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An Atlas of the Distribution and Abundance of Dominant Benthic Invertebrates in the New York Bight Apex with Reviews of Their Life Histories

Janice V. Caracciolo and Frank W. Steimle, Jr.

March 1983

U.S. DEPARTMENT OF COMMERCE
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John V. Byrne, Administrator
National Marine Fisheries Service
William G. Gordon, Assistant Administrator for Fisheries

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JANICE V. CARACCIOLO and FRANK W. STEIMLE, Jr.[1]

ABSTRACT

Distribution, abundance, and life history summaries are given for 58 important species of benthic invertebrates collected in the New York Bight apex during five sampling cruises in 1973 and 1974. These species showed affinities to major community types that have been previously identified in the Middle Atlantic Bight and some showed varying degrees of tolerance of areas in the apex where the dumping of New York Harbor dredge spoils and New York metropolitan area sewage sludge occurs. *Capitella capitata*, a species often associated with pollution stress, dominated the sewage sludge dump site.

INTRODUCTION

The New York Bight apex (Fig. 1), the area of continental shelf waters bounded on the north by Long Island and by New Jersey on the west, is one of the most intensely used areas of coastal marine waters in the world. It is impinged upon by a major population center, the New York-New Jersey metropolitan area, which uses the apex for recreation, for harvesting fish and (formerly) shellfish, and as a repository for waste products. The apex is also a thoroughfare for shipping to and from one of the busiest ports in the world, New York Harbor. These diverse uses or interests often conflict, and regulation, for the greatest public good, is a complex and difficult problem. Essential to the regulation of these conflicting interests are good assessments of the impacts each of the uses has upon the others.

The dumping of sewage sludge, dredging spoils, and industrial waste products into the apex and the flow of contaminants from the Hudson and Raritan Estuaries have affected the environment of the apex, degrading it for some purposes, e.g., recreation and shellfish harvesting. Surveys of the distribution and abundance of selected or indicator organisms or communities have often been used as an aid in determining the degree to which an environment has been degraded. Benthic invertebrates are particularly useful for this purpose because of their relative immobility, wide range of life histories, sensitivities to environmental change, and important role in marine food webs.

Man's impact on the New York Bight ecosystem has been noted for almost 100 yr, but surveys of the degree of impact were initiated only within the last two decades. Most studies concerned with benthic populations within the Bight and contiguous waters were also conducted from the mid-1950's to the present, after four decades of ocean disposal of sludges and spoils in the apex and over a century of industrial discharges into estuaries had already had an impact on the marine benthos inhabiting these waters. During 1957–60, Dean and Haskin (1964) and during 1973, McGrath (1974) studied the benthos of Raritan Bay, which borders the apex; in 1966, Steimle and Stone (1973) studied the inshore benthic macrofauna off southwest Long Island, primarily north of the lat. 40°30′N line within the Bight apex. The Middle Atlantic Bight study of Wigley and Theroux (1981) from August 1957 through August 1965 dealt with the New York Bight apex fauna only in major taxonomic groups. The first comprehensive studies of the benthic macrofauna of the New York Bight apex itself were made by personnel of the Sandy Hook Laboratory, National Marine Fisheries Service (NMFS). These studies, begun in 1968, have resulted in several published papers and reports (Pearce 1971, 1972, 1974a, b, 1975; National Marine Fisheries Service 1972[2]; National Oceanic and Atmospheric Administration 1976; Pearce, Caracciolo, Halsey, and Rogers 1976). Numerous benthic data reports have also been published by the NOAA-MESA Program (Pearce, Caracciolo, Frame, Rogers, Halsey, and Thomas 1976; Pearce, Thomas, Caracciolo, Halsey, and Rogers 1976a, b; Pearce, Caracciolo, Halsey, and Rogers 1977a, b; Pearce, Rogers, Caracciolo, and Halsey 1977; Pearce et al. 1978; Caracciolo et al. 1978). This atlas uses part of this extensive data set, collected during the MESA studies of 1973 and 1974, to present distribution and abundance patterns for the more important or dominant benthic macroinvertebrates in the New York Bight apex. The atlas describes and reviews the environment in which the species occur and presents a summary of aspects of their life histories. Through this approach, we hope to qualify the observed distributions and to gain insight into distinguishing natural and man- or pollution-induced population abundances and distributions. This report also forms a part of the baseline which is being established by the long-term ocean monitoring program, Ocean Pulse (Pearce 1977),[3] of the Northeast Fisheries Center, NMFS.

METHODS

Information on distribution patterns of species, sediment types, organic material, and heavy metals used in this paper was derived from approximately 500 benthic grab samples collected from a grid of 66 stations established in the New York Bight apex. These stations are bounded by lat. 40°16′ and 40°34′N and long. 73°36′

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[1] Northeast Fisheries Center Sandy Hook Laboratory, National Marine Fisheries Service, NOAA, Highlands, NJ 07732.

[2] National Marine Fisheries Service. 1972. The effects of waste disposal in the New York Bight. Final Report, Section 2: Benthic studies. A report submitted to the coastal Engineering Research Center, U.S. Army Corps of Engineers, Little Falls Road, Wash., D.C., 63 p.

[3] Pearce, J. 1977. A report on a new environmental assessment and monitoring program, Ocean Pulse. Int. Counc. Explor. Sea Pap. m1977/E:65, Fish. Improvement Comm., 12 p.

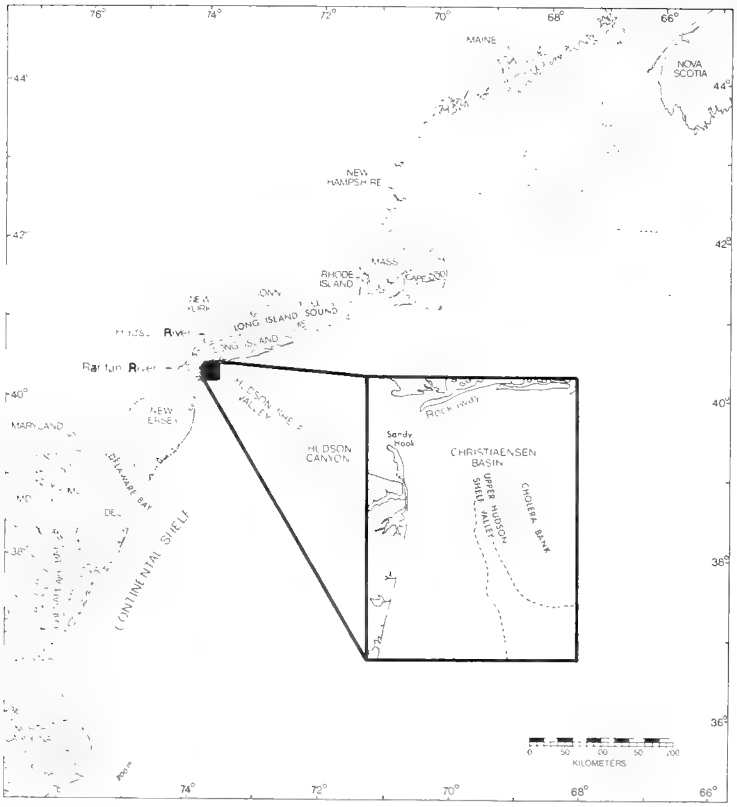

Figure 1.—New York Bight apex (enlarged) and surrounding area.

and 73°59′W, their depths ranging from 9.0 m nearshore (Station 16) to 45.6 m in the Hudson Shelf Valley (Station 56) (Fig. 2). Data were collected from on board the NOAA ships *Albatross IV*, *Oregon II*, and *Delaware II* during August 1973, October 1973, January 1974, March-April 1974, and August-September 1974 (Pearce, Rogers, Caracciolo, and Halsey 1977). Station positions were located and maintained by Raydist precision navigation and loran-A.

Benthic Fauna

At each station, during each cruise, five 0.1 m² Smith-McIntyre benthic grab samples were collected. Before the samples were disturbed, one 2.54 cm (inside diameter) core subsample was removed from each grab and preserved in Formalin for future study of meiofauna. Two sediment cores were also removed, and then the remainder of each grab sample was washed through a series of standard geological sieves with a minimum 1.0 mm mesh size. All materials retained on the sieves were fixed in 10% buffered Formalin and later transferred to and preserved in 70% ethanol containing 5% glycerol.

Dissecting microscopes were used as an aid in sorting organisms from preserved macrofauna samples. The organisms found were identified to the species level, whenever possible, using keys and descriptions developed by Hartman (1957, 1968, 1969), Pettibone (1963), Williams (1965), Day (1967), Abbott (1968, 1974), G. Schultz (1969), Gosner (1971), Bousfield (1973), and others. Competent taxonomists were consulted when necessary. After organisms were identified, counted, and tabulated, this information was coded and machine-listed by computer. The community found at each station was analyzed for total number of individuals per grab (N), total number of species (S), equitability ($J' = H'/H'$ max $= H'/\ln S$) (Pielou 1969), and diversity ($H' \cong -\frac{\Sigma n_i}{N} \ln \frac{n_i}{N}$ where n_i = the number in the ith species, Shannon and Weaver 1962).

Upon completion of a total of approximately 500 samples, a computer program was written to extract the "key" or "important" species found in the Bight apex. A species was defined as important if it was abundant, widely distributed, a known forage species for finfish (based on studies discussed later), a fishery resource species, or if it possessed characteristics or behavioral traits which make it useful as an "indicator" species, e.g., *Capitella capitata*. This selection yielded a total of 58 species.

The next step in our analysis was to combine and average distribution and abundance data from summer cruises (August 1973, October 1973, and August-September 1974) and from winter cruises (January 1974 and March-April 1974) for each of the 58 important species. This yielded average numbers of individuals of each species at each station sampled. These numbers were multiplied by 10 to give numbers per square meter, plotted, and contoured on standard station maps. In most cases, summer and winter species distributions were similar, so seasonal data were combined into one overall map for each species, which will be presented in the Life Histories.

Average species diversities and numbers of individuals at each station were plotted in Figures 3 and 4.

In the narrative sections of this atlas, we have reviewed and summarized available information on distribution, habitat, feeding ecology, reproduction, growth, and other unique or important characteristics for each of the above-mentioned "key" organisms, and have attempted to relate this information to the benthic environment in the New York Bight apex.

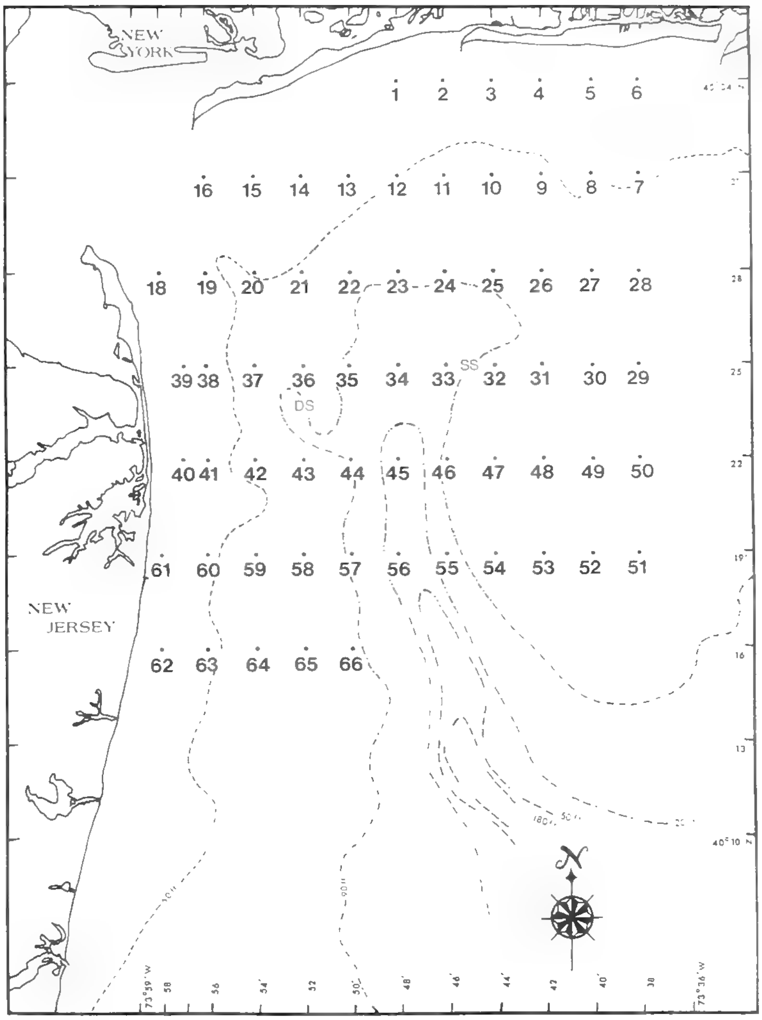

Figure 2.—New York Bight apex study area with station positions, and dredging spoils (DS) and sewage sludge (SS) dump sites indicated.

Sediments

Two 3.4 cm (inside diameter) sediment cores were removed from each grab sample, one for standard geological analyses (percentage oxidizable organics and grain size distribution) and the other for heavy metals analyses. These cores were frozen before being analyzed.

The percentage of oxidizable organic material in the sediments was calculated by the hydrogen peroxide digestion method, and grain size distribution was determined by processing each sediment sample in a Rapid Sediment Analyzer (Cok).[4] Grain size, expressed in the Wentworth scale (Wentworth 1922 after Udden 1898 as seen in Shepard 1963) is given in ϕ (phi) units, where $\phi = -\log_2 d$, and d = particle diameter in millimeters. Sediment heavy metals analyses for chromium, copper, nickel, lead, and zinc were performed using an atomic absorption spectrophotometer; details of these methods are given in Greig et al. (1976).

Sediment grain size, organic content, and heavy metals data were combined and averaged using procedures similar to those used for benthic fauna data. Mean grain size, expressed in ϕ units, was converted into sediment types based on the Wentworth scale. The categories thus established are as follows: -1 to $+1\phi$ = very coarse-coarse sand; $+1$ to $+2\phi$ = medium sand; $+2$ to $+4\phi$ = fine-very fine sand; $+4$ to $+6\phi$ = coarse to medium silt. These are mapped in Figure 5.

Sediment organic content was divided into three categories: $<3\%$ represents low organic areas; 3-5% represents medium organic areas; and $>5\%$ represents high organic areas (Fig. 6).

Average concentrations (ppm) for five heavy metals—chromium, copper, nickel, lead, and zinc—are presented in Figures 7-11.

The data file and benthic samples, upon which much of the information presented in this paper is based, are stored at the Northeast Fisheries Center, Sandy Hook Laboratory.

NEW YORK BIGHT APEX STUDY AREA

Environmental Characteristics

The oceanography of the New York Bight depends on larger scale processes of the entire Middle Atlantic Bight. Water depths in the Bight apex range from intertidal to approximately 62 m in the Hudson Shelf Valley. East coast continental shelf waters, in general, flow to the south at average speeds between 5 and 10 cm/s, however, storms can cause movements of 25-30 cm/s. Waters of the inner New York Bight exhibit estuarine circulation typical of coastal areas where discharge of river water exceeds evaporation. Near-surface waters move generally seaward, while near-bottom waters move generally landward (Beardsley et al. 1976).

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[4] Anthony Cok, Department of Earth Sciences, Adelphi University, Garden City, NY 11530, pers. commun. June 1973.

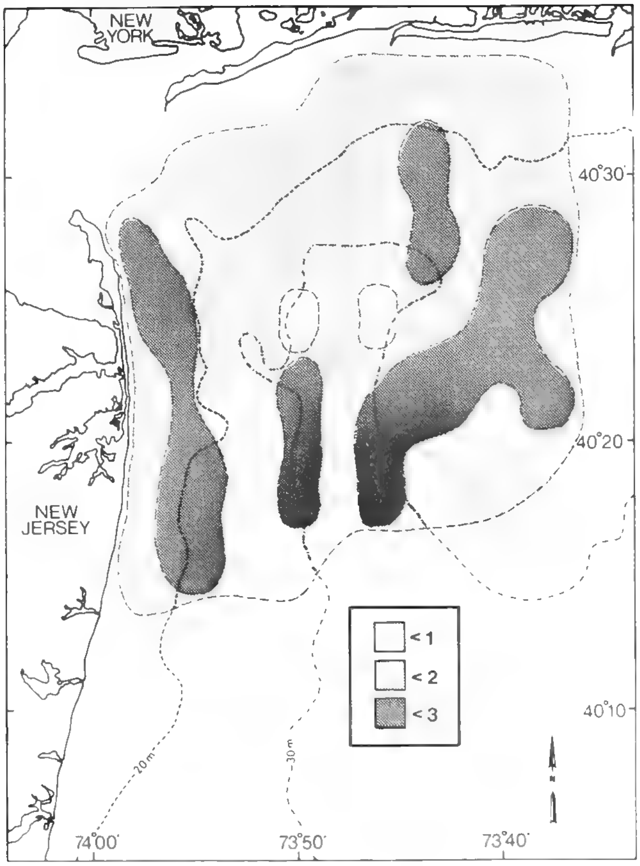

Figure 3.—Average species diversities (*H'*) of benthic invertebrates.

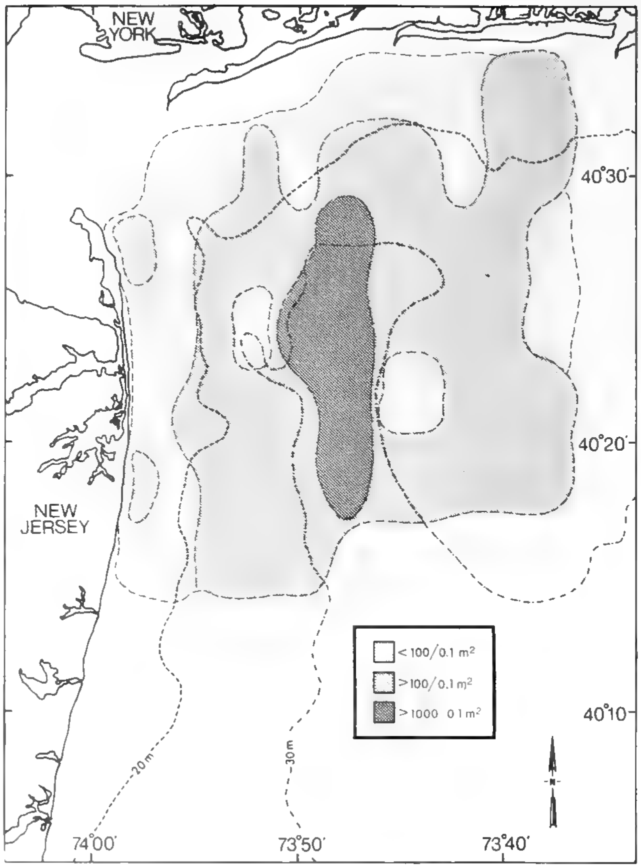

Figure 4.—Average numbers of benthic invertebrates per square meter.

In the Bight apex, surface salinities during January and February increase to the annual maximum of $>34‰$. Bottom salinities are $>34‰$ over most of the apex. Salinities begin to slowly decrease in March as river discharges increase. The spring (April, May) river runoff and penetration of slope water tend to increase vertical salinity gradients, however, these gradients vary greatly, even over a few days. Summer (June, July, August) surface salinities range from about 25–27‰ near the apex mouth to about 30–31‰ at the southeast corner. Bottom salinities range from 27–29‰ along the Sandy Hook-Rockaway transect to 30–32‰ at the outer edge of the apex. The seasonal minima occur in June. Vertical mixing during autumn (September, October) reduces vertical salinity gradients and leads to a steady increase in surface salinity, often as large as 0.8‰ between July and October. Surface and subsurface salinities continue to increase through early winter (November, December) until the winter maxima are attained in January.

A large range between summer and winter surface temperatures is characteristic of the Bight. River runoff into the apex is low in winter when strong vertical mixing unstratifies the water column and temperatures drop to their annual minimum, often $<2°C$ in mid-January. Bottom temperatures during November through February tend to be slightly higher than surface temperatures because vertical mixing does not keep pace with rapid surface cooling. Winter minima persist into late February or early March. During April, surface temperatures warm to $\approx 7°–8°C$, with bottom temperatures usually remaining at $<4°C$ except near the coast. A thermocline appears in May and intensifies during June when surface

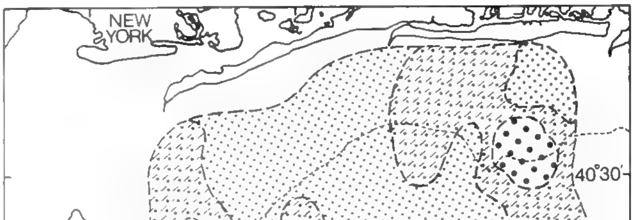

Figure 5.—Mean grain size (ϕ units) of sediments averaged over five quarterly cruises (August 1973–September 1974).

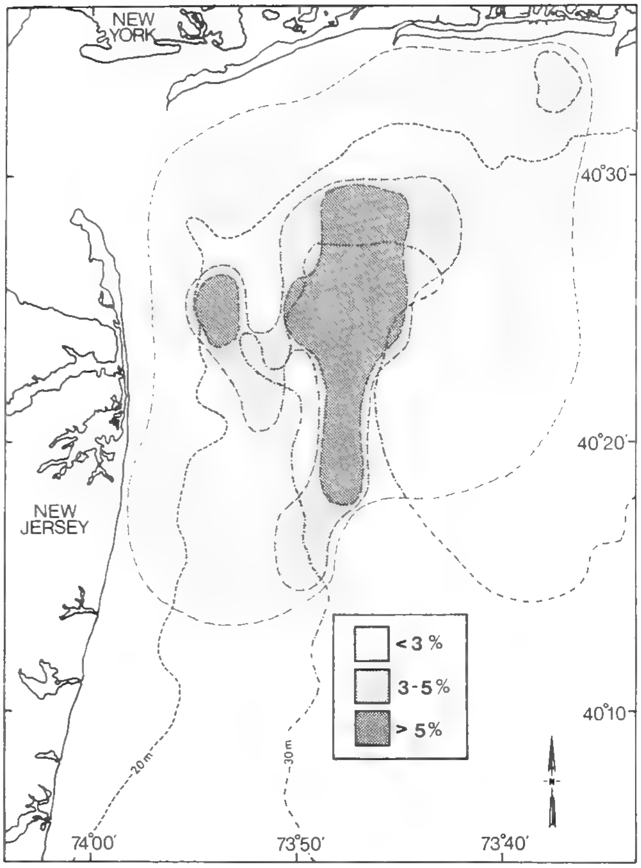

Figure 6.—Average percentage of digestible organic materials in sediments.

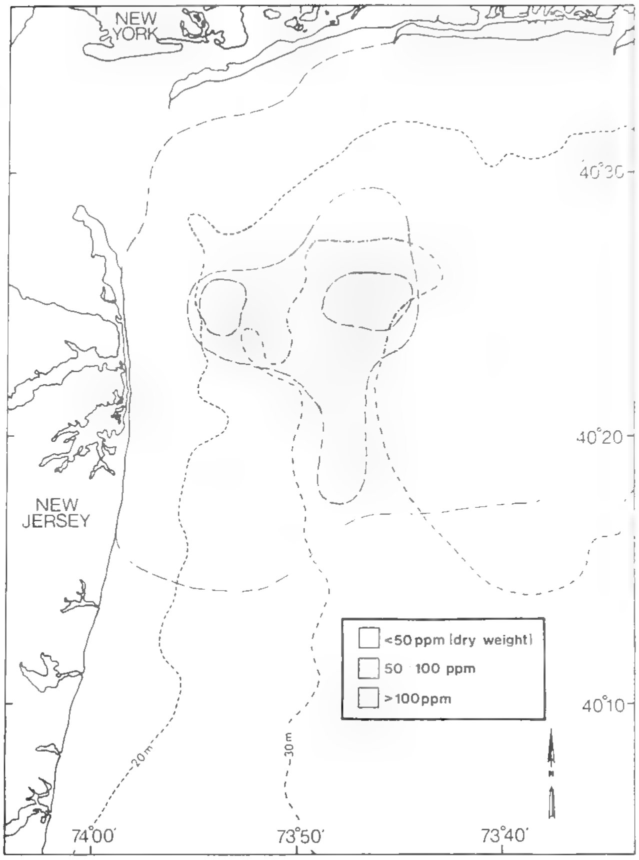

Figure 7.—Average concentrations of chromium in New York Bight apex sediments.

temperatures reach 17°C at the outer edges of the apex. Bottom water temperatures remain relatively unchanged at <6°C in the shelf valley. Surface temperatures reach their annual maximum value of about 26°C in August and bottom temperatures also show a steady rise to ≈10°C in the shelf valley. Surface cooling during early autumn begins to break down the summer thermocline. By the end of October, surface temperatures have dropped to ≈16°–18°C over much of the apex, while heat loss and vertical overturning increase the bottom water temperatures to ≈12°C inside the shelf valley. Vertical mixing down to about 30 m is usually complete by early or mid-November when water temperatures are 12°–14°C. Bottom temperatures attain their annual maximum in this period. Vertical mixing continues through December and surface and bottom temperatures decline and approach their winter minima (Bowman and Wunderlich 1976; Bowman 1977).

The dominant bottom feature of the New York Bight is the Hudson Shelf Valley, apparently cut by the ancestral Hudson River during times of low sea level. The center of the Christiaensen Basin (the landward terminus of the Hudson Shelf Valley Channel) is a natural collecting area for fine grained sediments. The apex outside the Christiaensen Basin is floored primarily by sand ranging from silty fine to coarse with small areas of sandy gravel, artifact gravel, and mud. In deeper water, in the Hudson Shelf Valley, where wave action is less pronounced, silt is the dominant sediment (Williams and Duane 1974; Freeland et al. 1976). Figure 5 shows mean grain size of sediments in the apex.

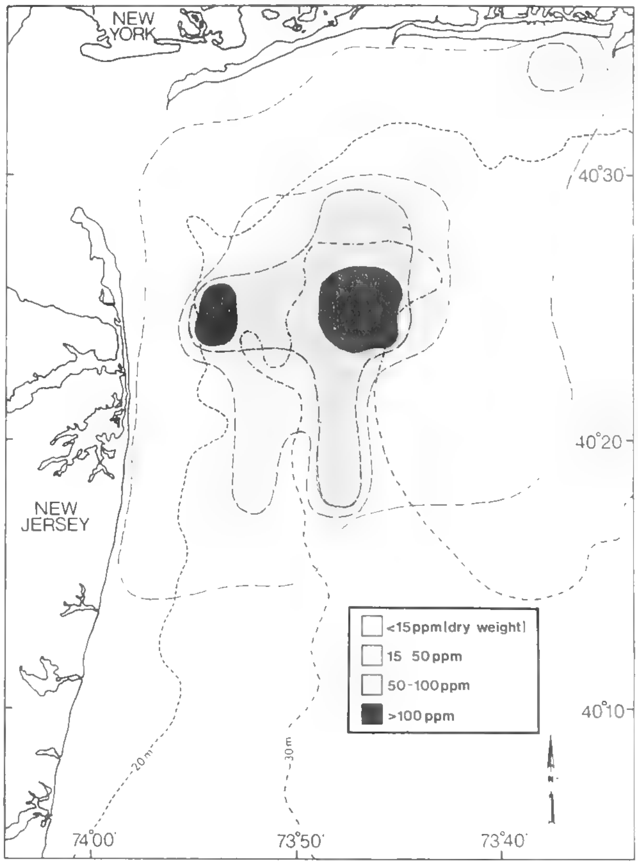

Figure 8.—Average concentrations of copper in New York Bight apex sediments.

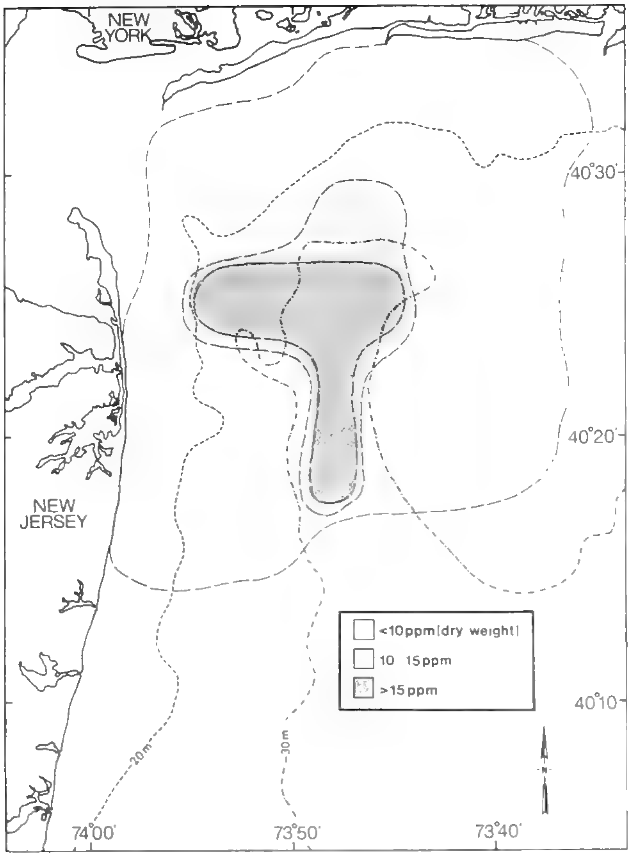

Figure 9.—Average concentrations of nickel in New York Bight apex sediments.

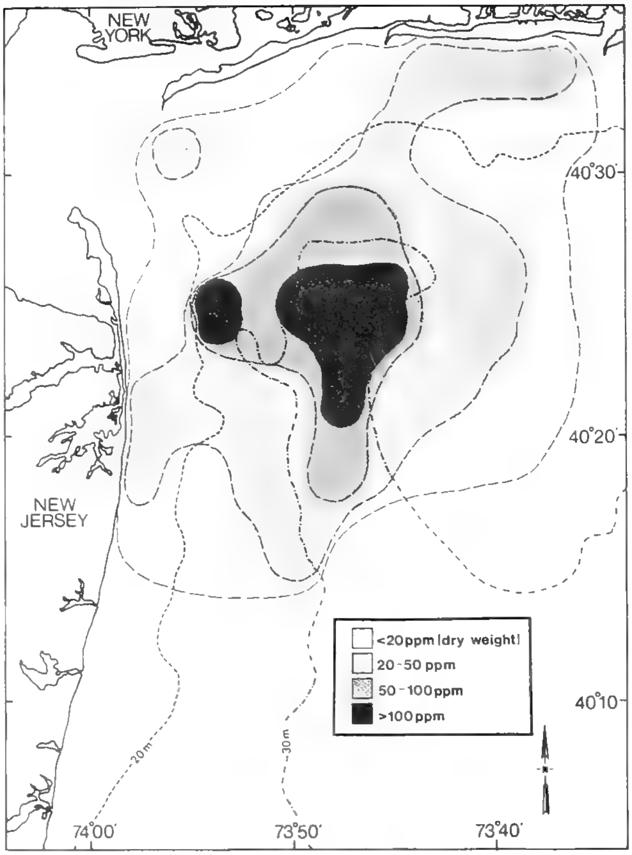

Figure 10.—Average concentrations of lead in New York Bight apex sediments.

Sources of oxygen-consuming organic matter in the New York Bight have been analyzed by Segar and Berberian (1976). They reported that locally produced carbon from phytoplankton accounted for most of the oxygen demand in the apex, especially in summer. Sewage sludge and river-borne organic materials were generally of equal importance. The major contaminants of the New York Bight originate from the highly populated New York metropolitan area and the Hudson River drainage basin. Sources include offshore barged discharges from sewage treatment plants, industrial outfalls, and storm water runoff and overflows.

Hatcher and Keister (1976) analyzed organic matter in the New York Bight sediments using the ratio of total carbohydrates (TCH) to total organic carbon (TOC). TCH:TOC ratios were ≈ 40 in the sewage sludge disposal site and 50 or more in the axis of the Hudson Shelf Channel. High TCH:TOC values (≥ 30) may be attributed to sewage-derived organic material in sediment deposits.

Figure 6 gives a detailed representation of the percentage of total digestible organic material in apex sediments based on our data from five seasonal cruises.

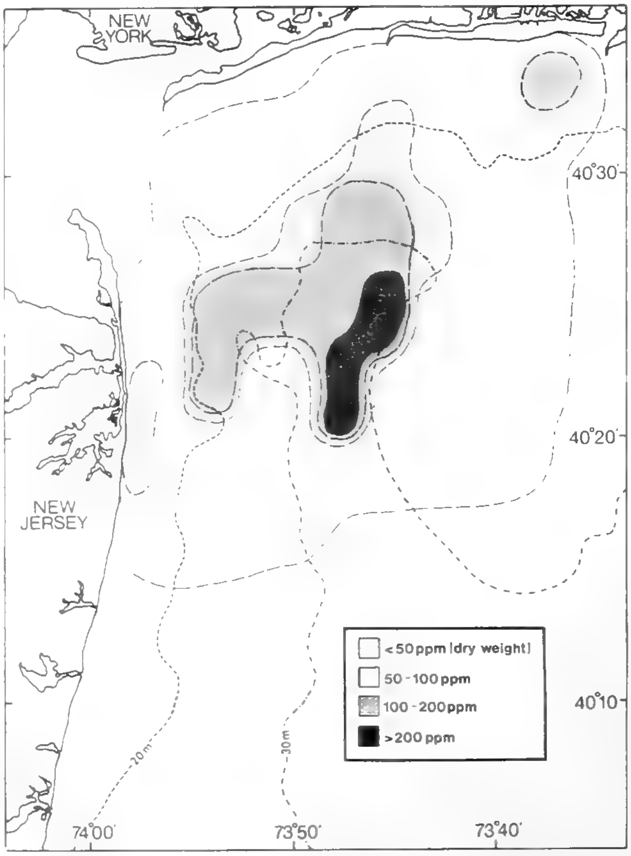

Figure 11.—Average concentrations of zinc in New York Bight apex sediments.

Life Histories and Distributions of Dominant Benthic Invertebrates

Phylum Coelenterata

Class Anthozoa

Edwardsia spp.: *elegans* Verrill, 1869 and *sipunculoides* Stimpson, 1854

DESCRIPTION: Small, slender, solitary anemones between 75 and 150 mm in length. They burrow in the sediment with their tapering "foot" and are often encrusted with sand and other foreign material. Sixteen to 36 mobile tentacles surround the mouth (Miner 1950).

DISTRIBUTION: These two species of *Edwardsia* occur from the Bay of Fundy to at least Chesapeake Bay (Boesch et al. 1977).

HABITAT: Gosner (1971) reported that *Edwardsia elegans* occurs between the littoral and 117 m, while *Edwardsia sipunculoides* is found in deeper water of 87–117 m. In this study, these species were found in depths between 23 and 46 m in abundances of 10–60/m^2. They were most abundant in high organic fine sands or silts (Fig. 12; Table 1).

FEEDING ECOLOGY: Anemones, in general, feed on live or dead animal material ranging from plankton and detritus, collected by ciliary currents, to larger organisms, captured by mucous secretions or nematocysts (Barnes 1963; Gosner 1971). No specific information on *Edwardsia* spp. was available.

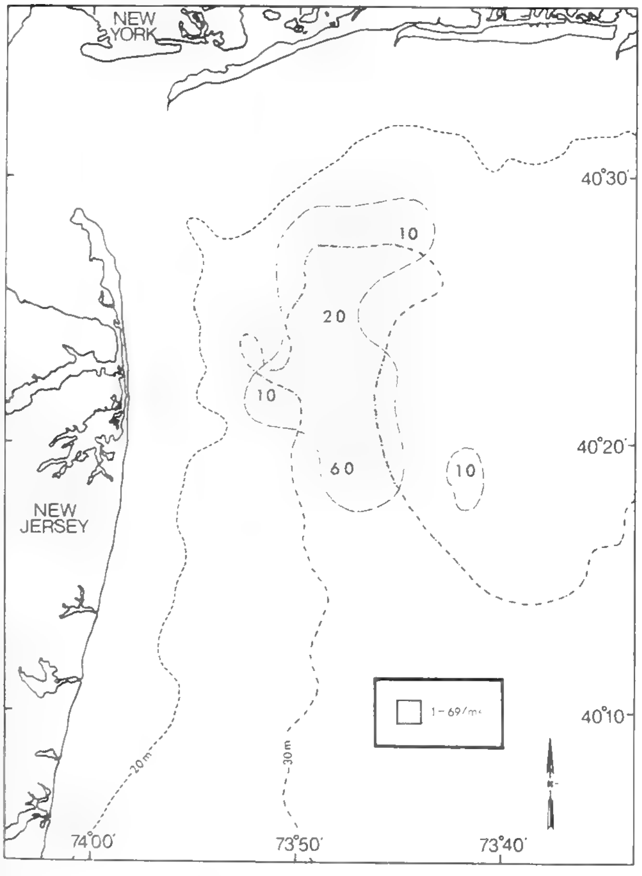

Figure 12.—Distribution and abundance of *Edwardsia* spp. (*E. elegans* and *E. sipunculoides*) in the New York Bight apex.

REPRODUCTION AND GROWTH: No information specific to *E. elegans* or *E. sipunculoides* was available in this category. However, anemones can reproduce both asexually and sexually. Asexual reproduction is chiefly by longitudinal fission (budding). Sexual reproduction can involve individuals which are males, females, or protandric hermaphrodites. A free-living larval form called the planula is produced in sexual reproduction. This larva eventually attaches to a substrate and metamorphoses into the adult benthic form (Barnes 1963; Gosner 1971).

The larvae of some species of *Edwardsia* are parasitic on the surface or in the gastrovascular system of medusae and ctenophores (*Mnemiopsis* sp.), adhering by means of the mouth margin and taking food particles from their hosts by means of the siphonoglyph current (Hyman 1940; Gosner 1971).

Ceriantheopsis americanus [*Cerianthus americanus*] (Verrill, 1866)

DESCRIPTION: A smooth-bodied, brownish, elongate (up to 200 mm), burrowing anemone. It inhabits a distinctive heavy mucous tube, constructed in part with its own nematocysts. The inner surfaces of the tubes are purple or lavender. One hundred or more tentacles, in each of two circlets, surround the mouth (Miner 1950; Gosner 1971).

DISTRIBUTION: Gosner (1971) considered *Ceriantheopsis americanus* to be a Virginian species, occurring from Cape Cod to Cape Hatteras. However, Pratt (1935) and Miner (1950) gave its range as Cape Cod to Florida.

HABITAT: Gosner (1971) reported occurrence of this species from the littoral zone to 21 m. Sanders (1956) reported it to be part of the typical soft bottom community in Long Island Sound; the species was also common in the sewage sludge disposal area of the New York Bight apex (National Marine Fisheries Service footnote 2). In the present study, *C. americanus* was collected in depths up to about 46 m in all sediment types. However, it was most abundant, occurring in numbers up to 340/m^2, in high organic fine sands to silt (Fig. 13; Table 1). The Cerianthidae are often found buried in the sediment with only the tentacles and oral disc protruding; their tubes may confer some protection from stressed environments.

FEEDING ECOLOGY: *C. americanus*, like most smaller anemones, is thought to be a suspension feeder, with its mucous secretions and nematocysts aiding in the capture of small planktonic organisms. An extracellular and extracorporeal contact digestion has also been demonstrated in species of *Ceriantheopsis*. This digestion occurs when prey come into contact with enzymes produced in the ectodermal layer of the labial tentacles (Barnes 1963; Tiffon 1975).

Since *C. americanus* is able to withdraw rapidly into its mucous tube, it avoids being preyed upon by many finfish. However, it has been shown by Wobber (1970) that California species of genus *Cerianthus*, closely related to genus *Ceriantheopsis*, are often the prey of a nudibranch, *Dendronotus iris*. *Dendronotus iris* feeds on *Cerianthus* spp. tentacles, but because it consumes an average of only 2–10 tentacles per anemone, it does minor damage to the anemone.

Table 1.—Total number of individuals per square meter averaged over five quarterly cruises (August 1973–September 1974).

						Sediment type			
	Depth (m)		Sediment organic level			Very coarse-coarse sand	Medium sand	Fine-very fine sand	Coarse-medium silt
Taxonomic group	0–24	25–49	High >5%	Medium 3–5%	Low <3%				
Phylum Coelenterata	470	2,170	1,910	340	390	60	120	1,710	750
Class Anthozoa	470	2,170	1,910	340	390	60	120	1,710	750
Edwardsia spp. (*E. elegans* and *E sipunculoides*)	10	190	130	30	40	0	10	110	80
Ceriantheopsis americanus	460	1,980	1,780	310	350	60	110	1,600	670
Phylum Phoronida	360	1,080	930	210	300	10	170	970	290
Phoronis architecta	360	1,080	930	210	300	10	170	970	290
Phylum Mollusca	12,390	42,154	44,810	1,247	8,487	1,150	2,500	37,954	12,940
Class Gastropoda	50	60	20	20	70	0	30	80	0
Nassarius trivittatus	50	60	20	20	70	0	30	80	0
Class Bivalvia	12,340	42,094	44,790	1,227	8,417	1,150	2,470	37,874	12,940
Nucula proxima	7,500	39,840	43,970	620	2,750	560	550	33,600	12,630
Astarte castanea	510	110	0	0	620	390	70	160	0
Arctica islandica	10	144	80	47	27	0	0	124	30
Cerastoderma pinnulatum	30	170	110	50	40	30	20	120	30
Pitar morrhuanus	190	690	400	110	370	20	50	640	170
Spisula solidissima	630	20	0	20	630	10	260	380	0
Tellina agilis	3,450	1,080	220	380	3,930	140	1,490	2,820	80
Ensis directus	20	40	10	0	50	0	30	30	0
Phylum Annelida	47,943	65,380	30,234	14,237	68,852	21,770	23,264	58,292	9,997
Class Polychaeta	43,782	64,016	30,207	13,147	64,444	19,980	20,537	57,301	9,980
Order Archiannelida									
Polygordius triestinus	4,161	1,364	27	1,090	4,408	1,790	2,727	991	17
Order Phyllodocida									
Phyllodoce arenae	208	215	31	30	362	17	101	298	7
Eteone longa	47	194	110	50	81	50	20	111	60
Harmothoe extenuata	141	189	61	54	215	87	101	115	27
Sthenelais limicola	372	187	40	47	472	17	151	381	10
Glycera dibranchiata	1,117	1,287	40	187	2,177	147	610	1,647	0
Goniadella gracilis	1,477	107	17	110	1,457	600	737	237	10
Nephtys bucera	1,017	188	30	27	1,148	200	507	468	30
Nephtys incisa	597	1,990	1,980	267	340	130	47	1,700	710
Nephtys picta	538	121	0	27	632	44	291	324	0
Nephtys (Aglaophamus) circinata	280	194	0	20	454	10	150	314	0
Order Capitellida									
Capitella capitata	34	6,145	5,028	20	1,131	0	1,027	5,131	21
Mediomastus ambiseta	546	7,334	6,430	380	1,070	320	308	2,242	5,010
Travisia carnea	137	71	0	0	208	24	48	136	0
Order Spionida									
Spio filicornis	349	862	51	440	720	87	228	889	7
Prionospio steenstrupi	1,165	2,780	610	1,460	1,875	977	944	1,774	250
Polydora ligni	228	208	81	40	315	20	161	211	44
Spiophanes bombyx	9,511	9,080	460	590	17,541	400	3,901	14,120	170
Paraonis gracilis	54	1,128	1,097	14	71	10	24	838	310
Aricidea catherinae	924	401	47	74	1,204	590	217	511	7
Order Eunicida									
Lumbrinerides acuta	351	80	10	10	411	287	107	27	10
Lumbrineris fragilis	622	594	67	310	839	490	278	428	20
Lumbrineris tenuis	564	1,537	600	410	1,091	410	327	1,234	130
Ninoe nigripes	344	1,484	470	300	1,058	340	120	1,168	200
Drilonereis longa	222	351	130	100	343	48	107	368	50
Order Magelonida									
Magelona riojai	238	7	0	0	245	10	88	147	0
Order Cirratulida									
Tharyx acutus	19,048	17,927	7,880	6,680	22,415	14,070	8,381	13,304	1,220
Tharyx annulosus	748	2,957	1,540	860	1,305	310	247	2,918	230
Caulleriella killariensis	297	97	10	10	374	37	190	167	0
Cossura longocirrata	40	370	400	10	0	0	0	260	150
Order Terebellida									
Ampharete arctica	322	224	67	130	349	57	107	365	17
Asabellides oculata	1,712	3,370	1,010	120	3,952	81	801	4,090	110
Order Flabelligerida									
Pherusa affinis	572	2,707	2,310	380	589	110	211	1,638	1,320
Phylum Arthropoda	4,230	1,340	380	270	4,920	410	1,740	3,120	300
Class Crustacea	4,230	1,340	380	270	4,920	410	1,740	3,120	300
Order Isopoda									
Edotea triloba	150	240	30	40	320	10	100	260	20

Table 1.—*Continued.*

Taxonomic group	Depth (m)		Sediment organic level			Sediment type			
	0–24	25–49	High >5%	Medium 3–5%	Low <3%	Very coarse-coarse sand	Medium sand	Fine-very fine sand	Coarse-medium silt
Order Amphipoda									
Ampelisca verrilli	810	0	0	0	810	0	140	670	0
Unciola irrorata	280	450	20	80	630	180	190	360	0
Pseudunciola obliquua	640	10	0	0	650	60	280	310	0
Protohaustorius deichmannae	920	0	0	0	920	0	370	550	0
Protohaustorius wigleyi	520	0	0	0	520	70	240	210	0
Leptocheirus pinguis	0	330	290	0	40	0	10	60	260
Rhepoxynius epistomus	350	60	0	30	380	10	160	240	0
Order Mysidacea									
Neomysis americana	200	0	10	10	180	0	50	140	10
Order Decapoda									
Crangon septemspinosa	160	40	0	20	180	20	70	110	0
Cancer irroratus	200	210	30	90	290	60	130	210	10
Phylum Echinodermata	350	310	0	0	660	20	240	400	0
Class Echinoidea	350	310	0	0	660	20	240	400	0
Echinarachnius parma	350	310	0	0	660	20	240	400	0

REPRODUCTION AND GROWTH: The Cerianthidae are protandrous hermaphrodites. The young sea anemone lives as a ciliated ball, unattached and free-swimming. During the *Edwardsia* stage, the larva usually settles and attaches to a variety of surfaces, develops tentacles, and adopts a benthic existence (Barnes 1963; Gosner 1971).

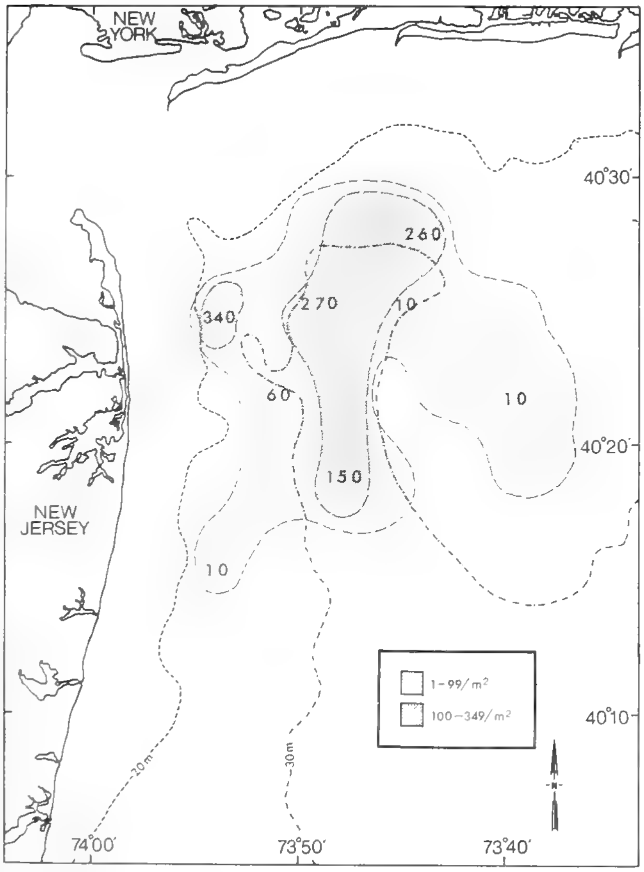

Figure 13.—Distribution and abundance of *Ceriantheopsis americanus* in the New York Bight apex.

Hyman (1940) stated that the life span of species of *Cerianthus* could range from 10 to 40 yr. Attempts at determining growth rates in the New York Bight apex have been unsuccessful (Fallon).[5]

Phylum Phoronida

Phoronis architecta (Andrews, 1890)

DESCRIPTION: Slender, flesh colored, wormlike tube dwellers; adults reach 50 mm in length. No annulations or setae present on the body; at the anterior end, the lophophore, two parallel horseshoe-shaped ridges, bears tentacles and a central mouth. The cylindrical, straight tube, more than twice as long as the worm itself, is produced as a chitinous secretion, and, being intially sticky, becomes covered with sand (Gosner 1971). Emig (1969, 1971) has synonymized *Phoronis architecta* with *Phoronis psammophila* Cori, but this synonomy has been the subject of debate. A count of longitudinal muscle bundles is the only method of positively separating *P. architecta* from *P. psammophila* (Paine 1961).

DISTRIBUTION: Both coasts of North America (Emig 1969); Florida Gulf coast to Biscayne Bay (Paine 1961); Gulf of Mexico (Louisiana and Texas) (Hedgpeth 1954).

HABITAT: Gosner (1971) reported the species as being found on sandy substrata from the lower littoral to depths of at least 18 m. Stancyk et al. (1976) stated that *P. architecta* occurred from sand to mud, from the intertidal to depths of 4 m. Wass (1972) reported densities of 90 individuals/m^2 in Chesapeake Bay. He also reported their occurrence in polyhaline waters with salinities as low as 18‰. Boesch (1973), however, believed *P. architecta* may occur in much higher densities than reported by Wass (1972) in Chesapeake Bay.

In the New York Bight apex, *P. architecta* occurred in depths ranging from 17 to 37 m. The species was collected from all sediment types but was most common in fine-sand, high organic areas, where densities reached 290 individuals/m^2 (Fig. 14; Table 1).

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[5] Phillip Fallon, Equitable Environmental Health, 333 Crossways Park Drive, Woodbury, NY 11797, pers. commun. April 1979.

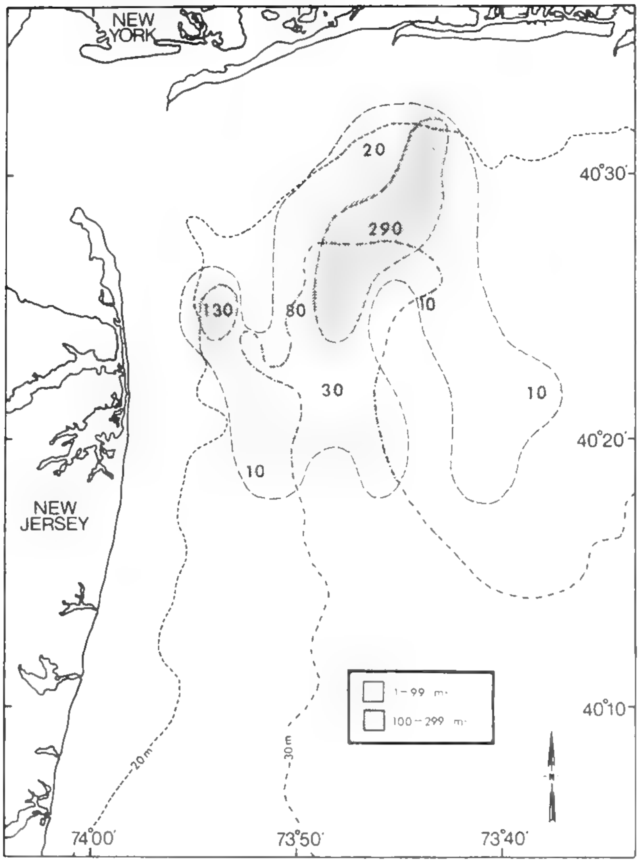

Figure 14.—Distribution and abundance of *Phoronis architecta* in the New York Bight apex.

FEEDING ECOLOGY: Phoronids, like other lophophorates, are ciliary mucous suspension feeders, subsisting on plankters or detritus fragments (Gosner 1971).

REPRODUCTION AND GROWTH: *P. architecta* has been regarded as a protandric hermaphrodite, but Hyman (1959) has questioned this view. Fertilization is external. No brooding occurs, with eggs hatching as an actinotroch larva (Gosner 1971). Typical actinotroch larvae were taken in plankton tows in Florida waters by Paine (1961) in December and February–August when towing was discontinuous. Adults reared in November had ova floating in their coelomic spaces, indicating a long, if not continuous, breeding season. Davis (1950) also collected actinotrochs in Florida in December and September and Hedgpeth (1954) recorded their presence during winter months in Louisiana and Texas.

After several weeks of a free-swimming planktonic existence, the actinotroch undergoes a rapid metamorphosis and sinks to the bottom, where it secretes a tube and begins its adult existence (Barnes 1963).

Phylum Mollusca

Class Gastropoda

Nassarius trivittatus (Say, 1822)

DESCRIPTION: 1.9 cm in length; rather light shelled, 8–9 whorls, nuclear whorls smooth. Whorls in spire with 4–5 rows of strong, distinct beads. Color light ash to yellowish gray (Abbott 1974). The Nassariidae are gregarious, often occurring in great numbers (Abbott 1968).

DISTRIBUTION: Newfoundland to off northeast Florida (Abbott 1974).

HABITAT: Common from shallow water to about 82 m (Abbott 1974). Franz (1976) stated that *Nassarius trivittatus* is characteristic of the medium sand community in Long Island Sound. However, *N. trivittatus* has also been recorded in muddy sediments in Delaware Bay (Kinner et al. 1974) and in high silt-clay sediments in northwestern Buzzards Bay (Driscoll and Brandon 1973).

Nassarius trivittatus was the only abundant gastropod, occurring in numbers up to 20/m², collected in the New York Bight apex. It was found in depths of 11–27 m and was most characteristic of low organic fine sands (Fig. 15; Table 1).

FEEDING ECOLOGY: *N. trivittatus*, as all nassa snails (Nassariidae), is one of the most active and responsive scavengers among marine invertebrates. It has a keen ability to detect the products of chemical decomposition of dead flesh. Within a few seconds of sensing such a stimulus, the snail heads directly for its source. Nassas eat decaying fish and invertebrates; polychaete egg masses; eggs of the moon snail, *Lunatia heros*; benthic diatoms; and detritus on the sediment surface (Clarke 1956; Scheltema 1964; Abbott 1968). They, in turn, are preyed upon by fish such as haddock, *Melanogrammus aeglefinus* (Wigley 1956).

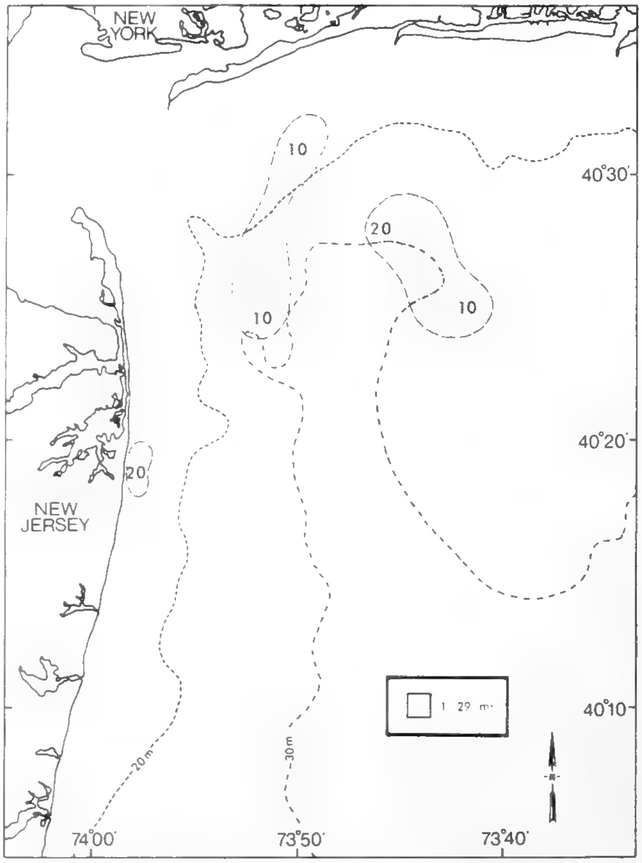

Figure 15.—Distribution and abundance of *Nassarius trivittatus* in the New York Bight apex.

REPRODUCTION AND GROWTH: Sexes are separate, with shells of males usually being smaller. Egg capsules, containing about 50 eggs, are laid in rows on algae, shells, stones, or sometimes on the underside of moon snail "sand collar" egg masses (Abbott 1968, 1974). In deeper waters of the continental shelf, *N. trivittatus* spawn during May and June when seawater temperatures are between 8° and 13°C. Intertidally, at Barnstable Harbor, Mass., spawning began in early May when seawater temperatures rose rapidly from about 9° to 15°C (Scheltema and Scheltema 1965). Pechenik (1978) reported spawning in the laboratory to occur at 7.4°C in December. Egg cases have been observed by Scheltema and Scheltema (1965) in Barnstable Harbor in early autumn. After about 1 wk at room temperature in the laboratory, 225 μm long free-swimming veliger larvae emerged from egg capsules. Under favorable conditions of laboratory culture, metamorphosis into snails occurred at 22 d following emergence, with most specimens between 0.9 and 1.1 mm in length at this stage.

ADDITIONAL INFORMATION: Unlike many marine snails, nassas are attracted toward light (Abbott 1968).

Class Bivalvia

Nucula proxima Say, 1822

DESCRIPTION: Atlantic nut clam; 0.6 cm in length, obliquely ovate, smooth. Color greenish gray with microscopic, embedded, axial gray lines and prominent, irregular, brownish concentric rings (Abbott 1974).

DISTRIBUTION: Nova Scotia to Florida and Texas; Bermuda (Abbott 1974).

HABITAT: Common in mud and sand, 0.9–30 m (Abbott 1968, 1974). Menzel (1964) listed *Nucula proxima* as a subtidal mud dweller occurring at salinities >25‰ in Florida. In Virginia, it occurs in sand to silty sand, at salinities >20‰ (Wass 1965). In samples taken near the mouth of Delaware Bay, *N. proxima* was among the three most abundant species collected; there, it was a member of a high silt-clay facies (>50% silt-clay) (Kinner et al. 1974). In the soft-bottom community of Buzzards Bay, Mass., *N. proxima* and *Nephtys incisa* dominated the fauna (Sanders 1958, 1960; Driscoll and Brandon 1973).

In a prior apex study, Pearce (1972) found *N. proxima* in greater abundance around sludge deposits than in natural communities. In the present study, *N. proxima* was again clearly most abundant in high organic fine sands and silt, although it was present in all sediment types. It occurred in numbers between 10 and about 22,000/m^2 and was by far the most abundant bivalve collected (Fig. 16; Table 1).

FEEDING ECOLOGY: *Nucula* spp. are sporadically mobile, normally lying at or just below the sediment surface feeding on the sediment just beneath them by means of long appendages derived from the palp. Only fine particles are moved along the groove to the palps where they are passed by cilia to the mouth. *Nucula* spp. are thus selective deposit feeders (Abbott 1968; McCall 1977).

Nucula spp. are a source of food for several species of bottom-feeding fish (Abbott 1968).

REPRODUCTION AND GROWTH: *N. proxima* exhibits no egg protection; larvae are lecithotrophic with a short pelagic development. Time to maturity is unknown (Chanley 1969; Scheltema 1972).

The size, shape, and coloration of this species vary according to substrate and water temperature. Among the probable forms are: *truncula* Dall, 1878; *ovata* Verrill and Bush, 1898; and *annulata* Hampson, 1971 (Abbott 1974).

Allen (1953, 1954) showed precise year-classes for five English species of this genus. He postulated that the largest individual in his samples was 12–20 yr old, depending on the species, and that the yearly increment in length varied from 0.94 to 1.01 mm, regardless of species or age. Blake and Jeffries (1971) grew *N. proxima* in tanks. They estimated 2.0 mm/yr growth for the first size-class of *N. proxima* and 1.0 mm/yr for the second size-class. These estimates are greater than Carey's (1962) estimate of 0.38 mm/yr for *N. proxima* in Long Island Sound, but are similar to Allen's (1953, 1954) estimates for British species.

ADDITIONAL INFORMATION: Levinton (1972) found *N. proxima* in Long Island Sound to be randomly distributed with a tendency toward aggregation in some cases. Juveniles were distributed essentially the same as adults. It is argued that the lack of defense mechanisms, the instability of the substrate, the small "reach" of the feeding organ, and the lack of advantage of territoriality to a mobile deposit feeder, all contribute to the observed random patterns of *N. proxima*.

In experiments using a radioactive tracer, cadmium-109 (^{109}Cd), Jackim et al. (1977) showed that an increase in temperature or a decrease in salinity increased the ^{109}Cd uptake rate of *N. proxima*.

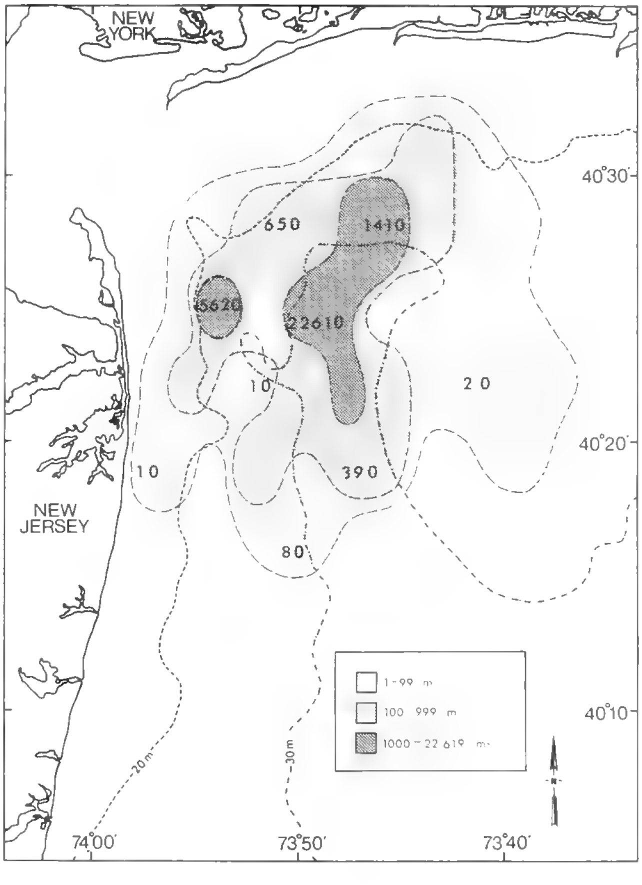

Figure 16.—Distribution and abundance of *Nucula proxima* in the New York Bight apex.

The infaunal filter feeder *Mulinia lateralis* accumulated about five times more ^{109}Cd than the deposit feeder *N. proxima*. Evidence presented indicated that early uptake rates might be indicative of subsequent acquired body burdens after long-term exposure.

Astarte castanea (Say, 1822)

DESCRIPTION: Commonly called the smooth *Astarte*; 2.5 cm in length and height, trigonal in shape, quite compressed. Shell almost smooth, except for weak, low concentric lines. Color a glossy light brown (Abbott 1974).

DISTRIBUTION: Nova Scotia to off New Jersey (Abbott 1974). Miner (1950) and Gosner (1971) recorded the range to Cape Hatteras.

HABITAT: Characteristic of coarse sand (Franz 1976); in mud, in fairly shallow water to 30 m (Abbott 1968). Gosner (1971) reported it in depths to 119 m.

Astarte castanea was collected in depths up to 25 m in the New York Bight apex. It occurred in all grades of sand but was most abundant in coarse sands. It was found only in low organic areas (Fig. 17; Table 1).

FEEDING ECOLOGY: *A. castanea* has no siphons and is a suspension feeder (Sanders 1956; Abbott 1968).

Astarte castanea is eaten especially by haddock, other groundfishes, and predator snails. According to Wigley and Theroux (1965), *Astarte* sp. is the third most important mollusk, behind *Nucula tenuis* and *Cerastoderma pinnulatum*, as food for haddock.

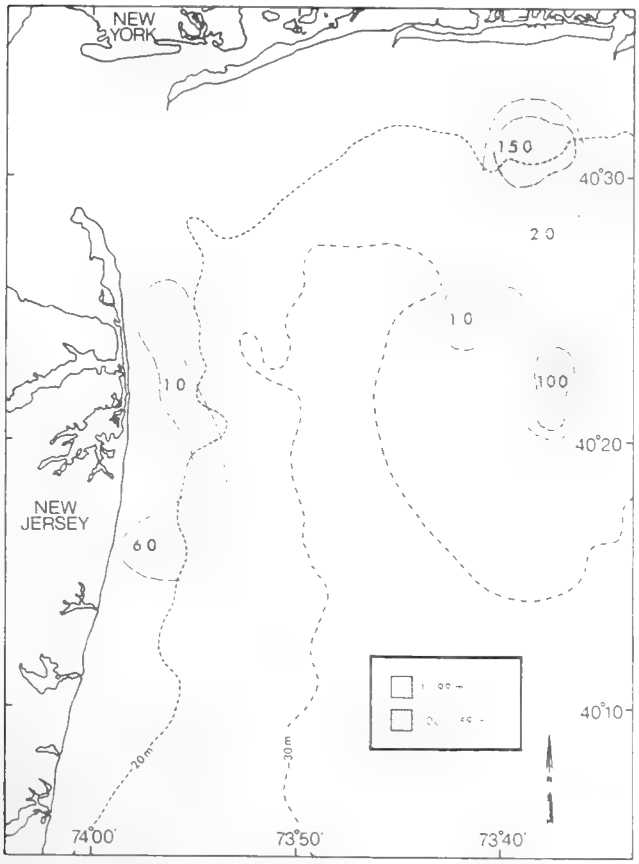

Figure 17.—Distribution and abundance of *Astarte castanea* in the New York Bight apex.

REPRODUCTION AND GROWTH: Sexes are separate, with male and female clams occurring in equal numbers (Abbott 1968). *Astarte castanea* begins producing mature viable gametes when 15–16 mm in length. Production of gametes is neither seasonal nor cyclic since mature gametes have been found in abundance in these animals throughout the year (Ruddell 1977).

Arctica islandica (Linné, 1767)

DESCRIPTION: The ocean quahog or mahogany clam; 8–13 cm in length, almost circular in outline, with a rather strong, porcelaneous shell which is commonly chalky. *Arctica islandica* is the only living species in its family (Arcticidae); there are numerous fossil species. Superficially, *A. islandica* resembles the hard clam, *Mercenaria mercenaria*, however, the dark brown to black periostracum (horny external covering) of *A. islandica* is the most obvious distinguishing characteristic (Abbott 1974).

DISTRIBUTION: Newfoundland to off North Carolina, northern Europe, Iceland (Pratt 1973; Abbott 1974).

HABITAT: The ocean quahog is a common, commercially dredged species, most abundant on silty sand and stable fine sand (Turner 1949; Parker and McRae 1970), but occasionally found on silt-clay bottoms (Arcisz and Sandholzer 1947; Bureau of Commercial Fisheries 1970[6]). Results of National Marine Fisheries Service surveys show that it is found at depths from 18–27 m to the shelf edge off New Jersey and the Delmarva Peninsula, and in scattered patches from 37 m off Virginia; it is also landed in small quantities in southern New England. While the shoreward boundary has been well established, distribution and abundance offshore is not well known. High temperatures limit the shoreward distribution of *A. islandica*; in the southern part of its range it is rarely found within the 17.5°C maximum isotherm as drawn by Walford and Wicklund (1968). In the laboratory, the upper lethal limit for fully acclimated Rhode Island animals is about 24°C; the ocean quahog is active at temperatures as low as 0°C, but activity decreases above 18°C (Saila and Pratt 1973).

Almost all *A. islandica* collected in New York Bight apex grab samples were juveniles. They were taken from depths between 23 and 37 m. *Arctica islandica* were most common in fine sands but occurred in low numbers in silt. Highest total numbers were in high organic sediments with fewer in medium and low organic areas (Fig. 18; Table 1).

FEEDING ECOLOGY: *A. islandica* has very short siphons and is a shallow burrower (Saleuddin 1964). It is a filter feeder with the capacity to filter large and variable amounts of water (Winter 1969). Merrill et al. (1969) stated that many dredged quahog shells have been found drilled by predatory, naticid gastropods.

Caloric values of Canadian specimens follow a seasonal trend, with a summer maximum and winter minimum (4,276 to 3,684 cal/g dry weight) (Tyler 1973).

REPRODUCTION AND GROWTH: The reproduction of an ocean quahog population off Rhode Island was studied by

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[6] Bureau of Commercial Fisheries. 1970. Ocean quahog survey. Cruise Report, *Delaware II* Cruise 70-5. National Marine Fisheries Service, Exploratory Fishing and Gear Research Base, Woods Hole, Mass., 6 p.

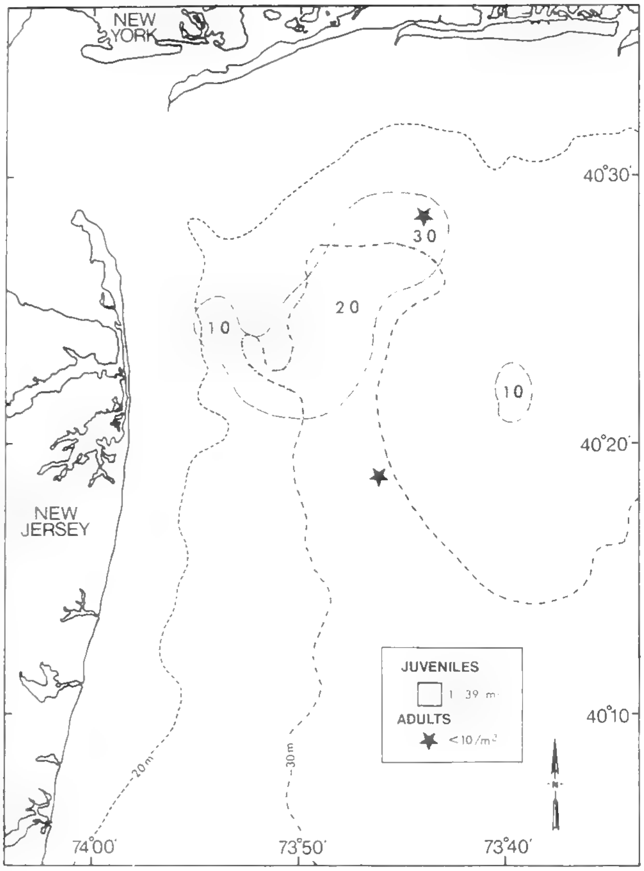

Figure 18.—Distribution and abundance of *Arctica islandica* in the New York Bight apex.

Loosanoff (1953). Rapid gonad growth took place during spring and spawning began at a temperature of 13.5°C in late June or early July and continued into October. Landers (1973) found that the planktonic larvae reared at 10°C metamorphosed in about 60 d when they were about 200 μm in length. His attempts to ripen clams out of season met with limited success.

Merrill et al. (1969) stated that it is not possible to estimate the age of adults. However, obvious annual rings indicate that commercial size individuals are over 10 yr old. Thompson[7] suggested that this species may even live over 60 yr, an estimate based on refined growth ring analysis.

ADDITIONAL INFORMATION: In laboratory tanks and in the sea, it has been shown that *A. islandica* can exhibit a high degree of respiratory independence under hypoxic conditions. Under these conditions, the periods the clam spends at the surface alternate with periods when it is buried several centimeters below the surface of the sand, during which the animal respires anaerobically. There is no obvious rhythmicity to this behavior; the durations of periods spent beneath the surface are variable, even in the same animal, but they normally last between 1 and 7 d. As in other species studied, respiratory independence in *A. islandica* increases markedly with increasing body size and can also be modified by temperature and physiological condition (Taylor and Brand 1975a, b; Taylor 1976).

The ocean quahog industry has developed more slowly than that of the surf clam, *Spisula solidissima*. It was not until the 1970's that a vigorous commercial ocean quahog fishery developed, primarily to supplement diminishing supplies of the more desirable surf clams.

Cerastoderma pinnulatum (Conrad, 1831)

DESCRIPTION: Northern dwarf cockle; 0.6–1.3 cm in length, thin, with 22–28 wide, flat ribs which have delicate, arched scales on the anterior slope of the shell. Exterior cream colored, interior glossy and white (Abbott 1974). Cockles are active animals, with larger species able to leap several inches off the bottom (Abbott 1968).

DISTRIBUTION: Labrador to off North Carolina (Abbott 1974).

HABITAT: Because of their very short siphons, cockles must live near the surface of the substrate and consequently are affected by shifting sands and, in shallow water, by great temperature changes. They are commonly collected from 6 to 183 m (Abbott 1968, 1974). Franz (1976) stated that *Cerastoderma pinnulatum* is characteristic of coarse sand in Long Island Sound.

In the apex of the New York Bight, *C. pinnulatum* was collected from depths of 22–37 m. It occurred in all sediment types but was most common in high organic fine sands (Fig. 19; Table 1).

FEEDING ECOLOGY: *C. pinnulatum* possesses short separate siphons and feeds on organic matter suspended in water (Sanders

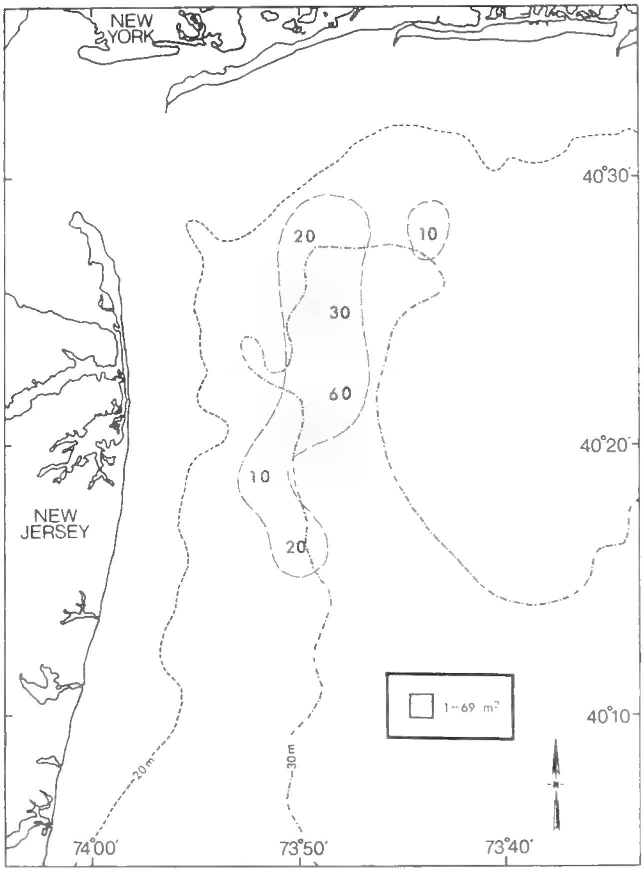

Figure 19.—Distribution and abundance of *Cerastoderma pinnulatum* in the New York Bight apex.

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[7] Ida Thompson, Princeton University, Princeton, NJ 08540, pers. commun. October 1979.

1956). Wigley (1956) reported that *C. pinnulatum* is the main prey item of haddock.

REPRODUCTION AND GROWTH: Cockles grow steadily except during the coldest months. Most are hermaphroditic (Abbott 1968).

Pitar morrhuanus Linsley, 1848

DESCRIPTION: Morrhua Venus clam; 2.5–3.8 cm in length, oval-elongate, moderately plump; numerous heavy lines of growth. Color dull-grayish to brownish red (Abbott 1974).

DISTRIBUTION: Gulf of St. Lawrence to North Carolina (Abbott 1974).

HABITAT: Fairly common; dredged from sand at 6–183 m (Abbott 1968).

In the New York Bight apex, *Pitar morrhuanus* was collected from depths between 19 and 37 m. It inhabited all sediment types but was most common in fine sands; total counts in high and low organic areas were almost equal, however, the largest concentration of *P. morrhuanus* was found at a high organic station. *Pitar morrhuanus* was the third most abundant bivalve, after *Nucula proxima* and *Tellina agilis*, collected in the Bight apex (Fig. 20; Table 1).

FEEDING ECOLOGY: *P. morrhuanus* is a suspension feeder, drawing in food-laden seawater. Young Veneridae, including *P. morrhuanus*, are important food sources of both the blue, *Callinectes sapidus*, and green, *Carcinus maenas*, crabs and the drilling moon snails, *Polinices* spp. (Abbott 1968).

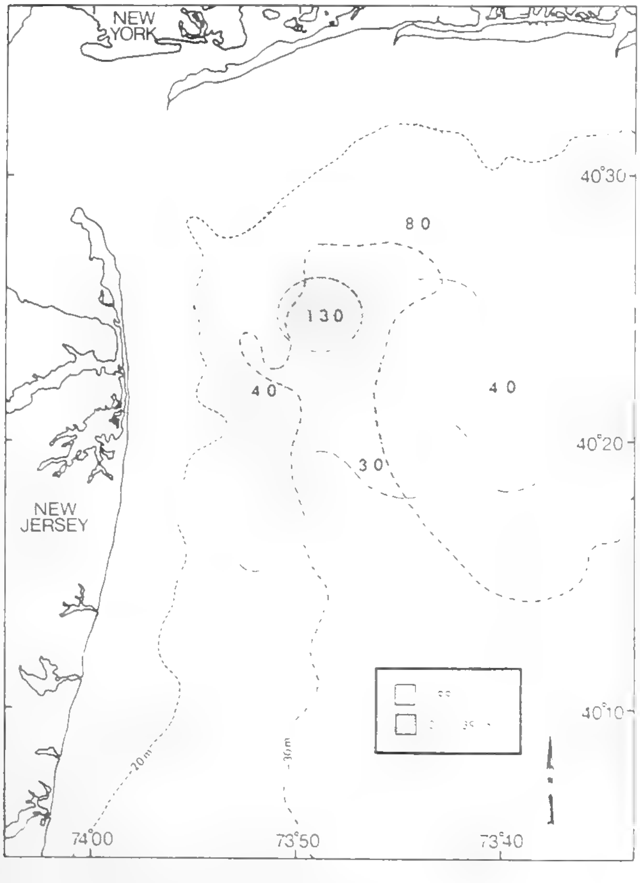

Figure 20.—Distribution and abundance of *Pitar morrhuanus* in the New York Bight apex.

REPRODUCTION AND GROWTH: The Veneridae are prolific and are adapted to survival under difficult conditions. Sexes are separate and fertilization is external (Gosner 1971). In general, they spawn when the tide is out and usually during a part of the month when the tidal fluctuation is small. The larvae swim and crawl over the bottom until a suitable mud-covered, hard surface is found. They then secrete a byssus and remain attached for about a week until siphons develop (Abbott 1968).

Spisula solidissima (Dillwyn, 1817)

DESCRIPTION: Atlantic surf clam; commercial size individuals are approximately 12–15 cm in length, the largest bivalve in the Middle Atlantic Bight. Shell is strong, oval and smooth except for light irregular growth lines; color is yellowish white with a thin yellowish brown periostracum (Abbott 1974). Over 70% of all clams harvested in North America are the Atlantic surf clam from the Middle Atlantic Bight.

DISTRIBUTION: Nova Scotia to South Carolina (Abbott 1968).

HABITAT: The surf clam is common below the low water mark on ocean beaches. After violent winter storms, they are cast ashore in numbers estimated as high as 50 million clams along a 10 mi stretch (Abbott 1974). NMFS surveys show *Spisula solidissima* to be abundant north of Hudson Channel in depths of not more than 18 m. It also occurs on coarse bottoms of Georges Bank. From New Jersey south, populations extend to depths of 46 m. Very dense beds at an average depth of 12 m occur off Point Pleasant and Cape May, N.J. The beds of the Delmarva Peninsula form a bank 24–28 km off the coast at a depth of 27–35 m, and currently support the bulk of the U.S. fishery.

Abundance of this clam is strongly correlated with coarse sediments. Parker (1967) and Parker and Fahlen (1968) reported that catches in gravel were 2.5 and 2 times those in sand, and 5.5 and 3 times those in silt-clay. Their size and burrowing ability give them advantages over other bivalves in unstable sediments.

In the New York Bight apex, primarily juvenile *S. solidissima* were collected in depths between 9 and 25 m. They were most abundant in medium and fine low organic sands. Very few occurred in coarse sand and none occurred in silt or high organic areas (Fig. 21; Table 1).

Wass (1965) stated that *S. solidissima* only occurs at salinities $>28‰$ under natural conditions, but may be able to tolerate much lower salinities. Schechter (1956) placed the minimum tolerance of both eggs and sperm of *S. solidissima* at "40% seawater" or about 15‰. Eggs in the polar body stage, however, disintegrate at this salinity. In laboratory experiments, Castagna and Chanley (1973) found that some surf clams survived direct transfer to salinities between 15 and 30‰. After acclimation, many survived salinities as low as 10‰. The authors believe that *S. solidissima* does not inhabit the lower extremes of its potential salinity range because of larval predation, not salinity intolerance. They state that when larvae of this species colonize inshore areas, they rarely develop because of intense predation by crabs, carnivorous gastropods, and bottom-feeding fish; this prevents the establishment of permanent populations of *S. solidissima* in estuarine areas.

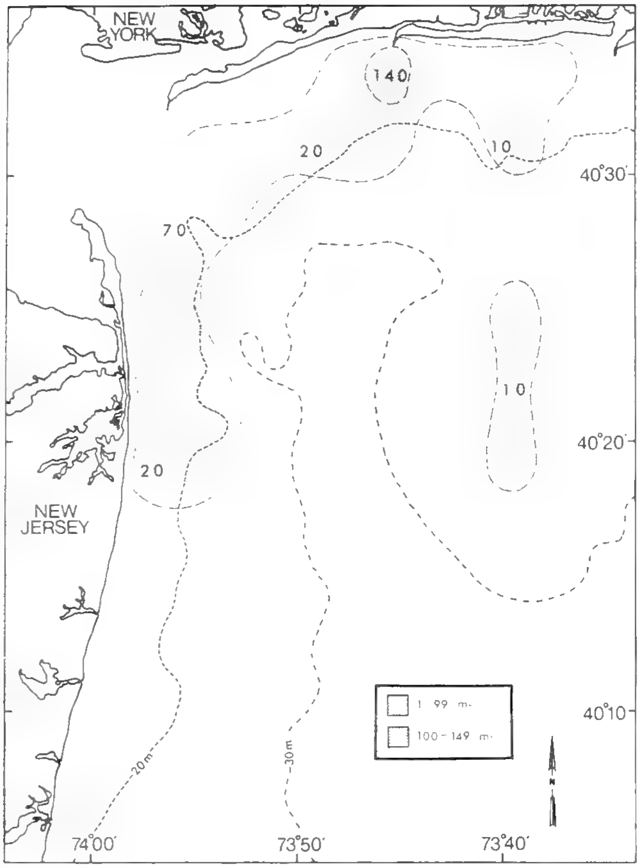

Figure 21.—Distribution and abundance of *Spisula solidissima* in the New York Bight apex.

FEEDING ECOLOGY: *S. solidissima* is a filter feeder; it lies near the sediment surface and extends short, fused siphons into the water. Stephens and Schinske (1961) reported that their experiments with *S. solidissima* indicate that, during a 16-h period, the removal of the amino acid glycine from solution took place in the mantle cavity of adult surf clams with an efficiency of 87%; the ecological significance of this remains to be fully examined. The food of larval *S. solidissima* consists of diatoms, green algae, and naked flagellates (Hirano and Oshima 1963).

Surf clams, when under stress of crowding or predator attack, may come to the surface and perform leaps of several feet. Predators of this clam include the moon snails, *Lunatia heros*, in deep water, and *Polinices duplicatus*, in shallow water. Smaller surf clams provide food for fish, including cod and haddock, and for diving ducks (Saila and Pratt 1973). Franz (1977) compared the size distribution of *S. solidissima* valves with and without bore holes of *L. heros*. In specimens collected off Long Island, he found that predation by *L. heros* is largely limited to clams <80 mm in size and under 5 yr of age. However, older and larger clams are not completely immune to attack, since bored valves to 160 mm in length were occasionally observed.

Thorson (1957) stated that communities where *Spisula elliptica* is dominant may have extremely high productivities; in European waters, these areas are growth centers for young flounder. The yield to man of *S. solidissima*-dominated bottoms in terms of fish food is probably lower in the Middle Atlantic Bight because much of the area where *S. solidissima* is most abundant is south of the range of the mass marketed groundfish such as cod, haddock, and yellowtail flounder.

REPRODUCTION AND GROWTH: According to Ropes (1968), sexes are separate in *S. solidissima* and it has been reported that two annual spawnings occurred in three successive years off New Jersey, a major one from mid-July to August and a minor one in mid-October to November. In a cool year (1965), a single spawning was observed during September and October (Ropes et al. 1969). Larvae took 19 d to reach setting size in the laboratory at 22°C (Loosanoff and Davis 1963).

Initial growth is rapid and clams can grow to 4.4 cm by the end of their first year (Yancey and Welch 1968). Clams reach commercial size of about 12.5 cm in 5–6 yr after which they grow at a much slower rate for as long as 17 yr. Maximum length is only 7.5–10 cm for specimens off Cape Cod but is about 17.5 cm for those off Long Island and to the south.

ADDITIONAL INFORMATION: The modern fishery which developed after World War II utilizes highly developed, efficient hydraulic dredges. Yearly landings of surf clam meats for 1978 off New Jersey totaled 6,904 t, which sold at a price of about $1,093/t (Current Fisheries Statistics 1978). This was a drop from 5 yr before when total New Jersey landings were 9,792 t, which sold for a low price of about $277/t (Current Fisheries Statistics 1973). Much of the stock in the New York Bight apex is closed to fishing by the U.S. Food and Drug Administration because of bacterial and chemical contamination.

The surf clam is particularly well adapted to withstand mechanical stress, however, little is known about its ability to withstand other types of stress, either as larvae or adults. For example, during the 1976 New York Bight oxygen depletion phenomenon, thousands of *S. solidissima* were found dead during surveys, with some recolonization by juveniles reported in the summer of 1977 (Steimle and Sindermann 1978; Steimle and Radosh 1979).

Tellina agilis Stimpson, 1857

DESCRIPTION: Northern dwarf tellin; 0.8–1.3 cm in length; moderately elongate, compressed, fairly fragile; glossy-white to rose externally with an opalescent sheen. External sculpture of faint, microscopic concentric, impressed lines (Abbott 1968, 1974).

DISTRIBUTION: Gulf of St. Lawrence to Georgia (Abbott 1974).

HABITAT: Common; in sandy mud, 0.9–45 m (Abbott 1968). In Long Island Sound, Franz (1976) found *Tellina agilis* to be characteristic of medium sand. In samples taken near the mouth of Delaware Bay, *T. agilis* was among the three most numerous species collected, occurring in the transition zone between pure sand and mud facies (Kinner et al. 1974). In Delaware's coastal waters, it was the most abundant and frequently occurring bivalve in clean medium-coarse sand (Maurer, Leathem, Kinner, and Tinsman 1979). The occurrence of *T. agilis* in large numbers throughout a wide sediment range indicates that it has a broad tolerance for sediment particle size.

Wass (1965) has determined that *T. agilis* prefers salinities $>18‰$ under natural conditions. However, in the laboratory, it tolerates a wide salinity range (2.5–30‰). In nature, it may not inhabit its potential salinity range because of biological interactions such as predation, competition from other species, or special environmental requirements, i.e., high levels of dissolved oxygen, low levels of suspended sediments, suitable bottom type, etc. (Castagna and Chanley 1973).

Tellina agilis was found at almost all stations sampled in the New York Bight apex. Although it tolerated a wide range of sediment types, it was most characteristic of fine or medium grain, low organic sands. *Tellina agilis* was the second most abundant bivalve in our samples, following *Nucula proxima* (Fig. 22; Table 1).

FEEDING ECOLOGY: Tellin clams have two long, slender siphons, which can be extended several times the length of the shell, permitting the clams to live well below the surface of the sand, while deposit feeding on the sediment surface. The large foot is suitable for rapid and deep burrowing and the clams travel extensively under the sand, both vertically and horizontally (Abbott 1968). Stomach analyses show that *T. agilis* feeds largely on diatoms and detritus (Sanders et al. 1962; Levinton 1972; Levinton and Bambach 1975). Kinner et al. (1974) stated that they may occasionally be suspension feeders. This dual feeding mechanism may explain the occurrence of *T. agilis* in a wide range of sediment types.

It has been found that the movement of siphons of *Tellina* spp. may attract visual predators such as the commercially important winter flounder, *Pseudopleuronectes americanus* (Gilbert 1970; Gilbert and Suchow 1977). Edwards et al. (1970) have shown that in Scotland, small flounder, *Pleuronectes platessa*, obtain a large part of their food by preying on siphons of *Tellina tenuis* da Costa, which can later be regenerated. However, more studies are needed to determine the importance of *T. agilis* siphons in the diet of young winter flounder.

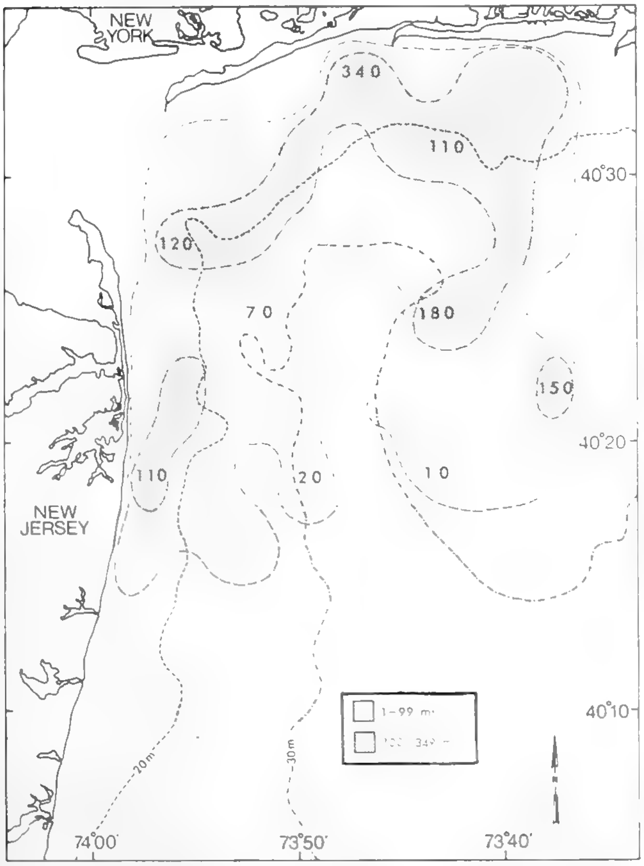

Figure 22.—Distribution and abundance of *Tellina agilis* in the New York Bight apex.

REPRODUCTION AND GROWTH: Sexes are separate and fertilization is external (Gosner 1971). The larvae of *T. agilis* are planktotrophic with a long pelagic development. Time to maturity is unknown (Sullivan 1948; Boss 1966).

***Ensis directus* Conrad, 1843**

DESCRIPTION: Atlantic jackknife clam; up to 25 cm in length; six times as long as high, moderately curved with sharp edges. Shell white, covered with a thin, varnish-like brownish-green periostracum (Abbott 1974). In its undisturbed state, *Ensis directus* occupies a vertical position in its burrow with an inch or two of shell exposed. When disturbed, it burrows rapidly to safety propelling itself by releasing jets of water around the base of the foot; it is also a capable swimmer (Drew 1907; Abbott 1968).

DISTRIBUTION: Labrador to South Carolina, Florida (Abbott 1974).

HABITAT: Common on sand flats of New England, but subtidal beds in sandy mud at depths of 3–9 m are not uncommon (Abbott 1974). In Long Island Sound, Franz (1976) found *E. directus* to be characteristic of the medium sand assemblage. In Virginia, it is an intertidal and subtidal form found in waters above 20‰ salinity (Wass 1965). Under experimental conditions, however, Chanley (1969) found that *E. directus* could be acclimatized to survive at 7.5–28‰, however, a rapid salinity change of 15‰ within this range was lethal.

In the New York Bight apex, *E. directus* occurred in low abundance, $10/m^2$, at each of six stations, in depths ≤ 28 m. It was present, almost exclusively, in low organic medium and fine sands (Fig. 23; Table 1).

FEEDING ECOLOGY: *E. directus* is a suspension feeder (Wigley 1968). It is a food item for man as well as for invertebrates. McDermott (1976) stated that *Cerebratulus lacteus* (a nemertean worm) feeds on *E. directus* by entering its burrow from below and engulfing the anterior end of the bivalve. This predation was observed from New Jersey to North Carolina. *Polinices duplicatus* (a moon snail) captures *E. directus* by approaching it below the surface of the substratum and irritating its lower portion so that the clam retreats upward. The snail then coats the razor clam with an envelope of slime which appears to have an anesthetic property. Successful capture probably depends on the ability of the snail to maintain contact with its prey until anesthesia has taken place (Turner 1955).

REPRODUCTION AND GROWTH: According to Williams and Porter (1971), planktonic juvenile *E. directus* occur abundantly from December to June in North Carolina. They exhibit long pelagic development with time to maturity unknown (Turner 1953).

ADDITIONAL INFORMATION: McCall (1977) characterized *E. directus* as an "equilibrium" species, i.e., it is present early in colonization, but remains at low and constant abundance. Relative to more opportunistic species, equilibrium species exhibit slow development, few reproductions per year, low recruitment, and low death rate.

Saila and Pratt (1973) stated that although the razor clam is abundant along the east coast, it has not been exploited commercially as on the west coast. Scattered fisheries for local markets in Massa-

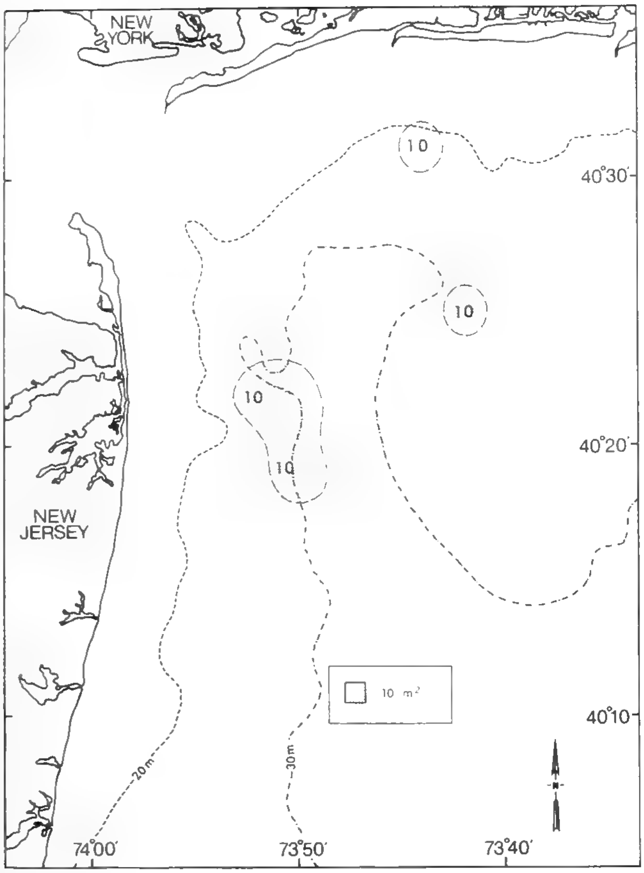

Figure 23.—Distribution and abundance of *Ensis directus* in the New York Bight apex.

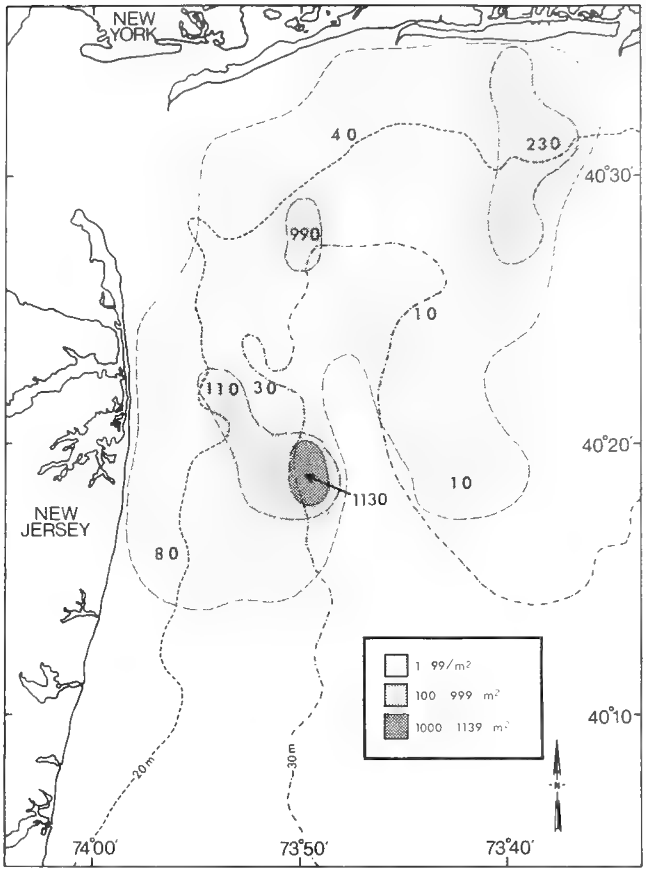

Figure 24.—Distribution and abundance of *Polygordius triestinus* in the New York Bight apex.

chusetts and New York and recreational clamming account for the east coast harvest.

Phylum Annelida

Class Polychaeta

Order Archiannelida

Polygordius triestinus Hempelmann, 1906

DESCRIPTION: *Polygordius triestinus* is a member of a group called the archiannelids, a heterogeneous assemblage of small worms that have been considered either derivatives of several polychaete families or specialized relicts of the ancestral polychaete stock. *Polygordius triestinus*, adapted for interstitial life, is a very slender worm, lacking obvious external annulation, eyes, and setae. Its only appendages are two cylindrical tentacles projecting from the head and two cirri projecting from the pygidium. Gosner (1971) reported them to be ≤ 15 mm in length; Fauvel (1927) reported them reaching lengths up to 30 mm.

DISTRIBUTION: Very little is known about the distribution of this species, however, Gosner (1971) classified it as a Virginian species, occurring from Cape Cod to Cape Hatteras.

HABITAT: An unidentified species of *Polygordius* was the most abundant macrobenthic species in clean medium grain sand off the Delmarva Peninsula (Maurer et al. 1976). Figure 24 and Table 1 indicate that *P. triestinus* was generally associated with sandy (primary medium-grain) sediments with low to medium organic content in the New York Bight apex.

FEEDING ECOLOGY: The antennae of this genus are actively cast about in front of it as it crawls along, very much as in some of the spionid polychaetes. Similarly, *Polygordius* spp. are deposit feeders (Hermans 1969).

REPRODUCTION AND GROWTH: Fauvel (1927) believed *P. triestinus* to be hermaphroditic. However, hermaphroditism in this species is doubted by Schroeder and Hermans (1975) because they believe that the coexistence of eggs and sperm observed in a single individual by Hempelmann (1906) was the result of fertilization, as has been shown in another archiannelid, *Protodrilus* sp. by Jägersten (1952). Gosner (1971) also reported sexes to be separate in most archiannelids. Salensky (1907) pointed out that some species of *Polygordius* released their eggs by a breaking off of the posterior end of the spawning adult. He suggested that such behavior may represent the origin of epitoky and stolonization found in a number of polychaete families. MacBride (1914) and Hermans (1969) stated that *Polygordius* spp. exhibit the primitive pattern of polychaete development by producing well developed planktotrophic trochophore larvae.

Order Phyllodocida

Phyllodoce (Anaitides) arenae Webster, 1879

DESCRIPTION: An active, crawling, mucus-secreting form, which moves freely over the sediment surface or swims. Dorsal surface with dark transverse bands; length to 100 mm, width to 2.5 mm, segments to 200 (Pettibone 1963).

DISTRIBUTION: Maine to North Carolina (Gardiner 1975).

HABITAT: Coarse to muddy sand mixed with some shell fragments, intertidal to 195 m (Pettibone 1963; Gardiner 1975). In the New York Bight apex, *Phyllodoce arenae* occurred primarily in fine to medium, low organic sandy substrates and was sparsely represented in coarse sands, silt, and medium to high organic areas (Fig. 25; Table 1).

FEEDING ECOLOGY: Their active habits and well-developed eyes imply that all phyllodocids are carnivorous, but no form of prey or plant remains has ever been found in the gut of *P. arenae* (Pettibone 1963; Day 1967). A closely related species, *Phyllodoce maculata*, is predaceous, attacking and devouring other polychaetes and nemerteans, being itself protected, to some extent, by its abundant, offensive mucus (Pettibone 1963).

REPRODUCTION AND GROWTH: *P. arenae* has been found swarming at the water surface in June, July, and August in Woods Hole, Mass., however, they are not epitokous. Many phyllodocids lay their greenish-colored eggs in gelatinous masses. The larvae of *P. arenae* may have a long pelagic existence as do those of several other species of *Phyllodoce* (Thorson 1946; Pettibone 1963).

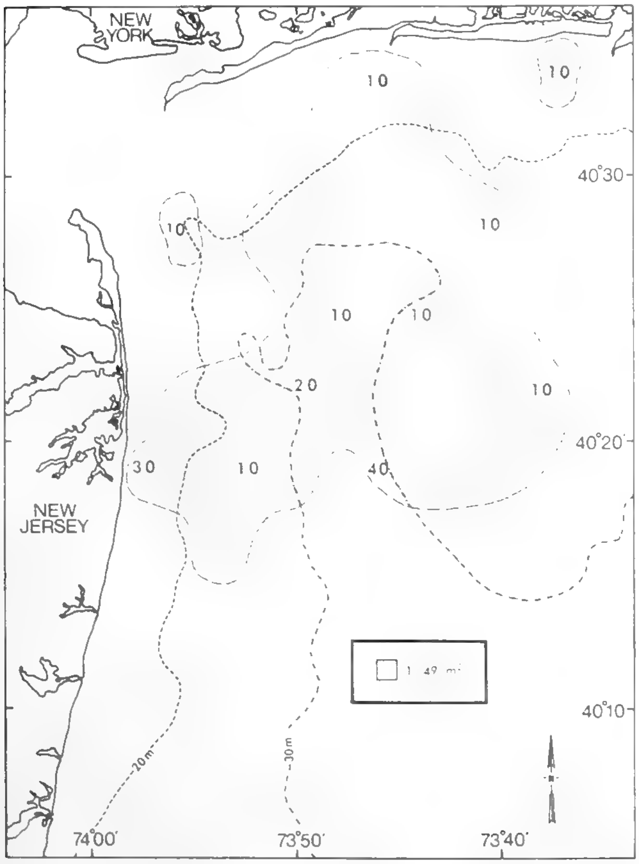

Figure 25.—Distribution and abundance of *Phyllodoce arenae* in the New York Bight apex.

ADDITIONAL INFORMATION: McLusky and Phillips (1975) studied the effects of copper on *P. maculata*. They found the threshold of toxicity of copper in seawater to this polychaete to be approximately 0.08 ppm. In a 1.00 ppm solution, worms accumulated 437.5 ppm copper within 2 d, after which death occurred. Higher accumulations, reaching 567.8 ppm, were found in worms which had been exposed to 0.06 ppm concentrations for 3 wk with no obvious side effects. This suggests that it is not the amount of copper contained in tissues which results in death, but some other factor such as rate of uptake. At lower rates of uptake, the animals may be able to cope by depositing the copper in the tissues or possibly by excreting it through the nephridial system. In a 0.08 ppm solution (the lethal concentration), the rate of uptake corresponds to an increase of about 25 ppm of copper per day, which is probably the critical rate of uptake.

Eteone longa (Fabricius, 1780)

DESCRIPTION: A slender-bodied burrowing form; length to 160 mm, width to 5 mm, segments to 200 (Pettibone 1963).

DISTRIBUTION: Widely distributed in the Arctic, also Iceland, Norway to English Channel, Hudson Bay to off North Carolina, Chukchi Sea to Mexico, north Japan Sea, China (Pettibone 1963; Reish 1965).

HABITAT: Found at low water in mud flats, muddy sand, sand, gravel, under stones, eelgrass. Also found in depths to 1,668 m in sandy mud, sand and shells, and in various combinations of soft mud, sand, gravel, pebbles, rocks, shells, and worm tubes (Pettibone 1963). In the New York Bight apex, *Eteone longa* was found in all sediment types in depths ≥14m, but was found in highest concentrations in high organic, silty-fine sand areas (Fig. 26; Table 1). Seasonal distributions were almost identical.

FEEDING ECOLOGY: Because of their active nature and well-developed eyes, it has been assumed that all phyllodocids are carnivores. Khlebovich (1959, cited in Fauchald and Jumars 1979) reported that *E. longa* feeds exclusively on the spionid polychaete, *Spio filicornis*; Michaelis (1971) found the same species to feed exclusively on another spionid polychaete, *Scolelepis squamata*, however, Retière (1967) found *E. longa* to be less selective, feeding on a variety of small metazoans.

Wigley (1956) stated that phyllodocids, in general, are among the most important foods of small (14–30 cm) Georges Bank haddock.

REPRODUCTION AND GROWTH: Pettibone (1963) reported that some specimens of *E. longa* were filled with yolky eggs during April 1954 in Rye Harbor and Hampton Harbor, N.H. According to Thorson (1946), the eggs are spawned in irregular, slimy masses and the larvae have a relatively short planktonic existence. In the Danish Isefjord, Rasmussen (1956, 1973) observed adults of *E. longa* swimming actively near the surface of the water in April and May, where eggs of 110 μm diameter were spawned. Planktonic larvae were found from late April to late May. The species is also known to reproduce at this time of year in England (Meek and Star-

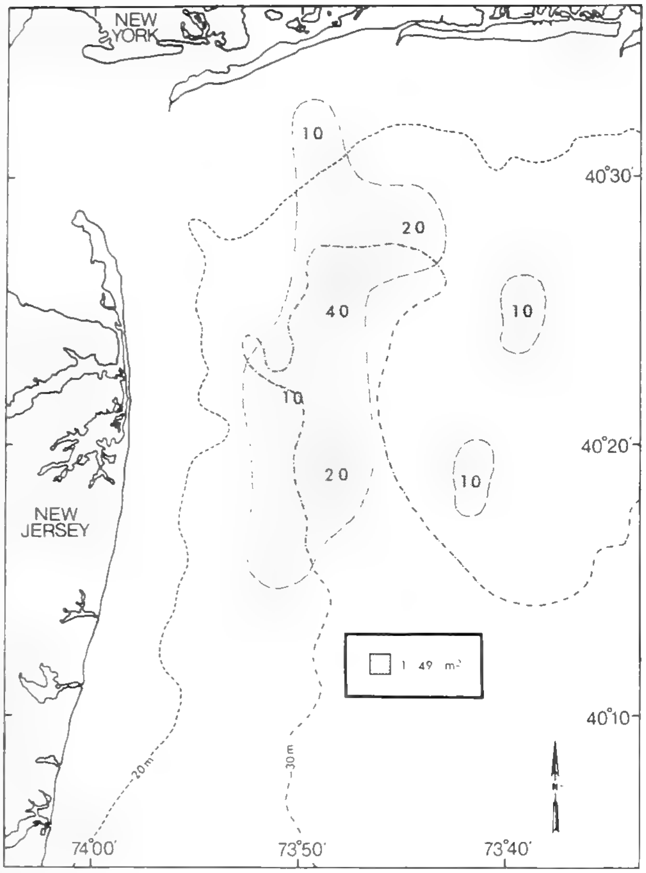

Figure 26.—Distribution and abundance of *Eteone longa* in the New York Bight apex.

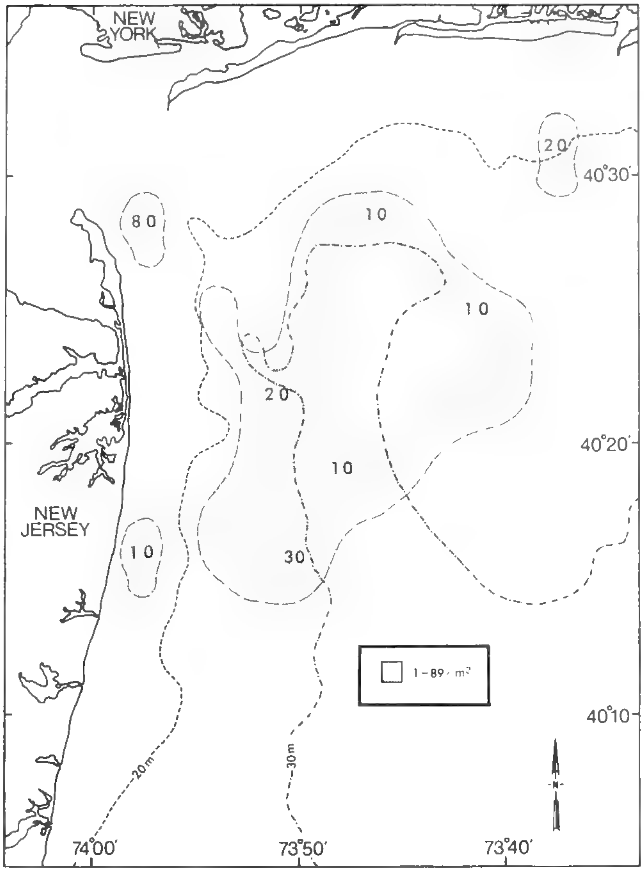

Figure 27.—Distribution and abundance of *Harmothoe extenuata* in the New York Bight apex.

row 1924). Rasmussen (1956, 1973) reported observing large numbers of young *E. longa* swimming in a warmer (12°C) backwater of a creek in East Jutland (Denmark), while mature adults in an adjacent colder portion (10°C) remained in the mud, indicating a possible correlation between temperature and spawning.

On the basis of living material, Rasmussen (1973) reported that *E. longa* is mature at a length of 20 mm (males) or 30 mm (females) in the Isefjord.

Harmothoe (Lagisca) extenuata (Grube, 1840)

DESCRIPTION: A crawling form, dorsal surface covered with elytra (scales). Body depressed, length to 74 mm, width including setae to 20 mm, segments 37–47.

DISTRIBUTION: Widely distributed in the Arctic. Also Iceland, Faroes, Norway to Mediterranean and Adriatic, Hudson Bay to Chesapeake Bay, North Carolina, Bering Sea to southern California, north Japan Sea, South Africa (Pettibone 1963; Gardiner 1975).

HABITAT: *Harmothoe extenuata* appears to have great powers of dispersal and adaptation, occurring from the intertidal to 1,830 m; euryhaline. It is often associated with two other common northern polynoids, *Lepidonotus squamata* and *Harmothoe imbricata* (often confused with *H. extenuata*). Intertidally, it is found under rocks, in tide pools with algae, sponges, etc.; on fronds of kelp; on pilings among mussels, tunicates, sponges, hydroids, etc.; abundant in beds of *Mytilus edulis*. *Harmothoe extenuata* is dredged on all types of bottom (Pettibone 1963). Our New York Bight apex data agree with these observations in that *H. extenuata* occurred, usually in small numbers, in all sediment types ranging from coarse sand to silt, with high to low organic levels (Fig. 27; Table 1).

FEEDING ECOLOGY: *H. extenuata* possesses a large proboscis, armed distally with two pairs of amber-colored interlocking jaws. They are slow-moving predators and, despite their strong jaws, feed on small prey (Pettibone 1963; Day 1967).

REPRODUCTION AND GROWTH: Reproductive strategies of *Harmothoe* spp. are variable.

In New Hampshire, female *H. extenuata* with coral-pink eggs inside the body were found in April 1954; other females were observed with eggs extruded and carried between the parapodia and on the ventral surface (Pettibone 1963).

Curtis (1977) observed that gametogenesis of *H. imbricata* (a closely related species) occurred in Greenland throughout autumn and winter with spawning activity confined to spring (March–May). Ripe, large eggs (150–180 μm) were richly supplied with yolk granules at spawning time. Maturity was reached at a length of 9–10 mm, with animals attaining a mean size of 6, 12, and 18 mm after their first, second, and third years of life, respectively; most individuals underwent reproductive development during their second year.

A population of *H. imbricata* at Arcachon, France, is described as having a completely planktonic larval development (Cazaux 1968), and Blake (1975) has also observed planktonic larvae on the California coast, where the species broods eggs of 120–123 μm diameter, releasing them into seawater after the trochophore larvae have developed.

The size of mature oocytes in the study by Curtis (1977) in Greenland was similar to that found for *H. imbricata* in the Isefjord, Denmark, where they measured 150 μm (Rasmussen 1956). In the Isefjord, the species spawns in winter and produces typical trochophore larvae with a pelagic phase after intial brooding under the female elytra. However, egg size for *H. imbricata* is variable and Rasmussen cited other observations ranging from 50 to 76 μm. It is postulated that such small ova probably give rise directly to pelagic planktotrophic larvae without any early protection of the embryos.

Daly (1972, 1974) stated that *H. imbricata* is capable of completing its life cycle in a single year in British waters, where all survivors of a new year class apparently spawned at the end of their first year. The smallest specimens in the population at the time had reached a size of 9 mm, which closely coincides with the minimum size reported for the Greenland population (Curtis 1977). Each female underwent two successive spawnings, about 1 mo apart, releasing large oocytes (140–160 μm) to be brooded beneath the elytra.

Sthenelais limicola (Ehlers, 1864)

DESCRIPTION: A burrowing form, with dorsal surface covered with translucent elytra (scales). Length to 100 mm, width including setae to 4 mm, segments to 200 or more (Pettibone 1963).

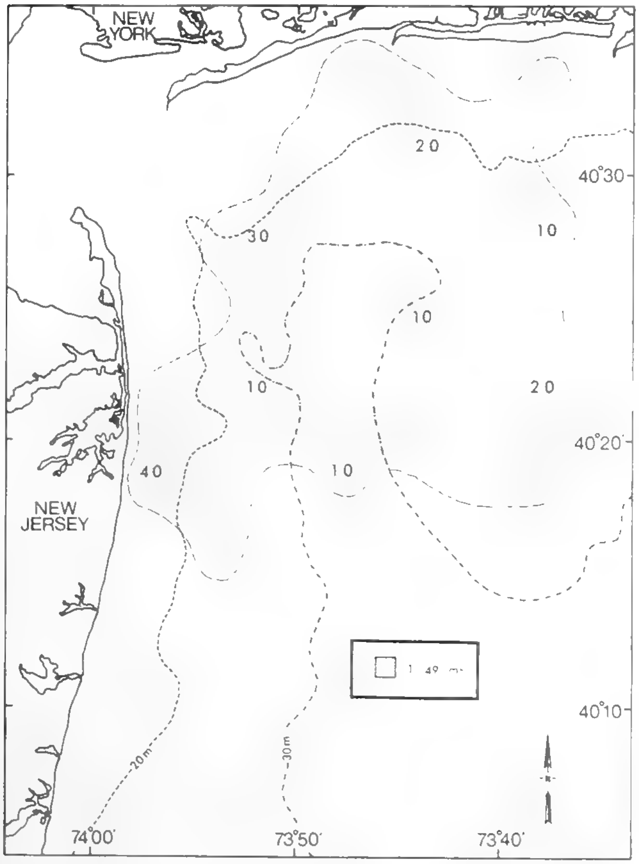

Figure 28.—Distribution and abundance of *Sthenelais limicola* in the New York Bight apex.

DISTRIBUTION: Gulf of St. Lawrence to North Carolina, Norway to Mediterranean, Adriatic, South and West Africa (Pettibone 1963).

HABITAT: Collected on sandy or muddy bottoms from the intertidal to 770 m (Pettibone 1963; Gardiner 1975). Kinner (1978) found *Sthenelais limicola* to be one of the dominant species in sand on the inner and mid-shelf from Georges Bank to Cape Hatteras. In the New York Bight apex, *S. limicola* was collected in all sediment types, usually in low numbers. It was most abundant in medium to fine, low organic sands (Fig. 28; Table 1).

FEEDING ECOLOGY: Members of this family (Sigalionidae) are, in general, burrowing predators (Day 1967). They are eaten by cod, flounder (McIntosh 1900), and haddock (Wigley 1956).

REPRODUCTION AND GROWTH: No information specific to the genus *Sthenelais* is available. Brooding among the Sigalionidae has not been reported as it has been for other scale worms of the family Polynoidae (Schroeder and Hermans 1975).

Glycera dibranchiata Ehlers, 1868

DESCRIPTION: Commonly known as the "bloodworm," a commercially valuable bait worm. Active burrowers; length to 510 mm (Klawe and Dickie 1957).

DISTRIBUTION: Gulf of St. Lawrence to West Indies, Gulf of Mexico, central California to the Pacific coast of Mexico (Pettibone 1963; Hartman 1969; Gardiner 1975).

HABITAT: Intertidal to 400 m. Found at low water and collected in deeper water on bottoms of sand, mud, mud mixed with gravel, rocks, and particularly, mud rich in detritus. Found on more exposed beaches than *Glycera americana*, especially where currents flow swiftly; found in brackish waters and tidal estuaries (Pettibone 1963; Gardiner 1975). From Cape Cod to Cape Hatteras, Kinner (1978) found *Glycera dibranchiata* to be a dominant mid-shelf sand species. Kinner and Maurer (1978) regularly collected *G. dibranchiata* in Delaware Bay, with increasing numbers associated with sediments containing increasing amounts of silt-clay; Pearce, Caracciolo, Halsey, and Rogers (1977a) also found it to be abundant in New York-New Jersey outer continental shelf samples.

In the New York Bight apex, *G. dibranchiata* was found in depths ranging from 9.6 to 33.1 m. It was present in all grades of sand (none was found in silt), but was most abundant in fine sand. *Glycera dibranchiata* was absent or occurred in low numbers (10/m^2) in sediments having the highest organic content; it was most abundant in low organic sediments (Fig. 29; Table 1).

FEEDING ECOLOGY: *Glycera* spp. possess a strong, muscular, clavate proboscis, armed distally with four equally spaced large jaws. The proboscis serves glycerids as an organ of special sense, with a remarkably well-developed nervous system (Gravier 1898). Both Day (1967) and Fauchald (1977) agreed that glycerids appear to be mainly carnivorous, for very little sand is ever found in the gut; however, Sanders et al. (1962) believed glycerids to be omnivores. Klawe and Dickie (1957) classified them as detritus feeders and Adams and Angelovic (1970), in a feeding experiment using a radioactive tracer, carbon-14, also found detritus to be an important food source. Studies on *Glycera alba* showed them to be predaceous (Ockelman and Vahl 1970), possesing both proteolytic and

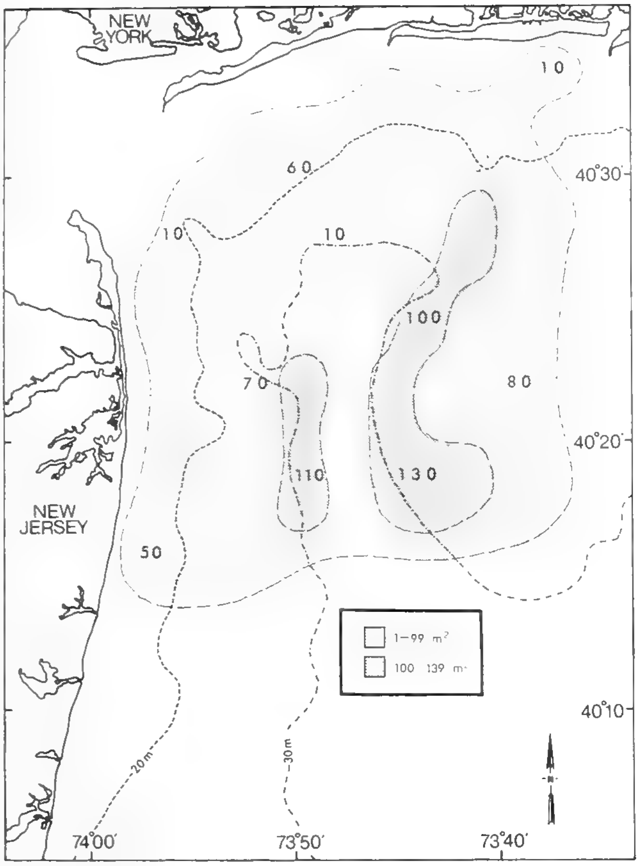

Figure 29.—Distribution and abundance of *Glycera dibranchiata* in the New York Bight apex.

lipolytic enzymes (Vahl 1976). On the basis of morphology, it may be postulated that glycerids are primarily carnivorous, but are capable of using other feeding modes under certain environmental conditions.

Spawning bloodworms are preyed on by herring gulls, *Larus argentatus*, and striped bass, *Morone saxatilis*, while spent epitokes are consumed by shrimp (*Crangon septemspinosa*) which, in turn, are eaten by striped bass (Creaser 1973). *Glycera dibranchiata* has also been found in the stomachs of haddock off Georges Bank (Wigley 1956).

REPRODUCTION AND GROWTH: The reproductive patterns of *G. dibranchiata* have been studied by several investigators. Klawe and Dickie (1957) made observations on a population of *G. dibranchiata* from Goose Bay at Wedgeport, Nova Scotia. They found that eggs and sperm began developing in late summer and were sexually mature by early April (fully developed eggs measured between 180 and 190 μm in diameter). The peak of spawning took place in mid-May; after spawning, remains of spent worms were found on the flats, appearing as "ghost worms," consisting of outer skin and atrophied digestive tract with everted proboscis. This indicated that life terminates after spawning (the spawning process itself was not observed). Eggs developed into planktonic larvae which, after a short time, transformed into bottom dwellers.

From an analysis of distribution of size classes in the population, Klawe and Dickie (1957) determined that most of the intertidal population lives for 3 yr and that they spawn before reaching the fourth year; a small fraction spawn when 4 or 5 yr old. Growth is most rapid during the second and third years, decreasing sharply thereafter.

In contrast, the study by Simpson (1962) showed *G. dibranchiata* to breed twice a year in Solomons, Md., during fall and during late spring or early summer as well. She observed swarming taking place over a moderately large area in shallow water during late afternoon on 5–8 November 1960. Her data suggested that the onset of swarming may be coordinated with tidal conditions. The pelagic larvae that were produced were nearly or fully indifferent to light in their early phases. Her other findings were in general agreement with those of Klawe and Dickie (1957).

Creaser (1973) studied a population of *G. dibranchiata* in Wiscasset, Maine. He found them to spawn annually in June, usually at an age of 3 or 4 yr. A bottom temperature in excess of 13°C seemed necessary for spawning to occur. Generally, between 2 h before and 1 h after high water in the afternoon, males emitted streams of sperm while swimming at the surface, while females swam rapidly at the surface and suddenly ruptured, liberating all eggs at once. Eggs usually measured 151–160 μm in diameter. Klawe and Dickie (1957) have calculated that a bloodworm measuring 22–24 cm may contain 1.5–2.0 million eggs. A Wiscasset bloodworm of this length would be expected to contain 3.0–3.5 million eggs. The emission of gametes in the Maine study was not, however, confined to surface waters. Creaser (1973) also observed a male in 3 m of water swimming in a vertical position just above the bottom emitting sperm.

All observations agree with the belief of Klawe and Dickie (1957) that all bloodworms die after spawning, with 5 yr the maximum life span. The size range of sexually mature bloodworms in Maine was between 18 and 51 cm (Creaser 1973); in Nova Scotia, 13–36 cm (Klawe and Dickie 1957); in Maryland, 7–26 cm (Simpson 1962). These geographical differences in size of bloodworms may be attributed to the effects of temperature on growth and maturity or possibly to differences in races of bloodworms. An interesting observation made by Klawe and Dickie (1957) was that *G. dibranchiata* does not grow in summer months. This finding is in direct contradiction to almost every other temperate or boreal invertebrate studied.

ADDITIONAL INFORMATION: *G. dibranchiata* is harvested extensively from the mud flats of Maine and other Gulf of Maine areas. There, it supports a multimillion dollar bait worm industry. In the New York Bight, it is not commercially harvested, but is collected by recreational fishermen.

Goniadella gracilis (Verrill, 1873)

DESCRIPTION: Active worms making temporary burrows in sand (Dales 1963). Length to 50 mm, width to 1 mm, segments to 100 or more (Pettibone 1963).

DISTRIBUTION: Massachusetts to Virginia; Irish Sea, Liverpool Bay, South Africa (Walker 1972; Day 1973).

HABITAT: Intertidal to 450 m (Day 1973). Found burrowing in fine sand at low water; collected on bottoms of fine gravel, fine to coarse sand and soft mud (Pettibone 1963; Walker 1972). *Goniadella gracilis* was one of the dominant species on the mid-continental shelf in the Delaware Bay region, associated with poorly sorted, coarse sediments (>1 mm) (Kinner and Maurer 1978), and was among the 15 most abundant taxa on Georges Bank in winter (Maurer and Leathem 1980). It was also abundant in some areas on the New York-New Jersey outer continental shelf (Pearce, Caracciolo, Halsey, and Rogers 1977a). In the New York Bight apex, *G. gracilis* occurred in depths ranging from 9.6 to 34.0 m. It was most abundant in coarse to medium sand with an organic content between 1.0 and 3.3%. It was not present in fine sediments with extremely high organic contents (Fig. 30; Table 1).

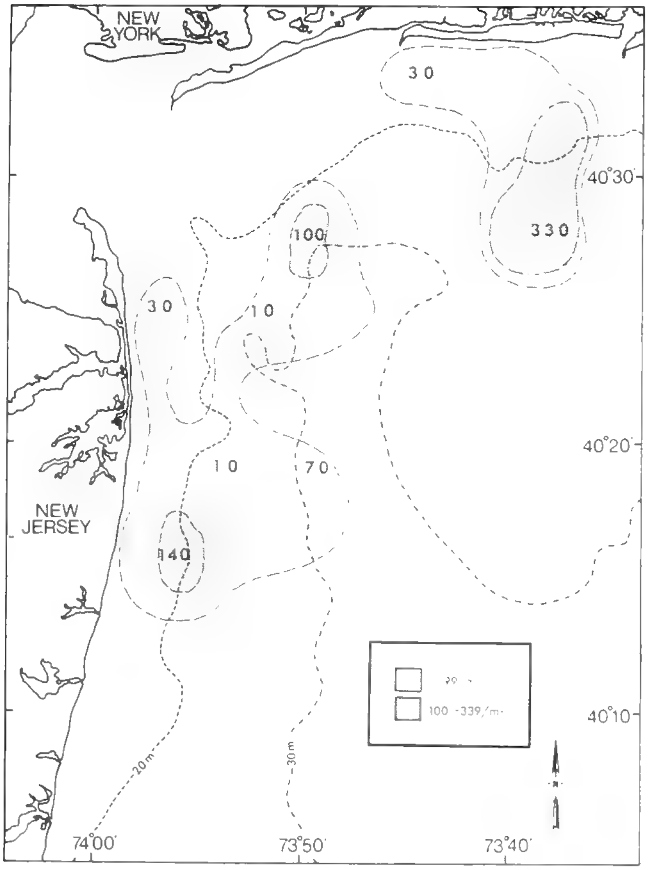

Figure 30.—Distribution and abundance of *Goniadella gracilis* in the New York Bight apex.

FEEDING ECOLOGY: The Goniadidae have well-developed jaws and probably most species are predators, or at least carnivores, for very little sand is ever found in the gut (Pettibone 1963; Day 1967).

Wigley (1956) reported that *G. gracilis* has been found in the stomachs of haddock off Georges Bank.

REPRODUCTION AND GROWTH: Pettibone (1963) reported that, when sexually mature, the Goniadidae may become modified into an epitokous swimming form. In the posterior region, where the sex products are formed, parapodial lobes become more elongate.

ADDITIONAL INFORMATION: During the 1976 anoxic event off the coast of New Jersey, *G. gracilis* was abundant at heavily impacted stations, implying a high tolerance of oxygen depletion (Steimle and Radosh 1979). This was unexpected because in the New York Bight apex samples, *G. gracilis* was rare in high organic areas; this species is also known to be characteristic of ridge environments (Boesch et al. 1977; Radosh et al. 1978[8]) in which anoxic episodes may be relatively rare.

Nephtys bucera Ehlers, 1868

DESCRIPTION: An active burrowing species, length to 300 mm, width to 20 mm, segments to 140 (Pettibone 1963).

DISTRIBUTION: Gulf of St. Lawrence to North Carolina, Gulf of Mexico (Pettibone 1963; Gardiner 1975).

HABITAT: Intertidal to 180 m; found at low water in sand bars, shifting sand, muddy sand, and collected from bottoms of sand and stones (Pettibone 1963; Gardiner 1975). *Nephtys bucera* was collected on the New York-New Jersey outer continental shelf (Pearce, Caracciolo, Halsey, and Rogers 1977a) as well as in the New York Bight apex, where it was found in all sediment types, particularly medium to fine grained low organic sand. *Nephtys bucera* was rarely found in high or medium organic content sediments (Fig. 31; Table 1).

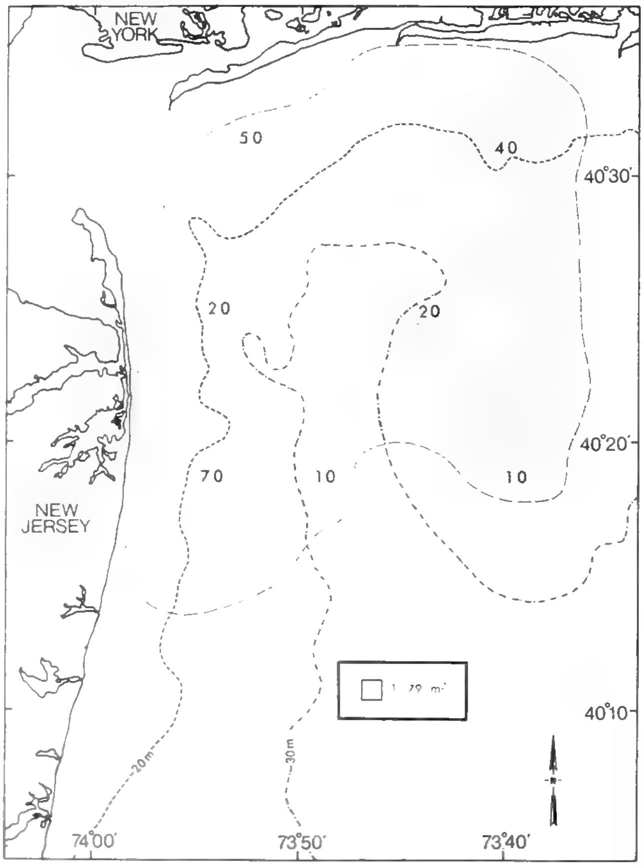

Figure 31.—Distribution and abundance of *Nephtys bucera* in the New York Bight apex.

FEEDING ECOLOGY: *N. bucera* is probably a surface deposit feeder and/or carnivore (see following account of *Nephtys incisa*).

REPRODUCTION AND GROWTH: No specific information was available for *N. bucera*, however, it is probable that they produce planktotrophic larvae (see *N. incisa*).

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[8] Radosh, D., A. Frame, T. Wilhelm, and R. Reid. 1978. Benthic survey of the Baltimore Canyon Trough, May 1974. Northeast Fisheries Center Sandy Hook Laboratory, Informal Rep. SHL 78-8, 133 p.

Nephtys incisa Malmgren, 1865

DESCRIPTION: A mobile, burrowing, large species, reaching a maximum length of 150 mm, width to 15 mm, segments to 75 (Pettibone 1963).

DISTRIBUTION: Greenland, Davis Strait, Ireland, Norway, Sweden, North Sea, Baltic to Portugal, Mediterranean, Gulf of St. Lawrence to Virginia, Chesapeake Bay, North Carolina (Pettibone 1963; Gardiner 1975).

HABITAT: Intertidal to 1,745 m; found on bottoms of soft or sticky mud, muddy sand, very fine or coarse sand, mud which contains gravel, shells, worm or amphipod tubes, or decaying debris (Pettibone 1963; Day 1967). Pettibone (1963) reported *Nephtys incisa* to be "the most common and abundant species on muddy bottoms along the New England coast, in bays and sounds as well as off the open coast." In these situations, it is usually associated with the bivalves *Nucula proxima* and *Yoldia limatula*, members of a distinct deposit-feeding soft bottom community (Sanders 1958, 1960). From Cape Cod to Cape Hatteras, Kinner (1978) found *N. incisa* to be a dominant on the mid-outer shelf in silt-clay. Pearce (1972) found *N. incisa* in greater abundance around sludge deposits in the New York Bight apex than in relatively unpolluted habitats.

In the present New York Bight apex study, *N. incisa* was present in all sediment types but was clearly most abundant in fine sand or silty areas having the highest percentages of sediment organic material (Fig. 32; Table 1).

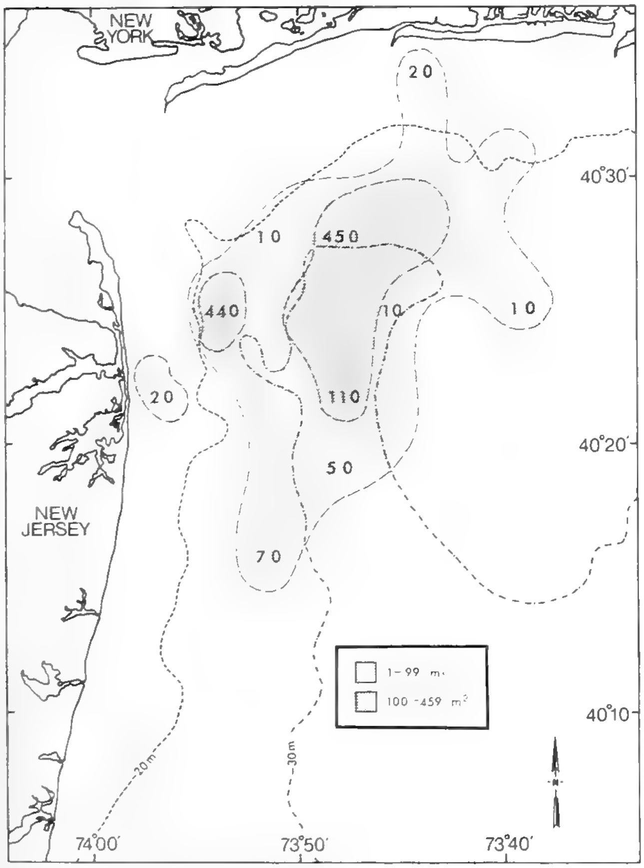

Figure 32.—Distribution and abundance of *Nephtys incisa* in the New York Bight apex.

FEEDING ECOLOGY: Until recently, it was thought that all nephtyids were strict carnivores, probably because they possess large jaws, but Sanders (1956, 1960) found *N. incisa* in Long Island Sound and in Buzzards Bay, Mass., to be nonselective deposit feeders. Sanders, however, did not deny that *N. incisa* was capable of acting as a carnivore under certain conditions. Conversely, Clark (1962) believed *N. incisa* is, at best, a facultative detritus feeder, primarily because its gut is almost always empty indicating a carnivorous diet and rapid digestion. Day (1967) believed them to be selective omnivores because they are found in such large numbers in certain areas.

Nephtys incisa is also important as a prey item. Wigley and Theroux (1965) found it to be a principal annelid, along with *Aphrodita hastata*, in the diet of haddock.

Tyler (1973) found Canadian specimens to have no seasonal trend in caloric value; the annual mean for *N. incisa* was 3,984 g cal/g dry weight.

REPRODUCTION AND GROWTH: *N. incisa* spawns year-round in Long Island Sound with peaks in early spring and late summer (Sanders 1956). Specimens of *N. incisa* with coral-pink eggs have been found in August in Massachusetts and young specimens of 28–32 segments have been found in August in Maine (Pettibone 1963). *Nephtys incisa* does not brood its young, but produces large numbers of planktotrophic larvae (10^3–10^6 per female) which undergo a long pelagic development. Time to maturity is unknown (Thorson 1946; Sanders 1956; Clark 1961, 1962).

Relative to more opportunistic species, *N. incisa* exhibits slow development, few reproductions per year, low recruitment, and low death rate. Because of these factors, because they do not brood developing young, and because they produce large numbers of planktotrophic larvae, they are classified as an "equilibrium" species, present early in colonization, but remaining at low and constant abundance (McCall 1977).

ADDITIONAL INFORMATION: There is some evidence, including that provided in this study, that *Nephtys* spp. are highly tolerant of some environmental stresses (Jones 1955; Weber 1971). They are also physiologically equipped for infrequent feeding and long periods of starvation (Clark 1964). Mobility and size could also aid these polychaetes in both escape from predators and migration to more favorable microenvironments.

Nephtys picta Ehlers, 1868

DESCRIPTION: A mobile species, length to 60 mm, width to 4 mm, segments to 100 (Pettibone 1963).

DISTRIBUTION: New England to Florida, Gulf of Mexico (Gardiner 1975).

HABITAT: Intertidal to 40 m (Pettibone 1963); 8–141 m, usually <50 m (Kinner 1978). Found at low water in muddy sand, sandy rubble, gravelly sand. Collected on bottoms of sand and muddy sand, with shells and sea weeds (Pettibone 1963). In the New York Bight apex, *Nephtys picta* was found in all grades of sand, most commonly in medium to fine sand. It was not found in high organic sediments and was rare in medium organic sediments (Fig. 33; Table 1). Kinner (1978) found *N. picta* to be a dominant species in sand on the inner shelf from Georges Bank to Cape Hatteras, while Kinner and Maurer (1978) reported increasing numbers of *N. picta* associated with sediments containing increasing amounts of silt-clay in Delaware Bay.

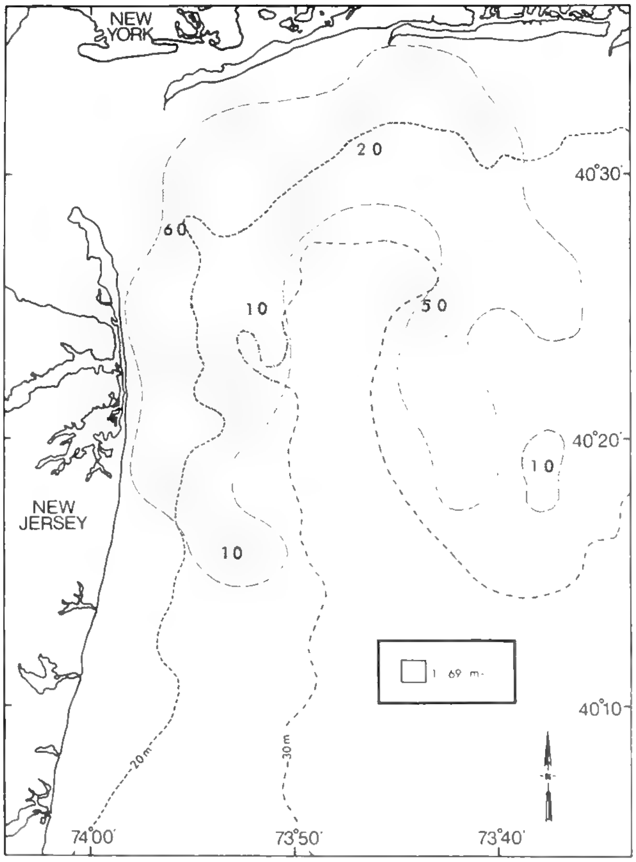

Figure 33.—Distribution and abundance of *Nephtys picta* in the New York Bight apex.

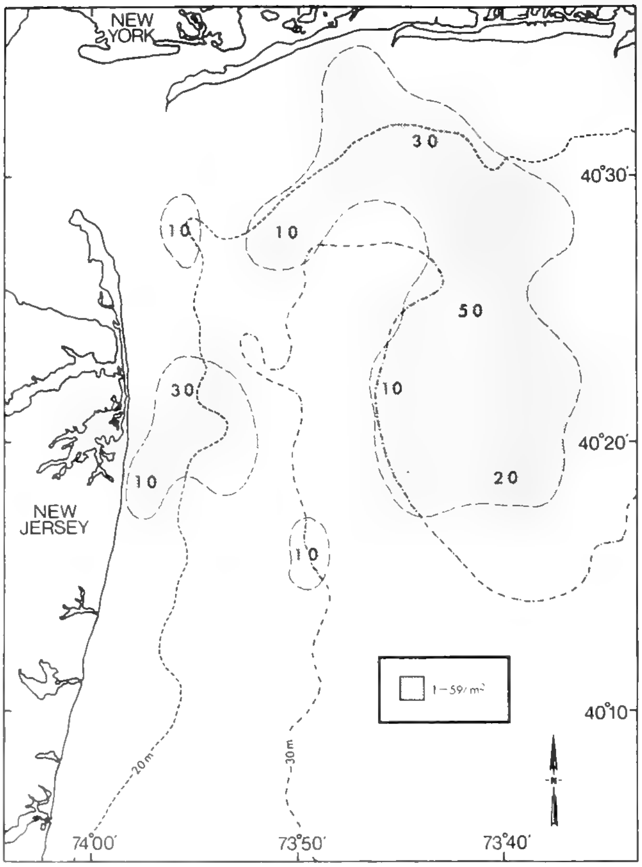

Figure 34.—Distribution and abundance of *Nephtys (Aglaophamus) circinata* in the New York Bight apex.

FEEDING ECOLOGY: *N. picta* is probably a surface deposit feeder and/or carnivore (see *Nephtys incisa*).

REPRODUCTION AND GROWTH: No information specific for *N. picta* was available, however, planktotrophic larvae are probably produced (see *N. incisa* for details).

Nephtys (Aglaophamus) circinata Verrill, 1874

DESCRIPTION: A mobile species; length to 50 mm, width to 5 mm (Pettibone 1963).

DISTRIBUTION: Gulf of St. Lawrence to North Carolina (Gardiner 1975).

HABITAT: Collected on bottoms of mud, sand with gravel, rocks, shells (Pettibone 1963); found from Cape Cod to Cape Hatteras in depths of 13–611 m (Kinner 1978). In Delaware Bay, *Nephtys circinata* was not significantly associated with any sediment parameters; it was found in a range of sediment types (Kinner and Maurer 1978). On Georges Bank, it was an abundant species negatively correlated with silt-clay (Maurer and Leathem 1980). Steimle and Radosh (1979) found it to be a ubiquitous species in sandy sediments off New Jersey. In the New York Bight apex, *N. circinata* was present in fine to coarse sandy sediments, most commonly in fine sands, but was absent from silty sediments and areas where sediment organic content exceeded 3.8% (Fig. 34; Table 1).

FEEDING ECOLOGY: *N. circinata* is probably a nonselective deposit feeder and/or carnivore (see *Nephtys incisa*).

REPRODUCTION AND GROWTH: Nothing is known of the reproductive patterns of *N. circinata* in this area. However, it is probable that it produces planktotrophic larvae (see *N. incisa*). Winter and summer distribution and abundance patterns were similar in the New York Bight apex.

Order Capitellida

Capitella capitata (Fabricius, 1780)

DESCRIPTION: Motile burrowers which form mucus-lined galleries; body slender, generally 30–50 mm long, dark red when alive (Day 1967; Gosner 1971). Grassle and Grassle (1976) believed that *Capitella capitata* is not a single species but a complex of at least six sibling species, each with a different life history. Therefore, information here reported may apply to a species complex rather than to a single species.

DISTRIBUTION: A cosmopolitan species, occurring in cold, temperate, and warm waters throughout the world (Warren 1976).

HABITAT: *C. capitata* is often used as an indicator of pollution and also of unpredictable environments all over the world (Muus 1967; S. Schultz 1969; Wolff 1973). The species becomes common in areas following a period of oxygen depletion (Leppäkoski 1969; Steimle and Radosh 1979), in sludge dumps (Halcrow et al. 1973; Pearce, Caracciolo, Halsey, and Rogers 1977b; Pearce, Rogers, Caracciolo, and Halsey 1977), and in sediments contaminated by oil (Reish 1965; Sanders et al. 1972). Henriksson (1969) demonstrated a linear correlation between counts of bacteria indicative of pollution and the abundance of *C. capitata* in the Oresund, Denmark.

Capitella capitata is found in numbers as high as 60,000/m^2 at depths up to 637 m off California in areas where the normally diverse deep-sea fauna is absent or uncommon (Hartman 1961). Similarly, it has been noted by several investigators (Leppäkoski 1969; Barnard 1970; Sanders et al. 1972) working in other areas, that for *C. capitata* to achieve large population sizes, other species must be absent or present in low numbers; this suggests that *C. capitata* is a poor competitor. Wolff (1973) showed that *C. capitata* was not very responsive to sediment differences and Reish (1971) even found them settling on blocks of wood in Los Angeles Harbor. Warren's (1977) study of environmental variables likely to affect the distribution of *C. capitata* suggested that a high organic content is most important, with particle size of sediments indirectly influencing the distribution of the species through its relationship with organic content, *C. capitata* being most common in fine sands. This appears to be true in the New York Bight apex where *C. capitata* was highly concentrated in high organic fine sand (up to 5,000/m^2) near the center of the sewage sludge disposal site. It occurred in other areas of the apex, but at much lower concentrations (10–40/m^2). Since fine sandy sediments with similar depth regimes and lower organic contents are common in the apex, it appears that the very high organic content and/or the lack of competitors in the sludge disposal area was the prerequisite for the dense settlement of the species (Fig. 35; Table 1).

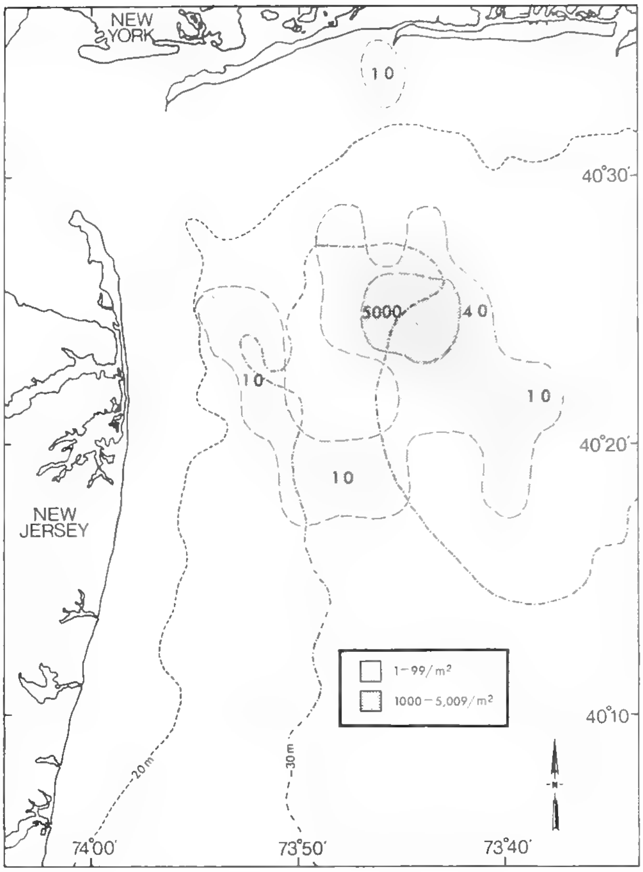

Figure 35.—Distribution and abundance of *Capitella capitata* in the New York Bight apex.

FEEDING ECOLOGY: Capitellids use their eversible proboscis to burrow, and they are generally thought to be nonselective deposit feeders. Since *C. capitata* does not possess the enzymes to digest plant material, Warren (1977) concluded that microorganisms form the bulk of its food. Stephens (1975) reported minimal bacterial consumption in *C. capitata* and believes nutrition is achieved by direct absorption of microorganism-associated dissolved amino acids across the body wall, however, the net energy gain is not clear. Tenore and Hanson (1980), in an experiment using different types of radioactively labelled detritus, found that the faster the decomposition of the detritus, the greater the amount utilized in the growth of *C. capitata*.

REPRODUCTION AND GROWTH: In West Greenland, small oocytes of *C. capitata* were formed during most of the year but these attained spawning size only in the spring (March–April 1959; April 1960) (Curtis 1977). In England, estimates of total number of oocytes produced ranged from 10,000 in young females to 14,400 in older worms, most eggs released in a single spawning (Warren 1976). However, *C. capitata* is able to breed throughout the year as it has been observed to do in Buzzards Bay, Mass., (Driscoll 1972) and at Warren Point, England (Warren 1976). When food is always available, their asynchronous mode of reproduction allows them to exploit their resources to the fullest without placing too heavy a demand on food supply at any one time. Muus (1967) found egg number in Danish specimens to average 130, with adults producing one to several broods.

Warren (1976) found the yolky egg to require 10–14 d development in the maternal tube and a further 7 d before metamorphosis as a lecithotrophic, planktonic larva. According to Eisig (1914), these larvae are photopositive. Rasmussen (1956, 1973) found two separate modes of development in the Isefjord, Denmark, where larvae developed nonpelagically during winter within adult tubes, but in summer, eggs were protected within the brood for only 10–14 d before a free-swimming stage emerged. Reish (1965) described a single specimen from the Bering Straits which was incubating eggs within the maternal tube during July. In West Greenland, a number of specimens were found brooding eggs and early unsegmented larvae within their tubes (Curtis 1977). Rasmussen (1956), Muus (1967), and Grassle and Grassle (1974) all agreed that larval development may be completely benthic. By this alternative mode of reproduction, *C. capitata* can rapidly exploit local concentrations of organic matter.

Newly metamorphosed larvae have been observed in the Woods Hole, Mass., plankton in June (Simon and Brander 1967), in spring in the Isefjord (Rasmussen 1973), and in late summer and early fall in the Elbe Estuary, Germany (Giere 1968). In Wild Harbor, Mass., settlement of planktonic larvae has been observed in late winter and summer with greatest settlement from May to October. Larvae have been collected from the plankton essentially year-round in the Oslofjord, Norway (Schram 1968), at Banyuls sur Mer (Bhaud 1967), and in the Gulf of Marseilles, France (Casanova 1953). It is possible that planktonic larvae are produced only in dense populations or when food is scarce.

Adult size can vary from about 1 mm to a maximum of 100 mm; Curtis (1977) reported maturity to be reached at a length of about 10 mm in West Greenland. Grassle and Grassle (1974) reported that time to maturity is fairly constant at about 30–40 d, thus emphasizing the importance of rapid maturation in opportunistic species, even where resources permit production of only a few eggs.

Sexes are normally separate and, according to Warren (1976), occur in approximately equal proportions. Males are readily distinguished by large copulatory setae on the eight and ninth setigers. In laboratory and field populations, Grassle and Grassle (1974) have found that some genetically distinct individuals change sex from male to female and may be self-fertilizing before the transition is complete. This is an obvious advantage where the pattern of dispersal and the distribution of suitable habitats results in only a few individuals reaching a particular unexploited habitat.

ADDITIONAL INFORMATION: The cosmopolitan distribution of *C. capitata* and its tolerance of wide ranges of temperature, salinity, oxygen content, and a variety of other conditions inimical to other organisms cannot fully be explained since laboratory studies do not show unusual ranges of tolerance to any of these environmental variables. For example, Reish (1970) compared *C. capitata* with three other species of polychaetes on the basis of their tolerance to different concentrations of nutrients, salinity, and oxygen. *Capitella capitata* was most sensitive to increased concentrations of silicates, second most sensitive to reduced oxygen conditions, but most tolerant of increased phosphates and reduced salinities. Henriksson (1969) found *C. capitata* to be less tolerant of low oxygen conditions than *Nereis diversicolor* or *Scoloplos armiger*. Mangum and Van Winkle (1973) demonstrated that *C. capitata* had no unusual regulatory ability in decreased oxygen concentrations although *C. capitata* could repay an oxygen debt whereas *Polydora ligni* could not. Laboratory studies do not reveal any unusual tolerance to detergents or to heavy metals (Kaim-Malka 1970; Bellan et al. 1972; Reish et al. 1974). The Wild Harbor (Massachusetts) studies (Sanders et al. 1972) indicate that *C. capitata* is more sensitive to high concentrations of oil than *Nereis succinea* and Rossi et al. (1976) found *C. capitata* to be more sensitive to three of four test oils used than *Nereis arenaceodonta*.

Results of these studies would seem to indicate that a synergistic effect of several factors, e.g., the concentrations of organic matter, dissolved oxygen, etc., may be responsible for determining population levels of *C. capitata* in a given situation. Another explanation might be that if *C. capitata* is indeed a complex of six sibling species (Grassle and Grassle 1976), and if all or a few of these species were present in a certain area, at a certain time, the most "fit" or tolerant of existing conditions could be selected for.

Mediomastus ambiseta (Hartman, 1947)

DESCRIPTION: Small burrowing, motile worms; length to about 38 mm in our collections.

DISTRIBUTION: East coast of United States, southern California, and lower California (Hartman 1969; Hobson 1971).

HABITAT: Intertidal and shelf depths (Hobson 1971). *Mediomastus ambiseta* was collected in high numbers from coarse sand and a serpulid polychaete assemblage in Delaware Bay (Maurer, Watling, Leathem, and Kinner 1979; Haines and Maurer 1980). In the New York Bight apex, *M. ambiseta* reached very high concentrations in high organic silty sediments (up to 8,820/m² in summer). It was also abundant in medium to high organic content fine sands (up to 840/m² in summer), but occurred in lower numbers in coarse and medium sand and in lower organic areas (Fig. 36).

FEEDING ECOLOGY: All members of this family (Capitellidae) are deposit feeders (Day 1967; Gosner 1971).

REPRODUCTION AND GROWTH: Although no specific information is available on the reproduction and growth of *M. ambiseta*, following the West Falmouth (Massachusetts) oil spill, it exhibited some degree of opportunism (Sanders et al. 1972). Therefore, it may be characterized by rapid development, many reproductions per year, high recruitment, high death rate, and some form of brood protection (McCall 1977).

There were 5.9 times more *M. ambiseta* at the Bight apex stations during summer months than in winter (Fig. 36).

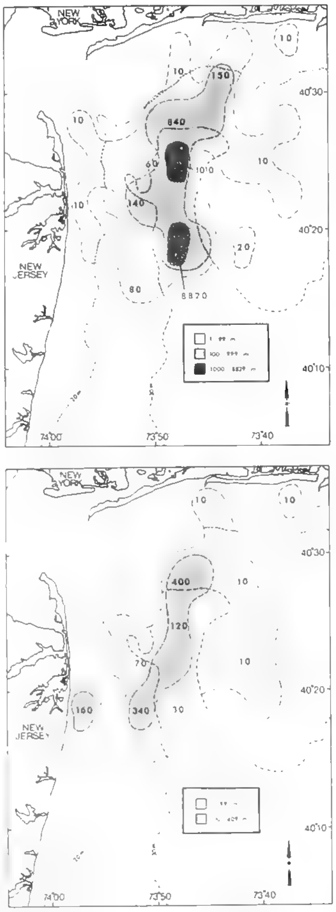

Figure 36.—Distribution and abundance of *Mediomastus ambiseta* in the New York Bight apex (top—summer, bottom—winter).

Travisia carnea Verrill, 1873

DESCRIPTION: A stout-bodied, grublike worm; length to 59 mm, width 8 mm, segments 25–29 (Pettibone 1954). (Only Alaskan specimens reach maximum size reported.)

DISTRIBUTION: Northeastern United States to Chesapeake Bay; Arctic Alaska (Verrill 1873; Pettibone 1954; Kinner and Maurer 1978).

HABITAT: Found at depths between 5.4 and 34.2 m. In the apex of the New York Bight, *Travisia carnea* occurred in low numbers,

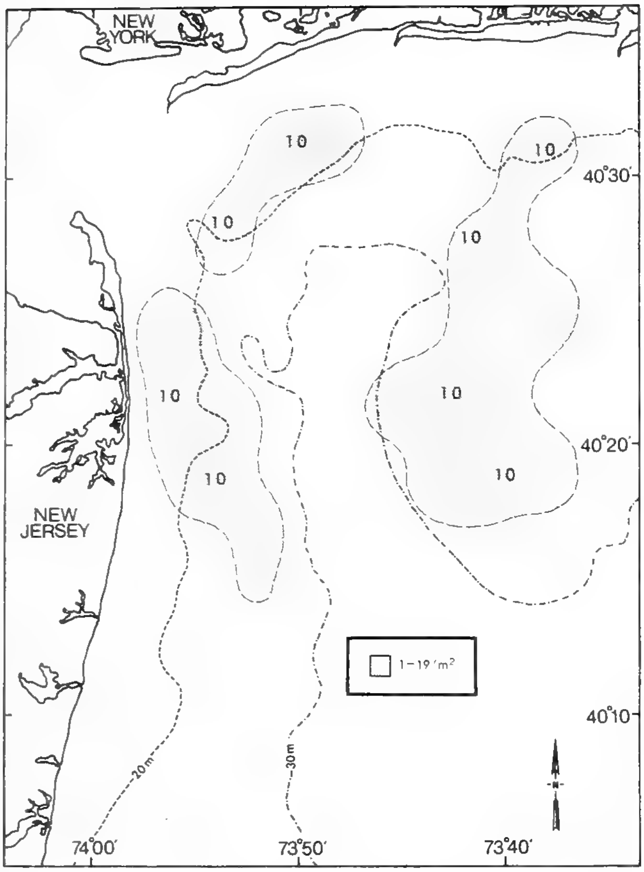

Figure 37.—Distribution and abundance of *Travisia carnea* in the New York Bight apex.

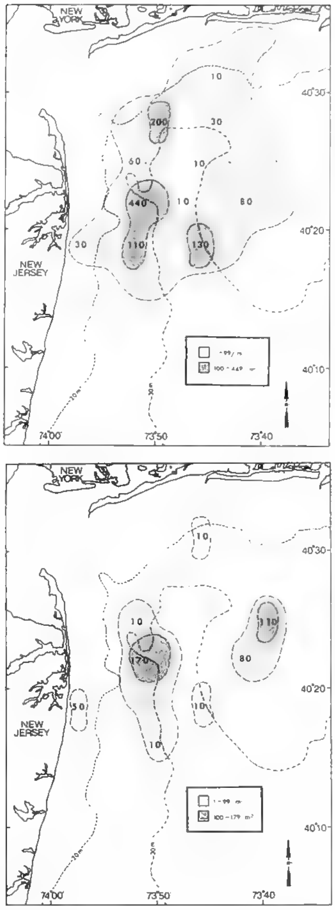

Figure 38.—Distribution and abundance of *Spio filicornis* in the New York Bight apex (top—summer, bottom—winter).

primarily in fine sand, and only in the lowest organic areas (<3%) (Fig. 37; Table 1).

FEEDING ECOLOGY: *T. carnea* is a motile deposit feeder which burrows head downward in the sediment. Its gut has often been observed to be full of sand grains ingested along with the organic matter in the substrate (Day 1967).

REPRODUCTION AND GROWTH: No information was available for this species.

Order Spionida

Spio filicornis (Muller, 1776)

DESCRIPTION: Usually tubicolous as are other spionids, but can leave tube (Remane 1933); length to 30 mm, 90 segments, usually smaller (Day 1967).

DISTRIBUTION: Worldwide (Hartman 1969).

HABITAT: *Spio filicornis* often forms dense colonies on sandbanks (Day 1967). In the New York Bight apex, we found *S. filicornis* in depths ranging from 9.6 to 45.6 m. It was usually associated with medium to fine sands with low to medium organic content (Fig. 38).

FEEDING ECOLOGY: *S. filicornis* is a tentaculate surface deposit feeder (Day 1967).

REPRODUCTION AND GROWTH: Although mating in *Spio* spp. has not been observed, on the basis of observations during culture experiments, Greve (1974) has hypothesized that *S. filicornis* is unusual in that it uses the indirect transfer of pelagic spermatophores to fertilize its eggs. Other marine organisms exhibiting a similar behavior are members of the Halacaridae (marine mites). The reproductive activities of *S. filicornis* have also been studied by Curtis (1977) in Godhavn, Greenland. He reported that spawning occurs during autumn or winter with the release of large (180–300 μm) eggs. Eggs were brooded within the female tubes until late spring, when they developed into larvae with three setigers bearing long swimming setae. As is the case with members of the genus *Polydora*, these larvae appeared to metamorphose within the parental tubes, some juveniles (1 mm, 10 setigers) being found in an adult tube collected in April 1959. The onset of maturity occurred at a length of about 10 mm (2–3 mg).

In the Gullmar Fjord, Sweden, Hannerz (1956) observed that *S. filicornis* laid its eggs in gelatinous masses within or on top of the substratum. Brood protection was lacking, and the pelagic larvae metamorphosed at the 15-setiger stage.

Simon (1967, 1968) found that *Spio setosa*, a close relative of *S. filicornis*, exhibited poecilogony, spawning once in the late spring resulting in benthic larvae, and again in the fall with pelagic larvae.

Planktotrophic pelagic larvae with from 4 to 22 setigers were collected between mid-October and mid-February in Great Harbor, Woods Hole, Mass. They metamorphosed generally at the 18–20 setiger stage. Following the spring spawning, development occurred entirely within the parent tube. Benthic larvae metamorphosed at the 15–17 segment stage, leaving the parent tube and burrowing into the surrounding substratum. In response to a lack of suitable substratum, most *S. setosa* metamorphosed anyway, forming tubes of mucus. However, some larvae did not metamorphose for periods of up to 2 mo, increasing in size and sometimes in number of segments. Larvae survived and metamorphosed in 50, 75, and 100% seawater.

In the New York Bight apex, during summer months, we found more widespread occurrence of *S. filicornis*, and higher numbers at several scattered locations (Fig. 38).

Prionospio steenstrupi Malmgren, 1867

[*Prionospio malmgreni* var. *dubia* Day, 1961]

DESCRIPTION: Length to 45 mm, 100 segments (Day 1967); tubicolous, but can leave tubes (Remane 1933).

DISTRIBUTION: North Atlantic from Norway to Greenland and New Brunswick to Florida; Alaska to southern California; Japan, South Africa (Day 1973).

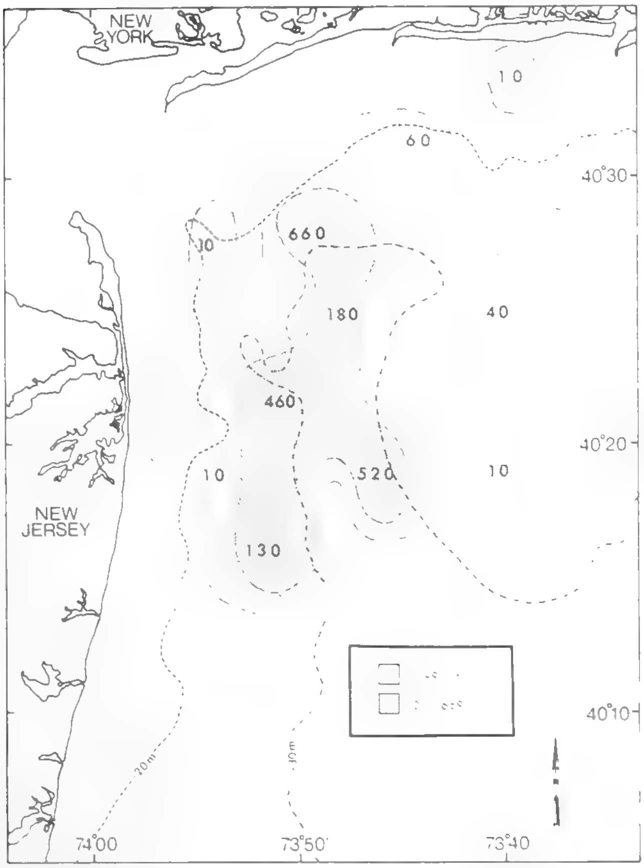

Figure 39.—Distribution and abundance of *Prionospio steenstrupi* in the New York Bight apex.

HABITAT: Intertidal to 1,745 m (Day 1973). Pearce (1972) found *Prionospio steenstrupi* to be more abundant in marginally polluted areas than in uncontaminated areas in the New York Bight apex. In the present samples, we also found *P. steenstrupi* to be most abundant in areas containing >3% organic material, occurring in highest concentrations in high organic (>5%) areas. They were abundant in all grades of sand and moderately abundant in silty sediments (Fig. 39; Table 1).

FEEDING ECOLOGY: The Spionidae are tentaculate, surface deposit feeders. They are probably nonselective since their guts contain many sand grains as well as detritus (Day 1967). Spionids are a major food item in the diet of haddock (Wigley and Theroux 1965).

REPRODUCTION AND GROWTH: Curtis (1977), in Greenland, found that the seasonal trend in oocyte size favored a winter or spring spawning period for *Prionospio malmgreni*. Hannerz (1956) reported that in the Gullmar Fjord, Sweden, mature ova measure 100 µm and development is planktotrophic with no brood protection. Day (1967) stated that various species of *Prionospio* must be very abundant, for their larvae are present in enormous numbers in neritic plankton samples.

Polydora ligni Webster, 1879

DESCRIPTION: Small, tubicolous worms; largest specimens measure 32 mm in length and have up to 80 segments (Blake 1971).

DISTRIBUTION: Cosmopolitan, in all oceans at all latitudes (Hartman 1969).

HABITAT: Intertidal to a few meters (Day 1973); *Polydora ligni* is a common inhabitant of estuaries in North America. In the New York Bight apex samples, *P. ligni* was found in depths to 46 m. They were present in all sediment types but were most common in medium to fine sand. Greatest abundance occurred in low organic areas; however, they were also represented in higher organic sediments (Fig. 40).

Hempel (1957) has studied the tubes of Spionidae and found that substrate materials used for building are not chosen at random, but are rather carefully selected. According to Kisseleva (1967), the determining factors in the selection of building materials are weight and quality of the substrate granules; for *Polydora ciliata* larvae, the critical factor is particle size, not composition.

FEEDING ECOLOGY: *P. ligni*, as all other spionids, is a surface deposit feeder (Day 1967). Breese and Phibbs (1972) found *P. ligni* in laboratory cultures feeding on larvae of the Manila clam, *Tapes semidecussata*, and the oyster *Crassostrea gigas*. One worm contained 20 larvae. The spionids entered the molluscan rearing tanks as larvae, and presumably fed on the algae *Monochrysis lutheri* and *Isochrysis galliana*, the food organisms used for culturing the molluscan larvae.

REPRODUCTION AND GROWTH: *P. ligni* lays its orange eggs (120 µm in diameter) in tough egg capsules. These may be protected inside the burrow, the female remaining with the developing larvae, and producing a current of water through the burrow, insuring continuous oxygenation. In Maine waters, these egg capsules have been collected from April to July with up to 132 eggs/capsule (Blake 1969); in the Woods Hole, Mass., area, the number

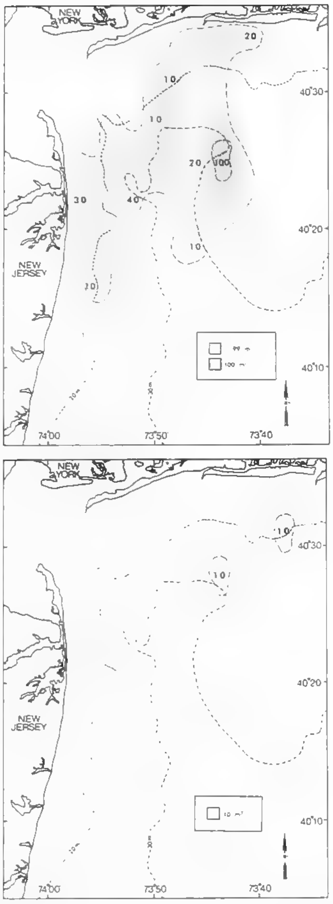

Figure 40.—Distribution and abundance of *Polydora ligni* in the New York Bight apex (top—summer, bottom—winter).

of egg capsules ranges from 4 to 29 with up to 216 eggs/capsule (Simon).[9] This agrees well with observations of up to 30 capsules with 25–225 eggs/capsule in the Isefjord, Denmark (Rasmussen 1973). Simon (1967) has observed developing larvae to sometimes use unfertilized eggs as a food source (adelphophagia). Two or more broods may be produced by each female in season (Blake 1969; Daro and Polk 1973). Larvae are not released into the plankton until they have reached the late 3-setiger stage (Hannerz 1956; Day 1967; Blake 1969). Large numbers of *P. ligni* larvae are present in the plankton of the Woods Hole area from March until September (Simon 1967). In the York River, Va., the occurrence of planktonic larvae of *P. ligni* was observed for a period of 12 wk in 1970. Larvae first appeared on 11 March and weekly samples generally showed a continuous increase in mean length. Maximum size was reached on 14 April, when inspection of test panels revealed an intitial settlement of metamorphosing larvae with a mean length of 1.25 mm. Larvae reared in the laboratory at 21°C required 19–28 d to develop fully, while larvae reared at 10°C required 60–69 d (Orth 1971). In another study, Breese and Phibbs (1972) observed *P. ligni* in laboratory culture to complete development to the adult stage and build tubes at salinities and temperatures ranging from 25 to 34‰ and 18° to 26°C.

In the Oslofjord, Norway, Schram (1968, 1970) found *P. ligni* to be the most abundant larval species every month of the year except December. *Polydora ligni* was also the most abundant larval polychaete in the Elbe Estuary, Germany (Giere 1968). The life cycle may be completed in 5 or 6 wk (about 2 wk in the plankton and about 3 wk to maturity following settlement). Some adults live for at least a year (Daro and Polk 1973).

In the New York Bight apex, we found *P. ligni* to be much more widespread and abundant during summer months than winter months (Fig. 40).

ADDITIONAL INFORMATION: Following the West Falmouth (Massachusetts) oil spill, *P. ligni* was the second most successful opportunistic species (following *Capitella capitata*). It settled primarily on muds or muddy sands but it is also known from hard substrata such as shells (Sanders et al. 1972). In the repopulation of the Raritan River Estuary following pollution abatement, *P. ligni* was among the most abundant colonists the first year and three subsequent years (Dean and Haskin 1964).

***Spiophanes bombyx* (Claparède, 1870)**

DESCRIPTION: A discretely motile species which inhabits a sand tube lined with a fragile mucoid secretion. Body up to 60 mm long with 180 segments (Day 1967).

DISTRIBUTION: Worldwide (Hartman 1969).

HABITAT: Intertidal to 200 m. Kinner and Maurer (1978) reported *Spiophanes bombyx* to be one of the dominant species on the mid-continental shelf in the Delaware Bay region. Off southwest Long Island, *S. bombyx* was a dominant polychaete in the medium-coarse grain sand community (Steimle and Stone 1973). On Georges Bank it was the most abundant polychaete collected, increasing in density with higher percent sand and lower carbon content of sediments (Maurer and Leathem 1980). *Spiophanes bombyx* was also extremely abundant and widespread at New York-New Jersey outer continental shelf stations sampled by Pearce, Caracciolo, Halsey, and Rogers (1977a). In the New York Bight apex, *S. bombyx* was collected at almost all stations in all sediment types, and was the second most abundant polychaete in our study. It occurred most often in fine sand, low organic areas, and showed moderate abundance in fine to medium sand, with medium to high organic contents (Fig. 41; Table 1).

FEEDING ECOLOGY: The Spionidae are tentaculate, surface deposit feeders. Their guts contain many sand grains as well as detritus (Day 1967).

Wigley and Theroux (1965) stated that spionids are important in the diet of haddock.

REPRODUCTION AND GROWTH: Day (1967) stated that most spionids lay large eggs enclosed in tough egg capsules. Depending upon environmental conditions, these may be liberated directly into seawater so that all development takes place in the plankton (remaining in the plankton for as long as 3 mo), or they may be protected inside the burrow during early developmental stages. However, Hannerz (1956) believed development in *Spiophanes* spp. to be entirely pelagic. The larvae can, within limits, delay leaving the plankton until they find and settle on a suitable substratum.

ADDITIONAL INFORMATION: *S. bombyx*, known to be a tolerant species, often occurring in stressed environments, showed a marked increase in abundance during the 1976 New Jersey anoxic event (Steimle and Radosh 1979). Boesch et al. (1977) likewise found *S. bombyx* to be resistant to anoxia and found it to be oppor-

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[9] J. L. Simon, pers. commun., cited by Grassle and Grassle (1974).

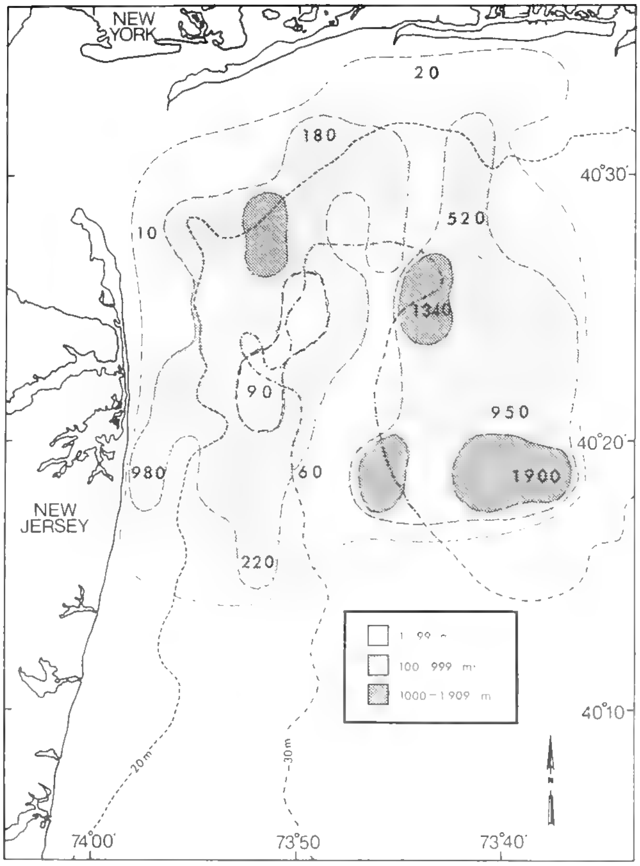

Figure 41.—Distribution and abundance of *Spiophanes bombyx* in the New York Bight apex.

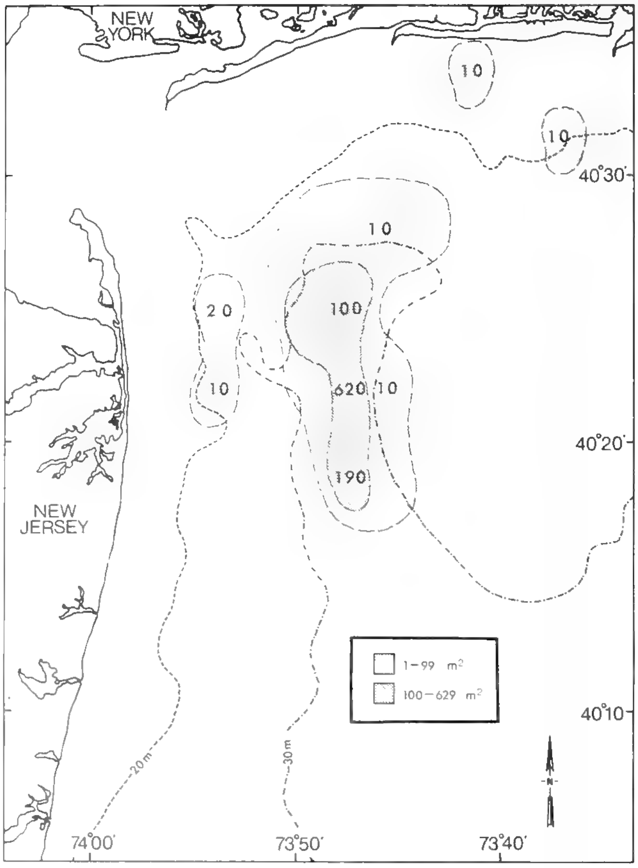

Figure 42.—Distribution and abundance of *Paraonis gracilis* in the New York Bight apex.

tunistic as well, showing substantial post-anoxic increases in population, possibly due to its capacity for rapid recolonization and its anoxia and sulfide tolerance.

***Paraonis gracilis* (Tauber, 1879)**

DESCRIPTION: Motile burrowers; body threadlike, length to 25 mm, width to 0.5 mm, segments to 100 (Pettibone 1963).

DISTRIBUTION: Cosmopolitan (Day 1967).

HABITAT: 5.4–2,002 m. Collected on bottoms of soft and sticky mud, muddy sand, mud with stones, gravel, and tubes (Pettibone 1963). In the New York Bight apex, *Paraonis gracilis* was almost always associated with fine sandy or silty sediments with high organic content (Fig. 42; Table 1).

FEEDING ECOLOGY: Paraonids burrow just below the sediment surface and are classified as nonselective deposit feeders (Dales 1963; Day 1967; Gosner 1971).

REPRODUCTION AND GROWTH: In August, in Maine, Pettibone (1963) has observed females of this species with large yolky, coral-pink eggs, about two per segment dorsally, and males with white sperm masses.

***Aricidea catherinae* (Laubier, 1967)**

[*Aricidea jeffreysii* (McIntosh, 1879)]

DESCRIPTION: Motile burrowers; length to 20 mm, width to 1.5 mm, segments to 120 (Pettibone 1963).

DISTRIBUTION: Ireland, Denmark, Mediterranean, Davis Strait to Delaware, North Carolina, Florida, western Canada (Gulf of Georgia) (Pettibone 1963; Day 1967).

HABITAT: Collected on bottoms of coarse to fine sand, sticky and soft mud, ooze, muddy sand, sand or mud with gravel, shells or tubes; 1.8 to 1,908 m depths (Pettibone 1963). On Georges Bank, *Aricidea catherinae* was abundant in coarse sand (Maurer and Leathem 1980). *Aricidea catherinae* was found in all sandy sediment types in the New York Bight apex, but was rare or absent in silt. They were uncommon in the highest organic areas, and were present in highest concentrations in low organic coarse sands (Fig. 43; Table 1). Conversely, in Delaware Bay, Kinner and Maurer (1978) found this species to be negatively correlated with an increase in grain size of sediments.

FEEDING ECOLOGY: The Paraonidae possess a simple proboscis for digging. They burrow just below the sediment surface

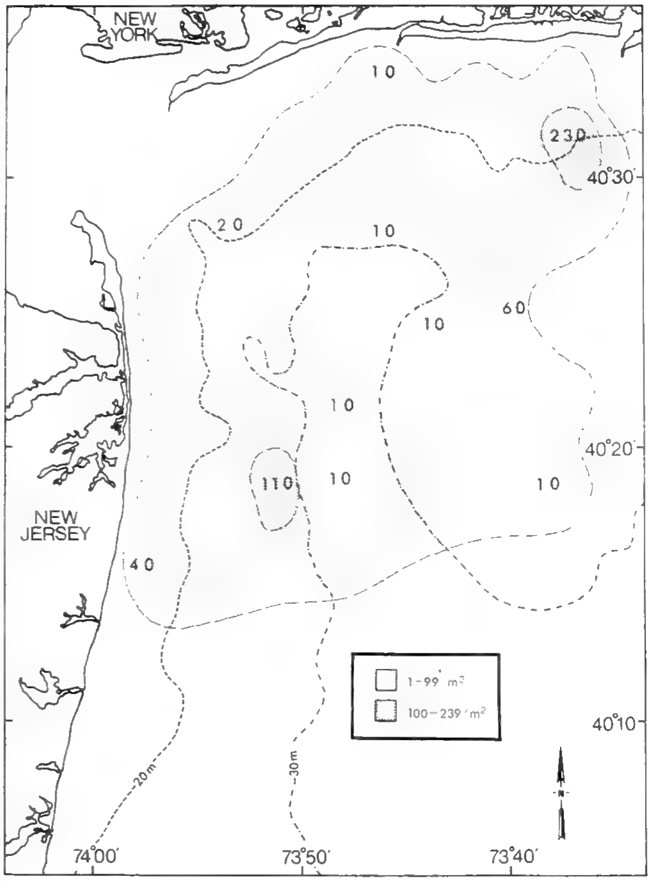

Figure 43.—Distribution and abundance of *Aricidea catherinae* in the New York Bight apex.

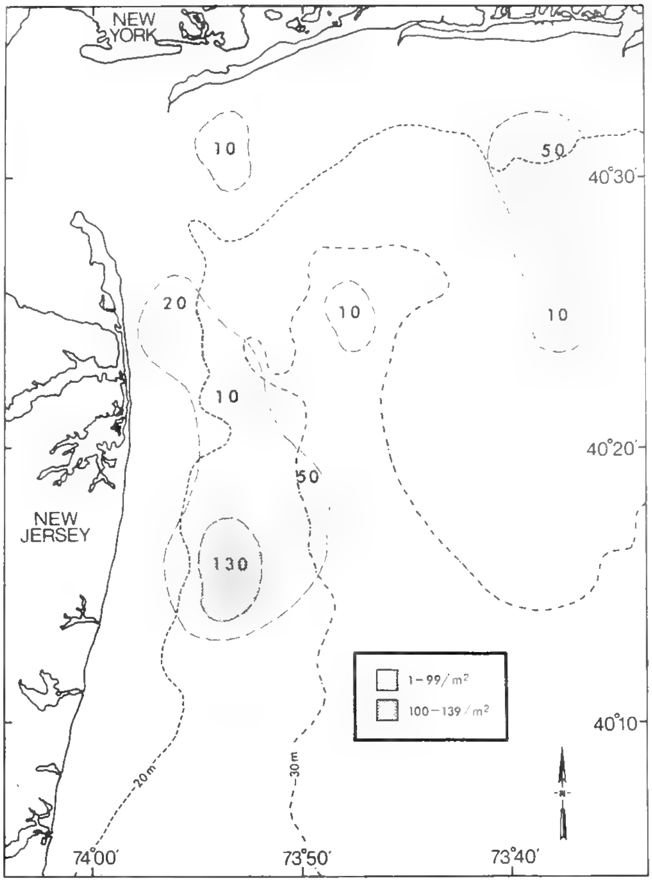

Figure 44.—Distribution and abundance of *Lumbrinerides acuta* in the New York Bight apex.

and are nonselective deposit feeders (Dales 1963; Day 1967; Gosner 1971).

Wigley (1956) has found *A. catherinae* in the stomachs of haddock off Georges Bank.

REPRODUCTION AND GROWTH: Pettibone (1963) has observed female *A. catherinae* massed with large yolky coral-pink eggs, and males with white sperm masses in Massachusetts during July. The large size of the ova indicates that the larvae are not pelagic. This agrees with Curtis' (1977) observation that *Aricidea suecica* (a related species), in Greenland, exhibits direct or lecithotrophic larval development.

Order Eunicida

Lumbrinerides acuta (Verrill, 1875)

DESCRIPTION: Motile burrowers; length to 40 mm, width to 1 mm, segments to 125 (Pettibone 1963; Jumars and Fauchald 1977).

DISTRIBUTION: Maine to New Jersey; southern California to western Mexico (Pettibone 1963).

HABITAT: Intertidal to about 185 m (Pettibone 1963); 16 to 450 m (Kinner 1978). Found at low water on mud and sand flats. Collected on bottoms of mud and coarse to medium sand (Pettibone 1963). In the Delaware Bay region, Kinner and Maurer (1978) found *Lumbrinerides acuta* to be one of the dominant species on the mid-continental shelf. There, it was associated with poorly sorted coarse sediments (>1 mm). In the New York Bight apex, except for one occurrence, *L. acuta* was absent from silty, high organic sediments, occurring in greatest abundance in coarse to medium, low organic content (<3%) sands (Fig. 44; Table 1).

FEEDING ECOLOGY: The Lumbrineridae are generally considered to be carnivorous, with some exceptions, but it is not known whether they are mainly predaceous or scavengers. The anterior end of the prostomium is richly supplied with nerves and the jaws are very powerful (Day 1967).

Lumbrinerides acuta has been found as a prey item in the stomachs of Georges Bank haddock (Wigley 1956).

REPRODUCTION AND GROWTH: No specific information was available for *L. acuta*. However, it probably exhibits nonpelagic development as do other lumbrinerids (see *Lumbrineris fragilis*, *Lumbrineris tenuis*, and *Ninoe nigripes*).

Lumbrineris fragilis (O. F. Müller, 1776)

DESCRIPTION: Burrowing, motile, length to 380 mm, width to 12 mm, segments to 340 (Pettibone 1963; Jumars and Fauchald 1977).

DISTRIBUTION: Arctic, Iceland, Faroes, Norway to Azores, Madeira, Mediterranean, Hudson Bay to North Carolina, Bering Sea, Alaska, north Japan Sea (Gardiner 1975).

HABITAT: Intertidal to 3,445 m. Found at low water on bottoms of mud, muddy sand, gravelly mud, and shifting sand. Collected on bottoms of sticky and soft mud, silty clay, various combinations of mud, sand, gravel, pebbles, stones, worm tubes, shells, and detritus (Pettibone 1963). In Kinner's (1978) study from Cape Cod to Cape Hatteras, *Lumbrineris fragilis* was a dominant species in sand on the inner and mid-shelf, and in silt-clay on the mid-outer shelf and slope. Greatest numbers occurred in medium, well-sorted sands. Steimle and Stone (1973) found *L. fragilis* to be a dominant species in medium-coarse grain sand off southwest Long Island. Similarly, in the New York Bight apex, *L. fragilis*, although present in all grades of sand, was most concentrated in medium-coarse sand with an organic content of <4%. It was absent from most stations with high organic contents or was present in very low numbers (10–20/m^2) (Fig. 45; Table 1).

FEEDING ECOLOGY: *L. fragilis*, as other lumbrinerids, is considered a carnivore. Blegvad (1914) listed the gut content for *L. fragilis* as polychaetes, ophiuroids, nemerteans, small crustaceans, and bivalves.

Lumbrineris fragilis has been found as a prey item in the stomachs of cod and haddock (Pettibone 1963).

Tyler (1973) found no seasonal trend in caloric value for Canadian specimens; the annual mean was 4,565 g cal/g dry weight.

REPRODUCTION AND GROWTH: *L. fragilis* has been observed containing large eggs in August in the Woods Hole, Mass., area (Pettibone 1963).

Within the *Lumbrineris* population at Disko Fjord, Greenland, Curtis (1977) observed that large oocytes (200–250 μm) of *L. fragilis* were present at all times of the sampling interval (1959–60) indicating that the species produces larvae having a direct development. Yet, although most specimens were large and presumably mature, only about 20% of those sampled were involved in gametogenesis. This suggests that a large segment of this population did not reproduce. Thorson (1946) also considered that *L. fragilis* has a direct larval development as did Pettibone (1954), who collected nonpelagic larval lumbrinerids, tentatively identified as *L. fragilis*, at Point Barrow, Alaska, during September. These larvae were found in mucus masses, sometimes attached to the tunicate, *Boltenia echinata*.

Lumbrineris tenuis Verrill, 1873

DESCRIPTION: Body threadlike, length to 150 mm, width to 1 mm, segments to 200 (Pettibone 1963).

DISTRIBUTION: Maine to North Carolina, Gulf of Mexico (Gardiner 1975).

HABITAT: Intertidal to abyssal depths. Found at low water burrowing in mud and sand beneath stones, in compact sand mixed with mud, and in sandy mud flats close to the low water mark. Collected on bottoms of gravel with shells, mud, compact mixtures of mud and sand, various combinations of mud, sand, gravel, with sponges, shells, and amphipod and worm tubes. Common among

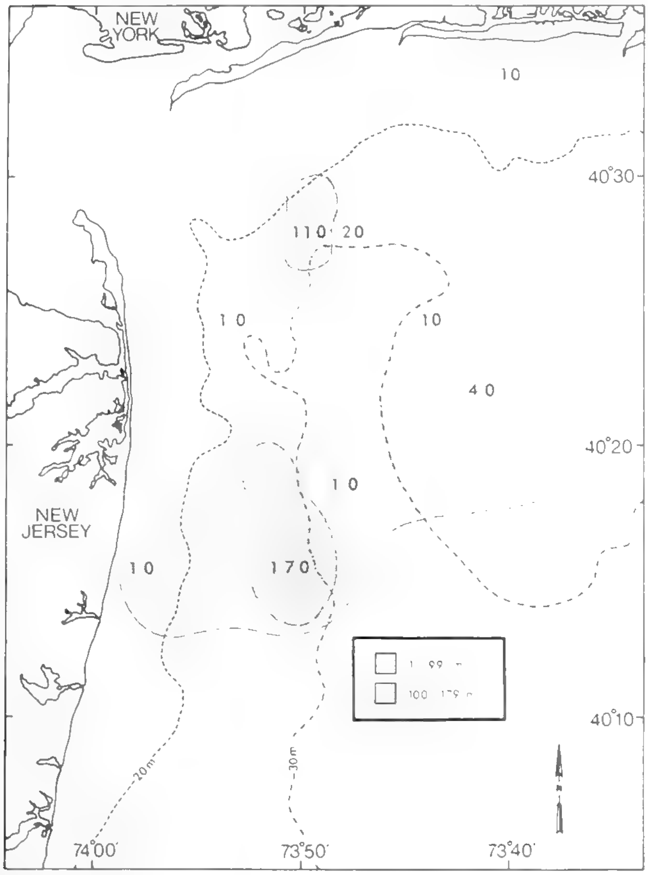

Figure 45.—Distribution and abundance of *Lumbrineris fragilis* in the New York Bight apex.

