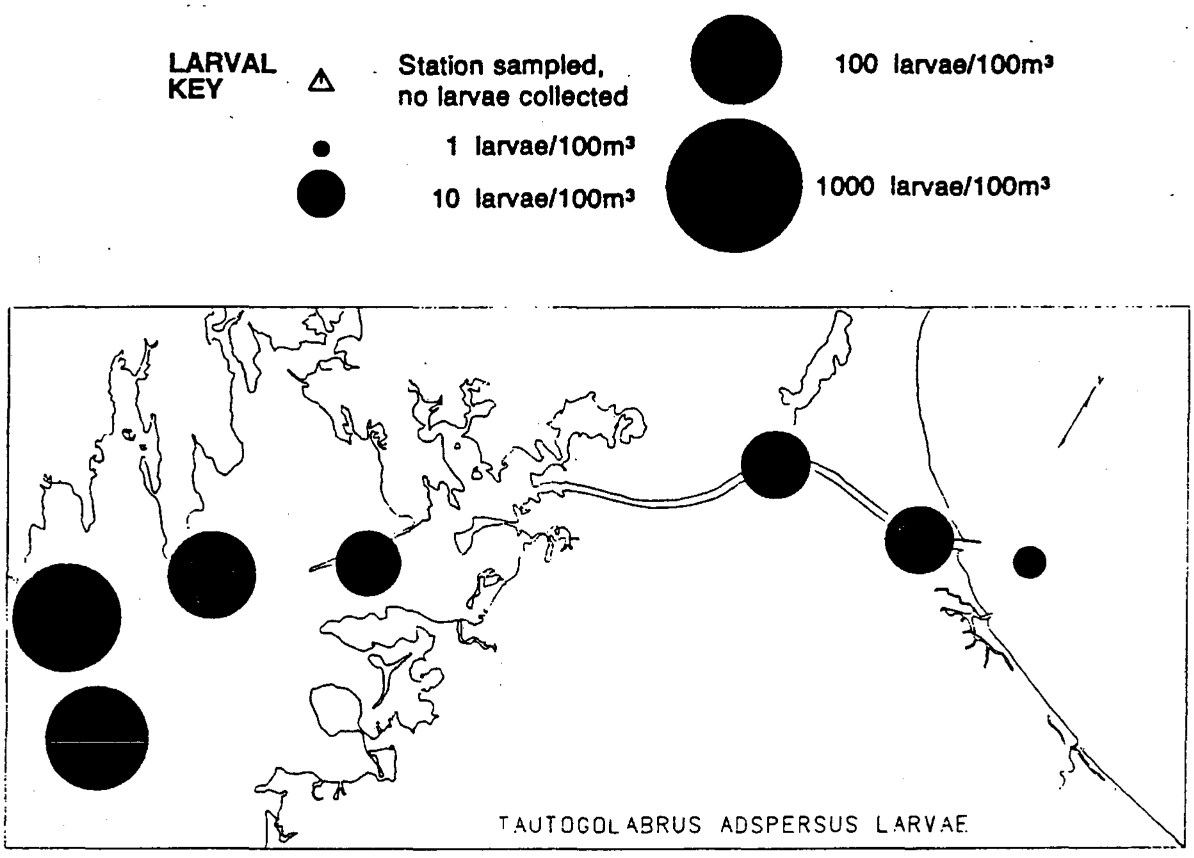
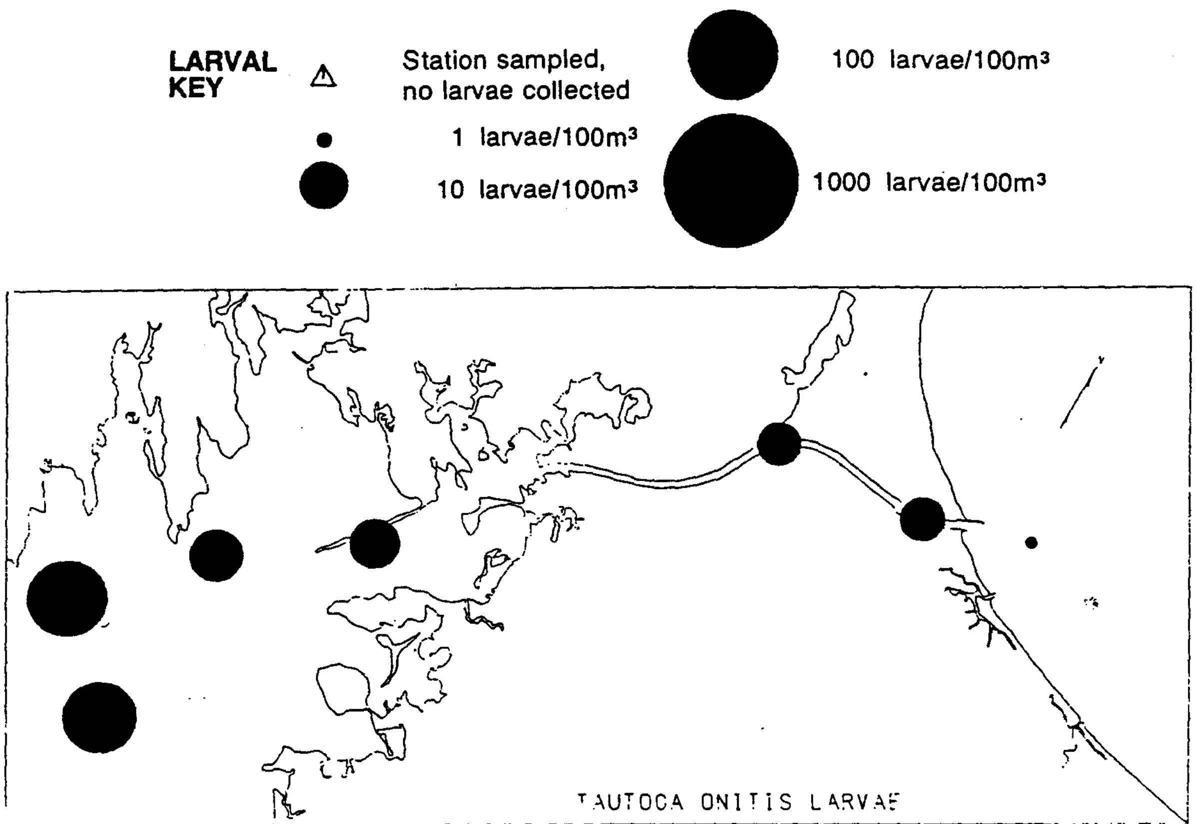


Figure 40. Spatial distribution of tautog (*Tautoga onitis*) larvae, May 20, 1976 to March 13, 1979.



(Bigelow and Schroeder 1953). Spawning is reported occurring at bottom temperatures of 10-18C and surface temperatures of 13-23C (Johnson 1978). Weakfish range from Nova Scotia to the east coast of Florida with spawning possibly occurring as far north as the Gulf of Maine (Johnson 1978) and spawn at temperatures between 15.5 and 23.5C. The major spawning areas of the silver hake lie between Nova Scotia and Cape Cod and generally spawning occurs from May to October. Silver hake spawn on the rising temperature but not until the water column is slightly above 5.5C although eggs apparently need water temperatures of approximately 13 to 15C to develop normally (Hardy 1978).

A total of 221,336 eggs from this group was collected from all stations. Scup-weakfish-silver hake eggs ranked second in total abundance comprising 19.1% of the total catch (Table 31). This egg grouping ranked first at Station 1 comprising 47.2% of the total catch. Water temperatures during periods of scup-weakfish-silver hake egg collections, May through mid-October, ranged from 8->24C (± 1C). The maximum density obtained was 35,507 eggs/100 m^3 at Station 1 on June 12, 1978. Eggs of this grouping decreased in densities with progression from Buzzards Bay stations through the Canal into Cape Cod Bay (Figure 41). This was due to the spawning of scup (*Stenotomus chrysops*), the most abundant species from this group in Buzzards Bay. Scup-weakfish (*Cynoscion regalis*) third stage eggs comprised 14.8% of the total eggs from this grouping while silver hake (*Merluccius bilinearis*) third stage eggs comprised only 0.12%. Also, the relative paucity of weakfish larvae (13) compared to the greater numbers of scup larvae (7,562) supports the assumption that the greater proportion of eggs in the scup-weakfish-silver hake egg grouping were scup.

A total of 32,674 scup-weakfish third stage eggs was collected from all stations. However, the greater densities of these eggs were collected in Buzzards Bay. The greatest number of scup-weakfish third stage eggs (12,036) was collected at Station 2. Station 1 samples contained 11,057 scup-weakfish eggs. Numbers of scup-weakfish third stage eggs decreased steadily through the Canal (Figure 42) and only 17 eggs were collected at Station 7. These were found at water temperatures ranging from 8->24C (± 1C).

Silver hake third stage eggs were collected only at Stations 4 through 7. The total number of eggs collected was 273; 223 from Station 7. Numbers of these eggs increased through the Canal from Station 4 to 7 (Figure 43) indicating that spawning of silver hake occurs primarily in Cape Cod Bay whereas spawning of scup and weakfish occurs primarily in Buzzards Bay (Figure 42). Silver hake third stage eggs were collected in water temperatures ranging from 14->24C (± 1C).

A total of 7,562 scup larvae was collected from all stations at water temperatures ranging from 14->24C (± 1C). The greatest densities of prolarvae and larvae were collected at 16 and 20C (± 1C). Scup larvae ranked fifth in total abundance comprising 4.5% of the total larvae (Table 32). The maximum density collected was 382.78 larvae/100 m³ at Station 1 on June 20, 1977 (Appendix B). Scup larvae decreased in density with progression through the Canal from Buzzards Bay to Cape Cod Bay (Figure 44).

Thirty-seven weakfish larvae were collected from all stations in water temperatures ranging from 16->24C (± 1C). The greatest densities of prolarvae and larvae were collected at 18 and 20C (± 1C). Weakfish ranked low in total abundance comprising less than 0.1% of the total larvae and the greatest total number of larvae collected from one station was 13 at Station 3 (Table 29). The largest density (6.17 larvae/100 m³) was collected on June 20, 1977 at Station 3 (Appendix D).

Ninety-two silver hake larvae were collected at Stations 4 through 7 in water temperatures ranging from 10->24C (± 1C). The largest densities of silver hake larvae were collected at 16C (± 1C). The largest total number collected at one station was 82 at Station 7 and the greatest den-

Figure 41. Spatial distribution of scup-weakfish-silver hake (*Stenotomus-Cynoscion-Merluccius*) eggs, May 20, 1976 to March 13, 1979.

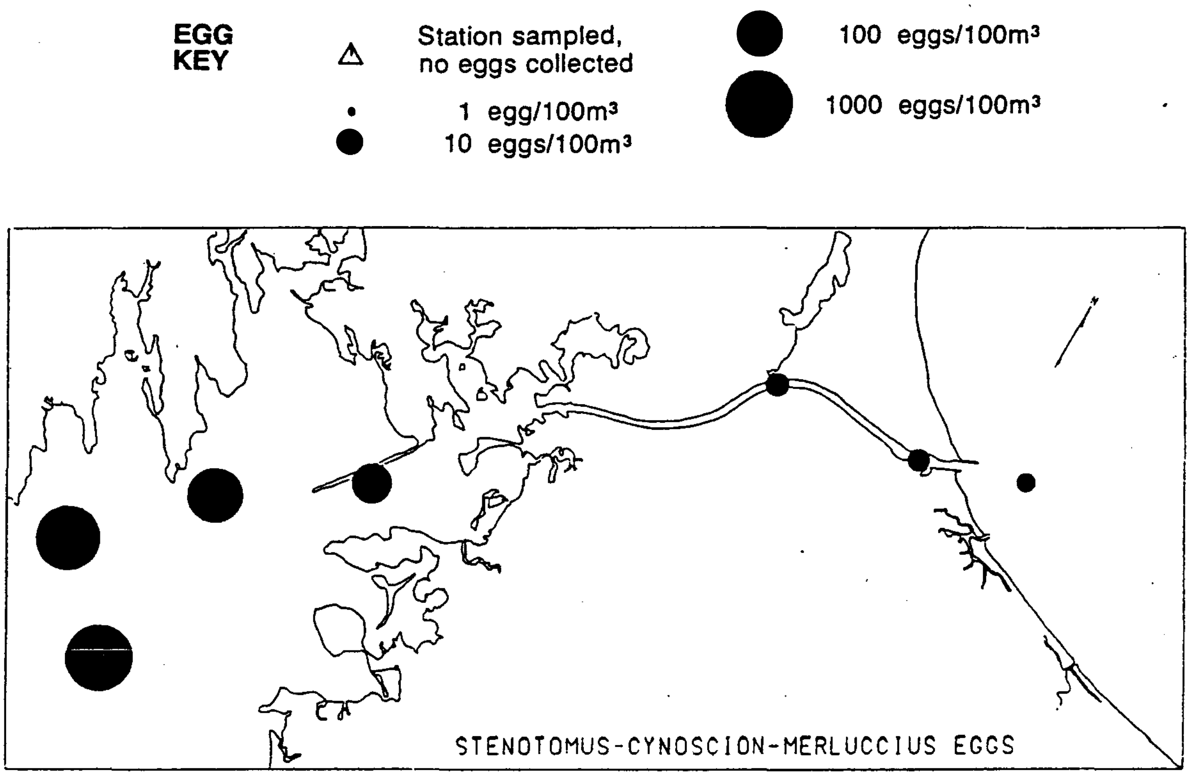


Figure 42. Spatial distribution of scup-weakfish (*Stenotomus-Cynoscion*) Stage III eggs, May 20, 1976 to March 13, 1979.

EGG KEY

- △ Station sampled, no eggs collected
- • 1 egg/100m³
- ● 10 eggs/100m³
- ● 100 eggs/100m³
- ● 1000 eggs/100m³

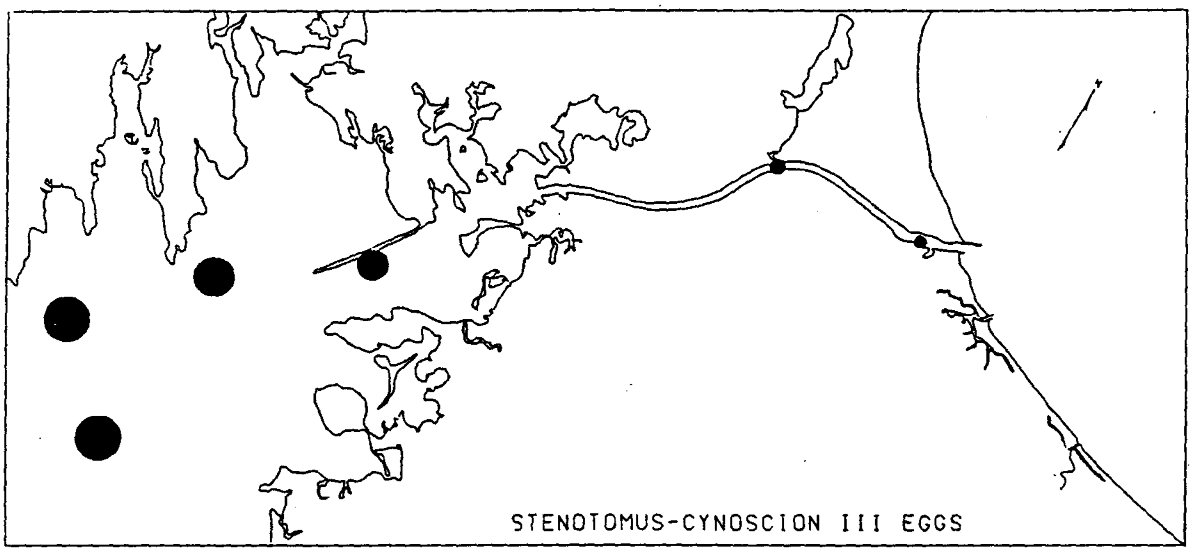


Figure 43. Spatial distribution of silver hake (*Merluccius bilinearis*) stage III eggs. May 20, 1976 to March 13, 1979.

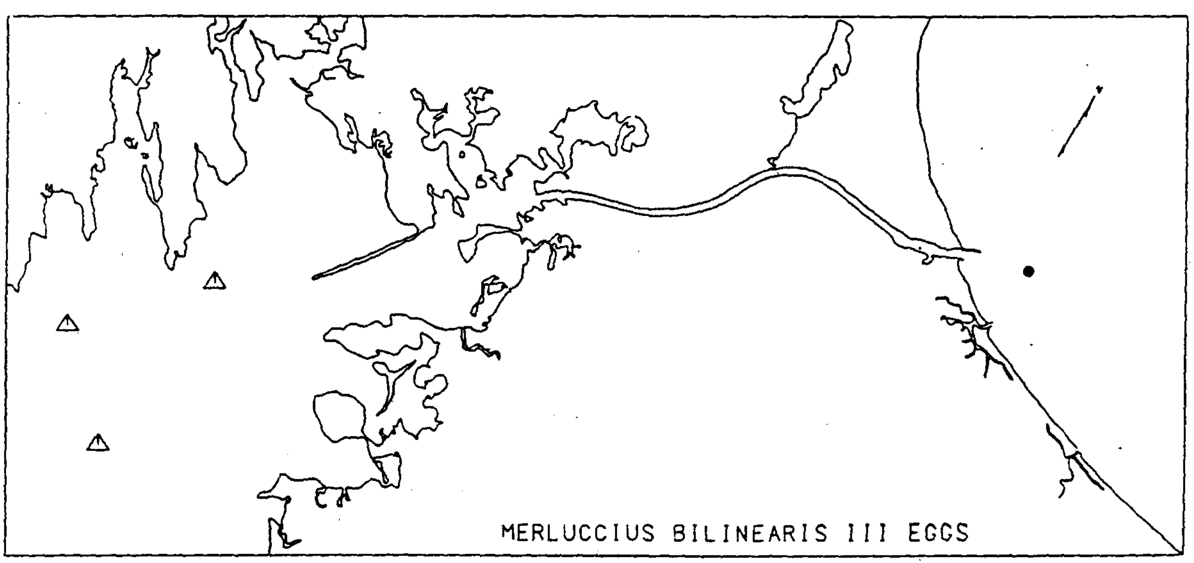


Figure 44. **Spatial distribution of scup (*Stenotomus chrysops*) larvae, May 20, 1976 to March 13, 1979.**