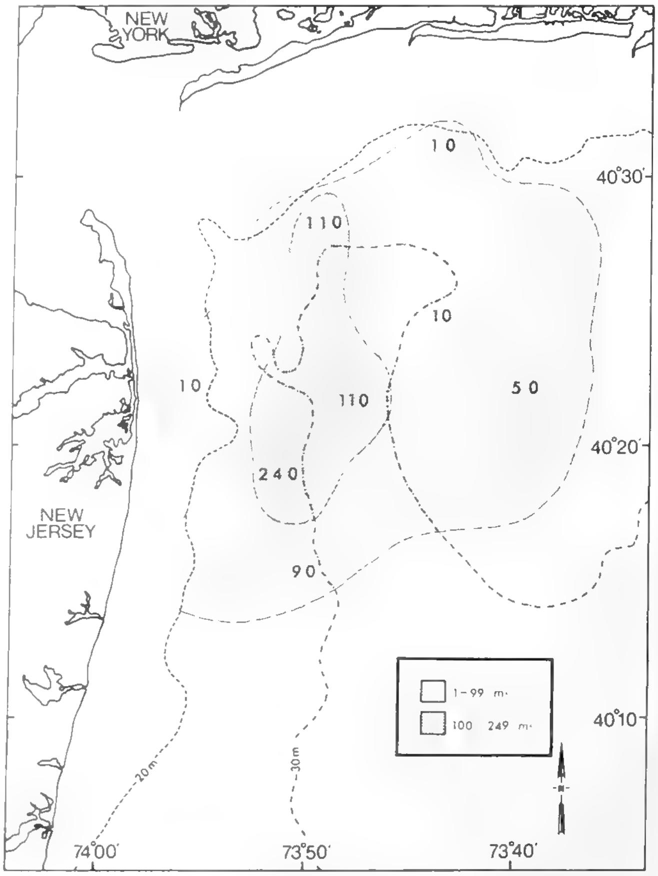

Figure 46.—Distribution and abundance of *Lumbrineris tenuis* in the New York Bight apex.

the sandy tunicates *Amaroecium pellucidum* (Pettibone 1963). *Lumbrineris tenuis* was abundant in samples collected on the New York-New Jersey outer continental shelf by Pearce, Caracciolo, Halsey, and Rogers (1977a). In the New York Bight apex, *L. tenuis* was present in all sediment types, occurring in high concentrations in a variety of sediments, particularly those with medium to high organic contents (Fig. 46; Table 1).

FEEDING ECOLOGY: The Lumbrineridae, in general, are thought to be carnivores, however, Sanders et al. (1962) found sand, diatoms, and detritus in the stomachs of *L. tenuis*, indicating that it may also be a deposit feeder.

In our collections, *L. tenuis* has been found in the gut of the polychaete *Tharyx acutus* on three occasions (Frame).[10]

REPRODUCTION AND GROWTH: Gelatinous egg masses with large, dull greenish yolky eggs have been found in the sand in Cuttyhunk Harbor, Mass., during June. Similar large yolky eggs were found inside some individuals found in the same area. Spherical gelatinous masses containing eggs and larvae were also observed attached to the surface of the mud (Pettibone 1963).

The early development of *Lumbriconereis* sp. from Newport, R.I., described by Fewkes (1883), may refer to this species. The eggs were found in all stages of growth in June, July, and August. Early development took place within the gelatinous egg masses, after which crawling, nonpelagic larvae emerged.

In Greenland, Curtis' (1977) collections of *Lumbrineris* spp. (tentatively identified as *L. tenuis* and *L. minuta*) included a number of females, often bearing coelomic oocytes of 150–250 μm. The appearance and size of the ripe ova seemed to him to be indicative of direct larval development. Spawning season could not be discerned.

Ninoe nigripes Verrill, 1873

DESCRIPTION: Motile, burrowing form; body elongate, slender. Length to 100 mm, width to 4 mm, segments to 150 (Pettibone 1963).

DISTRIBUTION: Gulf of St. Lawrence to Florida, Gulf of Mexico, Chile, off northwest Spain, Antarctic (Pettibone 1963; Gardiner 1975).

HABITAT: Intertidal to 1,170 m. Found at low water in mud. Collected on bottoms of soft or sticky mud, sandy mud, silty clay and fine sand, mud mixed with gravel, shells, and worm and amphipod tubes. *Ninoe nigripes* forms tubes of mucus mixed with mud and sand (Pettibone 1963). In Kinner's (1978) study from Cape Cod to Cape Hatteras, *N. nigripes* was one of the dominant species on the mid-outer shelf in silt-clay, occurring 43.8% of the time at stations with >10% silt-clay. In the New York Bight apex, *N. nigripes* occurred in high concentrations in a variety of sediment types and organic levels (Fig. 47; Table 1).

FEEDING ECOLOGY: The Lumbrineridae are generally considered to be carnivorous burrowers (Day 1967). However, Sanders (1960) found *N. nigripes* to be a selective deposit feeder, feeding on the surface of the mud.

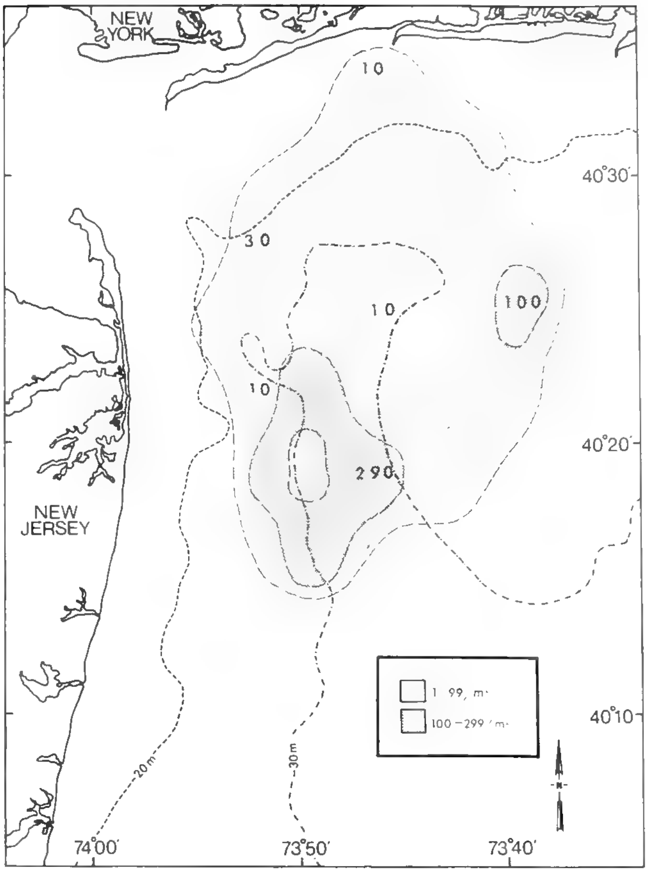

Figure 47.—Distribution and abundance of *Ninoe nigripes* in the New York Bight apex.

REPRODUCTION AND GROWTH: Males filled with white sperm masses and females with large orange yolky eggs (≈160–190 μm in diameter) have been found in the Cape Cod Bay (Massachusetts) region in June, July, and August, along with numerous very small specimens. Among the specimens collected in Massachusetts Bay, fertilized eggs were present among parapodia in the branchial region. The yolky eggs were being extruded from large pores below the parapodia (Pettibone 1963).

Drilonereis longa Webster, 1879

DESCRIPTION: Body threadlike, length to 710 mm, width to 1.5 mm, segments to 1,000 (Pettibone 1963).

DISTRIBUTION: Massachusetts to Georgia, West Indies, Washington, southern California (Pettibone 1963; Gardiner 1975).

HABITAT: Collected on bottoms of fine sand, silty clay, or mud, with worm tubes or fine gravel from the intertidal to depths of 2,450 m (Pettibone 1963; Gardiner 1975). In Kinner's (1978) study from Cape Cod to Cape Hatteras, *Drilonereis longa* was a dominant species on the inner shelf in sand and on the mid-outer shelf in silt-clay. In the New York Bight apex, *D. longa* occurred in all sediment types, primarily in fine sands, being absent from only the highest organic areas (Fig. 48; Table 1).

FEEDING ECOLOGY: Members of this family (the Arabellidae) are burrowers and are generally considered to be predaceous or

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[10] Ann Frame, Northeast Fisheries Center Sandy Hook Laboratory, National Marine Fisheries Service, NOAA, Highlands, NJ 07732, pers. commun. July 1978.

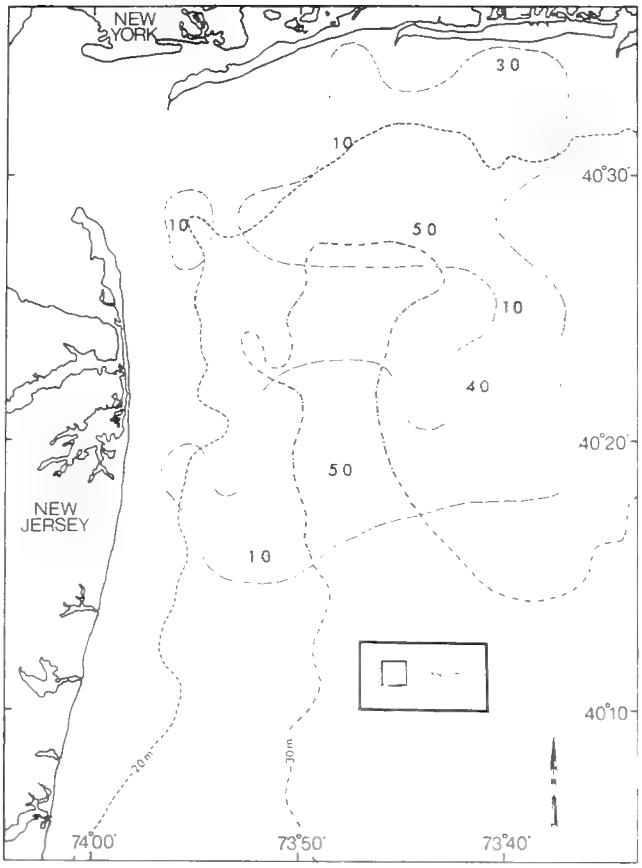

Figure 48.—Distribution and abundance of *Drilonereis longa* in the New York Bight apex.

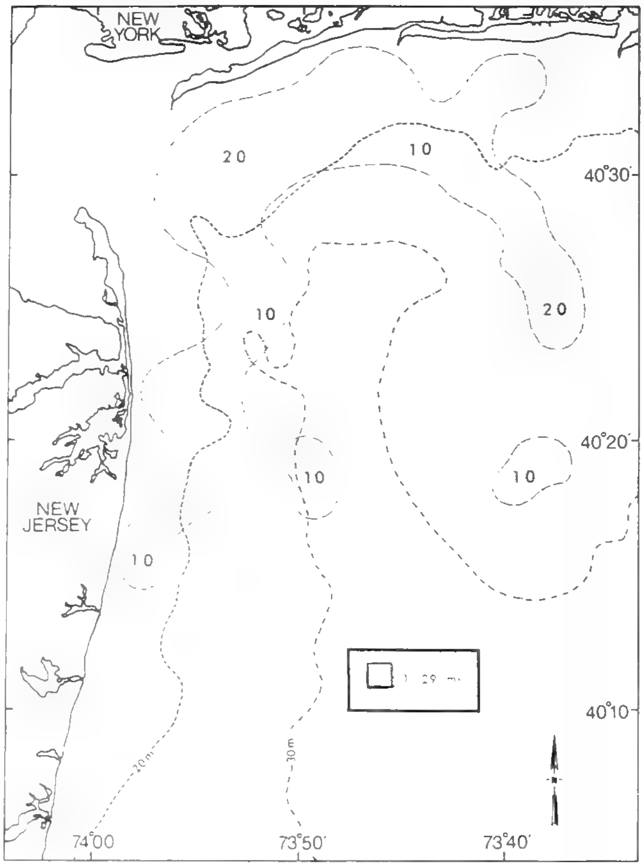

Figure 49.—Distribution and abundance of *Magelona* cf *riojai* in the New York Bight apex.

carnivorous (Pettibone 1963; Day 1967; Gosner 1971). However, Sanders et al. (1962) considered *D. longa* to be a sediment ingestor after finding sand, diatoms, and algae to be the main contents of its gut. It may be that *D. longa* exhibits both types of feeding behavior, each under different environmental conditions.

REPRODUCTION AND GROWTH: No information was found on the reproduction and growth of this species. However, planktonic larvae of this family (Arabellidae) were not found by Fewkes (1883), Thorson (1946), or Rasmussen (1956), and brooding has been recorded for another Arabellidae, *Notocirrus spiniferus*, (Pettibone 1957). These facts tend to support the idea that the Arabellidae exhibit nonpelagic development.

Order Magelonida

Magelona cf *riojai* Jones, 1963

DESCRIPTION: A slender-bodied, small worm with a spadelike head.

DISTRIBUTION: Maine to North Carolina (Kinner and Maurer 1978).

HABITAT: Jones (1968) has observed that *Magelona* sp. lives in a well-sorted, high energy, sand environment. In the New York Bight apex, *Magelona* cf *riojai* was found in low numbers in fine to medium sandy, low organic areas (<3%), and was restricted to depths of <25 m (Fig. 49; Table 1).

FEEDING ECOLOGY: Jumars and Fauchald (1977) classify the Magelonidae as surface deposit feeders; Day (1967) and Jones (1968) believed them to be burrowers, using the spadelike head and large distensible proboscis to force their way through the substrate. They feed on microscopic debris, diatoms, organic particles, and small plants and animals. While feeding, *Magelona* sp. utilizes the papillae of its paired prostomial tentacles. Food material adheres to distal papillae and is transferred to more proximal papillae when a loop is formed by the tentacle; by repetition of this activity, food material is passed stepwise toward the mouth (Day 1967; Jones 1968).

REPRODUCTION AND GROWTH: Specimens of *M. rosea* (a closely related species) collected from Cape Cod, Mass., by Moore (1900)[11] during the latter part of August contained nearly ripe eggs in the middle segments of the body. Bhaud (1972) reported larvae of *Magelona* sp. present in the plankton of the Danish Oresund from January through May.

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[11] Moore, J. 1900. The polychaetous annelids of the Woods Hole region. Unpubl. manuscr., 1032 p. U.S. Natl. Mus., Wash., D.C.

Order Cirratulida

Tharyx acutus Webster and Benedict, 1887

DESCRIPTION: Sluggish worms; threadlike bodies. Maximum size 15 mm by 2 mm; has a shallow, mucous-lined burrow (Webster and Benedict 1887).

DISTRIBUTION: Maine to Virginia.

HABITAT: *Tharyx acutus* was abundant in samples collected on the New York-New Jersey outer continental shelf by Pearce, Caracciolo, Halsey, and Rogers (1977a). It was also the most abundant polychaete collected in the New York Bight apex samples, occurring throughout the apex in all sediment types. Although it was most common in low organic areas, it was present in concentrations as high as 3,300/m² in high organic sediments (Fig. 50; Table 1).

FEEDING ECOLOGY: The cirratulids, in general, are surface deposit feeders, gathering food particles from the sea bottom by means of numerous grooved tentacular filaments (Dales 1963; Day 1967). However, in some of our Baltimore Canyon Trough samples (Radosh et al. footnote 8), specimens of *T. acutus* were observed to have consumed the polychaetes *Lumbrineris tenuis* and *Drilonereis magna* (Frame footnote 10).

REPRODUCTION AND GROWTH: No information is available for *T. acutus*, however, Gibbs (1971) studied *Tharyx marioni*, a closely related species, at Plymouth, England. He found that *T. marioni* is capable of spawning over several years, with females breeding for the first time in the second year of life. The main spawning season extends from late October to early November when water temperatures are between 10° and 12°C. As described by Dales (1951), *Tharyx* spp. larvae are bottom-living, nonpelagic, and lecithotrophic. Population densities are at their highest level just after spawning has taken place; in Plymouth, the highest densities recorded were approximately 100,000/m². At that time, juveniles of the previous year's brood composed about two-thirds of the population and were easily distinguished from the larger adult worms. During spring and summer, population levels gradually declined so that during the breeding season a mean density of only 33,000/m² was recorded, of which about 40% were breeding adults.

In the New York Bight apex, we observed *T. acutus* to be 1.6 times more abundant during winter months, which would indicate that this species may also breed here during fall or winter months.

Tharyx annulosus Hartman, 1955

DESCRIPTION: Slow-moving, threadlike worm, slightly smaller than *T. acutus*.

DISTRIBUTION: New England to tropical South America; South Africa (Day 1973).

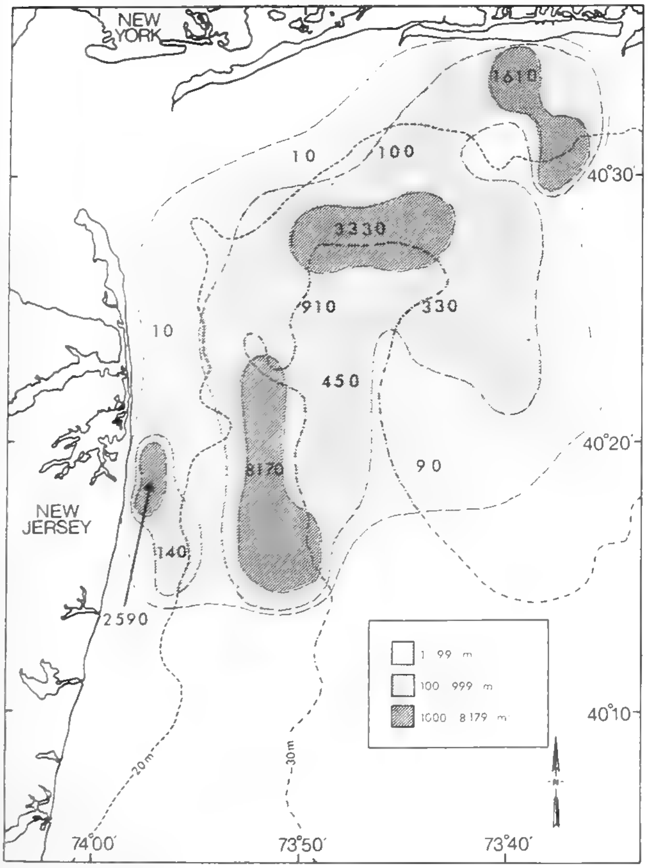

Figure 50.—Distribution and abundance of *Tharyx acutus* in the New York Bight apex.

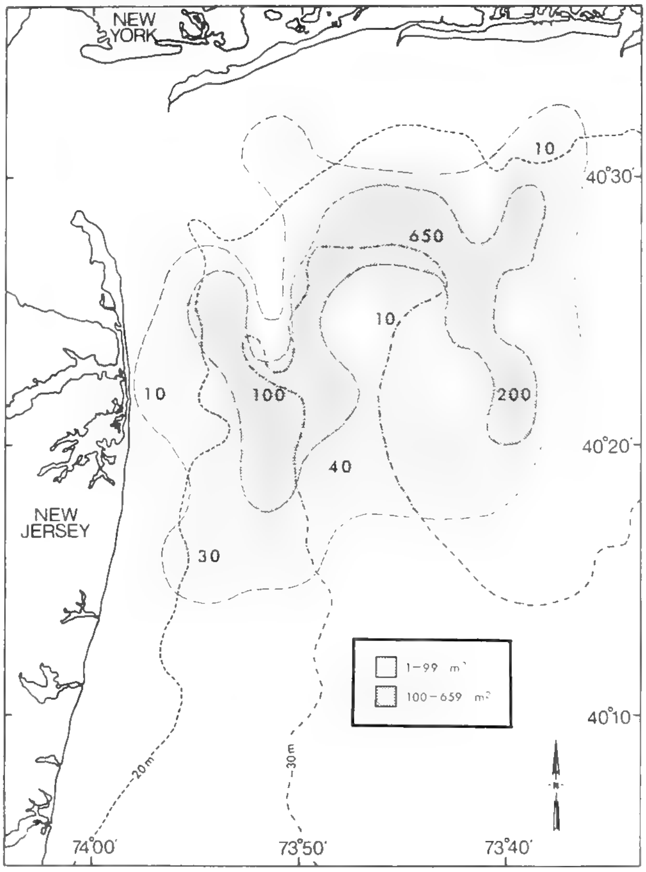

Figure 51.—Distribution and abundance of *Tharyx annulosus* in the New York Bight apex.

HABITAT: Collected in depths of 80–4,540 m (Day 1973). In the New York Bight apex, we found a few specimens of *Tharyx annulosus* in depths as shallow as 32 m, although the majority were found at greater depths. *Tharyx annulosus* was found in all sediment types, with largest numbers occurring in fine sand. Very high numbers were often found in sediments of high organic content but none were found at the station with the highest content of organic matter (13.9%). *Tharyx annulosus* was also present in large numbers in medium and low organic areas (Fig. 51; Table 1).

FEEDING ECOLOGY: *T. annulosus*, as other cirratulids, is a surface deposit feeder (see *Tharyx acutus* for details). However, in a New Jersey outer continental shelf sample, a specimen of *T. annulosus* was found to have eaten another polychaete of the genus *Lumbrineris* (Frame footnote 10).

REPRODUCTION AND GROWTH: In winter, there were 3.3 times more *T. annulosus* in the Bight than in summer, possibly indicating a fall or winter spawning period (see *T. acutus*).

***Caulleriella killariensis* (Southern, 1914)**

DESCRIPTION: Discretely motile, body threadlike, 8–12 mm long (Day 1973).

DISTRIBUTION: Ireland (Day 1973), New York Bight (Pearce, Rogers, Caracciolo, and Halsey 1977).

HABITAT: Reported from depths of 10–20 m (Day 1973). In the New York Bight apex, *Caulleriella killariensis* was present in depths up to 33 m in sediments ranging from coarse to fine sand. It was rarely present in sediments containing >3% organic material (Fig. 52; Table 1).

FEEDING ECOLOGY: *C. killariensis*, like other cirratulids, is a surface deposit feeder (see *Tharyx acutus*).

REPRODUCTION AND GROWTH: Gibbs (1971) reported *Caulleriella caput-esocis* to be capable of spawning over several years. He reported that the diameter of mature oocytes in Plymouth, England, was 110 μm and the main spawning season was from August to October. *Caulleriella caput-esocis* reached a maximum density of 22,000/m² in early summer. Females produced 1,000–5,000 oocytes.

In contrast to most species found in the New York Bight apex, which were present in greater numbers during summer months, *C. killariensis* was 2.3 times more abundant in winter than in summer in terms of more individuals at the same stations. This indicates that *C. killariensis* probably breeds here during fall or winter months (see *T. acutus*).

***Cossura longocirrata* Webster and Benedict, 1887**

DESCRIPTION: Small, threadlike, motile, burrowing form; length about 6 mm, 50–70 segments. A single, very long median

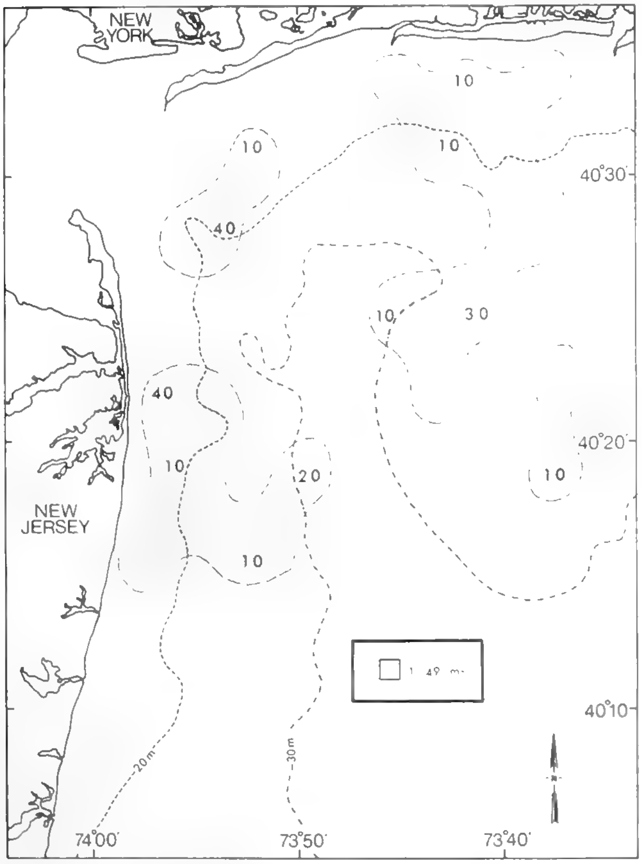

Figure 52.—Distribution and abundance of *Caulleriella killariensis* in the New York Bight apex.

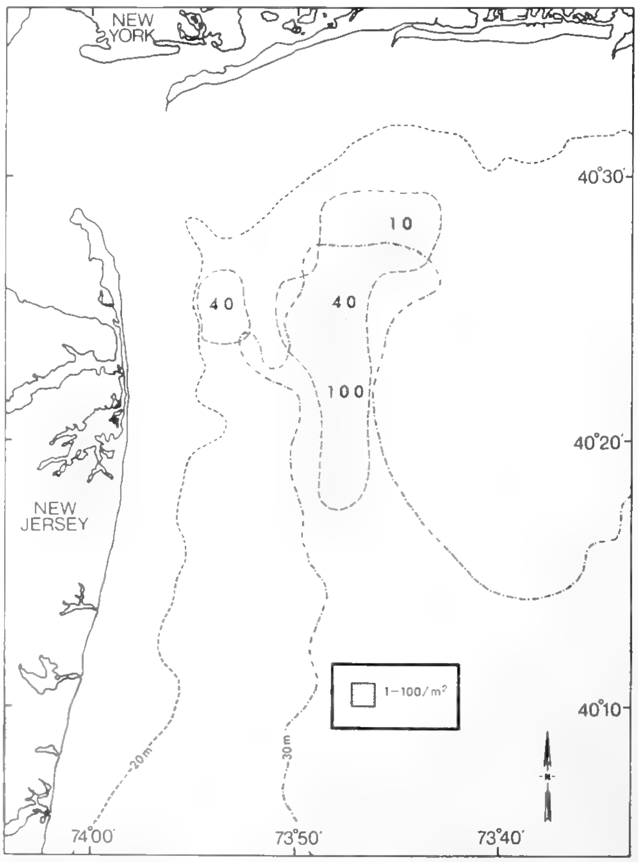

Figure 53.—Distribution and abundance of *Cossura longocirrata* in the New York Bight apex.

dorsal tentacle or gill originates on setiger four (Webster and Benedict 1887; Laubier 1963; Day 1967).

DISTRIBUTION: Listed by Gosner (1971) as a boreal species, found between Cape Cod and the Bay of Fundy. Also collected in the New York Bight and reported from Denmark, the North Atlantic, Greenland, the coast of Chile, and the Sea of Japan (Webster and Benedict 1887; Curtis 1977; Pearce, Rogers, Caracciolo, and Halsey 1977).

HABITAT: Inhabitant of mud and sandy mud in depths of 11–22 m (Webster and Benedict 1887; Day 1967; Gosner 1971). Fauchald (1977) says cossurids are common in sand and especially in deep slope abyssal muds.

In the New York Bight apex, *Cossura longocirrata* was collected in depths ranging from about 23 to 46 m. It was characteristic of the highest organic fine sandy and silty sediments (Fig. 53; Table 1). Summer and winter distributions were almost identical.

FEEDING ECOLOGY: Cossurids appear to be burrowing deposit feeders, using the eversible, soft, unarmed pharynx in feeding. The dorsal tentacle also appears to be sensory and, additionally, may be respiratory in function since it is well equipped with blood vessels (Day 1967; Fauchald 1977).

REPRODUCTION AND GROWTH: Curtis (1977) collected *C. longocirrata* in Greenland, however, no gametes were seen and the reproductive biology of the species remains unknown.

Order Terebellida

Ampharete arctica Malmgren, 1866

DESCRIPTION: Tubicolous worms, inhabitating a membranous tube covered with mud, sand grains, or foreign matter (Day 1967; Gosner 1971). In our collections, length averaged 15–18 mm.

DISTRIBUTION: Cosmopolitan (Hartman 1969).

HABITAT: In the New York Bight apex, *Ampharete arctica* was collected in depths from 10.9 to 45.6 m. It was usually associated with fine to medium sandy sediments with low to medium organic content, although it did occur in low densities (10/m²) in high organic areas (Fig. 54; Table 1).

FEEDING ECOLOGY: The Ampharetidae are sessile deposit feeders which gather food particles from the surface of sand or mud by means of buccal tentacles which can be extruded from the mouth (Day 1967; Jumars and Fauchald 1977).

Yablonskaya (1976) has found that the food of Ampharetidae from the Azov and Caspian Seas (U.S.S.R.) consists of flocculent organic-mineral particles with some remains of diatoms, blue-green and green algae. Most small ampharetids either collected particles of plant detritus from the sediment surface or filtered them from the water layer immediately above the sediment.

REPRODUCTION AND GROWTH: Little information was available on the reproduction and growth of *A. arctica*, however, Thorson (1946) stated that its wide distribution in Arctic seas indicated nonpelagic development because pelagic development is suppressed in nearly all Arctic species.

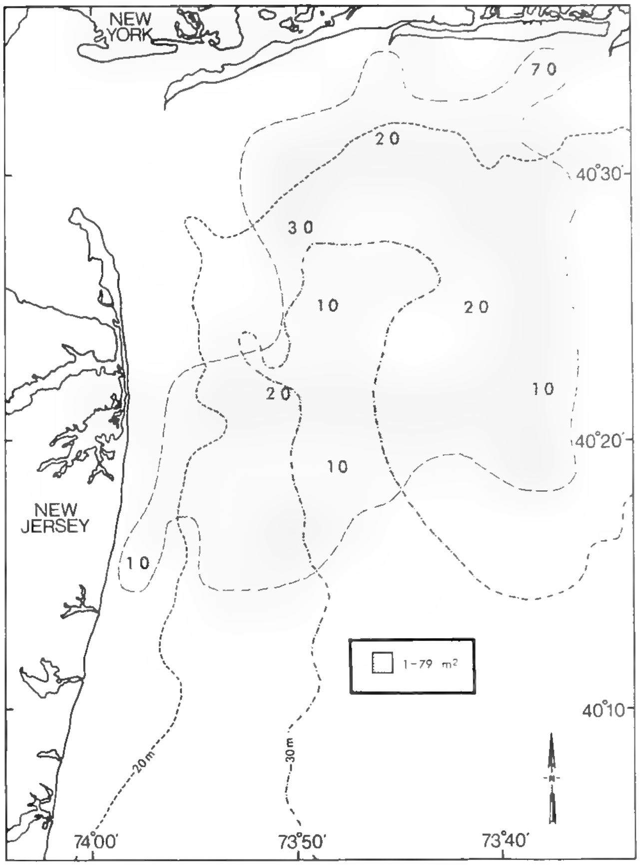

Figure 54.—Distribution and abundance of *Ampharete arctica* in the New York Bight apex.

Hutchings (1973) studied reproductive patterns of a related species, *Mellina cristata*. The Northumberland (England) population of *M. cristata* breeds annually over a period of about 2 wk at the end of December and beginning of January. Benthic larvae are produced which metamorphose into juveniles within 2 to 3 wk of spawning. *Mellina cristata* is potentially capable of breeding for the first time when 2 yr old. The majority of worms survive spawning and *M. cristata* probably breeds annually for several years. In this population, not all potential breeders spawn, some resorb their gametes and release another batch of gametes into the coelom. The Northumberland population of *M. cristata* is near the southernmost limit of the species distribution, which indicates that environmental conditions for this population are not optimum. The population appears to maintain itself by producing fewer oocytes and by only part of the population spawning.

Asabellides oculata (Webster, 1880)

DESCRIPTION: Sessile worms, dwelling in membranous tubes. In our collections, lengths reached 20 mm.

DISTRIBUTION: Cape Cod to Cape Hatteras (Gosner 1971).

HABITAT: Depths of 5–15 m (Gosner 1971). In the New York Bight apex, we found *Asabellides oculata* in depths of about 10–46 m. It was present in all sediment types but reached peak abundance in fine sand. Its total abundance was highest in low organic areas, reaching moderate abundance in high organic areas. However, the

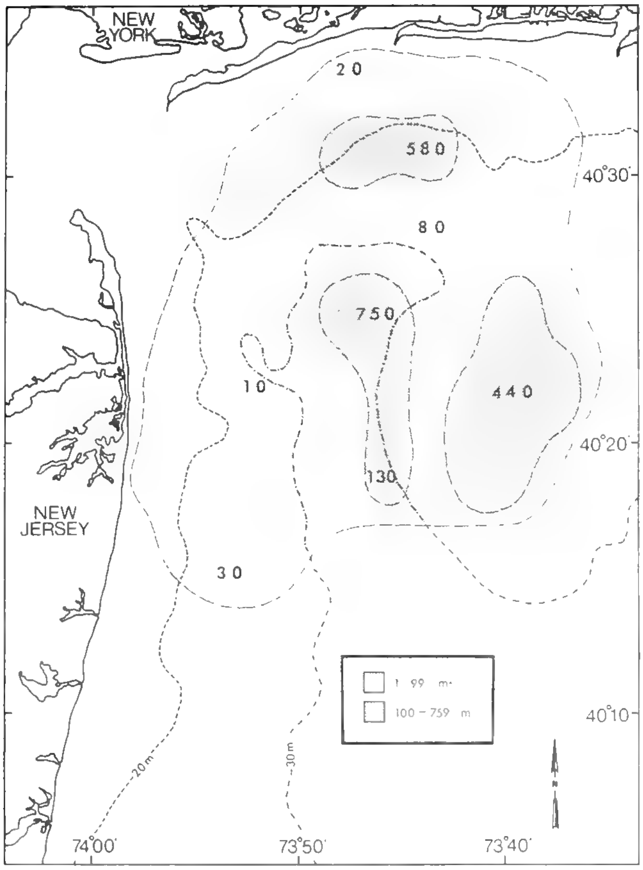

Figure 55.—Distribution and abundance of *Asabellides oculata* in the New York Bight apex.

highest concentration of *A. oculata* occurred at a high organic content station (Fig. 55; Table 1).

FEEDING ECOLOGY: *A. oculata*, like other Ampharetidae, is a surface deposit feeder (see *A. arctica*).

REPRODUCTION AND GROWTH: No specific information is available for *A. oculata* (see *Ampharete arctica*).

ADDITIONAL INFORMATION: It has been observed that *A. oculata* and several other tube dwelling polychaetes produce the enzyme protease externally. It is hypothesized by Zottoli and Carriker (1974) that this enzyme helps keep the internal surface of their tubes free of attaching organisms.

In recolonization studies during summer 1977, following the 1976 anoxic event in the New York Bight, "blooms" of *A. oculata* were observed in formerly oxygen depleted areas (Steimle and Radosh 1979). Although *A. oculata* is not generally regarded as an opportunist, we found it in highest concentration at a high organic station in the present study and we also found it in large numbers in an earlier unpublished study at an ocean sewer outfall off Deal, N.J. Fauvel (1958) remarked that the unusual pectinate gills found in this family (Ampharetidae) are adaptations for surviving in poorly oxygenated water.

Order Flabelligerida

Pherusa affinis (Leidy, 1855)

DESCRIPTION: A large, rather sedentary species characterized, in part, by the possession of mucus-secreting papillae to which sand or mud particles adhere. Lengths in our collections reached 75 mm.

DISTRIBUTION: Maine to Chesapeake Bay (Kinner and Maurer 1978).

HABITAT: *Pherusa affinis* has been collected in moderately high numbers from the New York-New Jersey outer continental shelf (Pearce, Caracciolo, Halsey, and Rogers 1977a). In a study of the New York Bight apex, Pearce (1972) found *P. affinis* to be more abundant around sludge deposits than in natural communties. In the present investigation of the apex, *P. affinis* was found in all sediment types but was again clearly most abundant in high organic fine sand and silty sediments, occurring in numbers as high as 800/m² (Fig. 56; Table 1).

FEEDING ECOLOGY: The Flabelligeridae are discreetly motile deposit feeders, using their large frilly palps to collect food particles from the sediment surface (Jumars and Fauchald 1977).

REPRODUCTION AND GROWTH: No specific information was available in the literature for this species. However, Fallon

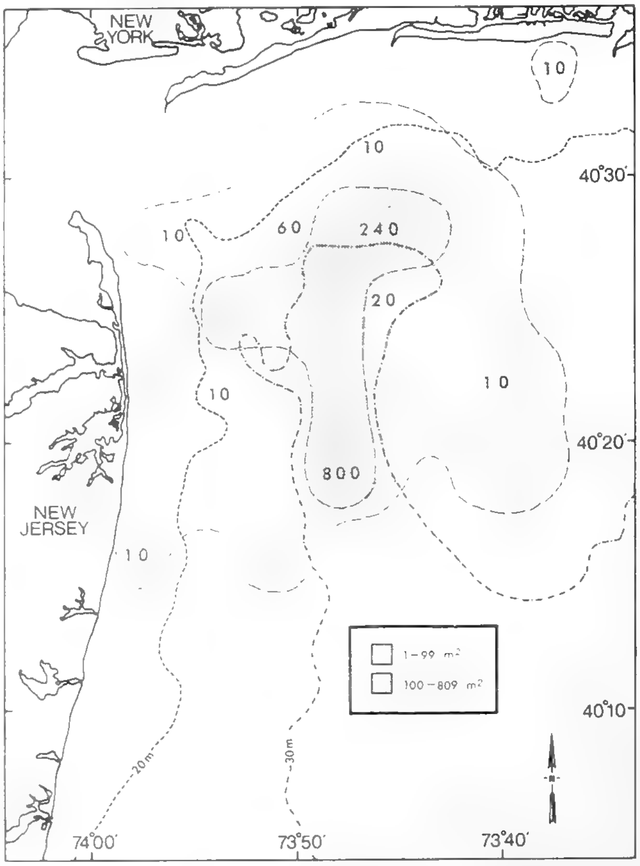

Figure 56.—Distribution and abundance of *Pherusa affinis* in the New York Bight apex.

(footnote 5) found the peak reproductive period for *P. affinis* in the New York Bight to be during spring and fall, with some recruitment almost all year. In our study of the apex, there were approximately 1.5 times more *P. affinis* in the Bight during summer months than during the winter in terms of higher densities at the same stations.

Phylum Arthropoda

Class Crustacea

Order Isopoda

***Edotea triloba* (Say, 1818)**

DESCRIPTION: The genus and species *Edotea triloba* has been revised to include the species *montosa* (Stimpson) and *acuta* (Richardson). It is a small, dorso-ventrally flattened, oval-shaped, muddy-colored isopod crustacean, which grows to about 10 mm in length (Miner 1950; G. Schultz 1969).

DISTRIBUTION: Miner (1950) reported that this species is distributed from Nova Scotia to New Jersey.

HABITAT: Smith (1964) reported that *E. triloba* is found on muddy shores, usually with dirt adhering to the carapace. Miner (1950) reported it from mud and fine sand from the surface to 46 m. In the New York Bight apex, *E. triloba* was widely distributed in depths ranging from about 9 to 46 m. It occurred in all sediment types but was most common in low organic fine to medium sands (Fig. 57; Table 1).

FEEDING ECOLOGY: Pearse et al. (1942) considered *E. triloba* a scavenger, Sanders (1956) classified it as a selective deposit feeder, and Myers (1977) called it an epistratal feeder.

G. Schultz (1969) reported finding *E. triloba* as a prey item in the stomachs of cod.

REPRODUCTION AND GROWTH: Sexes in isopods are separate. Eggs are brooded by the female in the marsupium. As in cumaceans and tanaidaceans, the hatching stage is a postlarva (manca stage), having the last pair of legs incompletely developed. The young usually do not remain with the female after they leave the marsupium (Barnes 1974).

Order Amphipoda

***Ampelisca verrilli* Mills, 1967**

DESCRIPTION: A small amphipod, males grow to 10.5 mm in length, females to 13.5 mm. Body compressed, smooth, two pairs of eyes. *Ampelisca verrilli* is a domiciliary form which constructs a shallow, thin-walled tube in sand. The tubes are open only at the upper end, the inner walls solidified by glandular secretions from the peraeopods (Bousfield 1973).

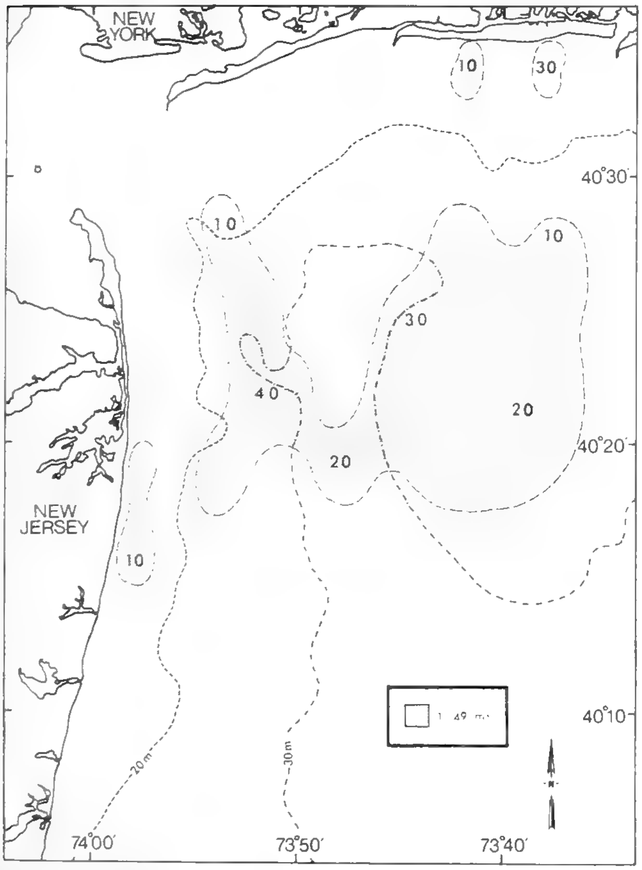

Figure 57.—Distribution and abundance of *Edotea triloba* in the New York Bight apex.

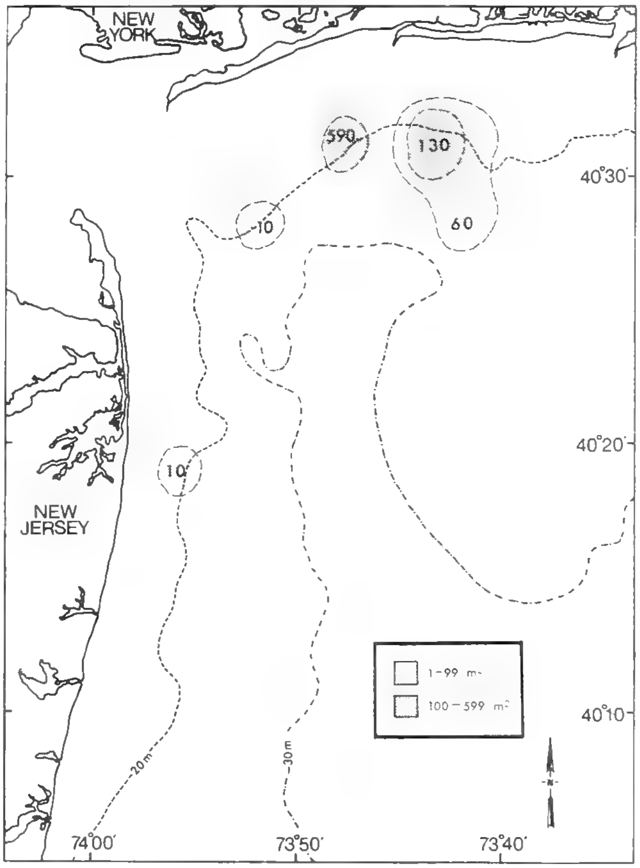

Figure 58.—Distribution and abundance of *Ampelisca verrilli* in the New York Bight apex.

DISTRIBUTION: Southern side of Cape Cod to North Carolina (Bousfield 1973); Gulf of Florida from Tampa north (Bousfield).[12]

HABITAT: Kinner et al. (1974) reported this species to dominate a transitional zone between sand and mud in Delaware Bay. Bousfield (1973) reported it to be abundant in coarse sand from low intertidal to depths of about 50 m. *Ampelisca verrilli* was the second most abundant amphipod collected in the New York Bight apex, most commonly found in fine sands with some occurring in medium sands off Long Island and New Jersey. This species was present only in low organic areas in depths to 24 m (Fig. 58; Table 1).

FEEDING ECOLOGY: *Ampelisca* spp. lie upside down in their tubes, projecting their setose antennae as filtering organs (Barnard 1969). *Ampelisca verrilli* has been classified as a suspension feeder-surface detritivore (Bousfield).[13]

REPRODUCTION AND GROWTH: Bousfield (1973) stated that *A. verrilli* has an annual life cycle in New England, with ovigerous females present in the summer. However, in a west Florida estuary, Thoemke (1977) found ovigerous females to be present year-round, averaging 9.6% of the population. He believed them to produce several broods per year. In view of these differences, temperature may be of importance in regulating the life cycle of this species.

In this family (Ampeliscidae), the mature male form emerges in abrupt metamorphosis from a femalelike penultimate stage (Bousfield 1973).

Unciola irrorata Say, 1818

DESCRIPTION: Smooth, slender, slightly depressed body with red spots or blotches when alive. Females grow to 10 mm, males to 13 mm. *Unciola irrorata* usually inhabits tubes constructed by other amphipods or polychaetes, but can build a tube of its own if no others are available (Bousfield 1973). Smith (1950) reported that these amphipods have been observed swimming or roaming across the bottom, leaving their tubes for considerable lengths of time.

DISTRIBUTION: Gulf of St. Lawrence to Cape Hatteras (Bousfield 1973); off South Carolina (Shoemaker 1945); also, Greenland, Norway (Holmes 1905).

HABITAT: Pratt (1973) and Maurer et al. (1976) included *U. irrorata* as a member of the silty sand fauna of the Middle Atlantic continental shelf and estuaries. Bousfield (1973) reported it to be found in coarse to medium sands from the lower intertidal to over 55 m in New England waters. Shoemaker (1945) recorded the species in depths to 283 m, Holmes (1905) recorded it to over 914 m and Schmitz (1959)[14] reported *U. irrorata* from muddy bottoms in North Carolina to depths of 1,500 m. Pearce (1972) found *U. irrorata* to be the only amphipod collected in the sewage sludge disposal area of the New York Bight apex. Michael (1973) called *U. irrorata* a cold water species which tolerates a wide range of sediment types, but prefers sand. The present collections in the Bight apex show *U. irrorata* to occur in all grades of sand, particularly in fine sand and in low organic areas. *Unciola irrorata* was widespread in the apex, the third most abundant amphipod collected, occurring in depths to 33 m (Fig. 59; Table 1).

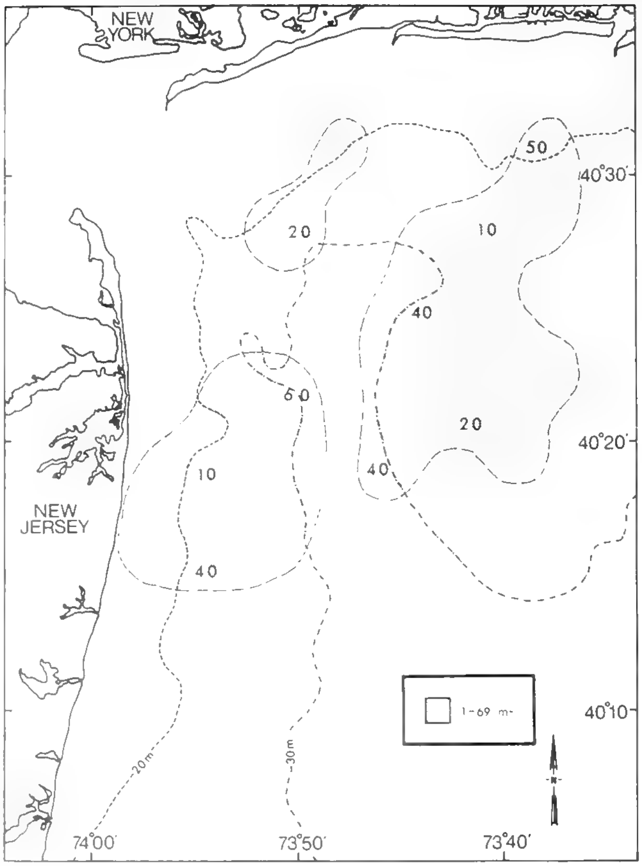

Figure 59.—Distribution and abundance of *Unciola irrorata* in the New York Bight apex.

FEEDING ECOLOGY: Smith (1950) reported *U. irrorata* to be a scavenger and detritus feeder, while Sanders (1956) classified it as a selective deposit feeder, which may feed on detritus or be herbivorous. Enequist (1949) reported members of this family to be primarily filter feeders, emerging from their tubes and feeding on detritus whenever concentrations of suspended material are low.

Unciola irrorata is a principal forage species for haddock collected off Cape Cod and Georges Bank (Wigley 1956; Wigley and Theroux 1965).

REPRODUCTION AND GROWTH: Bousfield (1973) reported an annual life cycle off New England, with ovigerous females present from March to July; one brood per female. Smith (1950) stated that *U. irrorata* breeds 10–11 mo of the year in Block Island Sound, with mid-summer the minimal spawning season.

Pseudunciola obliquua (Shoemaker, 1949)

DESCRIPTION: Body smooth, slender, lacking eyes; length to 6 mm (Bousfield 1973).

DISTRIBUTION: Bay of Fundy to New Jersey (Bousfield 1973).

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[12] Edward Bousfield, pers. commun., cited by Fox and Bynum (1975).

[13] Edward Bousfield, pers. commun., cited by Biernbaum (1979).

[14] Schmitz, E. 1959. A key to the marine Amphipoda of the Beaufort, North Carolina area. Unpubl. manuscr., 6 p. Duke Marine Laboratory, Beaufort, N.C.

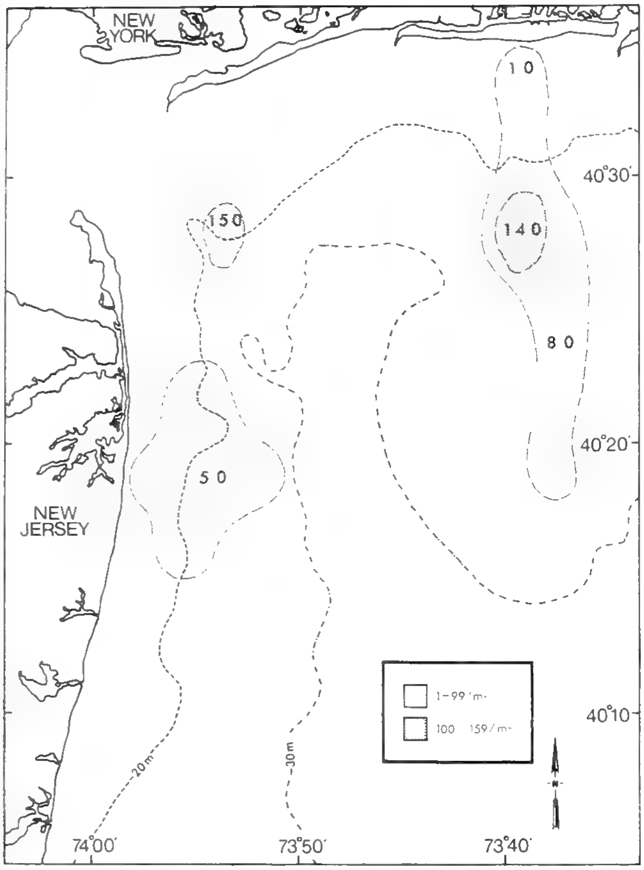

Figure 60.—Distribution and abundance of *Pseudunciola obliquua* in the New York Bight apex.

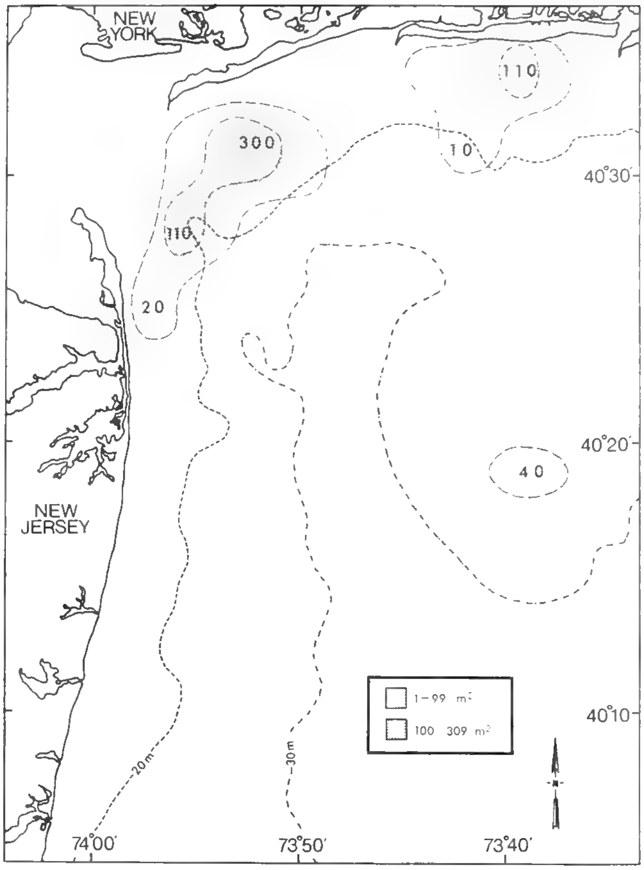

Figure 61.—Distribution and abundance of *Protohaustorius deichmannae* in the New York Bight apex.

HABITAT: Bousfield (1973) reported *Pseudunciola obliquua* to live in tubes in medium fine to coarse sand from just below the low water level to more than 50 m in depth off New England. In the New York Bight apex, *P. obliquua* was collected at several stations (9.6–25 m in depth) to the east and west of the dump sites. It was most common in fine-medium sands, but also occurred in coarse sand areas. *Pseudunciola obliquua* was collected only in low organic sediments (Fig. 60; Table 1).

FEEDING ECOLOGY: Mouthparts of *P. obliquua* are adapted for feeding on algae or detritus (Bousfield 1973).

Shoemaker (1949) found this species as a prey item in the stomachs of haddock.

REPRODUCTION AND GROWTH: Bousfield (1973) reported ovigerous females of this species off New England from April to August, with four–six relatively large eggs per brood. The life cycle is annual.

Protohaustorius deichmannae Bousfield, 1965

DESCRIPTION: A small, free-living, burrowing amphipod. Females of the species grow to 6 mm, but males are slightly smaller (4.5 mm) (Barnard 1969; Bousfield 1973).

DISTRIBUTION: Central Maine to Georgia (Bousfield 1973).

HABITAT: Bousfield (1973) reported that *Protohaustorius deichmannae* prefers shallow, warm water, protected bays and estuaries, depths up to about 20 m, and fine silty sand. This species was also considered characteristic of fine sand bottoms off the Delmarva Peninsula (Maurer et al. 1976). Sameoto (1969) reported a maximum lethal temperature of 36°C and migration of the species into deeper water as temperature decreases. *Protohaustorius deichmannae* is tolerant of low (10‰) salinity and low dissolved oxygen levels. In the New York Bight apex, we found *P. deichmannae* only in fine to medium grain, low organic sands in depths not exceeding 25 m (Fig. 61; Table 1). It was the most abundant amphipod collected during our study.

FEEDING ECOLOGY: Members of this family filter feed while burrowing through the sand. They use their mouthparts to set up a filter current that directs food particles onto mouthpart setae and then toward the mouth (Bousfield 1973). Sameoto (1969) reported this species to feed on diatoms, unidentified green/brown material, ciliates, and smaller crustaceans. According to Croker (1967), it would not feed on carrion.

REPRODUCTION AND GROWTH: *P. deichmannae* has an annual life cycle with ovigerous females found May to August in New England waters. There may be more than one brood per year, with brood size ranging from about 2 to 11 eggs. Copulation may take place in the substratum, mechanism as yet unknown (Sameoto 1969; Bousfield 1973).

Protohaustorius wigleyi Bousfield, 1965

DESCRIPTION: This species is very similar to *Protohaustorius deichmannae*, but is slightly larger, males reaching a length of 6.5 mm, females, 7.5 mm (Bousfield 1973).

DISTRIBUTION: Maine to North Carolina (Bousfield 1973).

HABITAT: Kinner et al. (1974) reported *Protohaustorius wigleyi* to be an important species in the sand bottom assemblage of Delaware Bay, closely associated with the bivalve *Tellina agilis* and the amphipod *Rhepoxynius epistomus*; *P. wigleyi* was the most abundant amphipod in clean medium grain sands off the Delaware coast (Maurer, Leathem, Kinner, and Tinsman 1979). Bousfield (1973) reported that it prefers subtidal clean sands off New England from the shoreline to over 146 m. In the New York Bight apex, *P. wigleyi* was most common near shore in depths up to 21 m. It occurred only in low organic sands, primarily of medium to fine grain size (Fig. 62; Table 1).

FEEDING ECOLOGY: See *Protohaustorius deichmannae*.

REPRODUCTION AND GROWTH: *P. wigleyi* has an annual life cycle in New England waters, with ovigerous females present from April to August (Bousfield 1973).

Leptocheirus pinguis (Stimpson, 1853)

DESCRIPTION: A relatively large gammarid amphipod with a long (up to 17 mm), slender body. *Leptocheirus pinguis* is an epifaunal organism, which constructs mucus and sediment tubes with one end open at the surface (Bousfield 1973).

DISTRIBUTION: American Atlantic coast from Labrador south to Virginia (Bousfield 1973); North Carolina (Fox and Bynum 1975).

HABITAT: Bousfield (1973) reported *L. pinguis* to occur from the low intertidal to >250 m, on sand, sandy mud, or mud bottom, especially in channels of estuaries. Michael (1973) reported this species to prefer cold water and intermediate, poorly sorted sediments. In the New York Bight apex, *L. pinguis* was found at five closely spaced stations south of the dump site. Sediments there are predominantly high organic silt-fine sand, with depths ranging from about 28 to 46 m (Fig. 63; Table 1).

FEEDING ECOLOGY: This filter feeding species uses filter setae of the anterior peraeopods from which food is transferred by maxilliped palps to the mouth (Sanders 1956; Bousfield 1973).

Leptocheirus pinguis is particularly important in the diet of haddock collected from Cape Cod and the south central portion of Georges Bank (Wigley 1956; Wigley and Theroux 1965). Smith (1950) also considered it to be the dominant food species for demersal finfish in Block Island Sound.

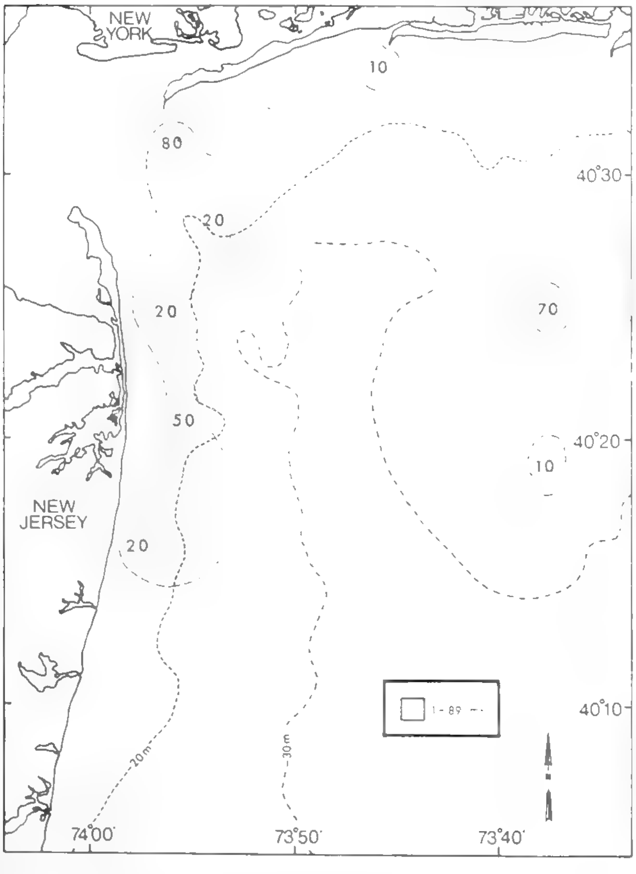

Figure 62.—Distribution and abundance of *Protohaustorius wigleyi* in the New York Bight apex.

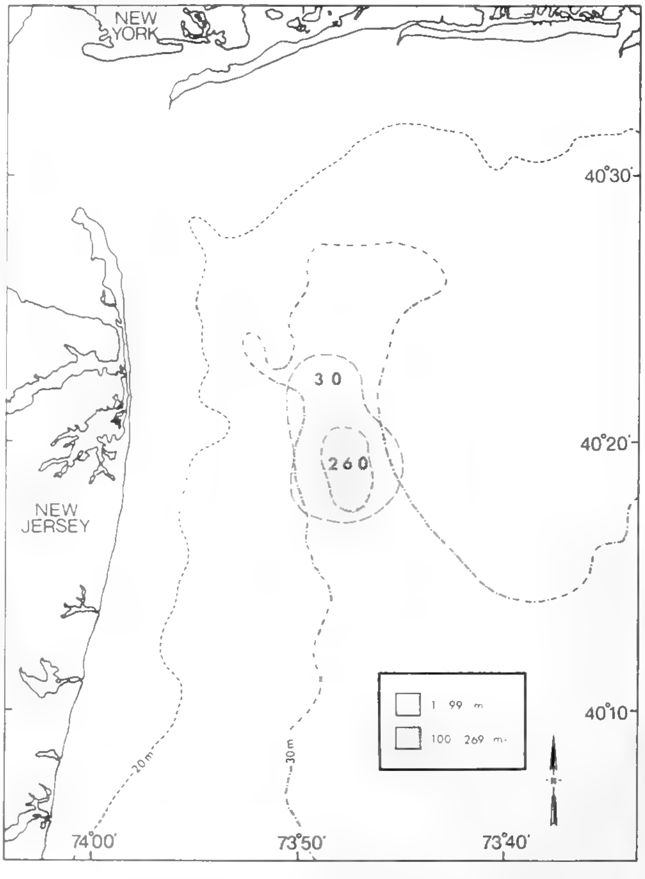

Figure 63.—Distribution and abundance of *Leptocheirus pinguis* in the New York Bight apex.

Tyler (1973) reported the species to have an average caloric value of 2,147 g cal/g dry weight, which is relatively low (2–50%) compared with values for other crustaceans.

REPRODUCTION AND GROWTH: Ovigerous females are present April to June in New England (Bousfield 1973). However, Smith (1950) believed spawning can occur throughout the year, with each female spawning more than once a year. The number of eggs per brood varies from a few to 70 ($\bar{x}=20$). Bousfield (1973) stated that the life span of *L. pinguis* is probably 2 yr.

***Rhepoxynius epistomus* (Shoemaker, 1938)**

[*Trichophoxus epistomus* (Shoemaker, 1938)]

DESCRIPTION: A burrowing species, body relatively broad with a rostral hood abruptly narrowing in front of the black eyes. Females reach a length of 7–8 mm, with males slightly smaller (Barnard 1969; Bousfield 1973).

DISTRIBUTION: American Atlantic between southern Maine and Georgia (Watling and Maurer 1972; Bousfield 1973); also reported from Cuban waters (Ortiz 1978).

HABITAT: Kinner et al. (1974) reported *Rhepoxynius epistomus* to be dominant in sandy areas of Delaware Bay, closely associated with *Tellina agilis* and *Protohaustorius wigleyi*. Bousfield (1973) reported that it is found in medium-fine unstable sands off New England, from immediately subtidal areas to depths of >50 m; males occasionally occur in the plankton. Watling and Maurer (1972) stated that this species is euryhaline in medium to fine sands (5–15% silt-clay). Feeley (1967) suggested a preference for coarse sand. In the apex of the New York Bight, *R. epistomus* was characteristic of medium to fine sands, with a few occurring in coarse sand. It was most common in low organic areas in depths up to 30 m; a few occurred in medium organic areas and none were found in high organic sediments (Fig. 64; Table 1).

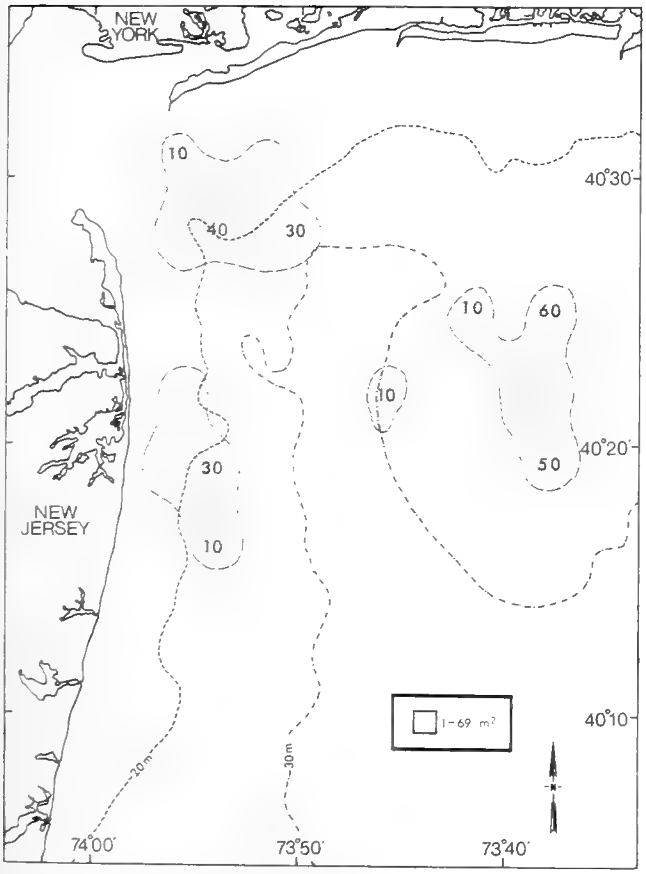

Figure 64.—Distribution and abundance of *Rhepoxynius epistomus* in the New York Bight apex.

FEEDING ECOLOGY: Barnard (1969) believed this species to be omnivorous, while Biernbaum (1979, citing Bousfield footnote 13) classified it as a burrowing detritivore.

REPRODUCTION AND GROWTH: Bousfield (1973) reported that *R. epistomus* has an annual life cycle, with ovigerous females present from May to September off New England. In this family (Phoxocephalidae), the mature male form emerges in abrupt metamorphosis from a femalelike penultimate stage.

Order Mysidacea

***Neomysis americana* (Smith, 1873)**

DESCRIPTION: The opossum shrimp; small shrimp-like crustaceans up to 12 mm in length; eyes on stalks (Gosner 1971).

DISTRIBUTION: Wigley and Burns (1971) reported this species to occur from the Gulf of St. Lawrence to Chesapeake Bay, however, Gosner (1971) extended its range south to Cape Hatteras.

HABITAT: *Neomysis americana* is the most common euryhaline mysid shrimp inhabiting the estuaries and coastal waters of the northeastern United States. Wigley and Burns (1971) regarded it as a shallow water species most commonly reported from the intertidal zone to depths of 60 m; Gosner (1971) reported it in depths up to 214 m. *Neomysis americana* is essentially a bottom dweller during the day, but undertakes regular vertical migrations to the surface during darkness (Herman 1963).

In the apex of the New York Bight, this species was collected nearshore in depths to about 24 m and was most abundant in low organic fine sands (Fig. 65; Table 1). Because the Smith-McIntyre grab sampler is not a particularly good sampling device for this highly motile species, our estimates of its abundance and distribution are probably very poor.

FEEDING ECOLOGY: The food of mysids consists of small plankters or bottom forms as well as detritus filtered from currents set up by the thoracic limbs, thus, mysids might be considered to be omnivorous (Smith 1950; Clutter 1967; Richards and Riley 1967; Gosner 1971).

Stickney et al. (1975) found that the estuarine sciaenid, *Cynoscion regalis*, fed heavily on *N. americana* in the southeastern United States; of a total of 120 fish examined, *N. americana* occurred in 55% of their stomachs. *Neomysis americana*, which is often known to live in large swarms, also forms an important part of the diet of shad, flounder, and haddock (Wigley 1956; Barnes 1963).

REPRODUCTION AND GROWTH: The sexes are separate and there is external dimorphism in this species. Females have a brood pouch and development of young is direct, occurring within the

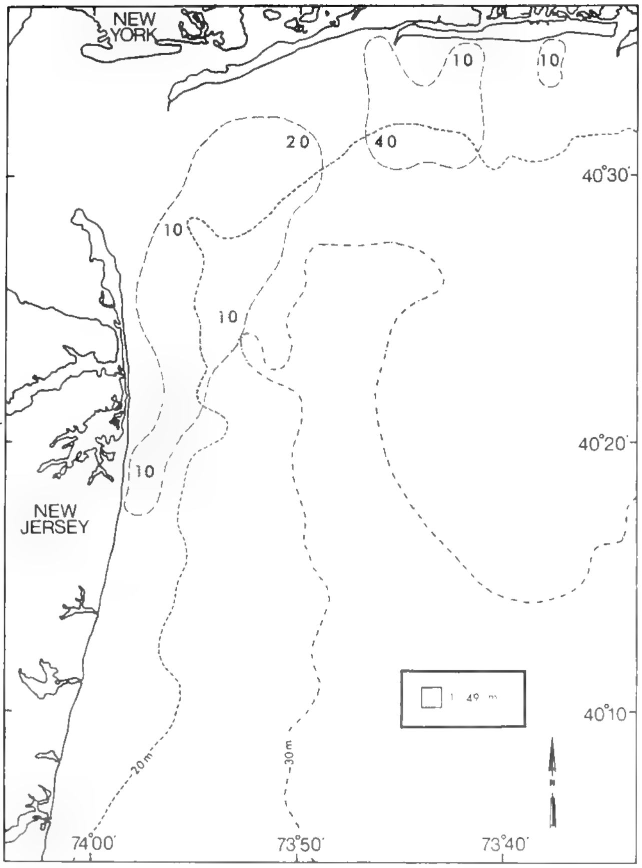

Figure 65.—Distribution and abundance of *Neomysis americana* in the New York Bight apex.

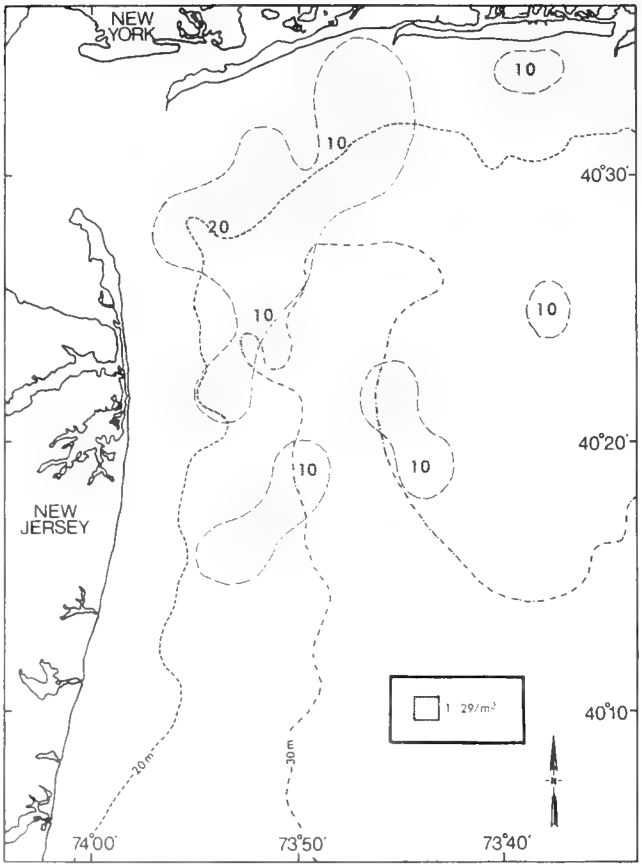

Figure 66.—Distribution and abundance of *Crangon septemspinosa* in the New York Bight apex.

brood chamber (Barnes 1963; Gosner 1971). Wigley and Burns (1971) reported that although spawning in coastal populations takes place throughout the year, it is much more intensive during the warmer months. Two distinct size groups of spawning females per year are discernible, the large spring spawners (11–12 mm) that have overwintered and smaller fall spawners (6–8 mm). Egg production also varies between the two groups, the overwintering group producing about 26 eggs/individual and the summer group about 6 eggs. The life cycle is a year or less and varies per seasonal population. Richards and Riley (1967) have estimated a production to biomass ratio of 3.66 for this species in Long Island Sound.

Order Decapoda

Crangon septemspinosa (Say, 1818)

DESCRIPTION: The common sand shrimp. Color ash-gray with numerous irregular, stellate, black or brown spots or chromatophores, or speckled with gray, imitating the color of sand. Length to 70 mm (Price 1962; Williams 1965).

DISTRIBUTION: In the Atlantic it occurs from Baffin Bay, Canada, to eastern Florida. It also occurs from Alaska to California on the Pacific coast and in Japan (Williams 1965).

HABITAT: *Crangon septemspinosa* occurs in great numbers from the littoral zone to depths of 91 m. It is common on sand flats, in tidepools, in bays and inlets along the coast, and in sandy bottoms in deeper water offshore. Its color imitates that of sand so closely that it is camouflaged when resting motionless on the bottom or when partially buried in the sand. Between tides, it uses its pleopods to bury itself in the moist sand to a considerable depth (Miner 1950; Williams 1965). *Crangon septemspinosa* can tolerate a salinity range of 4–32‰ and temperature extremes from 0.0° to 26.0°C (Price 1962).

In the New York Bight apex, *C. septemspinosa* occurred in low abundance, 10–20/m², in depths from 9.6 to 29.8 m. It was collected in all grades of medium and low organic content sand, but was most abundant in low organic fine-medium grain sand (Fig. 66; Table 1).

FEEDING ECOLOGY: Price (1962) considered this species to be an omnivore in Delaware Bay. Williams (1965) reported that it consumes planktonic crustacea and scavenged material. Sanders et al. (1962) found that *C. septemspinosa* ate detritus, diatoms, small crustacea (ostracods), small mollusks (*Gemma gemma*), nematodes, and algae in Long Island Sound. Wilcox and Jeffries (1974) found the species to prefer and grow best on animal tissues of marine origin although it was also able to utilize food of microbial and terrestrial origins.

Creaser (1973) stated that spent epitokes of the bloodworm, *Glycera dibranchiata*, are consumed by *C. septemspinosa*, which in turn is eaten by the striped bass, *Morone saxatilis*. *Crangon septemspinosa* must utilize all of its powers of concealment, for it is actively sought and consumed by nearly all of the larger fishes which frequent its waters. It constitutes a principal food for weakfish, *Cynoscion regalis*; kingfish, *Menticirrhus saxatilis*; bluefish, *Pomatomus saltatrix*; flounders (*Paralichtys dentatus* and *Pseudopleuronectes americanus*); striped bass, *Morone saxatilis*; and haddock, *Melanogrammus aeglefinus* (Whiteley 1948; Miner 1950; Wigley 1956).

REPRODUCTION AND GROWTH: Price (1962), studying the biology of *C. septemspinosa* in Delaware Bay, made collections in a salinity range of 4.4 to 31.4‰ at temperature extremes of 0.0° to 26.0°C. The major breeding season was judged to be March to October, but ovigerous females were found throughout the year in salinities of 17.7–29.3‰ and temperatures of 0.0°–25.0°C. He found females to mature in 1 yr, with egg production increasing with increasing size of the female. First egg bearers of the year were found to be large females, with smaller ovigerous females more numerous in July. An average of 300 eggs/female was produced in one annual brood. In Maine waters, Haefner (1972) suggested that there may be more than one brood per year. In the laboratory, eggs hatched into planktonic larvae after 6 or 7 d at 21°C. Fowler (1912) reported that larvae and young maintained a planktonic existence for a long period of time after hatching.

Females outnumbered the males especially during the most active spawning season in Price's (1962) study. Growth rate was estimated to be 1.6 mm/mo, with no observed seasonal variation in the rate. Richards and Riley (1967) also reported growth rates of 1.6 mm/mo in Long Island Sound. However, Wilcox and Jeffries (1973) found that growth was temperature dependent and varied between 0.4 and 1.1 mm/wk off Rhode Island.

Contrary to the appraisal of other authors, Price (1962) judged that three year classes of females and two year classes of males occur in the shoal waters of Delaware Bay in spring.

Ovigerous females have been found in North Carolina from December through May and August and late fall (Hay and Shore 1918). Individuals taken in winter are larger than those found in spring. Juveniles have been found there from December to July, but from mid-summer to late fall, juveniles and adults disappear from North Carolina estuaries.

Bigelow and Sears (1939) reported much the same pattern of occurrence in waters of the continental shelf from Cape Cod to Chesapeake Bay, with greatest occurrence in February dwindling to rare occurrence in July, but never abundant anywhere.

On Georges Bank, where Whiteley (1948) made all collections inside the 100-fathom curve, *C. septemspinosa* was most common in September and January, rarest in June, and usually occurred near the bottom. He reported maximum numbers in July at Woods Hole, and in August in the Bay of Fundy. Ovigerous females were found in spring and early summer. The species was judged to produce one brood a year and to have a life span of 1 yr.

In Long Island Sound, *C. septemspinosa* had mean abundances of 12/m^2 in July 1972, 1/m^2 in April, and 8/m^2 in September 1973 in grab samples taken in mud bottom areas. The species had similar abundances in sands ($\bar{x}=5$/m^2 in July 1972 and 16/m^2 in September 1973), and was slightly more common in sandy silts (18/m^2 in July 1972, 22/m^2 in September 1973) (Reid et al. 1979). In an April through September 1971 survey in the western Sound, using an epibenthic sled, both larvae and adults were most abundant in July and August (National Marine Fisheries Service 1972).[15]

Fish (1926) found the larvae appearing from February to May and as late as December at Woods Hole, Mass. Needler (1941) recorded hatching times from late spring to early summer (July) around Prince Edward Island, Canada. She described five larval stages and a postlarval stage. All these stages were obtained in July from plankton tows made about a meter below the surface along the shores of estuaries. Larvae were hatched in the laboratory, but the series of stages was worked out from plankton samples.

These data indicate an extended breeding season in high latitudes. Variations in seasonal abundance in different localities north of Chesapeake Bay are possibly the result, in part, of varied sampling methods in different years by different investigators.

ADDITIONAL INFORMATION: In acute toxicity bioassays with $CdC1_2{\cdot}2^1/_2H_20$ at 20°C and 20‰, Eisler (1971) found that the concentration, fatal to 50% of the organisms of various marine species in 96 h, ranged between 0.32 and 55.0 mg/1 Cd^{2+}. *Crangon septemspinosa*, at 0.32 mg/1, was most sensitive of the species tested.

In a study of acute toxicities of insecticides on marine decapod crustaceans, Eisler (1969) again found *C. septemspinosa* to be the most sensitive to 12 insecticides tested.

In studies of color discrimination among crustaceans, it has been observed that the chromatophores of *C. septemspinosa* adapt to a background of yellow, orange, and red, chromatophore changes being mediated through the eyes (Barnes 1963).

Cancer irroratus (Say, 1817)

DESCRIPTION: The rock crab. The carapace reaches a length of 65 mm (Williams 1965) and a maximum reported width of 160 mm (Gosner 1971); it is yellowish in color, closely dotted with dark purplish brown, becoming reddish brown after death. The anterolateral border is divided into nine teeth with margins granulate, not denticulate as in *Cancer borealis*. Crabs of the genus *Cancer* have been in existence since the Eocene epoch; today, there are 19 living species in the world (MacKay 1943).

DISTRIBUTION: Labrador to South Carolina (Williams 1965); Jeffries (1966) listed the southernmost limit as Florida.

HABITAT: Collected from the intertidal zone to depths of 574 m (Williams 1965). *Cancer irroratus* prefers sandy or rocky substrates, but has also been found on mussel beds (Jeffries 1966; Scarratt and Lowe 1972; Winget et al. 1974; Krouse 1976; Reilly and Saila 1978). In general, smaller individuals are found inshore and larger individuals inhabit offshore areas (Scarratt and Lowe 1972; Haefner 1976; Krouse 1976). For example, Haefner (1976), in a study of the Middle Atlantic Bight, found that rock crabs <50 mm in size were most abundant in depths of 15–150 m, and larger crabs (50–100 mm) were generally more common in depths of 150–400 m, however, the largest individuals (>100 mm) were most abundant at 20–60 m.

The preferred temperature range of *C. irroratus* is reported to be 6.8°–14°C, however, they are known to inhabit areas of 3°–20°C (Jeffries 1966). Salinities ranging from 14 to 33‰ are tolerable (Winget et al. 1974; Haefner and Van Engel 1975).

In cooler New England waters, larger individuals may emigrate into deeper, warmer offshore waters during winter (Jeffries 1966; Krouse 1976).

In the New York Bight apex, small *C. irroratus* were collected in depths ranging from about 11.5 to 29.8 m. They were found in all sediment types, but were most common in low organic medium-fine grain sands (Fig. 67; Table 1).

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[15] National Marine Fisheries Service. 1972. Davids Island Phase I: A short-term ecological survey of western Long Island Sound. Middle Atlantic Coastal Fisheries Center Informal Rep. 7, 29 p.

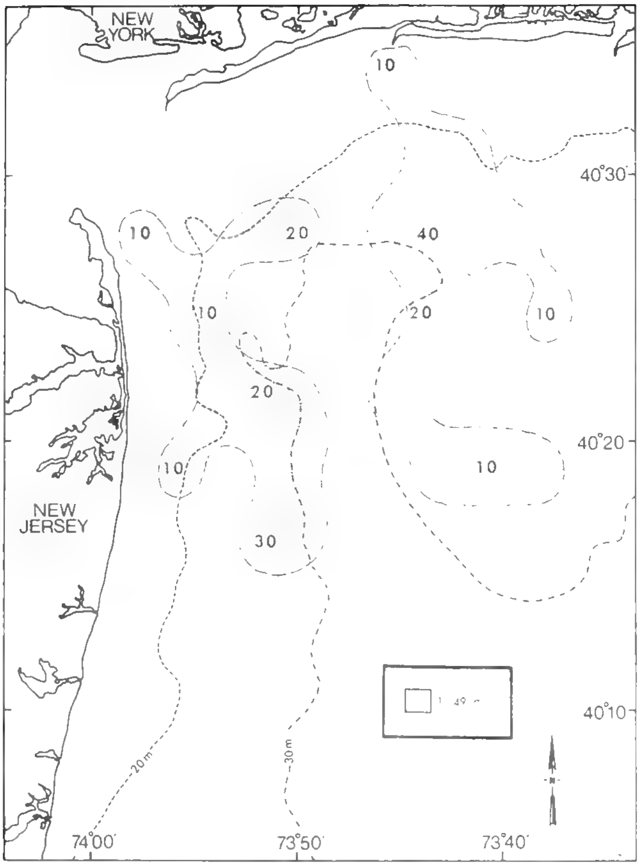

Figure 67.—Distribution and abundance of *Cancer irroratus* in the New York Bight apex.

FEEDING ECOLOGY: This species is known to be a scavenger and carnivore. MacKenzie (1977) reported that it preys upon small clams, while Scarratt and Lowe (1972) have observed that prey of rock crabs >25 mm in size consisted principally of polychaetes, mussels, starfish, and sea urchins.

Rock crab juveniles and adults are preyed upon by several species of fish including cod, *Gadus morhua*; little skates, *Raja erinacea*; red hake, *Urophycis chuss*; striped bass, *Morone saxatilis*; tautog, *Tautoga onitis*; and haddock, *Melanogrammus aeglefinus* (Field 1907; Bigelow and Schroeder 1953; Wigley 1956; Wigley and Theroux 1965; Reilly 1975; Reilly and Saila 1978).

Ennis (1973) reported that in Bonavista Bay, Newfoundland, *C. irroratus* and other decapods make up almost 50% of the gut contents of the lobster *Homarus americanus*.

REPRODUCTION AND GROWTH: In the Northumberland Strait, Gulf of St. Lawrence, Scarratt and Lowe (1972) found the smallest size at maturity was 60 mm for females and 69 mm for males, with breeding occurring in late summer and fall. Larvae are present in surface waters from June to September. In the Gulf of Maine, Krouse (1976) observed that most females attained sexual maturity between 70 and 80 mm carapace width, with a few at <70 mm. Spawning is believed to occur in late fall and early winter and hatching occurs in spring. In southern New England waters, Reilly and Saila (1978) reported that females in the 21–88 mm carapace width range could produce between 4,430 and 330,400 eggs/individual. The presence of ovigerous females <50 mm in size indicated early sexual maturity. Spawning occurred in the spring with major hatching in May. July was the principal period for larval settlement. In Narragansett Bay, Sastry and McCarthy (1973) found ovigerous females with eggs nearing hatching from late April to early June. Hillman (1964) first found *C. irroratus* larvae in Narragansett Bay in late May, while Frolander (1955) found larvae from April to late October in the same waters. Coastal New Jersey plankton surveys by Sage and Herman (1972) revealed *C. irroratus* larvae in late spring samples. In a Chesapeake Bay study, Sandifer (1975) observed that ovigerous females are infrequent in the bay and most larvae appear to hatch offshore. Although larvae are tolerant of moderate estuarine salinities, zoeae probably are retained within the Bay only by chance. Bay or nearshore populations are apparently restocked by migration or transport by currents of late larval stages and juveniles from the inner shelf area. The optimum growth rate of *C. irroratus* larvae occurs at 15°C and 30‰ (Sastry and McCarthy 1973).

Uneven sex ratios for this species are not unusual. Large male: female ratios have been observed in Maine (Dean 1972),[16] the Northumberland Strait (Scarratt and Lowe 1972), and in Virginia, where there is an absence of females in winter populations (Shotten and Van Engel 1971),[17] possibly the result of population movements restricted to one sex (Jones 1973).

Cancer irroratus lives for 7 to 8 yr (Reilly and Saila 1978). In the Middle Atlantic Bight, active molting takes place in April and June (Haefner 1976) and growth ceases in winter.

ADDITIONAL INFORMATION: Vargo and Sastry (1977) conducted an experiment to determine the tolerance limits to acute temperature and combinations of temperature and low dissolved oxygen stresses for five zoeal stages and the megalops of *C. irroratus*. Results showed that the acute temperature limits for a 120-min exposure were all approximately 29.0°C, with little interstage variation, while those for 240 min ranged from 27.3° to 28.5°C. Most interstage variation was shown when temperature and low dissolved oxygen were combined, with low oxygen tolerance decreasing as temperature increased. The megalops is relatively insensitive to changes in oxygen concentration with temperature. It was concluded that larval stages have the capacity to tolerate a wider range of these variables than they experience in the natural environment.

In another study, Bigford (1977) cultured larvae of *C. irroratus* and exposed them to 0.0, 0.1, and 1.0 ppm concentrations of a water-accommodated fraction of No. 2 fuel oil under static conditions. Behavioral changes were monitored in terms of water column reponses to various conditions of light, pressure, and gravity. The most important effects of these sublethal exposures were the reversals of normal larval gravity responses in the water column. Results were that the normally geonegative, early stage larvae moved lower in the water column and the normally benthic megalops stage rose in the water column. This depression of typical megalopal benthic behavior in exposed larvae could alter recruitment to adult populations. As noted previously, Sandifer (1975) stated that *C. irroratus* apparently do not return to their adult habitats during planktonic stages. Instead, late larval stages and juvenile crabs join adult populations via extensive migrations. Therefore, alteration of late larval stage benthic behavior patterns could keep most larvae out of bottom shoreward currents that aid in recruitment movements. It was also determined that the 1.0 ppm concentration of this fuel oil is very near the lethal dose for these larvae.

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[16] Dean, D. (editor). 1972. The University of Maine's Sea Grant Program for 1 May 1971 to 30 April 1972. Univ. Maine, Orono, 25 p.

[17] Shotten, L., and W. Van Engel. 1971. Distribution, abundance and ecology of the rock crab (*Cancer irroratus*) in Virginia coastal waters of the Chesapeake Bight of the Virginia Sea. Va. Inst. Mar. Sci. Rep. 40, 3 p.

Phylum Echinodermata

Class Echinoidea

Echinarachnius parma (Lamarck, 1816)

DESCRIPTION: This flat, circular echinoderm is the common sand dollar. It is usually purple-brown in color when alive and uninjured, but changes to dark green when exposed to air, injured, or recently dead. Size up to 83 mm in diameter (Lohavanijaya 1964).

DISTRIBUTION: This species is discontinuously circumboreal, being found both in the North Pacific and North Atlantic, but not in Arctic regions. In the western North Atlantic, the known range extends from Cape Hatteras to Labrador and Greenland (Mortensen 1948; Durham 1955); Lohavanijaya (1964) reported specimens observed from the Bahamas and Cuba, but Virginia is the limit of the U.S. coastal population.

HABITAT: Coe (1972) reported that in the northern part of its range, *Echinarachnius parma* is found near the low water mark, but further south it occurs only in deeper water, to 2,500 m. Lohavanijaya (1964) found them abundant in the surf zone in Maine. In the New York Bight apex, they were located in depths ranging from about 10 to 30 m (Fig. 68), however, they are known to occur in New York-New Jersey outer continental shelf samples in depths exceeding 75 m (Pearce, Caracciolo, Halsey, and Rogers 1977a). Stanley and James (1971) reported that the distribution of this species off Nova Scotia can be closely related to mean grain size of sediments. They were most abundant in fine (2–3ϕ) to medium (1–2ϕ) clean sands, not being found in very fine sand or in well-sorted sand. In the New York Bight apex, this species was also collected almost exclusively in fine or medium sand with an organic content of $<3\%$ (Fig. 68; Table 1). *Echinarachnius parma* is sensitive to anoxic conditions, and while they may be found in areas of organically enriched sediment sublayers, Parker (1927) reported that they will not burrow there. During the anoxic problem in the New York Bight in 1976, the *E. parma* population in a large area, over 1,000 km^2, was killed (Steimle and Radosh 1979). Redford (1978) reported that *E. parma* may also be sensitive to sewer outfalls because of a significant decrease in occurrence and abundance in an area off southern Long Island, 5 yr after the installation of a sewer outfall.

FEEDING ECOLOGY: *E. parma* has been reported to be both a deposit and suspension feeder. Stanley and James (1971), Coe (1972), and Timko (1976) regarded this species to be a microphagous deposit feeder, subsisting on microscopic organisms, particularly diatoms and other algal material. Phelan (1977) reported little or no sand in the intestinal tract, indicating *E. parma* is a selective feeder. In the Pacific, Sokolova and Kuznetsov (1960) and Zenkevitch (1963) considered the species to be a suspension feeder, based on their observations of high concentrations in some areas, such that individuals touch or overlap.

Feeding is accomplished by the use of some of the weak tube feet, cilia, and mucus strands (Parker and Van Alstyne 1932; Hyman 1955; Sokolova and Kuznetsov 1960; Phelan 1977), which collect and move food particles along furrows to the ventral mouth. Feeding may occur while the species is on the surface or burrowing in the sediment.

Ruddell (1977) found that approximately 8% of the sand dollars he examined in the New York Bight had commensal ciliates attached to their tests. Similar ciliates were noted on asteroid starfish.

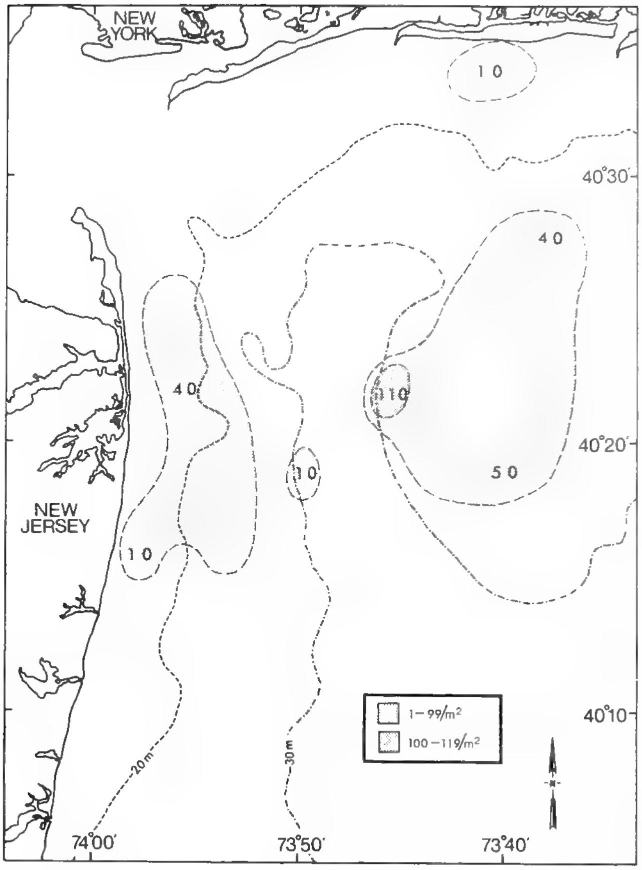

Figure 68.—Distribution and abundance of *Echinarachnius parma* in the New York Bight apex.

Coe (1972) reported that "in many localities, the species [*E. parma*] is so abundant as to form an important part of the food supply of certain fishes, particularly the flounder, codfish and tautog." In the northwest Atlantic, Maurer and Bowman (1975)[18] found *E. parma* to comprise 94% by weight of the diet of Conger eel, *Conger oceanicus*, 54–71% of the diet of ocean pout, *Macrozoarces americanus*, and 40–67% of the diet of American plaice, *Hippoglossoides platessoides*.

REPRODUCTION AND GROWTH: Cocanour and Allen (1967) reported that this species spawns during the fall (September-December) in Maine, and Ruddell (1977) reported similar findings in the southern New York Bight. Fewkes (1886) reported the appearance of larvae in September in Rhode Island. Maurer et al. (1976) reported finding juveniles (<5 mm) in early November off Delaware. Graef (1977),[19] after examining the size distribution of *E. parma* collected in New York Bight apex samples, suggested that new recruits (>10 mm) are available all year but peak in March. Ruddell (1977) found ripe females present from spring

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[18] Maurer, R., Jr., and R. Bowman. 1975. Food habits of marine fishes of the northwest Atlantic. Northeast Fisheries Center Data Report, Woods Hole, Mass., Lab. Ref. 75-3, 90 p.

[19] Graef, J. 1977. A preliminary investigation of the growth rate and natural history of *Echinarachnius parma* (Lamarck) in the New York Bight apex area. Unpubl. manuscr., 25 p. Northeast Fisheries Center Sandy Hook Laboratory, National Marine Fisheries Service, NOAA, Highlands, NJ 07732.

through fall off New Jersey and Costello et al. (1957) reported spawning in the Woods Hole region to occur between March and August.

Ruddell (1977) reported that sexual maturity is attained when individuals reach a size of 27 mm or larger off Delaware, while Cocanour (1969) reported gonad development at a size of about 40 mm in Maine, when the organisms are about 3 yr old.

Juveniles are reported to grow very slowly during the winter (Gordon 1929). Males and females occur in equal abundance without any size differential. Cocanour (1969) reported that maximum growth in Maine occurs during seasons of warmest water temperature, March through September. She also reports that during the winter there is some "negative" growth or shrinkage. The sand dollar may have alternating years of growth or gamete production, which may not occur simultaneously. Average growth rates were estimated at 2.0–6.4 mm/yr over a 24–30 mo period for mid-sized (30–50 mm) specimens. Durham (1955) estimated the age of a 48 mm Woods Hole specimen to be 7 yr, based on growth ring analysis, indicating a growth rate of almost 7 mm/yr. Graef (footnote 19) reported the maximum size *E. parma* found in New York Bight apex samples was 53 mm, at an age of about 6 yr, and Brykov (1975) reported a maximum age of 21 yr in specimens from the Sea of Japan, both estimates again based on growth ring analysis. This implies a growth of <9 mm/yr in the Bight apex. Younger individuals have a faster growth rate than mature individuals and Ebert (1975) suggested that, for many echinoids, growth is variable from season to season and from year to year.

Swan (1966) reported that *E. parma* is fully capable of regenerating nipped edges.

ADDITIONAL INFORMATION: *E. parma* has been reported to occur in numbers up to 180 individuals/m^2 off Nova Scotia (Stanley and James 1971) and over 200/m^2 in the North Pacific (Zenkevitch 1963). In the New York Bight apex, the maximum concentration found was 110/m^2. Steimle and Stone (1973) collected 195 individuals (>10 mm in diameter) in a 0.0625 m^2 sample (or 3,120/m^2) northeast of the apex boundaries. Graef (footnote 19) noted a tendency of size classes to be segregated in the New York Bight apex. Cocanour (1969) noted the tendency of larvae to aggregate together, but she believed that as animals get larger they become more evenly distributed. However, the collections reported upon above would indicate nonrandom aggregations of adults as well as larvae.

An interesting phenomenon which has been discovered is the presence of dark, heavy mineral grains in the intestinal diverticula of juvenile *E. parma*. Gregory (1905) noticed them first and Graef (footnote 19) also noticed them in New York Bight specimens. One hypothesis for this phenomenon is that these heavy grains are used as weights by juveniles to increase stability on the bottom.

Stanley and James (1971) reported that this species moves randomly over the sediment. In areas of high concentration, these movements are responsible for modifying ripple microridge and swale topography. Parker (1927) studied the locomotion of *E. parma* and found that it was a combination of rotation and progression. The maximum rate of progress was 18 mm/min, with the average about 14 mm/min. They can completely bury themselves in about 10 min and are capable of righting themselves if turned upside down. Hyman (1955) reported that locomotion is chiefly or wholly accomplished by the motion of the spines, however, Parker and Van Alstyne (1932) indicated that the peripheral tube feet are also of assistance in locomotion.

DISCUSSION

Faunal Composition of the Apex

Among the species in the apex reviewed in this atlas, the Polychaeta were dominant, representing over 64% of total individuals, followed by the Bivalvia representing over 30%. This relative abundance also holds true for the overall species composition (Fig. 69; Table 1). These species contain elements of major benthic faunal types, correlated with sediment composition, reported or defined elsewhere in the Middle Atlantic Bight. The selected species exhibited four general patterns of abundance concentrations: 1) Species which appeared most often in the fine sediments of the Christiaensen Basin and upper Hudson Shelf Valley; 2) species which appeared to be ubiquitous or generally widespread; 3) species which usually inhabited the shallower sandy areas near the New Jersey-Long Island shore and Cholera Bank; and 4) a few species whose distributions were irregular.

The first abundance distribution pattern included 20 species which were generally most abundant in the relatively deep, cool, silty-fine sand habitat offered by the Christiaensen Basin and upper Hudson Shelf Valley (Table 2). This habitat included the sewage sludge dump site and, peripherally, the dredge spoil dump site. Most of the species in this silty-sand apex assemblage show affinities to the following generalized faunal types defined by Pratt (1973): an estuarine silt-clay fauna (*Nephtys incisa*, *Nucula proxima*, *Ninoe nigripes*, *Lumbrineris tenuis*, *Pitar morrhuanus*, and *Cerastoderma pinnulatum*); a marine silty-sand fauna (*Pherusa affinis*, *Ceriantheopsis americanus*, and *Arctica islandica*); and an estuarine silty-sand fauna (*Leptocheirus pinguis* and *Prionospio steenstrupi*). The *Nephtys incisa-Nucula proxima* fauna is common in Long Island (Sanders 1956) and other southern New England sounds (Sanders 1968; Pratt 1973; Steimle et al. 1976[20]), Chesapeake and Delaware Bays (Kinner and Maurer 1978). The marine silty-sand fauna is a major faunal type on the mid-continental shelf and in southern New England sounds. The estuarine silty-sand fauna is usually dominated by *Ampelisca* spp. and also occurs in New England sounds and in mid-Atlantic estuaries. Thus, the spe-

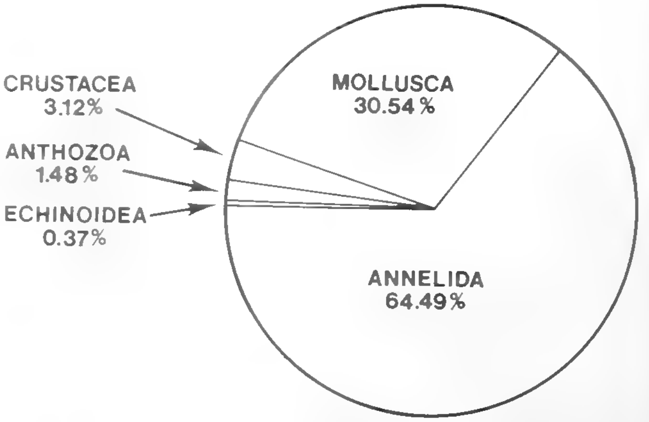

Figure 69.—Percentages of New York Bight apex benthic invertebrates in each phylum represented.

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[20] Steimle, F., C. Byrne, R. Reid, and T. Azarovitz. 1976. Hydrology, sediments, macrofauna, and demersal finfish of an alternate disposal site (East Hole in Block Island Sound) for the Thames River (Conn.) dredging project. Final Report to the U.S. Navy, New London, Conn. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Middle Atlantic Coast. Fish. Cent. Informal Rep. 110, 63 p.

Table 2.—Species whose abundance distributions indicate an association with fine silty sands with relatively high organic contents, as found in the Christiaensen Basin and upper Hudson Shelf Valley (Fig. 1). Feeding types and stress area tolerances (X = high tolerance, L = low tolerance) are also indicated.

Species	Dredge spoil	Sewage sludge	Feeding type[1]
Edwardsia spp.	L		S-SD
Ceriantheopsis americanus	X	L	S-SD
Phoronis architecta	L	L	S
Nucula proxima	L		SD
Arctica islandica	L		S
Cerastoderma pinnulatum			S
Pitar morrhuanus	X		S
Eteone longa	L		C
Nephtys incisa	L	L	O-SD
Capitella capitata	L	X	D
Mediomastus ambiesta	X	L	D
Prionospio steenstrupi	X		SD
Paraonis gracilis			D
Lumbrineris tenuis	X	L	C
Ninoe nigripes	L	L	C
Drilonereis longa	L		C
Cossura longocirrata			D
Asabellides oculata	L	X	SD
Pherusa affinis	L	L	SD
Leptocheirus pinguis			S

[1] Feeding type codes: S = suspension feeder, SD = surface deposit feeder, D = subsurface deposit feeder, C = carnivore, O = omnivore, and SV = scavenger.

cies we have collected in the Christiaensen Basin and upper Hudson Shelf Valley appear to be part of a continuum, transitional, or a mixture of three previously defined major community types which prefer high levels of silt and intrude into the inshore, predominantly sand, habitat within the confines of the upper Hudson Shelf Valley, and in Raritan Bay (McGrath 1974). The two capitellids, *Capitella capitata* and *Mediomastus ambiseta*, in this group are recognized opportunists. Feeding types of the 20 species within this group are diverse.

The second pattern included 17 species whose abundance and wide distribution in the apex could not be strongly correlated with a particular major habitat (Table 3). It included two species, *Spio filicornis* and *Polydora ligni*, that fit this category only during the summer (Fig. 38 (top), 40 (top)).

Most of the species in this group (*Sthenelais limicola*, *Nephtys bucera*, *Aricidea catherinae*, *Cancer irroratus*, *Lumbrineris fragilis*, *Spiophanes bombyx*, *Tellina agilis*) have been found to be members of a medium sand fauna which predominates in inshore areas (Pratt 1973; Steimle and Stone 1973; Maurer et al. 1976; Maurer, Leathem, Kinner, and Tinsman 1979). Two species, *Harmothoe extenuata* and *Edotea triloba*, are members of Pratt's silty sand assemblage, and *Tharyx acutus* and *Polydora ligni* were included as members of the estuarine *Ampelisca* spp. fauna. It should be noted that the collections of *Cancer irroratus* were dominated by juveniles. Examination of adults alone may indicate a far different abundance distribution pattern. This group of species also included a diversity of feeding types, with surface deposit feeders predominating.

Table 3.—Species whose abundance distributions indicate a lack of strong association with any particular habitat. Feeding types and tolerances of stress areas (X = high tolerance, L = low tolerance) are indicated.

Species	Dredge spoil	Sewage sludge	Feeding type[1]
Tellina agilis	X	X	SD
Polygordius triestinus	L	L	D
Phyllodoce arenae	L	L	C
Harmothoe extenuata	L		C
Sthenelais limicola	L	L	C
Glycera dibranchiata	X	X	C-D
Nephtys bucera	L	L	O-SD
Spio filicornis (summer)	X	L	SD
Polydora ligni (summer)	X	X	SD
Spiophanes bombyx	X	X	SD
Aricidea catherinae	L	L	D
Lumbrineris fragilis	L	L	C
Tharyx acutus	X	X	SD
Tharyx annulosus	X	L	SD
Ampharete arctica	L		SD
Edotea triloba	X	X	SV-SD
Cancer irroratus	L	L	SV-C

[1] For feeding type codes see Table 2.

The third pattern included those species whose abundance distribution indicated a strong association with the cleaner sandy sediments found inshore, off both New Jersey and Long Island, as well as the Cholera Bank on the eastern edge of the apex. Nineteen species, with a wide variety of feeding types, were included in this group (Table 4). *Spio filicornis* had a more limited distribution in the winter, which included it in this group as well as in the previous group.

Some of the species we have included in this group have been associated with sandy habitats elsewhere. Steimle and Stone (1973) included *Unciola irrorata*, *Protohaustorius deichmannae*, *Rhepoxynius epistomus*, *Echinarachnius parma*, and *Spisula solidissima* as dominants in the medium sand assemblage identified along southwestern Long Island. Most of these same species and *Magelona riojai*, *Goniadella gracilis*, *Nephtys picta*, and *Crangon septemspinosa* are included as dominants in Pratt's (1973) Middle Atlantic Bight sand assemblage. Maurer et al. (1976) found *N. picta* and *Ensis directus* to dominate medium to coarse clean sand stations on the inner continental shelf off the Delmarva Peninsula. *Nephtys picta*, *Spiophanes bombyx*, and *M. riojai* dominated sandy shoals in the Delaware Bay study of Kinner and Maurer (1978).

It is interesting to note that *Neomysis americana*, as it was collected in this survey, showed a preference for the mouth of the Hudson-Raritan Estuary. This could be an artifact of sampling, as the grab used is not particularly effective at collecting these mobile, semipelagic crustaceans.

The three final species, *Ensis directus*, *Nassarius trivittatus*, and *Polydora ligni* (during winter), exhibited an abundance distribution which lacked a definite pattern so as to be placed in any of the above three groups (Figs. 15, 23, 40 (bottom)). Their occurrence,

Table 4.—Species whose abundance distributions indicate an association with clean sand habitats. Feeding types are included.

Species	Feeding type[1]
Astarte castanea	S
Spisula solidissima	S
Goniadella gracilis	C
Nephtys picta	O-SD
Nephtys (Aglaophamus) circinata	O-SD
Travisia carnea	D
Spio filicornis (winter)	SD
Lumbrinerides acuta	C
Magelona riojai	D-SD
Caulleriella killariensis	SD
Ampelisca verrilli	S
Unciola irrorata	O-SV-SD
Pseudunciola obliquua	SD
Protohaustorius deichmannae	S
Protohaustorius wigleyi	S
Rhepoxynius epistomus	O
Neomysis americana	S-SD
Crangon septemspinosa	O-SV
Echinarachnius parma	S-SD

[1] Feeding type codes are listed in Table 2.

however, may indicate a preference for a transitional habitat between the fine silty sand and cleaner sand in the New York Bight apex. *Ensis directus* is a suspension feeder, *N. trivittatus* is considered a scavenger, and *P. ligni* is a surface deposit feeder.

Pratt (1973) included *E. directus* in his Middle Atlantic Bight sand community, and Franz found both *E. directus* and *N. trivittatus* to be characteristic of the medium sand assemblage in Long Island Sound. However, *N. trivittatus* has also been recorded from muddy sediments in Delaware Bay (Kinner et al. 1974). The summer distribution of *P. ligni* places it in the ubiquitous species category, however, its winter distribution is more limited.

The diversity and mixing of previously defined faunal groups in the deeper areas of the apex, especially the silty sand area, is, more than anything else, probably a reflection of the heterogeneity of the sediments there, disregarding local impacts of dumping. The sediments in the apex have been examined in great detail by Freeland et al. (1976), showing a complex distribution of surficial sediment types, including relic and anthropogenic deposits, as well as normal current and wave related distributions.

Anthropogenic Influences

The seabed of the New York Bight apex is influenced primarily by continental shelf water of high salinity (>32‰) and small temperature fluctuations. Inshore areas are less stable and fall under the influence of ocean waves and estuarine discharges, primarily from the Hudson-Raritan Estuary. The estuarine discharges contain relatively high levels of suspended sediment, organic material, and nutrient and toxic pollutant loadings, all of which contribute to altering the quality of the benthic environment, both inshore and in the deeper offshore depositional basins of the apex. Waste dumping also directly and indirectly impinges upon the benthos. The net result of decades of using the Hudson-Raritan Estuary and the apex as a repository for a variety of human wastes is that the apex benthic environment, particularly the sediments in and around the dredge spoil and sewage sludge dump sites, now contains a variety of contaminants occurring at levels that are stressful, lethal, or undesirable to many marine organisms. For example, high levels of five heavy metals have been measured, in our survey, in both the dredging spoils and sewage sludge dump sites (Figs. 7–11). They are, in general, correlated with sediments of highest organic content (Fig. 6). Metal concentrations in these areas are, in some cases, almost 50 times higher than those at apex stations away from the dump sites and background levels in uncontaminated sands and silt (Table 5).

Koons and Thomas (1979) also reported that total C_{15+} hydrocarbons are highest (3,600–6,500 ppm) in New York Bight areas where harbor dredge spoil and sewage sludge disposal occurs. Levels at the mouth of the Hudson-Raritan Estuary are reported as low as 6–22 ppm, with concentrations of 82 and 86 ppm reported at two locations approximately 80 km out on the mid-continental shelf.

Table 5.—Concentrations of metals in sediment unaffected by waste dumping (ppm in dry sediments) (Carmody et al. 1973).

	Cr	Cu	Pb	Ni	Zn
Sandy sediment of New York Bight	6	3	12	3	18
Silty sediment of Hudson Submarine (Shelf) Valley	6	5	14	8	20

Elevated levels of heavy metals and hydrocarbons are well known as being toxic to marine life. In high concentrations, they are lethal, but even in sublethal concentrations they can cause pathological conditions, physiological disturbances, and deviations from normal behavior. Larval stages are especially sensitive to heavy metal toxicity and usually show increased abnormalities and slow growth rates when exposed to such toxins (Sprague 1964; Saunders and Sprague 1967; Shuster and Pringle 1968[21]; Portmann 1970; Stirling 1970[22]; Calabrese 1972; Connor 1972; Calabrese et al. 1973, 1977; Vernberg et al. 1973; Reish et al. 1974).

The Christiaensen Basin and upper Hudson Shelf Valley benthic environments are also subject to frequent seasonal dissolved oxygen reductions to levels (<2 ml/1iter) critical to many species of marine organisms common in the New York Bight (Segar and Berberian 1976; Steimle 1976; Thomas et al. 1976). The dissolved oxygen reduction during the summer months is probably the result of the higher oxygen demand of organic rich sediments and overlying water in the central apex depression, coupled with the strong seasonal thermocline which prevents reoxygenation of bottom waters.

Impacts to the benthic community are strongly indicated in our data. Some abnormalities in faunal composition appear to be directly related to the dumping of dredge spoils and sewage sludge. Most of the species found in the upper Hudson Shelf Valley and Christiaensen Basin exhibited some avoidance of one or both dump sites (Tables 2–4) with a few exceptions: *Capitella capitata* was collected almost exclusively at the sewage sludge dump site, and *Asabellides oculata* occurred in greatest concentrations there; *Prionospio steenstrupi* and *Lumbrineris tenuis* showed high abundances at the dredge spoil dump site (Figs. 2, 35, 39, 46, 55).

The very low *H′* diversity values (Fig. 3), observed at stations within and just outside both dump sites, indicate that the overall benthic macroinvertebrate community structure in these areas has also been altered. Low *H′* values are often associated with highly stressed environments, where a few opportunistic or tolerant species become abundant, in part because of reduced competition. This results in a simple community, usually consisting of only a few species (Sanders 1968). In this study, the sewage sludge dump site was dominated by *Capitella capitata*, a highly opportunisitic species, and our data show the abundance distributions of only eight species to indicate tolerance of sewage sludge, all are deposit feeders. Thirteen species were observed to be tolerant of dredging spoils. Of these, 11 are deposit feeders, 1 is a suspension feeder, and 1 is a carnivore (Tables 2, 3). This predominance of deposit feeders in and around the dump sites indicates that there may also be a change in trophic composition of communities in these areas. An examination of the feeding types of all species in Groups 1 and 2, i.e., those which are ubiquitous or most often associated with fine sand-silt sediments with generally high organic content, shows a more equitable distribution of feeding types (Tables 2, 3).

Amphipod crustaceans, found to be important elements in most faunal groups described in the Middle Atlantic Bight, are virtually absent from coarse to medium silts and medium to high organic content sediments in apex collections, an observation previously reported by Pearce (1972). The marine silty sand group defined by Pratt (1973), which intrudes up the Hudson Shelf Valley to the

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[21] Shuster, C., and B. Pringle. 1968. Effects of trace metals on estuarine molluscs. *In* Proceedings of the 1st Mid-Atlantic Industrial Water Conference. Univ. Delaware, CE-5, p. 285–304.

[22] Stirling, E. 1970. Some observations on the response of the benthic bivalve *Tellina tenuis* to pollutants. Proc. Int. Counc. Explor. Sea, C.M. 1970/E:15, Fish. Improvement Comm., 6 p.

apex, contains several species of *Ampelisca* which are considered important elements of this faunal group, and in the silty sand areas of southern New England sounds they are numerical dominants. Ampeliscids also dominated many estuarine silty sand faunas, e.g., in southern New England (Sanders 1958), in Great Bay, N.J. (Durand and Nadeau 1972), in Chesapeake Bay (Feeley 1967), and in the Delaware Bay area (Watling and Maurer 1972). In our apex study, however, only one species of *Ampelisca* (*A. verrilli*) was collected, in moderate numbers, in low organic, fine to medium sandy sediments. The one species of amphipod, *Leptocheirus pinguis*, which was moderately abundant in high organic, silty sediments, was collected only at the southernmost stations of the upper Hudson Shelf Valley (Fig. 63), while Steimle and Stone (1973) collected it in the northern Christiaensen Basin in 1967.

The paucity of amphipods in the New York Bight apex and Raritan Bay (McGrath 1974) would appear to be very good evidence that man's use of the area has generally degraded the environment so that it is unsuitable for most amphipods. The dump sites are a part of this degradation, but a small part compared with the effects of pollution effluents in and emanating from the Hudson-Raritan Estuary. Amphipods, like other crustaceans, are known to be generally intolerant of pollutants (Blumer et al. 1970; Sanders et al. 1972), but they are important food items for most demersal finfish and their absence or reduction in numbers may alter normal food webs of several valuable resource species, reducing the potential harvest from the apex. Boesch (1982) has reviewed benthic-finfish trophic couplings in the apex, and also supports the hypothesis that resource potential is impaired.

The apex, in the past, has been a very productive area for fisheries, in part because of its uncontaminated shellfish and because it provided a hospitable environment for many species of demersal fish and crustaceans. If dumping in the area is reduced or terminated in the future, it will be important to monitor the recovery of the apex ecosystem.

The amount of time required for the fauna at these dump sites to recover is unknown at this time. Dean and Haskin (1964) found that the benthic community, particularly the small amphipod crustaceans, showed marked recovery after pollution abatement at the mouth of the Raritan River. Dredge spoil recolonization has also been shown to be relatively rapid in Long Island and Rhode Island Sounds (Pratt 1973; Reid and Frame 1977[23]). However, little work has been done on sewage sludge dump site recovery. Bioturbation may keep recycling some pollutants for a time before they are finally diluted to nonstressful levels or buried at a depth where they are no longer active.

In conclusion, our studies show that a heterogeneous benthic fauna exists in the New York Bight apex, which appears to be adversely altered, particularly in the vicinity of two dump sites, but perhaps throughout a major portion of the apex.

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Edwin P. Creaser, Jr., David A. Clifford,
Michael J. Hogan, and David B. Sampson

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A Commercial Sampling Program for Sandworms, *Nereis virens* Sars, and Bloodworms, *Glycera dibranchiata* Ehlers, Harvested Along the Maine Coast

Edwin P. Creaser, Jr., David A. Clifford,
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April 1983

U.S. DEPARTMENT OF COMMERCE
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A Commercial Sampling Program for Sandworms, *Nereis virens* Sars, and Bloodworms, *Glycera dibranchiata* Ehlers, Harvested Along the Maine Coast

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ABSTRACT

Brief discussions of the history and development of the marine worm fisheries for bloodworms, *Glycera dibranchiata*, and sandworms, *Nereis virens*, the methods of digging both species, the packing media used in their shipment, and the various marine worm markets, are presented.

The status of the commercial marine worm fishery between April and September 1973–76 was investigated. A sampling program for bloodworms and sandworms revealed that there was no significant difference in the mean size of bloodworms (18.72±0.60–20.83±0.54 cm) and sandworms (25.69±0.42–26.77±0.53 cm) harvested. Marine worm diggers avoid picking up potential spawning sandworms during the months of March, April, and May and bloodworms during the month of May. During August and September, potential sandworm spawners comprise 15.6–38.3% of the commercial catch; during April, potential bloodworm spawners comprise 7.33–13.58% of the commercial catch. Sandworm spawners were found coastwide but bloodworm spawners were never collected east of the Taunton River (Sullivan, Maine). Approximately 8% of the sandworms and 5–7% of the bloodworms had regenerated tails and approximately 19–23% of the sandworms and 12–13% of the bloodworms were broken.

The use of probability sampling expansions has enabled us to estimate that sandworm diggers dug a total of 45,746–66,004 hours/sampling season during a total of 23,402–31,587 tides/sampling season and landed a total catch of 307,426–409,189 pounds. Bloodworm diggers dug a total of 89,691–177,909 hours/sampling season during a total of 30,545–62,339 tides/sampling season and landed a total catch of 109,936–206,577 pounds.

It cannot be conclusively stated that sandworm and bloodworm abundance changed significantly between 1973 and 1976. Ratio estimates of the numbers of marine worms dug/digger tide varied between 1,024±60–1,184±38 (sandworms) and 536±36–662±26 (bloodworms).

The 6-month mean value/tide and value/hour varied between $27.97–$40.30 and $14.34–$19.15, respectively (sandworms), and $27.97–$31.59 and $10.11–$11.00, respectively (bloodworms).

A significant difference exists in the length-weight relationships for sandworms and bloodworms from eastern Maine and the Sheepscot River. This observation may result from the fact that bloodworm spawners are rare in eastern Maine and bloodworms may substitute an increase in weight for the production of gametes. No explanation for this observation in sandworms can presently be given.

The numbers of bloodworms and sandworms per pound were calculated from mean length and length-weight data. Although the mean number of bloodworms per pound decreased during the 4-year sampling period, the decrease was not significant at 95% confidence limits (1.96 SE). No significant changes in the mean number of sandworms per pound were recorded during the same period.

The MSY (maximum sustainable yield) for the fishery was obtained with approximately 815 bloodworm diggers, 386 sandworm diggers, and 99 diggers who dug both species. OSY (optimal sustainable yield) was approximately 564–689 bloodworm diggers, 267–327 sandworm diggers, and 69–84 diggers who dug both species. Very rough quotas of 28–33 million bloodworms, and 26–30 million sandworms are associated with these OSY figures.

The overall average frequencies of bloodworm and sandworm digging (expressed as the number of low tide periods occurring since the last low tide dug) were 5.3 and 3.4, respectively. The numbers of years of digging experience recorded for bloodworm and sandworm diggers show that worm digging is frequently a short-lived work experience, 35–51% of the bloodworm diggers and 22–34% of the sandworm diggers have dug between 1 and 4 years. The mean age of bloodworm and sandworm diggers varied between 27.7 and 31.9. The vast majority of both bloodworm and sandworm diggers are male.

INTRODUCTION

Two species of Annelid worms are harvested for bait in Maine: the sandworm or clamworm, *Nereis virens*, and the bloodworm or beak-thrower, *Glycera dibranchiata*. These worms are dug from mud flats by marine worm diggers who are licensed by the State of Maine, Department of Marine Resources (DMR). Worm diggers generally dig only one species or the other and sell their catch to wholesale shippers (dealers) who are also licensed by the State. The wholesale shippers pack and ship their worms to wholesale distributors from whom they have received purchase requests. Wholesale distributors sell their worms to bait shop retailers who divide the shipment into lots of a dozen worms and sell directly to recreational fishermen. The worms are used in recreational fisheries for blackfish, bluefish, fluke, kingfish, pogy, weakfish, sea bass, striped bass, spot, flounder, and smelt on the Atlantic, Gulf, and Pacific

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coasts. Although the fishery grew rapidly during the 30 yr prior to 1976 and developed into one of the top five commercial fisheries (landed value) in Maine, it was not until the advent of the State-Federal aid program (P.L. 88–309) that the State obtained funding to collect detailed catch, effort, and catch per effort data for the fishery.

DISTRIBUTION

The sandworm was first recorded as *Nereis grandis* from the mud flats of Grand Manan Island, New Brunswick, Canada, in the Bay of Fundy by Stimpson (1854). *Nereis grandis* was identified at Eastport, Maine, by Verrill (1871). Webster and Benedict (1887) reported *Nereis virens* as being very common in mud and sandy mud during low water in the vicinity of Eastport. *Nereis virens* has been reported from the western Atlantic along the U.S. coast from Virginia to Maine and in Canada from New Brunswick, Nova Scotia, the Gulf of the St. Lawrence, Newfoundland (Pettibone 1963), and Labrador (Miner 1950). It has been reported from the eastern Atlantic to Iceland and Ireland and in the North Sea to France. It is also found in Norway (Pettibone 1963) and in the White Sea of Russia (Sveshnikov 1955).

The bloodworm was first recorded as *Rhynchobolus dibranchiata* from Eastport, Maine, by Verrill (1874). *Glycera dibranchiata* has been reported from Prince Edward Island (MacPhail 1954), the Gulf of the St. Lawrence, Nova Scotia, and New Brunswick south through Maine, New Hampshire, Massachusetts, Rhode Island, Delaware, Maryland, Virginia, and North Carolina to Florida (Pettibone 1963) and the West Indies (Hartman 1944). In the Gulf of Mexico it is found from Florida to Texas (Pettibone 1963) and on the Pacific coast from Mazatlan, Mexico (Hartman 1950), north including Lower California (Pettibone 1963) to San Mateo County, Calif. (Hartman 1950).

HABITAT (SANDWORMS)

The sandworm is especially common in sheltered flats bordering the mouths of rivers, estuaries, and sounds (Pettibone 1963). Although sandworms can be found throughout the intertidal zone, they are commercially abundant in the coarse and fine muddy sands near the low water mark. Ganaros[4] reported that in the early 1940's, commercial sandworm diggers recalled that they could collect worms of commercial quality and quantity close to shore, thus suggesting that sandworms may have become depleted in the upper intertidal zone. In addition to being found in coarse and fine muddy sand, sandworms are often found under cobbles and large rocks along the shore, jetties, and piers, in marsh thatch, under or near mussel beds, in gravelly sand and clay, in water soaked wood, and among the roots of decaying marsh grass and eelgrass (Pettibone 1963). Crowder (1923) reported that young sandworms have been found in old sea shells and within the fronds of *Ulva*. At certain times of the year, sandworms of all sizes can be found swimming free in the river channels (Dean 1978a; Graham[5]). They have also been dredged to a depth of 154 m (Pettibone 1963).

In soft mud, the sandworm burrows to depths of 7–45 cm with the largest specimens usually found at the greatest depths (Pettibone 1963). Commercial sandworm diggers first remove the top 13 cm of soft mud and then dig down about 25 cm farther to reach these commercial quantities of large worms (Glidden[6]). In certain types of mud, the burrows are well defined on the mud surface and aid the diggers in locating areas of high concentration (Fairservice[7]). The burrows themselves are lined with an adhesive mucus that binds the walls (Crowder 1923). Several burrows often intersect so that any burrow may have several openings. The rhythmic undulations of the sandworm create a current of water through the burrow which supplies the worms' respiratory needs. The current of oxygen-rich water also results in the formation of a visible red iron oxide residue in the sediment immediately adjacent to the burrow (Pedrick[8]).

Brafield[9] has indicated that the water and intertidal salinity encountered by the Southend, England, sandworm population varied between 28 and 32‰ and 27.5 and 31.5‰, respectively, and the water temperature varied between 3.2°C (January) and 22.5°C (August). Gosner (1971) reported that sandworms are capable of withstanding salinity as low as 10‰ and Mazurkiewicz[10] found the lower salinity tolerance of sandworms to be 5‰. During a study of the sandworm population at Wiscasset, Maine (Creaser and Clifford[11]), the surface water salinity varied between 17.3 and 28.9‰ and the surface river temperature varied between −1.4° and 15.3°C. The bottom river salinity varied between 23.8 and 29.3‰ and bottom river temperature varied between −1.2° and 14.3°C. The interstitial mud temperature for this area varied between +0.3° and 15.6°C. The range of temperatures recorded for the sandworm population at Brandy Cove, New Brunswick (Snow 1972), are very similar to those recorded above for the Wiscasset studies. More recent salinity and temperature studies (Creaser et al.[12]) at the site of the Wiscasset sandworm work, have yielded surface and bottom salinities ranging between 9.7 and 30.8‰ and 10.0 and 31.6‰, respectively, and surface and bottom temperatures ranging between −1.3° and 20.1°C and −1.6° and 19.7°C, respectively.

The complete analysis of sediments from coastwide marine worm growing areas is lacking. Pedrick (footnote 8), however, analyzed the sandworm sediment within DMR's closed marine worm conservation area at Wiscasset, Maine, for a number of parameters. The results, presented in Table 1, demonstrate that the sediment in the closed area is primarily a silty clay and the concentrations of the seven heavy metals tested decrease with depth.

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[4] Ganaros, A. 1951. Commercial worm digging. Maine Dep. Sea Shore Fish. Bull., Augusta, 6 p.

[5] J. J. Graham, Marine resources scientist, Maine Department of Marine Resources Research Laboratory, West Boothbay Harbor, ME 04575, pers. commun. June 1974.

[6] Glidden, P. E. 1951. Three commercially important polychaete marine worms from Maine: *Nereis (Neanthas) virens*, *Glycera dibranchiata*, *Glycera americana*. A report to the Maine Department of Sea and Shore Fisheries, Augusta, 4 p.

[7] S. Fairservice, marine worm digger, Wiscasset, ME 04578, pers. commun. March 1977.

[8] R. A. Pedrick, Coordinator, Environmental Impact Statements, Natl. Mar. Fish. Ser., NOAA, Wash., DC 20230, pers. commun. April 1976.

[9] A. E. Brafield, Queen Elizabeth College, London, England, pers. commun. July 1968.

[10] M. Mazurkiewicz, Assistant Professor, University of Maine, Portland, ME 04103, pers. commun. June 1977.

[11] Creaser, E. P., and D. A. Clifford. 1981. Life history studies on the sandworm, *Nereis virens* Sars, in the Sheepscot estuary, Maine. Maine Dep. Mar. Res. Lab. Res. Ref. Doc. 81/16, 37 p.

[12] Creaser, E. P., Jr., D. C. Clifford, and M. J. Hogan. 1978. Hydrographic data report Part II. Salinity and temperature data obtained from simultaneous stations at Bluff Head and Long Ledge (Montsweag Bay, Maine) and the Wiscasset Bridge (Wiscasset, Maine) 1970–1976. Maine Dep. Mar. Res. Lab. Res. Ref. Doc. 78/12, 167 p.

Table 1.—Size and heavy metals analysis of sediment from the bloodworm and sandworm producing portions of the marine worm conservation area at Wiscasset, Maine.

	Sandworms				Bloodworms			
Subsample depth in core (cm)	0.0–3.0 cm	3.5–15.5	15.5–19.0	19.0–25.5	0.0–4.5	4.5–8.0	12.5–17.0	18.0–23.5
				Sediment size				
Gravel (>2.0 mm) (%)	0.32	0.65	0.31	0.36	0.02	0.06	0.10	0.22
Sand (2.0–0.063 mm) (%)	9.52	11.24	10.72	8.73	9.66	6.54	7.23	6.62
Silt (0.063–0.004 mm) (%)	49.18	54.95	56.30	58.53	75.77	63.60	61.46	59.25
Clay (<0.004 mm)(%)	40.99	33.16	32.67	32.39	14.55	29.79	31.21	33.92

		Heavy metals		
Subsample depth in core (cm)	0.4	12–16	0–4	12–16
Copper (ppm dry weight)	24.5	18.4	17.3	16.9
Zinc (ppm dry weight)	212	169.3	151	138.5
Manganese (ppm dry weight)	347	323.2	266	277.8
Chromium (ppm dry weight)	57.8	43.9	36.7	39.3
Cobalt (ppm dry weight)	18.4	15.4	10.9	14.0
Nickel (ppm dry weight)	37.0	30.7	37.7	30.7
Iron (%)	3.6	3.2	2.9	2.8
Organic carbon (%)	2.27	2.19	2.27	2.1

HABITAT (BLOODWORMS)

The bloodworm is a relatively common inhabitant of intertidal flats bordering brackish waters and tidal estuaries (Pettibone 1963). Bloodworm diggers generally share the opinion that bloodworms are found in greatest abundance around freshwater streams that empty into coves (Ganaros footnote 4). Under many circumstances, areas affected by considerable quantities of freshwater runoff may be occupied by bloodworms and not by sandworms and clams (Dow and Wallace;[13] Pettibone 1963). Although bloodworms are commonly found in soft organically rich muds (Klawe and Dickie 1957), the mud is usually more compact than that found in commercial sandworm digging areas (Ganaros footnote 4). Klawe and Dickie (1957) believed that a relationship exists between soil type and abundance; a continuous increase in abundance exists in the following series of sediment types: sand, hard clay, dark sand, sand and mud, and soft mud. Sanders et al. (1962), on the other hand, reported that in Barnstable Harbor, Mass., the largest numbers of bloodworms were found at sandy stations. Andrews (1892) has recorded bloodworms as inhabiting shoals in the Beaufort, N.C., area. In the same area, Adams and Angelovic (1970) described the bloodworm as one of the dominant species of infauna in estuarine eelgrass beds. At certain times of the year, bloodworms containing immature gametes can be found swimming free in some bays, harbors, and river channels (Graham and Creaser 1978; Dean 1978b). They have also been dredged in water up to approximately 400 m deep on bottoms of sand, mud, mud mixed with gravel, rocks, and particularly in mud rich in detritus (Pettibone 1963).

Bloodworms are dug commercially from the mud at depths up to 25 cm (Pettibone 1963). Commerical bloodworm concentrations are usually not as dense as commercial sandworm concentrations (Ganaros footnote 4).

Worm holes are not characteristic of a bloodworm flat (Ganaros footnote 4). However, evidence for the passage of oxygenated water through the burrows is revealed by the presence of a layer of lighter colored oxidized sediments around each burrow (Mangum;[14] Pedrick 1978).

During a study of the bloodworm population at Wiscasset, Maine (Creaser 1973), the surface water salinity varied between 10.4 and 30.2‰ and the surface river temperature varied between −1.2° and 20.3°C. The bottom river salinity varied between 15.1 and 30.5‰ and bottom temperature varied between −0.6° and 19.0°C. The interstitial mud temperature for this same area varied between 0.8° and 16.7°C. The results of more recent salinity and temperature studies from this same area (Creaser et al. footnote 12) have already been reported under sandworm habitat.

Bloodworm sediments within DMR's closed marine worm conservation area at Wiscasset were also analyzed by Pedrick (footnote 8). The results of size and heavy metals analysis of bloodworm sediments are presented in Table 1. The physical properties of the sediment taken approximately halfway between the bloodworm and sandworm producing portions of the flat are recorded in Table 2. A more detailed analysis of marine worm sediment size from Wiscasset and other areas along the Maine coast is available from DMR files.

Table 2.—Physical properties of the sediment taken approximately halfway between the bloodworm and sandworm producing portion of the closed conservation area at Wiscasset, Maine.

	Subsample depth in core (cm)[1]		
Property	0–6.5	6.5–18	18–24
Wet unit weight (g/cm^3)	1.42	1.48	1.53
Specific gravity of solids	2.62	2.60	2.62
Water content (% dry weight)	110.10	90.04	78.00
Void ratio	2.883	2.337	2.045
Saturated void ratio	2.883	2.337	2.045
Porosity (%)	74.2	70.0	67.2

[1] Subsampling depths determined by X-ray diffraction techniques.

HISTORY OF THE MARINE WORM FISHERY

It is generally agreed that a small marine baitworm fishery was in operation on Long Island, N.Y., during 1921–22. However, small scale worm transactions between a few individuals may have occurred on Long Island considerably before these dates (Wanser[15]). By the mid-1920's the Long Island fishery had become well

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[13] Dow, R. L., and D. E. Wallace. 1955. Marine worm management and conservation. Maine Dep. Sea Shore Fish., Fish. Circ. 16, 9 p.

[14] C. P. Mangum, Associate Professor, College of William and Mary, Williamsburg, VA 23185, pers. commun. May 1972.

[15] A. Wanser, marine worm dealer, Milbridge, ME 04658, pers. commun. July 1979.

established as the result of a demand for baitworms by party boats fishing for weakfish in Peconic Bay. Initially, clams and mussels had been used for bait in this fishery but when fishermen discovered that marine worms worked as well as or better than these baits, a preference for marine worms developed (Schmal[16]). Although initially sandworms were the most sought after species, it was not long before both sandworms and bloodworms were being dug in areas such as Stony Brook, St. James, Jamaica Bay, Brooklyn, and Staten Island. Throughout Long Island, the worms were dug from sand flats and beaches. Sandworms were short but fat and of excellent quality. Bloodworms were of similar quality to those now obtained in Maine. Exploratory digging was soon extended as far as Fairfield, Conn., and Massachusetts (Sandrof 1946). A fishery that dealt mainly with sandworms was established in the area north of Boston: Winthrop, Revere, Lynn, Swampscot, Marblehead, Salem, Gloucester, and Newburyport by 1929 during the depression (Greely [17]). By 1932, some digging had occurred south of Boston to Chatham on the Cape (Greely footnote 17). Marine worms were probably also being dug commercially in New Hampshire by this time. Yet, despite the exploration for and discovery of commercial marine worm populations prior to 1932, sufficient quantities were still not available to supply the market. This lack of availability has been attributed to: 1) an initial lack of abundance and the complaints of landowners who objected to worm digging in their sandy beaches (Sandrof 1946), 2) overdigging and depletion of the known stocks (Schmal footnote 16; Greely footnote 17), 3) increased demand for marine baitworms in the sportfish fisheries (MacPhail 1954; Dow[18]), 4) a decline due to increased pollution from heated effluent discharge and toxic heavy metal pollutants (Dow footnote 18), and 5) a demise in the fishery resulting from higher than optimal seawater temperatures (Dow footnote 18). Although some worming probably began in the Portland, Maine, area in the early 1920's, the fisheries' slow initial growth in Maine was partly due to a certain skepticism toward the digging of marine worms (Glidden footnote 6). In 1933, an abundant supply of worms was found in the area around Wiscasset (Sandrop 1946) and Boothbay Harbor (Schaml footnote 16; Greely footnote 17). Most of the digging in these areas was directed toward sandworms but some bloodworms were also obtained. By 1937, the industry had become well enough established for the Maine Legislature to instigate "control" legislation (Glidden footnote 6). The municipalities affected by this legislation were mainly located in Cumberland, Sagadahoc, and Lincoln Counties (Dow[19]). Nearly 40 laws were passed between 1937 and 1955 which prohibited nonresidents from digging worms within the political boundaries of numerous municipalities. All these laws were repealed in 1955 after it was established that many of these exclusions were motivated by coastal property owners who desired to prevent trespass rather than conserve marine worm stocks (Dow footnote 19). The fishery in Maine had been extended from Cumberland, Sagadahoc, and Lincoln Counties into Hancock and Washington Counties by the early 1940's (Flye[20]). By 1949, bait dealer inquiries from the United States had stimulated the Canadian Atlantic Biological Stations to initiate a program of exploration for baitworms along the Maritime coast. Stocks of sandworms were found in Charlotte County, New Brunswick, and in 1950 a bait business was established there. This initial endeavor was not successful due to the relatively small size of the worms and the lack of a suitable packing weed (MacPhail 1954). The search for worms was continued in the Maritimes during 1950–51 in New Brunswick, Nova Scotia, and Prince Edward Island. Although some worms were found in practically all the areas examined, commercial quantities of bloodworms were found only in Nova Scotia in certain regions within Annapolis, Digby, Yarmouth, and Shelburne Counties (Flye footnote 20; Klawe and Dickie 1957; MacPhail 1954). Although the size of the worms dug within these areas was smaller than their Maine counterparts, excellent transportation facilities were available and by 1952, three shippers were operating in Yarmouth County, Nova Scotia. In 1953, sandworms were again shipped from Charlotte County, New Brunswick, but the absence of a suitable packing weed prevented large scale development of the industry (MacPhail 1954).

Maine marine worm landings recorded in U.S. Department of Commerce (1946–80) in pounds and converted back into numbers, as well as landed value, are presented in Table 3.

Table 3.—The numbers and value of bloodworms and sandworms landed by licensed marine worm diggers in the State of Maine between 1946 and 1980.

		Bloodworms		Sandworms	
Year	Licensed marine worm diggers	Numbers	Value (dollars)	Numbers	Value (dollars)
1946	—	2,608,000	57,125	2,335,000	47,188
1947	—	7,200,000	144,530	2,046,000	37,086
1948	449	25,018,000	305,044	3,116,000	57,307
1949	498	17,700,000	297,021	1,356,000	18,910
1950	389	13,718,000	242,081	2,276,000	37,158
1951	324	9,511,000	157,966	5,868,000	88,412
1952	435	9,256,000	178,312	6,288,000	91,109
1953	522	11,198,000	217,966	9,744,000	148,499
1954	625	10,555,000	200,518	11,364,000	167,196
1955	551	8,921,000	167,004	7,176,000	110,283
1956	530	7,493,000	150,748	11,312,000	177,672
1957	640	10,485,000	246,436	11,636,000	214,344
1958	628	13,604,000	309,678	10,764,000	193,853
1959	784	18,837,000	371,832	21,548,000	334,285
1960	643	24,207,000	482,100	24,516,000	365,850
1961	729	26,176,000	515,979	25,720,000	387,066
1962	775	25,674,000	516,362	27,108,000	421,267
1963	921	32,198,000	696,887	32,532,000	506,578
1964	1,041	33,390,000	745,315	30,894,000	450,544
1965	1,015	33,918,000	759,582	29,545,000	447,341
1966	930	31,511,000	731,335	31,848,000	509,018
1967	1,025	32,956,000	834,826	28,257,000	492,384
1968	1,165	36,632,000	1,048,581	27,833,000	533,358
1969	1,168	34,449,000	999,787	26,914,000	523,836
1970	1,194	37,242,000	1,215,772	29,877,000	621,474
1971	1,396	35,603,000	1,381,676	30,115,000	674,296
1972	1,383	31,013,000	1,325,895	27,886,000	625,848
1973	1,451	35,381,000	1,744,832	28,135,000	1,060,402
1974	1,455	31,377,000	1,569,823	32,881,000	949,956
1975	1,267	35,634,000	1,779,266	29,935,000	862,854
1976	1,199	23,454,000	1,255,852	27,915,000	812,318
1977	1,197	17,474,000	1,313,987	29,506,000	1,000,432
1978	1,155	16,202,000	1,164,688	29,937,000	1,075,409
1979	1,105	19,387,000	1,434,258	29,776,000	1,109,292
1980	985	20,338,000	1,404,222	29,002,000	1,094,535

WORM DIGGING

One of the most attractive features associated with digging marine worms is the low initial cost of involvement in the fishery.

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[16] D. Schmal, marine worm digger, North Edgecomb, ME 04545, pers. commun. July 1979.

[17] O. Greeley, marine worm dealer, Sullivan, ME 04682, pers. commun. July 1979.

[18] Dow, R. L. 1977. The Maine marine baitworm fishery. Dep. Mar. Resour. statement, Augusta, 7 p.

[19] R. L. Dow, Coordinator, New England Regional Fisheries Management Council, Maine Dep. Mar. Resour., Augusta, ME 04330, pers. commun. July 1979.

[20] I. Flye, marine worm dealer, Newcastle, ME 04553, pers. commun. July 1979.

Based upon 1980 prices, a new digger is prepared to enter the fishery for an outlay of approximately $70–90 (license $10, bloodworm hoe $22 or sandworm hoe $45, boots $30, buckets $4, and perhaps a pair of gloves $4). The new digger can quickly recover his initial outlay with a little experience and two or three tides of digging effort. An experienced digger may desire a 14–16 ft aluminum boat and a 10–25 hp motor.

A good bloodworm digger will start digging high on the mud flat and follow the receding tide out with a trench measuring approximately 1 m in width. When the tide changes, the digger reverses direction and digs ahead of the incoming tide. A bloodworm flat is considered good if the digger can dig one commercial-sized worm for each four or five turns of the hoe. Although a good bloodworm digger may dig as long as 5 h on a low drain tide, 2 to 4 h is the general rule.

The sandworm digger generally waits until the tide is near the low water mark before he begins digging. He spends the entire tide digging parallel to the shore in the region of the low water mark. A sandworm flat is considered good if the digger can dig one commercial-sized worm for each turn of the hoe. Often the digger may be rewarded with three–four worms per hoe turn. Although a good sandworm digger may dig as long as 3–3½ h on a low drain tide, 1½ to 2½ h is the general rule.

MARINE WORM HOES

A commonly used form of the bloodworm hoe (Fig. 1A) is constructed from two small spading forks welded together on a V-shaped brace. The hoe handle is constructed from a portion of the handle of one of the original spading forks. The handle is pounded down onto a short tine that has been welded to the middle of the brace at a relatively sharp angle to the tines. Various important bloodworm hoe measurements from the areas east and west of Penobscot Bay during 1977 are presented in Table 4.

A commonly used form of the sandworm hoe (Fig. 1B) is constructed from parts of three large spading forks. One tine from each of two large 4-tined spading forks is removed. The remaining portions are then welded together to form a 6-tined hoe. Each tine is then lengthened by welding on four additional tines from the third spading fork plus the two tines that were removed from the first two spading forks. The hoe handle, obtained from a portion of one of the original spading fork handles, is attached to the tines in much the same manner described previously for the bloodworm hoe. Various important sandworm hoe measurements from the areas east and west of Penobscot Bay during 1977 are presented in Table 4.

Previous descriptions of Maine marine worm hoes have been presented by Ganaros (footnote 4) and Dow and Creaser (1970).

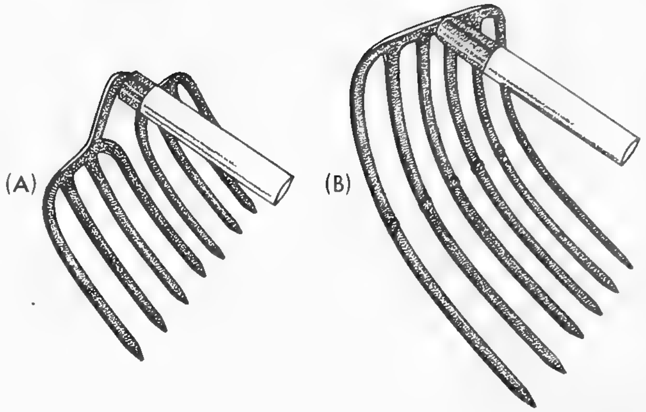

Figure 1.—Marine worm hoes commonly used by commercial diggers: (A) bloodworm hoe, (B) sandworm hoe.

According to the hoe description supplied by Ganaros (footnote 4), the hoe was constructed from a modified garden fork, the handle of which was cut off 9–10 in (22.9–25.4 cm) from the tines. Two additional tines were welded on either side of the fork and all six tines were bent at an angle of approximately 45° with the handle. Each tine was flattened and gently curved inward. The lengths of the tines were approximately 11½ in (29.2 cm) and the overall width obtained was 10½ in (26.7 cm). Although Ganaros (footnote 4) did not state which worm species this hoe was designed for, the tine lengths are midway between those reported for bloodworm and sandworm hoes (Table 4), thus suggesting that it might have been used for both.

The bloodworm and sandworm hoes described by Dow and Creaser (1970) are very similar in dimension to those summarized in Table 4.

Bloodworm hoes used by diggers in the Maritime Provinces were also constructed from garden forks (Klawe and Dickie 1957). The four tines on these hoes were tapered from 0.5 to 0.75 in (1.3–1.9 cm) in width, were 9 to 10.5 in long (22.9–26.7 cm), and were curved slightly inward. No other measurements were recorded.

PACKING AND SHIPPING MEDIUM

Seaweed gatherers collect packing weed for specific use by marine worm dealers. Dealers prefer to pack both species of worms in the young fine textured shoots of *Ascophyllum nodosum* f. *scorpiodes* and *Ascophyllum machaii*, both of which are found growing quite abundantly at the base of *Spartina* in salt and brackish water

Table 4.—A summary of bloodworm (B) and sandworm (S) hoe measurements recorded east and west of Penobscot Bay during 1977.

		Tine measurements (±1 SE)				Hoe measurements (± 1 SE)			
Species and area	No. hoes measured	Number	Length (cm)	Flat or round (%)	Width (cm)	Width (cm)	Handle length (cm)	Handle-tine angle (°)	Distance handle tine (cm)
B (east)	50	5.74	22.16	100 F	1.75	25.56	15.96	51.82	14.29
		±0.15	±0.48		±0.08	±0.31	±0.41	±1.07	±0.19
B (west)	55	7.11	21.39	100 F	1.01	27.75	20.91	42.07	18.01
		±0.10	±0.52		±0.01	±0.35	±0.16	±0.68	±0.27
S (east)	48	6	38.84	87.5 F	1.15	27.99	29.89	45.46	24.89
		±0	±0.57	12.5 R	±0.04	±0.33	±0.55	±0.80	±0.41
S (west)	50	5.62	34.74	76.0 F	1.00	25.21	23.17	46.54	23.35
		±0.07	±0.73	24.0 R	±0.05	±0.35	±0.16	±0.77	±0.25

marshes (Vadis;[21] Topinka[22]). Two precautionary measures are followed in the packing process for sandworms; pack life may be extended by the use of seaweed that is rather dry (compared with the wetter weed used in packing bloodworms) and the use of exceptionally fine seaweed is avoided because the sandworms cannot burrow down through it and consequently clump together on top. Many dealers prefer to use light-colored packing weed when it is available. The reason for this may be simply that the product looks better packed in light weed (Curtis[23]). Some dealers believe that dark weed is a better packing medium for bloodworms and light week is better for sandworms (Hammond[24]). In the past, sea lettuce, *Ulva*, has also been successfully used as a packing medium in those areas (such as Prince Edward Island) where conventional packing weeds are absent (MacPhail 1954).

The seaweed is placed in shallow newspaper-lined cardboard cartons with lids. In the recent past, shallow tomato boxes were used for this purpose. Canned milk cartons have also been used successfully for shipping bloodworms (Ganaros footnote 4). Each carton contains 250 bloodworms or 125 sandworms.

The worms are shipped to their destination by refrigerated truck, bus, or air freight. In the past, they were also shipped by railway express and parcel post (Sandrof 1946).

PRESENT MARINE WORM MARKETS

Marine worm dealers presently categorize their U.S. marine worm markets into four general areas of delivery: New York, Boston, the southern market, and California (Peaslee;[25] Wanser;[26] Wright;[27] Crowley;[28] Fairservice[29]). The approximate extent of the season and the worm species associated with each of these markets is described as follows.

The onset of the "New York market," including Connecticut, generally occurs some time between the end of February and the middle of March. This market is concluded between the middle and end of November. Both bloodworms and sandworms are marketed in New York but sandworms prevail in the "Connecticut market."

The "Boston market" is comprised of two divisions: a Boston proper market, including the area just east of Boston, and a market on the Cape Cod peninsula. The onset of the former occurs between the end of February and the end of March and it is concluded between the end of October and the end of November. The onset of the market on the Cape occurs in May, demand is high during June, July, and August, and the market is concluded by the first of September. Both divisions of the Boston market deal primarily with sandworms.

The "southern market" includes New Jersey; Delaware; Maryland; Washington, D.C.; Virginia; and North and South Carolina. The onset of this market occurs between the first of April and the end of May. It is concluded between the first of September and the end of October. Both bloodworms and sandworms are marketed in the northern New Jersey market. Bloodworms prevail in southern New Jersey and the remainder of the southern market.

Several previous references to marine worm markets are available in the literature. Ganaros (footnote 4) reported that bloodworms and sandworms were marketed in New York, New Jersey, Pennsylvania, and Connecticut. MacPhail (1954) and Pettibone (1963) reported on the use of marine worms in a sport fishery that was concentrated about Long Island and extended from Connecticut to Maryland. Dow (1969) stated that both species of marine annelids were marketed from Long Island Sound to Chesapeake Bay.

The "California market" is a relatively new market. Although marine worms are shipped to this market throughout the year, the greatest quantities are shipped during two specific periods. The first period begins in February and lasts through May or June. Few worms are shipped during the summer because of mortalities associated with overheating during delayed air transport. Market demand increases again during September, October, and November. Both bloodworms and sandworms are desired by the northern California market, whereas a preference for bloodworms prevails in the southern California market.

The most recent market to develop is the French market. The demand for worms increases around the end of May, remains good during the summer, and slows down during November. A small but continuous demand exists throughout the winter. Although both species are desired by the French market, 90% of the shipments consist of bloodworms (Flye footnote 20).

According to many of the dealers interviewed during the course of this research, the weather plays an important role in determining the extent of a given market's season; good weather will result in a market's beginning earlier and ending later than normal.

MATERIAL AND METHODS

Marine Worm Sampling Program

We developed a multistage sampling plan with monthly stratification that would yield information on: 1) Size and length frequency of the catch, 2) probability sampling expansions for total catch in numbers, total number of digger hours dug, total value of catch, total number of digger tides dug, total catch in pounds, and 3) ratio estimates (catch/effort data) for catch in numbers/hour, catch in numbers/tide, catch in pounds/hour, and catch in pounds/tide.

Selection of Commercial Sampling Period

A survey of the marine worm industry conducted in 1972 showed that the initial increased demand for marine worms occurred during March, peak demand occurred during June, July, and August, and by the end of November the demand had substantially subsided. This trend is also evident from the monthly bloodworm and sandworm landings obtained from U.S. Department of Commerce (1946–80), converted from pounds into numbers of worms, and presented in Figure 2. On the basis of the information above, we initially sampled commercial marine worm landings between 1 April and 31 October. However, the sampling period was shortened to 1 April–30 September after the first year's sampling (1973) when

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[21] R. L. Vadis, Professor, University of Maine, Orono, ME 04473, pers. commun. July 1979.

[22] J. Topinka, Principal investigator, Bigelow Laboratory for Ocean Sciences, West Boothbay Harbor, ME 04575, pers. commun. July 1979.

[23] C. Curtis, marine worm digger, Wiscasset, ME 04578, pers. commun. July 1979.

[24] F. H. Hammond, marine worm dealer, Wiscasset, ME 04578, pers. commun. 1979.

[25] F. E. Peaslee, marine worm dealer, Wiscasset, ME 04578, pers. commun. August 1979.

[26] R. Wanser, marine worm dealer, Wiscasset, ME 04578, pers. commun. August 1979.

[27] W. A. Wright, marine worm dealer, Addison, ME 04604, pers. commun. August 1979.

[28] K. A. Crowley, marine worm dealer, Addison, ME 04604, pers. commun. August 1979.

[29] S. H. Fairservice, Sr., marine worm dealer, Wiscasset, ME 04578, pers. commun. August 1979.

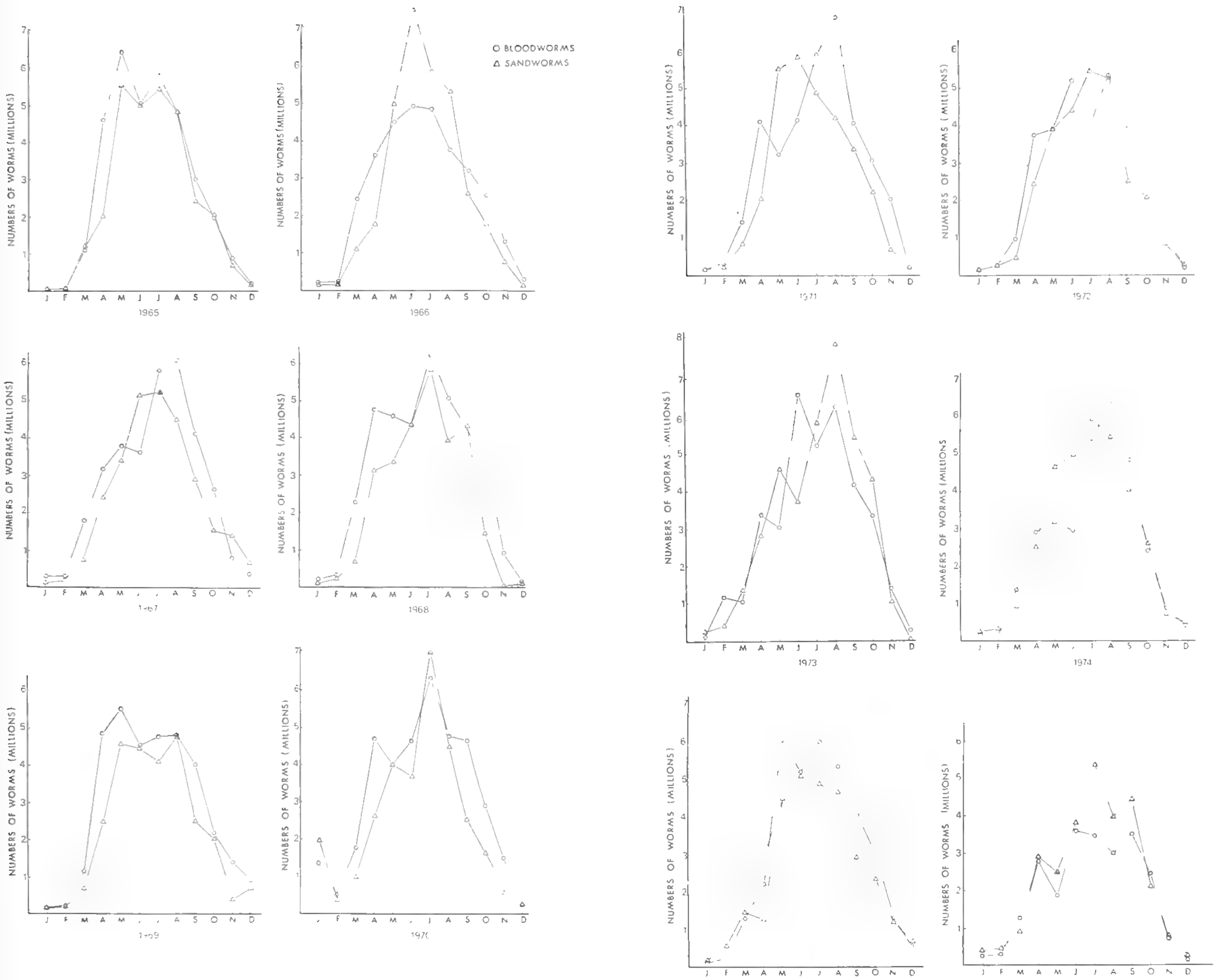

Figure 2.—Bloodworm and sandworm landings in numbers reported monthly for the period 1965–76.

it became evident that few dealers were purchasing large quantities of worms in October and the majority of our sampling trips during that month yielded no information at all.

Primary Sampling Unit

All daylight low tide periods occurring between one-half hour before sunrise and sunset during the months of April through September were listed and designated as the primary sampling unit. The time of sunrise and sunset at lat. 44°16′N, long. 68°38′W (a point near Blue Hill, Maine, that is halfway between the extreme dealer sampling locations of Wiscasset and Jonesport) was obtained from the Nautical Almanac Office of the U.S. Naval Observatory in Washington, D.C. Low tide periods were recorded for Portland, Maine (U.S. Department of Commerce 1973–76). Six randomly selected daylight low tide periods were chosen for sampling during any one month.

Secondary Sampling Units

All marine worm dealers who purchase their worms continually from 5 or more diggers during any given month were listed and designated as the secondary sampling units. A restriction of at least 5 diggers/dealer was necessary in order to eliminate a number of worm dealers (6 during 1976) in the western portion of the state who operated bait and tackle shops or who supplied marine worms to party boats and purchased their worms occasionally from 1 to 3 diggers. Marginal dealers, who might be buying continually from 4 diggers one month and 5 diggers the following month, were contacted monthly during the sampling period to determine whether or not they should be included as secondary sampling units. A dealer code number consisting of a county and number was assigned to each qualified dealer (Fig. 3).

Digger Interview

Marine worm diggers were interviewed as they delivered their catches to the dealer. It was often necessary to fractionally interview and sample the diggers (sample every 2nd, 3rd, 4th, or 5th digger) instead of sampling every digger that approached the dealer buying location because of the large numbers of diggers involved, and their grouped arrivals during one or two predominant periods after low water (an early arrival period for sandworm diggers and a later arrival period for bloodworm diggers).

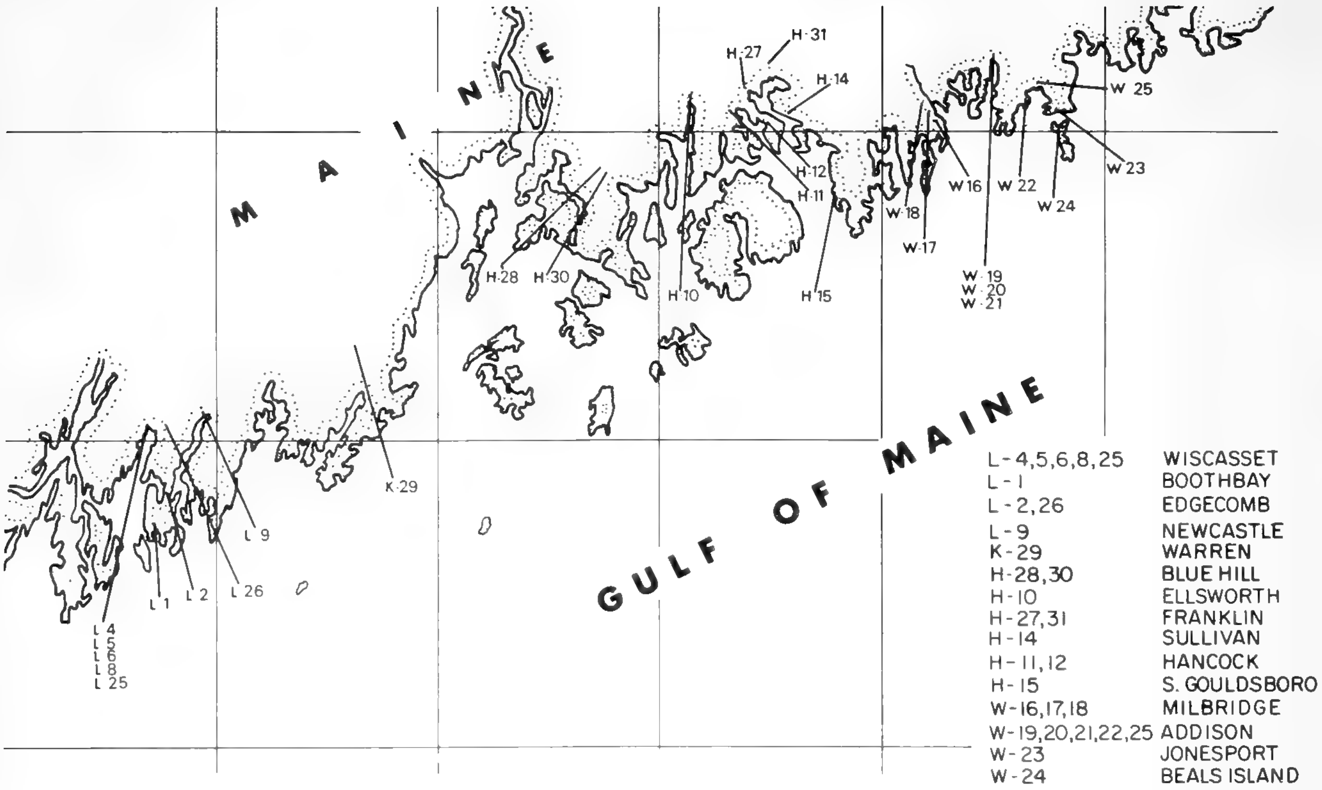

Figure 3.—Marine worm sampling locations along the Maine coast 1973–76.

Sampling the Catch

We attempted to collect worm samples from a maximum of 15 diggers at each dealer sampling location. Each sample contained 25 bloodworms or sandworms. Samples of marine worms were obtained directly from the digger's bucket or hod prior to his entering the worm cellar and therefore contained worms of commercial value as well as culls.

Bloodworm diggers virtually always transported their worms to the buying locations in plastic or stainless steel buckets. The contents of each bucket sample were stirred with a small paddle and while the water and worms were in motion, a fine meshed tropical fish net was used to obtain a sample from the bucket. Sandworm diggers transported their worms to the buying locations in round 5 gal plastic pails or in rectangular wooden hods. Usually, these containers held great quantities of worms in as little water as possible. It was not possible to stir the contents of these containers with a paddle without breaking the sandworms. Therefore the contents were mixed by reaching into the bottom of the container with both hands and gently drawing the bottom worms upward. After doing this three or four times in one area of the container, the sample was withdrawn with cupped hands. Samples of bloodworms and sandworms obtained in the above manner were deposited into a narrow wooden tray from which a random cluster of 25 bloodworms or sandworms was counted out. The remaining worms were returned to the digger.

Processing the Samples

The 25-worm samples of bloodworms or sandworms were immediately placed into containers of high salinity water (31–33‰) after being collected at the sampling location. When sampling was completed, the worms were transported to the laboratory and placed into trays with porous fiber glass screen bottoms floating in tanks of high-salinity flowing seawater. They remained in these trays until completely acclimated—a period of at least 24 h.

Bloodworms were anesthetized in 0.2% propylene phenoxytol. The breakage of sandworms was reduced to an absolute minimum by first briefly placing the sandworms in 0.1% propylene phenoxytol to quiet them down and then the 0.1% mixture was replaced with 0.2%. When completely anesthetized, the worms were measured in a V-shaped measuring trough while submerged in anesthetic. Their weight, sex, and condition (broken, punctured, regenerated) were also recorded.

Sex was determined during April and May for bloodworms and during August and September for sandworms. Sex was distinguished from a sample of the coelomic fluid withdrawn with a capillary pipette and examined under a microscope.

Unanesthetized length measurements in the natural state were derived from a photograph taken while the worms were immersed in a seawater bath containing a 15 cm rule.

Compilation of Interview and Cluster Sampling Information

The information compiled by digger from the interviews and cluster samples is presented in Table 5. The information recorded in Table 5A was then summarized for each dealer daylight low-tide period sampled and recorded in the form shown in Table 6.

Statistics

All formulas used to calculate: 1) Individual, monthly, and 6-mo means, variances, and standard errors, 2) monthly and 6-mo proba-

Table 5.—Forms used in the collection of (A) interview and sample information and (B) the total landings of acceptable and cull worms.

(A)

Commercial Catch - Sandworms - ~~Bloodworms~~

Dealer (Code No.) L-5 Limit No [✓ Yes] No. 750 Sampling fraction 1:1 (1:2) 1:3 1:4

Date 9/10/74 No. low tides on sample day 1 Sampler D.C. M.H. E.P.C.

Price/worm .04

	S or ~~B~~			S or ~~B~~			S or ~~B~~		
1) Digger No.	1			3			4		
2) Digger arrival time	1215			1247			1247		
3) Digger age, # years digging experience	34		25	39		20	39		27
4) Is catch 1 or 2 tides dig?	1			1			1		
6) What time stop dig?	1203			1141			1141		
5) Low tide at 1141 What time start dig?	1045			1100			1100		
7) OR How long on flats digging?	1.30 hrs. ~~1 hr. 18 min.~~			0.68 hrs. ~~0 hr. 41 min.~~			0.68 hrs. ~~0 hr. 41 min.~~		
8) Worms from 1 area or more?	1			1			1		
9) River or area worms dug from?	Back River Boothbay			Waldoboro			Waldoboro		
10) Last tide dug - morning or afternoon, day or night?	2 low tides prev. (day)			2 low tides prev. (day)			2 low tides prev. (day)		
11) Worm sample	Lgth.	Wt.	Sex	Lgth.	Wt.	Sex	Lgth.	Wt.	Sex
1	B	4.42	NS	B	9.55	NS	R	4.82	NS
2	27.4	7.89	F	32.1	7.90	NS	32.1	9.20	F
3	24.7	4.20	NS	30.8	6.63	NS	28.6	5.52	NS
4	24.2	4.58	NS	28.7	7.13	M	R	3.97	NS
5	38.4	11.40	F	43.0	14.83	M	22.8	3.00	NS
6	34.0	8.40	NS	29.8	6.15	NS	25.4	3.63	NS
7	27.9	5.13	NS	B	5.03	M	28.3	6.00	NS
8	37.7	12.46	NS	31.3	7.40	NS	B	4.50	NS
9	B	8.00	M	28.5	5.45	NS	B	6.87	NS
10	B	4.52	NS	B	4.30	F	28.7	6.40	M
11	B	6.53	F	B	8.23	NS	31.2	7.88	NS
12	25.0	4.56	NS	33.3	8.91	NS	30.6	8.00	F
13	B	4.30	NS	35.2	8.22	NS	25.8	3.62	NS
14	23.4	3.97	NS	28.1	6.00	NS	30.1	6.00	NS
15	29.1	6.22	NS	B	3.97	NS	R	2.90	NS
16	R	4.09	NS	B	3.87	NS	R	6.00	F
17	R	5.40	NS	24.1	3.80	NS	33.1	7.66	M
18	19.3	2.63	NS	28.5	4.74	NS	34.8	9.99	F
19	B	2.03	NS	25.3	4.00	NS	36.4	8.73	NS
20	R	6.91	F	B	4.38	NS	25.5	4.69	M
21	23.0	3.22	NS	35.7	9.50	F	29.0	6.23	NS
22	B	5.45	NS	B	5.27	NS	23.0	3.32	NS
23	B	7.82	M	27.6	5.89	M	R	3.20	NS
24	30.7	6.70	M	25.8	5.10	NS	R	5.21	F
25	R	3.24	NS	B	2.80	NS	29.5	5.70	NS
12) Total no. worms dug (include estimates of #'s of culls, if any)	13	25		16	25		17	25	
	364.8	134.07		487.8	159.05		494.9	143.04	
	775+8 = 783			775+5 - 780			775+3 = 778		

R = regenerated
B = broken
P = punctured
NS = nonspawner
M = male
F = female
FI = female (immature)

Weather: Wind velocity 1 Wind direction E Air Temp. 21°C Barometric Press. -
Cloud cover 7/8 clouds - rain clouds - no rain
Tide: Low tide (ft.) - tide table +1.00 Low tide (ft.) - actual +.75

Table 5.—*Continued.*

(B)

Dealer L-5 Mo. Sept. Day 10 Year 1974

M. R. No. (if any)	No. Worms Dug	Bloods (B) or Sands (S)	Culls	Other	Total, Including Culls
1	775	S	8	-	783
-	750	S	10	-	760
3	775	S	5	-	780
-	750	S	5	-	755
4	775	S	3	90B	778
-	750	S	0	35B	750
5	775	S	10	-	785
-	750	S	10	-	760
					Note - add 125 B to bloodworm form (L-5, 9/10/74)
	Total Dug 6100		Total Culls 51		Total Time 4.66 hrs
	Total From Diggers Sampled 3100		Culls from diggers sampled 26		

bility expansion and ratio estimates, 3) time efficiency values, 4) optimum and proportional allocation, and 5) length-weight relationships, are presented in Appendix A.

Verification of Sampling Procedures and Responses to Interview Questions

The methodology employed in several of the marine worm sampling and processing procedures was closely scrutinized. Since we anesthetize and measure the worm's length immediately prior to weighing them, studies were performed to determine what effect the anesthetic might have on the worm's weight. In these studies, worm weights were compared before and after anesthetization with 0.2% propylene phenoxytol.

Another problem associated with length measurements on soft-bodied Annelids involved a determination whether the measurements were reproducible. This was investigated by repetitious measurements, reviving of individuals of both species between measurements, and a comparison of the results.

Other experiments were performed to compare length differences resulting from relaxing and measuring the same assorted bloodworms in two different anesthetics. One group of bloodworms was first acclimated to high salinity water, anesthetized in 0.2% propylene phenoxytol, and then measured. These worms were then revived in high salinity water and the following day they were anesthetized and measured in 7.5% $MgCl_2$. The entire experiment was then reversed using another group of assorted worms and the results of both experiments were compared.

Experiments were performed to determine if the manner in which a 25-worm sample was obtained from the digger produced a mean length and weight estimate that was truly representative of the mean length and weight of all the worms present in the bucket (bloodworms) or hod (sandworms). All worms used in these experiments were obtained from two commercial diggers. A bucket con-

Table 6.—The summary sheet for catch statistics data collected during each dealer daylight low tide period sampled.

CATCH STATISTICS

bloodworms ~~sandworms~~

Dealer L-4 Day 4 Month June Year 1976

1. Value/worm $ 0.055
2. Number of diggers sampled 18
3. Accepted catch in numbers from diggers sampled 15,532
4. Catch in grams from diggers sampled 27216.52 lbs. (x.002205) 60.01
   (numbers from diggers sampled (3) x mean wt./worm)
5. Number of worms taken in DMR samples 450
6. Number of mature males in DMR samples -
7. Number of mature females in DMR samples -
8. Number of digger tides dug from diggers sampled 18
9. Number of digger hours dug from diggers sampled 63.42
10. Mean length of worms in DMR samples 16.77
    (from unbiased estimates of weighted means)
11. Mean weight of worms in DMR samples 1.75
    (from unbiased estimates of weighted means)
12. Catch in numbers/digger tide dug 862.89
    (catch in numbers from diggers sampled (3)
    (number of digger tides dug (8)
13. Catch in grams/digger tide dug 1512.03
    (catch in gms. from diggers sampled (4)
    (number of digger tides dug)(8)
14. Catch in lbs./digger tide dug 3.33
    (convert grams (13) to lbs. by multi. gms. x .002205)
15. Catch in numbers/digger hour dug 244.91
    (catch in numbers from diggers sampled (3)
    (number of digger hours dug from diggers sampled (9)
16. Catch in grams/digger hour dug 429.15
    (catch in grams from diggers sampled (4)
    (number of digger hours dug (9)
17. Catch in lbs./digger hour dug .95
    (convert grams (16) to lbs. by multi. gms. x .002205)
18. Value/digger tide dug $47.46
    (derive from (12) by multi. numbers x value/worm)
19. Value/digger hour dug $13.47
    (derive from (15) by multi. numbers x value/worm)
20. Value/gram $0.03139
    (catch in numbers from diggers sampled (3) x value/worm)
    (catch in grams from diggers sampled (4)
21. Value/lb. $14.24
    (convert value/gm. to value/lb. by multi. (20) x 453.59)
22. Total number of diggers that dug 37 men 36 women 1
23. Total number of digger tides dug for all diggers 37
24. Total accepted catch in numbers for all diggers entering cellar 26,107 (+ others)
25. Total estimated number of digger hours dug for all of accepted catch 130.36
    (estimate by interpolatation using $\frac{(9)}{(2)} \times \frac{x)}{(22)}$
26. Total catch in grams 45749.91 (+ others)
    (total accepted catch in numbers (24) x mean weight (11)
27. Total catch in lbs. 100.88 (+ others)
    (total catch in grams (26) x .002205)
28. Total value of catch $1435.89 (+ others)
    (total accepted catch in numbers (24) x value/worm)
29. Total number of culls in catch for all diggers entering cellar 622(% of total catch)2.33%
30. Total number of daylight low tides/month 42
31. Low tide magnitude - actual -.27 calculated -.2
32. Weather 1 K from E, air temp. 20.1°C, clear and sunny with scattered clouds

taining 581 bloodworms and a hod containing 1,041 sandworms were sampled as previously reported. The worms obtained in the sampling process were anesthetized, measured, weighed, and then returned to the original bucket or hod. After the worms had revived, the procedure was repeated a total of 10 times. The results obtained from these length and weight measurements on bloodworm and sandworm samples were then compared with the mean length of all measurable (461) and weighable (581) bloodworms in the bucket, and all measurable (779) and weighable (1,041) sandworms in the hod.

The digger responses to several questions asked during the sampling interview were routinely checked for accuracy. The total worm count dug and reported to the sampler by the digger was checked against the number reported on the dealer's record sheet (the number of worms the digger was actually paid for). The digger's response to questions dealing with the time digging began and ended on a given tide was compared with the actual digging time observed and recorded by the sampler for that digger from a concealed position along the shore.

Yield-Effort Curves

License and landings data used in bloodworm and sandworm yield-effort curves were obtained from DMR license records and U.S. Department of Commerce (1946–80) (for the appropriate years). Landings data reported in pounds in U.S. Department of Commerce (1946–80) were converted back into numbers using the appropriate conversion factors.

RESULTS AND DISCUSSION

Digger Interview

The proper use of a sampling fraction, in both the digger interview and the commercial sampling, requires that the diggers are approaching the cellar in random fashion. This requirement is probably met when one considers that some diggers dig for long periods and other dig for short periods, regardless of the distance between the digging site and the dealer buying locations. The use of a randomly selected choice of diggers has one advantage in that if the diggers were approaching the cellar in some sort of order, the order would in no way affect the selection of a random sample. For reasons of simplicity, the use of a sampling fraction was also the only logical choice; the act of interviewing different fractions of bloodworm and sandworm diggers as they were both entering and leaving the worm cellar simultaneously, was already complicated enough.

Sampling the Catch

We attempted to limit ourselves to collecting marine worm samples from a maximum of 15 diggers (at 25 worms/digger) per dealer buying location because of the time involved in processing 375 worms for length, weight, and sex. Occasionally, when the larger dealers were sampled, we were unable to determine how many bloodworm or sandworm diggers would be arriving at the cellar with worms during the sampling period and we had to estimate, on the basis of past experience, what sampling fraction to use for both species without exceeding a total of 15 samples. In some cases we were successful and approximately 15 samples were obtained. At other times, our estimates were erroneous and either more or fewer than 15 samples were obtained.

We chose to sample the diggers just prior to entering the dealer buying locations for several reasons. First, we did not desire to interfere with the dealer's handling practices and procedures. Second, the inclusion of cull worms in the sampling procedure is desirable because the vast majority of the culls were never returned to the flats alive; they were either discarded in the "discard" bucket, along the road side, or they were dumped on the flats or in the water where they were rapidly consumed by sea gulls and fish. Our commercial sampling therefore reveals what is lost from the natural population through commercial digging and it includes both commercially acceptable worms and a small percentage of cull worms that will be discarded and wasted. Our commercial sampling results indicate that bloodworm culls comprise 3.0–4.6% and sandworm culls comprise 2.6–5.1% of the worm catch brought into the cellar. The net result is that the mean lengths recorded from our samplings of the catch are actually slightly smaller (they contain length measurements for cull worms that would be discarded and wasted during the normal handling procedure in the cellar) than the mean size of worms shipped out of state.

Processing the Samples

Acclimation of all worm samples to high salinity water prior to anesthetization and measurement was necessary because the length and weight of marine worms vary with salinity. Preliminary investigations revealed that some marine worms had either been dug from varying salinity conditions or had been exposed to additional dilution by the diggers for varying periods of time prior to our obtaining them (Table 7). This practice of "watering down" the worms is prevalent among bloodworm diggers and rare among sandworm diggers. Although salinities as low as 10‰ have rarely been recorded from bloodworm bucket water, it is highly unlikely that the worms themselves are dug very often from mud of this salinity because salinity tolerance experiments conducted previously (Creaser[30]) showed that bloodworms are stressed after exposure to 10‰ for 24 h. Experiments designed to measure the time required for bloodworms to acclimate to a standard lab line salinity of 31–33‰ from a lower salinity were initiated at a salinity of approximately 16‰ because we did not wish to stress the bloodworms. Although sandworm diggers rarely "water down" their worms, an initial starting salinity of 16‰ was also used in similar sandworm experiments. The results of these acclimation experiments on bloodworms and sandworms are presented in Figure 4. The results in Figure 4 show that bloodworms required as much as 10 h and sandworms required as much as 16–18 h to completely acclimate to high salinity after being dug and transported under the conditions reported. In view of the facts that: 1) The experiments in

Table 7.—The salinity content of water obtained from the hods and buckets of marine worm diggers and used in transporting bloodworms and sandworms from the flats to the dealer.

Dealer code	Date (1972)	Number of samples	Bloods (B) or sands (S)	Mean salinity (‰)	1 standard error (‰)
L-4	4/24	19	B and S	16.09	±1.02
L-5	4/24	7	B and S	21.33	±2.26
L-6	5/07	13	S	26.61	±0.87
L-6	5/07	5	B	20.06	±3.77
W-18	5/02	14	B and S	20.29	±0.81

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[30] Creaser, E. P., Jr. 1971. Biological, environmental and technological research on marine worms. Project 3-16-R Completion Report covering the period 1966–1971. Dep. Sea Shore Fish., State House Annex, Capitol Shopping Center, Augusta, ME 04333, 224 p.

Figure 4 were conducted in the fall at temperatures of 4°–5°C when the acclimation time would be slower, 2) no changes in weight were noted after 18–20 h during repetitious weighings of a few randomly selected bloodworms and sandworms collected periodically during commercial sampling, and 3) commercial samples collected on one day were never processed until at least 24 h later, it is highly probable that all length and weight measurements were made on commercial samples only after all worms had been fully acclimated to standard high salinity conditions.

The length measurement of a marine worm in its natural state is a difficult if not impossible undertaking; the soft-bodied Annelid can coil, undulate, expand, and contract. To avoid these problems, we anesthetized the worms before measuring them. The relationships of natural lengths to anesthetized lengths for bloodworms and sandworms collected from the Sheepscot River are shown in Figure 5. These results demonstrate that the difference between anesthetized length and natural length is greater for bloodworms than for sandworms; a bloodworm of 20 cm anesthetized length is equivalent to approximately 13 cm natural length, whereas a sandworm of 20 cm anesthetized length is equivalent to approximately 17 cm natural length.

Bloodworm samples collected during April and May were sexed because in the region of Wiscasset, Maine, spawning occurs in June (Creaser 1973). Sandworm samples were sexed during August and September after spawning in April and May (Creaser and Clifford footnote 11).

Verification of Sampling Procedures and Interview Responses

Studies preformed to determine what effect the anesthetic might have on the worm's weight indicated that it had little effect.

Studies performed to determine if length measurements upon bloodworms and sandworms are true and reproducible indicated that bloodworm lengths, over the range of sizes tested (15.7–36.6 cm), are reproducible within ±0.2 to ±1.0 cm (at 95% confidence limits or 1.96 SE) and sandworm lengths, over the range of sizes tested (12.1–64.3 cm), are reproducible within ±0.4 to ±2.4 cm (at 95% confidence limits or 1.96 SE).

Studies in which lengths were obtained on individual worms after being relaxed in two different anesthetics (0.2% propylene phenoxytol and 7.5% $MgCl_2$) demonstrate that when bloodworms were first relaxed and measured in 0.2% propylene phenoxytol and then relaxed and measured in 7.5% $MgCl_2$, the lengths recorded in the $MgCl_2$ were usually smaller (23 out of 24 cases). The reduction in size varied between 0.8 and 23.4%. When bloodworms were first relaxed and measured in 7.5% $MgCl_2$ and then relaxed and measured in 0.2% propylene phenoxytol, the lengths recorded in the propylene phenoxytol were usually greater (16 out of 21 cases). Increased lengths varied between 1.0 and 12.0% and decreases varied between 1.5 and 13.0%. These results suggest that caution should be used when comparing the findings in this manuscript (where 0.2% propylene phenoxytol was used as as anesthetic) with the results in other publications (where other anesthetics were used).

More detailed information on the results of the studies above, which were performed to verify various sampling procedures, is reported in Creaser et al.[31]

The results of studies to determine if the 25 worm samples were truly representative of the entire contents of the bloodworm buckets and sandworm hods are presented in Table 8. It is evident from these results that on 10 out of 10 tries the range of bloodworm mean lengths and weights (±1.96 SE) overlapped the actual mean length and weight of the entire "bucket" population. On 9 out of 10 tries the range of sandworm mean lengths (±1.96 SE), and 8 out of 10 tries the range of sandworm mean weights (±1.96 SE), overlapped the actual mean length and weight of the entire "hod" population. There were few problems inherent in our method of selecting 25 bloodworms for measurement and most of the time the same holds true for sandworms.

Few errors were observed when comparing the total landings we recorded during the digger interview with the total the dealer recorded and paid the digger for. In only a few instances during a 4-yr period were intentional errors made by diggers. Occasionally, a digger failed to report to the dealer that we had collected 25 of his worms and his recorded landings with the dealer were therefore 25 worms short.

The results of our efforts to check the accuracy of the diggers' estimates of their digging time are shown in Table 9. This study was necessary because certain industry factions shared the opinion that diggers were reporting false information regarding their estimates of beginning and ending time. The results in Table 9 demonstrate that there is less than a 2% discrepancy between the time estimates of groups of diggers and their actual digging time recorded by observation from concealed positions. However, when time estimates for individual diggers are obtained through digger interviews on the flat, these estimates are probably more accurate than the estimates they would have made had they been interviewed at the worm cellar some distance away. Because of manpower limitations we were not able to follow individual diggers back to their respective cellars to obtain estimates of their digging time. We can only state that had we been able to do this the discrepancy might have been greater than 2%, but probably still within very acceptable limits. These data were analyzed to determine if the ratio of two variables (actual vs. reported time) was significantly different from a 1:1 ratio at 95% confidence limits (2 $SE_{\hat{R}}$). The results indicate that the relationship between actual and reported time is not significantly different from a 1:1 ratio (1.01764±0.02819 or 0.98945–1.04583). In other words, the mean estimate of digging time, as reported to the sampling crew, is quite accurate. As far as individual groups of diggers are concerned, some estimate a little high, some estimate a little low, and some estimate precisely. Verification of the accuracy of both reported landings and digging time estimates enables us to conclude that the estimates of catch/hour, one of the simplest indices of marine worm abundance, are probably quite accurate.

Commercial Sampling for Length, Weight, Sex, and Condition

Table 10 shows that the 6-mo mean lengths (±1 SE) for bloodworms were 18.72±0.60 cm (1973), 19.84±0.38 cm (1974), 20.74±0.59 cm (1975), and 20.83±0.54 cm (1976). These means are not significantly different from one another at 95% confidence limits (±1.96 SE). On the basis of this commercial sampling information, no significant differences occurred in the size of bloodworms harvested between 1973 and 1976.

It is also apparent from Table 10 that during April and May potential spawners comprise between 7.33–13.58% and 0.50–1.63%, respectively, of the commercial catch. Apparently, the diggers

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[31] Creaser, E. P., D. A. Clifford, M. J. Hogan, and D. B. Sampson. 1980. An analysis of the commercial baitworm fishery for sandworms *Nereis virens* Sars and bloodworms *Glycera dibranchiata* Ehlers in Maine. Maine Dep. Mar. Res. Lab. Res. Ref. Doc. 80/18, 180 p.

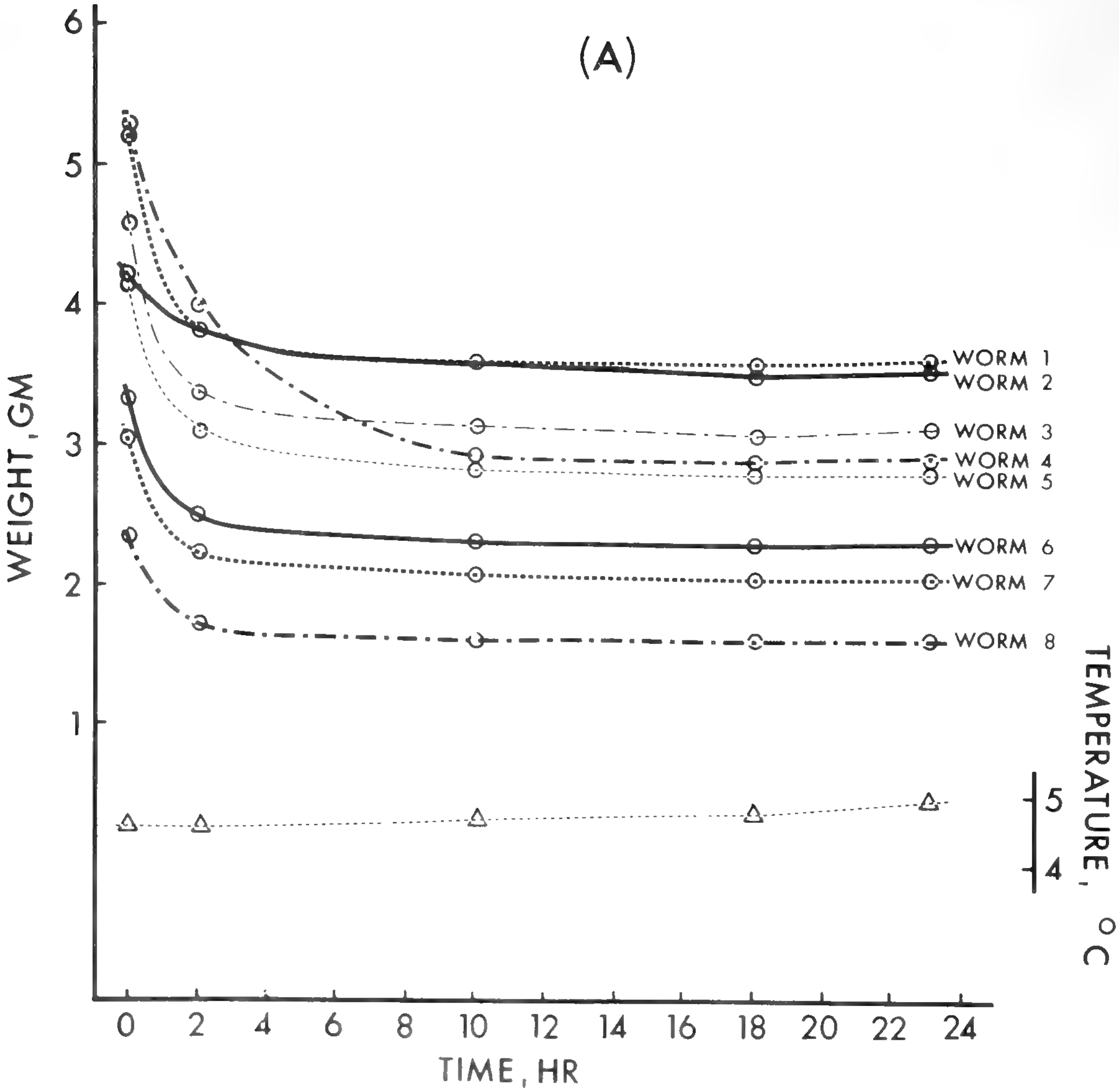


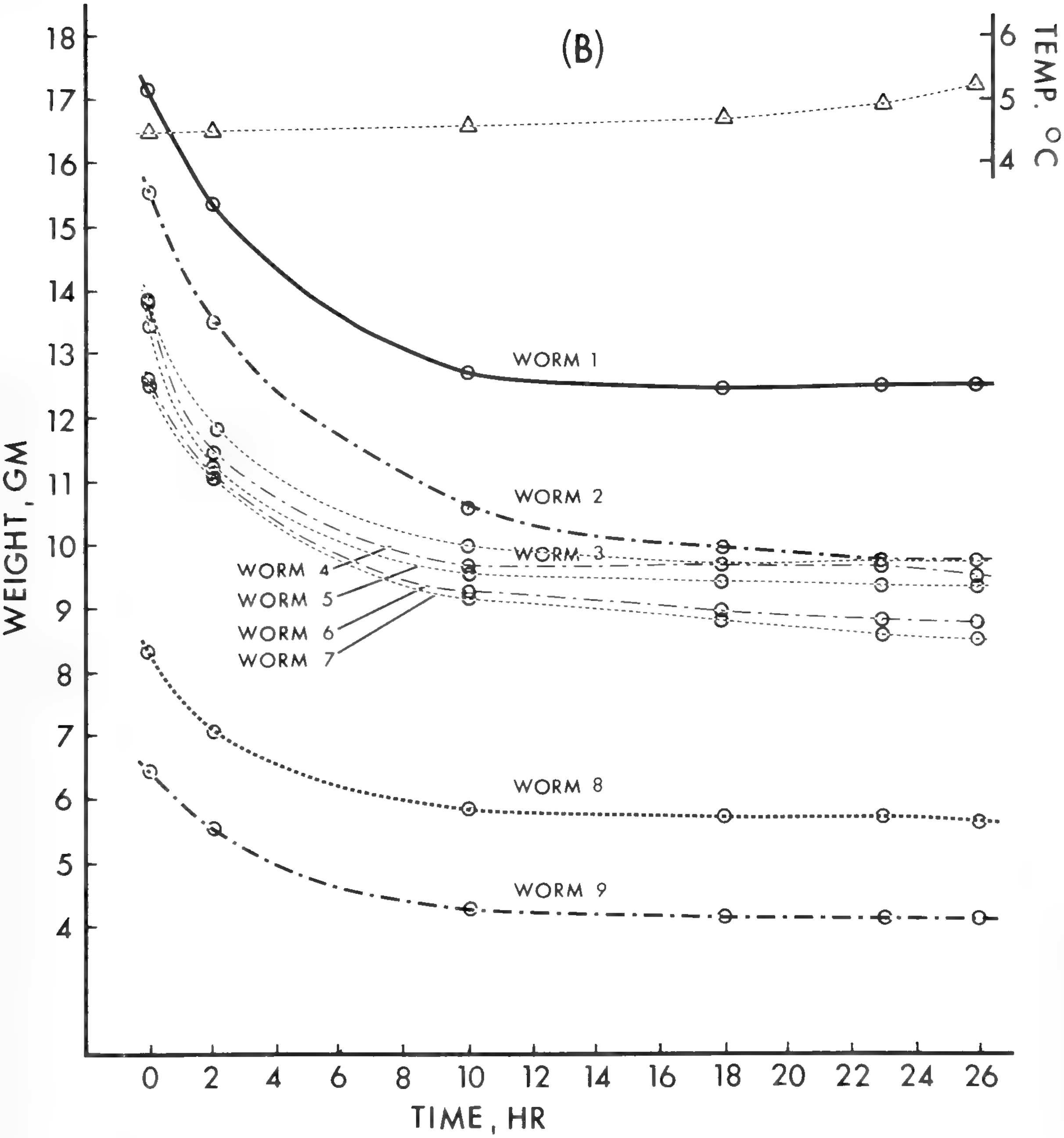
Figure 4.—The time required for assorted sizes of bloodworms and sandworms to acclimate to 32‰. (A) Bloodworms dug from an interstitial salinity of 19.52‰, transported to the laboratory in 16.09‰, and acclimated to 32‰. (B) Sandworms dug from an interstitial salinity of 22.00‰, transported to the laboratory in 16.49‰, and acclimated to 32‰.

avoid harvesting the fragile bloodworms that are approaching spawning condition in May. Diggers harvest slightly more female bloodworms than males. Potential bloodworm spawners are not evenly distributed along the coast; they were never collected east of the Taunton River (Sullivan, Maine) during 4 yr of commercial sampling. There are four possible sources of bloodworms recruited into the commercial fishery in eastern Maine. Trochophores (or juveniles) produced from the excellent spawning stocks in Nova Scotia (Klawe and Dickie 1957), may be carried on counterclockwise currents across the Bay of Fundy to eastern Maine. Evidence for these currents in the spring and summer is presented by Graham (1970) and also by Bumpus and Lauzier (1965). It is also possible that close inshore currents move clockwise and transport trochophores (or juveniles) from the abundant spawning stocks in the Taunton River and Sullivan Harbor to eastern Maine. Recruitment may occur from unknown subtidal or intertidal spawning communities in eastern Maine. However, since the worm digger is a hunter, it is unlikely that any large intertidal digging areas containing spawners could exist without the diggers' knowledge of them. An unlikely possibility is that the survival rate of the bloodworm trochophores produced by the rare spawners reportedly found by diggers in eastern Maine is exceptional and accounts for the excellent sporadic worm sets reported for numerous areas.

The 6-mo means reported in Table 10 show that approximately 5–7% of the catch consists of bloodworms with regenerated tails. Broken bloodworms comprised approximately 12–13% of the catch.

Table 11 shows that the 6-mo mean lengths (±1 SE) for sandworms were 26.11±0.98 cm (1973), 26.22±0.68 cm (1974), 26.77±0.53 cm (1975), and 25.69±0.42 cm (1976). These means are also not significantly different from one another at 95% confidence limits (±1.96 SE).

Sandworms spawn during March, April, and May and sandworm diggers also avoid picking up spawning worms. We waited until



August and September before attempting to sex sandworms obtained from the commercial catch. During these months potential spawners comprised between 15.6 and 38.3% of the commercial catch. Diggers usually harvested more female sandworms than males. Potential sandworm spawners were found all along the coast of Maine.

The 6-mo mean shows that approximately 8% of the catch consists of sandworms with regenerated tails. Broken worms comprised approximately 19–23% of the catch.

Variations in the mean size of bloodworms and sandworms harvested between dealers listed in Tables 10 and 11 can be explained by: 1) Dealer preference, 2) tidal amplitude, and 3) the length characteristics of the local worm populations being harvested on the days commercial samples were obtained.

Some previous information exists regarding the commercially acceptable size of bloodworms and sandworms harvested in western Maine. During March 1966, four dealers were asked to cull two bloodworm lots and two sandworm lots into commercial and noncommercial size groups. The results are shown in Figure 6.

Although the commercial length results presented in Figure 6 cannot be directly compared with the 6-mo mean lengths recorded for bloodworms and sandworms in Tables 10 and 11 (7.5% $MgCl_2$ was used to anesthetize the former, 0.2% propylene phenoxytol the latter), the results suggest that, had the 1966 bloodworm and sandworm samples been anesthetized in 0.2% propylene phenoxytol, their mean sizes would probably have been slightly larger than the 6-mo mean lengths reported for bloodworms and sandworms during the 1973–76 sampling program. These data suggest that there may have been a slight decrease in the acceptable size of commercial bloodworms and sandworms harvested between 1966 and 1973.

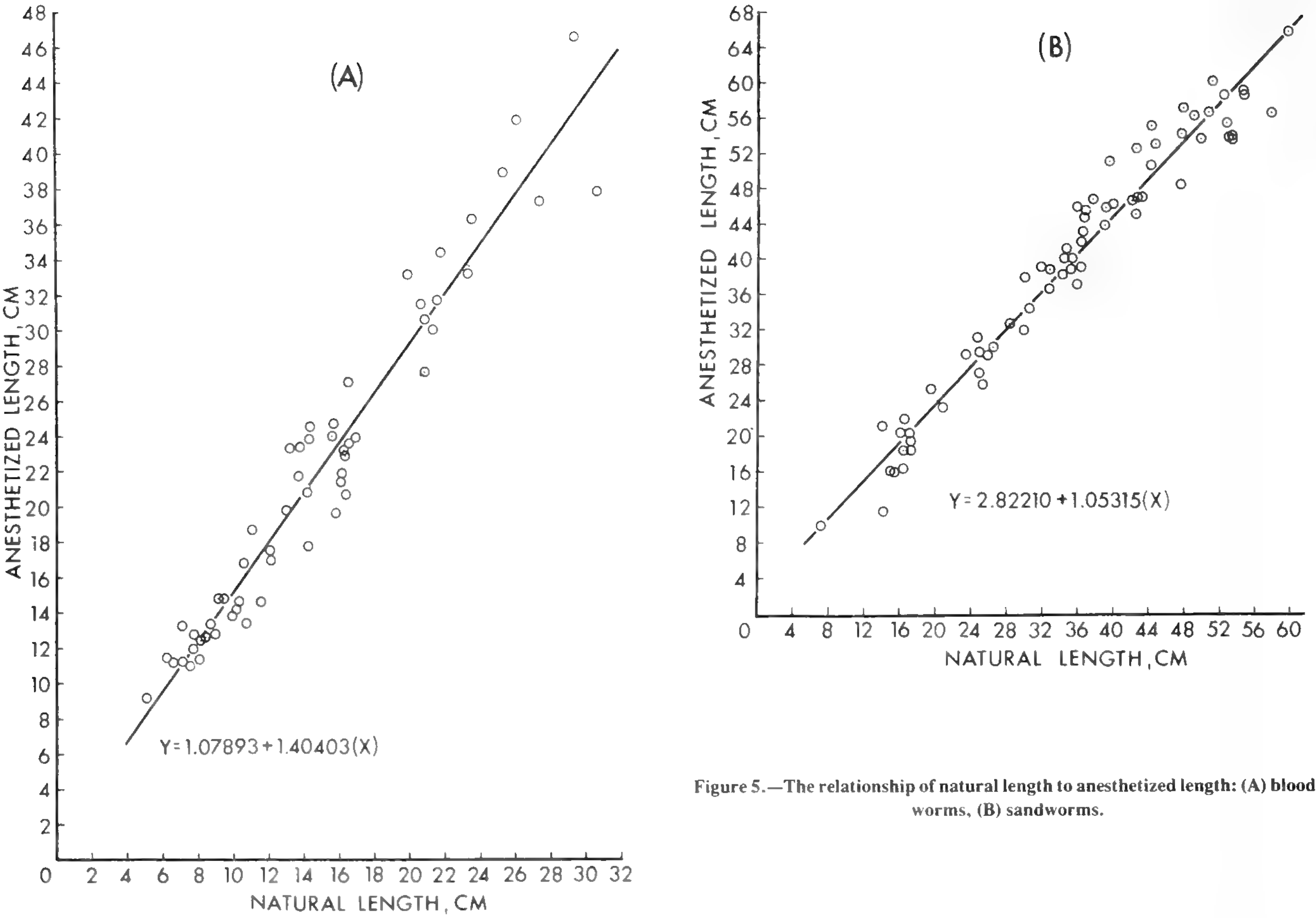


Figure 5.—The relationship of natural length to anesthetized length: (A) bloodworms, (B) sandworms.

Table 8.—Verification of the relationship of the mean length and weight (±1, ±1.96 SE) of a 25-worm sample to the mean length and weight of the total.

	Bloodworms length (cm) (N=461)				Sandworms length (cm) (N=779)		
N	$\bar{X}$(cm) ± 1 SE	± 1.96 SE	Mean ± 1.96 SE (95% confidence)	N	$\bar{X}$(cm) ± 1 SE	± 1.96 SE	Mean ± 1.96 SE (95% confidence)
21	20.42 ± 1.05	2.05	18.38-22.47	17	22.18 ± 0.57	1.12	21.05-23.30
23	20.89 ± 0.76	1.48	19.41-22.38	17	22.91 ± 0.49	0.96	21.94-23.87
20	19.44 ± 0.73	1.43	18.01-20.86	22	22.88 ± 0.82	1.61	21.27-24.49
20	19.93 ± 0.75	1.47	18.46-21.39	20	23.14 ± 1.10	2.15	20.99-25.28
19	20.78 ± 0.97	1.91	18.88-22.69	22	22.79 ± 0.71	1.39	21.40-24.18
19	19.78 ± 0.76	1.50	18.28-21.28	22	25.13 ± 0.62	1.21	23.92-26.34
15	18.35 ± 0.90	1.77	16.58-20.13	18	23.27 ± 0.87	1.71	21.56-24.99
24	19.22 ± 0.76	1.50	17.72-20.71	18	23.21 ± 0.65	1.27	21.94-24.48
22	20.39 ± 0.69	1.36	19.03-21.75	18	22.84 ± 0.62	1.21	21.63-24.05
22	20.55 ± 0.81	1.59	18.96-22.13	21	21.98 ± 0.60	1.18	20.80-23.16
461	19.94			779	22.49		
	weight (g) (N=581)				weight (g) (N=1,041)		
25	2.33 ± 0.28	0.54	1.78-2.87	25	3.58 ± 0.17	0.33	3.25-3.91
25	2.19 ± 0.19	0.37	1.81-2.56	25	3.90 ± 0.24	0.48	3.43-4.38
25	1.91 ± 0.22	0.42	1.48-2.33	25	3.98 ± 0.30	0.60	3.38-4.58
25	1.96 ± 0.19	0.38	1.58-2.34	25	4.15 ± 0.49	0.96	3.19-5.10
25	2.31 ± 0.27	0.54	1.77-2.85	25	4.09 ± 0.35	0.69	3.40-4.78
25	1.95 ± 0.17	0.33	1.63-2.28	25	4.55 ± 0.28	0.55	4.00-5.10
25	1.79 ± 0.20	0.39	1.40-2.18	25	3.94 ± 0.30	0.59	3.35-4.53
25	1.77 ± 0.17	0.33	1.40-2.10	25	4.56 ± 0.32	0.62	3.93-5.18
25	2.07 ± 0.21	0.41	1.67-2.47	25	3.66 ± 0.22	0.42	3.24-4.08
25	2.29 ± 0.22	0.43	1.86-2.71	25	3.76 ± 0.25	0.48	3.28-4.25
581	2.07			1,041	3.43		

Table 9.—A comparison of the diggers' time estimates with the actual time recorded.

Date	Area	No. diggers checked	S or B	Diggers estimate (h)	Actual recorded (h)	Error (%)
4/03/74	Cod Cove-Wiscasset	19	B	48.22	48.30	-0.17
4/12/74	Hilton Cove-Wiscasset	15	B	46.33	45.08	+2.77
4/14/74	Yacht Club-Wiscasset	6	B	18.45	18.42	+0.16
5/13/74	Back R.-Boothbay	6	S	8.33	8.33	0
8/17/77	Rays Pt.-Harrington	6	S	6.58	7.65	-13.99
8/18/77	Hog Bay-Franklin	8	B	18.50	16.50	+12.12
8/23/77	Skilling R.-Hancock	12	B	30.25	29.25	+3.42
10/12/77	Jones Cove-W. Gouldsboro	6	S	9.12	9.03	+1.00
		78		185.78	182.56	+1.77

The literature contains many references to the commercially acceptable size of bloodworms and sandworms. However, few of these measurements are comparable because the worms were measured by various means. Sandrof (1946) reported the average length of bloodworms at 6–8 in (15.2–20.3 cm) natural length. Ganaros (footnote 4) stated that the minimum size for bloodworms was 18–20 cm. Dow (footnote 18) reported that Ganaros' measurements were recorded from worms placed next to a ruler. Taxiarchis[32] reported that the minimum size for bloodworms was 16 cm. He first anesthetized his worms in 7.5% $MgCl_2$ and then measured them next to a ruler. MacPhail (1954) and Pettibone (1963) reported that the minimum marketable size was 6 in (15.2 cm). Klawe and Dickie (1957) reported that bloodworm diggers in Nova Scotia ordinarily harvest worms that are more than 20 cm (7.9 in) measured in 7.5% $MgCl_2$.

Sandrof (1946) reported that the normal size range for sandworms was 10–18 in (25.4–45.7 cm) natural length. Ganaros (footnote 4) reported the minimum commercial size of sandworms at between 21 and 22 cm. Following discussions with various Boothbay, Maine, worm dealers, Taxiarchis[33] concluded that the minimum commercial size for sandworms was 8 in (20.3 cm) natural length. MacPhail (1954) reported that the minimum marketable size for sandworms was 6–7 in (15.2–17.8 cm) and Pettibone (1963) stated that a sandworm length of 20 cm was required to be of commercial importance.

Length and Weight Frequency Samples

Monthly sexed length frequency data recorded for the commercial bloodworm and sandworm catches sampled between 1973 and 1976 are shown in Figures 7 and 8, respectively.

In Figure 7, the complete lack of maturing spawners during April 1975 may be attributed to the small sample size ($N=44$) and the fact that the random samples were only collected in the eastern portion of the state where bloodworm spawners were lacking from commercial samples.

The commercial sandworm samples for 1974, 1975, and 1976 (Fig. 8) show that during August and September individual female sandworms contained eggs of either one of two size ranges. This happens because spawning occurs annually in sandworm populations but the period of egg development in the coelom is longer than 12 mo. Therefore, worms containing larger eggs will spawn the following March–May, whereas those containing small eggs will spawn a year after that. Two general egg sizes have been recorded in the Wiscasset sandworm population between October–November and April–May (Creaser and Clifford footnote 11). Data presented by Brafield and Chapman (1967) suggest that two egg sizes may be present between September and April in the Thames estuary (Southend, England) and Snow (1972) reported the same phenomenon between September and June for sandworms collected at Brandy Cove, St. Andrews, New Brunswick.

Bloodworm and sandworm sexed length frequency data for 6 mo (April–September) combined sampling data are presented in Figures 9 and 10, respectively.

Weight frequency data from combined monthly samplings of the commercial bloodworm and sandworm catches collected during the period April–September (1974–76) are presented in Figures 11 and 12, respectively.

Probability Sampling Expansions and Ratios Estimates

Probability sampling expansions of catch and effort and ratios of two variables estimates (catch/unit effort) are presented by month and 6-mo sampling periods for bloodworms and sandworms in Tables 12 and 13, respectively.

The importance of these probability sampling expansions is considerable. Although estimates of total catch in numbers are already recorded in Maine Landings, estimates of some of the other parameters are either nonexistent (total number of digger tides dug, total number of digger hours dug) or they are reported in U.S. Department of Commerce (1946–80) in gross error (total catch in pounds). It is evident from the results presented in Tables 12 and 13 that the standard errors about the mean monthly probability sampling expansions are greater than those reported for the 6-mo expansions. Standard errors reported for the 6 mo combined data are 19.7–26.2% of the mean for bloodworm expansions and 19.2–31.9% of the mean for sandworm expansions. Although greater accuracy (smaller standard errors) of the expansions could be obtained by randomly selecting more than six daylight low tides per month, this could not be accomplished because of time and manpower limitations.

Based upon the results of the four 6-mo ratio estimates for bloodworm and sandworm catch in numbers/digger hour, it cannot be conclusively stated that bloodworm and sandworm abundance changed significantly between 1973 and 1976. The only indication of a decline in abundance of bloodworms occurred during 1976 when the catch in numbers/digger hour was significantly different (at ±1.96 SE or 95% confidence levels) from the same recorded during 1974 and 1975. However, there was no significant difference between the 1973 and 1976 bloodworm data for catch in numbers/digger hour at 95% confidence levels.

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[32] Taxiarchis, L. N. 1954. Field notes on marine worms. Dep. Sea Shore Fish., Augusta, 36 p.

[33] Taxiarchis, L. N. 1953. Survey of the littoral zone of York County, Maine with respect to commercial productivity. Dep. Sea Shore Fish. Gen. Bull. 2, 13 p.

Table 10.—A summary of bloodworm mean length (cm) and weight (g) data, and the percentages of males, females, regenerated, broken, and punctured individuals by dealer code, including monthly and combined 6-mo means (±1 SE) for the period April–September 1973–76.

Year	Dealer Code	No. Samples	Mean Length	Weight	Percent Male	Female	Regenerate.	Broken	Punctured
April									
1973	L-25	16	18.18	2.25	8.21	8.31	5.81	7.77	4.45
	W-22	2	19.58	2.30	.00	.00	8.00	6.41	.00
	H-10	11	20.52	2.70	5.70	8.61	6.42	9.15	2.58
	L-6	8	24.06	4.00	6.18	17.31	4.38	8.23	6.47
	L-5	-	-	-	-	-	-	-	-
	W-20	-	-	-	-	-	-	-	-
	Monthly Mean	37	20.59	2.81	5.02	8.56	6.15	7.89	3.37
	Standard Error		±1.25	±.41	±1.76	±3.53	±.75	±.57	±1.38
1974	H-12	11	19.77	2.45	4.49	5.26	3.59	6.52	1.95
	L-8	16	17.91	2.06	5.35	4.74	7.70	9.44	3.14
	H-14	10	17.18	1.72	1.46	7.60	5.84	8.38	4.53
	H-11	3	16.43	1.50	3.49	1.16	1.10	13.12	2.33
	W-23	-	-	-	-	-	-	-	-
	W-24	-	-	-	-	-	-	-	-
	Monthly Mean	40	17.82	1.93	3.70	4.69	7.02	9.37	2.98
	Standard Error		±.72	±.21	±.84	±1.33	±1.56	±1.39	±.57
1975	W-19	2	19.15	2.25	.00	.00	5.01	5.01	2.99
	W-18	-	-	-	-	-	-	-	-
	W-24	-	-	-	-	-	-	-	-
	L-8	-	-	-	-	-	-	-	-
	L-1	-	-	-	-	-	-	-	-
	H-14	-	-	-	-	-	-	-	-
	Monthly Mean	2	19.15	2.25	.00	.00	5.01	5.01	2.99
	Standard Error		-	-	-	-	-	-	-
1976	W-23	3	18.21	2.62	1.57	.00	1.78	13.37	4.85
	H-12	18	19.00	2.33	4.26	8.82	7.87	16.60	5.31
	W-17	-	-	-	-	-	-	-	-
	L-2	-	-	-	-	-	-	-	-
	L-25	-	-	-	-	-	-	-	-
	H-11	-	-	-	-	-	-	-	-
	Monthly Mean	21	18.60	2.48	2.92	4.41	4.82	14.99	5.08
	Standard Error		±.40	±.15	±1.34	±4.41	±3.05	±1.61	±.23

Year	Dealer Code	No. Samples	Mean Length	Weight	Percent Male	Female	Regenerate.	Broken	Punctured
May									
1973	W-18	9	21.76	2.99	.00	.00	5.96	13.25	.55
	W-23	1	24.24	3.80	.00	.00	4.00	.00	4.00
	H-12	7	18.66	1.89	.00	.00	3.84	17.87	3.84
	L-8	14	18.58	2.26	.37	2.55	1.89	10.11	4.81
	L-1	-	-	-	-	-	-	-	-
	W-24	-	-	-	-	-	-	-	-
	Monthly Mean	31	20.81	2.73	.09	.64	3.92	10.31	3.30
	Standard Error		±1.36	±.42	±.09	±.64	±.83	±3.79	±.94
1974	L-8	14	18.58	2.01	.00	1.63	3.96	11.96	5.54
	H-27	-	-	-	-	-	-	-	-
	H-15	-	-	-	-	-	-	-	-
	W-20	-	-	-	-	-	-	-	-
	H-11	-	-	-	-	-	-	-	-
	W-24	-	-	-	-	-	-	-	-
	Monthly Mean	14	18.58	2.01	.00	1.63	3.96	11.96	5.54
	Standard Error		-	-	-	-	-	-	-
1975	L-6	5	20.97	2.72	.00	.83	7.00	10.98	9.13
	H-14	6	19.51	2.57	.00	.68	4.77	22.83	5.05
	W-19	3	19.42	2.75	.00	.00	7.38	26.97	8.00
	L-2	-	-	-	-	-	-	-	-
	W-18	-	-	-	-	-	-	-	-
	W-31	-	-	-	-	-	-	-	-
	Monthly Mean	14	19.97	2.68	.00	.50	6.38	20.26	7.40
	Standard Error		±.50	±.05	-	±.26	±.81	±4.79	±1.22
1976	W-19	9	21.98	2.94	.00	.00	9.52	9.20	3.33
	L-2	-	-	-	-	-	-	-	-
	H-11	-	-	-	-	-	-	-	-
	H-30	-	-	-	-	-	-	-	-
	L-5	-	-	-	-	-	-	-	-
	W-21	-	-	-	-	-	-	-	-
	Monthly Mean	9	21.98	2.94	.00	.00	9.52	9.20	3.33
	Standard Error		-	-	-	-	-	-	-

Year	Dealer Code	No. Samples	Mean Length	Weight	Percent Male	Female	Regenerate.	Broken	Punctured
June									
1973	W-22	2	20.36	2.55			4.00	12.00	5.22
	L-4	10	17.22	1.79	-	-	5.65	18.01	4.19
	H-14	14	17.20	1.72	-	-	5.95	9.01	2.46
	L-1	-		-			-		
	W-21	-			-	-			-
	W-24	-		-				-	-
	Monthly Mean	26	18.26	2.02	-	-	5.20	13.01	3.96
	Standard Error		±1.05	±.27			±.61	±2.64	±.81
1974	L-5	6	19.80	2.43	-	-	4.80	11.80	4.81
	H-14	13	18.40	2.34	-	-	5.93	12.95	2.14
	W-22	1	23.44	4.83	-	-	.00	16.00	4.00
	L-8	14	19.85	2.28	-	-	5.28	9.98	5.19
	W-19	11	17.92	2.24	-	-	8.98	11.69	4.99
	W 23	-	-	-	-	-	-	-	-
	Monthly Mean	45	19.86	2.82	-	-	5.00	12.48	4.23
	Standard Error		±.97	±.50	-	-	±1.45	±1.00	±.56
1975	L-8	2	16.31	1.82	-	-	4.45	7.10	4.00
	H 15	9	22.27	3.16	-	-	9.73	11.52	2.92
	L 4	9	19.74	2.32	-	-	2.57	12.63	7.21
	W 21	9	19.72	2.98		-	7.02	7.48	3.41
	W-24						-	-	-
	L 9				-	-	-	-	-
	Monthly Mean	29	19.51	2.57	-		5.94	9.68	4.38
	Standard Error		±1.22	±.31	-	-	±1.56	±1.40	±.97
1976	L-4	18	16.77	1.75	-	-	6.84	17.69	8.51
	W-18	12	20.38	3.15	-	-	8.38	11.24	6.23
	H-28	-	-	-	-	-	-	-	-
	W-23		-	-	-	-	-	-	-
	L-1	-	-	-	-	-	-	-	-
	H-30	-	-	-	-	-	-	-	-
	Monthly Mean	30	18.57	2.45	-	-	7.60	14.46	7.37
	Standard Error		±1.81	±.70	-	-	±.76	±3.22	±1.14

Year	Dealer Code	No. Samples	Mean Length	Weight	Percent Male	Female	Regenerate	Broken	Punctured
July									
1973	L-4	11	16.69	1.63			18.16	11.61	2.81
	W 17	2	22.46	3.31			.00	8.92	2.46
	W-18	13	16.12	1.60			2.05	6.41	1.17
	W 19	10	17.38	2.05			4.58	14.70	1.93
	W-24							-	
	H-28		-		-	-	-	-	-
	Monthly Mean	36	18.16	2.15			6.20	10.41	2.09
	Standard Error		±1.46	±.40			±4.10	±1.78	±.36
1974	H-12	10	20.97	2.60	-	-	5.32	14.92	2.46
	L-8	10	21.77	3.06	-		3.55	15.66	5.56
	L-9		-	-					-
	H-28		-					-	-
	W-24	-	-						
	H-11								
	Monthly Mean	20	21.37	2.93	-		4.44	15.29	4.01
	Standard Error		±.40	±.23	-	-	±.89	±.37	±1.55
1975	H-12	12	19.56	2.88	-	-	12.06	18.37	1.69
	W-17	1	26.28	6.90		-	.00	12.00	12.00
	W-19	3	19.81	3.03			4.05	13.27	10.41
	W 23	3	18.46	2.41			9.53	12.20	9.56
	W 20			-	-	-	-	-	-
	H 30		-	-		-	-	-	-
	Monthly Mean	19	21.03	3.81	-	-	6.41	13.96	8.42
	Standard Error		±1.77	±1.04	-	-	±2.71	±1.50	±2.30
1976	W-19	11	19.91	2.90	-	-	6.73	17.95	.90
	W-21	8	19.79	3.09		-	9.49	22.03	4.46
	H-11	6	20.10	2.88	-		9.62	8.72	2.35
	L-6	3	20.41	3.18			2.36	4.99	11.48
	L-2	1	28.79	5.34	-	-	4.00	12.00	8.00
	W-23	-	-	-	-	-	-	-	-
	Monthly Mean	2[illegible]	21.80	3.48	-	-	6.44	13.14	5.44
	Standard Error		±1.75	±.47	-	-	±1.45	±3.08	±1.93

Table 10.—*Continued.*

	August									September								
	Dealer Code	No. Samples	Mean. Length	Weight	Percent Male	Female	Regenerate.	Broken	Punctured	Dealer Code	No Samples	Mean. Length	Weight	Percent Male	Female	Regenerate	Broken	Punctured
1973	L-26	6	15.24	1.36	-	-	1.33	15.83	.00	H-12	3	14.66	1.14	-	-	7.99	17.60	1.10
	W-19	4	14.46	1.12	-	-	1.06	13.93	1.67	H-11	4	17.17	2.14	-	-	4.11	14.16	2.72
	H-10	14	16.01	1.41	-		5.40	18.37	.78	W-18	8	17.43	2.57	-	-	3.96	8.73	1.19
	W-24	1	25.35	4.13	-	-	.00	20.00	8.00	H-14	4	20.41	2.37	-	-	6.66	12.27	.99
	K-29	7	13.88	1.05		-	3.30	17.29	1.05	W-23	-	-	-	-	-	-	-	-
	L-1		-	-	-	-	-	-	-	W-16	-	-	-	-	-	-	-	
	Monthly Mean	32	16.99	1.81	-	-	2.22	17.08	2.30	Monthly Mean	19	17.42	2.06	-	-	5.68	13.19	1.50
	Standard Error		±2.12	±.58	-	-	±.96	±1.04	±1.45	Standard Error		±1.18	±.32	-	-	±.99	±1.85	±.41
1974	K-29	3	18.59	1.94	-	-	8.65	16.78	8.63	L-5	10	20.64	2.73	-	-	1.44	10.23	6.25
	W-21	12	19.23	2.61	-	-	5.40	11.80	3.28	W-17	6	23.33	4.45	-	-	5.55	18.89	4.32
	L-2	1	16.23	1.35	-	-	36.00	4.00	4.00	L-25	7	21.66	3.00	-	-	13.50	10.86	7.29
	L-6	5	24.48	4.30	-	-	7.33	7.34	3.73	H-11	5	23.34	3.19	-	-	13.13	11.32	3.29
	H-27	-	-	-	-	-	-	-	-	W-21	6	19.42	3.20	-	-	10.26	8.70	3.90
	L-1	-	-	-	-	-	-	-	-	W-20	-	-	-	-	-	-	-	-
	Monthly Mean	21	19.63	2.52	-	-	14.34	9.98	4.91	Monthly Mean	34	21.68	3.31	-	-	8.77	12.00	5.01
	Standard Error		±1.74	±.58	-	-	±7.25	±2.77	±1.25	Standard Error		±.76	±.30	-	-	±2.32	±1.78	±.76
1975	H-14	6	22.38	3.29	-	-	5.74	12.06	4.21	W-17	8	26.19	5.10	-	-	4.46	11.25	6.50
	L-4	10	22.10	3.00	-	-	5.89	13.22	17.11	H-11	11	20.01	2.47	-	-	8.03	17.03	4.70
	H-15	8	21.95	4.00	-	-	9.43	18.06	3.03	L-1	-	-	-	-	-	-	-	-
	L-1	-	-	-	-	-	-	-	-	L-2	-	-	-	-	-	-	-	-
	L-9	-	-	-	-	-	-	-	-	H-14	-	-	-	-	-	-	-	-
	H-28	-	-	-	-	-	-			W-21	-	-	-	-	-	-	-	-
	Monthly Mean	24	22.14	3.43	-	-	7.02	14.45	8.12	Monthly Mean	19	23.10	3.78	-	-	6.25	14.14	5.60
	Standard Error		±.13	±.30	-	-	±1.21	±1.84	±4.51	Standard Error		±3.09	±1.31	-	-	±1.78	±2.89	±.90
1976	H-14	8	22.10	3.72	-	-	4.38	7.98	3.64	W-21	6	20.83	2.88	-	-	8.74	9.78	1.84
	W-21	3	22.60	3.47	-	-	12.74	9.42	5.42	H-11	5	18.68	2.56	-	-	4.64	10.43	4.14
	L-5	7	24.23	4.12	-	-	6.18	11.86	4.52	L-4	11	19.19	2.11	-	-	5.08	13.98	3.51
	L-9	-	-	-	-	-	-	-	-	W-17	3	27.25	6.92	-	-	6.10	10.13	4.87
	H-28	-	-	-	-	-	-	-	-	H-14	6	20.37	3.17	-	-	6.59	16.49	2.46
	H-30	-	-	-	-	-	-	-	-	L-6	5	22.07	2.97	-	-	5.02	9.68	8.92
	Monthly Mean	18	22.98	3.77	-	-	7.76	9.75	4.53	Monthly Mean	36	21.40	3.44	-	-	6.03	11.75	4.29
	Standard Error		±.64	±.19	-	-	±2.54	±1.13	±.51	Standard Error		±1.27	±.71	-	-	±.62	±1.15	±1.03

Six Month Estimates

1973	Mean Length	Weight	Percent Male	Female	Regenerate	Broken	Punctured
Mean	18.72				4.87	11.98	2.78
Standard Error	±.60				±.82	±.94	±.40
1974	**Mean Length**	**Weight**	**Percent**	**Female**	**Regenerate.**	**Broken**	**Punctured**
Mean	19.84	2.57			7.19	11.92	4.45
Standard Error	±.36	±.15			±1.34	±.61	±.39
1975	**Mean: Length**	**Weight**	**Percent Male**	**Female**	**Regenerate.**	**Broken**	**Punctured**
Mean	20.74	3.07		-	6.17	12.95	6.19
Standard Error	±.59	±.27			±.65	±1.05	±.90
1976	**Mean. Length**	**Weight**	**Percent. Male**	**Female**	**Regenerate.**	**Broken**	**Punctured**
Mean	20.83	3.11			6.88	12.44	5.16
Standard Error	±.54	±.20			±.77	±.93	±.48

Table 11.—A summary of sandworm mean length (cm) and weight (g) data, and the percentages of males, females, regenerated, broken, and punctured individuals by dealer code, including monthly and combined 6-mo means (±1 SE) for the period April–September 1973–76.

April

Year	Dealer Code	No. Samples	Mean Length	Weight	Percent Male	Female	Regenerate	Broken	Punctured
1973	W-22	9	26.64	7.26	-	-	8.21	21.28	1.85
	L-6	2	36.08	17.12	-	-	4.53	23.47	3.47
	L-5	-	-	-	-	-	-	-	-
	L-25	-	-	-	-	-	-	-	-
	H-10	-	-	-	-	-	-	-	-
	W-20	-	-	-	-	-	-	-	-
	Monthly Mean	11	31.36	12.19	-	-	6.37	22.37	2.66
	Standard Error		±4.72	±4.93	-	-	±1.84	±1.10	±.81
1974	L-8	5	20.82	4.61	-	-	6.51	28.41	.83
	H-11	2	24.42	5.39	-	-	3.15	20.00	7.15
	W-24	9	29.28	7.71	-	-	8.63	20.90	9.44
	W-23	-	-	-	-	-	-	-	-
	H-12	-	-	-	-	-	-	-	-
	H-14	-	-	-	-	-	-	-	-
	Monthly Mean	16	24.84	5.90	-	-	6.10	23.10	5.80
	Standard Error		±2.45	±.93	-	-	±1.59	±2.67	±2.57
1975	W-19	6	33.22	9.37	-	-	4.28	30.90	8.95
	L-1	5	31.43	10.32	-	-	6.75	17.67	4.60
	W-18	-	-	-	-	-	-	-	-
	W-24	-	-	-	-	-	-		-
	L-8	-	-	-	-	-	-	-	-
	H-14	-	-	-	-	-	-		-
	Monthly Mean	11	32.32	9.85	-	-	5.52	24.28	6.77
	Standard Error		±.90	±.47	-	-	±1.24	±6.61	±2.18
1976	L-2	6	24.58	6.12	-	-	8.22	17.29	2.39
	W-17	-	-	-	-	-	-	-	-
	W-23	-	-	-	-	-	-	-	-
	H-12	-	-	-	-	-	-	-	-
	L-25	-	-	-	-	-	-	-	-
	H-11	-	-	-	-	-	-	-	-
	Monthly Mean	6	24.58	6.12	-	-	8.22	17.29	2.39
	Standard Error		-	-	-	-	-	-	-

May

Year	Dealer Code	No. Samples	Mean Length	Weight	Percent Male	Female	Regenerate	Broken	Punctured
1973	W-18	5	27.32	7.73	-	-	6.65	23.98	.59
	L-1	4	30.49	10.08	-	-	3.14	12.57	1.71
	W-23	7	28.93	8.97	-	-	2.35	20.43	6.14
	L-8	1	22.24	4.73	-	-	12.00	16.00	12.00
	W-24	8	27.93	8.19	-	-	7.42	24.08	4.80
	H-12	-	-	-	-	-	-	-	-
	Monthly Mean	25	27.39	7.94	-	-	6.31	19.41	5.05
	Standard Error		±1.39	±.89	-	-	±1.72	±2.26	±2.01
1974	L-8	6	27.29	6.35	-	-	9.05	18.37	1.26
	H-27	-	-	-	-	-	-	-	-
	H-15	-	-	-	-	-	-	-	-
	W-20	-	-	-	-	-	-	-	-
	H-11	-	-	-	-	-	-	-	-
	W-24	-	-	-	-	-	-	-	-
	Monthly Mean	6	27.29	6.35	-	-	9.05	18.37	1.26
	Standard Error		-	-	-	-	-	-	-
1975	L-2	4	25.60	5.79	-	-	7.96	20.48	.59
	L-6	10	24.56	5.70	-	-	1.47	29.59	.61
	W-25	2	24.18	6.03	-	-	5.70	47.53	.00
	W-19	6	25.61	5.81	-	-	3.09	29.19	1.93
	W-18	-	-	-	-	-	-	-	-
	H-14	-	-	-	-	-	-	-	-
	Monthly Mean	22	24.99	5.83	-	-	4.55	31.70	.78
	Standard Error		±.36	±.07	-	-	±1.43	±5.68	±.41
1976	L-2	5	25.18	7.50	-	-	2.26	25.13	3.63
	W-19	12	28.63	6.61	-	-	1.80	25.52	6.10
	H-30	4	29.62	7.71	-	-	2.37	16.32	5.16
	L-5	7	26.39	5.79	-	-	3.28	20.60	3.79
	H-11	-	-	-	-	-	-	-	-
	W-21	-	-	-	-	-	-	-	-
	Monthly Mean	28	27.45	6.90	-	-	2.43	21.89	4.67
	Standard Error		±1.01	±.44	-	-	±.31	±2.17	±.59

June

Year	Dealer Code	No. Samples	Mean Length	Weight	Percent Male	Female	Regenerate	Broken	Punctured
1973	W-22	7	25.29	6.53	-	-	4.00	26.22	.00
	L-1	5	29.68	9.55	-	-	5.21	18.17	.00
	W-24	6	26.44	7.18			8.84	13.60	1.62
	L-4	5	28.59	8.53	-		1.20	27.86	2.69
	W-21	-	-	-	-	-			-
	H-14								
	Monthly Mean	23	27.50	7.95	-		4.81	21.46	1.08
	Standard Error		±1.00	±.68	-		±1.58	±3.37	±.66
1974	W-22	6	27.88	7.14	-		6.09	30.73	2.69
	L-8	7	26.08	6.04			8.70	22.64	1.83
	W-19	16	26.01	6.03		-	5.49	17.89	2.61
	W-23	-	-	-		-	-		-
	L-5	-	-	-		-	-	-	-
	H-14								
	Monthly Mean	24	26.66	6.40	-	-	6.76	23.75	2.38
	Standard Error		±.61	±.37			±.98	±3.75	±.27
1975	L-8	5	24.57	5.21	-		8.26	9.86	4.81
	W-21	7	26.51	5.52		-	12.52	18.72	6.21
	W-24	-	-	-	-	-	-	-	-
	H-15	-	-	-	-	-	-	-	-
	L-9	-	-	-	-	-	-		-
	L-4	-		-	-		-	-	-
	Monthly Mean	12	25.54	5.36	-	-	10.39	14.29	5.51
	Standard Error		±.97	±.15	-	-	±2.13	±4.43	±.69
1976	W-23	7	25.68	6.81	-	-	1.93	40.52	[illegible]
	W-18	2	26.44	5.12	-	-	24.70	14.17	[illegible]
	H-28	-	-	-	-	-	-	-	
	L-4								
	L-1								
	H-30	-	-	-	-				
	Monthly Mean	9	26.06	5.97	-	-	13.31	27.35	5.84
	Standard Error		±.38	±.85	-	-	±11.35	±13.17	±1.49

July

Year	Dealer Code	No. Samples	Mean Length	Weight	Percent Male	Female	Regenerate	Broken	Punctured
1973	W-17	3	20.77	4.34	-	-	7.79	28.67	5.05
	W-24	1	23.90	5.51	-	-	8.00	8.00	.00
	H-28	3	25.60	6.72	-	-	11.04	28.03	.00
	W-18	2	22.91	5.23	-	-	12.17	32.00	.00
	W-19	4	23.73	5.56	-	-	7.26	29.56	1.18
	L-4	-	-	-	-	-	-	-	-
	Monthly Mean	13	23.38	5.47	-	-	9.25	25.25	1.25
	Standard Error		±.79	±.38	-	-	±.98	±4.37	±.98
1974	L-8	8	21.87	3.95	-	-	5.07	14.87	.51
	W-24	9	26.62	6.20	-		8.35	18.98	2.10
	L-9	-	-	-	-	-	-	-	-
	H-28	-	-	-	-	-	-	-	-
	H-12	-	-	-	-	-	-	-	-
	H-11	-	-	-	-	-	-	-	-
	Monthly Mean	17	24.25	5.07	-	-	6.71	16.9[illegible]	1.30
	Standard Error		±2.38	±1.13	-	-	±1.64	±2.06	±.80
1975	W-17	3	22.94	4.63	-	-	20.42	21.41	2.26
	W-20	5	25.80	5.35	-	-	9.72	17.48	.00
	W-23	12	24.17	4.66	-	-	4.35	17.83	2.82
	H-12	-	-	-	-	-	-	-	-
	W-19	-	-	-	-	-	-	-	
	H-30	-	-	-	-	-	-	-	
	Monthly Mean	20	24.31	4.88			11.50	18.91	1.69
	Standard Error		±.83	±.24			±4.72	±1.26	±.86
1976	W-19	7	26.12	6.21			8.87	22.13	3.52
	W-21	9	[illegible]	5.44	-		20.75	17.81	1.44
	L-6	9	24.57	5.26			3.62	14.95	4.19
	L-2	7	26.63	5.79			3.80	17.08	2.23
	H-11								
	W-23								
	Monthly Mean	32	25.60	5.67	-	-	9.26	17.99	2.84
	Standard Error		±.48	±.21	-	-	±4.02	±1.60	±.6[illegible]

Table 11.—*Continued.*

August

Year	Dealer Code	No. Samples	Mean Length	Weight	Percent Male	Female	Regenerate	Broken	Punctured
1973	L-1	3	31.93	11.41	1.07	10.93	5.07	20.44	5.07
	W-19	13	22.69	5.12	1.05	18.59	11.71	23.68	5.83
	W-24	7	22.84	5.17	4.50	10.74	15.95	21.42	.81
	L-26	-	-	-	-	-	-	-	-
	H-10	-	-	-	-	-	-	-	-
	K-29	-	-	-	-	-	-	-	-
	Monthly Mean	23	25.82	7.23	2.21	13.42	10.91	21.85	3.90
	Standard Error		±3.05	±2.09	±1.15	±2.59	±3.16	±.96	±1.56
1974	W-21	5	25.55	5.22	1.62	7.14(2.37)	11.72	17.47	2.13
	L-2	10	26.17	5.13	8.43	22.16(7.47)	4.22	16.84	1.06
	L-6	3	29.68	6.19	13.66	28.64(.00)	10.98	11.51	2.46
	L-1	10	31.26	9.17	6.68	25.88(.00)	6.18	12.42	1.57
	H-27	-	-	-	-	-	-	-	-
	K-29	-	-	-	-	-	-	-	-
	Monthly Mean	28	28.16	6.43	7.6[illegible]	20.96 2.46)	8.27	14.56	1.81
	Standard Error		±1.38	±.95	±2.48	±4.79(1.76)	±1.83	±1.52	±.31
1975	L-1	9	25.43	5.53	11.02	19.08(3.82)	2.24	20.84	1.73
	L-9	5	27.58	6.21	25.43	20.54(5.26)	8.75	11.59	2.95
	H-28	4	24.73	4.77	14.61	24.20(5.87)	9.80	18.52	.35
	H-14	-		-	-	-	-	-	-
	L-4	-	-	-	-	-	-	-	-
	H-15	-	-	-	-	-	-	-	-
	Monthly Mean	18	25.91	5.50	17.02	21.27(4.98)	6.93	16.98	1.68
	Standard Error		±.86	±.42	±4.33	±1.52(±.61)	±2.37	±2.78	±.75
1976	L-5	8	25.23	5.53	7.89	18.44(3.68)	6.69	12.20	1.78
	H-30	6	28.88	7.58	13.48	21.24(4.06)	4.23	11.79	1.23
	H-14	-	-	-	-	-	-	-	-
	L-9	-	-	-	-	-	-	-	-
	W-21	-	-	-	-	-	-	-	-
	H-28	-	-	-	-	-	-	-	-
	Monthly Mean	14	27.06	6.56	10.68	19.84(3.87)	5.46	11.99	1.51
	Standard Error		±1.83	±1.03	±2.80	±1.40(±.19)	±1.23	±.20	±.27

September

Year	Dealer Code	No. Samples	Mean Length	Weight	Percent Male	Female	Regenerate	Broken	Punctured
1973	W-23	7	19.08	3.43	9.21	12.25	3.44	34.95	.79
	W-18	2	22.93	5.26	14.97	17.49	13.94	26.06	1.49
	H-12	-	-	-	-	-	-	-	-
	W-16	-	-	-		-	-	-	-
	H-11	-	-	-					
	H-14	-	-		-		-		
	Monthly Mean	9	21.00	4.34	12.09	14.87	8.69	30.50	1.14
	Standard Error		±1.93	±.92	±2.88	±2.62	±5.25	±4.45	±.25
1974	L-5	4	29.14	5.94	13.99	13.00(3.01)	11.99	24.01	.00
	W-17	4	23.21	3.95	7.51	4.64(1.03)	7.60	7.03	1.41
	W-21	5	25.79	4.84	6.47	3.08(3.78)	11.68	17.70	.00
	W-20	-	-	-	-	-	-	-	-
	L-25	-	-	-	-	-	-	-	
	H-11	-	-	-	-	-	-	-	-
	Monthly Mean	13	26.05	4.91	9.33	6.90(2.61)	10.42	16.25	.47
	Standard Error		±1.72	±.58	±2.35	±3.08(±.82)	±1.41	±4.95	-
1975	L-1	9	31.27	8.77	19.30	16.95(8.75)	7.49	14.53	2.49
	W-17	2	25.26	4.97	5.69	16.63(13.06)	4.00	16.63	2.31
	L-2	-	-	-	-	-	-	-	-
	H-14	-	-	-	-	-	-	-	-
	W-21	-	-	-	-	-	-	-	-
	H-11	-	-	-	-	-	-	-	-
	Monthly Mean	11	28.26	6.87	12.49	16.79(10.90)	5.75	15.58	2.40
	Standard Error		±3.01	±1.90	±6.80	±.16(±2.16)	±1.75	±1.05	±.09
1976	W-21	6	26.16	6.42	10.36	18.76(5.28)	8.72	14.90	.66
	L-4	7	21.81	3.26	16.18	20.18(3.92)	7.83	16.25	3.69
	L-6	7	23.26	4.14	17.49	15.48(2.56)	6.02	20.10	.97
	H-11	-	-	-	-	-	-	-	-
	W-17	-	-	-	-	-	-	-	
	H-14	-	-	-	-	-	-	-	
	Monthly Mean	20	23.74	4.61	14.68	18.14(3.92)	7.52	17.08	1.78
	Standard Error		±1.28	±.94	±2.19	±1.39(±.78)	±.79	±1.56	±.96

Six Month Estimates

Year		Mean Length	Weight	Percent Male	Female	Regenerate	Broken	Punctured
1973	Mean	26.11				7.71	23.26	2.54
	Standard Error	±.98				±1.05	±1.27	±.51
1974	Mean	26.22	5.86			7.85	18.81	2.14
	Standard Error	±.68	±.31			±.56	±1.16	±.43
1975	Mean	26.77	6.32			7.54	20.40	3.25
	Standard Error	±.53	±.29			±1.07	±1.75	±.45
1976	Mean	25.69	5.93			8.07	18.82	3.12
	Standard Error	±.42	±.29			±2.23	±2.44	±.35

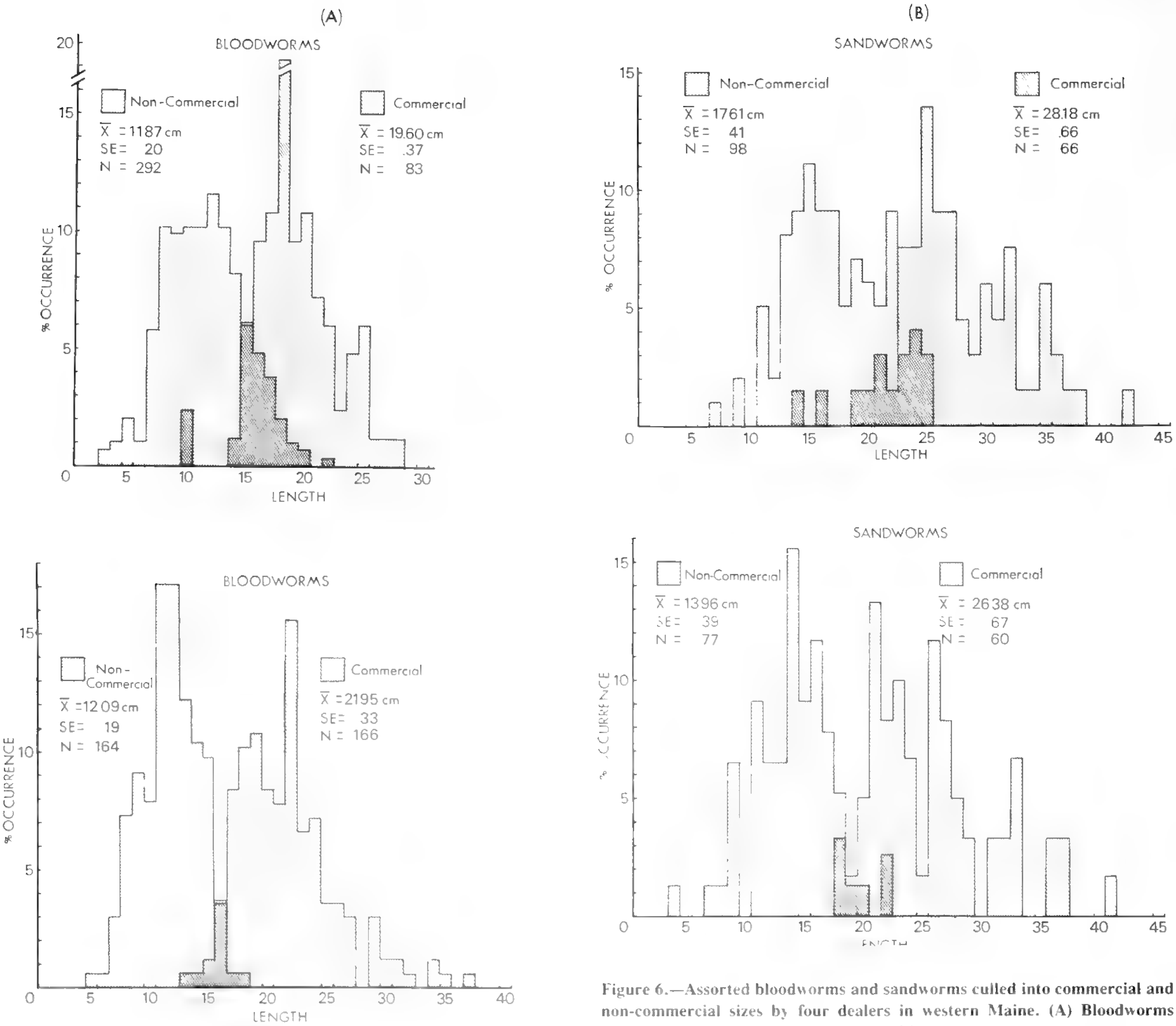

Figure 6.—Assorted bloodworms and sandworms culled into commercial and non-commercial sizes by four dealers in western Maine. (A) Bloodworms (March 1966), (B) sandworms (August 1966)

Monthly and combined 6-mo values for catch in numbers/digger tide and catch in numbers/digger hour recorded in Tables 12 and 13 are mean values derived from samples collected during all low tide amplitudes. It is generally known by marine worm diggers and dealers that the number of worms dug/tide fluctuates with variations in low tide amplitudes. During the early 1950's, marine biologists in Maine observed that a +1.0 ft low tide reduced the take of marine worms an average of 30% compared with a 0.0 low tide (Dow 1969).

The catch in numbers/digger hour for 6 mo combined bloodworm data (Table 12) varied between 193±6 and 233±6. Ganaros (footnote 4) reported that the catch/hour of commercial-sized bloodworms varied between 150 and 200. It is quite possible, however, that these lower catch/effort figures reported by Ganaros (footnote 4) resulted from the fact that larger bloodworms were demanded by the commercial market during 1951. Estimates of commercial bloodworm catch/hour have also been reported from the Marsh River (118–293 bloodworms/h) and Montsweag Bay (10–450 bloodworms/h) in the vicinity of Wiscasset, Maine, by Dean and Ewart.[14] The catch in numbers/digger tide for 6 mo combined bloodworm data (Table 12) varied between 536±36 and 662±26. Sandrof (1946) reported that bloodworm diggers dug approximately 350 commercial-sized bloodworms/tide. This reduction in catch/effort is also probably the result of larger worms being commercially harvested at that time. Sandrof (1946) reported that the average natural length of commercial-sized bloodworms was 6–8 in (15.2–20.3 cm), which is equivalent to approximately 22–29 cm relaxed length (Fig. 5A). It is also possible that this reduction in catch/effort may have resulted from frequent "limits" imposed upon bloodworm diggers.

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[14] Dean, D., and J. Ewart. 1978. Final report, environmental surveillance and studies at the Maine Yankee nuclear generating station 1969–1977. Section 10 Benthos (commercially important invertebrates). Maine Yankee Atomic Power Company, 830 p.

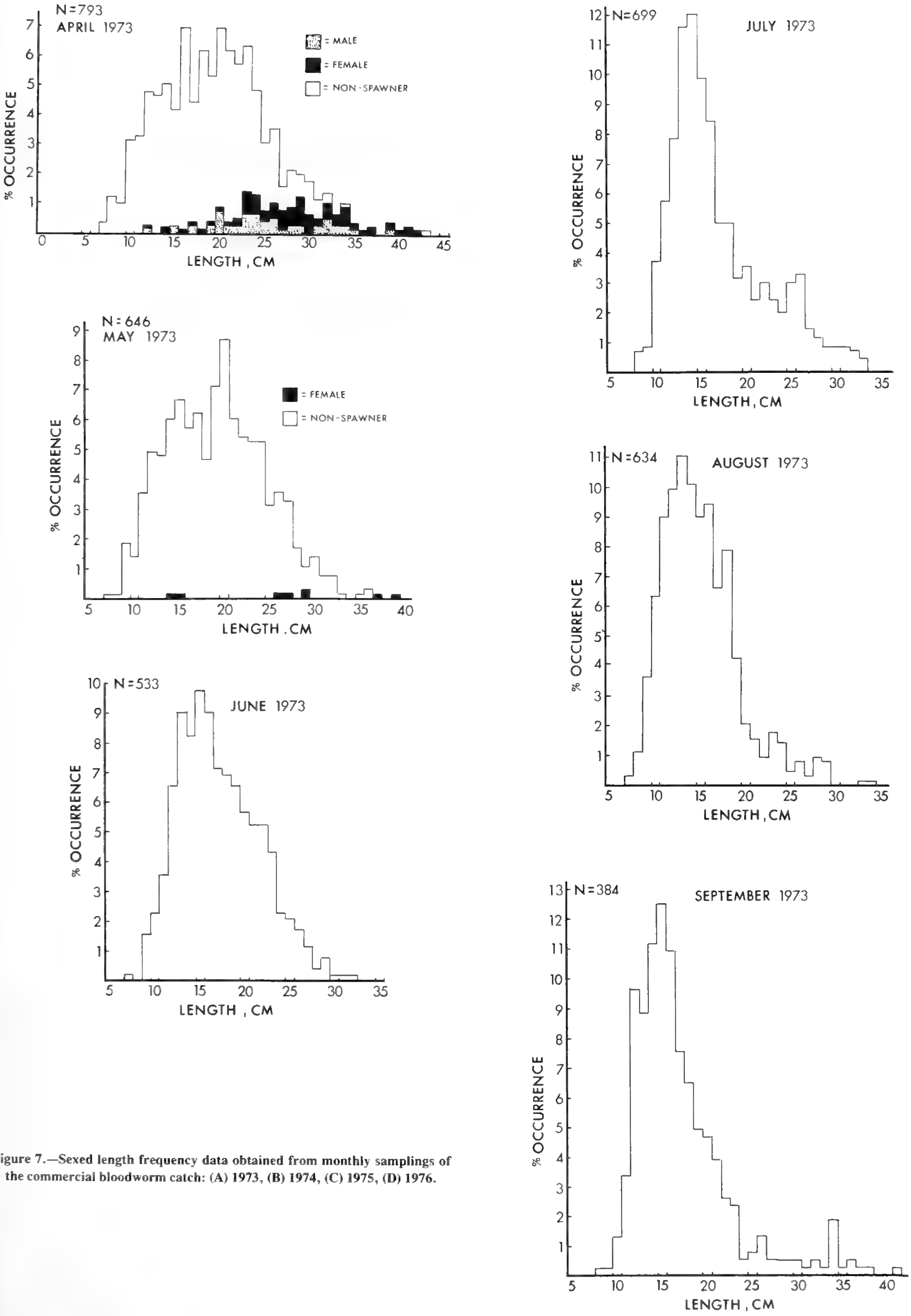


Figure 7.—Sexed length frequency data obtained from monthly samplings of the commercial bloodworm catch: (A) 1973, (B) 1974, (C) 1975, (D) 1976.

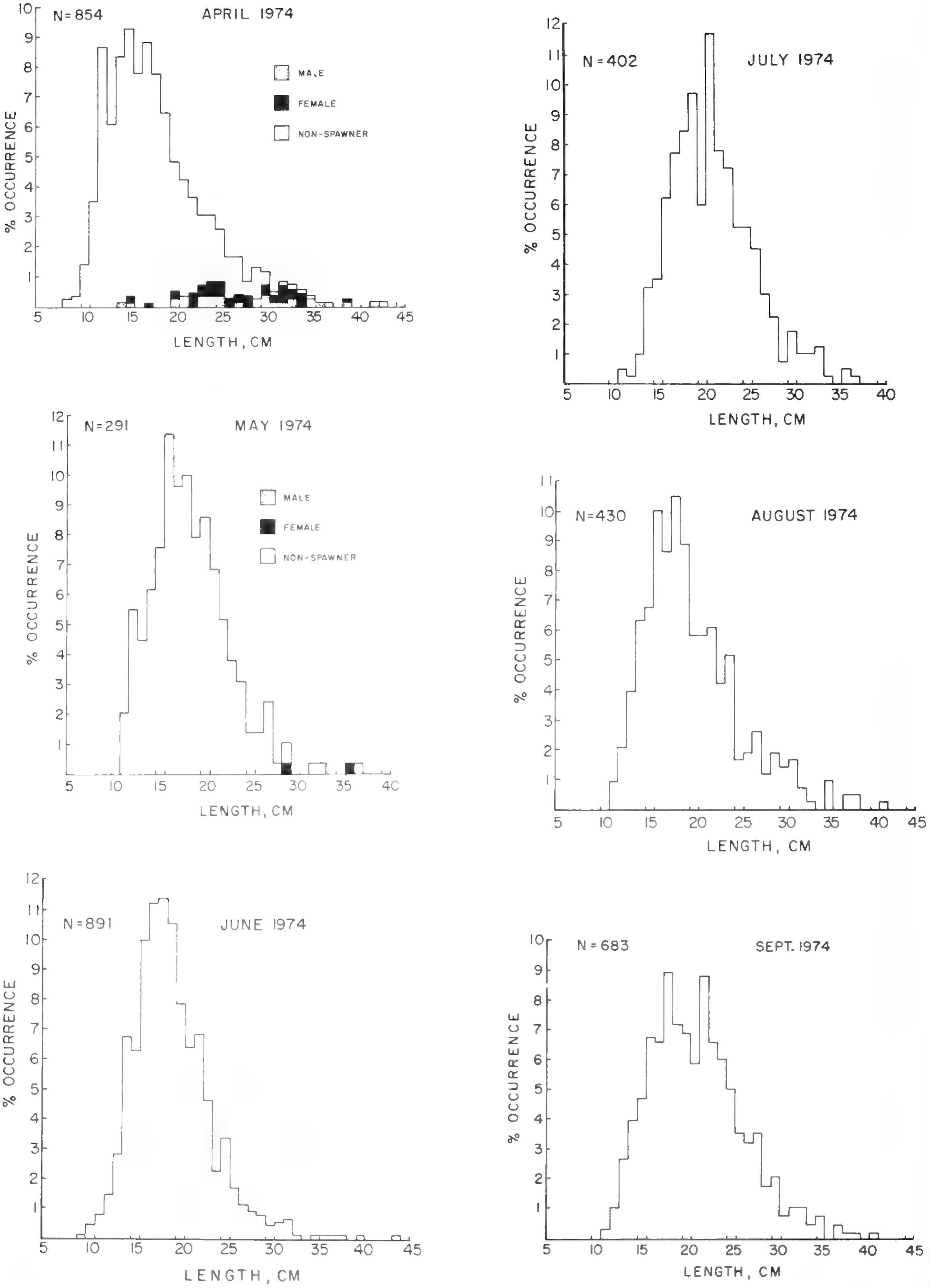
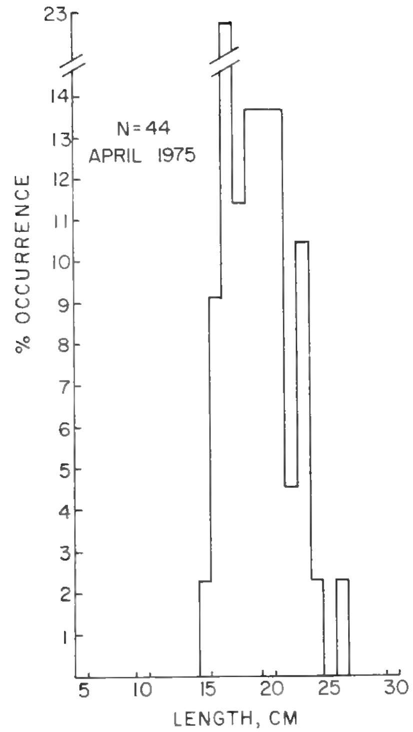
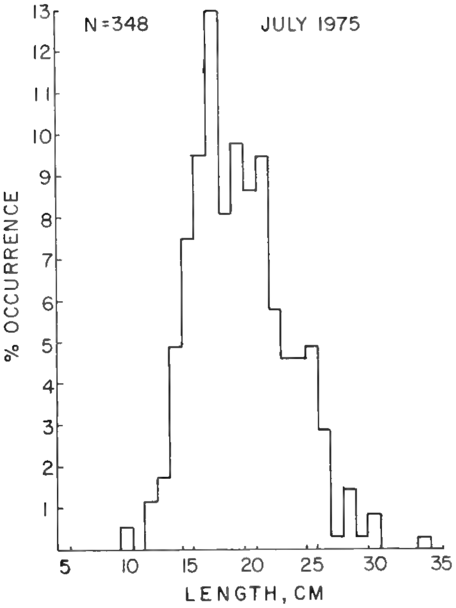
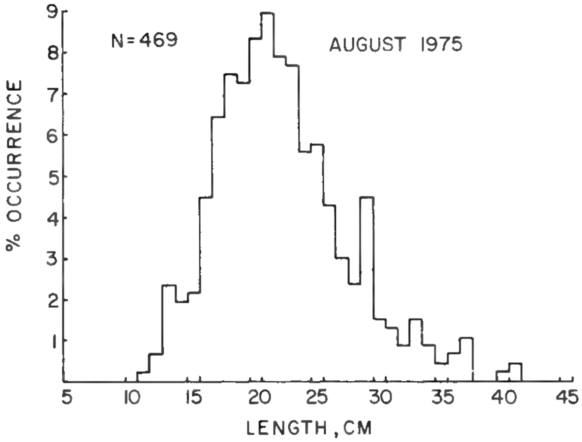
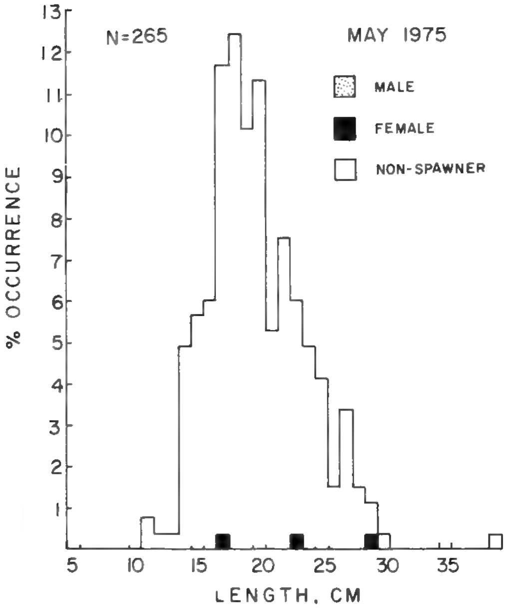


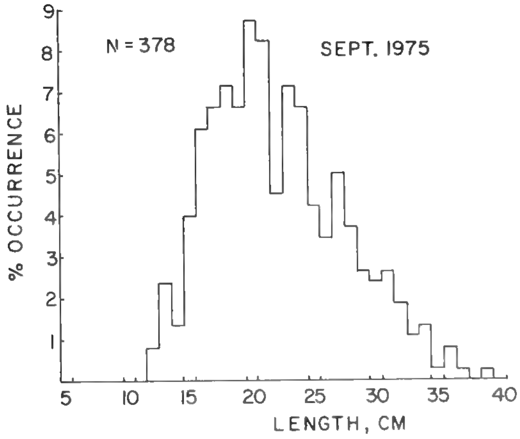
Figure 7.—*Continued.*











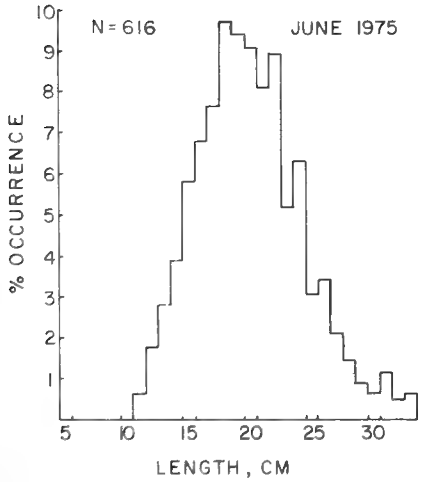


Figure 7.—*Continued.*

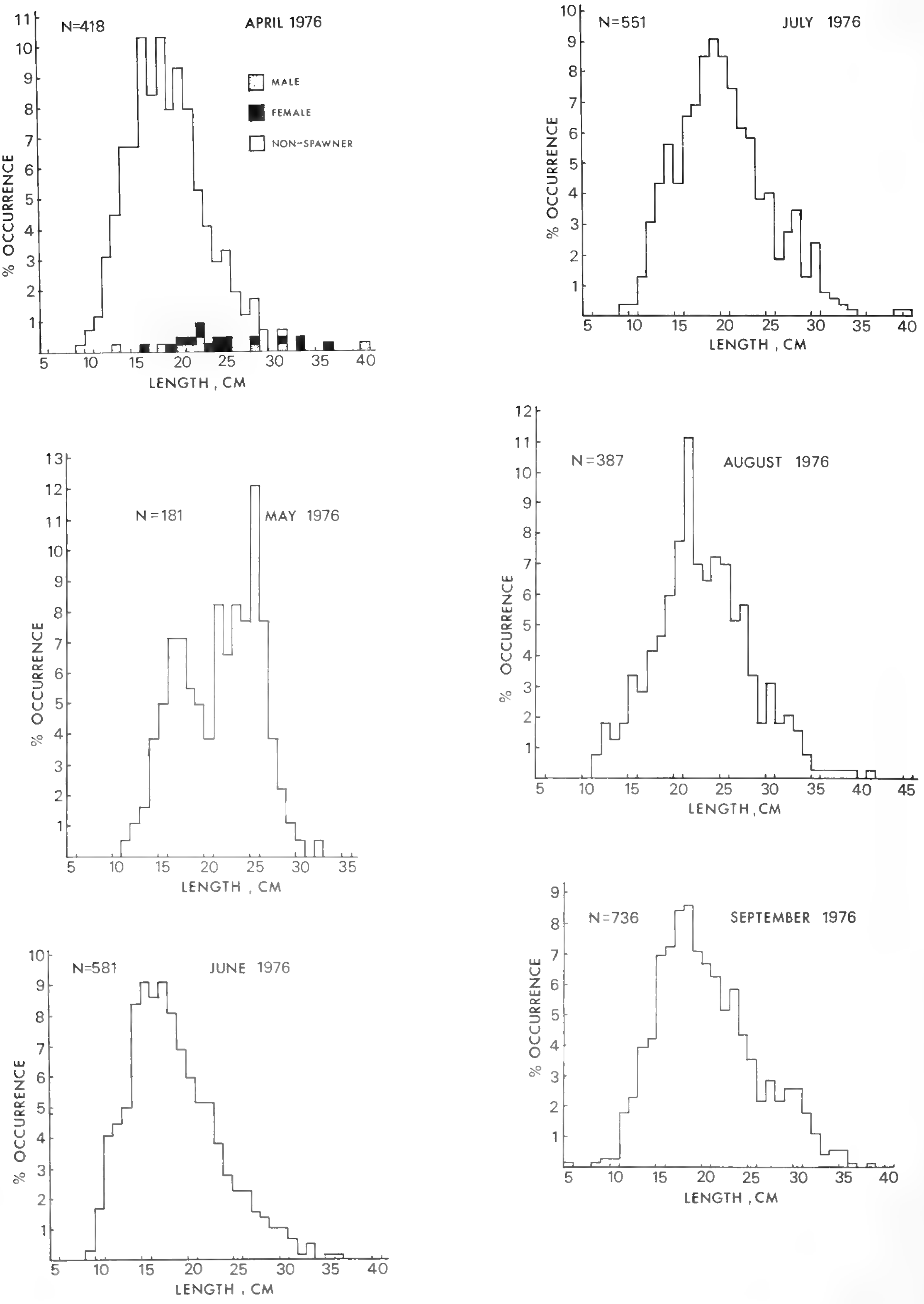


Figure 7.—*Continued.*

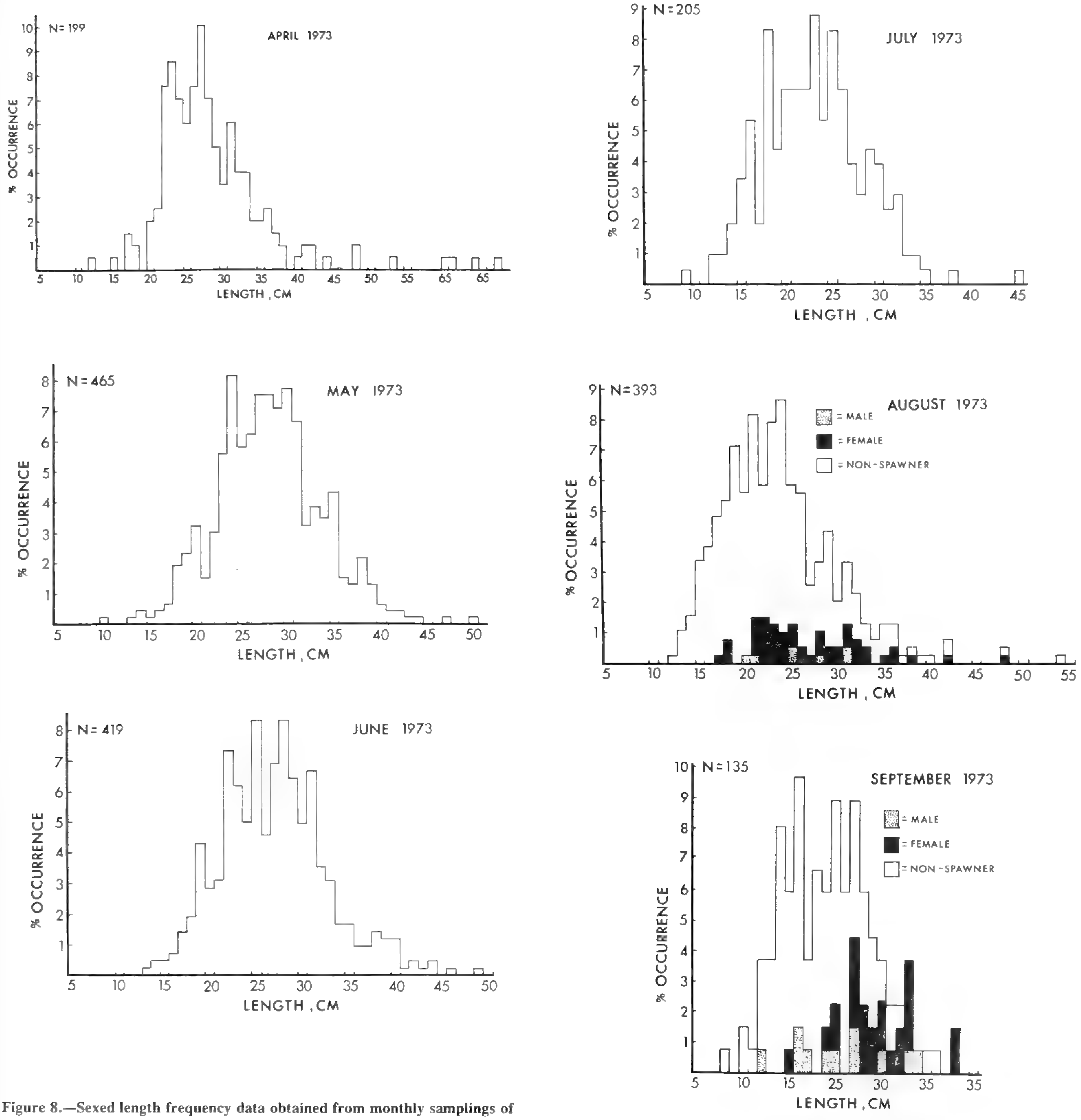


Figure 8.—Sexed length frequency data obtained from monthly samplings of the commercial sandworm catch: (A) 1973, (B) 1974, (C) 1975, (D) 1976.

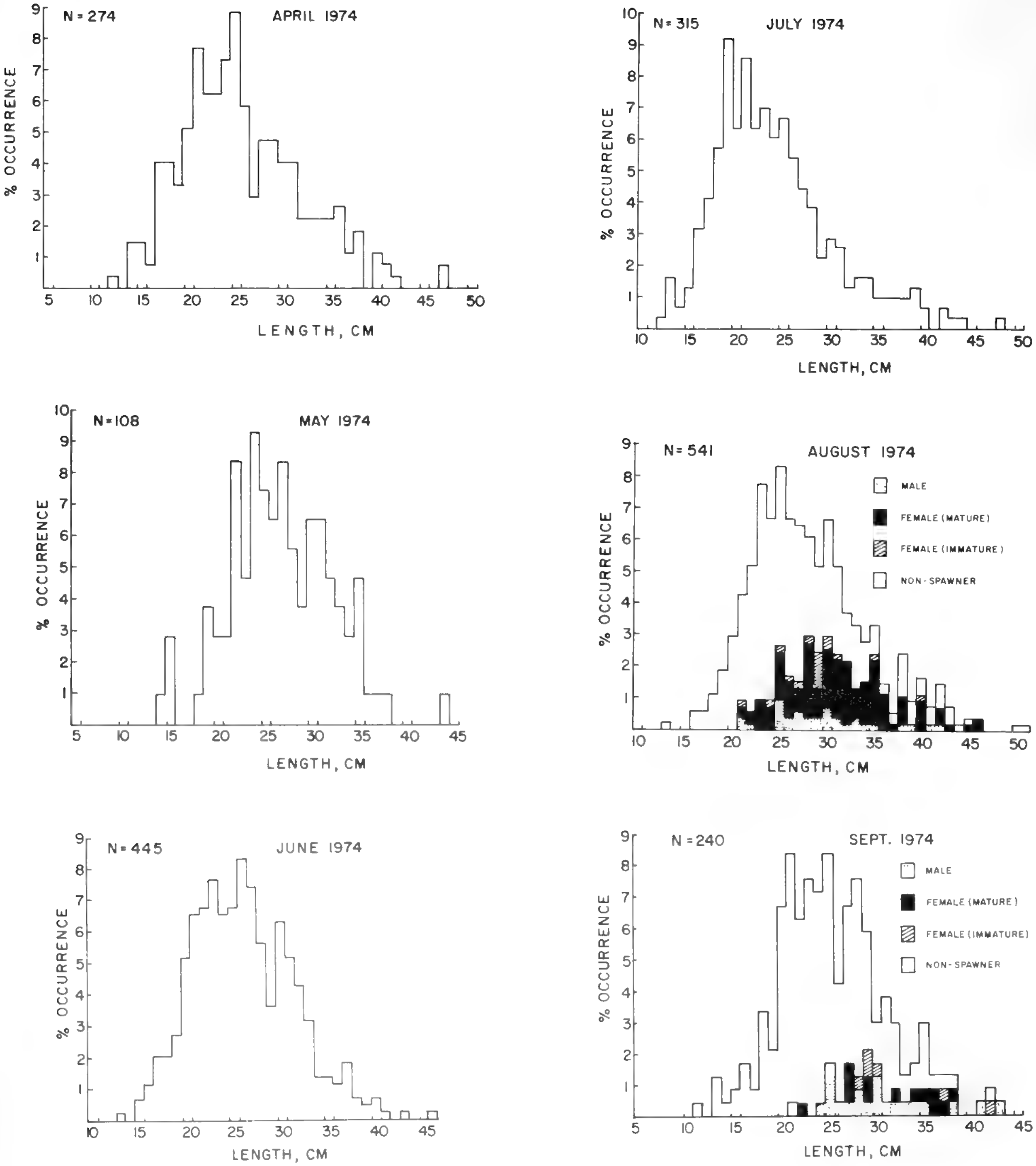


Figure 8.—*Continued.*

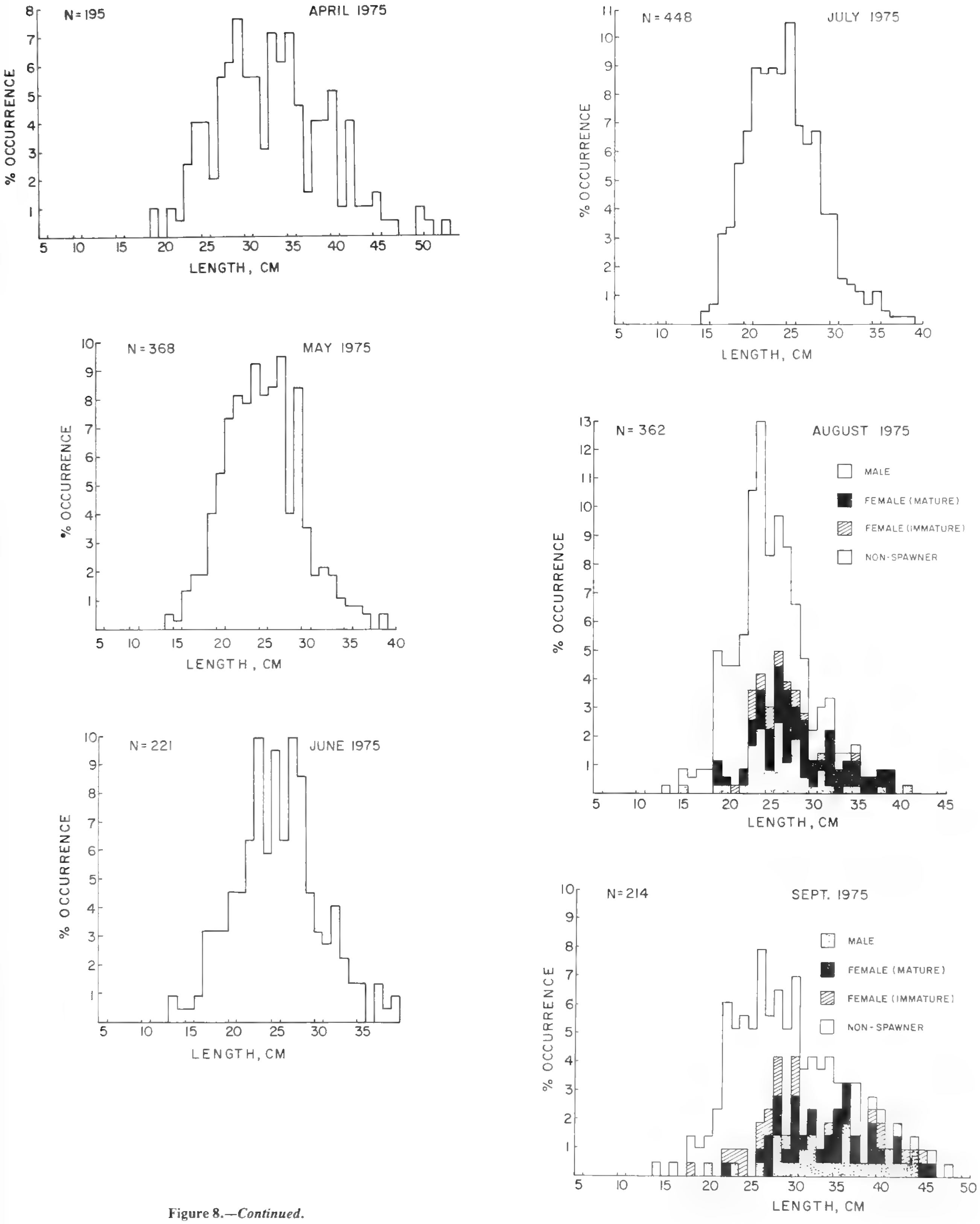


Figure 8.—*Continued.*

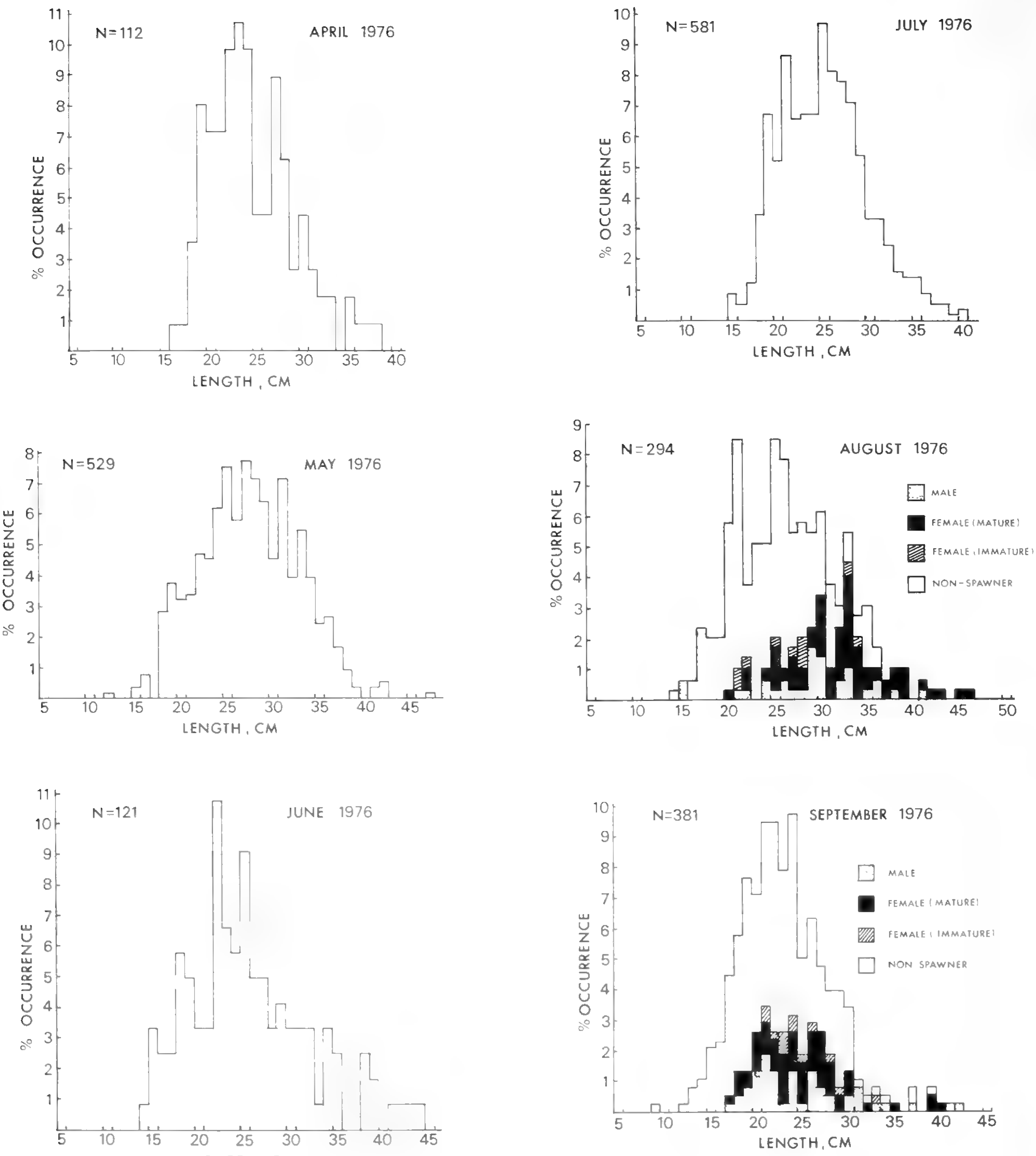


Figure 8.—*Continued.*

The catch in numbers/digger tide for 6 mo combined sandworm data (Table 13) varied between 1,028±60 and 1,184±38. Taxiarchis (footnote 33) judged the quality of sandworm digging on the basis of the catch/tide: 500–700 sandworms/tide (fair), 700–1,000 sandworms/tide (good), and 1,000 and over/tide (excellent).

Catch Statistics

Eighteen of the most important parameters included on the summary sheet for catch statistics data collected during each dealer daylight low tide period sampled (Table 6) were summarized by month and for the 6-mo sampling period. These data are presented in Tables 14 and 15 for bloodworms and sandworms, respectively. The values presented in these tables were derived directly from the sampling and interview data. Catch/effort values (catch in numbers/digger tide, catch in numbers/digger hour, catch in pounds/digger tide, catch in pounds/digger hour) derived in this manner, are similar to values derived through ratios estimates (Tables 12, 13). A comparison of catch/effort results obtained by both methods are presented in Table 16. It is evident from Table 14 that the 6-mo mean (total) value/tide and value/hour information collected for bloodworms during the commercial sampling program (1973–76) varied between \$27.97–\$31.59 and \$10.11–\$11.00, respectively. Similar information collected for sandworms (Table 15) varied between \$27.97–\$40.30 and \$14.34–\$19.15, respectively.

Information relevant to the price per worm paid to bloodworm and sandworm diggers is presented in Figure 13A and B. Figure 13A was derived from U.S. Department of Commerce (1946–80) information and Figure 13B was obtained directly from a Wiscasset dealer. It is apparent from Figure 13 (A and B) that the price/worm for both bloodworms and sandworms remained relatively constant between at least 1945 and 1965. After 1965, the price/worm increased rapidly for both species. The price of sandworms, however, has not increased as rapidly as the price of bloodworms. Figure 13B indicates that the Wiscasset dealer sometimes paid two to four different prices for bloodworms and two different prices for sandworms. These price differentials during a given year were the result of both quality differences and overall price increases. The price per worm recorded by month from the commercial sampling results for bloodworms and sandworms is shown in Table 17. Beginning in June 1976, a notable price increase for bloodworms occurred.

Length-Wet Weight Relationships

Length-wet weight relationships for whole bloodworms and sandworms obtained during samplings of the commercial catch are presented in Figures 14 and 15, respectively.

As mentioned previously, few sexually discernible bloodworms were obtained in our coastwide samplings of the commercial bloodworm catch between 1974 and 1976. The length-weight relationships for those few male and female sandworms obtained coastwide between 1974 and 1976 are presented in Figure 15A. A comparison of the slopes of the length-weight curves for males and females of each species (Table 18) shows that, at 95% confidence limits (±1.96 SE) overlap occurs in the upper and lower ranges of the *b* values. No significant differences therefore exist in the length-weight relationships for male and female bloodworms and sandworms.

Length-weight relationships for bloodworms and sandworms from 1) all areas and all sexes combined, and 2) eastern Maine (Jonesport, Beals, Addison, Milbridge, and Harrington) and the Sheepscot River (excluding Montsweag Bay), are displayed in Figure 14 (B and C) and Figure 15 (B and C), respectively. A comparison of the slopes of the length-weight curves for bloodworms and sandworms from eastern Maine and the Sheepscot River (Table 18) shows that, at 95% confidence limits (±1.96 SE), no overlap occurs in the upper and lower range of *b* values for these data. Significant differences therefore exist in the length-weight relationships for both bloodworms and sandworms in eastern Maine and the Sheepscot River.

One possible explanation for the existence of these significant differences in length-weight relationships for bloodworms from eastern Maine and the Sheepscot River may be related to the fact that mature bloodworms are rare in eastern Maine. Bloodworms in this area may substitute an increase in weight for the production of gametes. No explanation can presently be given for the significant differences in length-weight relationships for sandworms in both areas.

The authors were unable to locate any other bloodworm length-weight relationships in the literature to compare with data presented here. A scatter diagram for sandworm length-weight relationships is presented in Snow and Marsden (1974), but a comparison is difficult because their results are not fully analyzed.

Numbers of Bloodworms and Sandworms Per Pound

Given the mean length data (± SE) and length-wet weight relationships obtained from the commercial sampling program, we were able to calculate the numbers of bloodworms and sandworms per pound (±1.96 SE) for each 6-mo sampling period as well as the maximum and minimum values for individual months within that sampling period. These data are presented in Table 19. Although the mean number of bloodworms per pound decreased during the 4-yr sampling period, the decrease was not significant at 95% confidence levels (±1.96 SE). No significant changes were recorded in the numbers of sandworms per pound during the 4-yr sampling period either.

Past estimates of the numbers of bloodworms and sandworms per pound are presented in Table 20. Although some of these data (106 bloodworms/lb and 63 sandworms/lb) are biased in that they were obtained from a specific geographical area, the Sheepscot River (Walton[35]), they suggest that a progressive decrease occurred in size of both bloodworms and sandworms harvested prior to 1970. The 1950–52 figure of 44 bloodworms/lb (Cates and McKown[36]) may be questioned to some degree because a recent interview with one bloodworm dealer revealed that he supplied these port samplers with the largest bloodworms in his possession when asked for a representative bloodworm sample used in deriving this figure.

Estimates of Marine Worm Age

One of the most difficult problems encountered in our studies of the commercial baitworm fishery was the analysis of commercial

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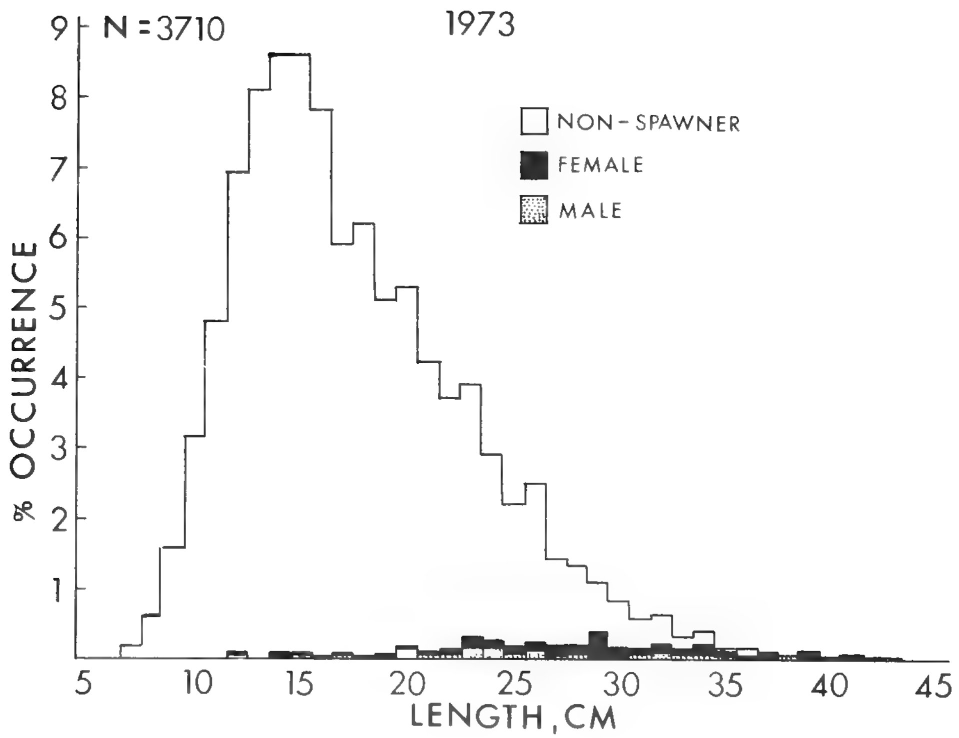
[35] C. J. Walton, Marine resources scientist, Maine Dep. Sea Shore Fish., West Boothbay Harbor, ME 04575, pers. commun. 1966, 1968

[36] L. B. Cates, Port sampler, Maine Dep. Sea Shore Fish., Augusta, ME 04330, pers. commun. and D. A. McKown, Port sampler, National Marine Fisheries Service, NOAA, Rockland, ME 04841, pers. commun



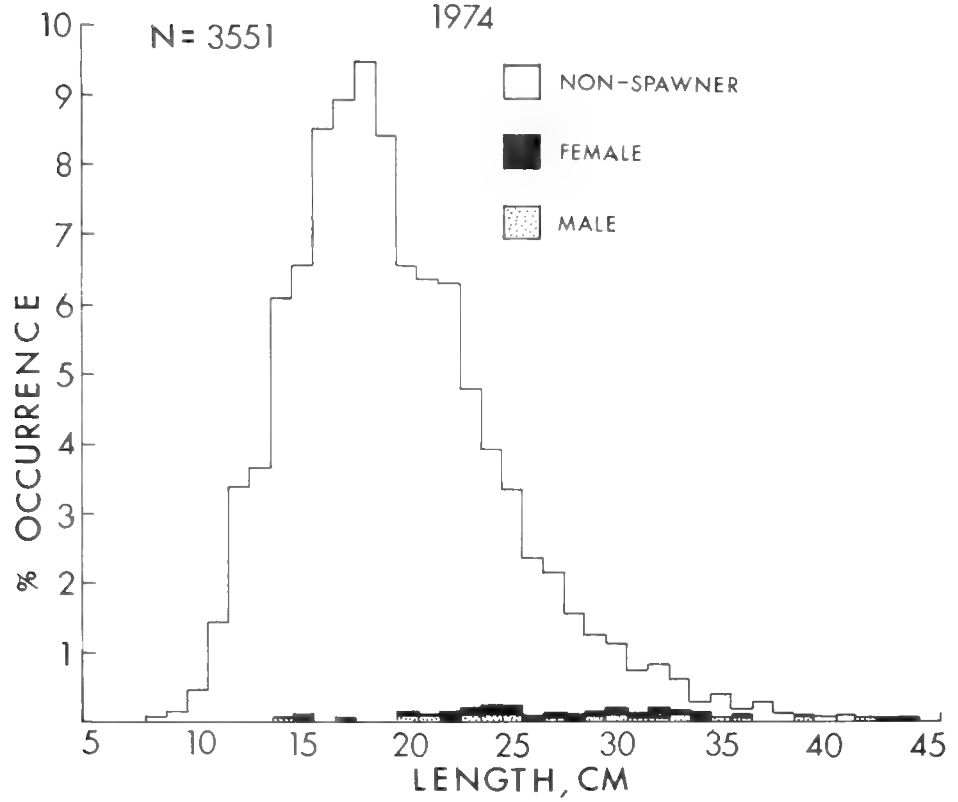
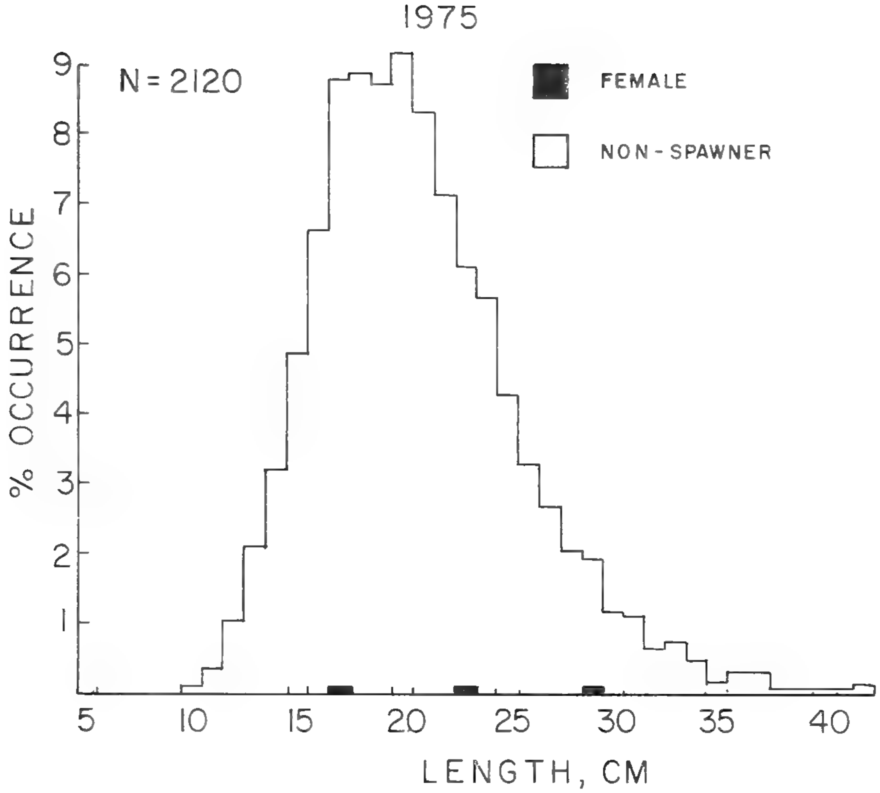
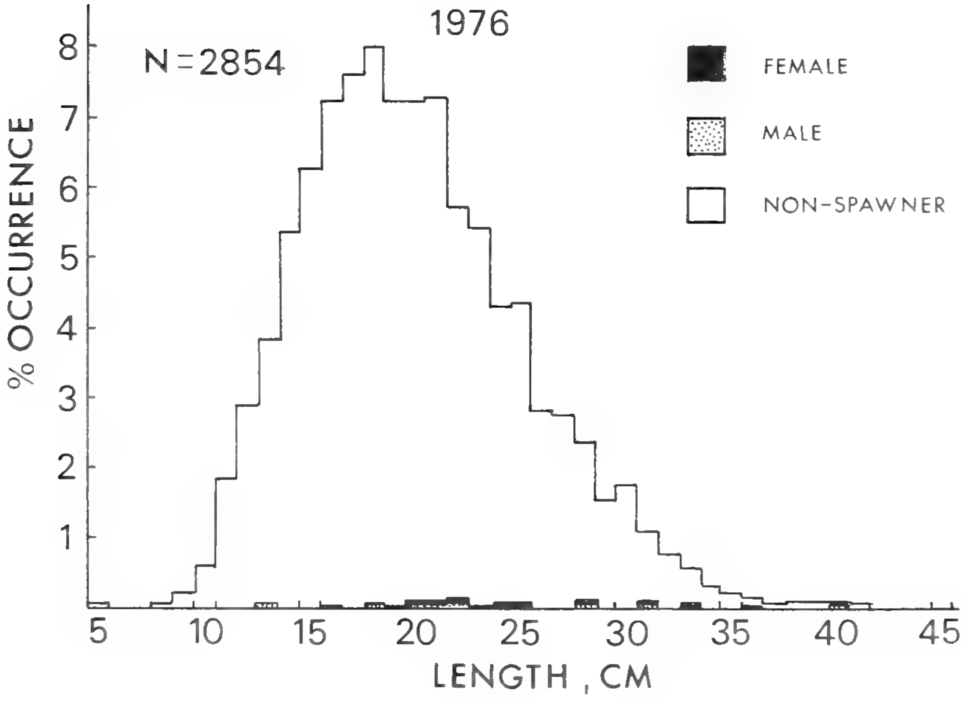


Figure 9.—Sexed length frequency data from combined monthly samplings of the commercial bloodworm catch collected between April and September of each year (1973–76).



1975
N = 2120
FEMALE
NON - SPAWNER
% OCCURRENCE
9
8
7
6
5
4
3
2
1
5
10
15
20
25
30
35
40
LENGTH, CM



1976
N=2854
FEMALE
MALE
NON-SPAWNER
% OCCURRENCE
8
7
6
5
4
3
2
1
5
10
15
20
25
30
35
40
45
LENGTH , CM

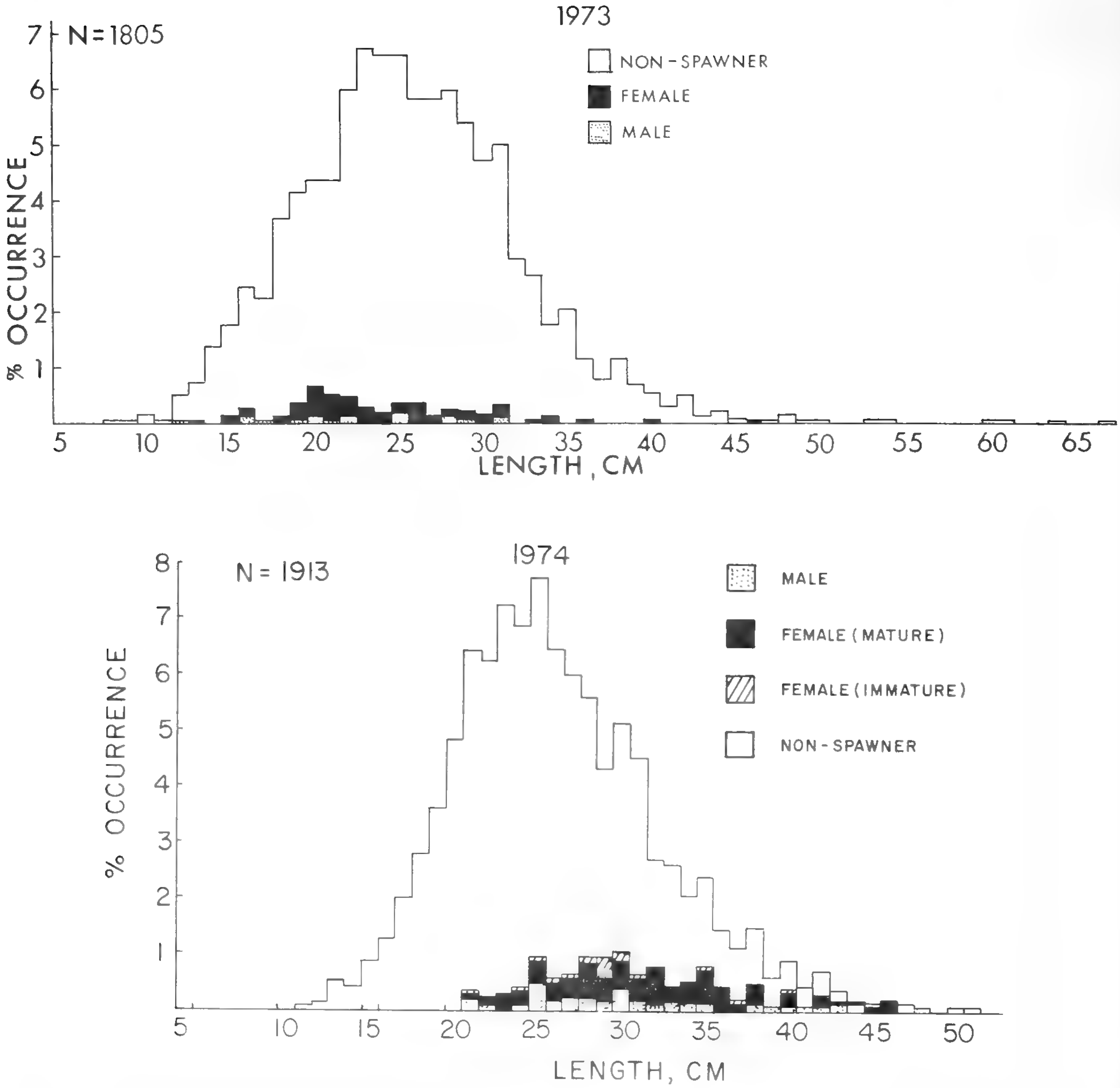
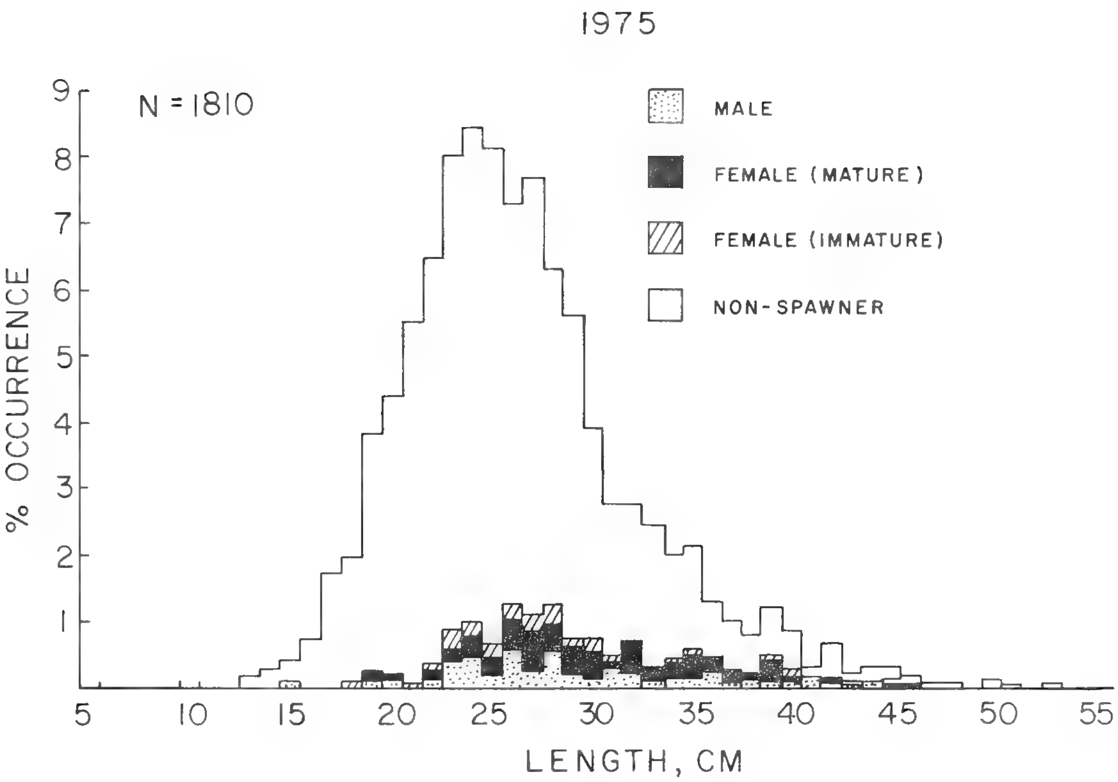
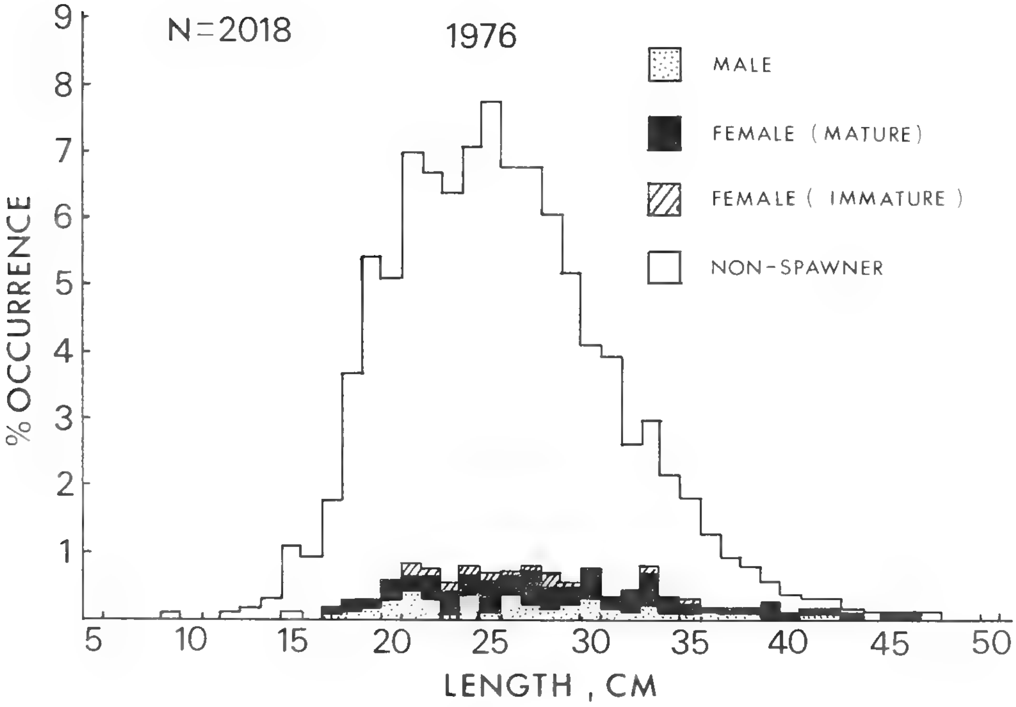


Figure 10.—Sexed length frequency data from combined monthly samplings of the commercial sandworm catch collected between April and September of each year (1973–76).


1975
N = 1810
9
8
7
6
5
4
3
2
1
% OCCURRENCE
5
10
15
20
25
30
35
40
45
50
55
LENGTH, CM
MALE
FEMALE (MATURE)
FEMALE (IMMATURE)
NON-SPAWNER


N=2018
1976
9
8
7
6
5
4
3
2
1
% OCCURRENCE
5
10
15
20
25
30
35
40
45
50
LENGTH , CM
MALE
FEMALE (MATURE)
FEMALE (IMMATURE)
NON-SPAWNER

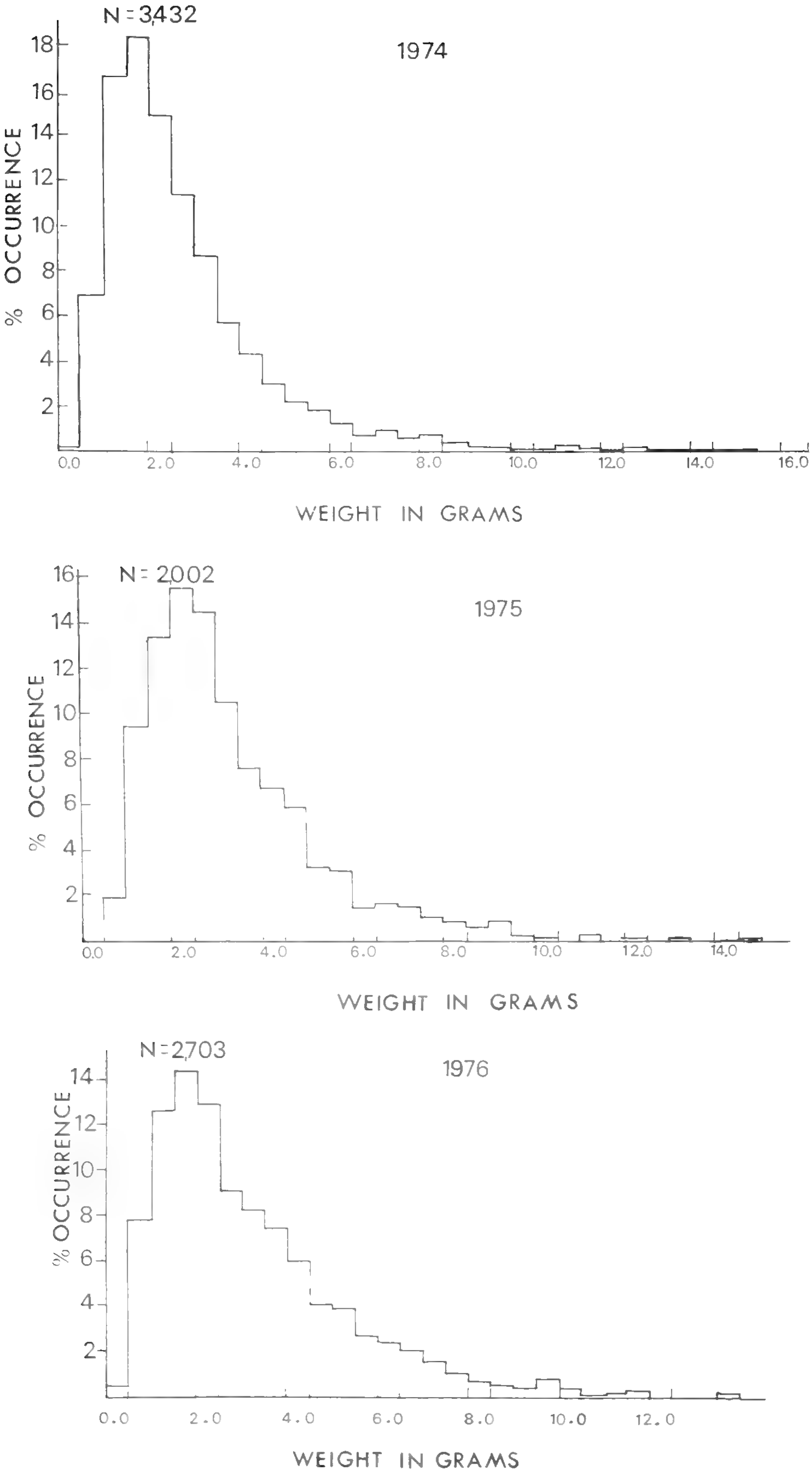


Figure 11.—Weight frequency data from combined monthly samplings of the commercial bloodworm catch collected during the period April–September of each year (1974–76).

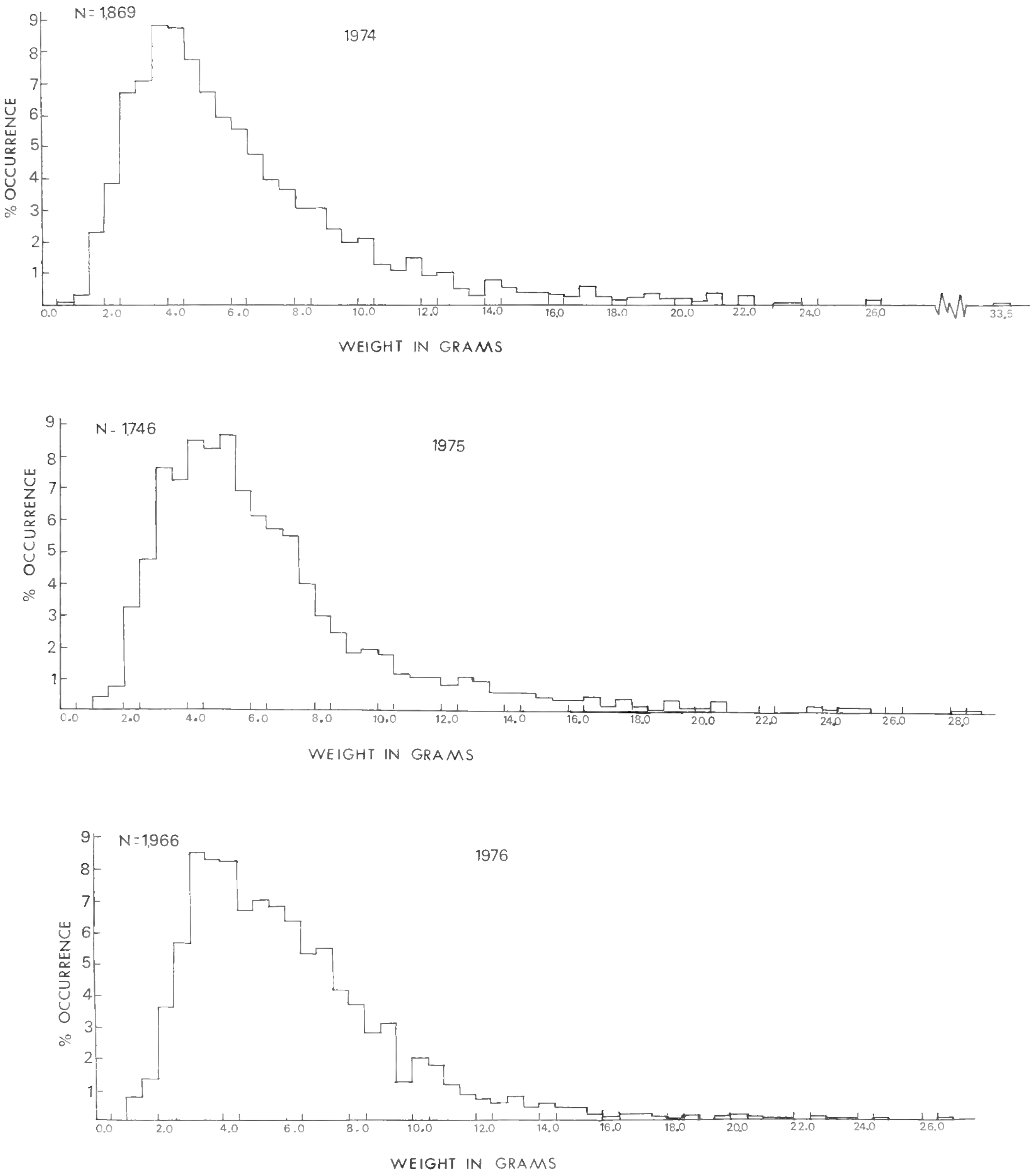


Figure 12.—Weight frequency data from combined monthly samplings of the commercial sandworm catch collected during the period April–September of each year (1974–76).

Table 12.—Probability sampling expansions of bloodworm catch and effort (±1 SE) and ratios estimates for catch/unit effort (±1 SE) by month and for the 6-mo sampling period (1973–76).

1973 Bloodworms

	Probability Sampling Expansions					Ratios of 2 Variables			
1973	Total Catch in Pounds	Total Catch in Numbers	Total Value of Catch in Dollars	Total No. of Digger-Tides Dug	Total No. of Digger-Hours Dug	Total Worm Catch in Number/Digger Tide	Total Catch in Numbers/Digger Hours	Total Catch in Pounds/Digger Tide	Total Catch in Pounds/Digger Hours
April	-	3,034,896 ±1,335,169	145,073 ± 64,674	6,900 ± 2,958	16,617 ± 7,739	418 ± 23	173 ± 19	-	-
May	-	5,888,974 ±2,609,582	293,411 ±130,875	13,832 ± 5,870	39,385 ±17,295	388 ± 55	139 ± 21	-	-
June	-	5,800,704 ±3,883,544	288,597 ±194,539	10,374 ± 6,756	26,638 ±17,028	524 ± 48	196 ± 18	-	-
July	-	6,766,569 ±3,079,667	338,328 ±153,983	13,537 ± 5,219	31,710 ±12,540	516 ± 82	215 ± 38	-	-
Aug.	-	7,515,040 ±3,827,157	375,752 ±191,358	9,440 ± 4,141	23,320 ±11,384	666 ±128	251 ± 32	-	-
Sept.	-	4,431,768 ±2,039,640	221,588 ±101,982	5,808 ± 2,472	12,309 ± 5,574	737 ±153	299 ± 33	-	-
Totals	-	33,437,951 ±7,208,753	1,662,750 ±360,396	59,891 ±11,804	149,978 ±31,094	536 ± 36	210 ± 12	-	-

1974 Bloodworms

	Probability Sampling Expansions					Ratios of 2 Variables			
1974	Total Catch in Pounds	Total Catch in Numbers	Total Value of Catch in Dollars	Total No. of Digger-Tides Dug	Total No. of Digger-Hours Dug	Total Worm Catch in Number/Digger Tide	Total Catch in Numbers/Digger Hours	Total Catch in Pounds/Digger Tide	Total Catch in Pounds/Digger Hours
April	26,303 ±12,841	5,778,108 ±2,693,900	288,905 ±134,695	11,214 ± 5,656	28,869 ±14,701	539 ±40	206 ±19	2.38 ± .08	.91 ±.03
May	27,388 ±25,251	6,165,533 ±5,684,341	308,277 ±284,217	8,127 ± 7,492	26,951 ±24,848	841 ±-	254 ±-	3.74 ± -	1.13 ± -
June	37,253 ±19,527	7,338,112 ±3,903,567	368,969 ±194,748	11,473 ± 5,378	32,439 ±17,320	571 ±40	216 ± 7	2.93 ± .19	1.11 ±.04
July	48,139 ±28,485	8,056,594 ±4,667,030	402,830 ±233,352	13,468 ± 8,158	37,550 ±22,942	605 ±28	218 ± 4	3.76 ± .13	1.36 ±.09
Aug.	27,323 ±14,675	4,362,800 ±2,250,516	218,140 ±112,526	9,360 ± 5,062	27,385 ±16,326	509 ±48	170 ±10	3.17 ± .30	1.06 ±.07
Sept.	40,171 ±10,725	5,744,270 ±1,745,874	309,865 ±104,836	8,698 ± 2,814	24,714 ± 9,372	718 ±98	256 ±20	5.32 ±1.23	1.90 ±.34
Totals	206,577 ±48,224	37,445,417 ±9,203,300	1,896,986 ±463,632	62,339 ±14,735	177,909 ±44,880	630 ±20	219 ± 5	3.53 ± .20	1.23 ±.06

Table 12.—*Continued.*

1975 Bloodworms

	Probability Sampling Expansions					Ratios of 2 Variables			
1975	Total Catch in Pounds	Total Catch in Numbers	Total Value of Catch in Dollars	Total No. of Digger-Tides Dug	Total No. of Digger-Hours Dug	Total Worm Catch in Number/Digger Tide	Total Catch in Numbers/Digger Hours	Total Catch in Pounds/Digger Tide	Total Catch in Pounds/Digger Hours
April	926	290,162	9,313	323	775	573	239	2.85	1.19
	± 850	± 266,271	± 8,546	± 296	± 711	± -	±-	± -	±-
May	24,771	4,219,618	210,981	5,023	15,773	846	259	4.95	1.51
	±11,031	±1,857,563	± 92,878	±2,197	± 6,755	± 59	±17	± .24	±.07
June	23,377	3,692,213	184,611	7,406	21,687	508	179	3.07	1.08
	±11,577	±1,671,937	± 83,597	±3,034	± 9,702	±100	±26	± .70	±.14
July	24,879	3,824,562	188,430	6,027	17,728	607	215	4.13	1.46
	±17,089	±2,704,017	±135,840	±4,318	±12,475	± 50	±13	± .50	±.13
Aug.	37,491	5,141,273	257,064	8,736	25,538	689	229	5.19	1.73
	±20,104	±2,880,779	±144,039	±5,004	±14,475	± 58	±10	± .66	±.16
Sept.	16,171	2,338,710	116,883	3,031	8,190	771	290	5.93	2.23
	± 9,461	±1,561,634	± 78,075	±1,978	± 5,488	± 51	± 1	±1.73	±.79
Totals	127,615	19,506,537	967,281	30,545	89,691	662	233	4.30	1.51
	±32,282	±4,936,204	±246,948	±7,865	±23,142	± 26	± 6	± .31	±.12

1976 Bloodworms

	Probability Sampling Expansions					Ratios of 2 Variables			
1976	Total Catch in Pounds	Total Catch in Numbers	Total Value of Catch in Dollars	Total No. of Digger-Tides Dug	Total No. of Digger-Hours Dug	Total Worm Catch in Number/Digger Tide	Total Catch in Numbers/Digger Hours	Total Catch in Pounds/Digger Tide	Total Catch in Pounds/Digger Hours
April	15,151	2,937,600	146,880	4,774	14,422	631	215	3.26	1.11
	±13,252	±2,586,339	±129,317	±3,887	±12,702	±103	± 1	±.49	±.02
May	6,127	954,270	47,714	1,573	5,217	548	181	3.56	1.17
	± 5,420	± 832,799	± 41,640	±1,392	± 4,615	± -	±-	±-	±-
June	21,217	4,685,850	257,429	6,880	23,052	759	234	3.68	1.13
	±13,218	±3,313,372	±182,326	±4,710	±16,547	±125	±14	±.41	±.24
July	31,656	4,831,974	267,706	9,828	27,030	455	167	3.02	1.11
	±12,647	±1,992,739	±108,930	±3,686	±10,837	± 51	±18	±.28	±.11
Aug.	12,010	1,466,724	83,035	3,648	9,875	458	169	3.84	1.41
	± 6,171	± 748,547	± 41,951	±1,697	± 4,838	± 88	±15	±.64	±.09
Sept.	23,775	3,809,360	215,477	6,347	19,634	554	189	3.74	1.27
	± 3,847	±1,045,432	± 60,033	±1,721	± 5,295	± 41	±14	±.76	±.26
Totals	109,936	18,685,778	1,018,241	33,049	99,230	567	193	3.50	1.20
	±24,343	±4,897,488	±262,544	±7,659	±25,007	± 35	± 6	±.21	±.07

Table 13.—Probability sampling expansions of sandworm catch and effort (±1 SE) and ratios estimates for catch/unit effort (±1 SE) by month and for the 6-mo sampling period (1973–76).

1973 Sandworms

	Probability Sampling Expansions					Ratios of 2 Variables			
1973	Total Catch in Pounds	Total Catch in Numbers	Total Value of Catch in Dollars	Total No. of Digger-Tides Dug	Total No. of Digger-Hours Dug	Total Worm Catch in Number/Digger Tide	Total Catch in Numbers/Digger Hours	Total Catch in Pounds/Digger Tide	Total Catch in Pounds/Digger Hours
April	-	3,536,940 ±3,032,880	72,111 ± 60,486	2,760 ±2,231	5,749 ±4,602	1,137 ±173	542 ± 97	-	-
May	-	10,140,130 ±4,240,642	280,531 ±116,073	8,372 ±3,430	17,184 ±7,216	1,165 ±198	577 ±120	-	-
June	-	9,597,224 ±3,810,652	276,118 ±111,477	10,010 ±3,071	21,742 ±7,162	875 ±245	412 ± 85	-	-
July	-	4,516,131 ±1,266,239	124,195 ± 34,822	3,241 ±1,210	5,545 ±2,056	1,482 ±273	863 ±112	-	-
Aug.	-	4,590,400 ±2,574,932	126,600 ± 70,722	4,960 ±2,518	9,517 ±5,125	930 ±215	506 ±131	-	-
Sept.	-	2,565,420 ±1,971,590	78,271 ± 54,344	2,244 ±1,638	6,267 ±5,003	1,102 ± 67	404 ± 48	-	-
Totals	-	34,946,245 ±7,336,435	957,825 ±196,789	31,587 ±6,055	66,004 ±13,418	1,120 ± 88	559 ± 43	-	-

1974 Sandworms

	Probability Sampling Expansions					Ratios of 2 Variables			
1974	Total Catch in Pounds	Total Catch in Numbers	Total Value of Catch in Dollars	Total No. of Digger-Tides Dug	Total No. of Digger-Hours Dug	Total Worm Catch in Number/Digger Tide	Total Catch in Numbers/Digger Hours	Total Catch in Pounds/Digger Tide	Total Catch in Pounds/Digger Hours
April	36,001 ±20,352	2,678,760 ±1,441,976	76,915 ±41,638	2,772 ±1,411	5,661 ±3,013	942 ±139	459 ±31	13.93 ±4.14	6.79 ±1.55
May	30,212 ±27,853	2,158,167 ±1,989,731	64,745 ±59,692	1,840 ±1,696	3,910 ±3,605	1,401 ± -	659 ±-	19.61 ± -	9.23 ± -
June	74,357 ±36,140	5,410,463 ±2,704,834	156,294 ±80,433	4,872 ±2,186	8,891 ±4,026	1,076 ±262	611 ±96	14.91 ±3.75	8.47 ±1.03
July	55,577 ±32,657	5,146,778 ±3,068,389	148,976 ±89,771	6,188 ±3,623	12,778 ±7,527	803 ± 39	391 ±16	9.00 ±1.56	4.38 ±1.15
Aug.	80,531 ±30,471	5,583,067 ±1,877,012	162,855 ±54,101	6,413 ±2,328	12,821 ±4,413	929 ± 85	433 ±59	14.04 ±3.48	6.55 ±1.78
Sept.	30,749 ±15,601	2,795,450 ±1,416,962	86,217 ±41,646	2,695 ±1,217	4,480 ±2,091	1,020 ±167	592 ±85	10.91 ±1.82	6.33 ±1.37
Totals	307,426 ±68,807	23,772,684 ±5,319,814	696,003 ±156,482	24,781 ±5,448	48,542 ±10,899	1,028 ± 60	523 ±24	13.75 ±1.16	6.96 ± .52

Table 13.—*Continued.*

1975 Sandworms

1975	Probability Sampling Expansions					Ratios of 2 Variables			
	Total Catch in Pounds	Total Catch in Numbers	Total Value of Catch in Dollars	Total No. of Digger-Tides Dug	Total No. of Digger-Hours Dug	Total Worm Catch in Number/Digger Tide	Total Catch in Numbers/Digger Hours	Total Catch in Pounds/Digger Tide	Total Catch in Pounds/Digger Hours
April	22,126	1,036,292	29,346	1,830	2,441	587	421	12.73	9.14
	±13,695	± 653,061	± 18,193	±1,190	± 1,506	± 39	± 29	±1.45	± .19
May	153,137	12,051,848	346,453	9,471	19,222	1,279	692	16.25	8.79
	±83,385	±6,578,737	±189,807	±4,702	±10,568	±335	± 71	±4.16	± .90
June	50,171	4,198,075	118,728	2,898	5,445	1,506	761	17.88	9.03
	±32,697	±2,704,852	± 75,205	±1,932	± 3,384	± 32	±119	± .12	±1.66
July	64,853	6,227,183	171,249	5,597	11,332	1,053	545	11.06	5.73
	±46,772	±4,554,999	±125,262	±3,955	± 8,690	± 89	± 50	± .64	± .66
Aug.	26,593	2,251,568	65,935	2,457	4,903	916	459	11.18	5.60
	±11,237	± 940,503	± 27,781	±1,134	± 2,144	±155	± 45	±1.99	± .36
Sept.	18,194	1,007,903	29,851	1,150	2,404	877	419	15.83	7.57
	±14,700	± 756,806	± 22,714	± 834	± 1,847	± 51	± 16	±2.82	± .62
Totals	335,075	26,772,867	761,562	23,402	45,746	1,051	558	14.16	7.65
	±103,633	±8,557,325	±242,882	±6,699	±14,455	± 67	± 28	± .93	± .37

1976 Sandworms

1976	Probability Sampling Expansions					Ratios of 2 Variables			
	Total Catch in Pounds	Total Catch in Numbers	Total Value of Catch in Dollars	Total No. of Digger-Tides Dug	Total No. of Digger-Hours Dug	Total Worm Catch in Number/Digger Tide	Total Catch in Numbers/Digger Hours	Total Catch in Pounds/Digger Tide	Total Catch in Pounds/Digger Hours
April	8,315	615,672	18,470	734	1,102	838	559	11.32	7.55
	± 7,716	± 571,319	± 17,140	± 681	±1,022	± -	± -	± -	± -
May	61,223	4,167,900	116,970	3,600	7,161	1,126	533	16.60	7.85
	±31,447	±2,168,487	± 59,382	±1,674	±2,714	±153	±109	±2.39	±1.52
June	65,004	4,441,554	135,375	3,229	5,654	1,469	822	20.72	11.59
	±54,839	±3,634,273	±110,857	±2,699	±4,651	± 75	± 2	± .99	±1.17
July	192,101	15,169,140	474,884	10,458	23,247	1,384	614	17.13	7.61
	±77,777	±5,933,135	±180,290	±3,949	±8,611	± 95	± 68	±1.03	± .87
Aug.	20,577	1,423,860	46,276	1,596	3,819	881	368	12.76	5.33
	±12,158	± 826,382	± 26,863	± 940	±2,253	±136	± 59	±3.96	±1.69
Sept.	61,970	6,318,333	194,715	4,533	9,834	1,356	626	13.56	6.26
	±25,811	±2,613,942	± 80,676	±1,869	±4,127	± 41	± 40	±2.87	±1.67
Totals	409,189	32,136,459	986,690	24,151	50,817	1,184	592	15.40	7.73
	±104,494	±7,807,329	±236,314	±5,525	±11,239	± 38	± 22	± .92	± .52

Table 14.—A monthly and 6 mo combined summary of bloodworm catch statistics data collected between 1973 and 1976.

CATCH STATISTICS (SUMMARY)		1973	BLOODWORMS				
	APRIL	MAY	JUNE	JULY	AUGUST	SEPT	TOTAL
1 TOTAL CATCH IN GRAMS (9ms)	56244.78	71862.53	56002.77	60927.36	59383.68	67803.83	372224.95
2 TOTAL ACCEPTED CATCH IN NUMBERS (nos)	20773	32005	31426	35489	46193	33574	199460
3 TOTAL VALUE OF CATCH ($)	1038.65	1612.15	1571.30	1774.45	2309.65	1678.70	9984.90
4 TOTAL No MALES IN SAMPLES	62	0					62
5 TOTAL No FEMALES IN SAMPLES	89	0					89
6 TOTAL No DIGGER TIDES	50	76	57	71	59	44	357
7 TOTAL No DIGGER HOURS	124.81	219.13	146.36	166.31	157.89	93.25	907.75
8 MEAN WEIGHT OF WORMS IN SAMPLES	2.71	2.25	1.78	1.72	1.29	2.02	1.87
9 CATCH IN Nos. DIGGER TIDE	415	421	551	500	783	763	559
10 CATCH IN 9ms/DIGGER TIDE	1124.90	945.56	982.50	858.13	1006.50	1541.00	1042.65
11 CATCH IN LBs/DIGGER TIDE	2.48	2.08	2.17	1.89	2.22	3.40	2.30
12 CATCH IN Nos/DIGGER HOUR	166	146	215	213	293	360	220
13 CATCH IN 9ms/DIGGER HOUR	450.64	327.94	382.64	366.35	376.11	727.12	410.05
14 CATCH IN LBs/DIGGER HOUR	.99	.73	.54	.81	.83	1.60	.90
15 VALUE DIGGER TIDE ($)	20.77	21.21	27.57	24.99	39.15	38.15	27.97
16 VALUE DIGGER HOUR ($)	8.32	7.36	10.74	10.67	14.63	18.00	11.00
17 VALUE 9m ($)	.01847	.02243	.02806	.02912	.03889	.02476	.02682
18 VALUE LB ($)	8.38	10.18	12.73	13.21	17.64	11.23	12.17

CATCH STATISTICS SUMMARY		1974	BLOODWORMS				
	APRIL	MAY	JUNE	JULY	AUG	SEPT	TOTAL
1 TOTAL CATCH IN GRAMS (9ms)	92664.20	80986.92	106,138.27	117692.78	70,191.48	145,725.60	613,399.25
2 TOTAL ACCEPTED CATCH IN NUMBERS nos	44,165	40,200	42,025	42,345	24,670	46,017	239,422
3 TOTAL VALUE OF CATCH $	2208.25	2010.00	2326.[illegible]3	2117.25	1,233.50	2,484.51	12,379.54
4 TOTAL No MALES IN SAMPLES	39	0					39
5 TOTAL No FEMALES IN SAMPLES	53	8					61
6 TOTAL No DIGGER TIDES	89	53	73	74	54	71	414
7 TOTAL No DIGGER HOURS	229.12	175.77	206.40	206.32	157.99	201.75	1,177.35
8 MEAN WEIGHT OF WORMS IN SAMPLES	2.10	2.01	2.53	2.78	2.85	3.17	2.56
9 CATCH IN Nos DIGGER TIDE	496	755	576	572	457	648	578
10 CATCH IN 9ms DIGGER TIDE	1041.17	1528.06	1453.95	1590.44	1,299.84	2,052.47	1,481.64
11 CATCH IN LBs DIGGER TIDE	2.30	3.37	3.21	3.51	2.87	4.53	3.27
12 CATCH IN Nos DIGGER HOUR	193	229	204	205	156	228	203
13 CATCH IN 9ms DIGGER HOUR	404.44	460.76	514.24	570.44	444.28	722.31	521.00
14 CATCH IN LBs DIGGER HOUR	.89	1.02	1.13	1.26	.98	1.59	1.15
15 VALUE DIGGER TIDE $	24.81	37.92	31.86	28.61	22.84	34.99	29.90
16 VALUE DIGGER HOUR ($	9.64	11.44	11.27	10.26	7.81	12.31	10.51
17 VALUE 9m ($)	.02383	.02482	.02192	.01799	.01757	.01705	.02018
18 VALUE LB ($)	10.81	11.26	9.94	8.16	7.97	7.73	9.15

Table 14.—*Continued.*

CATCH STATISTICS (SUMMARY) 1975 BLOODWORMS

		APRIL	MAY	JUNE	JULY	AUGUST	SEPT	TOTAL
1	TOTAL CATCH IN GRAMS (gms)	3,900.65	77,739.65	64,811.70	75,920.11	125,309.41	70,181.84	417,863.36
2	TOTAL ACCEPTED CATCH IN NUMBERS (nos)	1,730	28,815	22,583	25,215	37,665	22,370	138,378
3	TOTAL VALUE OF CATCH ($)	86.50	1,440.75	1,129.15	1,260.75	1,883.25	1,118.50	6,918.90
4	TOTAL No MALES IN SAMPLES	0	0	-	-	-	-	0
5	TOTAL No FEMALES IN SAMPLES	0	3			-	-	3
6	TOTAL No DIGGER TIDES	3	35	46	42	64	29	219
7	TOTAL No DIGGER HOURS	7.20	109.92	134.70	123.54	187.09	78.37	640.82
8	MEAN WEIGHT OF WORMS IN SAMPLES	2.25	2.70	2.87	3.01	3.33	3.14	3.02
9	CATCH IN Nos/DIGGER TIDE	577	823	491	600	589	771	632
10	CATCH IN gms/DIGGER TIDE	1,300.22	2,221.13	1,408.95	1,807.62	1,957.96	2,420.06	1,908.05
11	CATCH IN LBs/DIGGER TIDE	2.87	4.90	3.11	3.99	4.32	5.34	4.21
12	CATCH IN Nos/DIGGER HOUR	240	262	168	204	201	285	216
13	CATCH IN gms/DIGGER HOUR	541.76	707.24	481.16	614.54	669.78	895.52	652.08
14	CATCH IN LBs/DIGGER HOUR	1.19	1.56	1.06	1.36	1.48	1.97	1.44
15	VALUE/DIGGER TIDE ($)	28.83	41.16	24.55	30.02	29.43	38.57	31.59
16	VALUE/DIGGER HOUR ($)	12.01	13.11	8.38	10.21	10.07	14.27	10.80
17	VALUE/gm ($)	.02218	.01853	.01742	.01661	.01503	.01594	.01656
18	VALUE/LB ($)	10.06	8.41	7.90	7.53	6.82	7.23	7.51

CATCH STATISTICS (SUMMARY) 1976 BLOODWORMS

		APRIL	MAY	JUNE	JULY	AUGUST	SEPT	TOTAL
1	TOTAL CATCH IN GRAMS (gms)	56,133.81	33,559.78	68,535.90	111,930.92	47,779.81	93,999.79	411,940.01
2	TOTAL ACCEPTED CATCH IN NUMBERS (nos)	24,000	11400	33,337	37,727	12,546	33,310	152,320
3	TOTAL VALUE OF CATCH ($)	1,200.00	570.00	1833.54	2088.98	709.18	1,384.58	8286.28
4	TOTAL No MALES IN SAMPLES	17	0	-	-	-	-	17
5	TOTAL No FEMALES IN SAMPLES	27	0	-	-	-	-	27
6	TOTAL No DIGGER TIDES	39	18	49	78	32	56	272
7	TOTAL No DIGGER HOURS	117.83	63.01	164.19	214.52	86.62	173.23	819.40
8	MEAN WEIGHT OF WORMS IN SAMPLES	2.34	2.94	2.06	2.97	3.81	2.82	2.70
9	CATCH IN Nos/DIGGER TIDE	615	633	680	484	392	595	560
10	CATCH IN gms/DIGGER TIDE	1,439.33	1,864.43	1,398.69	1,435.01	1,493.12	1,678.57	1,514.49
11	CATCH IN LBs/DIGGER TIDE	3.17	4.11	3.08	3.16	3.29	3.70	3.34
12	CATCH IN Nos/DIGGER HOUR	204	181	203	176	145	192	186
13	CATCH IN gms/DIGGER HOUR	476.40	532.61	417.42	521.77	551.60	542.63	502.73
14	CATCH IN LBs/DIGGER HOUR	1.05	1.17	.92	1.15	1.22	1.20	1.11
15	VALUE/DIGGER TIDE ($)	30.77	31.67	37.42	26.78	22.16	33.65	30.46
16	VALUE/DIGGER HOUR ($)	10.18	9.05	11.17	9.74	8.19	10.88	10.11
17	VALUE/gm ($)	.02138	.01698	.02675	.01866	.01484	.02005	.02012
18	VALUE/LB ($)	9.70	7.70	12.13	8.47	6.73	9.09	9.12

Table 15.—A monthly and 6 mo combined summary of sandworm catch statistics data collected between 1973 and 1976.

	CATCH STATISTICS (SUMMARY)			1973	SANDWORMS			
		APRIL	MAY	JUNE	JULY	AUGUST	SEPT	TOTAL
1	TOTAL CATCH IN GRAMS (gms)	199,029.92	470638.60	413,145.72	130,278.11	153,122.73	71,393.75	1,437,608.83
2	TOTAL ACCEPTED CATCH IN NUMBERS (nos)	25,630	55,715	52732	23686	28,690	19,435	205,888
3	TOTAL VALUE OF CATCH ($)	522.54	1,541.37	1,517.13	651.37	791.25	592.96	5,616.62
4	TOTAL No MALES IN SAMPLES	-		-	-	11	24	35
5	TOTAL No FEMALES IN SAMPLES				-	84	31	115
6	TOTAL No DIGGER TIDES	20	46	55	17	31	17	186
7	TOTAL No DIGGER HOURS	41.66	94.42	119.46	29.08	59.48	47.48	391.58
8	MEAN WEIGHT OF WORMS IN SAMPLES	7.77	8.45	7.83	5.50	5.34	3.67	6.98
9	CATCH IN Nos/DIGGER TIDE	1282	1211	959	1393	925	1,143	1,107
10	CATCH IN gms. DIGGER TIDE	9951.50	10,231.27	7511.74	7663.42	4939.44	4,199.63	7,729.08
11	CATCH IN LBs/DIGGER TIDE	21.94	22.56	16.56	16.90	10.89	9.26	17.04
12	CATCH IN Nos/DIGGER HOUR	615	590	441	815	482	409	526
13	CATCH IN gms/DIGGER HOUR	4,777.48	4984.52	3458.44	4,479.99	2574.36	1,503.66	3,671.30
14	CATCH IN LBs/DIGGER HOUR	10.53	10.99	7.63	9.88	5.68	3.32	8.10
15	VALUE DIGGER TIDE ($)	26.13	33.51	27.58	38.32	25.52	34.88	30.20
16	VALUE DIGGER HOUR ($)	12.54	16.32	12.70	22.40	13.30	12.49	14.34
17	VALUE gm ($)	.00263	.00328	.00367	.00500	.00517	.00831	.00391
18	VALUE/LB ($)	1.19	1.49	1.67	2.27	2.34	3.77	1.77

	CATCH STATISTICS (SUMMARY)			1974	SANDWORMS			
		APRIL	MAY	JUNE	JULY	AUGUST	SEPT	TOTAL
1	TOTAL CATCH IN GRAMS (gms	120,939.09	89,356.40	214,561.20	136,734.33	210,701.94	113,838.62	886,131.58
2	TOTAL ACCEPTED CATCH IN NUMBERS (nos	19,385	14,075	34,425	27,834	32,210	22,820	150,749
3	TOTAL VALUE OF CATCH ($	554.19	422.25	994.45	805.20	939.55	703.81	4,419.45
4	TOTAL No MALES IN SAMPLES			-	-	49	21	. 70
5	TOTAL No FEMALES IN SAMPLES	-		-	-	155 (22I)	22 (9I)	177 (31I)
6	TOTAL No DIGGER TIDES	22	12	31	34	37	22	158
7	TOTAL No DIGGER HOURS	44.93	25.50	56.57	70.21	73.97	36.57	307.75
8	MEAN WEIGHT OF WORMS IN SAMPLES	6.24	6.35	6.23	4.91	6.54	4.99	5.88
9	CATCH IN Nos DIGGER TIDE	881	1173	1,110	819	871	1,037	954
10	CATCH IN gms DIGGER TIDE	5,497.23	3,504.17	6,921.33	4,021.60	5,694.65	5,174.48	5,608.43
11	CATCH IN LBs/DIGGER TIDE	12.12	7.73	15.26	8.87	12.56	11.41	12.37
12	CATCH IN Nos DIGGER HOUR	431	552	609	396	435	624	490
13	CATCH IN gms DIGGER HOUR	2,691.72	3,504.17	3,792.84	1,947.51	2,848.48	3,112.90	2,879.39
14	CATCH IN LBs DIGGER HOUR	5.94	7.73	8.36	4.29	6.28	6.86	6.35
15	VALUE DIGGER TIDE ($)	25.19	35.19	32.08	23.68	25.39	31.99	27.97
16	VALUE DIGGER HOUR ($)	12.33	16.56	17.58	11.47	12.70	19.25	14.36
17	VALUE gm ($)	.00458	.00473	.00463	.00589	.00446	.00618	.00499
18	VALUE LB ($)	2.08	2.14	2.10	2.67	2.02	2.80	2.26

Table 15.—*Continued.*

CATCH STATISTICS (SUMMARY) 1975 SANDWORMS

		APRIL	MAY	JUNE	JULY	AUGUST	SEPT	TOTAL
1	TOTAL CATCH IN GRAMS (gms)	93,198.89	483,966.67	141,303.33	204,965.15	90,843.24	78,963.80	1,093,241.08
2	TOTAL ACCEPTED CATCH IN NUMBERS (nos)	9,625	83,985	26,075	43,395	16,495	9,645	189,220
3	TOTAL VALUE OF CATCH ($)	272.56	2,414.31	737.44	1,193.37	483.04	285.66	5,386.38
4	TOTAL No MALES IN SAMPLES	-		-		66	43	109
5	TOTAL No FEMALES IN SAMPLES	-	-		-	97 (17 I)	46 (7 I)	143 (24 I)
6	TOTAL No DIGGER TIDES	17	66	18	39	18	11	169
7	TOTAL No DIGGER HOURS	22.66	133.95	33.82	78.97	35.92	23.00	328.32
8	MEAN WEIGHT OF WORMS IN SAMPLES	9.68	5.76	5.42	4.72	5.51	8.19	5.78
9	CATCH IN Nos/DIGGER TIDE	566	1,272	1449	1,113	916	877	1,120
10	CATCH IN gms/DIGGER TIDE	5,482.29	7,332.83	7,850.18	5,255.52	5,046.85	7,178.53	6,468.88
11	CATCH IN LBs/DIGGER TIDE	12.09	16.17	17.31	11.59	11.13	15.83	14.26
12	CATCH IN Nos/DIGGER HOUR	425	627	771	550	459	419	576
13	CATCH IN gms/DIGGER HOUR	4,112.93	3,613.04	4,178.10	2,595.48	2,529.04	3,433.21	3,329.80
14	CATCH IN LBs/DIGGER HOUR	9.07	7.97	9.21	5.72	5.58	7.57	7.34
15	VALUE/DIGGER TIDE ($)	16.03	36.58	40.97	30.60	26.84	25.97	31.87
16	VALUE/DIGGER HOUR ($)	12.03	18.02	21.80	15.11	13.45	12.42	16.41
17	VALUE/gm ($)	.00292	.00499	.00522	.00582	.00532	.00362	.00493
18	VALUE/LB ($)	1.33	2.26	2.37	2.64	2.41	1.64	2.23

CATCH STATISTICS (SUMMARY) 1976 SANDWORMS

		APRIL	MAY	JUNE	JULY	AUGUST	SEPT	TOTAL
1	TOTAL CATCH IN GRAMS (gms)	30,806.69	308,507.92	209,975.38	691,435.47	81,032.30	247,976.91	1,569,734.67
2	TOTAL ACCEPTED CATCH IN NUMBERS (nos)	5,030	46,310	31,635	120,390	12,340	55,750	271,455
3	TOTAL VALUE OF CATCH ($	150.90	1,299.67	964.21	3,768.92	400.98	1,718.07	8,302.75
4	TOTAL No MALES IN SAMPLES	-	-		-	34	74	108
5	TOTAL No FEMALES IN SAMPLES	-	-	-	-	69 (14 I)	91 (20 I)	160 (34 I)
6	TOTAL No DIGGER TIDES	6	40	23	83	14	40	206
7	TOTAL No DIGGER HOURS	9.00	79.57	40.27	184.50	33.50	86.77	433.61
8	MEAN WEIGHT OF WORMS IN SAMPLES	6.12	6.66	6.64	5.74	6.57	4.45	5.78
9	CATCH IN Nos/DIGGER TIDE	838	1,158	1,375	1,450	881	1,394	1,318
10	CATCH IN gms/DIGGER TIDE	5,134.45	7,712.70	9,129.36	8,330.55	5,788.02	6,199.42	7,620.07
11	CATCH IN LBs/DIGGER TIDE	11.32	17.01	20.13	18.37	12.76	13.67	16.80
12	CATCH IN Nos/DIGGER HOUR	559	582	786	653	368	643	626
13	CATCH IN gms/DIGGER HOUR	3,422.97	3,877.19	5,214.19	3,747.62	2,418.87	2,857.86	3,620.15
14	CATCH IN LBs/DIGGER HOUR	7.55	8.55	11.50	8.26	5.33	6.30	7.98
15	VALUE/DIGGER TIDE ($)	25.15	32.49	41.92	45.41	28.64	42.95	40.30
16	VALUE/DIGGER HOUR ($)	16.77	16.33	23.94	20.43	11.97	19.80	19.15
17	VALUE/gm ($)	.00490	.00421	.00459	.00545	.00495	.00693	.00529
18	VALUE/LB ($)	2.22	1.91	2.08	2.47	2.24	3.14	2.40

Table 16.—A comparison of catch/effort data obtained directly from the sampling and interview data and from ratio estimates.

	1973		1974		1975		1976	
	Sampling and interview	Ratio estimate (±1 SE)	Sampling and interview	Ratio estimate (±1 SE)	Sampling and interview	Ratio estimate (±1 SE)	Sampling and interview	Ratio estimate (±1 SE)
Bloodworms								
Catch in no./ digger tide	559	536±36	578	630±20	632	662±26	560	567±35
Catch in no./ digger hour	220	210±12	203	219±5	216	233±6	186	193± 6
Catch in lb./ digger tide	2.30		3.27	3.53±0.20	4.21	4.30±0.31	3.34	3.50±0.21
Catch in lb./ digger hour	0.90		1.15	1.23±0.06	1.44	1.51±0.12	1.11	1.20±0.07
Sandworms								
Catch in no./ digger tide	1,107	1,120±88	954	1,028±60	1,120	1,051±67	1,318	1,184±38
Catch in no./ digger hour	526	559±43	490	523±24	576	558±28	626	592±22
Catch in lb./ digger tide	17.04		12.37	13.75±1.16	14.26	14.16±0.93	16.80	15.40±0.92
Catch in lb./ digger hour	8.10		6.35	6.96±0.52	7.34	7.65±0.37	7.98	7.73±0.52

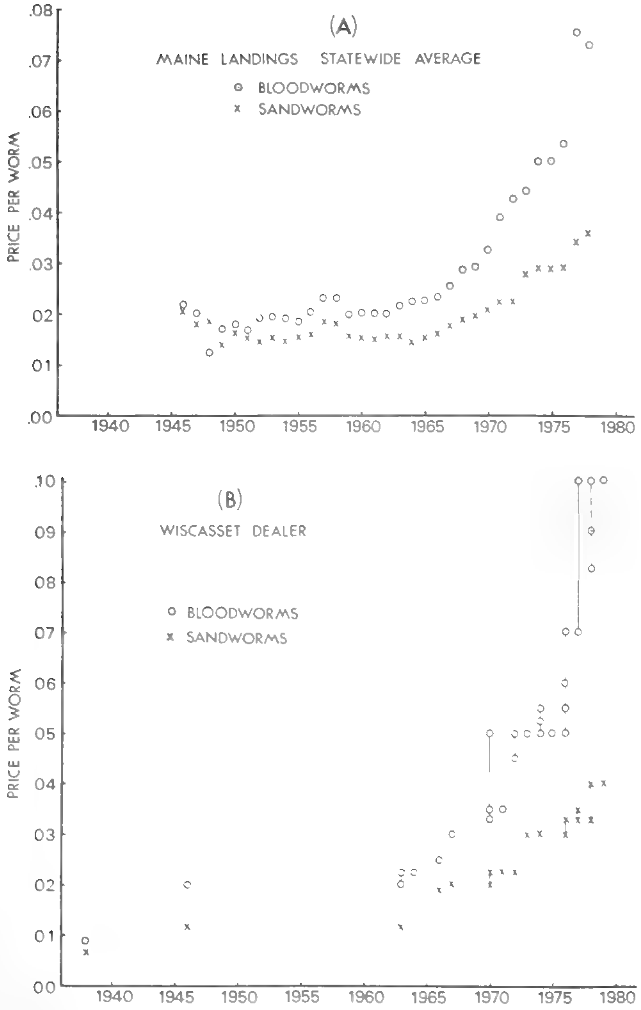


Figure 13.—The price/worm paid to bloodworm and sandworm diggers. (A) Price/worm information derived from Maine Landings estimates of landed value and pounds landed (converted to numbers landed). (B) Price/worm information recorded by a Wiscasset marine worm dealer.

Table 17.—The price/worm recorded by month during the commercial sampling program for bloodworms and sandworms (1973–76).

	1973		1974		1975		1976	
	Bloods	Sands	Bloods	Sands	Bloods	Sands	Bloods	Sands
April	$0.050	$0.024	$0.050	$0.028	$0.050	$0.029	$0.050	$0.030
May	.050	.028	.050	.030	.050	.029	.050	.029
June	.050	.029	.051	.028	.050	.029	.055	.030
July	.050	.028	.050	.029	.050	.028	.060	.032
August	.050	.028	.050	.029	.050	.029	.057	.032
Sept.	.050	.028	.052	.032	.050	.029	.056	.031

sampling data for age. The method of Cassie (1950) was applied in deriving estimates of the number of assumed year-class modes from the length-frequency data presented in Figures 9 and 10, respectively. The results of these analyses have been presented elsewhere (Creaser[37]). However, year-class modes are not obvious in these lumped length-frequency data, probably because worm growth varies between flats, worm growth occurs throughout the 6-mo commercial sampling period, and there is considerable overlap in length at age. The reliability of the age estimates presented in Creaser (footnote 37) are therefore questionable until the data can be verified against other aging techniques. Estimates of natural and fishing mortality, growth, and yield in weight per recruit are not included in this manuscript because of the problems inherent in the age analysis of the length-frequency data from which these estimates are derived.

Yield-Effort Curves

Fisheries can be managed through size restrictions, a reduction in fishing (digging) mortality, or a combination of both methods. Sufficient data presently exist to explore two means of limiting digging mortality: limited entry and quotas.

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[37] Creaser, E. P., Jr. 1978. Marine worm research. Completion report. Maine Dep. Mar. Resour., Augusta, 226 p.

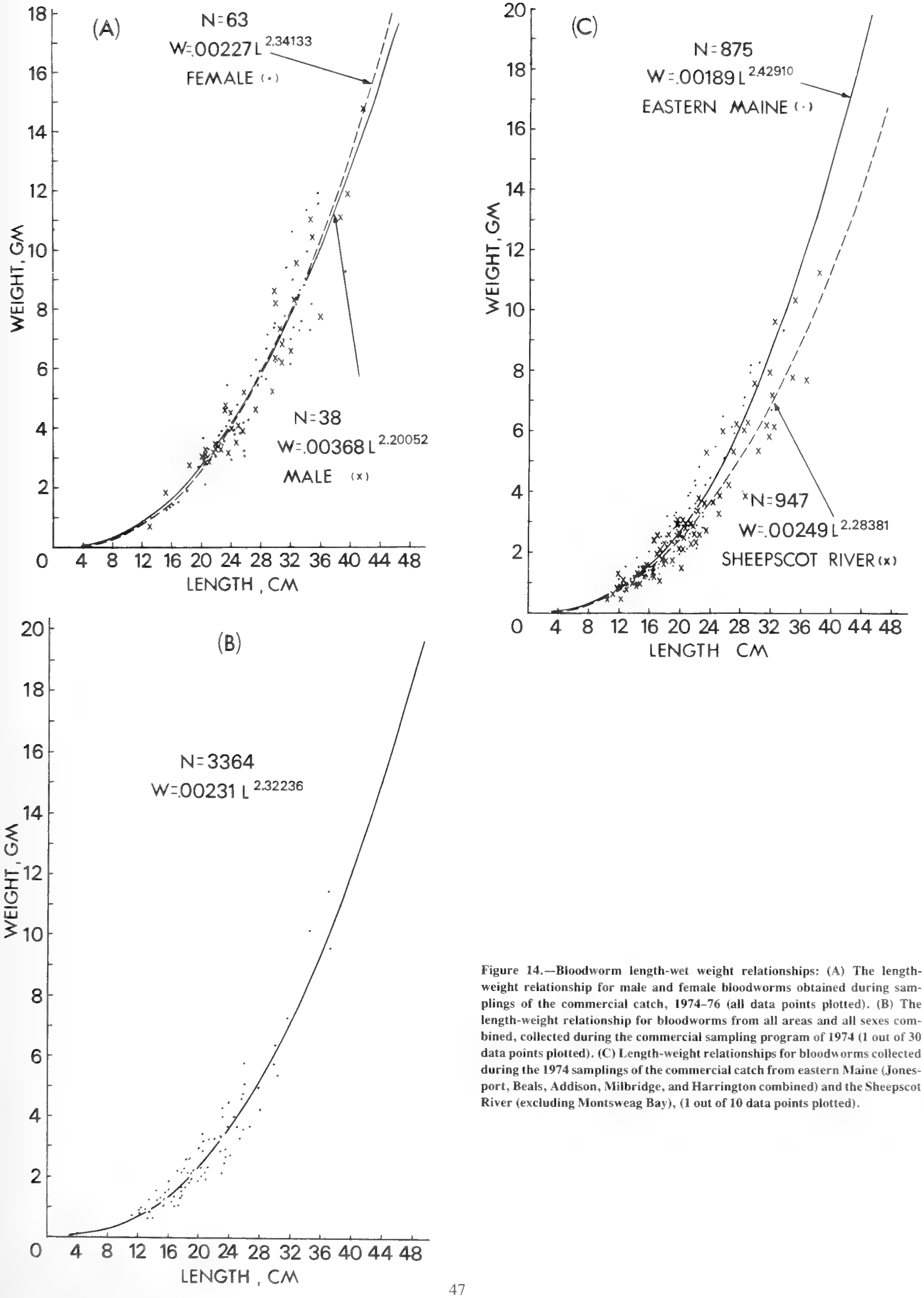

Figure 14.—Bloodworm length-wet weight relationships: (A) The length-weight relationship for male and female bloodworms obtained during samplings of the commercial catch, 1974–76 (all data points plotted). (B) The length-weight relationship for bloodworms from all areas and all sexes combined, collected during the commercial sampling program of 1974 (1 out of 30 data points plotted). (C) Length-weight relationships for bloodworms collected during the 1974 samplings of the commercial catch from eastern Maine (Jonesport, Beals, Addison, Milbridge, and Harrington combined) and the Sheepscot River (excluding Montsweag Bay), (1 out of 10 data points plotted).

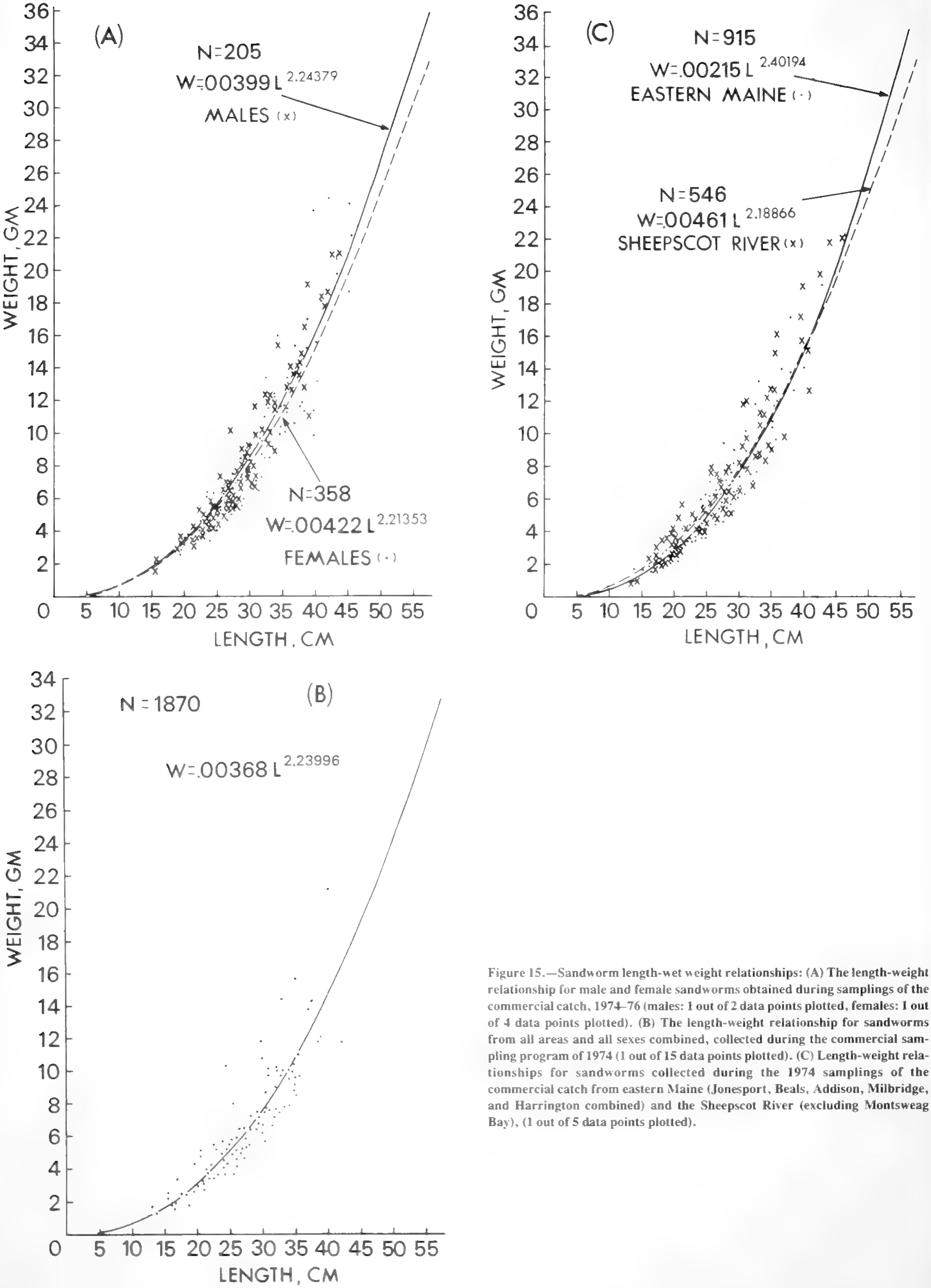

Figure 15.—Sandworm length-wet weight relationships: (A) The length-weight relationship for male and female sandworms obtained during samplings of the commercial catch, 1974–76 (males: 1 out of 2 data points plotted, females: 1 out of 4 data points plotted). (B) The length-weight relationship for sandworms from all areas and all sexes combined, collected during the commercial sampling program of 1974 (1 out of 15 data points plotted). (C) Length-weight relationships for sandworms collected during the 1974 samplings of the commercial catch from eastern Maine (Jonesport, Beals, Addison, Milbridge, and Harrington combined) and the Sheepscot River (excluding Montsweag Bay), (1 out of 5 data points plotted).

Table 18.—The upper and lower confidence limits about the slope (*b*) of bloodworm and sandworm length-weight regressions.

	Slope (*b*)	1 SE of *b* (68% confidence limits)	1.96 SE of *b* (95% confidence limits)	95% confidence limits about *b*-upper range	95% confidence limits about *b*-lower range
			Bloodworms		
Males (all areas)	2.20052	±0.09987	±0.19974	2.40314	1.99789
Females (all areas)	2.34133	±0.07225	±0.14450	2.53256	2.15010
All areas all sexes combined	2.32236	±0.01573	±0.03146	2.35319	2.29153
Eastern Maine	2.42910	±0.03297	±0.06594	2.49373	2.36447
Sheepscot River	2.28381	±0.02636	±0.05272	2.33549	2.23214
			Sandworms		
Males (all areas)	2.24379	±0.04789	±0.09578	2.33766	2.14993
Females (all areas)	2.21353	±0.04627	±0.09254	2.30422	2.12283
All areas all sexes combined	2.23996	±0.02022	±0.04044	2.27960	2.20033
Eastern Maine	2.40194	±0.02786	±0.05572	2.45656	2.34733
Sheepscot River	2.18866	±0.03385	±0.06770	2.25500	2.12231

Table 19.—The numbers of bloodworms and sandworms per pound.

	Bloodworms			Sandworms		
	Length (cm)	Weight[1] (g)	Worms/lb	Length (cm)	Weight[1] (g)	Worms/lb
1973						
6-mo $\bar{X}$	18.72	2.07	219	26.11	5.49	83
$\bar{X}$+1.96 SE	19.90	2.40	189	28.03	6.42	71
$\bar{X}$-1.96 SE	17.54	1.78	255	24.19	4.63	98
Max. month. $\bar{X}$	20.81	2.66	171	31.36	8.30	55
Min. month. $\bar{X}$	16.99	1.66	273	21.00	3.37	135
1974						
6-mo $\bar{X}$	19.84	2.37	191	26.22	5.53	82
$\bar{X}$+1.96 SE	20.58	2.60	174	27.55	6.22	73
$\bar{X}$-1.96 SE	19.10	2.18	208	24.89	4.94	92
Max. month. $\bar{X}$	21.68	2.93	155	28.16	6.52	70
Min. month. $\bar{X}$	17.82	1.85	245	24.25	4.67	97
1975						
6-mo $\bar{X}$	20.74	2.63	172	26.77	5.82	78
$\bar{X}$+1.96 SE	21.90	2.99	152	27.81	6.32	72
$\bar{X}$-1.96 SE	19.58	2.31	196	25.73	5.30	86
Max. month. $\bar{X}$	23.10	3.39	134	32.32	8.84	51
Min. month. $\bar{X}$	19.15	2.20	206	24.31	4.67	97
1976						
6-mo $\bar{X}$	20.83	2.66	171	25.69	5.30	86
$\bar{X}$+1.96 SE	21.89	2.99	152	26.51	5.68	80
$\bar{X}$-1.96 SE	19.77	2.37	191	24.87	4.94	92
Max. month. $\bar{X}$	22.98	3.35	135	27.45	6.17	74
Min. month. $\bar{X}$	18.57	2.05	221	23.74	4.42	103

[1] Weight values derived from length-weight conversions (all areas, all sexes combined).

Approximate values for a restriction on limited entry can be obtained from yield-effort curves (Pinhorn and Halliday 1975). Yield-effort relationships for bloodworms and sandworms are presented in Figure 16 (A and B). These results suggest that the maximum sustainable yield (MSY) in numbers of bloodworms and sandworms harvested was obtained with an effort of approximately 1,300 licensed marine worm diggers.

Prior to 1973, no attempt was made to record whether diggers to whom marine worm digging licenses were issued were engaged mainly in bloodworm or sandworm digging, or digging for both species. This information was extracted from licenses issued during the period 1973–78 and the results are presented in Table 21. The assumption has been made in Table 21 that the proportions calculated from completed application forms also apply to that 10.9–20.0% of the applicants who did not file completed applications. On the basis of the information presented in Table 21 and assuming that the percentage of licensed diggers who dug only bloodworms or sandworms prior to 1973 was the same as it was between 1973 and 1978, the MSY was obtained with approximately 815 bloodworm diggers (62.66% of 1,300), 386 sandworm diggers (29.72% of 1,300), and 99 diggers (7.62% of 1,300) who dug both species. A yield-effort relationship consisting of combined bloodworm and sandworm landings plotted against the total number of licensed marine worm diggers is presented in Figure 16C. These results suggest that the MSY for both species combined could be obtained at a limited entry figure of approximately 1,300 licensed marine worm diggers.

Where sufficient data exist on the total cost of digging, and the value of the catch over a period of time, a limited entry figure for

Table 20.—The numbers of bloodworms and sandworms per pound reported prior to 1970.

Date	Bloodworms (no./lb)	Sandworms (no./lb)	Source
1950–52	44	40	Cates and McKown (text footnote 36)
1964	100	50	Dow (1964)
1964	115	57	Cates and McKown (text footnote 36)
1966	106	63	Walton (text footnote 35)
1968	142	—	Walton (text footnote 35)
1969	150	80	Dow (1969)

Table 21.—The percentage of licensed marine worm diggers digging bloodworms, sandworms, and both species (1973–78).

	Percent of licensed diggers digging		
Year	Bloodworms	Sandworms	Both species
1973	64.77	28.42	6.81
1974	61.39	29.45	9.16
1975	61.36	30.23	8.41
1976	64.80	28.08	7.12
1977	63.88	29.99	6.13
1978	59.78	32.16	8.06
	[1]62.65 ±0.86	[1]29.72 ±0.60	[1]7.62 ±0.46

[1] Mean ±1 SE.

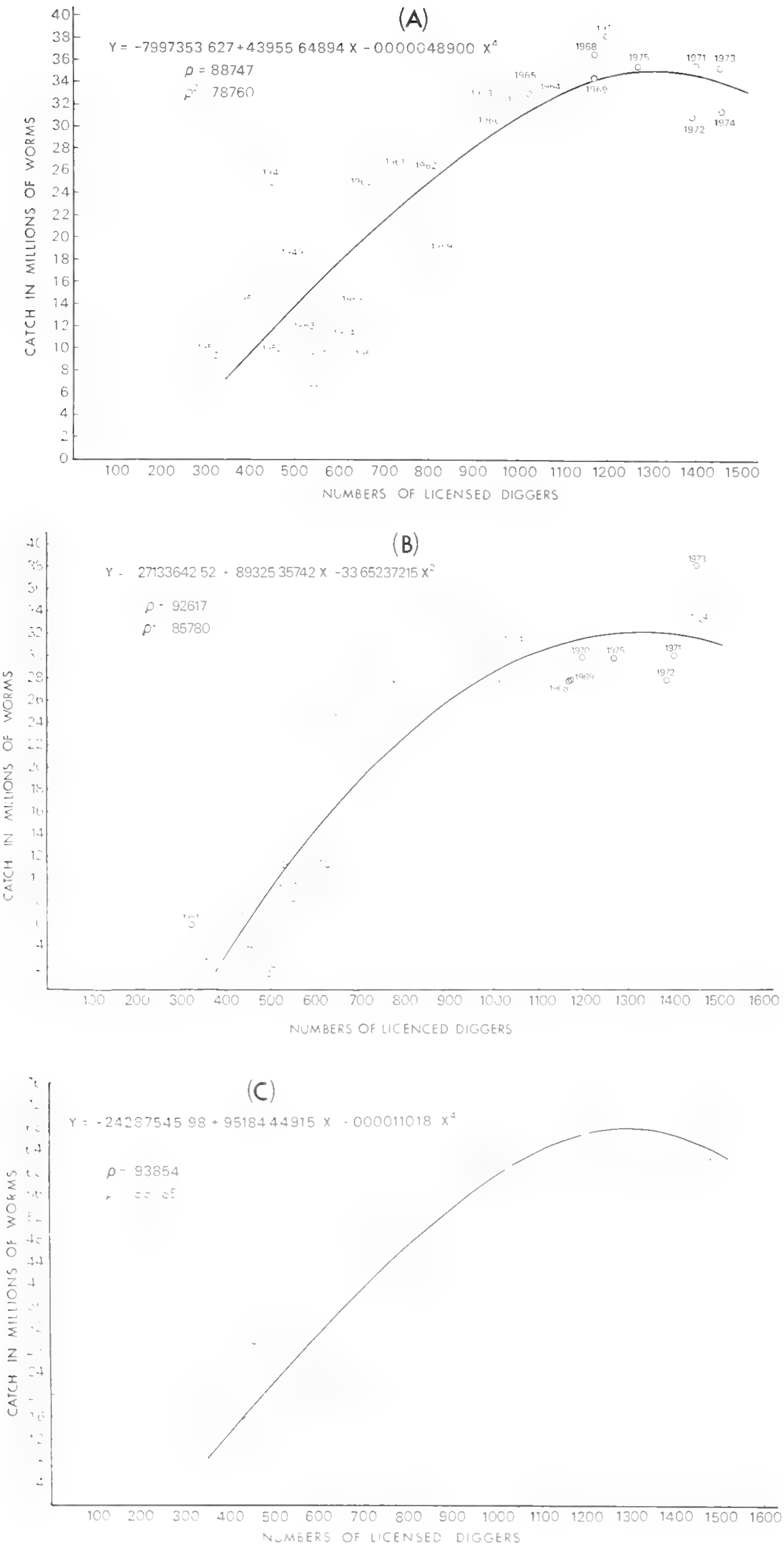

Figure 16.—Yield-effort curves: (A) bloodworms, (B) sandworms, (C) combined.

optimal sustainable yield (OSY) can be approximated by the method of Gulland (1968). In the present case where a portion of this information is lacking, the cost of digging, the OSY can only be very roughly approximated (by inspection of Fig. 16A, B, C) at somewhere between 900–1,100 licensed marine worm diggers. Based upon the proportions presented in Table 21, this would be equivalent to approximately 564–689 bloodworm diggers, 267–327 sandworm diggers, and 69–84 diggers who dig both species.

Assuming that OSY is very roughly approximated at 900–1,100 licensed marine worm diggers, very rough quotas of 28–33 million bloodworms and 26–30 million sandworms can be estimated from the data presented in Figure 16 (A and B).

Miscellaneous Information Obtained from Sampling Interview

Digging Frequency.—One interview question dealt with the frequency of bloodworm and sandworm digging expressed as the number of low tide periods occurring since the last low tide dug. The mean and standard error of the responses of all diggers interviewed during each month of each year (1973–76) are presented in Table 22.

Table 22.—The frequency of bloodworm and sandworm digging expressed as the mean (±1 SE) number of low tide periods occurring since the last low tide period dug.

	Bloodworm diggers			Sandworm diggers		
	No. diggers interviewed	$\bar{X}$	±1 SE	No. diggers interviewed	$\bar{X}$	±1 SE
1973						
A	37	6.5	±0.8	11	6.5	±2.0
M	31	5.6	±2.0	24	5.3	±1.0
J	26	3.3	±0.8	23	2.5	±0.6
J	36	2.1	±0.2	13	2.5	±0.5
A	32	4.0	±1.6	23	2.2	±0.3
S	20	10.1	±5.2	9	5.2	±1.3
	average	5.3		average	4.0	
1974						
A	34	3.0	±0.7	14	2.4	±0.2
M	14	4.4	±1.8	6	5.0	±1.4
J	44	11.2	±4.4	24	3.1	±0.6
J	20	3.2	±0.5	11	4.0	±0.5
A	21	3.0	±0.3	28	2.8	±0.4
S	33	1.9	±0.2	13	2.9	±0.9
	average	4.5		average	3.4	
1975						
A	2	8.0	±8.0	11	5.8	±1.5
M	14	2.1	±0.2	22	2.6	±0.7
J	29	4.1	±1.1	12	1.3	±0.3
J	19	2.0	±0.2	24	5.5	±1.7
A	24	3.8	±1.0	18	6.0	±2.9
S	19	3.3	±1.3	10	1.3	±0.2
	average	3.9		average	3.8	
1976						
A	19	2.2	±0.2	6	2.5	±1.3
M	9	5.3	±0.9	28	4.0	±0.4
J	30	13.1	±4.1	9	1.8	±0.2
J	39	5.7	±1.4	32	2.9	±0.3
A	18	2.3	±0.2	14	2.0	±0.0
S	36	16.9	±7.4	20	2.3	±0.3
	average	7.6		average	2.6	
	Overall average	5.3		Overall average	3.4	

Digging Experience.—The number of years of digging experience was recorded for those bloodworm and sandworm diggers who were interviewed during sampling. These data are expressed as a percent of the total number of diggers categorized in each increment of digging experience by year in Table 23. It is evident from these data that digging for worms is frequently a short-lived work experience; usually, the largest percentage of bloodworm and sandworm diggers interviewed had participated in marine worm digging activity for 4 yr or less.

Table 23.—The percent of the total number of bloodworm and sandworm diggers categorized in each increment of digging experience, 1973–76.

Number of years digging experience	1973	1974	1975	1976
		Bloodworm diggers		
1–4	50.51	37.58	37.73	35.25
5–8	15.82	16.76	23.59	23.02
9–12	15.31	13.87	13.21	9.35
13–16	6.12	17.34	12.26	11.51
17–20	6.63	6.36	7.54	13.67
21–24	2.04	1.73	1.89	1.44
25–28	2.55	5.20	1.89	2.88
29+	1.02	1.16	1.89	2.88
		Sandworm diggers		
1–4	34.23	22.12	23.71	27.52
5–8	16.22	11.54	17.53	13.76
9–12	24.33	13.46	17.53	22.02
13–16	9.01	20.19	11.34	6.43
17–20	11.71	14.42	12.37	16.51
21–24	—	2.88	8.24	3.67
25–28	1.80	10.58	2.06	2.75
29+	2.70	4.81	7.22	7.34

Age of Marine Worm Diggers.—Age-frequency distributions for bloodworm and sandworm diggers interviewed are expressed as a percent of the total number of bloodworm and sandworm diggers interviewed in each age category in Table 24. It is evident from these data that the numbers of diggers in age categories beyond age 40 decline rapidly. The results also show that there are few diggers under age 9 and over age 60. The mean age ±1 SE for all bloodworm and sandworm diggers interviewed during each sampling year is shown in Table 25.

Table 24.—The percent of the total number of bloodworm and sandworm diggers interviewed in each age category (1973–76).

Digger age	1973	1974	1975	1976
		Bloodworm diggers		
≤9	1.09%	0.00%	0.00%	0.00%
10–19	31.87	20.23	24.30	16.77
20–29	26.37	39.88	34.58	34.16
30–39	24.73	23.81	22.43	29.19
40–49	10.44	10.12	14.02	8.70
50–59	3.30	2.98	3.74	7.45
≥60	2.20	2.98	0.93	3.73
		Sandworm diggers		
≤9	0.00%	0.00%	0.00%	0.00%
10–19	21.15	12.38	17.53	21.11
20–29	34.62	35.24	31.96	31.11
30–39	25.00	24.76	22.68	25.56
40–49	9.62	19.05	16.49	17.78
50–59	7.69	8.57	11.34	3.33
≥60	1.92	0.00	0.00	1.11

Table 25.—The mean age ±1 SE of bloodworm and sandworm diggers interviewed during each sampling year (1973–76).

	Bloodworm diggers			Sandworm diggers		
Year	N	$\bar{X}$ age	±1 SE	N	$\bar{X}$ age	±1 SE
1973	182	27.7	±0.9	104	29.8	±1.2
1974	168	29.6	±0.9	105	31.9	±1.1
1975	107	29.1	±1.1	97	31.7	±1.2
1976	161	31.2	±1.0	90	30.9	±1.2

Percentage of Day and Nighttime Digging.—The results of one interview question regarding the percentage of bloodworm and sandworm diggers who responded that the last tide dug occurred during daylight (one-half hour before sunrise to one-half hour after sunset) or at night are presented in Table 26. These results indicate that most digging occurs during daylight. A greater percentage of sandworm than bloodworm diggers dig worms at night. Night digging is accomplished with the aid of a miner's light attached to the head.

Table 26.—The percent of bloodworm and sandworm diggers reporting that the last tide dug occurred during daylight or at night (1973–76).

	Bloodworms		Sandworms	
Year	Daylight	Night	Daylight	Night
1973	94	6	86	14
1974	97	3	92	8
1975	98	2	89	11
1976	97	3	80	20

Percentage of Male and Female Worm Diggers.—The percentage of male and female bloodworm and sandworm diggers recorded during sampling interviews is shown in Table 27. Few women are involved in this occupation.

Table 27.—The percent of male and female bloodworm and sandworm diggers recorded during sampling interviews (1973–76).

	Bloodworm diggers		Sandworm diggers	
Year	Males	Females	Males	Females
1973	98.4	1.6	99.5	0.5
1974	98.3	1.7	100.0	0.0
1975	99.1	0.9	98.8	1.2
1976	95.3	4.7	100.0	0.0

Decline of Bloodworm Landings After 1975

The bloodworm industry, unlike the sandworm industry, experienced a considerable decrease in production between 1975 and 1979 (Table 28). Many factors probably contributed to this decline.

Table 28.—The percent gain or reduction in bloodworm and sandworm production between 1975 and 1979.

Year	No. of bloodworms	% gain or reduction	No. of sandworms	% gain or reduction
1975	35,634,000		29,935,000	
1976	23,454,000	−34.18	27,915,000	−6.75
1977	17,474,000	−25.50	29,506,000	+5.70
1978	16,202,000	− 7.28	29,937,000	+1.46
1979	19,364,000	+19.52	29,776,000	+0.54

The failure of the Sheepscot River as a major bloodworm producer is probably responsible for a significant portion of the decline in production from western Maine. The exact nature of this continuing failure is unknown but it may be that oil (Page[38]) or toxic chemicals are contributing factors.

Dow (footnote 18) attributes the decline in production to the following causes: 1) Naturally occurring fluctuations in abundance and availability are associated with such environmental factors as seawater temperature. The mean annual sea temperature increased from an optimum of 8.4°C (1972) and 8.8°C (1973) to an above optimum of 9.2°C (1974). 2) A decline was apparent in the numbers of licensed marine worm diggers. Licenses dropped from 1,267 (1975) to 1,105 (1979). The possibility exists, however, that licenses declined as the result of decreased demand and production and not vice versa. 3) Toxic oil spills, heavy metals contamination, and possibly the presence of other pollutants may account for a portion of the decline. 4) A 3-wk strike during 1976 may have reduced production by as many as 3 million worms. 5) Poor market conditions resulted in a decrease in digging effort. Following a series of telephone conversations with marine worm wholesalers and retailers, Walton[39] concluded that the poor market conditions resulted from 1) a reduction in the availability of some sport fish (striped bass, flounder) in the central states (New Jersey, Delaware, Maryland) where bloodworms are used extensively, and 2) either switching from both species of marine worms to alternate and less expensive baits (clam necks, night crawlers) in the northeast (Rhode Island, New York, Massachusetts) or switching from bloodworms to less expensive sandworms.

A decline in fishing activity resulting from the gas shortage and the poor quality (small size) of bloodworms may be other contributing factors.

In many commercial digging areas, diggers and shippers report that overharvesting is a primary cause of the decline in production. However, no research directed toward collecting the catch/effort data necessary to confirm or deny these claims has existed since 1976.

Previous declines in marine worm landings have been attributed to cyclic changes in the environment (Dow;[40] Dow and Wallace footnote 13), gradual changes in soil composition (Klawe and Dickie 1957), expansion of the commercial area dug (Dow and Wallace footnote 13), and changes in tidal exposure because of bridge and highway construction (Ganaros footnote 4).

Suggestions for Improving Future Marine Worm Sampling Programs

It is apparent, from the magnitude of the standard errors about the monthly probability expansion estimates (Table 12), that greater accuracy (smaller standard errors) could be obtained by sampling on more than six daylight low tide periods per month. Although we were not initially optimistic about increasing the accuracy of probability estimates because of project restrictions on time, funding, and manpower, an attempt was made to estimate by optimum and proportional allocation the number of sampling daylight low tides

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[38] Page D. S. 1977. A survey of hydrocarbons in bloodworms and accompanying sediments from the Wiscasset, Maine area. Bowdoin College - A report to the Maine Department of Marine Resources, Augusta, 38 p.

[39] C. J. Walton, Marine resources scientist, Maine Dep. Mar. Resour., West Boothbay Harbor, ME 04575, pers. commun. July 1978.

[40] Dow, R. L. 1951. Marine worm report. Maine Dep. Sea Shore Fish., Augusta, 6 p

required to obtain a minimum desired accuracy of ± 15% about the mean expansion estimate (total catch in numbers, total number of digging hours dug, etc.) at the 90% confidence level. The results of these analyses on both bloodworms and sandworms are shown in Tables 29 and 30, respectively. In most cases (using both optimum and proportional allocation), the number of sampling daylight low tides required to obtain the desired accuracy exceeds the number of tides which could reasonably be sampled. Furthermore, to make use of optimal allocation, one must be able to reliably predict the relative variability which occurs in each stratum (month), but the 4 yr of data do not demonstrate consistent monthly variability from year to year. Because of these problems, we chose to sample six daylight low tide periods per month, and accept the large standard errors about the mean estimates for probability expansion estimates.

We applied the combined methodology of Gulland (1966), Pope (1956), and Snedecor and Cochran (1967) to determine whether satisfactory estimates of mean length in a future commercial marine worm sampling program could be obtained with less sampling of worms/digger, diggers/dealer, and dealers/month. The results of this analysis indicate that variability of no more than ± 15% of the estimated mean at the 95% confidence level could be obtained for bloodworm lengths by sampling approximately 10 measurable worms/digger, 6 diggers/dealer, and 2 dealers/mo (if only 1 mo was sampled). Similar data could be collected for sandworms by sampling approximately 14 measurable worms/digger, 5 diggers/dealer, and 1 dealer/mo (Creaser footnote 37). Obviously, the desire to obtain a variability of no more than 5 or 10% of the estimated mean at the 95% confidence level would be obtained by increasing the sample size. Since we sampled approximately 20 measurable bloodworms/digger and approximately 7 bloodworm diggers/dealer from an average of 3 bloodworm dealers/mo, and approximately 18 measurable sandworms/digger, and approximately 6 sandworm diggers/dealer from an average of nearly 3 sandworm dealers/mo between 1973 and 1976, we have sampled more than what was required to obtain the minimum desired degree of accuracy. The magnitude of the standard errors about the 6-mo mean lengths (Tables 10, 11) also demonstrates this point.

Considering that 1) probability expansion estimates could be improved (smaller standard errors obtained) by sampling more frequently each month, and 2) satisfactory monthly estimates of marine worm length could be obtained with fewer length samples, it would probably the possible to sample more frequently each month and improve the probability estimates if fewer worms were being obtained for length processing. Although it is not possible to increase sampling to the point at which we could attain the accuracy expressed in Tables 29 and 30, it would probably be possible to increase the amount of sampling to 8 or 10 daylight low tides per month. Sampling could furthermore be stratified so that each of 4 or 5 bloodworm and 4 or 5 sandworm shippers could be randomly sampled each month. Both worm species would be sampled at those shippers selected who purchase both species of worms.

Despite the decreased sampling required to estimate worm length, it might still be desirable to collect some length samples

Table 29.—Calculations of the desired frequency of monthly samplings for bloodworms to obtain a minimum accuracy of ±15% about the mean estimate for 1) total catch in numbers and 2) total number of digger hours dug, at the 90% confidence level.

	1973		1974		1975		1976	
Total catch in numbers (bloodworms)								
Optimum allocation								
A	[1](36)	[2] 8.72	(36)	15.15	(38)	2.75	(36)	24.20
M	(42)	16.81	(40)	31.65	(41)	19.03	(25)	8.17
J	(42)	25.01	(41)	21.69	(42)	17.09	(39)	30.81
J	(44)	19.76	(42)	25.88	(41)	27.70	(42)	20.47
A	(40)	24.75	(40)	12.53	(39)	29.64	(38)	7.76
S	(33)	13.45	(35)	9.85	(33)	16.34	(34)	10.96
Proportional allocation								
A	(36)	17.72	(36)	20.21	(38)	22.05	(36)	20.61
M	(42)	20.67	(40)	22.45	(41)	23.79	(25)	13.17
J	(42)	20.67	(41)	23.02	(42)	24.37	(39)	22.33
J	(44)	21.66	(42)	23.58	(41)	23.79	(42)	24.04
A	(40)	19.69	(40)	22.45	(39)	22.63	(38)	21.75
S	(33)	16.24	(35)	19.65	(33)	19.15	(34)	19.46
Total number of digger hours dug (bloodworms)								
Optimum allocation								
A	(36)	11.21	(36)	17.87	(38)	1.55	(36)	22.91
M	(42)	24.71	(40)	29.90	(41)	14.59	(25)	8.73
J	(42)	24.33	(41)	20.80	(42)	20.91	(39)	29.67
J	(44)	17.85	(42)	27.49	(41)	26.95	(42)	21.46
A	(40)	16.33	(40)	19.65	(39)	31.40	(38)	9.67
S	(33)	8.15	(35)	11.42	(33)	12.11	(34)	10.70
Proportional allocation								
A	(36)	16.86	(36)	20.71	(38)	22.34	(36)	19.98
M	(42)	19.67	(40)	23.01	(41)	24.07	(25)	12.77
J	(42)	19.67	(41)	23.59	(42)	24.65	(39)	21.65
J	(44)	20.61	(42)	24.16	(41)	24.07	(42)	23.32
A	(40)	18.73	(40)	23.01	(39)	22.89	(38)	21.10
S	(33)	15.46	(35)	20.14	(33)	19.37	(34)	18.88

[1]( ) = The total number of daylight low tides in the month.