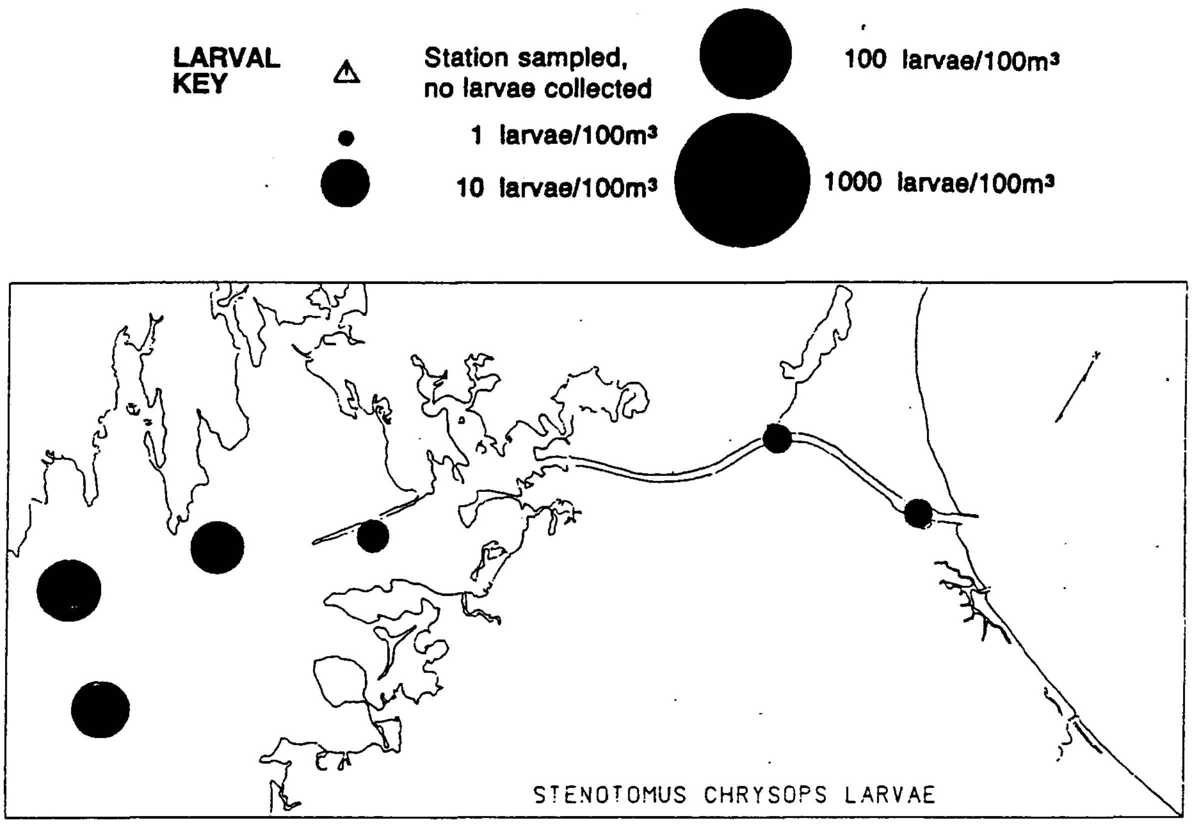
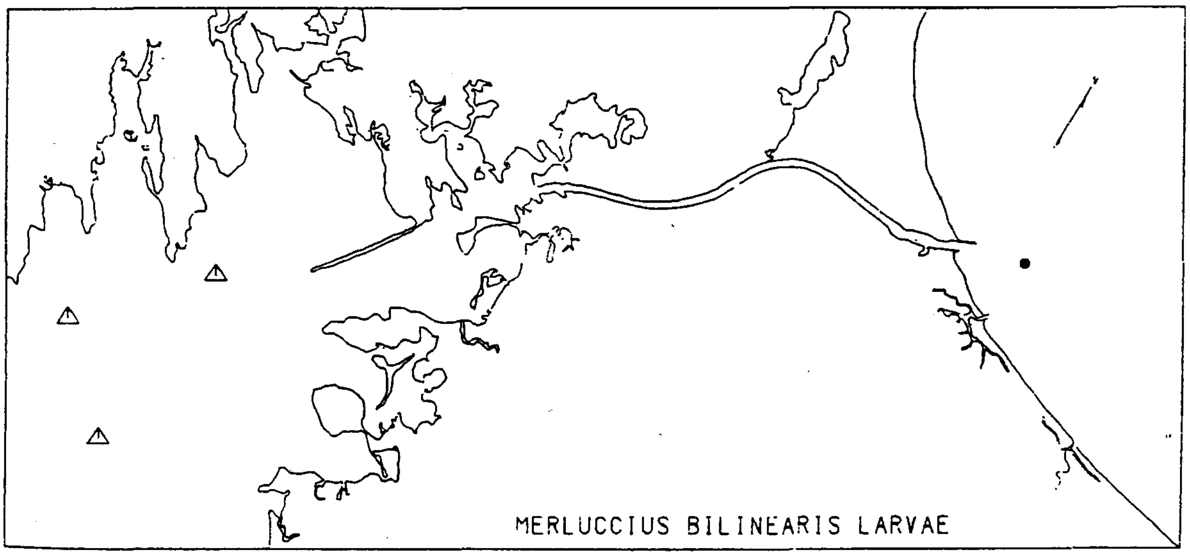


Figure 45. **Spatial distribution of silver hake (*Merluccius bilinearis*) larvae, May 20, 1976 to March 13, 1979.**



sity (15.03 larvae/100 m³) was also collected at Station 7 on September 23, 1978 (Appendix H). Silver hake larvae also ranked low in total abundance comprising less than 0.1% of the total larvae (Table 29). These larvae increased in numbers and densities with progression through the Canal from Station 4 to 7 (Figure 45).

Anchoa spp.

anchovies

A total of 81,116 anchovy eggs was collected during the three years of the study and was the third most abundant egg collected. Anchovy eggs represented 7.0% of all eggs collected (Table 28). More anchovy eggs (37,250) were collected at Station 2 than any other station. Over 85% of the anchovy eggs collected were from Buzzards Bay stations (Figure 46). Mean egg densities ranged from 2.28 eggs/100 m³ at Station 7 to 329.46 eggs/100 m³ at Station 2. Overall mean density was 103.01 eggs/100 m³. Eggs were present in the plankton from May into late August. The greatest density obtained in any one sample was 9,229.48 eggs/100 m³ (Station 2 on June 20, 1977). A sample collected at the same station one year later contained eggs at a density of 7,661.06/100 m³. Totals of 46,429 Stage I, 26,856 Stage II and 7,831 Stage III anchovy eggs were collected. Eggs were collected in waters ranging in temperature from 12->24C (± 1C) with greatest densities found in temperatures of 18-20C (± 1C).

Anchovy larvae were found in the plankton from June into September with larval densities peaking during July. The total of 19,323 larvae collected made anchovy the third most abundant species. As with eggs, the majority of larvae (74%) were collected from Buzzards Bay stations although 1,028 larvae (5.3%) were collected at Station 7 (Figure 47). Samples collected at Stations 2 and 3 contained 53% of the anchovy larvae collected. The greatest density of anchovy larvae encountered during the study was 697.05 larvae/ 100 m³ at Station 2 on July 11, 1978. On

Figure 46. Spatial distribution of anchovy (*Anchoa* spp.) eggs, May 20, 1976 to March 13, 1979.

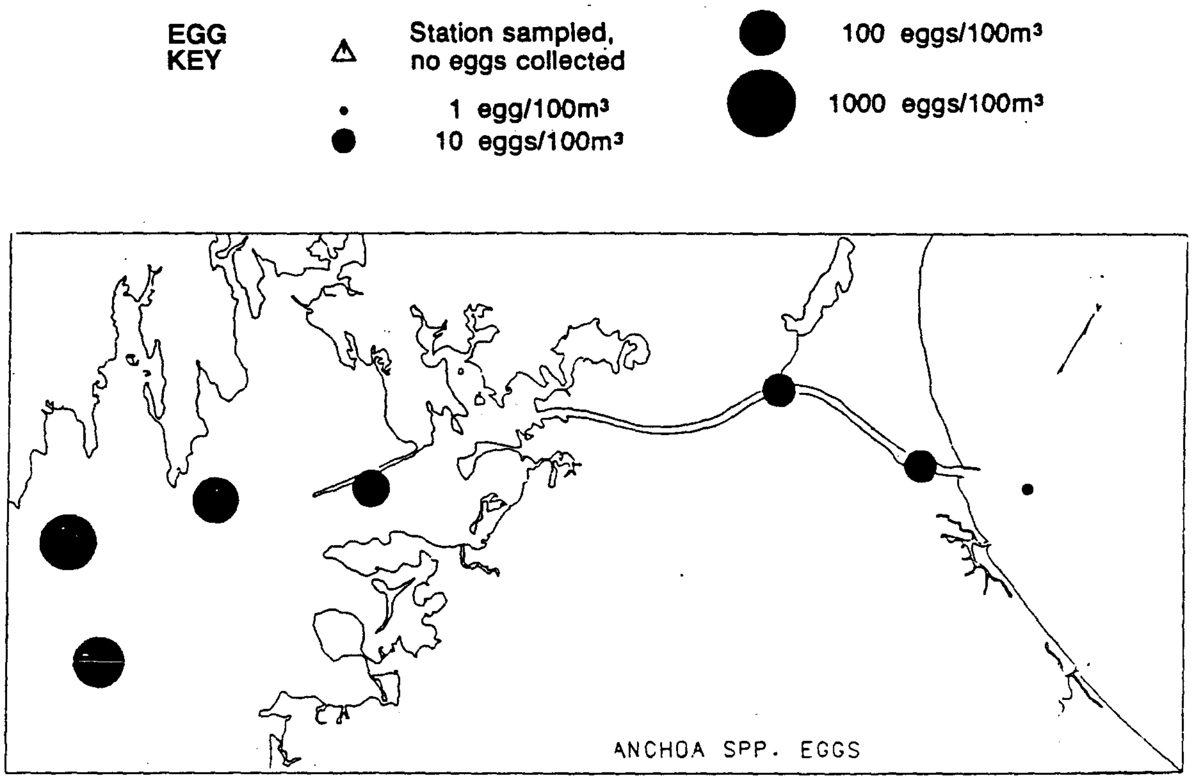
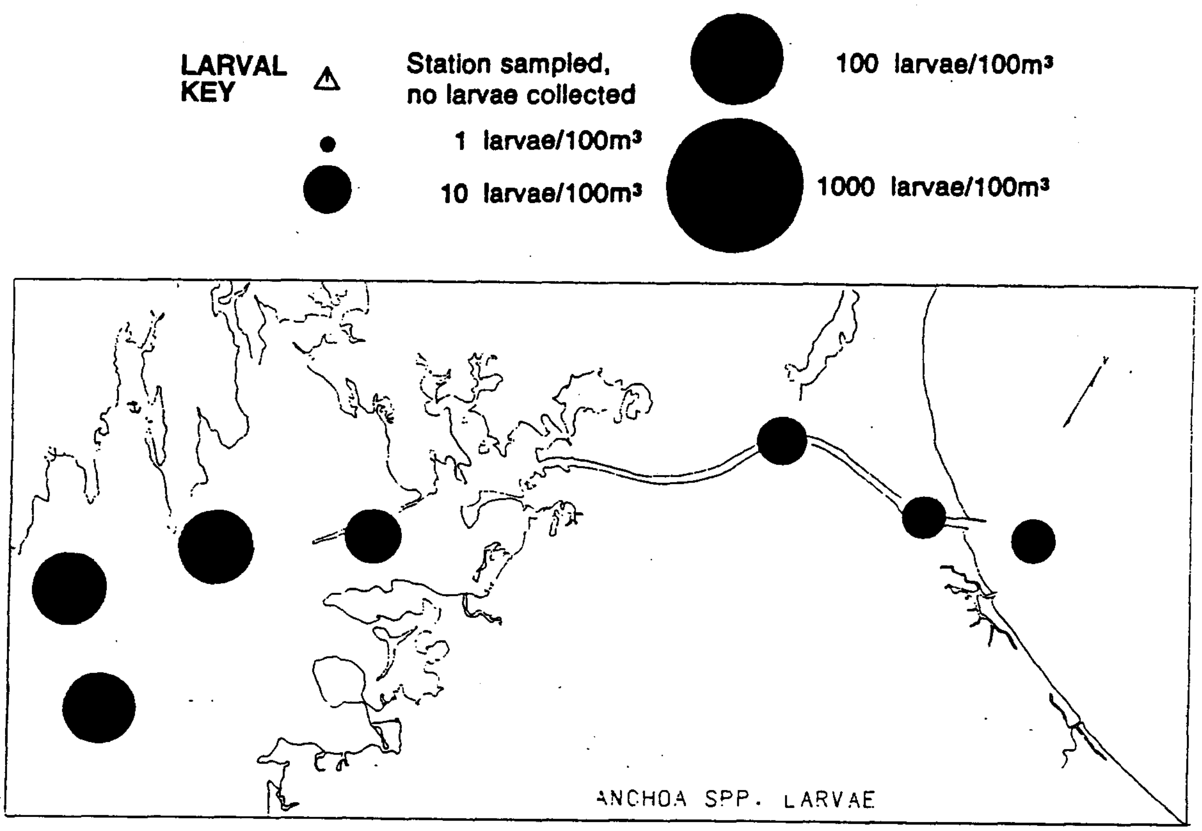


Figure 47. **Spatial distribution of anchovy (*Anchoa* spp.) larvae, May 20, 1976 to March 13, 1979.**



July 25, 1978 a sample taken at Station 1 contained 683.6 anchovy larvae/100 m^3. Mean larval densities ranged from 7.92/100 m^3 at Station 6 to 47.50/100 m^3 at Station 3. Overall mean density of anchovy larvae was 24.54 larvae/100 m^3. Larvae were collected at water temperatures ranging from 14->24C (± 1C).

Bigelow and Schroeder (1953) listed the anchovy as a stray in Gulf of Maine waters. Marine Research, Inc. (1978a) noted that anchovy larvae comprised 0.01% of their total larval catch in Cape Cod Bay. It appears that anchovy spawn in Buzzards Bay and eggs and larvae are carried through the Cape Cod Canal into Cape Cod Bay. Water temperatures during spawning range from 9 to 31C with spawning peaking above 20C (Jones et al. 1978).

Scophthalmus-Hippoglossina-Centropristis-Paralichthys

windowpane-fourspot flounder-black sea bass-summer flounder

The species comprising this egg group were windowpane flounder (*Scophthalmus aquosus*), fourspot flounder (*Hippoglossina oblonga*), black sea bass (*Centropristis striata*) and summer flounder (*Paralichthys dentatus*). Eggs of this group ranked fifth in overall abundance with a total of 23,087 eggs collected and represented 2.0% of the overall catch (Table 28). Seventy-nine percent of the eggs from this group were collected in Buzzards Bay with 7.8% collected in the Cape Cod Canal and 13.6% collected in Cape Cod Bay. While Marine Research, Inc. (1978a) did find summer flounder eggs and larvae during their Cape Cod Bay sampling program, we never collected late stage eggs or larvae of this species. Summer flounder was included in this grouping only because the potential existed for its collection. Since no black sea bass third stage eggs were collected at Station 7, it was assumed that the majority of Stage I and Stage II eggs collected at this station were windowpane and fourspot flounder eggs (Figures 48 49 and 50).

Figure 48. **Spatial distribution of windowpane-fourspot flounder-black sea bass-summer flounder (*Scophthalmus-Hippoglossina-Centropristis-Paralichthys*) eggs, May 20, 1976 to March 13, 1979.**

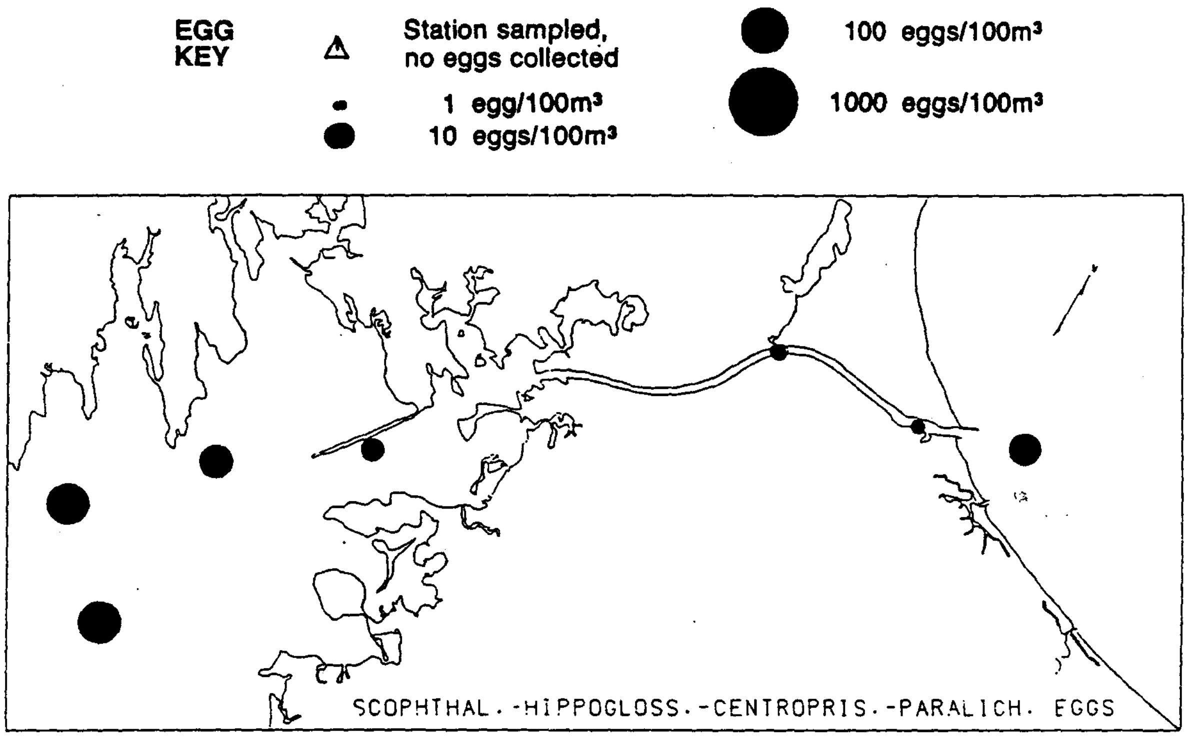
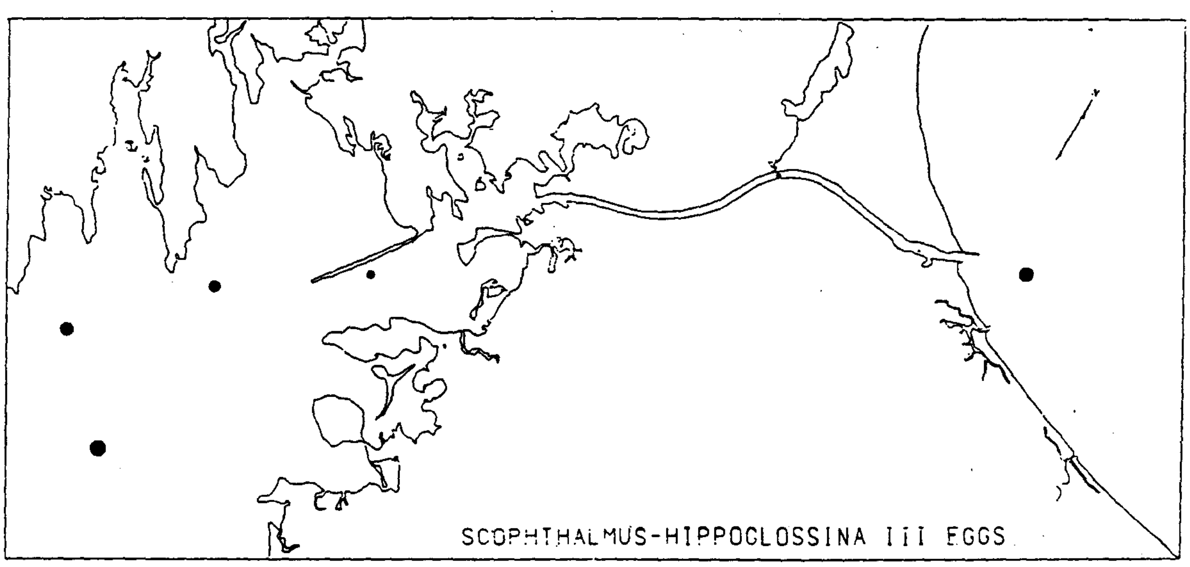


Figure 49. **Spatial distribution of windowpane-fourspot flounder (*Scophthalmus-Hippoglossina*) Stage III eggs, May 20, 1976 to March 13, 1979.**

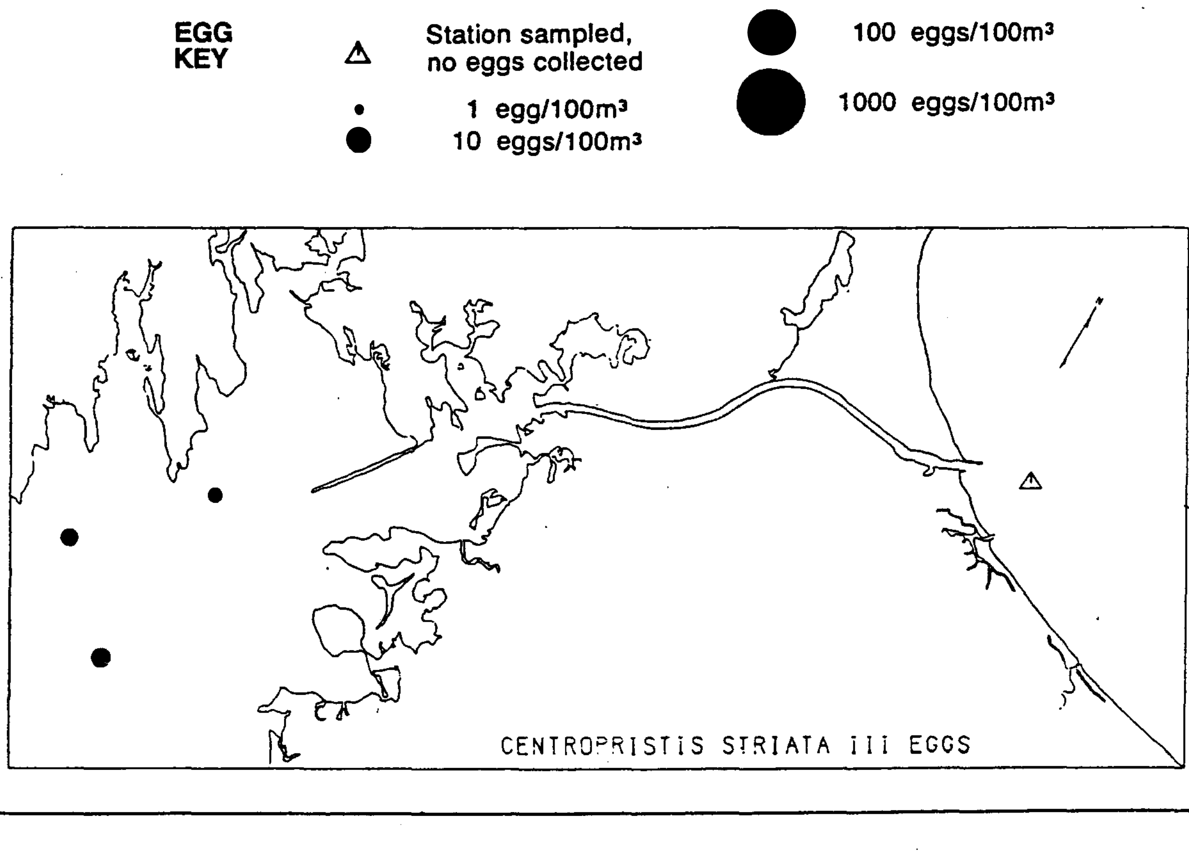


Eggs from the group were present in the ichthyoplankton from May into October. The maximum density obtained was 1,222.14 eggs/100 m^3 at Station 2 on June 20, 1977. A density of 1,026.12 eggs/100 m^3 at Station 1 was obtained on the same date. On June 12, 1978, a density of 1,212.19 eggs/100 m^3 was obtained at Station 1. Eggs were present in waters ranging from 8C ($\pm$ 1C) to temperatures in excess of 24C ($\pm$ 1C). Highest densities were found in water temperatures ranging from 14-20C ($\pm$ 1C).