[2]The calculated number of sampling tides required to obtain the desired accuracy.

Table 30.—Calculation of the desired frequency of monthly samplings for sandworms to obtain a minimum accuracy of ± 15% about the mean estimate for 1) total catch in numbers and 2) total number of digger hours dug, at the 90% confidence level.

	1973		1974		1975		1976	
Total catch in numbers (sandworms)								
Optimum allocation								
A	[1](36)	[2]18.57	(36)	13.30	(38)	4.04	(36)	2.90
M	(42)	25.61	(40)	18.17	(41)	40.46	(25)	11.41
J	(42)	23.01	(41)	24.64	(42)	16.60	(39)	18.32
J	(44)	7.62	(42)	27.90	(41)	28.01	(42)	33.05
A	(40)	15.61	(40)	17.14	(39)	5.81	(38)	4.64
S	(33)	12.19	(35)	13.10	(33)	4.75	(34)	14.86
Proportional allocation								
A	(36)	17.44	(36)	18.51	(38)	25.77	(36)	19.91
M	(42)	20.35	(40)	20.57	(41)	27.81	(25)	13.83
J	(42)	20.35	(41)	21.08	(42)	28.49	(39)	21.57
J	(44)	21.32	(42)	21.60	(41)	27.81	(42)	23.23
A	(40)	19.38	(40)	20.57	(39)	26.45	(38)	21.02
S	(33)	15.99	(35)	18.00	(33)	22.38	(34)	18.81
Total number of digger hours dug (sandworms)								
Optimum allocation								
A	(36)	14.94	(36)	13.17	(38)	5.62	(36)	3.41
M	(42)	23.11	(40)	15.61	(41)	39.20	(25)	9.38
J	(42)	22.93	(41)	17.39	(42)	12.53	(39)	15.40
J	(44)	6.56	(42)	32.45	(41)	32.23	(42)	31.51
A	(40)	16.48	(40)	19.10	(39)	7.99	(38)	8.32
S	(33)	16.40	(35)	9.17	(33)	7.00	(34)	15.40
Proportional allocation								
A	(36)	16.98	(36)	18.48	(38)	25.62	(36)	18.28
M	(42)	19.81	(40)	20.54	(41)	27.65	(25)	12.69
J	(42)	19.81	(41)	21.05	(42)	28.32	(39)	19.80
J	(44)	20.75	(42)	21.56	(41)	27.65	(42)	21.33
A	(40)	18.86	(40)	20.54	(39)	26.30	(38)	19.30
S	(33)	15.56	(35)	17.97	(33)	22.25	(34)	17.27

[1]( ) = The total number of daylight low tides in the month.

[2]The calculated number of sampling tides required to obtain the desired accuracy.

each month to enable us to determine whether worm size is affected by monthly or seasonal market demands. Monthly sampling would also allow us to accumulate more length, weight, sex, and condition information from assorted growing areas.

Problems inherent in the analysis of lumped commercial length frequency data for age (and the mortality estimates based upon that age structure) have been discussed previously under the section entitled "Estimates of Age." Despite the fact that commercial-length frequency data collected from specific growing areas over short periods of time may be more easily analyzed for age structure than similar data collected from a large geographical area and lumped over a longer period of time, the authors do not recommend the former approach either. Our experience has been that when the former procedure is followed, considerable overlap in the older year classes occurs and the validity of aging results may still be questioned. It would seem more appropriate to develop a means of aging marine worms other than by analyzing length frequency distributions. In this respect, aging by 1) the possible presence of annuli on bloodworm and sandworm mouth parts, and 2) mark and recapture techniques using tagged or dyed worms or worms with mutilated appendages, should be attempted. Age structure determined by these means in three or four commercial growing areas could then be used to determine the numbers of worms at each year class mode required for mortality estimates. Total and natural mortality rates could be estimated from length-frequency data collected from open and closed growing areas situated side by side in each of the three or four study areas. Fishing (digging) mortality (F) could be determined for each study area by $F = Z - M$ where Z = total mortality and M = natural mortality.

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APPENDIX A

The following formulas were used to calculate the means, variances, and standard errors for length and weight data and the percent males, females, broken, regenerated, and punctured individuals collected during each dealer daylight low tide period sampled.

$$\bar{Y}_i = \sum_j N_j \bullet \bar{Y}_j / \sum_j N_j \qquad (1)$$

$$\text{var}\ (\bar{Y}_i) = \sum_j (\bar{Y}_j - \bar{Y}_i)^2 / (m(m-1)) \qquad (2)$$

$$\bar{Y}_j = \sum_k Y_{jk} / n_j \qquad (3)$$

where $\bar{Y}_i$ = mean for the *i*th dealer daylight low tide,
$\bar{Y}_j$ = mean for the *j*th digger sampled,
N_j = number worms landed by the *j*th digger sampled,
m = number of diggers sampled,
Y_{jk} = measurement for the *k*th worm from the *j*th digger sampled,
n_j = number of worms measured from the *j*th digger sampled.

Formulas used to calculate the monthly means, variances, and standard errors for the same parameters above include the following:

$$\bar{Y}_h = \sum_i \bar{Y}_i / l \qquad (4)$$

$$\text{var}\ (Y_h) = \sum_i (\bar{Y}_i - \bar{Y}_h)^2 / (l(l-1)) \qquad (5)$$

where $\bar{Y}_h$ = mean for the *h*th month,
$\bar{Y}_i$ = mean for the *i*th dealer daylight low tide (Equation (1)),
l = number of dealer daylight low tides sampled.

Formulas used to calculate the 6-mo means and standard errors for the same parameters above include the following:

$$\bar{Y}_{st} = \sum_h N_h \bullet \bar{Y}_h / \sum_h N_h \qquad (6)$$

$$\text{var}\ (\bar{Y}_{st}) = \sum_h (N_h^2 \bullet \text{var}\ (\bar{Y}_h)) / (\sum_h N_h)^2 \qquad (7)$$

where $\bar{Y}_{st}$ = 6-mo stratified mean,
$\bar{Y}_h$ = mean for the *h*th month (Equation (4)),
N_h = number of daylight low tides in the *h*th month.

Probability expansions have been calculated for the following marine worm sampling data: total catch in numbers, total number of digger hours dug, total value of the catch, total number of digger tides dug, and total catch in pounds. The formulas used in calculating these expanded estimates, their variances, and standard errors on a monthly basis, conform to the methodology of Gulland (1966) and Snedecor and Cochran (1967) and are presented as follows:

$$\hat{X}_h = N_h \bullet D_h \bullet \bar{X}_h \qquad (8)$$

$$\text{var}\ (\hat{X}_h) = N_h\ (N_h - n_h) \bullet D_h^2 \bullet\ \text{var}\ (\bar{X}_h) \qquad (9)$$

where $\hat{X}_h$ = expanded estimate for the *h*th month,
$\bar{X}_h$ = mean for the *h*th month (Equation (4)),
N_h = number of daylight low tides in the *h*th month,
D_h = number of qualified dealer locations open during the *h*th month,
n_h = number of daylight low tides sampled in the *h*th month.

Formulas used to calculate probability expansions and their standard errors for the entire 6-mo sampling period include the following:

$$\hat{X}_{st} = \sum_h \hat{X}_h \qquad (10)$$

$$\text{var}\ (\hat{X}_{st}) = \sum_h \text{var}\ (\hat{X}) \qquad (11)$$

where $\hat{X}_{st}$ = 6-mo stratified total,
$\hat{X}_h$ = total for the *h*th month (Equation (8)).

Ratios of two variables (catch/effort data) have been calculated for the following marine worm sampling data: numbers dug/digger tide, numbers dug/digger hour, pounds dug/digger tide, and pounds dug/digger hour. The formulas used in calculating these ratios of two variables, their variances, and standard errors on a monthly basis, conform to the methodology of Cochran (1963) and are presented as follows:

$$R_h = \sum_i Y_i / \sum_i X_i \qquad (12)$$

$$\text{var}\ (R_h) = n_h \bullet \sum_i (Y_i - R_h \bullet X_i)^2 / (\ (n_h - 1)(\sum_i X_i)^2) \qquad (13)$$

where R_h = ratio estimate for the *h*th month,
Y_i = some measure of catch sold to the *i*th dealer daylight low tide sampled,
X_i = some measure of effort for diggers selling to the *i*th dealer daylight low tide sampled,
n_h = number of dealer daylight low tides sampled.

Formulas used to calculate the ratios of two variables and their standard errors for the entire 6-mo sampling period include the following:

$$R_{st} = \sum_h N_h \bullet R_h / \sum_h N_h \qquad (14)$$

$$\text{var}\ (R_{st}) = \sum_h (N_h^2 \bullet \text{var}\ (R_h)\ ) / (\sum_h N_h)^2 \qquad (15)$$

where R_h = ratio estimate for the *h*th month (Equation (12)),
N_h = number of daylight low tides in the *h*th month.

Estimates for the number of dealers that should be sampled each month, the number of diggers that should be sampled per dealer, and the number of worms that should be sampled from each digger, conform to the methodology of Snedecor and Cochran (1967). Information on the use of their methods may be found in Creaser (text footnote 29).

The relationship of worm weight to worm length was calculated using a logarithmic transformation of the basic equation $W = aL^b$.

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Roger B. Theroux and Roland L. Wigley

JUNE 1983

U.S. DEPARTMENT OF COMMERCE
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JUNE 1983

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Distribution and Abundance of East Coast Bivalve Mollusks Based on Specimens in the National Marine Fisheries Service Woods Hole Collection

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ABSTRACT

The distribution and numerical abundance of over 108,000 specimens of bivalve mollusks (81% of which were alive when captured) collected and maintained by the Benthic Dynamics Investigation at the NMFS Northeast Fisheries Center at Woods Hole, Mass., are presented. They are illustrated in a series of charts, and their bathymetric range and bottom sediment preferences are outlined in tabular form. Taxonomic groups represented include 5 subclasses, 8 orders, 46 families, 99 genera, and 164 species. The specimens are contained in 10,465 lots from 2,767 sampling sites along the east coast continental shelf and slope, and upper continental rise between Nova Scotia and southern Florida. Samples range in depth from 0 to nearly 4,000 m. The collections were obtained by a variety of research vessels and persons using quantitative and qualitative sampling devices (i.e., grabs, dredges, trawls, etc.) over a period of 21 yr. Also included are current vernacular names, zoogeographic data, and a reference to the original description of represented species.

The data upon which this report is based are stored on magnetic tape and disc files, and the specimens are stored in a Specimen Reference Collection at the Northeast Fisheries Center in Woods Hole, Mass.

INTRODUCTION

Bivalves, as a group, are a major component of the U.S. east coast macrobenthic invertebrate fauna accounting for 22% of the total number and 70% of the total biomass of invertebrates in the Middle Atlantic Bight (Wigley and Theroux 1981), and for 12% of the number and 44% of the biomass of invertebrates in the offshore New England region (Theroux and Wigley[3]). In addition, several species support important fisheries (e.g., sea scallops, oysters, surf clams, ocean quahogs, and bay scallops), especially in the northeastern sector, which, in 1979, accounted for landings of bivalve meats totaling 151 million lb valued at $205.1 million (Pileggi and Thompson 1980).

Since 1955 the Benthic Dynamics Investigation of the National Marine Fisheries Service's (NMFS) Northeast Fisheries Center (NEFC) at Woods Hole, Mass. (U.S. Department of Commerce, NOAA), has been conducting ecological studies relating to benthic invertebrates and demersal fishes. As a result of intensive sampling for these studies we have accumulated a large collection of invertebrate specimens from inshore and offshore locations which are maintained in a Specimen Reference Collection (SRC). Bivalve specimens make up a significant and diverse portion of the Collection accounting for 225 separate taxa, with representatives from estuaries, embayments, the shoreline, the continental shelf, slope, and portions of the upper continental rise. Sampling depths represented range from 0 to nearly 4,000 m.

This report deals with the geographic and bathymetric distribution and occurrence, and relationship to bottom sediments of all taxonomic groups of bivalves in our collection. Geographic distribution of each taxon, along with a sketch of the shell, is presented in a series of charts, whereas depth distribution and occurrence and sedimentological relationships are in tabular form. Also included are: 1) author and date of generic descriptions from Neaves' "Nomenclator Zoologicus"; 2) the vernacular name of species when available; and 3) a reference to specific descriptions, the originals of which were examined and cited in the References section.

The bivalve taxa are discussed in systematic order in the body of the report (see Contents); however, for reference facility figures are arranged alphabetically by genus on the last pages, and are cross referenced by figure number within each taxonomic section.

MATERIALS AND METHODS

The Specimen Reference Collection contains over 108,000 specimens of bivalve mollusks, 81% of which were alive when captured. The taxonomic groups of bivalves represented include: 5 subclasses, 8 orders, 46 families, 99 genera, and 164 species. The specimens are contained in 10,465 lots obtained from 2,767 sampling sites located along the shore, in estuaries and embayments, and on the continental shelf and slope of the eastern coast of the United States between Canada and southern Florida (Fig. 1).

Twenty-one years are represented in these data from the Specimen Reference Collection; included are samples from collections made in 1903, 1904, 1950, 1953 through 1968, 1970, and 1971. Samples obtained from 1972 to the present are not included in this report.

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[3] Theroux, R. B., and R. L. Wigley. Quantitative composition and distribution of the macrobenthic invertebrate fauna of the New England Region. Manuscr. in prep. Northeast Fisheries Center Woods Hole Laboratory, National Marine Fisheries Service, NOAA, Woods Hole, MA 02543.

The majority of the lots analyzed were obtained by 15 research vessels; a small percentage of the lots did not have a vessel designated or were obtained by hand sampling along the shore, scuba diving, or other means. Among the collecting vessels were: *Fish Hawk*, *Gilbert*, *Harengus*, *Albatross III*, *Delaware I*, *Delaware II*, *Albatross IV*, and *Blueback*, all operated by the National Marine Fisheries Service (NMFS), or its predecessor agencies the Bureau of Commercial Fisheries (BCF) and the U.S. Fish Commission (USFC). There were four commercial fishing vessels chartered by BCF for research purposes: *Whaling City*, *Shirley* and *Roland*, *Silver Mink*, and *Priscilla V*. The *A. E. Verrill*, operated by the Marine Biological Laboratory (MBL), Woods Hole, Mass., and the *Gosnold* and *Asterias* of the Woods Hole Oceanographic Institution (WHOI), Woods Hole, Mass., also provided collections included in this report. Table 1 lists the pertinent sampling statistics for each vessel. Data pertaining to each lot of bivalves in the NEFC Specimen Reference Collection are contained in Theroux and Wigley[4]; information for each group includes: vessel name, cruise number, station number, type of sampling gear, latitude, longitude, sampling date, water depth in meters, and bottom type.

Bathymetry

Water depths, in meters, were obtained by means of depth sounders at sea and from published navigation charts or bathythermographic records where actual depth soundings were not available at time of sampling or for inshore collections. For ease of processing and to facilitate discussion of distribution with depth, depths were grouped into eight depth range categories. Range groupings used are: 1) 0-24m, 2) 25-49 m, 3) 50-99 m, 4) 100-199 m, 5) 200-499 m, 6) 500-999 m, 7) 1,000-1,999 m, and 8) 2,000-3,999 m.

Geology

Data for the majority of the samples contained information on 34 different types of bottom sediments. Considering the areal scope of this report, and the restrictions on legibility enjoined by the amount of reduction required to the base charts, we have grouped the 34 more detailed sediment types into 2 separate, more generalized, subgroups. The first subgroup used in the tables accompanying the taxon/sediment relations discussion, contains nine sediment categories: 1) gravel, 2) sand-gravel, 3) till, 4) shell, 5) sand-shell, 6) sand, 7) silty sand, 8) silt, and 9) clay. The second subgroup, used in the sediment distribution chart (Fig. 2), groups the above nine categories into four, more general, classes for ease of interpretation on the chart; thus, in the chart, sediment types are: 1) gravel, 2) shell, 3) sand, and 4) silt-clay.

Sampling Gear

A total of 28 different sampling devices were used in obtaining the bivalves in the NEFC collection. Among the devices are a variety of grab samplers, dredges, and trawls, various nets, and skimmers; in addition scuba divers, and hand collecting yielded specimens, and some were obtained from fish stomachs. Table 2 lists the various types of sampling gear used and the number and percent samples for each type.

Data Treatment

Original samples were preserved in buffered formaldehyde solution at sea and subsequently transfered to alcohol preservative when sorted in the laboratory. All information pertaining to these collections has been stored on magnetic tape at the NEFC.

Whenever possible an attempt was made to arrive at a determination at the species level for all lots examined; however, time and personnel constraints as well as damaged specimens necessitated the use of higher taxonomic levels in some cases. Consequently this report contains determinations at the familial and generic levels as well as those to the specific level.

BOTTOM SEDIMENTS

The following discussion on the distribution of bottom sediments over the entire sampling area is based on the information contained in Figure 2.

The predominant sediments in the study area are of the sandy and muddy (silt-clay) types. Sandy substrates occupy nearly the whole of the continental shelf and nearshore regions from Georges Bank to Key West, Fla. Muddy substrates predominate on the outer continental shelf and slope, in many of the embayments, and in the deeper basins of the Gulf of Maine.

Gravelly substrates are quite widely distributed primarily in the Gulf of Maine and are patchily distributed on the Southern New England shelf and in the Mid-Atlantic Bight region between Cape Cod and Cape Hatteras, becoming almost nonexistent below Cape Hatteras. No gravelly substrates occur south of Myrtle Beach, S.C.

Shelly substrates occur predominantly on the continental shelf south of Cape Fear, N.C., and in some nearshore areas in rather discrete patches. Two of these small patches of shelly sediments were also encountered along the northeastern coast of Maine and south of Grand Manan Island.

DISTRIBUTION OF CLASS BIVALVIA

The areal distribution of samples with regard to water depth is shown in Figure 1.

Occurrence frequency of samples in the various water depth ranges shows a decided affinity for the midcontinental shelf depths. Fully one-third (33.6%) of the samples are from water depths of 50 to 99 m gradually diminishing in frequency with both increasing and decreasing water depth range.

The number of bivalve specimens was significantly highest (41%) in the 50-99 m depth range grouping; about equal (17 and 16%) in the shallower depth range groupings, 0-24 and 25-49 m, as well as the 100-199 m grouping (16%); and gradually decreased with increasing depth range beyond 200 m. Table 3 lists the occurrence of bivalve samples and specimens in relation to range in water depth.

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[4] Theroux, R. B., and R. L. Wigley. 1979. Collection data for U.S. east coast bivalve mollusks in the Northeast Fisheries Center Specimen Reference Collection Woods Hole, Massachusetts. Unpubl. manuscr., 471 p. Northeast Fisheries Center Woods Hole Laboratory, National Marine Fisheries Service, NOAA, Woods Hole, MA 02543.

The occurrence of samples containing bivalves was highest in sand and silty sand substrates, 32 and 13%, respectively. Next highest density of samples occurred in the finest grained substrates, silt (8%) and clay (7%). Areas of coarser grained sediments, gravel, shell, and sand-shell, each contained < 8% of the total number of samples, while sand-gravel sediments contained < 0.5% of the samples. Twenty-one percent of the samples are unclassified with regard to sediment type.

Specimen density in the various sediment types very closely approximates that of sampling intensity. Greatest numbers of organisms occurred in the sandy and muddy substrates with fewer in the coarse textured sediments. Table 4 lists the occurrence of bivalve samples and specimens in relation to bottom sediments.

The occurrence frequency of individual bivalve taxa adjusted for distribution of sampling intensity among the various depth range groupings or sediment types, although not tabulated herein, may be calculated from the data contained in Tables 3 and 4 for total samples, and Tables 6 through 327 for individual taxa.

SYSTEMATIC ARRANGEMENT

The systematic arrangement of R. T. Abbott (1974) has been, for the most part, followed in this report. The only exceptions involve the placement of families in the orders Veneroida and Pholadomyoida where we have followed the arrangement of N. D. Newell (in R. C. Moore, 1969a, vol. 1, p. N218).

There are 36 samples containing 76 specimens in our collection which we were only able to classify as Bivalvia. A variety of reasons necessitated this classification; the most common cause for failure to arrive at a lower taxonomic designation was lack of shell, especially of the smaller, thinner shelled species, whose hard parts were dissolved away by preservatives which were too acid. Another was shell structure so badly damaged that no definite determination, other than that of Bivalvia, could be made through examination of soft parts.

Further detailed discussion concerning this category would be pointless except to direct the interested reader's attention to the accompanying figures and tables which provide information about distributional and environmental parameters relating to areas where unidentifiable bivalve material was encountered. (See Fig. 21, and Tables 5, 6, 7; and Theroux and Wigley footnote 4, table 32.)

DISTRIBUTIONAL AND ECOLOGICAL DISCUSSION

Class BIVALVIA
Subclass PALAEOTOXODONTA
Order NUCULOIDA

The NEFC Specimen Reference Collection contains two specimens from two samples of organisms which are classified to the order level Nuculoida (Table 5).

One of the samples is from east of Cape Cod and the other sample is from Vineyard Sound, Mass. (Fig. 79; Theroux and Wigley footnote 4, table 134).

The depth of our samples is 15 and 103 m, placing them in two separate depth range groupings, each of which contained 50% of samples and specimens; the groupings concerned are the 0-24 m and the 200-499 m.

Only one sample contained information relating to bottom sediments; this sample was obtained from a clay substratum.

Family NUCULIDAE
Genus *Nucula* Lamarck 1799

Nucula delphinodonta Mighels and Adams 1842. Delphinula nut clam. Figure 71.

The distribution of the delphinula nut clam extends from Labrador to Maryland on the east coast of the United States as well as being moderately well distributed in Arctic regions and in northern Europe (Johnson 1934; La Rocque 1953; Ockelmann 1958; Clarke 1962; Abbott 1974).

This tiny bivalve is represented in our collection by 2,092 specimens from 145 samples (Table 5).

The NEFC samples range from the Scotian Shelf through the Gulf of Maine-Georges Bank complex onto the Southern New England shelf and the Mid-Atlantic Bight region south to the offing of Chesapeake Bay (Fig. 71; Theroux and Wigley footnote 4, table 123).

This species occupies the Boreal and Virginian provinces in eastern North America (Coomans 1962); Gosner (1971) placed it in the Boreal province.

The delphinula nut clam enjoys a fairly wide bathymetric range, occupying depths between 17 and 2,361 m (Clarke 1962).

The range in depth occupied by the samples in the NEFC collection is from 11 to 1,894 m with a mean of 197 m. The majority of both samples and specimens, 41 and 78%, respectively, are in the 50-99 m depth range grouping; considerably smaller amounts occur in other depth range groupings: abundance with increasing depth range is as follows: the 0-24 m depth range grouping contains 6% of the samples and 2% of the specimens; the 25-49 m grouping, 14% of the samples and 11% of the specimens; the 100-199 m grouping, 18 and 4%, respectively; the 200-499 m grouping, 14 and 2%, respectively; the 500-999 m grouping, 5 and 1%, respectively; and the 1,000-1,999 m depth range grouping contains 4% of the samples and 2% of the specimens (Table 8).

This bivalve was found in all of the sediment types considered in this report. Abundance with decreasing particle size is as follows: gravel contained 3% of the samples and 0.7% of the specimens; sand-gravel, 4 and 0.4%, respectively; till sediments, 4% of the samples and 0.8% of the specimens; shell contained 2% of the samples and 0.5% of the specimens; sand-shell contained 0.7% of the samples and 0.2% of the specimens; sand substrates, 24 and 16%, respectively; silty sand substrates contained the highest amounts, 29% for samples and 72% for specimens; silt contained 13% of the samples and 3% of the specimens; and clay substrates 20% for samples and 6% for specimens (Table 9). There are two samples containing six specimens which are unclassified with regard to sediment type.

Nucula proxima Say 1822. Atlantic nut clam. Figure 72.

The range of the Atlantic nut clam is from Newfoundland to Florida and Texas and it also occurs at Bermuda (Johnson 1934; Morris 1951 and 1973; La Rocque 1953; Ockelmann 1958; Abbott 1968, 1974; Emerson et al. 1976).

This tiny bivalve is a common member of the Northeast U.S. bivalve fauna. It bears the honor of being the most abundant member, at least in terms of specimens, of the NEFC Specimen Reference Collection which contains 12,091 specimens representing 11.1% of the entire collection; the specimens were obtained from 223 samples which represent 2% of the total number of samples in the collection (Table 5).

Our samples range nearly the entire length of the east coast continental shelf, beginning at the Scotian Shelf thence south to Jacksonville, Fla. (Fig. 72; Theroux and Wigley footnote 4, table 124).

The zoogeographic distribution of this species is Boreal, Virginian, and Carolinian (Coomans 1962); Gosner (1971) placed it in the Virginian province.

The Atlantic nut clam is quite widely distributed with regard to depth, ranging from approximately 1 to 805 m depth (Johnson 1934; Porter 1974).

The NEFC collection samples range in depth from 1 to 260 m with a mean of 48 m. Two depth range groupings vie for precedence in abundance of this organism: the 0-24 m depth range grouping contains 31% of the samples and 47% of the specimens, while the 50-99 m grouping contains 37% of the samples and 45% of the specimens; the 25-49 m grouping contains 27% of the samples and 7% of the specimens, while the 100-199 m grouping contains 5% of the samples and 0.8% of the specimens; the 200-499 m depth range grouping contains 0.9% of the samples and < 0.1% of the specimens (Table 10). There are 2 samples containing 18 specimens which do not have any depth information in their sampling data.

The Atlantic nut clam occupied all sediment types considered in this report in varying proportions. The majority of both samples and specimens occurred in sand substrates where 48% of the samples and 40% of the specimens were obtained; silty sand contained 17% of the samples and 33% of the specimens and clay contained 15% of the former and 22% of the latter. The abundance in the other sediment types, gravel, till, shell, sand-shell, and silt ranged from 10% to < 0.5% of the samples; silt contained < 4% of the specimens, all of the others contained < 1% of the specimens (Table 11). There are 9 samples containing 32 specimens which are unclassified with regard to sediment type.

Nucula tenuis Montagu 1808. Smooth nut clam. Figure 73.

The smooth nut clam is widely distributed, being known from all Arctic seas and occurring in the North Atlantic as well as North Pacific Oceans. In the Atlantic it ranges from Labrador to Florida, also occurring at Greenland and in northern Europe, there it ranges south to Gibraltar and possibly into the Mediterranean; in the Pacific it ranges from Arctic seas to as far south as northern Japan and to Baja, California (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Ockelmann 1958; Clarke 1962; Tebble 1966; Abbott 1974).

Nucula tenuis is a common small bivalve which is represented in the NEFC collection by 2,031 specimens, representing 2% of the total number of specimens, from 215 samples which also represent 2% of the total number of samples (Table 5).

The NEFC samples occupy nearly the whole of the Gulf of Maine, the periphery of Georges Bank, ranging onto the continental shelf area in the Mid-Atlantic Bight region between Cap Cod, Mass., and Cape Hatteras, N.C. (Fig. 73; Theroux and Wigley footnote 4, table 125).

Ockelmann (1958) considered its distribution to be panarctic-boreal and stated that it is circumpolar; Coomans (1962) placed it in the Boreal, Virginian, and Celtic provinces, while Gosner (1971) placed it in the Boreal and Virginian provinces; Dance (1974) placed it in the Arctic, Boreal, Californian, Mediterranean, and Japonic provinces.

Nucula tenuis enjoys a widespread bathymetric range, occupying water depths from slightly offshore to rather deep water, ranging from 4 to 2,297 m (Clarke 1962).

The NEFC suite of samples ranges in depth between 16 and 2,365 m with a mean of 320 m. There were members of the smooth nut clam occupying all of the depth range groupings used in this report; however, two mid to outer continental shelf depth range groupings contain the majority of both samples and specimens. Forty-one percent of the samples are in the 100-199 m grouping and 24% of the samples are in the 50-99 m grouping while specimen abundance is greatest in the 50-99 m grouping with 55%, and 24% occurs in the 100-199 m grouping. Significantly smaller amounts occur in the other depth range groupings. The 0-24 m grouping contains 0.5% of the samples and < 0.1% of the specimens; 8% of the samples and 4% of the specimens are in the 25-49 m grouping; there is 8% of the samples in the 200-499 m and 500-999 m groupings which contain 3 and 5%, respectively, for specimens; the 1,000-1,999 m depth range grouping contains 9% of the samples and 10% of the specimens; the 2,000-3,999 m depth range grouping contains 1% of the samples and 0.4% of the specimens (Table 12).

As with depth, the smooth nut clam occurred in all sediment types considered in this report. The distribution of both samples and specimens with decreasing particle size is as follows: 3% of the samples and 0.5% of the specimens occurred in gravel; sand-gravel contained 6% of the samples and 4% of the specimens; till substrates 3 and 0.8%, respectively; shell, 1% of the samples and 1% of the specimens; sand-shell, 0.5% of the samples and 0.1% of the specimens; sand substrates contained 18 and 8%, respectively; silty sand, which contained the greatest abundance, yielded 36 and 36%, respectively, while silt contained 16% of the samples and 20% of the specimens; the finest substrate, clay, contained 18% of the samples and 29% of the specimens (Table 13). There are 15 samples containing 75 specimens which are unclassified with regard to sediment type.

Nucula sp. Figure 74.

There are 961 specimens from 108 samples in the NEFC collection which bear the designation *Nucula* sp., members of the nut shell group (Table 5).

The distribution of samples containing members of this taxon of primarily deep water organisms ranges from off Nova Scotia south to Florida; however, there is one grouping of samples in the Gulf of Maine and the inshore waters of the Cape Cod region, and another off the Georgia Coast which are decidedly more inshore than the majority of samples (Fig. 74; Theroux and Wigley footnote 4, table 126).

The depth distribution for this taxon in the NEFC collection ranges from 13 to 2,722 m with a mean of 896 m. In terms of depth range groupings the majority of both samples and specimens follow the geographic distribution in that they occur in the 1,000-1,999 m grouping which contains 28% of the samples and 38% of the specimens. In terms of increasing depth range grouping the distribution of samples and specimens is as follows: the 0-24 m depth range grouping contains

3% of the samples and 15% of the specimens; the 25-49 m grouping, 10% of the former and 2% of the latter; the 50-99 m grouping contains 7 and 2%, respectively, while the 100-199 m grouping contains 12% of the samples and 20% of the specimens; the 200-499 m grouping contains 16 and 3%, respectively; the 500-999 m grouping 12 and 11%, respectively, and the deepest grouping, 2,000-3,999 m, contains 12% of the samples and 10% of the specimens (Table 14).

Shell was the only sediment type which did not contain any members of this taxon. In terms of decreasing particle size, distribution of samples and specimens is as follows: gravel contained 1% of the samples and 0.3% of the specimens; sand-gravel 2 and 19%, respectively; till substrates 1 and 2%, respectively, while sand-shell contained 6% of the samples and 2% of the specimens; sand sediments contained 17% of the samples and 5% of the specimens, while silty sand was equal with 30% for samples and specimens; silt contained the largest amounts of both samples and specimens with 32 and 37%, respectively, while the finest substrate, clay, contained 12% of the samples and 6% of the specimens (Table 15). There are 4 samples containing 200 specimens which are unclassified with regard to sediment type.

Family MALLETIIDAE
Genus *Malletia* Des Moulins 1832

Malletia obtusa G. O. Sars 1872. Blunt nutshell. Figure 60.

This nutshell is distributed from off Massachusetts to North Carolina in the western Atlantic and from Norway to off West Africa in the eastern Atlantic; it is also quite widely distributed in the Arctic and occurs in the Mediterranean and the Cape Verde Islands as well as the Canary Islands (Johnson 1934; Ockelmann 1958; Clarke 1962; Morris 1973; Abbott 1974).

The blunt nutshell is a deep water inhabitant which is represented by 145 specimens from 38 samples in the NEFC collection (Table 5).

Our samples are from the continental slope and upper continental rise between Nova Scotia and Cape Hatteras, N.C. (Fig. 60, Theroux and Wigley footnote 4, table 105).

The bathymetric range for this organism is 366 to 3,259 m (Johnson 1934; Clarke 1962).

The NEFC sample suite is from water depths ranging between 1,045 to 2,975 m with a mean of 1,998 m.

Fifty-three percent of the samples and 66% of the specimens are in the 1,000-1,999 m depth range grouping, and 47% of the samples and 34% of the specimens are in the 2,000-3,999 m grouping (Table 16).

Due to the deep dwelling habits of this species they were only found in sediment types of small particle size. The majority of samples (53%) and specimens (62%) occurred in silt. Clay substrates contained 26% of the samples and 21% of the specimens, and silty sand substrates contained 21% of the samples and 17% of the specimens (Table 17).

Genus *Saturnia* Sequenza 1877

Saturnia subovata Verrill and Bush 1897. Ovate nut shell. Figure 97.

This species is distributed from Nova Scotia to North Carolina (Johnson 1934; La Rocque 1953; Morris 1973).

Saturnia subovata is represented in the NEFC Specimen Reference Collection by 70 specimens from 22 samples (Table 5).

The NEFC samples are from the upper continental slope on the northeast peak of Georges Bank to the region between Delaware and Chesapeake Bays (Fig. 97; Theroux and Wigley footnote 4, table 171).

Johnson (1934) and La Rocque (1953) reported the depth range for this species as extending from 229 to 3,168 m.

Our samples are from deep water between 650 and 2,520 m with a mean of 1,911 m. The 500-999 m depth range grouping contains 5% of the samples and 4% of the specimens, while the 1,000-1,999 m grouping contains 46% of the samples and 57% of the specimens; the 2,000-3,999 m grouping contains 50% of the samples and 39% of the specimens (Table 18).

The ovate nut shell was found in the finer grained sediment types. Twenty-three percent of the samples and 23% of the specimens occurred in silty sand, while 64% of the samples and 59% of the specimens were found in silt; clay substrates contained 14% of the samples and 19% of the specimens (Table 19).

Family NUCULANIDAE

There are 98 samples in the NEFC collection containing 834 specimens which are classified to the family level of Nuculanidae (Table 5).

The samples containing this taxon range from the upper continental slope and lower continental shelf off Atlantic City, N.J., to south of Miami, Fla. (Fig. 79; Theroux and Wigley footnote 4, table 133).

Our samples range in depth from 45 to 2,680 m with a mean of 404 m. The majority of both samples (56%) and specimens (73%) are in the 200-499 m depth range grouping and diminish on either side of this grouping with increasing and decreasing water depth range. The 100-199 m grouping contains 10% of the samples and 18% of the specimens, the 50-99 m grouping, 4% of the samples and 1% of the specimens, and the 25-49 m grouping, the shallowest in which they are grouped, contains 3% of the samples and 0.5% of the specimens, the 500-999 m grouping contains 25% of the samples and 8% of the specimens, and the 2,000-3,999 m grouping contains 2% of the samples and 0.4% of the specimens (Table 20).

Members of this taxon were absent from two sediment types, sand-gravel and till. The majority of both samples and specimens occurred in sand, where 34% of the former, and 38% of the latter were found; silty sand substrates contained 29% of the samples, and 36% of the specimens, while silt substrates contained 20% of the former and 19% of the latter; the finest grained substrate, clay, contained 2% of the samples and 0.4% for specimens; sand-shell substrates contained 10% of samples and 4% of the specimens, while shell contained 2% for samples and 2% for specimens; the coarsest substrate, gravel, contained 3% for samples and 1% for specimens (Table 21).

Genus *Nuculana* Link 1807

Nuculana acuta (Conrad 1831). Pointed nut clam. Figure 75.

The pointed nut clam is found in both the North Atlantic and North Pacific Oceans. In the Atlantic it ranges from Cape Cod to Texas and the West Indies, and on to Brazil, while in the Pacific it ranges from the Aleutian Islands to the Gulf of California (Johnson 1934; La Rocque 1953; Abbott 1968, 1974; Morris 1973; Emerson et al. 1976).

This species, which is often very common in offshore areas, is represented by 352 specimens from 59 samples in our collection (Table 5).

The NEFC samples range from the continental shelf break south of Nantucket Shoals to the Mid-Atlantic Bight region (Fig. 75; Theroux and Wigley footnote 4, table 127).

Coomans (1962) placed this species in the Virginian, Carolinian, and Caribbean provinces, while Gosner (1971) placed it in the Virginian province.

The depth distribution of this specifies ranges from +1 to 412 m (Johnson 1934; Porter 1974).

Our samples are from depths ranging between 82 and 366 m with a mean of 149 m. The majority of both samples and specimens are in the 100-199 m depth range grouping which contains 80% of the samples and 90% of the specimens; the 50-99 m grouping contains 15% of the samples and 7% of the specimens, while the 200-499 m grouping contains 5% of the samples and 3% of the specimens (Table 22).

Silty sand substrates contained the majority of both samples and specimens with 42% of the former and 49% of the latter occurring in this sediment type; sand contained 34% of the samples and 38% of the specimens, while clay contained 19% of the samples and 11% of the specimens; the least preferred sediment type was silt where 5% of the samples and 2% of the specimens occurred (Table 23).

Nuculana carpenteri (Dall 1881). Carpenter's nut clam. Figure 75.

This species ranges from North Carolina to the West Indies (Johnson 1934; Morris 1973; Abbott 1974).

This is an uncommon bivalve of which the NEFC collection contains 45 specimens from 17 samples (Table 5).

Our samples are located at the continental shelf break between Cape Hatteras, N.C., and Key West, Fla. (Fig. 75; Theroux and Wigley footnote 4, table 128).

Although this species prefers deep water (Morris 1973), it ranges between 18 and 525 m depth (Abbott 1974).

Our samples range in depth between 140 and 400 m of water with a mean of 254 m. The 200-499 m depth range grouping contains the largest amounts of samples (82%) and specimens (89%); the 100-199 m grouping contains 18% of the samples and 11% of the specimens (Table 24).

Carpenter's nut clam was found in three sediment types within the study area. The majority of samples and specimens occured in silt, yielding 41 and 62%, respectively; silty sand sediments contained 41% of the samples and 22% of the specimens, and sand contained 18% of the samples and 16% of the specimens (Table 25).

Nuculana caudata (Donovan 1801). Tailed nut shell. Figure 75.

Johnson (1934) and Abbott (1974) reported this species as occurring from the Gulf of Maine to Virginia.

Nuculana caudata is uncommon in the region; the NEFC collection contains two specimens from one sample (Table 5).

Our sample is from the western tip of Browns Bank in the Gulf of Maine (Fig. 75; Theroux and Wigley footnote 4, table 129).

The tailed nut shell is a moderately deep water inhabitant, ranging in depth from 187 to 1,173 m (Johnson 1934; Abbott 1974). The NEFC sample is from a water depth of 253 m. This depth range places it in the 200-499 m depth range grouping.

Our sample was obtained in a substrate of till.

Nuculana pernula (Müller 1771). Müller's nut clam. Figure 76.

Müller's nut clam is distributed throughout the northern sections of both the Atlantic and Pacific Oceans. In the Atlantic it ranges from the Arctic Ocean to Cape Cod, Mass., while in the North Pacific it ranges from northern Alaska to Chatham Sound, British Columbia; it is also found in eastern Siberia (Johnson 1934; La Rocque 1953; Ockelmann 1958; Abbott 1968, 1974; Morris 1973).

Nuculana pernula is a common bivalve of northern waters; our collection contains 320 specimens from 199 samples (Table 5).

The NEFC samples are from the Gulf of Maine region with a few straggling samples on the northern part of Georges Bank (Fig. 76; Theroux and Wigley footnote 4, table 130).

Ockelmann (1958) considered this species to be panarctic-boreal in its distribution, while Gosner (1971) placed it in the Boreal province.

Müller's nut clam enjoys a rather widespread bathymetric range being found in water depths ranging between 3 and 1,643 m (Ockelmann 1958; Porter 1974).

Our samples are from water depths ranging from 46 to 611 m with a mean of 145 m. Distribution with increasing depth range is as follows: 3% of the samples and 3% of the specimens are in the 25-49 m depth range grouping, 34% of the samples and 51% of the specimens are in the 50-99 m grouping, 41% of the samples and 32% of the specimens in the 100-199 m grouping, 22% of the samples and 14% of the specimens in the 200-499 m grouping, < 1% of both samples and specimens are in the 500-999 m grouping (Table 26).

This species was found in all of the sediment types considered in this report. Sixteen percent of the samples and 17% of the specimens occurred in gravel, while sand-gravel contained 1% of the samples and 0.3% of the specimens; till substrates contained 24% of the samples and 21% of the specimens, while shell contained 2% of both samples and specimens; sand-shell substrates contained 3% of the samples and 2% of the specimens, sand substrates 8% of the former and 5% of the latter, with silty sand containing 14% samples and 26% of the specimens; the two finest grained substrates, silt, contained 8% of the samples and 4% of the specimens, and clay contained 25% of the samples and 25% of the specimens (Table 27). There are 6 samples containing 14 specimens which are unclassified with regard to sediment type.

Nuculana tenuisulcata (Couthouy 1838). Thin nut clam. Figure 77.

The thin nut clam is distributed from Arctic seas and the Gulf of St. Lawrence to Rhode Island (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Ockelmann 1958; Abbott 1974).

Nuculana tenuisulcata is the most common *Nuculana* of New England; it is represented in the NEFC Specimen Reference Collection by 469 specimens from 129 samples (Table 5).

The NEFC samples are distributed on the continental shelf, from around Nova Scotia, south into the Gulf of Maine (Fig. 77; Theroux and Wigley footnote 4, table 131).

Gosner (1971) placed this species in the Boreal province.

The bathymetric range of this species is from just below tide mark level to 275 m (Abbott 1974).

The samples in the NEFC collection range in depth between 38 and 366 m with a mean of 159 m. The majority of both samples and specimens are in the 100-199 m depth range grouping which contains 44% of the samples and 40% of the specimens; the 200-499 m grouping contains 29% of the samples and 31% of the specimens, while the 50-99 m grouping contains 23 and 27%, respectively; the smallest amounts of both samples and specimens are in the 25-49 m grouping with 4% of the former and 3% of the latter (Table 28).

Among the nine sediment types considered in this report, shell was the only one which did not contain any members of this species. In order of decreasing particle size, distribution of samples and specimens is as follows: 8% of the samples and 6% of the specimens occurred in gravel, 7% of the former and 3% of the latter in sand-gravel, while till contained 21% of the samples and 33% of the specimens; sand-shell substrates contained < 1% of the samples and 1% of the specimens, sand, 6% of the former and 3% of the latter; silty sand substrates, however, contained 28% of the samples and 29% of the specimens; the two finest grained substrates, silt and clay, contained 8 and 21%, respectively, for samples, and 9 and 17%, respectively, for specimens (Table 29). There are 9 samples containing 55 specimens which are unclassified with regard to sediment type.

***Nuculana* sp. Figure 78.**

The NEFC Specimen Reference Collection contains 448 specimens from 84 samples which are identified to the generic level of *Nuculana* sp. (Table 5).

Samples containing members of this genus are distributed from the central Gulf of Maine south to Key West, Fla., with a major gap occurring in the Middle Atlantic Bight Region (Fig. 78; Theroux and Wigley footnote 4, table 132).

The NEFC samples range in depth from 15 to 458 m of water with a mean of 141 m. The distribution of samples and specimens among the various depth range groupings is as follows: 2% of the samples and 0.7% of the specimens are in the 0-24 m depth range grouping, while 12% of the former and 4% of the latter are in the 25-49 m grouping. The 50-99 m grouping contains 21% of the samples and 61% of the specimens, with the 100-199 m grouping containing 42% of the former and 28% of the latter; the last depth range grouping in which these organisms are arrayed is the 200-499 m depth range grouping which contains 23% of the samples and 7% of the specimens (Table 30).

No member of this genus was found in either sand-gravel or till substrates; however, specimens were found in all other substrate types considered in this report. In order of decreasing particle size, the samples and specimens were distributed as follows: gravel contained 2% of the samples and 3% of the specimens, shell, 2% of the former and 1% of the latter; sand-shell substrates contained 17% of the samples and 28% of the specimens, while sand contained 24% of the former and 43% of the latter; silty sand contained 39% of the samples and 22% of specimens, silt, 1% for samples, 0.2% for specimens, and clay, the finest grained sediment type, contained 13% of the samples and 4% of the specimens (Table 31). There are two samples containing two specimens which are unclassified with regard to sediment type.

Genus *Yoldia* Möller 1842

***Yoldia limatula* (Say 1831). File yoldia. Figure 117.**

This species is widely distributed, occuring in both the North Atlantic and North Pacific Oceans. In the Atlantic it ranges from the Gulf of St. Lawrence and Nova Scotia, south to North Carolina, while in the Pacific it ranges from Alaska south to San Diego, Calif.; it also occurs in the eastern Atlantic (Johnson 1934; La Rocque 1953; Ockelmann 1958; Abbott 1968, 1974; Morris 1973; Emerson et al. 1976).

The file yoldia is represented in the NEFC collection by 375 specimens from 37 samples (Table 5), from the northern sector of the study area, ranging from off the coast of Maine, in the Gulf of Maine, on the southeastern part of Georges Bank, but primarily inshore from the Cape Cod region south into Chesapeake Bay (Fig. 117; Theroux and Wigley footnote 4, table 210).

The zoogeographic distribution of this species is in the Boreal and Virginian provinces according to Coomans (1962) and Gosner (1971); Dance (1974) placed it in the Transatlantic and Boreal provinces in eastern North America, and in the Arctic province.

This species is primarily a shallow water inhabitant, occupying water depths from just below the low water mark in bays and inlets in nearshore areas out to approximately 23 m (Abbott 1968, 1974; Porter 1974).

Our samples are from water depths which range from 0 to 121 m with a mean of 29 m. The majority of both samples and specimens are in the shallower depth range groupings with 60% of the samples and 64% of the specimens occurring in the 0-24 m grouping and 30% of the samples and 29% of the specimens in the 25-49 m grouping; the 50-99 and 100-199 m groupings each contain 5% of the samples and 6.7% and 0.5% of the specimens, respectively (Table 32).

Morris (1973) and Emerson et al. (1976) both reported this species as a mud bottom inhabitant.

Our samples were obtained from the finer grained sediments which ranged from sand down to clay. Sand contained 70% of the samples and 40% of the specimens; silty sand substrates yielded 23% of the samples and 22% of the specimens, while silt and clay each contained 3% of the samples but 38% and 0.3% of the specimens, respectively (Table 33). There are 7 samples containing 33 specimens which are unclassified with regard to sediment type.

***Yoldia myalis* (Couthouy 1838). Comb yoldia. Figure 118.**

The comb yoldia is found in both the North Atlantic and North Pacific Oceans. In the Atlantic it ranges from Hudson Strait in Labrador to Massachusetts while in the Pacific it ranges from Alaska to Puget Sound, Wash. (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Ockelmann 1958; Abbott 1974).

There are 47 specimens of this species in the NEFC collection from 21 samples (Table 5).

Our samples are from the Scotian Shelf and along the coast of Maine (Fig. 118; Theroux and Wigley footnote 4, table 211).

The comb yoldia is an inhabitant of the Boreal province (Gosner 1971).

The depth distribution of this species is from moderately shallow water to approximately 146 m (Morris 1973; Abbott 1974).

Our samples are from depths which range between 7 and 100 m with a mean of 72 m. The majority of both samples and specimens are in the 50-99 m depth range grouping, which contains 81% of the samples and 87% of the specimens; the 25-49 m grouping contains 10% of the samples and 4% of the specimens, while each of the 0-24 m and 100-199 m groupings contain 5% of the samples but 6 and 2%, respectively, for specimens (Table 34).

Morris (1973) indicated that this species prefers muddy substrates. Our samples were obtained from nearly all the sediment types considered in this report with the exception of sand and clay. Abundances of samples and specimens with regard to sediment type are as follows: gravel substrates contained 33% of the samples and 25% of the specimens, while sand-gravel yielded 28% of the samples and 32% of the specimens; three sediment types, till, silty sand, and silt, each contained 6% of the samples but 2.3% of the specimens for both till and silty sand, and 7% of the specimens occurred in silt; both shell and sand-shell each contained 11% of the samples and 27 and 5% of the specimens, respectively (Table 35). There are three samples containing three specimens which are unclassified with regard to sediment type.

Yoldia regularis Verrill 1884. Figure 118.

Published distributional information for this species shows it to occur from Newfoundland to off Martha's Vineyard, Mass. (Johnson 1934; Ockelmann 1958; Abbott 1974).

There are 43 specimens from 6 samples of this species in the NEFC Specimen Reference Collection (Table 5). The NEFC suite of samples is from the Gulf of Maine, ranging from south of Grand Manan Island south to Cape Cod Bay (Fig. 118; Theroux and Wigley footnote 4, table 212).

Both Johnson (1934) and Gosner (1971) listed the depth range for this species as being 179 to 639 m.

The NEFC samples are from water depths which range between 44 and 142 m with a mean of 83 m. The 50-99 m depth range grouping contains 82% of the samples and 76% of the specimens, while each of the 25-49 m and 100-199 m groupings contain 9% of the samples but 2 and 21%, respectively, of the specimens (Table 36).

Specimens of *Yoldia regularis* were obtained from three sediment types, all of which were the finer grained substrates. The majority of samples were in silty sand which contained 55% of the samples, but only 21% of the specimens; silt, however, while containing 36% of the samples provided the majority of specimens 57%; clay sediments contained 9% of the samples and 21% of the specimens (Table 37).

Yoldia sapotilla (Gould 1841). Short yoldia. Figure 119.

This species, although primarily a northern or Arctic inhabitant ranges from Arctic seas and Labrador and Newfoundland to approximately North Carolina (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Ockelmann 1958; Abbott 1968, 1974).

Yoldia sapotilla is common and is represented in the NEFC collection by 279 samples, constituting 2.5% of the total number of samples, containing 2,128 specimens or nearly 2% of the total number of specimens (Table 5). The NEFC samples occur in the Gulf of Maine and Georges Bank with a large concentration of them on the Southern New England shelf and upper slope regions ranging south to approximately north and east of the entrance to Chesapeake Bay (Fig. 119; Theroux and Wigley footnote 4, table 213).

Coomans (1962) reported this species as an Arctic, Boreal, and Virginian province inhabitant, while Gosner (1971) placed it in the Boreal and Virginian provinces.

This species is considered to be a moderately deep water inhabitant occupying depths which range between 7 and 250 m (Abbott 1968; Porter 1974).

Our samples are from depths which range between 15 and 421 m with a mean of 109 m. The majority of both samples and specimens are in the 50-99 m depth range grouping which contains 55% of the samples and 66% of the specimens; the 100-199 m grouping contains 21% of the samples and 17% of the specimens, while the 200-499 m grouping contains 14% of the samples and 8% of the specimens, smaller amounts are in the shallower depth range groupings, 0-24 and 25-49 m which contain 0.7 and 10%, respectively, for samples and 0.1 and 8.2%, respectively, for specimens (Table 38). There is 1 sample containing 148 specimens for which no depth information is available.

Morris (1951) and Abbott (1968) both reported this species as normally found in mud habitats.

The only sediment type considered in this report in which this species was not found was gravel; it did, however, prefer the finer grained substrates over the coarser ones. Abundances in terms of decreasing particle size are as follows: sand-gravel substrates contained 0.4% of the samples and < 0.1% of the specimens, till substrates, 5% of the samples and 3% of the specimens, shell substrates, 0.4% of the samples and < 0.1% of the specimens, while sand-shell substrates contained 0.7% of the samples and 0.2% of the specimens; sand, however, contained 28% of the samples and 25% of the specimens, while silty sand contained 33% of the samples and 38% of the specimens; silt substrates contained 6% of the samples and 7% of the specimens, while clay contained 26% of the samples and 27% of the specimens (Table 39). There are 9 samples containing 158 specimens which are unclassified with regard to sediment type.

Yoldia thraciaeformis Storer 1838. Broad yoldia. Figure 120.

The broad yoldia occurs in both the Atlantic and Pacific Oceans; in the Atlantic it is distributed from the Arctic Ocean and Greenland to the New England coast at Massachusetts; in the Pacific it ranges from the Arctic Ocean to Puget Sound, Wash. (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Ockelmann 1958; Abbott 1968, 1974).

Yoldia thraciaeformis is moderately common and is represented in the NEFC collection by 158 specimens from 46 samples (Table 5).

The NEFC samples are from the western portion of the Gulf of Maine ranging from south of Grand Manan Island south into Cape Cod Bay (Fig. 120; Theroux and Wigley footnote 4, table 214).

Coomans (1962) reported the distribution of this species to be in the Arctic, Boreal, and Virginian provinces while Gosner (1971) placed it in the Boreal province. The depth distribution of this species ranges from shallow to deep water with a range of approximately 18 to 418 m (Johnson 1934; Abbott 1974; Porter 1974).

Our samples are from water depths which range between 46 and 271 m with a mean of 98 m. The majority of both samples and specimens are in the 50-99 m depth range grouping which contains 65% of the samples and 73% of the specimens, while 26% of the samples and 23% of the specimens are in the 100-199 m grouping; both the 25-49 and 200-499 m groupings contain 4% of the samples and 1.3 and 1.9% of the specimens, respectively (Table 40).

Morris (1973) reported that *Yoldia thraciaeformis* is normally found in mud substrates.

The majority of our samples and specimens occurred in clay substrates which contained 49% of the samples and 42% of the specimens while silt and silty sand substrates each contained 12% of the samples, but 34 and 8%, respectively, of the specimens. Other sediment types in which *Yoldia thraciaeformis* were found were till with 24% of the samples and 15% of the specimens and gravel which contained 2% of the samples and specimens (Table 41). There are 5 samples containing 14 specimens which are unclassified with regard to sediment type.

***Yoldia* sp. Figure 121.**

The NEFC Specimen Reference Collection contains 303 specimens of bivalves from 88 samples which, since many specimens had badly broken and/or eroded shells precluding exact classification, were identified only to the generic level *Yoldia* sp. (Table 5).

Samples containing members of the genus *Yoldia* are from the Gulf of Maine region extending from the Nova Scotian shelf to Cape Cod; there is also a group occurring on the outer continental shelf and upper slope from south of Cape Cod, Mass., into Long Island Sound (Fig. 121; Theroux and Wigley footnote 4, table 215).

The range of depth for these samples is 20 to 1,480 m with a mean of 196 m. The majority of both samples and specimens are in mid to lower continental shelf depth range groupings with the bulk in the 100-199 m grouping which contains 43% of the samples and 51% of the specimens; the 200-499 m grouping contains 35% of the samples and 25% of the specimens, while the 50-99 m grouping contains 15% of the samples and 20% of the specimens; 5% of the samples and 2% of the specimens are in the 25-49 m grouping and each of the 0-24 m and 1,000-1,999 m groupings contain 1% of the samples and 0.7 and 1.3%, respectively, of the specimens (Table 42).

As with other members of this group the fine sediment types were preferred over the coarser ones with the majority of both samples (34%) and specimens (40%) occurring in clay substrates; silty sand substrates accounted for 31% of both samples and specimens, while silt contained 12% of the samples and 11% of the specimens; both till and sand substrates each contained 10% of the samples, but 6 and 7%, respectively, for the specimens, and the coarsest fractions, sand-gravel and gravel, contained 2.4 and 1.2%, respectively for samples and 5 and 0.4%, respectively, for specimens (Table 43). There are 5 samples containing 31 specimens which are unclassified with regard to sediment type.

Genus *Portlandia* Moerch 1857.

***Portlandia fraterna* (Verrill and Bush 1898). Figure 92.**

This species is widely distributed throughout Arctic regions and also ranges from the Gulf of St. Lawrence to off Georgia; it is also found in northern Eurasia and in Norway (Johnson 1934; La Rocque 1953; Ockelmann 1958; Clarke 1962; Abbott 1974).

There are three samples containing five specimens of this tiny bivalve in the NEFC collection (Table 5).

The NEFC samples are from the Gulf of Maine (Fig. 92; Theroux and Wigley footnote 4, table 160).

Ockelmann (1958) reported that this species is probably panarctic and that it is abyssal in the North Atlantic only; Gosner (1971) placed it in the Boreal and Virginian provinces.

The reported depth range for *Portlandia fraterna* is from 5.5 to 2,943 m (Johnson 1934; Clarke 1962; Abbott 1974).

The range in depth of our samples is 183 to 211 m with a mean of 196 m. The 100-199 m depth range grouping contains 67% of the samples and 60% of the specimens, while the only other depth range, the 200-499 m grouping, contains 33% of the samples and 40% of the specimens (Table 44).

Samples containing *Portlandia fraterna* were found in silty sand and clay sediments; the former contained 67% of the samples and 60% of the specimens, the latter 33% of the samples and 40% of the specimens (Table 45).

***Portlandia frigida* (Torell 1859). Figure 92.**

The presence of this small bivalve is questionable in our waters according to Ockelmann (1958). He questioned the occurrence of this species in New England waters as reported by Verrill (1882a), and Verrill and Bush (1898), stating that it is truly high Arctic in distribution. Pending a revision of the group, and since our specimens agree with other investigator's descriptions and figures, we will tentatively maintain it as presently identified.

According to reports we have seen, this species is thought to range from Arctic seas and the Gulf of St. Lawrence to Massachusetts (Johnson 1934; La Rocque 1953; Clarke 1962; Abbott 1974). However, Ockelmann, as stated above, considered it to occur only in Arctic regions and listed a fairly widespread distribution for it there.

There are five specimens from three samples of this species in the NEFC collection (Table 5). Our samples are from the Gulf of Maine north and east of Cape Cod (Fig. 92; Theroux and Wigley footnote 4, table 161).

The depth range for this species is between 6 and 2,297 m (Clarke 1962; Abbott 1974).

The NEFC samples are from depths which range between 55 and 213 m with a mean of 160 m. The samples are grouped in two depth range groupings, the 50-99 m, which contains 33% of the samples and 20% of the specimens, and the 200-499 m grouping which contains 67% of the former and 80% of the latter (Table 46).

Thirty-three percent of our samples and 60% of our specimens occurred in silty sand sediments, while 67% of the samples and 40% of the specimens occurred in clay substrates (Table 47).

***Portlandia inconspicua* (Verrill and Bush 1898). Inconspicuous yoldia. Figure 92.**

This species is distributed in the Arctic and occurs from Nova Scotia to North Carolina in the northwestern Atlantic (Johnson 1934; La Rocque 1953; Ockelmann 1958; Abbott 1974).

The inconspicuous yoldia is represented by three specimens from one sample in our collection (Table 5).

Our sample is from the continental shelf south of Nantucket Shoals (Fig. 92; Theroux and Wigley footnote 4, table 162).

This species occupies water depths which range between 183 to 1,290 m (Abbott 1974).

Our sample is from a water depth of 59 m. This depth places it in the 50-99 m depth range grouping.

The sample in the NEFC collection was obtained in a sand sediment.

Portlandia inflata **(Verrill and Bush 1897). Inflated yoldia. Figure 93.**

This species normally occurs from off Massachusetts to North Carolina (Johnson 1934; Clarke 1962; Abbott 1974).

The inflated yoldia is represented in the NEFC collection by 197 specimens obtained from 24 samples (Table 5).

The majority of samples in the NEFC collection are from north and east of Cape Cod in the Gulf of Maine; however, there are two samples on the outer continental shelf and upper slope south of Nantucket Shoals (Fig. 93; Theroux and Wigley footnote 4, table 163).

The depth range for this species is between 73 and 2,943 m (Abbott 1974).

Our samples are from depths which range between 55 and 458 m with a mean of 259 m. The largest amounts of both samples and specimens are in the 200-499 m depth range grouping which contains 75% of the samples and 92% of the specimens; the 50-99 m grouping contains 21% of the samples and 6% of the specimens, and the 100-199 m grouping contains 4% of the former and 2% of the latter (Table 48).

The greatest number of samples (50%) occurred in clay substrates; however, the largest number of specimens occurred in sand-gravel which contained 65% of the specimens but only 17% of the samples; clay sediments contained 20% of the specimens; other sediment types in which this organism was found were till, with 4% of the samples, and 0.5% of the specimens, and silt which contained 25% of the samples and 13% of the specimens (Table 49).

Portlandia iris **(Verrill and Bush 1897). Iris yoldia. Figure 94.**

This species occurs from the Gulf of St. Lawrence to North Carolina as well as being distributed in some sections of the Arctic (Johnson 1934; La Rocque 1953; Ockelmann 1958; Morris 1973; Abbott 1974).

The NEFC Specimen Reference Collection contains 334 specimens of the iris yoldia from 47 samples (Table 5).

The NEFC samples are principally from the Gulf of Maine region, but four samples occur on the upper continental slope off Long Island, N.Y. (Fig. 94; Theroux and Wigley footnote 4, table 164).

Gosner (1971) placed this species in the Boreal and Virginian zoogeographic provinces.

Published reports on the depth distribution of this species list it as occurring between 37 and 2,928 m (Gosner 1971; Abbott 1974).

The range in depth of our samples is between 15 and 376 m with a mean of 191 m. There is a gradual diminution in the abundance of both samples and specimens with decreasing water depth with regard to depth range groupings. The majority of samples (55%) and specimens (61%) are in the 200-499 m depth range grouping, while the 100-199 m grouping contains 28% of the samples and 26% of the specimens; the 50-99 m grouping contains 15% of the samples and 13% of the specimens, while the shallowest depth range grouping, 0-24 m, contains only 2% of the samples and 0.3% of the specimens (Table 50).

Our data show that this species prefers finer grained sediments to the coarser ones with the majority of both samples and specimens occurring in the three finest grained sediments, clay, silt, and silty sand: clay contained 30% of the samples and 38% of the specimens, silt sediments contained 15% of the samples and 13% of the specimens, while silty sand substrates contained 28% of the samples and 35% of the specimens. Sand substrates contained 7% of the samples and 7% of the specimens, till 15% of the samples and 5% of the specimens, gravel, the coarsest, contained only 4% for samples and 2% for specimens (Table 51). One sample containing three specimens is unclassified with regard to sediment type.

Portlandia lenticula **(Möller 1842). Figure 94.**

The widest distribution of this species occurs in Arctic regions according to Ockelmann (1958) where he considered it to be panarctic and possibly circumpolar. In Boreal areas it occurs north of Cape Cod, Mass. (Johnson 1934; Abbott 1974).

This is a rather uncommon species of which there are four specimens from four samples in our collection (Table 5).

Our samples are from the Gulf of Maine and Massachusetts Bay (Fig. 94; Theroux and Wigley, footnote 4, table 165).

Johnson (1934) and Abbott (1974) reported the depth range for this species in southerly regions to be from 201 to 223 m, while Ockelman (1958), giving the depth distribution for northern regions, listed it as occurring from 0 to 1,400 m.

Our samples are from water depths which range between 59 and 265 m with a mean of 122 m. The 50-99 m depth range grouping contains 75% each of samples and specimens, while the 200-499 m grouping contains 25% of each (Table 52).

The distribution of samples and specimens with regard to sediment type is similar to that which occurred for depth range in that 75% of both samples and specimens occurred in one sediment type, silty sand, while 25% of each occurred in silt (Table 53).

Portlandia lucida **(Lovén 1846). Lucid yoldia. Figure 95.**

The lucid yoldia is distributed from Greenland to North Carolina in the Northwest Atlantic and from Norway to the Mediterranean in European waters, as well as being widespread throughout Arctic regions (Johnson 1934; La Rocque 1953; Ockelmann 1958; Clarke 1962; Tebble 1966; Morris 1973; Abbott 1974).

Portlandia lucida is uncommon to rare; it is represented in the NEFC collection by 161 specimens from 27 samples (Table 5).

Our samples are distributed in the Gulf of Maine to the north and east of Cape Cod, Mass. (Fig. 95; Theroux and Wigley footnote 4, table 166).

The main distribution of this species according to Ockelmann (1958) is low Arctic-boreal, and Mediterranean-Atlantic, and is abyssal in the North Atlantic only; Gosner (1971) placed it in the Boreal and Virginian provinces.

The lucid yoldia is an inhabitant of moderately deep water occupying depths which range between 28 and 2,943 m (Clarke 1962).

The samples in the NEFC collection are from waters which range in depth between 10 and 366 m with a mean of 167 m. The occupation of moderately deep water by this species is reflected in the depth range distribution of the samples in the NEFC collection in that 45% of the samples and 48% of the specimens are in the 100-199 m depth range grouping; the 200-499 m grouping contains 33% of the samples and 40% of the specimens, while the 50-99 m grouping contains 19% for samples and 11% of the specimens; one sample (4%) and one specimen (0.6%) are in the 0-24 m grouping (Table 54).

The majority of our samples (40%) occurred in clay sediments; however, the greatest number of specimens (45%) occurred in till sediments which contained 16% of the samples, clay on the other hand contained 16% of the specimens; silty sand sediments contained 24% of the samples and 26% of the specimens. Other sediment types in which this species was found in our region were gravel, sand-gravel, sand-shell, sand, and silt substrates (Table 55). There are 2 samples containing 29 specimens which are unclassified with regard to sediment type.

Portlandia minuscula **(Verrill and Bush 1897). Figure 95.**

Johnson (1934), Clarke (1962), and Abbott (1974) reported the distribution of this species to extend from off Massachusetts to Virginia.

The NEFC collection contains two specimens from one sample of this rather rare bivalve species (Table 5).

Our sample is from the Gulf of Maine proper adjacent to the northern edge of Georges Bank (Fig. 95; Theroux and Wigley footnote 4, table 167).

The above authors gave the depth distribution of this species as being 924 to 2,361 m.

Our sample is from a water depth of 192 m which places it in the 100-199 m depth range grouping.

The sample from which the specimens of this species were obtained was unclassified with regard to sediment type.

Subclass CRYPTODONTA
Order SOLEMYOIDA
Family SOLEMYACIDAE
Genus *Solemya* Lamarck 1818

Solemya borealis **Totten 1834. Boreal awning clam. Figure 99.**

The boreal awning clam is normally found in the Canadian Maritime Provinces of Newfoundland, Labrador, and Nova Scotia and ranges south to the shores of Connecticut (Johnson 1934; La Rocque 1953; Ockelmann 1958; Abbott 1968, 1974; Morris 1973; Emerson et al. 1976).

Although *Solemya borealis* is a moderately common to frequently occurring form within its range, the NEFC Specimen Reference Collection contains only one specimen from one sample (Table 5).

Our sample comes from the shore of Martha's Vineyard, Mass. (Fig. 99; Theroux and Wigley footnote 4, table 177).

Gosner (1971) reported this species from the Boreal province, while Dance (1974) claimed that is a Transatlantic inhabitant.

The normal depth range for this species occurs in shallow waters; however, it does range from 6 to 183 m in depth (Abbott 1968, 1974; Gosner 1971).

Our sample is from the shore at 0 m depth which places it in the 0-24 m depth range grouping.

We have not found any sediment preferences in the literature and unfortunately the collection data did not contain any sediment information for our sample.

Solemya velum **Say 1822. Common Atlantic awning clam. Figure 100.**

The range of this species is from Nova Scotia and Newfoundland to Florida (Johnson 1934; La Rocque 1953; Ockelmann 1958; Abbott 1968, 1974; Emerson et al. 1976).

Solemya velum is common to frequently occurring and is represented in our collection by 67 specimens from 33 samples (Table 5).

Our samples are from the Gulf of Maine, the periphery of Cape Cod, Mass., Georges Bank, and range on the outer continental shelf and slope, south to slightly north of Miami, Fla. (Fig. 100; Theroux and Wigley footnote 4, table 178).

This species is an inhabitant of the Boreal, Virginian, and Carolinian provinces (Coomans 1962); Gosner (1971) placed it in the Boreal and Virginian, and Dance (1974) stated that it is a Transatlantic inhabitant.

This species is normally found in intertidal areas and in shallow water bays but it does range out to 90 m (Abbott 1968, 1974; Porter 1974; Emerson et al. 1976).

The depth range of our samples is from 1 to 1,660 m with a mean of 105 m. The 0-24 m depth range grouping contains 42% of the samples and 65% of the specimens, while the 25-49 m grouping contains 15% of the samples and 8% of the specimens; the 50-99 m grouping contains 27% of the samples and 20% of the specimens, while the 100-199 m and the 200-499 m groupings each contain 6% of the samples and 3% of the specimens; the 1,000-1,999 m grouping contains 3% of the samples and 2% of the specimens (Table 56).

Morris (1951), Abbott (1974), and Emerson et al. (1976) all considered this species to inhabit mud and sand substrates.

Our samples also occupied medium to fine-grained substrates. Sand-shell substrates contained 10% of the samples and 5% of the specimens; sand substrates 57% of the samples and 35% of the specimens; silty sand sediments contained 14% of the former and 49% of the latter, while silt and clay substrates each contained 10% of the samples and 5% of the specimens (Table 57). There are 12 samples containing 28 specimens which are unclassified with regard to sediment type.

Subclass PTERIOMORPHIA
Order ARCOIDA
Family ARCIDAE

Our collection contains 7 samples yielding 15 specimens of members of the family Arcidae (Table 5).

The distribution of our samples is split into two groupings; one involves three samples in Chesapeake Bay, and the other, more loosely distributed off the middle and southern New England coast (Fig. 7; Theroux and Wigley footnote 4, table 11).

Members of this family are distributed in the Virginian, Carolinian, and Caribbean provinces in the western Atlantic and in the Celtic province in Europe (Coomans 1962).

Samples in our collection containing this taxon range from 13 to 3,820 m in depth, this range includes the deepest sampling site in our data base, the mean depth is 615 m. The 0-24 m depth range grouping contains 43% of the samples and 53% of the specimens; the 50-99, 100-199, 200-499, and 2,000-3,999 m depth range groupings each contain 14% of the remaining samples; specimen density in the above groupings is 13, 7, 7, and 20%, respectively (Table 58).

Fourteen percent of the samples containing Arcidae occurred in each of the following sediment types (percent specimens in parentheses): gravel (7), sand-gravel (7), till (7), silty sand (20), and clay (13). Sand contained 29% of the samples and 47% of the specimens (Table 59).

Genus *Anadara* Deshayes 1830.

***Anadara ovalis* (Bruguière 1789). Blood ark. Figure 4.**

The blood ark is distributed from Massachusetts to the Gulf States; it also occurs in the West Indies and Brazil (Morris 1973; Abbott 1968, 1974; Emerson et al. 1976).

There are three samples containing three specimens of this species in our collection (Table 5). It is considered to be common to very abundant within its range (Abbott 1968, 1974; Dance 1974).

Our samples are from Woods Hole, Mass., on the southern Rhode Island shore, and east of Atlantic City, N.J. (Fig. 4; Theroux and Wigley footnote 4, table 6).

The main distribution is Transatlantic and Caribbean (Dance 1974).

The reported depth distribution for this species is from 0.3 to 31 m (Abbott 1968; Porter 1974).

Our samples range in depth from 0 to 24 m with a mean depth of 8 m.

Two samples containing *A. ovalis* were in a sand substratum, while the third was unclassified with regard to sediment type.

***Anadara transversa* (Say 1822). Transverse ark. Figure 4.**

The transverse ark is reported to occur from Massachusetts to Florida, and is also found in Texas, the West Indies, and the Caribbean (Johnson 1934; Abbott 1968, 1974; Morris 1973; Emerson et al. 1976).

There are 6 samples containing 17 specimens of this fairly common species in our collection (Table 5).

Our samples are from off the New England coast with one sample in the shoal region of Georges Bank and the remainder in Vineyard Sound and at the entrance to Long Island Sound (Fig. 4; Theroux and Wigley footnote 4, table 7).

The main distribution of this species is Virginian and Carolinian in the western Atlantic, and Celtic in Europe for the family (Coomans 1962); Gosner (1971) listed it as Virginian, and Dance (1974) as Transatlantic and Caribbean.

The bathymetric distribution of the transverse ark is from below low water to about 37 m. (Abbott 1968, 1974; Porter 1974).

The depth range of our samples is from 0 to 37 m with a mean of 12 m. The 0-25 m depth range grouping contains 83% of the samples and 94% of the specimens while the remaining 17 and 6%, respectively, are in the 25-49 m grouping.

Anadara transversa is found on rocks in sandy mud, and in sandy and mud bottoms (Abbott 1968, 1974; Morris 1973; Emerson et al. 1976).

One of our samples containing two specimens was obtained from a silty sand substratum; the remainder of our samples were unclassified with regard to sediment type.

Genus *Arca* Linné 1758

***Arca* sp. Figure 7.**

There are 11 samples in our collection containing 19 specimens of the genus *Arca* (Table 5).

All of our samples occur between Cape Hatteras, N.C., and Miami, Fla. (Fig. 7; Theroux and Wigley footnote 4, table 10). Although the distribution chart shows only nine locations for this genus, one of the sampling sites yielded three replicate samples containing specimens.

This genus is Virginian, Carolinian, and Caribbean in distribution (Coomans 1962).

Our samples range from 6 to 852 m in depth with a mean of 192 m. The majority of samples (36%) and specimens (37%) are in the 25-49 m depth range grouping. The 0-24 and 500-999 m groupings contain 27 and 18% of the samples and 26 and 21% of the specimens, respectively; both the 50-99 and 200-499 m groupings contain 9% of the samples but 5 and 11% of the specimens, respectively (Table 60).

Members of the genus *Arca* were found in four sediment types: 45% of the samples and 47% of the specimens occurred in sand with lesser amounts occurring in sand-shell, silty sand, and silt substrates (Table 61).

Genus *Bathyarca* Kobelt 1891

***Bathyarca anomala* (Verrill and Bush 1898). Figure 18.**

Both Johnson's (1934) and Abbott's (1974) information concerning this species is the reiteration of that provided by Verrill and Bush (1898) that it occurs off Cashes Ledge in the Gulf of Maine at 49 m depth.

There are 9 samples containing 129 specimens of this small bivalve in our collection (Table 5).

Our samples are all from the Gulf of Maine and at the mouth of the Bay of Fundy (Fig. 18; Theroux and Wigley footnote 4, table 29).

The samples in our collection range from 73 to 234 m in depth with a mean of 147 m. The majority of both samples and specimens, 44 and 58%, respectively, are in the 100-199 m depth range grouping; lesser amounts, 22% of samples and 39% of specimens, are in the 50-99 m grouping, and 33% of samples but only 3% of specimens are in the 200-499 m grouping (Table 62).

The majority of our samples and specimens were found in till substrates, 38 and 90%, respectively; 25% of the samples and 4% of specimens were in clay, while sand-gravel, sand, and silty sand sediments each contained 13% of the samples and from 4 to 2% of the specimens (Table 63). One sample containing 72 specimens is unclassified with regard to sediment type.

***Bathyarca pectunculoides* (Scacchi 1834). Scalloplike ark. Figure 19.**

Bathyarca pectunculoides occurs from the Gulf of St. Lawrence to off Cape Cod, Mass., and is also found in Greenland (Johnson 1934; La Rocque 1953; Morris 1973; Abbott 1974). Ockelmann (1958) showed a fairly widespread distribution in Arctic regions and the North Sea, while Clarke's (1962) data extended its distribution to include the Gulf of Mexico, North Eurasia, Western Europe, the Canaries, and the Mediterranean Sea.

There are 1,297 specimens from 157 samples of this species in our collection (Table 5).

Our samples, in the main, are from the Gulf of Maine and around Nova Scotia with a few occurring on the mid to upper continental slope from southern Georges Bank south to off Atlantic City, N.J. (Fig. 19; Theroux and Wigley footnote 4, table 30).

Gosner (1971) placed this species in the Boreal province.

The scalloplike ark is a deep water inhabitant, occupying a depth range of from 49 to 926 m (Johnson 1934); Clarke (1962) listed a depth range of 37 to 3,312 m.

Our samples range from 73 to 458 m in depth with a mean of 184 m. The majority of our samples (61%) and specimens (73%) are in the 100-199 m depth range grouping; the 200-499 m grouping contains 34% of the samples and 20% of the specimens, while the 50-99 m grouping contains only 5 and 7% of the samples and specimens, respectively (Table 64).

Sand and sand-shell were the only two sediment types which did not contain members of this species. The largest number of samples were in silty sand (36%), with till, gravel, and clay containing diminishing but significant amounts (20, 16, and 10%, respectively). Sand-gravel, sand, and silt sediments each contained < 8% of the samples. Gravel yielded the greatest amount of specimens (44%), followed by till (32%) and silty sand (14%). Sand-gravel, sand, silt, and clay each accounted for < 4% of the specimens (Table 65). There are 17 samples containing 202 specimens which are unclassified with regard to sediment type.

***Bathyarca* sp. Figure 20.**

The NEFC collection contains 14 specimens of *Bathyarca* sp. from 9 samples (Table 5).

Samples yielding spcimens of *Bathyarca* sp. are from the Gulf of Maine (Fig. 20; Theroux and Wigley footnote 4, table 31).

The depth range of our samples is 128 to 242 m with a mean of 182 m. Two-thirds of the samples and 79% of the specimens are in the 100-199 m depth range grouping, and 33% of the samples with 21% of the specimens are in the 200-499 m grouping (Table 66).

No members of this taxon were found in gravel, sand-shell, or silt substrates. One-third of the samples containing 50% of the specimens occurred in clay sediments; 11 to 22% of the samples and 7 to 14% of the specimens occurred in other sediment types (Table 67).

Genus *Noetia* Grey 1840

***Noetia ponderosa* (Say 1822). Ponderous ark. Figure 70.**

The distribution of this species is from Cape Cod to Florida and Texas and it also occurs in the West Indies. It is uncommon in the northern reaches of the study area but very abundant south of Cape Hatteras, N.C. (Johnson 1934; Morris 1951, 1973; Abbott 1968, 1974; Emerson et al. 1976).

Noetia ponderosa is very common and abundant in southern regions; there are only five specimens of this species from one sample in our collection (Table 5).

Our sample is from inshore Connecticut waters (Fig. 70; Theroux and Wigley footnote 4, table 122).

The zoogeographic distribution of this species is in the Virginian and Carolinian provinces for American waters (Coomans 1962); Gosner (1971) placed it in the Virginian province, while Dance (1974) placed it in the Transatlantic and Caribbean provinces.

The ponderous ark is primarily a shallow water inhabitant but does range out to 37 m in depth (Abbott 1968, 1974; Porter 1974).

Our sample is from a water depth of 1 m. This depth places it in the 0-24 m depth range grouping.

Abbott (1958, 1974) and Morris (1973) reported the ponderous ark from sand bottoms. The NEFC sample is unclassified with regard to sediment type.

Family LIMOPSIDAE

There are 16 samples containing 1,052 specimens which are identified to the level of family Limopsidae in our collection (Table 5).

Samples containing members of this taxon are distributed from slightly south and offshore of Delaware Bay and at the entrance to Chesapeake Bay and range, with a gap at Cape Hatteras, N.C., to Key West, Fla. (Fig. 52; Theroux and Wigley footnote 4, table 85).

Our samples of this taxon range in depth from 13 to 60 m with a mean of 259 m. Fifty percent of the samples and 3% of the specimens are in the 100-199 m depth range grouping while 25% of the samples but 97% of the specimens are in the 200-499 m grouping; the 500-999 m grouping contains 13% of the samples but only 0.3% of the specimens; the 0-24 m grouping and the 50-99 m grouping each contain 6% of the samples but 0.2 and 0.1% of the specimens, respectively (Table 68).

The majority of samples and specimens were obtained in sand which contained 50% of the samples and 99% of the specimens; gravel contained 6% of the samples and 0.2% of the specimens, sand-shell 19% of the samples and 0.5% of the specimens, while silty sand and silt each contained 13% of the samples and 0.3 and 0.2% of the specimens, respectively (Table 69).

Genus *Limopsis* Sassi 1827

***Limopsis affinis* Verrill 1885. Gregarious limopsis. Figure 52.**

Both Johnson (1934) and Abbott (1974) reported this species as occurring south of Martha's Vineyard, Mass., whereas, Morris (1973) reported it as occurring from Massachusetts to Florida.

There are 10 specimens from 4 samples of this rather rare species in the NEFC collection (Table 5).

Our samples are from the upper continental slope between Delaware Bay and Cape Hatteras, N.C. (Fig. 52; Theroux and Wigley footnote 4, table 86).

Johnson (1934) and Abbott (1974) reported a depth occurrence of 361 m for this species.

Our samples are from between 1,100 and 1,800 m in depth with a mean of 1,540 m. This depth range places all samples and specimens in the 1,000-1,999 m depth range grouping (Table 70).

Our samples occurred in three sediment types: silty sand, silt, and clay. Fifty percent of the samples and 20% of the specimens occurred in silt while each of the remaining two types, silty sand and clay, contained 25% of the samples and 40% of the specimens (Table 71).

***Limopsis cristata* Jeffreys 1876. Cristate limopsis. Figure 52.**

The distribution of this species is from Cape Cod, Mass., to southeast Florida (Johnson 1934; Abbott 1974). It is also found in the Caribbean and western Europe (Clarke 1962).

This species which is commonly dredged off Florida, is represented by four specimens from three samples in our collection (Table 5).

Our samples are from continental slope waters south of Georges Bank with one inshore sample north of Jacksonville, Fla. (Fig. 52; Theroux and Wigley footnote 4, table 87).

Johnson (1934) reported a depth distribution of 156 to 2,004 m, while Clarke (1962) reported a depth range of 117 to 5,014 m.

Our samples are from water depths ranging from 8 to 1,625 m with a mean of 699 m. Thirty-three percent of the samples and 25% of the specimens are in the 0-24 m and 200-499 m depth range groupings; whereas, 33% of the samples and 50% of the specimens are in the 1,000-1,999 m grouping (Table 72).

Two of our samples occurred in silty sand accounting for 67% of the samples and 50% of the specimens, and one sample or 33% of the samples occurred in silt which contained 50% of the specimens (Table 73).

***Limopsis minuta* Philippi 1836. Minute limopsis. Figure 53.**

The distribution of this species ranges from Newfoundland to both sides of Florida (Johnson 1934; La Rocque 1953; Morris 1973; Abbott 1974). Ockelmann (1958) and Clarke (1962) reported on the distribution of this species for Arctic and European regions where it is fairly widespread, including the Canary Islands and the Mediterranean.

Limopsis minuta is represented by 30 specimens from 13 samples in the NEFC collection (Table 5).

Of the 13 samples in the NEFC collection, 1 is in the Gulf of Maine, the remainder are on the upper continental slope between Browns Bank and Chesapeake Bay (Fig. 53; Theroux and Wigley footnote 4, table 88).

The minute limopsis is a deep water species which ranges between 55 and 5,014 m depth (Clark 1962).

Our samples range from 16 to 1,660 m in depth with a mean of 1,038 m. Sixty-two percent of the samples and 60% of the specimens are in the 1,000-1,999 m depth range grouping; 23% of the samples and 33% of the specimens are in the 500-999 m grouping and both the 200-499 m and 0-24 m groupings contain 8% of the samples and 3% of the specimens (Table 74).

Two sediment types, silty sand and silt, each yielded 31% of the samples but 23 and 17% of the specimens, respectively; however, clay accounted for 23% of the samples and 37% of the specimens; it was found in one other sediment type within our study area, sand-gravel, which contained 8% of the samples and 3% of the specimens (Table 75).

***Limopsis sulcata* Verrill and Bush 1898. Sulcate limopsis. Figure 53.**

This species is reported to occur from Cape Cod, Mass., to Florida; it ranges into the Gulf States and the West Indies (Johnson 1934; Morris 1973; Abbott 1974).

The NEFC collection contains 21 specimens from 6 samples of this common species (Table 5).

Our samples are located at the continental shelf break and on the upper continental slope between Nova Scotia and Hudson Canyon (Fig. 53; Theroux and Wigley footnote 4, table 89).

The sulcate limopsis is a moderately shallow to deep water inhabitant occupying depths between 80 and 639 m (Abbott 1974; Porter 1974).

Our samples are from water depths ranging between 93 and 1,934 m with a mean of 1,406 m. The 50-99 m depth range grouping contains 17% of the samples and 48% of the specimens, while the 1,000-1,999 m grouping contains 83% of the samples and 52% of the specimens (Table 76).

Our samples were obtained from three sediment types: silty sand, silt, and clay, each of which contained 33% of the samples but 14, 33, and 52% of the specimens, respectively (Table 77).

***Limopsis* sp. Figure 53.**

The NEFC collection contains two specimens from two samples of this genus (Table 5).

Our samples are located on the upper portion of the continental slope south of Cape Cod, Mass. (Fig. 53; Theroux and Wigley footnote 4, table 90).

The samples are from 400 and 1,550 m water depth. Fifty percent of both samples and specimens are in the 200-499 m depth range grouping; the remaining 50% of the samples and specimens are in the 1,000-1,999 m grouping (Table 78).

Our samples were obtained from silty sand and silt sediments, each of which contained one sample and one specimen (Table 79).

Family GLYCYMERIDIDAE
Genus *Glycymeris* Costa 1778

***Glycymeris americana* (DeFrance 1829). Giant American bittersweet. Figure 46.**

This species occurs from North Carolina to Florida; it also occurs in the West Indies, Texas, and Brazil (Johnson 1934; Abbott 1968, 1974; Morris 1973; Emerson et al. 1976). Although Morris' (1973) work includes the distribution of the other authors, he extended it northward to include Virginia.

Glycymeris americana is a relatively rare bivalve represented in our collection by one specimen from one sample (Table 5).

The NEFC sample is from the continental shelf east of Jacksonville, Fla. (Fig. 46; Theroux and Wigley footnote 4, table 76).

This species is found in moderately shallow water ranging from 2 to 119 m in depth (Johnson 1934; Abbot 1974). Our sample is from 24 m, placing it in the 0-24 m depth range grouping.

The substrate type for our sample is sand.

***Glycymeris pectinata* (Gmelin 1791). Comb bittersweet. Figure 47.**

The known distribution of this species is from the Carolinas to Florida, the West Indies, onward to Texas and Mexico, and south to Brazil (Johnson 1934; Abbott 1968, 1974; Morris 1973; Emerson et al. 1976).

The comb bittersweet is a common to moderately common bivalve species of the U.S. east coast; the NEFC collection contains 40 specimens from 20 samples (Table 5).

Our samples are from the continental shelf ranging from Cape Fear, N.C., south to the southern tip of Florida with a moderate gap in the latitude of Charleston, S.C. (Fig. 47; Theroux and Wigley footnote 4, table 77).

Dance (1974) placed this species in the Caribbean zoogeographic province.

The bathymetric range of this species is from shallow to moderately deep water which ranges from 4 to 320 m (Johnson 1934).

Our samples range from 12 to 112 m in depth with a mean of 40 m. The majority of samples (55%) and specimens (38%) are in the 25-49 m depth range grouping with 30% of the samples and 30% of the specimens in the 0-24 depth range grouping; 15% of the samples, and 33% of the specimens are in the 100-199 m depth range grouping (Table 80).

This species is found on sand and gravel bottom (Abbott 1968; Morris 1973; Emerson et al. 1976).

Our samples occurred in sand-gravel, sand-shell, sand, and silty sand substrates. There were more samples (50%) in sand than specimens (30%); however, sand-shell substrates contained 40% of the samples and 55% of the specimens; sand-gravel and silty sand each contained 5% of the samples but 10 and 5%, respectively, for specimens (Table 81).

***Glycymeris* sp. Figure 48.**

The NEFC collection contains 48 specimens of bivalves from 23 samples which have been classified to the generic level *Glycymeris* sp. (Table 5).

Samples of this taxon are from the continental shelf and slope between Cape Fear, N.C., and Key West, Fla. (Fig. 48; Theroux and Wigley footnote 4, table 78).

Our samples range in depth from 10 to 580 m of water with a mean of 133 m. Thirty-nine percent of the samples and 42% of the specimens are in the 25-49 m depth range grouping; 30% of the samples and 23% of the specimens are in the 200-499 m grouping; 22% of the samples and 29% of the specimens are in the 0-24 m depth range grouping; the 100-199 m and the 500-999 m groupings each contain 4% of the samples and 2 and 4% of the specimens, respectively (Table 82).

Our samples occurred in three sediment types, shell, sand-shell, and sand. Sand was the predominant substrate, containing 74 and 83% of samples and specimens, respectively; sand-shell contained 22% of samples and 15% of the specimens, while shell contained 4 and 2%, respectively (Table 83).

Order MYTILOIDA
Family MYTILIDAE

The NEFC Specimen Reference Collection contains 201 specimens of members of the family Mytilidae which were obtained from 33 samples (Table 5).

Samples containing members of the mussel family range from offshore Nova Scotia south through the Gulf of Maine onto the Southern New England continental shelf and slope off Atlantic City, N.J., and Delaware Bay (Fig. 69; Theroux and Wigley footnote 4, table 119).

The range in depth for these samples is 15 to 564 m with a mean of 139 m. The majority of both samples and specimens are in the 100-199 m depth range grouping which contains 36 and 49%, respectively; the 50-99 m grouping contains 21% of the samples and 18% of the specimens, while the 200-499 m grouping contains 24% of the samples and 8% of the specimens; the 25-49 m grouping contains 6% of the samples and 21% of the specimens; the 0-24 m and 500-599 m groupings contain 9 and 3%, respectively, for samples and 2% each of specimens (Table 84).

Members of this taxon were obtained from all sediment types considered in this report except shell. Abundance in terms of decreasing sediment particle size was 8% of the samples and 20% of the specimens in gravel; 12 and 42%, respectively, in sand-gravel; 8 and 2%, respectively, in till; 4 and 14%, respectively, in sand-shell; 19 and 3%, respectively, in sand; 8 and 8%, respectively, in silty sand; 15% of the samples and 6% of the specimens occurred in silt, and 27 and 5%, respectively, occurred in clay (Table 85). There are 7 samples containing 30 specimens which are unclassified with regard to sediment type.

Genus *Brachidontes* Swainson 1840

***Brachidontes exustus* (Linné 1758). Scorched mussel. Figure 21.**

This mussel is distributed from Cape Hatteras, N.C., to Texas and the West Indies, and Brazil to Uruguay, and is often locally abundant (Morris 1973; Abbott 1974).

Our collection contains 12 specimens from 2 samples of this species (Table 5). Abbott (1974) noted that this species prefers brackish waters.

One of our samples is from north of Charleston, S.C., and the other north of Jacksonville, Fla. (Fig. 21; Theroux and Wigley footnote 4, table 33).

This species, which is normally found on rocks and pilings and commonly found washed ashore on shells and seaweed (Abbott 1974), also occurs in moderately shallow water (Morris 1973). Our samples are from 5 and 6 m of water.

One sample containing six specimens was obtained from a sand substratum while the second, also with six specimens, was from a silty sand sediment.

Genus *Crenella* Brown 1827

***Crenella decussata* (Montagu 1808). Decussate crenella. Figure 31.**

This species is thought to be continuously circumpolar and occurs in both the North Atlantic and North Pacific Oceans. The Atlantic distribution extends from Greenland to North Carolina in the region of Cape Hatteras. It is also reported from the Gulf of Mexico and the Caribbean. In the Pacific it is distributed from the low Arctic regions to California and Korea. It also occurs off the northern Eurasian continent, in western Europe, Norway, and is considerably distributed throughout the Arctic, south to the British Isles (Johnson 1934; La Rocque 1953; Ockelmann 1958; Clarke 1962; Tebble 1966; Morris 1973; Abbott 1974).

Crenella decussata is represented in the NEFC collection by 443 specimens from 83 samples (Table 5).

Our samples are from the fishing banks east of Nova Scotia, the Scotian Shelf, the Gulf of Maine basin, on the periphery of Georges Bank, and on the outer continental shelf in the Middle Atlantic Bight region south to Cape Hatteras, N.C.; one sample occurs south of Cape Fear on the mid-continental shelf (Fig. 31; Theroux and Wigley footnote 4, table 50).

The zoogeographic provinces occupied by this species are the Arctic, the Boreal, the Virginian, and Celtic in Europe (Coomans 1962), while Ockelmann (1958) listed it as low Arctic-boreal and circumpolar.

This small bivalve has a considerable bathymetric range occurring from just offshore out to considerable depths, a depth range extending from 4 to 3,203 m (Clarke 1962); however, Ockelmann (1958) reported that in northern seas this species is mainly littoral.

The depth range of our samples is from 23 to 201 m with a mean of 83 m. The distribution of our samples with regard to depth range groupings is as follows: 62% of the samples and 68% of the specimens are in the 50-99 m depth range grouping; 21% of the samples and 13% of the specimens are in the 100-199 m depth grouping, while 12% of the samples but 18% of the specimens are in the 25-49 m grouping; the 0-24 m grouping contains 4% of the samples and only 1% of the specimens, while the 200-499 m grouping contains 2% of the samples and 0.5% of the specimens (Table 86).

This species occurs in sand and clay and on sand or gravel bottoms (Tebble 1966); Morris (1973) considered it to inhabit mud bottoms.

Our samples occurred in all but one of the nine sediment types we are using for purposes of this report, none were found in sand-shell. Sand, silty-sand, and clay substrates were preferred, 35% of the samples and 25% of the specimens occurred in sand; silty sand contained 30% of the samples and 56% of the specimens, while clay substrates contained 17% of the samples and 9% of the specimens. Significantly smaller amounts occurred in the remaining sediment types, gravel, sand-gravel, till, shell, and silt (Table 87). Two samples containing four specimens are unclassified with regard to sediment type.

Crenella glandula (Totten 1834). Glandula crenella. Figure 32.

This very common mussel is distributed from Labrador to North Carolina (Johnson 1934; La Rocque 1953; Ockelmann 1958; Morris 1973; Abbott 1974).

This small mussel is represented in the NEFC collection by 229 samples (2.2% of samples) containing 1,135 specimens (1.7% of specimens) (Table 5).

Our samples are widely distributed on the continental shelf and upper slope; they range from both sides of Nova Scotia, throughout the Gulf of Maine, onto Georges Bank, and the Southern New England shelf and slope, into the Middle Atlantic Bight region, south to the mouth of Chesapeake Bay (Fig. 32; Theroux and Wigley footnote 4, table 51).

This species occupies the Boreal and Virginian zoogeographic provinces (Coomans 1962).

The bathymetric range of this species is from 6 to 110 m (Johnson 1934).

The depth range of our samples is from 0 to 406 m with a mean of 99 m. Distribution of samples and specimens with regard to depth range groupings is 4% of the samples and 6% of the specimens are in the 0-24 m grouping, while 9% of the samples but 46% of the specimens are in the 25-49 m depth range grouping; the largest number of samples (55%) are in the 50-99 m depth range grouping, but it contains only 31% of the specimens; 30% of the samples and 16% of the specimens are in the 100-199 m grouping and 4% of the samples and 1% of the specimens are in the 200-499 m grouping (Table 88).

Crenella glandula occurred in all of our sediment types. There appears to be a preference for till, sand, silty-sand, and clay sediments both in terms of numbers of samples found in these sediment types as well as the number of specimens; significantly smaller amounts are found in gravel, sand-gravel, shell, sand-shell, and silt substrate types. Table 89 lists the pertinent data for this species in relation to bottom sediments. Twenty-four samples containing 139 specimens are unclassified with regard to sediment type.

Crenella sp. Figure 33.

The NEFC collection contains 35 samples with 69 specimens identified to the generic level of *Crenella* sp. (Table 5).

Samples in our collection containing members of this genus are from the Gulf of Maine, Georges Bank, the Middle Atlantic Bight, off the coast of South Carolina, and the mid-section of Florida off Jacksonville (Fig. 33; Theroux and Wigley footnote 4, table 52).

Members of this genus are found in the Arctic, Boreal, and Virginian provinces in the northwest Atlantic, and in the Celtic province in Europe (Coomans 1962).

The depth range of our samples is 15 to 2,412 m with a mean of 209 m. The majority of samples are in the 100-199 m depth range grouping which contains 37% of the samples and 57% of the specimens. The 50-99 m grouping contains 29% of the samples and 19% of the specimens; the 0-24 and 25-49 m groupings each contain 14% of the samples but 7 and 13% of the specimens, respectively; 3% of the samles are in the two deepest range groupings, 1,000-1,999 and 2,000-3,999 m which account for 3 and 1% of the specimens, respectively (Table 90).

Samples containing *Crenella* sp. occurred in all but one sediment type, till. Sand yielded the largest amount of samples (34%) followed by silty sand (22%) and gravel (13%); the other sediment types had amounts ranging between 3 and 9%. Sand-gravel yielded the greatest amount of specimens (29%) closely followed by sand (27%); much smaller amounts (3 to 11%) occurred in other sediment types (Table 91). There are three samples containing six specimens which are unclassified with regard to sediment type.

Genus *Dacrydium* Torell 1859

Dacrydium vitreum **(Hölboll in Möller 1842). Glassy teardrop. Figure 41.**

This species is somewhat shrouded in controversy reflected in the variability of its distribution as claimed by different authors. Ockelmann (1958) voiced his concern in believing that this species "has a panarctic distribution, but is absent from truly boreal regions." He postulates that there are "4 different forms from the N. Atlantic, most probably distinct species." We, however, have found no clear differentiation among the various sources examined and, therefore, are maintaining, at this time, the integrity of this species as it presently exists. Our distributional records, however, contain an intriguing inshore-offshore disparity which should be investigated further (see below).

Johnson (1934) and La Rocque (1953) reported the glassy teardrop as occurring from the Arctic Ocean to Florida; Morris (1951) included the preceding range and added that it also occurs in the English Channel, at the Azores, and in the Mediterranean. Ockelmann (1958), who reported it widely distributed throughout Arctic regions, stated that it also probably occurs in the Gulf of St. Lawrence and in Nova Scotia, and extends from Newfoundland to Cape Cod. Clarke (1962), in addition to Arctic and subarctic distributional data, reported it occurs in Norway, Northern Eurasia, West Europe, the Canaries, and on the Middle Atlantic Ridge in the region of the Azores. Abbott's (1974) distributional range is from Greenland to the Gulf of Mexico, he also included Norway.

Dacrydium vitreum is common; our collection contains 522 specimens from 95 samples (Table 5).

The NEFC sampling data shows two separate groupings of samples, one of which occurs in the Gulf of Maine Basin area, including the Scotian Shelf and Browns Bank, ranging onto the southwestern part of Georges Bank; the second grouping occurs in deep offshore waters beyond the shelf break on the continental slope, ranging from the Northeast Peak of Georges Bank to slightly south of Delaware Bay with one other sample occurring south of Cape Hatteras at the shelf break (Fig. 41; Theroux and Wigley footnote 4, table 67). This distributional disparity bears further investigation as this pattern may indicate the existence of two separate populations or, indeed, separate species occupying different bathymetric ranges and habitats.

In addition to Ockelmann's (1958) reporting of this species as panarctic in the North Atlantic only, Gosner (1971) reported it occupying the Boreal and Virginian zoogeographic provinces as well.

The glassy teardrop enjoys a wide bathymetric range occupying water depths from 6 to 4,454 m (Ockelmann 1958; Clarke 1962).

Our samples are also widely distributed by depth, ranging from 38 to 3,055 m with a mean depth of 305 m. The majority of samples and specimens are in the 100-199 m grouping, which contains 52% of the samples and 71% of the specimens, and the 200-499 m grouping containing 38% of the former and 26% of the latter. Significantly smaller amounts occur in the other depth range groupings: the 25-49, 500-999, 1,000-1,999 and the 2,000-3,999 m groupings (Table 92). There is no depth information concerning one sample which contains three specimens.

No samples obtained from till, shell, or sand-shell sediments contained specimens of the glassy teardrop. The majority of both samples and specimens occurred in clay where 54% of the former and 74% of the latter were obtained. The next most plentiful amounts of samples and specimens occurred in silty sand where 19 and 14%, respectively, occurred. Smaller amounts occurred in gravel, sand-gravel, sand, and silt substrates (Table 93). There are 3 samples containing 11 specimens which are unclassified with regard to sediment type.

Genus *Geukensia* Poel 1959

Geukensia demissa **(Dillwyn 1817). Atlantic ribbed mussel. Figure 46.**

This is a common and locally abundant species which has been introduced into California at San Francisco Bay (Abbott 1974).

The range of this species extends from the Gulf of St. Lawrence to South America as well as having been introduced in California (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Ockelmann 1958; Abbott 1968, 1974; Emerson et al. 1976).

The NEFC collection contains 38 specimens from 11 samples (Table 5).

Our samples are from the shores of Cape Cod, Mass., with one sampling site on the Connecticut shore (Fig. 46; Theroux and Wigley footnote 4, table 75).

This species occurs in the Boreal, Virginian, and Carolinian provinces (Coomans 1962); Gosner (1971) listed it as occupying the Boreal and Virginian provinces, while Dance (1974) placed it in the Boreal, Transatlantic, and Californian provinces.

This species is found in the intertidal region from low tide to approximately 6 m (Abbott 1968, 1974; Porter 1974).

All of our samples, with the exception of one containing two specimens which had no depth information, were collected at a depth of 1 m which places them in the 0-24 m depth range grouping (Table 94).

This species is an inhabitant of salt marshes, mud-sand flats, and also occurs on muddy or peaty bottoms (Morris 1951, 1973; Abbott 1968, 1974; Emerson et al. 1976).

Seventy-five percent of our samples and 94% of our specimens occurred in silty sand substrates with 25% of the samples and 6% of the specimens occurring in sand (Table 95). There are 7 samples containing 20 specimens which are unclassified with regard to sediment type.

Genus *Modiolus* Lamarck 1799

Modiolus modiolus **(Linné 1758). Northern horse mussel. Figure 62.**

The northern horse mussel is widely distributed throughout northern seas ranging in the Atlantic from Arctic seas to Cape Hatteras, N.C., and in the Pacific from Arctic seas south to San Pedro, Calif.; it is also widely distributed throughout Arctic regions and in northern Europe (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Ockelmann 1958; Tebble 1966; Abbott 1968, 1974).

Modiolus modiolus is the largest and commonest mussel of New England (Abbott 1968); it is represented in the NEFC collection by 1,132 specimens from 127 samples each of which represent approximately 1% of their respective group (Table 5).

Our samples are from the periphery of the Gulf of Maine and Georges Bank, and extend onto the Southern New England shelf and slope region with two isolated samples on the continental shelf off New York and Atlantic City, N.J. (Fig. 62; Theroux and Wigley footnote 4, table 108).

This species occupies the Arctic, Boreal, Virginian, and Carolinian zoogeographic provinces in the western Atlantic, and the Celtic province in Europe (Coomans 1962); Gosner (1971) listed it as occurring in the Boreal and Virginian provinces, and Dance (1974) placed it in the Boreal, Transatlantic, Aleutian, and Japonic provinces.

This species ranges from slightly below low tide level out to approximately 81 m depth (Gosner 1971; Porter 1974).

The samples in the NEFC collection range in depth between 13 and 256 m with a mean of 77 m. The majority of our samples are in the 50-99 m depth range grouping which contains 55% of the samples and 27% of the specimens; the largest number of specimens (58%), however, are in the 25-49 m grouping which contains 23% of the samples. Seventeen percent of the samples and 10% of the specimens, are in the 100-199 m depth range grouping, while the 200-499 m grouping contains 2% of the samples and 5% of the specimens; the smallest amount of each is in the 0-24 m depth range grouping which contains 2% of the samples and 0.3% of the specimens (Table 96).

Morris (1951) reported this species as an inhabitant of rocky bottoms.

Our samples occupied all sediment types considered in this report. The majority of samples occurred in sand which contained 34% of the former and 10% of the specimens. The largest number of specimens (54%) were in sand-shell bottoms which contained only 6% of the samples; sand-gravel substrates contained 24% of each, samples and specimens; significantly smaller amounts occurred in gravel, till, shell, sand-shell, silty sand, silt, and clay sediments (Table 97). There are 29 samples containing 179 specimens which are unclassified with regard to sediment type.

Genus *Musculus* Bolten 1798

Musculus corrugatus (Stimpson 1851). Wrinkled musculus. Figure 64.

The wrinkled musculus occurs in both the North Atlantic and North Pacific Oceans. In the Atlantic it ranges from Arctic seas and northern Europe to off North Carolina and is considered to be circumpolar, while in the Pacific it ranges from Alaska to Puget Sound (Johnson 1934; Ockelmann 1958; Abbott 1974).

This small mussel is represented in the NEFC collection by 88 specimens from 11 samples (Table 5).

Our samples are confined to the Georges Bank-Gulf of Maine and Nantucket Shoals regions (Fig. 64; Theroux and Wigley footnote 4, table 112).

It is an inhabitant of the Arctic, Boreal, and Virginian provinces (Coomans 1962); however, Gosner (1971) placed it in the Boreal and Virginian provinces.

The range of depth in which this species is found is from 2 to 183 m (Johnson 1934; Abbott 1974).

The NEFC samples are from water depths ranging between 35 and 102 m with a mean of 77 m. The majority of samples (73%) and specimens (75%) are in the 50-99 m depth range grouping; 18% of the samples and 2% of the specimens are in the 25-49 m grouping, and 9% of the samples, but 23% of the specimens are in the 100-199 m depth range grouping (Table 98).

The majority of both samples and specimens occurred in sand-gravel substrates where 40% of the samples and 61% of the specimens were found; till substrates contained 30% of the samples and 33% of the specimens, while shell contained 10% of the samples and 4% of the specimens: sand substrates yielded 20% of the samples and 2% of the specimens (Table 99). There is one sample containing one specimen which is unclassified with regard to sediment type.

Musculus discors (Linné 1767). Discord musculus. Figure 65.

This mussel occurs in both the Atlantic and Pacific Oceans. In the Atlantic it ranges from Labrador and Arctic seas to Long Island and is considered to be circumpolar; in the Pacific it ranges from Arctic seas to Puget Sound and to Japan; it is also found in western Europe, in the Mediterranean, and in northern Eurasia (Johnson 1934; Ockelmann 1958; Clarke 1962; Tebble 1966; Morris 1973; Abbott 1974).

This is a commonly dredged deep water mussel which is represented in our collection by 457 specimens from 80 samples (Table 5).

Our samples are from the periphery of the Gulf of Maine and the Northeast Peak and Southwestern Part of Georges Bank (Fig. 65; Theroux and Wigley footnote 4, table 113).

This species is Arctic, Boreal, Virginian, and Celtic in zoogeographic distribution (Coomans 1962); Gosner (1971) placed it in the Virginian province; Dance (1974) placed it in the Boreal, Mediterranean, Transatlantic, Arctic, Indo-Pacific, and Japonic provinces.

The depth range for this species is from 0 to 3,267 m (Clarke 1962).

Our samples are from depths which range between 29 and 198 m with a mean of 81 m. Fifty-nine percent of the samples and 40% of the specimens are in the 50-99 m depth range grouping; 18% of the samples and 54% of the specimens are in the 25-49 m grouping, and 24% of the samples and 6% of the specimens are in the 100-199 m grouping (Table 100).

The only sediment type in which this species was not found was silt. The majority of both samples and specimens 42 and 82%, respectively, occurred in sand-gravel; gravel substrates contained 21% of the samples and 5% of the specimens; till substrates contained 16% of the samples and 4% of the specimens; shell contained 2% of the samples and 4% of the specimens; sand-shell contained 4% of the samples, and < 1% of the specimens; sand contained 9% of the samples, 2% of the specimens; while silty sand had 2% and < 1%, respectively; clay 5% of the samples and 1% of the specimens (Table 101). There are 23 samples containing 40 specimens which are not classified with regard to sediment type.

Musculus niger (Gray 1824). Black musculus. Figure 66.

The black musculus is found in both the North Atlantic and North Pacific Ocean. In the Atlantic it ranges from Arctic seas and Greenland to North Carolina, and in the Pacific from

Alaska to Puget Sound; it is also present in northern Europe and in the Sea of Okhotsk and enjoys a widespread distribution throughout the Arctic, it is considered to be a circumpolar species (Johnson 1934; Morris 1951, 1973; Ockelmann 1958; Tebble 1966; Abbott 1974; Emerson et al. 1976).

Musculus niger is a common musculus represented in our collection by 406 specimens from 115 samples (Table 5).

The samples in the NEFC collection occur from Nova Scotia to slightly south of Delaware Bay, on the continental shelf, and around the periphery of the Gulf of Maine and on Georges Bank (Fig. 66, Theroux and Wigley footnote 4, table 114).

The main distribution for this species is panarctic and Boreal (Ockelmann 1958); Coomans (1962) placed it in the Arctic, Boreal, Virginian, and Celtic provinces; Gosner's (1971) view was that it is Boreal and Virginian, while Dance (1974) placed it in the Arctic, the Boreal, Transatlantic, and Aleutian zoogeographic provinces.

The bathymetric range of this species extends from 2 to 110 m (Gosner 1971; Abbott 1974).

Our suite of samples ranges in depth between 15 and 264 m with a mean of 76 m. The majority of the samples (55%) and specimens (58%) are in the 50-99 m depth range grouping; the 100-199 m grouping contains 22% of the samples and 16% of the specimens; the 25-49 m grouping, 20% of the samples and 24% of the specimens; 3% of the samples and 1% of the specimens are in the 0-24 m depth range grouping and < 1% of both samples and specimens in the 200-499 m grouping (Table 102).

This species can be found in rock crevices and it is also found attached to empty shells (Morris 1973).

Our samples occupied all the sediment types considered in this report. The preferred sediment type, at least with regard to amounts of samples and specimens, was sand which contained 40% of the samples and 25% of the specimens; sand-gravel substrates were next with 15% of the samples and 20% of the specimens while till contained 7% of the samples but 25% of the specimens. Smaller amounts were recorded from gravel, shell, sand-shell, silty sand, silt, and clay substrates (Table 103). There are 10 samples containing 34 specimens which are unclassified with regard to sediment type.

***Musculus* sp. Figure 67.**

The NEFC specimen reference collection contains 13 samples which yielded 75 specimens of this genus (Table 5).

Samples containing specimens of *Musculus* are from the Gulf of Maine and the northern edge of Georges Bank (Fig. 67; Theroux and Wigley footnote 4, table 115).

The depth range of the NEFC samples is from 35 to 256 m with a mean of 115 m. The majority of the samples (54%) are in the 50-99 m grouping, but the majority of specimens (57%) are in the 100-199 m grouping, the former contained 23% of the specimens and the latter 15% of the samples; 23% of the samples and 9% of the specimens are in the 200-499 m grouping and 8% of the samples and 11% of the specimens in the 25-49 m depth range grouping (Table 104).

There was not a great deal of variability in the abundance of samples occurring in the various sediment types in which they were found, but more discrepancy in the amounts of specimens obtained from each sediment type. Sand-gravel contained 30% of the samples, while gravel and clay each contained 20% of the samples; till, sand, and silty sand each contained 10% of the samples. In terms of numbers of organisms the majority of specimens (61%) were obtained from gravel substrates; there was 27% in sand-gravel substrates, 5.6% in clay, 4% in till, and 1.4% each in sand and silty sand (Table 105). There are three samples containing four specimens which are unclassified with regard to sediment type.

Genus *Mytilus* Linné 1758

***Mytilus edulis* Linné 1758. Blue mussel. Figure 70.**

The blue mussel enjoys a widespread distribution throughout northern oceans occurring in both the North Atlantic and North Pacific Oceans. In the Atlantic it occurs from the Arctic Ocean to South Carolina while in the Pacific it ranges from Alaska to California and is also found in Japan; in Europe it ranges along the European coast into the Mediterranean and Baltic Seas (Johnson 1934; La Rocque 1953; Ockelmann 1958; Tebble 1966; Abbott 1968, 1974; Morris 1973; Emerson et al. 1976). Porter (1974) stated that below Cape Hatteras, N.C., specimens are usually small or young.

Mytilus edulis, which is very common in New England and common elsewhere throughout its range, is well represented in the NEFC collection which contains 5,272 specimens which make up 5% of the total number of specimens from 107 samples or 1% of the total number of samples (Table 5).

Our samples range from the Scotian Shelf into the Gulf of Maine, on Georges Bank, in the Cape Cod region, south to inshore waters off New York City; they occur in the mouth of Delaware Bay, in Chesapeake Bay, and Pamlico Sound; there is one offshore sample off Charleston, S.C. (Fig. 70; Theroux and Wigley footnote 4, table 120).

The main distribution, according to Ockelmann (1958), is low Arctic-boreal and discontinuously circumpolar; it is also Mediterranean-Atlantic. Coomans (1962) placed it in the Arctic-boreal, Virginian, and Celtic provinces, while Gosner (1971) placed it in the Boreal and Virginian provinces; Dance (1974) considered it to occupy the Boreal, Mediterranean, Atlantic, Aleutian, Caribbean, and Transatlantic provinces and mentioned that it was introduced into the Japonic and the Indo-Pacific provinces.

Ockelmann (1958) listed the depth range for this species as occurring between the tidal zone to 180 m at Jan Mayen and mentioned that it is only occasionally found at depths below 50 m; Gosner (1971) and Morris (1973) reported it from the littoral region intertidally to shallow water.

The NEFC samples range in depth from 0 to 232 m with a mean of 52 m. In order of decreasing depth range, 34% of the samples and 15% of the specimens are in the 0-24 m grouping, 22% of the samples and 73% of the specimens in the 25-49 m grouping, 33% of the samples and 12% of the specimens in the 50-99 m grouping with a sharp dropoff in abundance occurring at the 100-199 m grouping which contains 9% of the samples and 0.5% of the specimens, while 3% of the samples and 0.1% of the specimens are in the 200-499 m grouping (Table 106). There is one sample which contains three specimens which has no associated depth information.

The only sediment type, of the nine considered in this report, which did not contain specimens of *Mytilus edulis* was sand-shell. Abundance in terms of decreasing particle size was as follows: 7% of the samples and 3% of the specimens occurred in gravel; 16 and 44%, respectively, in sand-gravel; 3 and 1%, respectively, in till; 2 and 0.3%, respectively, in shell, with an increase in sand to 44% for samples and 13% for specimens; silty sand contained 23% of the samples and 38% of the specimens, silt 2% for samples and 0.1% of the specimens, while clay contained 5% of the samples and 1% of the specimens (Table 107). There are 45 samples containing 4,189 specimens which are unclassified with regard to sediment type.

Order PTERIOIDA
Family PECTINIDAE

The NEFC collection contains 14 samples yielding 23 specimens which are classified to the family level Pectinidae (Table 5).

Samples containing members of this taxon are distributed throughout the study area in isolated patches from Nova Scotia south to north of Miami, Fla. (Fig. 84; Theroux and Wigley footnote 4, table 145).

Members of the family Pectinidae in the NEFC collection range in depth between 23 and 310 m with a mean of 104 m. Table 108 lists the occurrence of members of the Pectinidae in relation to range in water depth.

Sediment types in which members of this family were found included gravel, shell, sand-shell, sand, silty sand, and silt. Table 109 lists the occurrence of Pectinidae in our collection in relation to bottom sediments. There are two samples containing two specimens which are unclassified with regard to sediment type.

Genus *Aequipecten* Fischer 1886

Aequipecten phrygium (Dall 1886). Spathate scallop. Figure 3.

This scallop is distributed from Cape Cod, Mass., to Florida and the West Indies (Johnson 1934; Abbott 1974; Porter 1974). Abbott (1974) considered it uncommon off Miami and the lower Florida Keys.

The spathate scallop is represented by 10 specimens from 1 sample in the NEFC collection (Table 5).

Our sample is from the outer continental shelf southeast of the eastern tip of Long Island, N.Y. (Fig. 3; Theroux and Wigley footnote 4, table 4).

The main distribution is Boreal, Virginian, and Carolinian in American waters (Coomans 1962).

The spathate scallop is a moderately deep water inhabitant occupying depths which range from 92 to 1,449 m (Johnson 1934; Morris 1951).

Our sample is from a depth of 93 m in a clay bottom.

Genus *Argopecten* Monterosato 1889

Argopecten gibbus (Linné 1758). Calico scallop. Figure 9.

The calico scallop occurs from off Maryland to Florida, in the Gulf of Mexico, and at south Texas (Johnson 1934; Morris 1951, 1973; Abbott 1968, 1974; Emerson et al. 1976).

Although *Argopecten gibbus* is a common, warm water, commercially important bivalve our collection contains only two specimens from two samples (Table 5) due to the lack of sampling activity by NEFC in its distributional range in comparison to that in more northerly areas.

Our samples are from the northern Florida continental shelf (Fig. 9; Theroux and Wigley footnote 4, table 14).

Published depth data for this species shows a distribution ranging from shallow water to 366 m (Abbott 1968, 1974; Morris 1973).

Our samples are from 28 and 35 m with a mean depth of 32 m. All samples and specimens are in the 25-49 m depth range grouping.

The samples are from sand substrates.

Argopecten irradians (Lamarck 1819). Atlantic bay scallop. Figure 9.

The Atlantic bay scallop is an abundant, commercially important bivalve of the U.S. east coast, especially in the northeastern region, although elsewhere along the coast, where locally abundant, important fisheries also exist (Gutsell 1931; Marshall 1960; Clarke 1964).

Clarke (1964), in his review of the taxonomy of the genus *Aequipecten*, agreed with Abbott's (1954) differentiation of the *A. irradians* superspecies into three subspecies: *A. irradians* s.s., *A. i. concentricus* (Say), and *A. i. amplicostatus* (Dall), and added a new subspecies, *A. i. sablensis*, which occurs only at Cape Sable, Nova Scotia, to the list. Our specimens are *A. irradians* s.s..

Most published distributional records are for the so-called superspecies *A. irradians* which ranges from Newfoundland to Florida and Texas (Johnson 1934; La Rocque 1953; Ockelmann 1958; Abbott 1968, 1974; Morris 1973; Emerson et al. 1976). Gutsell (1931) listed the occurrence of this organism, in important commercial abundance, to range from Cape Cod to Bogue Sound, N.C., but cited other authors, namely Dall (1889, 1898), Belding (1910), Kellogg (1910), and Ingersoll (1887) who considered it distributed from Maine to Texas, the West Indies, and Brazil. Clarke (1964) considered the superspecies *A. i. irradians* to inhabit the region from the north shore of Cape Cod at Barnstable and Provincetown, Mass., to New Jersey with disjunct populations at Cohasset and Scituate, Mass.

Due to the restriction of this species to inshore habitats and the relatively few samples from these areas in our collection, we have only 5 samples containing 17 specimens of this animal (Table 5).

Our samples are all from the south shore of Cape Cod and adjacent Vineyard Sound (Fig. 9; Theroux and Wigley footnote 4, table 15).

The zoogeographic distribution of this species complex is Boreal, Virginian, and Carolinian in the western Atlantic, and Celtic for the genus in Europe (Coomans 1962); Gosner (1971) considered it Boreal and Virginian, while Dance (1974) placed it in the Transatlantic and Caribbean provinces.

The depth range of this species is relatively narrow restricting it to inshore embayments and sounds. Reported depths range from 0.3 to 18 m (Gutsell 1931; Abbott 1974).

Our samples range from 0 to 3 m with a mean of 1.2 m, placing them in our 0-24 m depth range grouping.

Argopecten irradians has a close affinity to eelgrass (Zostera) beds and other vegetation areas on bottom types composed of soft mud to hard, non-shifting sand (Gutsell 1931; Marshall 1960; Clarke 1964; Abbott 1974).

Thirty-three percent of our samples and specimens came from a sand-gravel bottom, 67% of each were in sand, while 2 samples containing 14 specimens had no sediment data included among recorded environmental parameters.

Genus *Chlamys* Bolten 1798

Chlamys islandica (Müller 1776). Iceland scallop. Figure 26.

This species is reported to occur from Arctic seas to Buzzards Bay, Mass., in the North Atlantic, and in the North Pacific ranges from Alaska south to Puget Sound, Wash. (Johnson 1934; La Rocque 1953; Ockelmann 1958; Clark 1962; Abbott 1968, 1974; Morris 1973; Emerson et al. 1976). In addition to giving a detailed description of the distribution of this species in Arctic regions, Ockelmann (1958) mentioned that in addition to published distributional records, dead shells have been found from Bohusland in Sweden, in the North Sea, west of Scotland, in Ireland, France, around the Azores, and in the Mediterranean Sea.

Chlamys islandica is a very common inhabitant of the cold waters of the North Atlantic and North Pacific Oceans. The NEFC collection contains 76 samples which yielded 361 specimens of this species (Table 5).

Our samples are from continental shelf areas north and east of Cape Cod, Mass., on Georges Bank, in the Gulf of Maine, and on the Scotian Shelf west of Nova Scotia (Fig. 26; Theroux and Wigley footnote 4, table 41).

Zoogeographic distribution of this species, according to Ockelmann (1958), is subarctic in both the North Atlantic and North Pacific Oceans; he reported it as continuously circumpolar and found lacking in typically high Arctic seas. Gosner (1971) placed it in the Boreal province in the North Atlantic, while Dance (1974) assigned it to the Arctic, the Boreal east of eastern North America, the Transatlantic, the Aleutian, and Californian provinces.

Although *Chlamys islandica* is primarily a continental shelf inhabitant it does range to continental slope depths with reported depth records showing it inhabiting water depths which range from 1.8 to 2,031 m (Clarke 1962; Abbott 1968, 1974).

The depth range of our samples is 40 to 421 m with a mean of 118 m. The majority of samples (53%) are in the 100-199 m depth range grouping, 38% in the 50-99 m grouping, 5% in the 200-400 m depth range grouping, and 4% in the 25-49 m grouping; whereas, the specimen distribution is 75% of the specimens in the 50-99 m grouping, 22% in the 100-199 m grouping, 2% in the 200-499 m grouping and < 1% in the 25-49 m grouping (Table 110).

Abbott (1968) reported that the Iceland scallop occurs on coarse sand sediments.

Our samples occurred in all but two of the nine sediment types included in this report. No specimens were obtained from shell or sand-shell substrates. Largest amounts of both samples and specimens occurred in the coarser grained substrate types, gravel, sand-gravel, till, and sand with significantly lesser amounts of each occurring in the finer grained sediments, silty sand, silt, and clay (Table 111). There are 28 samples containing 85 specimens which are unclassified with regard to sediment type.

Genus *Cyclopecten* Verrill 1897

Cyclopecten nanus Verrill and Bush 1897. Dwarf round scallop. Figure 40.

The dwarf round scallop occurs from off Virginia to Texas, and at Puerto Rico and Brazil (Johnson 1934; Warmke and Abbott 1961; Morris 1973; Abbott 1974).

The NEFC collection contains 21 specimens of this species from 3 samples (Table 5).

Our samples are located on the edge of the Continental shelf off Atlantic City, N.J. (Fig. 40; Theroux and Wigley footnote 4, table 64).

The depth range for this tiny species is 40 to 538 m (Abbott 1974).

Samples in our collection range from 89 to 102 m depth with a mean of 93 m. Two depth range groupings contain members of this species, the 50-99 m grouping with 67% of the samples and 52% of the specimens and the 100-199 m grouping containing 33% of the samples and 48% of the specimens (Table 112).

All of our samples were obtained in sand substrates (Table 113).

Cyclopecten pustulosus Verrill 1873a. Figure 40.

Cyclopecten pustulosus ranges from Newfoundland to Cape Cod and Martha's Vineyard, Mass. (Johnson 1934; La Rocque 1953; Ockelmann 1958; Abbott 1974).

The NEFC Specimen Reference Collection contains 58 specimens from 30 samples of *Cyclopecten pustulosus* (Table 5).

Our samples are from north and east of Cape Cod, Mass., the Gulf of Maine, the Scotian Shelf, and on the outer continental slope south of Georges Bank (Fig. 40; Theroux and Wigley footnote 4, table 65).

The bathymetric range of this species is 211 to 787 m of water (Johnson 1934; Abbott 1974).

The range in depth of our samples is from 110 to 690 m with a mean of 218 m. Three depth range groupings are incuded in this bathymetric range with abundance decreasing with increasing depth range. The 100-199 m depth range grouping contains 63% of the samples and 54% of the specimens, while the 200-499 m grouping contains 30 and 43%, respectively; the 500-999 m grouping contains 7% of the samples and 3% of the specimens (Table 114).

There is no great disparity of abundance among the several sediment types in which this species was found. Twenty-four percent of the samples occurred in both sand-gravel and sand substrates which contained 16 and 14% of the specimens, respectively; 20% of the samples occurred in both till and silty sand where 32 and 14% of the specimens occurred, respectively; gravel substrates contained 8% of the samples and 23% of the specimens, while clay contained the least with 4% of the samples and 2% of the specimens (Table 115). There are 5 samples containing 14 specimens which are unclassified with regard to sediment type.

Genus *Delectopecten* Stewart 1920

***Delectopecten vitreus* (Gmelin 1791). Vitreous scallop. Figure 41.**

Johnson (1934), La Rocque (1953), Morris (1973), and Abbott (1974) reported the distribution of this species for U.S. waters as ranging from Newfoundland and Nova Scotia to Martha's Vineyard, Mass. In addition, Abbott (1974) stated that it is also found in northern Europe and at Clipperton Island in the eastern Pacific. Ockelmann (1958) listed the Arctic distribution, Clarke (1962) listed the worldwide distribution, and Tebble (1966) listed the northern European distribution for this species, he also mentioned the Indo-Pacific as a site of habitation.

This small, uncommon scallop is represented in the NEFC collection by 12 specimens from 3 samples (Table 5).

Our samples, two of which occurred at one sampling site, are from the edge of the continental shelf off the Northeast Peak of Georges Bank (Fig. 41; Theroux and Wigley footnote 4, table 68).

The vitreous scallop is a deep water scallop, ranging in depth from 28 to 4,258 m (Clarke 1962; Morris 1973).

The depth range of our samples is 412 to 549 m with a mean of 458 m. The 200-499 m depth range grouping contains 66% of both samples and specimens; the 500-999 m grouping contains the remaining 33% of each (Table 116).

Only one of our samples contains information regarding sediment type, it was obtained in till and contained four specimens (Table 117). The remaining two samples with eight specimens are unclassified with regard to bottom sediments.

Genus *Placopecten* Verrill 1897

***Placopecten magellanicus* (Gmelin 1791). Atlantic deepsea scallop. Figure 90.**

Placopecten magellanicus is one of the most valuable commerical shellfish resources of the U.S. east coast, especially in the northeast and middle Atlantic coastal regions, which in 1978 yielded approximately 31 million pounds of meats valued at $76.4 million in the United States, while Canada's catch was 26.7 million pounds (Pileggi and Thompson 1979).

The natural history of this species has been well documented in the literature, especially by investigators at the NEFC where, for many years, an investigation of the sea scallop fishery was active (see Merrill 1959b, 1960, 1961; Merrill and Burch 1960; Merrill and Posgay 1964; Merrill et al. 1966; Posgay 1957, among others). There is also extensive information from Canadian researchers.

It must be pointed out that the dta for this species contained in this report are solely based on collections which are currently, physically present in the NEFC collection. No data from the extensive sea scallop data base here at NEFC have been included in this analysis.

The Atlantic deepsea scallop is distributed from Newfoundland to North Carolina with a questionable record from Labrador (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Abbott 1968, 1974; Emerson et al. 1976.

There are 1,225 specimens of the sea scallop in the NEFC Specimen Reference Collection representing slightly over 1% of all specimens; these are from 164 samples accounting for nearly 2% of the samples in the bivalve collection (Table 5).

The NEFC samples are from the continental shelf in the northeastern region around the periphery of the Gulf of Maine, with large series of collections on the northeast peak of Georges Bank, extending south over the Southern New England Continental shelf into the Mid-Atlantic Bight region south to approximately the mouth of Chesapeake Bay (Fig. 90; Theroux and Wigley footnote 4, table 155).

This species inhabits the Boreal and Virginian provinces (Coomans 1962; Gosner 1971).

The depth range for the Atlantic deepsea scallop extends from offshore to moderately deep waters which range between 6 and 183 m (Johnson 1934; Abbott 1968).

Our samples are from depths which range from 36 to 293 m of water with a mean of 96 m. The majority of both samples and specimens are in the depth range groupings of the middle shelf regions. Sixty percent of the samples and 62% of the specimens are in the 50-99 m depth range grouping, while 31% of the samples and 33% of the specimens are in the 100-199 m grouping; significantly smaller amounts of both samples and specimens are in the 25-49 and 200-499 m groupings (Table 118).

Sea scallops were found in all sediment types considered in this report with the exception of till. The majority of both samples and specimens were obtained from sand substrates where 39% of the samples and 30% of the specimens occurred. Table 119 shows the distribution of both samples and specimens with regard to the other sediment types. There are 66 samples containing 603 specimens which are unclassified with regard to sediment type.

Genus *Propeamussium* Gregorio 1884

***Propeamussium thalassinum* (Dall 1886). Figure 95.**

This species ranges from off Martha's Vineyard, Mass., to the West Indies (Johnson 1934; Abbott 1974).

There are 28 specimens from 6 samples of *Propeamussium thalassinum* in the NEFC Specimen Reference Collection (Table 5).

Our samples are from the outer continental shelf and the upper continental slope between Cape Cod, Mass., and Atlantic City, N.J. (Fig. 95; Theroux and Wigley footnote 4, table 168).

Gosner (1971) placed *Propeaumussium thalassinum* in the Virginian zoogeographic province.

The depth range for this species as reported by Abbott (1974) is 40 to 580 m.

Our samples are from water depths which range between 84 and 201 m with a mean of 149 m. The 50-99 m depth range grouping contains 17% of the samples and 7% of the specimens; the 100-199 m grouping contains 67% of the samples and 50% of the specimens, and the 200-499 m grouping contains 17% of the samples and 43% of the specimens (Table 120).

Both gravel and sand sediments contained 25% of the samples, but 8 and 46%, respectively, for specimens, while silty sand sediments contained 50% of the samples and 46% of the specimens (Table 121). There are two samples containing two specimens which are unclassified with regard to sediment type.

Family PLICATULIDAE
Genus *Plicatula* Lamarck 1801

Plicatula gibbosa **Lamarck 1801. Kitten's paw. Figure 91.**

The kitten's paw is distributed from North Carolina into the Gulf States and the West Indies; it also occurs at Bermuda and at Brazil (Johnson 1934; Morris 1973; Abbott 1968, 1974; Emerson et al. 1976).

Plicatula gibbosa is a common bivalve of which there are six specimens from four samples in our collection (Table 5).

Our samples are from the continental shelf with a series of samples off the North Carolina coast and another series off the northern and middle sections of Florida (Fig. 91; Theroux and Wigley footnote 4, table 158).

Depths at which kitten's paws are found range from the intertidal zone to approximately 140 m (Abbott 1968, 1974; Porter 1974).

The depth range for our samples is from 12 to 74 m with a mean of 37 m. The 0-24, the 25-49, and the 50-99 m depth range groupings each contain 33% of the specimens; however, in terms of sample distribution, 50% are in the 25-49 m grouping and 25% in each of the other two (Table 122).

Sediment types at sampling sites yielding specimens of kitten's paw were sand-shell and sand, with 75% of the samples and 83% of the specimens occurring in sand-shell, and 25% of the former and 17% of the latter in sand (Table 123).

Family SPONDYLIDAE
Genus *Spondylus* Linné 1758

Spondylus **sp. Figure 102.**

There is one sample in the NEFC collection which contains two specimens of bivalves classified as *Spondylus* sp. (Table 5).

The sample containing *Spondylus* sp. is from the continental shelf north of Miami Beach, Fla. (Fig. 102; Theroux and Wigley footnote 4, table 182).

The water depth at the sampling site was 28 m which places it in the 25-49 m depth range grouping, and the bottom sediment type was sand.

Family ANOMIIDAE
Genus *Anomia* Linné 1758.

Anomia simplex **Orbigny 1842. Common jingle shell. Figure 5.**

In the northwest Atlantic it occurs from Newfoundland to Florida; it is also found along the Gulf States, at Bermuda, the West Indies, and ranges into the Caribbean and to Cuba and Brazil (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Ockelmann 1958; Abbott 1968, 1974; Emerson et al. 1976).

This small, very common bivalve occurs in nearly 3% of our samples and represents 10% of all specimens in our collection (Table 5).

The majority of our samples are in the Gulf of Maine-Georges Bank region on the continental shelf and slope. Sample density decreased rapidly with decreasing latitude south of Cape Cod, Mass., becoming sparse in the Middle Atlantic Bight shelf region. Only three samples south of Delaware Bay contained specimens (Fig. 5; Theroux and Wigley footnote 4, table 8).

The main distribution is Boreal, Virginian, Carolinian, and Caribbean in American waters, and Celtic in Europe for the genus and family (Coomans 1962); Gosner (1971) listed it as Boreal and Virginian, while Dance (1974) assigned it a Transatlantic and Caribbean distribution.

The common jingle shell has been reported from shallow, inshore waters (Abbott 1968; Morris 1973) to moderately deep (183 m) water (Gosner 1971).

The samples in our collection range in depth from 0 to 549 m with a mean of 120 m. The majority of samples (47%) and specimens (70%) are in the 50-99 m depth range grouping; abundance of both samples and specimens diminishes with increasing and decreasing depth range beyond this grouping (Table 124).

Specimens of *A. simplex* occurred in all sediment types considered in this report, usually attached to rocks, gravel, shells, or other debris. The majority of samples (33%) occurred in sand but significant amounts also occurred in the harder substrates; sand-gravel, gravel, and till (20, 14, and 13%, respectively); other sediment types contained 8% or less of the samples. Thirty-eight percent of the specimens occurred in sand, 31% in sand-gravel, and 17% in gravel. Each of the remaining sediment types contained 5% or less of the specimens (Table 125). There are 76 samples containing 1,902 specimens which are unclassified with regard to sediment type.

Anomia squamula **Linné 1758. Prickly jingle shell. Figure 6.**

Anomia squamula is widely distributed throughout the Arctic and subarctic regions. Johnson (1934), La Rocque (1953), Abbott (1968, 1974), and Emerson et al. (1976) all listed it as occurring from Labrador to North Carolina; in addition La Rocque (1953) reported it from Denmark, and Abbott recorded it from North Europe. Ockelmann (1958) showed this species to be distributed from Newfoundland to Cape Cod on the North American continental shelf and from the Parry Islands to and including Labrador; he also reported it as occurring around Iceland, north and south Norway, including Lofoten and the Faroes. Clarke's (1962) distributional records include: Labrador, Newfoundland, North America, North Eurasia, Norway, and Western Europe. Morris (1973) reported it to occur from Maine to North Carolina.

This small, common bivalve occurs in nearly 3% of our samples representing nearly 4% of all specimens in our collection (Table 5).

Our samples are, for the most part, confined to the northern sector of the study area including the Scotian Shelf, the Gulf of Maine, and Georges Bank down to the Nantucket Shoals region; there are three samples below Cape Cod, one in Narragansett Bay, and the others on the continental shelf off Long Island, N.Y. (Fig. 6; Theroux and Wigley footnote 4, table 9).

The main distribution for this species is Boreal, Virginian, and Celtic (Coomans 1962).

Reported depths for this species range from 0 to 2,002 m (Johnson 1934; Clarke 1962).

Our samples range in depth from 13 to 549 m with a mean of 128 m. The majority of samples (75%) and specimens (69%) occupy mid to outer continental shelf depths between 50 and 200 m. A substantially smaller number of samples and specimens are in other depth ranges groupings (Table 126).

The prickly jingle shell is found on rocks and broken shells (Abbott 1974), and on stones and seaweed (Morris 1951).

Our samples occurred in all sediment types considered in this report. The coarser sediments, gravel, sand-gravel, till, and sand, contained the majority of samples (82%) and specimens (84%); finer sediments, not offering as good a substratum for attachment, accounted for significantly fewer samples and specimens (Table 127). There are 62 samples containing 1,148 specimens which are unclassified with regard to sediment type.

Family LIMIDAE
Genus *Limatula* Wood 1839.

***Limatula subauriculata* (Montagu 1808). Small-eared lima. Figure 51.**

The small-eared lima is widely distributed in the North Atlantic and North Pacific Oceans. In the Atlantic it ranges from Greenland to Puerto Rico and the West Indies; in the Pacific it ranges from Alaska to Mexico; it is also found in northwest Europe (Johnson 1934; La Rocque 1953; Morris 1973; Abbott 1974). The distribution of this species in Arctic regions is outlined by Ocklemann (1958), and for Europe and the British Isles by Tebble (1966).

Limatula subauriculata is a moderately common cool water bivalve which is represented by 328 specimens from 14 samples in the NEFC collection (Table 5).

Our samples occupy the edge of the continental shelf and mid to upper portions of the continental slope from Nova Scotia to slightly south of Delaware Bay (Fig. 51; Theroux and Wigley footnote 4, table 83).

This species occupies the subarctic-boreal and Mediterranean-Atlantic provinces (Ockelmann 1958).

The small-eared lima has a wide bathymetric range, being found in water depths from 4 to 1,830 m (Tebble 1966; Abbott 1974); in the Arctic, Ockelmann (1958) reported it to range from 7 m in the Faroes to possibly 3,300 m in depth.

Our samples range from 114 to 1,800 m in depth with a mean of 844 m. The majority of samples (43%) are in the 1,000-1,999 m depth range grouping; however, the largest number of specimens (93%) is in the 200-499 m grouping. Twenty-one percent of the samples are in both the 100-199 m and 200-499 m groupings while 14% of the samples are in the 500-999 m grouping. With regard to specimens the 100-199 m depth range grouping contains 2% of the specimens, the 1,000-1,999 m grouping, 5%, and less than 1% of the specimens are in the 500-999 m depth range grouping (Table 128).

This species is found in gravel, sandy gravel, and muddy substrates (Tebble 1966).

The majority of our samples (36%) occurred is silt, 29% of samples occurred in both sand and silty sand, and 7% of the samples occurred in sand-gravel substrates. The majority of specimens (94%) occurred in sand, while 3 and 2% occurred in silty sand and silt, respectively. Less than 1% occurred in sand-gravel (Table 129).

***Limatula* sp. Figure 51.**

There are 14 samples containing 22 specimens identified as *Limatula* sp. in the NEFC collection (Table 5).

The samples containing members of this genus are distributed from between Cape Hatteras and Cape Fear, N.C., to slightly north of Miami, Fla. (Fig. 51; Theroux and Wigley footnote 4, table 84).

Our samples range in depth from 22 to 595 m with a mean of 172 m. Thirty-six percent of the samples and specimens are in the 200-499 m depth range grouping; 22% of the samples and 14% of the specimens are in the 25-49 m grouping; the 0-24 m and 50-99 m groupings each contain 14% of the samples, but 27 and 9% of the specimens, respectively; the 100-199 m and 500-999 m groupings each contain 7% of the samples, but 9 and 5% of the specimens, respectively (Table 130).

Silt substrates contained 43% of the samples and 41% of the specimens while sand-shell and sand each contained 21% of the samples, and 32 and 18% of the specimens, respectively; sand-gravel and silty sand substrates contained 7% of the samples and 5% of the specimens, respectively (Table 131).

Family OSTREIDAE
Genus *Ostrea* Linné 1758.

***Ostrea* sp. Figure 79.**

The NEFC collection contains one specimen from one sample of an unidentifiable oyster which was classified to the generic level of *Ostrea* sp. (Table 5).

The single sample of this taxon is from the continental shelf south of Cape Fear, N.C. (Fig. 79; Theroux and Wigley footnote 4, table 135).

The depth of the water at the sampling site is 25 m, placing it in the 25-49 m depth range grouping; the sediment type is shell.

Genus *Crassostrea* Sacco 1897.

***Crassostrea virginica* (Gmelin 1791). American oyster. Figure 31.**

Crassostrea virginica is one of the most valuable of commercially exploited shellfish stocks. Oysters have been used by man since the dawn of history, and have existed as a group for millions of years. In 1978 total U.S. landings yielded 51 million pounds of meats valued at $60.9 million, an increase of 5 million pounds and $8.4 million compared with 1977 (Pileggi and Thompson, 1979).

This species is reported to occur from the Gulf of St. Lawrence to the Gulf of Mexico; it also occurs in the West Indies and at Panama (Johnson 1934; La Rocque 1953; Ockelmann 1958; Tebble 1966; Abbott 1968, 1974; Morris 1973; Emerson et al. 1976).

Although the American oyster is very common within the area reported on, there is only one specimen from one sample in the NEFC collection (Table 5). This lack is a direct result of this organism's choice of habitat in the intertidal and subtidal regions of bays, sounds, and estuaries which are outside the area of responsibility of this Center.

The specimen in our collection is from shallow water in the midsection of Cape Cod, Mass. (Fig. 31; Theroux and Wigley footnote 4, table 49).

The zoogeographic distribution of this species includes the Boreal, Virginian, Carolinian, Caribbean, and Celtic provinces (Coomans 1962); Dance (1974) placed it in the Transatlantic, Caribbean, and Boreal provinces and mentioned that it has been introduced into British waters.

As previously mentioned, this organism is primarily subtidal but ranges out to moderately shallow water. In the southern reaches of its range it does occur intertidally. The sample containing the one specimen of the American oyster in our collection is from a depth of 1 m.

Our sample has no sediment data associated with it. However, due to the life habits of the organism, it is normally found on hard bottom as a result of its habit of attaching itself to the substratum.

Subclass HETERODONTA
Order VENEROIDA
Family LUCINIDAE

The NEFC collection contains 166 specimens from 44 samples which are identified to the level of family Lucinidae (Table 5).

Samples containing members of this family occur in the middle and southern reaches of our study area from Chesapeake Bay southward to just north of Miami, Fla.; however, there is one sample from Buzzards Bay, Mass., which contains some members of this family (Fig. 56; Theroux and Wigley footnote 4, table 95).

Our samples range in depth from 4 to 53 m with a mean of 18 m. The majority of samples and specimens are in the shallowest depth range grouping, 0-24 m, which contains 82% of the samples and 93% of the specimens; 14% of the samples and 5% of the specimens are in the 25-49 m depth range grouping, and 5% of the samples and 1% of the specimens are in the 50-99 m grouping (Table 132).

Sand was the predominant substrate in which members of the family Lucinidae were found. This substrate contained 73% of the samples and 87% of the specimens; the next preferred substrate type was sand-shell which contained 23% of the samples and 11% of the specimens. Each of the following sediment types, shell and silty sand, contained 2.3% of the samples and 1.2 and 0.6% of the specimens, respectively (Table 133).

Genus *Lucinoma* Dall 1901. Figure 54.

Lucinoma blakeana Bush 1893.

This species occurs from Massachusetts Bay to off Cape Fear, N.C. (Johnson 1934; Abbott 1974).

Lucinoma blakeana is represented in the NEFC collection by 34 specimens from 6 samples (Table 5).

Our samples are from the continental shelf in the Middle Atlantic Bight region off New York (Fig. 54; Theroux and Wigley footnote 4, table 92).

The bathymetric range of this species is from 33 to 849 m depth (Johnson 1934; Abbott 1974).

Our samples occupy a depth range of between 84 and 266 m with a mean of 142 m. Fifty percent of the samples and 38% of the specimens are in the 50-99 m depth range grouping, while 33% of the samples and 59% of the specimens are in the 100-199 m grouping; 17% of the samples but only 3% of the specimens are in the deepest depth range grouping, 200-499 m (Table 134).

Our samples occurred in sand and silty sand substrates, each of which contained 50% of the samples, but 38 and 62% of the specimens, respectively (Table 135).

Lucinoma filosa (Stimpson 1851). Northeast lucina. Figure 55.

The northeast lucina has a fairly wide distribution ranging from Newfoundland to northern Florida and on to the Gulf States (Johnson 1934; Ockelmann 1958; Morris 1973; Abbott 1974).

This is a common offshore species having a fairly strong representation in the NEFC collection which contains 2,266 specimens from 241 samples (Table 5).

Samples in the NEFC collection occur throughout the study area; however, there is a greater concentration in the Southern New England shelf and slope region (Fig. 55; Theroux and Wigley footnote 4, table 93).

The zoogeographic distribution of this species is Boreal, Virginian, and Caribbean (Coomans 1962).

The northeast lucina is a moderately deep dwelling bivalve occupying water depths between 29 and 966 m (Johnson 1934). Morris (1973) stated that there is an increase in depth in which this species is found with a decrease in latitude.

Our samples are from water depths ranging between 15 and 1,408 m with a mean of 147 m. The majority of both samples and specimens are from mid-depth regions represented by the 50-99 m depth range grouping which contains 45% of the samples and 32% of the specimens and the 100-199 m grouping with 38 and 51%, respectively. Significantly smaller amounts of both samples and specimens occur in other depth range groupings (Table 136).

The northeast lucina was absent from coarser grained substrates but occurred in sand, sand-shell, and finer substrates. Sand yielded 42% of the samples and 39% of the specimens, silty sand 37% of the samples and 48% of the specimens. Other substrates in which this species was found were clay, with 14% of the samples and 11% of the specimens, silt with 5% of the samples and 1% of the specimens, and sand-shell with 2% of the samples and 0.4% of the specimens (Table 137).

Lucinoma sp. Figure 55.

The NEFC collection contains four specimens from four samples which bear the designation *Lucinoma* sp. (Table 5).

Members of the genus *Lucinoma* in our collection are from the continental shelf region in the Gulf of Maine and on the continental slope south of the Northeast Peak of Georges Bank (Fig. 55; Theroux and Wigley footnote 4, table 94).

Our samples are from depths which range between 23 and 1,240 m with a mean of 554 m. Twenty-five percent of the samples and 25% of the specimens occur in each of the following four depth range groupings: 0-24, 200-499, 500-999, and 1,000-1,999 m (Table 138).

Members of the genus *Lucinoma* were found in two sediment types, silty sand and silt which contained, with regard to both samples and specimens, 75% of each in the former and 25% of each in the latter (Table 139).

Genus *Myrtea* Turton 1822

***Myrtea pristiphora* Dall and Simpson 1902. Lamellated lucina. Figure 68.**

This species is found at Puerto Rico (Abbott 1974).

There are eight specimens from four samples of this species in the NEFC collection (Table 5).

The NEFC samples are from the continental shelf ranging from the central part to the southern tip of Florida (Fig. 68; Theroux and Wigley footnote 4, table 117).

Abbott (1974) reported the depth range for this species to be 55 to 82 m.

Our samples are from depths between 250 and 310 m with a mean of 281 m. All of our samples and specimens are in the 200-499 m depth range grouping.

Fifty percent of the samples occurred in each of two sediment types, silty sand and silt; silty sand substrates contained 75%, and silt, 25% of the specimens.

Genus *Parvilucina* Dall 1901

***Parvilucina blanda* (Dall and Simpson 1902). Three-ridged lucina. Figure 84.**

The distribution of this species is from North Carolina to Brazil (Abbott 1974).

Parvilucina blanda is a moderately common southern bivalve of which there are six specimens from five samples in the NEFC collection (Table 5).

The samples in the NEFC collection are distributed on the continental shelf from south of Cape Hatteras, N.C., to slightly north of Jacksonville, Fla. (Fig. 84; Theroux and Wigley footnote 4, table 144).

Abbott (1974) reported the depth range of this species to be from 18 to 37 m.

Our samples range in depth between 15 and 35 m with a mean of 26 m. The majority of both samples and specimens, 80% for the former and 83% for the latter, are in the 25-49 m depth range grouping with 20% of the samples and 17% of the specimens in the 0-24 m grouping (Table 140).

Sand was the predominant substrate type inhabited by *Parvilucina blanda* in our collection with 60% of the samples and 67% of the specimens occurring in this substrate type; both sand-shell and silty sand each contained 20% of the samples and 17% of the specimens (Table 141).

Family THYASIRIDAE
Genus *Axinopsida* Sars 1878

***Axinopsida orbiculata* (G. O. Sars 1878). Figure 17.**

The general distribution of this species is from Greenland to Casco Bay, Maine (Johnson 1934; La Rocque 1953; Abbott 1974). Ockelmann (1958) listed a widespread occurrence in Arctic regions and considered it to extend to north of Cape Cod, Mass. The distribution of variety *inaequalis* according to Johnson (1934) and Abbott (1974) is in the Bay of Fundy and the Gulf of Maine.

The NEFC collection contains one specimen of *Axinopsida orbiculata* from one sample (Table 5). Although a final determination has not yet been made, we suspect that, due to its distribution, it is the variety *inaequalis* Verrill and Bush 1898 of this species.

Our sample was obtained in Vineyard Sound, Mass. (Fig. 17; Theroux and Wigley footnote 4, table 26).

The zoogeographic provinces occupied by this species are the panarctic and Atlanto-arctic (Ockelmann 1958), while Gosner (1971) placed it in the Boreal.

In Atlantic waters, *A. orbiculata* is found at depths of from 18 to 55 m (Abbott 1974), while in the Arctic it ranges from 2 to 944 m (Ockelmann 1958). The variety *inaequalis*, according to Johnson (1934) and Abbott (1974), is found in waters from 33 to 64 m deep. Our specimen was captured at a depth of 3 m.

The only information pertaining to sediments we have found relates to our sample which was in a sand substrate.

Genus *Thyasira* Lamarck 1818

***Thyasira brevis* Verrill and Bush 1898. Figure 108.**

Johnson (1934), Clarke (1962), and Abbott (1974) reported this species as being distributed from Georges Bank to off Cape Hatteras, N.C.

There are three specimens of this uncommon tiny bivalve in the NEFC collection from one sample (Table 5).

Our sample is from the upper continental slope south of Nantucket Shoals, Mass. (Fig. 108; Theroux and Wigley footnote 4, table 195).

The bathymetric range of this bivalve is from 183 to 3,340 m (Abbott 1974).

Our sample is from a depth of 440 m which places it in the 200-499 m depth range grouping.

The sample was obtained from a sand bottom.

***Thyasira croulinensis* Jeffreys 1847. Figure 108.**

This species is widely distributed throughout Arctic regions, western Europe and into the Mediterranean Sea, it occurs from West Greenland to off Bermuda in the northwest Atlantic (Johnson 1934; La Rocque 1953, Ockelmann 1958; Clarke 1962; Tebble 1966; Abbott 1974).

This tiny bivalve is represented in the NEFC collection by four specimens from three samples (Table 5).

One of our samples is from the coast of Maine, another from the eastern portion of the Gulf of Maine, and the third sample is on the Southern New England shelf west of Nantucket Shoals (Fig. 108; Theroux and Wigley footnote 4, table 196).

Ockelmann (1958) reported that the species is low Arctic-boreal in distribution, it also occupies the Mediterranean-Atlantic province, and is abyssal.

Thyasira croulinensis enjoys a wide bathymetric range, occupying water depths which range from 7 to 2,700 m (Clarke 1962; Tebble 1966).

Our samples are from water depths which range between 49 and 353 m with a mean of 153 m. In terms of depth range groupings, 33% of the samples are in each of the 25-49, 50-99, and the 200-499 m groupings, while the distribution of specimens was 25% in the 25-49 and 50-99 m groupings, and 50% of the specimens are in the 200-499 m grouping (Table 142).

Three sediment types each contained 33% of the samples; these were till, silty sand, and silt substrates. In terms of specimens, till and silt contained 25%, while silty sand substrates contained 50% of the specimens (Table 143).

Thyasira elliptica Verrill and Bush 1898. Figure 108.

Johnson (1934), Clarke (1962), and Abbott (1974) all stated that this species is found off Martha's Vineyard, Mass.

The NEFC collection contains 12 specimens from 4 samples of this rather rare bivalve species (Table 5).

Our samples are from the New England region, one sample off the coast of Maine, two south of Martha's Vineyard, Mass., at the edge of the continental shelf, and another in the Middle Atlantic Bight off Long Island, N.Y. (Fig. 108; Theroux and Wigley footnote 4, table 197).

The above cited authors all state one depth occurrence for this species at 2,655 m.

Our samples containing *Thyasira elliptica* are from water depths which range between 64 and 114 m with a mean of 91 m. Seventy-five percent of the samples and 92% of the specimens are in the 50-99 m depth range grouping, and 25% of the samples and 8% of the specimens are in the 100-199 m grouping (Table 144).

Clay substrates contained 75% of the samples and 67% of the specimens, while sand sediments contained 25% of the samples and 33% of the specimens (Table 145).

Thyasira equalis Verrill and Bush 1898. Figure 109.

This species occurs in various sections of the Arctic, the north Eurasian continent and Norway, and in the northwest Atlantic it ranges from Nova Scotia to Chesapeake Bay (Johnson 1934; La Rocque 1953; Ockelmann 1958; Clarke 1962; Abbott 1974).

Thyasira equalis is represented in the NEFC collection by 309 specimens from 44 samples (Table 5).

The NEFC suite of samples ranges from the environs of Nova Scotia down through the Gulf of Maine and Georges Bank region to the Middle Atlantic Bight region off Atlantic City, N.J. (Fig. 109; Theroux and Wigley footnote 4, table 198).

Ockelmann (1958) considered the distribution of this species as being probably panarctic and abyssal in the North Atlantic only.

The above cited authors report the depth range for this species as occurring between 172 to 2,813 m.

Our samples are from depths which range between 37 and 2,910 m with a mean of 283 m which could possibly be an extension of existing depth records. In terms of depth range groupings the mid-depth groupings contain almost equal amounts of samples and specimens. In order of increasing depth range the abundance of samples and specimens is as follows: the 25-49 m depth range grouping contains 5% of the samples and 3% of the specimens; the 50-99 m grouping, 14% of the samples and 19% of the specimens; the 100-199 m grouping contains 34% of the former and 28% of the latter, while the 200-499 m grouping contains the same amount of samples (34%) and 25% of the specimens; the 500-999 m grouping contains 11% of the samples and 25% of the specimens, while the 2,000-3,999 m grouping contains 2% of the samples and 0.3% of the specimens (Table 146).

Members of this species were obtained from four sediment types. Sand substrates contained 11% of the samples and 12% of the specimens; silty sand contained 32% of the samples and 36% of the specimens; silt sediments contained 7% of the former and 4% of the latter, while clay contained the largest amounts, 50% of the samples and 48% of the specimens (Table 147).

Thyasira ferruginea Winckworth 1932. Figure 110.

This species enjoys a wide distribution in both Atlantic and Pacific Oceans and also extends possibly worldwide. In the Atlantic it ranges from Arctic seas to off North Carolina, while in the North Pacific it ranges from the Aleutian Islands to Alaska; it also occurs at Scotland and the North Sea, in the Mediterranean, and at the Madeira Islands; it has also been reported from off the coast of Africa, off the coast of India, and possibly into Antarctic regions; it has also been recorded from the Mid-Atlantic Ridge region (Johnson 1934; La Rocque 1953; Clarke 1962; Tebble 1966; Abbott 1974).

Our collection contains 1,381 specimens from 92 samples of this small bivalve species which, among the members of the genus *Thyasira*, is the most abundant in our waters (Table 5).

Our samples are distributed from the northeast peak of Georges Bank on the upper reaches of the continental slope, south to Cape Hatteras, N.C., with one sample occurring in the complex of Massachusetts and Cape Cod bays (Fig. 110; Theroux and Wigley footnote 4, table 199).

As well as enjoying wide geographic distribution, this species is also widely distributed with depth ranging from 20 to 3,000 m (Clarke 1962; Tebble 1966).

The NEFC samples are from water depths which range between 41 and 2,715 m with a mean of 1,388 m. The 25-49 m and the 50-99 m depth range groupings each contain 1% of the samples and $<$ 0.5% of the specimens; the 200-499 m grouping contains 8% of the samples and 6% of the specimens, while the 500-999 m grouping contains 28% of the samples and the largest amount of specimens, 54%; the 1,000-1,999 m grouping contains the largest amount of samples, 37%, and 20% of the specimens, while the 2,000-3,999 m grouping contains 25% of the samples and 20% of the specimens (Table 148).

Thyasira ferruginea appears to prefer silty substrates to others for its habitat. Silty sand substrates contained 26% of the samples and 45% of the specimens, while silt sediments contained 50% of the samples and 43% of the specimens; clay sediments contained 15% of the samples and 5% of the specimens with sand containing the smallest amounts of both, 9% of samples and 6% of specimens (Table 149).

Thyasira flexuosa Verrill and Bush 1898. Figure 111.

This species is reported to occur in both the North Atlantic and North Pacific Oceans. In the Atlantic it ranges from Greenland to off North Carolina but has also been reported from Norway, Western Europe, and the Mediterranean; whereas in the Pacific it ranges from the Bering Sea to off San Diego, Calif. (Johnson 1934; La Rocque 1953; Ockelmann 1958; Clarke 1962; Abbott 1974).

This tiny bivalve is represented in the NEFC collection by 1,044 specimens from 104 samples each of which make up 1% of their respective groups (Table 5).

Our samples are from the Gulf of Maine-Nova Scotian shelf region, around the periphery of Georges Bank, south onto the Southern New England continental shelf and slope region, with two samples, in deep water, off the mouth of Chesapeake Bay (Fig. 111; Theroux and Wigley footnote 4, table 200).

Ockelmann (1958) mentioned in his report on the Arctic bivalves "In all probability, *T. flexuosa* has a boreal-lusitanian main distribution and is absent from arctic waters."

The reported depth range for this species is from 4 to 2,006 m (Clarke 1962).

Our samples are from depths which range between 16 and 1,550 m with a mean of 170 m. In terms of depth range groupings the majority of both samples and specimens are more plentiful in the mid-continental shelf to upper slope water depth ranges, with 31% of the samples and 59% of the specimens in the 50-99 m grouping, and 34% of the samples and 17% of the specimens in the 100-199 m grouping; the 200-499 m depth range grouping contains 22% of the samples and 13% of the specimens. Significantly smaller amounts occur on either side of these depth ranges, with 1% of the samples and 0.2% of the specimens in the 0-24 m grouping, 9% of the samples and 7% of the specimens in the 25-49 m grouping, 3% of the samples and 4% of the specimens in the 500-999 m grouping, and 1% of the samples and 0.1% of the specimens in the 1,000-1,999 m grouping (Table 150).

Thyasira flexuosa specimens were found in all sediment types considered in this report; however, they were most abundant in the medium-coarse to fine grained sediments with smallest amounts occurring in the coarser grained fractions. Silty sand substrates contained 20% of the samples and 38% of the specimens, while clay substrates contained 32% of the samples and 32% of the specimens; silt sediments contained 11% of the samples and 15% of the specimens, while sand contained 28% of the samples and 12% of the specimens. Gravel, sand-gravel, till, shell, and sand-shell substrates contained between 1 and 4% of the samples and from 1.3 to 0.1% of the specimens (Table 151).

Thyasira flexuosa forma *gouldii* Philippi 1845. Flexuose cleft clam. Figure 112.

The flexuose cleft clam occurs in both the North Atlantic and North Pacific Oceans and is fairly widely distributed throughout Arctic regions. In the Atlantic it ranges from Greenland and Labrador to Cape Hatteras, N.C.; in the North Pacific it ranges from the Bering Sea to off San Diego, Calif.; it is also reported from northern Eurasian waters and in northern European waters (Johnson 1934; La Rocque 1953; Ockelmann 1958; Clarke 1962; Morris 1973; Abbott 1974).

This tiny common bivalve is represented in the NEFC collection by 415 specimens from 37 samples (Table 5).

Our samples are from the Gulf of Maine region, the Cape Cod region, and the periphery and the outer aspects of Georges Bank onto the Mid-Atlantic continental shelf, with two samples in slope water off the mouth of Chesapeake Bay (Fig. 112; Theroux and Wigley footnote 4, table 201).

Ockelmann (1958) considered this to be a panarctic species and stated that it probably is continuously circumpolar, while Coomans (1962) placed it in the Arctic, Boreal, Virginian, and Carolinian provinces in the northwest Atlantic and Celtic in European waters; Gosner (1971) placed it in the Boreal province.

The reported depth range for this species is from 2 to 2,685 m (Clark 1962).

Our samples are from water depths which range between 32 and 720 m with a mean of 155 m. In terms of depth range groupings, this species seems to prefer the mid-continental shelf depth grouping, 50-99 m, in which 57% of the samples and 55% of the specimens are grouped; the 100-199 m grouping contains 22% of the samples and 5% of the specimens; the 200-499 m and the 500-999 m groupings each contain 8% of the samples but 4 and 27%, respectively, of the specimens; the only other range grouping in which specimens of this species are grouped is the 25-49 m grouping which contains 5% of the samples and 9% of the specimens (Table 152).

As with other members of this genus the medium to fine substrates appear to be preferred above coarser ones. The majority of both samples and specimens occurred in silty sand substrates which contained 38% of the samples and 45% of the specimens; sand sediments contained 33% of the samples and 11% of the specimens, while clay substrates contained 22% of the samples and 34% of the specimens; silt sediments contained 5% of the samples and 10% of the specimens, while sand-gravel, the only coarse grained substrate in which members of this genus were found, contained 3% of the samples and 0.5% of the specimens (Table 153).

Thyasira pygmaea Verrill and Bush 1898. Figure 113.

Johnson (1934), La Rocque (1953), and Abbott (1974) report this species as occurring from Halifax, Nova Scotia, to Martha's Vineyard, Mass.

There are 64 specimens from 8 samples of this small bivalve species in the NEFC collection (Table 5).

Our samples are from the continental slope southeast of Nova Scotia, in the Gulf of Maine, the outer aspects of the Georges Bank continental slope, and two samples on the southern New England continental shelf south of Nantucket Shoals (Fig. 113; Theroux and Wigley footnote 4, table 202).

The depth range for this species, according to the above-cited authors, is 377 to 913 m.

Our samples are from depths which range between 62 and 720 m with a mean of 308 m. The majority of both samples and specimens are in the 200-499 m grouping which contains 38% of the samples and 45% of the specimens; the 50-99 m and the 500-999 m groupings each contain 25% of the samples and 28 and 25% of the specimens, respectively; smallest amounts are in the 100-199 m grouping which contains 13% of the samples and 2% of the specimens (Table 154).

Thyasira pygmaea was found in three sediment types with the majority of both samples and specimens occurring in clay substrates which contained 50% of the samples and 56% of the specimens; silty sand substrates yielded 38% for samples and 41% of the specimens; sand substrates accounted for 13% of the samples and 3% of the specimens (Table 155).

Thyasira subovata Jeffreys 1881. Figure 113.

Both Johnson (1934) and Abbott (1974) listed this species as occurring off Martha's Vineyard, Mass., while Clarke (1962) reported that it occurs in North American waters, western European waters, and at the Canary Islands.

The NEFC collection contains 18 specimens from 7 samples of this uncommon species (Table 5).

Our samples are from the Southern New England continental shelf and slope region south of Nantucket Shoals (Fig. 113; Theroux and Wigley footnote 4, table 203).

Both Johnson and Abbott reported a 915 m depth for this species, while Clarke (1962) listed it as occurring between 300 to 2,564 m.

Our samples are from depths which range from 62 to 567 m with a mean of 256 m. Fifty-seven percent of the samples and 44% of the specimens are in the 50-99 m grouping, 29% of the samples and 50% of the specimens in the 200-499 m grouping, and 14% of the samples and 6% of the specimens are in the 500-999 m grouping (Table 156).

Thyasira subovata specimens were found in four sediment types with 43% of the samples and 56% of the specimens occurring in silt substrates, and 29% of the samples and 28% of the specimens occurring in sand substrates; both silty sand and clay substrates each contained 14% of the samples, but 11 and 6%, respectively, for specimens (Table 157).

Thyasira trisinuata Orbigny 1842. Atlantic cleft clam. Figure 114.

It occurs in both the North Atlantic and North Pacific Oceans and ranges from Labrador and Nova Scotia to the southern half of Florida, and on into the West Indies in the Atlantic; in the Pacific it ranges from Alaska to San Diego, Calif. An interesting observation is that at least for the northwest Atlantic there appears to be an increase in depth occurrence with decreasing latitude (Johnson 1934; La Rocque 1953; Ockelmann 1958; Clarke 1962; Abbott 1968, 1974; Morris 1973).

Thyasira trisinuata is moderately common; the NEFC collection contains 1,079 specimens of this species from 133 samples (Table 5).

The NEFC samples range from the environs of the Nova Scotian shelf, in the inshore regions of the Gulf of Maine, onto the Southern New England shelf and south to Miami, Fla., with, as mentioned earlier, increasing depth occurrence with decreasing latitude (Fig. 114; Theroux and Wigley footnote 4, table 204).

Coomans (1962) placed the Atlantic cleft clam in the Boreal, Virginian, Carolinian, and Caribbean zoogeographic provinces while Gosner (1971) placed it in the Boreal and Virginian provinces.

The reported depth range for this species is from 22 to 2,361 m with the possibility of abyssal records having been transported from shallow waters (Clarke 1962). Other authors report the deepest depth recorded as being 351 m (Johnson 1934; Abbott 1968, 1974).

Our samples are from depths ranging between 23 and 2,520 m with a mean of 156 m. All of the depth range groupings in this report contain specimens and samples of the Atlantic cleft clam with the majority in the mid-continental shelf depth range grouping of 50-99 m which contains 61% of the samples and 62% of the specimens. The 100-199 m grouping contains 22% of the samples and 17% of the specimens, while the 200-499 m grouping contains 8% of the samples and 12% of the specimens; other depth range groupings contain significantly smaller amounts, the shallowest (0-24 m), and the two deepest groupings (1,000-1,999 and 2,000-3,999 m) each contain < 1% of both samples and specimens (Table 158).

Specimens of the Atlantic cleft clam were found in all sediment types, except shell; however, sand and silty sand contained the majority of both samples and specimens, silty sand was first with 40% of the samples and 53% of the specimens while sand sediments contained 35% of the samples and 26% of the specimens; clay substrates contained 15% of the samples and 12% of the specimens, all other sediment types, gravel, sand-gravel, till, and silt contained 5% or less of both samples and specimens (Table 159).

Thyasira sp. Figure 115.

One of the reasons for the moderately large number of specimens (734) and samples (142) of this genus in the NEFC collection is the fact that this bivalve is tiny and has a very soft, thin shell which is easily eroded in preservative. This shell erosion results in only the soft parts of the organism remaining in samples with subsequent difficulty in arriving at a species determination (Table 5).

Samples yielding specimens of the genus *Thyasira* in our collection are from two major regions, one of which is the Gulf of Maine proper, and another suite of samples from the outer continental shelf and upper slope regions beginning on the northeast peak of Georges Bank and extending south to approximately Cape Hatteras, N.C. (Fig. 115; Theroux and Wigley footnote 4, table 205).

The depth range of samples containing *Thyasira* sp. is 15 to 2,645 m with a mean of 295 m. The mid to lower continental shelf depth range groupings contain the majority of both samples and specimens while groupings on either side of the central portion contain significantly fewer samples and specimens. The 100-199 m grouping contains 31% of the samples and 31% of the specimens, while the 200-499 m grouping contains 35% of the samples and 23% of the specimens; 11% of the samples and 23% of the specimens are in the 500-999 m grouping, and 13% of the samples and 18% of the specimens in the 50-99 m grouping; the 0-24, 25-49, 1,000-1,999, and 2,000-3,999 m groupings contain significantly smaller amounts of both samples and specimens (Table 160). There is one sample containing three specimens which does not contain any depth information.

The only sediment type devoid of specimens of this genus was shell. The majority of both samples and specimens occurred in the finer grained substrates with clay containing 34% of the samples and 33% of the specimens; silty sand yielded 30% of the samples and 31% of the specimens; silt contained 16% of the samples and 19% of the specimens, and sand substrates, 11% of the samples and 11% of the specimens. Considerably smaller amounts occurred in gravel, sand-gravel, and till (Table 161). There are 8 samples containing 33 specimens which are unclassified with regard to sediment type.

Family UNGULINIDAE
Genus *Diplodonta* Bronn 1831

Diplodonta sp. Figure 42.

There are 90 specimens from 58 samples classified as *Diplodonta* sp. in the NEFC collection (Table 5).

The distribution of samples containing members of this taxon occurs in two groupings, one off Chesapeake Bay over the edge of the continental shelf north of Cape Hatteras, N.C., the other on the continental shelf ranging from south of Cape Hatteras, N.C., to Miami, Fla. (Fig. 42; Theroux and Wigley footnote 4, table 69).

Our samples are from water depths ranging from 7 to 1,615 m with a mean of 63 m. Placement of samples in depth range groupings shows a diminution in abundance of both samples and specimens with increasing water depth range. Greatest amounts are in the 0-24 depth range grouping which contains 43% of the samples and 38% of the specimens; the 25-49 m depth range grouping contains 40% of the samples and 34% of the specimens while the 50-99 m grouping contains 14 and 21%, respectively; 2% of the samples occur in the 200-499 and 1,000-1,999 m depth range groupings, each of which contained 1 and 6%, respectively, of the specimens (Table 162).

Members of the genus *Diplodonta* occurred in sand-shell, sand, silty sand, and silt sediments. Sand-shell sediments contained 19% of the samples and 18% of the specimens, while sand substrates yielded 74% of the samples and 73% of the specimens; amounts diminished as particle size diminished. Silty sand contained 5% of the samples and 3% of the specimens while silt contained 2% of the samples and 6% of the specimens (Table 163).

Family CHAMIDAE
Genus *Arcinella* Oken 1815

Arcinella cornuta Conrad 1866. Florida spiny jewel box. Figure 7.

This species occurs from North Carolina to Florida and the West Indies in the Atlantic and from the west coast of Florida to Texas in the Gulf of Mexico (Abbott 1968, 1974; Morris 1973; Emerson et al. 1976).

Our collection contains three specimens from three samples of this common bivalve (Table 5), the samples are from the continental shelf between Charleston, S.C., and Jacksonville, Fla. (Fig. 7; Theroux and Wigley footnote 4, table 12).

Abbott (1968, 1974) reported a depth range of 3.7 to 73 m for this species.

Our samples range in depth from 19 to 35 m with a mean of 29 m. Thirty-three percent of samples and specimens are in the 0-24 m depth range grouping, the remaining samples and specimens (67% for each) are in the 25-49 m depth range grouping (Table 164).

The only mention of sediment relation in reports we have seen is a reference to this species being found on old shells (Abbott 1968). Sixty-seven percent of our samples and specimens occurred in sand, and 33% of each were from a sand shell substratum (Table 165).

Family CARDIIDAE
Genus *Chama* Linné 1758

Chama sp. Figure 24.

The NEFC collection contains one sample containing one specimen of material which was identified to the generic level of *Chama* sp. (Table 5).

The sample containing the specimen is from off Miami, Fla. (Fig. 24; Theroux and Wigley footnote 4, table 37).

Our sample of *Chama* is from a water depth of 42 m in a substrate of sand.

Family LASAEIDAE
Genus *Aligena* Lea 1843

Aligena elevata (Stimpson 1851). Eastern aligena. Figure 3.

The eastern aligena is distributed from Massachusetts to North Carolina (Johnson 1934; Abbott 1974; Emerson et al. 1976).

There are two samples containing three specimens of this species in the NEFC collection (Table 5). Abbott (1974) and Emerson et al. (1976) considered it a common species.

Our samples are from Nantucket Sound and just off the outer shore of Long Island, N.Y. (Fig. 3; Theroux and Wigley footnote 4, table 5).

Abbott (1974) reported that the depth range of *A. elevata* is from the shoreline to 18 m, while Porter (1974) reported it from 0.3 to 11 m.

Our two samples are from 18 and 31 m depths with a mean of 25 m. Two specimens occurred in the shallower depth and one at the deeper site.

Both of our samples for this species were in a sand substratum.

Family LEPTONIDAE
Genus *Montacuta* Turton 1822

Montacuta sp. Figure 63.

The NEFC collection contains one specimen from one sample of this genus (Table 5).

The sample in the NEFC collection is from inshore waters at the elbow of Cape Cod, Mass. (Fig. 63; Theroux and Wigley footnote 4, table 109). The depth from which this sample was taken is 18 m which places it in the 0-24 m depth range grouping. The sediment type was sand.

Genus *Mysella* Angas 1877

Mysella sp. Figure 69.

The NEFC Specimen Reference Collection contains two members of this genus from one sample (Table 5).

Our sample is from the upper portion of the continental slope off the midsection of the Florida Peninsula (Fig. 69; Theroux and Wigley footnote 4, table 118). The sample was in a water depth of 400 m placing it in the 200-499 m depth range grouping. Substrate type at the sampling site was silt.

Family TURTONIIDAE
Genus *Turtonia* Alder 1848

Turtonia sp. Figure 115.

Our collection contains one sample which yielded one specimen of the genus *Turtonia* (Table 5).

Our sample is from the northern edge of Browns Bank (Fig. 115; Theroux and Wigley footnote 4, table 206). The sample is from a water depth of 119 m placing it in the 100-199 m depth range grouping, and is from a gravel substratum.

Family CARDITIDAE
Genus *Cyclocardia* Conrad 1867

Cyclocardia borealis (Conrad 1831). Northern cardita. Figure 38.

The northern cardita is reported from both the North Atlantic and North Pacific Oceans, but is more common in the North Atlantic extending from the Arctic Ocean to Cape Hatteras, N.C., while in the Pacific it ranges from the Arctic Ocean to Oregon; it is also found in subarctic regions, ranging from the Parry Islands to and including Labrador (Dall 1902b; Johnson 1934; Morris 1951, and 1973; La Rocque 1953; Ockelmann 1958; Abbott 1974; Emerson et al. 1976).

Cyclocardia borealis is a very common bivalve species in the northwest Atlantic. This commonness is reflected in the NEFC collection where there are 475 samples, representing 4.5% of all samples, containing 8,842, or 8.1% of all specimens (Table 5).

The NEFC samples are from continental shelf and slope waters in the northern reaches of the study area including the Scotian Shelf on the east and west coasts of Nova Scotia, throughout the Gulf of Maine-Georges Bank complex, on the Southern New England shelf and slope to north and east of Cape Hatteras, N.C. (Fig. 38; Theroux and Wigley footnote 4, table 61). There are two apparently disparate samples, one south of Charleston, S.C., on the continental shelf and the other in the inner Florida Keys; these will be investigated further to determine whether they are range extensions or not.

The zoogeographic range is Boreal and Virginian (Coomans 1962; Gosner 1971); whereas, Dance (1974) listed it as occurring in the Boreal and Transatlantic provinces.

The bathymetric range is 1.8 to 796 m (Abbott 1968; Porter 1974).

Our samples are from depths between 15 and 293 m with a mean of 91 m. The 50-99 m depth range grouping contains 56% of the samples and 63% of the specimens; next greatest amounts are in the 100-199 m grouping which contains 24 and 25% of samples and specimens, respectively. The 25-49 m grouping contains 13% of the samples and 11% of the specimens; the 0-24 m grouping 3 and 0.4%, respectively, while the 200-499 m grouping contains 4.4 and 1% of samples and specimens, respectively (Table 166). Two samples containing three specimens have no associated depth information.

Specimens of the northern cardita were found in all of the sediment types considered in this report. The greatest number of samples (36%) were found in sand, but the largest number of specimens (38%) were obtained in till. Sand, silty sand, and clay substrates contained between 15 and 22% of the specimens in each type and silty sand and clay contained 13 to 14% of the specimens (Table 167). Forty-five samples containing 148 specimens are unclassified with regard to sediment type.

Cyclocardia novangliae (Morse 1869). Figure 39.

For many years *Cyclocardia novangliae* has been considered to be a variety of *Cyclocardia borealis*. It has recently achieved the status of a valid species (J. J. Kosmark[5]).

The range of this species extends from Newfoundland to Cape Cod, Mass. (Johnson 1934; La Rocque 1953). Abbott (1974) reported it to be distributed from Nova Scotia to New York.

There are 89 specimens from 26 samples of this species in the NEFC collection (Table 5).

The samples in our collection are from the Nova Scotian banks and shelf, the Gulf of Maine continental shelf off the coast of Maine, and the Northeast Peak of Georges Bank as well as Great South Channel southeast of Cape Cod (Fig. 39; Theroux and Wigley footnote 4, table 62).

The range in depth from which our specimens were obtained is 46 to 249 m with a mean of 95 m. The 50-99 m depth range grouping contains the largest amount of both samples (65%) and specimens (90%). Twenty-three percent of the samples and 7% of the specimens are in the 100-199 m depth range grouping, 8% of the samples and 2% of the specimens occur in the 25-49 m grouping, and 4 and 1%, respectively, in the 200-499 m grouping (Table 168).

Sand-gravel was the predominant substrate type containing 44% of the samples and 43% of the specimens, while gravel, although containing 20% of the samples, contained only 7% of the specimens; till substrates yielded 12% of the samples and 27% of the specimens; shell and sand each contained 8% of the samples but 18 and 2% of the specimens, respectively; both clay and sand-shell each contained 4% of the samples and 1% of the specimens (Table 169). There is one sample containing one specimen which is unclassified with regard to sediment type.

Cyclocardia sp. Figure 39.

There are 22 specimens from 16 samples in the NEFC collection which are identified as *Cyclocardia* sp.(Table 5).

The NEFC samples of this taxon are located on the continental shelf from Cape Hatteras southward to just north of Miami, Fla. (Fig. 39; Theroux and Wigley footnote 4, table 63).

Water depths at which our samples of *Cyclocardia* were obtained range between 8 and 80 m with a mean of 30 m. Three depth range groupings are involved with this distribution, 50% of the samples and 59% of the specimens are in the 0-24 m depth range grouping, 38% of the samples and 32% of the specimens are in the 25-49 m grouping, and 13 and 9% of samples and specimens, respectively, are in the 50-99 m grouping (Table 170).

Fifty percent of the samples and specimens occurred in sand-shell substrates while sand sediments contained 31 and 32%, respectively. Each of the following sediment types contained 6% of the samples: gravel, shell, and silty sand; gravel and shell substrates contained 5% of the specimens, while 9% of the specimens were obtained from silty sand substrates (Table 171).

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[5] J. J. Kosmark, graduate student, Graduate School of Oceanography, University of Rhode Island, Kingston, RI 02881, pers. Commun. May 1978.

Genus *Pleuromeris* Conrad 1867

***Pleuromeris tridentata* (Say 1827).[6] Three-toothed cardita. Figure 91.**

The three-toothed cardita is distributed from North Carolina to all of Florida and into the Gulf of Mexico (Johnson 1934; Morris 1973; Abbott 1974).

Pleuromeris tridentata is represented in the NEFC Specimen Reference Collection by 168 specimens from 61 samples (Table 5).

Our samples are from the continental shelf between Cape Hatteras, N.C., and the Florida Keys (Fig. 91; Theroux and Wigley footnote 4, table 157).

Pleuromeris tridentata is commonly found in moderately shallow to moderately deep water which ranges from 0.3 to 227 m (Johnson 1934; Porter 1974).

Our samples are from depths which range between 9 and 233 m with a mean of 33 m. The bulk of our samples are in the 0-24 m and 25-49 m depth range groupings which contain 43 and 32% of the samples and specimens, respectively, in the former and 44 and 56% of the samples and specimens in the latter; 10% each of samples and specimens are in the 50-99 m grouping while 2 and 1%, respectively, are in the 100-199 m and 200-499 m depth range groupings (Table 172).

Samples containing the three-toothed cardita were obtained from gravel, shell, sand-shell, sand, and silty sand substrates. Sand sediments contained the greatest amount of both samples and specimens which was 48 and 66%, respectively, while sand-shell was next with 41% of the samples and 23% of the specimens. Significantly lower amounts occurred in the other sediment types (Table 173).

Genus *Pteromeris* Conrad 1862

***Pteromeris perplana* (Conrad 1841a). Flattened cardita. Figure 96.**

This species occurs from North Carolina to Florida and is also found in the Gulf of Mexico (Morris 1973; Abbott 1974; Porter 1974).

Pteromeris perplana is a common bivalve represented in our collection by 28 specimens from 14 samples (Table 5).

Our samples are from the continental shelf between Cape Fear, N.C., and slightly north of Miami, Fla. (Fig. 96; Theroux and Wigley footnote 4, table 169).

Depths in which this species is found range between 2 and 116 m of water (Abbott 1974; Porter 1974).

Our samples are from water depths which range between 10 and 43 m with a mean of 30 m. The majority of both samples and specimens are in the 25-49 m depth range grouping which contains 79% of the samples and 89% of the specimens; the 0-24 m grouping contains 21% of the samples and 11% of the specimens (Table 174).

The flattened cardita samples were obtained from four sediment types: sand-gravel contained 7% of the samples and 4% of the specimens; shell contained 14% of the samples and 7% of the specimens; sand-shell contained 21% of the samples and 36% of the specimens; and sand contained 57% of the samples and 54% of the specimens (Table 175).

Family ASTARTIDAE
Genus *Astarte* Sowerby 1816

***Astarte borealis* (Schumacher 1817). Boreal astarte. Figure 10.**

This species is reported to occur from Arctic seas and Greenland to Massachusetts in the North Atlantic, and from Alaska to Japan in the North Pacific (Johnson 1934; Clarke 1962; Tebble 1966; Morris 1973; Abbott 1974; Emerson et al. 1976). Ockelmann's (1958) records for Arctic regions are quite extensive showing the boreal astarte occurring at East and West Greenland, Jan Mayen, Spitzbergen, Franz Joseph Land, Novaya Zemblya, the White Sea, along the Murman Coast, Finmark, in the Barents, Kara, and Siberian Ice Seas, in the Bering Sea and Strait in Alaska, the seas north of America, Grinnell Land, Baffinland, the Parry Islands, Hudson Strait, Labrador, Newfoundland, Nova Scotia, Iceland, Massachusetts Bay, off Norway south to Bergen, in the northern part of the North Sea, the Kattygat, Danish Belts, the Sounds in the Baltic to east of Bornholm. In the Pacific it extends southward from the Sea of Okhotsk to the Aleutians, Japan, and Forrester Island.

The boreal astarte, a common bivalve of North Atlantic waters, is represented in our collection by 22 specimens from 18 samples (Table 5).

The majority of our samples are from the continental shelf and adjacent banks south of Nova Scotia. Several samples occur on the Northeast Peak of Georges Bank and three samples on the southern New England continental shelf (Fig. 10; Theroux and Wigley footnote 4, table 16).

The main distribution of this species is panarctic and circumpolar with Boreal outposts (Ockelmann 1958); Dance (1974) placed it in the Arctic, Boreal, Aleutian, and Transatlantic provinces.

The boreal astarte is found at depths ranging from 0 to over 2,500 m (Ockelmann 1958; Clarke 1962).

The depth range of our samples is 30 to 95 m with a mean of 74 m. Eighty-nine percent of our samples and 91% of our specimens are in the 50-99 m depth range grouping, the remainder are in the 25-49 m grouping (Table 176).

Astarte borealis appears to prefer coarse grained sediments. Thirty-five percent of our samples occurred in each of two sediment types: gravel and sand-gravel, while 24 and 6%, respectively, occurred in sand and sand-shell sediments. In terms of specimen density, 43% occurred in sand-gravel, 29% in gravel, 24% in sand, and 5% in sand-shell (Table 177). One sample with one specimen was unclassified with regard to sediment type.

***Astarte castanea* (Say 1822). Smooth astarte. Figure 11.**

The smooth astarte is distributed from Arctic seas to Cape Hatteras, N.C. (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Ockelmann 1958; Abbott 1968, 1974; Emerson et al. 1976).

Our samples are from the continental shelf ranging from the Northeast Peak of Georges Bank to slightly north of the mouth of Chesapeake Bay off Maryland; a small group of samples on the Scotian Shelf and at the mouth of the Bay of

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[6] Abbot (1974) has "(Say, 1826)" for this species, it should be (Say 1827), see under References.

Fundy also provided specimens (Fig. 11; Theroux and Wigley footnote 4, table 17).

The zoogeographic distribution of this species is Boreal and Virginian (Coomans 1962; Gosner 1971), but Dance (1974) assigned it to the Boreal and Transatlantic provinces.

Depths occupied by *A. castanea* range from 9 to 152 m (Johnson 1934; Abbott 1968).

This common species is well represented in the NEFC collection which contains 458 specimens from 106 samples (Table 5).

Our samples are from depths between 0 and 123 m with a mean of 46 m. Samples and specimens are fairly evenly distributed among three of our depth range groupings (0-24, 25-49, and 50-99 m) which collectively account for nearly 96% of the samples and 99% of the specimens, the balance is in the 100-199 m grouping (Table 178). One sample with one specimen had no information relating to depth.

Samples containing the smooth astarte were absent in till and silt sediments. The majority of samples (65%) and specimens (63%) occurred in sand; sand-gravel yielded 14% of the samples and 24% of the specimens; other sediments in which they occurred (gravel, shell, sand-shell, silty sand, and silt) each contained significantly smaller quantites of both samples and specimens (Table 179). There are 12 samples containing 74 specimens which are unclassified with regard to sediment type.

Astarte crenata subequilatera Sowerby 1854. Lentil astarte. Figure 12.

This species is reported to occur from Arctic seas including Labrador and the Gulf of St. Lawrence to Florida (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Abbott 1968, 1974). It is widely distributed in the Arctic and is considered by Ockelmann (1958), along with its subspecies, to be panarctic and circumpolar.

The lentil astarte is a common bivalve which occurs in 4% of our samples representing nearly 5% of the total number of specimens (Table 5). These values make it the fourth most plentiful in terms of samples and fifth ranked in terms of specimens.

Our samples are concentrated, for the most part, in the more northerly regions of our study area. The majority of samples are in the Gulf of Maine and around the periphery of Georges Bank; others, in diminishing numbers, occupy the continental shelf, slope, and rise in the region of southern New England and off the Middle Atlantic Bight south to off Maryland; no samples occur between Maryland and south of Cape Hatteras, N.C., but reappear on the outer shelf and upper slope between South Carolina and Jacksonville, Fla.; two samples contaning specimens occur off the Florida Keys (Fig. 12; Theroux and Wigley footnote 4, table 18).

The zoogeographic distribution is Arctic,Boreal, Virginian, and Carolinian (Coomans 1962); Gosner (1971) considered it Boreal and Virginian.

The reported depth range of the lentil astarte is 24 to 783 m (Morris 1973; Abbott 1974). This species occurs in shallow water in the northern reaches of its range, but in the southern sectors is found only below 92 m (Abbott 1974). Ockelmann's (1958) reported depth range for Arctic regions is from 4 m at Spitzbergen down to 1,275 m near Jan Mayen.

Our samples range from 23 to 611 m in depth with a mean of 150 m. The majority of both samples and specimens are in the mid to deep (shelf break) continental shelf depth range groupings and in the upper slope grouping (50-99, 100-199, and 200-499 m); fewer samples occur in both shallower and deeper depth range groupings (Table 180).

Moderate amounts of samples occurred in a variety of sediment types: till (22%), sand (18%), silty sand (17%), gravel (14%), clay (13%), and sand-gravel (11%); significantly lower amounts occurred in silt (3%), shell (2%), sand-shell (0.5%). There is a wider disparity among sediment types with regard to number of specimens; 49% of the specimens were in till substrates, 15, 14, and 13% in gravel, sand, and silty sand, respectively, with other sediments containing between 5 and 0.5% (Table 181). There are 42 samples containing 323 specimens which are unclassified with regard to sediment type.

Astarte elliptica (Brown 1827). Elliptical astarte. Figure 13.

This species occurs from Arctic seas near Greenland to Massachusetts and also in Europe (Johnson 1934; La Rocque 1953; Abbott 1974). Ockelmann's (1958) distributional data show it occupying most Arctic regions including Denmark and Great Britain, it also occurs in the west Baltic to Bornholm and in France; he considers it panarctic-boreal only in the North Atlantic.

The elliptical astarte, which is a moderately common bivalve, is represented in our collection by 317 specimens from 42 samples (Table 5).

Our samples are from the periphery of the Gulf of Maine, on the Northeast Peak and Southwest Part of Georges Bank, some are in Cape Cod Bay and a few on the Middle Atlantic Bight continental shelf (Fig. 13; Theroux and Wigley footnote 4, table 19).

The reported depth range for this species is 15 to 165 m (Johnson 1934; La Rocque 1953; Abbott 1974); Ockelmann (1958) reported it from 2 m at East Greenland to 442 m at West Greenland. He further stated that dead shells of this species have been found in the North Atlantic down to 2,465 m.

Our samples range in depth from 23 to 156 m with a mean of 77 m. The majority of samples (76%) and specimens (83%) are in the 50-99 m depth range grouping with lesser amounts in the 0-24, 25-49, and 100-199 m groupings (Table 182).

The relation of this species to bottom sediments contains some disparities depending upon which measure is being considered, 1) number of samples or, 2) number of specimens, occurring in each sediment type. To avoid possible misunderstanding each sediment type will be taken in turn, see Table 183. Gravel contained 13% of the samples and 18% of the specimens; sand-gravel contained the highest proportion of samples (23%), but only yielded 4% of the specimens; till had a fairly even ratio, 19% of the samples and 21% of the specimens; shell with only 10% of the samples yielded the greatest number of specimens (41%) of any bottom type; only 3% of the samples and 0.3% of the specimens occurred in sand-shell; 19% of the samples and 4% of the specimens occurred in sand; silty sand contained 3% of the samples and 3.5% of the specimens; none occurred in silt, but clay contained 10% of the samples and 9% of the specimens. There are 11 samples with 33 specimens which are unclassified with regard to sediment type.