Black sea bass are common from Cape Cod to Cape Canaveral, Florida with occasional strays recorded in the Gulf of Maine (Kendall 1977). Spawning of *C. striata* occurs during late May off Chesapeake Bay and in early summer off southern New England. Adult windowpane flounder, *S. aquosus*, range from the Gulf of St. Lawrence, Nova Scotia to Florida. Adults found north of Cape Cod are restricted to isolated locations (Martin and Drewry 1978). Spawning is temperature dependent and bimodal. In New York, spawning commences in April or May at 7C and ceases in June or July when temperatures rise above 20C. The second peak occurs in September or October when temperatures drop below 20C. Fourspot flounder range from Georges Bank south to Florida (Martin and Drewry 1978). Colton et al. (1979) state that fourspot flounder spawn on Nantucket Shoals from May to July. Spawning occurs from 6.2 to 9.0C, but eggs have been collected at 22.4C (Martin and Drewry 1978). While we collected eggs from this group in water of >24C ($\pm$ 1C), the maximum temperatures reported in the literature for windowpane and fourspot flounder egg collections were 20C and 22.4C.

Only 40 fourspot flounder larvae were collected with 14 (35%) collected at Station 2 and 9 at Station 1. Larvae were collected from waters ranging in temperature from 14->24C ($\pm$ 1C) with the greatest numbers collected from water of 18-20C ($\pm$ 1C). Larvae were present in the ichthyoplankton from May to September with greatest densities occurring in June. The largest density encountered was 5.01 larvae/100 m^3 on

Figure 50. Spatial distribution of black sea bass (*Centropristis striata*) Stage III eggs, May 20, 1976 to March 13, 1979.



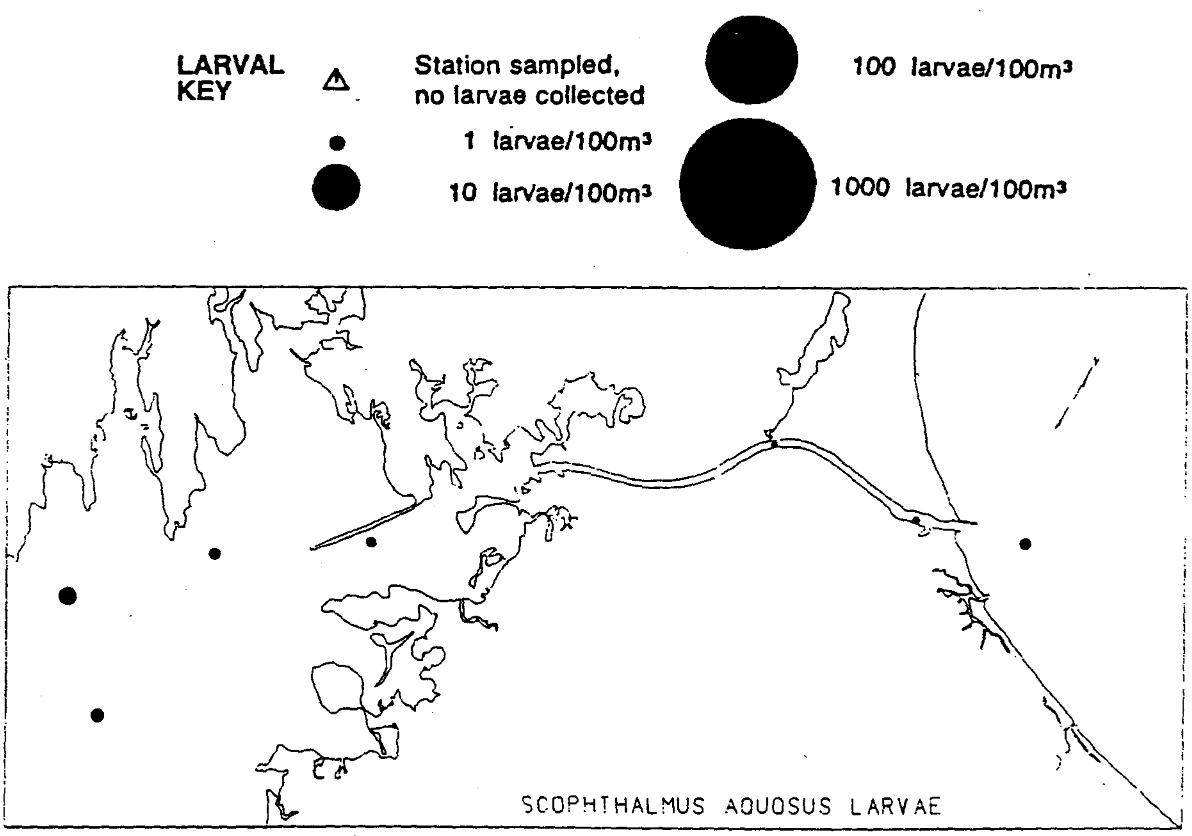
June 20, 1977 at Station 2.

The most abundant larva originating from the egg grouping of *Scophthalmus-Hippoglossina Centropristis-Paralichthys* was the windowpane flounder. Six hundred and twenty-six larvae were collected from all stations (Figure 51). More (172) were collected at Station 2 than any other station. Station 1 samples contained 102 windowpane larvae. Windowpane larvae represented 0.4% of the total larval catch. Larvae were collected from May into November with the greatest densities being collected during June. The greatest density collected was 22.56 larvae/100 m³ at Station 2 on June 7, 1977. Larvae were collected at water temperatures ranging from 8->24C (± 1C) with greatest densities found from 16-18C (± 1C).

Miller (1959) states that three species of *Centropristis* occur along the Atlantic coast, the most widespread being *Centropristis striata* which occurs from the Gulf of Maine to the Florida Keys. *C. striata* is expected to spawn from Cape Cod to the Chesapeake Bay (Miller 1959). Larvae have been identified from collections made at the mouth of the Chesapeake (Pearson 1941), Long Island Sound (Perlmutter 1939a and b), Narragansett Bay (Herman 1963, Marine Research, Inc. 1975) and Block Island Sound (Marine Research, Inc. 1974). Kendall (1972) observed an apparent northward progression of larval occurrence but no eggs have been identified from Atlantic coast collections (Kendall 1977). Egg and prolarval descriptions of *C. striata* are limited. Kendall (1972) gave a very thorough description of *C. striata* postlarvae. His specimens ranged in size from 2 mm to 10 mm. However, prolarval characteristics were not discussed except to note that general body shape and proportions remain distinguishable and characteristic even at the 2 mm size. Wilson (1889) thoroughly described black sea bass embryology; however, he did not provide any egg identification characteristics. Hoff (1970) presented drawings of an egg and prolarva but provided no written description.

In 1977, ichthyoplankton samples collected in Buzzards Bay yielded large numbers of *C. striata* postlarvae, several small prolarvae and some

Figure 51. Spatial distribution of windowpane flounder (*Scophthalmus aquosus*) larvae, May 20, 1976 to March 13, 1979.



unique third stage eggs. These eggs and prolarvae were tentatively identified as *C. striata* due to their similarity to *C. striata* postlarval and prolarval characteristics. Other pieces of evidence supported these identifications. The Division's Resource Assessment Project working in Nantucket Sound in the fall of 1977 noted a substantial increase in the number of young-of-the-year black sea bass collected over the previous year's collections (Howe, personal communication)[1]. No other species have eggs with the same morphological characteristics as *C. striata* and spawn in the study area. Prolarvae were sent to the NMFS Sandy Hook Laboratory (Naplin, personal communcation)[2] for confirmation of our identification and were identified as *C. striata*. Eggs were sent to the Florida Department of Natural Resources (Roberts, personal communcation)[3] for comparison with his reared *C. melana* eggs and differences were found. Descriptions of eggs and prolarvae collected during this study are provided in Appendix K. However, there is lack of agreement on whether *Centropristis melana* is a separate species from *Centropristis striata*.

Since *C. striata* eggs were not identified as black sea bass until 1977 and time constraints did not allow re-examination of 1976 samples, there may be a small number of black sea bass eggs mistakenly identified as windowpane-fourspot flounder-summer flounder late stage eggs in 1976 samples. In 1977, late stage eggs positively identified as black sea bass were collected at Stations 1-4. Eggs were first identified in samples collected on June 7. A sample collected on June 20, 1977 at Station 2 contained the maximum density of 160.28 eggs/100 m^3. The last sample containing sea bass eggs was collected July 21. The largest densities of late stage black sea bass eggs were collected at water temperatures of 18C.

In 1978, sea bass eggs were collected at all stations except the Cape Cod Bay station. Late stage sea bass eggs were first collected on June 12. The greatest density (170.75 eggs/100 m^3) was collected on this date at Station 1. The last egg was collected on September 23 at Station 3. Eggs were collected in water temperatures ranging from 17-23C with the greatest numbers collected again at approximately 18C.

In 1976, eighteen *C. striata* postlarvae were collected; 16 were taken on June 23. Ten larvae were collected at Cleveland Ledge for a maximum density of 3.52 larvae/100 m^3, five were collected at Bow Bells and one larva was collected at the power plant station. The remaining two larvae were collected on July 13, one each at Stations 1 and 2. The largest number of larvae were collected at 22C.

[1]Arnold B. Howe, Massachusetts Division of Marine Fisheries.
[2]Ann Naplin, National Marine Fisheries Service.
[3]Daniel Roberts, Florida Department of Natural Resources.

A total of 148 black sea bass larvae was collected in 1977. Buzzards Bay samples, Stations 1, 2 and 3, contained 132 larvae while only 16 were found in samples collected in the Cape Cod Canal. Of the 148 larvae collected, 25 were prolarvae and 123 were postlarvae. The first black sea bass larvae appeared in Buzzards Bay samples collected on June 7 and the first prolarva was identified in a sample collected at Station 3. Surface water temperature was 17C. On June 20, 140 black sea bass larvae were collected. Twenty-four were prolarvae and all were separated from samples collected in Buzzards Bay. The maximum density of prolarvae collected was 11.69/100 m^3 (14 larvae) at Station 2. Surface water temperature was 19C. The maximum number of postlarvae collected was 44.99/100 m^3 at Station 1. The last larva was collected on August 3 at Station 2. The greatest number of larvae was collected at a temperature of 18C.

In 1978, sixty-five larvae were collected, of which 7 were prolarvae and 58 were postlarvae. Again, prolarvae were collected at Buzzards Bay stations only. Larvae were first collected on June 12. On this date at Station 3, the maximum density of prolarvae was collected (1.52/100 m^3). The surface water temperature was 18C. The last prolarva was collected on June 20. Postlarvae were collected in samples until August 21. On this date the maximum density of 6.10 larvae/100 m^3 was collected at Station 1. Larvae were collected at water temperatures which ranged from 17.5->24C, with the greatest numbers caught at 20C.

C. striata eggs and larvae were routinely collected in Buzzards Bay with densities decreasing in the Cape Cod Canal. No eggs or larvae were collected at Station 7 (Figures 50 and 52).

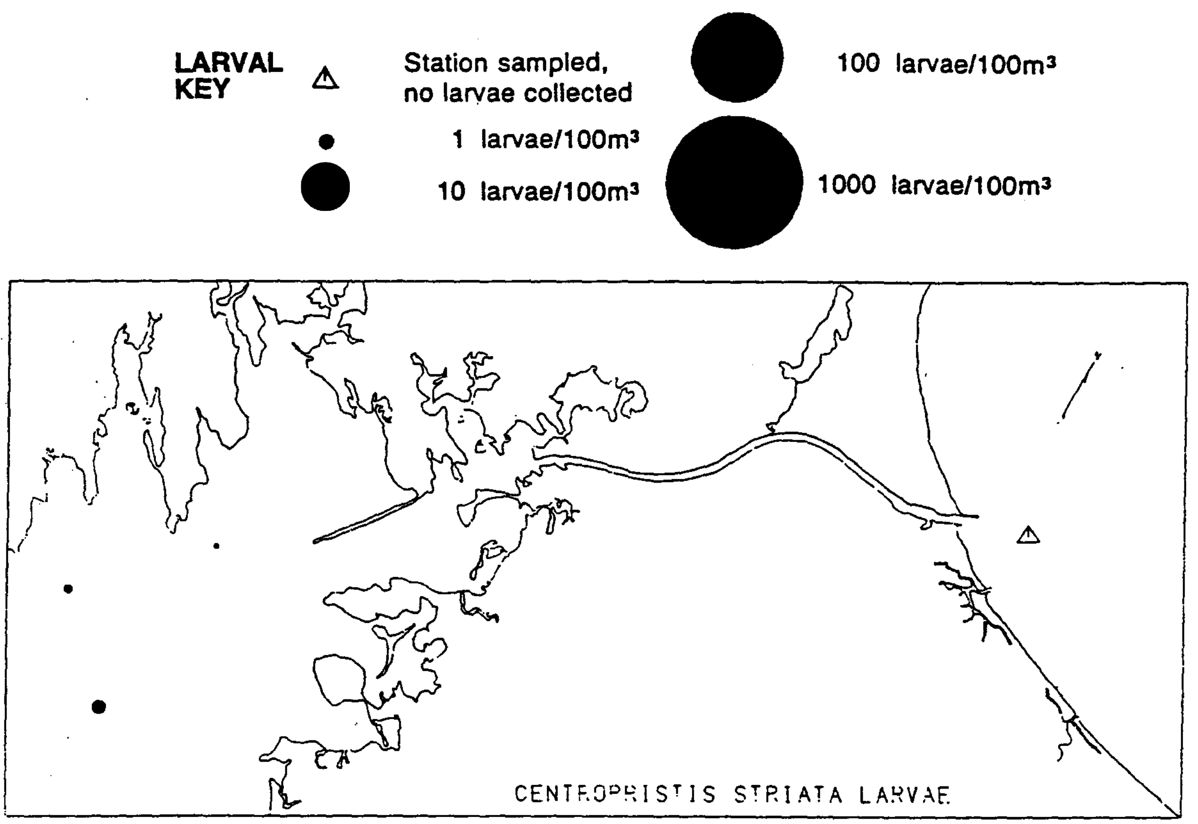
Enchelyopus-Urophycis-Peprilus

fourbeard rockling-red hake-butterfish

Hardy (1978a) lists fourbeard rockling, *Enchelyopus cimbrius*, as spawning from February to August in New England waters. Colton et al. (1979) state that the spawning season runs from April to July, peaking in May and June. Red hake, *Urophycis chuss*, spawn on the continental shelf with concentrations on southeastern Georges Bank and south of Long Island (Hardy 1978a). Colton et al. (1979) indicate that red hake spawn on Nantucket Shoals from April to August, peaking in May and June. Butterfish, *Peprilus triacanthus*, spawn in June and July in New England (Martin and Drewry 1978). Spawning on Nantucket Shoals occurs from May to August, peaking in June and July (Colton et al. 1979).

The fourbeard rockling (*E. cimbrius*), red hake (*U. chuss*), butterfish (*P. triacanthus*) egg grouping ranked sixth in total abundance with a total of

Figure 52. Spatial distribution of black sea bass (*Centropristis striata*) larvae, May 20, 1976 to March 13, 1979.



23,076 eggs being collected (Table 28). Eggs from this group were collected at every station (Figure 53), but the distribution of Stage III eggs is a better index of the spawning activity of the species in the grouping (Figures 54-56). From the 3,471 rockling Stage III eggs collected, 2,668 were collected at Station 7. A similar situation existed for red hake Stage III eggs. A total of 3,133 was collected, 2,806 from Station 7. The inverse was true with butterfish Stage III eggs. Of the 589 collected only 13 came from Station 7 with the majority (81.8%) found at Station 1. Based on this information, it appeared that the major spawning activity of fourbeard rockling and red hake occurred in Cape Cod Bay and butterfish in Buzzards Bay, possibly south of our Station 1. A ranking of larvae provided by Marine Research, Inc. (1978a) for their 1975 ichthyoplankton sampling showed fourbeard rockling ranking second in abundance, red hake ranking sixth and butterfish ranking twenty-seventh. Eggs from this group accounted for 11.9% of the total eggs collected at Station 7, and were second in abundance at this station.

Eggs were collected from February to November with the greatest densities generally occurring in June. The largest density encountered for the grouping was 946.78 eggs/100 m³ on August 21, 1978 at Station 7. The greatest density of fourbeard rockling Stage III eggs encountered was 258.82/100 m³ on June 23, 1976 at Station 7 while red hake eggs were collected at a density of 914.33/100 m³ on August 21, 1978 at Station 7. Butterfish eggs were collected on June 2, 1976 at Station 1 at a density of 106.28/100 m³. The ratio of all fourbeard rockling, red hake and butterfish Stage III eggs collected was 5.9:5.3:1.0.

Eggs from this group were collected in a wide range of water temperatures, 0->24C (± 1C). Fourbeard rockling Stage III eggs were collected at temperatures ranging from 6->24C (± 1C). Red hake and butterfish Stage III eggs were found at similar water temperatures, 8-22C (± 1C). The majority of fourbeard rockling Stage III eggs was collected in water ranging from 12-20C

Figure 53. Spatial distribution of fourbeard rockling-red hake-butterfish (*Enchelyopus-Urophycis-Peprilus*) eggs, May 20, 1976 to March 13, 1979.