Astarte montagui (Dillwyn 1817). Montagu's astarte. Figure 13.

This species occurs in Arctic seas and from Greenland to Massachusetts in the Atlantic; it also ranges from the Bering Sea to British Columbia in the Pacific (Johnson 1934; La Rocque 1953; Morris 1973; Abbott 1974). The distribution in Arctic regions as outlined by Ockelmann (1958) and Tebble (1966) show it occurring very widely throughout the area as well as ranging to the Aleutians, Queen Charlotte Islands, Massachusetts Bay, Denmark, the Western Baltic, and the Bay of Biscay to the south.

This small (12 to 19 mm) member of the genus *Astarte*, considered abundant by Abbott (1974), is represented by only two specimens from one sample in our collection (Table 5).

The sample in our collection is from the Bigelow Bight off the coast of Maine northeast of Portland (Fig. 13; Theroux and Wigley footnote 4, table 20).

Zoogeographic distribution is panarctic-boreal and circumpolar (Ockelmann 1958); Gosner (1971) listed it as Boreal, and Dance (1974) referred to it as occupying the Boreal, Arctic, and Aleutian provinces.

Published records show this species to range from 0 to 445 m in depth (Ockelmann 1958; Abbott 1974).

Our sample is from 79 m depth.

Tebble (1966) listed Montagu's astarte as being found in clean sand, and in muddy and sandy gravel. Our sample is from a till bottom.

Astarte nana Dall 1886. Southern dwarf astarte. Figure 13.

The range of this species is from Cape Hatteras, N.C., to Florida, the Gulf States, and the West Indies (Johnson 1934; Abbott 1974).

The southern dwarf astarte is reported to be very abundant especially off eastern Florida (Abbott 1974). The NEFC collection contains 4 samples with a total of 18 specimens (Table 5).

Our samples range from south of Cape Hatteras to slightly south of Miami, Fla. (Fig. 13; Theroux and Wigley footnote 4, table 21).

The published depth range for this species is 11 to 824 m (Johnson 1934; Abbott 1974; Porter 1974).

Our samples range from 248 to 765 m with a mean of 552 m. The 200-499 and 500-999 m depth range groupings each contain 50% of the samples and 33 and 67% of the specimens, respectively (Table 184).

Our samples were found in sand, silty sand, and silt substrates (Table 185).

Astarte quadrans Gould 1841. Figure 14.

This species occurs from the Gulf of St. Lawrence to Long Island Sound (Johnson 1934; La Rocque 1953; Abbott 1974); Ockelmann (1958) listed its distribution from Newfoundland to Cape Cod.

The NEFC collection contains 48 specimens of *A. quadrans* from 28 samples (Table 5).

Our samples occur on the Scotian Shelf, in the Gulf of Maine, on outer Georges Bank and on the Middle Atlantic Bight continental shelf south to off Chesapeake Bay (Fig. 14; Theroux and Wigley footnote 4, table 22).

Coomans (1962) listed this species as occupying the Boreal and Virginian provinces, while Gosner (1971) assigned it to Boreal regions.

The published depth distribution of *A. quadrans* ranges from 11 to 73 m (Abbott 1974).

Samples in the NEFC collection range from 22 to 188 m with a mean of 55 m. The majority of our samples and specimens occur in two depth range groupings: 1) 50-99 m, and 2) 25-49 m, the former contains 46 and 56% of the samples and specimens, respectively, and the latter 32 and 23%, respectively, smaller amounts occur in the 0-24 and 100-199 m groupings (Table 186).

The majority of samples (69%) and specimens (80%) of this species occurred in sand sediments, while 19 and 13% of samples and specimens, respectively, occurred in sand-gravel; smaller amounts were obtained in till and sand-shell sediments (Table 187). There are two samples containing two specimens which are unclassified with regard to sediment type.

Astarte smithii Dall 1886. Smith's astarte. Figure 14.

Smith's astarte occurs from the Gulf of Mexico to the West Indies and in the Caribbean (Johnson 1934; Clarke 1962; Abbott 1974).

Our collection contains two samples from one sampling site, providing three specimens of *A. smithii* (Table 5).

Our samples are from off the Florida coast southeast of Jacksonville (Fig. 14; Theroux and Wigley footnote 4, table 23).

Depth range for this species according to the above three authors is 99 to 2,869 m. Our samples are from 455 m depth. This depth places it in the 200-499 m depth range grouping.

The substrate at the site of our samples was silt.

Astarte undata Gould 1841. Waved astarte. Figure 15.

Widely distributed on the continental shelf and upper continental slope of the northwest Atlantic, it ranges from West Greenland and arctic Canada to cold, deep waters south of Cape Hatteras, N.C. (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Ockelmann 1958; Emerson et al. 1976).

"Probably the most common Astarte of New England" (Abbott 1974). The waved astarte occurs in 4.3% of our samples and composes 4.3% of the specimens (Table 5).

Samples in the NEFC collection range from southern Nova Scotia, the Gulf of Maine, Georges Bank, southern New England shelf, Middle Atlantic Bight, to deep water off Chesapeake Bay; three samples occur at the continental shelf break south of Cape Hatteras, N.C. (Fig. 15; Theroux and Wigley footnote 4, table 24).

The waved astarte inhabits the Arctic, Boreal, and Virginian provinces (Coomans 1962); Gosner (1971) listed it as Boreal, and Dance (1974) as Boreal and Transatlantic.

Reported water depths for this species range from below, but near, the tide mark (Abbott 1968) to 190 m (Porter 1974).

Our samples range in depth from 15 to 720 m with a mean depth of 96 m. Fifty-five percent of the samples and 59% of the specimens are from mid-shelf depths (50-99 m). Abundance of samples and specimens outside of this range diminish with increasing and decreasing depth range (Table 188).

Our collections of waved astarte occurred in all sediment types, but most frequently in sand (30% of samples), and till (37% of specimens). They were least frequent in sand-shell, shell, and silt (Table 189).

***Astarte* sp. Figure 16.**

The NEFC collection contains 533 specimens from 94 collections which are classified as *Astarte* sp. (Table 5).

The collections of *Astarte*, without specific determinations, are distributed along the continental shelf to the north of Delaware Bay in a fairly widespread pattern on the Southern New England shelf, on Georges Bank, and into the Gulf of Maine (Fig. 16; Theroux and Wigley footnote 4, table 25).

The depth range for our collections is from 0 to 690 m with a mean of 192 m. A fairly consistent pattern of diminishing sample and specimen density persists from the 50-99 m grouping to the 500-999 m grouping; small quantities occur in the two shallowest groupings (Table 190).

The largest percentages of samples for this genus were found in sand and silty sand substrates which contained 42% and 17%, respectively; gravel, sand-gravel, till, silt, and clay accounted for from 3 to 13% of the samples. One anomaly with regard to the number of specimens occurred in till substrates which contained 16% of the specimens but only 9% of the samples while silty sand areas accounting for 17% of samples yielded 13% of the specimens (Table 191). There are 6 samples containing 18 specimens which are unclassified with regard to sediment type.

Family CRASSATELLIDAE

Genus *Crassinella* Guppy 1874

***Crassinella lunulata* (Conrad 1834). Lunate crassinella. Figure 30.**

The lunate crassinella is reported to occur from Massachusetts to Florida, and from Texas to Brazil; it has also been reported in the West Indies and Bermuda (Johnson 1934; Abbott 1968, 1974; Emerson et al. 1976).

Crassinella lunulata is represented in the NEFC collection by 226 specimens from 87 samples (Table 5).

Our samples are from the southern portion of the study area beginning southeast of the mouth of Chesapeake Bay, on the continental shelf south to Miami, Fla.; however, three samples were obtained in the Vineyard Sound-Nantucket Sound region (Fig. 30; Theroux and Wigley footnote 4, table 47).

This species inhabits the Virginian zoogeographic province (Coomans 1962).

The bathymetric distribution of this species ranges from 1 to 549 m (Abbott 1968; Porter 1974). Our samples are from depths which range from 7 to 135 m with a mean of 29 m. The amounts of both samples and specimens in our collection diminish with increasing depth range. Forty-nine percent of the samples and 54% of the specimens are in the 0-24 m depth range grouping; 40% and 39% respectively, are in the 25-49 m grouping while 6% of the samples and 4% of the specimens are in the 50-99 m depth range grouping; 5 and 4% of samples and specimens, respectively, are in the 100-199 m grouping (Table 192).

This species is reported to occur on gravelly or shelly bottom (Emerson et al. 1976).

The majority of our samples were in sand substrates where 46% of the samples and 47% of the specimens were found. The next highest amounts of both samples and specimens occurred in sand-shell substrates where 37 and 32%, respectively, were found; silty sand substrates yielded 8% of the samples and 14% of the specimens, while gravel and sand-gravel substrates each contained 2% of the samples but the former contained 3% and the latter 1% of the specimens (Table 193).

***Crassinella* sp. Figure 30.**

The NEFC collection contains nine specimens of this taxon from three samples (Table 5).

Our three samples of this taxon are from the continental shelf; one sample is off Cape Hatteras, N.C., and the other two are northeast of Charleston, S.C. (Fig. 30; Theroux and Wigley footnote 4, table 48).

Our samples are from water depths between 7 and 25 m with a mean of 14 m. Two-thirds of the samples are in the 0-24 m depth range grouping and the remaining third in the 25-49 m grouping; 56% of the specimens are in the 0-24 m depth range grouping and 44% in the 25-49 m grouping (Table 194).

The majority of our samples and specimens, 67 and 78%, respectively, occurred in sand while 33% of the samples and 22% of the specimens occurred in sand-shell (Table 195).

Genus *Eucrassatella* Iredale 1924

***Eucrassatella speciosa* (A. Adams 1852). Gibb's clam. Figure 44.**

This species occurs from North Carolina to both sides of Florida and the West Indies and is found elsewhere in the Caribbean (Johnson 1934; Abbott 1968, 1974).

This species is a moderately common to frequent southern form which is represented in our collection by three specimens from two samples (Table 5).

Our samples are from the continental shelf between Cape Fear, N.C., and Charleston, S.C. (Fig. 44; Theroux and Wigley footnote 4, table 73).

This species is a Transatlantic and Carolinian province inhabitant (Dance 1974).

The reported depth range for Gibb's clam is from 4 to 183 m (Johnson 1934; Abbott 1968).

The two samples in the NEFC collection are from 25 and 38 m of water. This depth range places both samples in the 25-49 m depth range grouping.

Our samples were obtained on a sand substrate.

Family CARDIIDAE

Genus *Cerastoderma* Poli 1795

***Cerastoderma pinnulatum* (Conrad 1830). Northern dwarf cockle. Figure 23.**

This species occurs from Labrador to off North Carolina in the Cape Lookout region (Johnson 1934; La Rocque 1953; Abbott 1968, 1974; Morris 1973; Emerson et al. 1976).

Cerastoderma pinnulatum is a common bivalve which occurs in 4.5% of our samples composing 3% of the total number of specimens in our collection (Table 5).

The distribution of our samples is widespread throughout the northern reaches of the study area extending from Nova Scotia and overspreading the entire Gulf of Maine-Georges Bank complex. It ranges onto the Southern New England shelf area and into the Middle Atlantic Bight south to Cape Hatteras, N.C.; one sample occurs on the continental shelf southeast of Charleston, S.C. (Fig. 23; Theroux and Wigley footnote 4, table 36).

This species inhabits the Boreal and Virginian provinces (Coomans 1962; Gosner 1971); Dance (1974) assigned it to the Boreal province in the eastern and western North American sectors and also the Transatlantic province.

The reported depth range for this species is 6 to 260 m (Abbott 1968; Porter 1974).

Our samples range in depth from 0 to 1,865 m with a mean of 95 m. The majority of samples (44%) and 35% of the specimens are in the 50-99 m depth range grouping; distribution of samples on either side of this range grouping decrease with both increasing and decreasing depth range; the largest number of specimens (40%) is in the 0-24 m range grouping (Table 196).

Specimens of the northern dwarf cockle occurred in all sediment types. Largest quantities of samples (44%) and specimens (58%) were found in sand; significantly smaller quantities occurred in each of the other sediment types (Table 197). There are 64 samples containing 1,497 specimens which are unclassified with regard to sediment type.

Genus *Clinocardium* Keen 1936

***Clinocardium ciliatum* (Fabricius 1780). Iceland cockle. Figure 27.**

This species is circumboreal and circumpolar, occurring in both the Atlantic and Pacific Oceans in Arctic and subarctic regions. Published reports list it as occurring from Arctic seas south to Cape Cod in the Atlantic and from the Arctic Ocean to Puget Sound and Japan in the North Pacific (Johnson 1934; Clench and Smith 1944; Morris 1951, 1973; La Rocque 1953; Ockelmann 1958; Abbott 1968, 1974).

The Iceland cockle is a very common Arctic and subarctic bivalve which is especially abundant in offshore waters from Maine northward. There are six specimens of this species from four samples in the NEFC collection (Table 5).

The four samples in the NEFC collection are restricted to the continental shelf in the Gulf of Maine, ranging from nearshore Nova Scotia and along the coast of Maine, south to Cape Cod, Mass. (Fig. 27; Theroux and Wigley footnote 4, table 42).

The zoogeographic distribution of this species is Arctic (Ockelmann 1958).

Reported depth range for this species is from 6 to 183 m in Atlantic waters (Abbott 1968, 1974; Gosner 1971; Morris 1973). Ockelman (1958), in his study of Arctic regions, reported it as ranging from 2 to 677 m. He further stated that dead shells are commonly found in the Norwegian Sea down to 2,465 m.

Our samples range from 51 to 114 m in depth with a mean of 79 m. Seventy-five percent of the samples and 83% of the specimens are in the 50-99 m depth range grouping, while 25% of samples and 17% of specimens are in the 100-199 m depth range grouping (Table 198).

Our samples were found in three sediment types. One-third of the samples and 25% of the specimens occurred in gravel; 33% of the samples and 50% of the specimens occurred in till; the remaining 33% of samples occurred in clay which contained 25% of the specimens (Table 199). One sample which contained two specimens is unclassified with regard to sediment type.

Genus *Laevicardium* Swainson 1840

***Laevicardium mortoni* (Conrad 1830). Morton's egg cockle. Figure 50.**

This species is distributed from Nova Scotia to Florida, and ranges into the Gulf of Mexico to Texas and south to Brazil and Guatemala (Johnson 1934; Clench and Smith 1944; Morris 1951, 1973; La Rocque 1953; Abbott 1968, 1974; Emerson et al. 1976). Ockelmann (1958) reported it from Newfoundland to Cape Cod, Mass.

This small cockle, which is especially common in the Southern New England area, is represented by 104 specimens from 47 samples in the NEFC collection (Table 5).

The samples in the NEFC collection occur in two distinct groupings, one of which is in the Cape Cod region and the other beginning south of Cape Hatteras, N.C., on the continental shelf, extending south to slightly below Jacksonville, Fla. (Fig. 50; Theroux and Wigley footnote 4, table 82).

The zoogeographic distribution of Morton's egg cockle, according to Coomans (1962), is Virginian, Caribbean, and Celtic; Gosner (1971) placed it in the Virginian province.

Morton's egg cockle commonly occurs from the low tide zone to 8 m depth (Abbott 1968; Porter 1974).

Our samples are from 0 to 50 m depth with a mean of 9 m. Forty-nine percent of the samples and 57% of the specimens are in the 0-24 m depth range grouping, 47% of the samples and 39% of the specimens are in the 25-49 m grouping, and only 4% of the samples and 4% of the specimens are in the deeper water, 50-99m, depth range grouping (Table 200).

This species occupies muddy bottoms (Emerson et al. 1976).

The NEFC samples were obtained in four sediment types. The majority of the samples (56%) and specimens (59%) occurred in sand substrates with next greatest quantities, 33% for samples and 28% for specimens, occurring in sand-shell; silty sand substrates contained 6% of the samples and 9% of the specimens, while sand-gravel substrates contained 6 and 4%, respectively (Table 201). There are 11 samples containing 28 specimens which are unclassified with regard to sediment type.

Genus *Nemocardium* Meek 1876

***Nemocardium peramabile* (Dall 1881). Eastern microcockle. Figure 70.**

The eastern microcockle occurs from Rhode Island to the Gulf of Mexico, and the West Indies on to Brazil (Johnson 1934; Morris 1973; Abbott 1974).

Nemocardium peramabile, which is very commonly dredged off eastern Florida (Abbott 1974), is represented in our collection by only two specimens from one sample (Table 5).

The single sample containing this species in our collection is from off Key West, Fla. (Fig. 70, Theroux and Wigley footnote 4, table 121).

Coomans (1962) listed this species from the Virginian, Carolinian, and Caribbean zoogeographical provinces.

The depth range for this species is 33 to 641 m (Abbott 1974).

Our sample is from a depth of 220 m. This depth places it in the 200-499 m depth range grouping. The sample was obtained from a silty sand substratum.

Genus *Papyridea* Swainson 1840

***Papyridea semisulcata* (Gray 1825). Frilled paper cockle. Figure 84.**

The frilled paper cockle occurs at Bermuda and is also distributed from southern Florida to Brazil (Johnson 1934; Abbott 1974).

Papyridea semisulcata is an uncommon warm water bivalve of which there are three specimens from two samples in our collection (Table 5).

The two samples in the NEFC collection are from the continental shelf north of Miami, Fla. (Fig. 84; Theroux and Wigley footnote 4, table 143).

According to Abbott (1974), depths at which this species may be found range from low tide line to approximately 73 m.

Our samples are from 28 and 36 m of water. This depth range places both samples and their three specimens in the 25-49 m depth range grouping.

Our samples were obtained in a sand substratum.

Family MACTRIDAE

Genus *Mulinia* Gray 1837

***Mulinia lateralis* (Say 1822). Dwarf surf clam. Figure 63.**

The dwarf surf clam is distributed from the Gulf of St. Lawrence to northern Florida, it extends into Texas, and is also present in the West Indies (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Ockelmann 1958; Abbott 1974; Emerson et al. 1976).

This is a very abundant east coast bivalve species of which there are 897 specimens from 51 samples in the NEFC collection (Table 5).

Our samples are primarily from inshore waters; however, there are two offshore samples on the continental shelf, one on Georges Bank and one off Chesapeake Bay; the range of the inshore samples is from slightly off the coast of Maine south along the Cape Cod region into Long Island Sound, and to Pamlico Sound and Cape Hatteras, N.C. (Fig. 63; Theroux and Wigley footnote 4, table 110).

The dwarf surf clam inhabits the Boreal, Virginian, and Carolinian zoogeographic provinces (Coomans 1962); Gosner (1971) placed it only in the Boreal and Virginian provinces.

This species is a shallow water inhabitant with a depth range extending from +1 to 28 m (Abbott 1974; Porter 1974).

Our samples range from 0 to 55 m with a mean of 13 m. The majority of our samples are in the 0-24 m depth range grouping which contains 84% of the samples and 98% of the specimens; the 25-49 m grouping contains 14% of the samples, and 2% of the specimens, while the 50-99 m grouping contains 2% of the samples, and $< 0.1\%$ of the specimens (Table 202).

Abbott (1974) reported that the dwarf surf clam is normally found in sand sediments.

Among our samples 30% were found in sand which contained 24% of the specimens; however, the majority of the specimens (52%) came from silt substrates which contained 11% of the samples; silty sand contained 30% of the samples and 8% of the specimens; clay contained 24% of the samples and 16% of the specimens; sand-gravel and sand-shell contained significantly smaller amounts of each (Table 203). There are 14 samples containing 143 specimens which are unclassified with regard to sediment type.

***Mulinia* sp. Figure 63.**

The NEFC collection contains two specimens from one sample of this genus (Table 5).

The sample is from the continental shelf south and east of Nantucket Shoals (Fig. 63; Theroux and Wigley footnote 4, table 111), from a water depth of 84 m, in sand.

Genus *Rangia* DesMoulins 1832

***Rangia cuneata* (Sowerby 1832). Common rangia. Figure 96.**

The common rangia is normally found from northern Chesapeake Bay to Texas and Mexico (Johnson 1934; Abbott 1968, 1974; Morris 1973; Emerson et al. 1976).

Rangia cuneata is a locally very abundant to common bivalve which inhabits coastal areas and freshwater to brackish marshes. Our collection contains nine specimens of this species from four samples (Table 5).

Our samples are from Pamlico Sound, N.C. (Fig. 96; Theroux and Wigley footnote 4, table 170).

This bivalve is a shallow water inhabitant occupying water depths between 1 and 4 m according to Porter (1974).

Our samples are from water depths which range between 4 and 6 m with a mean of 5 m. This depth range places it in the 0-24 m depth range grouping.

The NEFC samples containing this species were obtained in clay sediments.

Genus *Spisula* Gray 1837

***Spisula polynyma* (Stimpson, W. 1860). Stimpson's surf clam. Figure 100.**

Stimpson's surf clam is found in both the North Atlantic and North Pacific Oceans. In the Atlantic it ranges from Arctic seas to Rhode Island and in the Pacific from Arctic seas to Puget Sound and is also found at Japan (Johnson 1934; La Rocque 1953; Ockelmann 1958; Morris 1973; Abbott 1974, Emerson et al. 1976). Chamberlin and Stearns (1963) have extended the southern reaches of the range of Stimpson's surf clam to Hudson Canyon.

The NEFC Specimen Reference Collection contains 14 specimens from 2 samples of this species (Table 5).

Our two samples are from off the tip of Cape Cod, Mass., at Provincetown (Fig. 100; Theroux and Wigley footnote 4, table 179).

Morris (1973), Abbott (1974), and Emerson et al. (1976) stated that this moderately common species, which is plentiful at Eastport and other coastal areas in Maine, ranges in depth from the low tide line to approximately 110 m.

The NEFC samples are from water depths of 38 and 42 m which places them in the 25-49 m depth range grouping.

Chamberlin and Stearns (1963) reported that Stimpson's surf clam is normally found in medium sediments of sand, gravel, and mixtures of sand gravel. Unfortunately, there was no sediment information contained in the sampling data of the samples from which we obtained our specimens.

Spisula solidissima (Dillwyn 1817). Atlantic surf clam. Figure 101.

Spisula solidissima is one of the most economically important shellfish resources of the U.S. east coast. Landings in 1977 were 51.0 million pounds of meats valued at $26.4 million, in 1978 landings decreased to 39.2 million pounds of meat with a value of $20.9 million (Pileggi and Thompson 1979). As such, it is, and has been, the subject of intensive studies by various elements of the old Bureau of Commercial Fisheries and presently the NEFC of the NMFS. As with other commercially important bivalve species, the NEFC possesses a broad data base on this species; however, the data herein presented are based solely on the collections which physically reside in the Specimen Reference Collection at the NEFC.

This species is known by a variety of common names in addition to that which appears above: surf clam; hen clam; sea clam; bar clam; skimmer; dipper clam; beach clam; and giant clam, and is extremely important in some areas, especially in the inshore and near offshore waters of coastal New Jersey between Sandy Hook and Cape May.

The Atlantic surf clam is normally found in some outlying areas of the Arctic but principally from the Gulf of St. Lawrence to Cape Hatteras, N.C. (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Ockelman 1958; Abbott 1968, 1974; Yancey and Welch 1968; Emerson et al. 1976).

The NEFC collection has on hand 764 specimens from 166 samples (Table 5).

The NEFC samples are from the continental shelf ranging from the Nova Scotian shelf and Browns Bank, the inshore regions of the Gulf of Maine and the Cape Cod region out onto Georges Bank and south to approximately Jacksonville, Fla. (Fig. 101; Theroux and Wigley footnote 4, table 180).

This species inhabits the Boreal, Virginian, and Carolinian provinces in the northwest Atlantic; the genus and family are Celtic in Europe which harbors another species, *Spisula solida* (Coomans 1962); Gosner (1971) placed it in the Boreal and Virginian provinces, while Dance (1974) stated it occupies the Boreal and Transatlantic zoogeographic provinces.

Although the Atlantic surf clam primarily inhabits inshore, shallow waters, it does range out to 146 m depth (Abbott 1968, 1974; Yancey and Welch 1968).

The depth range of our samples is 0 to 110 m with a mean of 33 m. In terms of depth range groupings, the majority of both samples and specimens are in the shallowest, 0-24 m grouping, which contains 42% of the samples and 67% of the specimens; the 25-49 m grouping contains 40% of the samples and 27% of the specimens; the 50-99 m grouping, 17% of the samples and 6% of the specimens; only 2% of the samples and 0.4% of the specimens are in the 100-199 m grouping (Table 204). There are 2 samples containing 21 specimens which do not contain depth information in their sampling data.

Morris (1951) and Yancey and Welch (1968) reported that this species is normally found in sand and gravel substrates.

Our samples were found in nearly all substrate types considered in this report, the only exceptions were till and clay. The major sediment type was sand which contained 69% of the samples and 82% of the specimens; next greatest abundance of both samples and specimens occurred in sand-shell substrates which contained 12% of the samples and 10% of the specimens; gravel, sand-gravel, shell, silty sand, and silt substrates, although containing samples which yielded specimens of *Spisula solidissima*, contained significantly smaller amounts of both samples and specimens (Table 205). There are 40 samples containing 96 specimens which are unclassified with regard to sediment type.

Family MESODESMATIDAE
Genus *Ervilia* Turton 1822

Ervilia concentrica (Holmes 1860). Concentric ervilia. Figure 44.

The concentric ervilia is a southern species occurring from North Carolina to both sides of Florida and to Brazil, it is also found at Bermuda (Johnson 1934; Abbott 1974).

Ervilia concentrica is a common warm water species of which there are 192 specimens from 112 samples in our collection (Table 5).

Our samples range from just north of Cape Hatteras, N.C., to the southern two-thirds of Florida (Fig. 44; Theroux and Wigley footnote 4, table 72).

Abbott (1974) and Porter (1974) reported a bathymetric range for this species which extends from 0.3 to 92 m in depth.

Our samples are from water depths which range from 6 to 50 m with a mean of 24 m. Three depth range groupings are occupied with diminishing abundance as depth range increases. The 0-24 m depth range grouping contains 54% of the samples and 55% of the specimens; the 25-49 m grouping contains 45% of the samples and 44% of the specimens, while the 50-99 m grouping contains 2% of the samples and < 1% of the specimens (Table 206).

Sand substrates were decidedly preferred over other types of sediments, accounting for 63% of the samples and 61% of the specimens. Next preferred sediment type, sand-shell, contained 28% of the samples and 30% of the specimens. Gravel, sand-gravel, silty sand, and silt substrates contained between 1 and 4% of the samples, and 0.3 to 3% of the specimens (Table 207).

Genus *Mesodesma* Deshayes 1831

Mesodesma arctatum (Conrad 1830). Arctic wedge clam. Figure 61.

This species ranges from Greenland to Chesapeake Bay and Virginia (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Ockelmann 1958; Abbott 1968, 1974; Emerson et al. 1976).

There are 52 specimens from 2 samples of Arctic wedge clams in the NEFC collection (Table 5).

Our samples are from the edge of the continental shelf off the eastern tip of Long Island, N.Y. (Fig. 61; Theroux and Wigley footnote 4, table 107).

The Arctic wedge clam occupies the Arctic, Boreal, and Virginian zoogeographic provinces (Coomans 1962); Gosner (1971) placed it only in the Boreal province, while Dance (1974) placed it in the Arctic, Boreal, and Transatlantic provinces.

Depths occupied by this species range from low water to approximately 92 m (Abbott 1968, 1974).

Our two samples are from 93 and 99 m water depths. This depth range places both samples in the 50-99 m depth range grouping (Table 208).

Morris (1951), Abbott (1968), and Emerson et al. (1976) reported that this species is normally found in sand substrates.

Our samples occurred in silty sand which contained 50% of the samples and 4% of the specimens, and clay with 50% of the samples and 96% of the specimens (Table 209).

Family SOLENIDAE

The NEFC Specimen Reference Collection contains 39 specimens of bivalves from 11 samples which were classified only to the familial level of Solenidae (Table 5).

One sample containing members of this family is from east of Nantucket Shoals in the Great South Channel area, another from the continental shelf off the entrance to Delaware Bay, the remainder are from around Cape Hatteras, N.C., extending from the mouth of Chesapeake Bay to south of Cape Fear, N.C. (Fig. 102; Theroux and Wigley footnote 4, table 181).

Samples containing members of the family Solenidae range in depth from 13 to 53 m with a mean of 26 m. The majority of these samples are in the 0-24 m depth range grouping which contains 64% of the samples and 36% of the specimens, while the 25-49 m grouping contains 27% of the samples and 26% of the specimens; the 50-99 m grouping contains the smallest amount of samples, 9%, but the greatest number of specimens, 39% (Table 210).

Samples containing members of the family Solenidae were found in four different sediment types: gravel, sand-shell, sand, and silty sand. Sand sediments contained the majority of both samples and specimens, 50% for the former and 63% for the latter; sand-shell substrates contained 30% of the samples and 21% of the specimens; silty sand contained 10% of the samples and 13% of the specimens, while gravel substrates contained 10% of the samples and 4% of the specimens (Table 211). There is 1 sample containing 15 specimens which is unclassified with regard to sediment type.

Genus *Ensis* Schumacher 1817

Ensis directus **(Conrad 1843). Atlantic jackknife clam. Figure 43.**

This species is distributed from the Gulf of St. Lawrence and Newfoundland, along the whole U.S. Atlantic coast, south to Florida (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Ockelmann 1958; Abbott 1968, 1974).

Ensis directus is a very common bivalve of the northwest Atlantic whose commonness is reflected in our Specimen Reference Collection which contains 2,150 specimens from 206 samples, each accounting for 2% of their respective category for the entire sampling suite (Table 5).

Our samples are distributed from the Northeast Peak of Georges Bank ranging along the entire continental shelf south to just north of Miami, Fla. (Fig. 43; Theroux and Wigley footnote 4, table 71).

This species inhabits the Boreal, Virginian, and Carolinian zoogeographic provinces (Coomans 1962); Gosner (1971) placed it in the Boreal and Virginian provinces, while Dance (1974) placed it in the Boreal, in east North America, and the Transatlantic provinces.

This species bathymetric habits are principally littoral and intertidal but does extend down to approximately 37 m in depth (Morris 1973; Porter 1974).

Our samples are from depths which range between 1 and 100 m with a mean of 31 m. The majority of samples are in the shallowest depth range grouping 0-24 m which contains 45% of the samples and 67% of the specimens; there is a gradual decline in abundance with increasing depth range with 38% of the samples and 30% of the specimens occurring in the 25-49 m depth range grouping; 17 and 3%, respectively, in the 50-99 m grouping and traces occurring in the 100-199 m grouping (Table 212).

The Atlantic jackknife clam is commonly found on sandy mud or sand bottom near the low water mark (Abbott 1968, 1974).

In our collection 70% of the samples and 60% of the specimens occurred in sand, 20% of the samples and 13% of the specimens occurred in sand-shell, and between 1 and 3% of the samples and < 1 to 2% of the specimens occurred in gravel, sand-gravel, shell, silty sand, and silt substrates (Table 213). There are 12 samples containing 37 specimens which are unclassified with regard to sediment type.

Genus *Siliqua* Megerle 1811

Siliqua costata **Say 1822. Atlantic razor clam. Figure 99.**

The Atlantic razor clam is distributed from eastern portions of Canada, the Gulf of St. Lawrence, and Newfoundland south to North Carolina (Johnson 1934; La Rocque 1953; Ockelmann 1958; Abbott 1968, 1974; Morris 1973, Emerson et al. 1976).

Siliqua costata is a common northwestern Atlantic bivalve, the NEFC Specimen Reference Collection contains 104 specimens of this species from 32 samples (Table 5).

The NEFC samples are primarily from the Georges Bank region with a few inshore collections in the New England region (Fig. 99; Theroux and Wigley footnote 4, table 176).

Coomans (1962) and Gosner (1971) reported this species an an inhabitant of the Boreal and Virginian provinces, while Dance (1974) listed it as occupying the Arctic and Boreal provinces in eastern North America as well as the Transatlantic province.

This species is primarily a shallow water inhabitant but does range out to approximately 29 m depth (Abbott 1974; Porter 1974).

Our samples are from water depths which range between 8 and 260 m with a mean of 55 m. The majority of the samples occurred in mid-shelf depths and shallower. In terms of depth range groupings, 47% of the samples and 39% of the specimens are in the 50-99 m depth range grouping, while 31% of the samples and 41% of the specimens are in the 25-49 m grouping; the 0-24 m grouping contains 16% of the samples and 12% of the specimens; two other depth range groupings which contain samples and specimens of this species are the 100-199 m and the 200-499 m groupings each of which contain 3% of the samples and 7 and 1%, respectively, of the specimens (Table 214).

Abbott (1968, 1974), Morris (1973), and Emerson et al. (1976) all stated that this species is an inhabitant of mud and sand bottoms.

The majority of our samples (97%), and specimens (97%), occurred in sand substrates with silty sand containing 3% for each (Table 215). There are two samples containing eight specimens which are unclassified with regard to sediment type.

Family TELLINIDAE

The NEFC collection contains 67 specimens from 26 samples which are identified to the taxonomic level of family Tellinidae (Table 5).

Samples containing this taxon are sparsely distributed along the east coast continental shelf from New York to Miami, Fla. (Fig. 106; Theroux and Wigley footnote 4, table 190).

The depth distribution of samples containing members of the Tellinidae ranges between 4 and 112 m with a mean of 28 m. The majority of both samples and specimens are in the 0-24 m depth range grouping, which contains 65% of the samples and 73% of the specimens; the 25-49 m and 50-99 m groupings each contain 15% of the samples while the former contains 8% and the latter 18% of the specimens; only one other depth range grouping contains members of this taxon, the 100-199 m grouping with 4% of the samples and 2% of the specimens (Table 216).

No samples containing members of this taxon occurred in sand-gravel, till, or clay sediments; however, sand and sand-shell substrates contained 46 and 31% of the samples, and 48 and 30% of the specimens, respectively; shell and silty sand substrates each contained 8% of the samples and 3 and 16%, respectively, for specimens; gravel and silt substrates each contained 4% of the samples and 2% of the specimens (Table 217).

Genus *Macoma* Leach 1819

Macoma balthica (Linné 1758). Baltic macoma. Figure 58.

The Baltic macoma is widely distributed throughout the northern reaches of the Atlantic and Pacific Oceans. In the Atlantic it extends from Arctic seas to Georgia while in the Pacific from Arctic seas to San Diego, Calif., and Japan; it also occurs in northern Europe where it is very common in Norway and Sweden extending south to the Iberian Peninsula (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Ockelmann 1958; Tebble 1966; Abbott 1968, 1974; Emerson et al. 1976).

This common and abundant bivalve of northern seas is represented by 783 specimens from 45 samples in our collection (Table 5).

The NEFC suite of samples ranges from the Scotian Shelf, south through the Gulf of Maine onto the Middle Atlantic Bight continental shelf to Charleston, S.C. (Fig. 58; Theroux and Wigley footnote 4, table 101).

La Rocque (1953) considered this species to be circumboreal; Coomans (1962) placed it in the Arctic, Boreal, Virginian, and Caribbean zoogeographic provinces and mentioned that the species, genus, and family are Celtic in Europe; Dance (1974) placed it in the Boreal, Mediterranean (on the Atlantic Coast), Aleutian, and Californian provinces.

The bathymetric range of this species extends from the intertidal zone to deep water (Johnson 1934; Abbott 1974).

Our samples are from depths ranging between 1 and 403 m of water with a mean of 75 m. The shallowest, the 0-24 m, depth range grouping contains the largest number of samples (42%) as well as specimens (77%); the next grouping containing significant amounts of both samples and specimens is the 50-99 m grouping with 24 and 16%, respectively. The 100-199 m grouping contains 18% of the samples but only 3% of the specimens, while the 25-49 m grouping and the 200-499 m grouping contain 9 and 7%, respectively, for samples, and 4 and 0.4%, respectively, for specimens (Table 218).

The only sediment type in which no *Macoma balthica* were encountered was shell. The greatest number of samples (32%) occurred in silty sand while the largest number of specimens occurred in sand (47%); sand contained only 23% of the samples and silty sand 14% of the specimens. The finer substrates, from silty sand through clay, contained larger amounts in terms of both samples and specimens than the coarser grained sediments (Table 219). One sample containing one specimen is unclassified with regard to sediment type.

Macoma calcarea (Gmelin 1791). Chalky macoma. Figure 59.

The chalky macoma is widely distributed throughout northern Atlantic and Pacific waters. In the Atlantic it ranges from Arctic seas to Long Island, N.Y., and in the Pacific from Arctic seas to California and Japan; it is also widely distributed throughout Arctic regions (Johnson 1934; La Rocque 1953; Ockelmann 1958; Clarke 1962; Abbott 1968, 1974).

This common cold water species is represented in our collection by 542 specimens from 75 samples (Table 5).

Our samples range from the Scotian Shelf down to the outer shores of Long Island, N.Y. (Fig. 59; Theroux and Wigley, footnote 4, table 102).

La Rocque (1953) listed the chalky macoma as circumpolar; Coomans (1962) listed it as occupying the Arctic, Boreal, and Virginian provinces; Gosner (1971) placed this species only in the Boreal province, while Dance (1974) considered it to inhabit the Arctic, Aleutian, Transatlantic, Californian, and Japonic provinces; Ockelmann's (1958) view is that the chalky macoma is panarctic, and that it is circumpolar with Boreal outposts.

This species enjoys a wide bathymetric range occupying water depths which range from +1 to 2,297 m (Clark 1962; Abbott 1968).

Our samples are from water depths that range from 1 to 720 m with a mean of 136 m. Thirty-one percent of the samples and 26% of the specimens are in the 50-99 m depth range grouping, while the 100-199 m grouping contains 25% of the samples and 27% of the specimens. Amount of both samples and specimens decreases in the depth range groupings on either side of the mid and lower shelf groupings outlined above (Table 220).

Sand and silty sand substrates contained the largest amounts of both samples, 24 and 29% respectively, and specimens, 44 and 36% respectively. Other sediment types contained significantly smaller quantities with the exception of shell and sand-shell sediments from which they were absent (Table 221). There are five samples containing eight specimens which are unclassified with regard to sediment type.

Macoma tenta **(Say 1834). Tenta macoma. Figure 59.**

The tenta macoma is distributed throughout the northwest Atlantic ranging from Newfoundland to Florida; it also occurs at Bermuda, in the Gulf of Mexico, the West Indies, and ranges south to Brazil (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Ockelmann 1958; Abbott 1968, 1974; Emerson et al. 1976).

Macoma tenta is a very common bivalve species of which we have 708 specimens from 22 samples (Table 5).

Our samples occur in the New England region. They are located in the environs of Cape Cod, Mass., and the outer islands, on the outer continental shelf of Georges Bank, and the Gulf of Maine (Fig. 59; Theroux and Wigley footnote 4, table 103).

The main distribution of this species is Virginian, Carolinian, and Caribbean in the Western Atlantic; the genus and family are Celtic in Europe (Coomans 1962); Gosner (1971) considered it to be Boreal and Virginian in distribution.

The tenta macoma is essentially an inshore, shallow water dweller with a depth preference ranging between 0.3 and 31 m (Abbott 1968, 1974; Porter 1974).

Our samples range in depth between 1 and 73 m with a mean of 24 m. The majority of samples and specimens are in the shallowest, 0-24 m, depth range grouping which contains 68% of the samples and 98% of the specimens; the 25-49 m grouping contains 14% of the samples and 0.6% of the specimens while the 50-99 m grouping contains 18% of the samples and 2% of the specimens (Table 222).

Abbott (1968, 1974), and Emerson et al. (1976) reported that this species is normally found in sand or muddy substrates.

The majority of our samples (46%) occurred in sand; the largest number of specimens (73%) occurred in clay. Sand-gravel substrates contained 18% of the samples and 8% of the specimens; sand contained 16% of the specimens; silty sand substrates contained 9% of the samples and 3% of the specimens, and clay contained 27% of the samples (Table 223). There are 11 samples containing 671 specimens which are unclassified with regard to sediment type.

Macoma **sp. Figure 60.**

There are 12 specimens from 10 samples in the NEFC collection which bear the designation *Macoma* sp. (Table 5).

Our samples containing members of this genus are from two of the primary fishing banks in the area, Browns Bank and Georges Bank, and also from coastal waters of Massachusetts and off Long Island, N.Y. (Fig. 60; Theroux and Wigley footnote 4, table 104).

The NEFC samples are from water depths ranging from 1 to 103 m with a mean depth of 48 m. Thirty percent of the samples are in the 0-24 m and the 25-49 m depth range groupings which contain 25 and 33% of the specimens, respectively; 20% of the samples occur in each of the 50-99 m and 100-199 m groupings which contain 25 and 17% of the specimens, respectively (Table 224).

Fifty percent of the samples and specimens occurred in sand substrates with 25% of the samples and 30% of the specimens occurring in silt substrates; the coarse grained fractions, gravel and sand-gravel, each contained 13% of the samples and 10% of the specimens (Table 225). There are two samples containing two specimens which are unclassified with regard to sediment type.

Genus *Strigilla* Turton 1822

Strigilla mirabilis **(Philippi 1841). White strigilla. Figure 102.**

This southern species, which occurs in Bermuda, is also found from Cape Hatteras, N.C., extending around the Florida Peninsula, into the Gulf of Mexico, where it extends from Texas to the Yucatan in Mexico; it has also been reported from Brazil (Johnson 1934; Boss 1969; Morris 1973; Abbott 1974; Emerson et al. 1976).

The white strigilla is represented in the NEFC collection by 12 specimens from 9 samples (Table 5).

The samples in the NEFC collection are from the continental shelf between Cape Fear, N.C., and Jacksonville, Fla. (Fig. 102; Theroux and Wigley footnote 4, table 183).

This species normally ranges in depth from just offshore at +1 to 57 m (Abbott 1968, 1974).

Our samples range in depth from 6 to 30 m with a mean of 17 m. The 0-24 m depth range grouping contains 67% of the samples and 75% of the specimens and the 25-49 grouping contains 33% of the samples and 25% of the specimens (Table 226).

Samples containing the white strigilla were obtained from areas containing sand and sand-shell substrates. The former contained 67% of the samples and 75% of the specimens, while the latter contained 33% of the samples and 25% of the specimens (Table 227).

Genus *Tellina* Linné 1758

Tellina aequistriata **Say 1824. Striated tellin. Figure 103.**

The distribution of this species is from North Carolina to Texas and Brazil; it also occurs in the West Indies (Johnson 1934; Boss 1966; Abbott 1968, 1974; Andrews 1971; Morris 1973).

The NEFC collection contains one specimen from one sample of this species (Table 5).

Our sample comes from inshore waters south of Cape Fear, N.C. (Fig. 103; Theroux and Wigley footnote 4, table 185).

The depth range for the striated tellin is 2 to 64 m (Boss 1966; Abbott 1968).

The NEFC sample is from a water depth of 20 m; this depth places it in the 0-24 m depth range grouping.

Both Boss (1966) and Andrews (1971) reported that this species is normally found on sandy bottoms. Our sample was also obtained from a sand substratum.

Tellina agilis **Stimpson 1858.[7] Northern dwarf tellin. Figure 103.**

This common bivalve occurs from the Gulf of St. Lawrence to Georgia (Abbott 1968, 1974; Boss 1968; Morris 1973; Emerson et al. 1976).

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[7] Abbott (1974) has "Stimpson, 1857" for this species, it should be Stimpson 1858, see under References.

Tellina agilis is represented in the NEFC Specimen Reference Collection by 1,131 specimens, representing 1% of the total number of specimens, from 114 samples which also represent 1% of the total number of samples (Table 5).

The NEFC samples are distributed from Georges Bank and the Cape Cod region along the continental shelf into the Middle Atlantic Bight region south to the environs of Cape Hatteras, N.C.; there is also one sample in the mid-section of the Florida Peninsula (Fig. 103; Theroux and Wigley footnote 4, table 186).

Gosner (1971) stated that this species is Boreal and Virginian in distribution while Dance (1974) placed it in the Boreal as well as the Transatlantic province.

The range of water depth occupied by this species is from 0 to 120 m (Porter 1974).

Our samples are from water depths which range between 1 and 146 m with a mean of 22 m. The majority of both samples and specimens are in the shallowest depth range grouping, 0-24 m, which contains 69% of the samples and 91% of the specimens; the 25-49 m grouping which contains 27% of the samples and 9% of the specimens, while the 50-99 m grouping contains 3% of the samples and 0.5% of the specimens; the 100-199 m grouping contains 2% of the samples and 0.5% of the specimens (Table 228). There are 2 samples containing 12 specimens which do not contain any depth information.

Abbott (1968) reported that this species is normally found in sandy-mud bottoms.

Our samples occurred in all sediment types but in varying proportions. The majority of both samples and specimens occurred in sand substrates which contained 72% of the samples and 92% of the specimens; next largest amounts of samples and specimens occurred in silty sand containing 11% of the samples and 3% of the specimens; there were significantly lower amounts in gravel, sand-gravel, shell, sand-shell, silt, and clay substrates (Table 229). There are 13 samples containing 56 specimens which are unclassified with regard to sediment type.

***Tellina consobrina* Orbigny 1842. Consorbine tellin. Figure 104.**

The distributional range for this species is southeast Florida to the Lesser Antilles and Tobago, it also occurs at Bermuda (Boss 1968; Abbott 1974).

This small tellin is uncommon and is represented in the NEFC collection by 20 specimens from 7 samples (Table 5).

One of our samples is from Cape Fear, N.C., the majority, however, are between Charleston, S.C., and the mid-section of the Florida Peninsula below Jacksonville (Fig. 104; Theroux and Wigley footnote 4, table 187).

The consobrine tellin occupies offshore waters down to approximately 128 m (Abbott 1974).

Our samples occupy water depths which range between 8 and 16 m with a mean of 11 m. This depth range places them in the 0-24 m depth range grouping.

Sediment types in which our samples were found were sand and sand-shell; the former contained 57% of the samples and 65% of the specimens, while the latter contained 43% of the samples and 35% of the specimens.

***Tellina versicolor* DeKay 1843. DeKay's dwarf tellin. Figure 105.**

DeKay's dwarf tellin occurs from Cape Cod to Trinidad in the West Indies and in the Gulf of Mexico, on the west coast of Florida to west Texas (Abbott 1968, 1974; Andrews 1971; Morris 1973; Porter 1974; Emerson et al. 1976).

This is a common northwest Atlantic tellin of which there are 297 specimens from 58 samples in our collection (Table 5).

The NEFC samples are distributed from Atlantic City, N.J., to north of Miami, Fla., on the continental shelf (Fig. 105; Theroux and Wigley footnote 4, table 188).

The zoogeographic distribution of this species is Virginian, Carolinian, and Caribbean (Coomans 1962); Gosner (1971) placed it in the Virginian province.

The depth distribution for this fairly common species is from 2 to 92 m (Johnson 1934; Abbott 1968, 1974).

Our samples are from water depths which range between 6 and 65 m with a mean of 23 m. The majority of both samples and specimens are in the shallowest, 0-24 m depth range grouping which contains 64% of the samples and 87% of the specimens; the 25-49 m grouping contains 33% of the samples and 13% of the specimens, while the 50-99 m grouping contains 3% of the samples and 1% of the specimens (Table 230).

Both Abbott (1968) and Andrews (1971) reported this species occupies sand substrates.

This sand preference is also apparent in our samples with 67% of the samples and 68% of the specimens occuring in this sediment type, while sand-shell substrates contained 29% of the samples and 31% of the specimens; gravel and silty sand substrates each contained 2% of the samples and 0.3 and 0.7%, respectively, of the specimens (Table 231).

***Tellina* sp. Figure 106.**

There are 151 specimens from 70 samples in the NEFC collection which are classified to the level of genus *Tellina* (Table 5).

Samples containing this genus are from the mouth of the Bay of Fundy in the Gulf of Maine, and on Georges Bank, and also range from Cape Cod, Mass., to Miami and the Florida Keys (Fig. 106; Theroux and Wigley footnote 4, table 189).

Our samples are from water depths which range between 0 and 146 m with a mean of 37 m. The majority of both samples and specimens are in the 0-24 m depth range grouping which contains 44% of the samples and 53% of the specimens; there is a gradual diminution in abundance with increasing depth range; the 25-49 m grouping contains 39% of the samples and 34% of the specimens; the 50-99 m grouping contains 11% of the samples and 11% of the specimens, while the 100-199 m grouping contains 6% of the samples and 3% of the specimens (Table 232).

No samples containing members of the genus *Tellina* were found in gravel, sand-gravel, or till sediments, but were found in all the other sediment types considered in this report. The majority of samples (68%) and specimens (71%) occurred in sand, while sand-shell substrates contained 19% of the samples and 18% of the specimens; all other sediment types in which they were found, shell, silty sand, silt, and clay, contained 6% or less of both samples and specimens (Table 233). There are two samples containing nine specimens which are unclassified with regard to sediment type.

Family DONACIDAE
Genus *Donax* Linné 1758

***Donax* sp. Figure 42.**

There are two specimens from one sample of the genus *Donax* in the NEFC specimen collection (Table 5).

The one sample in our collection is from nearshore waters along the outer banks between Cape Hatteras and Cape Fear, N.C. (Fig. 42; Theroux and Wigley footnote 4, table 70).

Our sample is from 18 m of water placing it in the 0-24 m depth range grouping.

The substrate at the sampling site containing the two specimens of wedge shells was sand.

Family SEMELIDAE
Genus *Abra* Lamarck 1818

***Abra* sp. Figure 3.**

Although there are several Atlantic species of this genus none have as yet been identified in the NEFC Specimen Reference Collection due to smallness of size or damage to shells. Members of *Abra* sp. occur in 60 samples yielding 125 specimens (Table 5).

The distribution of our samples of this genus ranges from the entrance of Delaware Bay to off Key West, Fla. (Fig. 3; Theroux and Wigley footnote 4, table 3).

The main distribution for this genus according to Coomans (1962) is Virginian, Carolinian, and Caribbean in the northwest Atlantic and Celtic in Europe.

The depth range of our samples is 6 to 500 m with a mean depth of 81 m. The majority of samples are from continental shelf depths of < 200 m. One-third of the samples are in the 0-24 m depth range grouping, 25% are in the 100-199 m grouping and nearly 22% in depths between 25 and 49 m. In terms of density, *Abra* distribution is greatest (33%) in the shallowest depth range grouping, while 25 and 22% of the specimens are in the 100-199 m and 25-49 m groupings, respectively (Table 234).

Samples containing *Abra* were most plentiful (35 to 25%) in sandy substrates (sand, sand-shell, and silty sand); somewhat lower quantities (2 to 7%) occurred in other substrates (gravel, shell, and silt). The greatest density of specimens, 35%, was found in sand; sand-shell and silty sand substrates each yielded 25% of the specimens; gravel, shell, and silt sediments contained small percentages of specimens (Table 235).

Genus *Cumingia* Sowerby 1833

***Cumingia tellinoides* (Conrad 1830).[8] Tellin-like cumingia. Figure 33.**

The tellin-like cumingia is reported from Canadian waters, and to range from Nova Scotia to Saint Augustine, Fla.; it is also found in Texas (Johnson 1934; La Rocque 1953; Ockelmann 1958; Abbott 1968, 1974; Morris, 1973; Emerson et al. 1976).

This species is represented in our collection by two specimens from two samples (Table 5).

Our two samples are from off Portland, Maine, and in Buzzards Bay, Mass. (Fig. 33; Theroux and Wigley footnote 4, table 53).

This species is found in the Boreal, Virginian, and Carolinian zoogeographic provinces (Coomans 1962).

The depth range of this species is from 0.3 to 70 m (Porter 1974).

Our samples are from water depths of 1 and 45 m with a mean of 23 m. The 0-24 m and 25-49 m depth range groupings each contain 50% of both samples and specimens.

Only one of our samples contained information relating to the type of bottom upon which the organism was found, sand.

Genus *Semele* Schumacher 1817

***Semele bellastriata* (Conrad 1837). Cancellate semele. Figure 97.**

The cancellate semele occurs from Cape Hatteras, N.C., to Florida; it is found at Texas and the West Indies, and at the Bahamas and Bermuda and ranges south to Bahia, Brazil (Johnson 1934; Abbott 1968, 1974; Boss 1972; Morris 1973; Emerson et al. 1976).

Semele bellastriata is fairly common and is represented in the NEFC collection by 38 specimens from 19 samples (Table 5).

Our samples are on the continental shelf ranging from Cape Fear, N.C., to the midsection of the Florida Peninsula (Fig. 97; Theroux and Wigley footnote 4, table 172).

The published depth range for this species is 2 to 116 m (Porter 1974).

The range of depth occupied by our samples is 15 to 41 m with a mean of 29 m. The 25-49 m depth range grouping contains 68% of the samples and 79% of the specimens while the 0-24 m grouping contains 35% of the samples and 21% of the specimens (Table 236).

Boss (1972) reported that the cancellate semele is normally found in coarse sandy substrates.

Our samples were obtained from sand-shell and sand substrates; 63% of the samples and 79% of the specimens occurred in the latter and 37% of the samples and 21% of the specimens in the former (Table 237).

***Semele nuculoides* (Conrad 1841a). Nuculalike semele. Figure 98.**

This species is distributed from North Carolina at Cape Hatteras south through the Gulf of Mexico, it also occurs at the West Indies, the Lesser Antilles, and in the Caribbean, south to Brazil (Johnson 1934; Boss 1972; Morris 1973; Abbott 1974).

Semele nuculoides is represented in the NEFC Specimen Reference Collection by 146 specimens from 62 samples (Table 5).

The samples in the NEFC collection range from Cape Hatteras, N.C., on the continental shelf, south to the middle portion of the Florida Peninsula (Fig. 98; Theroux and Wigley footnote 4, table 173).

According to Boss (1972) the depth range for this species is between 4 and 183 m.

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[8] Abbott (1974) has "(Conrad, 1831)" for this species, it should be (Conrad 1830), see under References.

The NEFC samples are from depths which range between 6 and 50 m with a mean of 26 m. The 25-49 m depth range grouping contains the majority of both samples (52%), and specimens (68%); next most plentiful amounts of samples and specimens are in the 0-24 m grouping which contains 45% of the samples and 30% of the specimens, while the deepest grouping in which they are grouped, 50-99 m, contains 3% of the samples and 3% of the specimens (Table 238).

Boss (1972), in his monograph on the family Semelidae, reported that this species is normally found in offshore sandy substrates.

Our samples occurred in shell, which contained 2% of the samples and 0.7% of the specimens, sand-shell with 27% of the samples and 23% of the specimens; the majority occurred in sand, which contained 66% of the samples and 59% of the specimens, while silty sand substrates contained 5% of the samples and 17% of the specimens (Table 239).

Semele purpurascens **(Gmelin 1791). Purplish semele. Figure 98.**

The purplish semele is distributed from North Carolina to Florida and the Gulf of Mexico, it occurs in the West Indies, and is also found at Uruguay and Brazil along the South American coast (Johnson 1934; Abbott 1968, 1974; Boss 1972; Morris 1973; Emerson et al. 1976).

Semele purpurascens is fairly common, however, the NEFC collection contains only six specimens from four samples (Table 5).

Our samples are from the continental shelf with one sample occurring off the Cape Hatteras, N.C., coast, another off Charleston, S.C., and another slightly north of Miami, Fla. (Fig. 98; Theroux and Wigley footnote 4, table 174).

This species has a fairly wide bathymetric range, occurring in water depths which range from ± 1 to 130 m (Abbott 1968; Porter 1974).

The NEFC samples are from water depths which range between 30 and 80 m with a mean of 59 m. The 25-49 m and 50-99 m depth range groupings contain 25 and 75% of the samples, and 33 and 67% of the specimens, respectively (Table 240).

Boss (1972) reported that this species is normally found in sandy substrates.

Our samples were found in sand-gravel, sand-shell, and sand. Sand-gravel substrates contained 50% of the samples and 50% of the specimens; sand-shell contained 25% of the samples as did sand, but 17% of the specimens occurred in sand-shell and 33% in sand (Table 241).

Semele **sp. Figure 98.**

The NEFC Specimen Reference Collection contains three specimens from two samples which are classified to the generic level *Semele* sp. (Table 5).

The samples bearing this designation are from the continental shelf off the central section of the Florida Peninsula (Fig. 98; Theroux and Wigley footnote 4, table 175).

The samples are from water depths of 20 and 22 m. These depths place both samples in the 0-24 m depth range grouping.

One of our samples containing two specimens (68%), occurred in shell, while the other sample occurred in sand-shell and contained 32% of the specimens.

Family SOLECURTIDAE
Genus *Tagelus* Gray 1847

Tagelus plebeius **(Lightfoot 1786). Stout tagelus. Figure 103.**

This species is distributed from Cape Cod, Mass., to Florida and Texas and other Gulf States, it is also present in the West Indies and has been found in Brazil (Abbott 1968, 1974; Morris 1973; Emerson et al. 1976).

Tagelus plebeius, which is moderately common to locally abundant throughout its range, is represented in the NEFC collection by four specimens from one sample (Table 5).

Our sample is from the western slope of Cape Cod, Mass., in Buzzards Bay (Fig. 103; Theroux and Wigley footnote 4, table 184).

Coomans (1962) placed the distribution of this species in the Virginian, Carolinian, and Caribbean provinces.

The stout tagelus is normally an intertidal inhabitant and ranges down to approximately 8 m depth (Abbott 1968, 1974).

Our sample is from a water depth of 1 m placing it in the 0-24 m depth range grouping. The bottom sediment was sand-gravel.

Family ARCTICIDAE
Genus *Arctica* Schumacher 1817

Artica islandica **(Linné 1767). Ocean quahog. Figure 8.**

Arctica islandica (formerly *Cyprina islandica*) is a commercially important bivalve of the northeastern United States with landings in 1978 totalling 23 million pounds of meats, an increase of 22% over the 1977 landings (Pileggi and Thompson 1979).

In the western Atlantic the ocean quahog ranges from the Arctic Ocean and Newfoundland to off Cape Hatteras, N.C. (Johnson 1934); La Rocque (1953), Abbott (1974), Morris (1973), and Emerson et al. (1976) listed it as also occurring at Iceland. In the eastern Atlantic, Tebble (1966) reported it from the British Isles, Iceland, the Faroes, Onega Bay in the White Sea, and the Bay of Biscay.

The ocean quahog occurs in 3.6% of our samples and represents 1.9% of the specimens in the collection (Table 5). It must be remembered, however, that these samples represent only material presently on hand in the Specimen Reference Collection and not the complete list of records concerning this species at the NEFC.

Our samples of this species range from Nova Scotia to Cape Hatteras, N.C. (Fig. 8; Theroux and Wigley footnote 4, table 13). The only embayment in which we found specimens was Cape Cod Bay, all other samples were confined to more offshore regions.

The zoogeographic distribution of the ocean quahog is Arctic, Boreal, and Virginian in the western Atlantic and Celtic in Europe (Coomans 1962); Gosner (1971) assigned it to the Boreal and Virginian provinces, and Dance (1974) to the Arctic, Boreal, and Transatlantic.

Reported water depths for this species range from 9 to 165 m (Johnson 1934; Abbott 1974). Clarke (1962) reported a depth of 1,094 m, but stated that this needs further confirmation.

Our samples range in depth from 10 to 400 m with a mean depth of 79 m. Fifty-seven percent of samples and specimens are in the 50-99 m depth range grouping; abundance of both samples and specimens diminishes with increasing and decreasing depth range beyond this range (Table 242). Eleven samples containing 143 specimens are lacking information with regard to depth.

It has been reported that the ocean quahog is found on sandy mud substrates in the western Atlantic (Abbott 1974), and on firm bottoms of sand and muddy sand in the eastern Atlantic (Tebble 1966).

Fifty-six percent of our samples occurred in sand, 12% in clay, and 9% in silty sand. In terms of density 43% of the specimens occurred in clay, 32% in sand, and 12% in silty sand. Other sediment types provided 6% or less of both samples and specimens (Table 243). There are 52 samples containing 256 specimens which are unclassified with regard to sediment type.

Family VENERIDAE

There are 54 samples in our collection which yielded 117 specimens of organisms classified only to the familial level, Veneridae (Table 5).

Samples yielding members of this family range from Cape Hatteras, N.C., on the continental shelf, south to the environs of Miami, Fla. (Fig. 116; Theroux and Wigley footnote 4, table 207).

The range of depth for these samples is 10 to 62 m with a mean of 29 m. The majority of both samples and specimens are in the 25-49 m grouping which contains 57% of the samples and 59% of the specimens, while the 0-24 m grouping contains 37% of the samples and 36% of the specimens; the 50-99 m grouping contains 6% of the samples and 5% of the specimens (Table 244).

Members of the family Veneridae occurred most abundantly in sand-shell substrates which yielded 44% of the samples and 47% of the specimens, while sand substrates contained 35% of the samples and 35% of the specimens. Other sediment types in which members of this family occurred were gravel, sand-gravel, shell, and silty sand (Table 245).

Genus *Callista* Poli 1791

Callista eucymata (Dall 1890). Glory-of-the-seas venus. Figure 21.

Abbott (1968, 1974) noted that this species is distributed from north Carolina to the southern half of Florida, and from Texas to Brazil, and is uncommon to moderately common within its range.

There are 14 specimens of this species from 12 samples in the NEFC collection (Table 5).

Our material ranges from Delaware Bay to southern Florida; there are three occurrences north of Cape Hatteras, N.C.: one in Delaware Bay and two at the mouth of Chesapeake Bay; the remaining nine samples are south of Cape Hatteras (Fig. 21; Theroux and Wigley footnote 4, table 34).

The depth range for this species is from 4 to 214 m (Abbott 1968, 1974; Porter 1974). Our samples range from 7 to 74 m in depth with a mean of 21 m. Eighty-three percent of the samples and 79% of the specimens are in the shallowest (0-24 m) depth range grouping; the 25-49 m and 50-99 m groupings each contain 8% of the samples but 7 and 14% of the specimens, respectively (Table 246).

The glory-of-the-seas venus is usually found in sand substrates (Abbott 1968). This observation is true for 58% of our samples and 57% of our specimens. Twenty-five percent of the samples and 29% of the specimens were in sand-shell substrates, while 8 and 7%, respectively, occurred in gravel and silty sand substrates (Table 247).

Genus *Chione* Megerle 1811

Chione intapurpurea (Conrad 1849). Lady-in-waiting venus. Figure 24.

Chione intapurpurea is reported to occur from North Carolina to Florida, the West Indies, Texas, and the Gulf of Mexico south to Brazil (Johnson 1934; Abbott 1968, 1974; Morris 1973; Emerson et al. 1976).

The NEFC collection contains eight samples yielding nine specimens of this uncommon species (Table 5).

Our samples are distributed on the continental shelf from south of Charleston, S.C., to slightly north of Miami, Fla. (Fig. 24; Theroux and Wigley footnote 4, table 38).

This species is reported to occur in water depths from 2 to 86 m (Abbott 1974).

Our samples are from water depths of from 10 to 28 m with a mean of 17 m. Eighty-eight percent of the samples and 89% of the specimens are in the 0-24 m depth range grouping, while 13% of the samples and 11% of the specimens are in the 25-49 m depth range grouping (Table 248).

This species is found on coarse gray sand and under rocks (Abbott 1968); it also occurs on gravelly bottom (Morris 1973).

Our specimens were found in sand-shell and sand substrates. These two sediment types each contained 50% of the samples but sand-shell substrates contained 56% of the specimens while sand contained 44% (Table 249).

Chione latilirata (Conrad 1841b). Imperial venus. Figure 25.

This species occurs from North Carolina to Florida and to Texas; it also occurs in the West Indies and Brazil (Johnson 1934; Abbott 1968, 1974; Morris 1973).

The imperial venus is a rather uncommon offshore species of the U.S. east coast of which there are 24 specimens from 17 samples in our collection (Table 5).

Our samples are located on the continental shelf between Cape Hatteras, N.C., and the central portion of Florida (Fig. 25; Theroux and Wigley footnote 4, table 39).

Depths in which this organism is found range from 18 to 227 m (Johnson 1934).

The depth range of our samples is from 19 to 66 m with a mean of 36 m. The majority of both samples (76%) and specimens (83%) are in the 25-49 m depth range grouping. Twelve percent of the samples and 8% of the specimens occur in both the 0-24 m and the 50-99 m depth range groupings (Table 250).

Our samples were found in sand-shell and sand substrates. Sand contained the majority of samples (71%) and specimens (67%) while the remainder were in sand-shell (Table 251).

***Chione* sp. Figure 26.**

There are 58 specimens from 36 samples in our collection which bear the designation *Chione* sp. (Table 5).

Our samples are distributed on the continental shelf from just southeast of Cape Hatteras, N.C., south to the southern third of Florida, north of Miami (Fig. 26; Theroux and Wigley footnote 4, table 40).

The 36 samples, yielding specimens of this taxon, are from water depths ranging between 10 and 43 m with a mean of 21 m. Seventy-eight percent of the samples and 83% of the specimens are in the 0-24 m depth range grouping, whereas 22% and 17% of the samples and specimens, respectively, are in the 25-49 m grouping (Table 252).

The majority of both samples and specimens occurred in sand which contained 42 and 43%, respectively; the next major substrate type was sand-shell, which contained 39 and 38% of samples and specimens, respectively. Shell substrates accounted for 14% of the samples and 16% of the specimens, while silty sand substrates accounted for 6 and 4%, respectively (Table 253).

Genus *Gemma* Deshayes 1853

Gemma gemma **(Toten 1834). Amethyst gem clam. Figure 45.**

This tiny bivalve is very common to excessively abundant (Abbott 1974; Emerson et al. 1976).

Gemma gemma occurs from northern seas around Newfoundland to Florida and the Bahamas, and ranges into Texas and along the Gulf Coast; it has also been introduced into the Pacific at Puget Sound, Wash., and extends south to San Francisco; in the Arctic it extends from the Parry Islands south to and including Labrador (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Ockelmann 1958; Abbott 1968, 1974; Emerson et al. 1976).

The NEFC collection contains 2,211 specimens representing 2% of the entire number of specimens from only 33 samples (Table 5).

The distribution of the NEFC collection samples is patchy although they did yield large numbers of specimens. The first patch occurs in the Cape Cod region, the next small number of samples is in Delaware Bay; another region from which samples were obtained is in Albemarle Sound and off the coast of Cape Hatteras, N.C., and another sampling site is on the continental shelf to the east of Jacksonville, Fla. (Fig. 45; Theroux and Wigley footnote 4, table 74).

This species is found in the Boreal, Virginian, and Carolinian zoogeographic provinces (Coomans 1962); Gosner (1971) placed it in the Boreal and Virginian provinces.

The depth range of the amethyst gem clam is from the littoral zone to 30 m (Morris 1951; Abbott 1968, 1974; Gosner 1971; Porter 1974).

The depth range of our samples is 0 to 66 m with a mean of 6 m. Ninety-four percent of the samples and nearly 100% of the specimens are in the 0-24 m depth range grouping; 3% of the samples are in the 25-49 m and 50-99 m groupings with each accounting for < 0.1% of the specimens (Table 254).

This species occurs on sandy shores (Morris 1951).

Our samples were found in three sediment types: sand-shell, sand, and silty sand. Sand substrates accounted for 75% of the samples but only 15% of the specimens, while sand-shell substrates contained 6% of the samples but 80% of the specimens; silty sand contained 19% of the samples and 5% of the specimens (Table 255). Seventeen samples containing 1,803 specimens are unclassified with regard to sediment type.

Genus *Liocyma* Dall 1870

Liocyma fluctuosa **(Gould 1841). Fluctuating liocyma. Figure 54.**

This northern species is found in both the Atlantic and Pacific Oceans. In the Atlantic it occurs from Greenland to Nova Scotia and in the Pacific from Alaska to British Columbia (Johnson 1934; La Rocque 1953; Clarke 1962; Morris 1973; Abbott 1974). Ockelmann (1958), who reported its occurrence in Arctic regions, stated that it is panarctic and probably truly circumpolar.

This moderately common bivalve species is represented in the NEFC collection by 22 specimens from 1 sample (Table 5).

Our sample is from the Scotian Shelf (Fig. 54; Theroux and Wigley footnote 4, table 91).

Ockelmann (1958) reported it as occurring in from 2 to 228 m of water; Clarke (1962) reported it as occurring in from 18 to 2,440 m of water, but stated that the authenticity of the abyssal records is questionable.

Our sample is from a depth of 51 m which places it in the 50-99 m depth range grouping.

The sample was obtained from a gravel substratum.

Genus *Mercenaria* Schumacher 1817

Mercenaria mercenaria **(Linné 1758). Northern quahog. Figure 61.**

Mercenaria mercenaria is the commercially important bivalve also known as the hard shelled clam, quahog, stuffer, cherry stone, or littleneck among other common names, which vary from locality to locality within its range. Landings in 1978 produced 13.3 million pounds of meat, valued at $29.7 million (Pileggi and Thompson 1979).

The normal distribution of this species is from the Gulf of St. Lawrence to Florida, into the Gulf of Mexico, south to the Yucatan Peninsula; further, *Mercenaria mercenaria* has been introduced to Humboldt Bay, Calif., and into England and other European waters (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Ockelmann 1958; Tebble 1966; Abbott 1968, 1974; Emerson et al. 1976).

Although it is very common and locally very abundant within our study area, there are only 21 specimens from 9 samples in the NEFC collection (Table 5). This paucity of material is directly attributable to this species preference for intertidal and shallow water habitats which are not normally sampled during research cruises conducted by this Center.

The majority of our samples are from the Cape Cod region with one sample from the coast of New York (Fig. 61; Theroux and Wigley footnote 4, table 106).

The zoogeographic distribution of this species is Boreal, Virginian, and Carolinian in the western Atlantic, and Celtic in Europe (Coomans 1962). Gosner (1971) considered it Boreal and Virginian, while Dance (1974) placed it in the Boreal province in eastern North America as well as in the Transatlantic, Caribbean, and Californian provinces.

As previously mentioned this is a shallow water organism ranging from between tide marks down to only a few meters depth (Gosner 1971; Morris 1973).

The NEFC samples are from water depths ranging between 1 and 15 m with a mean of 5 m, which places them in the 0-24 depth range grouping (Table 256).

Only three of our samples, containing eight specimens, had sediment information included in the sampling data. Two samples (67%) occurred in silty sand substrates, containing six specimens (75%); one sample occurred in sand-gravel and contained two specimens (Table 257). The remaining 6 samples with 13 specimens are unclassified with regard to sediment type.

Genus *Periglypta* Jukes-Browne 1914

***Periglypta listeri* (Gray 1838). Princess venus. Figure 85.**

The princess venus occurs from southeast Florida to the West Indies and to southern Texas (Johnson 1934; Morris 1973; Abbott 1974; Emerson et al. 1976).

Periglypta listeri is a moderately common warm water bivalve of which there are six specimens from two samples in the NEFC collection (Table 5).

Our two samples are from the continental shelf, one off the Florida keys, the other off the central coast of Florida (Fig. 85; Theroux and Wigley footnote 4, table 146).

Both Morris (1973) and Abbott (1974) reported that this is a shallow water inhabitant while Emerson et al. (1976) reported that it is occasionally found on beaches.

The two samples in the NEFC collection are from water depths of 71 and 84 m. This depth range places both samples in the 50-99 m depth range grouping.

Two sediment types were involved in the distribution of this species, sand-shell and silty sand, each of which contained 50% of the samples; 17% of the specimens occurred in sand-shell, while 83% of the specimens occurred in silty sand.

Genus *Pitar* Roemer 1857

***Pitar morrhuanus* Linsley 1845.[9] Morrhua venus. Figure 89.**

Pitar morrhuanus is a fairly common species, especially off the New England coast; there are 723 specimens from 102 samples in the NEFC Specimen Reference Collection (Table 5).

The morrhua venus is distributed from the Gulf of St. Lawrence and Prince Edward Island to approximately North Carolina (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Ockelmann 1958; Abbott 1968, 1974; Emerson et al. 1976).

The samples in our collection are distributed on the continental shelf from Maine to Cape Hatteras, N.C. (Fig. 89; Theroux and Wigley footnote 4, table 153).

This species is an inhabitant of the Boreal and Virginian provinces of the northwest Atlantic (Coomans 1962; Gosner 1971).

The published depth range for this species is 4 to 183 m (Abbott 1968; Gosner 1971).

Our samples are from depths which range between 0 and 900 m with a mean of 62 m. The anomalous deep water record involves only one small juvenile clam, the majority were well within normal depths for this species. The majority of both samples and specimens are in the shallowest depth range grouping, 0-24 m, which contains 35% of the samples and 80% of the specimens; the 25-49 m depth range grouping contains 24% of the samples and 7% of the specimens; the 50-99 m grouping, 32% of the samples and 10% of the specimens; the remaining three groupings, 100-199, 200-499, and 500-999 m contain 5% or less of the samples and 1.4 to 0.1% of the specimens (Table 258).

Two sediment types predominated for this species, sand and silty sand; these substrates contained 62 and 25% of the samples, respectively, and 63 and 25% of the specimens, respectively; other sediment types in which the species occurred, in significantly smaller amounts, were till, sand-shell, silt, and clay. Table 259 lists the abundances for these sediment types of samples and specimens. There are 13 samples containing 468 specimens which are unclassified with regard to sediment type.

***Pitar* sp. Figure 90.**

Samples containing members of this genus are distributed from south of Cape Hatteras on the continental shelf to the Florida Keys (Fig. 90; Theroux and Wigley footnote 4, table 154).

The NEFC Specimen Reference Collection contains 130 specimens from 60 samples of bivalves which are classified to the generic level *Pitar* (Table 5).

The NEFC samples are from depths which range between 13 and 102 m with a mean of 33 m. The majority of these samples are in the 25-49 m depth range grouping which contains 70% of the samples and 72% of the specimens; the 0-24 m grouping contains 25% of the samples and 23% of the specimens, while the two range groupings in deeper areas, the 50-99 m and 100-199 m contain 3.3 and 2%, respectively, for samples and 4 and 1%, respectively, for specimens (Table 260).

Sand and sand-shell substrates were the preferred sediment types for this genus, with sand the leader accounting for 68% of the samples and 69% of the specimens; sand-shell contained 22% of the samples and 23% of the specimens; other sediment types in which samples containing *Pitar* were found were gravel, with 2% of the samples and 2% of the specimens, shell, with 3% of the samples and 2% of the specimens, and silty sand where 5% of the former and 5% of the latter were obtained (Table 261).

Family PETRICOLIDAE
Genus *Petricola* Lamarck 1801

***Petricola pholadiformis* Lamarck 1818. False angel wing. Figure 88.**

The false angel wing is a widely distributed species occurring in both the Atlantic and Pacific Oceans. In the northwest Atlantic it ranges from the Gulf of St. Lawrence into the Gulf of Mexico to Texas; it is also present in the Caribbean south to Uruguay; it also occurs in the Mediterranean Sea, Black Sea, and along the west African coast to Senegal, and the French Congo; in the Pacific it occurs at California (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Ockelmann 1958; Tebble 1966; Abbott 1968, 1974; Emerson et al. 1976).

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[9] Abbott (1974) has "Linsley, 1848" for this species, it should be Linsley 1845, see under References.

Although *Petricola pholadiformis* is very common, the NEFC collection contains only 27 specimens from 7 samples of this species (Table 5).

The samples in the NEFC collection are from two localities; the majority of samples are in the Cape Cod region, especially in Buzzards Bay, and one sample is from just north of Jacksonville, Fla. (Fig. 88; Theroux and Wigley footnote 4, table 152).

The real or main distribution of this species is in the Boreal, Virginian, and Carolinian provinces in the northwest Atlantic and Celtic in the eastern Atlantic (Coomans 1962); Gosner (1971) placed it in the Boreal and Virginian provinces, while Dance (1974) considered it to occupy the Boreal, Mediterranean, West African, Transatlantic, Caribbean, and Californian provinces.

This species is primarily intertidal; however, it does range down to approximately 13 m depth (Morris 1951, 1973; Porter 1974).

The range of depth for the NEFC samples is 1 to 26 m with a mean of 7 m. The majority of both samples and specimens are in the shallowest depth range grouping, the 0-24 m, where 86% of the samples and 96% of the specimens are grouped; the 25-49 m grouping contains 14% of the samples and 4% of the specimens (Table 262).

The most common habitat for the false angel wing is in stiff clays, peats, and in mud banks since it is a borer (Morris 1951, 1973; Abbott 1968, 1974).

There was only a small amount of sediment information accompanying the NEFC samples. Three samples contained sediment data: one from shell, one in sand, and one in silty sand. Table 263 lists the distribution of samples and specimens with regard to sediment type. There are 4 samples containing 21 specimens which are unclassified with regard to sediment type.

Order MYOIDA
Family MYIDAE

Genus *Mya* Linné 1758

***Mya arenaria* Linné 1758. Soft-shell clam. Figure 68.**

Mya arenaria is a commercially valuable bivalve of the northeast United States which, in 1978, yielded 10.1 million pounds of meats (Pileggi and Thompson 1979). Its commercial importance has resulted in a multitude of common names by which this bivalve is known, among them are the following: soft-shell clam, steamer clam, long clam, soft clam, sand gaper, long neck clam, nannynose, mannynose, and soft-shelled clam.

The normal distribution of the soft-shell clam is from Labrador to South Carolina, extending, locally, south to Florida; it is also distributed throughout western Europe and has been introduced to western U.S. waters at Alaska and Monterey, Calif.; there are also small isolated populations in Arctic regions (Johnson 1934; Foster 1946; Morris 1951, 1973; La Rocque 1953; Ockelmann 1958; Tebble 1966; Abbott 1968, 1974; Emerson et al. 1976).

There are 290 specimens of this bivalve from 64 samples in the NEFC collection (Table 5).

Our samples are from the northeastern sector of the study area from the inshore waters of Maine, New Hampshire, Massachusetts, south to New York State, and New Jersey; there is one isolated community at Charleston, S.C. (Fig. 68; Theroux and Wigley footnote 4, table 116).

Coomans (1962) placed the distribution of *Mya arenaria* in the Arctic, Boreal, and Virginian zoogeographic provinces in the western Atlantic, and the Celtic province in Europe; Gosner (1971) placed it in the Boreal and Virginian provinces; Dance (1974) considered it to occupy the Boreal, Transatlantic, Aleutian, Californian, and Japonic provinces.

Mya arenaria is primarily an intertidal organism; however, it does on occasion, in certain areas, reach subtidal depths, 3 to 9 m, and perhaps deeper (Abbott 1968; Gosner 1971).

The depth range of our samples is from 0 to 192 m with a mean depth of 43 m. The majority of samples (44%) and specimens (50%) are in the 0-24 m depth range grouping; 32% of the samples and 34% of the specimens are in the 50-99 m grouping; 16% of the samples and 10% of the specimens are in the 25-49 m grouping, and 8% of the samples and 6% of the specimens in the 100-199 m grouping (Table 264). There are two samples containing nine specimens for which no depth information is available.

Of the nine sediment types considered in this report, *Mya arenaria* was absent from only one, sand-shell. The majority of samples and specimens occurred in silty sand substrates which contained 38% of the samples and 42% of the specimens; next highest amount occurred in clay with 21% of the samples and 20% of the specimens. Both sand and silt contained 13% of the samples, but 5 and 29% of the specimens, respectively. Smaller amounts occurred in gravel, sand-gravel, till, and shell substrates (Table 265). Eleven samples containing 28 specimens are unclassified with regard to sediment type.

Family CORBULIDAE

Our collection contains 150 specimens from 56 samples which for various reasons were identified to the family level Corbulidae (Table 5).

The samples containing members of this taxon are distributed on the continental shelf between Cape Hatteras, N.C., and Miami, Fla. (Fig. 29; Theroux and Wigley footnote 4, table 46).

The samples containing members of the Corbulidae range in depth from 5 to 128 m with a mean of 30 m. Fifty-nine percent of the samples and 56% of the specimens are in the 0-24 m range grouping; 21 and 25%, respectively, in the 25-49 m grouping; 18% of both samples and specimens are in the 50-99 m range grouping, and 2% of the samples and 1% of the specimens are in the 100-199 m grouping (Table 266).

Members of this taxon preferred sandy substrates over coarser or finer sediments. Forty-one percent of the samples and 38% of the specimens occurred in sand; 38% of the samples and 38% of the specimens occurred in sand-shell, and 14 and 19%, respectively, occurred in silty sand. The other two sediment types which contained members of this taxon were shell with 5% of the samples and 4% of the specimens and gravel with 2 and 1%, respectively (Table 267).

Genus *Corbula* Brugière (1792)

***Corbula contracta* Say 1822. Contracted corbula. Figure 27.**

The contracted corbula is reported to occur from Cape Cod to Florida, the West Indies, and is also found in Brazil (Johnson 1934; Morris 1951, 1973; Abbott 1968, 1974; Emerson et al. 1976).

Corbula contracta is a common bivalve species of the northwest Atlantic of which there are 22 samples containing 46 specimens in our collection (Table 5).

Our samples are primarily from off New England shores. A group of samples occurs on the central part of Georges Bank, one off the coast of Maine, several occur in Nantucket and Vineyard Sounds, and another grouping south of Nantucket Shoals on the outer edge of the continental shelf (Fig. 27; Theroux and Wigley footnote 4, table 43).

The bathymetric distribution of this species ranges from 0.5 to 115 m (Johnson 1934; Porter 1974).

Our samples are from water depths ranging between 15 and 150 m with a mean of 58 m. Forty-six percent of the samples and 41% of the specimens are in the 50-99 m depth range grouping, 27% of the samples and 28% of the specimens in the 25-49 m grouping, 13% of the samples are in the 0-24 m and 100-199 m groupings, specimen percentage in each of these groupings is 9 and 22%, respectively (Table 268).

This species reportedly inhabits sand and mud substrates (Morris 1951).

Our samples also came from sand and muddy substrates, although the sandier substrates were preferred. Sand contained 53% of the samples and 49% of the specimens, while silty sand contained 32 and 27%, respectively. Muddy fractions, silt and clay, contained 5% of the samples and 10% of the specimens for the former and 11% and 15% for the latter, respectively (Table 269). There are three samples containing five specimens which are unclassified with regard to sediment type.

Corbula krebsiana C. B. Adams 1852. Kreb's corbula. Figure 28.

It is reported to occur at Florida and the West Indies by Johnson (1934) and Abbott (1974), while Andrews (1971) listed it as occurring at Jamaica and Texas; Andrews further stated that it is an uncommon, infaunal creature residing on offshore banks.

This species is represented by 97 specimens from 41 samples in the NEFC collection (Table 5).

Samples in the NEFC collection occur on the outer continental shelf from Cape Hatteras, N.C., to Miami, Fla. (Fig. 28; Theroux and Wigley footnote 4, table 44).

Depth range of this species is from 5 to 156 m (Johnson 1934).

Our samples range from 18 to 135 m in depth with a mean of 44 m. Sixty-three percent of the samples and 56% of the specimens are in the 25-49 m depth range grouping, while 22% of the samples and 35% of the specimens are in the 50-99 m grouping. The 0-24 m grouping and the 100-199 m grouping contain 10 and 5% of the samples and 6 and 3% of the specimens, respectively (Table 270).

Our specimens inhabited shelly and sandy substrates. Sand was by far the preferred sediment type, containing 63% of the samples and 59% of the specimens. Next largest amounts, 29 and 36% for samples and specimens, respectively, were in sand-shell substrates; shell substrates contained 5 and 3%, respectively, while silty sand substrates had the least with 2% of the samples and 2% of the specimens (Table 271).

Corbula sp. Figure 28.

The NEFC collection contains one sample with two specimens of this taxon (Table 5).

The single sample containing the specimens of *Corbula* sp. is from the Maine coast (Fig. 28; Theroux and Wigley footnote 4, table 45), at 45 m depth in a clay sediment.

Family HIATELLIDAE

The NEFC collection contains 17 specimens from 7 samples which bear the classification Hiatellidae (Table 5).

There are two groups of samples containing members of the family Hiatellidae, one group occurs north of Cape Cod in the Gulf of Maine containing one sample on the Scotian Shelf and two samples in the southern Gulf of Maine, one north of Boston and the other east of Cape Cod. The second group occurs south of Charleston, S.C., to the northern portion of Florida (Fig. 49; Theroux and Wigley footnote 4, table 81).

Our samples range in depth from 29 to 110 m with a mean of 56 m. Three depth range groupings contain members of this taxon; they are the 25-49 m grouping with 57% of the samples and 29% of the specimens, the 50-99 m grouping with 29% of the samples and 12% of the specimens, and the 100-199 m grouping with 14 and 59%, respectively (Table 272).

Sand substrates contained 71% of samples but only 35% of the specimens, while sand-gravel substrates, although containing 14% of the samples, contained 59% of the specimens. One sample (14%) containing one specimen (6%) occurred in clay substrates (Table 273).

Genus *Cyrtodaria* Cuvier 1800

Cyrtodaria siliqua (Spengler 1793). Northern propeller clam. Figure 40.

This species is moderately common offshore, and occasionally found in fish stomachs (Abbott 1974).

The northern propeller clam is distributed from Arctic Ocean regions to Cape Cod, Mass., Georges Bank, and Rhode Island (Johnson 1934; La Rocque 1953; Ockelmann 1958; Morris 1973; Abbott 1974).

This species is represented in our collection by two specimens from one sample (Table 5).

The single sample we have in our collection is from off Cape Ann, Mass. (Fig. 40; Theroux and Wigley footnote 4, table 66).

The reported depth range for this species is 9 to 165 m (Johnson 1934; Abbott 1974).

The sample in our collection is from 70 m of water placing it in the 50-99 m depth range grouping.

There is no information relating to sediment in our sample.

Genus *Hiatella* Daudin, in Bosc 1801

Hiatella arctica (Linné 1767). Arctic saxicave. Figure 48.

This species is widely distributed throughout the Northern Hemisphere, it ranges from Arctic seas to deep water in the West Indies and off Panama; it is also found in the British Isles, in the Mediterannean and Bering Seas, and in the Pacific Ocean (Johnson 1934; La Rocque 1953; Ockelmann 1958; Clarke 1962; Tebble 1966; Abbott 1968, 1974; Morris 1973).

This is a common, small bivalve which is well represented in the NEFC collection which contains 3,474 specimens, approximately 3% of the entire collection, from 149 samples, representing 1% of the entire collection (Table 5).

All of our samples are in the northern sector of our study area, occupying the periphery of the Gulf of Maine, the Scotian Shelf, and Georges Bank to deep slope water areas south of Cape Cod, Mass. (Fig. 48; Theroux and Wigley footnote 4, table 79).

The zoogeographic distribution of this species, according to several authors, is as follows: Ockelmann (1958) listed it as occupying the Panarctic-Boreal and Mediterannean-Atlantic provinces, stating that it is probably cosmopolitan and circumpolar; Clarke (1962) listed it as occupying the Panarctic and Boreal provinces; Coomans (1962) placed it in the Arctic-boreal, Virginian, Caribbean, Carolinian, and Celtic provinces; Gosner (1971) placed it in the Boreal and Virginian provinces, while Dance (1974) placed it in the Mediterannean, Atlantic, Transatlantic, and Caribbean provinces.

The Arctic saxicave enjoys a wide bathymetric range occurring from intertidal and littoral regions out to 366 m in the northwest Atlantic (Johnson 1934; Abbott 1968, 1974). Ockelmann (1958) reported it as occurring from 0 down to 2,190 m at West Ireland and mentions that dead shells are found in the North Atlantic down to about 2,380 m. Clarke (1962) reported it as occurring between 0 and 2,968 m in depth.

Our samples range from 18 to 232 m in depth with a mean of 81 m. Fifty-one percent of the samples and 24% of the specimens are in the 50-99 m depth range grouping while 23% of the samples containing 69% of the specimens are in the 25-49 m grouping; the 100-199 m grouping contains 22% of the samples but only 5% of the specimens; the 200-499 m grouping contains 3% of the samples but only 0.1% of the specimens, while the shallowest depth range grouping, 0-24 m contains 2% of the samples and 2% of the specimens (Table 274).

Morris (1951) reported that the Arctic saxicave may be found in clay and limestone substrates while Abbott (1968, 1974) reported it occurring among kelp holdfasts and in rock crevices and also that it has been found in sponges.

Our samples were found in all of the 9 substrate types considered in this report. Chief among substrate types is gravel which contained 29% of the samples and 61% of the specimens, sand-gravel contained 24% of the samples and 20% of the specimens. There is a general tendency of decreasing abundance, both in terms of samples and specimens, with decreasing sediment particle size. Both till and sand substrates contained 12% of the samples but only 4 and 10% of the specimens, respectively. In order of diminishing abundance, silty sand contained 8%, clay 5%, shell 3%, and silt 2% of the samples, and lowered specimen amounts as well (Table 275). Thirty-two samples containing 121 specimens are unclassified with regard to sediment type.

Hiatella striata Fleuriau 1802. Figure 49.

Hiatella striata is represented in the NEFC collection by eight specimens from two samples (Table 5).

Our two samples are from the western end of Georges Bank east of Great South Channel (Fig. 49; Theroux and Wigley footnote 4, table 80).

Porter (1974) reported a +1 m depth range for this species.

Our samples containing *Hiatella striata* are from 49 and 70 m water depth. The 25-49 m and 50-99 m depth range groupings each contain 50% of both samples and specimens.

No information with regard to sediment type is available for the two samples in our collection.

Genus *Panomya* Gray 1857

Panomya arctica (Lamarck 1818). Arctic rough mya. Figure 83.

The Arctic rough mya is circumpolar and inhabits both the North Atlantic and North Pacific Oceans. In the Atlantic it ranges from Arctic seas to Chesapeake Bay, while in the Pacific it occurs from Unalaska to Point Barrow, Alaska; it is also known from northern European waters (Johnson 1934; Morris 1951, 1973; Tebble 1966; Abbott 1974).

Panomya arctica is a common northern seas bivalve that is represented in the NEFC collection by 64 specimens from 19 samples (Table 5).

Our samples are from the Gulf of Maine region with one sample occurring in upper continental slope waters south and east of Long Island, N.Y. (Fig. 83; Theroux and Wigley footnote 4, table 142).

Coomans (1962) placed this species in the Arctic, Boreal, and Virginian provinces in the western Atlantic, and in the Celtic province in Europe.

The depth distribution of this species ranges from approximately 46 m down to 600 m (Johnson 1934; Abbott 1974).

Our samples range in depth between 38 and 293 m with a mean of 126 m. The majority of both samples and specimens are in the 50-99 m depth range grouping which contains 53 and 78%, respectively; next largest amounts occur in the 100-199 m grouping which contains 26 and 14%, respectively; there are 16% of samples and 6% of specimens in the 200-499 m grouping; the shallowest depth range is the 25-49 m grouping which contains 5% of the samples and 2% of the specimens (Table 276).

This species inhabits mud, gravelly mud, and sandy gravel substrates (Morris 1951, 1973; Tebble 1966; Abbott 1974).

Our samples were obtained from a variety of sediment types including: silty sand which contained the majority of samples (33%) but only 10% of the specimens; till, however, contained the majority of the specimens (73%) but 25% of the samples; gravel contained 17% of the samples and 6% of the specimens; shell, sand, and clay each contained 8% of the samples but 4, 2, and 4% of the specimens, respectively (Table 277). There are 7 samples containing 16 specimens which are unclassified with regard to sediment type.

Family PHOLADIDAE
Genus *Barnea* Risso 1826

Barnea truncata (Say 1822). Fallen angel wing. Figure 17.

This species enjoys a wide distribution along our shores ranging from Newfoundland, along the entire U.S. east coast into the Gulf of Mexico and south to Brazil; it also occurs in the West Indies and from Senegal to the Gold Coast in West Africa (Johnson 1934; La Rocque 1953; Ockelmann 1958; Abbott 1968, 1974; Morris 1973; Emerson et al. 1976).

The NEFC collection contains 83 specimens from 4 replicate samples of this common and locally abundant species (Table 5).

Our specimens are all from one locality from replicate samples with different sampling gear in Great Harbor, Woods Hole, Mass. (Fig. 17; Theroux and Wigley footnote 4, table 27).

Provinces occupied by this species are the Boreal, Virginian, and Carolinian (Coomans 1962); Dance (1974) placed it in the Transatlantic province.

The fallen angel wing is a shallow water inhabitant ranging from the intertidal zone to about 7.6 m in depth (Abbott 1968, 1974; Porter 1974). The depth range of our samples is from 1 to 3 m with a mean of 1.7 m.

This species bores into mud, clay, and peat banks (Abbott 1968, 1974; Morris 1973; Emerson et al. 1976). Our samples came from the muds of Great Harbor at Woods Hole, Mass.

Barnea sp. Figure 18.

Our collection contains two specimens from two samples of members of the genus *Barnea* (Table 5). The samples are from Buzzards Bay (Fig. 18; Theroux and Wigley footnote 4, table 28). Depth of the samples was 13 and 35 m with a mean of 24 m; sediment types at the sampling sites were gravel at one and clay at the other.

Genus *Xylophaga* Turton 1822

Xylophaga atlantica H. G. Richards 1942. Atlantic wood eater. Figure 117.

This species ranges from Newfoundland and the Gulf of St. Lawrence to Virginia in the northwestern Atlantic (Ockelmann 1958; Clarke 1962; Morris 1973; Abbott 1974).

The NEFC Specimen Reference Collection contains 76 specimens of this species from 3 samples (Table 5).

Our samples are from two areas, one north of Cape Ann, Mass., and two replicate samples on the lower portion of the continental shelf opposite Atlantic City, N.J. (Fig. 117; Theroux and Wigley footnote 4, table 209).

This species has been found to occupy water depths which range between 0 and 3,720 m (Clarke 1962).

Our samples are from water depths which range between 60 and 458 m with a mean of 325 m. The depth range groupings which contain samples of this species are the 200-499 m grouping, which contains 67% of the samples and 96% of the specimens and the 50-99 m grouping which contains 33% of the samples and 4% of the specimens.

Although our samples did not contain any sediment information per se, the specimens were obtained from waterlogged wood which was collected at the sampling sites indicated in the distributional chart.

Subclass ANOMALODESMATA
Order PHOLADOMYOIDA
Family PANDORIDAE
Genus *Pandora* Lamarck 1799

Pandora bushiana Dall 1886. Bush's pandora. Figure 80.

This species is distributed from North Carolina to Florida on the U.S. east coast. It occurs at Texas, and the West Indies; it is also present at the Bahama Islands, in Cuba, and south to Yucatan and Brazil (Johnson 1934; Boss and Merrill 1965; Abbott 1974).

Pandora bushiana is an uncommon warm water bivalve represented in our collection by 15 specimens from 8 samples (Table 5).

Our samples range from offshore of the outer banks of Cape Hatteras, N.C., to south of Charleston, S.C. (Fig. 80; Theroux and Wigley footnote 4, table 136).

The reported depth range for this species is between 6 and 46 m (Boss and Merrill 1965; Abbott 1974).

Our samples are from water depths ranging between 20 and 40 m with a mean of 32 m. The majority of samples (88%) and specimens (93%) are in the 25-49 m depth range grouping; the remaining 13% of the samples and 7% of the specimens are in the 0-24 m grouping.

All eight of our samples were obtained in sand sediment.

Pandora gouldiana Dall 1886. Gould's pandora. Figure 80.

This species is distributed from the Gulf of St. Lawrence and Prince Edward Island in Canada to North Carolina (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Ockelmann 1958; Boss and Merrill 1965; Abbott 1968, 1974; Emerson et al. 1976).

Pandora gouldiana is represented in the NEFC collection by 144 specimens from 33 samples (Table 5).

Our samples range from the Nova Scotian continental shelf, along the inner periphery of the Gulf of Maine, out onto the southern part of Georges Bank, to the edge of the continental shelf off the entrance to Chesapeake Bay (Fig. 80; Theroux and Wigley footnote 4, table 137).

The distribution of this species is Boreal and Virginian on the eastern coast of North America (Coomans 1962; Gosner 1971).

The reported depth range for this species is from 0 to 183 m (Johnson 1934; Boss and Merrill 1965; Abbott 1974).

The NEFC samples range in depth from 0 to 119 m with a mean of 52 m. Abundance with increasing depth range is: the 0-24 m depth range grouping contains 21% of the samples and 28% of the specimens, the 25-49 m grouping 27% of the samples and 14% of the specimens, the 50-99 m grouping 39% of the samples and 51% of the specimens, while the 100-199 m grouping contains 12% of the samples and 8% of the specimens (Table 278).

All sediment types considered in this report, except sand-shell, contained members of this taxon. Five sediment types contained 4% of the samples, namely, gravel, sand-gravel, till, shell, and silty sand; in turn these contained 8, 1, 1, 3, and 1% of the specimens, respectively; sand substrates, however, contained the largest proportion of both samples and specimens with 63% for the former and 82% for the latter; silt and clay, the two finest grained substrates, contained 7.4 and 11%, respectively, for samples and 2 and 3%, respectively, for specimens (Table 279). There are 6 samples containing 39 specimens which are unclassified with regard to sediment type.

Pandora inflata Boss and Merrill 1965. Inflated pandora. Figure 81.

This species is distributed from New Jersey to both sides of Florida, and according to Boss and Merrill is most populous in the Straits of Florida (Boss and Merrill 1965; Abbott 1974).

Pandora inflata is represented in the NEFC collection by 34 specimens from 17 samples (Table 5).

Our samples are from continental shelf and upper slope waters south of Nantucket Shoals, south to the offing of Chesapeake Bay (Fig. 81; Theroux and Wigley footnote 4, table 138).

Gosner (1971) reported the inflated pandora from the Carolinian zoogeographic province.

The range in depth of this species is from 48 to 165 m (Boss and Merrill 1965; Abbott 1974).

The range in depth for our samples is 21 to 194 m with a mean of 107 m. The majority of both samples and specimens are in the 100-199 m depth range grouping where 59 and 68%, respectively, occur; the 25-49 m grouping and the 50-99 m grouping each contain 18% of the samples but 18 and 12% of the specimens, respectively; the smallest number of samples and specimens are in the 0-24 m depth range grouping which contains 6% of the samples and 3% of the specimens (Table 280).

The NEFC samples of the inflated pandora were obtained from three sediment types with the majority occurring in silty sand substrates which contained 53% of the samples and 50% of the specimens, while sand substrates contained 41% of the samples and 47% of the specimens; sand-gravel contained 6 and 3%, respectively (Table 281).

Pandora inornata Verrill and Bush 1898. Inornate pandora. Figure 82.

The inornate pandora occurs from Newfoundland to Cape Cod, Mass. (Johnson 1934; Ockelmann 1958; Boss and Merrill 1965; Abbott 1974).

Pandora inornata is an uncommon species, of which there are 159 specimens from 21 samples in the NEFC collection (Table 5).

Our samples are from the continental shelf on Georges Bank and in the Cape Code region (Fig. 82; Theroux and Wigley footnote 4, table 139).

Both Johnson (1934) and Abbott (1974) reported that this species occupies water depths between 18 and 82 m.

The NEFC samples are from water depths which range between 1 and 79 m with a mean of 34 m. The majority of samples are in the 0-24 m depth range grouping which contains 57% of the samples; however, this grouping only contains 33% of the specimens; the 25-49 m grouping contains 29% of the samples and 20% of the specimens, while the 50-99 m grouping, although containing 14% of the samples, contains the majority of the specimens, 47% (Table 282).

The distribution of samples and specimens in bottom sediment types ranging from coarsest to finest grained is as follows: three sediment types, gravel, sand-gravel, and sand-shell each contained 9% of the samples but 6, 1, and 1% of the specimens, respectively; sand contained the greatest amounts, 55% for samples and 88% of the specimens, while silty sand contained 18% of the samples and 4% of the specimens (Table 283). There are 10 samples containing 49 specimens which are unclassified with regard to sediment type.

Pandora trilineata Say 1822. Say's pandora. Figure 82.

The distribution of this species is from North Carolina to Florida and Texas (Johnson 1934; Boss and Merrill 1965; Morris 1973; Abbott 1974; Emerson et al. 1976).

Pandora trilineata is a moderately common bivalve of which the NEFC collection contains 11 specimens from 9 samples (Table 5).

Our samples are from the continental shelf from slightly north of Cape Hatteras, N.C., south to the central section of the Florida Peninsula (Fig. 82; Theroux and Wigley footnote 4, table 140).

According to Morris (1973), Abbott (1974), and Porter (1974), the range of depth in which this species may be found is between 0 and 110 m.

Our samples are from water depths which range between 11 and 33 m with a mean of 21 m. Two-thirds of the samples are in the 0-24 m depth range grouping which contains 73% of the specimens, the remaining 33% of the samples are in the 25-49 m grouping, which contains 27% of the specimens (Table 284).

The majority of both samples and specimens occurred in sand substrates which contained 78% of the samples and 82% of the specimens; the only other substrate type in which this species occurred in our sample suite was sand-shell which contained 22% of the samples and 18% of the specimens (Table 285).

Pandora sp. Figure 83.

The NEFC collection contains 8 samples from which 11 specimens are identified to the generic level of *Pandora* sp. (Table 5).

Our samples are from the continental shelf between Cape Cod, Mass., and Cape Fear, N.C., with one sample occurring in the eastern portion of the Gulf of Maine adjacent to Georges Bank (Fig. 83; Theroux and Wigley footnote 4, table 141).

Our samples range in depth between 15 and 230 m with a mean of 72 m. The majority of both samples and specimens are in the 50-99 m depth range grouping which contains 38% of the samples and 36% of the specimens; 25% of the samples and 27% of the specimens are in the 0-24 m depth range grouping, the same percentage of samples (25%), but 18% of the specimens occurs in the 25-49 m grouping while the 200-499 m depth range grouping contains 13% of the samples and 18% of the specimens (Table 286).

Samples yielding specimens of the genus *Pandora* occurred in two substrate types, sand and silty sand. Eighty-three percent of the samples and 75% of the specimens occurred in sand; and 17% of the samples and 25% of the specimens occurred in silty sand (Table 287). There are two samples containing three specimens which are unclassified with regard to sediment type.

Family LYONSIIDAE
Genus *Lyonsia* Turton 1822

Lyonsia arenosa Möller 1842. Sanded lyonsia. Figure 56.

This small bivalve enjoys a wide distribution both in the Atlantic and Pacific Oceans. In the Atlantic it ranges from Greenland to Cape Ann, Mass., and in the Pacific from Alaska to Vancouver, British Columbia, and to Japan (Johnson 1934; La Rocque 1953; Clarke 1962; Morris 1973; Abbott 1974).

This is a moderately common bivalve species of which there are 81 specimens from 20 samples in the NEFC collection (Table 5).

Our samples are from the Georges Bank region, and also the Cape Cod region (Fig. 56; Theroux and Wigley footnote 4, table 96).

With regard to its zoogeographic distribution La Rocque (1953) considered it circumboreal; Ockelmann (1958) and Clarke (1962) considered it panarctic and circumpolar while Gosner (1971) placed it in the Boreal province.

The depth range for this species is 24 to 2,440 m (Johnson 1934; Clarke 1962).

Our samples are from water depths ranging between 1 and 426 m with a mean of 57 m. The 0-24 m and the 25-49 m depth range groupings contain 29% of the samples and 21 and 25% of the specimens, respectively; the 50-99 m grouping contains the majority of samples (38%) as well as the majority of specimens (53%); only one other depth range grouping contains members of this taxon, the 200-499 m grouping, with 5% of the samples and 1% of the specimens (Table 288).

The majority of our samples (60%) as well as specimens (67%) were found in sand; sand-gravel contained 20% of the samples and 20% of the specimens while silty sand and silt substrates each contained 10% of the samples and 5 and 8%, respectively, of specimens (Table 289). One sample containing five specimens is unclassified with regard to sediment type.

***Lyonsia hyalina* (Conrad 1830).**[10]**Glassy lyonsia. Figure 57.**

The geographic range is from the Gulf of St. Lawrence to Texas (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Ockelmann 1958; Abbott 1968, 1974; Emerson et al. 1976).

Lyonsia hyalina is common in the Northern Hemisphere, the NEFC collection contains 544 specimens of this species from 129 samples (Table 5).

Our samples are similarly distributed in that they range from the Scotian Shelf off Nova Scotia south to slightly north of Miami, Fla., occupying nearly the whole of the east coast continental shelf (Fig. 57; Theroux and Wigley footnote 4, table 97).

The main distribution is Boreal, Virginian, and Caribbean in the northwest Atlantic (Coomans 1962). Gosner (1971) listed it as occupying the Boreal and Virginian provinces, while Dance (1974) assigned it to the Boreal and Transatlantic provinces in eastern North America.

The depth range for this species is from low water at +1 to 62 m (Abbott 1974; Porter 1974).

Our samples range from 0 to 80 m depth with a mean of 38 m. The 0-24 m depth range grouping contains 33% of the samples and 22% of the specimens; the 25-49 m grouping contains 35% of the samples and 46% of the specimens, and the 50-99 m grouping contains 33% of the samples and 32% of the specimens (Table 290).

This species occupies sand and sandy mud bottoms (Morris 1951; Abbott 1968).

Among the various types of sediments in which we found this species the majority occupied sand substrates which yielded 78% of the samples and 91% of the specimens. Significantly smaller amounts occurred in sand-gravel, sand-shell, silty sand, silt, and clay substrates (Table 291). There are 14 samples containing 52 specimens which are unclassified with regard to sediment type.

***Lyonsia* sp. Figure 56.**

The NEFC collection contains five specimens from six samples classified to the generic level *Lyonsia* (Table 5).

The five samples of this taxon are from inshore areas and the outer continental shelf of the Middle Atlantic Bight region between Cape Cod, Mass., and the offing of Chesapeake Bay (Fig. 56; Theroux and Wigley footnote 4, table 98).

Our samples are from waters which range from 8 to 63 m in depth with a mean of 39 m. Forty percent of the samples occur in the 0-24 and 50-99 m depth range groupings which contain 33 and 50% of the specimens, respectively; the 25-49 m grouping contains 20% of the samples and 17% of the specimens (Table 292).

Members of this taxon occurred in three sediment types, the majority of samples (60%), as well as specimens (67%), were obtained from sand substrates; sand-gravel, and silty sand each contained 20% of the samples and 17% of the specimens (Table 293).

Family PERIPLOMATIDAE
Genus *Periploma* Schumacher 1816

***Periploma affine* Verrill and Bush 1898. Figure 85.**

According to Johnson (1934) and Abbott (1974), this species occurs only off Martha's Vineyard, Mass.

The NEFC collection contains 21 specimens from 2 samples of this rather rare bivalve species (Table 5).

The two samples in the NEFC Specimen Reference Collection are from off the tip of Cape Cod, Mass., in Cape Cod Bay (Fig. 85; Theroux and Wigley footnote 4, table 147).

According to the previously cited authors the depth range of this species is from 183 to 211 m.

Our samples are from 46 and 49 m of water, placing them in the 25-49 m depth range grouping.

This species was found in two substrate types, till and clay, each containing 50% of the samples; however, the tilloid substrate contained 95% of the specimens while the sample in clay contained 5% of the specimens.

***Periploma fragile* (Totten 1835). Fragile spoon clam. Figure 85.**

The distribution of the fragile spoon clam is from Newfoundland and Labrador to Cape Cod, Mass., with Arctic outposts at the Parry Islands (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Ockelmann 1958; Abbott 1974).

Periploma fragile is represented in the NEFC collection by 101 specimens obtained from 27 samples (Table 5).

The NEFC samples are from three separate areas; two samples occur in the Gulf of Maine off Portland, Maine, another group of samples is on the southern New England shelf and slope area south of Nantucket Shoals, and two more samples occur on the continental shelf off Atlantic City, N.J. (Fig. 85; Theroux and Wigley footnote 4, table 148).

Coomans (1962) placed this species in the Boreal and Virginian provinces.

The fragile spoon clam is a moderately shallow water inhabitant whose depth distribution ranges between 7 and 73 m (Abbott 1974).

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[10] Abbott (1974) has "Conrad, 1831" for this species, it should be Conrad 1830, see under References.

Our suite of samples is from water depths which range between 23 and 458 m with a mean of 106 m. The majority of samples are in the 50-99 m depth range grouping which contains 78% of the samples and 88% of the specimens; the 0-24 and 25-49 m groupings each contain 4% of the samples, and 3 and 4% of the specimens, respectively, while the 100-199 m and 200-499 m groupings each contain 7% of the samples and 2 and 3% of the specimens, respectively (Table 294).

Morris (1951) reported that the fragile spoon clam inhabits sand substrates.

The distribution of NEFC samples with regard to sediments with decreasing particle size is as follows: 4% of the samples and 3% of the specimens occurred in sand-shell; 37% of the samples and 22% of the specimens in sand; one-third (33%) of the samples and 21% of the specimens occurred in silty sand; 11% of the samples and 21% of the specimens occurred in silt; while 15% of the samples and 34% of the specimens occurred in clay substrates (Table 295).

Periploma leanum (Conrad 1830).[11] Lea's spoon clam. Figure 86.

Lea's spoon clam is distributed from the Gulf of St. Lawrence and Nova Scotia to off North Carolina (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Abbott 1974; Emerson et al. 1976).

Periploma leanum is an uncommon to fairly common bivalve; there are 60 specimens of this species from 27 samples in the NEFC Specimen Reference Collection (Table 5).

Our specimens are from the continental shelf off the coast of Maine, in the Cape Cod region, and the offshore continental shelf and slope waters south of Nantucket Shoals (Fig. 86, Theroux and Wigley footnote 4, table 149).

The main distribution of this species is in the Boreal and Virginian provinces (Coomans 1962; Gosner 1971).

The depth range of this species extends from just offshore in moderately shallow water to approximately 29 m (Johnson 1934; Abbott 1974).

Our samples are from depths which range between 1 and 135 m with a mean of 48 m. The abundance of samples and specimens with regard to depth range groupings is as follows: 33% of the samples and 30% of the specimens are in the 0-24 m grouping; 26% of the samples and 38% of the specimens in the 25-49 m grouping; 26% of the samples and 22% of the specimens in the 50-99 m grouping and 15% of the samples and 10% of the specimens in the 100-199 m grouping (Table 296).

The samples yielding our specimens occurred in four sediment types. The majority of samples and specimens occurred in sand substrates which contained 46% of the samples and 61% of the specimens; sand-gravel substrates contained 23% of the former and 18% of the latter, while silty sand sediments contained 18% of the samples and 10% of the specimens; clay was the only other sediment type in which these organisms were found and it contained 14% of the samples and 10% of the specimens (Table 297). There are 5 samples containing 11 specimens which are unclassified with regard to sediment type.

Periploma papyratium (Say 1822). Paper spoon clam. Figure 87.

The paper spoon clam is distributed from Labrador to Rhode Island and from South Carolina to the Gulf of Mexico (Johnson 1934; Clarke 1962; Morris 1973; Abbott 1974).

Periploma papyratium is a moderately common bivalve which is normally found in the northern reaches of the study area as reflected by the abundance of samples and specimens in the NEFC collection. *Periploma papyratium* is represented by 2,976 specimens, nearly 3% of the entire collection, from 265 samples, again, nearly 3% of the entire collection (Table 5).

Samples in the NEFC collection range from the Nova Scotian shelf, along the inner edge of the Gulf of Maine extending out towards the northern edge of Georges Bank and south onto the Southern New England shelf area and the Middle Atlantic Bight region (Fig. 87; Theroux and Wigley footnote 4, table 150).

The paper spoon clam inhabits the Boreal and Virginian provinces (Coomans 1962); Gosner (1971) placed it only in the Boreal province.

The published depth range for this species is from 1.8 to 2,297 m (Clarke 1962; Abbott 1974).

The NEFC samples range in depth from 7 to 458 m with a mean of 121 m. In terms of distribution among the depth range groupings there is a general tendency for a decrease in abundance with both increasing and decreasing depth range grouping from the 50-99 m grouping which contains 49% of the samples and 69% of the specimens; next greatest abundance occurs in the 100-199 m grouping with 25% of the samples and 14% of the specimens; the 25-49 m and the 0-24 m groupings each contain 8 and 1% of the samples, respectively, and 10 and 1% of the specimens, respectively, while the 200-499 m grouping contains 17% of samples and 7% of the specimens (Table 298).

The finer grained substrates contained significantly greater amounts of both samples and specimens of this species than the coarser ones. In order of decreasing particle size, abundance is as follows: gravel contained 1% of the samples and 0.4% of the specimens; sand-gravel, 2% for samples and 9% for specimens; till, 8% for samples and 14% for specimens; sand-shell substrates had traces of both, 0.4% samples and 0.1% specimens, while sand contained 23% for samples and 8% of the specimens; silty sand substrates accounted for 28% of the samples and 26% of the specimens; silt contained 10% of the samples and 12% of the specimens; and clay substrates contained the largest amounts, 29% of the samples and 31% of the specimens (Table 299). There is one sample containing one specimen which is unclassified with regard to sediment type.

Periploma sp. Figure 88.

There are four specimens from four samples in the NEFC collection which bear the classification *Periploma* sp. (Table 5).

Samples containing members of this genus are from the Gulf of Maine, the southern part of Georges Bank, and the Southern New England shelf area (Fig. 88; Theroux and Wigley footnote 4, table 151).

Our samples are from depths which range from 59 to 232 m with a mean of 117 m. The 50-99 m depth range grouping

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[11] Abbott (1974) has "(Conrad, 1831)" for this species, it should be (Conrad 1830), see under References.

contains 75% of the samples and 75% of the specimens, and the 200-499 m grouping contains 25% of each (Table 300).

Fifty percent of both samples and specimens occurred in two substrate types: sand and silty sand (Table 301).

Family THRACIIDAE

Our collection contains 36 specimens from 19 samples which are classified at the familial level Thraciidae (Table 5).

Samples containing members of this family are from the inner and outer continental shelf ranging between the mouth of Delaware Bay south to slightly north of Jacksonville, Fla. (Fig. 107; Theroux and Wigley footnote 4, table 194).

Our samples are from depths which range between 13 and 365 m with a mean of 68 m. The 0-24 m depth range grouping contains 37% of the samples and 33% of the specimens; the 25-49 m grouping contains 26% of the samples and 25% of the specimens; the 50-99 m grouping contains 21% of the samples and 25% of the specimens; the 100-199 m grouping is one exception with low quantities, containing 5% of the samples and 3% of the specimens, while the 200-499 m grouping contains 11% of the samples and 14% of the specimens (Table 302).

Three sediment types yielded samples which contained members of this family with sand containing the majority, 74% of samples and 78% of the specimens; sand-shell substrates contained 16% of samples and 8% of the specimens, while silty sand substrates contained 11% of the samples and 14% of the specimens (Table 303).

Genus *Thracia* Leach 1823

Thracia conradi Couthouy 1839.[12] Conrad's thracia. Figure 106.

The geographic range of this species is from the Canadian Maritime Provinces to North Carolina (Johnson 1934; La Rocque 1953; Ockelmann 1958; Abbott 1968, 1974; Morris 1973).

Thracia conradi is fairly common and oftentimes frequently encountered; the NEFC collection contains 10 specimens from 6 samples of this species (Table 5).

Our samples are distributed from slightly south of Grand Manan Island off the coast of Maine to slightly north and east of the mouth of Delaware Bay (Fig. 106; Theroux and Wigley footnote 4, table 191).

This species occupies the Boreal and Virginian provinces (Coomans 1962); Dance (1974) placed it in the Boreal and Transatlantic provinces.

Conrad's thracia ranges from just below the low water mark to approximately 275 m (Abbott 1968, 1974; Morris 1973).

Our samples are from water depths which range between 34 and 126 m with a mean of 70 m. The majority of both samples and specimens are in the 0-24 m depth range grouping, which contains 50% of the samples and 70% of the specimens, while the 50-99 m grouping contains 33% of the samples and 20% of the specimens; smallest amounts are in the 25-49 m depth range grouping which contains 17% of the samples and 10% of the specimens (Table 304).

Specimens of *T. conradi* were found in four sediment types; 33% of the samples occurred in both silty sand and silt and 17% of the samples occurred in till and sand. The distribution of specimens, however, differed in each sediment type with silt containing 40%, till, 30%, silty sand, 20%, and sand, 10% of the specimens (Table 305).

Thracia myopsis Möller 1842. Figure 107.

This species, which is widely distributed throughout Arctic regions ranges south to the Massachusetts coast (Johnson 1934; La Rocque 1953; Ockelmann 1958; Abbott 1974).

This uncommon bivalve is represented in the NEFC collection by six specimens from three samples (Table 5).

One of the three samples in the NEFC collection was from Browns Bank, another from east of Cape Ann, Mass., and the third at the tip of Cape Cod, Mass. (Fig. 107; Theroux and Wigley footnote 4, table 192).

Ockelmann (1958) reported that this species is panarctic in the American sector only.

The depth range for this species according to Johnson (1934), Ockelmann (1958), and Abbott (1974), is between 2 and 350 m.

Our samples are from water depths which range between 95 and 114 m with a mean of 105 m. The 50-99 m and 100-199 m depth range groupings each contain 50% of the samples while the former contains 60% and the latter 40% of the specimens. There is one sample containing one specimen which does not have any depth information in the sampling data.

Two of the samples containing five specimens were found in gravel substrates. One sample containing one specimen is unclassified with regard to sediment type.

Thracia septentrionalis Jeffreys 1872. Northern thracia. Figure 107.

The northern thracia is widely distributed throughout Arctic regions and ranges from Greenland south to Block Island, R.I. (Johnson 1934; La Rocque 1953; Ockelmann 1958; Morris 1973; Abbott 1974).

Thracia septentrionalis is represented in the NEFC collection by 46 specimens from 13 samples (Table 5).

Our samples are from the Georges Bank region and the surrounding offshore waters of Cape Cod, Mass. (Fig. 107; Theroux and Wigley footnote 4, table 193).

Gosner (1971) placed this species in the Boreal zoogeographic province and Ockelmann (1958) reported that it is panarctic in the North Atlantic.

The northern thracia occupies water depths which range between 9 and 113 m (Ockelmann 1958).

Our samples are from depths which range between 23 and 74 m with a mean of 54 m. In terms of depth range groupings there is a diminution of both sample and specimen abundance with decreasing depth range from 50-99m. The majority of both samples and specimens are in the 50-99 m depth range grouping which contains 62% of the samples and 74% of the specimens, while the 25-49 m grouping contains 31% of the former and 22% of the latter; the 0-24 m depth range grouping contains the smallest amount of both samples and specimens with 8% of the former and 4% of the latter (Table 306).

Our samples of the northern thracia were found in two sediment types with the majority of them occurring in sand

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[12] Abbott (1974) has "Couthouy, 1838" for this species, it shold be Couthouy 1839, see under References.

which contained 92% of the samples and 93% of the specimens. The only other sediment type in which specimens were found was sand-gravel which contained 8% of the samples and 7% of the specimens (Table 307). There is one sample containing one specimen which is unclassified with regard to sediment type.

Family POROMYIDAE
Genus *Poromya* Forbes 1844

***Poromya* sp. Figure 91.**

The NEFC collection contains six specimens from six samples which are classified as *Poromya* sp. (Table 5).

The samples containing specimens of *Poromya* are distributed on the edge of the continental shelf with two samples occurring between Delaware and Chesapeake Bays; two samples, one north and one south of Cape Hatteras, N.C., and two between Charleston, N.C., and Jacksonville, Fla. (Fig. 91; Theroux and Wigley footnote 4, table 159).

Our samples are from depths which range between 17 and 400 m with a mean of 131 m. The 0-24 and the 200-499 m groupings each contain 17% of both samples and specimens, while the 25-49 and 100-199 m groupings each contain 33% of both samples and specimens (Table 308).

Samples containing *Poromya* were obtained from three sediment types: sand-shell, sand, and silty sand. Sand substrates contained 50% of both samples and specimens, while sand-shell contained 17% for each and silty sand 33% for each (Table 309).

Family CUSPIDARIIDAE

There are 11 specimens from 9 samples in the NEFC collection classified as Cuspidariidae (Table 5).

Samples containing members of this taxon are from the continental shelf and upper slope in the southern regions of the study area extending from south of Cape Fear, N.C., to Key West, Fla. (Fig. 37; Theroux and Wigley footnote 4, table 60).

The depth range of our samples is 30 to 257 m with a mean of 156 m. The majority of samples and specimens are in the 200-499 m depth range grouping accounting for 45% of both samples and specimens. Two of the depth range groupings, the 50-99 m and the 100-199 m, each account for 22% of the samples but 18 and 23% of the specimens, respectively. The shallowest depth range grouping, 25-49 m, contains 11% of the samples and 9% of the specimens (Table 310).

This taxon was found in three sediment types, sand-shell, sand, and silty sand. Sand substrates predominate in both sample and specimen strength containing 56% of the former and 55% of the latter. One-third of the samples occurred in silty sand which contained 36% of the specimens; whereas, sand-shell substrates contained 11% of the samples and 9% of the specimens (Table 311).

Genus *Cardiomya* Adams 1864

***Cardiomya perrostrata* (Dall 1881). West Indian dipper shell. Figure 22.**

This species occurs from south of Martha's Vineyard, Mass., to the West Indies and Brazil (Johnson 1934; Morris 1973; Abbott 1974).

There are 24 specimens from 13 samples of this species in the NEFC collection (Table 5).

Our samples are distributed along the outer continental shelf and slope in the Middle Atlantic Bight Region between Cape Cod, Mass., and Cape Hatteras, N.C. (Fig. 22; Theroux and Wigley footnote 4, table 35).

The West Indian dipper shell occupies the Virginian province (Gosner 1971).

The depth range of this species is 106 to 761 m (Johnson 1934).

Our samples are from water depths ranging from 141 to 500 m with a mean of 212 m. The majority of both samples (77%) and specimens (88%) are in the 100-199 m depth range grouping; diminishing amounts of each occur in the 200-499 m and 500-999 m groupings (Table 312).

Members of this species were found in sand, silty sand, silt, and clay substrates. There is a general tendency of decreasing abundance of both samples and specimens with decreasing sediment particle size (Table 313).

Genus *Cuspidaria* Nardo (1840)

***Cuspidaria glacialis* (G. O. Sars 1878). Northern dipper shell. Figure 34.**

The northern dipper shell is widely distributed throughout the Northern Hemisphere, occurring in both the North Atlantic and North Pacific Oceans. Ockelmann (1958) and Clarke (1962) have extensive lists of its Arctic and subarctic distribution, claiming that it is panarctic but probably abyssal only in the North Atlantic. Other authorities report its distribution to be from Canadian Arctic seas south to Florida in the Atlantic and from Alaska to San Diego, Calif., in the Pacific (Johnson 1934; Morris 1951, 1973; La Rocque 1953; Abbott 1968, 1974).

The NEFC collection contains 184 specimens of this common species from 49 samples (Table 5).

Samples in our collection are primarily in the Gulf of Maine region; however, a few isolated samples occur in the Middle Atlantic Bight off Long Island, N.Y., a few off Atlantic City, N.J., and two occur farther south on the continental slope east of Norfolk, Va. (Fig. 34; Theroux and Wigley footnote 4, table 54).

The zoogeographic provinces occupied by this species are the Boreal and Virginian (Gosner 1971).

The reported depth range for this species is from 15 to 2,685 m (Johnson 1934; Clarke 1962; Abbott 1968).

The NEFC samples are from depths which range from 75 to 3,820 m with a mean of 281 m. The majority of our samples (55%) and specimens (60%) are in the 100-199 m depth range grouping; the 50-99 m and the 200-499 m groupings each contain 18% of the samples but 23 and 13% of the specimens, respectively. Six percent of the samples and 4% of the specimens are in the 500-999 m grouping and 2 and 0.5%, respectively, in the 2,000-3,999 m grouping (Table 314).

This species is an inhabitant of sand substrates (Abbott 1968).

Our samples were found in gravel, till, sand, silty sand, silt, and clay substrates. Table 315 lists the amounts of samples and specimens that were found in each sediment type. One sample containing three specimens is unclassified with regard to sediment type.

Cuspidaria obesa (Lovén 1846). Obese dipper shell. Figure 35.

The distribution of this species ranges from the Arctic Ocean to the West Indies in the northwest Atlantic (Johnson 1934; La Rocque 1953; Abbott 1974). Ockelmann (1958) and Clarke (1962) have compiled extensive lists of its distribution throughout Arctic regions as well as the European side of the North Atlantic showing it to range from Norway, western Europe, and the Canary Islands, south into the Mediterranean Basin.

This species is represented in the NEFC collection by 14 samples containing 30 specimens (Table 5).

Our samples are from the Gulf of Maine Basin and slope waters from Georges Bank to the offing of Delaware Bay (Fig. 35; Theroux and Wigley footnote 4, table 55).

This species is subarctic-boreal, Mediterranean-Atlantic, and abyssal (Ockelmann 1958).

This species inhabits water depths between 18 and 4,456 m (Clarke 1962).

Our samples are from depths ranging between 114 and 720 m with a mean of 401 m. The 200-499 m and the 500-999 m depth range groupings each contain 36% of the samples, but the former contains 23% and the latter 40% of the specimens. The other range grouping in which this species occurs is the 100-199 m grouping containing 29% of the samples and 37% of the specimens (Table 316).

Our samples were obtained from a variety of sediment types which included gravel, till, sand, silty sand, silt, and clay. The largest amount of samples (29%) were in silty sand; this substrate also contained the greatest number of specimens (37%). Other sediment types contained 7 to 21% of the samples and from 6 to 17% of the specimens (Table 317).

Cuspidaria parva Verrill and Bush 1898. Figure 35.

This species occurs off Cape Cod, Mass., in the North American Basin (Johnson 1934; Clarke 1962; Abbott 1974). The locations of our two samples are: 1) off the coast of Maine in the Gulf of Maine, and 2) on the continental slope between New York and Atlantic City, N.J. (Fig. 35; Theroux and Wigley footnote 4, table 56).

The reported depth range for this species is 90 to 2,361 m (Abbott 1974; Porter 1974).

There are three specimens from two samples of this rather rare bivalve species in the NEFC collection (Table 5).

The two samples in the NEFC collection are from 95 and 1,328 m of water. The shallower sample is in the 100-199 m depth range grouping and contains one specimen while the deep one is located in the 500-999 m depth range grouping and contains two specimens (Table 318).

One sample occurred in silt sediments and contained two specimens while the second sample was obtained from clay substrates and contained one specimen (Table 319).

Cuspidaria pellucida Stimpson 1853. Figure 36.

The geographic distribution of this species ranges from the Gulf of St. Lawrence to Casco Bay, Maine (Johnson 1934; La Rocque 1953; Abbott 1974); Ockelmann (1958) reported it to occur from Newfoundland to Cape Cod, Mass.

This rather rare species is represented in the NEFC collection by 19 specimens from 4 samples (Table 5).

Our samples are from off the coast of Maine on the continental shelf and from the Gulf of Maine Basin proper (Fig. 36; Theroux and Wigley footnote 4, table 57).

The bathymetric range of this species is from 73 to 174 m (Abbott 1974).

Our samples range in depth from 75 to 178 m with a mean of 123 m. Seventy-five percent of the samples and 74% of the specimens are in the 100-199 m depth range grouping and 25% of the samples and 26% of the specimens are in the 50-99 m depth range grouping (Table 320).

Sixty-seven percent of the samples and 36% of the specimens occurred in silty sand substrates (Table 321). One sample containing five specimens is unclassified with regard to sediment type.

Cuspidaria rostrata (Spengler 1793). Rostrate cuspidaria. Figure 36.

This species is reported to occur from Arctic seas to the West Indies in the North Atlantic and is also found in Europe (Johnson 1934; La Rocque 1953; Morris 1973; Abbott 1974). Ockelmann (1958), Clarke (1962), and Tebble (1966) have complete lists of its Arctic and subarctic distribution as well as its European distribution. Tebble mentioned that it is also present in the Mediterranean, along the Atlantic coast of Morocco, in the Canary Islands, the Azores, and Sierra Leone and Liberia on the African coast.

This is a moderately common bivalve of which there are two samples containing nine specimens in the NEFC Specimen Reference Collection (Table 5).

Our samples are from the edge of the continental shelf south of Georges Bank (Fig. 36; Theroux and Wigley footnote 4, table 58).

The rostrate cuspidaria is a deep water species which ranges from 64 to 2,999 m in depth (Johnson 1934; Clarke 1962).

The NEFC samples are from depths ranging from 121 to 144 m with a mean of 133 m. This depth range places both samples in the 100-199 m depth range grouping.

The two samples which yielded specimens of the rostrate cuspidaria were obtained in a sand substrate.

Cuspidaria sp. Figure 37.

There are 114 specimens from 69 samples which are identified to the generic level *Cuspidaria* in the NEFC collection (Table 5).

The 69 samples containing members of the genus *Cuspidaria* are distributed in two groupings within the study area. The first group ranges from the Gulf of Maine Basin south to the outer banks of Cape Cod, Mass.; the second is a more deeply distributed group of samples on the continental shelf and slope, ranging from the middle part of southern Georges Bank to the offing of Chesapeake Bay (Fig. 37; Theroux and Wigley footnote 4, table 59).

Our samples are from water depths which range from 44 to 2,035 m with a mean of 331 m. The majority of samples are in the 100-199 m depth range grouping which contains 49% of the samples and 55% of the specimens. Next largest amounts are in the 200-499 m depth range grouping accounting for 39 and 30% for samples and specimens, respectively; significantly lower amounts of both samples and specimens occur in the other depth range groupings (Table 322).

Specimens of *Cuspidaria* occurred in all but two of our nine sediment types, namely, shell and sand-shell. The greatest numbers of samples and specimens occurred in clay which yielded 41% of the former and 45% of the latter; another sediment type which contained substantial amounts was silty sand accounting for 30% of the samples and 30% of the specimens; sand yielded 11% of the samples and 11% of the specimens with smaller amounts of samples and specimens occurring in the remaining sediment types (Table 323). There are three samples containing eight specimens which are unclassified with regard to sediment type.

Genus *Plectodon* Carpenter 1864

***Plectodon* sp. Figure 90.**

The NEFC collection contains six specimens from four samples which bear the generic designation *Plectodon* sp. (Table 5).

The samples containing this taxon are from the edge of the continental shelf in the Mid-Atlantic Bight region between Chesapeake Bay and Delaware Bay (Fig. 90; Theroux and Wigley footnote 4, table 156).

The range in depth for these four samples is 77 to 118 m with a mean of 100 m. Seventy-five percent of the samples and 83% of the specimens are in the 100-199 m depth range grouping with 25% of the former and 17% of the latter in the 50-99 m grouping (Table 324).

Two sediment types contained *Plectodon* specimens, these were sand-shell and sand; the former contained 75% of the samples and 83% of the specimens and the latter 25% of the samples and 17% of the specimens (Table 325).

Family VERTICORDIIDAE
Genus *Lyonsiella* Sars 1868

***Lyonsiella abyssicola* (G. Sars 1872). Figure 57.**

This species is reportedly found south of Martha's Vineyard, Mass., (Johnson 1934; Abbott 1974) but also occurs in northern Europe and in Arctic regions (Ockelmann 1958; Clarke 1962).

The NEFC collection contains one specimen from one sample of this rather rare bivalve species (Table 5).

Our sample is from slightly south of the northeast peak of Georges Bank at the juncture of the continental shelf and the upper portion of the continental slope (Fig. 57; Theroux and Wigley footnote 4, table 99).

Ockelmann (1958) reported that this species is panarctic-boreal and that it is abyssal in the North Atlantic only.

This species enjoys a wide bathymetric range occupying water depths between 37 and 2,654 m (Clarke 1962).

Our sample is from a water depth of 617 m which places it in the 500-999 m depth range grouping.

Our sample was obtained from a sand substrate.

***Lyonsiella* sp. Figure 57.**

Abbott (1974) noted that members of this genus are mostly very deep water inhabitants and that there are several Atlantic species. The NEFC collection contains one specimen from one sample (Table 5).

Our sample is from the continental slope adjacent to the entrance to Northeast Channel (Fig. 57; Theroux and Wigley footnote 4, table 100). It is from a water depth of 1,934 m in a silty sand substrate.

Genus *Verticordia* Gray 1840

***Verticordia ornata* (Orbigny 1842). Ornate verticord. Figure 117.**

This species occurs in both the Atlantic and Pacific Oceans; in the Atlantic it ranges from Massachusetts to Florida, and the West Indies, it also occurs at Bermuda and Brazil; in the Pacific Ocean it occurs from Catalina Island, Calif., south to Panama (Johnson 1934; Morris 1973; Abbott 1974).

This species is represented in our collection by eight specimens from seven samples (Table 5).

The NEFC samples are from the east coast continental shelf between Cape Fear, N.C., and the central section of the Florida Peninsula (Fig. 117; Theroux and Wigley footnote 4, table 208).

This species occupies the Virginian, Caribbean, and Carolinian zoogeographic provinces (Coomans 1962).

The ornate verticord enjoys a rather wide bathymetric range, occurring in water depths which range between 9 and 1,257 m (Johnson 1934; Abbott 1974).

Our samples are from water depths which range between 30 and 420 m with a mean of 148 m. The majority of both samples and specimens in our collection are in the 25-49 m depth range grouping which contains 57% of the samples and 63% of the specimens; the 200-499 m grouping contains 29% of the samples and 25% of the specimens, while the 100-199 m grouping contains 14% of the samples and 13% of the specimens (Table 326).

All of our samples yielding specimens of the ornate verticord were obtained in sand substrates (Table 327).

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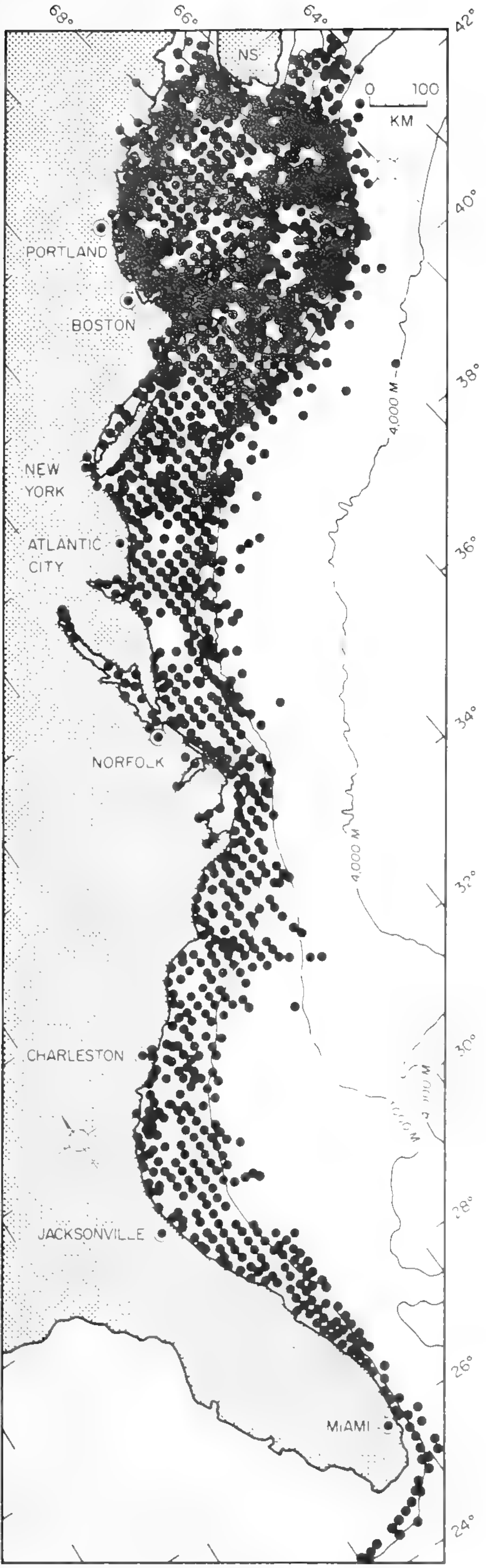


Figure 1.—Chart of U.S. east coast showing sampling locations for bivalve collection.

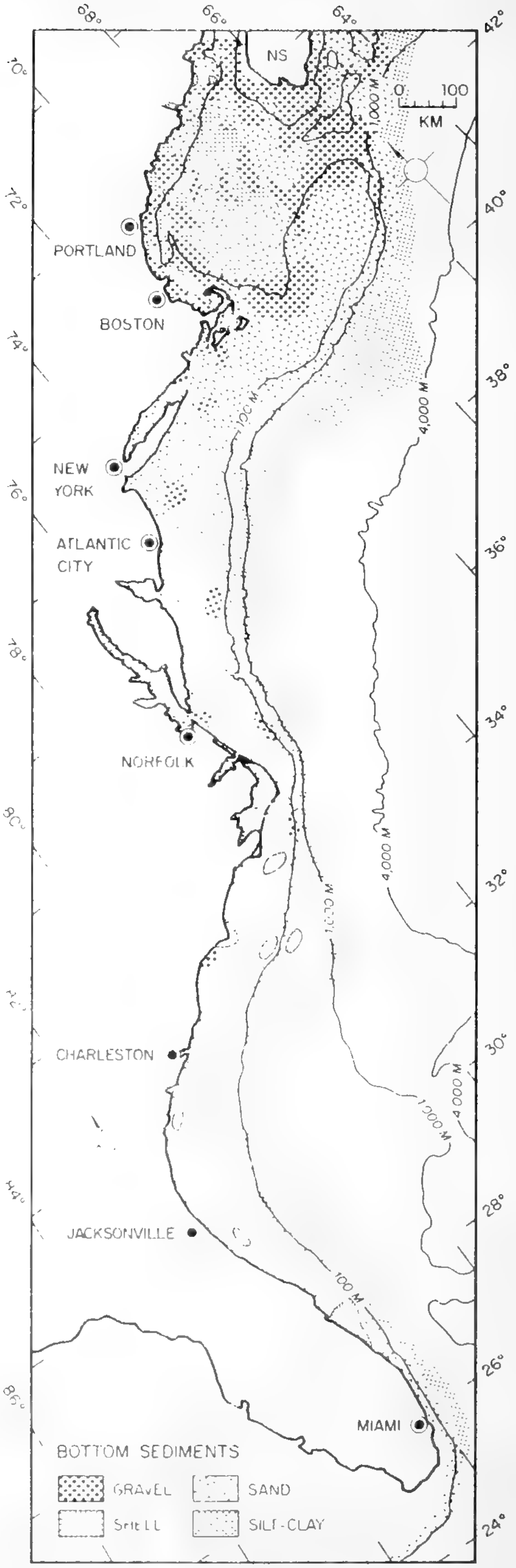


Figure 2.—Distribution of predominant bottom sediments.

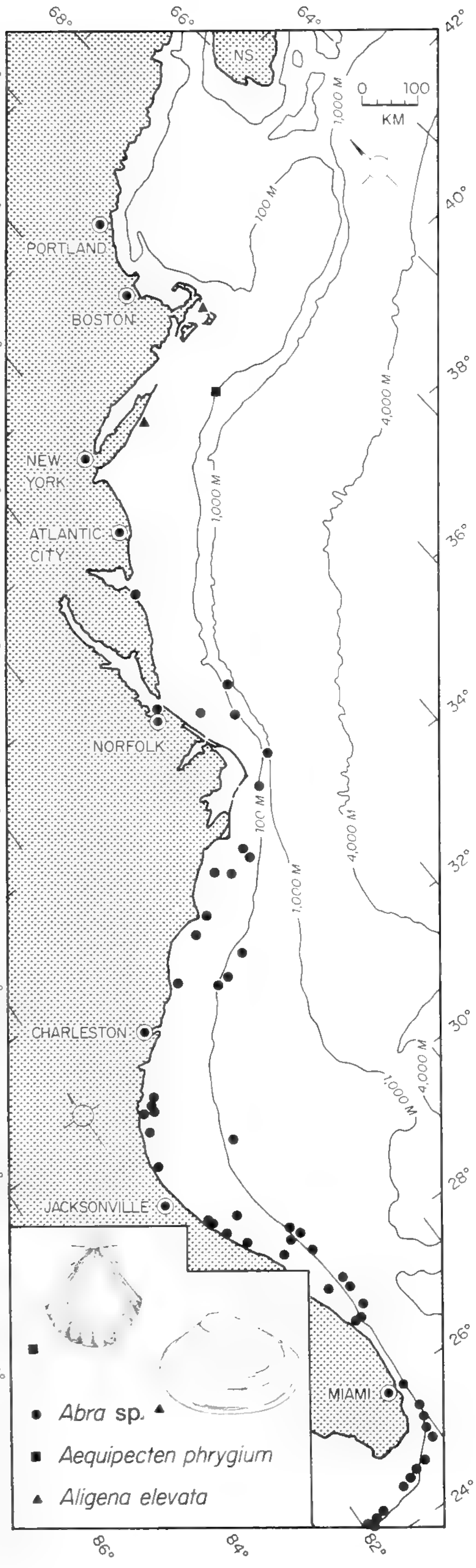


Figure 3.—Geographic distribution of *Abra* sp., *Aequipecten phrygium*, and *Aligena elevata*.

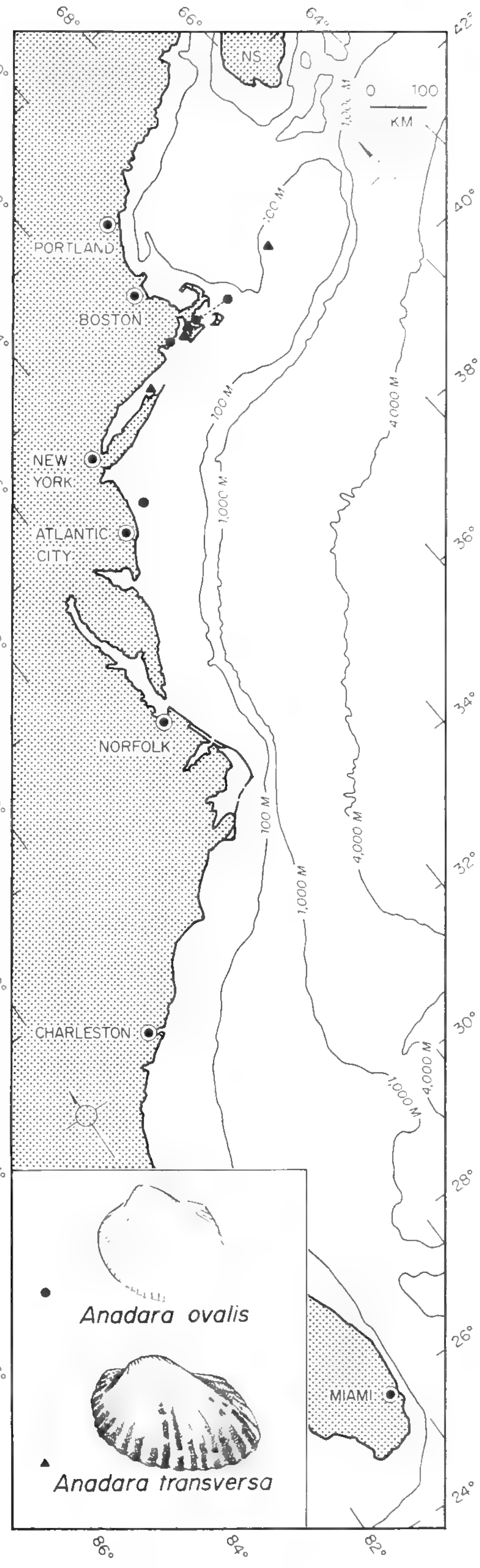


Figure 4.—Geographic distribution of *Anadara ovalis* and *Anadara transversa*.

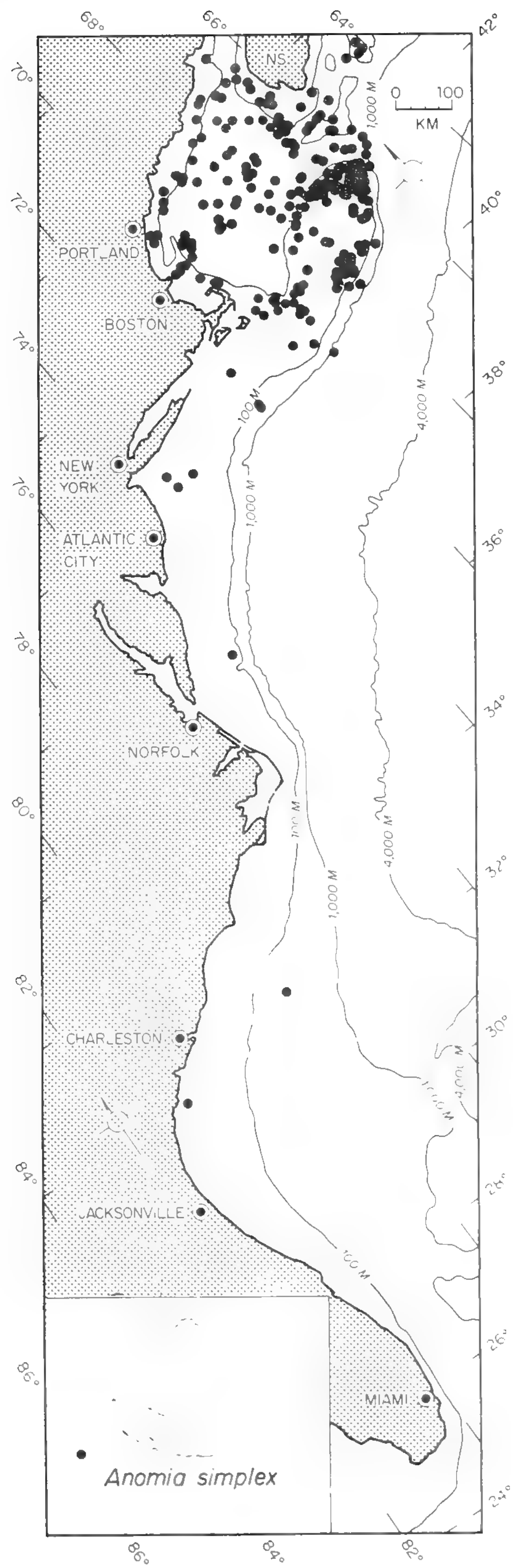


Figure 5.—Geographic distribution of *Anomia simplex*.

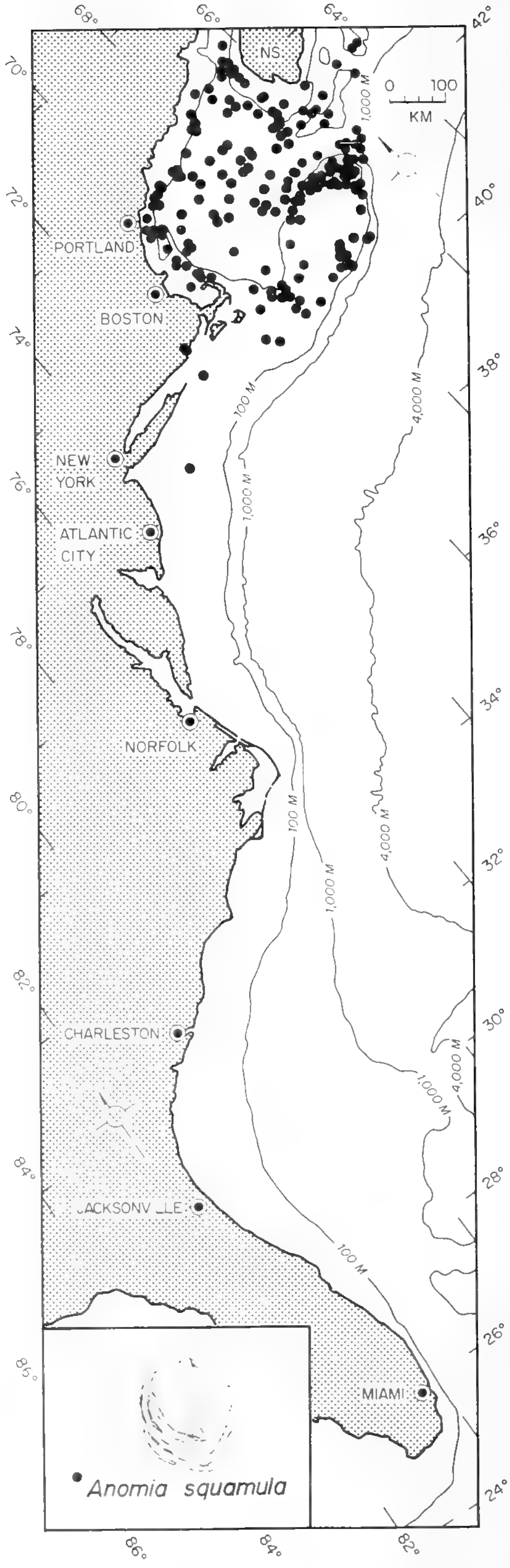
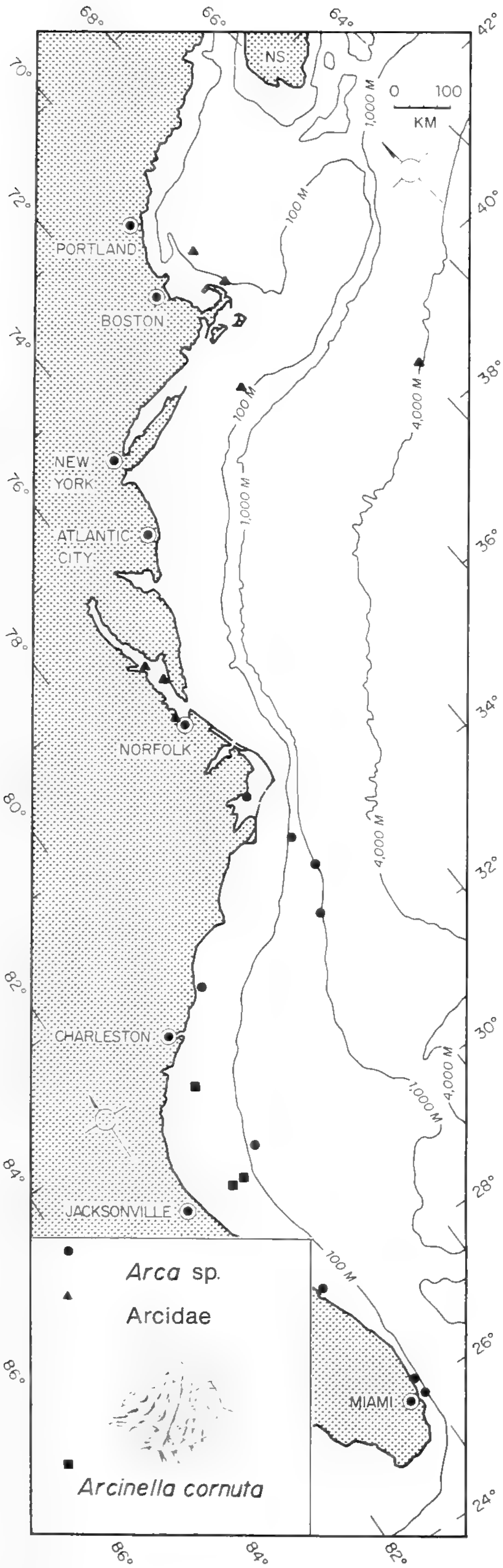


Figure 6.—Geographic distribution of *Anomia squamula*.



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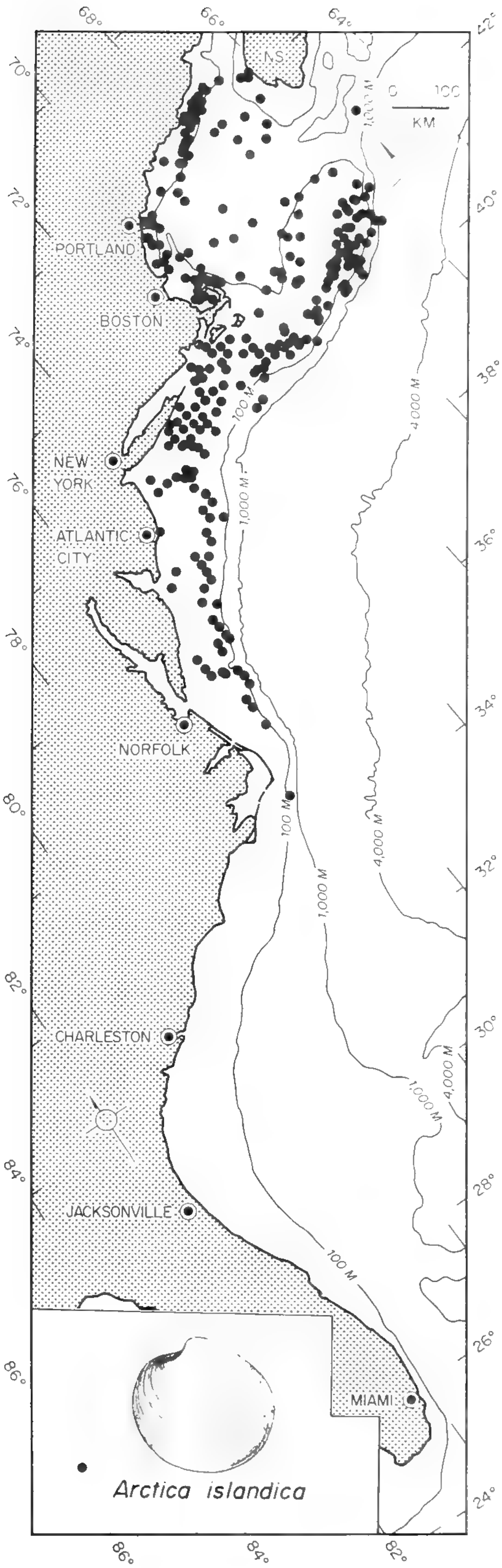

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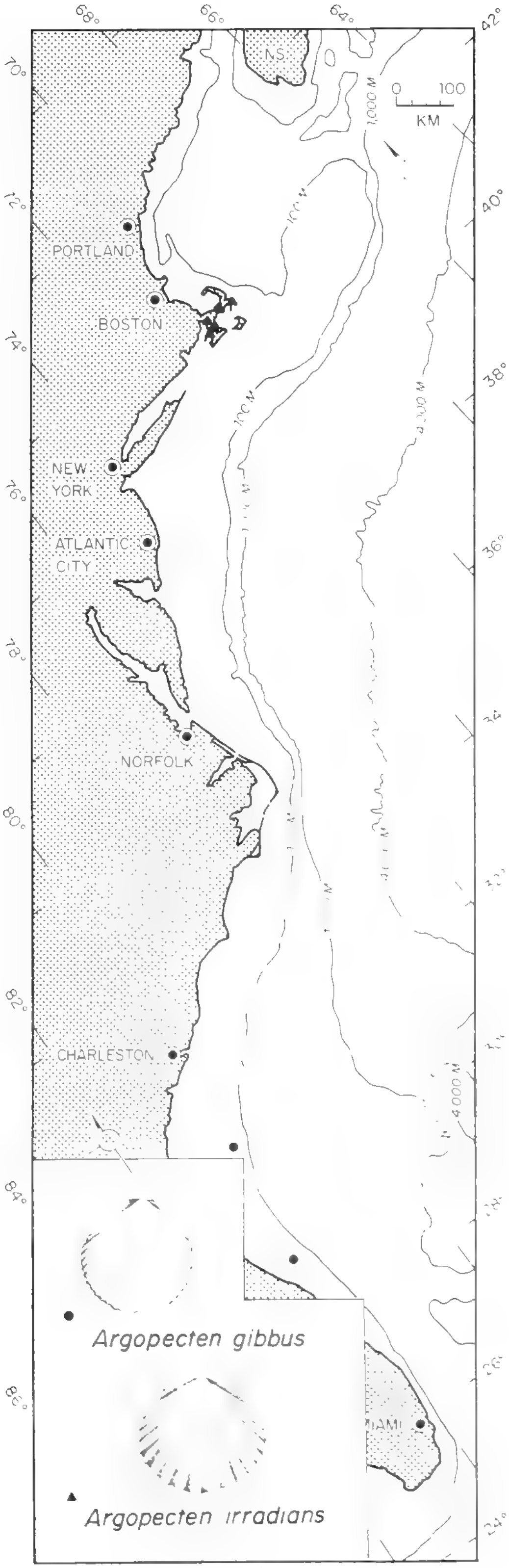


Figure 9.—Geographic distribution of *Argopecten gibbus* and *Argopecten irradians*.

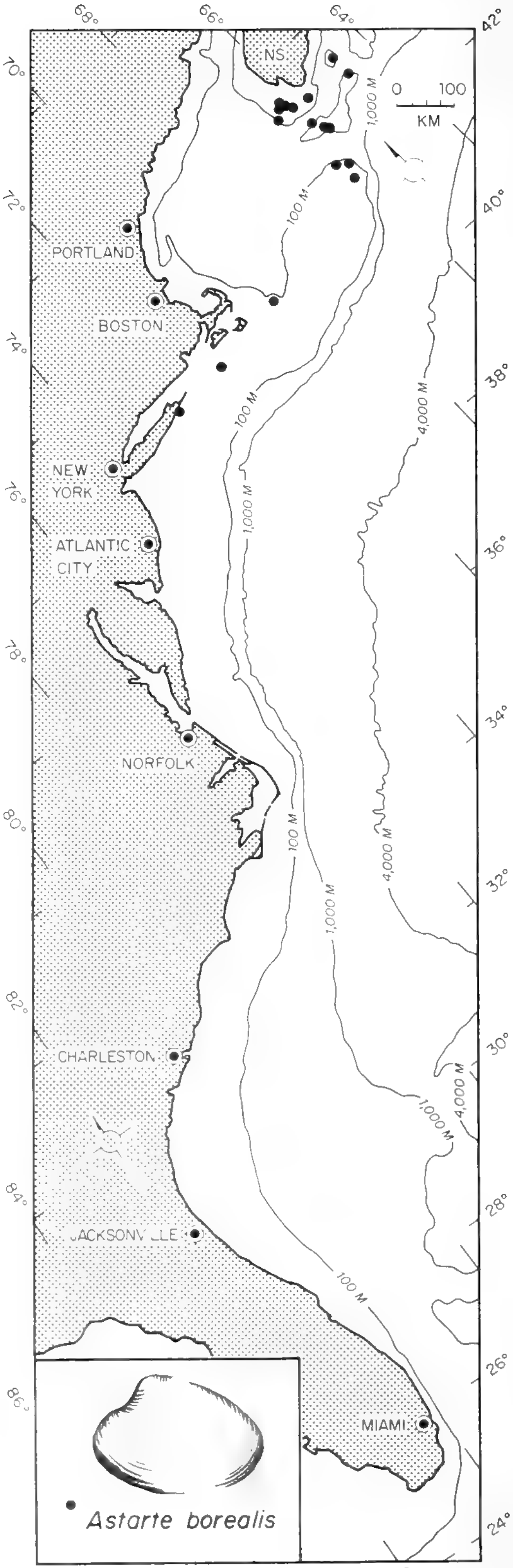


Figure 10.—Geographic distribution of *Astarte borealis*.

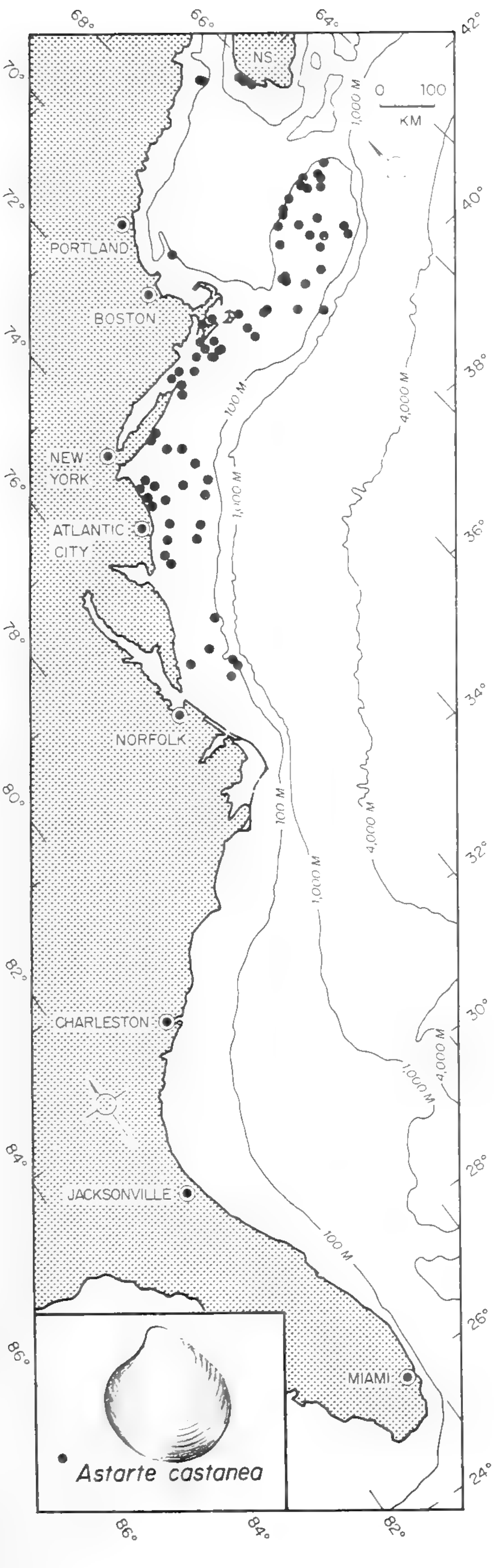
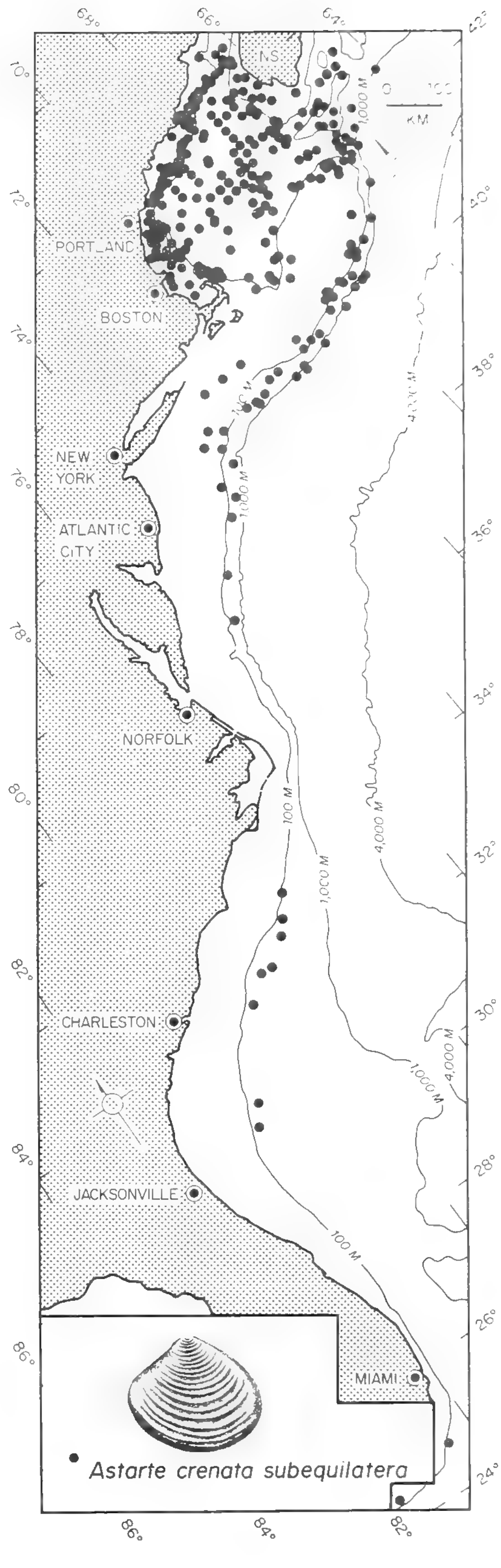


Figure 11.—Geographic distribution of *Astarte castanea*.



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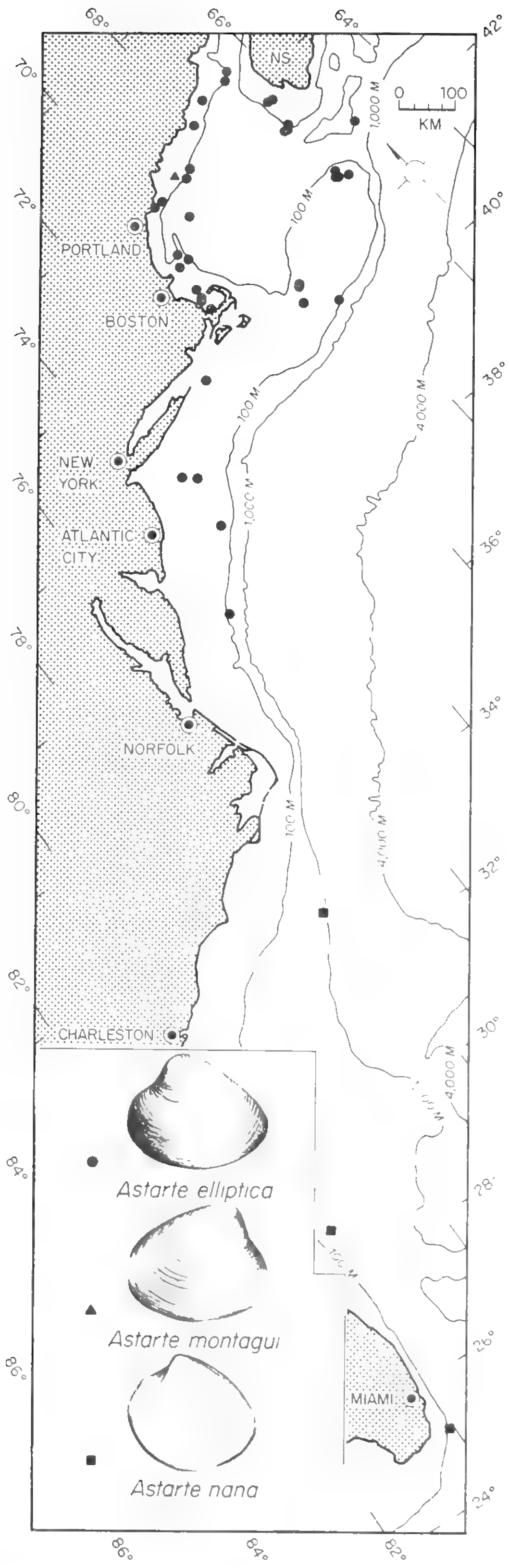

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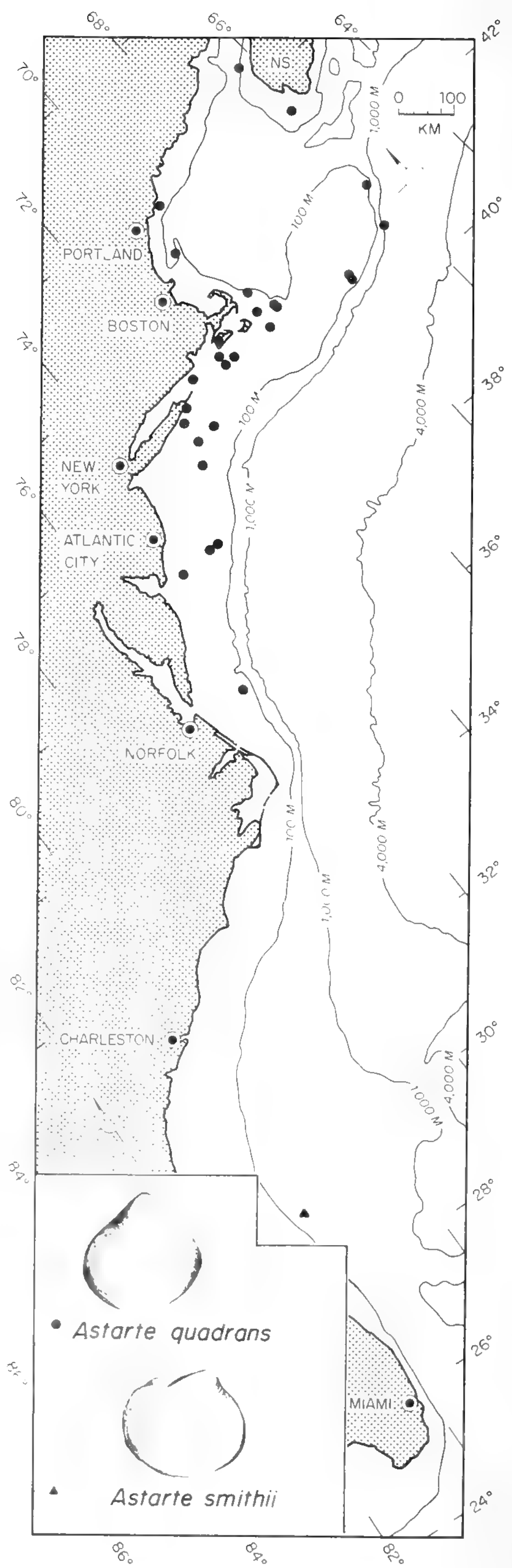

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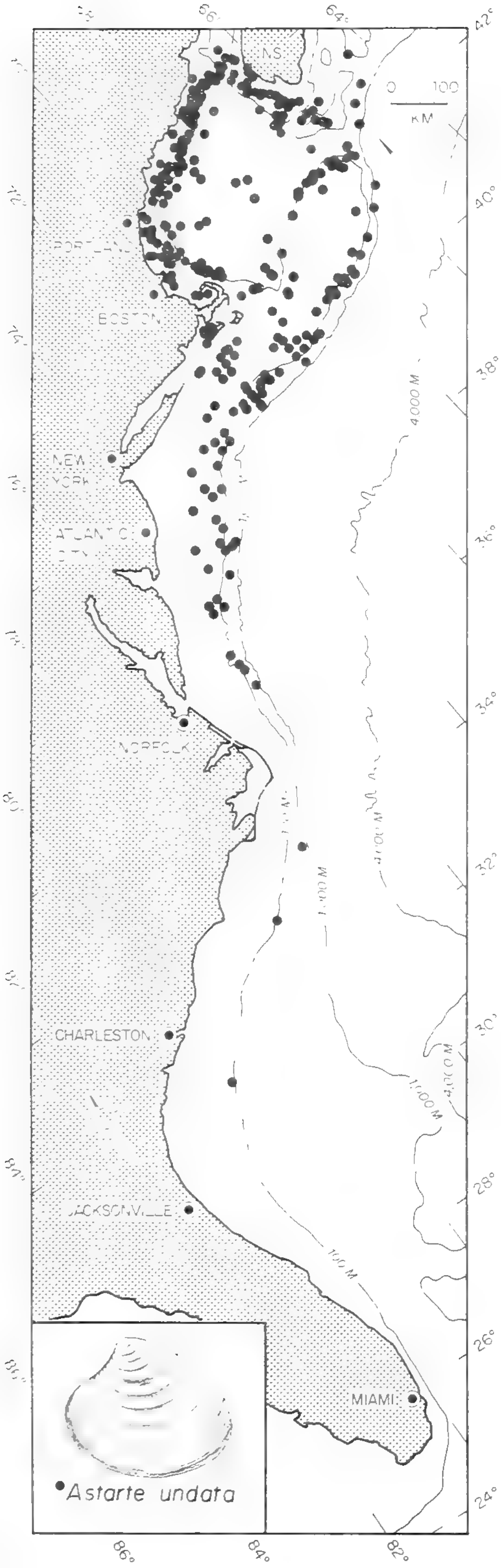

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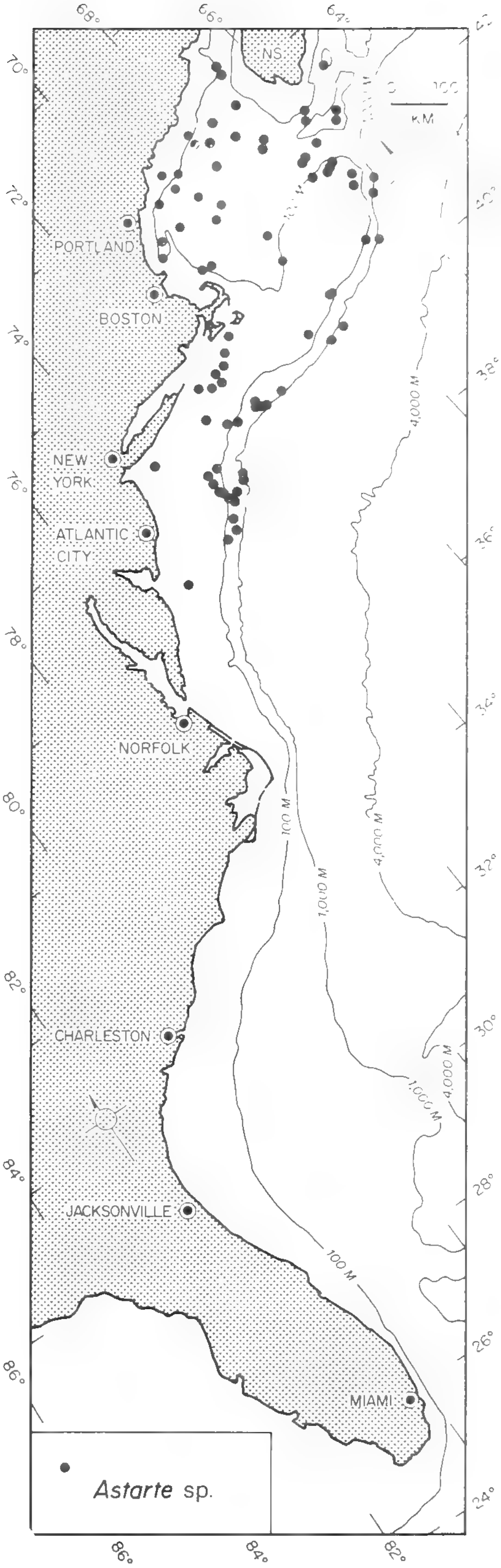


Figure 16.—Geographic distribution of *Astarte* sp.

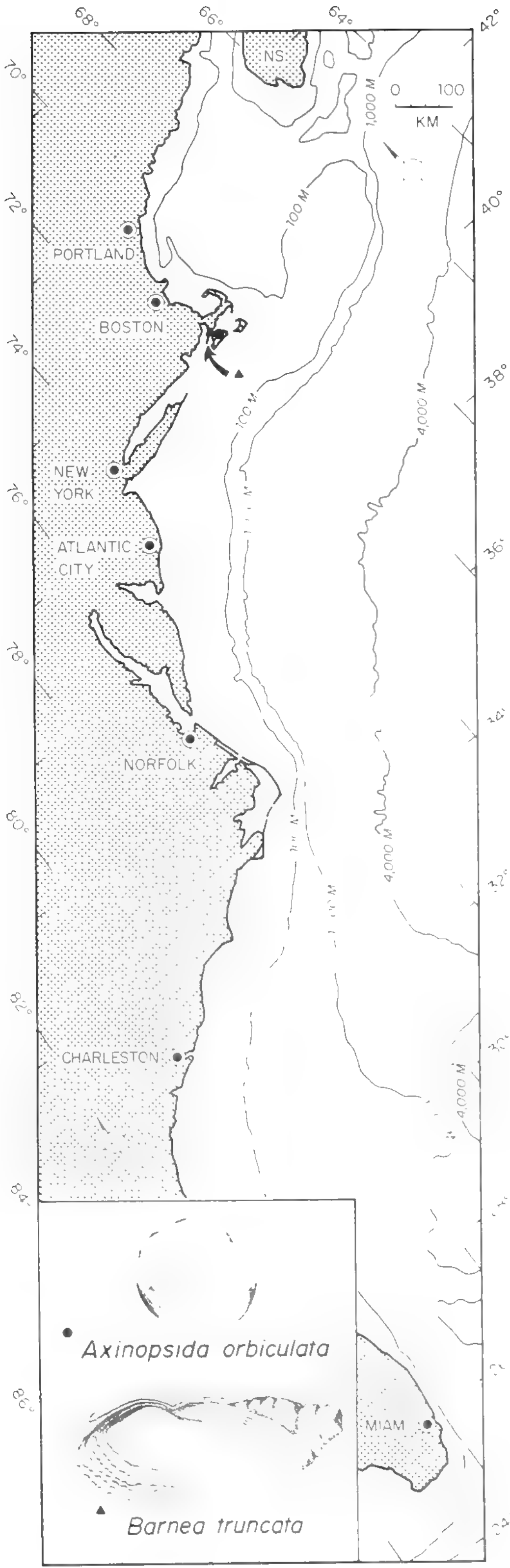


Figure 17.—Geographic distribution of *Axinopsida orbiculata* and *Barnea truncata*.

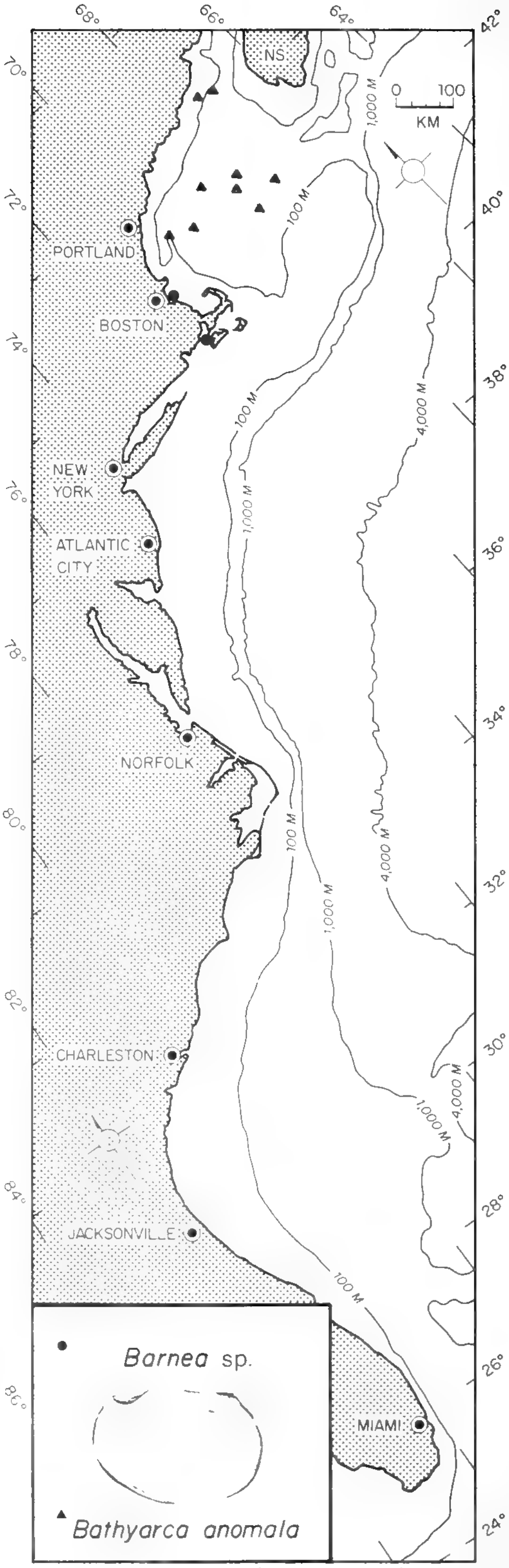
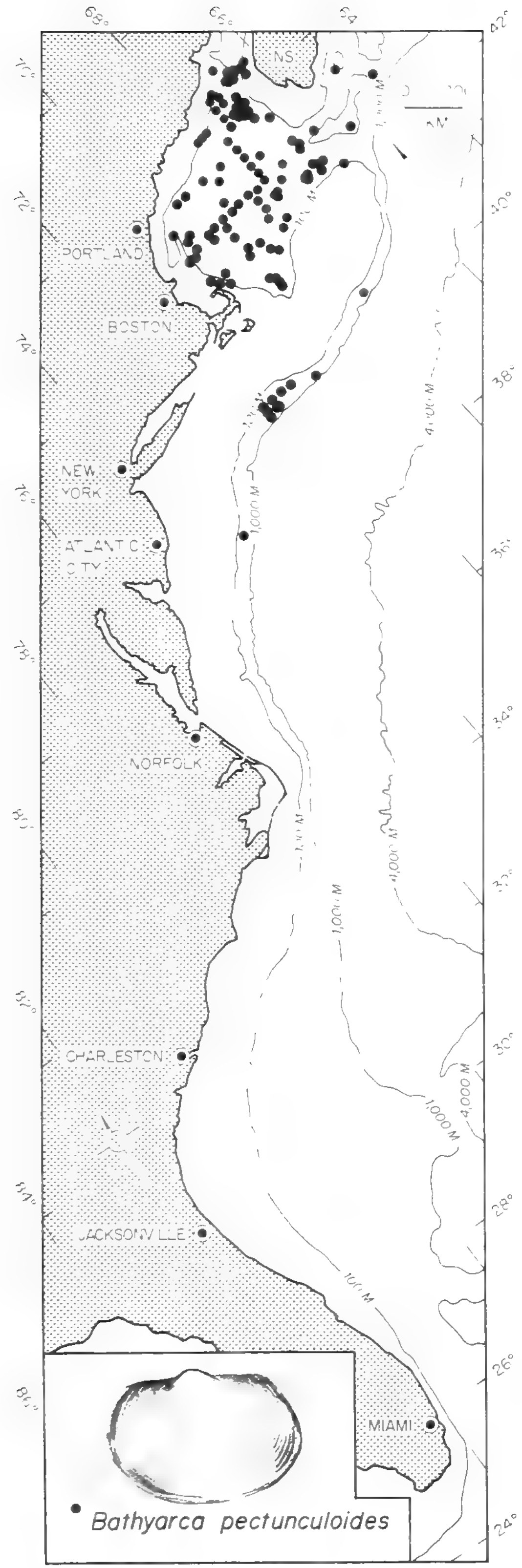


Figure 18.—Geographic distribution of *Barnea* sp. and *Bathyarca anomala*.



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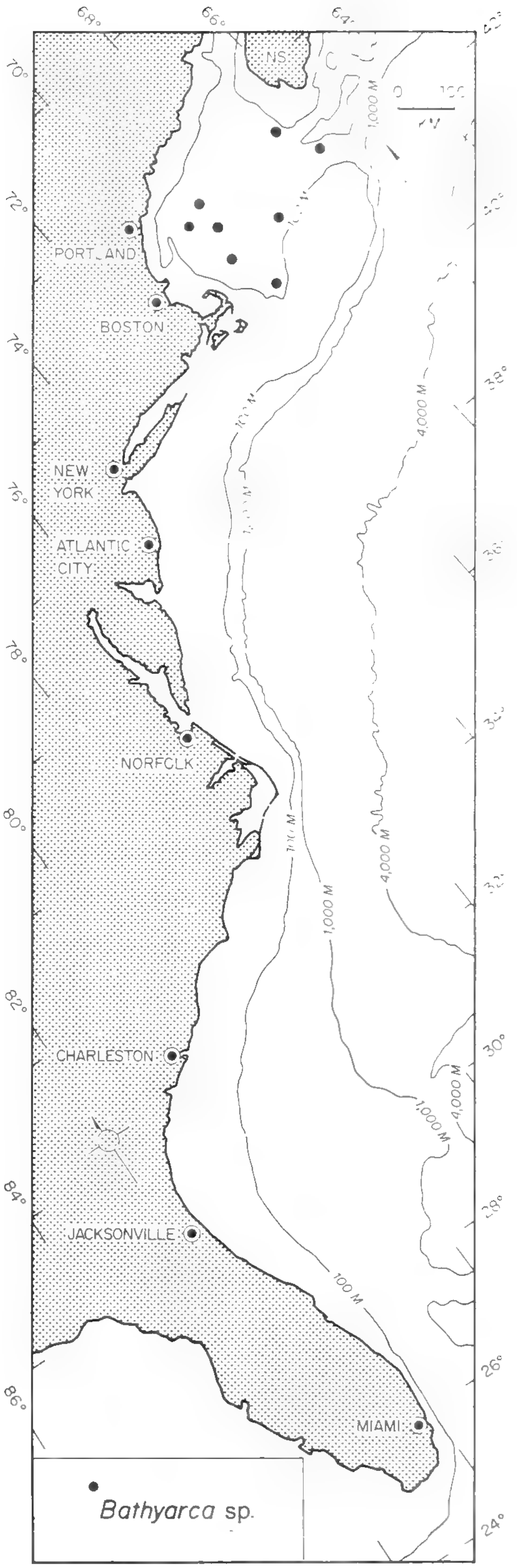

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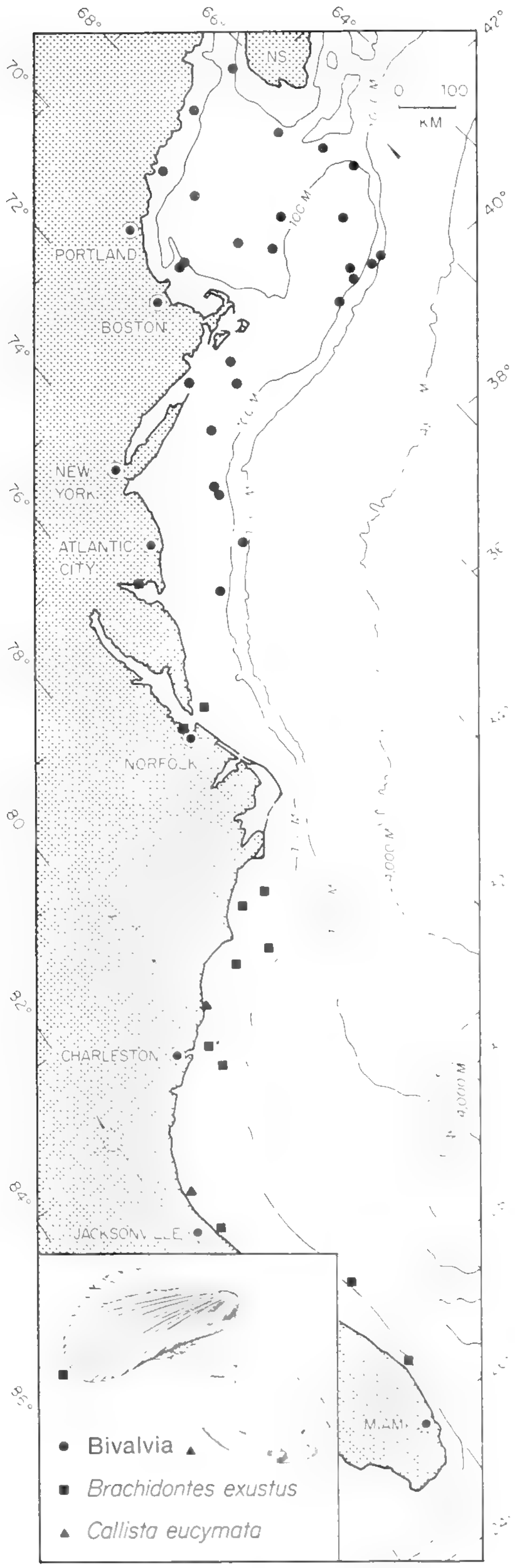
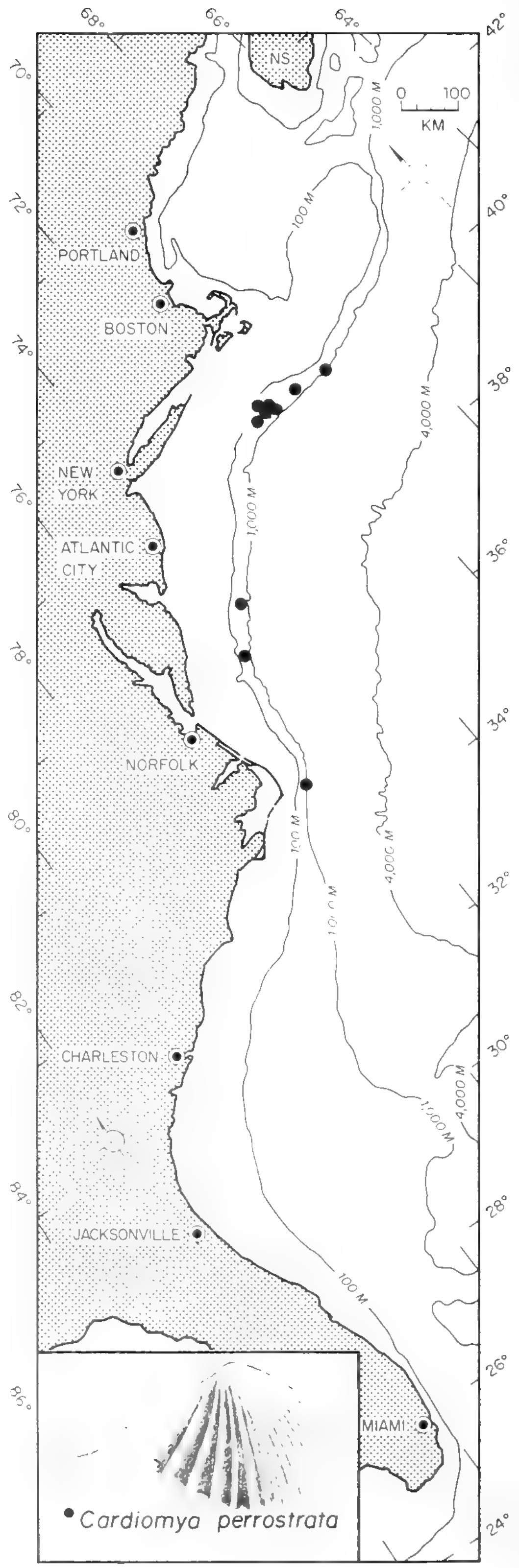


Figure 21.—Geographic distribution of Bivalvia, *Brachidontes exustus*, and *Callista eucymata*.



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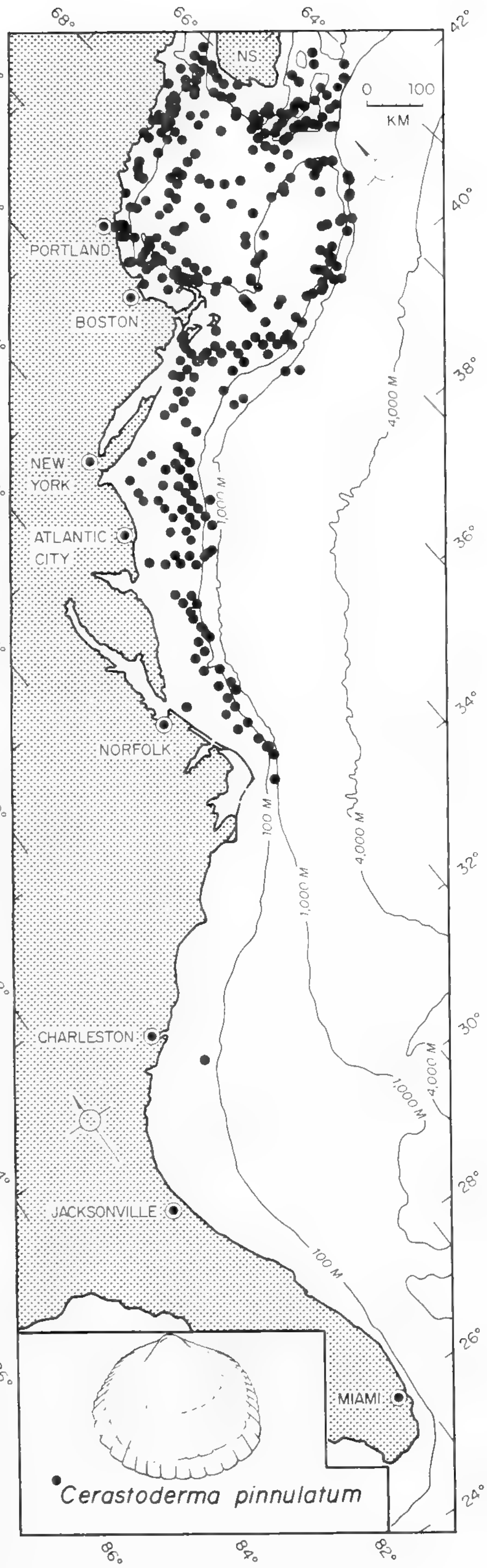

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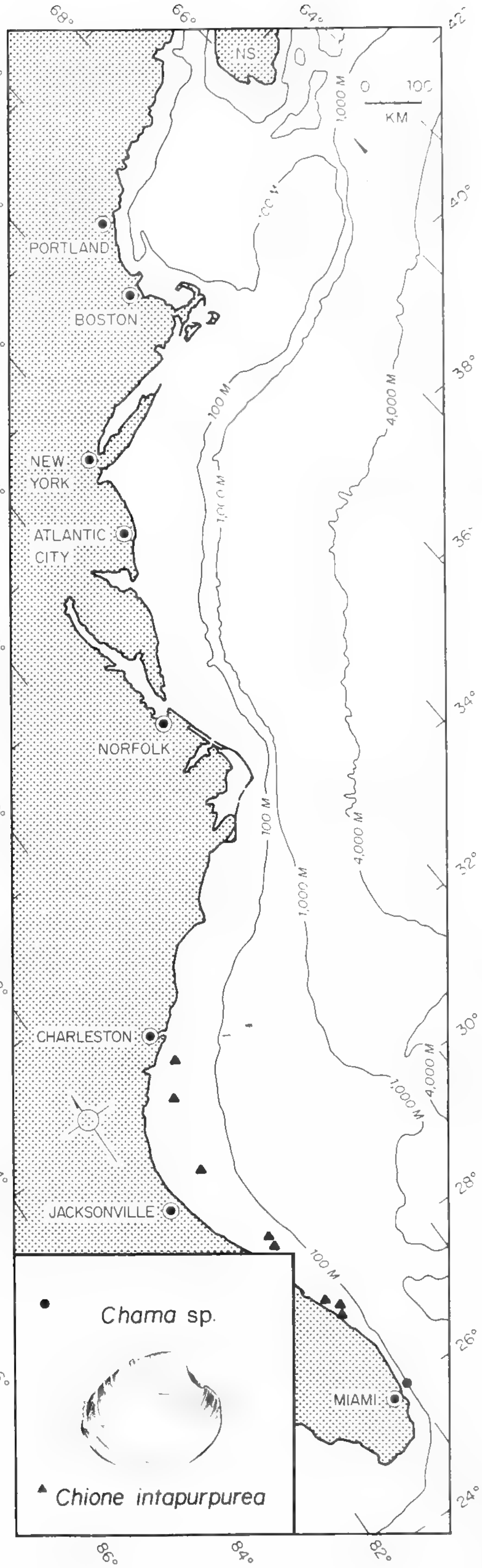
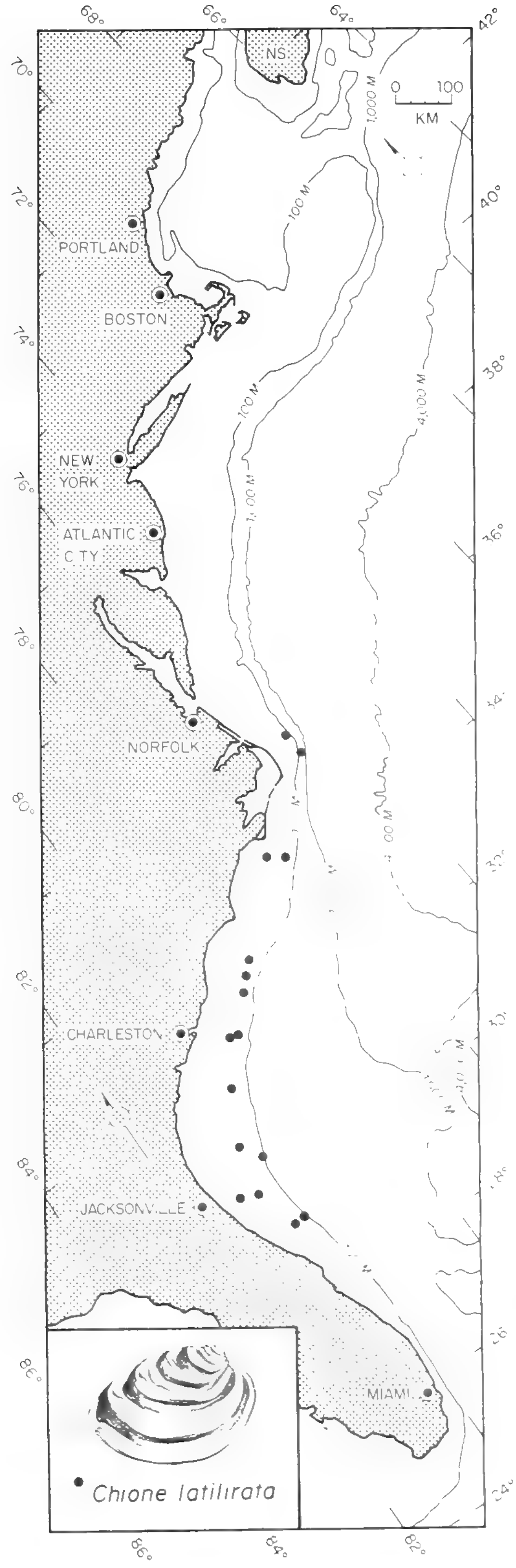


Figure 24.—Geographic distribution of *Chama* sp. and *Chione intapurpurea*.



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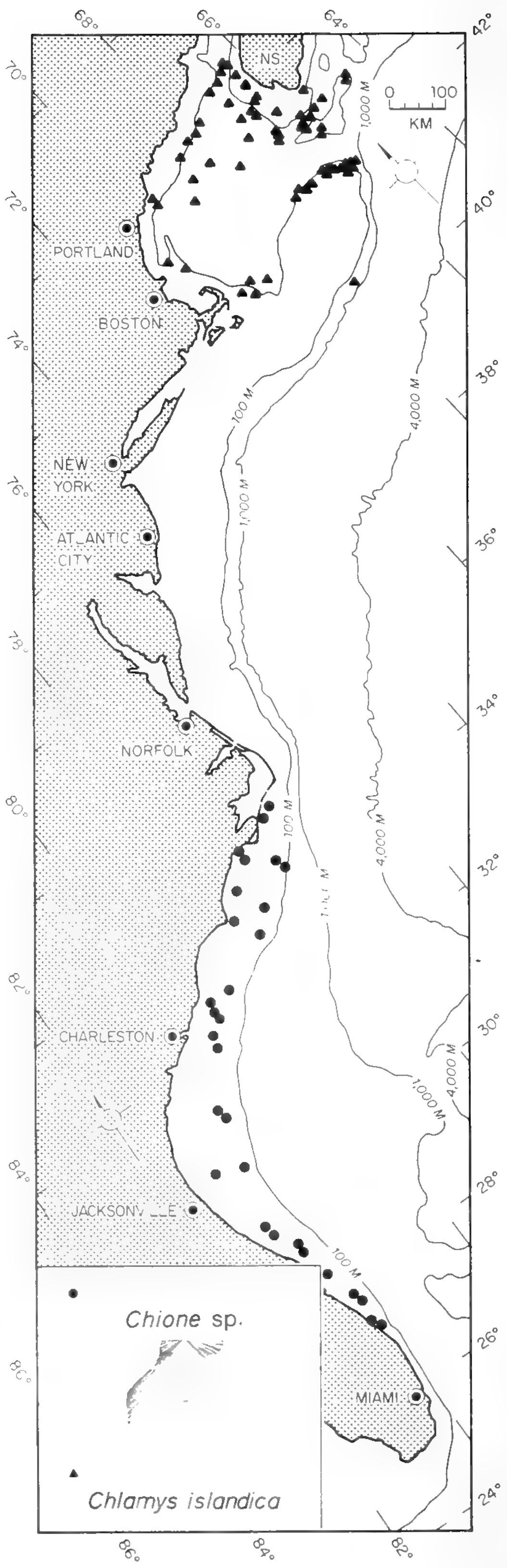

Figure 26.—Geographic distribution of *Chione* sp. and *Chlamys islandica*.

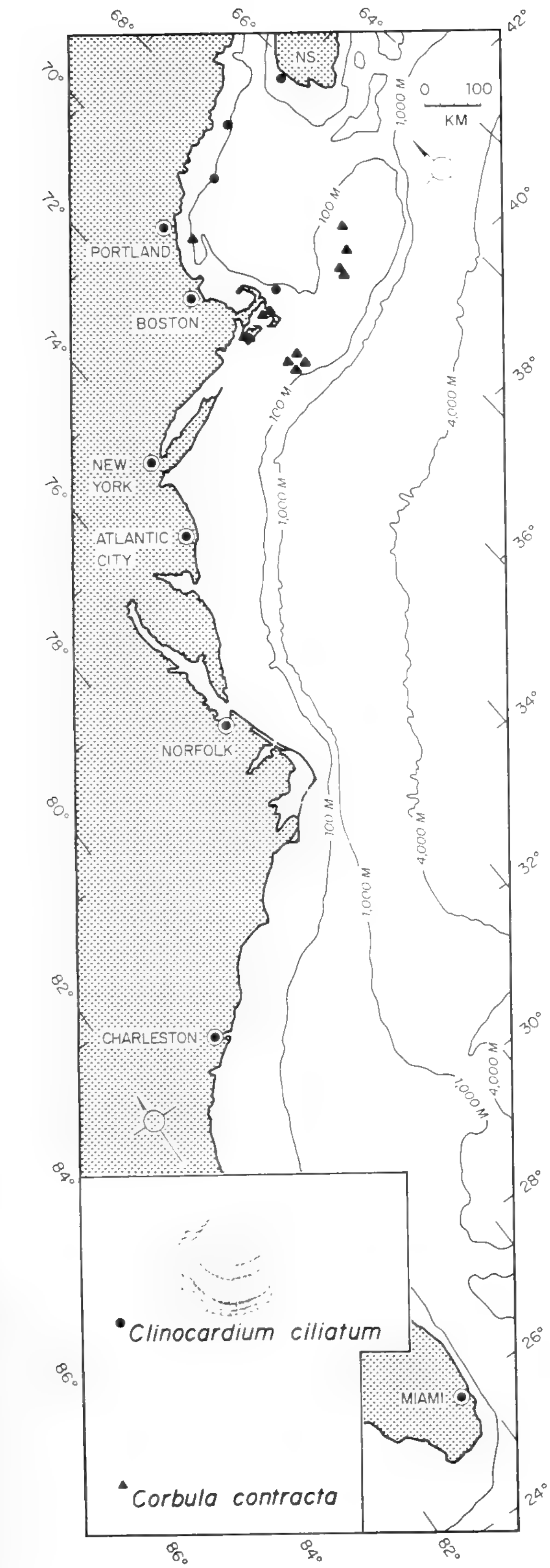

Figure 27.—Geographic distribution of *Clinocardium ciliatum* and *Corbula contracta*.

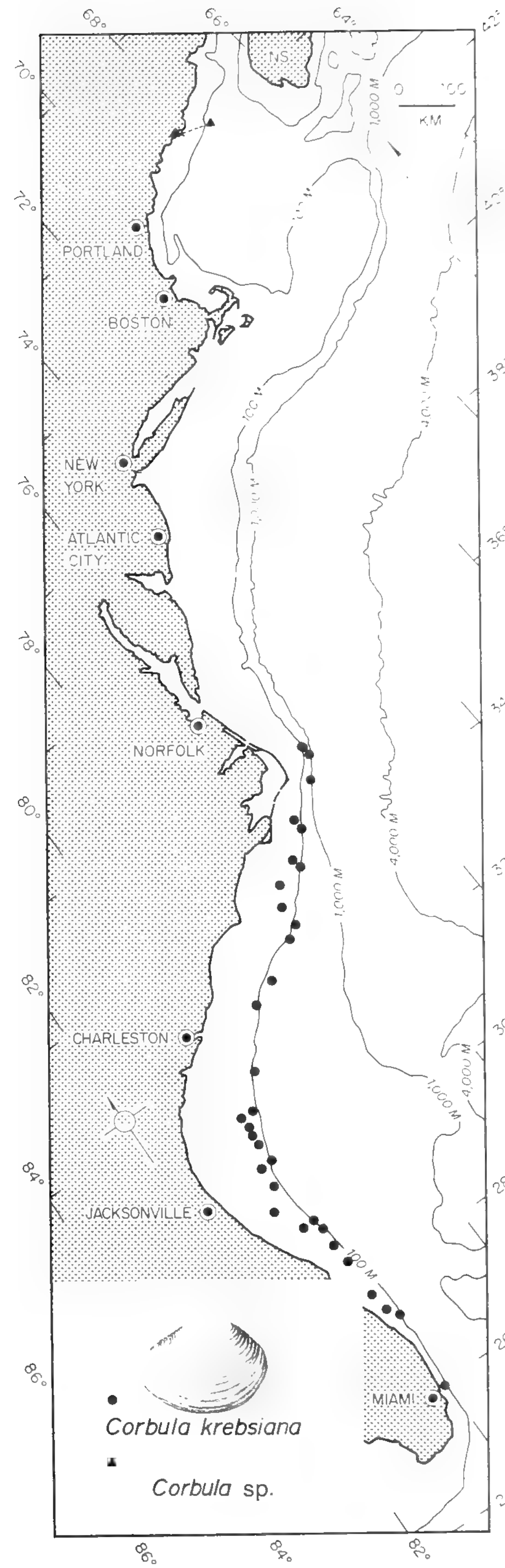

Figure 28.—Geographic distribution of *Corbula krebsiana* and *Corbula* sp.

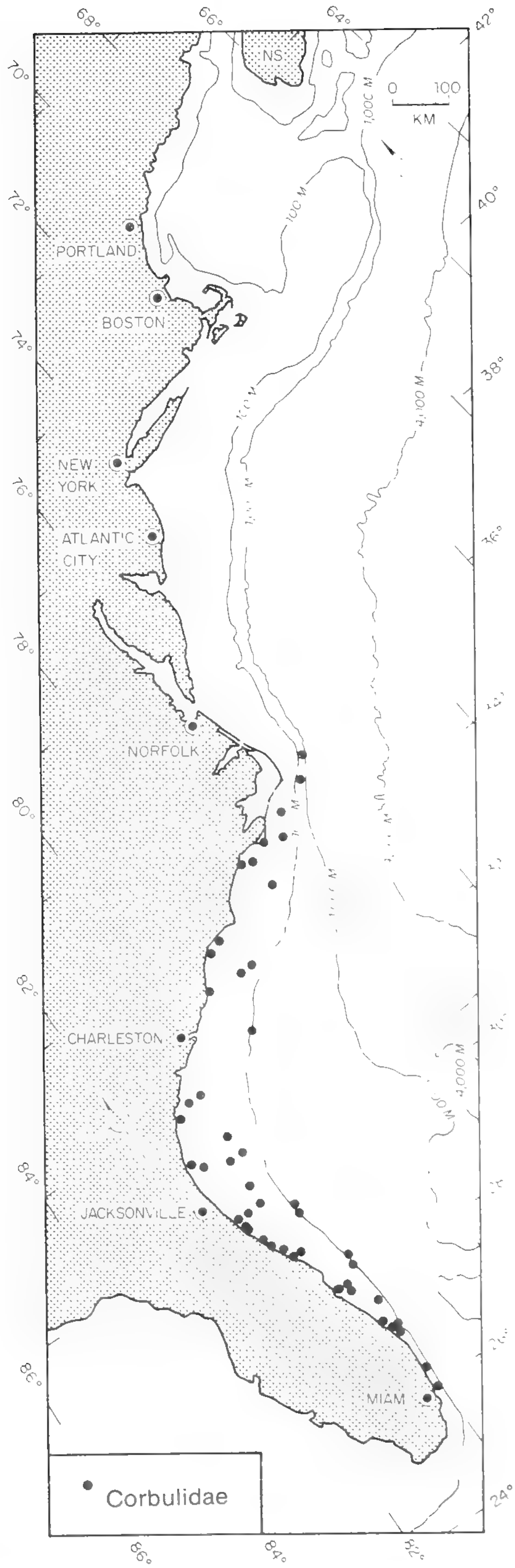

Figure 29.—Geographic distribution of Corbulidae.

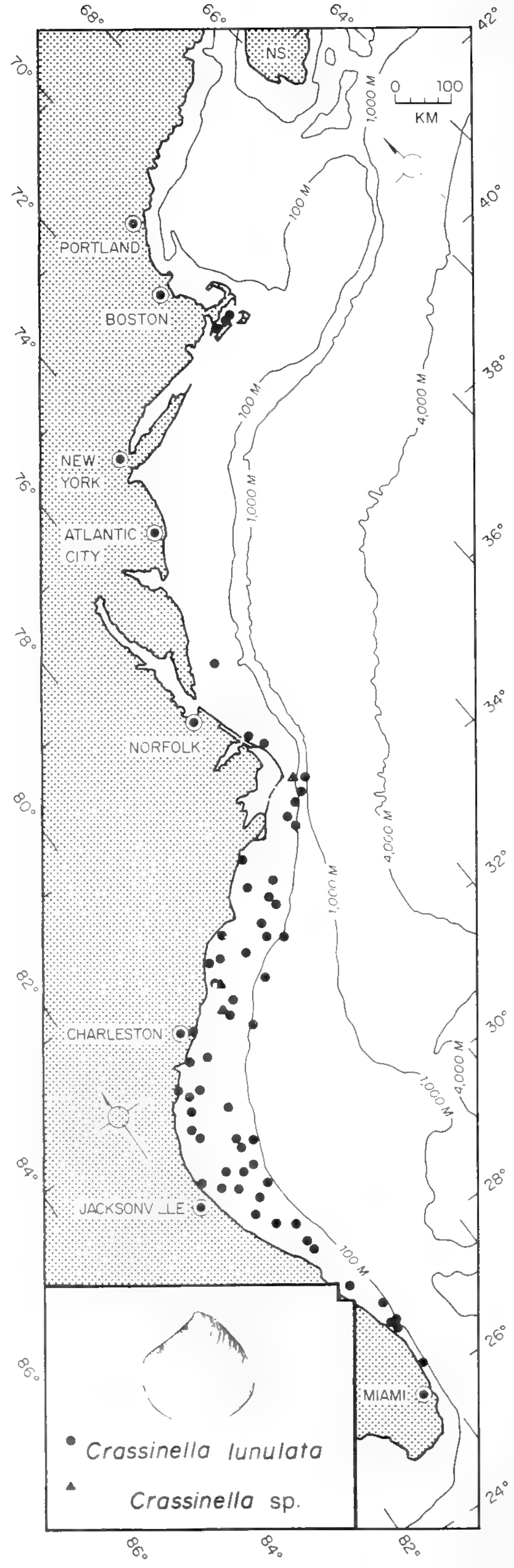

Figure 30.—Geographic distribution of *Crassinella lunlata* and *Crassinella* sp.

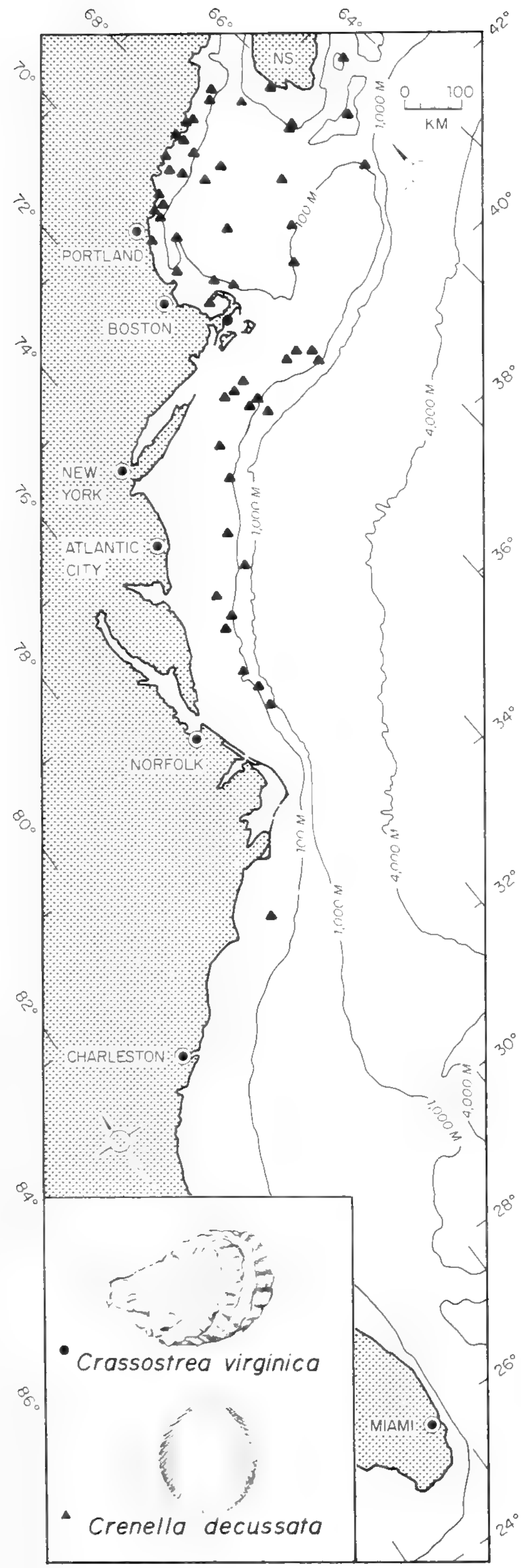

Figure 31.—Geographic distribution of *Crassostrea virginica* and *Crenella decussata*.

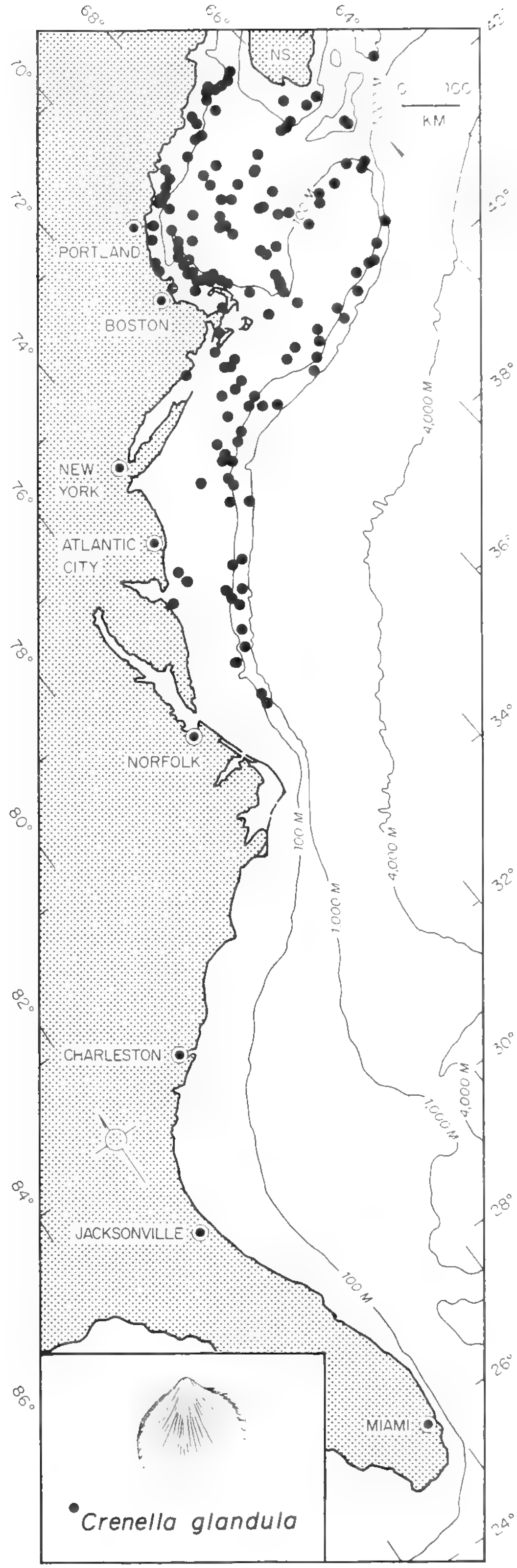

Figure 32.—Geographic distribution of *Crenella glandula*.

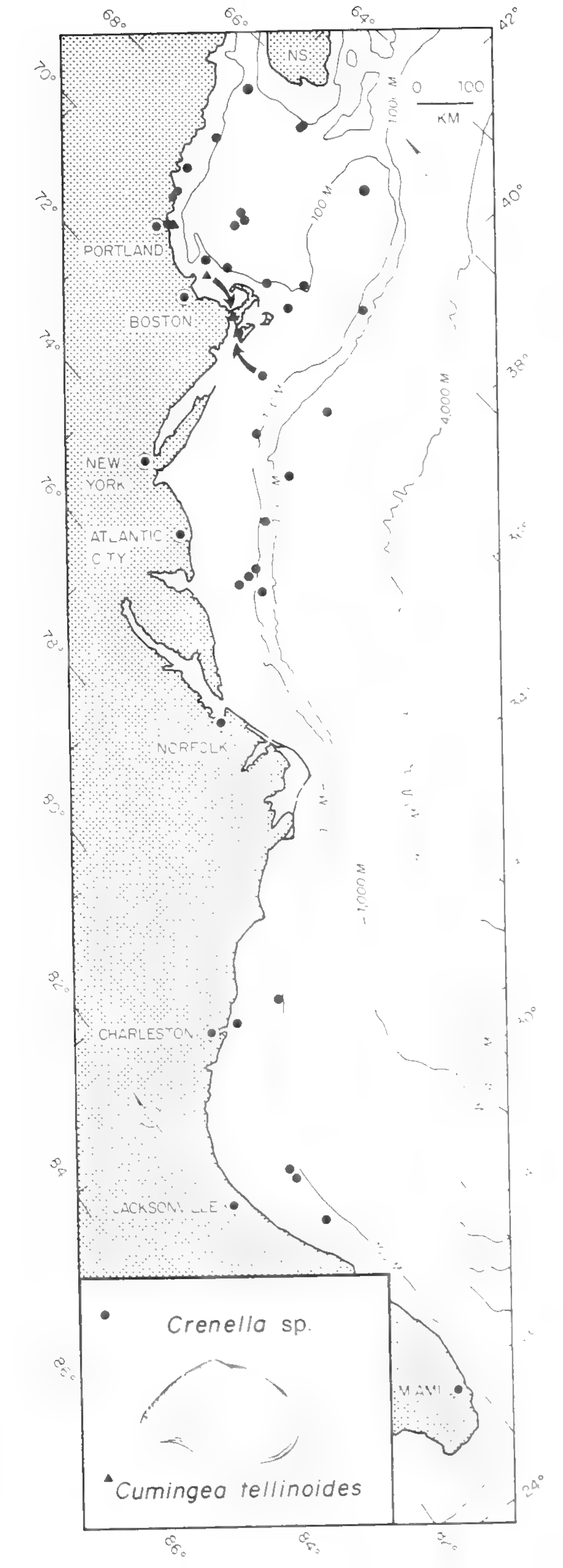

Figure 33.—Geographic distribution of *Crenella* sp. and *Cumingea tellinoides*.

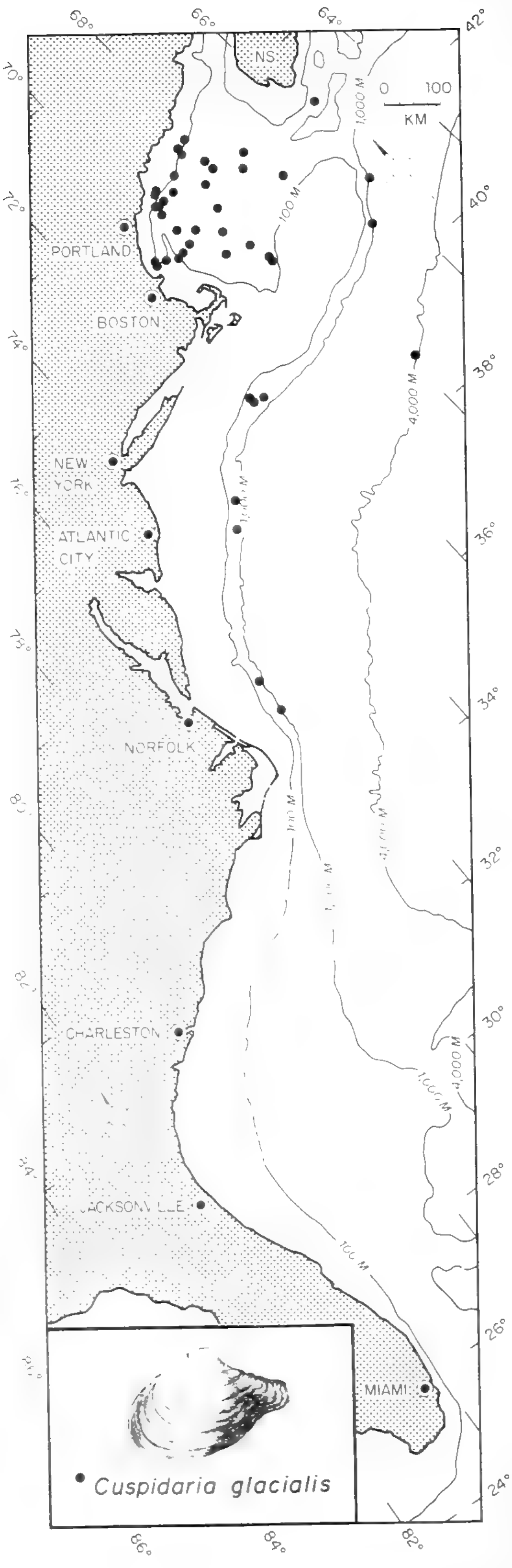

Figure 34.—Geographic distribution of *Cuspidaria glacialis*.

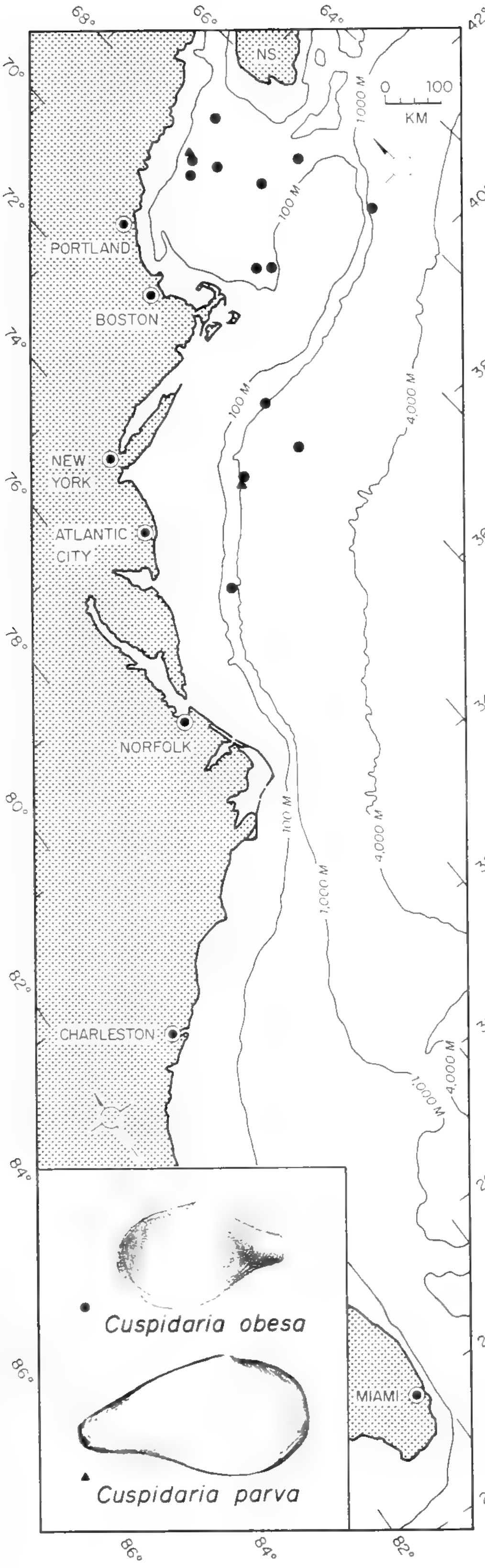

Figure 35.—Geographic distribution of *Cuspidaria obesa* and *Cuspidaria parva*.

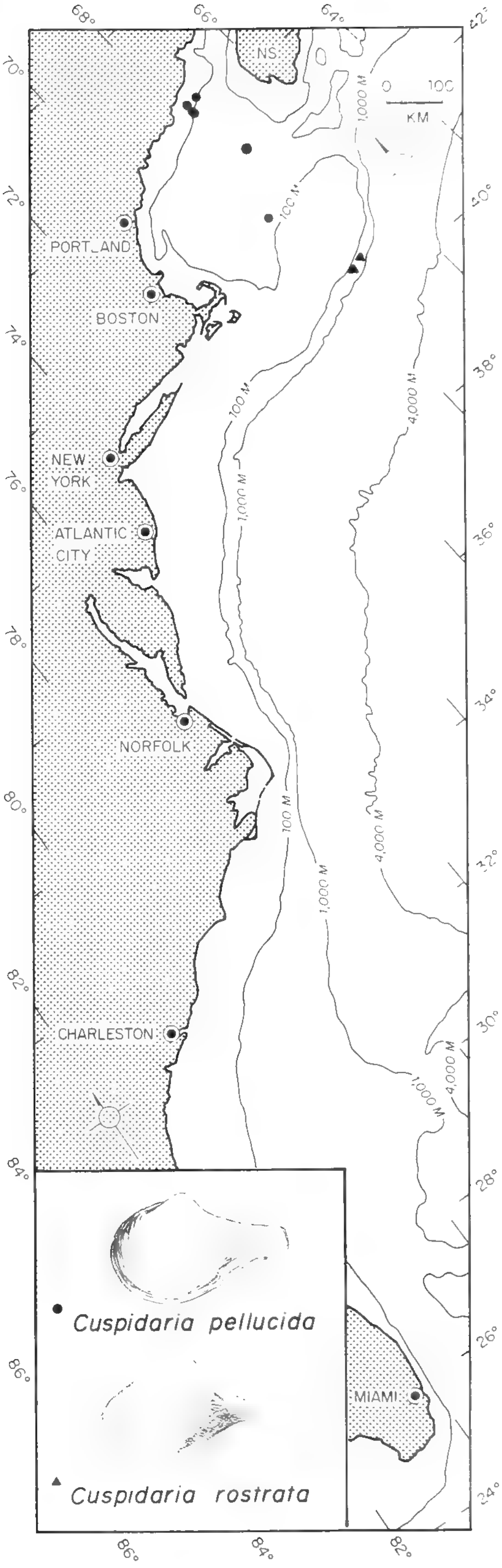

Figure 36.—Geographic distribution of *Cuspidaria pellucida* and *Cuspidaria rostrata*.

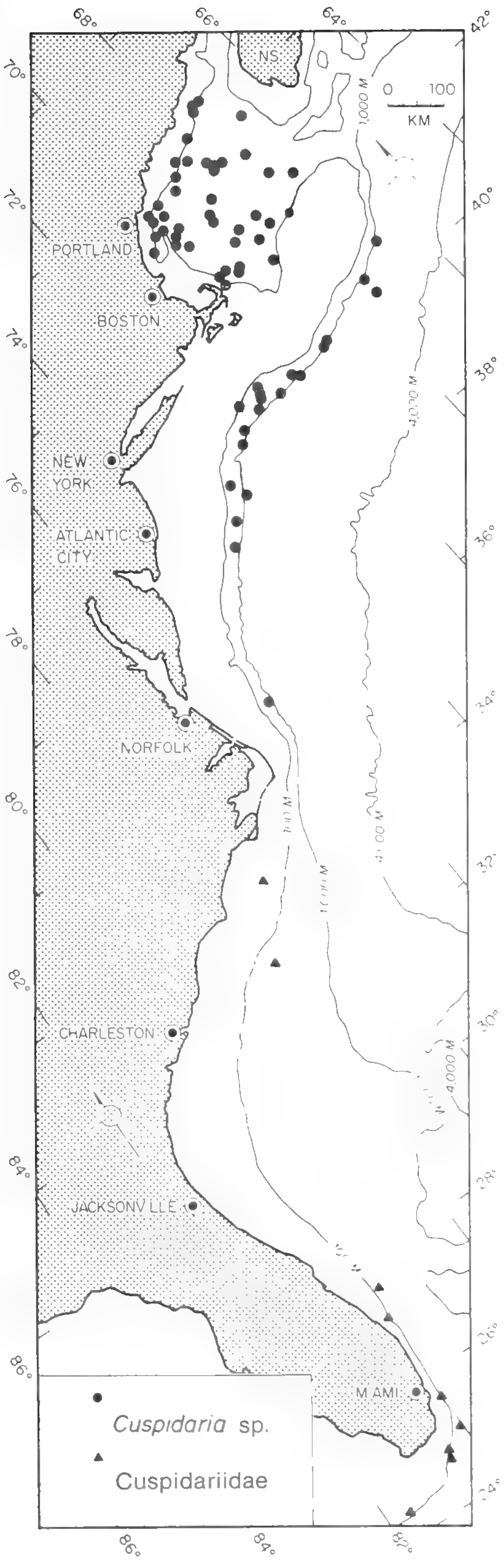

Figure 37.—Geographic distribution of *Cuspidaria* sp. and Cuspidariidae.

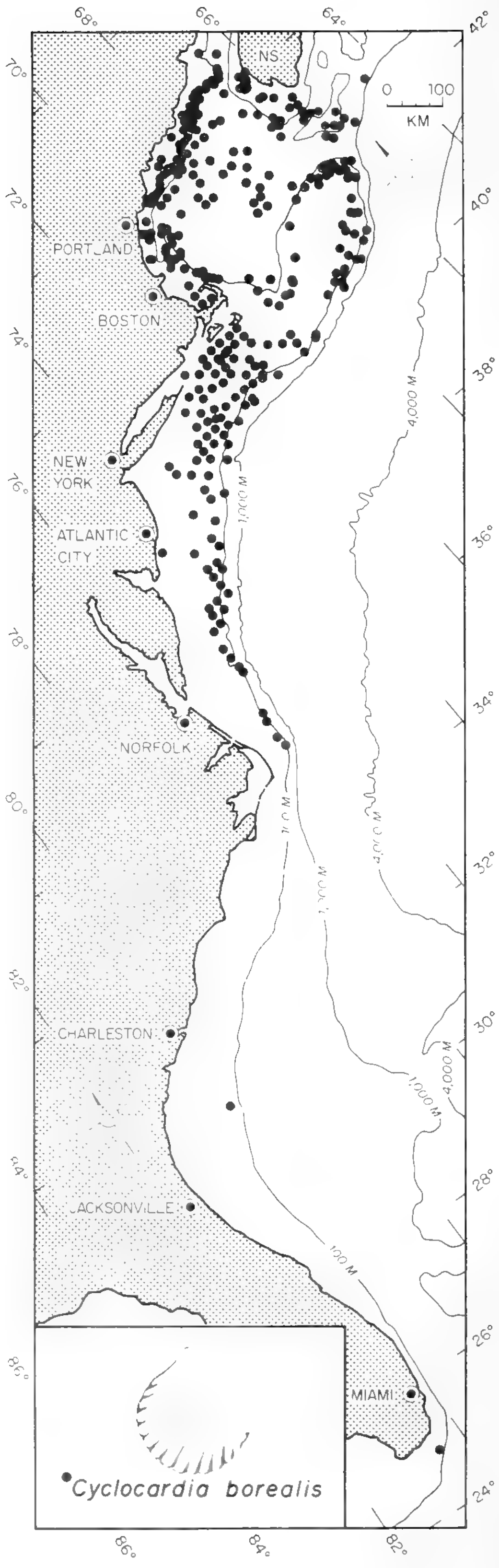

Figure 38.—Geographic distribution of *Cyclocardia borealis*.

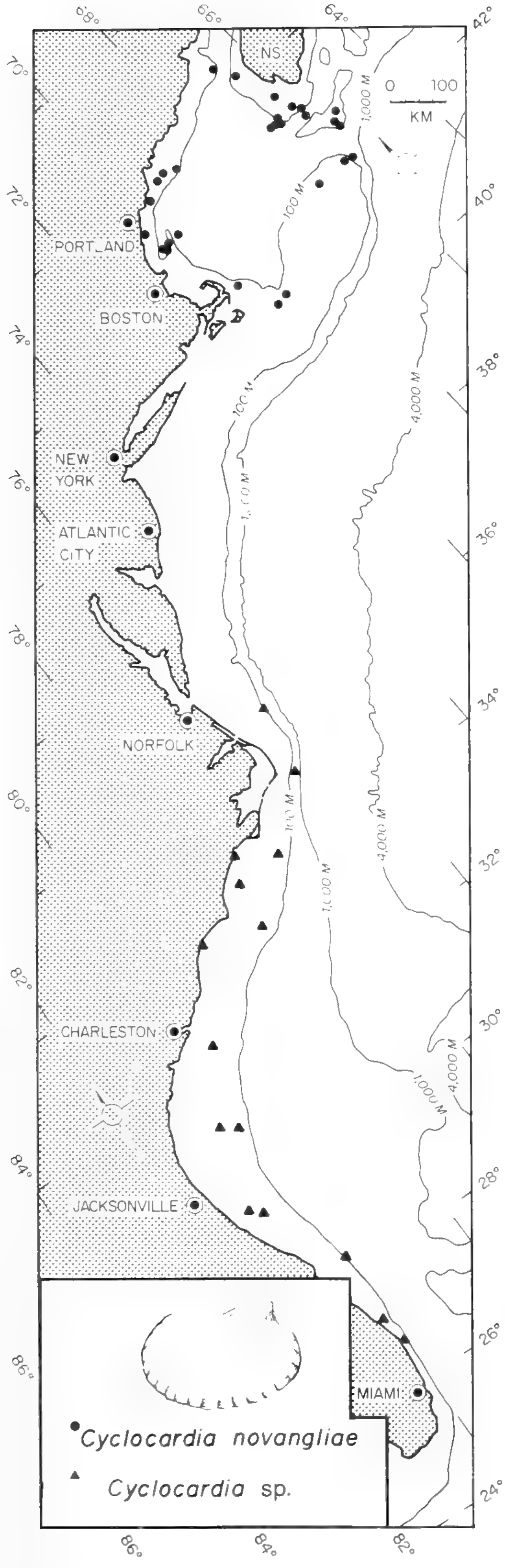

Figure 39.—Geographic distribution of *Cyclocardia novangliae* and *Cyclocardia* sp.

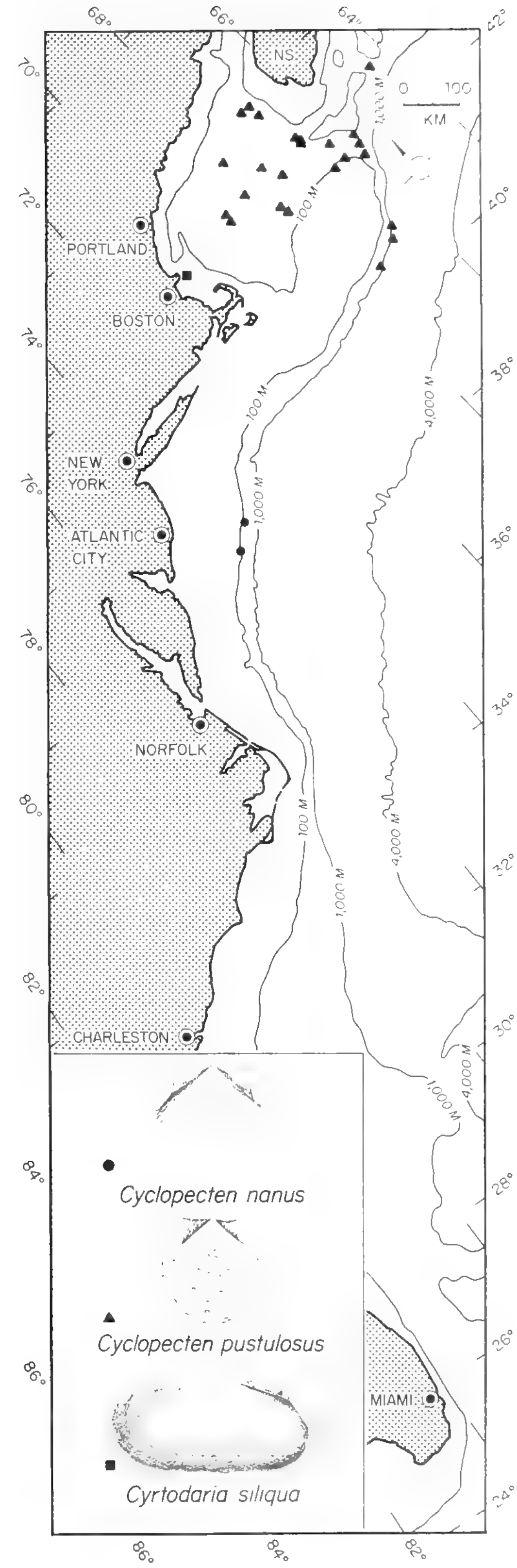

Figure 40.—Geographic distribution of *Cyclopecten nanus*, *Cyclopecten pustulosus*, and *Cyrtodaria siliqua*.

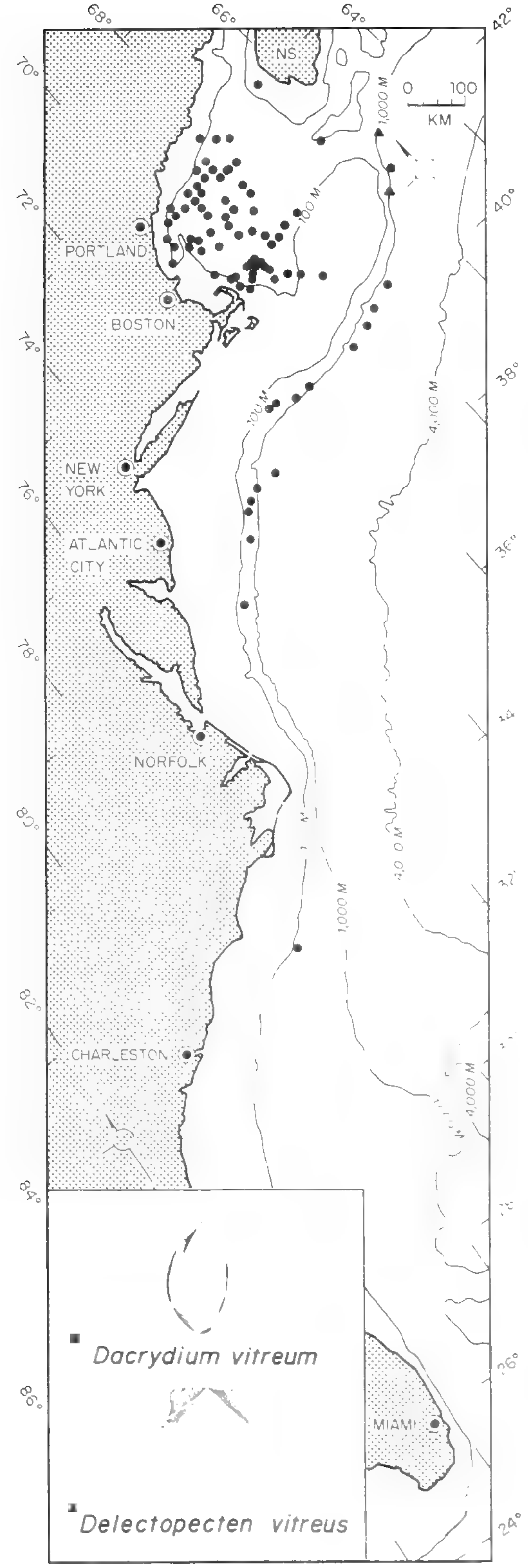

Figure 41.—Geographic distribution of *Dacrydium vitreum* and *Delectopecten vitreus*.

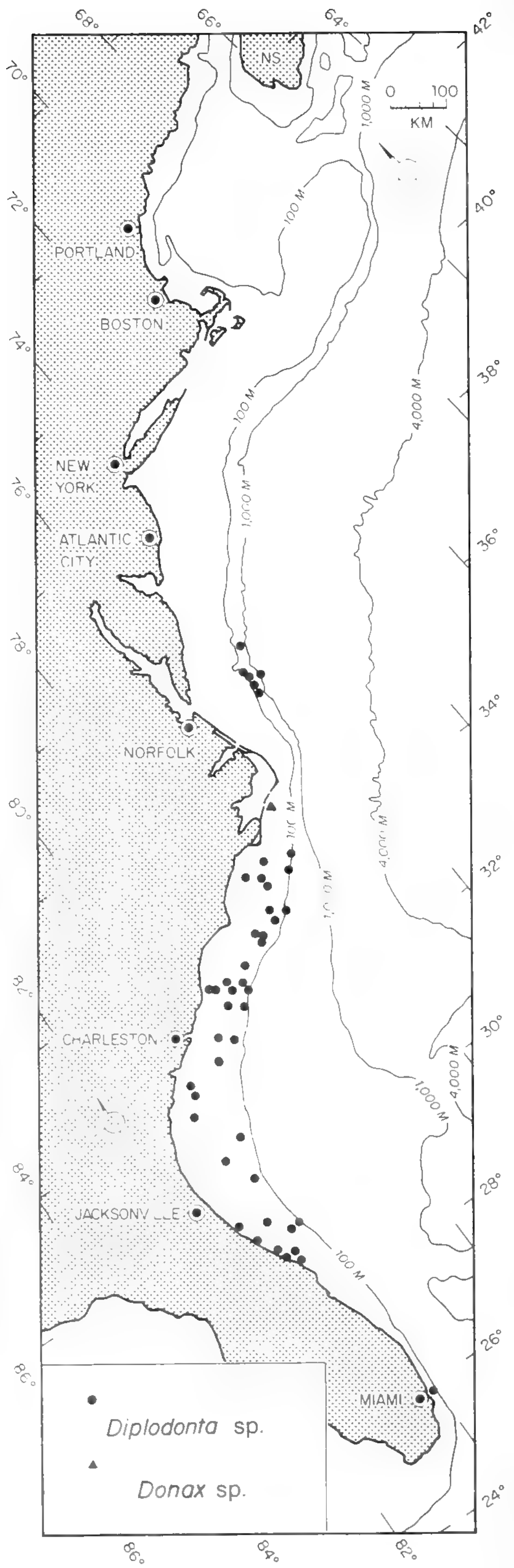

Figure 42.—Geographic distribution of *Diplodonta* sp. and *Donax* sp

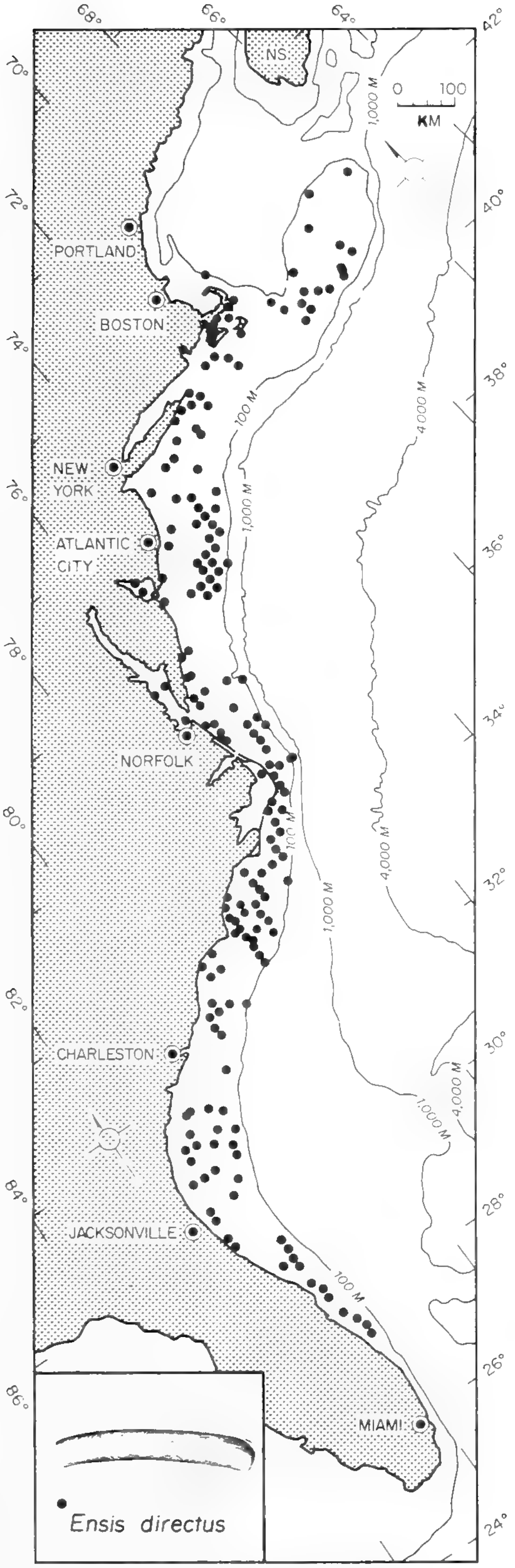

Figure 43.—Geographic distribution of *Ensis directus*.

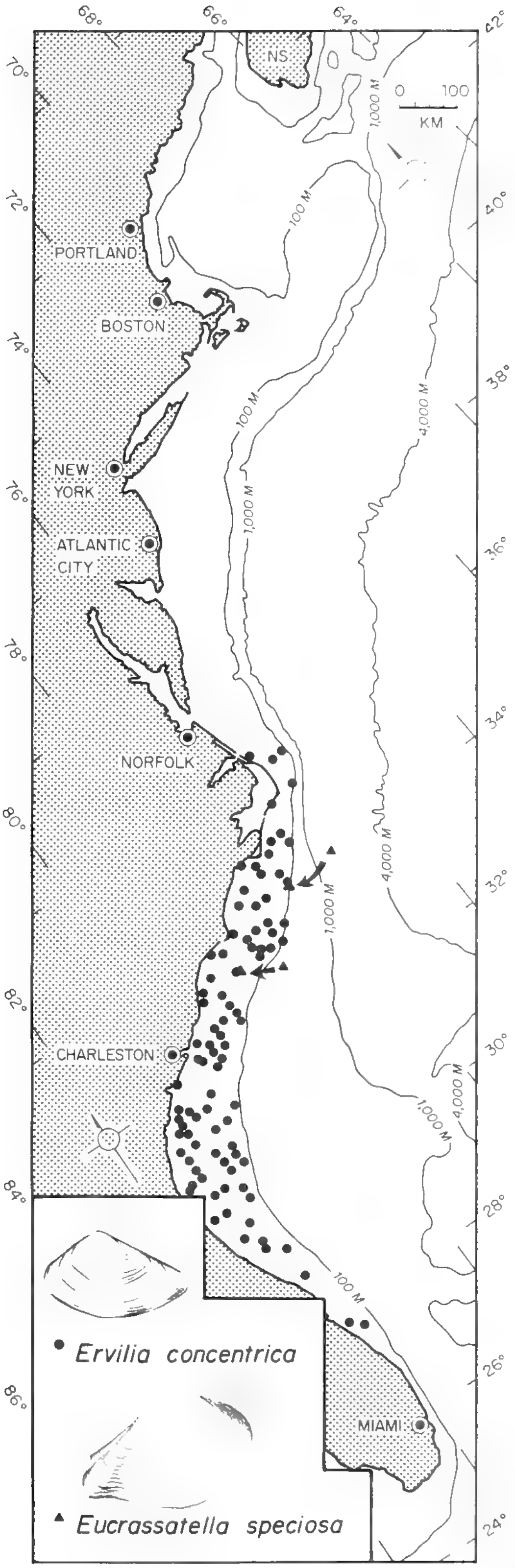

Figure 44.—Geographic distribution of *Ervilia concentrica* and *Eucrassatella speciosa*.

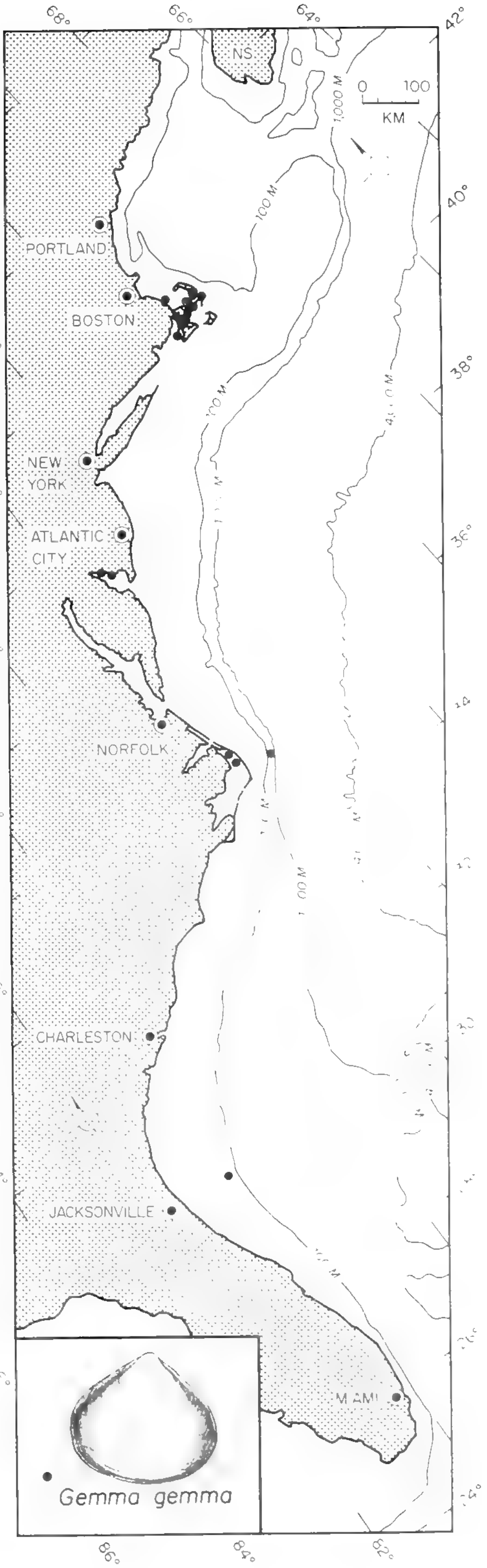

Figure 45.—Geographic distribution of *Gemma gemma*.

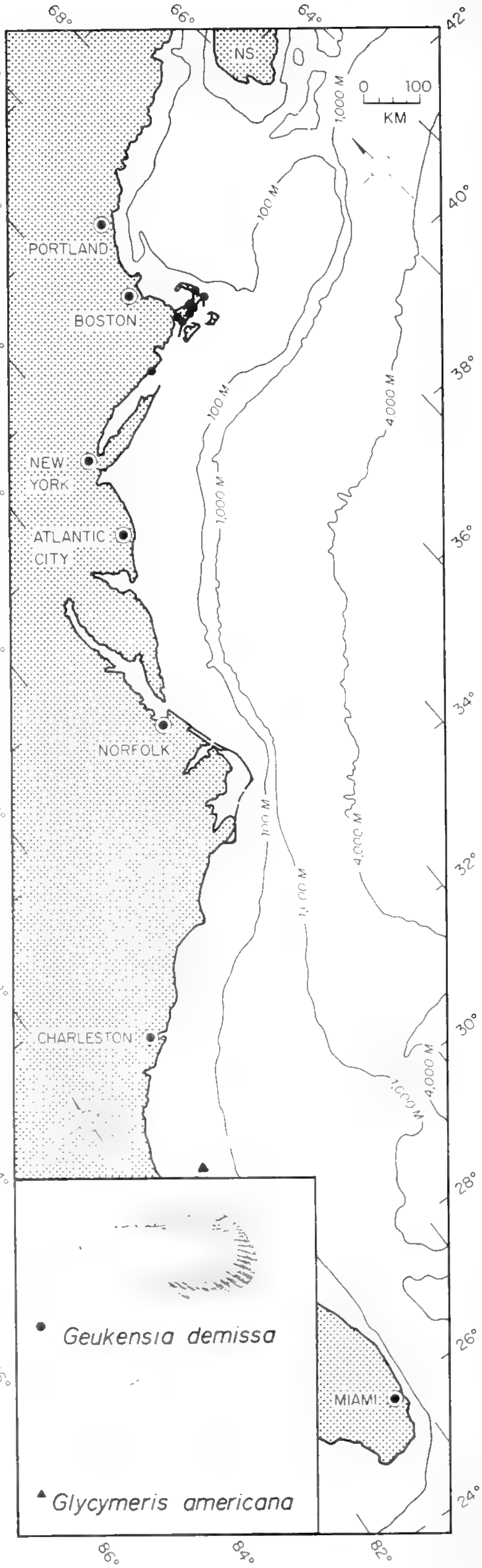

Figure 46.—Geographic distribution of *Geukensia demissa* and *Glycymeris americana*.

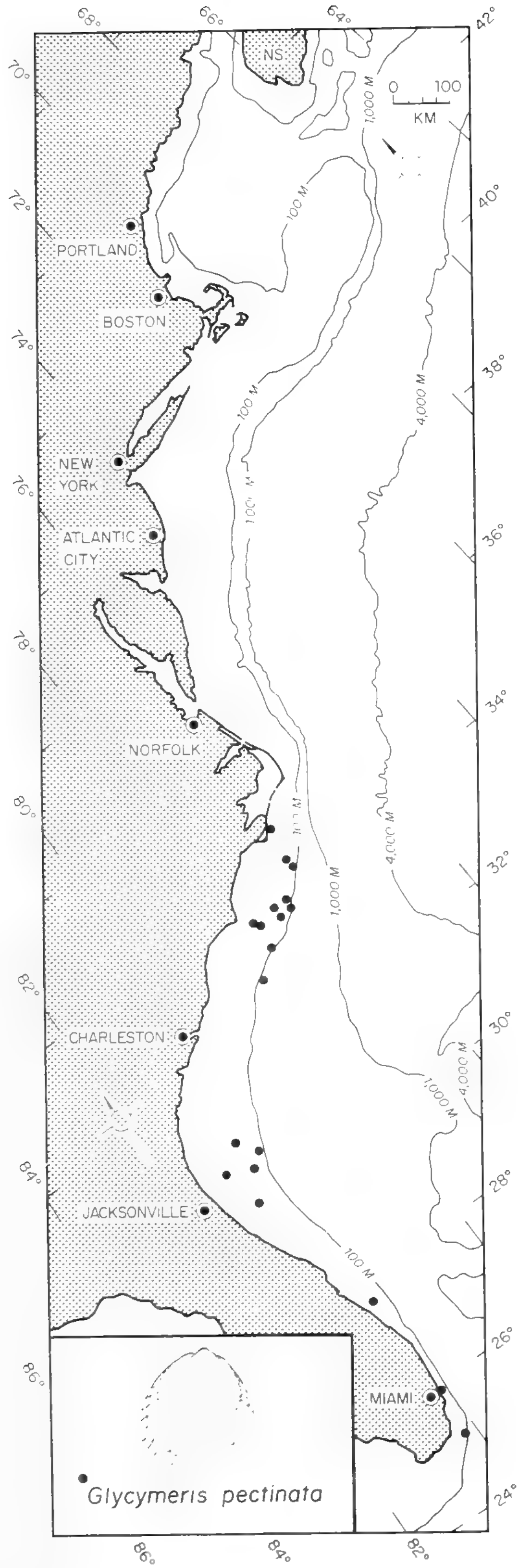

Figure 47.—Geographic distribution of *Glycymeris pectinata*.

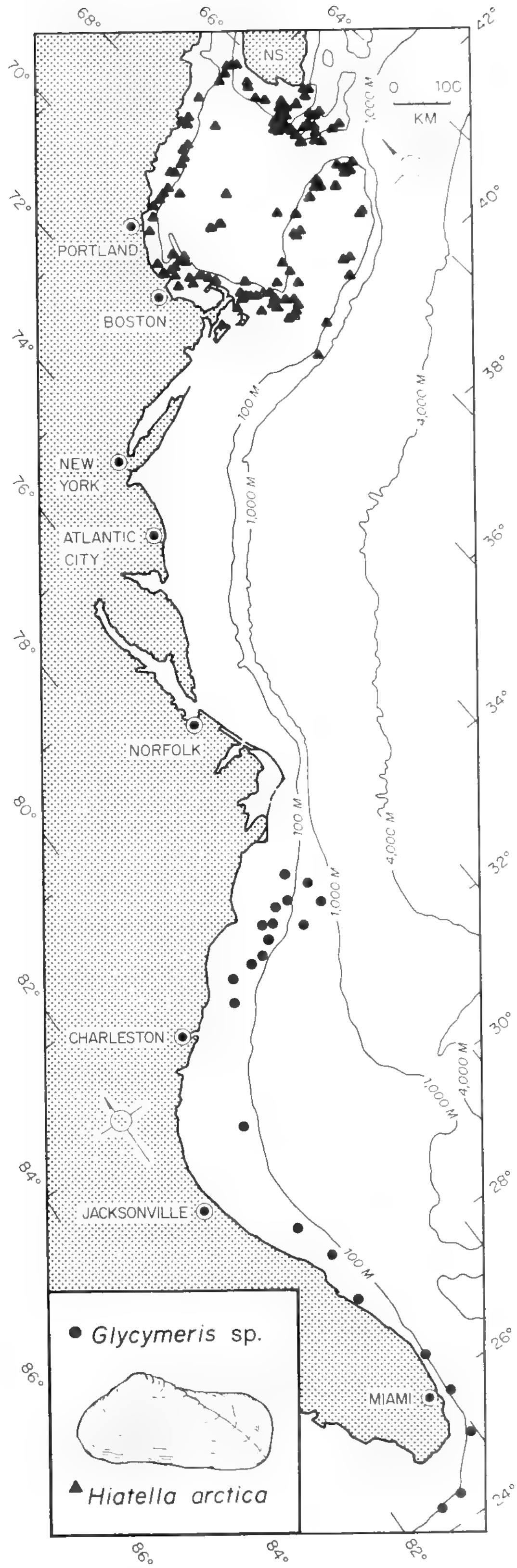

Figure 48.—Geographic distribution of *Glycymeris* sp. and *Hiatella arctica*.

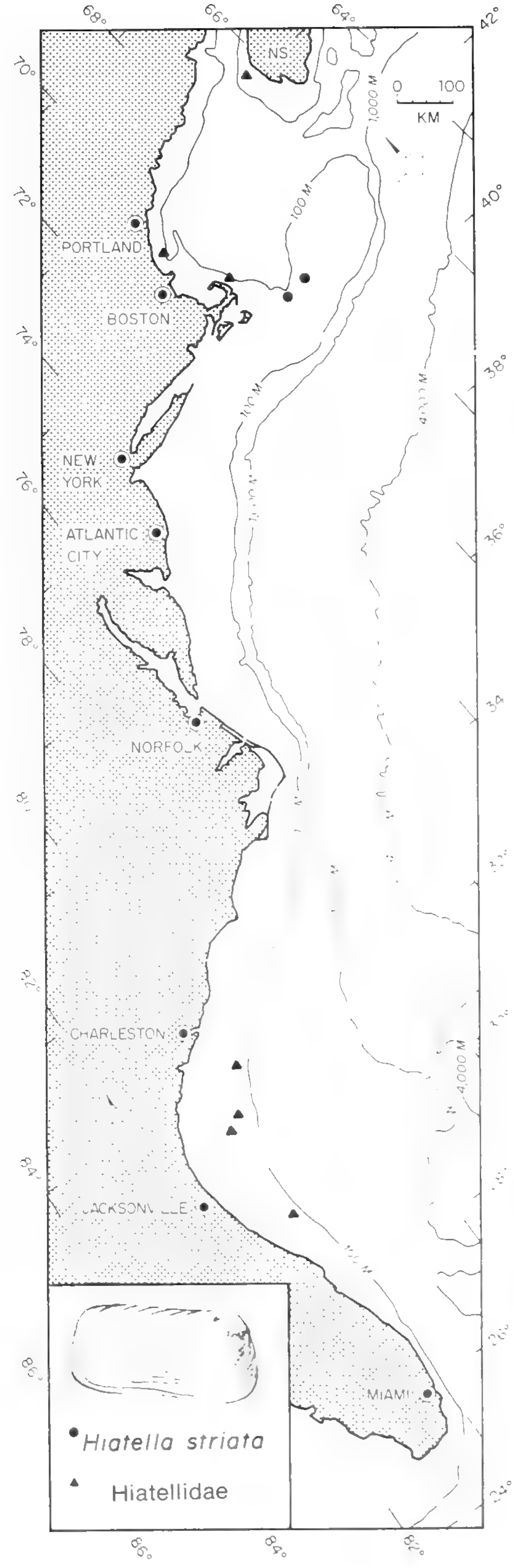

Figure 49.—Geographic distribution of *Hiatella striata* and Hiatellidae.

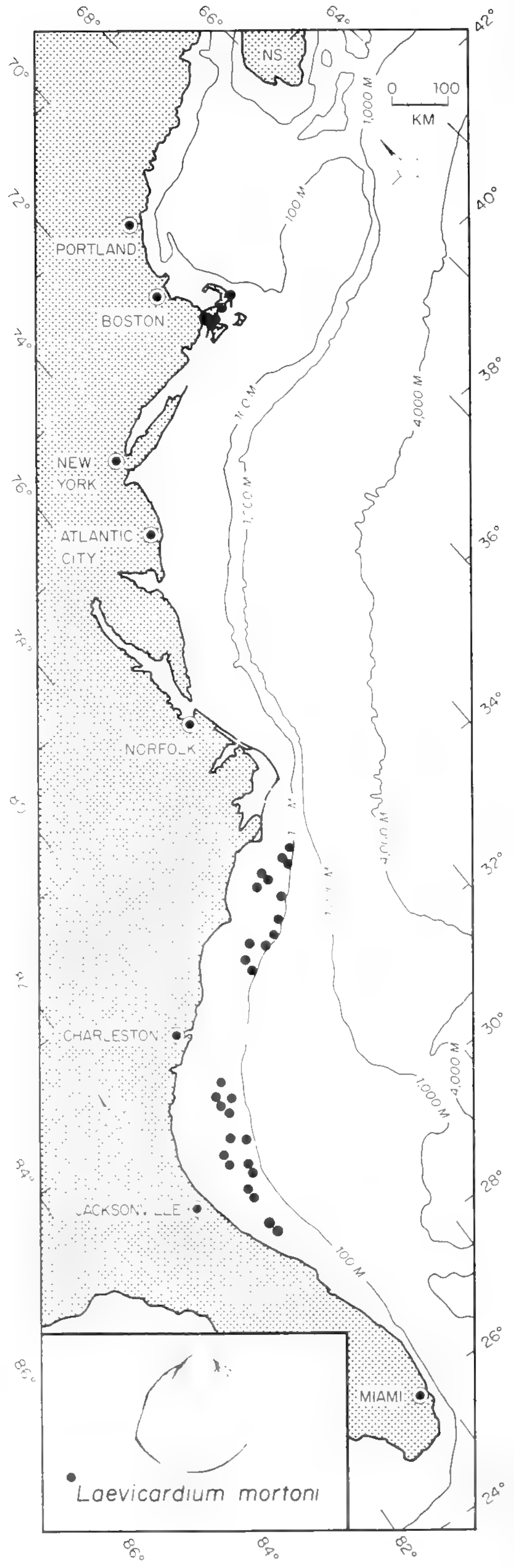

Figure 50.—Geographic distribution of *Laevicardium mortoni*.

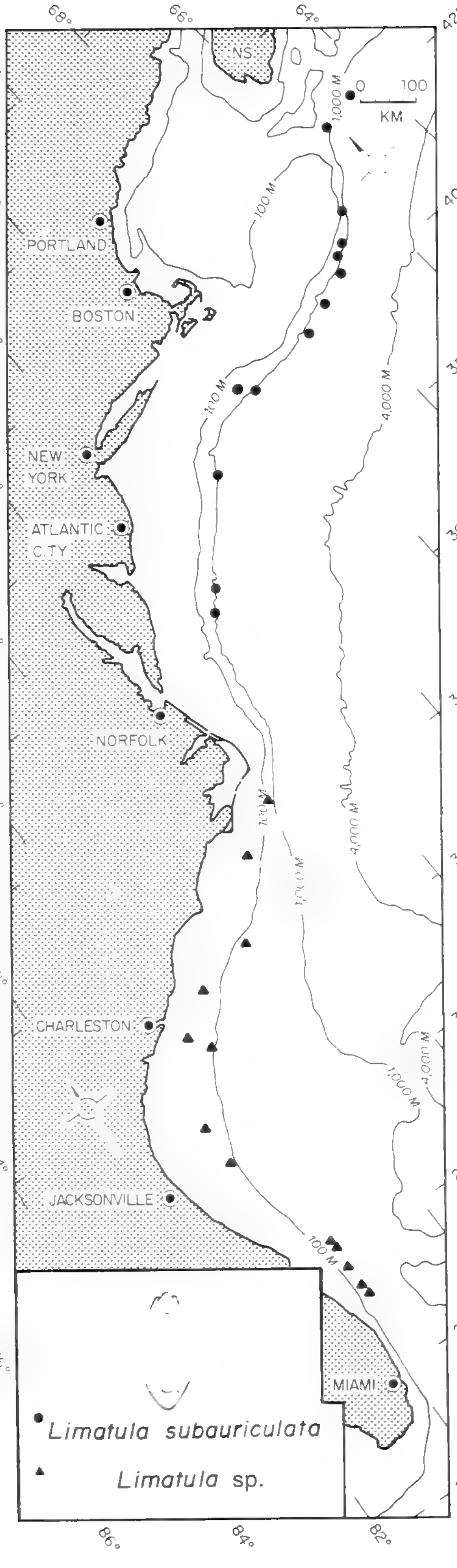

Figure 51.—Geographic distribution of *Limatula subauriculata* and *Limatula* sp.

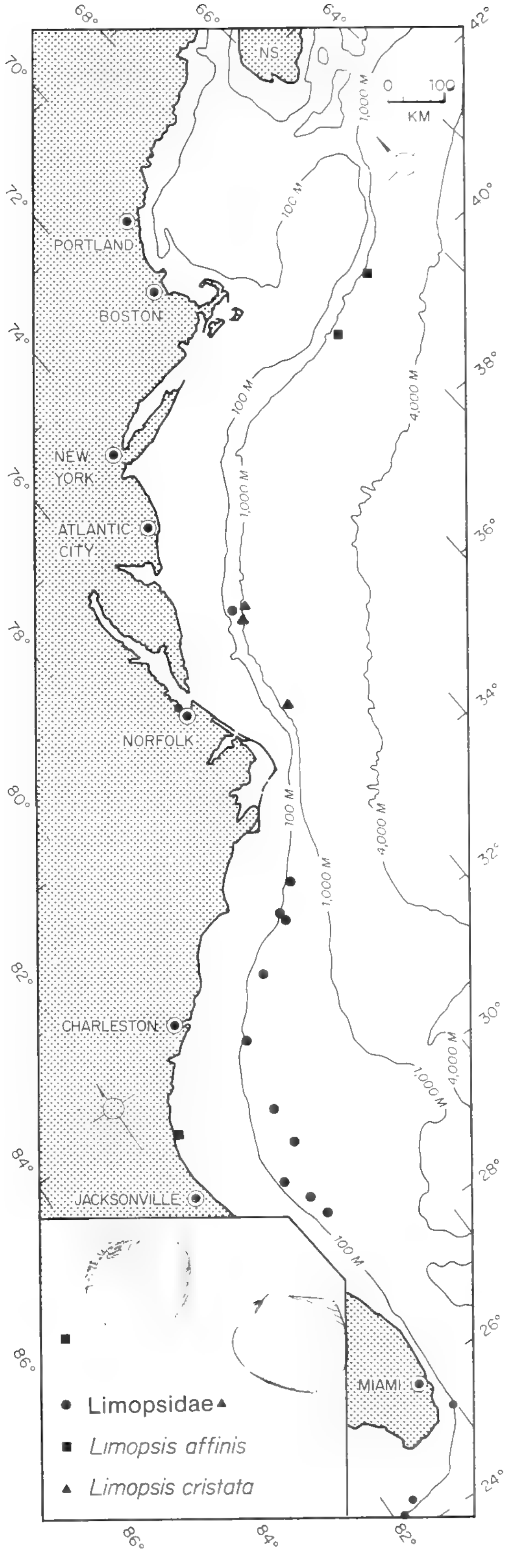

Figure 52.—Geographic distribution of Limopsidae, *Limopsis affinis*, and *Limopsis cristata*.

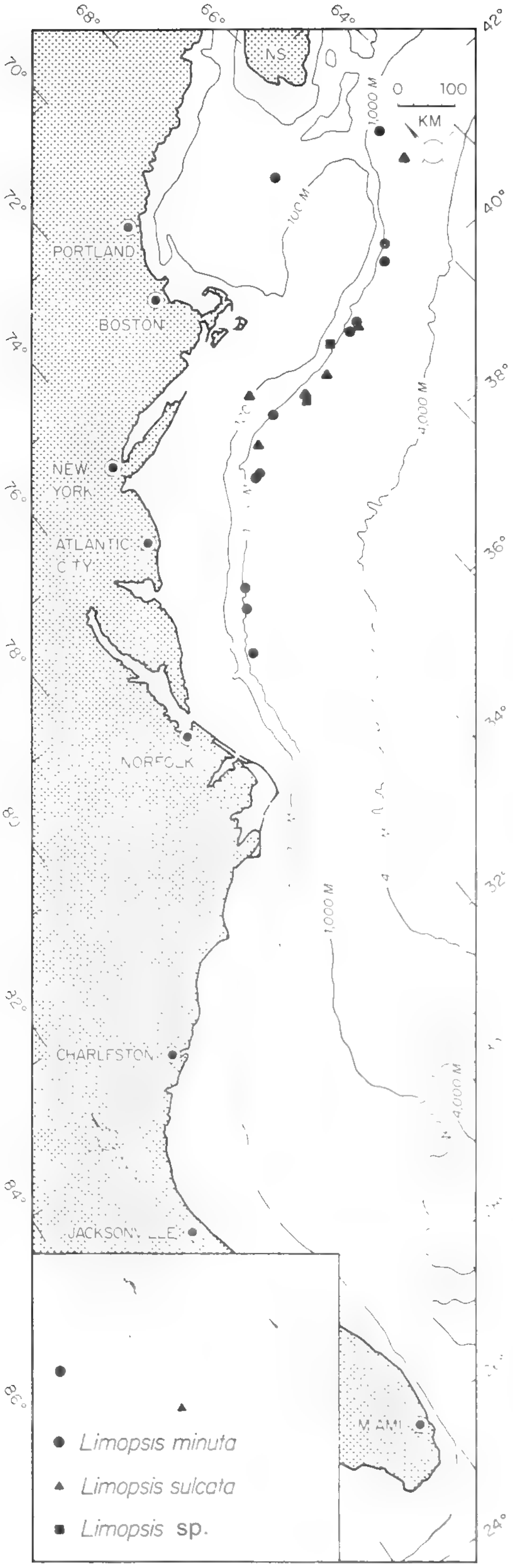

Figure 53.—Geographic distribution of *Limopsis minuta*, *Limopsis sulcata*, and *Limopsis* sp.

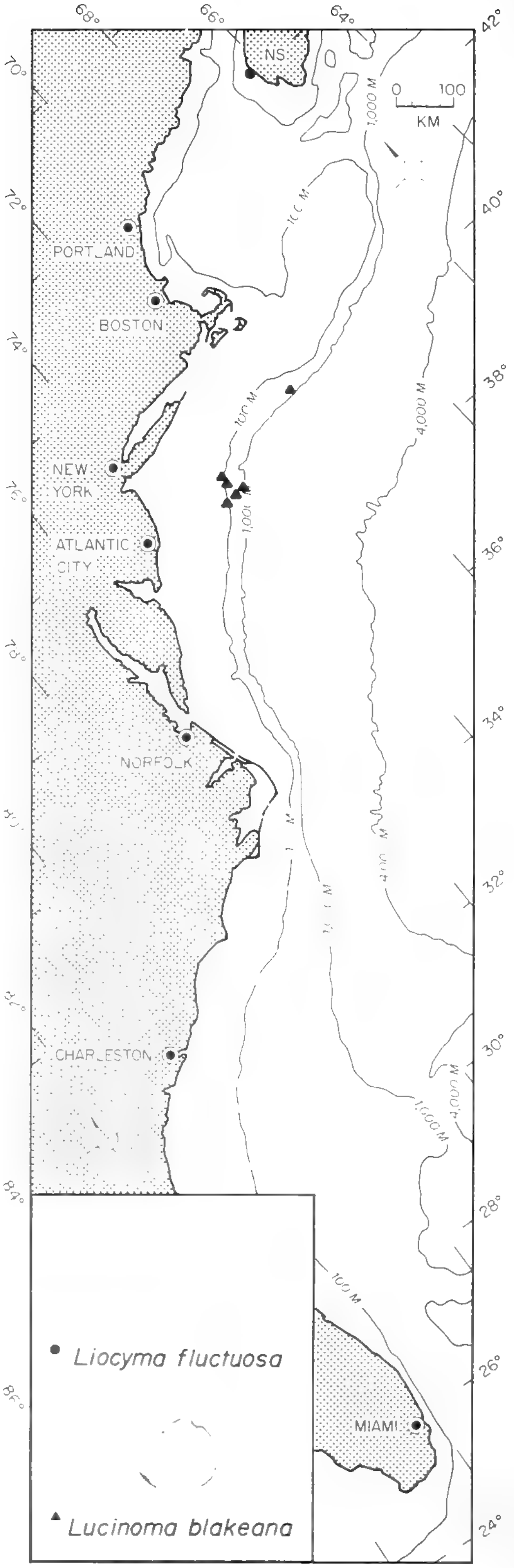

Figure 54.—Geographic distribution of *Liocyma fluctuosa* and *Lucinoma blakeana*.

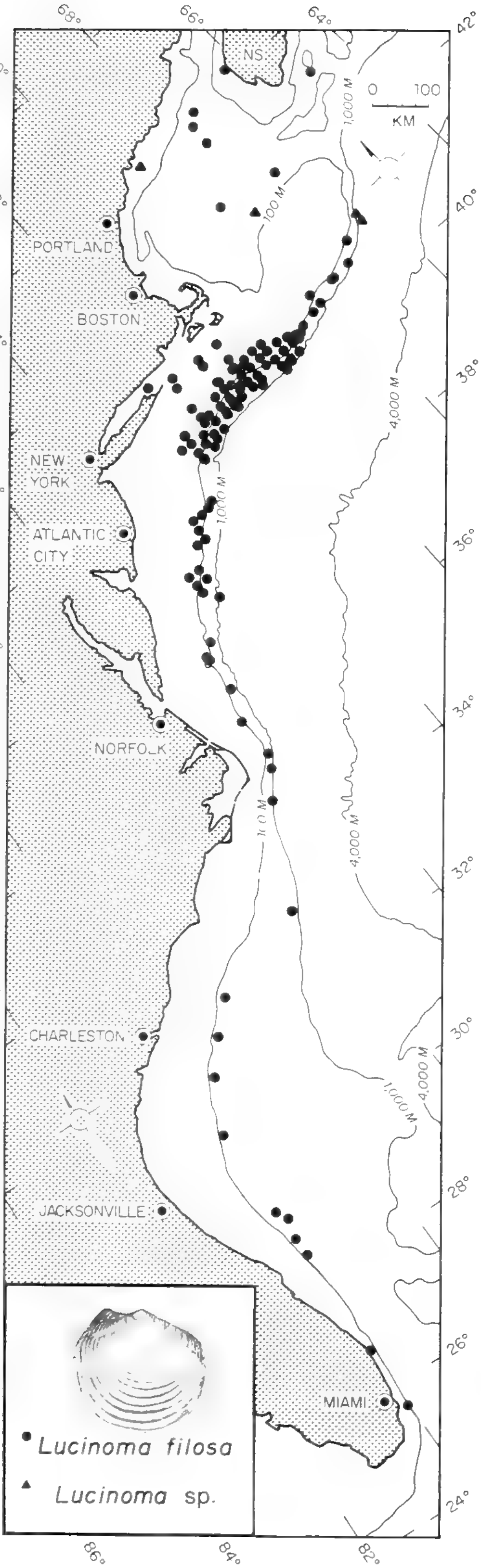

Figure 55.—Geographic distribution of *Lucinoma filosa* and *Lucinoma* sp.

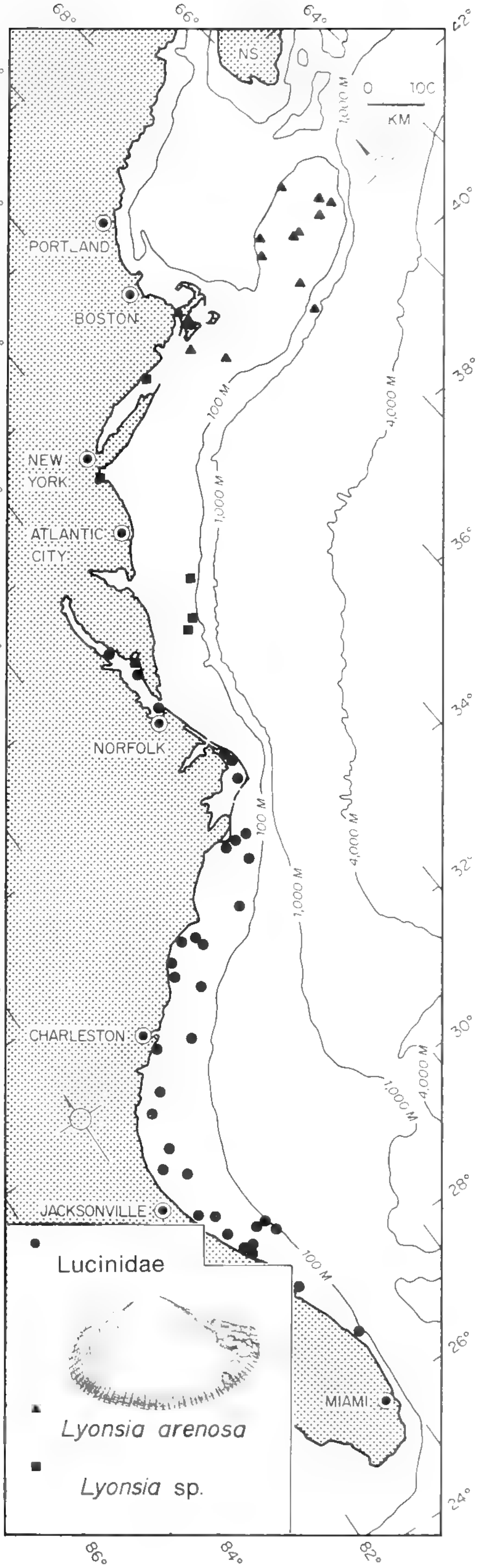

Figure 56.—Geographic distribution of Lucinidae, *Lyonsia arenosa*, and *Lyonsia* sp.

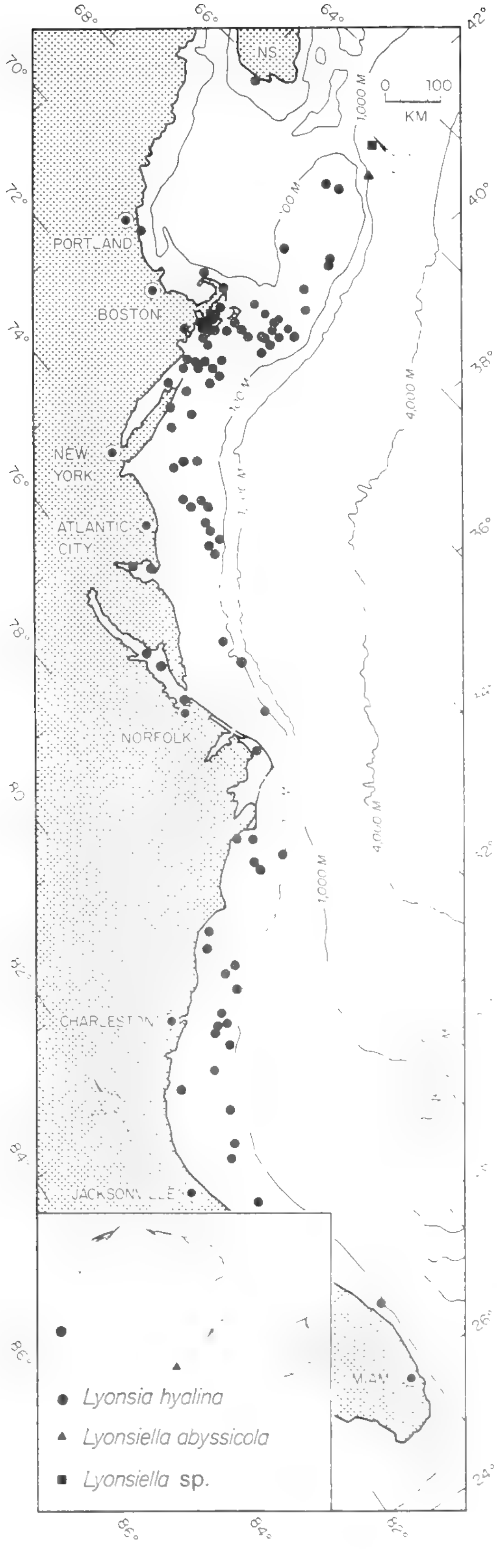

Figure 57.—Geographic distribution of *Lyonsia hyalina*, *Lyonsiella abyssicola*, and *Lyonsiella* sp.

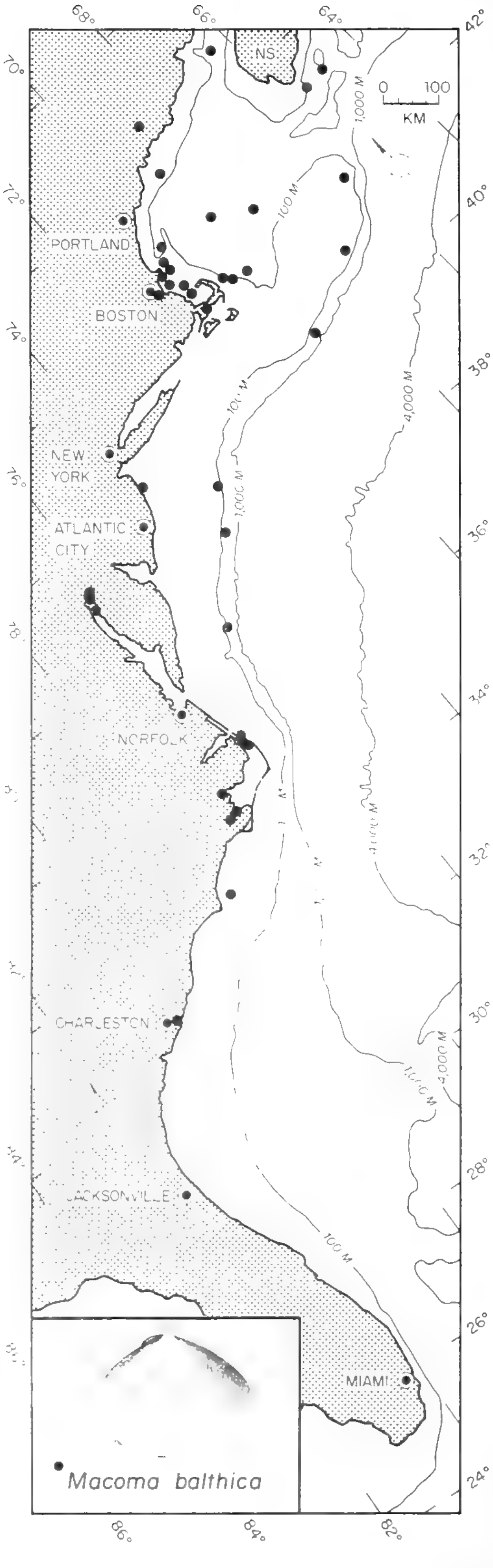

Figure 58.—Geographic distribution of *Macoma balthica*.

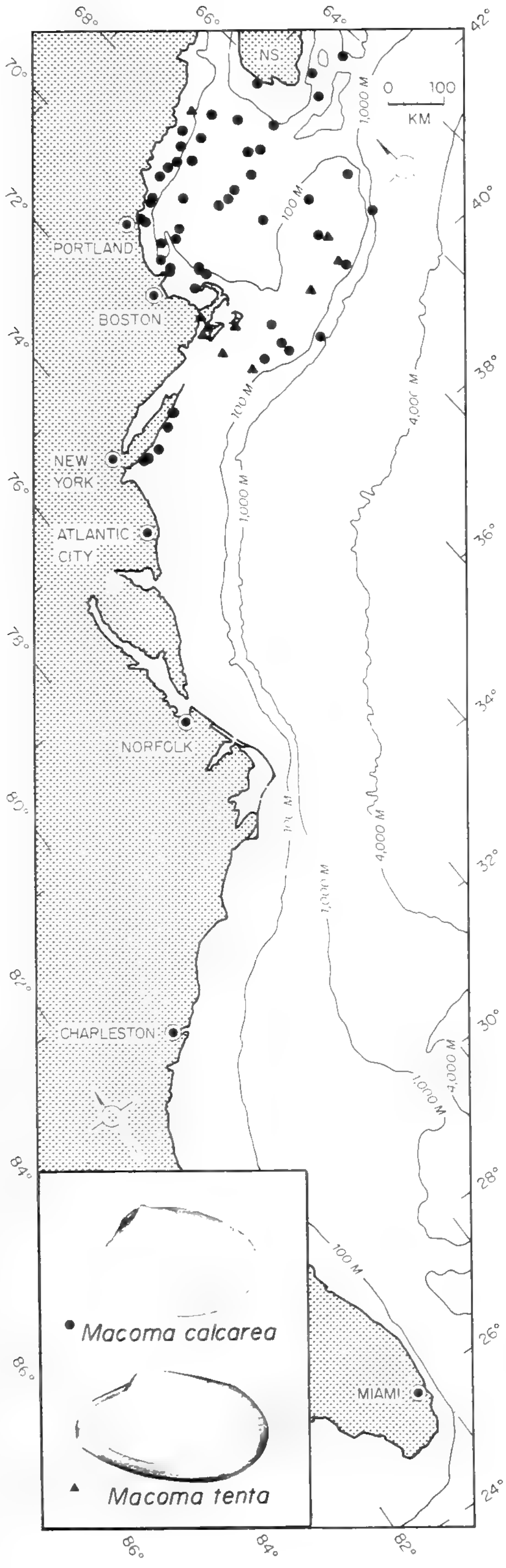

Figure 59.—Geographic distribution of *Macoma calcarea* and *Macoma tenta*.

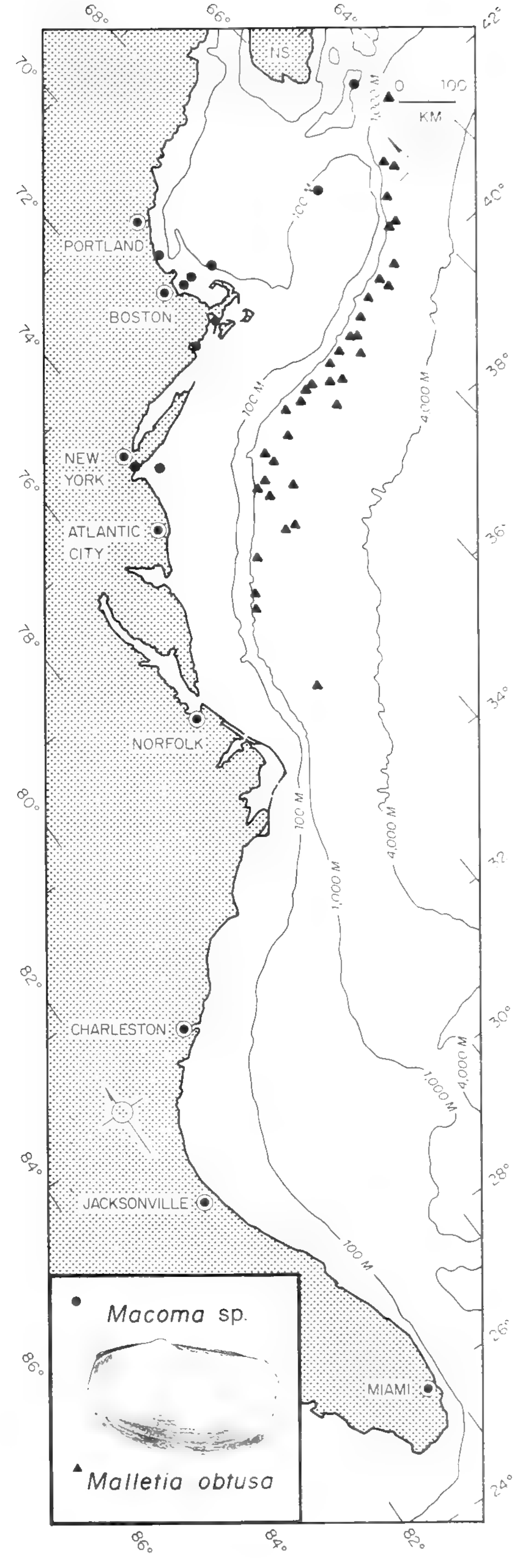

Figure 60.—Geographic distribution of *Macoma* sp. and *Malletia obtusa*.

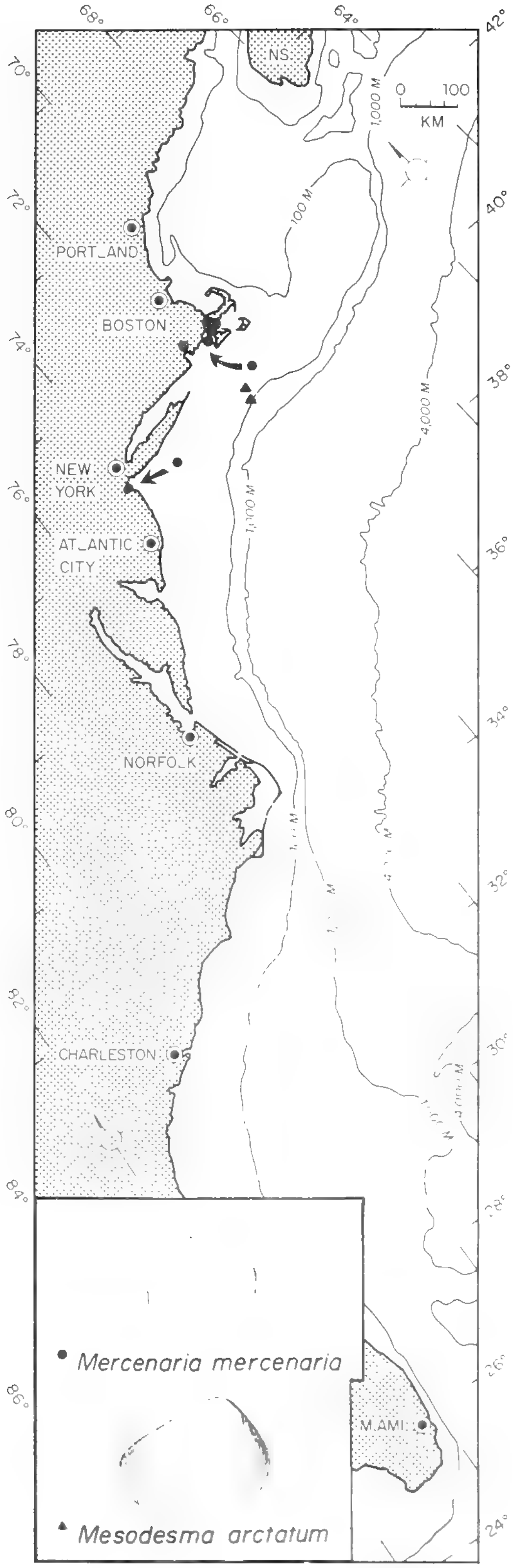

Figure 61.—Geographic distribution of *Mercenaria mercenaria* and *Mesodesma arctatum*.

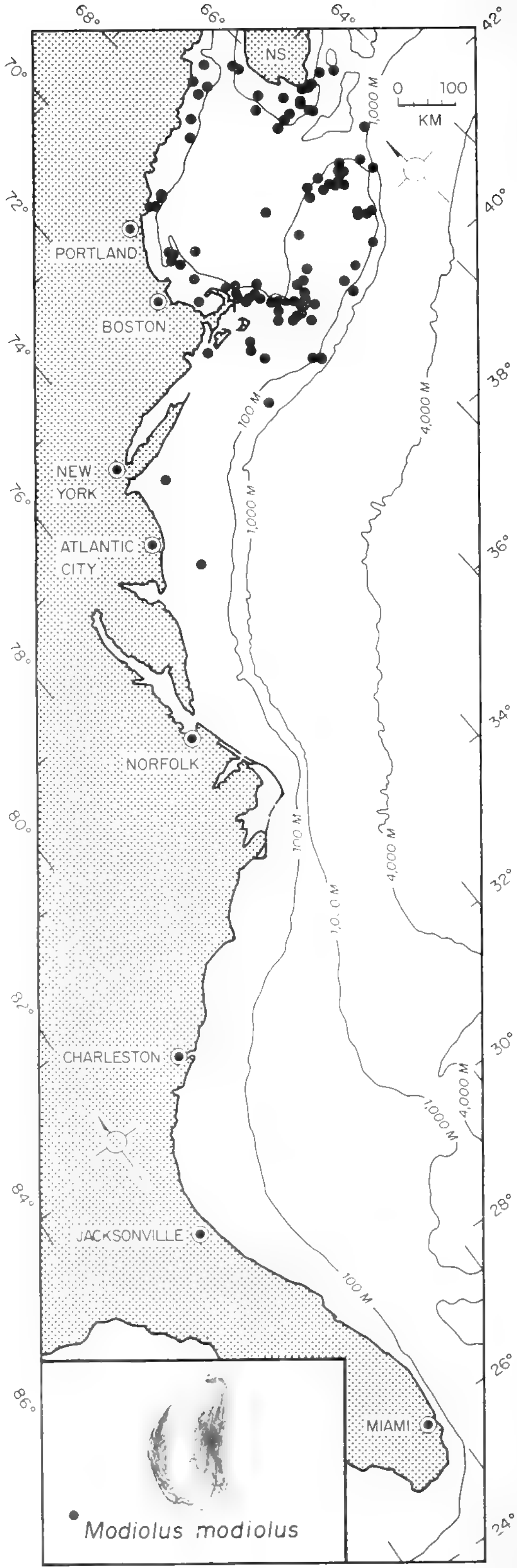

Figure 62.—Geographic distribution of *Modiolus modiolus*.

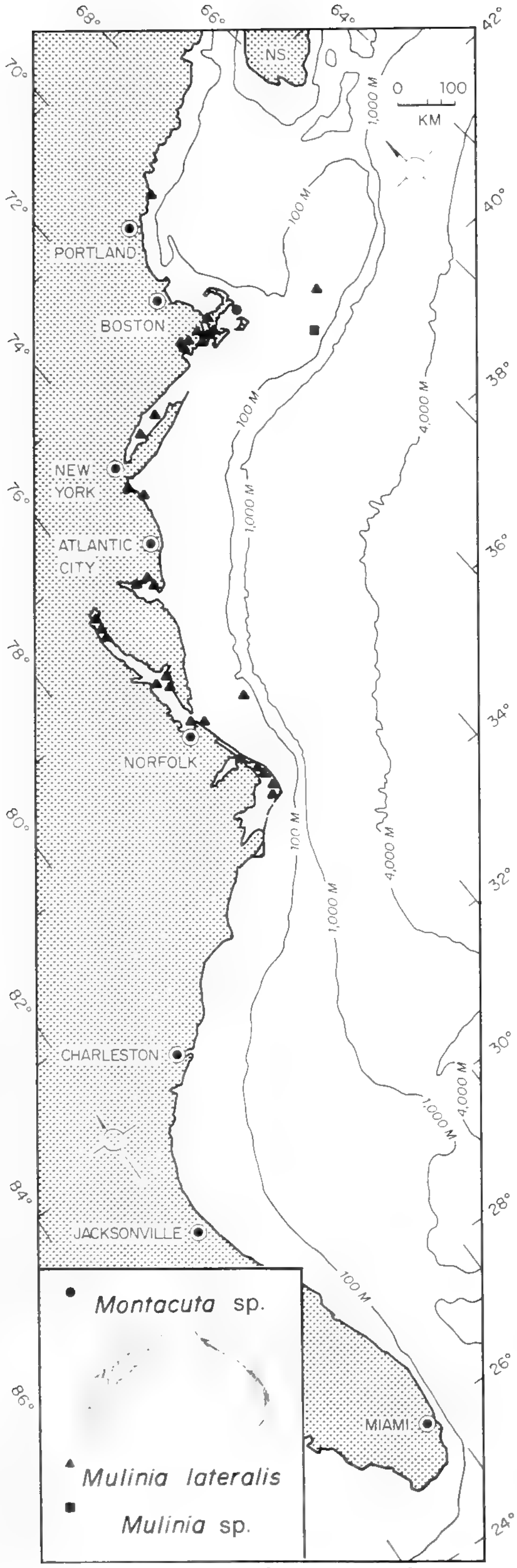

Figure 63.—Geographic distribution of *Montacuta* sp., *Mulinia lateralis*, and *Mulinia* sp.

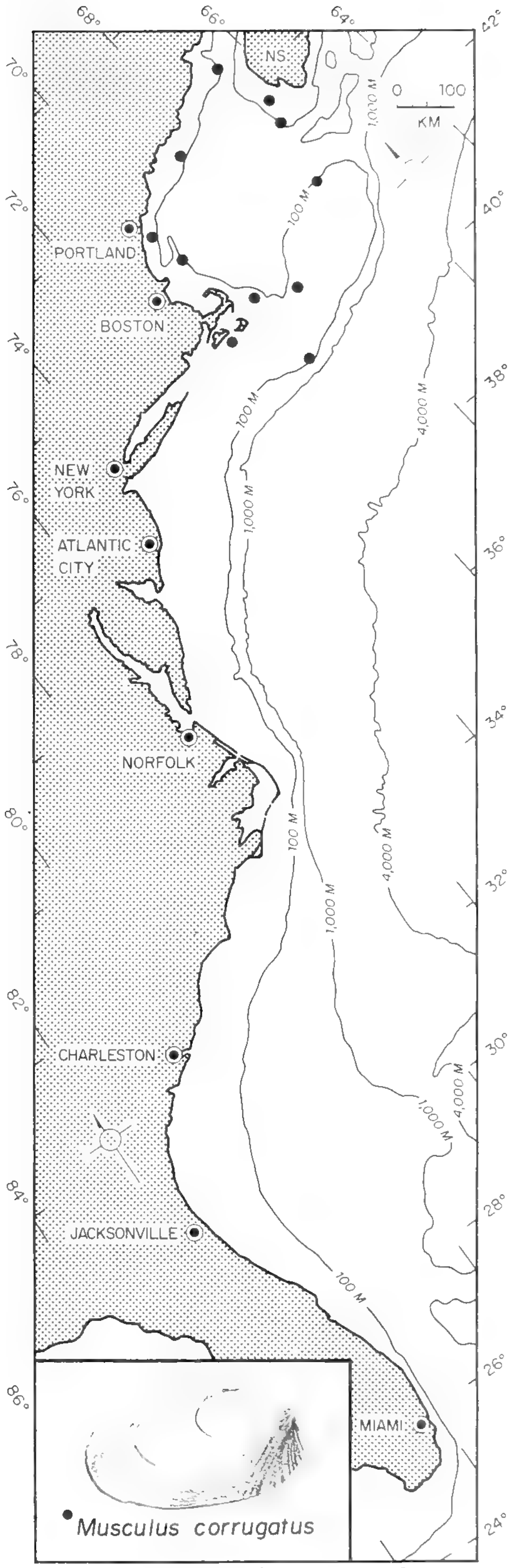

Figure 64.—Geographic distribution of *Musculus corrugatus*.

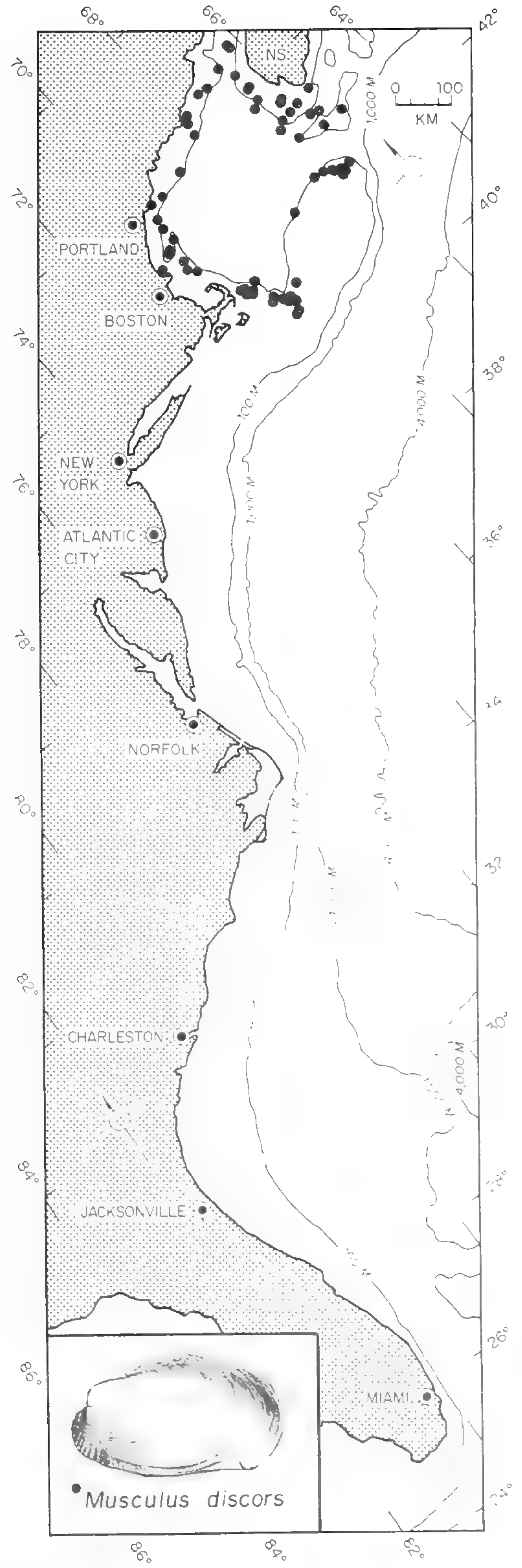

Figure 65.—Geographic distribution of *Musculus discors*.

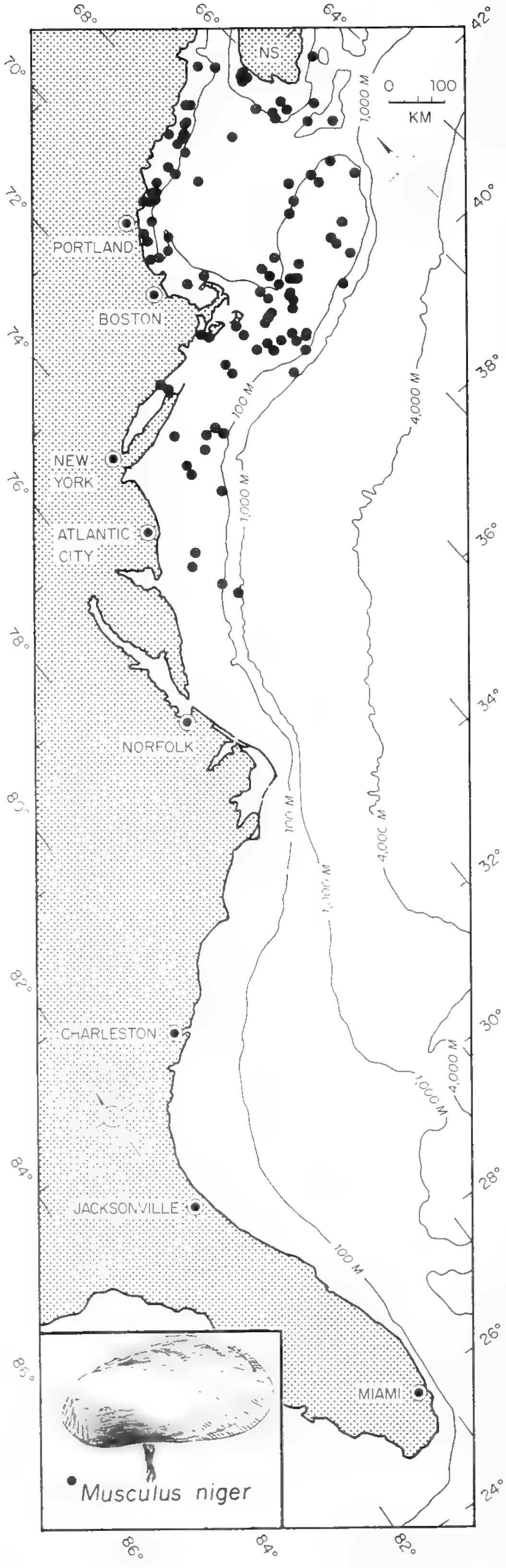

Figure 66.—Geographic distribution of *Musculus niger*.

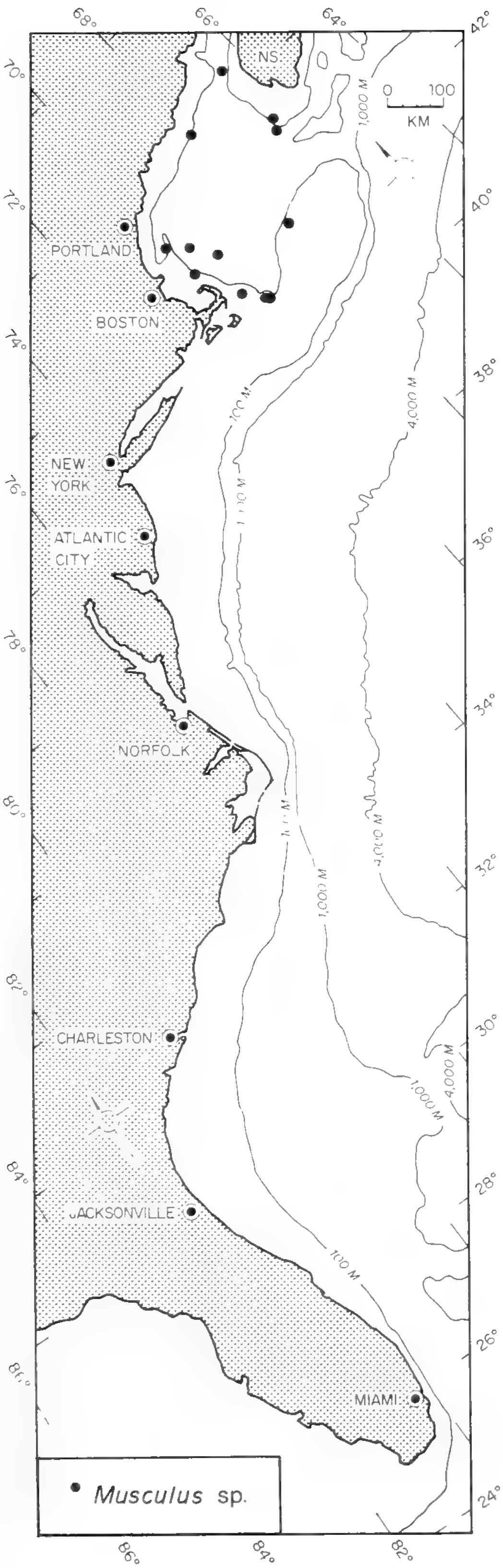

Figure 67.—Geographic distribution of *Musculus* sp.

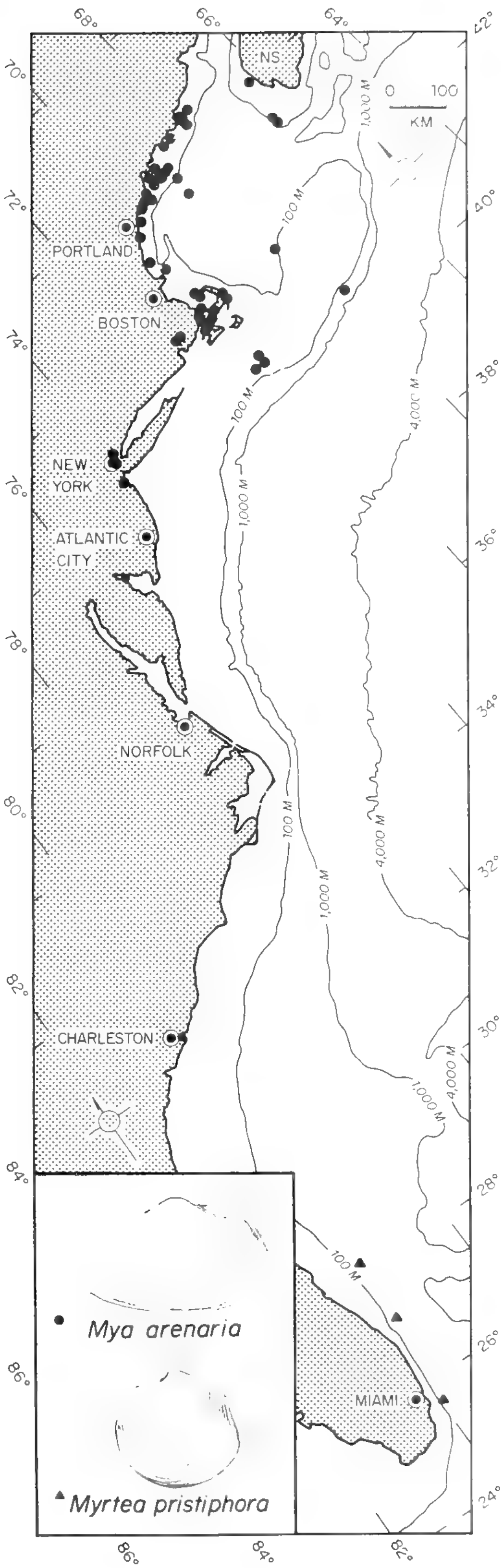

Figure 68.—Geographic distribution of *Mya arenaria* and *Myrtea pristiphora*.

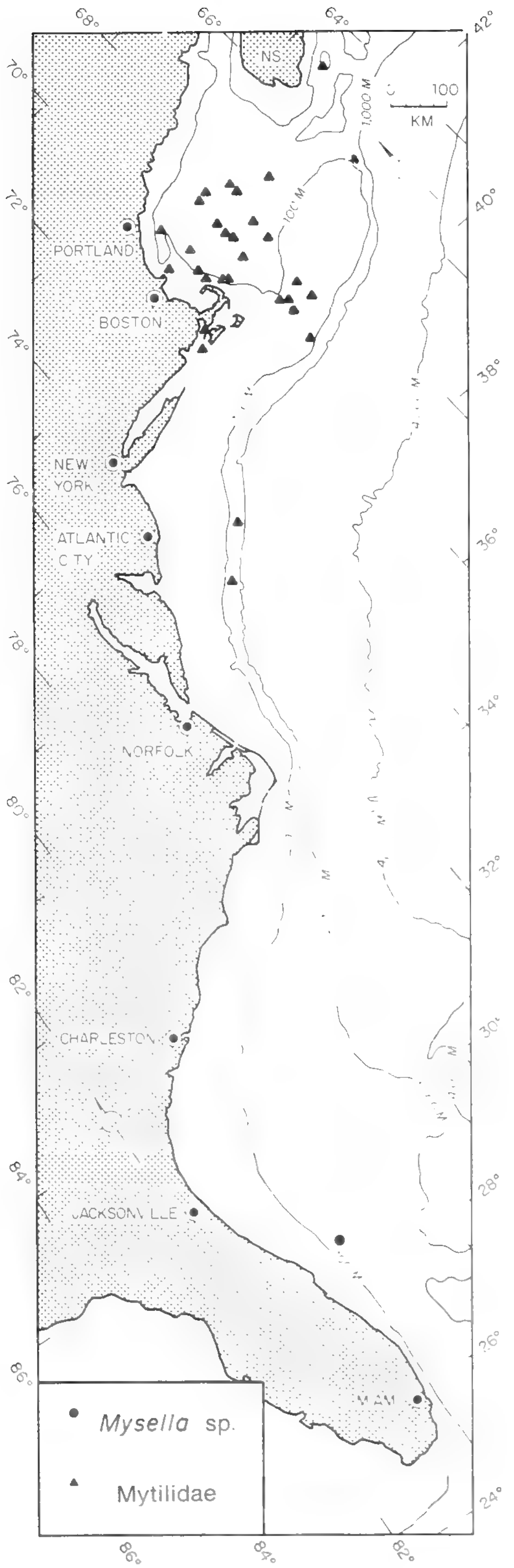

Figure 69.—Geographic distribution of *Mysella* sp. and Mytilidae.

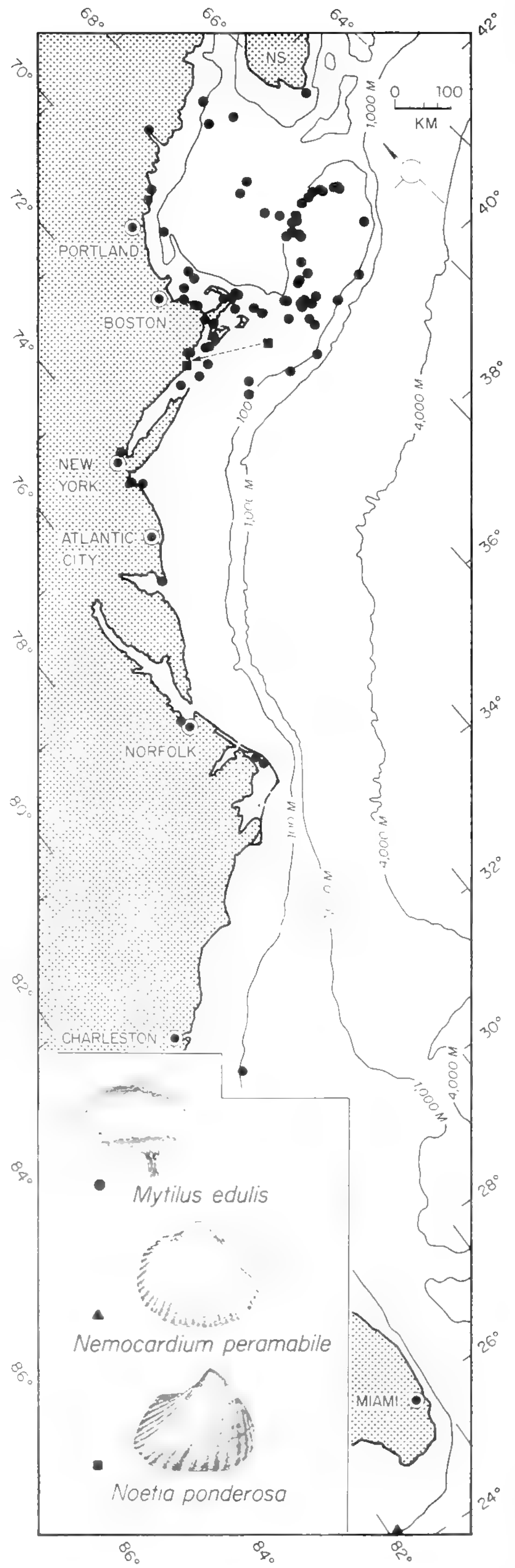

Figure 70.—Geographic distribution of *Mytilus edulis*, *Nemocardium peramabile*, and *Noetia ponderosa*.

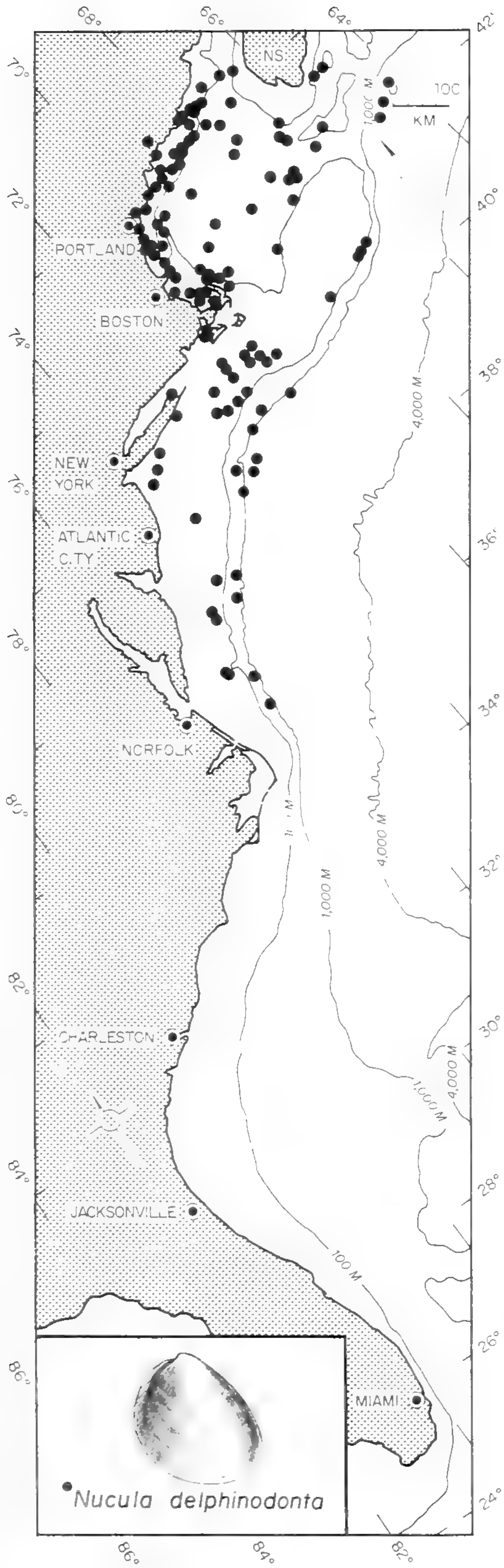

Figure 71.—Geographic distribution of *Nucula delphinodonta*.

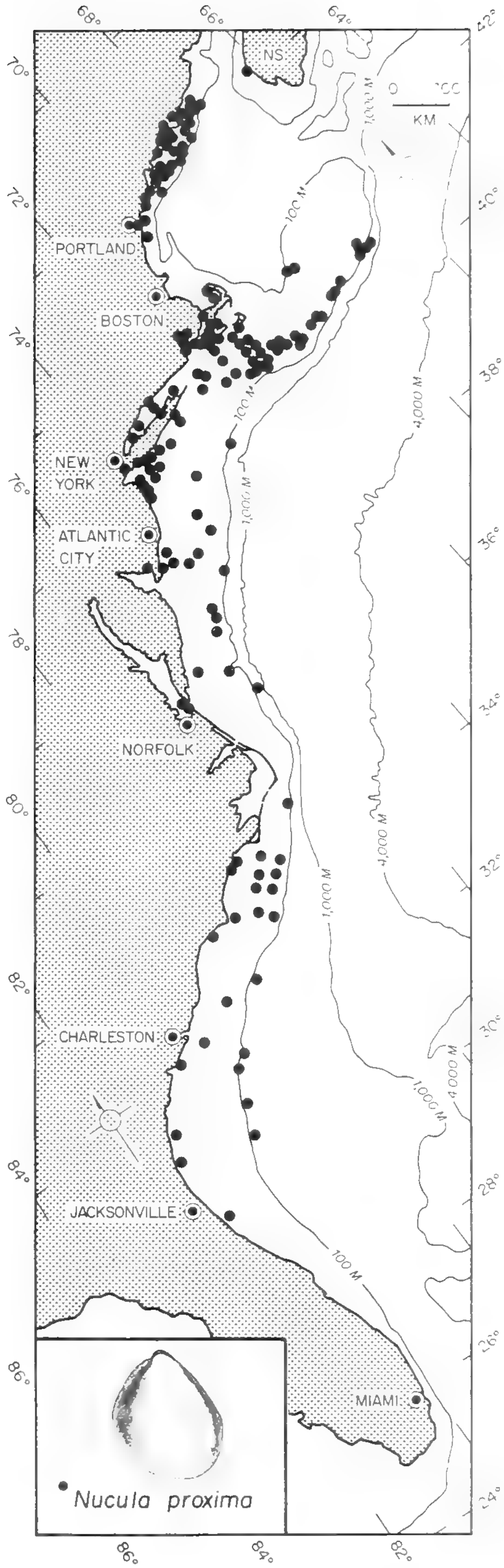

Figure 72.—Geographic distribution of *Nucula proxima*.

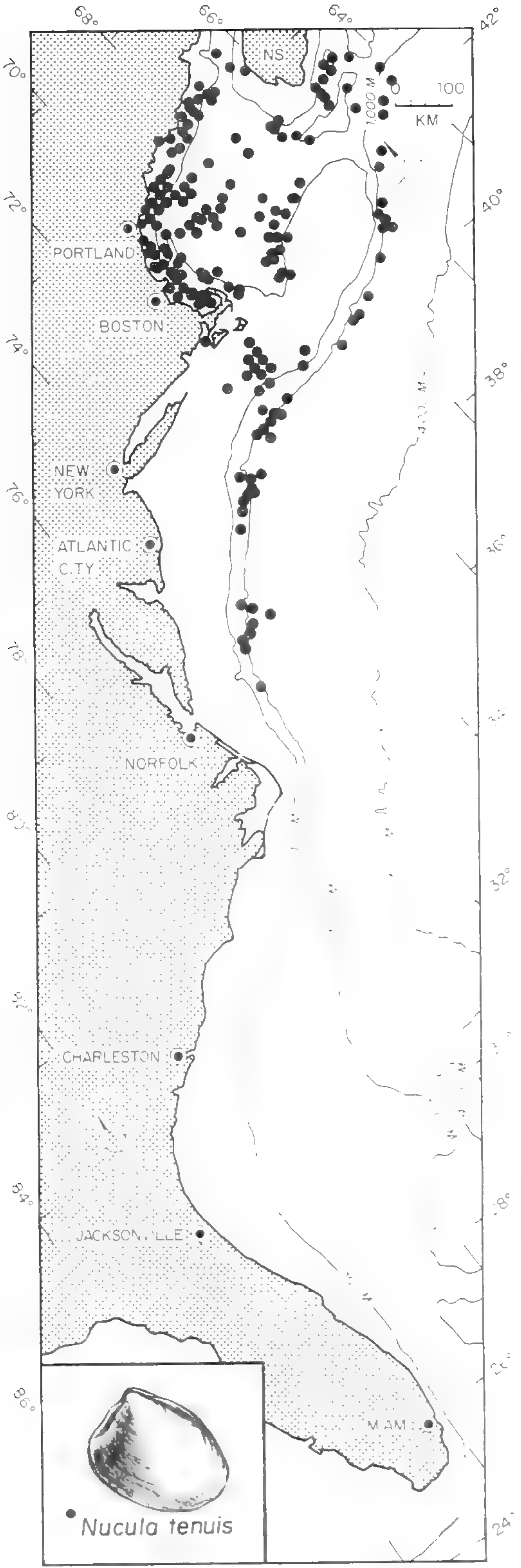

Figure 73.—Geographic distribution of *Nucula tenuis*.

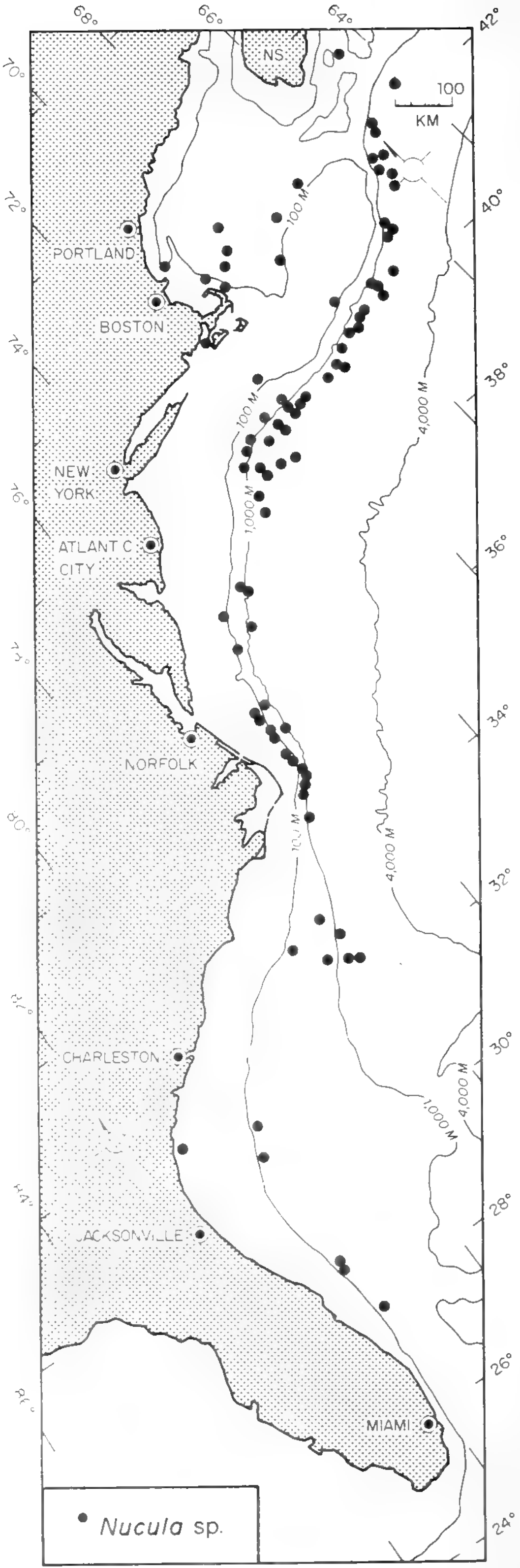

Figure 74.—Geographic distribution of *Nucula* sp.

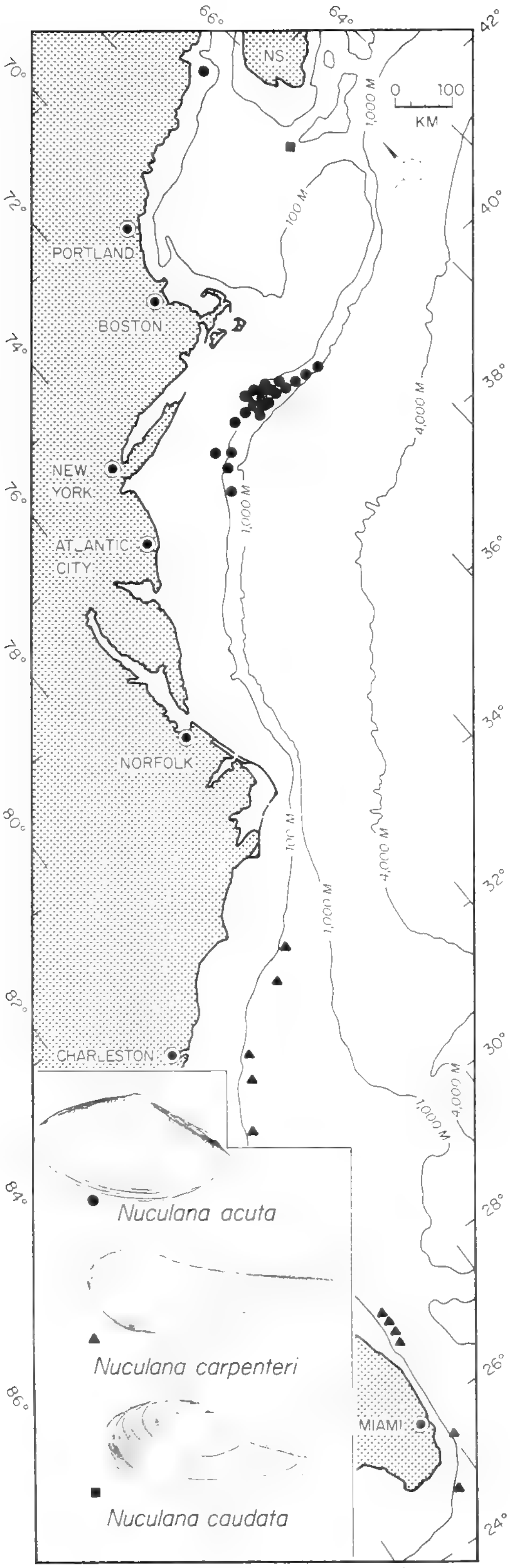

Figure 75.—Geographic distribution of *Nuculana acuta*, *Nuculana carpenteri*, and *Nuculana caudata*.

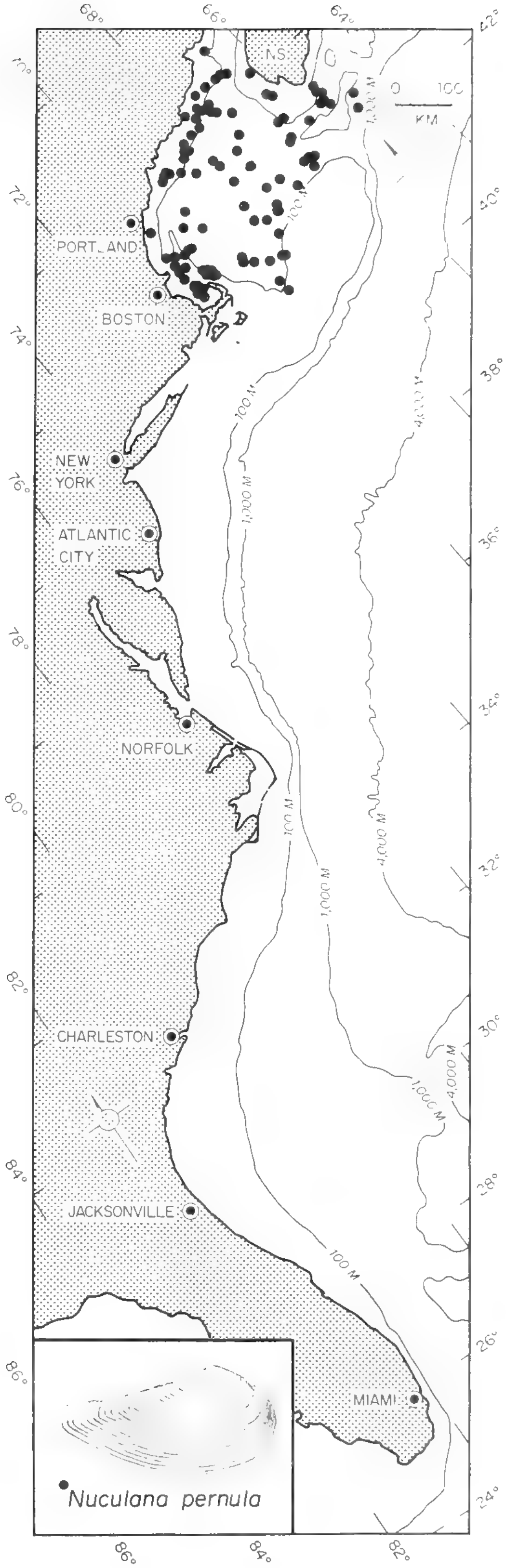

Figure 76.—Geographic distribution of *Nuculana pernula*.

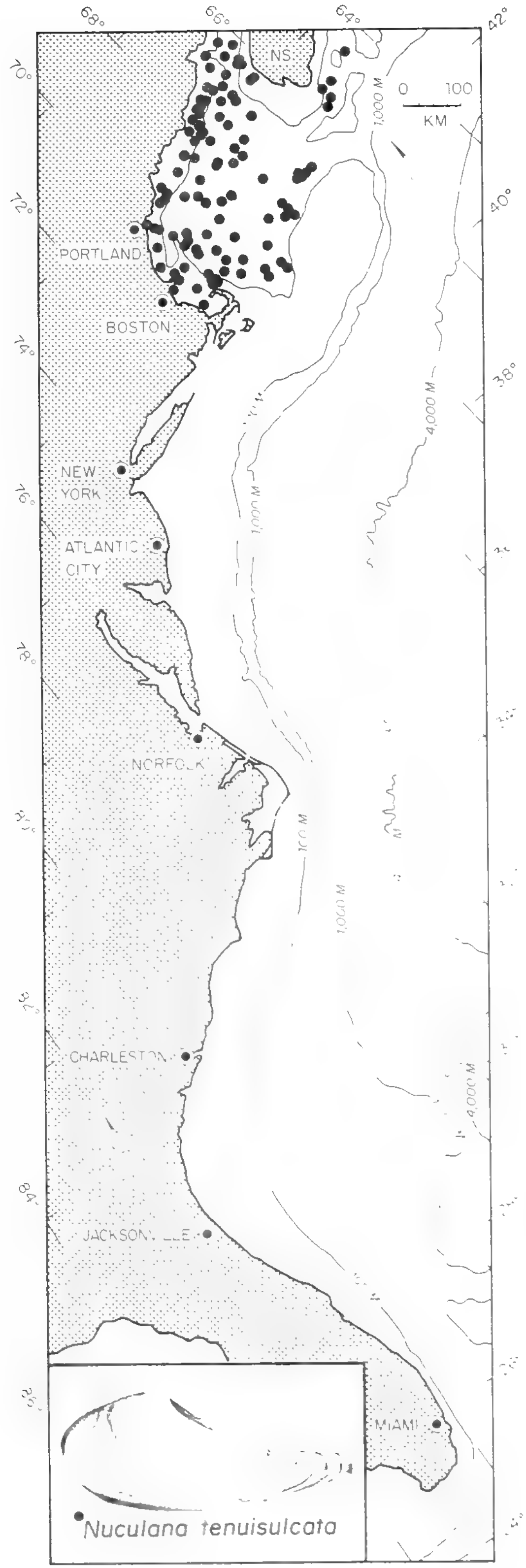

Figure 77.—Geographic distribution of *Nuculana tenuisulcata.*

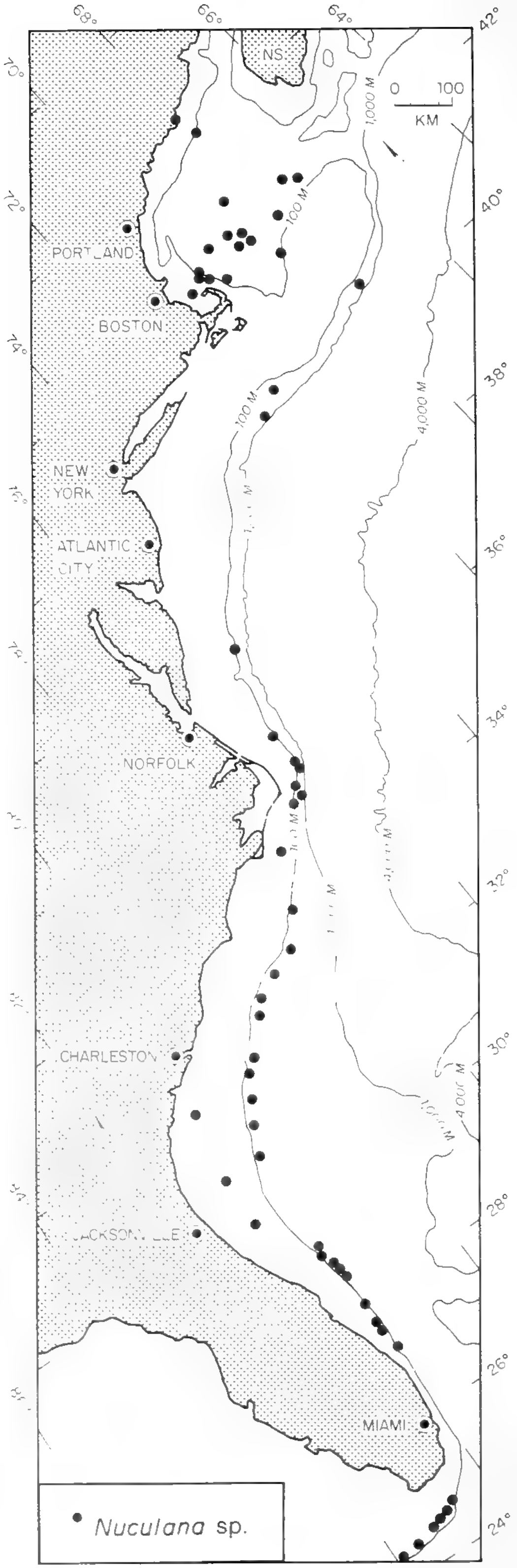

Figure 78.—Geographic distribution of *Nuculana* sp.

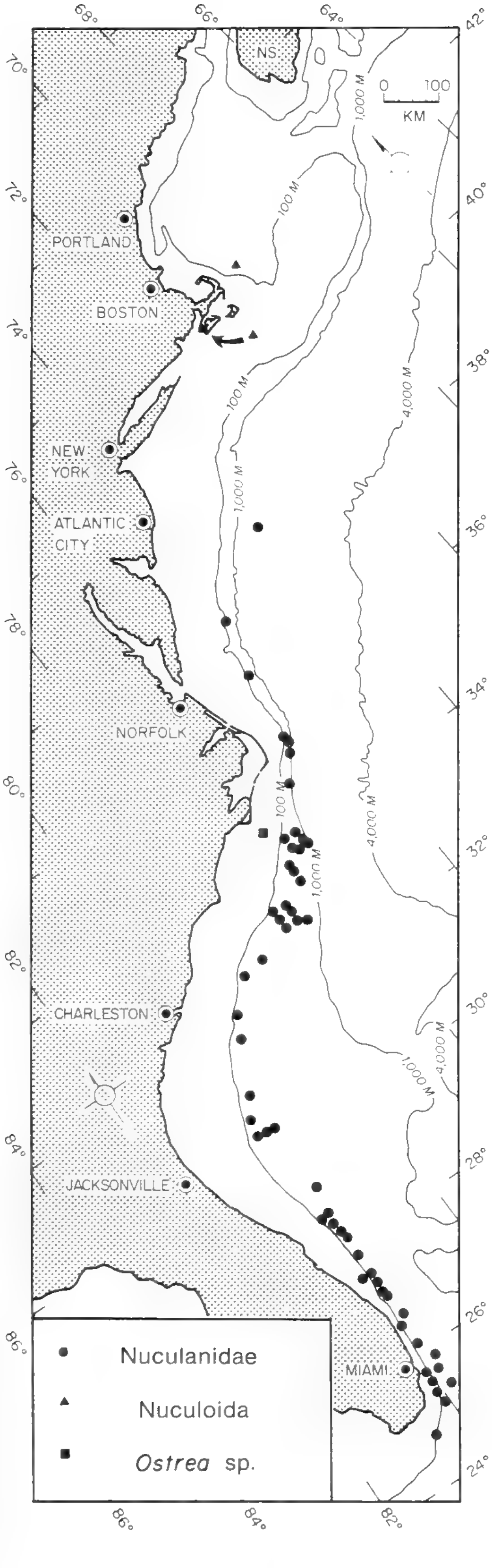

Figure 79.—Geographic distribution of Nuculanidae, Nuculoida, and *Ostrea* sp.

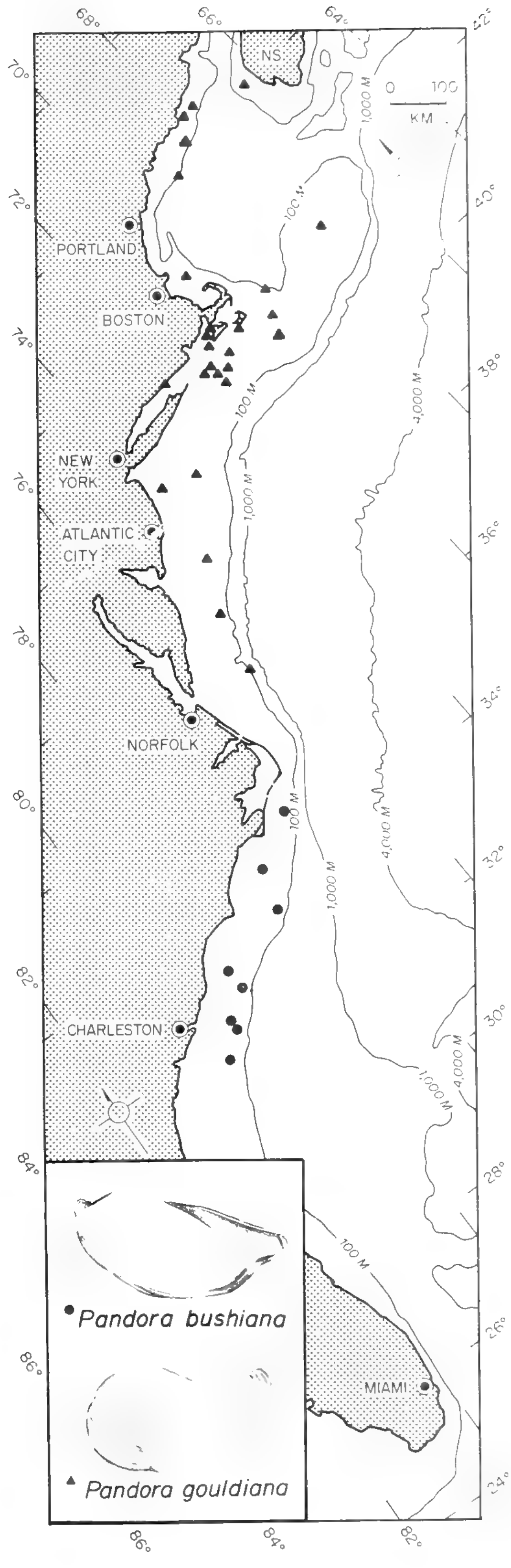

Figure 80.—Geographic distribution of *Pandora bushiana* and *Pandora gouldiana*.

Figure 81.—Geographic distribution of *Pandora inflata*.

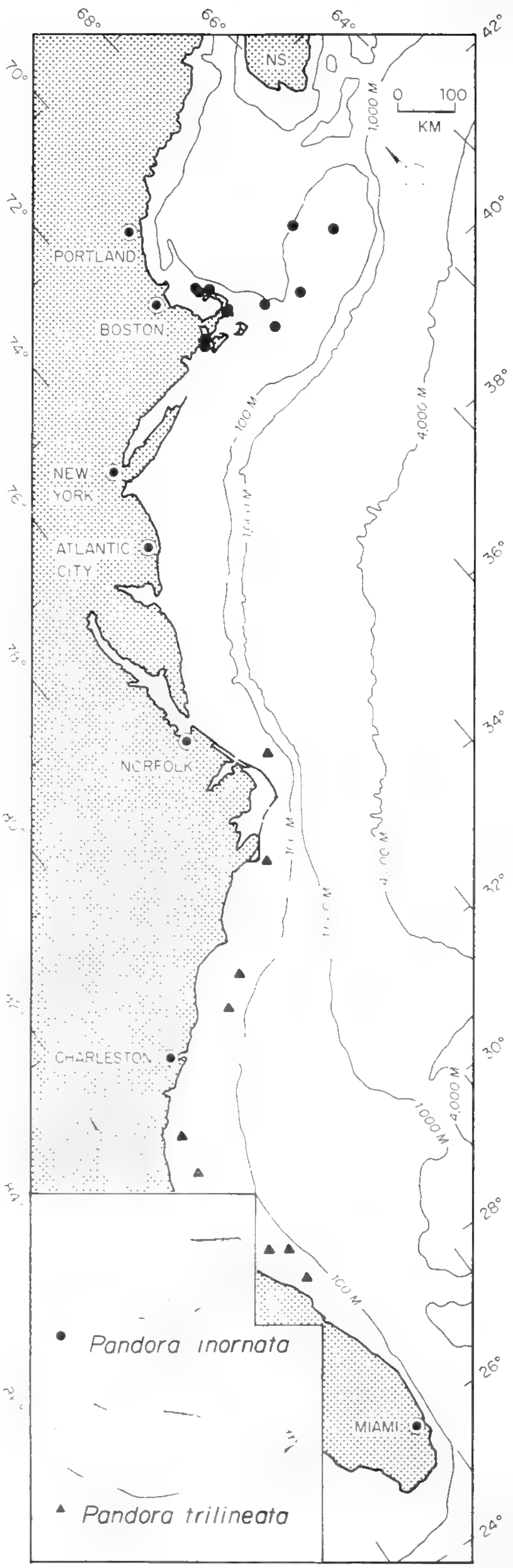

Figure 82.—Geographic distribution of *Pandora inornata* and *Pandora trilineata*.

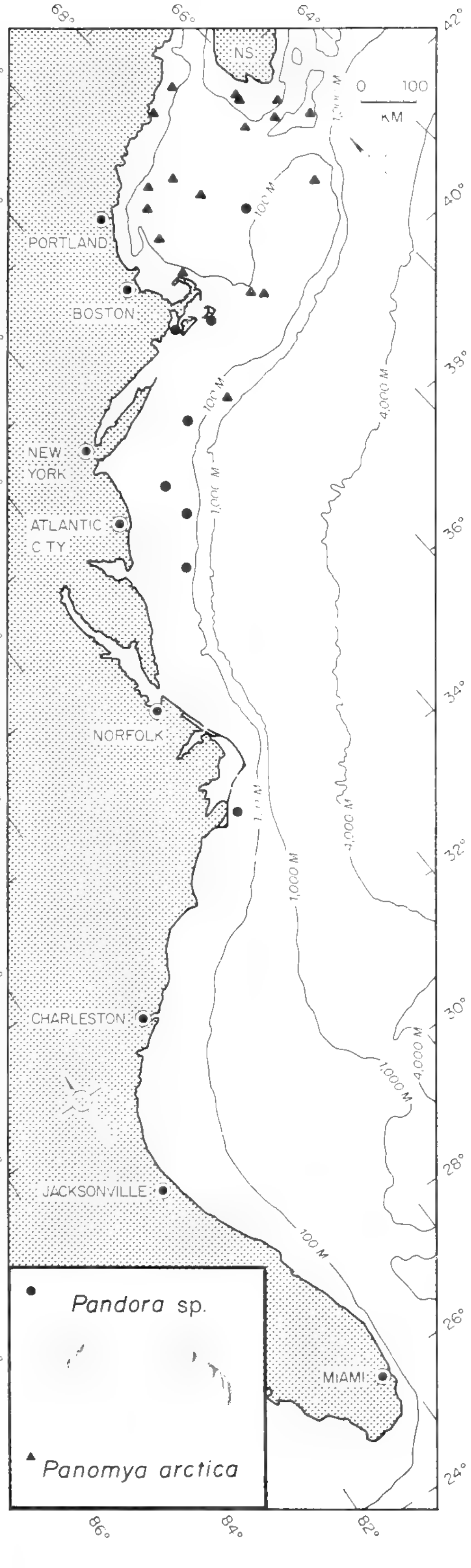

Figure 83.—Geographic distribution of *Pandora* sp. and *Panomya arctica.*

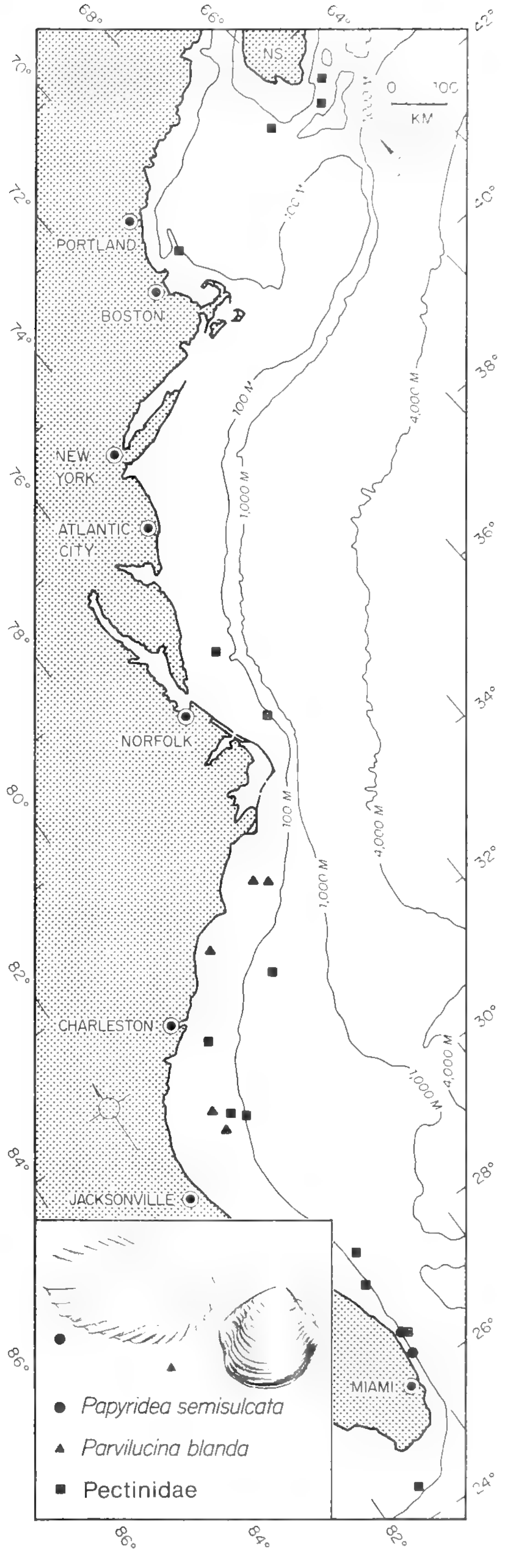

Figure 84.—Geographic distribution of *Papyridea semisulcata, Parvilucina blanda*, and Pectinidae.

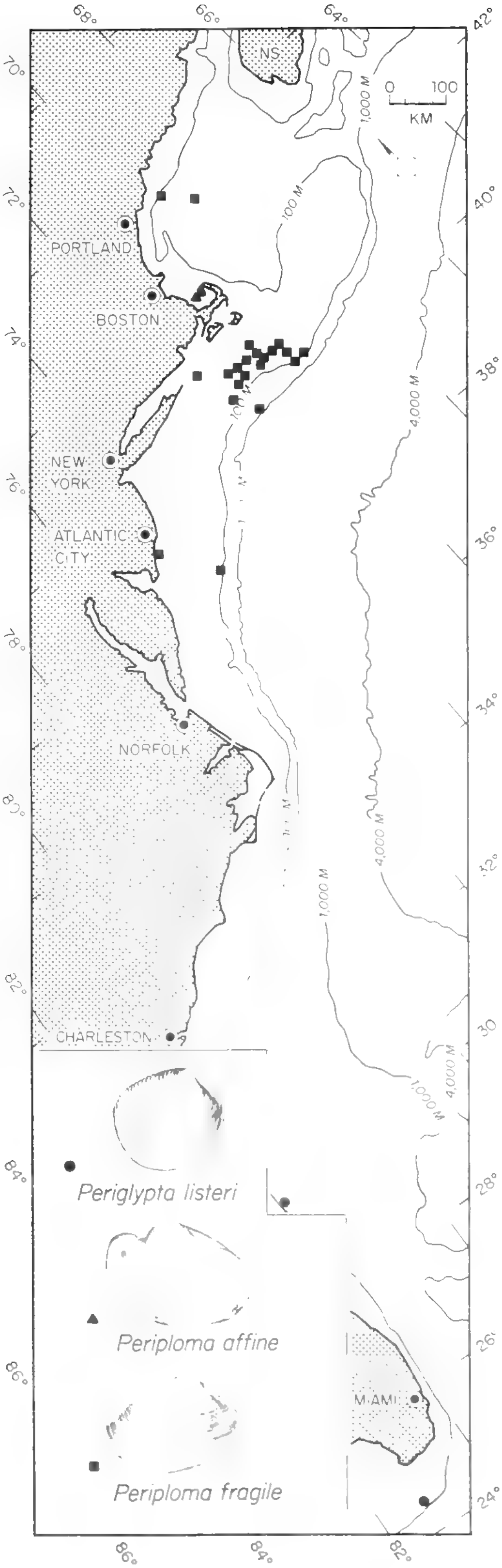

Figure 85.—Geographic distribution of *Periglypta listeri*, *Periploma affine*, and *Periploma fragile*.

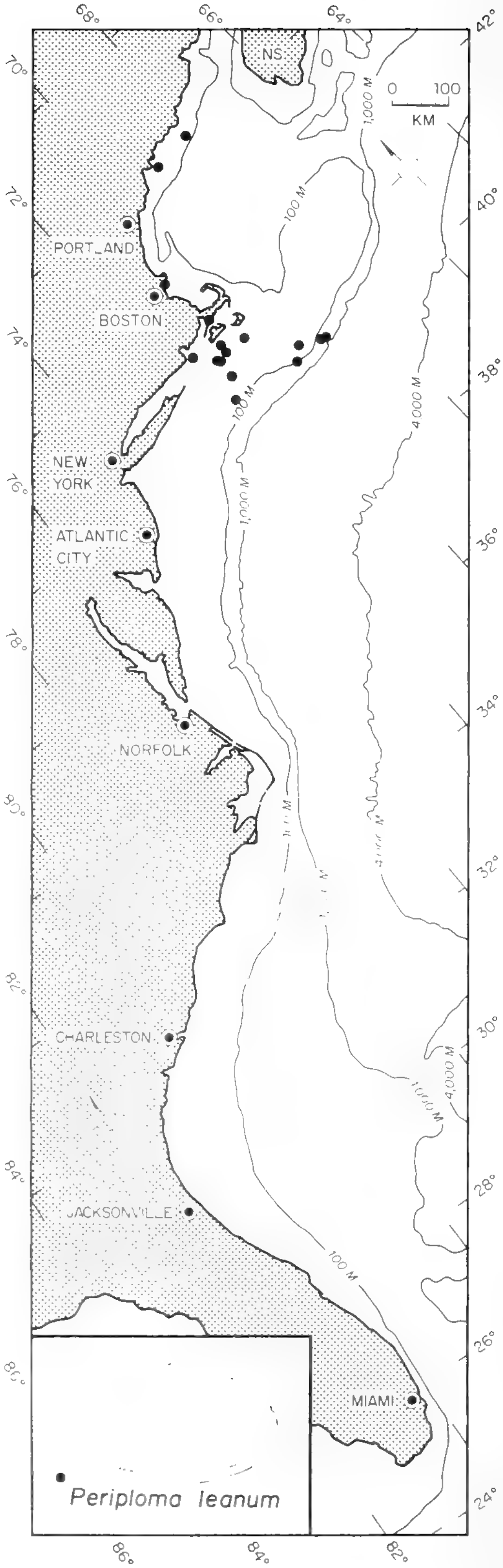

Figure 86.—Geographic distribution of *Periploma leanum*.

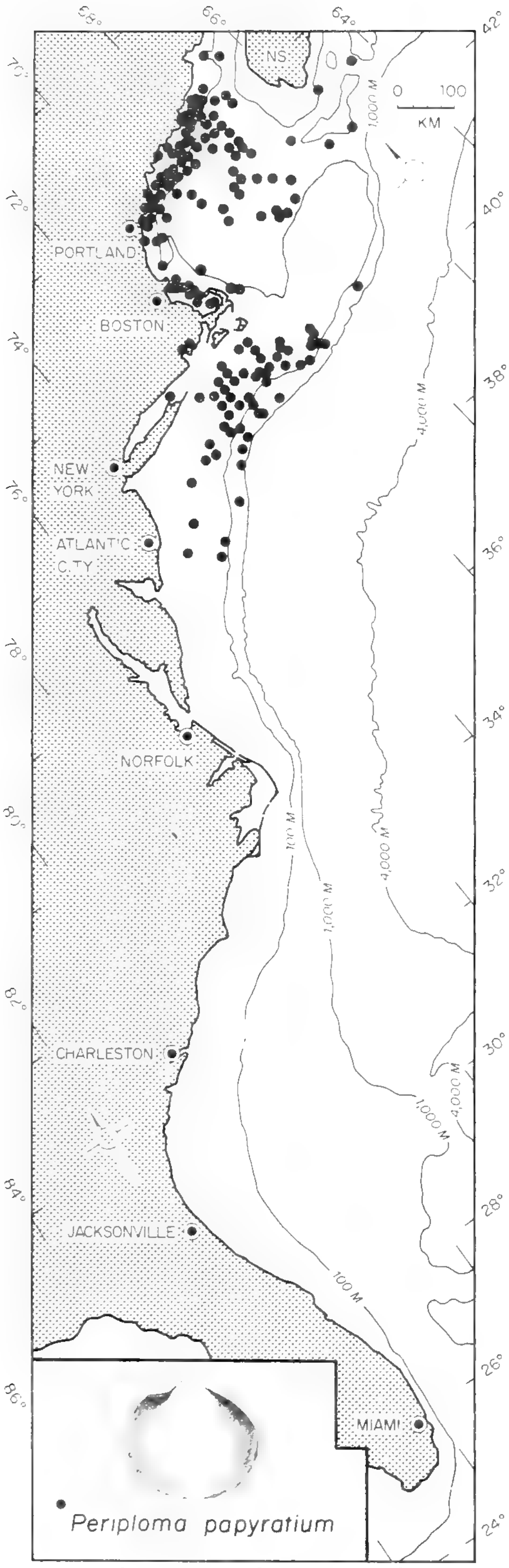

Figure 87.—Geographic distribution of *Periploma papyratium*.

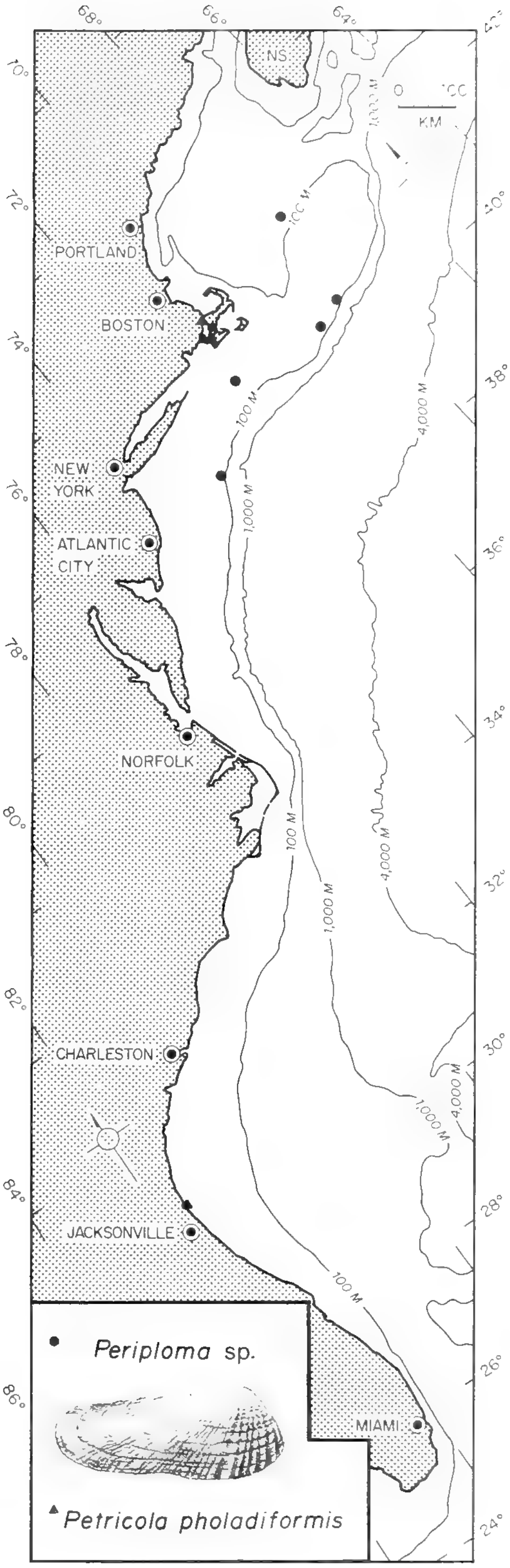

Figure 88.—Geographic distribution of *Periploma* sp. and *Petricola pholadiformis*.

Figure 89.—Geographic distribution of *Pitar morrhuanus*.

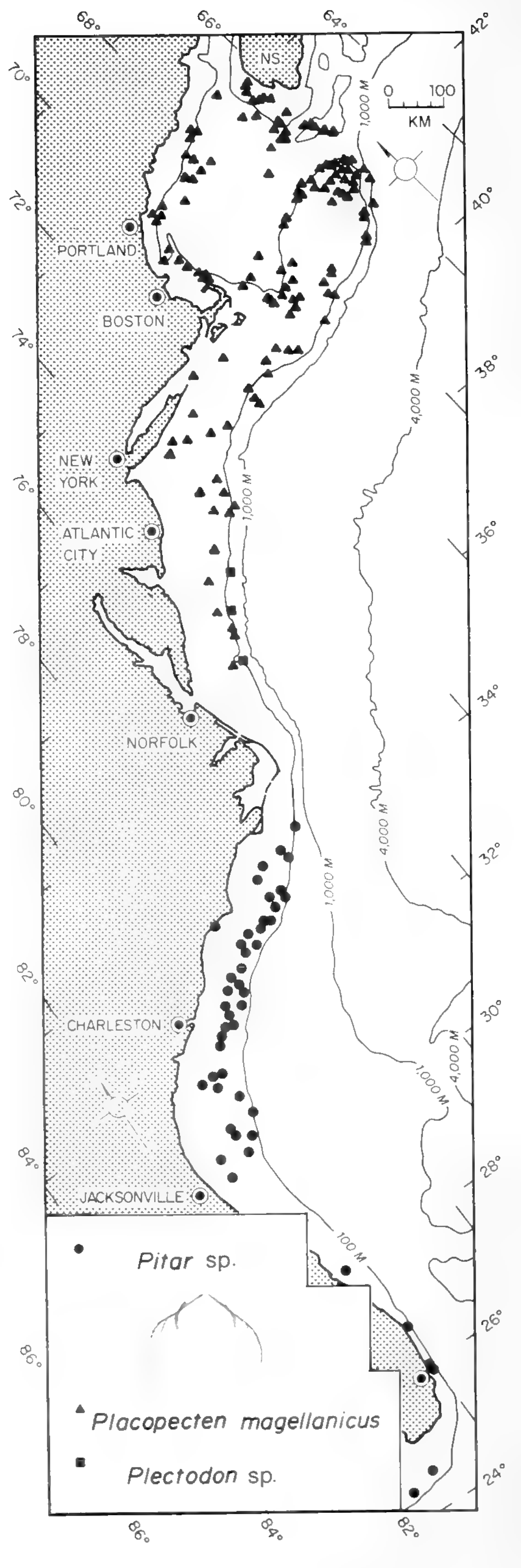

Figure 90.—Geographic distribution of *Pitar* sp., *Placopecten magellanicus*, and *Plectodon* sp.

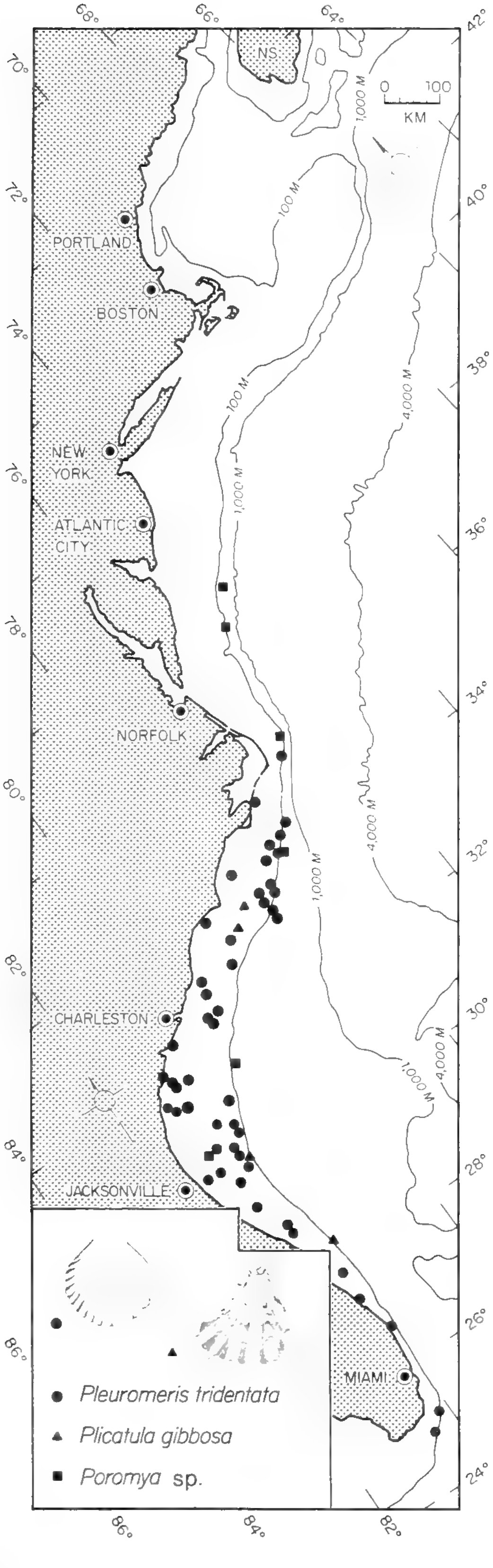

Figure 91.—Geographic distribution of *Pleuromeris tridentata*, *Plicatula gibbosa*, and *Poromya* sp.

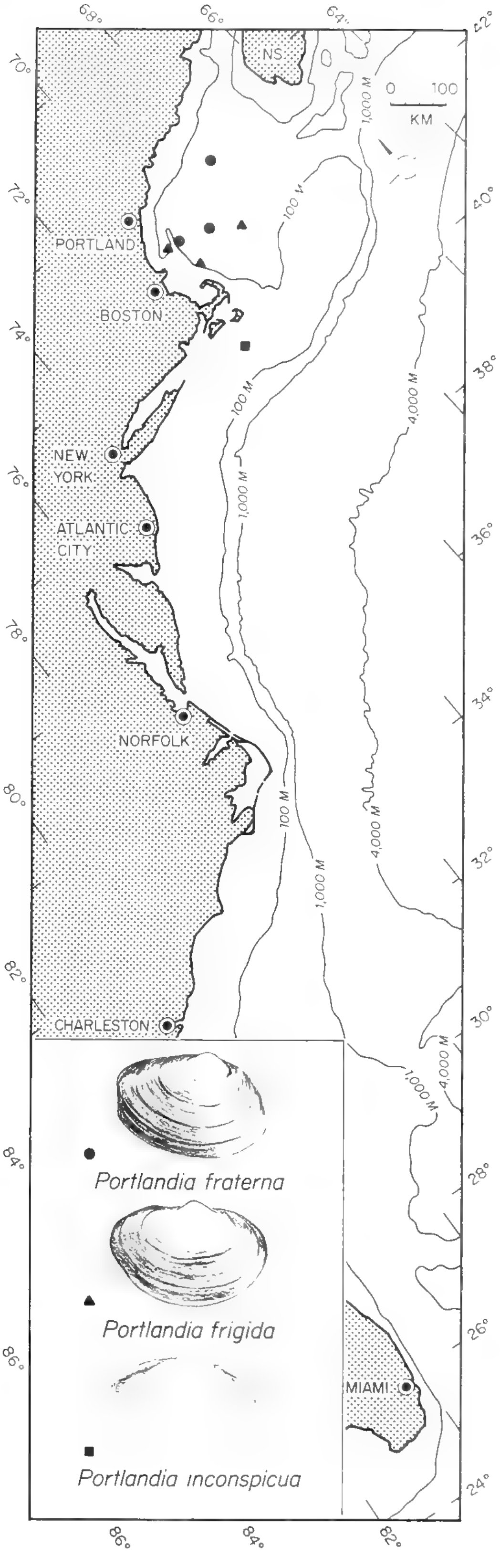

Figure 92.—Geographic distribution of *Portlandia fraterna*, *Portlandia frigida*, and *Portlandia inconspicua*.

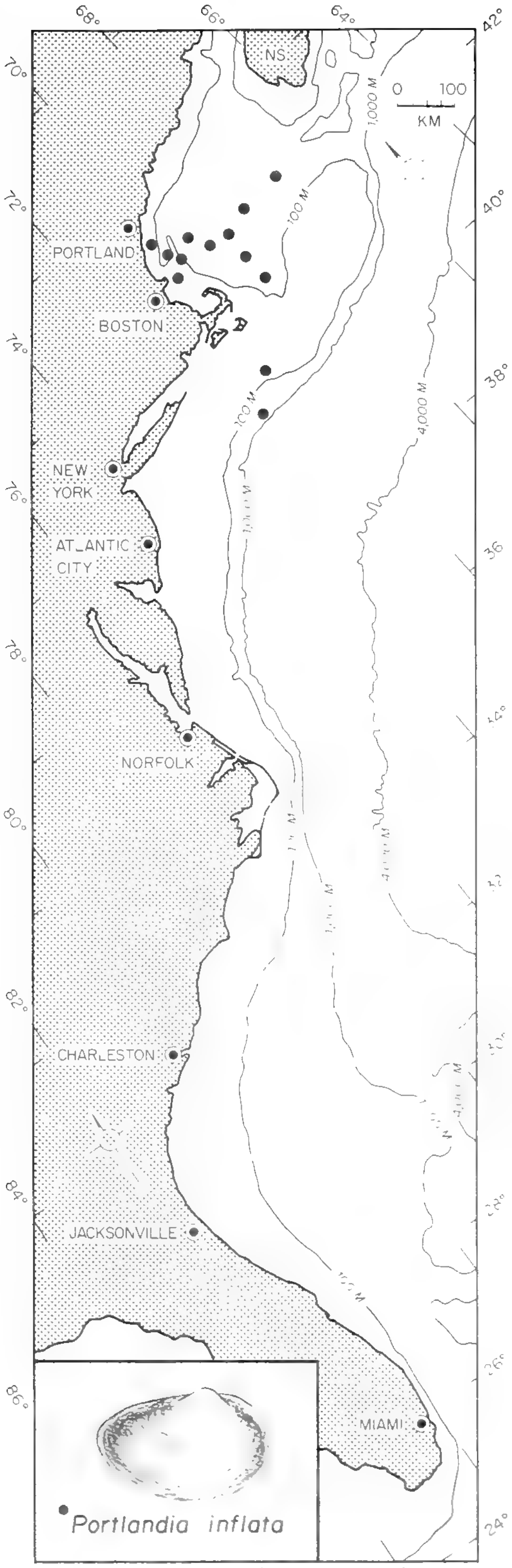

Figure 93.—Geographic distribution of *Portlandia inflata*.

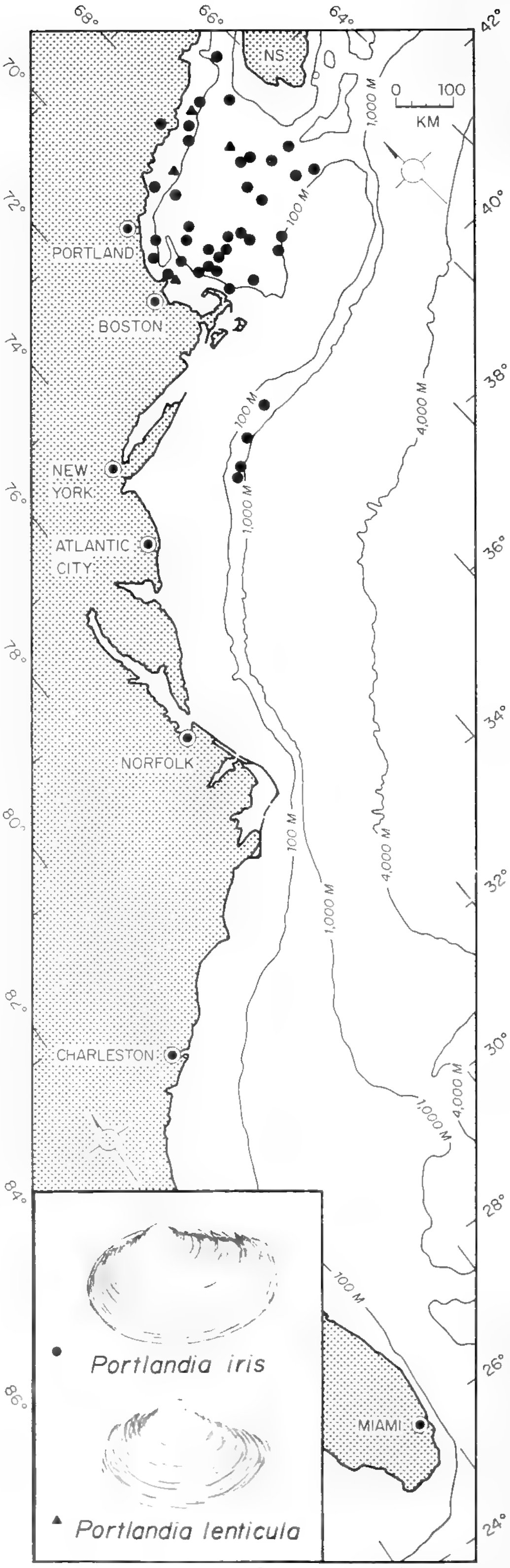

Figure 94.—Geographic distribution of *Portlandia iris* and *Portlandia lenticula*.