EGG KEY

△ Station sampled, no eggs collected

• 1 egg/100m³

● 10 eggs/100m³

● 100 eggs/100m³

● 1000 eggs/100m³

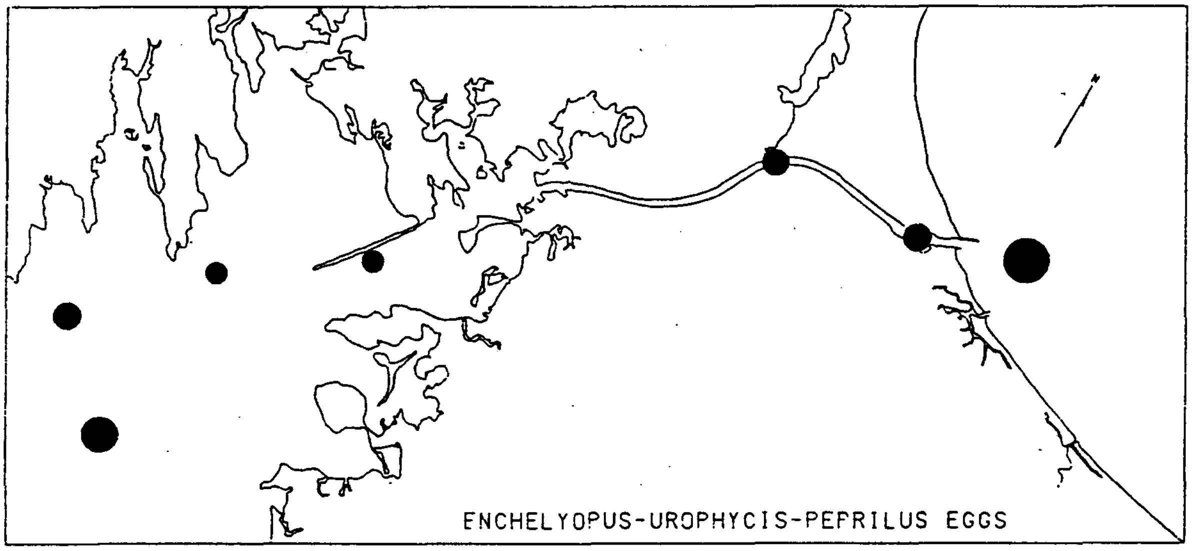


Figure 54. Spatial distribution of fourbeard rockling (*Enchelypus-cimbrius*) Stage III eggs, May 20, 1976 to March 13, 1979.

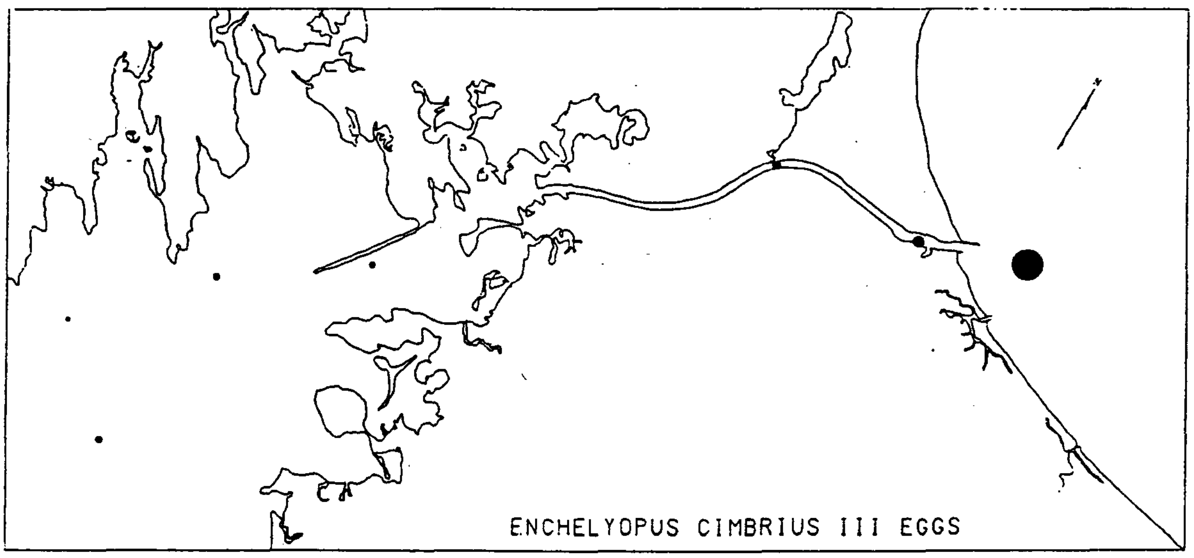


Figure 55. **Spatial distribution of red hake (*Urophycis chuss*) Stage III eggs, May 20, 1976 to March 13, 1979.**

EGG KEY	△	Station sampled, no eggs collected	●	100 eggs/100m³
	•	1 egg/100m³	●	1000 eggs/100m³
	●	10 eggs/100m³		

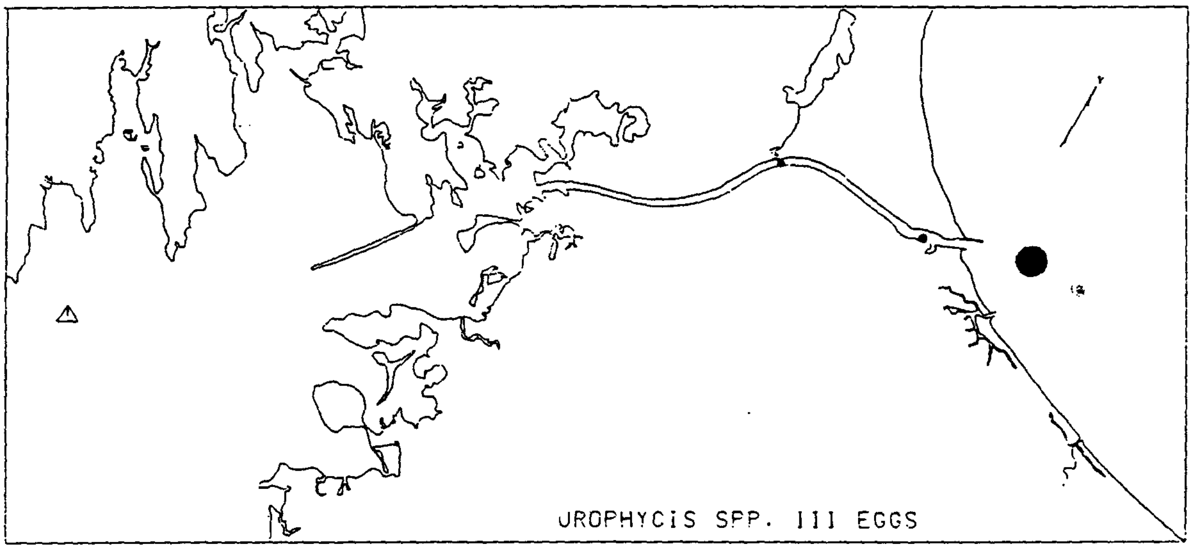
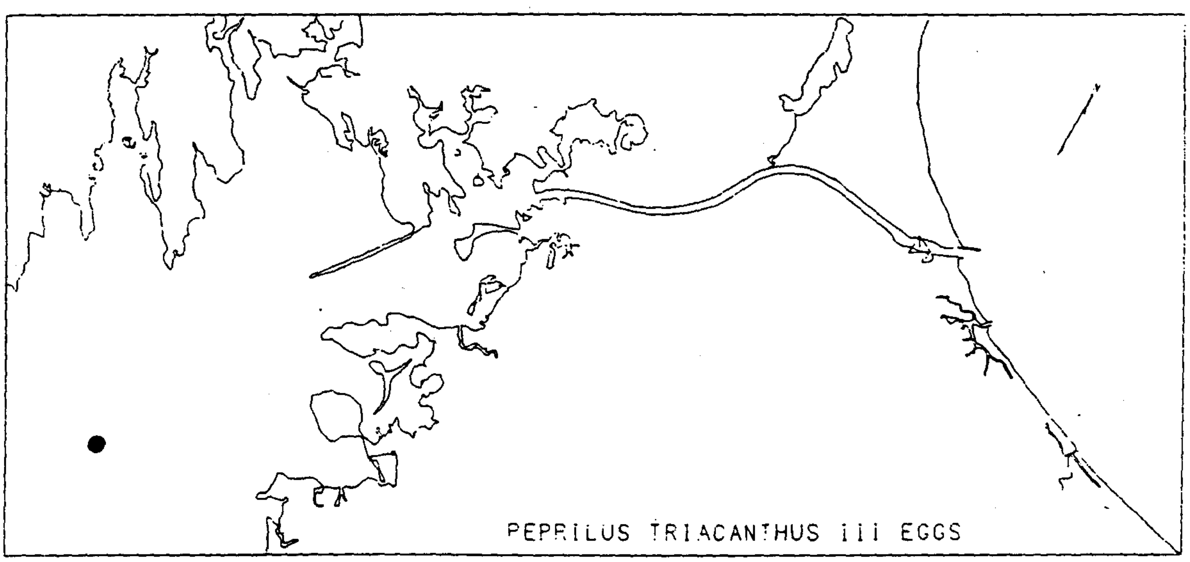


Figure 56. **Spatial distribution of butterfish (*Peprilus triacanthus*) Stage III eggs, May 20, 1976 to March 13, 1979.**



(± 1C) while the greatest density of red hake Stage III eggs was collected at 20C (± 1C). The greatest density of *P. triacanthus* Stage III eggs was collected at Station 1 between 16-18C (± 1C).

Hardy (1978a) mentions spawning of fourbeard rockling taking place at temperatures from 1.15 to 16.1C and activity peaking at 9 to 10C. Mention is also made of red hake spawning from 5 to 10C and butterfish from 12.8 to 22.5C.

Larval distribution patterns were similar to those of the eggs of fourbeard rockling, red hake and butterfish (Figures 57-59). Rockling and red hake larvae were found in greatest densities at Station 7 while butterfish larvae were concentrated at Stations 1 and 2.

Fourbeard rockling larvae were present in the ichthyoplankton from May to November, although in 1979, larvae were collected in March. The greatest density encountered was 36.05 larvae/100 m³ at Station 6 on June 20, 1977. A total of 686 larvae was collected with 306 being collected at Station 7 and 146 at Station 6.

Fourbeard rockling larvae represented 0.4% of all larvae collected. Mean larval densities ranged from 0.21 larvae/100 m³ at Station 2 to 2.62 larvae/100 m³ at Station 7 with a total mean larval density of 0.87 larvae/100 m³. Larvae were collected in waters ranging in temperatures from 8->24C (± 1C).

Red hake larvae represented 0.1% of the total larval catch with 218 larvae being collected. Larvae were collected from May until November. More (159) of the 218 red hake larvae were collected at Station 7 that at any other station. The maximum density of 28.70 larvae/100 m³ was collected at this station on October 16, 1978. Larvae were collected in water of 10->24C (± 1C) with greatest densities found at ~15C. Mean larval density was 0.28 larvae/100 m³.

Slightly fewer butterfish larvae (191) were collected with 40.8% collected at Station 1. Butterfish larvae represented 0.1% of the total larval catch. Larvae were collected from June through September. The greatest density recorded was 10.91 larvae/100 m³ at Station 1 on June 23,

Figure 57. Spatial distribution of fourbeard rockling (*Enchelyopus cimbrius*) larvae, May 20, 1976 to March 13, 1979.

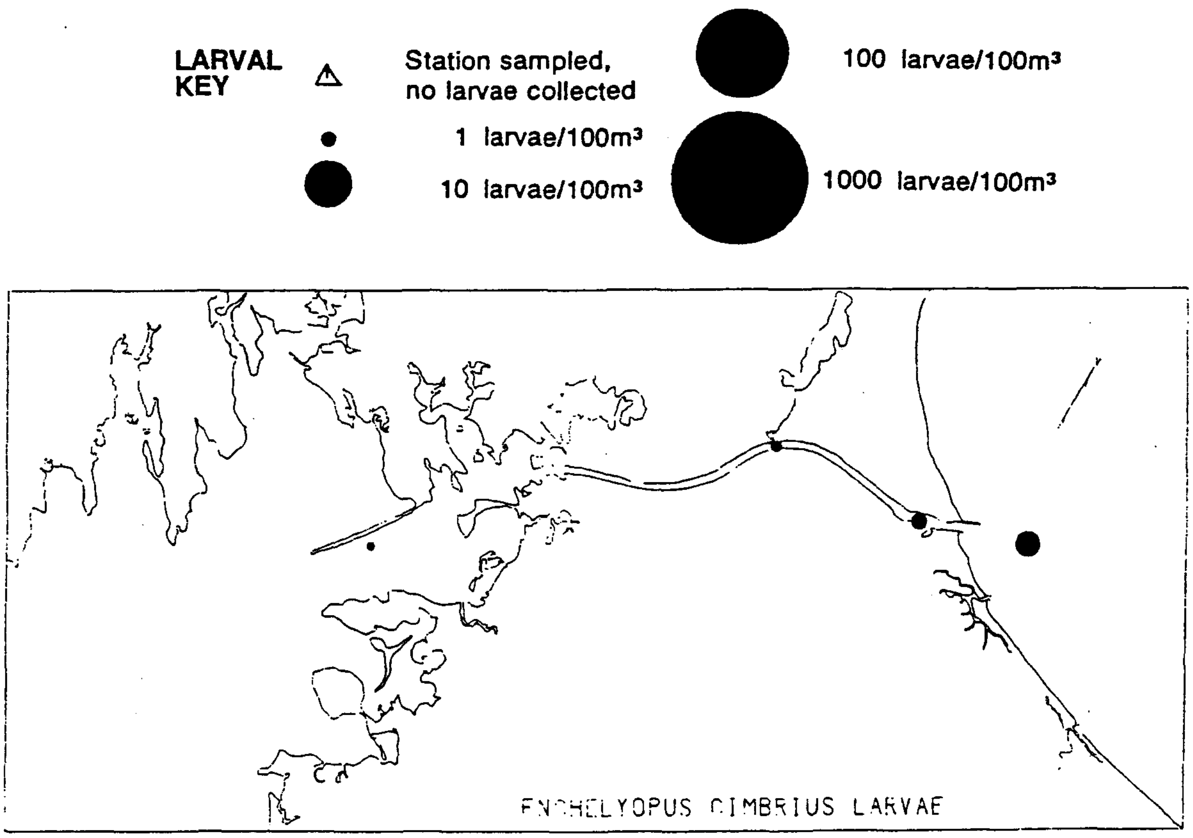


Figure 58. Spatial distribution of red hake (*Urophycis chuss*) larvae, May 20, 1976 to March 13, 1979.

LARVAL KEY

△ Station sampled, no larvae collected

● 1 larvae/100m³

● 10 larvae/100m³

● 100 larvae/100m³

● 1000 larvae/100m³

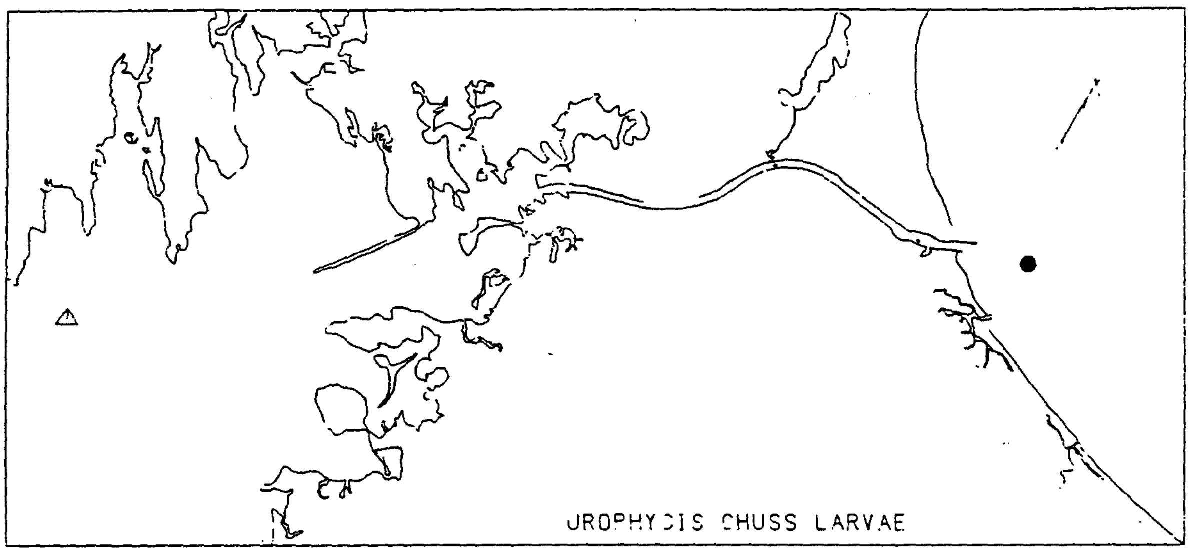
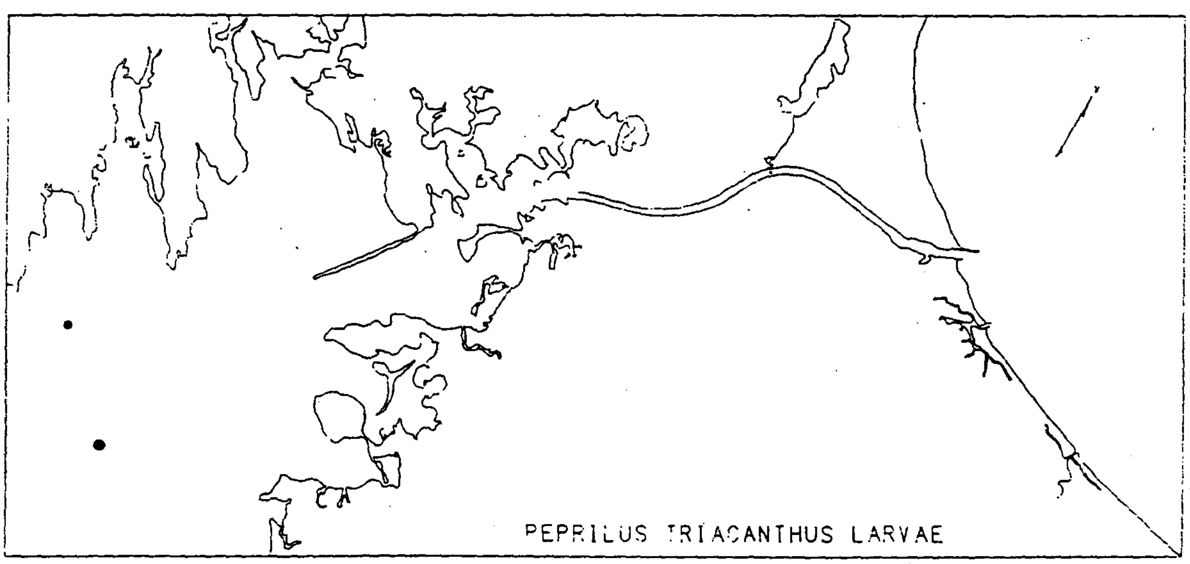


Figure 59. Spatial distribution of butterfish (*Peprilus triacanthus*) larvae, May 20, 1976 to March 13, 1979.



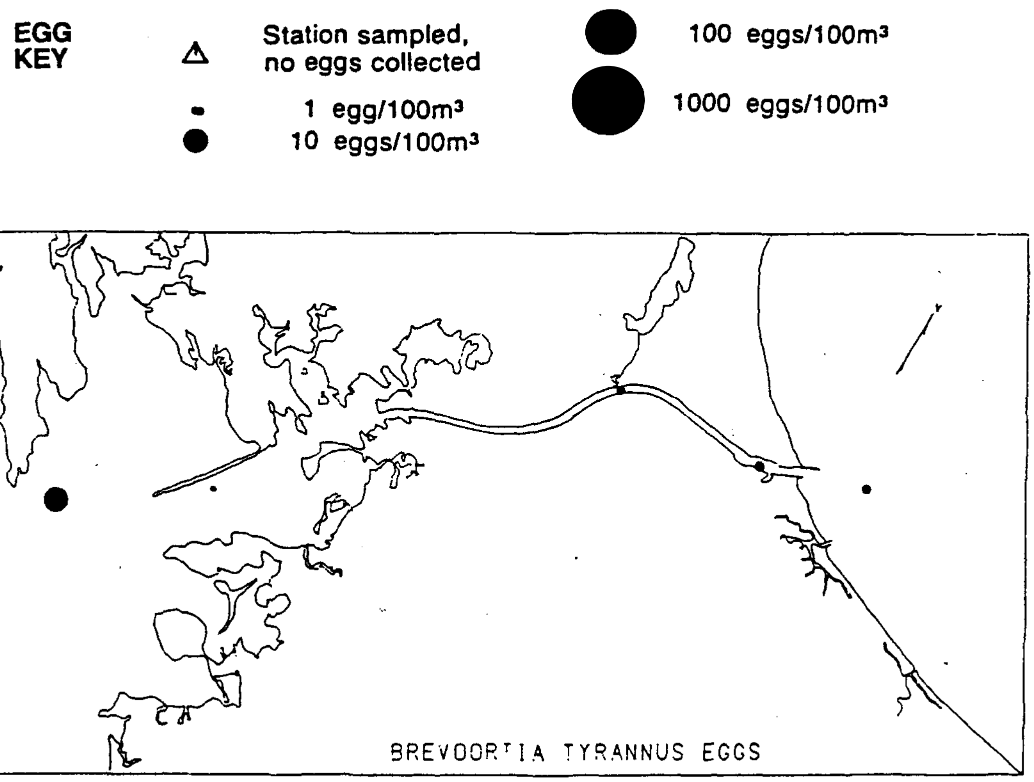
1976. Water temperatures during their collection period ranged from 14->24C (± 1C). Mean larval density for all stations was 0.24 larvae/100 m³ with the highest mean larval density being found at Station 1 (0.76 larvae/100 m³).

Brevoortia tyrannus

Atlantic menhaden

As Higham and Nicholson (1964) report, the Atlantic menhaden (*Brevoortia tyrannus*) spawns along the entire east coast from May into December. In our study area, menhaden eggs ranked fourth in total abundance and accounted for 2.5% of all eggs collected. Over 97% of the menhaden eggs collected were from Buzzards Bay stations with 75.7% collected at Station 2 (Table 28, Figure 60). Eggs were collected from May through June in 1976-1978. In 1976 a secondary spawning peak was noted during September and October. The maximum density of menhaden eggs obtained during all sampling was 3,822.88 eggs/100 m³ on May 20, 1976 at Station 2. The density of eggs encountered at the same station on June 2 was similar (3,811.89 eggs/100 m³). Spring and fall spawning peaks are not uncommon for this species (Bigelow and Schroeder 1953), and on occasion bimodal spawning occurs in the study area. Marine Research, Inc. (1978a) collected menhaden eggs into October in 1976 and into November in 1975 during their ichthyoplankton sampling in Cape Cod Bay. The maximum density of menhaden eggs encountered during the 1976 secondary spawning peak was 159.85 eggs/100 m³. Menhaden eggs were collected from waters ranging in temperature from 8-22C (± 1C) (Appendix J). Jones et. al. (1978) reports that menhaden spawning takes place in waters between 4.4 and 23.6C with peak activity at temperatures between 15 and 18C. Largest densities of eggs were collected in water of 16C (± 1C). Average density of menhaden eggs from all samples was 37.46 eggs/100 m³ with Station 2 samples containing the greatest mean density (197.57 eggs/100 m³).

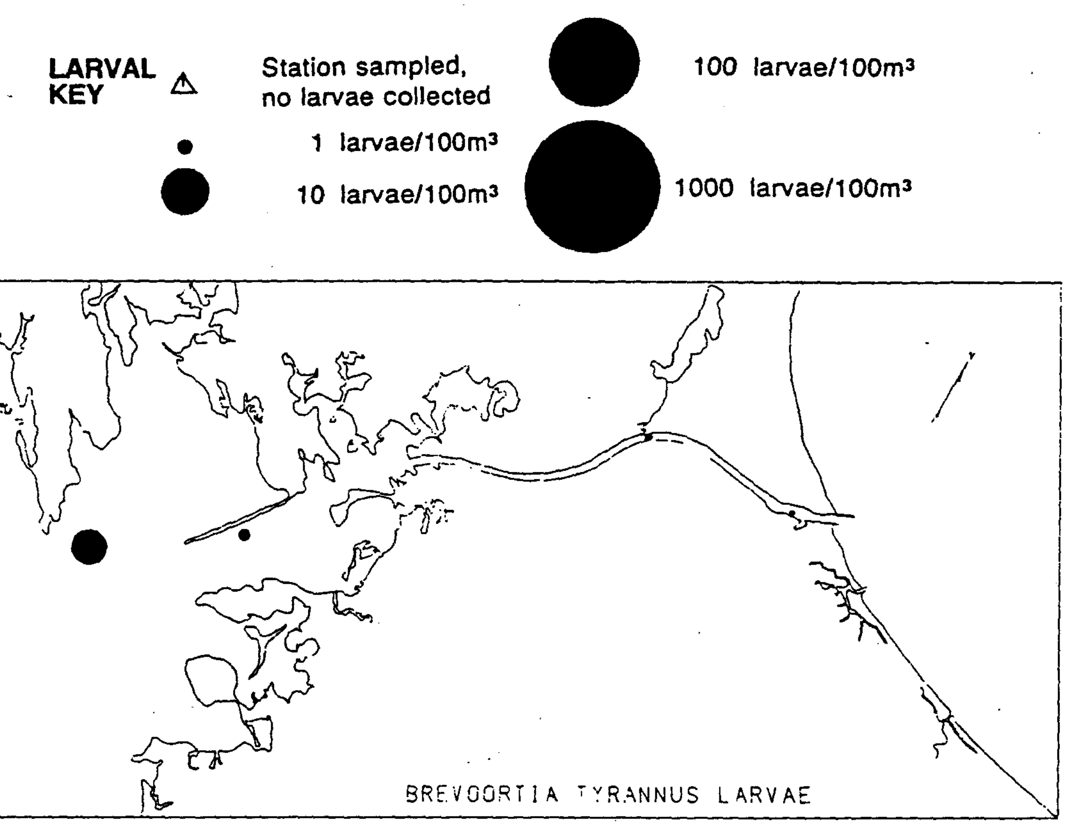
Figure 60. Spatial distribution of Atlantic menhaden (*Brevoortia tyrannus*) eggs, May 20, 1976 to March 13, 1979.



Menhaden larvae were collected during June and July every year with the greatest densities found in June. The 1976 spawning year extended from May into October with the greatest density (135.18 larvae/100 m^3) found on June 2 at Station 2. Menhaden larvae ranked sixth in total larval abundance with 88.8% collected in Buzzards Bay. The greatest number of larvae (661) were collected at Station 2 and represented 34.8% of all larvae collected (Figure 61).

Maximum larval densities encountered in 1977 and 1978 were lower than 1976 values with densities of 39.66 larvae/100 m^3 collected at Station 2 on June 7, 1977 and 62.74 larvae/100 m^3 at Station 3 on June 20, 1978. The average density for all years was 2.41 larvae/100 m^3 with Station 2 samples averaging 5.85 larvae/100 m^3 during the spawning seasons. Menhaden larvae were collected from waters ranging in temperature from 12-22C (± 1C) with the greatest densities found between 16 and 20C (± 1C).

Figure 61. Spatial distribution of Atlantic menhaden (*Brevoortia tyrannus*) larvae, May 20, 1976 to March 13, 1979.



Ammodytes spp.

sand lance

The sand lance spawns along the eastern seaboard from Canada to Virginia with spawning activity occurring from late November into May at water temperatures generally below 9C (Fritzsche 1978). Colton et al. (1979) report that *Ammodytes* spp. spawn in the Gulf of Maine from December into April with spawning activity greatest in January and February.

Ammodytes spp. eggs are demersal and were only collected in the Cape Cod Canal and at Station 7 (Figure 62). Strong currents and upwellings account for egg collections at these locations.

Sand lance eggs were generally collected from mid-November into March. Sand lance eggs were never collected in great numbers with a grand total of 283 eggs being collected. The greatest density obtained (16.89 eggs/100 m^3) was collected at Station 7 on November 16, 1979. Sta-

Figure 62. Spatial distribution of American sand lance (*Ammodytes* spp.) eggs, May 20, 1976 to March 13, 1979.

EGG KEY
- △ Station sampled, no eggs collected
- 1 egg/100m³
- 10 eggs/100m³
- 100 eggs/100m³
- 1000 eggs/100m³

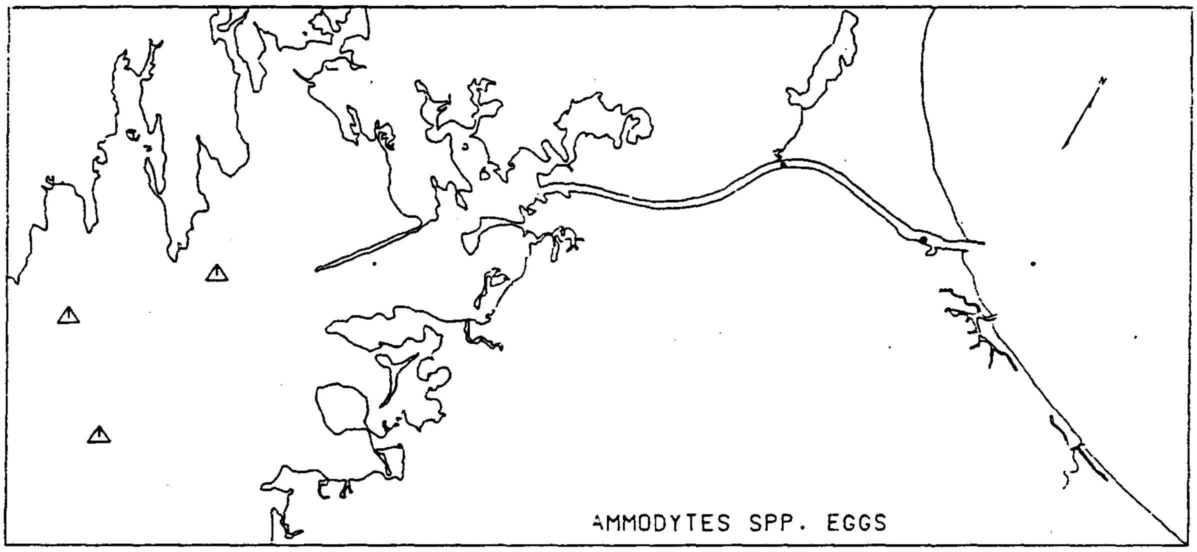
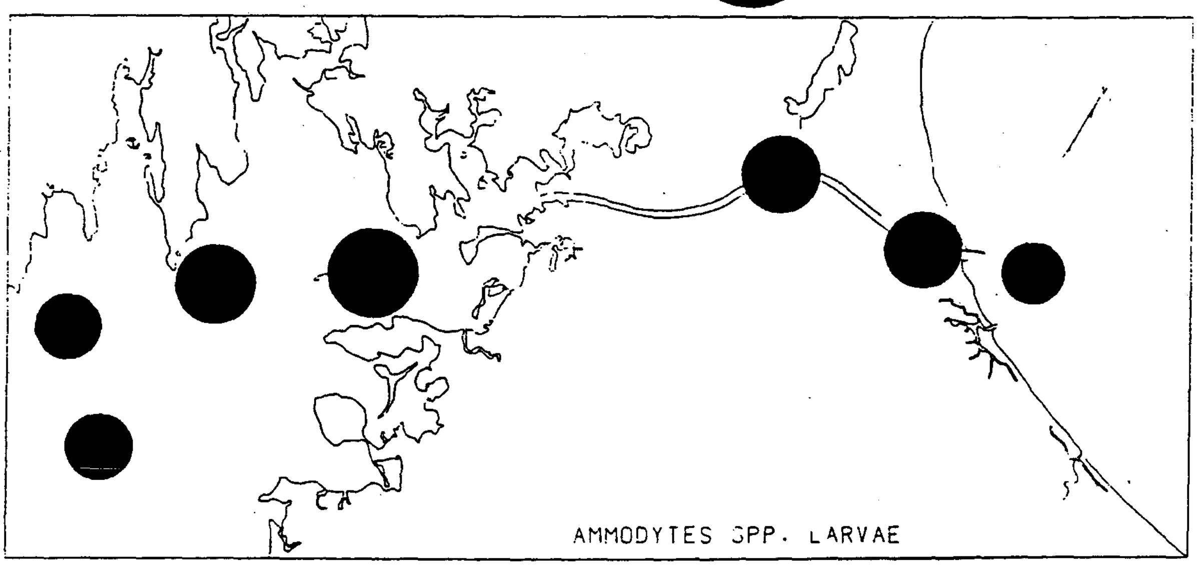


Figure 63. Spatial distribution of American sand lance (*Ammodytes* spp.) larvae, May 20, 1976 to March 13, 1979.

LARVAL KEY
- △ Station sampled, no larvae collected
- 1 larvae/100m³
- 10 larvae/100m³
- 100 larvae/100m³
- 1000 larvae/100m³



tion 6 samples contained 44.5% (126) of all *Ammodytes* spp. eggs collected. The overall average density of eggs was 0.36/100 m^3 with the highest average density (1.11 eggs/100 m^3) recorded at Station 6. Eggs were collected at water temperatures of 0-10C (± 1C) with the greatest densities occurring at 8-10C (± 1C).

Sand lance larvae ranked second in overall abundance (39,432 larvae) accounting for 23.6% of the total larvae collected. They were collected at all stations (Figure 63) with a maximum density of 1,251.86 larvae/100 m^3 being collected at Station 4 on March 16, 1978. Larvae were collected from mid-December into June at temperatures of 0-16C (± 1C) with the greatest densities found at 0-4C (± 1C).

While sand lance larvae did rank second in total overall abundance, at Stations 4, 5, 6 and 7 they ranked first in abundance, representing 59.1% of the total larvae collected at Station 4. The mean density of larvae was 50.08 larvae/100 m^3 and the station with the highest mean density was Station 4 with 102.3 larvae/100 m^3.

Ammodytes spp. eggs were not collected in Beverly-Salem Harbor, but larvae of the genus were the most abundant larvae collected (Elliot et al. 1979). Hatching times and temperatures were similar to those in our study area.

Pseudopleuronectes americanus

winter flounder

Winter flounder eggs are demersal and adhesive and may be found singly or in groups of 2, 3 or 4 (Bigelow and Schroeder 1953, Lippson and Moran 1974). Due to these characteristics and the sampling method, it was not unusual that only one egg was collected from Buzzards Bay (Figure 64, Table 28). The greatest number of eggs (277) was collected at Station 7 with a total of 218 collected at Station 6. Over 88% of all winter flounder eggs collected were Stage I eggs with smaller percentages of Stage II (9.1%) and Stage III (2.7%). The percentage of Stage I eggs at Stations 4, 5, 6 and 7 was 84.6, 87.2, 80.2 and

Figure 64. Spatial distribution of winter flounder (*Pseudopleuronectes americanus*) eggs, May 20, 1976 to March 13, 1979.

EGG KEY

△ Station sampled, no eggs collected
• 1 egg/100m^3
● 10 eggs/100m^3
● 100 eggs/100m^3
● 1000 eggs/100m^3

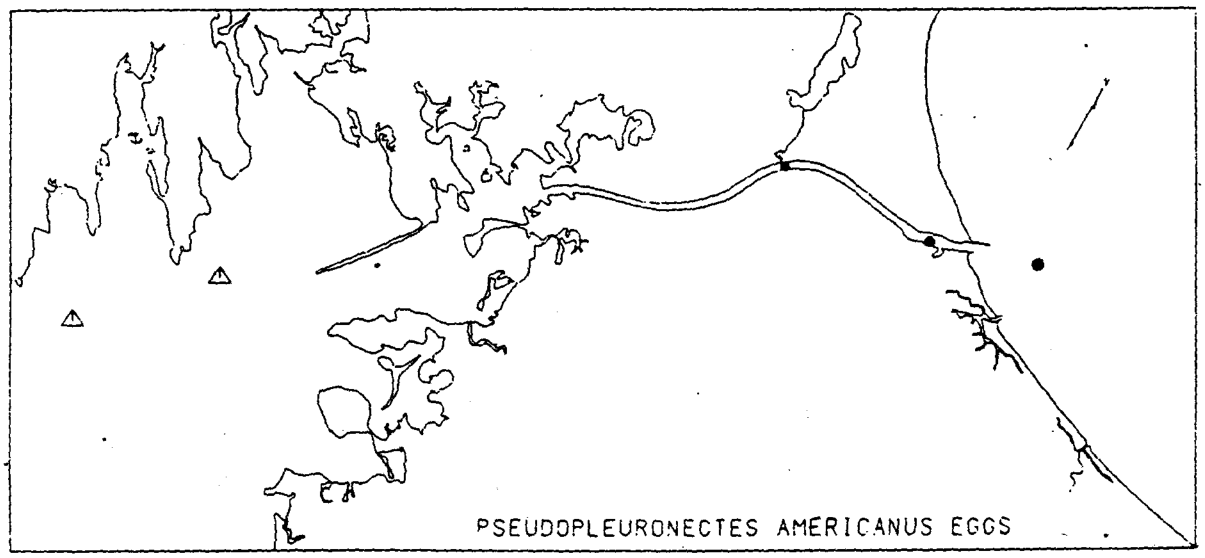
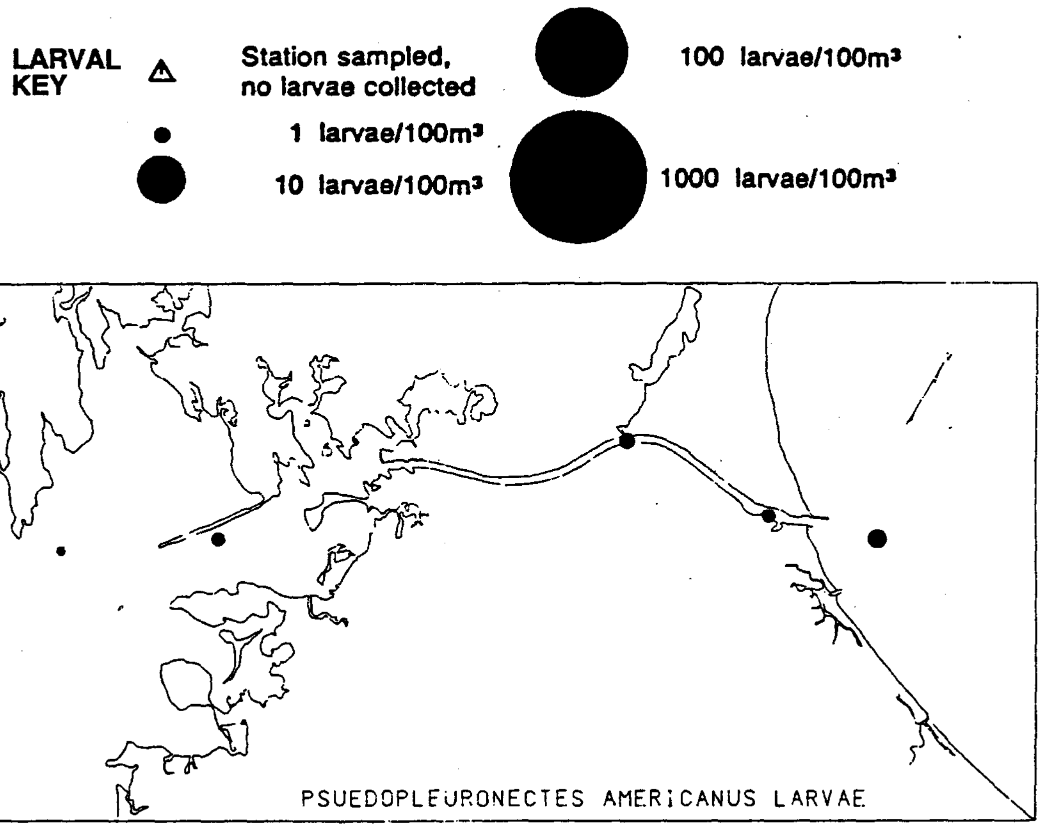


Figure 65. Spatial distribution of winter flounder (*Pseudopleuronectes americanus*) larvae, May 20, 1976 to March 13, 1979.



96.0. The average density of winter flounder eggs was 0.95/100 m³ with Station 7 having the greatest average density of 2.37/100 m³. Winter flounder eggs represented only 0.1% of all eggs collected.

Eggs were collected in water temperatures ranging from 0-16C (± 1C) with the majority of eggs collected in 6-8C (± 1C) water. Martin and Drewry (1978) state that spawning takes place in waters from 1 to 10C and peaks at 2 to 5C. Collections were generally made from March to May although in 1977 eggs were found as early as December. Colton et al. (1979), while uncertain as to actual spawning times, do list the winter flounder as spawning in the Gulf of Maine from March to June. Martin and Drewry (1978) state that the spawning season occurs from mid-December to May, peaking in March from Chesapeake Bay to Cape Cod and in April in southern New England. Our greatest densities were collected on March 28, 1977 with densities of 43.92/100 m³, 42.64/100 m³ and 65.88/100 m³ collected at Stations 5, 6 and 7.