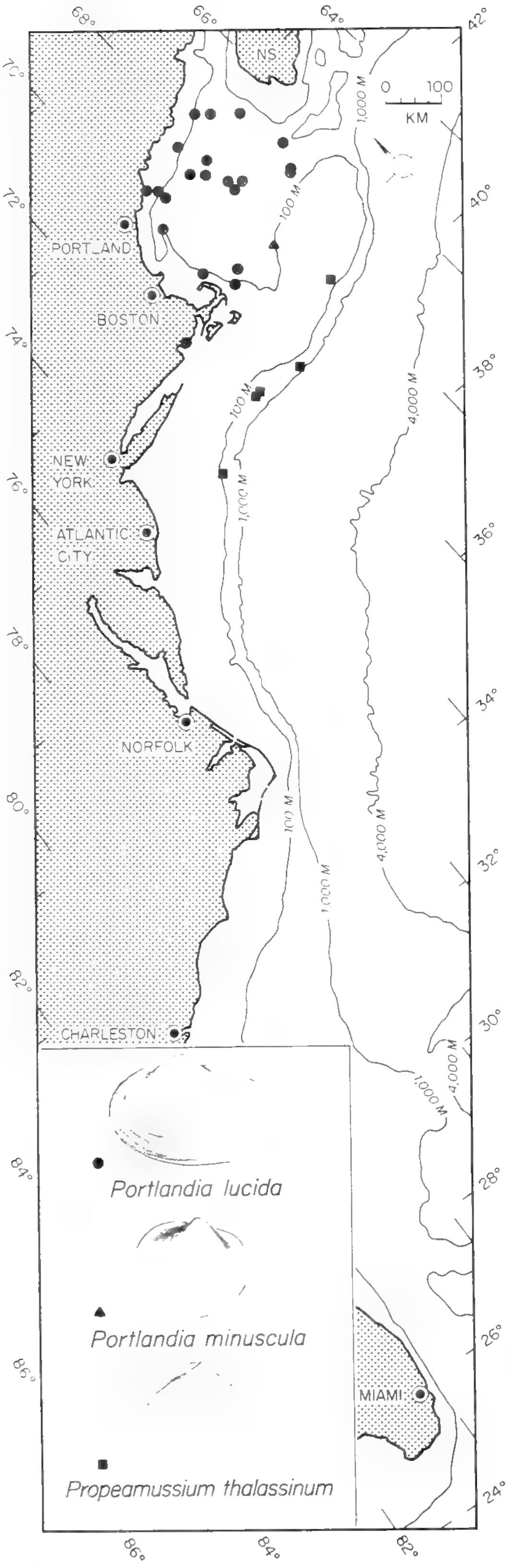

Figure 95.—Geographic distribution of ***Portlandia lucida, Portlandia minuscula,*** **and** ***Propeamussium thalassinum.***

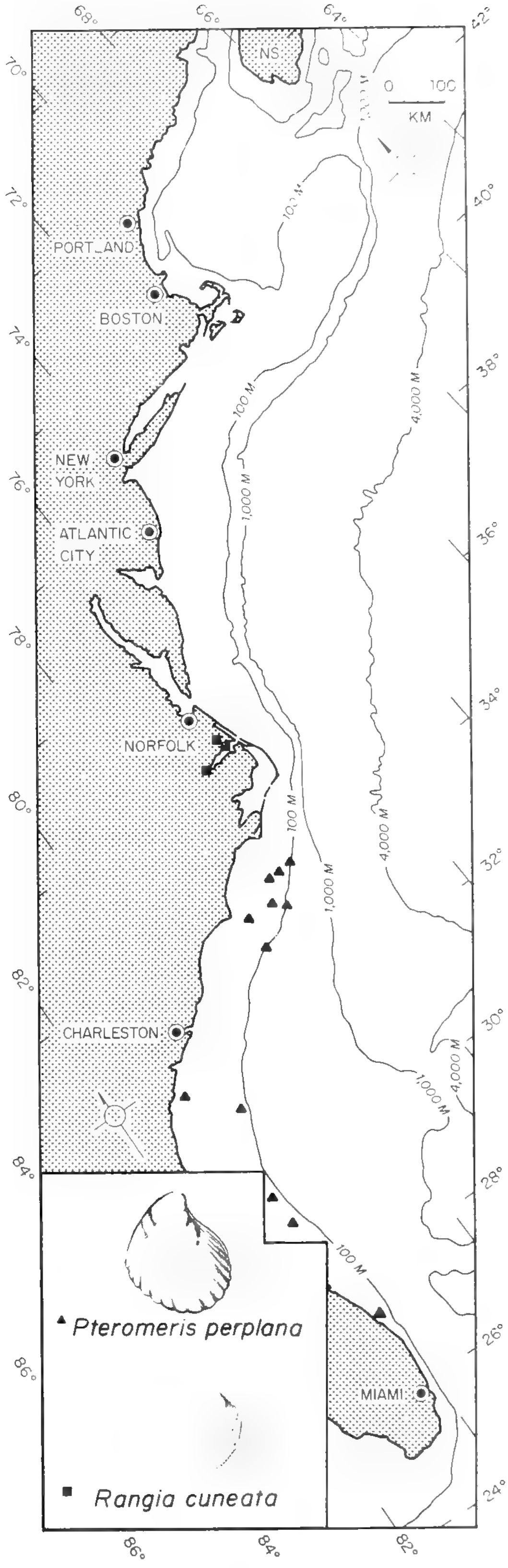

Figure 96.—Geographic distribution of ***Pteromeris perplana*** **and** ***Rangia cuneata.***

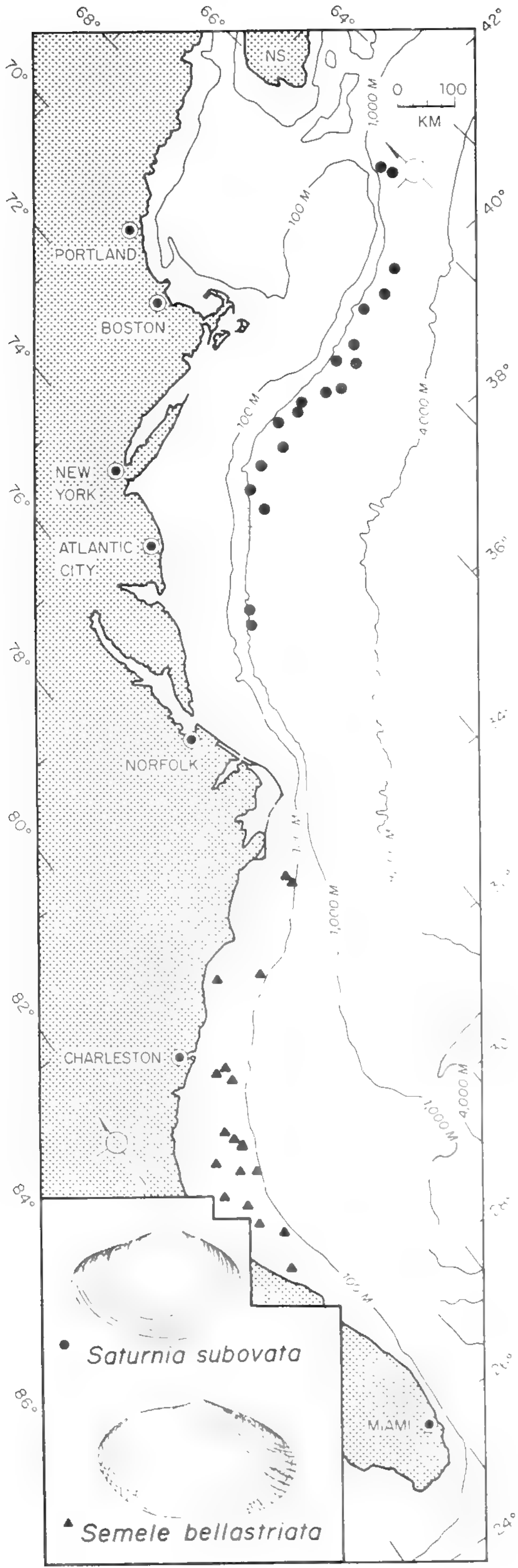

Figure 97.—Geographic distribution of *Saturnia subovata* and *Semele bellastriata.*

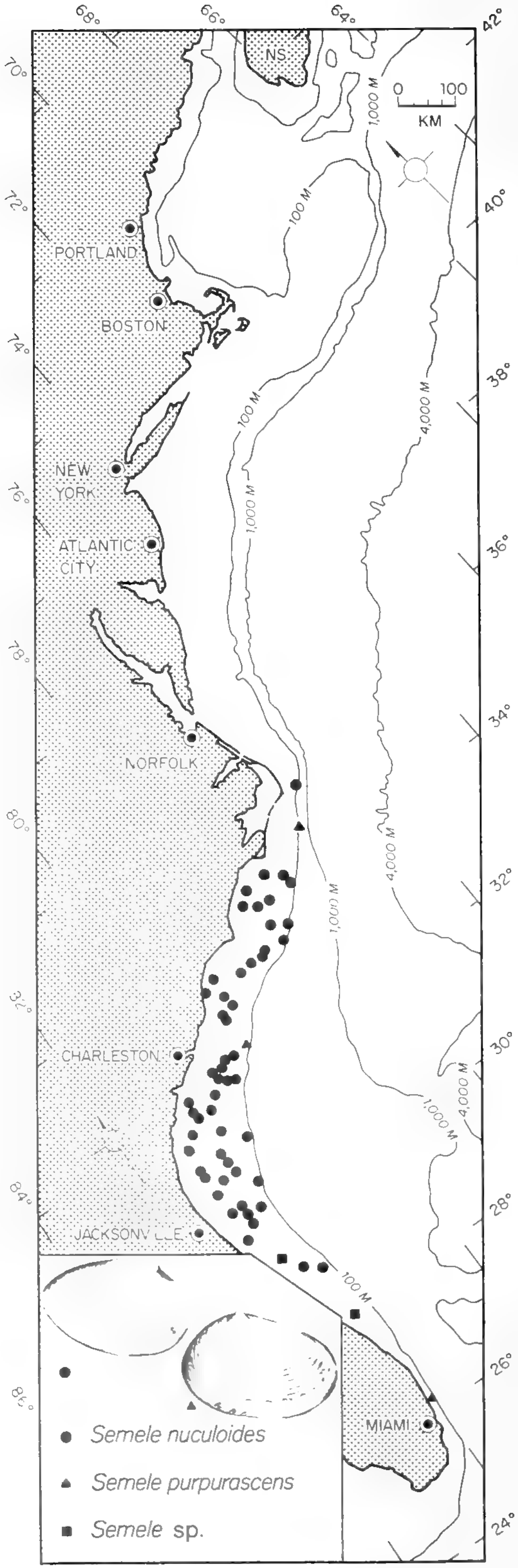

Figure 98.—Geographic distribution of *Semele nu*
and *Semele*

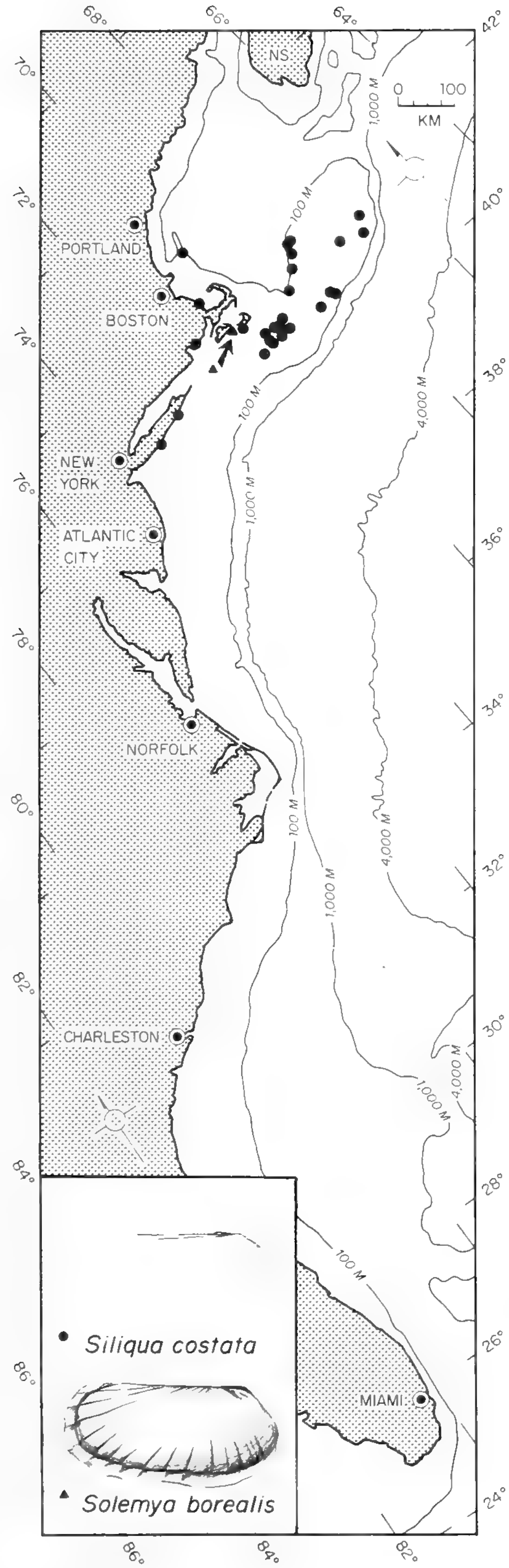

Figure 99.—Geographic distribution of *Siliqua costata* and *Solemya borealis*.

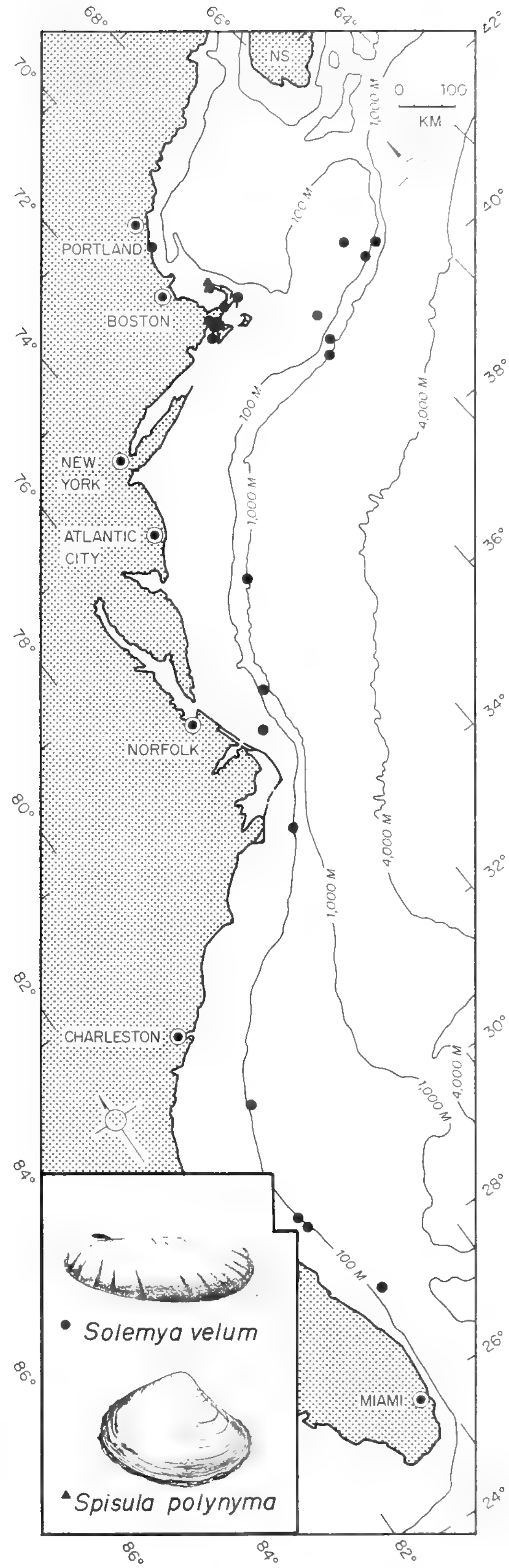

Figure 100.—Geographic distribution of *Solemya velum* and *Spisula polynyma*.

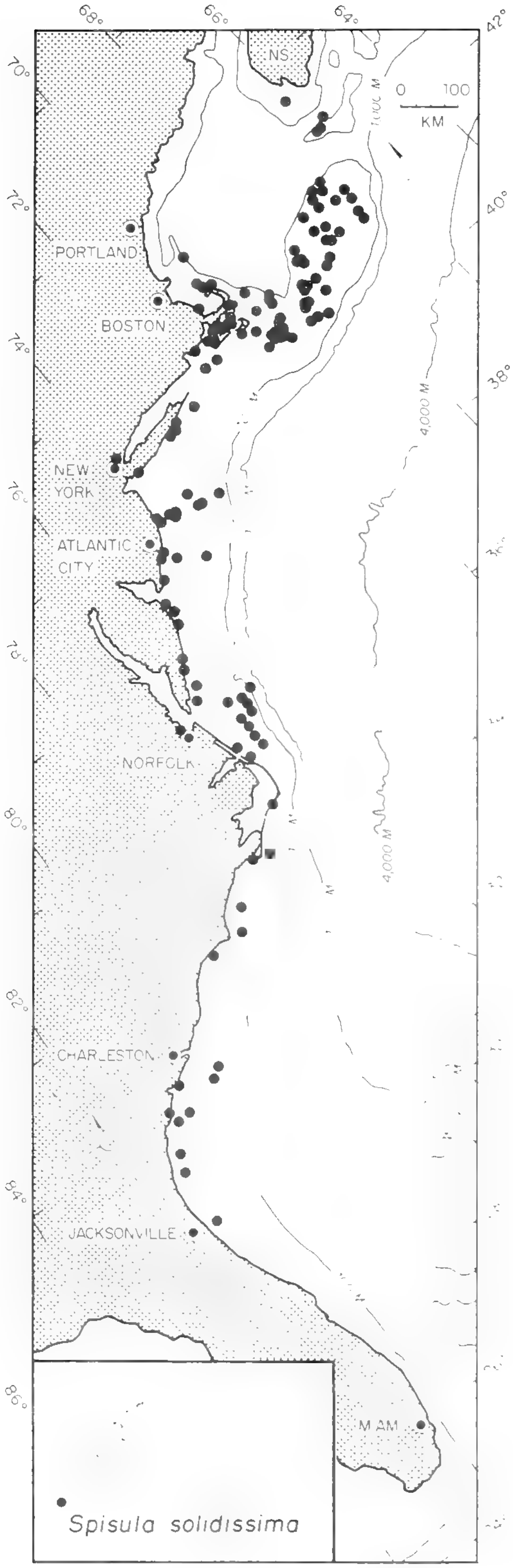

Figure 101.—Geographic distribution of *Spisula solidissima*.

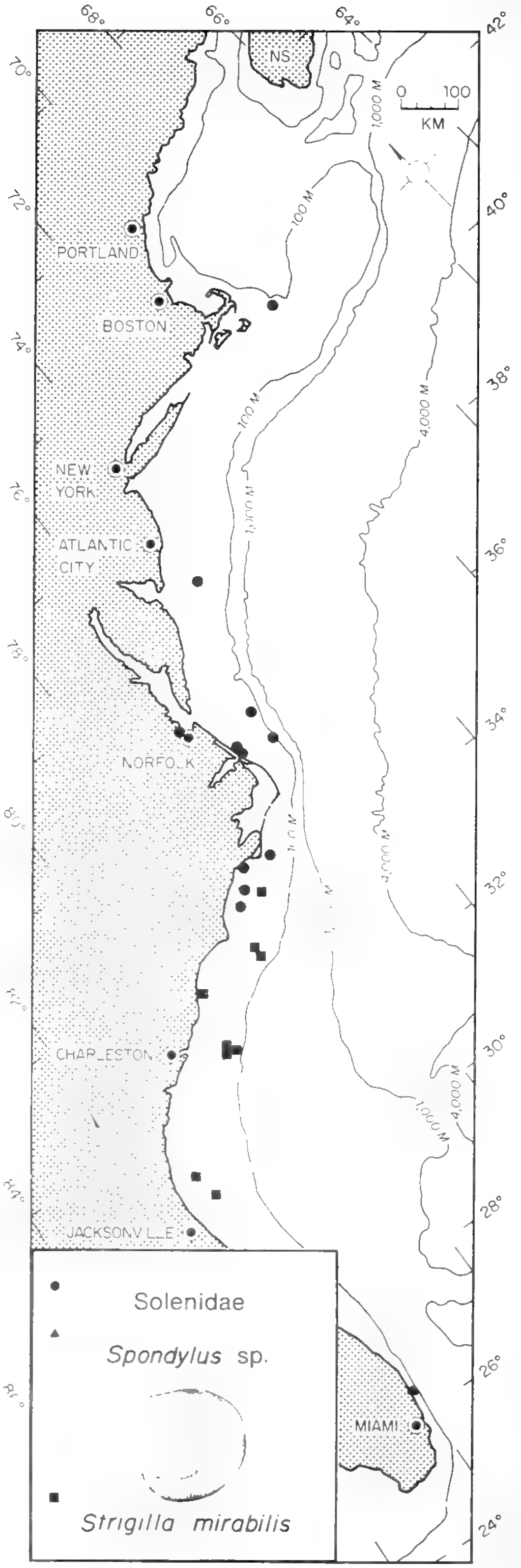

Figure 102.—Geographic distribution of Solenidae, *Spondylus* sp., and *Strigilla mirabilis*.

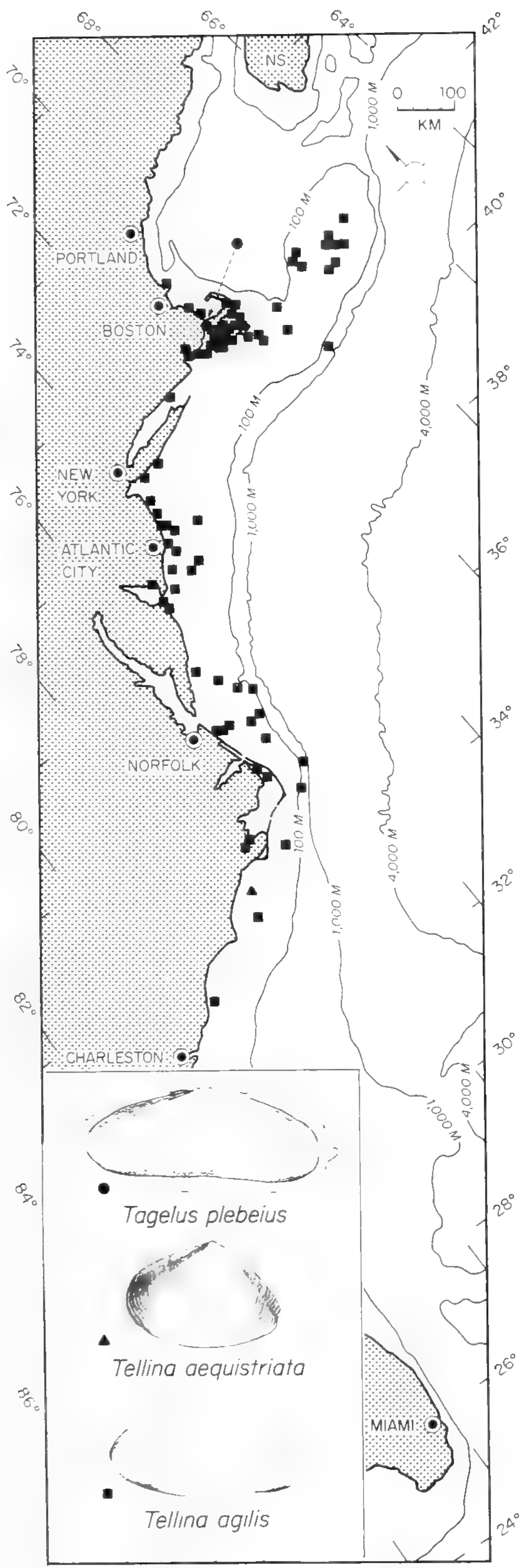

Figure 103.—Geographic distribution of *Tagelus plebeius*, *Tellina aequistriata*, and *Tellina agilis*.

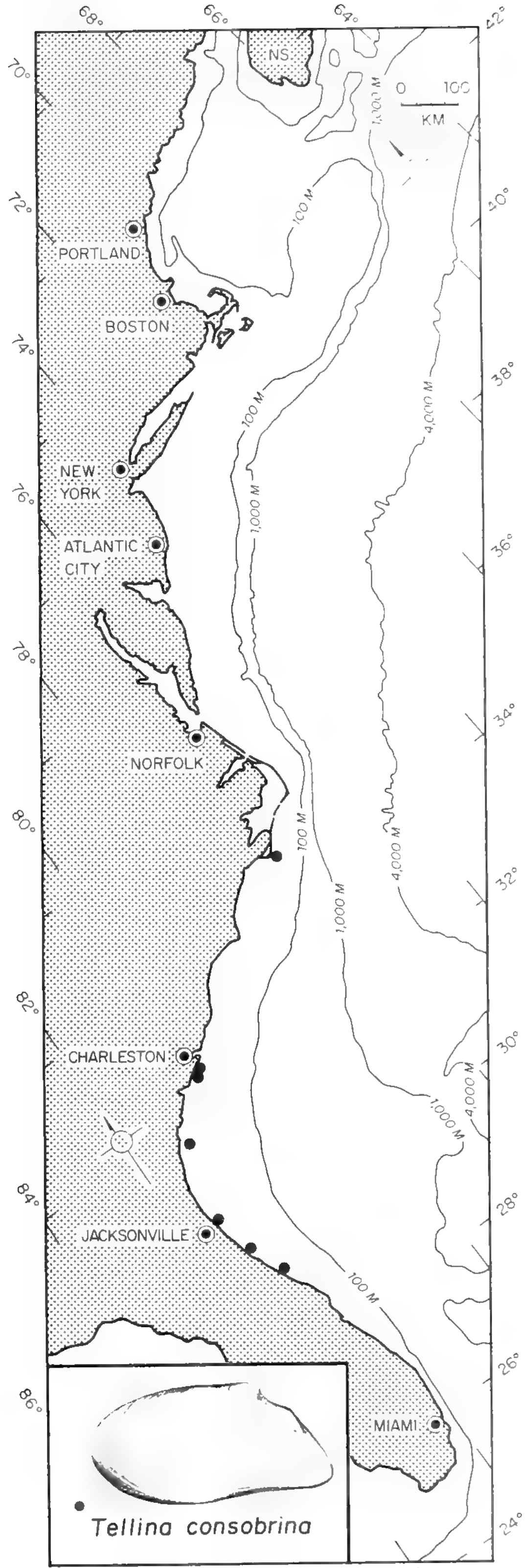

Figure 104.—Geographic distribution of *Tellina consobrina*.

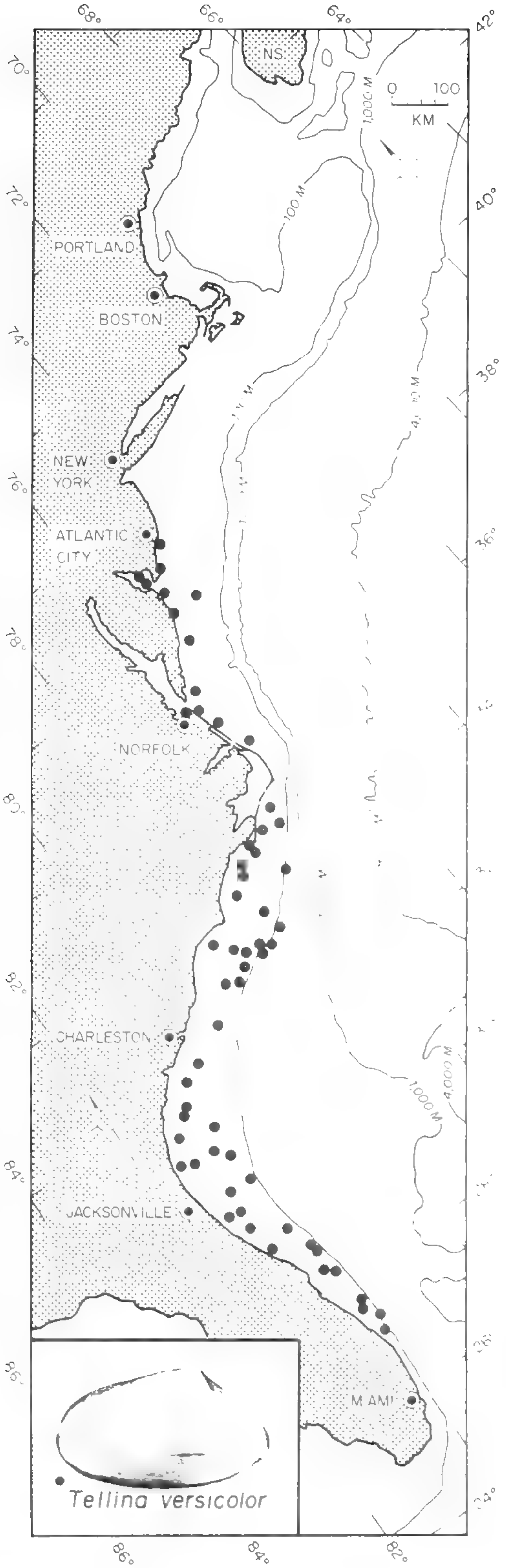

Figure 105.—Geographic distribution of *Tellina versicolor*.

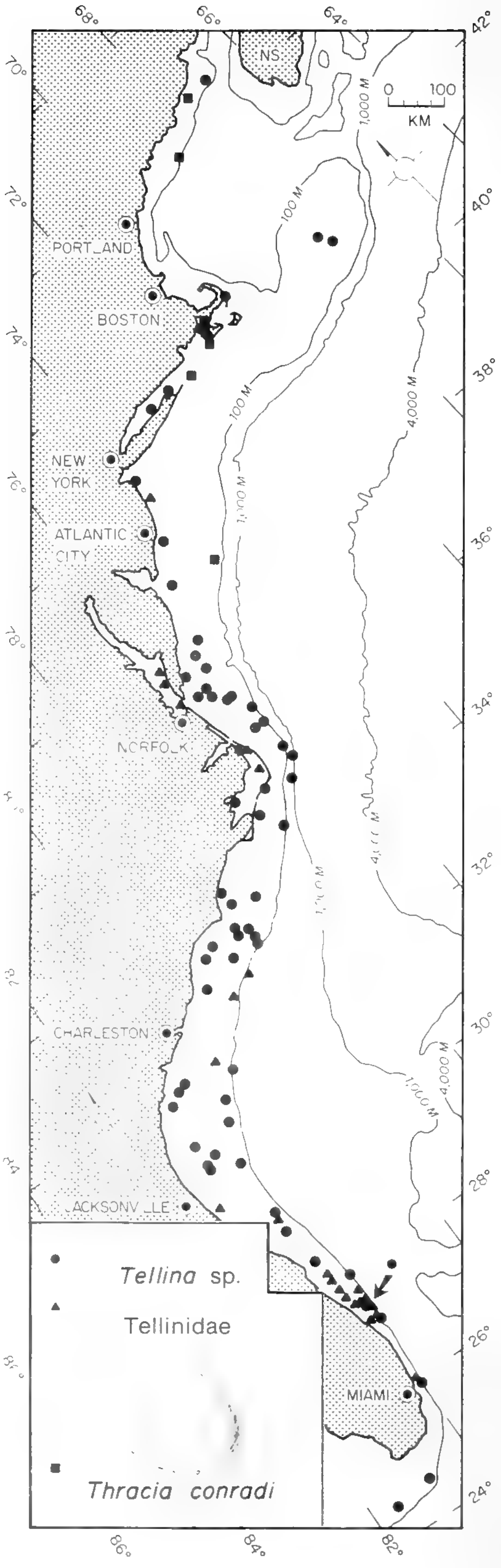

Figure 106.—Geographic distribution of *Tellina* sp., Tellinidae, and *Thracia conradi*.

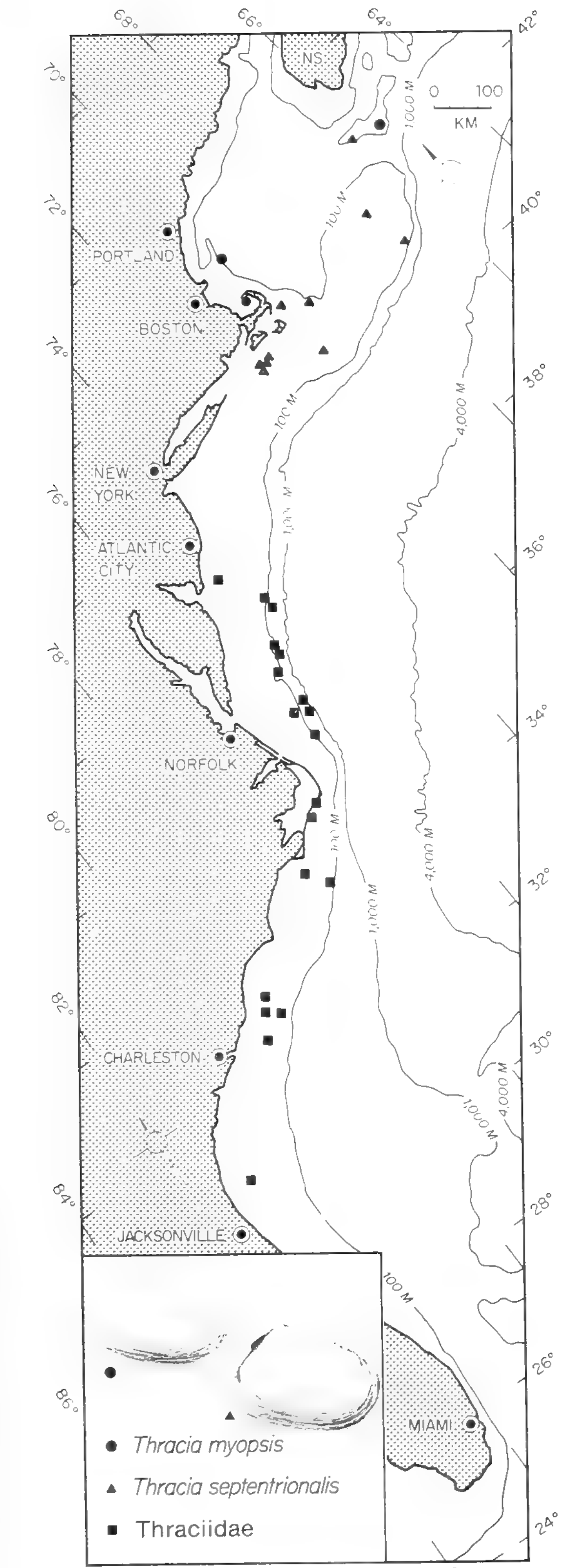

Figure 107.—Geographic distribution of *Thracia myopsis*, *Thracia septentrionalis*, and Thraciidae.

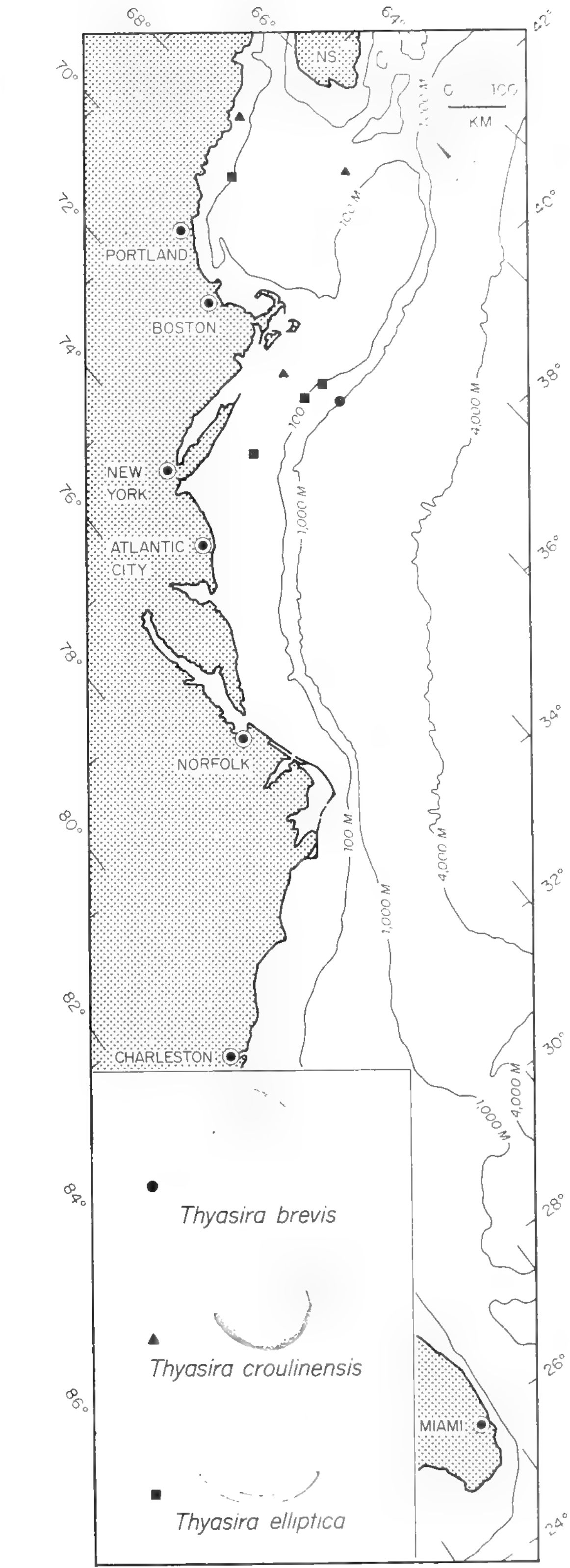

Figure 108.—Geographic distribution of *Thyasira brevis*, *Thyasira croulinensis*, and *Thyasira elliptica*.

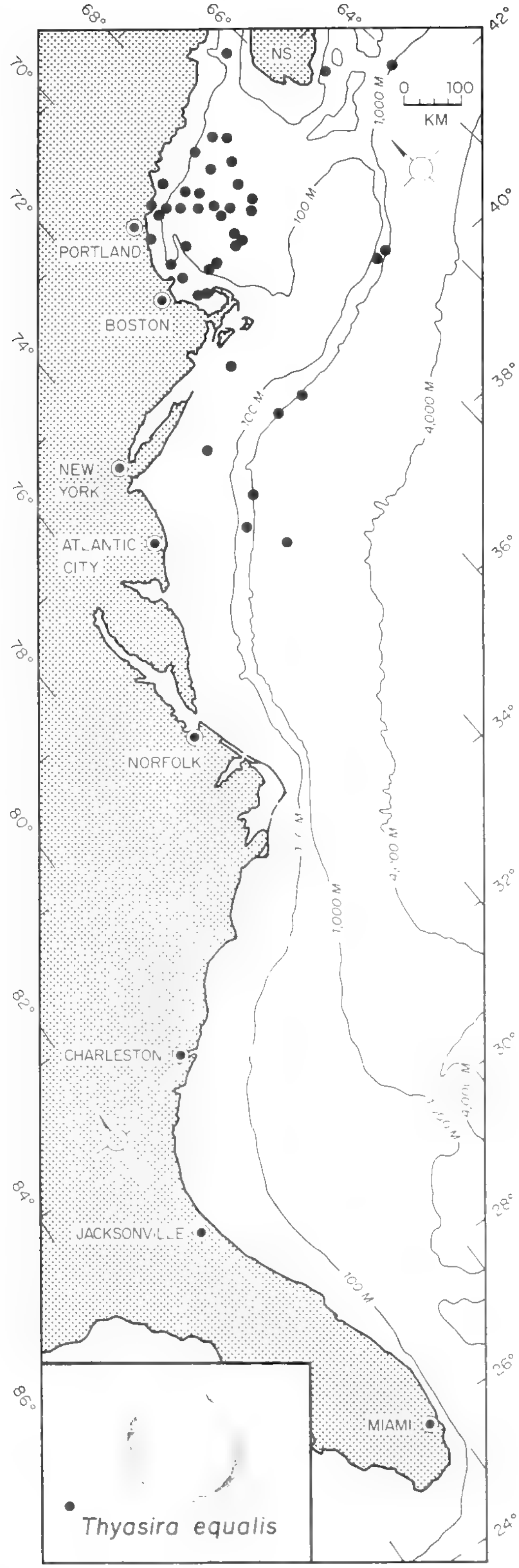

Figure 109.—Geographic distribution of *Thyasira equalis*.

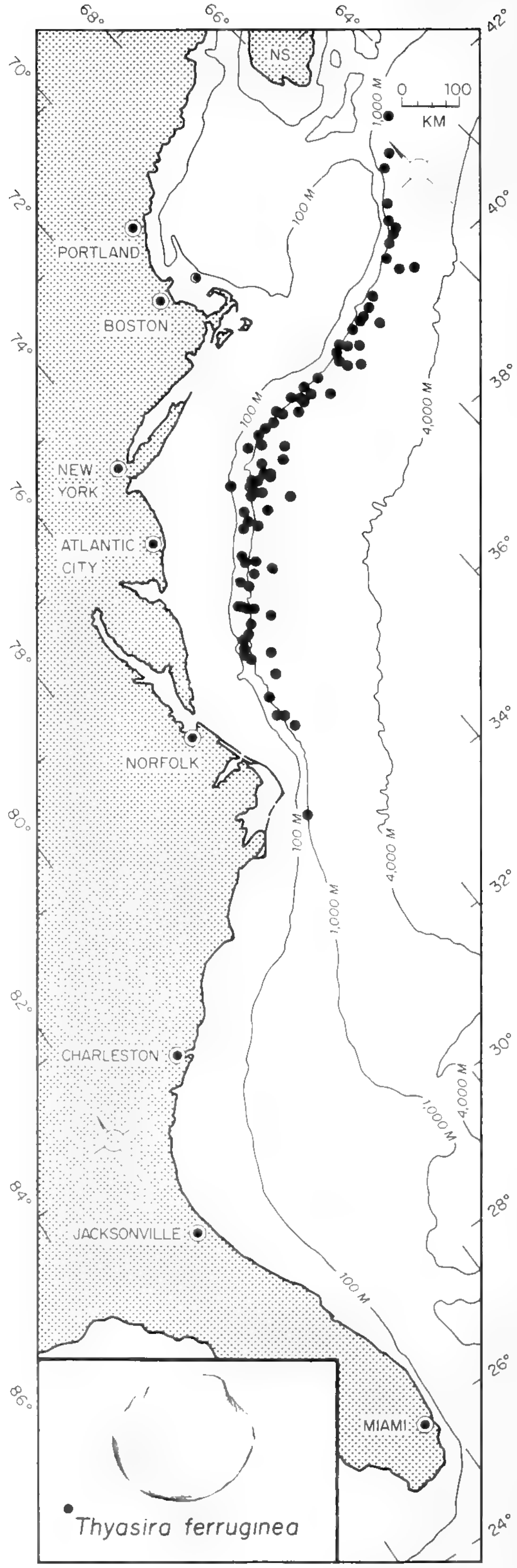

Figure 110.—Geographic distribution of *Thyasira ferruginea*.

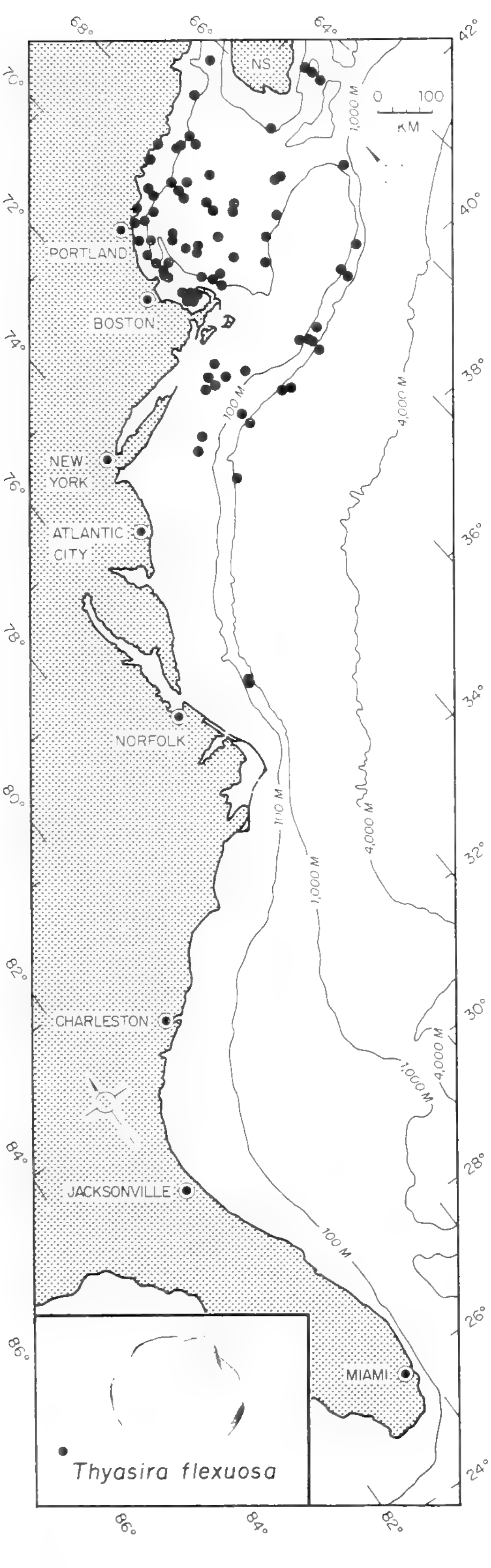

Figure 111.—Geographic distribution of *Thyasira flexuosa.*

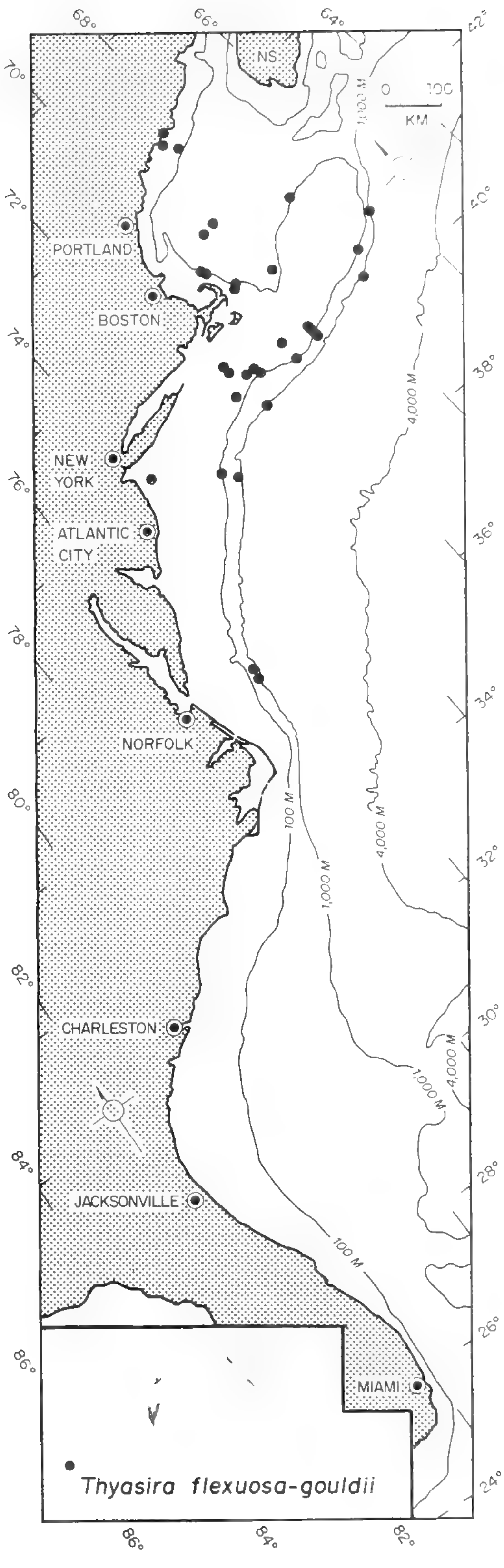

Figure 112.—Geographic distribution of *Thyasira flexuosa-gouldii.*

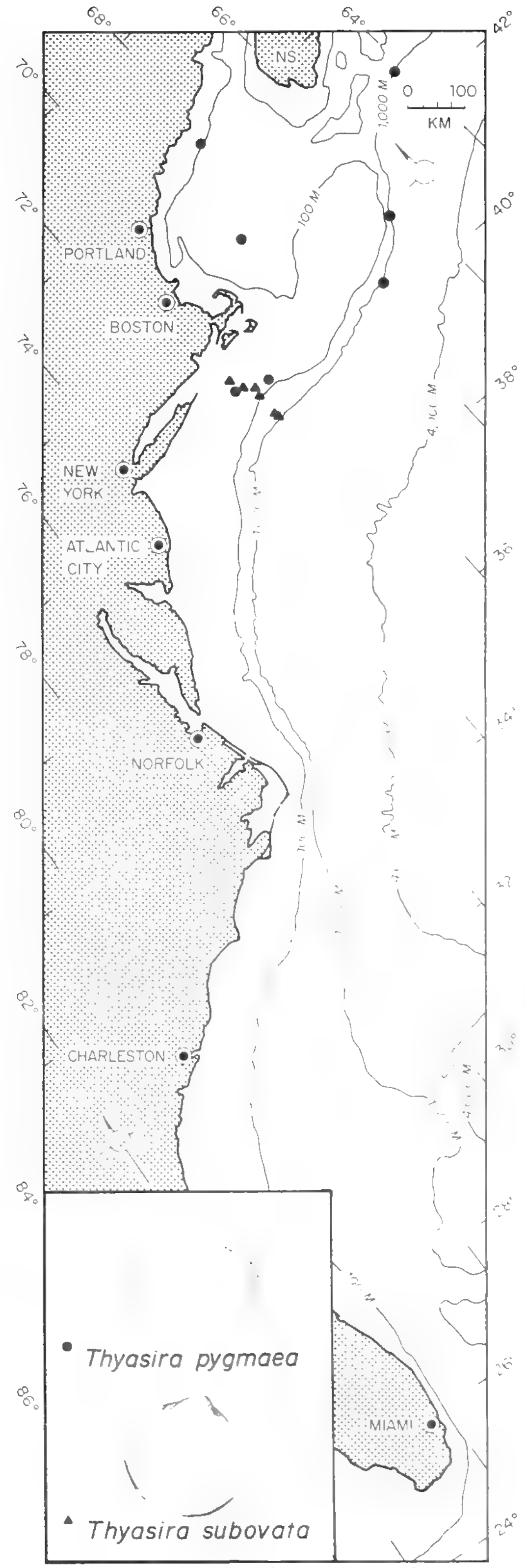

Figure 113.—Geographic distribution of *Thyasira pygmaea* and *Thyasira subovata*.

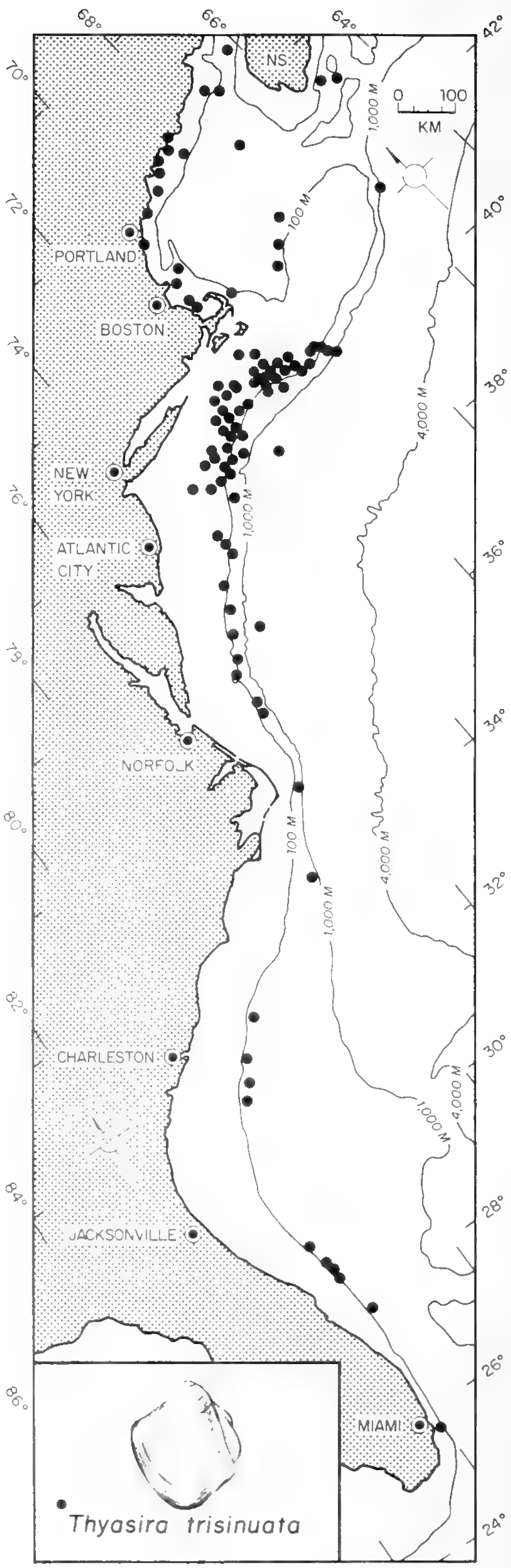

Figure 114.—Geographic distribution of *Thyasira trisinuata*.

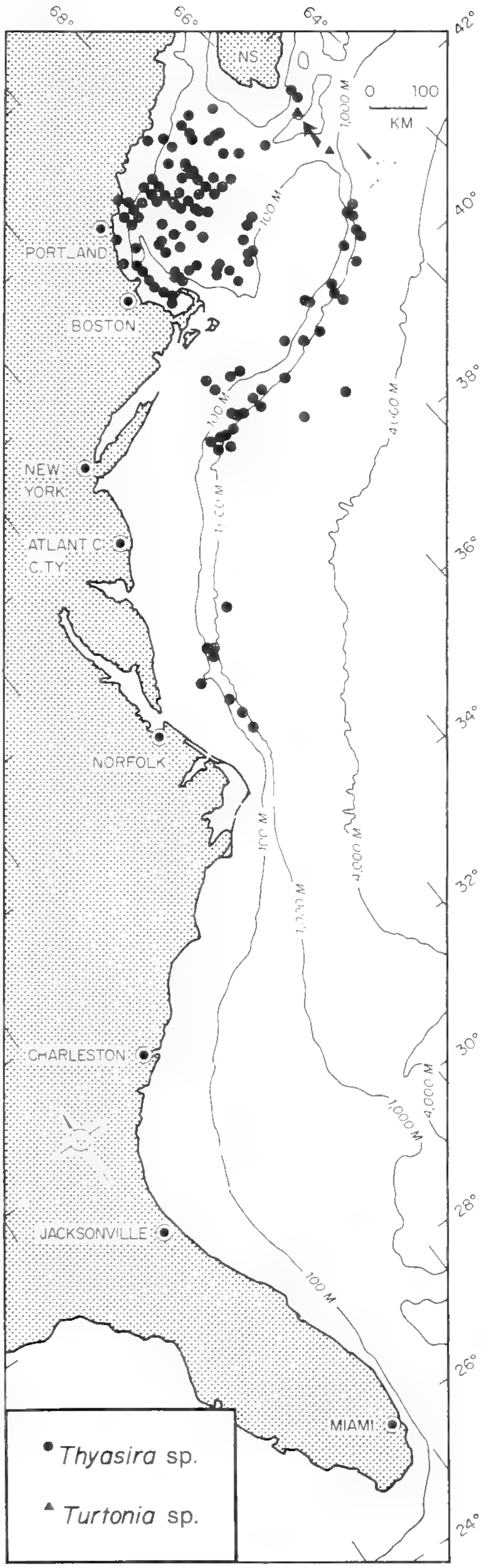

Figure 115.—Geographic distribution of *Thyasira* sp. and *Turtonia* sp.

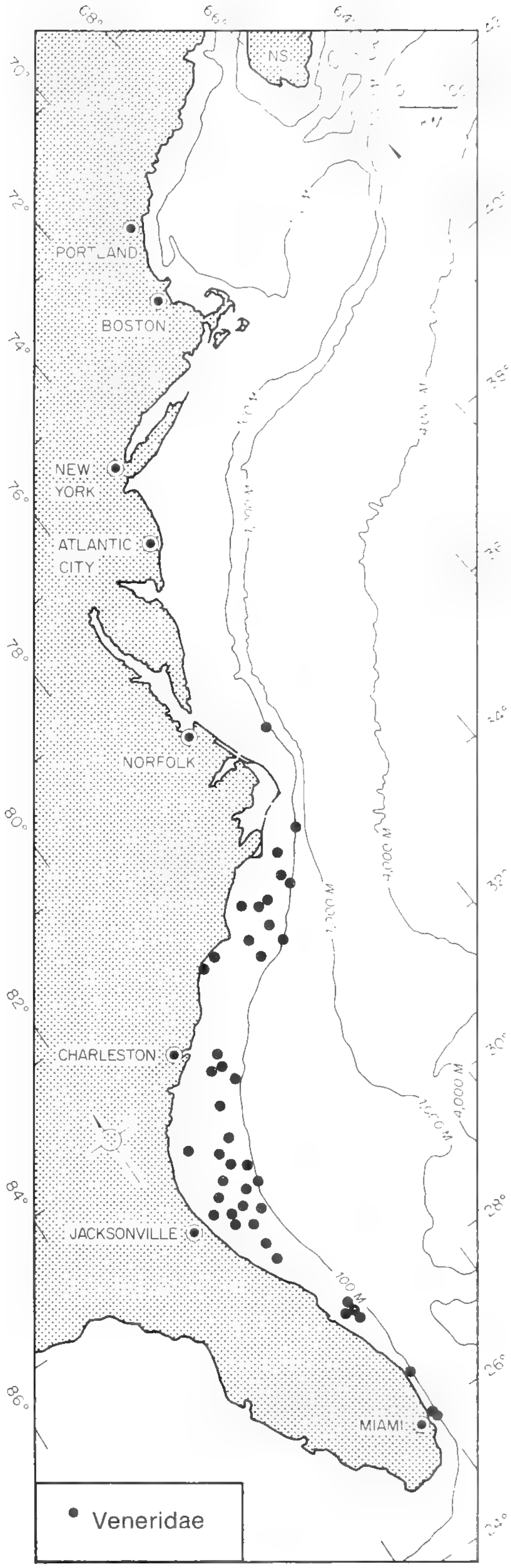

Figure 116.—Geographic distribution of Veneridae.

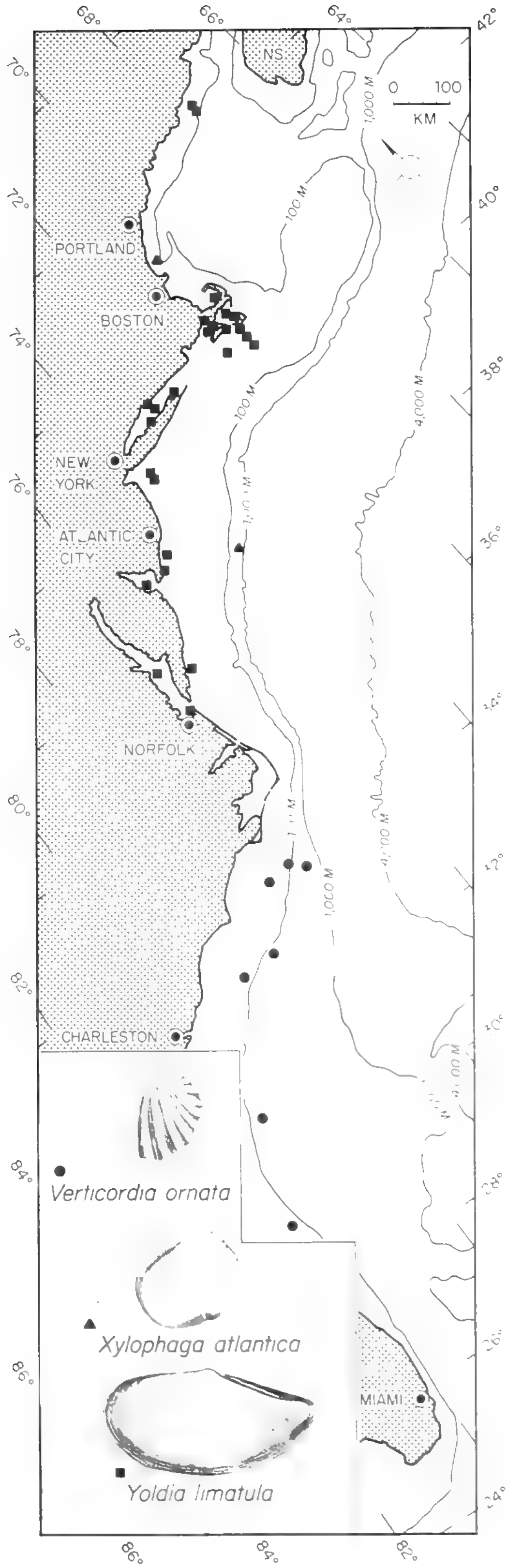

Figure 117.—Geographic distribution of *Verticordia ornata*, *Xylophaga atlantica*, and *Yoldia limatula*.

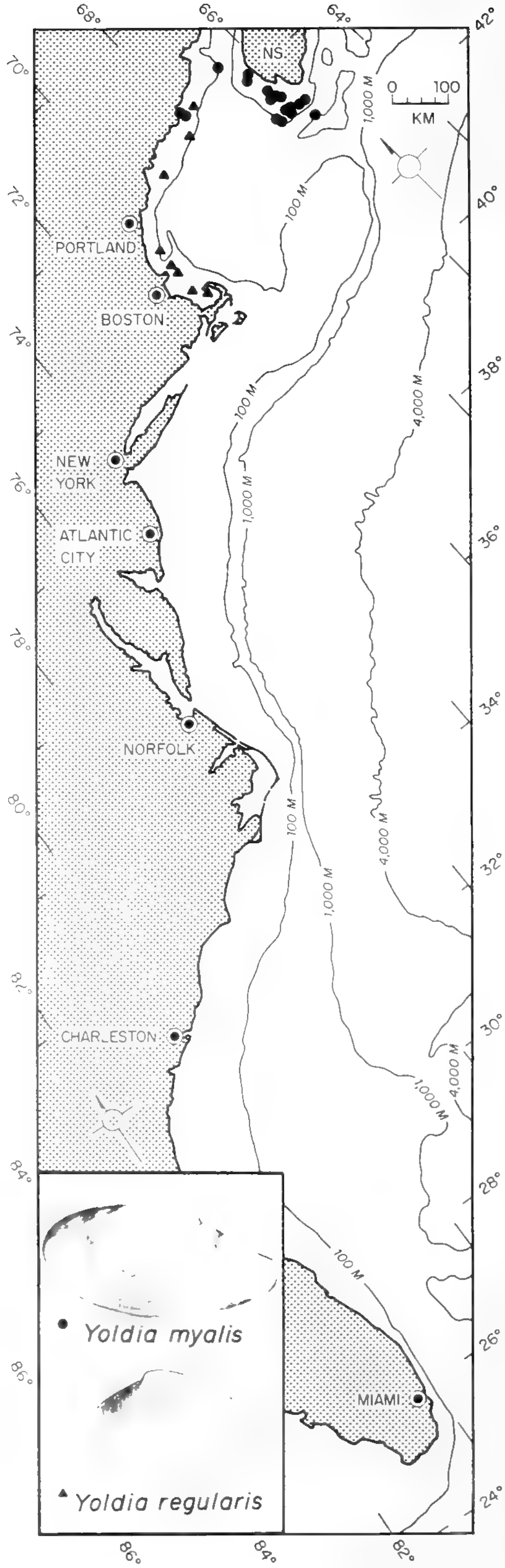

Figure 118.—Geographic distribution of *Yoldia myalis* and *Yoldia regularis*.

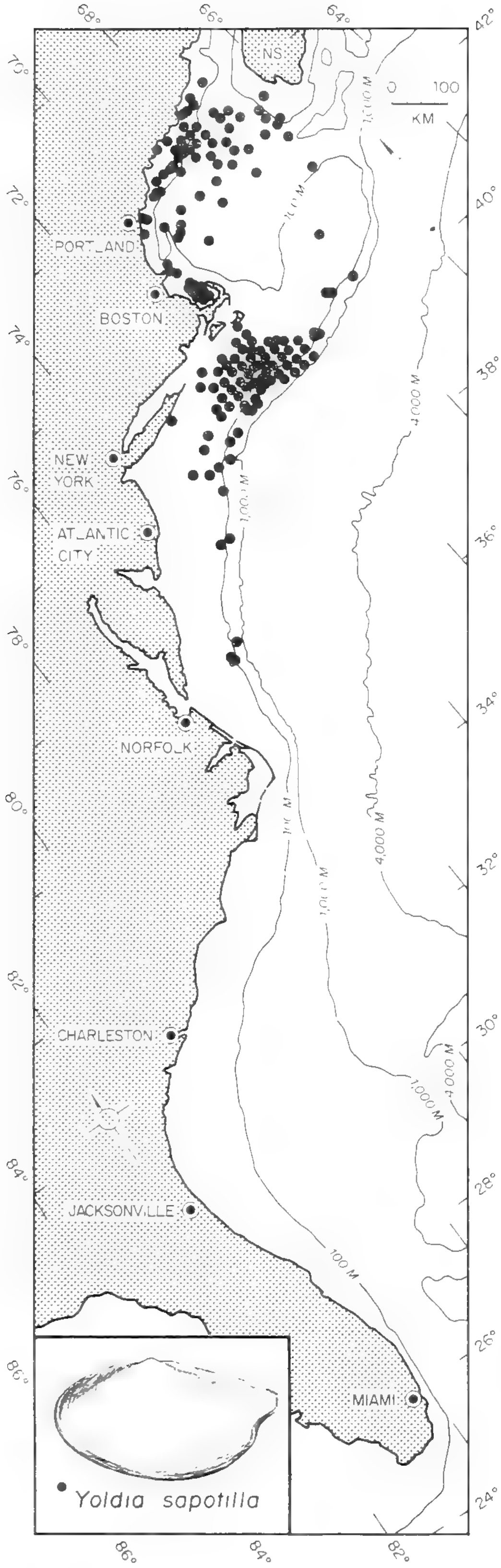

Figure 119.—Geographic distribution of *Yoldia sapotilla*.

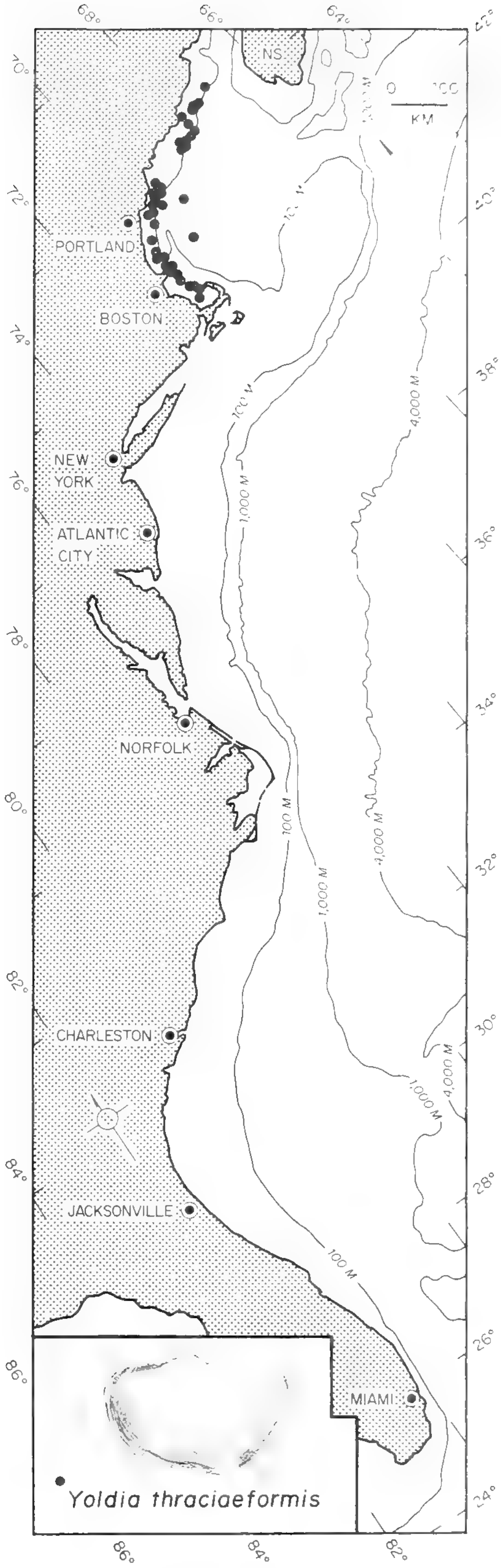

Figure 120.—Geographic distribution of *Yoldia thraciaeformis*.

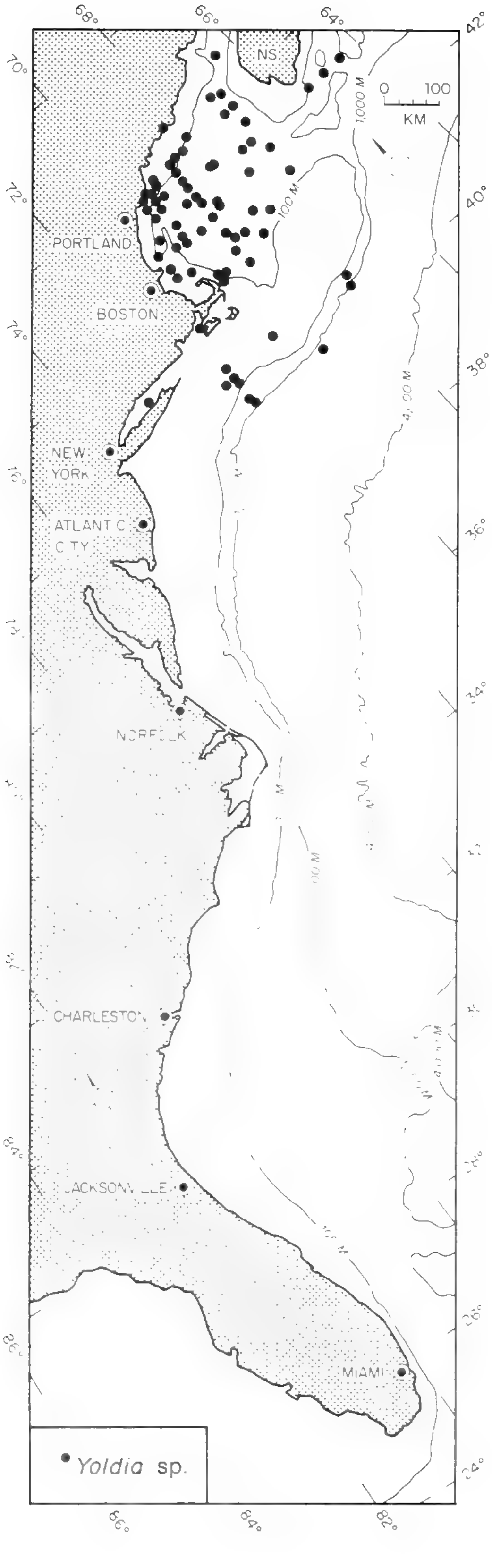

Figure 121.—Geographic distribution of *Yoldia* sp.

Table 1.--The distribution of samples containing bivalve mollusks in the NEFC Specimen Reference Collection by collecting vessel.

Vessel	Samples Number	Samples Percent
A. E. Verrill	6	0.1
Albatross III	984	9.4
Albatross IV	2,735	26.2
Asterias	571	5.5
Blueback	25	0.2
Delaware I & II	1,998	19.1
Fish Hawk	1	<0.1
Gilbert	4	<0.1
Gosnold	3,820	36.6
Harengus	1	<0.1
Priscilla V	3	<0.1
Shirley and Roland	3	<0.1
Silver Mink	18	0.2
Whaling City	1	<0.1
Samples with no designated vessel	295	2.7

Table 2.--The distribution of samples containing bivalve mollusks in the NEFC Specimen Reference Collection by type of sampling gear.

Sampling Gear	Samples No.	Samples %
Bottom Grabs		
Campbell	3,716	35.7
Dietz-LaFond	3	<0.1
Petersen	5	<0.1
Smith-McIntyre	2,099	20.1
Van Veen	90	0.9
WHOI Miniature Van Veen	2	<0.1
Dredges		
Digby drag	323	3.1
Digby scoop	29	0.3
Hydraulic Clam Dredge	37	0.3
MBL Naturalist Dredge	6	0.1
Quahog Dredge	19	0.2
Scallop Dredge	296	2.8
Rock Dredge	19	0.2
WHOI Chain Bag Dredge	19	0.2
WHOI Pipe Dredge	4	<0.1
1-Meter Naturalist Dredge	2,351	22.6
Trawls		
Beam Trawl	1	<0.1
Dutch Herring Trawl	1	<0.1
Isaacs-Kidd Trawl	2	<0.1
Otter Trawl	2	<0.1
6-Foot Seine	33	0.3
Miscellaneous		
Bottom Skimmer	196	1.0
Dip Net	71	0.7
Diver (Scuba)	4	<0.1
Fish Stomachs	97	0.9
Ring Net	181	1.7
1-Meter Sled	83	0.8
Other	92	0.9
Samples with no gear designation	40	0.4

Table 3.--Bathymetric occurrence of Bivalvia, based on 10,465 samples and 108,934 specimens.

Depth Range	Samples	Specimens
m	%	%
0-24	13.7	17.4
24-49	15.8	15.5
50-99	33.6	40.5
100-199	22.1	16.3
200-499	10.4	7.0
500-999	1.7	1.6
1000-1999	1.6	1.0
2000-3999	0.8	0.4
Unknown	0.3	0.3
Total	100.0	100.0

Table 4.--Occurrence of Bivalvia in bottom sediments, based on 10,465 samples and 108,934 specimens.

Bottom Type	Samples	Specimens
	%	%
Gravel	5.5	6.7
Sand-gravel	0.4	0.3
Till	6.0	9.9
Shell	1.4	0.9
Sand-shell	6.0	3.2
Sand	32.0	24.8
Silty sand	12.8	13.8
Silt	8.0	7.8
Clay	6.5	5.3
Unclassified	21.4	27.3
Total	100.0	100.0

Table 5.--Total and percent number of specimens and samples of each bivalve taxon in the NMFS collection.

	Samples		Specimens	
	No.	%	No.	%
Abra sp.	60	0.57	125	0.12
Aequipecten phrygium	1	0.01	10	0.01
Aligena elevata	2	0.02	3	<0.01
Anadara ovalis	3	0.03	3	<0.01
Anadara transversa	6	0.06	17	0.02
Anomia simplex	301	2.88	10,880	9.99
Anomia squamula	279	2.67	4,231	3.88
Arca sp.	11	0.11	19	0.02
Arcidae unident.	7	0.07	15	0.01
Arcinella cornuta	3	0.03	3	<0.01
Arctica islandica	378	3.60	2,081	1.91
Argopecten gibbus	2	0.02	7	0.01
Argopecten irradians	5	0.05	17	0.02
Astarte borealis	18	0.17	22	0.02
Astarte castanea	106	1.02	458	0.42
Astarte crenata subequilatera	433	4.14	4,972	4.56
Astarte elliptica	42	0.40	317	0.29
Astarte montagui	1	0.01	2	<0.01
Astarte nana	4	0.04	18	0.02
Astarte quadrans	28	0.27	48	0.04
Astarte smithii	2	0.02	3	<0.01
Astarte undata	444	4.25	4,705	4.32
Astarte sp.	94	0.90	533	0.49
Axinopsida orbiculata	1	0.01	1	<0.01
Barnea truncata	4	0.04	83	0.08
Barnea sp.	2	0.02	2	<0.01
Bathyarca anomala	9	0.09	129	0.12
Bathyarca pectunculoides	157	1.50	1,297	1.19
Bathyarca sp.	9	0.09	14	0.01
Bivalvia unident.	36	0.34	76	0.07
Brachidontes exustus	2	0.02	12	0.01
Callista eucymata	12	0.12	14	0.01
Cardiidae unident.	6	0.06	15	0.01
Cardiomya perrostrata	13	0.12	24	0.02
Cerastoderma pinnulatum	467	4.46	3,322	3.05
Chama sp.	1	0.01	1	<0.01
Chione intapurpurea	8	0.08	9	0.01
Chione latilirata	17	0.16	24	0.02
Chione sp.	36	0.35	58	0.05
Chlamys islandica	76	0.73	361	0.33
Clinocardium ciliatum	4	0.04	6	0.01
Corbula contracta	22	0.21	46	0.04
Corbula krebsiana	41	0.39	97	0.09
Corbula sp.	1	0.01	2	<0.01
Corbulidae unident.	56	0.54	150	0.14
Crassinella lunulata	87	0.83	226	0.21
Crassinella sp.	3	0.03	9	0.01
Crassostrea virginica	1	0.01	1	<0.01
Crenella decussata	83	0.79	443	0.41
Crenella glandula	229	2.19	1,835	1.68
Crenella sp.	35	0.33	69	0.06
Cumingea tellinoides	2	0.02	2	0.01
Cuspidaria glacialis	49	0.47	184	0.17
Cuspidaria obesa	14	0.13	30	0.03
Cuspidaria parva	2	0.02	3	<0.01
Cuspidaria pellucida	4	0.04	19	0.02
Cuspidaria rostrata	2	0.02	9	0.01
Cuspidaria sp.	69	0.65	114	0.10
Cuspidariidae unident.	9	0.09	11	0.01
Cylcocardia borealis	475	4.54	8,842	8.12
Cyclocardia novangliae	26	0.23	89	0.08
Cyclocardia sp.	16	0.15	22	0.02
Cyclopecten nanus	3	0.03	21	0.02
Cyclopecten pustulosus	30	0.29	58	0.05
Cyrtodaria siliqua	1	0.01	1	<0.01
Dacrydium vitreum	95	0.91	522	0.48
Delectopecten vitreus	3	0.03	12	0.01
Diplodonta sp.	59	0.56	90	0.08
Donax sp.	1	0.01	1	<0.01
Ensis directus	206	1.97	2,150	1.97
Ervilia concentrica	112	1.07	592	0.54
Eucrassatella speciosa	2	0.02	3	<0.01
Gemma gemma	33	0.32	2,211	2.03
Geukensis demissa	11	0.11	38	0.04
Glycymoris americana	1	0.01	1	<0.01
Glycymeris pectinata	20	0.19	40	0.04
Glycymeris sp.	23	0.22	48	0.04
Hiatella arctica	149	1.43	3,474	3.19
Hiatella striata	2	0.02	9	0.01
Hiatellidae unident.	7	0.07	17	0.02
Laevicardium mortoni	47	0.45	104	0.10
Limatula subauriculata	14	0.13	325	0.30
Limatula sp.	14	0.13	22	0.02
Limopsidae unident.	16	0.15	1,052	0.97
Limopsis affinis	4	0.04	10	0.01
Limopsis cristata	3	0.03	4	<0.01
Limopsis minuta	13	0.12	30	0.03
Limopsis sulcata	6	0.06	21	0.02
Limopsis sp.	2	0.02	1	<0.01
Liocyma fluctuosa	1	0.01	22	0.02
Lucinoma blakeana	6	0.06	34	0.03
Lucinoma filosa	241	2.31	2,266	2.08
Lucinoma sp.	4	0.04	4	<0.01
Lucinidae unident.	44	0.42	166	0.15
Lyonsia arenosa	20	0.19	81	0.07
Lyonsia hyalina	129	1.24	544	0.50
Lyonsia sp.	5	0.05	6	0.01
Lyonsiella abyssicola	1	0.01	1	<0.01
Lyonsiella sp.	1	0.01	1	<0.01
Macoma balthica	45	0.43	783	0.72
Macoma calcarea	75	0.72	542	0.50
Macoma tenta	22	0.21	708	0.65
Macoma sp.	10	0.10	12	0.01
Malletia obtusa	38	0.36	145	0.14
Mercenaria mercenaria	9	0.09	21	0.02
Mesodesma arctatum	2	0.02	52	0.05
Modiolus modiolus	127	1.22	1,132	1.04
Montacuta sp.	1	0.01	1	<0.01
Mulinia lateralis	51	0.50	897	0.82
Mulinia sp.	1	0.01	2	<0.01
Musculus corrugatus	11	0.11	88	0.08
Musculus discors	80	0.77	457	0.42
Musculus niger	115	1.10	406	0.37
Musculus sp.	13	0.12	75	0.07
Mya arenaria	64	0.61	290	0.27
Myrtea pristiphora	4	0.04	8	0.01
Mysella sp.	1	0.01	2	<0.01
Mytilidae unident.	33	0.32	201	0.19
Mytilus edulis	107	1.02	5,272	4.84
Nemocardium peramabile	1	0.01	2	<0.01
Noetia ponderosa	1	0.01	5	0.01
Nucula delphinodonta	145	1.39	2,092	1.92
Nucula proxima	223	2.13	12,091	11.10
Nucula tenuis	215	2.06	2,031	1.86
Nucula sp.	108	1.03	961	0.88
Nuculana acuta	59	0.56	352	0.32
Nuculana carpenteri	17	0.16	45	0.04
Nuculana caudata	1	0.01	2	<0.01
Nuculana pernula	119	1.14	320	0.29
Nuculana tenuisulcata	129	1.23	469	0.43
Nuculana sp.	84	0.80	448	0.41
Nuculanidae unident.	98	0.94	834	0.77
Nuculoida	2	0.02	2	<0.01
Ostrea sp.	1	0.01	1	<0.01
Pandora bushiana	8	0.08	15	0.01
Pandora gouldiana	33	0.32	144	0.13
Pandora inflata	17	0.16	34	0.03
Pandora inornata	21	0.20	159	0.15
Pandora trilineata	9	0.09	11	0.01
Pandora sp.	8	0.08	11	0.01
Panomya arctica	19	0.18	64	0.06
Papyridea semisulcata	2	0.02	3	<0.01
Parvilucina blanda	5	0.05	6	0.01
Pectinidae unident.	14	0.13	23	0.02
Periglypta lister	2	0.02	6	0.01
Periploma affine	2	0.02	21	0.02
Periploma fragile	27	0.26	101	0.09
Periploma leanum	27	0.26	60	0.06
Periploma papyratium	265	2.54	2,976	2.73
Periploma sp.	4	0.04	4	<0.01
Petricola pholadiformis	7	0.07	27	0.03
Pitar morrhuanus	102	0.98	723	0.66
Pitar sp.	60	0.57	130	0.12
Placopecten magellanicus	164	1.57	1,225	1.13
Plectodon sp.	4	0.04	6	0.01
Pleuromeris tridentata	61	0.58	168	0.15
Plicatula gibbosa	4	0.04	6	0.01
Poromya sp.	6	0.06	6	0.01
Portlandia fraterna	3	0.03	5	0.01
Portlandia frigida	3	0.03	5	0.01
Portlandia inconspicua	1	0.01	3	<0.01
Portlandia inflata	24	0.23	197	0.18
Portlandia iris	47	0.45	334	0.31
Portlandia lenticula	4	0.04	4	<0.01
Portlandia lucida	27	0.26	161	0.15
Portlandia minuscula	1	0.01	2	<0.01
Propeamussium thalassinum	6	0.06	28	0.03
Pteromeris perplana	14	0.13	28	0.03
Rangia cuneata	4	0.04	9	0.01
Saturnia subovata	22	0.21	70	0.06
[illegible] *bellastriata*	19	0.18	38	0.04
[illegible] *nuculoides*	62	0.59	146	0.13
[illegible] *purpurascens*	4	0.04	6	0.01
[illegible] sp.	2	0.02	3	<0.01
[illegible] *costata*	32	0.31	104	0.10
[illegible] *borealis*	1	0.01	1	<0.01
Solemya velum	33	0.32	67	0.06
Spisula polynyma	2	0.02	14	0.01
Spisula solidissima	166	1.59	764	0.70
Solenidae unident.	11	0.11	39	0.04
Spondylus sp.	1	0.01	2	<0.01
Strigilla mirabilis	9	0.09	12	0.01
Tagelus plebeius	1	0.01	4	<0.01
[illegible] *aequistriata*	1	0.01	1	<0.01
[illegible] *agilis*	114	1.09	1,131	1.04
[illegible] *consobrina*	7	0.07	20	0.02
[illegible]	58	0.55	297	0.27
Tellina sp.	70	0.67	151	0.14
Tellinidae unident.	26	0.25	67	0.06

Table 5.--Cont'd.

	Samples		Specimens	
	No.	%	No.	
Thracia conradi	6	0.06	10	0.01
Thracia myopsis	3	0.03	6	0.01
Thracia septentrionalis	13	0.12	46	0.04
Thraciidae unident.	19	0.18	36	0.03
Thyasira brevis	1	0.01	3	<0.01
Thyasira croulinensis	3	0.03	4	<0.01
Thyasira elliptica	4	0.04	12	0.01
Thyasira equalis	44	0.42	309	0.28
Thyasira ferruginea	92	0.88	1,381	1.27
Thyasira flexuosa	104	1.00	1,044	0.96
Thyasira flexuosa-gouldi	37	0.35	415	0.38
Thyasira pygmaea	8	0.08	64	0.06
Thyasira subovata	7	0.07	18	0.02
Thyasira trisinuata	133	1.27	1,079	0.99
Thyasira sp.	142	1.36	734	0.67
Turtonia sp.	1	0.01	1	<0.01
Veneridae unident.	54	0.52	117	0.11
Verticordia ornata	7	0.07	8	0.01
Xylophaga atlantica	3	0.03	76	0.07
Yoldia limatula	37	0.35	375	0.34
Yoldia myalis	21	0.20	47	0.04
Yoldia regularis	11	0.11	42	0.04
Yoldia sapotilla	279	2.67	2,128	1.95
Yoldia thraciaeformia	46	0.44	158	0.15
Yoldia sp.	88	0.84	303	0.28
Total	10,465		108,934	

Table 6. --Bathymetric occurrence of Unidentified Bivalvia, based on 36 samples and 76 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	19.4	15.8
25-49	5.6	2.6
50-99	41.6	55.3
100-199	16.7	14.5
200-499	16.7	11.8
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 7.--Occurrence of Unidentified Bivalvia in bottom sediments, based on 29 samples and 60 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	3.4	1.7
Sand-gravel	13.8	8.3
Till	3.4	26.7
Shell	3.4	1.7
Sand-shell	3.4	1.7
Sand	44.8	45.0
Silty sand	10.3	6.7
Silt	6.9	3.3
Clay	10.3	4.9
Total	100.0	100.0

Table 8. --Bathymetric occurrence of *Nucula delphinodonta*, based on 145 samples and 2,092 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	5.5	1.8
25-49	13.8	10.6
50-99	40.7	78.2
100-199	17.9	4.3
200-499	13.8	1.6
500-999	4.8	1.3
1000-1999	3.5	2.2
2000-3999	--	--
Total	100.0	100.0

Table 9. --Occurrence of *Nucula delphinodonta* in bottom sediments, based on 143 samples and 2,086 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	2.8	0.7
Sand-gravel	4.2	0.4
Till	4.2	0.8
Shell	2.1	0.5
Sand-shell	0.7	0.2
Sand	23.8	15.6
Silty sand	29.3	72.2
Silt	13.3	3.3
Clay	19.6	6.3
Total	100.0	100.0

Table 10. --Bathymetric occurrence of *Nucula proxima*, based on 221 samples and 12,073 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	30.8	46.9
25-49	26.7	6.9
50-99	36.6	45.4
100-199	5.0	0.8
200-499	0.9	<0.1
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 11. --Occurrence of *Nucula proxima* in bottom sediments, based on 214 samples and 12,059 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	0.9	<0.1
Sand-gravel	2.3	0.2
Till	0.5	0.1
Shell	1.4	0.2
Sand-shell	9.9	0.4
Sand	48.1	40.4
Silty sand	17.3	32.9
Silt	4.2	3.7
Clay	15.4	22.1
Total	100.0	100.0

Table 12. --Bathymetric occurrence of *Nucula tenuis*, based on 215 samples and 2,031 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	0.5	<0.1
25-49	8.4	4.0
50-99	23.7	54.6
100-199	41.4	23.8
200-499	7.9	2.7
500-999	7.9	4.5
1000-1999	9.3	10.0
2000-3999	0.9	0.4
Total	100.0	100.0

Table 13. --Occurrence of *Nucula tenuis* in bottom sediments, based on 200 samples and 1,956 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	3.0	0.5
Sand-gravel	5.5	4.2
Till	3.0	0.8
Shell	1.0	0.9
Sand-shell	0.5	0.1
Sand	17.5	7.8
Silty sand	35.5	36.2
Silt	16.0	20.4
Clay	18.0	29.1
Total	100.0	100.0

Table 14. --Bathymetric occurrence of *Nucula* sp., based on 108 samples and 961 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	2.8	14.5
25-49	10.2	2.3
50-99	7.4	2.1
100-199	12.1	19.8
200-499	15.7	2.7
500-999	12.0	11.1
1000-1999	27.8	37.6
2000-3999	12.0	9.9
Total	100.0	100.0

Table 15. --Occurrence of *Nucula* sp. in bottom sediments, based on 104 samples and 761 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	1.0	0.3
Sand-gravel	1.9	18.5
Till	1.0	1.6
Shell	--	--
Sand-shell	5.8	2.4
Sand	17.3	4.5
Silty sand	29.8	29.8
Silt	31.7	37.2
Clay	11.5	5.7
Total	100.0	100.0

Table 16. --Bathymetric occurrence of *Malletia obtusa*, based on 38 samples and 145 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	--	--
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	52.6	66.2
2000-3999	47.4	33.8
Total	100.0	100.0

Table 17. --Occurrence of *Malletia obtusa* in bottom sediments, based on 38 samples and 145 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	--	--
Silty sand	21.1	17.2
Silt	52.6	62.1
Clay	26.3	20.7
Total	100.0	100.0

Table 18. --Bathymetric occurrence of *Saturnia subovata*, based on 22 samples and 70 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	--	--
100-199	--	--
200-499	--	--
500-999	4.5	4.3
1000-1999	45.5	57.1
2000-3999	50.0	38.6
Total	100.0	100.0

Table 19. --Occurrence of *Saturnia subovata* in bottom sediments, based on 22 samples and 70 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	--	--
Silty sand	22.7	22.8
Silt	63.7	58.6
Clay	13.6	18.6
Total	100.0	100.0

Table 20. --Bathymetric occurrence of Nuculanidae, based on 98 samples and 834 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	3.1	0.5
50-99	4.1	1.0
100-199	10.2	17.6
200-499	56.1	73.0
500-999	24.5	7.5
1000-1999	--	--
2000-3999	2.0	0.4
Total	100.0	100.0

Table 21. --Occurrence of Nuculanidae in bottom sediments, based on 98 samples and 834 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	3.1	1.4
Sand-gravel	--	--
Till	--	--
Shell	2.0	1.8
Sand-shell	10.2	4.1
Sand	33.7	37.9
Silty sand	28.6	35.5
Silt	20.4	18.9
Clay	2.0	0.4
Total	100.0	100.0

Table 22.--Bathymetric occurrence of Nuculana acuta, based on 59 samples and 352 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	15.3	7.1
100-199	79.7	89.5
200-499	5.0	3.4
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 23.--Occurrence of Nuculana acuta in bottom sediments, based on 59 samples and 352 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	33.9	38.3
Silty sand	42.4	48.6
Silt	5.1	1.7
Clay	18.6	11.4
Total	100.0	100.0

Table 24.--Bathymetric occurrence of Nuculana carpenteri, based on 17 samples and 45 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	--	--
100-199	17.6	11.1
200-499	82.4	[illegible]
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 25.--Occurrence of Nuculana carpenteri in bottom sediments, based on 17 samples and 45 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	[illegible]	[illegible]
Silty sand	[illegible]	[illegible]
Silt	[illegible]	[illegible]
Clay	--	--
Total	100.0	100.0

Table 26.--Bathymetric occurrence of Nuculana pernula, based on 119 samples and 320 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	2.5	3.1
50-99	33.6	50.6
100-199	41.2	31.9
200-499	21.9	13.8
500-999	0.8	0.6
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 27.--Occurrence of Nuculana pernula in bottom sediments, based on 113 samples and 306 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	15.9	16.7
Sand-gravel	0.9	0.3
Till	23.9	20.6
Shell	1.8	2.0
Sand-shell	2.6	1.6
Sand	8.0	4.6
Silty sand	14.1	25.5
Silt	8.0	3.9
Clay	24.8	24.8
Total	100.0	100.0

Table 28.--Bathymetric occurrence of Nuculana tenuisulcata, based on 129 samples and 469 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	3.9	2.6
50-99	23.2	26.6
100-199	44.2	40.3
200-499	28.7	30.5
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 29.--Occurrence of Nuculana tenuisulcata in bottom sediments, based on 120 samples and 414 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	8.3	5.6
Sand-gravel	6.7	2.7
Till	20.9	33.3
Shell	--	--
Sand-shell	0.8	1.4
Sand	5.8	2.9
Silty sand	28.3	28.5
Silt	8.3	8.9
Clay	20.9	16.7
Total	100.0	100.0

Table 30. --Bathymetric occurrence of *Nuculana* sp., based on 84 samples and 448 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	2.4	0.7
25-49	11.9	3.8
50-99	21.4	60.9
100-199	41.7	27.9
200-499	22.6	6.7
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 31. --Occurrence of *Nuculana* sp. in bottom sediments, based on 82 samples and 446 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	2.4	2.5
Sand-gravel	--	--
Till	--	--
Shell	2.4	1.1
Sand-shell	17.1	27.6
Sand	24.4	42.8
Silty sand	39.1	21.5
Silt	1.2	0.2
Clay	13.4	4.3
Total	100.0	100.0

Table 32. --Bathymetric occurrence of *Yoldia limatula*, based on 37 samples and 375 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	59.5	64.3
25-49	29.7	28.5
50-99	5.4	6.7
100-199	5.4	0.5
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 33. --Occurrence of *Yoldia limatula* in bottom sediments, based on 30 samples and 342 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	70.1	40.1
Silty sand	23.3	21.6
Silt	3.3	38.0
Clay	3.3	0.3
Total	100.0	100.0

Table 34. --Bathymetric occurrence of *Yoldia myalis*, based on 21 samples and 47 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	4.8	6.4
25-49	9.5	4.3
50-99	80.9	87.2
100-199	4.8	2.1
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 35. --Occurrence of *Yoldia myalis* in bottom sediments, based on 18 samples and 44 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	33.3	25.0
Sand-gravel	27.7	31.8
Till	5.6	2.3
Shell	11.1	27.3
Sand-shell	11.1	4.5
Sand	--	--
Silty sand	5.6	2.3
Silt	5.6	6.8
Clay	--	--
Total	100.0	100.0

Table 36. --Bathymetric occurrence of *Yoldia regularis*, based on 11 samples and 42 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	9.1	2.4
50-99	81.8	76.2
100-199	9.1	21.4
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 37. --Occurrence of *Yoldia regularis* in bottom sediments, based on 11 samples and 42 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	--	--
Silty sand	54.5	21.4
Silt	36.4	57.2
Clay	9.1	21.4
Total	100.0	100.0

Table 38. --Bathymetric occurrence of Yoldia sapotilla, based on 278 samples and 1,980 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	0.7	0.1
25-49	9.7	8.2
50-99	54.7	66.4
100-199	21.2	17.0
200-499	13.7	8.3
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 39. --Occurrence of Yoldia sapotilla in bottom sediments, based on 270 samples and 1,970 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	0.4	<0.1
Till	5.2	2.7
Shell	0.4	<0.1
Sand-shell	0.7	0.2
Sand	27.8	25.2
Silty sand	33.3	37.9
Silt	5.9	6.6
Clay	26.3	27.4
Total	100.0	100.0

Table 40. --Bathymetric occurrence of Yoldia thraciaeformis, based on 46 samples and 158 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	4.3	1.3
50-99	65.3	73.4
100-199	26.1	23.4
200-499	4.3	1.9
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 41. --Occurrence of Yoldia thraciaeformia in bottom sediments, based on 41 samples and 144 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	2.4	2.1
Sand-gravel	--	--
Till	24.4	14.6
Shell	--	--
Sand-shell	--	--
Sand	--	--
Silty sand	12.2	7.6
Silt	12.2	34.0
Clay	48.8	41.7
Total	100.0	100.0

Table 42. --Bathymetric occurrence of Yoldia sp., based on 88 samples and 303 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	1.1	0.7
25-49	4.5	1.7
50-99	14.8	20.1
100-199	43.3	51.4
200-499	35.2	24.8
500-999	--	--
1000-1999	1.1	1.3
2000-3999	--	--
Total	100.0	100.0

Table 43. --Occurrence of Yoldia sp. in bottom sediments, based on 83 samples and 272 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	1.2	0.4
Sand-gravel	2.4	4.8
Till	9.7	5.9
Shell	--	--
Sand-shell	--	--
Sand	9.7	6.9
Silty sand	31.3	31.2
Silt	12.0	10.7
Clay	33.7	40.1
Total	100.0	100.0

Table 44. --Bathymetric occurrence of Portlandia fraterna, based on three samples and five specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	--	--
100-199	66.7	60.0
200-499	33.3	40.0
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 45. --Occurrence of Portlandia fraterna in bottom sediments, based on three samples and five specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	--	--
Silty sand	66.7	60.0
Silt	--	--
Clay	33.3	40.0
Total	100.0	100.0

Table 46. --Bathymetric occurrence of *Portlandia frigida*, based on three samples and five specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	33.3	20.0
100-199	--	--
200-499	66.7	80.0
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 47. --Occurrence of *Portlandia frigida* in bottom sediments, based on three samples and five specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	--	--
Silty sand	33.3	60.0
Silt	--	--
Clay	66.7	40.0
Total	100.0	100.0

Table 48. --Bathymetric occurrence of *Portlandia inflata*, based on 24 samples and 197 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	20.8	6.1
100-199	4.2	1.5
200-499	75.0	92.4
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 49. --Occurrence of *Portlandia inflata* in bottom sediments, based on 24 samples and 197 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	16.6	65.0
Till	4.2	0.5
Shell	--	--
Sand-shell	--	--
Sand	--	--
Silty sand	4.2	1.5
Silt	25.0	13.2
Clay	50.0	19.8
Total	100.0	100.0

Table 50. --Bathymetric occurrence of *Portlandia iris*, based on 47 samples and 334 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	2.1	0.3
25-49	--	--
50-99	14.9	12.6
100-199	27.7	26.0
200-499	55.3	61.1
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 51. --Occurrence of *Portlandia iris* in bottom sediments, based on 46 samples and 331 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	4.3	2.4
Sand-gravel	--	--
Till	15.2	4.5
Shell	--	--
Sand-shell	--	--
Sand	6.5	7.0
Silty sand	28.3	35.3
Silt	15.3	13.3
Clay	30.4	37.5
Total	100.0	100.0

Table 52. --Bathymetric occurrence of *Portlandia lenticula*, based on four samples and four specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	75.0	75.0
100-199	--	--
200-499	25.0	25.0
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 53. --Occurrence of *Portlandia lenticula* in bottom sediments, based on four samples and four specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	--	--
Silty sand	75.0	75.0
Silt	25.0	25.0
Clay	--	--
Total	100.0	100.0

Table 54. --Bathymetric occurrence of Portlandia lucida, based on 27 samples and 161 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	3.7	0.6
25-49	--	--
50-99	18.5	11.2
100-199	44.5	47.8
200-499	33.3	40.4
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 55. --Occurrence of Portlandia lucida in bottom sediments, based on 25 samples and 132 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	4.0	5.3
Sand-gravel	4.0	0.8
Till	16.0	44.7
Shell	--	--
Sand-shell	4.0	4.5
Sand	4.0	0.8
Silty sand	24.0	25.7
Silt	4.0	2.3
Clay	40.0	15.9
Total	100.0	100.0

Table 56.--Bathymetric occurrence of Solemya velum, based on 33 samples and 65 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	42.4	64.6
25-49	15.1	7.7
50-99	27.3	20.0
100-199	6.1	3.1
200-499	6.1	3.1
500-999	--	--
1000-1999	3.0	1.5
2000-3999	--	--
Total	100.0	100.0

Table 57. --Occurrence of Solemya velum in bottom sediments, based on 21 samples and 37 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	9.5	5.4
Sand	57.2	35.1
Silty sand	14.3	48.6
Silt	9.5	5.4
Clay	9.5	5.4
Total	100.0	100.0

Table 58.--Bathymetric occurrence of Arcidae, based on 7 samples and 15 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	42.8	53.3
25-49	--	--
50-99	14.3	13.3
100-199	14.3	6.7
200-499	14.3	6.7
500-999	--	--
1000-1999	--	--
2000-3999	14.3	20.0
Total	100.0	100.0

Table 59.--Occurrence of Arcidae in bottom sediments, based on 7 samples and 15 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	14.3	6.7
Sand-gravel	14.3	6.7
Till	14.3	6.7
Shell	--	--
Sand-shell	--	--
Sand	28.5	46.6
Silty sand	14.3	20.0
Silt	--	--
Clay	14.3	13.3
Total	100.0	100.0

Table 60. --Bathymetric occurrence of Arca sp., based on 11 samples and 19 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	27.3	26.3
25-49	36.3	36.8
50-99	9.1	5.3
100-199	--	--
200-499	9.1	10.5
500-999	18.2	21.1
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 61.--Occurrence of Arca sp. in bottom sediments, based on 11 samples and 19 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	27.3	21.0
Sand	45.4	47.4
Silty sand	18.2	26.3
Silt	9.1	5.3
Clay	--	--
Total	100.0	100.0

Table 62.--Bathymetric occurrence of Bathyarca anomala, based on 9 samples and 129 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	22.3	38.8
100-199	44.4	58.1
200-499	33.3	3.1
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 63.--Occurrence of Bathyarca anomala in bottom sediments, based on 8 samples and 57 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	12.5	3.5
Till	37.5	89.6
Shell	--	--
Sand-shell	--	--
Sand	12.5	1.7
Silty sand	12.5	1.7
Silt	--	--
Clay	25.0	3.5
Total	100.0	100.0

Table 64.--Bathymetric occurrence of Bathyarca pectunculoides, based on 157 samples and 1,297 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	5.1	6.7
100-199	61.1	72.9
200-499	33.8	20.4
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 65.--Occurrence of Bathyarca pectunculoides in bottom sediments, based on 140 samples and 1,095 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	15.7	43.8
Sand-gravel	5.0	1.2
Till	20.0	31.9
Shell	--	--
Sand-shell	--	--
Sand	7.9	2.7
Silty sand	35.7	13.8
Silt	5.7	2.7
Clay	10.0	3.9
Total	100.0	100.0

Table 66.--Bathymetric occurrence of Bathyarca sp., based on 9 samples and 14 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	--	--
100-199	66.7	78.6
200-499	33.3	21.4
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 67. --Occurrence of Bathyarca sp. in bottom sediments, based on 9 samples and 14 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	11.1	7.1
Till	11.1	7.1
Shell	11.1	14.3
Sand-shell	--	--
Sand	11.1	7.1
Silty sand	22.3	14.3
Silt	--	--
Clay	33.3	50.1
Total	100.0	100.0

Table 68. --Bathymetric occurrence of Limopsidae, based on 16 samples and 1,052 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	6.2	0.2
25-49	--	--
50-99	6.2	0.1
100-199	50.0	2.9
200-499	25.0	96.5
500-999	12.6	0.3
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 69. --Occurrence of Limopsidae in bottom sediments, based on 16 samples and 1,052 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	6.2	0.2
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	18.8	0.5
Sand	50.0	98.8
Silty sand	12.5	0.3
Silt	12.5	0.2
Clay	--	--
Total	100.0	100.0

Table 70. --Bathymetric occurrence of Limopsis affinis, based on 4 samples and 10 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	--	--
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	100.0	100.0
2000-3999	--	--
Total	100.0	100.0

Table 71. --Occurrence of Limopsis affinis in bottom sediments, based on 4 samples and 10 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	--	--
Silty sand	25.0	40.0
Silt	50.0	20.0
Clay	25.0	40.0
Total	100.0	100.0

Table 72. --Bathymetric occurrence of Limopsis cristata, based on three samples and four specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	33.3	25.0
25-49	--	--
50-99	--	--
100-199	--	--
200-499	33.3	25.0
500-999	--	--
1000-1999	33.3	50.0
2000-3999	--	--
Total	100.0	100.0

Table 73. --Occurrence of Limopsis cristata in bottom sediments, based on three samples and four specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	--	--
Silty sand	66.7	50.0
Silt	33.3	50.0
Clay	--	--
Total	100.0	100.0

Table 74. --Bathymetric occurrence of Limopsis minuta, based on 13 samples and 30 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	7.7	3.3
25-49	--	--
50-99	--	--
100-199	--	--
200-499	7.7	3.3
500-999	23.1	33.3
1000-1999	61.5	60.1
2000-3999	--	--
Total	100.0	100.0

Table 75. --Occurrence of Limopsis minuta in bottom sediments, based on 13 samples and 30 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	7.7	3.3
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	7.7	20.0
Silty sand	30.8	23.3
Silt	30.8	16.7
Clay	23.0	36.7
Total	100.0	100.0

Table 76. --Bathymetric occurrence of Limopsis sulcata, based on 6 samples and 21 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	16.7	47.6
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	83.3	52.4
2000-3999	--	--
Total	100.0	100.0

Table 77. --Occurrence of Limopsis sulcata in bottom sediments, based on 6 samples and 21 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	--	--
Silty sand	33.3	14.3
Silt	33.3	33.3
Clay	33.3	52.4
Total	100.0	100.0

Table 78. --Bathymetric occurrence of *Limopsis* sp., based on two samples and two specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	--	--
100-199	--	--
200-499	50.0	50.0
500-999	--	--
1000-1999	50.0	50.0
2000-3999	--	--
Total	100.0	100.0

Table 79. --Occurrence of *Limopsis* sp. in bottom sediments, based on two samples and two specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	--	--
Silty sand	50.0	50.0
Silt	50.0	50.0
Clay	--	--
Total	100.0	100.0

Table 80. --Bathymetric occurrence of *Glycymeris pectinata*, based on 20 samples and 40 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	30.0	30.0
25-49	55.0	37.5
50-99	--	--
100-199	15.0	32.5
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 81. --Occurrence of *Glycymeris pectinata* in bottom sediments, based on 20 samples and 40 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	5.0	10.0
Till	--	--
Shell	--	--
Sand-shell	40.0	55.0
Sand	50.0	30.0
Silty sand	5.0	5.0
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 82. --Bathymetric occurrence of *Glycymeris* sp., based on 23 samples and 48 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	21.7	29.2
25-49	39.1	41.6
50-99	--	--
100-199	4.4	2.1
200-499	30.4	22.9
500-999	4.4	4.2
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 83. --Occurrence of *Glycymeris* sp. in bottom sediments, based on 23 samples and 48 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	4.4	2.1
Sand-shell	21.7	14.6
Sand	73.9	83.3
Silty sand	--	--
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 84. --Bathymetric occurrence of Mytilidae, based on 33 samples and 201 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	9.1	2.0
25-49	6.1	21.4
50-99	21.2	17.9
100-199	36.4	49.2
200-499	24.2	7.5
500-999	3.0	2.0
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 85. --Occurrence of Mytilidae in bottom sediments, based on 26 samples and 171 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	7.7	19.9
Sand-gravel	11.6	41.5
Till	7.7	2.4
Shell	--	--
Sand-shell	3.8	14.0
Sand	19.2	2.9
Silty sand	7.7	7.6
Silt	15.4	6.4
Clay	26.9	5.3
Total	100.0	100.0

Table 86.--Bathymetric occurrence of *Crenella decussata*, based on 83 samples and 443 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	3.6	0.9
25-49	12.0	18.1
50-99	61.5	67.9
100-199	20.5	12.6
200-499	2.4	0.5
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 87.--Occurrence of *Crenella decussata* in bottom sediments, based on 81 samples and 439 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	3.7	4.1
Sand-gravel	7.4	3.9
Till	1.2	0.5
Shell	2.5	0.6
Sand-shell	--	--
Sand	34.6	25.1
Silty sand	29.6	56.0
Silt	3.7	0.9
Clay	17.3	8.9
Total	100.0	100.0

Table 88.--Bathymetric occurrence of *Crenella glandula*, based on 229 samples and 1,835 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	3.5	6.4
25-49	8.7	45.8
50-99	54.6	30.7
100-199	29.7	16.2
200-499	3.5	0.9
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 89.--Occurrence of *Crenella glandula* in bottom sediments, based on 205 samples and 1,696 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	7.8	6.7
Sand-gravel	7.8	5.8
Till	15.6	33.4
Shell	1.5	0.3
Sand-shell	2.3	0.6
Sand	33.7	21.3
Silty sand	17.1	27.0
Silt	2.0	1.2
Clay	12.2	3.7
Total	100.0	100.0

Table 90.--Bathymetric occurrence of *Crenella* sp., based on 35 samples and 69 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	14.3	7.3
25-49	14.3	13.0
50-99	28.6	18.8
100-199	37.0	56.5
200-499	--	--
500-999	--	--
1000-1999	2.9	2.9
2000-3999	2.9	1.5
Total	100.0	100.0

Table 91.--Occurrence of *Crenella* sp. in bottom sediments, based on 32 samples and 63 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	12.5	9.5
Sand-gravel	9.4	28.6
Till	--	--
Shell	3.1	11.1
Sand-shell	6.2	3.2
Sand	34.4	27.0
Silty sand	21.9	11.1
Silt	3.1	3.2
Clay	9.4	6.3
Total	100.0	100.0

Table 92.--Bathymetric occurrence of *Dacrydium vitreum*, based on 94 samples and 519 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	1.1	0.4
50-99	--	--
100-199	52.1	71.3
200-499	38.3	26.2
500-999	2.1	0.4
1000-1999	5.3	1.5
2000-3999	1.1	0.2
Total	100.0	100.0

Table 93.--Occurrence of *Dacrydium vitreum* in bottom sediments, based on 92 samples and 511 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	4.3	2.9
Sand-gravel	2.2	0.4
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	12.0	5.5
Silty sand	18.5	14.3
Silt	8.7	3.3
Clay	54.3	73.6
Total	100.0	100.0

Table 94. --Bathymetric occurrence of *Geukensia demissa*, based on 10 samples and 36 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	100.0	100.0
25-49	--	--
50-99	--	--
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 95. --Occurrence of *Geukensia demissa* in bottom sediments, based on 4 samples and 18 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	25.0	5.6
Silty sand	75.0	94.4
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 96. --Bathymetric occurrence of *Modiolus modiolus*, based on 127 samples and 1,132 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	2.4	0.3
25-49	22.8	58.3
50-99	55.1	26.8
100-199	17.3	9.7
200-499	2.4	4.9
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 97. --Occurrence of *Modiolus modiolus* in bottom sediments, based on 98 samples and 953 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	17.4	4.7
Sand-gravel	23.5	23.5
Till	6.1	3.6
Shell	5.1	0.8
Sand-shell	6.1	54.4
Sand	33.7	9.9
Silty sand	6.1	2.9
Silt	1.0	0.1
Clay	1.0	0.1
Total	100.0	100.0

Table 98. --Bathymetric occurrence of *Musculus corrugatus*, based on 11 samples and 88 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	18.2	2.3
50-99	72.7	75.0
100-199	9.1	22.7
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 99. --Occurrence of *Musculus corrugatus* in bottom sediments, based on 10 samples and 87 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	40.0	60.9
Till	30.0	33.3
Shell	10.0	3.5
Sand-shell	--	--
Sand	20.0	2.3
Silty sand	--	--
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 100.--Bathymetric occurrence of *Musculus discors*, based on 80 samples and 457 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	17.5	53.8
50-99	58.8	40.3
100-199	23.7	5.9
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 101.--Occurrence of *Musculus discors* in bottom sediments, based on 57 samples and 417 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	21.1	5.1
Sand-gravel	42.1	82.0
Till	15.8	4.3
Shell	1.7	3.8
Sand-shell	3.5	0.8
Sand	8.8	2.4
Silty sand	1.7	0.2
Silt	--	--
Clay	5.3	1.4
Total	100.0	100.0

Table 102.--Bathymetric occurrence of *Musculus niger*, based on 115 samples and 406 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	2.6	1.0
25-49	20.0	24.4
50-99	54.8	58.1
100-199	21.7	16.3
200-499	0.9	0.2
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 103.--Occurrence of *Musculus niger* in bottom sediments, based on 105 samples and 372 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	9.5	7.0
Sand-gravel	15.2	19.9
Till	6.7	24.5
Shell	1.0	0.5
Sand-shell	1.9	0.5
Sand	40.0	25.2
Silty sand	10.5	9.7
Silt	5.7	4.6
Clay	9.5	8.1
Total	100.0	100.0

Table 104.--Bathymetric occurrence of *Musculus* sp., based on 13 samples and 75 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	7.7	10.7
50-99	53.8	22.7
100-199	15.4	57.3
200-499	23.1	9.3
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 105.--Occurrence of *Musculus* sp. in bottom sediments, based on 10 samples and 71 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	20.0	60.6
Sand-gravel	30.0	26.8
Till	10.0	4.2
Shell	--	--
Sand-shell	--	--
Sand	10.0	1.4
Silty sand	10.0	1.4
Silt	--	--
Clay	20.0	5.6
Total	100.0	100.0

Table 106.--Bathymetric occurrence of *Mytilus edulis*, based on 106 samples and 5,269 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	34.0	14.5
25-49	21.7	72.5
50-99	33.0	12.4
100-199	8.5	0.5
200-499	2.8	0.1
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 107.--Occurrence of *Mytilus edulis* in bottom sediments, based on 62 samples and 1,083 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	6.5	2.7
Sand-gravel	16.2	43.8
Till	3.2	1.1
Shell	1.6	0.3
Sand-shell	--	--
Sand	43.5	12.9
Silty sand	22.6	37.8
Silt	1.6	0.1
Clay	4.8	1.3
Total	100.0	100.0

Table 108.--Bathymetric occurrence of Pectinidae, based on 14 samples and 23 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	7.1	4.4
25-49	35.7	30.4
50-99	14.3	8.7
100-199	28.6	21.7
200-499	14.3	34.8
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 109.--Occurrence of Pectinidae in bottom sediments, based on 12 samples and 21 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	8.3	4.8
Sand-gravel	--	--
Till	--	--
Shell	8.3	9.5
Sand-shell	25.0	14.3
Sand	33.4	28.6
Silty sand	16.7	9.5
Silt	8.3	33.3
Clay	--	--
Total	100.0	100.0

Table 110.--Bathymetric occurrence of *Chlamys islandica*, based on 76 samples and 361 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	3.9	0.9
50-99	38.2	74.8
100-199	52.6	22.4
200-499	5.3	1.9
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 111.--Occurrence of *Chlamys islandica* in bottom sediments, based on 48 samples and 276 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	52.1	59.8
Sand-gravel	18.7	31.9
Till	10.4	2.5
Shell	--	--
Sand-shell	--	--
Sand	10.4	4.0
Silty sand	2.1	0.7
Silt	2.1	0.4
Clay	4.2	0.7
Total	100.0	100.0

Table 112.--Bathymetric occurrence of *Cyclopecten nanus*, based on 3 samples and 21 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	66.7	52.4
100-199	33.3	47.6
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 113.--Occurrence of *Cyclopecten nanus* in bottom sediments, based on 3 samples and 21 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	100.0	100.0
Silty sand	--	--
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 114.--Bathymetric occurrence of *Cyclopecten pustulosus*, based on 30 samples and 58 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	--	--
100-199	63.3	53.5
200-499	30.0	43.1
500-999	6.7	3.4
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 115.--Occurrence of *Cyclopecten pustulosus* in bottom sediments, based on 25 samples and 44 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	8.0	22.8
Sand-gravel	24.0	15.9
Till	20.0	31.8
Shell	--	--
Sand-shell	--	--
Sand	24.0	13.6
Silty sand	20.0	13.6
Silt	--	--
Clay	4.0	2.3
Total	100.0	100.0

Table 116.--Bathymetric occurrence of *Delectopecten vitreus*, based on 3 samples and 12 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	--	--
100-199	--	--
200-499	66.7	66.7
500-999	33.3	33.3
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 117.--Occurrence of *Delectopecten vitreus* in bottom sediments, based on one sample and four specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	100.0	100.0
Shell	--	--
Sand-shell	--	--
Sand	--	--
Silty sand	--	--
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table118. --Bathymetric occurrence of Placopecten magellanicus, based on 164 samples and 1,225 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	6.7	3.5
50-99	59.8	61.5
100-199	30.5	33.8
200-499	3.0	1.2
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 119.--Occurrence of Placopecten magellanicus in bottom sediments, based on 98 samples and 622 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	15.3	4.7
Sand-gravel	19.4	50.3
Till	--	--
Shell	1.0	0.5
Sand-shell	5.1	2.6
Sand	37.8	30.2
Silty sand	7.1	3.8
Silt	2.0	0.5
Clay	11.2	7.4
Total	100.0	100.0

Table 120.--Bathymetric occurrence of Propeamussium thalassinum, based on 6 samples and 28 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	16.7	7.1
100-199	66.6	50.0
200-499	16.7	42.9
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 121. --Occurrence of Propeamussium thalassinum in bottom sediments, based on 4 samples and 26 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	25.0	7.8
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	25.0	46.1
Silty sand	50.0	46.1
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 122.--Bathymetric occurrence of Plicatula gibbosa, based on four samples and six specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	25.0	33.3
25-49	50.0	33.3
50-99	25.0	33.3
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 123.--Occurrence of Plicatula gibbosa in bottom sediments, based on four samples and six specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	75.0	83.3
Sand	25.0	16.7
Silty sand	--	--
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 124.--Bathymetric occurrence of Anomia simplex, based on 301 samples and 10,880 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	3.0	0.2
25-49	5.6	9.6
50-99	47.2	70.3
100-199	28.3	12.5
200-499	15.6	7.3
500-999	0.3	<0.1
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table125.--Occurrence of Anomia simplex in bottom sediments, based on 225 samples and 8,978 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	14.3	17.2
Sand-gravel	20.0	31.2
Till	12.5	3.4
Shell	1.3	0.7
Sand-shell	4.4	5.3
Sand	32.9	38.3
Silty sand	8.0	1.8
Silt	1.3	1.1
Clay	5.3	1.0
Total	100.0	100.0

Table 126.--Bathymetric occurrence of Anomia squamula, based on 279 samples and 4,231 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	1.8	0.2
25-49	5.4	11.9
50-99	39.7	41.7
100-199	35.1	27.1
200-499	17.6	19.1
500-999	0.4	<0.1
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 127.--Occurrence of Anomia squamula in bottom sediments, based on 217 samples and 3,083 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	17.6	22.4
Sand-gravel	22.1	29.9
Till	18.4	13.1
Shell	1.8	1.2
Sand-shell	0.9	0.4
Sand	24.5	18.5
Silty sand	8.3	4.3
Silt	0.9	5.5
Clay	5.5	4.7
Total	100.0	100.0

Table 128.--Bathymetric occurrence of Limatula subauriculata, based on 14 samples and 328 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	--	--
100-199	21.4	1.8
200-499	21.4	92.7
500-999	14.3	0.9
1000-1999	42.9	4.6
2000-3999	--	--
Total	100.0	100.0

Table 129.--Occurrence of Limatula subauriculata in bottom sediments, based on 14 samples and 328 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	7.1	0.3
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	28.6	93.9
Silty sand	28.6	3.4
Silt	35.7	2.4
Clay	--	--
Total	100.0	100.0

Table 130.--Bathymetric occurrence of Limatula sp., based on 14 samples and 22 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	14.3	27.3
25-49	21.5	13.6
50-99	14.3	9.1
100-199	7.1	9.1
200-499	35.7	36.4
500-999	7.1	4.5
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 131.--Occurrence of Limatula sp. in bottom sediments, based on 14 samples and 22 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	7.2	4.5
Till	--	--
Shell	--	--
Sand-shell	21.4	31.9
Sand	21.4	18.2
Silty sand	7.1	4.5
Silt	42.9	40.9
Clay	--	--
Total	100.0	100.0

Table 132.--Bathymetric occurrence of Lucinidae , based on 44 samples and 166 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	81.8	93.4
25-49	13.7	5.4
50-99	4.5	1.2
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 133.--Occurrence of Lucinidae in bottom sediments, based on 44 samples and 166 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	2.3	1.2
Sand-shell	22.7	11.4
Sand	72.7	86.8
Silty sand	2.3	0.6
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 134.--Bathymetric occurrence of *Lucinoma blakeana*, based on 6 samples and 34 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	50.0	38.3
100-199	33.3	58.8
200-499	16.7	2.9
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 135.--Occurrence of *Lucinoma blakeana* in bottom sediments, based on 6 samples and 34 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	50.0	38.2
Silty sand	50.0	61.8
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 136.--Bathymetric occurrence of *Lucinoma filosa*, based on 241 samples and 2,266 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	0.4	<0.1
25-49	2.5	0.4
50-99	44.8	31.7
100-199	38.2	51.4
200-499	12.0	16.3
500-999	1.7	0.2
1000-1999	0.4	<0.1
2000-3999	--	--
Total	100.0	100.0

Table 137.--Occurrence of *Lucinoma filosa* in bottom sediments, based on 241 samples and 2,266 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	1.7	0.4
Sand	42.3	39.4
Silty sand	37.3	48.1
Silt	5.0	1.4
Clay	13.7	10.7
Total	100.0	100.0

Table 138.--Bathymetric occurrence of *Lucinoma* sp., based on four samples and four specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	25.0	25.0
25-49	--	--
50-99	--	--
100-199	--	--
200-499	25.0	25.0
500-999	25.0	25.0
1000-1999	25.0	25.0
2000-3999	--	--
Total	100.0	100.0

Table 139.--Occurrence of *Lucinoma* sp. in bottom sediments, based on four samples and four specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	--	--
Silty sand	75.0	75.0
Silt	25.0	25.0
Clay	--	--
Total	100.0	100.0

Table 140.--Bathymetric occurrence of *Parvilucina blanda*, based on five samples and six specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	20.0	16.7
25-49	80.0	83.3
50-99	--	--
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 141.--Occurrence of *Parvilucina blanda* in bottom sediments, based on five samples and six specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	20.0	16.7
Sand	60.0	66.6
Silty sand	20.0	16.7
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 142.--Bathymetric occurrence of *Thyasira croulinensis*, based on three samples and four specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	33.3	25.0
50-99	33.3	25.0
100-199	--	--
200-499	33.3	50.0
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 143.--Occurrence of *Thyasira croulinensis* in bottom sediments, based on three samples and four specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	33.3	25.0
Shell	--	--
Sand-shell	--	--
Sand	--	--
Silty sand	33.3	50.0
Silt	33.3	25.0
Clay	--	--
Total	100.0	100.0

Table 144.--Bathymetric occurrence of *Thyasira elliptica*, based on 4 samples and 12 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	75.0	91.7
100-199	25.0	8.3
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 145.--Occurrence of *Thyasira elliptica* in bottom sediments, based on 4 samples and 12 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	25.0	33.3
Silty sand	--	--
Silt	--	--
Clay	75.0	66.7
Total	100.0	100.0

Table 146.--Bathymetric occurrence of *Thyasira equalis*, based on 44 samples and 309 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	4.5	2.9
50-99	13.6	18.8
100-199	34.1	27.9
200-499	34.1	25.2
500-999	11.4	24.9
1000-1999	--	--
2000-3999	2.3	0.3
Total	100.0	100.0

Table 147.--Occurrence of *Thyasira equalis* in bottom sediments, based on 44 samples and 309 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	11.4	12.3
Silty sand	31.8	35.9
Silt	6.8	3.6
Clay	50.0	48.2
Total	100.0	100.0

Table 148.--Bathymetric occurrence of *Thyasira ferruginea*, based on 92 samples and 1,381 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	1.1	0.1
50-99	1.1	0.1
100-199	--	--
200-499	7.6	6.4
500-999	28.3	54.0
1000-1999	36.9	19.8
2000-3999	25.0	19.6
Total	100.0	100.0

Table 149.--Occurrence of *Thyasira ferruginea* in bottom sediments, based on 92 samples and 1,381 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	8.7	6.4
Silty sand	26.1	45.2
Silt	50.0	43.0
Clay	15.2	5.4
Total	100.0	100.0

Table 150.--Bathymetric occurrence of Thyasira flexuosa, based on 104 samples and 1,044 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	1.0	0.2
25-49	8.6	6.6
50-99	30.8	59.2
100-199	33.6	16.7
200-499	22.1	13.3
500-999	2.9	3.9
1000-1999	1.0	0.1
2000-3999	--	--
Total	100.0	100.0

Table 151.--Occurrence of Thyasira flexuosa in bottom sediments, based on 104 samples and 1,044 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	3.8	0.4
Sand-gravel	1.0	1.0
Till	2.9	1.3
Shell	1.0	0.6
Sand-shell	1.0	0.1
Sand	27.8	12.1
Silty sand	20.2	38.3
Silt	10.6	14.7
Clay	31.7	31.5
Total	100.0	100.0

Table 152.--Bathymetric occurrence of Thyasira flexuosa forma gouldii, based on 37 samples and 415 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	5.4	8.9
50-99	56.8	54.5
100-199	21.6	5.1
200-499	8.1	4.3
500-999	8.1	27.2
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 153.--Occurrence of Thyasira flexuosa forma gouldii in bottom sediments, based on 37 samples and 415 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	2.7	0.5
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	32.5	10.6
Silty sand	37.8	45.3
Silt	5.4	9.6
Clay	21.6	34.0
Total	100.0	100.0

Table 154.--Bathymetric occurrence of Thyasira pygmaea, based on 8 samples and 64 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	25.0	28.1
100-199	12.5	1.6
200-499	37.5	45.3
500-999	25.0	25.0
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 155.--Occurrence of Thyasira pygmaea in bottom sediments, based on 8 samples and 64 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	12.5	3.1
Silty sand	37.5	40.6
Silt	--	--
Clay	50.0	56.3
Total	100.0	100.0

Table 156.--Bathymetric occurrence of Thyasira subovata, based on 7 samples and 18 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	57.1	44.4
100-199	--	--
200-499	28.6	50.0
500-999	14.3	5.6
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 157.--Occurrence of Thyasira subovata in bottom sediments, based on 7 samples and 18 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	28.6	27.8
Silty sand	14.3	11.1
Silt	42.8	55.5
Clay	14.3	5.6
Total	100.0	100.0

Table 158.--Bathymetric occurrence of *Thyasira trisinuata*, based on 133 samples and 1,079 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	0.7	0.4
25-49	4.6	6.3
50-99	60.9	61.6
100-199	21.8	16.9
200-499	7.6	11.6
500-999	3.0	2.9
1000-1999	0.7	0.2
2000-3999	0.7	0.1
Total	100.0	100.0

Table 159.--Occurrence of *Thyasira trisinuata* in bottom sediments, based on 133 samples and 1,079 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	0.8	0.1
Sand-gravel	0.8	2.2
Till	1.5	1.6
Shell	--	--
Sand-shell	1.5	1.1
Sand	35.3	25.9
Silty sand	39.8	52.5
Silt	5.3	4.9
Clay	15.0	11.7
Total	100.0	100.0

Table 160.--Bathymetric occurrence of *Thyasira* sp., based on 141 samples and 731 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	0.7	0.3
25-49	4.3	4.1
50-99	12.8	17.5
100-199	31.2	30.6
200-499	34.7	22.7
500-999	10.6	23.2
1000-1999	4.3	1.2
2000-3999	1.4	0.4
Total	100.0	100.0

Table 161.--Occurrence of *Thyasira* sp. in bottom sediments, based on 134 samples and 701 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	0.7	0.1
Sand-gravel	3.7	1.7
Till	4.5	3.4
Shell	--	--
Sand-shell	0.7	0.1
Sand	10.5	11.3
Silty sand	29.9	31.0
Silt	15.7	19.4
Clay	34.3	33.0
Total	100.0	100.0

Table 162.--Bathymetric occurrence of *Diplodonta* sp., based on 58 samples and 90 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	43.1	37.8
25-49	39.7	34.4
50-99	13.8	21.1
100-199	--	--
200-499	1.7	1.1
500-999	--	--
1000-1999	1.7	5.6
2000-3999	--	--
Total	100.0	100.0

Table 163. --Occurrence of *Diplodonta* sp. in bottom sediments, based on 58 samples and 90 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	19.0	17.8
Sand	74.1	73.3
Silty sand	5.2	3.3
Silt	1.7	5.6
Clay	--	--
Total	100.0	100.0

Table 164.--Bathymetric occurrence of *Arcinella cornuta*, based on three samples and three specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	33.3	33.3
25-49	66.7	66.7
50-99	--	--
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 165.--Occurrence of *Arcinella cornuta* in bottom sediments, based on three samples and three specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	33.3	33.3
Sand	66.7	66.7
Silty sand	--	--
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 166.--Bathymetric occurrence of *Cyclocardia borealis*, based on 473 samples and 8,839 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	3.0	0.4
25-49	12.7	11.3
50-99	55.8	62.6
100-199	24.1	24.7
200-499	4.4	1.0
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 167.--Occurrence of *Cyclocardia borealis* in bottom sediments, based on 430 samples and 8,694 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	7.4	3.5
Sand-gravel	10.2	4.3
Till	12.3	38.4
Shell	1.2	0.4
Sand-shell	3.7	0.5
Sand	36.3	15.0
Silty sand	13.1	15.2
Silt	2.1	0.6
Clay	13.7	22.1
Total	100.0	100.0

Table 168.--Bathymetric occurrence of *Cyclocardia novangliae*, based on 26 samples and 89 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	7.7	2.2
50-99	65.4	89.9
100-199	23.1	6.6
200-499	3.8	1.1
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 169.--Occurrence of *Cyclocardia novangliae* in bottom sediments, based on 25 samples and 88 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	20.0	6.8
Sand-gravel	44.0	43.2
Till	12.0	27.3
Shell	8.0	18.2
Sand-shell	4.0	1.1
Sand	8.0	2.3
Silty sand	--	--
Silt	--	--
Clay	4.0	1.1
Total	100.0	100.0

Table 170.--Bathymetric occurrence of *Cyclocardia* sp., based on 16 samples and 22 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	50.0	59.1
25-49	37.5	31.8
50-99	12.5	9.1
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 171.--Occurrence of *Cyclocardia* sp. in bottom sediments, based on 16 samples and 22 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	6.2	4.5
Sand-gravel	--	--
Till	--	--
Shell	6.2	4.5
Sand-shell	50.0	50.0
Sand	31.4	31.9
Silty sand	6.2	9.1
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 172.--Bathymetric occurrence of *Pleuromeris tridentata*, based on 61 samples and 168 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	42.7	32.1
25-49	44.3	56.0
50-99	9.8	9.5
100-199	1.6	1.2
200-499	1.6	1.2
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 173.--Occurrence of *Pleuromeris tridentata* in bottom sediments, based on 61 samples and 168 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	1.6	2.4
Sand-gravel	--	--
Till	--	--
Shell	6.6	7.1
Sand-shell	41.0	23.2
Sand	47.5	65.5
Silty sand	3.3	1.8
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 174.--Bathymetric occurrence of *Pteromeris perplana*, based on 14 samples and 28 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	21.4	10.7
25-49	78.6	89.3
50-99	--	--
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 175.--Occurrence of *Pteromeris perplana* in bottom sediments, based on 14 samples and 28 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	7.2	3.6
Till	--	--
Shell	14.3	7.1
Sand-shell	21.4	35.7
Sand	57.1	53.6
Silty sand	--	--
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 176.--Bathymetric occurrence of *Astarte borealis*, based on 18 samples and 22 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	11.1	9.1
50-99	88.9	90.9
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 177.--Occurrence of *Astarte borealis* in bottom sediments, based on 17 samples and 21 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	35.3	28.6
Sand-gravel	35.3	42.9
Till	--	--
Shell	--	--
Sand-shell	5.9	4.7
Sand	23.5	23.8
Silty sand	--	--
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 178.--Bathymetric occurrence of *Astarte castanea*, based on 105 samples and 457 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	22.8	30.4
25-49	36.2	33.7
50-99	36.2	34.6
100-199	4.8	1.3
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 179.--Occurrence of *Astarte castanea* in bottom sediments, based on 94 samples and 384 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	4.2	2.1
Sand-gravel	13.8	24.2
Till	--	--
Shell	3.2	1.6
Sand-shell	9.6	7.5
Sand	64.9	63.3
Silty sand	3.2	1.0
Silt	--	--
Clay	1.1	0.3
Total	100.0	100.0

Table 180.--Bathymetric occurrence of *Astarte crenata subequilatera*, based on 433 samples and 4,972 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	0.2	0.1
25-49	4.2	7.7
50-99	32.6	35.8
100-199	41.1	44.7
200-499	21.2	11.5
500-999	0.7	0.2
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 181.--Occurrence of *Astarte crenata subequilatera* in bottom sediments, based on 391 samples and 4,649 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	14.3	14.6
Sand-gravel	11.3	2.1
Till	21.7	49.3
Shell	1.8	0.7
Sand-shell	0.5	0.5
Sand	17.9	13.6
Silty sand	16.9	12.9
Silt	2.8	1.2
Clay	12.8	5.1
Total	100.0	100.0

Table 182.--Bathymetric occurrence of *Astarte elliptica*, based on 42 samples and 317 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	2.4	0.6
25-49	9.8	9.5
50-99	75.6	83.2
100-199	12.2	6.7
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 183.--Occurrence of *Astarte elliptica* in bottom sediments, based on 31 samples and 284 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	12.9	17.6
Sand-gravel	22.6	3.9
Till	19.4	20.8
Shell	9.7	41.2
Sand-shell	3.2	0.3
Sand	19.3	3.9
Silty sand	3.2	3.5
Silt	--	--
Clay	9.7	8.8
Total	100.0	100.0

Table 184.--Bathymetric occurrence of *Astarte nana*, based on 4 samples and 18 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	--	--
100-199	--	--
200-499	50.0	33.3
500-999	50.0	66.7
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 185.--Occurrence of *Astarte nana* in bottom sediments, based on 4 samples and 18 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	25.0	11.1
Silty sand	50.0	66.7
Silt	25.0	22.2
Clay	--	--
Total	100.0	100.0

Table 186.--Bathymetric occurrence of *Astarte quadrans*, based on 28 samples and 48 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	14.3	16.7
25-49	32.2	22.9
50-99	46.4	56.2
100-199	7.1	4.2
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 187.--Occurrence of *Astarte quadrans* in bottom sediments, based on 26 samples and 46 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	19.3	13.0
Till	3.8	2.2
Shell	--	--
Sand-shell	7.7	4.4
Sand	69.2	80.4
Silty sand	--	--
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 188.--Bathymetric occurrence of *Astarte undata*, based on 444 samples and 4,705 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	2.0	0.6
25-49	11.8	10.1
50-99	55.2	58.5
100-199	27.7	30.0
200-499	2.7	0.6
500-999	0.6	0.2
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 189.--Occurrence of *Astarte undata* in bottom sediments, based on 444 samples and 4,705 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	12.2	8.8
Sand-gravel	10.7	2.4
Till	13.8	37.2
Shell	2.7	6.4
Sand-shell	1.7	0.8
Sand	30.3	16.7
Silty sand	12.7	16.2
Silt	3.2	1.4
Clay	12.7	10.1
Total	100.0	100.0

Table 190.--Bathymetric occurrence of *Astarte* sp., based on 94 samples and 533 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	1.1	1.1
25-49	4.3	2.2
50-99	37.2	39.6
100-199	28.7	23.3
200-499	19.1	16.9
500-999	9.6	16.9
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 191.--Occurrence of *Astarte* sp. in bottom sediments, based on 88 samples and 515 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	3.4	1.4
Sand-gravel	9.1	5.2
Till	9.1	15.5
Shell	--	--
Sand-shell	--	--
Sand	42.1	57.1
Silty sand	17.0	13.2
Silt	6.8	3.5
Clay	12.5	4.1
Total	100.0	100.0

Table 192.--Bathymetric occurrence of *Crassinella lunulata*, based on 87 samples and 226 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	49.4	53.5
25-49	40.3	38.9
50-99	5.7	3.5
100-199	4.6	4.1
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 193.--Occurrence of *Crassinella lunulata* in bottom sediments, based on 87 samples and 226 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	2.3	3.1
Sand-gravel	2.3	1.3
Till	--	--
Shell	4.6	3.1
Sand-shell	36.8	31.9
Sand	46.0	46.9
Silty sand	8.0	13.7
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 194.--Bathymetric occurrence of *Crassinella* sp., based on three samples and nine specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	66.7	55.6
25-49	33.3	44.4
50-99	--	--
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 195.--Occurrence of *Crassinella* sp. in bottom sediments, based on three samples and nine specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	33.3	22.2
Sand	66.7	77.8
Silty sand	--	--
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 196.--Bathymetric occurrence of *Cerastoderma pinnulatum*, based on 466 samples and 3,317 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	4.5	40.2
25-49	18.7	12.9
50-99	43.5	35.0
100-199	27.3	10.1
200-499	5.8	1.7
500-999	--	--
1000-1999	0.2	<0.1
2000-3999	--	--
Total	100.0	100.0

Table 197.--Occurrence of *Cerastoderma pinnulatum* in bottom sediments, based on 403 samples and 1,825 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	8.9	7.7
Sand-gravel	13.7	8.4
Till	5.9	2.5
Shell	1.6	4.5
Sand-shell	5.7	7.5
Sand	43.7	58.3
Silty sand	9.9	6.4
Silt	2.2	0.8
Clay	8.4	3.9
Total	100.0	100.0

Table 198.--Bathymetric occurrence of *Clinocardium ciliatum*, based on four samples and six specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	75.0	83.3
100-199	25.0	16.7
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 199.--Occurrence of *Clinocardium ciliatum* in bottom sediments, based on four samples and six specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	33.3	25.0
Sand-gravel	--	--
Till	33.3	50.0
Shell	--	--
Sand-shell	--	--
Sand	--	--
Silty sand	--	--
Silt	--	--
Clay	33.3	25.0
Total	100.0	100.0

Table 200.--Bathymetric occurrence of *Laevicardium mortoni*, based on 47 samples and 104 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	49.0	56.7
25-49	46.8	39.4
50-99	4.2	3.9
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 201.--Occurrence of *Laevicardium mortoni* in bottom sediments, based on 36 samples and 76 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	5.6	3.9
Till	--	--
Shell	--	--
Sand-shell	33.3	27.6
Sand	55.5	59.3
Silty sand	5.6	9.2
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 202.--Bathymetric occurrence of *Mulinia lateralis*, based on 51 samples and 897 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	84.3	98.4
25-49	13.7	1.5
50-99	2.0	0.1
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 203.--Occurrence of *Mulinia lateralis* in bottom sediments, based on 37 samples and 754 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	2.7	0.5
Till	--	--
Shell	--	--
Sand-shell	2.7	0.4
Sand	29.7	23.5
Silty sand	29.7	8.1
Silt	10.9	51.5
Clay	24.3	16.0
Total	100.0	100.0

Table 204.--Bathymetric occurrence of *Spisula solidissima*, based on 164 samples and 743 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	41.5	67.1
25-49	40.2	26.7
50-99	16.5	5.8
100-199	1.8	0.4
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 205.--Occurrence of *Spisula solidissima* in bottom sediments, based on 126 samples and 668 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	8.7	5.4
Sand-gravel	4.8	1.2
Till	--	--
Shell	2.4	1.2
Sand-shell	11.9	9.6
Sand	69.0	81.8
Silty sand	2.4	0.6
Silt	0.8	0.2
Clay	--	--
Total	100.0	100.0

Table 206.--Bathymetric occurrence of *Ervilia concentrica*, based on 112 samples and 592 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	53.6	55.2
25-49	44.6	43.9
50-99	1.8	0.9
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 207.--Occurrence of *Ervilia concentrica* in bottom sediments, based on 112 samples and 592 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	0.9	1.4
Sand-gravel	0.9	0.3
Till	--	--
Shell	3.6	3.2
Sand-shell	27.7	30.4
Sand	63.3	61.4
Silty sand	2.7	3.0
Silt	0.9	0.3
Clay	--	--
Total	100.0	100.0

Table 208.--Bathymetric occurrence of *Mesodesma arctatum*, based on 2 samples and 52 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	100.0	100.0
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 209.--Occurrence of *Mesodesma arctatum* in bottom sediments, based on 2 samples and 52 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	--	--
Silty sand	50.0	3.8
Silt	--	--
Clay	50.0	96.2
Total	100.0	100.0

Table 210.--Bathymetric occurrence of Solenidae, based on 11 samples and 39 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	63.6	35.9
25-49	27.3	25.6
50-99	9.1	38.5
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 211.--Occurrence of Solenidae in bottom sediments, based on 10 samples and 24 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	10.0	4.2
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	30.0	20.8
Sand	50.0	62.5
Silty sand	10.0	12.5
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 212.--Bathymetric occurrence of *Ensis directus*, based on 206 samples and 2,150 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	45.1	67.4
25-49	37.9	29.5
50-99	16.5	3.1
100-199	0.5	<0.1
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 213.--Occurrence of *Ensis directus* in bottom sediments, based on 194 samples and 2,113 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	1.0	0.4
Sand-gravel	3.1	2.4
Till	--	--
Shell	3.1	0.7
Sand-shell	20.1	13.0
Sand	69.6	60.1
Silty sand	2.6	23.2
Silt	0.5	0.2
Clay	--	--
Total	100.0	100.0

Table 214.--Bathymetric occurrence of *Siliqua costata*, based on 32 samples and 104 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	15.6	11.5
25-49	31.3	41.4
50-99	46.9	39.4
100-199	3.1	6.7
200-499	3.1	1.0
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 215.--Occurrence of *Siliqua costata* in bottom sediments, based on 30 samples and 96 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	96.7	96.9
Silty sand	3.3	3.1
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 216.--Bathymetric occurrence of Tellinidae, based on 26 samples and 67 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	65.4	73.1
25-49	15.4	7.5
50-99	15.4	17.9
100-199	3.8	1.5
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 217.--Occurrence of Tellinidae in bottom sediments, based on 26 samples and 67 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	3.8	1.5
Sand-gravel	--	--
Till	--	--
Shell	7.7	3.0
Sand-shell	30.8	29.8
Sand	46.2	47.8
Silty sand	7.7	16.4
Silt	3.8	1.5
Clay	--	--
Total	100.0	100.0

Table 218.--Bathymetric occurrence of *Macoma balthica*, based on 45 samples and 783 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	42.2	76.5
25-49	8.9	4.1
50-99	24.4	16.1
100-199	17.8	2.9
200-499	6.7	0.4
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 219.--Occurrence of *Macoma balthica* in bottom sediments, based on 44 samples and 782 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	2.3	1.9
Sand-gravel	4.5	1.2
Till	2.3	2.8
Shell	--	--
Sand-shell	2.3	0.1
Sand	22.7	46.8
Silty sand	31.8	13.8
Silt	11.4	12.7
Clay	22.7	20.7
Total	100.0	100.0

Table 220.--Bathymetric occurrence of *Macoma calcarea*, based on 75 samples and 542 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	10.7	15.9
25-49	9.3	25.3
50-99	30.7	26.4
100-199	25.3	26.5
200-499	21.3	5.2
500-999	2.7	0.7
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 221.--Occurrence of *Macoma calcarea* in bottom sediments, based on 70 samples and 534 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	2.9	0.6
Sand-gravel	2.9	0.9
Till	17.1	6.9
Shell	--	--
Sand-shell	--	--
Sand	24.3	44.2
Silty sand	28.6	35.6
Silt	7.1	2.2
Clay	17.1	9.6
Total	100.0	100.0

Table 222.--Bathymetric occurrence of *Macoma tenta*, based on 22 samples and 708 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	68.2	97.9
25-49	13.6	0.6
50-99	18.2	1.5
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 223.--Occurrence of *Macoma tenta* in bottom sediments, based on 11 samples and 37 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	18.1	8.1
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	45.5	16.2
Silty sand	9.1	2.7
Silt	--	--
Clay	27.3	73.0
Total	100.0	100.0

Table 224.--Bathymetric occurrence of *Macoma* sp., based on 10 samples and 12 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	30.0	25.0
25-49	30.0	33.3
50-99	20.0	25.0
100-199	20.0	16.7
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 225.--Occurrence of *Macoma* sp. in bottom sediments, based on 8 samples and 10 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	12.5	10.0
Sand-gravel	12.5	10.0
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	50.0	50.0
Silty sand	--	--
Silt	25.0	30.0
Clay	--	--
Total	100.0	100.0

Table 226.--Bathymetric occurrence of *Strigilla mirabilis*, based on 9 samples and 12 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	66.7	75.0
25-49	33.3	25.0
50-99	--	--
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 227.--Occurrence of *Strigilla mirabilis* in bottom sediments, based on 9 samples and 12 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	33.3	25.0
Sand	66.7	75.0
Silty sand	--	--
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 228.--Bathymetric occurrence of *Tellina agilis*, based on 112 samples and 1,119 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	68.8	90.5
25-49	26.8	8.5
50-99	2.6	0.5
100-199	1.8	0.5
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 229.--Occurrence of *Tellina agilis* in bottom sediments, based on 101 samples and 1,075 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	1.0	0.1
Sand-gravel	2.0	0.2
Till	--	--
Shell	1.0	0.3
Sand-shell	9.9	4.2
Sand	72.2	91.9
Silty sand	10.9	2.7
Silt	1.0	0.2
Clay	2.0	0.4
Total	100.0	100.0

Table 230.--Bathymetric occurrence of *Tellina versicolor*, based on 58 samples and 297 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	63.8	86.5
25-49	32.8	12.5
50-99	3.4	1.0
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 231.--Occurrence of *Tellina versicolor* in bottom sediments, based on 58 samples and 297 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	1.7	0.3
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	29.4	30.6
Sand	67.2	68.4
Silty sand	1.7	0.7
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 232.--Bathymetric occurrence of *Tellina* sp., based on 70 samples and 151 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	44.3	52.9
25-49	38.6	33.8
50-99	11.4	10.6
100-199	5.7	2.7
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 233.--Occurrence of *Tellina* sp. in bottom sediments, based on 68 samples and 142 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	4.4	2.1
Sand-shell	19.1	18.3
Sand	67.6	71.1
Silty sand	5.9	3.6
Silt	1.5	0.7
Clay	1.5	4.2
Total	100.0	100.0

Table 234.--Bathymetric occurrence of *Abra* sp., based on 60 samples and 125 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	33.3	32.8
25-49	21.7	21.6
50-99	8.3	7.2
100-199	25.0	25.6
200-499	10.0	11.2
500-999	1.7	1.6
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 235.--Occurrence of *Abra* sp. in bottom sediments, based on 60 samples and 125 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	1.7	3.2
Sand-gravel	--	--
Till	--	--
Shell	6.7	8.0
Sand-shell	26.6	24.8
Sand	35.0	35.2
Silty sand	25.0	24.8
Silt	5.0	4.0
Clay	--	--
Total	100.0	100.0

Table 236.--Bathymetric occurrence of *Semele bellastriata*, based on 19 samples and 38 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	31.6	21.1
25-49	68.4	78.9
50-99	--	--
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 237.--Occurrence of *Semele bellastriata* in bottom sediments, based on 19 samples and 38 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	36.8	21.1
Sand	63.2	78.9
Silty sand	--	--
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 238.--Bathymetric occurrence of *Semele nuculoides*, based on 62 samples and 146 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	45.2	29.5
25-49	51.6	67.8
50-99	3.2	2.7
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 239.--Occurrence of *Semele nuculoides* in bottom sediments, based on 62 samples and 146 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	1.6	0.7
Sand-shell	27.4	23.3
Sand	66.2	58.9
Silty sand	4.8	17.1
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 240.--Bathymetric occurrence of *Semele purpurascens*, based on four samples and six specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	25.0	33.3
50-99	75.0	66.7
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 241.--Occurrence of *Semele purpurascens* in bottom sediments, based on four samples and six specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	50.0	50.0
Till	--	--
Shell	--	--
Sand-shell	25.0	16.7
Sand	25.0	33.3
Silty sand	--	--
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 242.--Bathymetric occurrence of *Arctica islandica*, based on 367 samples and 1,938 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	3.1	0.9
25-49	21.8	11.9
50-99	56.7	56.8
100-199	14.9	28.2
200-499	3.5	2.2
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 243.--Occurrence of *Arctica islandica* in bottom sediments, based on 326 samples and 1,825 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	3.4	0.9
Sand-gravel	4.0	0.9
Till	5.6	2.9
Shell	--	--
Sand-shell	4.7	2.9
Sand	55.8	32.0
Silty sand	8.9	12.4
Silt	5.6	4.9
Clay	12.0	43.1
Total	100.0	100.0

Table 244.--Bathymetric occurrence of Veneridae, based on 54 samples and 117 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	37.0	35.9
25-49	57.4	59.0
50-99	5.6	5.1
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 245.--Occurrence of Veneridae in bottom sediments, based on 54 samples and 117 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	5.6	5.1
Sand-gravel	3.7	2.6
Till	--	--
Shell	7.4	6.0
Sand-shell	44.4	47.0
Sand	35.2	35.0
Silty sand	3.7	4.3
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 246.--Bathymetric occurrence of *Callista eucymata*, based on 12 samples and 14 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	83.4	78.6
25-49	8.3	7.1
50-99	8.3	14.3
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 247.--Occurrence of *Callista eucymata* in bottom sediments, based on 12 samples and 14 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	8.3	7.1
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	25.0	28.6
Sand	58.4	57.2
Silty sand	8.3	7.1
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 248.--Bathymetric occurrence of *Chione intapurpurea*, based on eight samples and nine specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	87.5	88.9
25-49	12.5	11.1
50-99	--	--
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 249.--Occurrence of *Chione intapurpurea* in bottom sediments, based on eight samples and nine specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	50.0	55.6
Sand	50.0	44.4
Silty sand	--	--
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 250.--Bathymetric occurrence of *Chione latilirata*, based on 17 samples and 24 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	11.8	8.3
25-49	76.4	83.4
50-99	11.8	8.3
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 251.--Occurrence of *Chione latilirata* in bottom sediments, based on 17 samples and 24 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	29.4	33.3
Sand	70.6	66.7
Silty sand	--	--
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 252.--Bathymetric occurrence of *Chione* sp., based on 36 samples and 58 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	77.8	82.8
25-49	22.2	17.2
50-99	--	--
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 253.--Occurrence of *Chione* sp. in bottom sediments, based on 36 samples and 58 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	13.9	15.5
Sand-shell	38.9	37.9
Sand	41.7	43.1
Silty sand	5.5	3.5
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 254.--Bathymetric occurrence of *Gemma gemma*, based on 33 samples and 2,211 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	94.0	99.8
25-49	3.0	0.1
50-99	3.0	0.1
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 255.--Occurrence of *Gemma gemma* in bottom sediments, based on 16 samples and 408 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	6.2	79.6
Sand	75.0	15.0
Silty sand	18.8	5.4
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 256.--Bathymetric occurrence of *Mercenaria mercenaria*, based on 9 samples and 21 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	100.0	100.0
25-49	--	--
50-99	--	--
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 257.--Occurrence of *Mercenaria mercenaria* in bottom sediments, based on three samples and eight specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	33.3	25.0
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	--	--
Silty sand	66.7	75.0
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 258.--Bathymetric occurrence of *Pitar morrhuanus*, based on 102 samples and 723 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	35.3	80.2
25-49	23.5	7.3
50-99	32.4	10.0
100-199	2.9	1.0
200-499	4.9	1.4
500-999	1.0	0.1
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 259.--Occurrence of *Pitar morrhuanus* in bottom sediments, based on 89 samples and 255 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	2.2	0.8
Shell	--	--
Sand-shell	2.2	0.8
Sand	61.9	63.1
Silty-sand	24.8	24.7
Silt	2.2	1.2
Clay	6.7	9.4
Total	100.0	100.0

Table 260.--Bathymetric occurrence of *Pitar* sp., based on 60 samples and 130 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	25.0	23.1
25-49	70.0	72.3
50-99	3.3	3.8
100-199	1.7	0.8
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 261.--Occurrence of *Pitar* sp. in bottom sediments, based on 60 samples and 130 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	1.7	1.5
Sand-gravel	--	--
Till	--	--
Shell	3.3	1.5
Sand-shell	21.7	23.2
Sand	68.3	69.2
Silty sand	5.0	4.6
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 262.--Bathymetric occurrence of *Petricola pholadiformis*, based on 7 samples and 27 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	85.7	96.3
25-49	14.3	3.7
50-99	--	--
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 263.--Occurrence of *Petricola pholadiformis* in bottom sediments, based on three samples and six specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	33.3	16.7
Sand-shell	--	--
Sand	33.3	66.6
Silty sand	33.3	16.7
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 264.--Bathymetric occurrence of *Mya arenaria*, based on 62 samples and 281 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	43.5	49.8
25-49	16.1	10.0
50-99	32.3	33.8
100-199	8.1	6.4
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 265.--Occurrence of *Mya arenaria* in bottom sediments, based on 53 samples and 262 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	1.9	0.4
Sand-gravel	5.7	2.3
Till	5.7	1.5
Shell	1.9	0.4
Sand-shell	--	--
Sand	13.2	5.0
Silty sand	37.7	41.6
Silt	13.2	29.3
Clay	20.7	19.5
Total	100.0	100.0

Table 266.--Bathymetric occurrence of Corbulidae, based on 56 samples and 150 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	58.9	56.0
25-49	21.4	24.7
50-99	17.9	18.0
100-199	1.8	1.3
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 267.--Occurrence of Corbulidae in bottom sediments, based on 56 samples and 150 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	1.8	1.3
Sand-gravel	--	--
Till	--	--
Shell	5.3	4.0
Sand-shell	37.5	38.0
Sand	41.1	38.0
Silty sand	14.3	18.7
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 268.--Bathymetric occurrence of *Corbula contracta*, based on 22 samples and 46 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	13.6	8.7
25-49	27.3	28.3
50-99	45.5	41.3
100-199	13.6	21.7
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 269.--Occurrence of *Corbula contracta* in bottom sediments, based on 19 samples and 41 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	52.6	48.8
Silty sand	31.6	26.8
Silt	5.3	9.8
Clay	10.5	14.6
Total	100.0	100.0

Table 270.--Bathymetric occurrence of *Corbula krebsiana*, based on 41 samples and 97 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	9.8	6.2
25-49	63.4	55.7
50-99	21.9	35.0
100-199	4.9	3.1
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table271.--Occurrence of *Corbula krebsiana* in bottom sediments, based on 41 samples and 97 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	4.9	3.1
Sand-shell	29.3	36.1
Sand	63.4	58.7
Silty sand	2.4	2.1
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 272.--Bathymetric occurrence of Hiatellidae, based on 7 samples and 17 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	57.1	29.4
50-99	28.6	11.8
100-199	14.3	58.8
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 273.--Occurrence of Hiatellidae in bottom sediments, based on 7 samples and 17 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	14.3	58.8
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	71.4	35.3
Silty sand	--	--
Silt	--	--
Clay	14.3	5.9
Total	100.0	100.0

Table 274.--Bathymetric occurrence of *Hiatella arctica*, based on 149 samples and 3,474 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	2.0	2.3
25-49	22.8	68.8
50-99	51.0	24.1
100-199	21.5	4.7
200-499	2.7	0.1
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 275.--Occurrence of *Hiatella arctica* in bottom sediments, based on 117 samples and 3,353 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	29.0	61.4
Sand-gravel	23.9	20.0
Till	12.0	4.1
Shell	2.6	1.8
Sand-shell	6.0	2.1
Sand	12.0	9.7
Silty sand	7.7	0.6
Silt	1.7	0.1
Clay	5.1	0.2
Total	100.0	100.0

Table 276.--Bathymetric occurrence of *Panomya arctica*, based on 19 samples and 64 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	5.3	1.6
50-99	52.6	78.1
100-199	26.3	14.1
200-499	15.8	6.2
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 277.--Occurrence of *Panomya arctica* in bottom sediments, based on 12 samples and 48 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	16.8	6.2
Sand-gravel	--	--
Till	25.0	72.9
Shell	8.3	4.2
Sand-shell	--	--
Sand	8.3	2.1
Silty sand	33.3	10.4
Silt	--	--
Clay	8.3	4.2
Total	100.0	100.0

Table 278.--Bathymetric occurrence of *Pandora gouldiana*, based on 33 samples and 144 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	21.2	27.8
25-49	27.3	13.9
50-99	39.4	50.7
100-199	12.1	7.6
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 279.--Occurrence of *Pandora gouldiana* in bottom sediments, based on 27 samples and 105 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	3.7	7.5
Sand-gravel	3.7	1.0
Till	3.7	1.0
Shell	3.7	2.9
Sand-shell	--	--
Sand	63.0	81.8
Silty sand	3.7	1.0
Silt	7.4	1.9
Clay	11.1	2.9
Total	100.0	100.0

Table 280.--Bathymetric occurrence of *Pandora inflata*, based on 17 samples and 34 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	5.9	2.9
25-49	17.6	17.6
50-99	17.6	11.8
100-199	58.9	67.7
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 281. --Occurrence of *Pandora inflata* in bottom sediments, based on 17 samples and 34 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	5.9	2.9
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	41.2	47.1
Silty sand	52.9	50.0
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 282.--Bathymetric occurrence of *Pandora inornata*, based on 21 samples and 159 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	57.1	33.3
25-49	28.6	19.5
50-99	14.3	47.2
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 283.--Occurrence of *Pandora inornata* in bottom sediments, based on 11 samples and 110 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	9.1	6.4
Sand-gravel	9.1	0.9
Till	--	--
Shell	--	--
Sand-shell	9.1	0.9
Sand	54.5	88.2
Silty sand	18.2	3.6
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 284.--Bathymetric occurrence of *Pandora trilineata*, based on 9 samples and 11 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	66.7	72.7
25-49	33.3	27.3
50-99	--	--
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 285.--Occurrence of *Pandora trilineata* in bottom sediments, based on 9 samples and 11 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	22.2	18.2
Sand	77.8	81.8
Silty sand	--	--
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 286.--Bathymetric occurrence of *Pandora* sp., based on 8 samples and 11 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	25.0	27.3
25-49	25.0	18.2
50-99	37.5	36.3
100-199	--	--
200-499	12.5	18.2
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 287.--Occurrence of *Pandora* sp. in bottom sediments, based on six samples and eight specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	83.3	75.0
Silty sand	16.7	25.0
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 288.--Bathymetric occurrence of *Lyonsia arenosa*, based on 20 samples and 81 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	28.6	21.0
25-49	28.6	24.7
50-99	38.1	53.1
100-199	--	--
200-499	4.7	1.2
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 289.--Occurrence of *Lyonsia arenosa* in bottom sediments, based on 19 samples and 76 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	20.0	19.7
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	60.0	67.1
Silty sand	10.0	5.3
Silt	10.0	7.9
Clay	--	--
Total	100.0	100.0

Table 290.--Bathymetric occurrence of *Lyonsia hyalina*, based on 129 samples and 544 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	32.6	21.5
25-49	34.8	46.1
50-99	32.6	32.4
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 291.--Occurrence of *Lyonsia hyalina* in bottom sediments, based on 115 samples and 492 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	4.3	1.6
Till	--	--
Shell	--	--
Sand-shell	7.8	3.9
Sand	78.3	90.7
Silty sand	7.0	2.0
Silt	1.7	1.6
Clay	0.9	0.2
Total	100.0	100.0

Table 292.--Bathymetric occurrence of *Lyonsia* sp., based on five samples and six specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	40.0	33.3
25-49	20.0	16.7
50-99	40.0	50.0
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 293.--Occurrence of *Lyonsia* sp. in bottom sediments, based on five samples and six specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	20.0	16.7
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	60.0	66.6
Silty sand	20.0	16.7
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 294.--Bathymetric occurrence of *Periploma fragile*, based on 27 samples and 101 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	3.7	3.0
25-49	3.7	4.0
50-99	77.8	88.0
100-199	7.4	2.0
200-499	7.4	3.0
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 295.--Occurrence of *Periploma fragile* in bottom sediments, based on 27 samples and 101 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	3.7	3.0
Sand	37.1	21.8
Silty sand	33.3	20.8
Silt	11.1	20.8
Clay	14.8	33.6
Total	100.0	100.0

Table 296.--Bathymetric occurrence of *Periploma leanum*, based on 27 samples and 60 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	33.3	30.0
25-49	25.9	38.3
50-99	25.9	21.7
100-199	14.9	10.0
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 297.--Occurrence of *Periploma leanum* in bottom sediments, based on 22 samples and 49 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	22.7	18.4
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	45.5	61.2
Silty sand	18.2	10.2
Silt	--	--
Clay	13.6	10.2
Total	100.0	100.0

Table 298.--Bathymetric occurrence of *Periploma papyratium*, based on 265 samples and 2,976 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	1.1	1.3
25-49	7.9	9.7
50-99	49.4	68.5
100-199	24.5	13.5
200-499	17.1	7.0
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 299.--Occurrence of *Periploma papyratium* in bottom sediments, based on 264 samples and 2,975 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	1.1	0.4
Sand-gravel	1.5	9.2
Till	7.6	13.9
Shell	--	--
Sand-shell	0.4	0.1
Sand	22.7	7.5
Silty sand	28.4	26.2
Silt	9.5	11.7
Clay	28.8	31.0
Total	100.0	100.0

Table 300.--Bathymetric occurrence of *Periploma* sp., based on four samples and four specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	75.0	75.0
100-199	--	--
200-499	25.0	25.0
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 301.--Occurrence of *Periploma* sp. in bottom sediments, based on four samples and four specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	50.0	50.0
Silty sand	50.0	50.0
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 302.--Bathymetric occurrence of Thraciidae, based on 19 samples and 36 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	36.8	33.3
25-49	26.3	25.0
50-99	21.1	25.0
100-199	5.3	2.8
200-499	10.5	13.9
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 303.--Occurrence of Thraciidae in bottom sediments, based on 19 samples and 36 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	15.8	8.3
Sand	73.7	77.8
Silty sand	10.5	13.9
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 304.--Bathymetric occurrence of *Thracia conradi*, based on 6 samples and 10 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	50.0	70.0
25-49	16.7	10.0
50-99	33.3	20.0
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 305.--Occurrence of *Thracia conradi* in bottom sediments, based on 6 samples and 10 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	16.7	30.0
Shell	--	--
Sand-shell	--	--
Sand	16.7	10.0
Silty sand	33.3	20.0
Silt	33.3	40.0
Clay	--	--
Total	100.0	100.0

Table 306.--Bathymetric occurrence of *Thracia septentrionalis*, based on 13 samples and 46 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	7.7	4.4
25-49	30.8	21.7
50-99	61.5	73.9
100-199	--	--
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 307.--Occurrence of *Thracia septentrionalis* in bottom sediments, based on 12 samples and 45 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	8.3	6.7
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	91.7	93.3
Silty sand	--	--
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 308.--Bathymetric occurrence of *Poromya* sp., based on six samples and six specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	16.7	16.7
25-49	33.3	33.3
50-99	--	--
100-199	33.3	33.3
200-499	16.7	16.7
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 309.--Occurrence of *Poromya* sp. in bottom sediments, based on six samples and six specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	16.7	16.7
Sand	50.0	50.0
Silty sand	33.3	33.3
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 310.--Bathymetric occurrence of Cuspidariidae, based on 9 samples and 11 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	11.1	9.1
50-99	22.2	18.2
100-199	22.2	27.3
200-499	44.5	45.4
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 311.--Occurrence of Cuspidariidae in bottom sediments, based on 9 samples and 11 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	11.1	9.1
Sand	55.6	54.5
Silty sand	33.3	36.4
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 312.--Bathymetric occurrence of *Cardiomya perrostrata*, based on 13 samples and 24 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	--	--
100-199	76.9	87.5
200-499	15.4	8.3
500-999	7.7	4.2
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 313.--Occurrence of *Cardiomya perrostrata* in bottom sediments, based on 13 samples and 24 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	46.2	41.6
Silty sand	38.5	50.0
Silt	7.7	4.2
Clay	7.7	4.2
Total	100.0	100.0

Table 314.--Bathymetric occurrence of *Cuspidaria glacialis*, based on 49 samples and 184 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	18.4	22.8
100-199	55.1	60.4
200-499	18.4	12.5
500-999	6.1	3.8
1000-1999	--	--
2000-3999	2.0	0.5
Total	100.0	100.0

Table 315.--Occurrence of *Cuspidaria glacialis* in bottom sediments, based on 48 samples and 181 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	2.1	0.6
Sand-gravel	--	--
Till	20.8	38.1
Shell	--	--
Sand-shell	--	--
Sand	12.5	16.0
Silty sand	22.9	14.4
Silt	4.2	5.5
Clay	37.5	25.4
Total	100.0	100.0

Table 316.--Bathymetric occurrence of *Cuspidaria obesa*, based on 14 samples and 30 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	--	--
100-199	28.6	36.7
200-499	35.7	23.3
500-999	35.7	40.0
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 317.--Occurrence of *Cuspidaria obesa* in bottom sediments, based on 14 samples and 30 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	7.1	13.3
Sand-gravel	--	--
Till	14.3	13.3
Shell	--	--
Sand-shell	--	--
Sand	14.3	13.3
Silty sand	28.6	36.7
Silt	14.3	6.7
Clay	21.4	16.7
Total	100.0	100.0

Table 318.--Bathymetric occurrence of *Cuspidaria parva*, based on two samples and three specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	--	--
100-199	50.0	33.3
200-499	--	--
500-999	50.0	66.7
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 319.--Occurrence of *Cuspidaria parva* in bottom sediments, based on two samples and three specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	--	--
Silty sand	--	--
Silt	50.0	66.7
Clay	50.0	33.3
Total	100.0	100.0

Table 320.--Bathymetric occurrence of *Cuspidaria pellucida*, based on 4 samples and 19 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	25.0	26.3
100-199	75.0	73.7
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 321.--Occurrence of *Cuspidaria pellucida* in bottom sediments, based on 3 samples and 14 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	--	--
Silty sand	33.3	64.3
Silt	--	--
Clay	66.7	35.7
Total	100.0	100.0

Table 322.--Bathymetric occurrence of *Cuspidaria* sp., based on 69 samples and 112 specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	1.4	3.5
50-99	1.4	0.9
100-199	49.4	55.4
200-499	39.2	29.5
500-999	5.8	8.9
1000-1999	1.4	0.9
2000-3999	1.4	0.9
Total	100.0	100.0

Table 323.--Occurrence of *Cuspidaria* sp. in bottom sediments, based on 66 samples and 104 specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	1.5	1.0
Sand-gravel	3.0	4.8
Till	4.5	3.8
Shell	--	--
Sand-shell	--	--
Sand	10.6	10.6
Silty sand	30.4	29.8
Silt	9.1	4.8
Clay	40.9	45.2
Total	100.0	100.0

Table 324.--Bathymetric occurrence of *Plectodon* sp., based on four samples and six specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	--	--
50-99	25.0	16.7
100-199	75.0	83.3
200-499	--	--
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 325.--Occurrence of *Plectodon* sp. in bottom sediments, based on four samples and six specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	75.0	83.3
Sand	25.0	16.7
Silty sand	--	--
Silt	--	--
Clay	--	--
Total	100.0	100.0

Table 326.--Bathymetric occurrence of Verticordia ornata, based on seven samples and eight specimens.

Depth range (m)	Percentage of	
	Samples	Specimens
0-24	--	--
25-49	57.1	62.5
50-99	--	--
100-199	14.3	12.5
200-499	28.6	25.0
500-999	--	--
1000-1999	--	--
2000-3999	--	--
Total	100.0	100.0

Table 327.--Occurrence of Verticordia ornata in bottom sediments, based on seven samples and eight specimens.

Bottom type	Percentage of	
	Samples	Specimens
Gravel	--	--
Sand-gravel	--	--
Till	--	--
Shell	--	--
Sand-shell	--	--
Sand	100.0	100.0
Silty sand	--	--
Silt	--	--
Clay	--	--
Total	100.0	100.0

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NOAA Technical Report NMFS SSRF-769

Krill and Its Utilization: A Review

John D. Kaylor and Robert J. Learson

July 1983

U.S. DEPARTMENT OF COMMERCE
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NOAA Technical Report NMFS SSRF-769

Krill and Its Utilization: A Review

John D. Kaylor and Robert J. Learson

July 1983

U.S. DEPARTMENT OF COMMERCE
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Krill and Its Utilization: A Review

JOHN D. KAYLOR and ROBERT J. LEARSON[1]

ABSTRACT

This article is based on a review of the literature on 1) the Antartic krill resource, 2) multinational efforts to use krill as food, and 3) technological, economic, and marketing aspects of krill. The decimation of baleen whales, significant krill predators, has brought about an apparent overabundance of this protein-rich crustacean. Since the krill biomass exceeds the world's annual tonnage of fishery products, a close examination of the potential of krill stocks is justified.

Krill is an extremely rich source of protein and fat, and there is the potential of valuable byproducts such as chitin and chitosan. However, the harvesting operation may prove to be one of somewhat low economic return. The technology of using krill to form various food products acceptable to western preferences is not yet well developed. Utilization technology seriously lags behind harvesting technology.

Finding the potential value of krill requires an appraisal of 1) feasibility of producing krill products with a reasonable degree of marketing acceptability, 2) the value of our lending technical assistance to some nation to achieve the above, and 3) the economic and international pressures that are likely to favor those nations that are already completely subsidized and have vertical integration of their fisheries.

It is widely believed that abundant, protein-rich krill could contribute substantially to the world protein food supplies. Owing to the lack of development of a krill product possessing wide appeal and the unknown economic return of this potential fishery, eventual success seems dependent on government-subsidized operations.

INTRODUCTION

The most abundant and yet relatively untapped marine food source in the world is the Antarctic krill, *Euphausia superba* Dana. This shrimp-like crustacean has several features that enhance its value for human food: 1) Biomass abundance that exceeds the world's present total annual catch of all fish and shellfish, 2) a high nutritive value, and 3) an ability to produce sustained annual harvests of tens of millions of metric tons annually.

These attributes prompted us to examine and review the feasibility of using krill for human consumption, animal consumption, and for other uses. Our approach was to first study the literature on krill dealing with Antarctic explorations dating from the years between World Wars I and II to the present. More importantly, we studied the literature on krill utilization generated in about the last dozen years, principally by the U.S.S.R., Japan, Poland, Federal Republic of Germany, and the Food and Agriculture Organization of the United Nations.

Although more than half a century has been spent in studying Antarctic krill, much is still unknown about it. Bakus et al. (1978) stated, "The most important information gaps appear to be the relationship between currents, surface rings, and krill distribution; the biology of all Antarctic krill species, feeding habits of *E. superba* in relation to its aggregation and the abundance of phytoplankton; the exact location of krill spawning areas; the causes and maintenance of swarming; longevity and mortality of krill; the rates of predation on krill by squid and fish; and the role of krill detritus in the Antarctic ecosystem."

Technologists have been trying since the early 1970's to produce acceptable krill products. Bardach and Pariser (1978) stated, "Japan and Russia have each invested about $200 million towards krill harvesting and utilization." Research expenses of this magnitude are prohibitive for private industry. Only nations can afford to speculate to this extent, still fail to produce reasonably marketable products, and still keep on spending for more research, both biological and technological, in hopes of attaining success.

A review of the many products that have been made from krill shows that whole or nearly intact krill tail meat is the only product that meets with generally wide acceptance (Grantham 1977). Successful peeling at a high rate of speed and with a high yield, so far has eluded the various investigators.

While accurate figures on the economic return are not available, we are certain that no krill expedition can be economically successful unless it is equipped to process as many products as possible from krill in addition to producing tail meats. These operations would require a high degree of technology using sophisticated processes and equipment. Some processes such as solvent extraction and acid-alkali treatments aboard a moving ship will present hazards over and above those to be expected ashore.

From a political standpoint, some of the advanced nations simply will not wait once they have perfected their food technology studies. We firmly believe that in < 5 yr Japan, Poland, and the U.S.S.R. will be satisfied that they can exploit krill. Unlike our concept of feasibility, theirs embraces more than economics.

This article represents a five-part approach to the overall study. The first part concerns the krill resource itself—its distribution, magnitude, biological aspects, and pressures both present and anticipated. The second deals with the harvesting of krill including location and detection, harvesting, and the natural restrictions on an unlimited fishery. The third discusses the processing technology including fabrication into many forms for human consumption, for animal food, and for byproduct use in the form of various chemical products. The fourth deals with marketing krill. This includes a description of the types of food products made from krill by various nationals, development of domestic or foreign markets, and the need for market research and economic analyses. The last part deals with the problems that can possibly be expected to arise. Our intent is merely to call attention to their existence rather than to attempt to solve the problems they may present. We present our conclusions based upon a technological approach to utilization of

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a potential but remote food resource. We acknowledge that as members of the world's greatest food exporting nation, we stand in no present need for krill and all that it may promise. As fishery technologists, however, from a nation that is a major importer of fish and fish products, we cannot ignore the activities of other nations.

THE KRILL RESOURCE

The Norwegian noun "kril" means "young fry of fish" but is generally interpreted to mean "whale food." This term was used by Norwegian whalers originally to apply to a particular shrimp-like euphausid known scientifically as *Meganyctiphanes norvegicus* that is common to North Atlantic waters. It was the basic food of baleen whales that were hunted in the 1800's. Shortly after the 1900's, whaling interests shifted to Antarctic waters where baleen whales fed upon related euphausids, chief among which was *Euphausia superba* which was later dubbed "krill." There is no known reason for the extra "l" in krill.

The South Atlantic krill differs from its North Atlantic relative in that it is larger and feeds upon phytoplankton chiefly in the form of algae, principally diatoms. The northern krill reverses the feeding role and preys upon animal life in the form of copepods although both can, under certain circumstances, reverse their roles.

For the purposes of this report, the term "krill" will mean *Euphausia superba* that is common to Antarctic waters[2]. Krill have transparent bodies and are highly luminescent at night as they bear light-producing organs on the outer side of the eyestalk, on the underside of the first four abdominal segments, and two pairs under the thorax (Hardy 1967). The carapace is enlarged and connected with all the segments of the thorax except the last. The eyes are mounted on the eyestalks, and the heart and gills are in the thorax. Both sexes have well developed swimmerets. In the female the egg pouch is located at the rear on the thorax. They are 3 to 6 cm long, and the color of living specimens is pink to brilliant red. (In dense swarms, they give the appearance of a sea of tomato soup.) Their weight ranges from 0.3 to 1.2 g.

Distribution

While krill is circumpolar in distribution, its concentration is asymmetric. Figure 1 shows a much heavier concentration in the polar Atlantic than in the polar Indian or Pacific Oceans. Historically, the greatest concentrations of baleen whales has always been in the Atlantic sector between long. 60°W and 30°E, and it is natural that the concentration of whales would be in proportion to the amount of food that they could obtain for the limited time they feed upon krill before the whales disperse.

The reasons for the concentration of krill are not yet completely understood. Soviet scientists have shown that young and mature krill are seldom found together (Makarov 1970). Usually mature krill are found to the north, and the young are found to the south. The dividing point between young and mature is placed at 1 to 1.5 yr of age, and it is the young which comprise most of the stock. The Soviets hold that the separation of the young and mature krill is due to a seasonal migration which is occasioned by the difference in horizontal movement. They maintain that the young are carried to the south as a result of their vertical migration to the depths. Mature krill that do not engage in deep vertical migrations are swept to the north. The vertical distribution of adult krill is about 90% between the surface and 100 m. Daily, vertical migrations do occur with daytime concentrations occurring between 10 and 40 m, as opposed to nighttime concentrations located from the surface to a depth of 10 m (Marr 1962).

Magnitude and Potential Yield

Estimates of the magnitude of the stock and its potential yield vary considerably because *E. superba* has a remarkably long life (25-48 mo) for a euphausid. The lack of reliable data on the productivity of Antarctic krill makes estimations of magnitude of stocks and annual yields debatable. For example, Langunov et al. (1973) placed the potential annual catch at 100 million t (metric tons), yet Gulland (1970) estimated it to be 200 million t. Using a 1 yr life span in relation to the standing crop biomass, Gulland arrived at approximately a 75 million t annual production. Allen (1971) revised Gulland's estimate by assuming a 4-yr life span of *E. superba* and claimed that the annual production figure should be 150 million t. Not all parts of the Antarctic where krill occur are as readily exploitable as the Atlantic sector, thus tending to make the total potential yield figure somewhat uncertain. A conservative estimate would place the annual harvestable yield at several tens of millions of metric tons.

Harvesting Feasibility

As used here, the term "harvesting feasibility" refers solely to the presence of concentrations of krill that would make a krill fishery successful in respect to rate and size of catch. It is a peculiarity of krill that they are marked by a very strong habit of concentrating in dense masses, so dense that they impart a discoloration to the water intense enough to be sensed by remote satellites (El Sayed 1975). The unexplained phenomenon of dense concentrations is further complicated by the fact that individuals in a particular subdivision of a patch called a "swarm" possess the same degree of maturity. One large patch of krill may be composed of several swarms of krill, and each swarm will consist entirely of either adults or juveniles with very little admixture.

The density of the patches of swarming krill are not evenly distributed in the water column. Some may easily be spotted visually near the surface, and others may be located as deep as 100 m by electronic sensing devices. Regardless of their depth, it is agreed by both scientists and practical fishermen who have been observers of the habits of krill, that the concentrations would support a high rate and volume of catch.

Political and International Pressures

For years Argentina, Australia, Chile, France, Great Britain, New Zealand, and Norway have made territorial claims in Antarctica. Many nations (U.S.A., U.S.S.R., Japan, Sweden, Belgium, and Federal Republic of Germany) have made Antarctic explorations without lodging such territorial claims. The United States, in spite of the years of exploration by Admiral Richard Byrd and others, has chosen not to make such demands in agreement with the policy announced by Secretary of State Charles Evans Hughes in 1924: "It is the opinion of this Department that the discovery of lands unknown to civilization, even when coupled with a formal taking of possession, does not support a valid claim of sovereignty, unless the discovery is followed by an actual settlement of the discovered

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[2] Other species of Antarctic euphausids are: *crystallorphias, frigida, hanseni, longirostris, lucens, similis, spinifera, triacantha,* and *vallentini.*

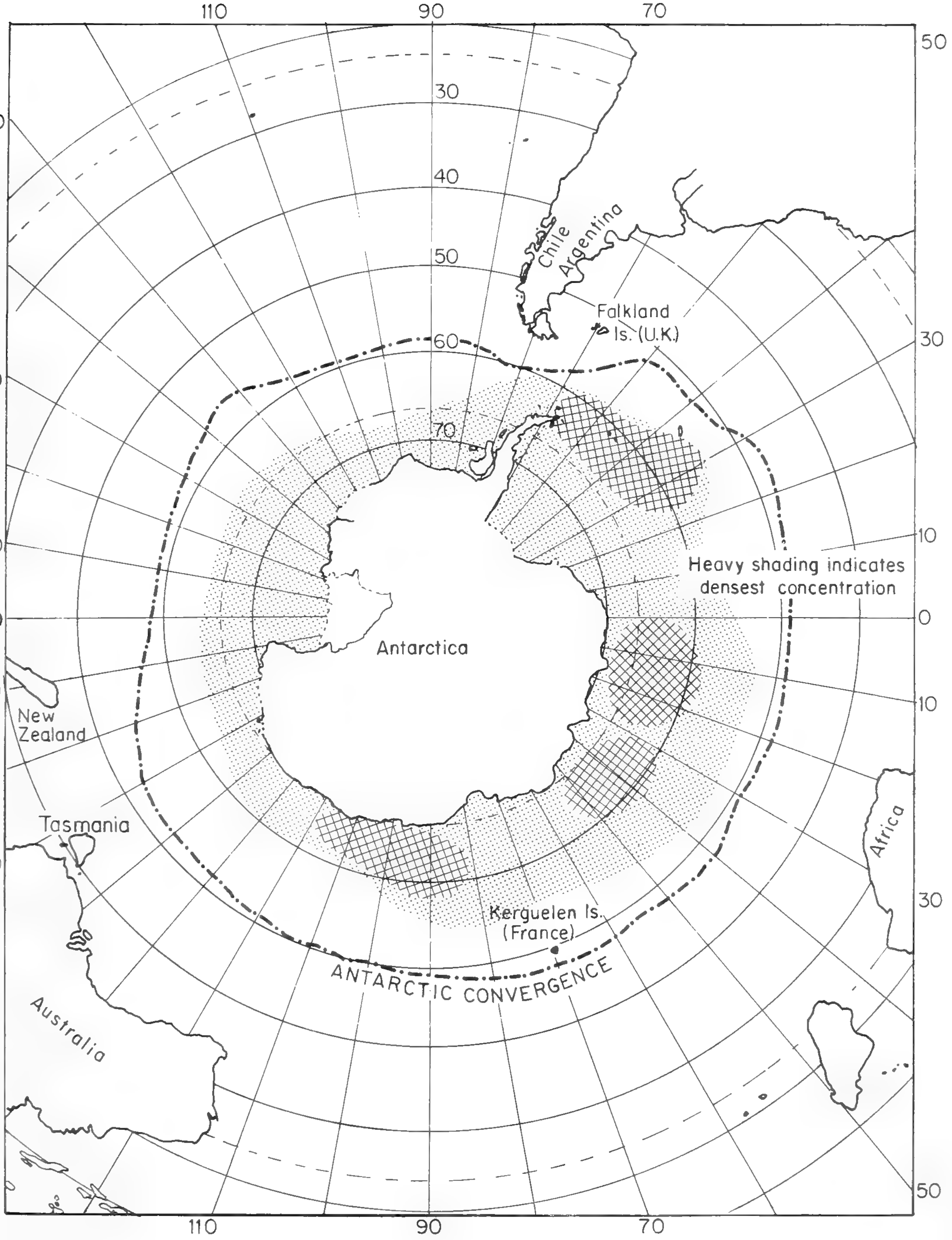

Figure 1.—Distribution of krill in the Southern Ocean. (Source: Joyner et al. 1974.)

country" (Ford 1981). This is a policy that has been reiterated many times, even when U.S. astronauts landed on the moon in 1969. Instead of claiming the moon for the United States alone, it was claimed for all mankind.

It was in this spirit that the United States persuaded Argentina, Australia, Belgium, Chile, France, Japan, New Zealand, Norway, South Africa, United Kingdom, and the U.S.S.R. to sign the Antarctic Treaty in 1959 which became effective in June 1961. Poland later became signatory, thus becoming the 13th member. This remarkable treaty reserved an entire continent for free and nonpolitical scientific investigation.

Later, Brazil, Bulgaria, Czechoslovakia, Denmark, Federal Republic of Germany, German Democratic Republic, Netherlands, and Romania became signatories. It is highly unlikely that the original land-claiming signatories of Antarctica at the time of signing ever considered extending the Antarctic Treaty into the contiguous seas. With the recent worldwide practice of extending national jurisdiction seaward for 200 mi for fishery management purposes, a point of disagreement might possibly intrude on an otherwise amicable arrangement among the signatories.

The area of greatest abundance of krill lies not far from areas claimed by several nations. It is conceivable that after 1990 when the present Antarctic Treaty expires claims may be made to extend the jurisdiction of one or more nations seaward by 200 mi. Serious discord and overlapping conflicting claims might well result not only for the potential fisheries but also for unproved petroleum reserves. The dispute between Argentina and Chile with respect to the Beagle Channel claims of each nation might well be a precursor of what may come.

LOCATING AND HARVESTING KRILL

The location (bringing a vessel to an area where there is a high probability of catch) of krill by experienced fishermen is no more difficult than it is for any other fishery (Eddie 1977). For the relatively short summer period when climatic conditions favor a krill fishery, usually dense swarms of krill are known to inhabit certain areas more than others. Historically, the southern Atlantic, more than the southern Pacific or the southern Indian Ocean, has been the haunt of baleen whales. The chief areas of krill abundance have been over the shelves and slopes and deeper water near South Georgia, in the northern part of the Weddell Sea, in the Scotia Sea north of the Orkney Islands, the South Sandwich Islands, the South Shetland Islands, in the Bransfield Strait, and in the Bellinghausen Sea (El Sayed and McWhinney 1979). Unpredictable occurrence of swarms is commonplace. In the 1979-80 season the krill crop failed to materialize in the South Georgia area. Yet, during 1980-81 First International Biomass Experiment (FIBEX) observers detected a mass of krill estimated at 10 million t near the South Shetland Islands. As Alverson (1979) stated "substantial year-to-year variations in population sizes occur which are the result of recruitment failure or changes in behavior or both." Surface fishing strategy, in addition to visual location of swarms of krill, also depends upon the presence of other natural indicator predators such as birds, seals, and whales.

The detection of deeper lying quantities of krill seems to be most effective with the vertical echo sounder. The frequency of the acoustic transmission used is between 100 and 200 kHz. For stocks of krill not visible on or near the surface, fishing echo sounders can be used to detect the fish which are feeding upon krill. Experienced fishing skippers have, in some cases, been able to distinguish between desirable krill and unwanted salpas (Eddie 1977). As yet, it has not been possible to use echo sounders to distinguish between krill of different sizes. The capability of acoustic devices to discriminate between sizes of krill may depend on frequency, frequency variation, beam width, and pulse length. It is generally agreed by both scientists and experienced skippers that with the present stocks of krill, location and detection, by and large, are not much different from regular fishing operations (Eddie 1977).

An unusual attempt at krill detection was reported to have been developed by Japanese scientists of Tokyo University of Fisheries for the 1978-79 exploration. A miniature model plane with a wing span of about 2 m would be launched from the bow of the University research vessel *Umitaka Maru*. The model plane would have a payload of 1.5 kg and would carry two motor-driven cameras and a transmitter capable of taking a total of 30 color and black-and-white photographs. The plane would be able to ascend to about 1,200 m and reach a speed of about 83 km/h. Recovery of the plane would be made with netting on the windward side of the deck. The plane's engine revolutions, rudder, elevator, and two cameras would be controlled from the deck of the ship by a hand-held transmitter (Anonymous 1979).

Several methods of capturing krill have been tried with varying degrees of success. Efforts have been made to use single-boat and two-boat purse seines, but efforts to use any kind of purse seines have been given up because 1) it is expensive and very difficult to repair seines, and 2) purse seining is primarily a good weather operation. The summer weather in the Antarctic is usually foul and very often dangerously windy for this method of capture. The most effective methods appear to be variations in surface-midwater trawls.

Early attempts at harvesting krill were based on the assumption that patches of krill were to be found chiefly at or near the surface of the ocean. It was also assumed that krill could take evasive action to avoid an approaching net or ship. (The 1981 FIBEX cruise confirmed that krill can avoid the nets.) It was considered that a ship plowing through a swarm would scatter the krill and that the best way to catch them would be to tow a surface trawl with a mouth opening wider than the trawler. Another method was to use an outrigger on each side of the trawler each one of which towed a surface trawl. An additional method was to tow a trawl on the surface and have the ship move in a curved path so that the trawl would not follow in the wake of the trawler. Another method was to affix a net to a metal frame that would form an inflexible mouth opening of the net. The whole arrangement was suspended from the side of the ship and some attempts even included the principle of continuous discharge by pump and flexible hose to a screen on the trawler deck. The screen retained the krill and the seawater escaped via the scuppers. Again, this type of catching-unloading is good only for surface krill, and it operates reasonably well only in calm weather which is a scarce commodity in the Antarctic (Eddie 1977).

Only recently (1970's) was it appreciated that patches of krill could be located well below the ocean surface in large quantities. By means of echo sounders and well designed krill trawls in the hands of skilled fishing captains, it has been established that aimed midwater trawls shot by single trawlers are the most efficient krill catchers (except whales).

Practical catching rates can be achieved by using much smaller trawls than are used in conventional fisheries. The increased drag caused by the use of small mesh in order to contain the krill without escapement, necessitates the use of smaller trawl nets. An alternative is to use a relatively large mesh trawl with a fine mesh liner. Mesh sizes for krill have ranged from as little as 8 mm (stretched) to as great as 12 to 24 mm.

The consensus of skilled skippers is that surface-midwater trawls as presently used are entirely satisfactory. The reason for their confidence is that the catching rate is, at present at least, enormously higher than the processing-preservation rate. Catching technology far outruns utilization technology.

Natural Restrictions

In any consideration of Antarctic fishing, it should be realized that nature has imposed restrictions on successful fishing on a year-round basis. The first is ice. During the Antarctic "winter" (May to November) about 22 million km^2 (60% of the total oceanic area) is covered by ice. Fishing during the winter is very difficult although the Soviets and the Poles have accomplished it. In the milder "summer" period (December to April), the ice cover is reduced to 4 million km^2 or 11% of the oceanic area. This 150-d period is the longest that is feasible for fishing of any kind, and even then the weather in early spring and late autumn is inclement.

A second less important hindrance is the constant high wind. The chief contrast to the Arctic Ocean, latitude for latitude, is the extremely high wind velocity. In this respect, it has been postulated that it may not be "beyond the bounds of possibility to conceive of a floating plant, anchored in deep water, powered by the ever-blowing westerly winds, uninhabited and automatic, and visited at intervals of months for the removal of the crustacean sludge extracted by mechanical separation. Such development would seem more promising than direct fishery in antarctic waters" (Bertram and Blyth 1956).

Fishermen and scientists have chosen to ignore the above suggestion of automated equipment powered by the ever-blowing wind. They have, instead, relied on adaptations of conventional fishery techniques. One advantage of free fishing is being able to actively seek planktonic patches of krill rather than passively waiting for krill to be drifted to the automated plant. A second advantage is the choice of product forms that can be made with human supervision.

Financial Assistance

It is highly significant that all of the nations that have sent exploratory krill operations in the last decade have been official representatives of their respective governments—either directly as government employees or as contractors to a government agency. Most prominent have been the U.S.S.R., Japan, Poland, and the Federal Republic of Germany. To a lesser extent, Chile, the United Kingdom, the German Democratic Republic, Norway, and Taiwan have experimented with krill.

The cost to outfit, crew, and operate a large ship thousands of miles away from its home port is so great that private industry cannot afford it. At present, the costs are so staggering compared with the returns that only completely government-subsidized krill explorations can be undertaken. The United Kingdom has already gone on record stating that the disadvantages of a krill operation exceed the advantages (Anonymous 1976). Further, it has stated that it would prefer to investigate the possibility of exploiting blue whiting stocks close to its shores although in very deep water.

The position of West Germany is somewhat complicated by the fact that West German processors have expressed criticism of the explorations. They definitely prefer "closer-to-home research with more immediate prospects of tangible results" (Anonymous 1977). Chile and Argentina are in the advantageous position of being able, theoretically at least, to establish land-based operations at their southern extremity. The economics and feasibility of building facilities in this desolate area of the world would have to be carefully weighed against the use of factory ships.

Norway and Taiwan interests are so deeply committed to conventional fishery operations that can be performed at a profit that it is considered unlikely that they will be serious contenders in this fishery. Japanese efforts to the present have been carried out jointly between private industry and the Japan Marine Resource Research Center. A refrigerated transport owned jointly by several companies accompanied by large trawlers to act as krill catchers was subsidized by the Fisheries Agency of Japan. If Japanese food technologists have not improved upon the final product forms of krill by the mid-1980's, it is likely that Japanese government subsidies will either cease or be greatly reduced. The aim will be to shift financial responsibility upon industry.

The U.S.S.R. has spent more years and effort than any other nation in krill research and utilization. The determination and persistence of Soviet scientists may soon result in products that will be acceptable in world markets. Poland's interest, while spanning only about 6 yr, is intense and the Poles have become competent. In the hope of resolving a quality control problem, the Northeast Fisheries Center, Gloucester Laboratory, sent an observer to the Antarctic aboard the Polish Research Vessel *Professor Siedlecki* during its 1978-79 expedition.

The United States has not shown an interest in krill harvesting or utilization in the recent past nor is it likely to in the near future. There are several reasons for its abstention from this type of fishery. The first is that we do not have any pressing need for this source of protein and fat since we are the world's largest exporter of food. The second is that as yet no product made from krill has been acceptable to western tastes and no demand exists. A third is that the private sector has no incentive to invest in the krill fishery because of prohibitive costs of maintaining a fleet in such a remote area. A fourth reason is that Americans will not willingly accept employment which requires their being away from home for such extended periods. Government subsidy such as is done by Russia and Poland would not work with Americans unless there were enormous benefits comparable with those which resulted from the construction of the Alaskan oil pipeline.

PROCESSING TECHNOLOGY

Composition

As with any fishery resource, the protein, fat, mineral, and vitamin content are related to physiological condition, age, diet, and sex of the particular animal. Grantham (1977) has summarized the results of 20 papers which report values for the proximate composition of whole krill (Table 1).

Table 1.—Proximate composition of whole *Euphausia superba:* Summary of literature values.

	% Dry weight			% Wet weight		
	Moisture %	Crude[1] protein	Crude fat	Ash	Crude[1] protein	Crude fat
Average	80.1	65.1	14.2	13.9	13.0	2.8
Mean maximum	83.1	77.5	26.0	16.7	15.4	5.1
Mean minimum	77.9	59.7	6.7	11.7	11.9	1.3

[1] Total nitrogen x 6.25, includes nonprotein material. (Source: Grantham 1977.)

The proportionate percentage of body components of whole krill according to Grantham (1977) are about 28% tail meat, about 34% cephalothorax, and about 26% carapace. The remaining 12% is exudate lost on separation of the body parts.

Protein.—According to Grantham (1977), the 13% wet weight of protein appearing in Table 1 comprises about 8.5% true protein and 2.5% free amino acids. Volatile bases, chitin, and nucleic acids account for the remainder of the nitrogen. Krill exhibits a high content (46%) of the essential amino acids, thus making krill an extremely rich source of amino acids.

Fat.—The literature reports that although the amount of fat in krill will vary with season, the composition of krill fat seems to remain quite constant. Krill fat has a high content of complex (phospho) lipids (50%), about 30-40% neutral fats (glycerides) and about 8% unsaponifiable fat. Unlike other Antarctic zooplankters, krill contains no waxes during the winter period and probably feeds on detritus in the absence of primary production (algae). According to Grantham (1977), about 70% of the fatty acids are unsaturated with the three essential fatty acids—linoleic, linolenic, and arachidonic—totaling about 5%.

Vitamins.—Significant amounts of vitamin A and the B complex group occur in krill with lesser amounts of E and D. Astaxanthin, the vitamin A precursor, is found to be high in the exoskeleton and is particularly rich in the eyes. The characteristic color of krill is due to the presence of this pigment.