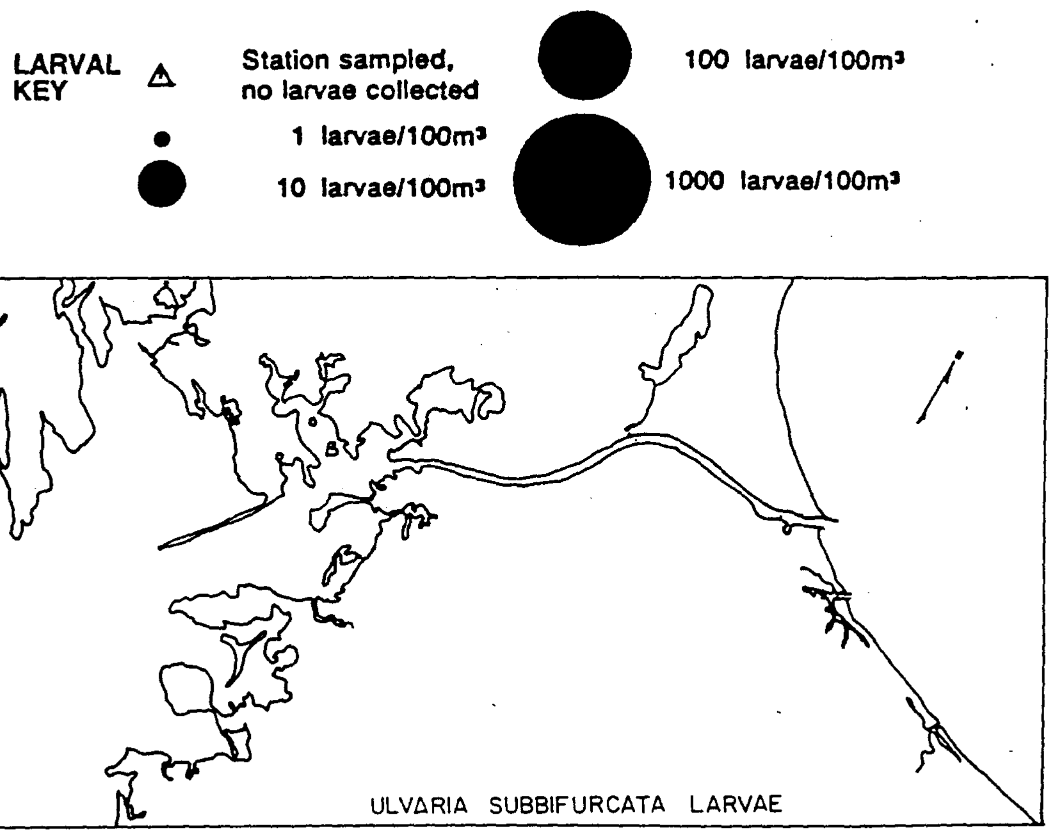
Winter flounder larvae were collected from March to July with the greatest density of 30.89 larvae/100 m³ found at Station 7 on May 20, 1976. Larvae were collected at all seven stations with the greatest number collected at Station 7. A total of 687 larvae was collected (Table 29). Average larval density was 0.87 larvae/100 m³ and winter flounder larvae represented 0.4% of the total larval catch. Many more Stage II larvae were collected than Stage I (653 versus 34). Larvae were collected in water ranging in temperatures from 2-22C (± 1C) with the majority found at 10-14C (± 1C).

Ulvaria subbifurcata

radiated shanny

The radiated shanny, *Ulvaria subbifurcata*, has demersal eggs and none were collected in the bongo nets, however, 58 larvae were collected. Twenty-nine larvae were collected in the Cape Cod Canal and nine in Buzzards Bay with the

Figure 66. **Spatial distribution of radiated shanny (*Ulvaria subbifurcata*) larvae, May 20, 1976 to March 13, 1979.**



balance (20) taken at Station 7. The larvae represented less than 0.1% of the total larval catch during the sampling program but represented 0.3% of the larvae collected at Station 7 and 0.1% of the larvae collected at Station 6. Larvae were collected from the end of April through June in waters ranging in temperature from 10-18C (± 1C).

The radiated shanny deposits eggs in a mass which is guarded by a male during incubation (LeDrew and Green 1975). Egg deposition normally occurs in an estuarine area. These two factors would explain the lack of shanny eggs in bongo collections. LeDrew and Green (1975) working in Newfoundland found that hatching took place in July at water temperatures of 4-9C. Elliot et al. (1979) working in Beverly-Salem Harbor, Massachusetts, found that radiated shanny larval densities peaked in late April-early May. Water temperatures during larval collections ranged from 6-20C (± 1C). While their hatching season and water temperatures correspond quite closely with ours, the total number of larvae (1,603) collected in Beverly-Salem Harbor in one year (1976-1977) is much greater than the total number (58) collected in our study area. Marine Research, Inc. (1978a) sampling in Cape Cod Bay from 1974-1976 found *U. subbifurcata* spawning in the western part of Cape Cod Bay with high densities in the vicinity of Plymouth. They collected larvae from April to August with maximum densities collected during May and June. Colton and St. Onge (1974) list larvae as being collected from Nova Scotia to Long Island during January to September.

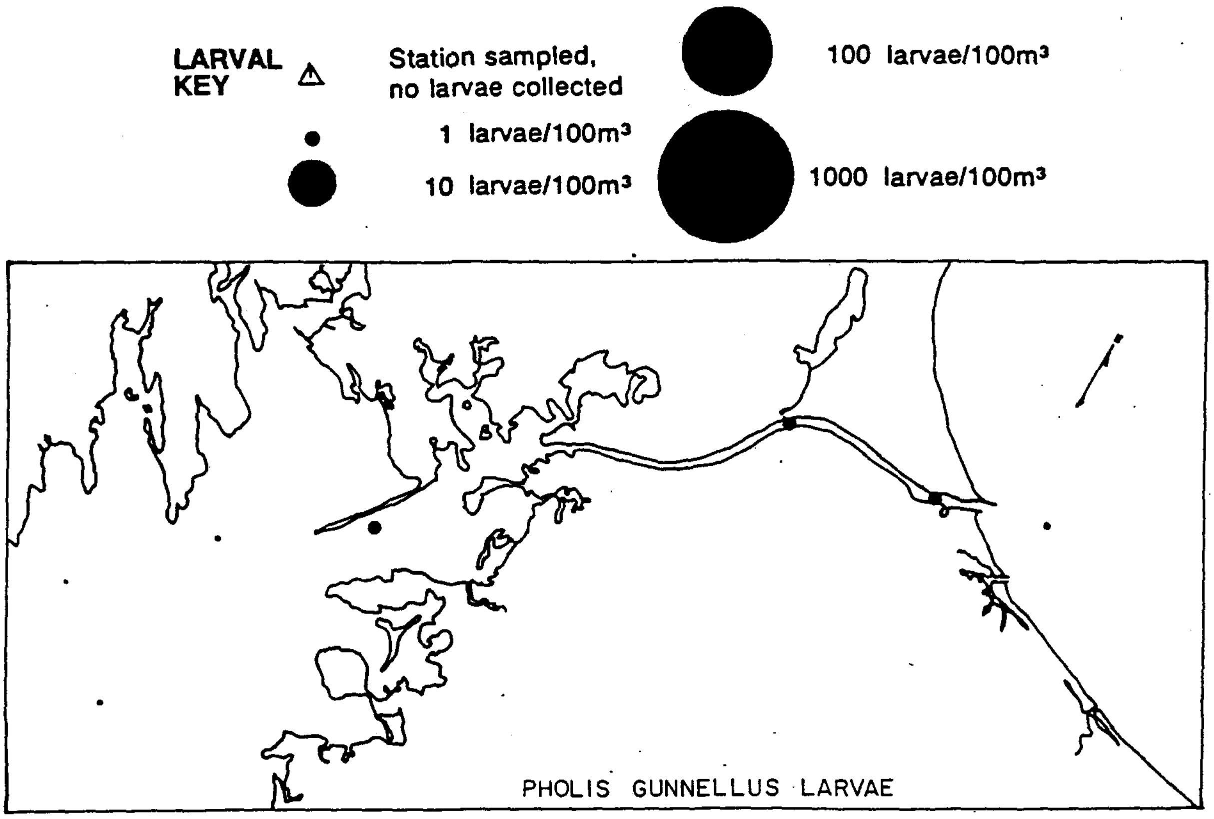
Pholis gunnellus

rock gunnell

No rock gunnel, *Pholis gunnellus*, eggs were collected during the study. The rock gunnel deposits eggs in a cluster or mass, thereby greatly reducing the chance for collection in bongo nets (Sawyer 1967).

A total of 379 rock gunnel larvae were col-

Figure 67. Spatial distribution of rock gunnel (*Pholis gunnellus*) larvae, May 20, 1976 to March 13, 1979.



lected with the greatest densities collected in the Cape Cod Canal and Cape Cod Bay (Figure 67). Ninety-six larvae were collected at Station 5. The largest density of larvae found was 15.99 larvae/100 m³. These larvae were collected at Station 6 on March 28, 1977. Larvae were collected from January to April with greatest densities occurring in March. Water temperatures when rock gunnel larvae were collected ranged from 0-14C (± 1C) with the greatest numbers collected in water temperatures ranging from 4-8C (± 1C).

Totals of 187 Stage I and 192 Stage II larvae were collected. The average density of each developmental stage for all stations and all years was 0.24 larvae/100 m³. The average density for both stages for all stations and all years was 0.48 larvae/100 m³. Sawyer (1967) reported that in New Hampshire spawning starts in late December and probably continues through February. Our collections of larvae from January to April would support Sawyer's data. The ratio of Stage I larvae to Stage II larvae in Buzzards Bay (1:4), Cape Cod Canal (1:0.7) and Cape Cod Bay (1:0.7) suggests that rock gunnel spawn in the Cape Cod Canal and Cape Cod Bay. Sawyer suggested that *P. gunnellus* move from the intertidal area to deeper water to spawn. The availability of deep water in the Canal could provide a suitable spawning site for this species.

Myoxocephalus spp.

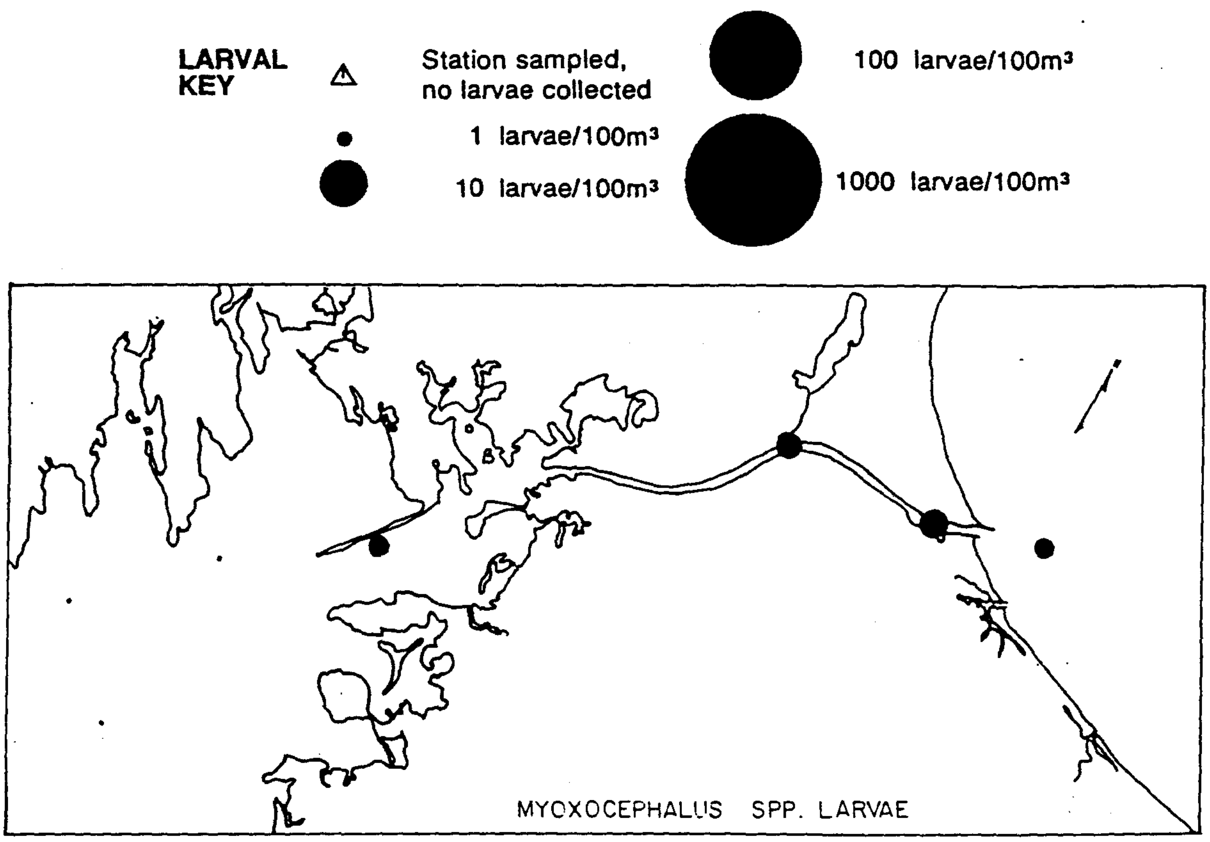
sculpins

Only one *Myoxocephalus* spp. (sculpin) egg was collected in bongo samples. This lone egg was collected at Station 5 on March 28, 1977 and was a Stage III egg. The water temperature at the time of collection was 9C.

Sculpin larvae were collected at all stations with 8.5% of the total larvae being collected in Buzzards Bay (Stations 1, 2 and 3), 75% in the Cape Cod Canal (Stations 4, 5 and 6), and 16.5% at Station 7, Cape Cod Bay (Figure 68). A total of 1,052 larvae was collected with the largest number (341) collected at Station 6. Larvae were collected in waters ranging from 0-12C (± 1C) from mid-January until the third week in May with the greatest densities found in 8C (± 1C) water. The highest density collected in one tow was 48.45 larvae/100 m³ (Station 5 on March 28, 1977). The highest average density of *Myoxocephalus* spp. larvae for all years was found at Station 6 (3.0 larvae/100 m³) while the overall average of all stations for all years was 1.34 larvae/100 m³. Greater numbers of Stage I larvae (834) were collected than Stage II (218) with the ratio of Stage I larvae to Stage II larvae fairly uniform from station to station.

Morrow (1951) states that the spawning season for the longhorn sculpin (*Myoxocephalus octodecimspinosus*) is from November through January while Lund and Marcy (1975) state that the grubby, *Myoxocephalus aenaeus* spawns from December through March. Our collection period for larvae agrees with these reports. Colton and St. Onge (1979) list spawning of the longhorn sculpin in the Gulf of Maine as occurring from November to February with spawning peaking in December and January.

Figure 68. Spatial distribution of sculpin (*Myoxocephalus* spp.) larvae, May 20, 1976 to March 13, 1979.



Prionotus spp.

searobins

Fritzsche (1978) reports the range of the northern searobin, *P. carolinus*, as being from the Bay of Fundy to South Carolina and spawning occurring as early as May in Long Island Sound and as late as August in the northern portions of its range. Water temperatures at spawning range between 12.8 and 24.4C.

From May into September, searobin (*Prionotus* spp.) eggs were present in the plankton, peaking in June all three years (Appendix A). A total of 22,138 eggs comprising 1.9% of the total eggs collected was separated from the samples. Eighty-nine percent of the searobin eggs were collected in Buzzards Bay (Table 28, Figure 69). The maximum density collected was at Station 1 on June 20, 1977 (1,638.57 eggs/100 m³) with a density of 1,576.09 eggs/100 m³ collected at Sta-

Figure 69. Spatial distribution of searobin (*Prionotus* spp.) eggs, May 20, 1976 to March 13, 1979.

EGG KEY

△ Station sampled, no eggs collected

● 1 egg/100m³

● 10 eggs/100m³

● 100 eggs/100m³

● 1000 eggs/100m³

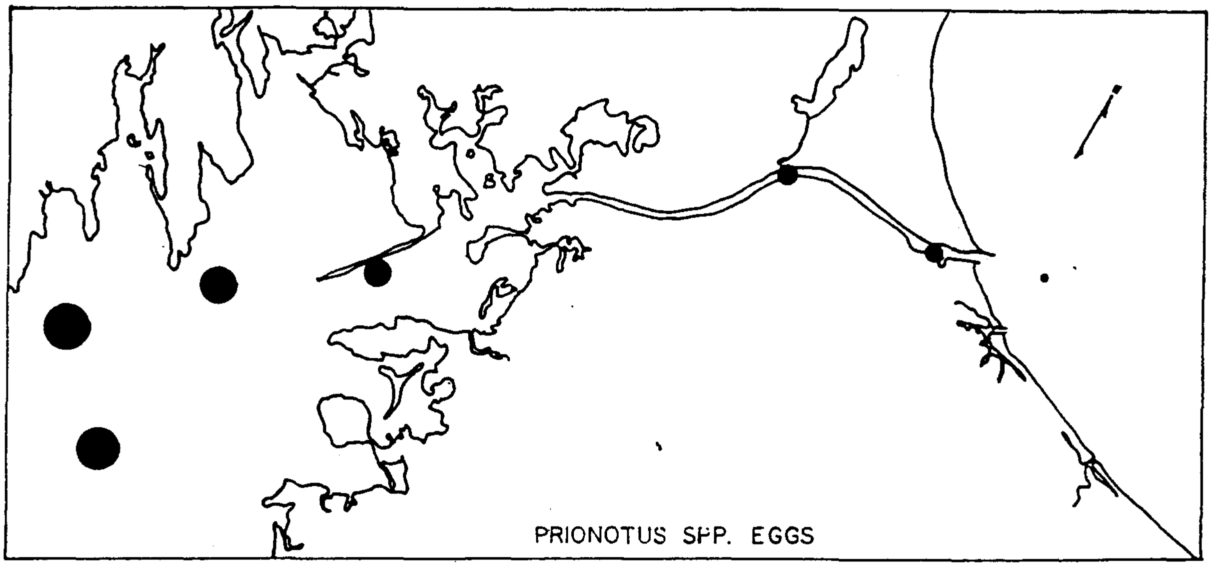


Figure 70. Spatial distribution of searobin (Prionotus spp.) larvae, May 20, 1976 to March 13, 1979.

LARVAL KEY

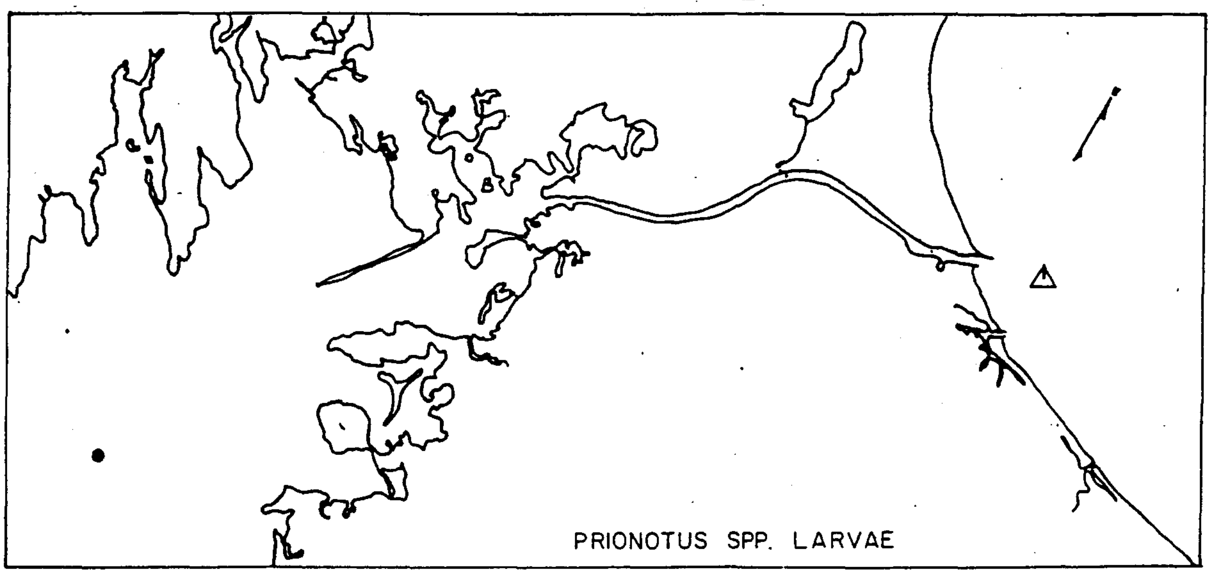
△ Station sampled, no larvae collected

● 1 larvae/100m³

● 10 larvae/100m³

● 100 larvae/100m³

● 1000 larvae/100m³



tion 2 on the same date. Of the total number of searobin eggs collected, 66% were Stage I, 22% were Stage II, and 12% were Stage III eggs. Searobin eggs ranked seventh in total egg abundance. Eggs were collected in water ranging in temperature from 8->24C (± 1C). The mean density of searobin eggs was 28.11 eggs/100 m³ and ranged from 0.98 eggs/100 m³ at Station 7 to 84.73 eggs/100 m³ at Station 2.

Only 134 searobin larvae were collected and were found in the plankton from June through August. Numbers of larvae peaked in late June with the maximum density of 23.5 larvae/100 m³ collected on June 20, 1977 at Station 1. No searobin larvae were collected at Station 7. As with eggs, the majority of the larvae (82.1%) were collected in Buzzards Bay (Table 29, Figure 70). Searobin larvae were low in total abundance contributing less than 0.1% to the total larval catch. The mean density of larvae was 0.17 larvae/100 m³ and ranged from 0.0 larvae/100 m³ at Station 7 to 0.69 larvae/100 m³ at Station 1. Larvae were collected at water temperatures ranging from 16->24C (± 1C).

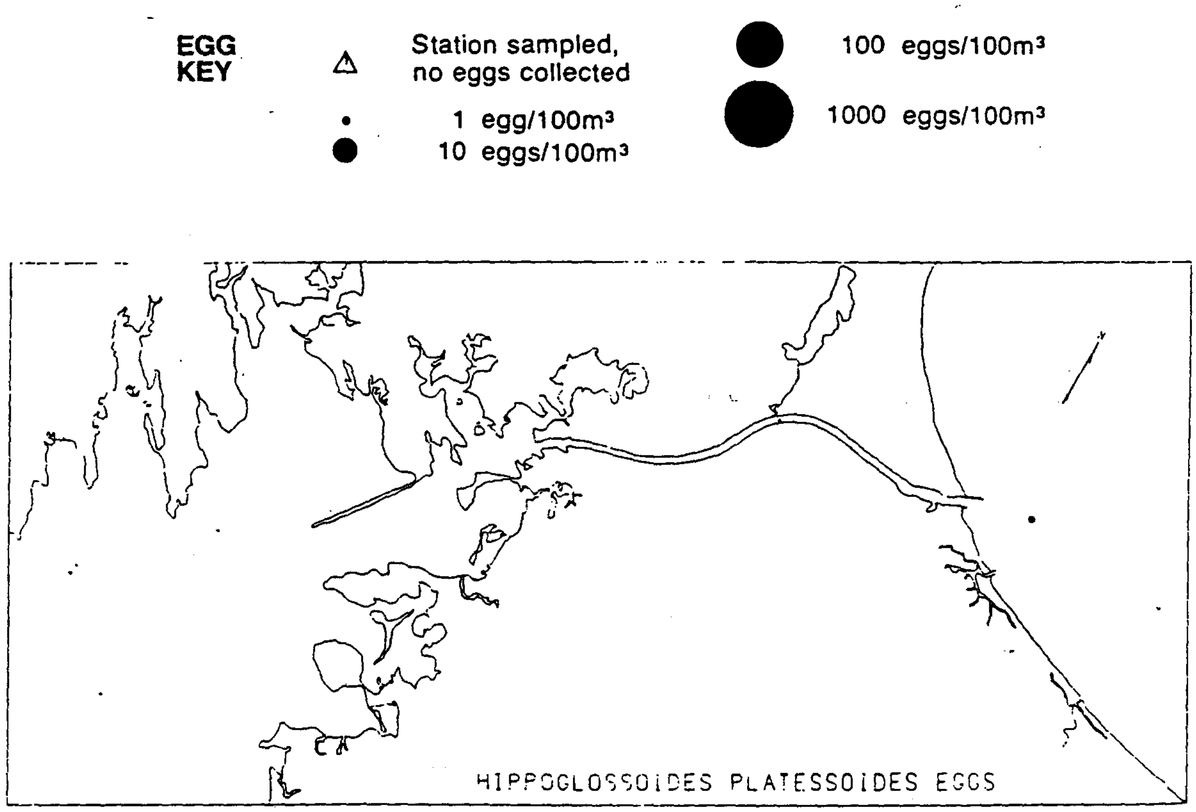
Hippoglossoides platessoides

American plaice

American plaice eggs were collected primarily at Station 7 where 113 of the 174 eggs collected were found (Table 28, Figure 71). Eggs were collected from February to May with the maximum density of 36.24 eggs/100 m³ collected at Station 7 on April 30, 1977. Eggs were collected in waters ranging from 0-20C (± 1C) with the greatest densities found in 8C water. The mean density of eggs was 0.22 eggs/100 m³ and ranged from 0.01 eggs/100 m³ at Station 1 to 0.97 eggs/100 m³ at Station 7.

Only 34 larvae were collected with 26 being collected at Station 7. Larvae were generally collected from April to June, but single larvae were collected in August and September on two occa-

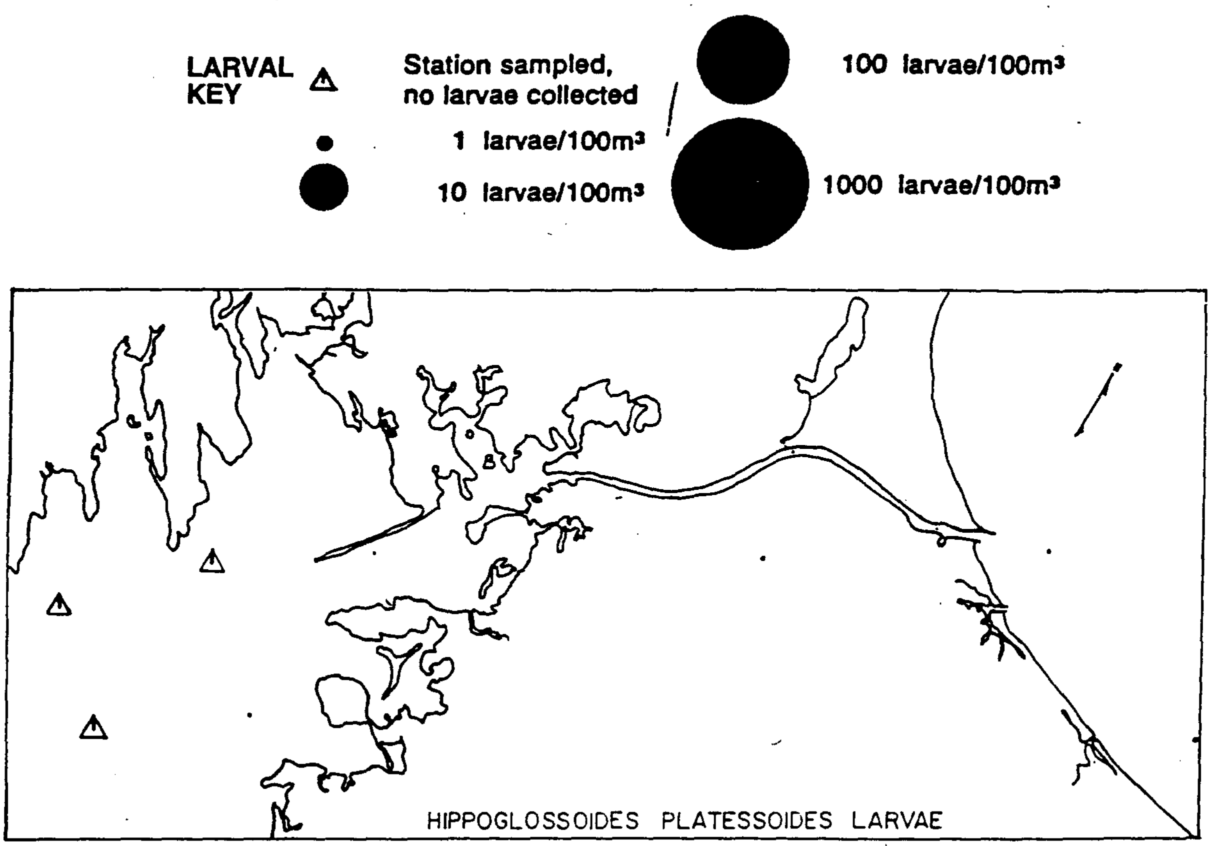
Figure 71. Spatial distribution of American plaice (*Hippoglossoides platessoides*) eggs, May 20, 1976 to March 13, 1979.



sions. Marine Research, Inc. (1978a) listed *H. platessoides* eggs as present in Cape Cod Bay from January to July and larvae from January to August. Larvae were collected in water ranging in temperature from 6-22C (± 1C). Larval densities are depicted in Figure 72.

The spawning range of the American plaice is from Labrador to Cape Cod (Bigelow and Schroeder 1953) so the small number of eggs collected in Buzzards Bay is not unusual. Smith et al. (1975) report that Martha's Vineyard marks the southern limit of its range and that spawning begins in March, peaks in May and ends by mid-June north of Cape Cod.

Figure 72. Spatial distribution of American plaice (*Hippoglossoides platessoides*) larvae, May 20, 1976 to March 13, 1979.



Gadidae-*Glyptocephalus*

Codfishes-witch flounder

The species comprising this egg group are pollock (*Pollachius virens*), Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and the witch flounder (*Glyptocephalus cynoglossus*). While at times it is possible to identify eggs from this grouping to species, the overlapping spawning seasons and similar morphological characteristics necessitated the utilization of the grouping technique. The data displayed in Appendices A through H depict species specific egg densities when this determination could be made.

A total of 1,629 eggs from this group was collected with the majority (68.7%) being collected at Station 7 (Figure 73). Gadidae-*Glyptocephalus* eggs were the fifth most abundant egg group collected at this station comprising 1.1% of the total eggs collected there.

Atlantic cod spawn along the North American coast from Newfoundland Banks south to at least New Jersey and possibly to North Carolina (Hardy 1978). Spawning in Massachusetts could extend from September to April and possibly into June (Hardy 1978 and Colton et al. 1979). Pollock have been reported to spawn from Nova Scotia to Cape Cod with the greatest spawning activity reported in the vicinity of Massachusetts Bay (Hardy 1978). Larvae have been collected as far south as Long Island, New York (Hardy 1978).

In Massachusetts Bay spawning begins as early as September and may be carried on into February with spawning peaking from November to January (Hardy 1978 and Colton et al. 1979). Haddock spawning off New England occurs from mid-January to mid-June and peaks during February and March (Hardy 1978 and Colton et al. 1979). Witch flounder spawning in the Gulf of Maine occurs from April to August, peaking in May and June, while in the waters from Cape Cod to Delaware Bay spawning starts in May and is carried on into August. Eggs were collected in every month of the year with greater densities found in the late fall and winter. The greatest density of Gadidae eggs was collected on December 12, 1977 at Station 7 (126.88 eggs/100 m^3). Since witch flounder spawn later in the year (March to August) than cod, pollock and haddock (Colton and Marak 1969), the peaks displayed in July of 1976, 1977 and 1978 were apparently a result of witch flounder spawning. Densities of 33.1 and 27.7 eggs/100 m^3 found in April at Station 7 undoubtedly reflect spawning of witch flounder, cod and pollock. Water temperatures at time of spawning for cod, pollock, haddock and witch flounder are 0.6 to 12.0C, 3.0 to 10.0C, 2.5 to 6.5C and < 0.0 to 10.0C. Eggs were collected over the temperature range of 0 to > 24C (± 1C).

Larvae of all four species comprising the egg grouping were collected (Figures 74-76). Cod larvae were the most abundant with 195 larvae collected; witch flounder ranked second with 93 larvae, pollock third with 41 larvae and haddock fourth with 3 larvae. As with the distribution of eggs, most larvae from this grouping (70%) were collected at Station 7. Larvae were collected in every month except April. Pollock were found from November into July, cod generally from May into October, haddock from January into June and witch flounder from June through October. The highest densities encountered were 17.35 larvae/100 m^3 for cod, 2.28 larvae/100 m^3 for pollock, 0.64 larvae/100 m^3 for haddock and 5.19 larvae/100 m^3 for witch flounder.

Figure 73. Spatial distribution of codfishes-witch flounder (*Gadidae-Glyptocephalus*) eggs, May 20, 1976 to March 13, 1979.

EGG KEY

- Station sampled, no eggs collected
- 1 egg/100m^3
- 10 eggs/100m^3
- 100 eggs/100m^3
- 1000 eggs/100m^3

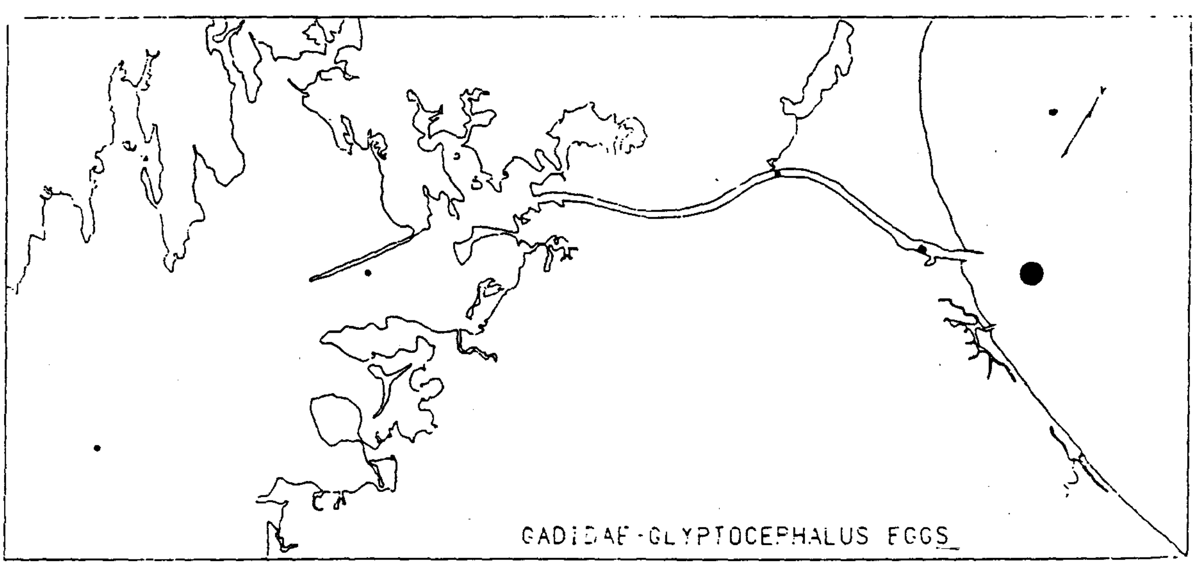


Figure 74. **Spatial distribution of Atlantic cod (*Gadus morhua*) larvae, May 20, 1976 to March 13, 1979.**

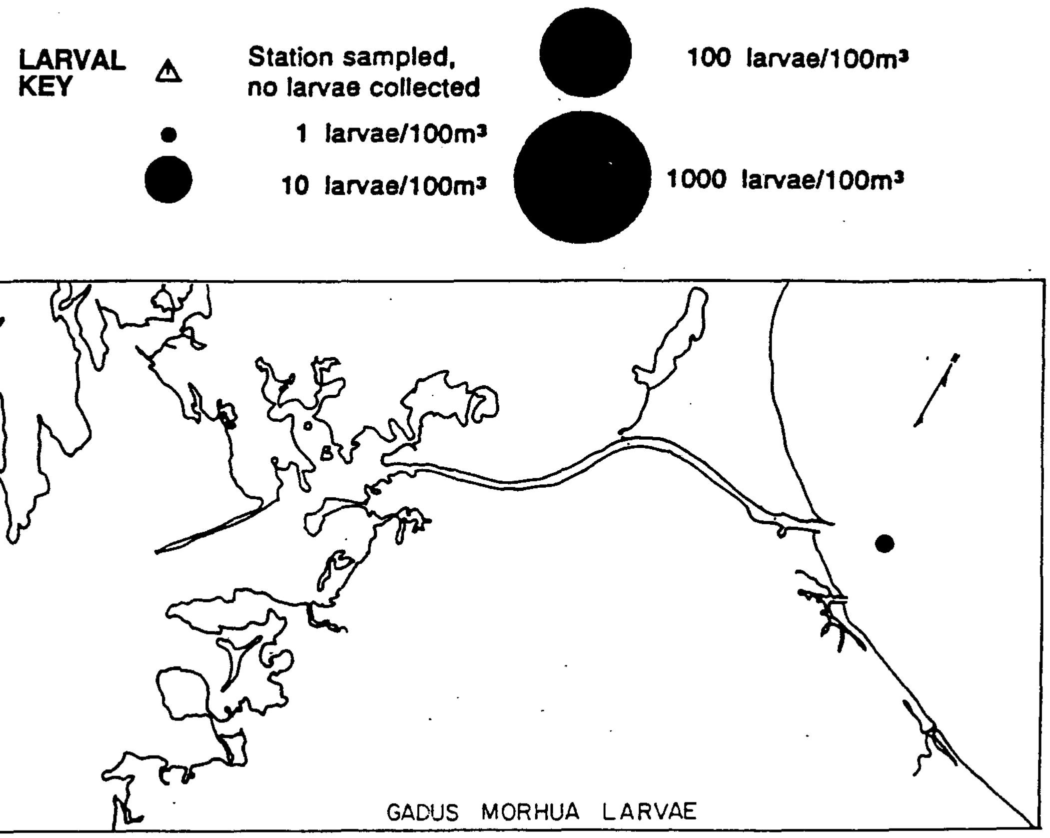


Figure 75. **Spatial distribution of witch flounder (*Glyptocephalus cynoglossus*) larvae, May 20, 1976 to March 13, 1979.**

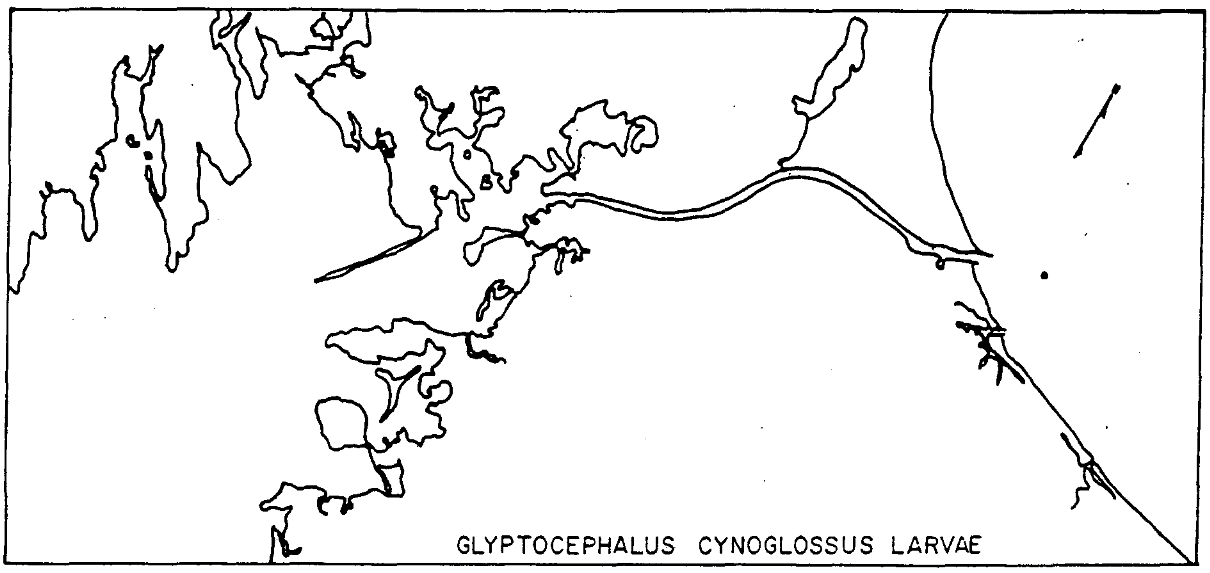
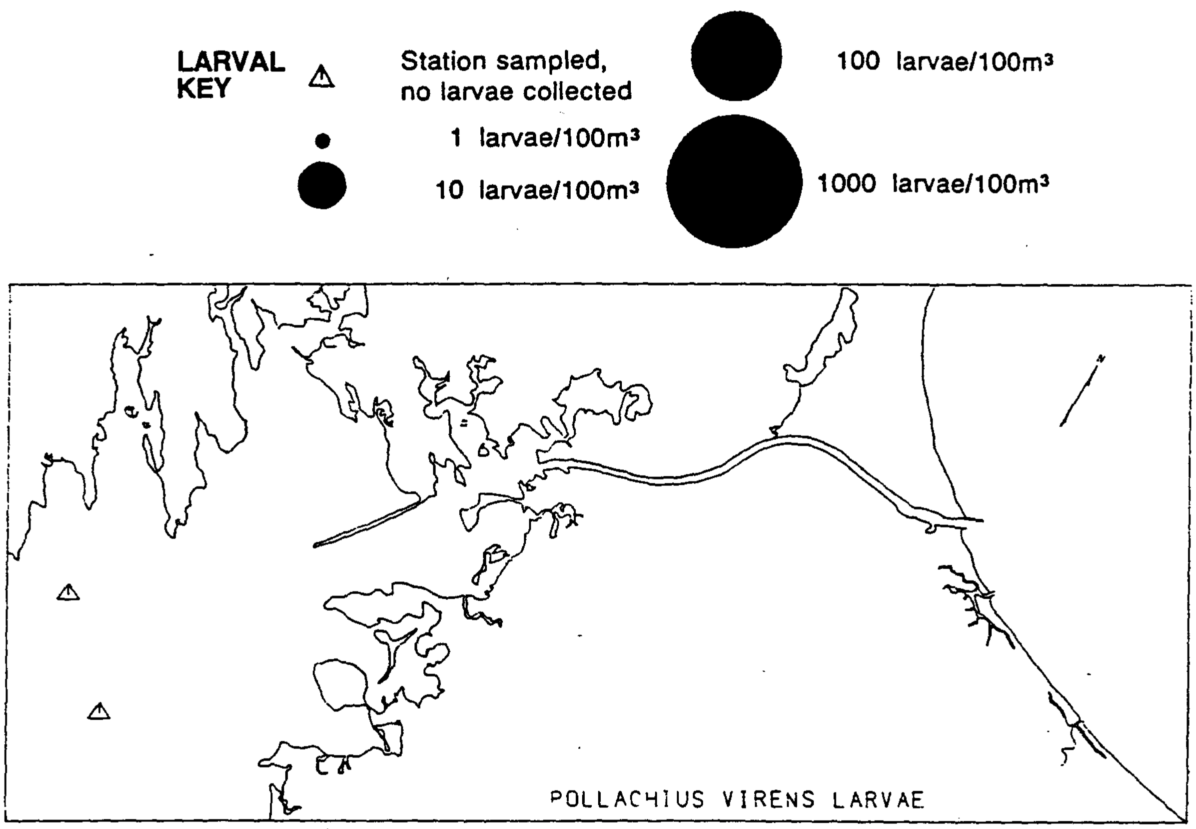


Figure 76. **Spatial distribution of pollock (*Pollachius virens*) larvae, May 20, 1976 to March 13, 1979.**



Scomber-Brosme

Atlantic mackerel-cusk

The two species making up the *Scomber-Brosme* egg group are Atlantic mackerel (*Scomber scombrus*) and cusk (*Brosme brosme*).

Atlantic mackerel spawn in several major areas including the continental shelf from Cape Cod to Cape Hatteras and the Gulf of Maine. Spawning is initiated in late May off southern Massachusetts and continues into September. Spawning is carried out at temperatures from 7.3 to 17.6C (Fritzsche 1978). Cusk spawning occurs from April to July, peaking in April and May (Colton et al 1979). Colton and St. Onge (1974) recorded eggs as being collected from Nova Scotia to Long Island.

A total of 17,460 eggs from this group were collected from all stations with 47.7% collected at Station 7 (Figure 77). *Scomber-Brosme* eggs ranked third in abundance at Station 7 but eighth in total abundance. Eggs were collected from April to August with the greatest densities found in June. The maximum density sampled was 2,227.22 eggs/100 m³ at Station 1 on May 22, 1978. Eggs were collected at water temperatures ranging from 8->24C (± 1C) with the greatest densities collected at 14C (± 1C). Johnson (1977) felt that the optimal temperature range for mackerel spawning was 10-15C. No cusk third stage eggs were collected, but eight larvae were separated from samples. Seven larvae were separated from Station 7 samples collected in June and July.

Mackerel larvae were collected from May into August with densities peaking in June. A total of 1,289 larvae was collected with 1,226 found at Station 7 (Figure 78). Mackerel larvae ranked second in abundance at Station 7 representing 16.9% of the total larvae collected at this station; however, they represented only 0.8% of the total larval catch of all stations. The maximum density collected was 367.90 larvae/100 m³ at Station 7 on June 7, 1977. Larvae were collected in water temperatures of 14-20C (± 1C) with the highest

Figure 77. **Spatial distribution of *Scomber-Brosme* (Atlantic mackerel-cusk) eggs, May 20, 1976 to March 13, 1979.**

EGG KEY
- △ Station sampled, no eggs collected
- 1 egg/100m³
- 10 eggs/100m³
- 100 eggs/100m³
- 1000 eggs/100m³

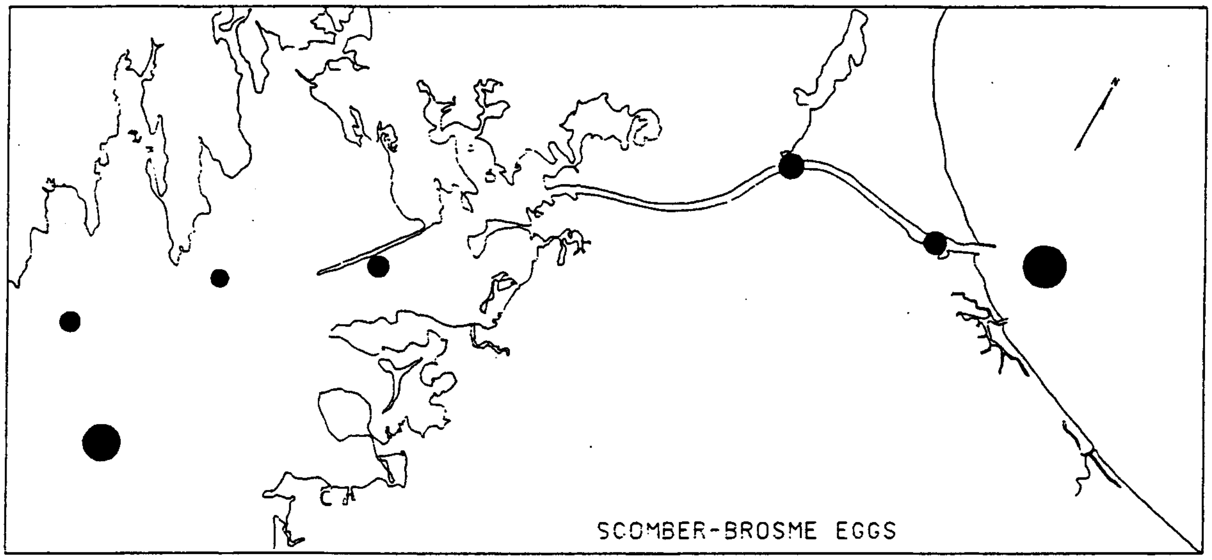
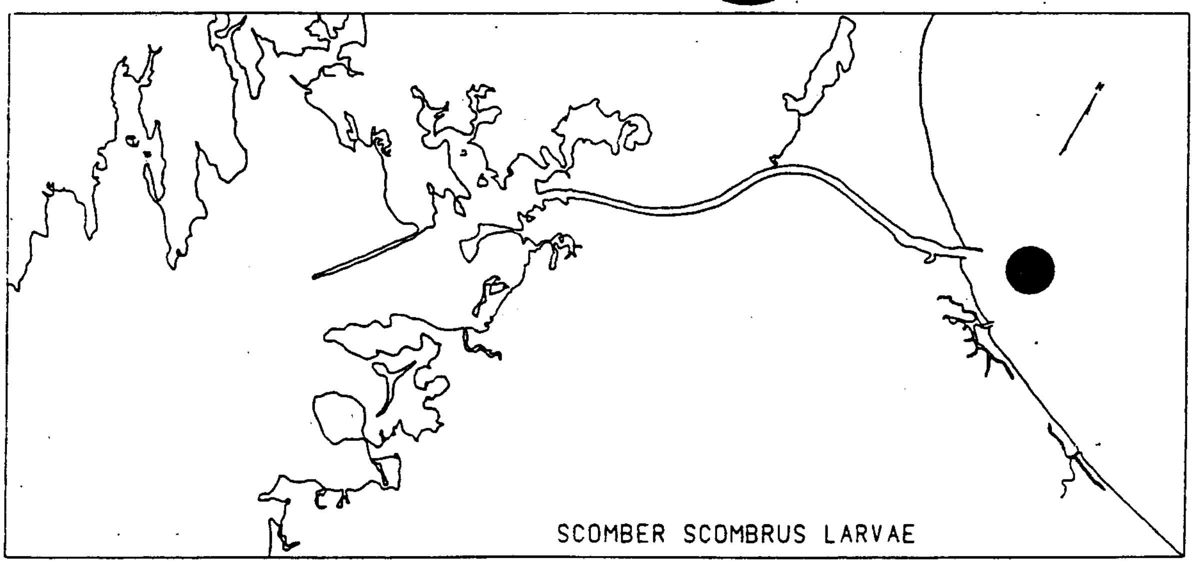


Figure 78. Spatial distribution of Atlantic mackerel (*Scomber scombrus*) larvae, May 20, 1976 to March 13, 1979.

LARVAL KEY
- △ Station sampled, no larvae collected
- 1 larvae/100m³
- 10 larvae/100m³
- 100 larvae/100m³
- 1000 larvae/100m³



density samples found in 14C (± 1C) water. Marine Research, Inc. (1978a) reported that mackerel larvae ranked third in total abundance for their 1975 Cape Cod Bay ichthyoplankton survey and made up 14.5% of their total larval catch.

Menticirrhus-Trinectes

northern kingfish-hogchoker

The species comprising this egg grouping are hogchoker (*Trinectes maculatus*) and kingfish (*Menticirrhus saxatilis*). Hogchoker spawn from April to October when water temperatures reach 20C, activity peaking at 25C (Martin 1978). Kingfish spawn from June to August in the Gulf of Maine and eggs will hatch in 46-50 hours at 20-21C (Johnson 1978). A total of 3,286 eggs of this grouping was collected from May through August. Water temperatures when Northern kingfish-hogchoker eggs were collected ranged from 14->24C (± 1C). Northern kingfish-hogchoker eggs ranked ninth in overall abundance. Northern kingfish-hogchoker eggs were collected predominantly in Buzzards Bay (Figure 79). Station 3 had the greatest density (189.36 eggs/100 m^3) on June 23, 1976 and ranked first in total eggs (1,303) collected. Hogchoker appears to account for the major portion of eggs in this grouping. Hogchoker third stage eggs comprised 13.1% of the total eggs whereas kingfish third stage eggs comprised only 0.6% of the total eggs collected for this group.

A total of 431 hogchoker third stage eggs was collected from Stations 1 through 6 at temperatures ranging from 18->24C (± 1C). However, the greater densities were collected at 20C (± 1C). The most eggs collected at one station was 179 at Station 3 (Table 28).

A total of 20 kingfish third stage eggs was collected from Stations 1 through 4 at temperatures ranging from 14-22C (± 1C). The greater densities were collected at 18C (± 1C). The largest number of eggs collected at one station was eight at Station 1 (Table 28).

Figure 79. Spatial distribution of kingfish-hogchoker (*Menticirrhus-Trinectes*) eggs, May 20, 1976 to March 13, 1979.

EGG KEY		
△	Station sampled, no eggs collected	
•	1 egg/100m^3	
●	10 eggs/100m^3	
●	100 eggs/100m^3	
●	1000 eggs/100m^3	

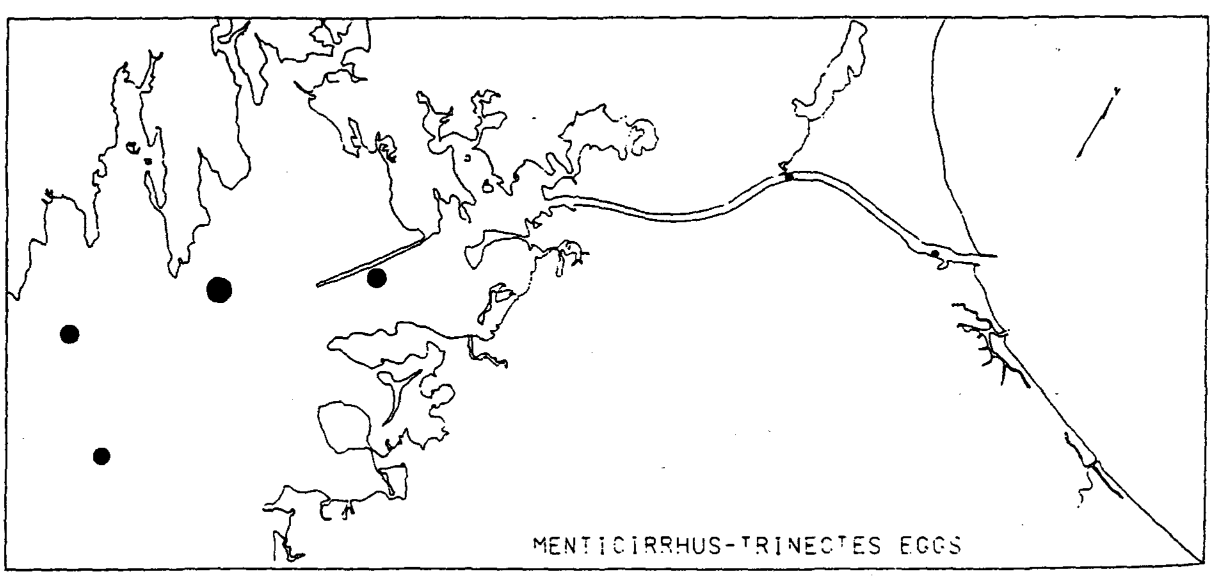
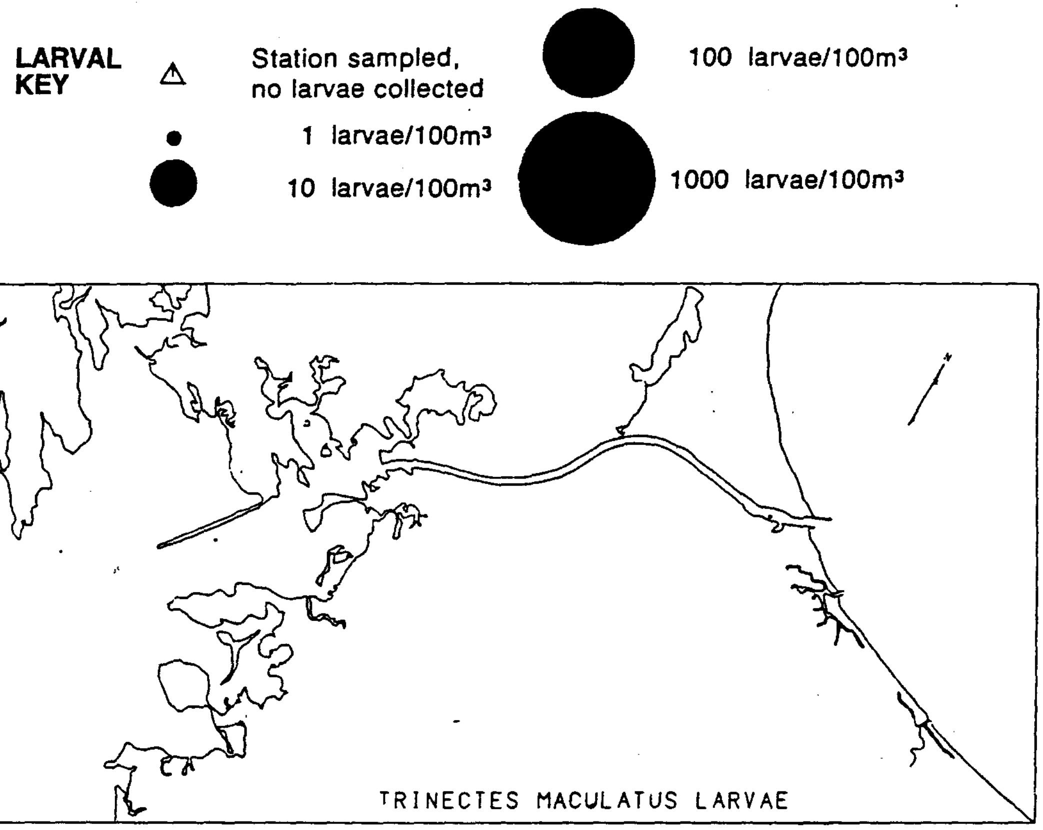


Figure 80. **Spatial distribution of hogchoker (*Trinectes maculatus*) larvae, May 20, 1976 to March 13, 1979.**



A total of 150 hogchoker larvae was collected from Stations 1 through 7 at temperatures ranging from 16->24C (± 1C). The greater densities were collected at 22C (± 1C). The maximum density found was 13.13 larvae/100 m³ at Station 1 on August 9, 1978. Larval densities appeared to be uniformly distributed among stations (Figure 80). The greatest number of larvae collected from one station was 51 at Station 1 (Table 29). Hogchoker comprised less than 0.1% of the total larvae collected (Table 29).

No kingfish larvae were identified in bongo collections from May, 1976 through March, 1979.

Discussion

The Cape Cod land mass forms a definite zoogeographical boundary which delineates the range of northern and southern species. Colton et al. (1979) felt that there was an abrupt general division between the biological and physical properties of waters east and west of Cape Cod. Cape Cod Bay is characterized by well mixed boreal waters, while the waters west of Cape Cod are warmer due partially to the sluggish currents and circulation patterns. There are generally more tropical forms and greater plankton densities found in waters to the west and more subarctic forms in the Gulf of Maine. Species composition and abundance of benthic and pelagic fishes vary markedly between the two regions with boreal species dominating in the Gulf of Maine and warm water species being more abundant in the Middle Atlantic Bight (Colton 1964). Colton et al. (1979) state that the bulk or total spawning of many species of fishes (haddock, pollock and redfish) is restricted to areas east of Nantucket Shoals. Bluefish, menhaden and anchovies are examples of fish spawning in areas west of Nantucket Shoals. Notable exceptions of this general rule are yellowtail flounder and silver hake.

In our study area, some species such as *Ammodytes* spp., *U. subbifurcata, P. gunnellus, S. scombrus, T. onitis, T. adspersus* and *Anchoa* spp. appear to spawn in Buzzards Bay through the Cape Cod Canal into Cape Cod Bay. Other species restrict spawning activity to either Buzzards Bay or Cape Cod Bay. Examples of Buzzards Bay spawners are *Prionotus* spp., *C. striata, S. chrysops, P. triacanthus* and *B. tyrannus*. A list of Cape Cod Bay spawners would have to include *P. americanus, Myoxocephalus* spp., *H. platessoides, G. morhua, G. cynoglossus, P. virens, M. bilinearis, E. cimbrius* and *U. chuss.*

The possible extension of the spawning range of *Etropus microstomus,* the smallmouth flounder, is worthy of note. Smith et al. (1975), reporting on larval flatfish (Pleuronectiformes) distribution between Cape Lookout, North Carolina and Cape Cod, felt that smallmouth flounder have an extended spawning season which progresses northward in the spring and southward in the fall. While they captured larvae from the eastern end of Long Island to Cape Lookout, spawning was most concentrated from Virginia to North Carolina. No larvae occurred as far north and east as their transect off southern New England. While Marine Research, Inc. (1974) did not collect *E. microstomus* eggs or larvae in Narragansett Bay, they report them as rarely collected during their Cape Cod Bay sampling program (Marine Research, Inc. 1978a). They theorized that spawning occurred south of the Cape and larvae were carried through the Cape Cod Canal into Cape Cod Bay. While we collected only one egg and thirty-three larvae, this may indicate an extension of the spawning range of *E. microstomus.*