Minerals.—Krill contains 28 elements in its mineral composition and is a particularly rich source of calcium, iron, magnesium, and phosphorus. Fluoride has been reported present by Bykov (1975) but Soevik and Braekkan (1979) reported that values for fluoride in krill greatly exceed the upper permissible limit of 100 mg/kg calculated as sodium fluoride established by the U.S. Food and Drug Administration (FDA) for fish protein concentrate (FPC) in 1967. They conclude that "The present values for fluoride in krill exceed this limit by more than seven times for the freeze dried and extracted meat, and 24 times for the entire shellfish. This would make krill in any form, even peeled, fail to comply with requirements for human consumption."

This warning may not be applicable because there is an essential difference between krill and FPC. The latter is a highly concentrated processed fish product arrived at by sophisticated chemical processes. In its most desirable form of tail meat, krill is a naturally occurring crustacean with no added fluoride within the meaning of the Federal Food, Drug and Cosmetic Act. In mid-1981 the FDA announced that it had decided that the edible tail meat of krill would be regarded as a food and not a food additive. It also stated that the amount of fluoride (14 ppm) in krill did not render the krill injurious to health.

Calorific value.—The reported literature values for the proximate composition of krill have been concerned with whole krill rather than the edible tail meat. Chekunova and Rynkova (1974) have determined that juvenile and adult krill have calorific values of 1.0 and 1.1 kcal/g wet weight, respectively.

Chitin.—According to Mauchline and Fisher (1969), the exoskeleton of krill accounts for about 10% of its dry weight. The high content of chitin—about 40% of the dry weight (Yanase 1975)—makes chitin a potentially valuable byproduct.

Autolytic Degradation of Whole Krill

Krill is one of the most perishable of marine products owing to the presence of very active enzymes which initiate several forms of degradation including rapid and severe autolysis. This is somewhat noteworthy in view of the generally low temperature conditions that prevail during the catching period. Mean air temperature in the areas most likely to be fished in January is about 5 °C (41 °F). Lagunov et al. (1973) stated that at a storage temperature of 5 °-7 °C the volatile base nitrogen content increases from 5-6 mg % to 17 mg % in 24 h and accelerates to 66 mg % in 72 h. Accompanying this change are a pronounced textural change from firm to flaccid, high drip losses, and sensory depreciation. When stored more than 40 cm deep at 5 °-7 °C (41 °-45 °F), the internal organs are ruptured and release the highly active enzymes. Even shallow heaps of krill stored exposed on deck will generate significant heating.

At relatively cool temperatures of about 10 °C (50 °F) in a matter of a few hours on deck, various discoloration patterns develop. The krill become pale in color and lose their usual crustacean transparency; they soon change to a yellow-grayish color accompanied by what is termed "black spot," in the shrimp industry, of the tissue beneath the exoskeleton of both the abdomen and cephalothorax. The color degradation can even affect the end product. Another fairly common color change is that occasioned by the incomplete digestion of chlorophyll-containing phytoplankton in the stomach or filtering apparatus. The result is a greenish tinge imparted to the final product in addition to a disagreeable flavor change (Grantham 1977).

If these were not enough, there is also a microbiological transition that must be reckoned with. Like most marine fish, krill have a low bacterial content at the moment of catching but soon afford an excellent medium for bacterial growth once the krill die and are landed on deck or stored. Concommitant with this normal bacterial buildup in krill, Sieburth (1959, 1960, 1961) has found that krill feeding upon certain species of phytoplankton contain an antibacterial component that has been identified as acrylic acid. At present, not enough is known of this antibacterial agent to take advantage of its apparent unusual properties.

To most fishery people, the storage temperatures mentioned above (5 °-7 °C) seem unduly high in an Antarctic environment when compared with normal North Atlantic fishery operations. Under good conditions of operation of the latter, gutted fish are stored in ice in such a fashion that fish temperatures of < 2 °C are soon achieved and maintained or even lowered before discharge of the cargo. Polish investigators have tried holding krill at 0 °C and < 1°C, but, although some extension of storage life was obtained, the amount of extended storage life was not considered worth the effort.

International Efforts and Food Product Forms

The nations that have worked with krill as a potential food source have generally agreed that efforts should be made to use krill as a food for direct human consumption rather than as feed for animals. The conversion of krill presents technological problems of a serious nature owing to the small size of the animal and the possession of active enzymes which cause rapid autolysis.

It is agreed among the Russian, Polish, and West German investigators that krill should not be held at 10 °C (50 °F) for more than an hour before processing or held longer than 3 h at 0 °-7 °C (32 °-45 °F). Any increase in either temperature or holding period results in undesirable autolysis. Krill should be piled < 30 cm (12 in) deep, and immature krill should be handled faster and piled shallower because they are more prone to degradation than mature krill.

Regardless of the method of pretreatment, it is the marketability of the form of the finished product that matters. In this respect, it is interesting to review the final product forms developed by various national interests bearing in mind that intrinsically krill do not possess any particular merits or attributes over other crustaceans or finfish. In fact, were it not for their tremendous abundance and nutritional potential, krill would not be the object of various national surveys.

U.S.S.R.—The Soviet Union first started its investigations of krill stocks in the Antarctic summer of 1961-62 with the research vessel *Muksun*. Since then, the greatest amount of research has been carried out by the research vessel *Akademik Knipovich*. The Soviets have almost exclusively directed their efforts to the production of a paste made from krill as follows:

1) Press raw krill for its liquid protein fraction.
2) Collect juice under controlled conditions of time and temperature.
3) Heat juice to coagulate the protein.
4) Separate coagulated protein from liquid fraction.
5) Condense, coagulate, and package.
6) Freeze and store.

The krill paste has a sweetish delicate flavor similar to shrimp and is pink in color. The chief use so far has been as an additive. It has been found to go well with cheese, butter, mayonnaise, and various vegetables. It can also fortify such foods as salads, stuffed eggs, and dumplings. Attempts have been made to make sausages with as much as 60% krill paste.

Trade sources (Anonymous 1977c) stated that a 5-yr agreement had been concluded between a Norwegian fish soup manufacturer, Rieber and Son of Bergen, and the Soviet Union's Ministry of Fisheries. Under the terms of the agreement, they will exchange information on the production of krill paste for sandwiches and as an additive in other foods, especially dried soups. The Soviet investigators have patented three products made from krill paste as follows: 1) U.S.S.R. Patent 258,846 (1970) "Shrimp Butter." This product contains krill paste, butter, and flavoring. 2) U.S.S.R. Patent 390,804 (1974) Snack Product. This product contains mussels, malt extract, rye wort, krill paste, and a gelling agent. 3) U.S.S.R. Patent 284,589 (1970) Krill Sausage. This product contains krill paste, sodium alginate, dried milk, salt, and spices.

In an effort to diversify krill products, the Russians have investigated methods of separating krill meat from the exoskeleton. The krill are cooked and dried in a fluidized bed with short wave infrared radiation. The shells are mechanically broken and removed. The meat and other internal organs are separated by flotation in freshwater at 5°-10°C. The process has been patented under U.S.S.R. Patent 581,918 (1977).

It would appear that Soviet investigators are now de-emphasizing their work on krill paste and are experimenting with krill products embodying whole or nearly whole krill tail meats. Grantham (1977) indicated that the krill paste was no longer being marketed in the U.S.S.R. but other sources indicate that limited quantities (500-800 t) are being used annually in various products.

Japan.—Small, dried whole shrimp called sakura-ebi (*Sergestes phosphoreus*) about the size of adolescent krill, are very commonly eaten in Japan. In recent cruises to the Antarctic, the Japanese cooked and froze whole krill aboard ship and dried it ashore later. The krill product apparently has not yet received as much acceptance as the regular sakura-ebi. It is interesting to note in this respect the food laws of Japan require that a distinction in labeling of krill be made in order to avoid deception to the consumer.

Frozen raw krill has been offered as well as the boiled, dried product since early 1978. The product is thawed and consumed raw shell-on as sashimi (a general term for raw seafood) or it may be used as a flavoring ingredient for other dishes. It is also used as an ingredient in sushi which is made by fermentation of pickled krill, boiled rice, and salt. In restaurants, the raw krill may be served with boiled rice flavored with vinegar. Preliminary reports indicate that the response is encouraging.

Other product forms are frozen attrition-peeled tail meats which are designed to simulate small frozen peeled shrimp. No reports have been obtained on the reception this product has been accorded. Considerable experimentation has been done with krill muscle processed by meat-bone separators. The minced product may be used in many ways similar to minced fish. One form of minced krill may be washed, and to the resultant product sugar and starch may be added to form a base for krill kamaboko. The latter is a hardened jellied product usually not favored outside Japan.

The 1977-78 catch for Japan was reported to be 21,000 t. The chief products prepared aboard ship were peeled frozen krill, frozen raw krill, boiled frozen krill, and krill meal. No information is available as to how the krill was peeled, but one ship of the Japanese fleet was reported to have had a shipboard facility to produce individually quick-frozen krill.

Chile.—Like Argentina, Chile is nearer to abundant krill stocks by many hundred miles than any other nation. Reports available from the Office of International Fisheries Affairs of the National Marine Fisheries Service indicate that Chile's first efforts in krill exploration were made in 1975. In April of that year, the 640 t vessel *Valparaiso* landed 40 t of frozen krill. The Chilean Institute of Fisheries Development (IFDP) reported good results with peeling machines used aboard ship and ashore (make of machines not known[3]). IFDP and the Catholic University of Valparaiso are reported to have developed over 20 different krill products which include minced krill, dried krill, krill paste, and krill sticks. The krill sticks were reported by the State-owned fishing company Pesquera, Chile, to have achieved good success. In 1977, Chile distributed batter-dipped krill sticks at the annual trade fair in Cologne, Germany (FRG).

In 1978, it was reported that Chile was to construct a vessel to be used in the krill fishery. The vessel was to have a carrying capacity of 1,200 t and a catching rate of about 100 t/d. No further reports of the status of the ship construction project have been received. The original plans called for a krill-catching period of about 240 d for the vessel. This is an almost impossibly long krill fishing period because of the natural ice restrictions on krill fishing unless finfish are to be caught.

In 1978, reports of proposals for establishing joint ventures with Chile to catch and process krill have mentioned Spain, France, and Japan in particular. Nothing concrete had developed by the spring of 1980. This apparent lack of firm agreements may be due in part to the Chilean government's failure to adopt a proposed Krill Development Law. Chilean interest in krill exploration and utiliza-

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[3] Trade source indicates that the peeling was accomplished by Laitram shrimp peelers made in the United States.

tion still seems high because Chile was an active member of the FIBEX conducted from about mid-January to the end of March 1981.

Federal Republic of Germany.—Trade reports appearing in the press (Anonymous 1977b) state that "in spite of West Germany's recent energetic research work in Antarctic waters, the Soviet Union already has a five-year lead but is declining to co-operate in sharing any scientific discoveries she may have made."

Unlike the U.S.S.R., Germany has not concentrated most of its experimental work on krill paste. Instead, in the relatively short time since operations began in 1975-76, it has tried the following product forms: 1) Comminuted krill meat from boiled krill, 2) fried krill portions made from frozen comminuted krill, 3) souplike preparation obtained through an enzymatic process using raw (nonboiled) krill, and 4) meat product analogues from krill, dried milk, and saltfish.

Trade sources hint that the 1978-79 German venture into the Antarctic may well be its last. This is because West German fishery industry people have expressed criticism of krill exploration. They definitely prefer "closer-to-home research with more immediate prospects of tangible results" (Anonymous 1977). In view of the alleged German industry attitude, it would appear that German Antarctic explorations may be curtailed except for multinational ventures such as the recently completed (1981) FIBEX.

Poland.—Polish investigators have had little experience with crustaceans other than three species of freshwater crayfish that are native to Poland and eastern Europe. Following the lead of the U.S.S.R., the Poles have made six annual trips to the Antarctic in the pursuit of krill and its manufacture into food. From all accounts, the Polish investigators have avoided the U.S.S.R.'s heavy emphasis upon krill paste and have chosen to explore other alternatives. In the short time Poland has been active in krill research and processing, its investigators have developed a method of peeling krill that is alleged to be in the process of being patented. The krill are first boiled, then individually quick-frozen, and peeled in a machine resembling a potato peeler. The principle of continuous centrifugal abrasion appears to be central to the method. The meats and shell fragments are then separated by air. The yield of meats is reportedly between 16 and 20%. The resultant tail meats are said to be of attractive appearance.

A slightly different peeling principle has been patented by Dalmor Deep Sea Fishery of Gdynia, Poland (Kryszewski and Jasniewicz 1977). While little detailed information is available, it is believed that the krill are cooked and then subjected to mechanical treatment that includes a high speed rotating drum and large quantities of water. The yield from the prototype model is about 10%, but it is believed that with further improvement, the yield could be raised to 15%. It is to be noted that with both Polish peeling machines the krill are cooked before peeling whereas with the American-made peelers by Laitram and Skrmetta the krill must be fresh raw or thawed raw. Yields with the American peelers are in excess of 15%.

Argentina.—Despite its proximity to abundant krill stocks, reports of active work on krill studies by Argentina are lacking except for the sending of a scientific observer on a German research vessel to the Antarctic. It would appear that Argentina's interest in the Antarctic lies more in oceanographic and other operations that come within the purview of the Argentine Navy. Plans of Centro De Investigaciones de Tecnologia Pesquera (CITEP) do not call for immediate krill studies. CITEP is fully aware, however, of the international interest in the potential of krill.

United Kingdom.—Despite the years of exploratory work done by the British in the years between the two World Wars recorded in the Discovery Reports, the British have never sent an expedition aimed solely at utilizing krill for human food. Germany invited British fishery investigators as observers in the German expeditions of 1975-76 and 1977-78.

The Torry Research Station Annual Report of 1976 stated among other things "Euphausia when cooked has a mild shrimp-like flavor and the texture of the meat is slightly sloppy. It has potential as a raw material for food, but no product of wide appeal has yet been made from it."

In the 1977 annual report from Torry, it was stated "The economic viability of an Antarctic fishery done by the UK fishing industry would depend critically on the existence of a profitable market for the products; suitable products still remain to be developed. Whilst limited research is prudent, any major effort does not seem justified at this stage."

A British fisheries trade journal (Anonymous 1976) stated that the Fisheries Research and Development Board has gone on record to the effect that the disadvantages of a krill operation exceed the advantages. It has stated that it would prefer to investigate the possibility of exploiting deep-water blue whiting stocks that exist close to its shores.

Norway.—Norway has given the world the word "krill" (kril) to identify the luminescent euphausids which form the chief food of baleen whales. Norway is one of the seven nations that claims sovereignty over certain parts of Antarctica itself; yet, it has not engaged in extensive efforts to explore the possibilities latent in krill. The reason for Norway's apparent lack of interest is not known, but since Norway is one of the top protein exporters in the form of fishery products, it would appear that the supply of fish in home waters is more inviting than in the Antarctic.

Taiwan.—This country first became involved in krill exploration in 1975 with the catching of 136 t of krill. Products made from the catch include krill vegetable stew, fried krill rolls, krill soup, bean curd stuffed with krill, and other Chinese foods. The investigators have emphasized the problem of enzymatic degradation of krill, drip loss, and discoloration of the krill. No further explorations have been made expressly for krill although an Antarctic trip was made in 1977-78 for finfish.

Byproducts

The exoskeleton of krill, like that of many crustaceans, is rich in two byproducts of potential interest. These are chitin, a polysaccharide similar to cellulose of plant cells, and astaxanthin, a natural pigment associated with many Crustacea.

Chitin and its deacetylated derivative chitosan are presently being produced commerically for use in a number of applications, particularly wastewater treatment. Both chitin and chitosan are at least equal to, if not superior to, bovine cartilage in accelerating the healing of wounds. They can serve as replacements for arteries, veins, bones, and cartilage in human protheses. Chitin and chitosan are nontoxic and biodegradable, and research has shown that applications are valuable in the food industry, as coatings and for wet-strength paper, for encapsulating drugs, and as chelating and flocculating agents for water treatment.

The main deterrent to the commercial development of chitin from shellfish waste in this country has been the lack of a constant supply of shellfish waste in a given locale. Since the theoretical yield of chitin is <1.4% of whole krill, a well-developed krill fishery might be an ideal source of raw material. At reported catch rates of 100 t daily, the production of chitin/chitosan could well represent a significant aspect of the krill fishery.

Reports reaching us indicate that Polish investigators have pretty well solved the problems associated with the manufacture of chitin and chitosan aboard ship and are now reported to be nearly ready to supply markets for these high grade finished products.

The pigment astaxanthin can be extracted from a number of crustacea, such as pelagic red crab, *Pleuroncodes planipes*, deep sea red crab, *Geryon quinquedens*, and several species of shrimp. In recent years, this pigment has been shown to be of value in feeding hatchery-bred trout and salmon because the pigment enhances the red color of the fish flesh. Krill contains about 3,600 μg/100g of astaxanthin (range 600-9,700) which can be extracted as part of the derivation of chitin.

A more prosaic byproduct is krill meal which presents no particular problems of manufacture. Krill meal, according to Grantham (1977), has a protein content of about 55% which is generally lower than most fish meals. The fat content, however, ranges from 12 to 20%. The high fat content gives the krill meal a higher calorific value so that despite its apparent lower composition value based upon protein content alone, feeding trials indicate that it is of higher feed quality than expected.

MARKETING

National Accomplishments

Study of the literature, in addition to personal examination of various krill products made by Polish and West German investigators, lead us to conclude that krill manufacture has a long way to go. Neither country is satisfied that it has produced a krill product sufficiently appealing to satisfy international tastes and cultural differences.

Japan has tried to make more products than Russia, and with the high rate of seafood consumption in Japan, it is likely that Japan will produce krill products that will establish some sort of home market but not necessarily an international market. In 1976, Japan introduced whole, boiled, frozen krill for about $700/t at the wholesale level. At retail, ton lots of krill packed in 300 g containers are sold at prices ranging from $1,000 to as much as $1,600. All products were sold within Japan.

Trade sources state that Chileans have marketed canned roller-peeled meats at about $1.50/lb ($3.20/kg). Chile has also introduced block-frozen meats at $1.00 to $1.10 for packs weighing 80-90 g (2.8-3.2 oz). In paste form, the Russian block-frozen and canned product has been sold at retail levels for $2.00-$2.80/kg. It is reported that for a while block-frozen krill paste was available at about $1,600/t.

Frozen blocks of minced krill made from both raw and cooked krill have been made by both Polish and West German investigators. Minced krill made from raw material has a shelf life of only 2 to 3 mo at −25°C (Grantham 1977). A minced product made from cooked krill is much more stable in the frozen state than the minced product made from raw krill. Frozen, cooked krill tail meats are considered of greater value than cooked minced krill. Other product forms such as concentrates, hydrolysates, meal, and protein isolates have been made but, again, none can command a market price, much less create a market demand.

Market Research and Economic Analyses

It would appear that each nation that has tried to utilize krill has done so through government scientists or, in some cases, through government-supported contractors. No mention is made of conducting market research to determine the suitability of various forms of krill products. It would appear that those who make the products are those who would presume to pass upon the acceptability or usefulness. The fact that there are no market-ready forms of krill that have much national potential, much less international appeal, may indicate a weakness in the approach so far.

The energy requirements to sail a vessel many thousands of miles to and from Antarctica in addition to heat-processing krill aboard ship and also to freeze and maintain proper freezing storage temperatures are tremendously high. Yet, seldom in the literature reviewed have any considerations been given to making complete economic analyses. It is not likely that any combination of private interests would dare to tackle a task of as great a magnitude without first running even an abbreviated economic analysis.

POSSIBLE PROBLEM AREAS

Krill Resource

At present, there seems to be no immediate problem with the maintenance of the krill stocks in Antarctic waters. No concerted fishery for krill is likely to be mounted until more efficient peeling machines are devised to produce attractive tail meats at an acceptable yield and high rate of speed. The limited fishery season (November to April) in addition to the sailing distance to Antarctic krill stocks serve as effective constraints to immediate overexploitation. If baleen whales were to increase due to reduced whaling activity, they would be natural competitors during the same season.

Harvesting Krill

Problems could arise when competing vessels have different end-use applications in krill harvesting. Most notably would be the presence of vessels geared to harvest large amounts of krill for manufacture into meal if krill meal manufacture is of itself economically feasible. Such vessels would be designed and equipped to capture and process larger amounts of krill than vessels engaged in krill utilization for human use. Physical damage to newly caught krill is of far less importance for krill meal or byproduct use than krill destined for human use. Conflicts might eventually develop because both types would hunt the same prolific area but not at the same catch rate, thus leading to potential problems of resentment of one type of fishery against the other.

Problems may yet occur when the present Antarctic Treaty expires in 1990. Failure on the part of some signatories to ratify an extension of the treaty might signal an intention to extend the jurisdiction of those nations. Some of the very richest krill areas lie within a 200-mi limit of important islands in the Antarctic area. This is particularly true of the dependencies of the Falkland Islands which include the South Sandwich and South Orkney Islands as well as South Georgia. These areas are administered by the United Kingdom but are still claimed by Argentina.

Extension of jurisdiction from the southern tip of the South American continent by both Chile and Argentina could also include rich krill areas. Territorial claims in Antarctica have been made by Argentina, Australia, Chile, France, Great Britain, New Zealand, and Norway. It is of interest that each of these nations now subscribes to the 200-mi extended jurisdiction philosophy. Whether or not any of these nations would make such claims is, at the present time, a matter of speculation. Conditions after 1990 may be appreciably different.

Processing Technology

Although no vessels have been expressly designed and built for the harvesting and processing of krill, in late 1979 a Finnish shipyard, Wartsila Turku, announced that it had designed, but not built, a powerful stern trawler for harvesting krill. The proposed factory trawler is designed to lower its warps under the ice to fish in ice fields up to 60 cm thick. It would have a fully covered deck and would be equipped with the Wartsila air bubbling system to reduce ice resistance. Included in its design is a processing capacity of about 200 t of krill a day. End products would be peeled krill, krill meal, and krill oil. No details were released about krill processing equipment.

We emphasize that harvesting technology far outstrips processing technology. Additional catching ability will avail little until krill peeling equipment is advanced to the point at which it will process an economically justifiable portion of the catch. One of the most critical deterrents to the successful production of intact krill tail meats is the lack of equipment that will produce such desirable meats at a high rate of yield and production.

Marketing

Krill products have been many and varied, although none are outstanding. The lack of a reasonably acceptable product could very well hamper further efforts at development. A critical analysis of the products made to date should be made to determine which type offers the greatest promise. Experimental work concentrated on one or a few end products having promise will probably result in a product(s) with favorable marketing appeal.

CONCLUSIONS

Owing to the many and long-standing uncertainties about krill stocks and the coming development of acceptable krill products for human consumption, we conclude that:

1) Necessary knowledge for judicious management of krill stocks will continue to lag behind technological development.

2) Technology of krill utilization will be accomplished by one or more nations before 1986.

3) There is a likelihood that intensive exploitation of krill stocks will be underway well before the expiration of the Antarctic Treaty in 1990.

4) There is little or no possibility that underdeveloped countries will tap krill stocks for human protein needs.

5) The nations that will be successful in exploiting krill stocks will be 1) those whose fisheries are fully government subsidized and vertically integrated, or 2) those that have great expertise in fishing enterprises in some form of cooperation of industry with government.

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Population Characteristics of the American Lobster, *Homarus americanus*, in Eastern Long Island Sound, Connecticut

Milan Keser, Donald F. Landers, Jr., and
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Population Characteristics of the American Lobster, *Homarus americanus,* in Eastern Long Island Sound, Connecticut

MILAN KESER, DONALD F. LANDERS, JR., and JEFFREY D. MORRIS[2]

ABSTRACT

Population characteristics of the American lobster have been studied extensively in the vicinity of Millstone Point, Conn. Since 1975, 22,150 lobsters have been tagged, and pertinent biological data recorded. Catch per unit effort was similar among years, but was significantly higher for wire than wooden pots. Legal-sized individuals ranged from 4.5 to 18.1% of the total catch. The percentage of culled lobsters ranged from 9.7 to 17.4%, and was greater for wood than wire pots. The sampled population was comprised of 51% males and 49% females. Berried females accounted for 3.1-6.7% of the total catch, and over half of these were of sublegal size. Growth per molt averaged 13.0% and was not significantly different between sexes. A major period of molting occured in the late spring and early summer.

INTRODUCTION

The American lobster, *Homarus americanus,* has been studied extensively throughout much of its range (Cobb and Phillips 1980a,b). Quantitative investigations of lobster populations within Long Island Sound (LIS) have begun only in the past 10 yr. Stewart (1972) studied the ecology of lobsters in the vicinity of Fisher's Island Sound; Lund et al. (1973)[3] inventoried lobster habitats and gathered data on movements throughout LIS; Smith (1977)[4] described population characteristics in LIS and socioeconomic aspects of the commercial fishery along the Connecticut coast; Briggs and Mushacke (1979) published results of a 3-yr study on selected population characteristics of lobsters in western LIS. The present study is part of a larger monitoring program at the Millstone Nuclear Power Station (MNPS) and is the first long term investigation of a lobster population in the eastern portion of LIS, representing results from 1975 to 1981.

This study was designed to assess the potential impact of construction and operation of MNPS on the local lobster population. Data on catch per unit effort, size frequencies, sex ratios, growth rates, incidence of berried females, number of culls, molting patterns, and gear effectiveness are presented here. These parameters are compared year to year, seasonally, between stations, and with data reported throughout northeastern North America.

MATERIALS AND METHODS

The study area is located in Waterford, Conn., adjacent to MNPS (Fig. 1). The power station includes two operating nuclear reactors and a third under construction. Unit 1 is a 652 MWe reactor and has operated since November 1970. Unit 2 is a 850 MWe reactor operating since October 1975. The third reactor will be 1,150 MWe, and is scheduled for commercial operation in 1986.

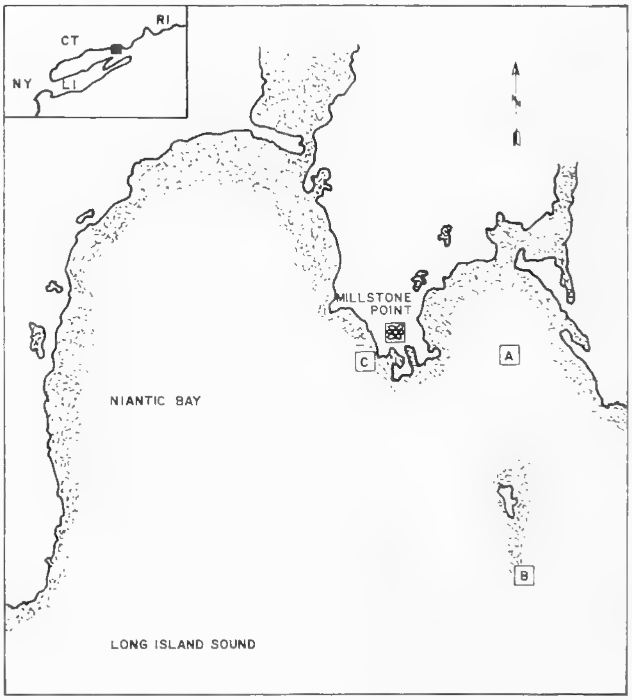

Figure 1.—Map of Millstone Point area showing the location of the lobster sampling stations (A-Jordan Cove, B-Twotree, C-Intake).

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[1] Northeast Utilities Environmental Laboratory, P.O. Box 128, Waterford, CT 06385.

[2] Northeast Utilities Environmental Laboratory, P.O. Box 128, Waterford, Conn.; present address: Biometric Unit, Cornell University, Ithaca, NY 14853.

[3] Lund, W. A., L. L. Stewart, and C. J. Rathbun. 1973. Investigation on the lobster. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Commer. Fish. Res. Dev. Act, Project No. 3-130-R, 189 p.

[4] Smith, E. M. 1977. Some aspects of catch/effort, biology, and the economics of the Long Island Sound lobster fishery during 1976. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Commer. Fish. Res. Dev. Act, Project No. 3-253-R-1, 97 p.

Suitable lobster habitats in the vicinity of MNPS (6.5 km^2) are characterized by rocky outcrops interspersed with patches of hard sand.

Beginning in January 1975, lobsters were sampled from natural and artificial habitats using scuba, from fish trawls, and from impingement studies at Units 1 and 2 intake structures. In September, 20 double entry wooden lobster pots (91 x 51 x 30 cm; 3-5 cm lath space) were set at each of three stations (Fig. 1): Jordan Cove, (east of Millstone Point; 500 m from discharge) Intake, (along the western shore of Millstone Point near the power plant intake structures; 600 m from discharge) and Twotree (1,600 m offshore, near Twotree Island). Year round sampling continued until November 1978. Subsequently, the sampling period was reduced to the months of high catch, May-October. In August 1978, half of the wood pots (10 per station) were replaced with commercial vinyl coated wire pots (76 x 51 x 30 cm; 2.5 cm^2 mesh).

Throughout the study, pots were hauled on Monday, Wednesday, and Friday, weather permitting. At each station, lobsters were removed from traps, claws restrained with rubber bands, and pots rebaited. Prior to 1979, an assortment of locally caught fish was used as bait; subsequently, to standardize the effect of bait on catchability, flounder carcasses were used exclusively. Carapace length (CL), sex, presence of eggs (berried), missing claws, and molt stage were reported for each lobster captured.

Molt stage was determined using criteria established by Aiken (1973). Recaptured tagged lobsters, severely injured individuals, and those < 55 mm CL were returned to the water untagged. All others were returned to the laboratory and maintained in continuous flow saltwater tanks, segregated by station and pot type. Each Friday, all lobsters were tagged with a numbered international orange sphyrion tag (Scarratt and Elson 1965; Cooper 1970; Scarratt 1970), and returned to the site of capture.

From 1979 to 1981, during each sampling trip, surface and bottom water temperatures and salinities were recorded at each station with a Beckman salinometer.

RESULTS AND DISCUSSION

Physical Measurements

Water temperature and salinity were measured from May through October (1979-81). Bottom temperatures ranged from 7°C in early May to 22°C in summer, and were up to 2.1°C lower than corresponding surface temperatures (Table 1). Temperatures (surface and bottom) at Jordan Cove and Intake (4-6 m in depth) were similar to each other, but slightly warmer than at Twotree (12 m). At present (two unit operation), the thermal plume does not reach the bottom sediments at any station.

Salinity was constant between stations and between surface and bottom; values ranged from 29.1 to 32‰. Due to the spring freshwater runoff, salinities were 1.2‰ lower in May and June than in the rest of the sampling period.

Abundance and Catch Per Unit Effort

A total of 27,019 lobsters were collected in the study area from 1975 to 1981 (Table 2). The increased catches from 1978 to 1981 were the result of the addition of wire pots into the sampling program (Table 3).

Catch per unit effort (CPUE) for wood pots was similar in magnitude from 1976 to 1981, but peaked at different times within each year (Fig. 2). At temperatures > 10°C lobster catch began to increase at Jordan Cove and Intake and peaked between 15° and 20°C (Fig. 3). However, at Twotree (our deep station), the catch was highest between 7° and 15°C. Since catches at Twotree decreased concurrently with increases at Jordan Cove and Intake, the movement of lobsters from Twotree into our inshore stations may have been the cause of the increased inshore catch; however, preliminary data on interstation movements do not support this hypothesis (NUSCo 1979, 1980)[5]. The relationship between catch and water temperature has been reported by other researchers (McLesse and Wilder 1958; Dow 1966, 1969, 1976; Flowers and Saila 1972).

Results from the 1978-80 sampling period indicated that wire pots caught significantly more lobsters than did wood pots (Table 3); however, this was not the case in 1981. The wire pots used in

Table 1.—Mean monthly surface (S) and bottom (B) water temperature (°C) at each station (1979-81).

Month	Jordan Cove S	Jordan Cove B	Intake S	Intake B	Twotree S	Twotree B
			1979			
May	10.3	9.5	10.5	9.5	9.9	9.2
June	15.0	14.2	15.2	14.4	14.5	13.9
July	19.9	17.8	19.2	18.3	18.3	17.7
August	20.6	19.6	20.2	19.8	19.7	19.2
September	19.8	19.2	19.8	19.3	19.2	18.9
October	17.0	15.9	15.8	15.7	15.6	15.5
			1980			
May	10.8	9.8	10.6	9.7	9.9	9.4
June	14.8	14.1	14.7	14.3	14.4	13.9
July	19.6	17.8	19.2	18.3	18.4	17.7
August	21.2	19.9	21.0	20.1	20.2	19.7
September	20.7	19.8	20.5	20.0	20.1	19.9
October	16.1	15.9	16.1	16.0	16.2	16.1
			1981			
May	9.8	9.0	9.6	9.1	9.3	8.8
June	16.0	14.1	15.3	14.6	14.6	14.0
July	19.9	19.0	19.8	19.2	19.3	18.6
August	21.8	20.5	21.2	20.7	20.6	20.3
September	20.4	19.5	19.8	19.6	19.7	19.4
October	15.2	14.6	14.7	14.5	14.2	14.1

Table 2.—Summary of lobster mark-recapture program, 1975 through 1981.

Sampling period Months	Year	Number caught	Number tagged	Recaptures N	Recaptures %
Sept.-Dec.	1975	1,501	1,501	97	6.5
Jan.-Dec.	1976	3,498	2,962	341	11.5
Jan.-Dec.	1977	3,242	2,876	240	8.3
Jan.-Dec.	[1]1978	4,371	3,199	378	11.8
May-Oct.	1979	5,031	3,732	674	18.1
May-Oct.	1980	4,266	3,634	485	13.3
May-Oct.	1981	5,110	4,246	571	13.4
Total		27,019	22,150	2,786	12.6

[1] Wire pots added to sampling scheme in August.

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[5] NUSCo. 1979. Lobster population estimates. *In* The annual report on ecological and hydrographic studies at the Millstone Nuclear Power Station, p. E1-E27. Northeast Utilities Service Co., Waterford, Conn.
NUSCo. 1980. Lobster population dynamics. *In* The annual report on ecological and hydrographic studies at the Millstone Nuclear Power Station, p. 195-231. Northeast Utilities Service Co., Waterford, Conn.

Table 3.—Monthly catch per unit effort (catch/100 pots hauled) for wood and wire pots from 1978 to 1981 at Millstone Point.

	Total catch		Legal catch	
	Wood	Wire	Wood	Wire
		1978		
August	55	215	8	18
September	96	177	14	19
October	54	132	8	15
November	98	162	16	12
		1979		
May	86	132	6	6
June	103	183	18	15
July	124	195	23	25
August	95	164	15	12
September	69	151	10	9
October	55	112	9	9
		1980		
May	79	180	15	15
June	65	170	14	12
July	69	177	18	17
August	56	131	13	12
September	69	84	12	8
October	78	74	6	3
		1981		
May	118	134	8	8
June	153	116	15	8
July	157	124	21	13
August	122	100	13	11
September	122	73	11	10
October	112	66	13	9

1981 had a slightly different parlor entry funnel than those used in previous years, and apparently did not trap lobsters as effectively. An experiment to test this is underway; preliminary data indicate that slight changes in parlor head design can greatly affect trap efficiency. Similarly, Spurr (1972)[6] reported that the principal factor affecting pot efficiency was parlor head design, and Thomas (1959) found that the high-rigged heads deterred escape.

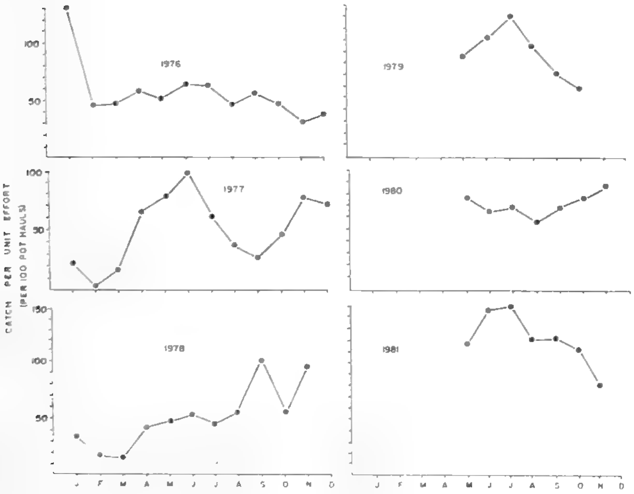

Figure 2.—Monthly lobster catch per unit effort (per 100 pot hauls) for wood pots 1976-81.

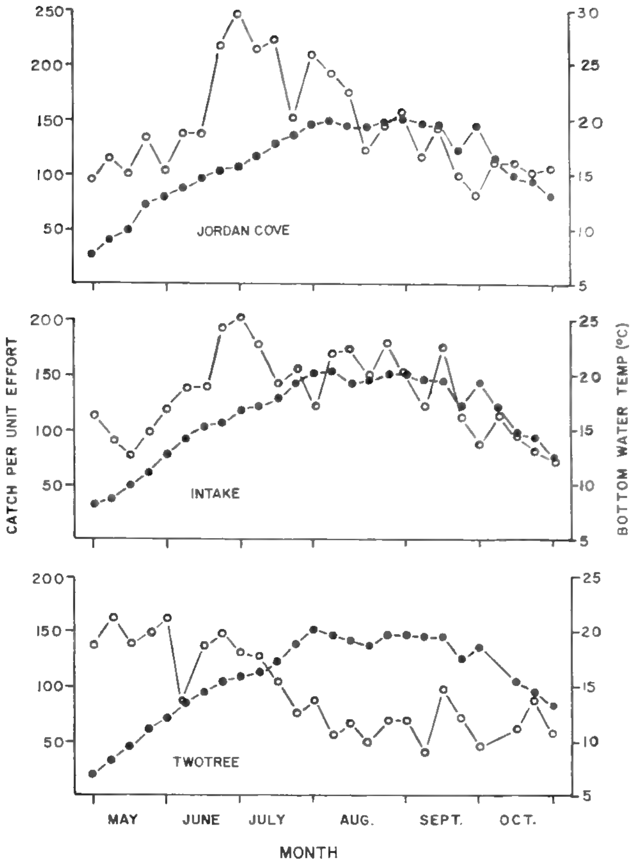

Figure 3.—Catch per unit effort (open circles) (per 100 pot hauls) and bottom water temperature (solid circles) for each station based on 1979 data.

Size Frequencies

The yearly size distributions of lobsters caught in the Millstone Point area from 1975 to 1981 are presented in Figures 4 and 5. The relatively larger proportion of smaller sized individuals in 1975 was attributed to sampling methodology. During 1975, lobsters were acquired from artificial habitats using scuba, from fish trawls, and from impingement studies at Units 1 and 2 intake structures. Subsequently, lobsters were captured using commercial pots, which do not sample small individuals as effectively. Pecci et al. (1978) reported that lobsters in surface-hauled pot catches were larger than ones caught by divers.

Since lobsters have been collected using wood pots, yearly mean carapace length and percent legal catch have not varied greatly. From 1976 to 1981, average CL ranged from 73.3 to 76.6 mm. Two other investigations within LIS that used wood pots found larger lobsters: mean CL of 78.9 mm was reported by Smith (footnote 4) for an area east of the Connecticut River, and 78.2 mm was reported for western LIS (Briggs and Mushacke 1979). Our study also used wire pots since 1978, and yearly mean CL for these traps ranged from 70.9 to 71.5 mm. Marcello et al. (1979)[7], using wire

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[6] Spurr, E. W. 1972. Lobster research project: Final report of 3-105-R, July 1969-June 1971. N.H. Fish Game Dep., Fish. Div., Concord, N.H., 22 p.

[7] Marcello, R. A., Jr., W. Davis III, T. O'Hara, and J. Hartley. 1979. Population statistics and commercial catch rate of American lobster (*Homarus americanus*) in the Charlestown-Matunuck, Rhode Island region of Block Island Sound. Submitted to New England Power Company, YAEC1175, 40 p. Yankee Atomic Electric Company, 20 Turnpike Road, Westboro, MA 01581.

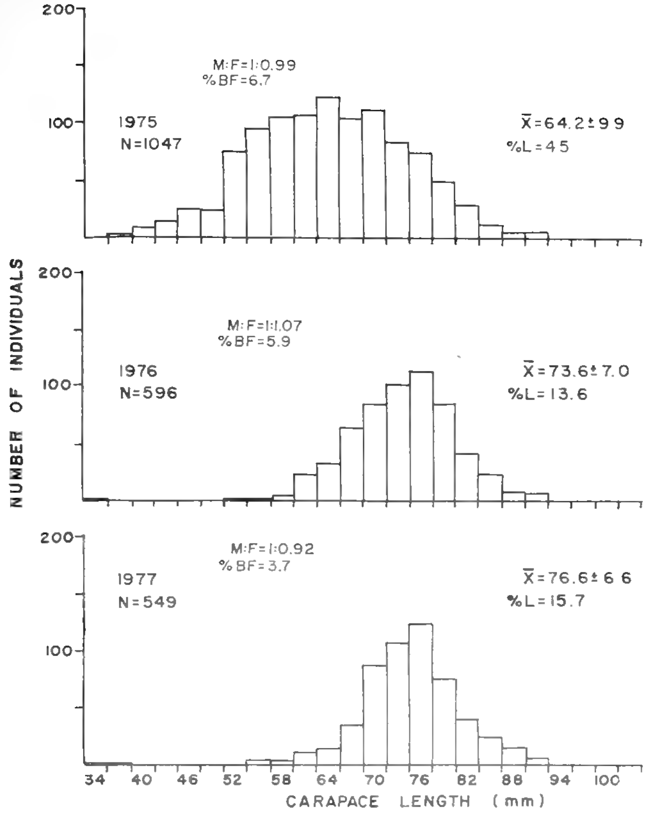

Figure 4.—Annual size distribution of lobsters in the Millstone Point area, 1975-77 (wood pots). Values for male:female sex ratios (M:F), percent of berried females (% BF), mean carapace length (X̄), and percent legal catch (%L) are also presented.

pots (2.5 cm² mesh) in Block Island Sound (BIS), calculated an average CL of 74 mm.

The percent of legal-sized (CL ⩾ 81 mm) individuals in our catch ranged from 7.2 to 18.1% (1976-81). The values reported by other area investigators range between 16.7 and 34.0% (Smith footnote 4; Briggs and Mushacke 1979; Marcello et al. footnote 7). Over 92% of the legal-sized lobsters in our study were newly recruited from the sub-legal class (assuming 13% growth per molt).

Our study area has a higher proportion of small lobsters and a smaller proportion of legal-sized individuals than has been reported from surrounding areas. Over 75% of the legal-sized individuals that we tagged and released were subsequently caught by commercial fishermen, and removed from the population. These data attest to the high exploitation of the local lobster population, especially in the summer when recreational fishing increases. Availability of shelters and physical habitat characteristics appear to be the primary naturally occuring limiting factors (excluding the physical parameters of temperature, salinity, and oxygen) of lobster populations (Phillips et al. 1980).

Sex Ratios

Since 1975, the yearly mean sex ratio of males to females was close to 1:1 (Figs. 4, 5). However, when three stations were compared, Twotree had consistently higher proportions of females, whereas Intake and Jordan Cove had slightly more males. Sex ratios close to 1:1 were also reported by other researchers working in nearshore waters (Herrick 1909; Templeman 1936; Ennis 1971, 1974; Stewart 1972; Krouse 1973; Thomas 1973; Cooper et al. 1975; Briggs and Mushacke 1980). However, Smith (footnote 4), working in four different areas of LIS, found male to female ratios ranging from 1:1.06 to 1:1.81. Dominance of females in the catch

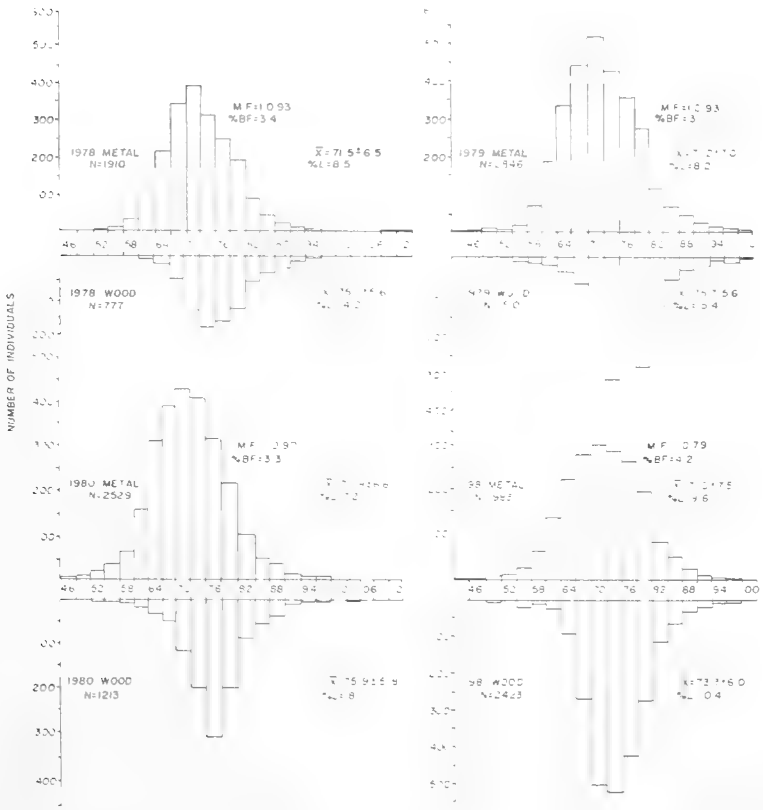

Figure 5.—Annual size distribution of lobsters in the Millstone Point area caught in wood and wire pots, 1978-81. Values of male:female sex ratios (M:F) and percent of berried females (%BF) represent combined pot type data. Mean carapace length (X̄) and percent legal catch (%L) values are presented for each pot type.

was also reported by Marcello et al. (footnote 7) and by Briggs and Mushacke (1979). Variability in the sex ratios of lobsters is often associated with size composition of the catch, which is affected by sampling methods and depth of water (Ennis 1980). Ratios close to 1:1 occur up to the size at which females are sexually mature, after which females tend to predominate in the catch (Skud and Perkins 1969; Ennis 1980).

Growth

As a result of the mark and recapture tagging program, growth expressed as percent increase in carapace length between molts was calculated for 270 individuals that molted between the time of release and the time of recapture. The growth per molt ranged from 12.1 to 13.4% (1978-81). There was no significant difference in growth between males and females. Stewart (1972) reported growth per molt of 15.8% for males and 15.4% for females from eastern LIS and Briggs and Mushacke (1979) reported 10.4% from western LIS. In inshore waters, growth per molt has been reported from 12.0 to 17.5% (Wilder 1953; Cooper 1970; Ennis 1972; Fair 1977[8]). Cooper and Uzmann (1971) found growth increments of 16.7% for females and 18.7% for males caught in deep offshore waters. Smaller growth of inshore lobsters is attributed to their relative inactivity (feeding) during the colder months of the year (Cooper and Uzmann 1980).

Berried Females

From 1975 to 1981, the percentage of females that were bearing eggs ranged from 3.1 to 6.7% (Table 4). However, the 1975-76 values were based on small sample sizes so the 1977-81 values of about 3% are more representative. Twotree had a significantly ($P < 0.05$) greater proportion of berried females of the three stations (Duncan's Multiple Range Test), and this was attributed to shelter availability and water depth. Other investigators in eastern LIS and BIS have reported percentages of berried females ranging from 2.5 to 8.2% (Stewart 1972; Smith footnote 4; Marcello et al. footnote 7). These values differ considerably from those in western LIS, where Smith (footnote 4) reported 27.3% and Briggs and Mushacke (1979) 27.8% of females berried.

Table 4.—The percentage, number, size range, and mean carapace length (CL) ± SD of egg-bearing females collected from 1975 to 1981 at Millstone Point.

Year	Intake	Jordan Cove	Twotree	Overall	*N*	Range	CL
[1]1975	3.5	4.5	9.7	6.7	7	73-84	79.1 ± 3.7
1976	3.3	1.9	11.2	5.9	16	70-102	82.9 ± 7.7
1977	3.5	1.4	6.2	3.7	35	68-92	79.7 ± 6.4
[2]1978	2.8	1.7	5.4	3.4	58	74-88	80.1 ± 4.0
1979	2.8	1.7	5.2	3.1	67	64-93	80.6 ± 5.4
1980	1.8	2.8	5.0	3.3	71	72-93	79.2 ± 5.1
1981	2.6	1.6	6.7	4.2	82	70-97	81.2 ± 6.1

[1]Wood pots only (1975-77).
[2]Wood and wire pots (1978-81).

The mean CL of berried females in our study ranged between 79.1 and 82.9 mm. Other investigators in our area reported average sizes of berried females from 80.0 to 86.2 mm. The smallest berried female caught during our study was 64 mm CL and was smaller than has been reported by any of the area investigators. Female lobsters in LIS and BIS apparently mature at a smaller size than those off the coast of Maine (Krouse 1973; Thomas 1973), the outer shelf (Skud and Perkins 1969), and the south shore of Long Island (Briggs and Mushacke 1980).

Culls

The percentage of culled lobsters (missing either one or both claws) has ranged from 9.7 to 17.4% (Table 5). Smith (footnote 4) reported 26.4% culled in LIS, east of the Connecticut River, and Briggs and Mushacke (1979) reported culls varying between 7.4 and 22.8% in western LIS.

Table 5.—The percentage of catch missing one claw, two claws, and total percent cull for both wood and wire pots from 1975 to 1981 at Millstone Point.

	Percent missing one claw		Percent missing two claws		Percent cull	
Year	Wood	Wire	Wood	Wire	Wood	Wire
1975	7.8	—[1]	1.9	—	9.7	—
1976	13.5	—	2.0	—	15.4	—
1977	10.4	—	1.2	—	11.7	—
1978	14.1	14.0	1.9	0.9	15.9	15.0
1979	15.0	14.4	2.4	1.2	17.4	15.5
1980	14.7	11.9	2.2	1.4	16.9	13.4
1981	12.6	11.2	1.4	0.9	14.0	12.1

[1]Wire pots not used.

Percent culled in wood pots (range 14.0-17.4%) was slightly greater than that observed in wire pots (range 12.1-15.5%), 1978-81. Trap related injuries resulting in claw loss are often associated with water temperature, fishing pressure (i.e., handling by lobstermen), trap set over days, and physical condition of the lobster (i.e., its nearness to molt; Pecci et al. 1978).

Molting Patterns

Molting was first noted in May, although at low levels (< 1%) (Fig. 6). Incidence of molters reached a peak in June (6-8%), coin-

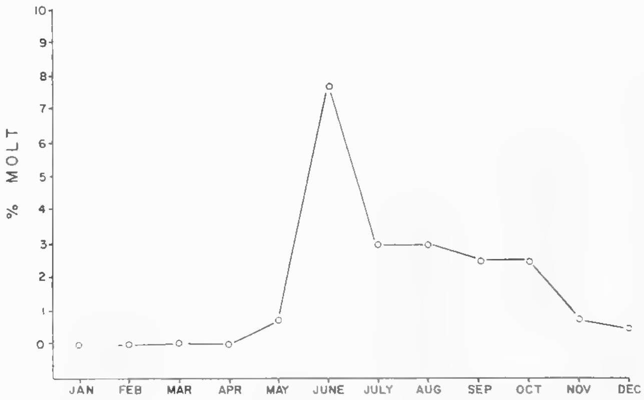

Figure 6.—Molting patterns for lobsters in the Millstone Point area based on data from 1975 to 1981.

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[8] Fair, J. J., Jr. 1977. Lobster investigations in management area I; Southern Gulf of Maine. Mass. Div. Mar. Fish., Contract No. 03-5-043-328, 8 p. Fish. Manage. Branch, State-Fed. Relationships Div., Natl. Mar. Fish. Serv., NOAA, State Fish Pier, Gloucester, MA 01930.

ciding with bottom water temperatures of 14°-16°C. Subsequently, molting continued at a low level (1-4%) from July to October and ceased in January. The variability of incidence of molting among stations and years made it difficult to discern a distinct peak occurring in autumn, as indicated by Lund et al. (footnote 3) for LIS, and by Russell et al. (1978)[9] for Narragansett Bay. A single molting peak per year has been described in Maine and in offshore waters (Dow 1966; Skud and Perkins 1969; Krouse 1973).

Gear Effectiveness

An important objective of this study was to gather information on as large a segment of the local lobster population as possible. Through the use of wire pots (2.5 cm^2 mesh) we anticipated increased catch of smaller sized lobsters capable of escaping through the 3-5 cm gap between the laths of the commercial wood pots. A Kolmogorov-Smirnov test on the size distribution of lobsters caught in the two pot types indicated that wire pots caught significantly ($P < 0.05$) more of the $<$ 75 mm CL size class than did the wood pots. These results are similar to those of Krouse (1973) who found that CL of the catch from wire pots averaged between 67.9 and 70.5 mm. He considered the modal size of his catch (70 mm CL) to be the size at which lobsters are less apt to escape the traps; using the same reasoning, lobsters in our study are vulnerable to the wire pots at 70 mm CL and to the wood pots at about 76 mm CL. Lobsters of 70-76 mm CL are important, since these individuals constitute a large proportion of the prerecruits (i.e., those individuals within one molt of legal size). The lobster population of the Millstone Point region is subjected to a high exploitation rate. The size of the legal catch is therefore largely determined by these prerecruit size classes.

Some factors to consider in the selection of lobster pots include the cost, the catch efficiency, the ease of handling, the expected life of the trap, and its susceptibility to storm loss. Wire pots caught more lobsters, were more easily hauled, required less maintenance, and were capable of fishing effectively up to 3 yr. Wood pots allowed escapement of smaller lobsters, required more ballast, travelled through the water slowly thus requiring more effort to haul, and could only be fished for one season ($<$ 1 yr) because of wood borer attack. There was no significant difference (ANOVA $P < 0.05$) between the CPUE of legal-sized lobsters caught in wood and wire pots. However, wood pots caught more legal-sized lobsters in 3 of 4 yr (Table 3).

In conclusion, the lobster population of the Millstone Point region has remained stable since 1976. The values for size structure, sex ratios, growth rates, number of berried females, incidence of culled lobsters, and molting patterns of our catch, are within ranges reported throughout northeastern North America. Results indicated that the local population was highly exploited with the commercial and recreational catch ($\geq$ 81 mm CL) being highly dependent on the prerecruit size class. The seasonal variation in catch was shown to be a function of molting patterns and changes in catchability, induced by the seasonal change in water temperature. No power plant induced change in water temperature was observed at any station, and any power plant induced effect (if any) on lobster population parameters cannot be distinguished from naturally occurring variability.

ACKNOWLEDGMENTS

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NOAA Technical Report NMFS SSRF-771

Mesh Size and the New England Groundfishery—Applications and Implications

Ronald Joel Smolowitz

July 1983

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NOAA Technical Report NMFS SSRF-771

Mesh Size and the New England Groundfishery — Applications and Implications

Ronald Joel Smolowitz

July 1983

U.S. DEPARTMENT OF COMMERCE
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Mesh Size and the New England Groundfishery — Applications and Implications

RONALD JOEL SMOLOWITZ[1]

ABSTRACT

Mesh size control has been advocated from the earliest days of the otter trawl fishery in the United States. Researchers determined that larger meshes in the cod end of a trawl reduce discarding by allowing small fish to escape; a process known as size-selection. This selectivity is measured by the selection factor — the relationship between the 50% retention length and the stretched length of the mesh. Selection factors vary by species, net material, duration of tow, speed of tow, size of catch, and with variations in mesh size.

Cod end mesh size experiments were conducted aboard eight New England otter trawlers during the period December 1977 to October 1978 to examine the possible effects of increasing the mesh size in that fishery. Selection factors were determined for Atlantic cod, *Gadus morhua* (3.33-3.80), haddock, *Melanogrammus aeglefinus* (3.04-3.47), yellowtail flounder, *Limanda ferruginea* (2.16-2.29), pollock, *Pollachius virens* (3.26-3.33), winter flounder, *Pseudopleuronectes americanus* (2.04-2.27), and American plaice, *Hippoglossoides platessoides* (2.25-2.41). For Atlantic cod, haddock, and winter flounder, there was a reduction of discards, up to 93%, and an increase in landings, by as much as 44%, with the larger mesh (133-138 mm). For yellowtail flounder, there was a reduction of discards and of landings.

Mesh size regulation as a management tool first requires the determination of the objectives in order to choose the size mesh. Enforcement difficulty, especially in the New England mixed fishery, is the greatest obstacle to overcome. The implications of mesh management reach beyond the fishery into the processing and financial sectors of the industry.

HISTORICAL PERSPECTIVE

For hundreds of years men have been harvesting groundfish off of New England, but until 1905 this fishery consisted almost entirely of sailing vessels using hand lines and bottom longlines. In 1905 the Bay State Fishing Co. of Boston built the first American steam otter trawler at Quincy, Mass., the steamer *Spray*. By 1912 there were 11 steam-driven otter trawlers from New England fishing groundfish.

With the rapid rise of this new fishing method, the line fishermen grew apprehensive about the conservation of their fishery. This resulted in a government act, approved 24 August 1912, making appropriations as follows: "To enable the Commissioner of Fisheries to investigate the method of fishing known as beam or otter trawling and to report to Congress whether or not this method of fishing is destructive to the fish species or is otherwise harmful or undesirable, $5,000, or so much thereof as may be necessary."

Alexander et al. (1915) began the work that year. Some of their tasks were to determine: 1) The general effects of trawl nets and hook gear on the fish populations. 2) The nature and extent of the destruction of juvenile fish. 3) The waste of "edible fishes that have no present market value." 4) The extent that trawl nets catch fish not taken by other gear. 5) Any evidence of depletion of fish stocks by trawl nets. 6) The extent of any gear conflicts. 7) The necessity of international agreements to regulate the fisheries.

Results of this study indicated that average mesh sizes (stretched mesh measured between knots) used by otter trawlers were 6 in in the forward parts of the net, 3 in in the bellies, and 2.5 in in the cod end. Between 30 and 40% of the cod and haddock caught by these nets were too small to market, and it was concluded that not only does the otter trawl destroy more undersized fish than line trawls, but it was also more destructive to the fish stocks because of the smaller average size of the landings.

The study's recommendations noted that certain European authorities had proposed increasing the size of the meshes of the net to let the small fish escape. The American authors felt this would not be a feasible approach because they believed that 1) the meshes tend to close as the trawl catches fish, 2) the fish in the cod end block escape, 3) the fish would not attempt to escape until haulback, and 4) more fish would be gilled in the larger meshes. The study recommended against banning otter trawls or limiting entry. It solely proposed area restrictions for otter trawlers, but industry did not support this recommendation and thus no action was taken (Herrington 1935).

During the 1920's, a new market for fresh and frozen haddock fillets was developed. The large demand for this product resulted in the New England otter trawl fleet growing to 323 vessels by 1930. The catch of haddock grew from 93.5 million lb in 1924 to 256 million lb by 1929 (Herrington 1936); then came a rapid decline. Industry grew concerned and funds were allotted to the Bureau of Fisheries to study the haddock fishery.

This study soon identified two major causes of the decline. The first was the failure of annual spawning for several years; the second, a high rate of fishing mortality, this latter factor possibly influencing the spawning failures. A good percentage, as high as 75%, of the haddock being caught were undersized (22-42 cm) and discarded at sea. Herrington (1932) estimated that in 1930, 37 million haddock were landed and as many as 90 million were discarded.

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It was fairly well established by the 1930's, by many European researchers, that a definite relationship existed between cod end mesh size and the escapement of small fish from the trawl. Herrington (1935) conducted mesh experiments aboard the research vessel *Albatross III* and the commercial draggers *Exeter* and *Kingfishery* using "trouser trawls" and large mesh cod ends (about a 5-in mesh). He recommended, from the results of this work, that industry adopted at least a 4¾-in mesh size and that even a 5¼-in mesh should be considered. Many leading captains were already fishing large-mesh trawls.

In 1934 the haddock landings had dropped to 50 million lb and then steadily increased to 122 million lb by 1941. From 1941 to 1951 the average annual landings from Georges Bank was 96 million lb. There were no definite trends in abundance evident, so the fishery was assumed to be in some state of equilibrium (Graham 1952a). During this period the commonly used cod ends averaged 2⅞ in stretched mesh (Graham 1952b).

Graham (1952a) estimated that the annual discard rate of small haddock during this equilibrium period was over 5 million lb. It was felt that if this destruction could be decreased the fishery could be stabilized at a higher level of production, as long as there were not any major changes in the socioeconomic relationships.

At the first annual meeting of the International Commission for the Northwest Atlantic Fisheries (ICNAF) in 1951, the subject of protecting the small haddock received much attention, and by June 1953 a 4.5-in mesh size (stretched mesh) went into effect on Georges Bank and in the Gulf of Maine (Graham and Premetz 1955). The idea was to advance the age of first capture (actually the 50% retention length of first capture) to 3 yr in two steps so as to avoid major short-term reduction in catch. The 4.5-in mesh size was the first step and was calculated to advance the age of first capture to 2.5 yr. This was calculated to increase the annual landings to a level 30% higher than the existing equilibrium if fishing effort remained constant (Graham 1954).

After the first step was taken, the plan was to monitor the effects of the regulation. This was performed by issuing a special license to several trawlers (eight in 1955) to fish small mesh nets while the remainder of the fleet fished the new, larger regulation mesh.

There was objection to the new mesh size by many in the industry. Graham (1954) quoted fishermen as saying, "We can't possibly make a living fishing with a large mesh like that." "This won't hold any fish at all. They'll all get through." However, by the end of the first year of regulation the results were increased landings. The large-mesh nets were more efficient in capturing larger fish. They landed more fish (by weight) than the small mesh in three of the four quarters (Graham and Premetz 1955).

During the 1950's, extensive gear studies were carried out by many nations in ICNAF areas. The majority of the work was on otter trawl (cod end) selectivity for haddock; lesser amounts on cod, redfish, American plaice, and silver hake. Clark et al. (1958) summarized the gear-selection information for the ICNAF area up until 1958. These experiments, along with numerous experiments in Europe, tremendously improved the state of knowledge on selectivity.

Two major publications summarize this state of knowledge. The first contains 24 papers given at the Joint ICNAF/ICES/FAO special scientific meeting in Lisbon in 1957 (ICNAF 1963). The second is the report of the ICES/ICNAF working groups on selectivity analysis edited by M. J. Holden (1971). This report contains an extensive bibliography and tabulation of selectivity experiments.

In 1961 a working group of ICNAF scientists met to discuss the possible effects of increased mesh size (4 to 6 in) on cod, haddock, redfish, and other species (ICNAF 1962). Their conclusions did not take into account the large increase in fishing effort that soon followed, and thus underestimated the benefits of increasing mesh size (Templeman and Gulland 1965). A review of this period in the haddock fishery can be found in Clark et al. (1982).

In March of 1977 the Fisheries Management and Conservation Act became law, forming regional councils to manage the nation's fisheries. Also in 1977 the large 1975 year class of haddock entered the Georges Bank fishery and there was a major discard of undersized fish. A cooperative study, under the auspices of the New England Fishery Management Council, began in late 1977 to study the possible effects of increasing mesh size and is contained in this report following the next section. To better understand this study, a review of selectivity follows.

SELECTIVITY REVIEW

Selectivity is the measure of the process of selection; the process in which a subgroup of a population is distinguished from the whole. The characteristics that create the selection process can be almost anything intrinsic to a particular fish — size, shape, sex, and behavior. The fishing gear and methods used and the area fished will determine what species and size fish will be selected from the overall population.

This paper is primarily concerned with the size selectivity of the cod ends of otter trawls used in the New England groundfishery. The forward parts of the trawl do affect the size selection of the trawl, but the study of these effects is beyond the scope of this paper.

As mentioned previously, Alexander et al. (1915) did not believe the cod end mesh size would affect the escapement of small fish. The research referenced by Herrington (1935) demonstrated this was not the case in fact, but how and when escapement did occur was still unknown. Many fishermen felt that the fish could not escape while the net was being towed but only during haulback when the vessel was not moving (Davis 1934a). Davis went on to prove that greater escapement occurred while under tow as compared with haulback.

Herrington (1935) quantified his data in terms of a coefficient of selection; a measure of the sharpness of selection. He could not determine whether the size of the catch affected the selectivity but did determine that the type of twine played an important role. Using European data and his own, he found that the coefficient of selection over a range of mesh sizes was approximately constant.

Jensen (1949) identified Todd and Buchanan-Wollaston as some of the first users of the 50% retention point (or release point) in describing selectivity. This is the point at which half the fish of a particular size are retained by a certain mesh size and the other half escape. Jensen developed the straight line relationship between 50% release (retention) length (l) and the inner length of the mesh (m):

$$c = \frac{l}{m}.$$

He called c the relative releasing effect; today we call it the selection factor. For cod and haddock he found c to be about 3.0.

As the concept of the selection factor came into standard use, researchers were better able to compare their results on a quantitative basis to gain understanding of those things that affect selection. What follows is a summary of this knowledge in regard to gear-related effects as demonstrated by shifts in the value of selection factors.

The most important aspect of determining a selection factor is the actual method employed. There are two basic methods used for studying the selectivity of an otter trawl cod end: 1) Covered cod end method. A small-mesh cover is placed over the cod end, loosely fitted, so as to capture all those fish that escape through the cod end meshes. The catches of the cod end and cover are then compared. 2) Alternate haul method. Two uncovered cod ends are fished; one being much smaller in mesh size than the one for which the selection curve is being determined. The experiment can be conducted by one vessel alternating cod ends either systematically or randomly, by two vessels parallel fishing the two different meshes, or by one vessel fishing a trouser trawl (a trawl with two cod ends side by side). This latter variant is considered by most as unsatisfactory because the cod end catches may be affected by factors other than mesh size.

The covered cod end method is normally considered the best as it takes the least amount of time to obtain good results and is a true measure of what actually escapes the cod end. The major drawback of this method is the possibility of the cover "masking" the cod end. This masking effect can consist of the cover physically blocking the cod end meshes, fish swimming back into the cod end from the cover, fish perceiving the presence of the cover, and effects on water flow through the cod end.

The main advantage of the alternate tow method is that there is no cover bias. For this reason it may more accurately reflect the real selectivity that would be experienced in the related commercial fishery. However, a larger number of tows is needed to generate comparable selection curves. Assumptions also have to be made on the relative efficiency of the two mesh sizes in order to calculate the selection factor. Alternate tows usually give higher selection factors than covered tows, probably due to the masking effects of the cover and the increased efficiency of uncovered cod ends on the larger size fish. This phenomenon has mostly been observed with cod and haddock but not with plaice (Saetersdal 1963).

Another aspect of the experimental design that ultimately affects the selection factor is the mesh-measuring method used. The two common methods employed are the use of a vertical gauge, such as a wedge-shaped one inserted into the mesh (Clark 1963), or a longitudinal gauge which looks like a slide caliper (Fig. 1). Most of the gauges have a means to exert a known pressure so as to stretch the mesh in a consistent manner. Hodder and May (1965) found that a gauge set for 5.5 kg pressure gave readings 1.04 times higher than one set for 4 kg pressure, providing different selection factors. Beverton and Bedford (1958) discussed variations in measurement between operators and gauge types.

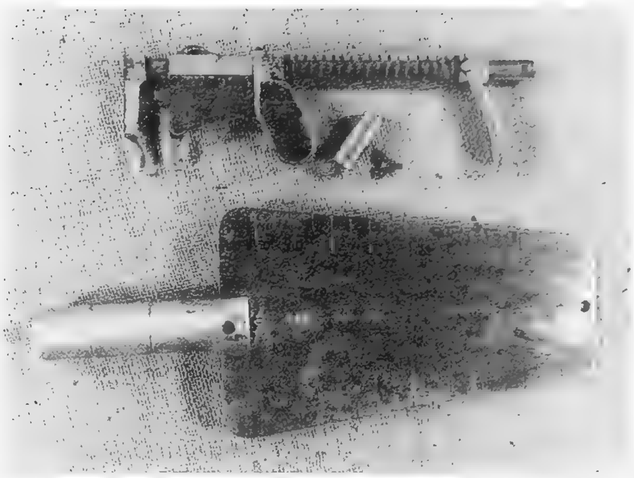

Figure 1. — Mesh gauges.

Once a fish enters the trawl it may escape through the forward netting sections as well as the cod end. Ellis (1951) discussed some unpublished work of Bowman from 1923 that demonstrated that forward escapement does occur, although Clark (1963) determined escapement in the body of the trawl to be small for haddock. Of those that do escape, he estimated 10% escape through the top belly, 30% through the lower belly, 60% through the lower wings, and none through the square and top wings. Nearly all of the smaller haddock escaped through the forward parts. Ellis (1963) reported higher escapement from the forward parts for active swimming fish, the lengths of the fish being similar to those escaping through the cod end.

Margetts (1963) found that escapement varied with species and between the two vessels used in his experiment. He hypothesized that this was due to the rigging of the nets and related fish behavior. He concluded that considerable, and highly variable, quantities of fish can escape from the forward parts of the trawl. For this reason the fish entering the cod end are not necessarily representative of the fish entering the mouth of the trawl. Indications are that due to variations in the forward parts of the trawl the selection factor calculated for a particular cod end mesh size may vary. There are other, more complicated, factors such as the physical condition of the fish entering the trawl and the hydrodynamic relationships between the parts of the trawl that may play an important role (Clark 1960).

There are variations in the cod end itself that affect the selection factor. It has been shown that escapement is mostly from the aft upper portion of the cod end (Beverton 1963; Clark 1963). It is usually this part of the cod end where the meshes have been stretched the most by the weight of the fish when hauled out on deck. When calculating the selection factor, this should be taken into account if these stretched meshes differ from the overall mean cod end mesh size.

The type of material a cod end is made of affects its selectivity, but how and why are still mysteries. Two twines may differ in more than a dozen ways, such as material, type of fiber, method of construction, Rtex value, runnage, treatment, elongation properties, strength, flexibility, and physical size.

The two most common materials used in the New England fishery are nylon (polyamide) and polypropylene. In comparison fishing these two materials, Bohl (1966) found that for haddock a polyamide cod end gave selection factors about 7-10% higher than a polypropylene one. He reasoned this was due to the greater extensibility of the polyamide and the fact the polypropylene webbing had larger knots. In further studies, Bohl (1968) compared three different types of polypropylene twine (splitfiber, continuous, and monofilament); results indicated no significant difference in selectivity even though physical properties were very different. Bohl (1971) also found no significant differences in the selection factor between a "normal" polyamide cod end and an extrastrong one. He also failed to find a correlation between elongation and selectivity. In general, polyamide gives the highest selection factors, followed by polyester, polypropylene, and manila (Pope et al. 1975).

Very little is known about the relationship between towing speed and selectivity. This is probably due to the practical difficulty of accurately measuring the speed of the trawl over the bottom and maintaining other parameters constant. Trawl mensuration studies at the Northeast Fisheries Center on "36" and "41" Yankee trawls indicated that varying towing speed within the range of 2.5-4.0 kn can change the headrope height by several feet. If, for example, the larger fish of a particular species stay further off the bottom than the smaller ones, by varying speed so as to increase headrope height the trawl will select the larger fish. This will ultimately show up in the selection factor calculated for the cod end.

It has also been shown that towing speed affects the hydrodynamics of the trawl. Beverton and Margetts (1963) found the drag increases approximately exponentially with towing speed. They calculated, at speeds of 3-4 kn, drag forces on 53, 69, and 215 mm mesh cod ends of 800, 700, and 150 lb, respectively. There is little doubt that speed affects the tension in the twine of the cod end meshes and thus probably the selectivity. The Russians, realizing this fact, have studied this approach in their trawl design efforts (Treschev 1963). Saetersdal (1960) did find a tendency of the selection factors for cod to increase with decreasing speed in the range of 2-3 kn as indicated by the ship's speed log, but this was not evident for haddock.

Clark (1963) found that the longer the tow the higher the escapement and thus the selection factor for haddock. The selection factors went from 3.0 for 20-min tows to 3.4 for 80-min tows. Pope and Hall (1966) did not find a marked effect, like Clark, for haddock but did see a tendency for higher selection factors in 2-h tows compared with 1-h tows. The general explanation for the above phenomenon is that the longer tow time gives a fish more opportunity to make repeated attempts at escape. As tow time increases so usually does the catch and this may have a counterbalancing effect.

Clark (1963) found that for haddock the selection factor decreased with larger catches; the 50% retention point decreasing by as much as 5 cm. McCracken (1963) reported no change in haddock selection factors for catches up to 1,000 fish/tow; however, there was a slight drop in selection factors for larger tows. He could not demonstrate this effect for cod. Hodder and May (1964) presented data indicating slight decreases in selection factors for cod and haddock with larger catches, but not of a magnitude to affect assessments. There are several papers that report no apparent effects (ICES 1965; Pope and Hall 1966).

There are a number of reasons that have been advanced to explain lower selection factors for larger catches. The fish would have less of a chance to be selected by the larger meshes at the aft end of the cod end. There may be more tension on the meshes making them less flexible, or the meshes may just become blocked. Schooling behavior may even come into play. On the other hand, Pope et al. (1975) reported that this effect has only been observed in covered cod end tows and thus may be an artifact of the method. With larger catches more fish may be swimming back into the cod end from the cover or may be escaping forward of the cover, thus reducing the apparent selectivity.

While it is generally assumed that selection factors are relatively constant through a range of mesh sizes, this has been shown not to hold in certain cases. Clark (1963) demonstrated that for silver hake the selection factor increases with mesh size. He reasoned that this was due to a greater flexibility of the larger mesh allowing more fish to force their way through.

Another aspect of selectivity that varies with mesh size is the selection range, the area between the 25% and 75% retention lengths on the selection curve where most of the escapement occurs. The smaller the selection range, the sharper the selection. Clark et al. (1958) found that for haddock the selection range for a 75 mm mesh was 4 cm compared with 14 cm for a 150 mm mesh.

As mentioned previously, trawl efficiency apparently increases with cod end mesh size for most species. Davis (1934b) was one of the first to observe this phenomenon for haddock. A larger mesh caught more of the larger size fish. Clark (1963) and Templeman (1963) reported similar results. Evidence exists that indicates this increased efficiency is not related to an increase in speed or ground covered by the larger mesh (Beverton and Margetts 1963; Clark 1963). Beverton and Margetts also indicated that the decrease in drag of a trawl caused by having a larger mesh cod end is relatively insignificant.

The escapement ability, hence the selection factor, can vary considerably from one species to another. The relationship between the shape of the mesh and the shape of the fish is considered important. Roundfish tend to have a cross-sectional shape more nearly matching that of a mesh than flatfish, and thus tend to have a higher escapement rate for a particular length. The behavioral response of a particular species to a net is a key factor also. Clark (1963) has demonstrated for silver hake that this species has a lower escape response when compared with other species. In general, for roundfish, when girth is compared with mesh circumference, the majority of the fish that theoretically can fit through do in fact escape. Draganik and Zukowski (1966) found that haddock which escaped from

Table 1. — Selection factors.

	Single-twine	
Species	Polyamide (nylon)	Polypropylene
Atlantic cod	3.6	3.5
Haddock	3.4	3.3
Yellowtail flounder	2.3	NA[1]
Winter flounder	NA	NA
American plaice	2.3	NA
Pollock	NA	NA

[1] NA = Not available.

the cod end, and were retained in the cover, weighed less than fish of equal length retained in the cod end.

In experiments conducted by Pope and Hall (1966), they could find no relationship between selection factor and depth or daylight vs. darkness. It is also the general opinion of researchers that cod end selectivity is not appreciably affected, at least directly, by the size of the vessel or gear (McCracken 1963; Pope and Hall 1966; Bohl 1967).

Table 1 is a summary, from the best information available as reported by Holden (1971), of the selection factors of the species with which this report is concerned for New England waters.

NEW ENGLAND MESH STUDY

This study consisted of four series of experiments in which two commercial fishing vessels performed both covered and uncovered cod end tows. In general, the procedures used were adopted from Pope et al. (1975). All tows were 1-h duration, conducted during daylight hours. The captains followed normal commercial practice of changing course to follow contours, going around hard bottom (rock piles), and pursuing fish traces on the echo sounder. Vessel and gear specifications can be found in Appendices A and B.

The sampling techniques were basically the same in all four experiments. At the conclusion of each tow, the cod end and cover catches (if a cover was used) were kept segregated. The gear was meticulously checked and net damage and other occurrences that may have affected the validity of the tow were recorded. Cod end and cover knots were tied tight and a piece of old webbing was placed in the end to prevent leakage of catch.

After each tow, 30 cod end meshes were measured along the top of the cod end in one row starting aft and running forward. They were measured using an ICES longitudinal-type mesh gauge set at 4 kg pressure. The segregated catches (cod end and cover, when used) were worked up separately. Any fish found forward of the cod end were excluded because they may not have undergone the cod end selection process. The catch was sorted by species into 1- and 2-bu baskets, weighed, and length-frequency data recorded for each species. In many cases, to save time, the catch was not weighed but all lengths were taken and length-weight equations used to determine catch weight. Randomly selected 2-bu subsamples were taken if the catch was too large to handle by this means. Girth data were also recorded at intervals throughout the experiments using tape measures.

In 1975, mesh sizes used in the USA Subarea 5 (Gulf of Maine and Georges Bank) cod and haddock fisheries ranged from 110 to 129 mm (4.3 to 5.1 in), with the majority of cod ends examined (>85%) having mesh sizes from 115 to 124 mm (4.5 to 4.9 in) (ICNAF 1976). Trawl cod end mesh sizes used in the 1975 yellowtail flounder fishery ranged from 110 to 139 mm (4.3 to 5.5 in), with most cod end meshes between 115 and 129 mm (4.5 and 5.1 in).

The small mesh size chosen for these experiments was the most commonly used "large" mesh cod end available in New England. It was constructed of #102 braided nylon twine (runnage 73.76 m/kg) and sold as 4.5-in webbing. The actual average dry-mesh measurement of these cod ends new was 108 mm (4.25 in), due to steam treatment during manufacture. The larger mesh size was chosen on the basis of increasing the minimum size of cod to 52 cm (20.5 in) or an age-at-first-capture of 3 yr. Using a selection factor of 3.6, this indicated a mesh size of 144 mm (5.7 in). As no webbing of this size was available, handmade cod ends of 154 mm (6.06 in) were constructed to allow for shrinkage.

It was noted that measurements for the small "4.5-inch" commercial cod ends used tended to be smaller than the recorded average for the fishing fleet — 4.2 in vs. the fleet's 4.75 in. It was assumed that this was due to differences in methodology and a mesh-measuring comparison test was conducted. A National Marine Fisheries Service (NMFS) enforcement agent, using a wedge-type gauge, measured 10 meshes on one of the large experimental cod ends. The same meshes were then measured using the wedge gauge with a 5 kg weight and the ICES gauge set at 4 kg tension (Fig. 1). The average readings were 144.8 mm (5.7 in), 143.0 mm (5.63 in), and 135.0 mm (5.3 in), respectively. Random measurements were then taken on our commercial-sized cod end. The ICES gauge indicated a little over 4 in. The wedge gauge readings were about 4.5 in; however, the gauge could be wedged in further to read 4.75 in or greater (the NMFS enforcement agent said that this is the routine procedure in the field).

Experiment One

This experiment was conducted from the fishing vessels *Frances Elizabeth* and *Christopher Andrew* on 12, 13, and 15 December 1977 in inshore waters off Scituate, Mass. (Fig. 2). On each of the 3 d four tows were made; small- and large-mesh cod ends fished covered and uncovered. The order of the tows was chosen at random and followed by both vessels together, usually within a kilometer of each other. Vessel speed was maintained at 2.0-2.5 kn.

All cod ends were measured dry before starting the experiment. The small cod ends of machine-made webbing initially

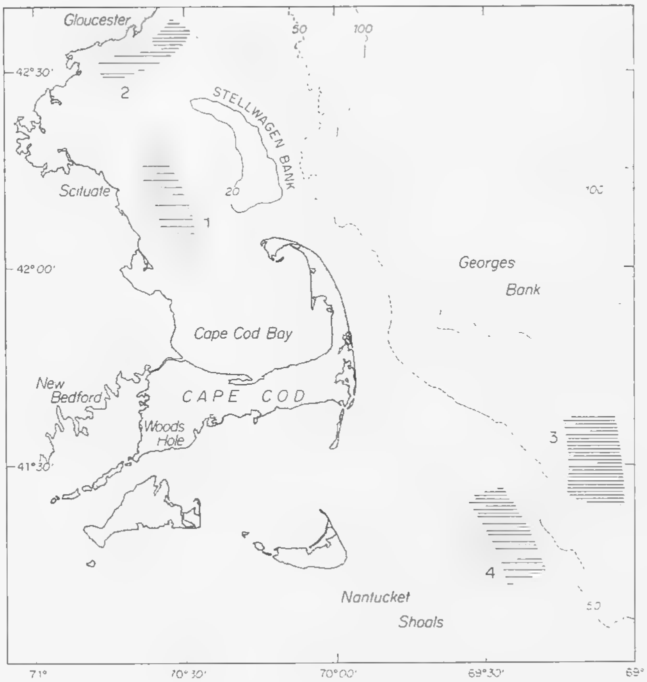

Figure 2. — Location chart of mesh experiments.

averaged 108 mm in size but by the second and third day of the experiment averaged 106 mm. The twine used for the handmade larger cod ends apparently was not heat-treated. The dry measurements averaged 154 mm and during the experiment the mesh averaged 139 mm, a 10% shrinkage rate. No stretching of the twine was observed during the experiment. There was no consistent variation between meshes of the forward and aft parts of the cod end as would be logically expected with larger catches. In the small mesh there was a maximum range of 16 mm (0.6 in) between mesh sizes. In the large mesh the maximum range was 23 mm (0.9 in). A series of standard error calculations (Appendix C) shows that the 95% confidence limits are within 1 mm of the sample mean.

The tows were conducted as described previously. On the first day a number of problems were encountered. The twine started to freeze before mesh measurements could be taken. During Tow 2 a cover float flooded on the *Christopher Andrew,* causing a marked masking effect. During Tow 3 the *Frances Elizabeth* caught a large object that caused a door (otter board) to capsize. Tow 4 was scrubbed because of darkness and the resulting change in fish population available to the gear. For these reasons the first day's data were not used in the overall analysis. All data presented, unless otherwise indicated, are for only the second and third days of this experiment. Appendix D presents the basic tow information. Appendix E is a listing of the catch by weight per tow. The "flounders" category consisted mostly of winter flounder, though some American plaice were included. The "other" category consisted mainly of skates; sculpin (*Myoxocephalus* sp.), goosefish, *Lophius americanus;* crabs; and windowpane flounder, *Scophthalmus aquosus.*

Experiment Two

This experiment was conducted from the fishing vessels *Linda B* and *Metacomet* on 22, 23, 25, and 28 March 1978, in inshore waters off Gloucester, Mass. (Fig. 2). The experiment consisted of four four-tow series by each vessel. The towing order was chosen to minimize cod-end changes during the experiment and thus consisted of the following:

Day 1	*Day 2*	*Day 3*	*Day 4*
Sm mesh	Lg mesh w/cover	Sm mesh w/cover	Lg mesh
Sm mesh w/cover	Lg mesh	Sm mesh	Lg mesh w/cover
Lg mesh	Sm mesh w/cover	Lg mesh w/cover	Sm mesh
Lg mesh w/cover	Sm mesh	Lg mesh	Sm mesh w/cover

Both vessels towed together at 2.5-3.0 kn.

Thirty meshes were measured after each tow, and means, standard deviations, and standard errors calculated (Appendix C). The mean mesh size for the small cod ends on both vessels was practically the same, equalling 99 mm (3.9 in) when rounded off to the nearest millimeter. These same cod ends were used in the previous Scituate experiment and had averaged 106 mm (4.2 in). The large cod ends, which had averaged 139 mm (5.5 in) during the Scituate experiment, had a mean mesh size during this experiment of 131 mm (5.2 in). However, the difference between the average mesh size of the two large cod ends, which was 3.5 mm during the Scituate experiment, had grown to 5.3 mm (0.2 in). Both mesh gauges were tested against each other by measuring 10 of the same meshes and found to be reading the same. In addition, each gauge was tested by pulling against a calibrated spring scale and found to be calibrated correctly at 4 kg pressure.

There were large variations in catch size and composition between tows, even on a daily basis, making an actual catch comparison between cod end sizes difficult. Many tows came up with lost lobster traps and big pieces of waterlogged wood that were in the area due to a large February storm. The *Linda B* snagged 14 lobster traps in 6 tows, the largest catch being 4 traps. The *Metacomet* snagged 6 traps in 2 tows, one tow accounting for 5 traps. The traps' condition varied from good to broken up. There were no lobsters in any of the traps nor any good buoys or lines attached. The traps were all found on sand or mud bottom. Most of the traps were caught on the twine forward of the trawl extension. No obvious effect on mesh selectivity was apparent.

The basic catch data are presented in Appendix E. The "other" category consisted mainly of windowpane flounder, sculpin, skates, crabs, and sea ravens. The *Metacomet* grouped the ocean pout with the "other" category. There was a small incidental catch of goosefish; lumpfish, *Cyclopterus lumpus*; Atlantic wolffish, *Anarhichas lupus*; grey sole, *Glyptocephalus cynoglossus*; and 12 lobsters (*Homarus americanus*). One small Atlantic halibut, *Hippoglossus hippoglossus,* a 15-lb sturgeon, and a 74 cm haddock were caught. Only a few small pollock were caught throughout the study except for *Metacomet* Tow 11 where 140 pollock (13 kg) were found in the cover, measuring 18-30 cm, the majority being 19-22 cm.

Experiment Three

This experiment was conducted from the Gloucester based fishing vessels *Joseph & Lucia II* and *Joseph & Lucia III,* 13-15 August 1978, in the offshore waters of Georges Bank (Fig. 2). The experiment consisted of three four-tow series by each vessel. The series was initially chosen, as in Experiment Two, to minimize cod end changes. However, due to problems with the covers and a large catch of pollock on board (from commercial fishing at night) that had to be landed early, the experiment consisted of the following:

Day 1	*Day 2*	*Day 3 (J&L II)*	*Day 3 (J&L III)*
Sm mesh w/cover	Sm mesh	Lg mesh	Sm mesh
Sm mesh	Sm mesh w/cover	Sm mesh	Lg mesh
Lg mesh w/cover	Lg mesh	Lg mesh	Sm mesh
Lg mesh	Lg mesh w/cover	Sm mesh	Lg mesh

On the first two days both vessels towed in the same order; on the third day the vessels alternated uncovered tows. The vessels towed within a kilometer of each other at 3.5 kn.

Thirty meshes were measured after each tow; and means, standard deviations, and standard errors calculated (Appendix C). The small cod ends on the *Joseph & Lucia II* and *Joseph & Lucia III* had mean mesh sizes of 103.7 mm (4.1 in) and 109.6 mm (4.3 in), respectively. These same cod ends averaged 99 mm (3.9 in) in the second experiment and apparently stretched during the night fishing that preceded the experiment on this trip. The large cod ends both averaged 140 mm after a 2-h break-in tow. However, during the experiment the mean mesh sizes were 135.9 mm (5.3 in) and 140.8 mm (5.5 in), respectively.

The area fished had very few small fish of any species and the catch was quite "clean" or lacking much "trash" fish.

There was hardly any fish discarded. The lack of small fish did not provide for a good data base for the use of the covered-tow method. In addition, the covers did not seem to function well. The 72-thread twisted cotton twine that the covers were made of apparently filled up with sand and mud particles, causing the covers to become exceptionally heavy. That, and the fact that our catches were large, tended to cause a masking of the cod ends. We thus switched to alternate tows exclusively on the third day. The basic catch data are presented in Appendix E. There was a small incidental catch of goosefish; wolffish; cusk, *Brosme brosme*; *Illex* squid; grey sole; and halibut.

Experiment Four

This experiment was conducted from the New Bedford based fishing vessels *Valkyrie* and *Gen. George S. Patton,* 8-11 October 1978, in the waters east of Nantucket Shoals (Fig. 2). The experiment consisted of four four-tow series and was performed in the same order as Experiment Two. Vessel speed was maintained at 3.0-3.5 kn.

Thirty meshes were measured after each tow, and means, standard deviations, and standard errors calculated (Appendix C). The small cod ends on the *Valkyrie* and *Patton* had mean mesh sizes of 108.3 mm (4.3 in) and 106.0 mm (4.2 in), respectively. The large cod end on the *Valkyrie* averaged 127.4 mm (5.0 in) and on the *Patton* averaged 134.6 mm (5.3 in).

During the nonexperimental commercial tows the vessels fished the hard bottom of Nantucket Shoals, making good catches of Atlantic cod and winter flounder. However, they tore up their nets on almost every tow. Since tear-ups invalidate experimental tows, we had to conduct our selectivity experiment on smoother bottom. Here our catches were poor and highly variable. There were very few small fish.

There were incidental catches of skates, goosefish, sculpins, squid, scallops (*Placopecten magellanicus*), herring, lobster, and halibut. The *Patton* hardly caught any Atlantic cod, compared with the *Valkyrie,* on Tows 5, 7, 14, and 16. In one case it can be attributed to a tear-up (Tow 14) and in another case to a foul-up (Tow 16). Both vessels had numerous small "hangs." All the problems added together make the data from experiment four questionable in regard to catch comparisons and selectivity analysis. The reader must keep this in mind when reviewing the following sections.

RESULTS

The results of the four experiments worked up on an independent basis can be found in the Woods Hole Laboratory reference series as Laboratory Report No. 78-12, 78-24, 78-48, and 78-54 (Smolowitz et al.[2-5]). What follows is a summary and synthesis of the four experiments on a species basis.

Atlantic Cod

The selection factors for Atlantic cod were determined from each experiment's data and from combined data (Tables 2-5, Fig. 3). The range of values of these selection factors falls within the range of those reported by Holden (1971). Assuming the true selection factor lies somewhere between those determined from the covered and alternate tow methods, these experiments confirm the average polyamide selection factor of 3.6 for Atlantic cod in the North Atlantic reported by Holden

Table 2. — Atlantic cod selection factor summary.

Experiment	Total no. of fish	Selection factor: Small mesh	Selection factor: Large mesh	Selection factor: Alternate tow
One	492	3.21	3.31	3.88
Two	2,510	3.19	3.37	3.59
Three	686	—	—	4.00
Four	2,024	3.64	3.74	3.96
Combined	5,712	3.33	3.41	3.80

Table 3. — Atlantic cod length frequency distributions and percent retained for the small-mesh (105 mm overall average) covered tows — all vessels.

Length interval (cm)	Numbers caught: 105 mm	Numbers caught: 105 mm plus covers	Percent retained
10-12	0	0	0.0
13-15	1	7	14.3
16-18	2	27	7.4
19-21	5	52	9.6
22-24	3	32	9.4
25-27	7	26	26.9
28-30	17	42	40.5
31-33	42	110	38.2
34-36	104	181	57.5
37-39	206	264	78.0
40-42	203	219	92.7
43-45	220	226	97.3
46-48	153	158	96.8
49-51	79	79	100.0
52-54	109	111	98.2
55-57	74	76	97.4
58-60	69	71	97.2
61-63	46	46	100.0
64-66	75	76	98.7
67-69	81	81	100.0
70-72	82	82	100.0
73-75	86	86	100.0
76-78	79	79	100.0
79-81	53	53	100.0
82-84	33	33	100.0
85-87	20	20	100.0
88-90	12	12	100.0
91-93	21	21	100.0
94-96	8	8	100.0
97-99	12	12	100.0
100-102	9	9	100.0
103-105	11	11	100.0
106-108	4	4	100.0
109-111	3	3	100.0
112-114	—	—	—
115-117	1	1	100.0
118-120	—	—	—
121-123	—	—	—
124-126	1	1	100.0
Totals	1,931	2,319	

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[2] Smolowitz, R. J., D. Arnold, and F. Mirarchi. 1978. New England mesh selectivity studies. Experiment one, inshore groundfish. Northeast Fish. Cent., Woods Hole Lab. Ref. 78-12, 44 p.

[3] Smolowitz, R. J., R. Testaverde, and M. DiLiberti. 1978. New England mesh selectivity studies. Experiment two, inshore groundfish. Northeast Fish. Cent., Woods Hole Lab. Ref. 78-24, 82 p.

[4] Smolowitz, R. J., A. Brancaleone, and G. Brancaleone. 1978. New England mesh selectivity studies. Experiment three, offshore groundfish. Northeast Fish. Cent., Woods Hole Lab. Ref. 78-48, 39 p.

[5] Smolowitz, R. J., L. Sovik, and P. Jacobsen. 1978. New England mesh selectivity studies. Experiment four, offshore groundfish. Northeast Fish. Cent., Woods Hole Lab. Ref. 78-54, 31 p.

Table 4. — Atlantic cod length frequency distributions and percent retained for the large-mesh (135 mm overall average) covered tows — all vessels.

Length interval (cm)	Numbers caught: 135 mm	Numbers caught: 135 mm plus covers	Percent retained
10-12	0	3	—
13-15	0	6	—
16-18	1	25	—
19-21	0	49	—
22-24	1	46	—
25-27	0	44	0.0
28-30	1	50	2.0
31-33	2	71	2.8
34-36	7	71	9.9
37-39	12	61	19.7
40-42	13	60	21.7
43-45	20	59	33.9
46-48	21	32	65.6
49-51	19	26	73.1
52-54	19	26	87.1
55-57	27	31	94.2
58-60	49	52	95.8
61-63	46	48	100.0
64-66	54	54	100.0
67-69	73	73	100.0
70-72	94	94	98.2
73-75	55	56	100.0
76-78	60	60	100.0
79-81	43	43	100.0
82-84	29	29	100.0
85-87	12	12	100.0
88-90	11	11	100.0
91-93	5	5	100.0
94-96	12	12	100.0
97-99	—	—	—
100-102	7	7	100.0
103-105	4	4	100.0
106-108	3	3	100.0
109-111	1	1	100.0
135	1	1	100.0
Totals	702	1,225	

Table 5. — Atlantic cod length frequency distributions and percent retained from uncovered cod end tows — all vessels.

Length interval (cm)	Numbers caught: (*A*) 105 mm	Numbers caught: (*B*) 135 mm	$\frac{B}{A}$		% retained by 135 mm $\frac{B}{1.6A} \times 100$
10-12	0	0	0.00		0.0
13-15	0	0	0.00		0.0
16-18	0	0	0.00		0.0
19-21	1	0	0.00		0.0
22-24	1	0	0.00		0.0
25-27	5	0	0.00		0.0
28-30	16	1	0.06		3.9
31-33	31	2	0.06		4.0
34-36	64	4	0.06		3.9
37-39	83	12	0.14		9.0
40-42	124	14	0.11		7.0
43-45	99	22	0.22		13.9
46-48	59	30	0.51		31.8
49-51	60	33	0.55		34.4
52-54	61	55	0.90		56.4
55-57	51	60	1.18		73.5
58-60	61	80	1.31		82.0
61-63	58	88	1.52		94.8
64-66	50	106	2.12		132.5
67-69	58	108	1.86	Avg.	116.4
70-72	63	109	1.73	1.60	108.1
73-75	55	106	1.93		120.4
76-78	44	60	1.36		85.2
79-81	33	49	1.48		92.8
82-84	15	23	1.53		95.4
85-87	17	12	0.71		44.1
88-90	7	12	1.71		107.1
91-93	8	8	1.00		62.5
94-96	8	7	0.88		54.7
97-99	5	1	0.20		12.5
100-102	1	5	5.00		312.5
103-105	3	1	0.33		20.8
106-108	2	5	2.50		156.3
109-111	2	2	1.00		62.5
112-114	1	1	1.00		62.5
121-123	1	0	0.00		—
135	1	0	0.00		—
Totals	1,148	1,016			

$\sum_{55} A = 544$ $\quad \sum_{55} B = 843$ $\quad \frac{\sum_{55} B}{\sum_{55} A} = 1.55$

(1971). It is also interesting to note that in each experiment the selection factor determined for the large mesh size was greater than that found for the small mesh. This may indicate a nonlinearity in the selection factor for Atlantic cod similar to that found by Clark (1963) for silver hake. However, there was no appreciable difference in selection range between the two mesh sizes which in each case was about 9 cm.

Atlantic cod girths were taken randomly throughout the experiment and found to have little variance from the published means for girth-length ratios. The girth-length relationships from Margetts (1957) and later confirmed by Messtorff (1958) are represented by the following equations:

$$\text{length} = \text{natural girth} \times 1.95$$

$$\text{length} = (\text{constricted girth} \times 2.03) + 0.7.$$

Most of the sample girths during this series of experiments fell close to the range indicated by the above two equations (Fig. 4).

Table 6 demonstrates an interesting point. For the combined catch during the experiment the large mesh outfished the small mesh, on a weight comparison basis, in all conditions: no discard, 42 cm (16 in) discard, and 52 cm (20 in) discard lengths.

Haddock

The tables and graphs in this section represent the data from 24 tows made during the third experiment. The total catch consisted of 4,463 haddock. Looking at the length frequency distributions (Table 7) of the haddock from cod ends and covers, it can be seen that both vessels and both size cod ends sampled the same populations. This is further demonstrated in Figure 5. Reviewing the "cod ends only" distributions, "masking" can be detected when comparing the 138 mm covered cod ends with the 138 mm uncovered; a higher percentage of smaller fish were caught in the former.

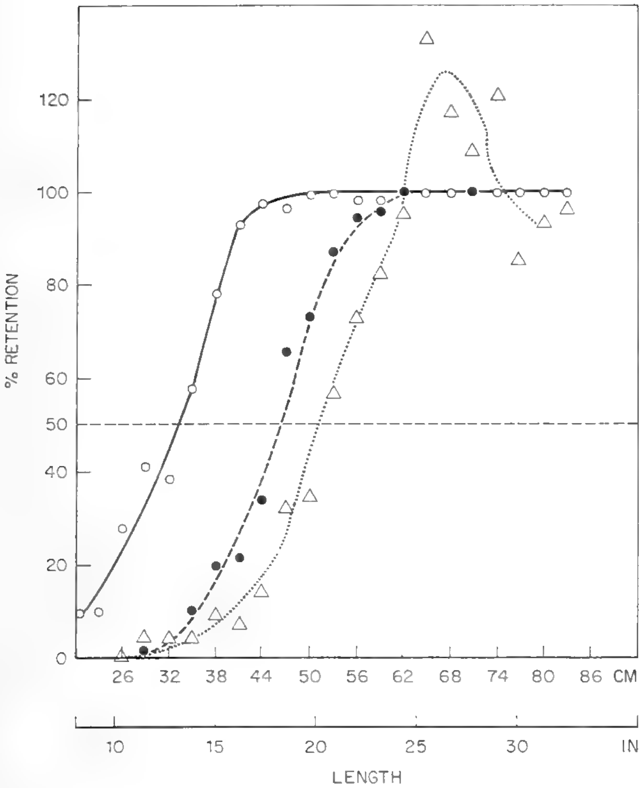

Figure 3. — Selection curves — cod. Solid line = 105 mm covered; dash line = 135 mm covered; dot line = 135 mm uncovered.

Selection data for the 107 mm covered cod end tows are given in Table 8 and the corresponding selection curve, drawn by eye, is shown in Figure 6. The 50% retention length of approximately 34 cm (13.4 in) gives a selection factor of 3.17. Selection data for the 138 mm covered cod end tows are given in Table 9, and the corresponding selection curve is shown in Figure 6. The 50% retention length of approximately 42 cm (16.5 in) gives a selection factor of 3.04. Selection data for the 107 mm and 138 mm uncovered tows are given in Table 10. (For a detailed explanation of the methodology, refer to Pope et al. 1975.) From this method, a 50% retention length of 48 cm (18.9 in) is obtained for the 138 mm cod end which gives a selection factor of 3.47.

The portion of the available population, represented by the cod-ends-plus-covers curve, that each cod end selects is shown in Figure 7. Very few fish were present below the selection range of the 107 mm cod ends. As expected, the larger cod end caught fewer of the smaller fish. A review of the length frequency distributions shows that the larger cod end caught more of the larger size fish than the small cod end. Table 11 shows the effect of this increased efficiency in higher landings of the large cod end.

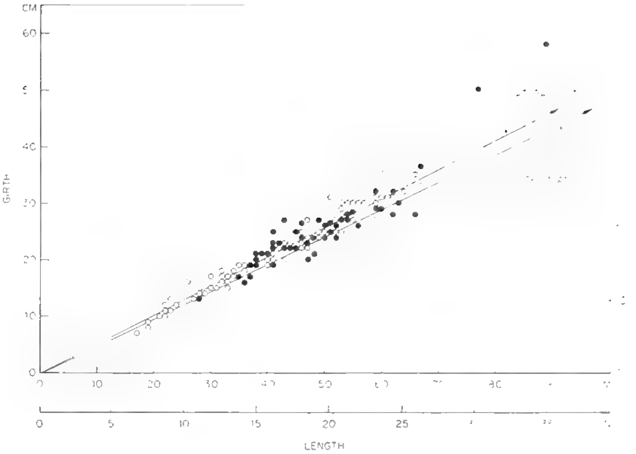

Figure 4. — Cod girth to length relationships. Solid circles = Scituate; open circles = Gloucester.

Table 6. — Atlantic cod landings.

Length interval (cm)	Kg/fish	Small uncovered No.	Small uncovered Kg	Large uncovered No.	Large uncovered Kg
10-12	0.03				
13-15	0.04				
16-18	0.04				
19-21	0.04	1	0.04		
22-24	0.09	1	0.09		
25-27	0.13	5	0.7		
28-30	0.22	16	3.5	1	0.2
31-33	0.34	31	10.5	2	0.7
34-36	0.45	64	28.8	4	1.8
37-39	0.58	83	48.1	12	7.0
40-42	0.67	124	83.1	14	9.4
43-45	0.85	99	84.2	22	18.7
46-48	1.03	59	60.8	30	30.9
49-51	1.21	60	72.6	33	39.9
52-54	1.44	61	87.8	55	79.2
55-57	1.71	51	87.2	60	102.6
58-60	2.07	61	126.3	80	165.6
61-63	2.30	58	133.4	88	202.4
64-66	2.66	50	133.0	106	282.0
67-69	3.02	58	175.2	108	326.2
70-72	3.38	63	212.9	109	368.4
73-75	4.10	55	225.5	106	434.6
76-78	4.50	44	198.0	60	270.0
79-81	5.40	33	178.2	49	264.6
82-84	5.90	15	88.5	23	135.7
85-87	6.30	17	107.1	12	75.6
88-90	7.20	7	50.4	12	86.4
91-93	7.70	8	61.6	8	61.6
94-96	8.60	8	68.8	7	60.2
97-99	9.90	5	49.5	1	9.9
100-102	10.80	1	10.8	5	54.0
103-105	11.70	3	35.1	1	11.7
106-108	12.60	2	25.2	5	63.0
109-111	13.50	2	27.0	2	27.0
112-114	14.40	1	14.4	1	14.4
121-123	19.40	1	19.11		
135	29.70	1	29.7		
Totals		1,148	2,537.4	1,016	3,203.7
Landings (discard <42 cm)			2,362.6		3,184.6
Landings (discard <52 cm)			2,145.0		3,095.1

Table 7. — Length frequency distribution (%) of haddock.

Length interval (cm)	Cod ends and covers					Cod ends only			
	Overall average	107 mm	138 mm	*Joseph & Lucia II*	*Joseph & Lucia III*	107 mm covered	107 mm uncovered	138 mm covered	138 mm uncovered
28-30	0.1	0.2		0.1		0.2			
31-33	0.2	0.4	0.1	0.1	0.3	0.0		0.1	
34-36	0.3	0.6	0.2	0.5	0.1	0.4	0.1	0.0	
37-39	1.2	1.5	1.1	1.6	0.9	0.9	0.9	0.2	
40-42	4.7	5.6	4.2	5.0	4.3	5.3	3.5	2.5	0.6
43-45	5.7	5.9	5.6	6.2	5.2	6.0	6.2	3.9	1.2
46-48	4.5	4.1	4.7	4.5	4.5	4.1	5.9	4.4	2.8
49-51	12.7	13.5	12.2	13.9	11.5	13.6	12.9	12.1	10.7
52-54	26.2	27.2	25.6	24.4	27.7	27.7	26.2	26.7	28.8
55-57	28.2	25.4	29.7	28.4	28.0	25.8	26.9	31.9	34.3
58-60	12.8	11.1	13.7	11.7	13.7	11.3	13.1	14.9	15.8
61-63	2.3	2.6	2.1	2.1	2.4	2.6	2.5	2.3	4.0
64-66	0.6	0.6	0.6	0.5	0.6	0.6	0.9	0.7	0.8
67-69	0.3	0.4	0.3	0.4	0.3	0.4	0.2	0.3	0.1
70-72	0.3	0.7		0.3	0.3	0.8	0.3		0.3
73-75	0.0	0.0		0.0		0.0	0.2		0.3
76-78	0.1	0.4		0.3		0.4	0.1		0.3
79-81									0.0
82-84									0.1
Totals	1,547	540	1,007	761	786	531	1,372	915	1,544

Table 8. — Haddock length frequency distributions and percent retained for 107 mm cod end covered tows — both vessels.

Length interval (cm)	Numbers caught		Percent retained
	107 mm	107 mm plus covers	
28-30	1	1	100.0
31-33	0	2	0.0
34-36	2	3	66.6
37-39	5	8	62.5
40-42	28	30	93.3
43-45	32	32	100.0
46-48	22	22	100.0
49-51	72	73	98.6
52-54	147	147	100.0
55-57	137	137	100.0
58-60	60	60	100.0
61-63	14	14	100.0
64-66	3	3	100.0
67-69	2	2	100.0
70-72	4	4	100.0
73-75	0	0	100.0
76-78	2	2	100.0
Totals	531	540	

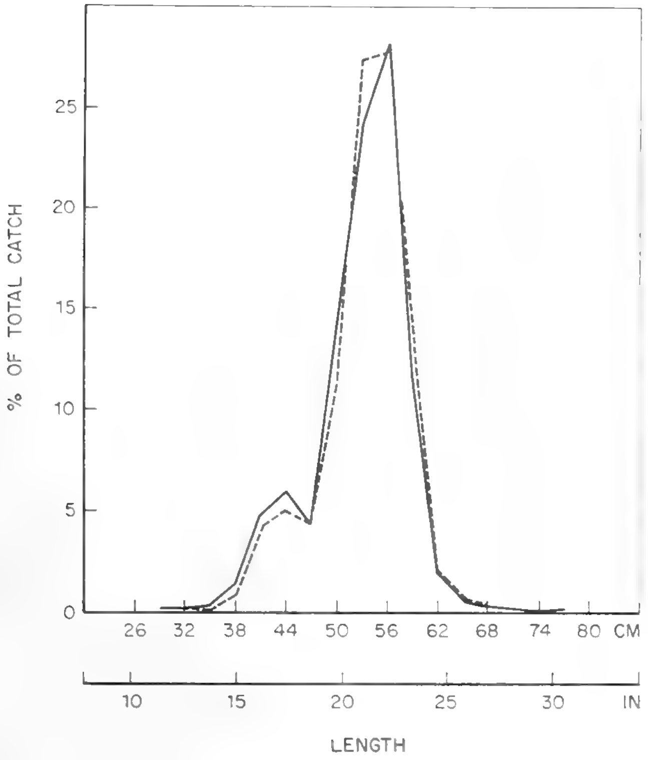

Figure 5. — Vessel comparisons — haddock. Cod ends + covers: solid line = *Joseph & Lucia II*; dash line = *Joseph & Lucia III.*

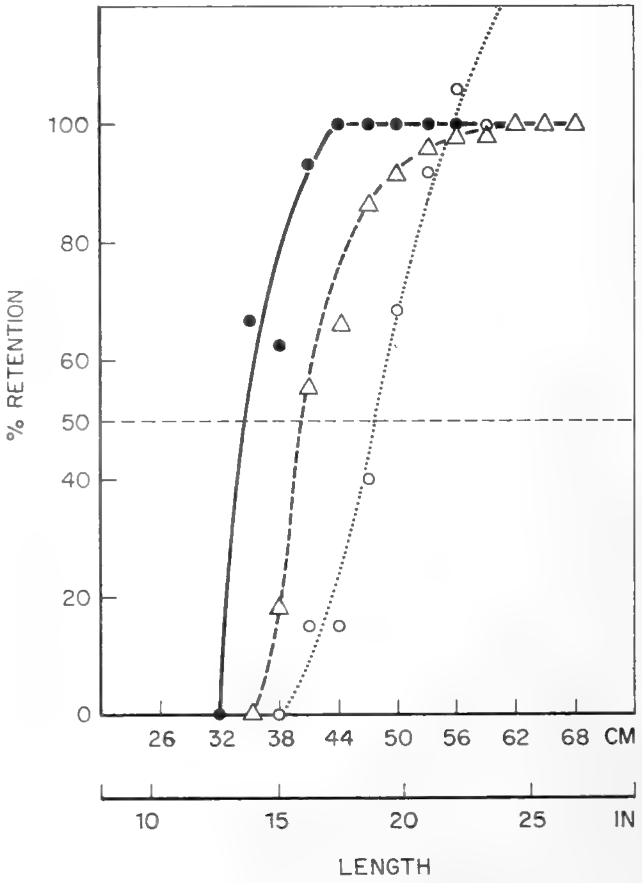

Figure 6. — Selection curves — haddock. Solid circles = 107 mm covered; open circles = 138 mm uncovered; open triangles = 138 mm covered.

Table 9 — Haddock length frequency distributions and percent retained for 138 mm cod end covered tow — both vessels.

Length interval (cm)	Numbers caught 138 mm	 138 mm plus covers	Percent retained
31-33	1	1	100.0
34-36	0	2	0.0
37-39	2	11	18.2
40-42	23	42	54.8
43-45	36	56	64.3
46-48	40	47	85.1
49-51	111	123	90.2
52-54	244	258	94.6
55-57	292	299	97.7
58-60	136	138	98.6
61-63	21	21	100.0
64-66	6	6	100.0
67-69	3	3	100.0
Totals	915	1,007	

Table 10. — Haddock length frequency distributions and percent retained for the 138 mm uncovered cod end compared with the 107 mm uncovered cod end both vessels.

Length interval (cm)	Numbers caught (*A*) 107 mm	 (*B*) 138 mm	$\frac{B}{A}$		$\frac{B}{1.37\,A} \times 100$
34-36	1	0	0.00		0.0
37-39	13	0	0.00		0.0
40-42	48	10	0.21		15.2
43-45	85	18	0.21		15.5
46-48	81	44	0.54		39.7
49-51	177	165	0.93		68.0
52-54	360	445	1.24	Avg. 1.38	90.2
55-57	369	529	1.43		104.6
58-60	180	244	1.35		98.9
61-63	34	61	1.79		131.0
64-66	12	13	1.08		79.1
67-69	3	2	0.67		48.7
70-72	4	4	1.00		73.0
73-75	3	4	1.34		97.3
76-78	2	4	2.00		36.4
79-81	0	0	—		—
82-84	0	1	—		—
Totals	1,372	1,544			

$\sum_{52}^{81} A = 967$ $\quad \sum_{52}^{81} B = 1{,}303$ $\quad \frac{B}{A} = 1.35$

Table 11. — Weights of haddock by 3 cm groups.

Length interval (cm)	Kg/fish	Small uncovered No.	Small uncovered Kg	Small covered No.	Small covered Kg	Large uncovered No.	Large uncovered Kg	Large covered No.	Large covered Kg
10-12	0.013								
13-15	0.027								
16-18	0.048								
19-21	0.08								
22-24	0.12								
25-27	0.18								
28-30	0.25			1	0.3				
31-33	0.34			0	0			1	0.3
34-36	0.44	1	0.4	2	0.9			0	0
37-39	0.57	13	7.4	5	2.9			2	1.1
40-42	0.72	48	34.6	28	20.2	10	7.2	23	16.6
43-45	0.90	85	76.5	32	28.8	18	16.2	36	32.4
46-48	1.10	81	89.1	22	24.2	44	48.4	40	44.0
49-51	1.32	177	233.6	72	95.0	165	217.8	111	146.5
52-54	1.58	360	568.8	147	232.3	445	703.1	244	385.5
55-57	1.88	369	693.7	137	257.6	529	994.5	292	549.0
58-60	2.20	180	396.0	60	132.0	244	536.8	136	299.2
61-63	2.56	34	87.0	14	35.8	61	156.2	21	53.8
64-66	2.96	12	35.5	3	8.9	13	38.5	6	17.8
67-69	3.40	3	10.2	2	6.8	2	6.8	3	10.2
70-72	3.88	4	15.5	4	15.5	4	15.5		
73-75	4.41	3	13.2	0	0	4	17.6		
76-78	4.98	2	10.0	2	10.0	4	19.9		
79-81	5.60					0	0		
82-84	6.27					1	6.3		
85-87	6.99								
88-90	7.77								
Totals		1,372	2,271.5	531	871.2	1,544	2,784.8	915	1,556.4
Total weight			2,271.5		871.2		2,784.8		1,556.4
Landings (discard <52)			1,829.9		698.9		2,495.2		1,315.5
% discards			19.4		19.8		10.4		15.5

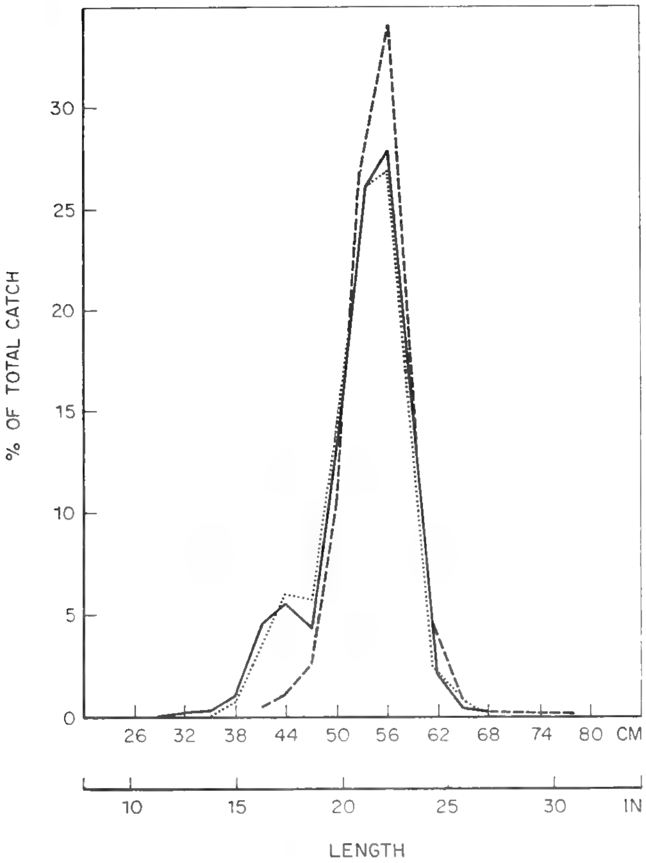

Figure 7. — Catch distributions — haddock. Solid line = cod ends + covers; dash line = 138 mm cod ends; dot line = 107 mm cod ends.

Yellowtail Flounder

These results are based on catch data from Experiments One, Two, and Four. The selection factors determined during this series of experiments (Table 12) show the alternate tow selection factors are in close agreement with those found by Lux (1968). Assuming the real selectivity lies between the two methods used, 2.25 is a fair choice for the selection factor. The selection curves determined from the combined data (Fig. 8, Tables 13 to 15) indicate the 25-75% selection ranges found throughout the experiment varied from 3 to 6 cm. Again, as with the Atlantic cod data, the selection factors for the small covered mesh are lower than those determined for the larger mesh.

It should be noted that a comparison of the two large-mesh selection curves determined by the two methods used is not strictly valid. This is due to the fact that the uncovered selection curve was derived by comparing the large-mesh uncovered cod ends with the small-mesh uncovered cod ends and the covered selection curve was derived by comparing the large-mesh covered cod ends with the 50 mm covers. In the first case the retention percentages will be affected by the selectivity of the small-mesh cod ends, this occurring where the selection process overlaps (in this case about 17 to 27 cm). The degree of inaccuracy introduced was checked by adjusting the large-

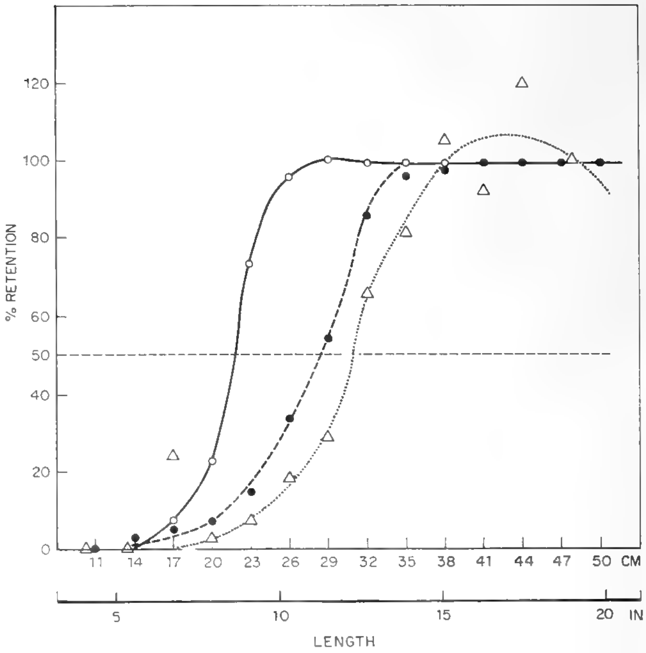

Figure 8. — Selection curves — yellowtail flounder. Solid circles = 133 mm covered; open circles = 102 mm covered; open triangles = 133 mm uncovered.

Table 12. — Yellowtail flounder selection factor summary.

Experiment	Total no. of fish	Selection factor Small mesh	Large mesh	Alternate tow
One	3,581	2.07	2.16	2.37
Two	8,881	2.08	2.09	2.30
Four	321	—	—	—
Combined[1]	12,783	2.16	2.18	2.29

[1] Combined also contains data from Experiment Four.

Table 13. — Yellowtail flounder length frequency distributions and percent retained for the small-mesh (102 mm overall average) covered tows — six vessels.

Length interval (cm)	Numbers caught 102 mm	102 mm plus covers	Percent retained
10-12	0	2	0.0
13-15	0	36	0.0
16-18	14	185	7.6
19-21	78	335	23.3
22-24	242	333	72.7
25-27	274	286	95.8
28-30	216	216	100.0
31-33	491	496	99.0
34-36	715	720	99.3
37-39	523	524	99.8
40-42	282	284	99.3
43-45	182	182	100.0
46-48	52	52	100.0
49-51	9	9	100.0
52-54	4	4	100.0
55-57	2	2	100.0
Totals	3,084	3,666	

Table 14. — Yellowtail flounder length frequency distributions and percent retained for the large-mesh (133 mm overall average) covered tows — six vessels.

Length interval (cm)	Numbers caught 133 mm	Numbers caught 133 mm plus covers	Percent retained
10-12	0	0	0.0
13-15	1	25	4.0
16-18	13	221	5.9
19-21	26	460	5.7
22-24	62	460	13.5
25-27	109	316	34.5
28-30	132	243	54.3
31-33	335	392	85.5
34-36	532	550	96.7
37-39	319	323	98.8
40-42	199	199	100.0
43-45	118	118	100.0
46-48	46	46	100.0
49-51	9	9	100.0
52-54	0	0	—
Totals	1,901	3,362	

Table 15. — Yellowtail flounder length frequency distributions and percent retained from uncovered cod end tows — six vessels.

Length interval (cm)	Numbers caught (A) 102 mm	Numbers caught (B) 133 mm	$\frac{B}{A}$		% retained by 133 mm $\frac{B}{0.82A} \times 100$
10-12	0	0	0.00		0.0
13-15	0	1	0.00		0.0
16-18	15	3	0.20		24.4
19-21	118	2	0.02		2.1
22-24	460	27	0.06		7.2
25-27	430	68	0.16		19.3
28-30	395	94	0.24		29.0
31-33	567	301	0.53		64.7
34-36	833	551	0.66	Avg. 0.82	81.0
37-39	513	444	0.87		105.5
40-42	295	223	0.76		92.2
43-45	146	144	0.99		120.3
46-48	46	38	0.83		100.7
49-51	20	11	0.55		67.1
52-54	2	2	1.00		121.6
55-57	2	0	0.00		—
Totals	3,842	1,909			

Table 16. — Yellowtail flounder landings and discards.

Length interval (cm)	Kg/fish	Small uncovered No.	Small uncovered Kg	Large uncovered No.	Large uncovered Kg
10-12		0	0.0	0	0.0
13-15	0.02	0	0.0	1	0.02
16-18	0.04	15	0.6	3	0.1
19-21	0.07	118	8.3	2	0.1
22-24	0.09	460	41.4	27	2.4
25-27	0.13	430	55.9	68	8.8
28-30	0.22	395	86.9	94	20.7
31-33	0.31	567	175.8	301	93.3
34-36	0.41	833	341.5	551	225.9
37-39	0.59	513	302.7	444	262.0
40-42	0.68	295	200.6	223	151.6
43-45	0.86	146	125.6	144	123.8
46-48	1.04	46	47.8	38	39.5
49-51	1.17	20	23.4	11	12.9
52-54	1.44	2	2.9	2	2.9
55-57	1.67	2	3.3	0	0.0
58-60	2.14				
Totals		3,842	1,416.7	1,909	944.0
Landings (discard ≤30 cm)			1,223.6		911.9
Discards		1,418	193.1	195	32.14
% discards		36.9	13.6	10.2	3.4
% reduction in discards between mesh sizes: 75% by weight.					

mesh uncovered retention percentages with the small-mesh covered retention percentages and was found to be small. Continuing in the same vein, if all four types of tows (small and large, covered and uncovered) were compared with the same base (covered cod ends plus covers) and adjusted on a numbers-per-tow basis, a comparison could be made between the two mesh sizes that might indicate some degree of relative efficiency. A larger number of tows than performed during this series of experiments is required to do this with any degree of confidence.

An analysis of combined landings and discards (Table 16) indicates a smaller catch with the larger mesh. From observations made during the experiments, it was noted that the majority of fish 30 cm (11.8 in) and smaller were discarded. This is a lower cull point than in the past. Hennemuth and Lux (1970) reported a cull midpoint for yellowtail by the commerical fleet of 34 cm (13.5 in). Using 30 cm as the cull point, the data from this series of experiments indicates a 36.9% discard rate (by number of fish) for a 4-in mesh. A 5.5-in mesh reduces this discard by 75% when compared on a weight basis.

Pollock

These results are based on a catch of 1,118 pollock made during Experiment Three. (It should be noted that at night in the same area catches of 14,000 lb of pollock in 2 to 3 h tows were common.) Both vessels fished the same basic population distribution (Fig. 9). The covered-tow method could not be

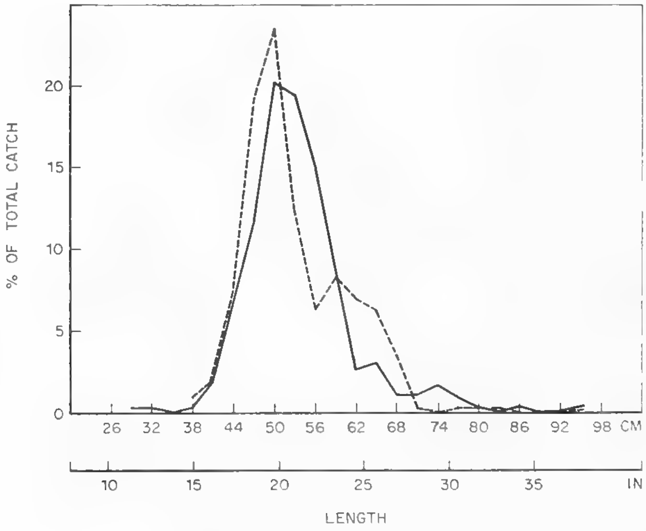

Figure 9. — Vessel comparisons — pollock. Cod ends + covers: solid line = *Joseph & Lucia II*; dash rule = *Joseph & Lucia III*.

used to determine the selection of the small cod end due to lack of small fish. Selection data for the 138 mm covered cod end tows are given in Table 17 and Figure 10. The 50% retention length of about 45 cm (17.7 in) gives a selection factor of 3.26. Selection data for the 107 mm and 138 mm uncovered tows are given in Table 18 and Fig. 10. A 50% retention length of 46 cm (18.1 in) is obtained for the 138 mm cod end which gives a selection factor of 3.33. It is interesting to note that the same large covered tows showed a definite masking effect in regard to haddock during this experiment but it did not show up for pollock. The larger cod end caught fewer small fish (Fig. 11).

Table 17. — Pollock length frequency distributions and percent retained for 138 mm cod end covered tows — both vessels.

Length interval (cm)	Numbers caught 138 mm	138 mm plus covers	Percent retained
37-39	0	2	0.0
40-42	1	11	9.1
43-45	17	37	45.9
46-48	48	87	55.2
49-51	78	115	67.8
52-54	64	83	77.1
55-57	42	50	84.0
58-60	47	48	97.9
61-63	24	24	100.0
64-66	28	28	100.0
67-69	15	15	100.0
70-72	2	2	100.0
73-75	2	2	100.0
76-78	0	0	100.0
79-81	1	1	100.0
82-84	0	0	100.0
85-87	1	1	100.0
Totals	370	506	

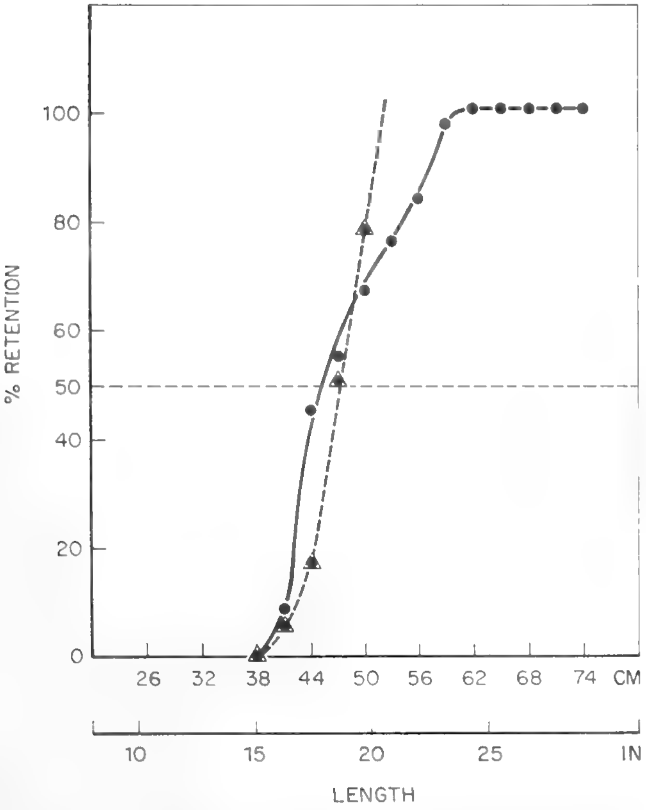

Figure 10. — Selection curves — pollock. Solid circles = 138 mm covered; solid circles in triangles = 138 mm uncovered.

Table 18. — Pollock length frequency distributions and percent retained for the 138 mm uncovered cod end compared with the 107 mm uncovered cod end — both vessels.

Length interval (cm)	Numbers caught (A) 107 mm	(B) 138 mm	$\frac{B}{A}$		$\frac{B}{2.9A} \times 100$
37-39	1	0	0.00		0.0
40-42	5	1	0.20		6.9
43-45	13	7	0.54		18.6
46-48	23	34	1.48	Avg. 2.94	51.0
49-51	40	91	2.28		78.4
52-54	21	78	3.71		128.1
55-57	21	78	3.71		128.1
58-60	15	38	2.53		87.4
61-63	4	24	6.00		206.9
64-66	5	15	3.00		103.4
67-69	4	5	1.25		43.1
70-72	2	5	2.50		86.2
73-75	2	1	0.50		17.2
76-78	1	4	4.00		137.9
79-81	1	3	3.00		103.4
82-84	1	3	3.00		103.4
85-87	1	0	—		
88-90	2	0	—		
91-93	0	3	—		
94-96	0	0	—		
97-99	0	0	—		
100-102	2	0	—		
Totals	164	390			
	120 ΣA = 122 49	102 ΣB = 348 49	$\frac{B}{A}$ = 2.85		

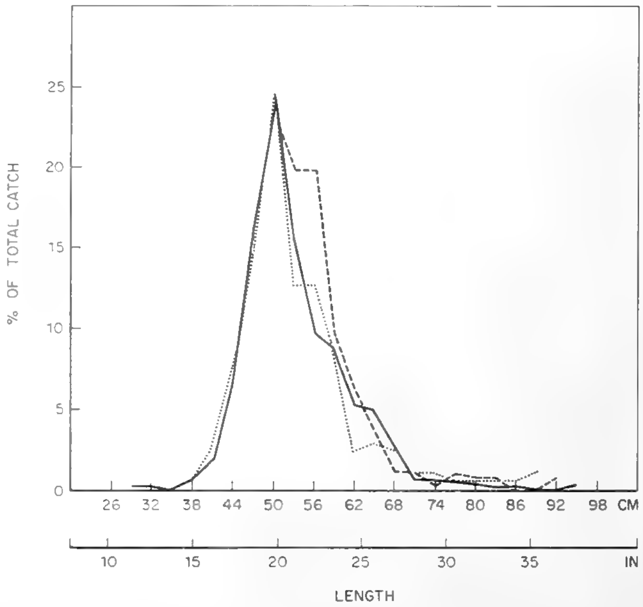

Figure 11. — Catch distributions — pollock. Solid line = cod ends + covers; dash line = 138 mm cod ends; dot line = 107 mm cod ends.

Winter Flounder

The results in this section are based on data from Experiments One, Two, and Four, representing a total catch of 4,152 winter flounder. There were insufficient data to calculate the selection factors from the uncovered tows in Experiment One and from both covered and uncovered tows in Experiment Four. However, with all data combined, fairly good results were obtained (Tables 19 to 21, Fig. 12). There again is an increase in selection factor with the larger mesh. An overall selection factor of 2.2 for winter flounder seems a reasonable choice based on this data. The 25-75% selection range was in most cases about 5 cm.

From the uncovered-tow data (Table 22) there seems to be an increase in efficiency for the larger mesh starting at about

Table 19. — Winter flounder selection factor summary.

Experiment	Total no. of fish	Selection factor Small mesh	 Large mesh	 Alternate tow
One	725	2.07	2.23	—
Two	2,398	2.02	2.05	2.21
Four	1,029	—	—	—
Combined	4,152	2.04	2.07	2.27

Table 20. — Winter flounder length frequency distributions and percent retained for the small-mesh (103 mm overall average) covered tows — six vessels.

Length interval (cm)	Numbers caught 103 mm	 103 mm plus covers	Percent retained
10-12	0	0	0.0
13-15	1	9	11.1
16-18	3	11	27.3
19-21	10	30	33.3
22-24	96	109	88.1
25-27	161	170	94.7
28-30	204	209	97.6
31-33	161	164	98.2
34-36	83	84	98.8
37-39	68	68	100.0
40-42	70	70	100.0
43-45	46	46	100.0
46-48	24	24	100.0
49-51	15	15	100.0
52-54	2	2	100.0
55-57	2	2	100.0
58-60	1	1	100.0
Totals	947	1,014	

Table 21. — Winter flounder length frequency distributions and percent retained for large-mesh (133 mm overall average) covered tows — six vessels.

Length interval (cm)	Numbers caught 133 mm	 133 mm plus covers	Percent retained
10-12	0	0	0.0
13-15	0	6	0.0
16-18	1	45	2.2
19-21	9	107	8.4
22-24	17	120	14.2
25-27	58	158	36.7
28-30	145	241	60.2
31-33	127	155	81.9
34-36	86	92	93.5
37-39	54	56	96.4
40-42	58	59	98.3
43-45	51	51	100.0
46-48	19	19	100.0
49-51	16	16	100.0
52-54	11	11	100.0
55-57	6	6	100.0
58-60	3	3	100.0
61-63	1	1	100.0
Totals	662	1,146	

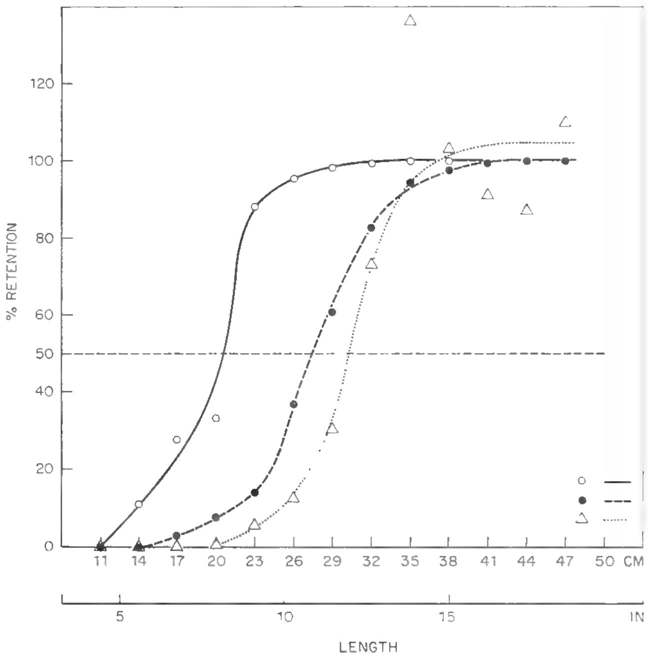

Figure 12. — Selection curves — winter flounder. Solid circles = 133 mm covered; open circles = 103 mm covered; open triangles = 133 mm uncovered.

Table 22. — Winter flounder length frequency distributions and percent retained from uncovered cod end tows — six vessels.

Length interval (cm)	Numbers caught (A) 103 mm	 (B) 133 mm	$\frac{B}{A}$		% retained by 133 mm $\frac{B}{1.2A} \times 100$
10-12	0	0	0.00		0.0
13-15	0	0	0.00		0.0
16-18	0	0	0.00		0.0
19-21	16	0	0.00		0.0
22-24	115	10	0.08		7.2
25-27	204	30	0.15		12.3
28-30	265	99	0.37		31.1
31-33	168	148	0.88		73.4
34-36	90	185	2.06		171.3
37-39	85	106	1.25		103.9
40-42	103	113	1.10	Avg.	91.4
43-45	62	65	1.05	1.2	87.4
46-48	32	43	1.34		110.1
49-51	8	16	2.00		166.7
52-54	6	13	2.17		180.6
55-57	3	6	2.00		166.7
58-60	1	0	0.00		0.0
Totals	1,158	834			

the 34 to 36 cm fish length interval. Choosing a discard (cull) point of 30 cm, it can be seen that the large mesh landed more fish by numbers and weight (Table 23). The large mesh using the 30 cm cull point, decreased discards by 73% by weight.

Table 23. — Winter flounder landings.

Length interval (cm)	Kg/fish	Small uncovered		Large uncovered	
		No.	Kg	No.	Kg
10-12	0.05	0	0.0	0	0.0
13-15	0.07	0	0.0	0	0.0
16-18	0.09	0	0.0	0	0.0
19-21	0.11	16	1.8	0	0.0
22-24	0.18	115	20.7	10	1.8
25-27	0.23	204	46.9	30	6.9
28-30	0.36	265	95.4	99	35.6
31-33	0.45	168	75.6	148	66.6
34-36	0.55	90	49.5	185	101.8
37-39	0.77	85	65.5	106	81.6
40-42	0.91	103	93.7	113	102.8
43-45	1.14	62	70.7	65	74.1
46-48	1.36	32	43.5	43	58.5
49-51	1.68	8	13.4	16	26.9
52-54	2.05	6	12.3	13	26.7
55-57	2.43	3	7.3	6	14.6
58-60	2.93	1	2.9	0	0.0
61-63	3.42	0	0.0	0	0.0
Totals		1,158	599.2	834	597.9
Landings (discard ≤30 cm)		558	434.4	695	553.6
Discards		600	165.0	139	44.3
% discards		51.8%	27.5%	16.6%	7.4%

% reduction in discards between mesh sizes: 73% by weight.

American Plaice

The results in this section represent the data from 32 tows made during Experiment Two. The total catch consisted of 3,798 American plaice. A visual inspection of Figure 13 shows the length-frequency distribution between the two vessels to be about the same. Some masking was evident in the large covered cod ends, but with the large number of small fish caught, this was probably unavoidable.

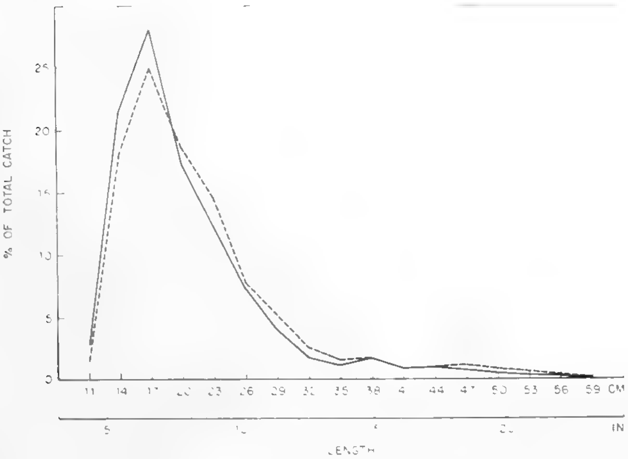

Figure 13. — Vessel comparisons — American plaice. Cod ends + covers: solid line = *Metacomet;* dash line = *Linda B.*

Selection data for the 99 mm covered cod end tows are given in Table 24 and the corresponding selection curve is shown in Figure 14. The 50% retention length of approximately 23.3 cm (9.2 in) gives a selection factor of 2.35. The 25-75% selection range is approximately 3.6 cm (1.4 in). Selection data for the 131 mm covered cod end tows are given in Table 25 and Figure 14. The 50% retention length of approximately 29.5 cm (11.6 in) gives a selection factor of 2.25. The 25-75% selection range is approximately 6 cm (2.4 in). Selection data for the 99 mm and 131 mm uncovered tows are given

Table 24. — American plaice length frequency distributions and percent retained for 99 mm cod end covered tows — *Linda B* and *Metacomet*.

Length interval (cm)	Numbers caught		Percent retained
	99 mm	99 mm plus covers	
10-12	1	10	10.0
13-15	12	114	10.5
16-18	22	254	8.7
19-21	26	206	12.6
22-24	58	152	38.2
25-27	87	101	86.1
28-30	67	67	100.0
31-33	36	37	97.3
34-36	24	24	100.0
37-39	20	20	100.0
40-42	16	16	100.0
43-45	12	12	100.0
46-48	16	16	100.0
49-51	11	12	91.7
52-54	6	6	100.0
55-57	3	3	100.0
58-60	1	1	100.0
Totals	418	1,051	

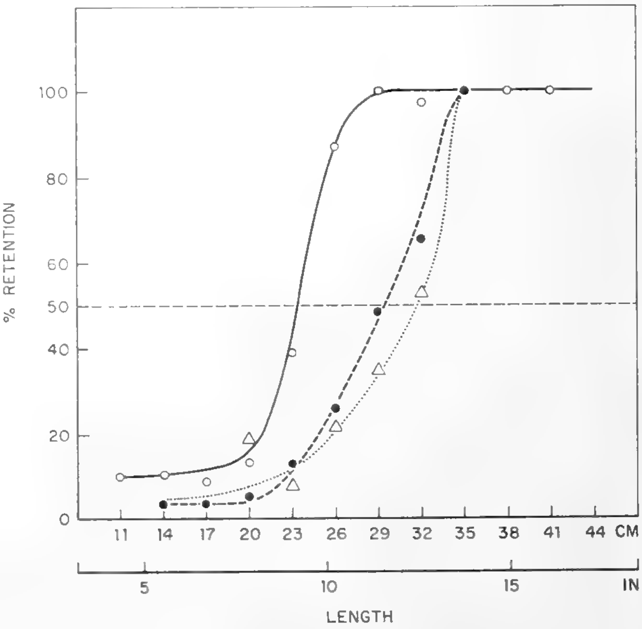

Figure 14. — Selection curves — American plaice. Solid circles = 131 mm covered; open circles = 99 mm covered; open triangles = 131 mm uncovered.

in Table 26 and Figure 14. There was near equal retention above the 100% retention point, thus the distributions were considered equivalent. From this method, a 50% retention length of 31.6 cm (12.4 in) is obtained for the 131 mm cod end which gives a selection factor of 2.41. The 25-75% selection range is approximately 7 cm (2.8 in). From this data a choice of 2.3 for the American plaice selection factor seems reasonable and is in agreement with past studies (Holden 1971). The catch distribution of the two cod end sizes compared with the overall available population (Fig. 15) along with catch data (Table 27) do not indicate anything in regard to efficiency but show discards can be reduced by 50% using the larger mesh.

Table 25. — American plaice length frequency distributions and percent retained for 131 mm cod end covered tows — *Linda B* and *Metacomet*.

Length interval (cm)	Numbers caught 131 mm	Numbers caught 131 mm plus covers	Percent retained
10-12	0	27	0.0
13-15	16	487	3.3
16-18	16	563	2.8
19-21	18	349	5.2
22-24	32	263	12.2
25-27	34	134	25.4
28-30	36	75	48.0
31-33	20	31	64.5
34-36	19	19	100.0
37-39	29	29	100.0
40-42	12	12	100.0
43-45	19	19	100.0
46-48	14	14	100.0
49-51	9	9	100.0
52-54	8	8	100.0
55-57	4	4	100.0
58-60	2	2	100.0
Totals	288	2,045	

Table 26. — American plaice length frequency distributions and percent retained for the 131 mm uncovered cod end compared with the 99 mm uncovered cod end — *Linda B* and *Metacomet*.

Length interval (cm)	Numbers caught (*A*) 99 mm	Numbers caught (*B*) 131 mm	$\frac{B}{A} \times 100 =$ % retained by 131 mm
10-12	0	0	0.0
13-15	4	1	25.0
16-18	11	1	9.1
19-21	26	4	16.7
22-24	74	6	8.1
25-27	109	24	22.0
28-30	79	28	35.4
31-33	44	23	52.3
34-36	35	40	114.3
37-39	25	19	76.0
40-42	12	15	125.0
43-45	27	17	63.0
46-48	15	17	113.3
49-51	10	9	90.0
52-54	9	9	100.0
55-57	2	4	200.0
58-60	1	0	—
61-63	1	0	—
64-66	0	1	—
Totals	484	218	

$\sum_{34}^{66} A = 137$ $\sum_{34}^{66} B = 131$

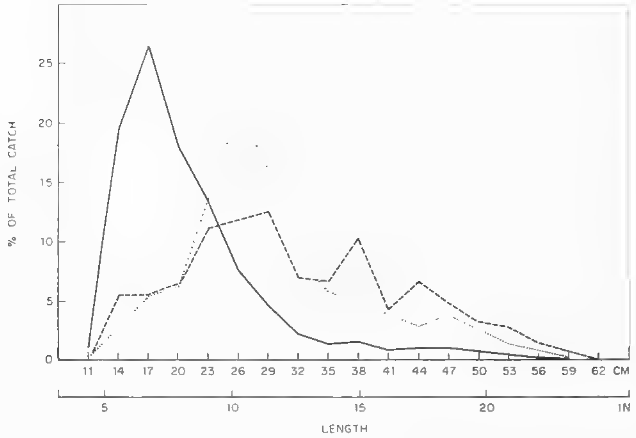

Figure 15. — Catch distribution — American plaice. Solid line = total cod ends + covers; dash line = total 131 mm cod ends; dot line = total 99 mm cod ends.

Table 27. — American plaice landed weight and discard summary — *Linda B* and *Metacomet*, with an assumed discard at 30 cm (11.8 in).

	Small cod ends Weight (kg)	Small cod ends % discards	Large cod ends Weight (kg)	Large cod ends % discards
Day 1	28.4	29.4	32.7	15.6
Day 2	149.4	25.1	44.2	15.6
Day 3	12.0	41.2	7.5	20.2
Day 4	34.8	30.0	133.7	11.4
Overall discard average:		31.4		15.7

Reduction in discards: 50.0%

Catch, summary by numbers of fish

No. discarded	Small uncovered - 303	Large uncovered - 64
No. landed	- 181	- 154
Total	- 484	- 218
% discard	- 62.6	- 29.4

MANAGEMENT IMPLICATIONS

Discards

In New England the term "discard" can mean anything in the catch that is thrown back overboard. This can include desirable species too small to market, unmarketable species, and bottom trash such as rocks and shell. A marketable fish can become discard by management decisions such as quotas or size limits. The captain also makes the economic decision of retaining certain species and sizes based on price and markets available. Probably ever since commercial fishing with nets began, fishermen have been discarding fish too small to market and hook-and-line fisherman have been complaining about it. In England in 1558 these complaints caused Queen Elizabeth I to issue a royal decree setting a minimum mesh size of 2.5 in (Jensen 1972).

In New England the complaints reached a crescendo soon after the introduction of the otter trawl — an introduction made by Captain Collins, Chairman of the U.S. Fish Commission, in 1903. By 1912 the first American steam trawler, *Spray,* and five sister ships, *Foam, Ripple, Crest, Surf,* and *Swell,* were routinely fishing Georges Bank. To address the complaints, David Belding, a biologist for the Massachusetts Commission on Fisheries and Game, conducted an investigation on the effects of otter trawling by making a trip on the FV *Foam* in that year (Belding 1916). During Belding's trip the vessel discarded as undersized about 25% of the haddock and 14% of the Atlantic cod caught. He assumed 100% mortality for these discarded fish. The cod end mesh size was probably smaller than 3 in.

Belding's work was soon followed by that of Alexander et al. (1915) as described in the introduction of this report. From data collected on 61 trips, they found that by weight "... 40 per cent of the cod and 38 per cent of the haddock taken by the otter trawlers from June to December were fish too small to market. From January to May but 3 per cent of the cod and 11 per cent of the haddock were unmarketable on account of their size." By numbers, for haddock, this amounted to 77 and 40%, respectively (Herrington 1935). Their observers reported practically all of these discarded fish as dead when thrown over the side. The cod end mesh size was about 2.5 in.

Herrington's work in the 1930-31 period, when small haddock were unusually abundant, indicated discards of undersized fish two to three times larger than marketable haddock (Herrington 1932). He went on to say that the commercial captains were concerned enough about this to make an agreement among themselves to avoid grounds where small fish predominated. However, the small fish were everywhere, making the agreement ineffective. In that 1-yr period, 1930-31, about 63 million baby haddock were destroyed, "...about equal to the number of haddock in a commercial catch of 200,000,000 pounds" (Herrington 1936). Again, this destruction varied by season, area fished, and yearly.

Premetz (1953) reported that for the 1947-51 period annual discards of undersized haddock were over 4.5 million lb, representing over 6% of the catch. The greatest part of the destruction occurred from June to November. His data further show that the overlap in culling between discards and fish retained for market ranged from 11 to 19 in (0.5 to 2.3 lb) and was usually a function of the size of the catches. The majority of the culling occurred between 13 and 15 in (33 and 38 cm).

From fishermen's reports, the discard of 1975 year-class haddock during 1977 was very high. It may have been of the same order of magnitude as that reported for the 1930-31 period mentioned above. Even though there was a mesh-size regulation in effect, reports indicate that many fishermen geared down, either using a smaller mesh or liner, to catch the abundant small haddock that are sold as "scrod."

Haddock and Atlantic cod are not the only fish discarded. Lux (1968) reported yellowtail flounder discards of 50% of the catch by weight. This was using mesh sizes of about 114 mm and a cull point of about 35 cm. The survival of discarded yellowtail was estimated by Lux to be about 25% The average discards and landings for 1963-66 averaged about 11,000 and 33,000 t, respectively (Hennemuth and Lux 1970).

A summary of the results, in regard to discards, of the catches made during the series of experiments reported in the previous sections of this paper is contained in Table 28. For Atlantic cod, haddock, and winter flounder, there was a reduction of discards and an increase in landings by the larger mesh. For yellowtail flounder there was a reduction of discards and of landings. In reviewing this data, the question arises that if this overall increase in catch and decrease in discards is in fact true, why have not the fishermen optimized their operation by going to a larger mesh (5 in or greater)? Several hypotheses are offered.

1) Evolutionary development (gear). The otter trawl has only been fished in New England for 75 yr. During this period there has been an increase in mesh size and many "highliner" captains do use mesh sizes over 5 in. Evolutionary development is a long process and just may not be complete in regard to optimizing mesh size.

2) Economics. The catch of smaller species of fish, i.e., whiting, may offset the loss of catch of larger groundfish caused by reduced trawl efficiency. The inshore fleet may be a good example of this.

3) Natural cycle variations. Every so often a good year class of Atlantic cod or haddock comes along. The fishermen will fish these schools when only a small portion of the fish have reached market size and thus will use a mesh size that would retain 100% of the scrod, roughly a 4-in mesh. Anyone using a larger mesh will most likely catch fewer marketable fish.

Table 28. — Discard summary for New England mesh experiments using only uncovered cod-end data.

Species	Discard size (mm)	105 mm cod ends % discard		135 mm cod ends % discard		Large mesh % discard reduction	Large mesh landings % change
		No.	Kg	No.	Kg		
Atlantic cod	≤42	28.3	6.9	3.2	0.6	93	+35
	≤52	47.3	15.5	11.6	3.4	78	+44
Haddock	≤42	4.5	1.9	0.6	0.3	84	+25
	≤52	29.5	19.4	15.3	10.4	46	+36
Yellowtail flounder	≤30	36.9	13.6	10.2	3.4	75	−25
	≤36	73.3	50.1	54.8	37.2	26	−16
Winter flounder	≤30	51.8	27.5	16.6	7.4	73	+37
	≤36	74.1	48.4	56.6	35.6	26	+25

4) Observation. It is harder to see catch-efficiency improvements when compared with seeing marketable fish escaping through the meshes when the net is at the surface.

Application of Mesh Management

Deciding to use mesh size regulation as a management tool is only the first step on a long road towards successful application. The second, and probably the most important, step is to determine what goals are to be attained by mesh size regulation. The most obvious role mesh size can play is in the reduction of discards of undersized fish. The problem here is to define what an undersized fish is. To a fisherman it may be any fish too small to market profitably, or legally, if there is a minimum size regulation enforced. To a scientist or manager it may be any fish smaller than some optimized size based on yield or yield per recruit.

Generally, discards of undersized fish decrease with increasing mesh size. At a certain point, under steady state conditions, a mesh size that would maximize the yield from the fishery, in weight, will be reached. The key variables that affect this point are fishing mortality, natural mortality, and growth rate. A mesh size can be chosen to attain this goal. Mesh size can also be chosen to protect a certain portion of the spawning stock, i.e., allow the fish to reach a size to spawn at least once or twice before recruiting to the fishery. The size mesh needed to accomplish this usually lies between that necessary to reduce discards of fish too small to market and that needed to maximize the yield of the fishery by weight. There may also be an economically optimum mesh size, one that would provide a supply of certain size fish that would maximize the return to the fishermen or stabilize prices.

Mesh size may even be used to limit effort over the short term. Increasing the mesh size by an increment that would offset any catch increases due to improved efficiency would cause a decrease in catch per unit effort. However, a new steady state condition will eventually be reached where CPUE may be greater than before or the fishery would be beyond the optimum point of harvesting. Assume that a mesh size is chosen that is a compromise between reducing discards of unmarketable fish and optimizing the overall yield (weight landed) of the fishery and in so doing protects the first spawners. Assume also, for now, that it is a single species fishery that is being discussed. The next step is implementation of the mesh regulation and, correspondingly, the enforcement of it.

It has been argued that if fishermen are fully informed and believe in the benefits that would accrue to the fishery there would be no implementation problems. However, the benefits accrue to the fishery, not necessarily to an individual fisherman. It is easier for a fisherman to see marketable fish escaping his large mesh cod end than to see gradual long-term increases in catch for the industry. Better prospects in the fishery may encourage more entries and an individual's share might not change at all. Whatever the reason, there is an incentive for fishermen to look at short-term losses rather than long-term gains. This incentive is highest when recruitment is strong.

The simplest way to avoid the regulation is to fish an undersized cod end and hope not to get caught. If the fisherman does get caught, the penalty, if any, is usually insignificant compared with the gains made by cheating. If a fisherman wants to decrease his chances of getting caught, he can fish a small mesh liner inside the regulation cod end. This allows him to remove it before entering port or upon the arrival of a Coast Guard vessel. There is also the technical loop-hole. For example, if the regulation does not specify the length of the cod end required, the fishermen could attach an extra short cod end of regulation mesh to an extension piece of smaller mesh size. A way to avoid this may be in using more general definitions such as defining cod end as the "terminal portion of a trawl in which the catch is normally retained." There can also be the honest mistake of a fisherman using a nonregulation mesh because he was sold the wrong size.

In a single species fishery the above problems should be relatively easy to solve. To counter the incentive to cheat, a greater disincentive must be present. Fishermen in New England suggest vessel "tie-ups" for those that violate the regulations. Some fishermen believe repeated violations should lead to suspension and even loss of license to fish. To aid in clear-cut identification of violators, the regulations must be black and white; no gray areas. One rule, for example, could be that a vessel may only have one mesh size onboard even to the point of requiring all parts of the trawl be at least the same mesh as the cod end.

To eliminate problems of what constitutes a legal cod end, a certification program may be in order. Such a program existed in New England during the 1950's on a voluntary basis. Fisheries enforcement agents were contacted by a dealer when a shipment of new cod ends arrived. The agents would go to the dealer and certify the cod ends by measuring and comparing with a set of standards that took into account material type and shrinkage rates. Upon passing, the cod end had four numbered brass tags squeezed onto it and then soldered. The cod end was then considered certified legal unless major (10%) repairs were undertaken. The system worked fairly well until the number of variations in twine type and quality became excessive and many failed to meet government specifications. At this point cod end manufacturers guaranteed their cod ends to the fishermen as legal size or they would stand the consequences. Eventually the voluntary certification program was phased out. Today, however, there seems to be a need for a certification program, quite possibly with a less rigorous set of criteria. Too many cod ends are being sold as legal size when they are not even close, even before shrinkage.

Another solution that is commonly advanced is the use of minimum size limits. A minimum size limit serves two main purposes. First it encourages fishermen to use the regulation mesh and, secondly, it discourages fishermen from fishing on populations of predominantly small fish. The problem with size limits is how to set them in relation to the 50% retention point of the regulation mesh. If the size limit is set lower than the 50% point, the fishermen have incentive to cheat as legal size fish are escaping the regulation mesh. If the size limit is set too high in relation to the 50% point there would be high discard rates nullifying the benefits of the regulation mesh. Setting the minimum size limit to correspond with the 50% retention point is a poor compromise at best. What may be a better approach to the problem is to set the size limit on a proportional basis closely corresponding with the selection curve of the regulation mesh, e.g., no more than 20% of the cod and/or haddock landings of a trip can be scrod (by weight). This sort of system would require better accountability at wharfside. One way to do this is to require all boxes of fish to be labeled (vessel, trip number, market category, and serial number) and listed by serial number on the weighouts.

There are other problems that surface when the application of mesh regulations is discussed in New England. One common objection some fishermen voice is that dogfish (*Squalus acanthias* and *Mustelus canis*) will gill in the large cod end meshes creating time-consuming labor requirements for their removal. Comparing a 5-in or greater mesh vs. a 4-in or smaller mesh, this may be a valid concern. However, the difference between using a 5⅛-in and a 5¾-in mesh, in regards to dogfish gilling, may be insignificant. One way to look at it is that there are fewer meshes in the larger cod end thus less gilled fish to remove.

Another concern of fishermen is the effect of a bar breaking in a cod end mesh. In a 3-in cod end a bar breaks leaving a 6-in hole; a failure that can be tolerated. Unfortunately, the days of using a 3-in mesh are gone. The difference between a bar failure between a 5⅛ and a 5¾- in cod end is a hole 10¼ in vs. one of 11½ in; both probably will give the same losses. One other common complaint is that the large cod end just will not be strong enough to handle large catches. So far there is no evidence that this complaint is valid but if it does turn out to be a problem there should be an easy technical solution available.

It should be kept in mind that the application of large mesh cod ends may have certain advantages to the fishermen, other than catch related, that outweigh the above disadvantages. The larger mesh should have a "cleaner" catch requiring easier landing and handling on deck. The cost of webbing, which is sold by weight, should be less, and it should be easier to mend. The larger mesh should also offer less towing resistance which may save on fuel costs.

Unfortunately, in New England, the relatively simple case of a single species groundfishery does not exist. However, New England is fortunate in that one mesh size probably can be chosen to accommodate management requirements for many key species—Atlantic cod, haddock, pollock, yellowtail flounder, winter flounder, and American plaice. Two important commercial species that require a smaller mesh are redfish and silver hake.

From a mesh based viewpoint there are two basic systems of management for New England's mixed bottom trawl fishery; one that allows a vessel to go to sea with more than one mesh size aboard and the other that does not. Present fishing strategies of most inshore and offshore vessels make it desirable to carry two mesh sizes to sea. The main reason is that it gives the captain flexibility in making his trip profitable. However, most fishermen and enforcement personnel agree that it is difficult, if even possible, to enforce a mesh size regulation with two mesh sizes aboard. No matter how technically sophisticated a dual mesh regulation can be made, the psychological barrier, i.e., the temptation to cheat, that exists when a fisherman knows the "other fellow" has a small mesh onboard and could be using it to outfish him, is insurmountable.

The solution seems to be in the one mesh only form of regulation. There are areas and seasons where this probably can work well without too many changes in fishing strategies. In some areas there may have to be major changes in traditional practices but these changes will not necessarily be detrimental to the fishermen. In other areas, mostly inshore, small mesh even for the larger groundfish may be the only way possible to fish. The main applications problem in determining a workable management scheme with mesh size regulation as a primary tool is effective enforcement.

Another point that must be kept in mind is that if a fishery has several different gears involved, the regulations must be balanced so that the fish become vulnerable to them at about the same age. There may be economic factors, due to differences in operating costs, that would create the need to adjust a balance based strictly on age of first capture.

Summation

The most recent groundfish management proposals in the northeast have included mesh size regulations as one of the main management tools. This basically entails increasing the size of the cod-end mesh to allow greater escapement of the smaller fish. Besides increasing the mean size of the fish caught, there are many direct and indirect effects on the fishing industry, resource management, and the ecosystem itself.

An example of direct economic impact is that in most cases larger fish bring a better price to the fishermen. When small flounders are worth only $0.10/lb, large flounders are bringing about $0.80 to the fishermen. This, in large part, is due to the fact that larger fish allow for more efficient processing. In many aspects larger fish are also of better quality, e.g., large whiting have improved texture and firmness. Larger whiting can also be processed as fillets worth a lot more than the smaller fish that mostly have to go into reduction. The above discussion points out that a change in mesh size can impact the processing sector of the fishing industry and the availability of certain processed products.

Larger mesh has direct impacts on the fishermen. The catch usually comes up cleaner, less by-catch of trash and unmarketable species. Compared with a smaller mesh that catch is usually greater by weight but fewer in number because it is composed of larger fish. This would then create less work on deck sorting, cutting, and gutting. The by-catch control aspect here is a double-edged sword. Some of the smaller species, whiting and redfish for example, are marketable and this catch would be reduced by a larger mesh. In the same manner less work on deck could lead to reduced crewing which has both positive and negative economic consequences.

Going to a larger mesh will allow more fish to grow to a larger size. This has the direct benefit of increasing the overall yields of the resource. It also puts more age groups and greater numbers of fish into the spawning pool, thus increasing the spawning potential and possible future year class strengths. What is not known is how more larger fish in the sea may impact the overall ecological balance. Larger mesh may increase resource stability, and correspondingly, reduce market cycles. This could lead to increased price stability and thus improved capability for financial planning for both fishermen and processor. However, a better financial climate may increase investment into fishing operations and in fact bring an increase in effort that could lead to overfishing. To carry this train of thought further, a larger industry, during a natural downturn in the fish populations, may be strong enough politically to bring on protectionist (predator, not the prey) regulations. These regulations, such as mortgage guarantees, fuel subsidies, lost gear replacement, etc., have the tendency to keep marginal operators in the fishery longer, thus adding to the overfishing pressure. The professional fisherman plays the cycles for maximum profit and thus has something to lose in a more controlled market.

Fisheries management itself is directly affected. The delayed recruitment brought about by the larger mesh would allow another survey data point on population size to be analyzed. This should improve estimates of projected landings which in itself could have many ramifications.

Any management regime based on some aspect of gear control (mesh size) can have significant long-term effects. Larger mesh saves energy by creating less drag. This in turn would allow fishermen to use larger nets which may be a lot more effective, thus increasing CPUE. If the mesh regulation tends to be restrictive, as would be the case if it effectively limited effort, fishermen would tend to shift to other gears. If this shift is to gill nets, for example, this can lead to increased gear conflict situations and product quality problems. Very little is known about the destructive fishing aspects of other gears and these impacts can be significant. This would increase the need for gear research to answer management questions.

ACKNOWLEDGEMENT

When the idea of managing the New England groundfishery by mesh size regulation in lieu of catch quotas was proposed in 1977, very few people actively supported it. I would like to acknowledge those members of the New England Fishery Management Council who promoted this study, the captains and crews of the eight fishing vessels that volunteered to conduct the work, and the state and federal scientists and managers that participated at sea and ashore. In all, over 100 people devoted significant time and effort because they believed there had to be a better way to manage the groundfishery. The industry today owes a debt of gratitude to these individuals. I hope this report does justice to their efforts.

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APPENDIX A

VESSEL SPECIFICATIONS

Item	FRANCES ELIZABETH	CHRISTOPHER ANDREW
Type vessel	Stern (net drum) trawler	
Call sign	KXS 387	WYP 9523
Length	16.8 meters (55 feet)	18.9 meters (62 feet)
Gross tons	36 tons	54 tons
Draft	2 meters(6.5 feet)	2.7 meters (9 feet)
Speed	9 knots	9 knots
Engine and Drive	GM V671 Diesel 3:1 reduction	Detroit SV71N Diesel 4.5:1 reduction
Horsepower	170 SHP	240 SHP @ 1800 rpm

Item	LINDA B	METACOMET
Type vessel	Eastern rig side trawler	
Home port	Gloucester, Massachusetts	
Call sign	WC 8799	WF 2782
Length	17.4 m (57 ft)	16.8 m (55 ft)
Gross tons	32 tons	33 tons
Draft	2.3 m (7.5 ft)	1.9 m (6.2 ft)
Speed	10 knots	9 knots
Engine and Drive	Detroit Diesel 8V71N 3:1 reduction	Detroit Diesel 8V71N 4.5:1 reduction
Horsepower	240 SHP @ 1800 rpm	240 SHP @ 1800 rpm

APPENDIX A

VESSEL SPECIFICATIONS (cont'd)

Item	JOSEPH & LUCIA II	JOSEPH & LUCIA III
Type vessel	Eastern rig side trawler	
Home port	Gloucester, Massachusetts	
Call sign	WU 8451	WY 3319
Length	26.8 m (88 ft)	29.3 (96 ft)
Gross tons	179 tons	192 tons
Draft	4.3 m (14 ft)	4.3 m (14 ft)
Speed	11 knots	11 knots
Engine and Drive	Fairbanks Morse 8 cylinder OP; 4:1 reduction	Fairbanks Morse
Horsepower	680 SHP @ 1300 rpm	900 SHP

Item	VALKYRIE	PATTON
Type vessel	Stern drum trawler	
Home port	New Bedford, Massachusetts	
Call sign	WX 8041	WYP 2632
Length	29.9 m (98 ft)	23.7 m (77.6 ft)
Gross tons	198 tons	155 tons
Draft	3.7 m (12 ft)	3.4 m (11.3 ft)
Speed	10.5 knots	10.5 knots
Engine and Drive	CAT. 398 3.5:1 reduction	CAT. 850 3:1 reduction
Horsepower	1000	765

APPENDIX B

GEAR SPECIFICATIONS

	FRANCES ELIZABETH	CHRISTOPHER ANDREW
Trawl	133 mm average mesh size throughout. #54 braided nylon twine.	
Cod ends	Type 1 - 106 mm average mesh size; 80 meshes around by 50 deep; #102 braided nylon twine, machine made. Type 2 - 139 mm average mesh size; 80 meshes around by 35 deep; #102 braided nylon twine, hand made.	
Cover (when used)	50 mm mesh size; #72 twisted nylon; 225 meshes around by 133 meshes deep, machine made.	
Headrope	15.8 meters total of 19 mm polypro	
Footrope (sweeps)	9.5 mm chain in wing section and 12.7 mm chain in bosom; strung with 10 cm diameter rubber "cookies" over 60% of its length.	11 mm chain strung with 10 cm diameter "cookies;" about 30 per meter of length. Groundrope of 19 mm poly connected to sweep by 7.6 cm scallop rings and shackles about every 40 cm.
Floats	7-8" diameter aluminum spheres	9-8" diameter aluminum spheres; 2 along each wing and 5 along center
Chafing gear	Mat of polyethylene strands covering aft half (and underside only) of cod end and cover.	
Doors	Rectangular shaped of wood construction 2.13 meters long by 1.11 meters wide weighing 270 kg. Bracket triangular shaped in two parts of iron bar located 1/3 back from forward end.	Oval shaped steel 2.13 meters long by 1.11 meters wide weighing 382.5 kg. Solid bracket in two parts located 1/4 and 1/2 back from forward end.

APPENDIX B

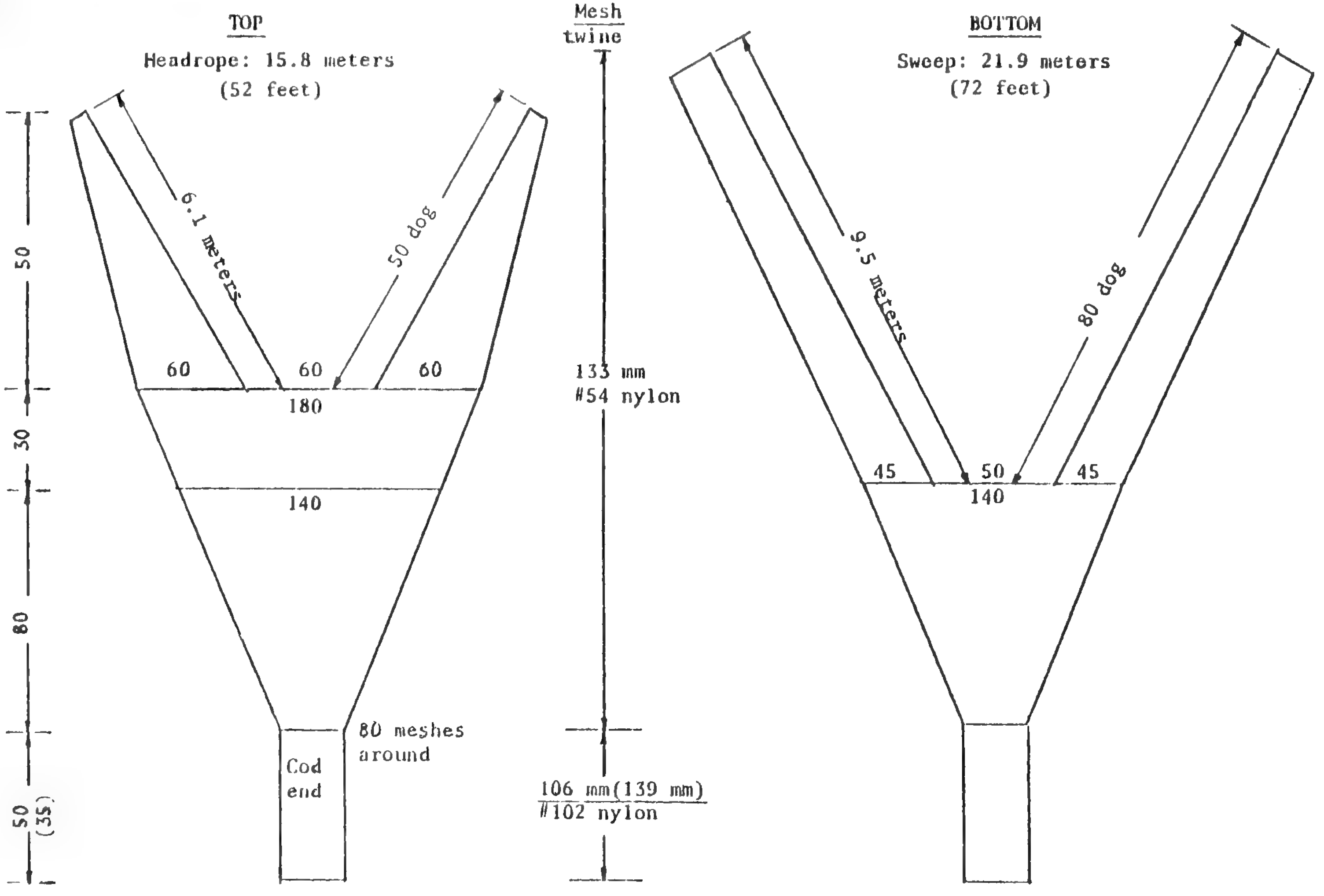
GEAR SPECIFICATIONS (cont'd)

	FRANCES ELIZABETH	CHRISTOPHER ANDREW
Backstraps	Two 2.13 meter lengths of 9.5 mm chain	
Bridle wires (legs)	13.7 meters long 9.5 mm chain on bottom and 9.5 mm wire on top.	9.1 meters long 9.5 mm chain on bottom and 12.7 mm wire (6x19) on top.
Trawl wire	14.3 mm 6x19 wire	15.8 mm 6x19 wire
Ground cables	36.5 meters 15.8 mm 6x19 wire	55 meters of 15.8 mm 6x19 wire
Miscellaneous	No quarter ropes, bull rope, lazy line or tickler chains used.	

Gear	LINDA B	METACOMET
Trawl (forward parts)	114 mm average mesh size with 108-mm mesh extension. 30-thread polypropylene.	108-mm average mesh size. 36-thread polypropylene.
Cod ends	Type 1: 99-mm average mesh size; 80 meshes around by 50 deep; #102 braided nylon twine, machine made. Type 2: 131-mm average mesh size; 80 meshes around by 35 deep; @102 braided nylon twine, handmade.	
Cover (when used)	50-mm average mesh size; 225 meshes around by 133 deep; #72 twisted nylon twine, machine made.	
Headrope	23.2 m (76 ft) of 1-inch polypropylene.	21.0 m (69 ft) of 7/8-inch nylon.
Footrope (sweeps)	5/16-inch chain hung in small bights.	3/8-inch chain hung in small bights.

TRAWL DIAGRAM

FRANCIS ELIZABETH and **CHRISTOPHER ANDREW**



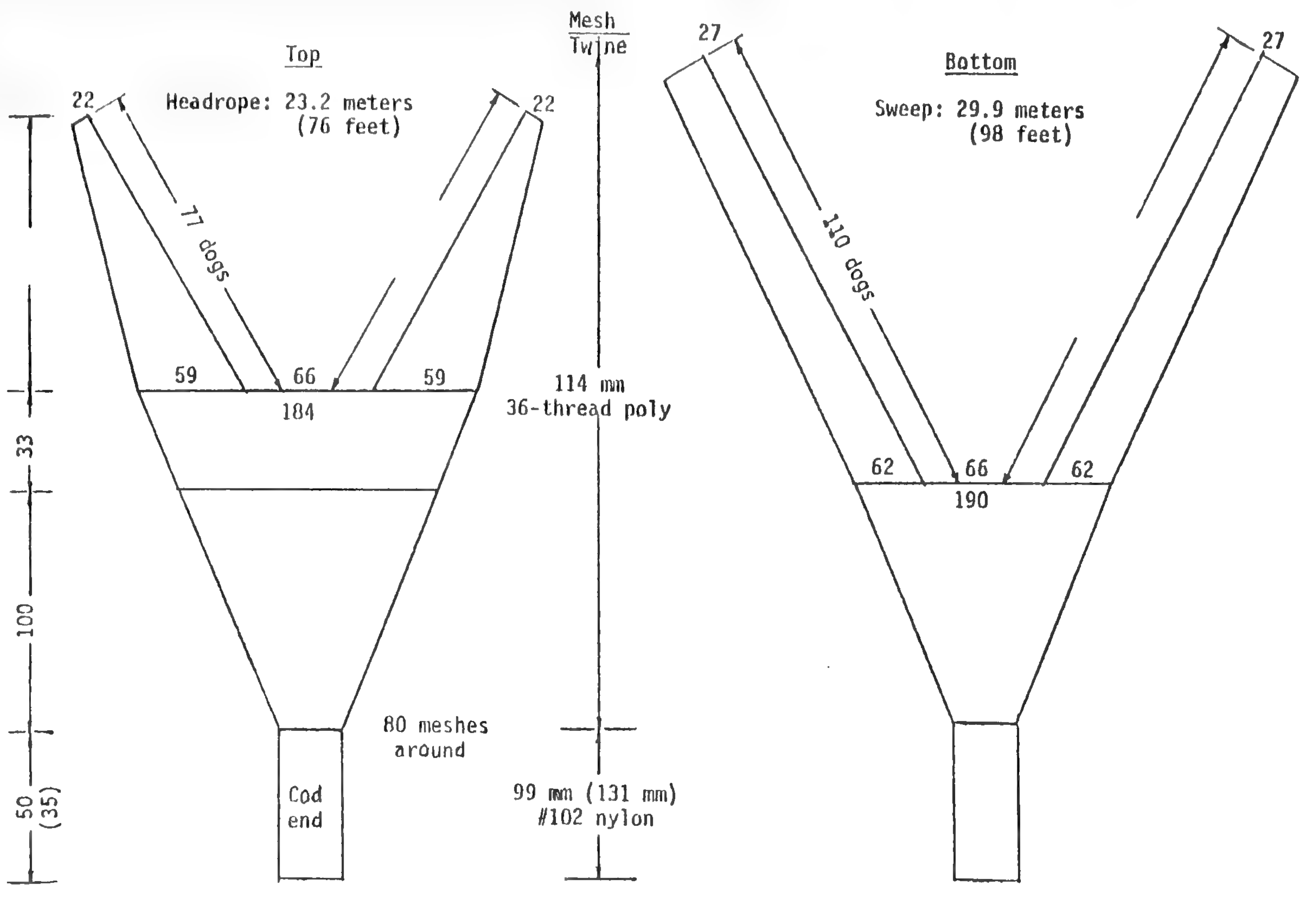
Trawl dimensions in meshes

APPENDIX B

GEAR SPECIFICATIONS (cont'd)

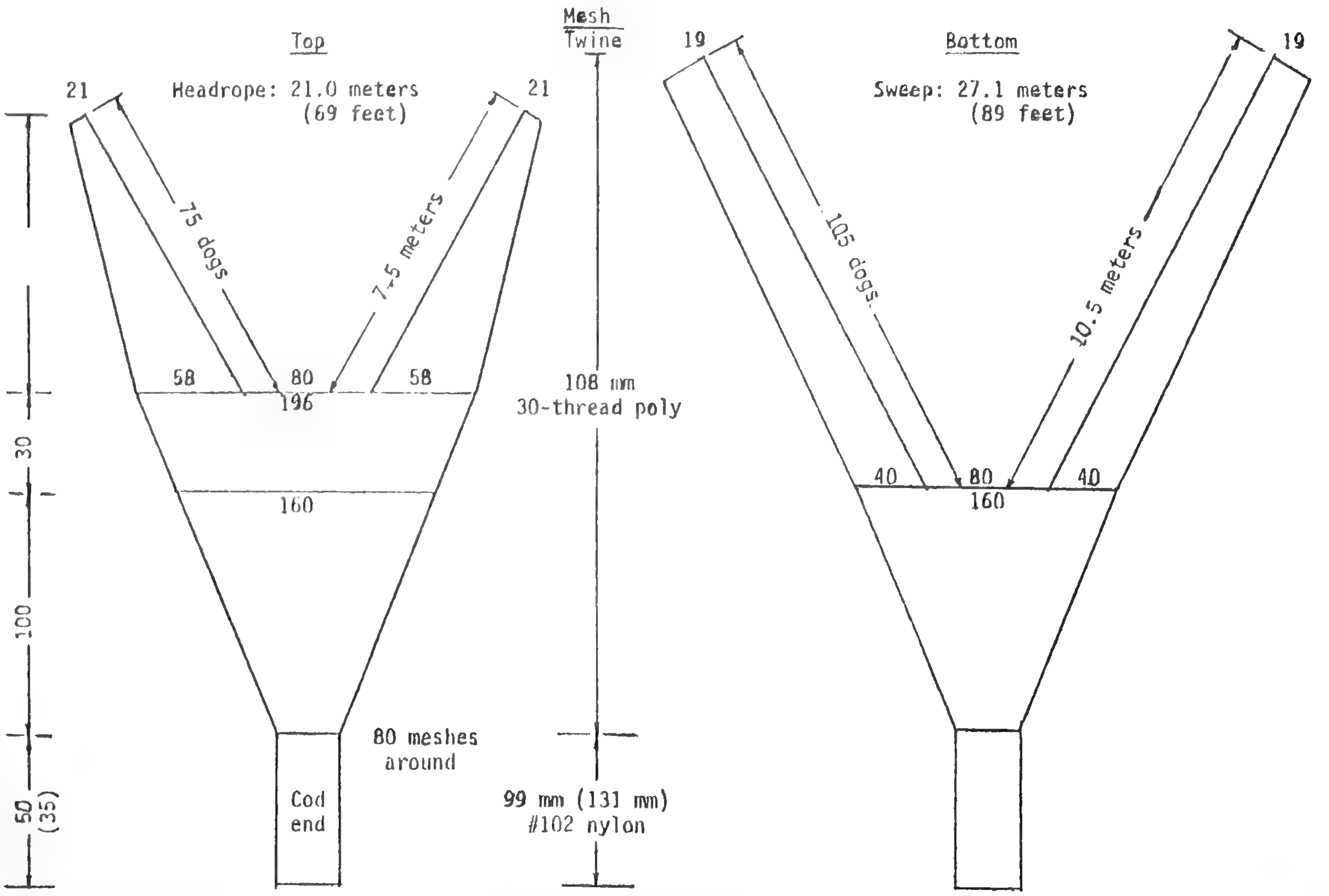
Gear	LINDA B	METACOMET
Floats	8 plastic floats(8-inch).	9 plastic floats(8-inch).
Chafing gear	Mat of polyethylene strands covering aft half (and underside only) of cod end and cover.	
Doors	Rectangular-shaped of wood and steel construction, 2 m (6.5 ft) long by 1.1 m (3.6 ft) wide, weighing 270 kg (600 lb). Bracket triangular-shaped of steel bar.	Rectangular shaped of wood and steel construction, 2 m (6.5 ft) long by 1.1 m (3.6 ft) wide, weighing 337 kg (750 lb). Bracket triangular-shaped of steel bar, located 0.48 m (1.6 ft) from forward end.
Backstraps	Two 2-m (6.5 ft) lengths of 9.5-mm (3/8-inch) chain.	
Bridle wires (legs)	18.3 m (60 ft) of 12.7-mm (1/2-inch) 6x19 wire.	
Trawl wire	14.3-mm (9/16-inch)6x19 wire.	12.7-mm (1/2-inch) 6x19 wire.
Ground cables	27.4 m (90 ft) of 14.3-mm (9/16-inch) 6x19 wire.	36.6 m (120 ft) of 12.7-mm (1/2-inch) 6x19 wire.
Miscellaneous	No quarter ropes, bull rope, or tickler chains used during test (bull rope normally used). Lazy-line 36.6-m (120-ft) loop and 18.3-m (60-ft) lead. 36.6-m (120-ft) loop and 18.3 m (60-ft) lead.	

Trawl Diagram, F/V LINDA B.



Trawl dimensions in meshes

Trawl Diagram, F/V METACOMET

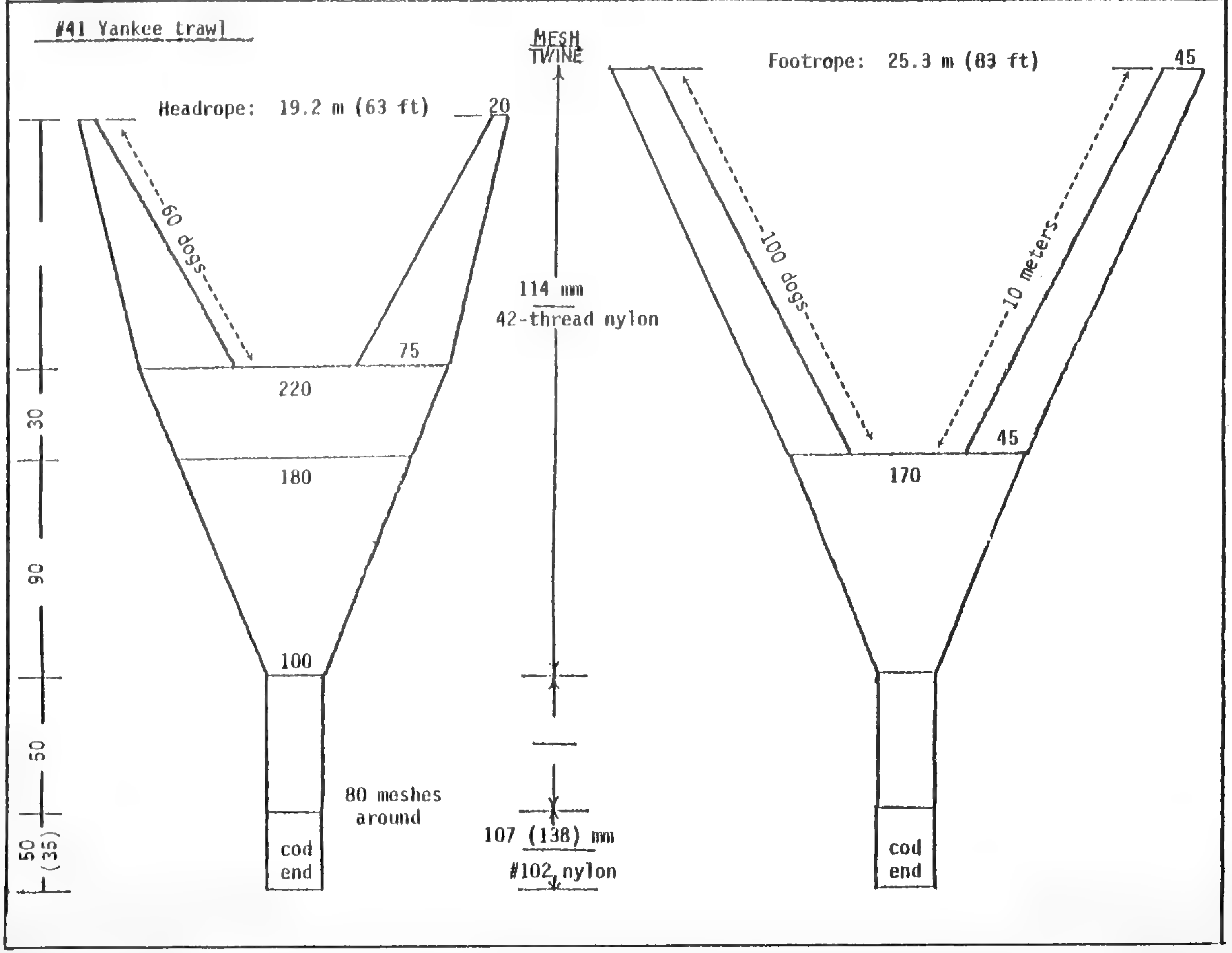


APPENDIX B

GEAR SPECIFICATIONS (cont'd)

	JOSEPH & LUCIA II AND III (Vessels had nearly identical trawls)
Trawl (forward parts)	- 114 mm (4.5 inches) average mesh size; mostly #42 thread nylon twine.
Cod ends	- Type 1: 107 mm average mesh size; 80 meshes around x 50 deep; #102 braided nylon twine; machine-made. - Type 2: 138 mm average mesh size; 80 meshes around x 35 deep; #102 braided nylon twine; handmade.
Cover (when used)	- 50 mm average mesh size; 225 meshes around x 133 deep; #72 twisted nylon twine; machine-made.
Headrope	- 19.2 m (63 ft) of 1.5-inch nylon.
Footrope (sweeps)	- 25.3 m (83 ft) of 5/8-inch chain; belly has 18-inch rollers with 2 spacers between each; wings have 14-inch and 18-inch bobbins with 3 spacers between each.
Floats	- 22 on belly and 8 on each wing (8-inch aluminum).
Chafing gear	- Mat of polyethylene strands covering aft half (and underside only) of cod end and cover.
Doors	- Rectangular-shaped of wood and steel construction; 2.7 m (9 ft) long x 1.4 m (4.5 ft) wide; weighing 818 kg (1,800 lb). Bracket triangular-shaped of steel bar.
Backstraps	- Two 2.7-m (9-ft) lengths of 5/8-inch chain.
Bridle wires(legs)	- 18.3 m (60 ft) of 7/8-inch 6x19 wire.
Trawl wire	- 7/8-inch 6x19 wire.
Ground cables	- 18.3 m (60 ft) of 7/8-inch 6x19 wire.
Miscellaneous	- Trawl equipped with quarter ropes, bullrope, lazy-line, and splitting straps.

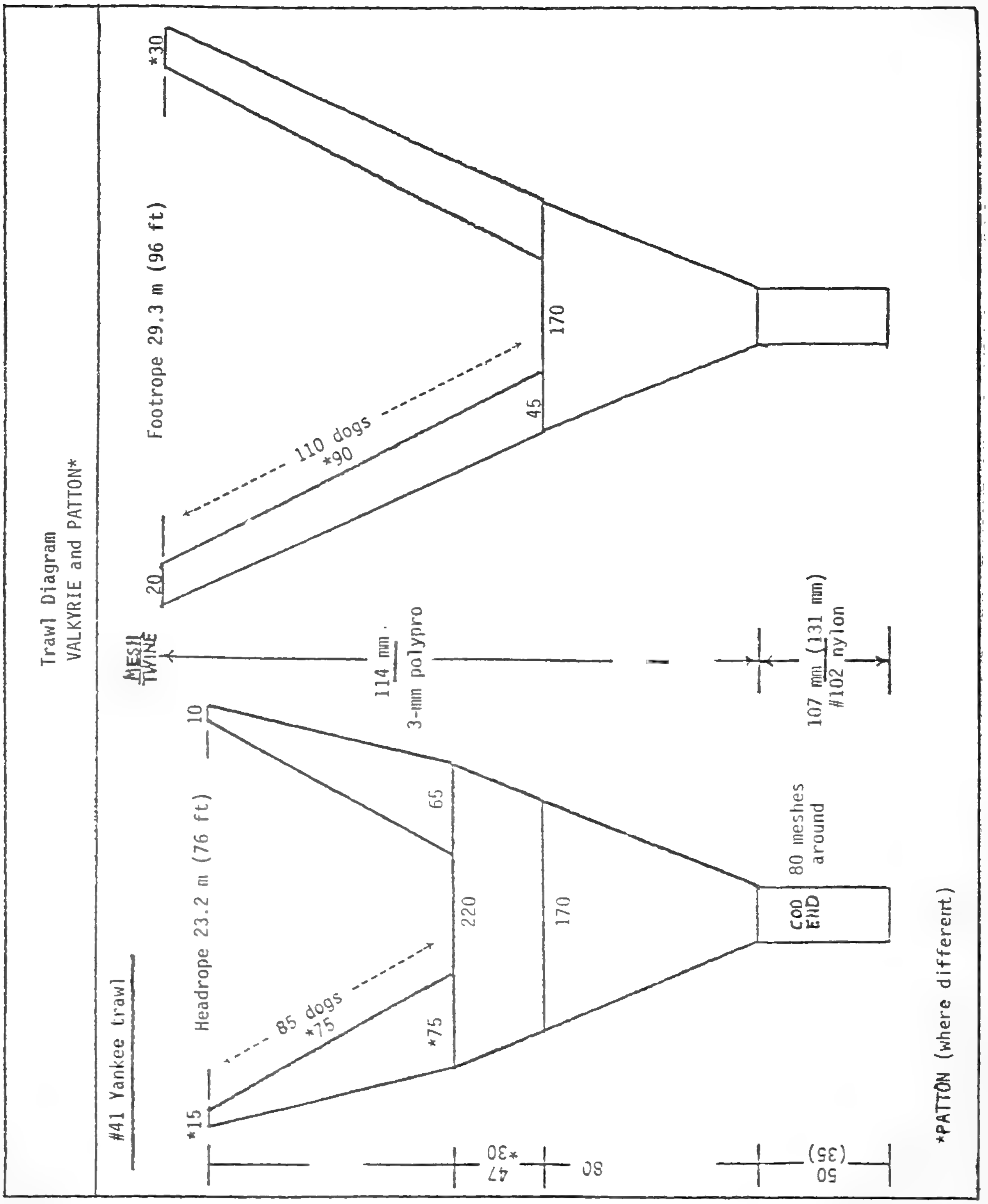
Trawl diagram
JOSEPH & LUCIA II AND III



APPENDIX B

GEAR SPECIFICATIONS (cont'd)

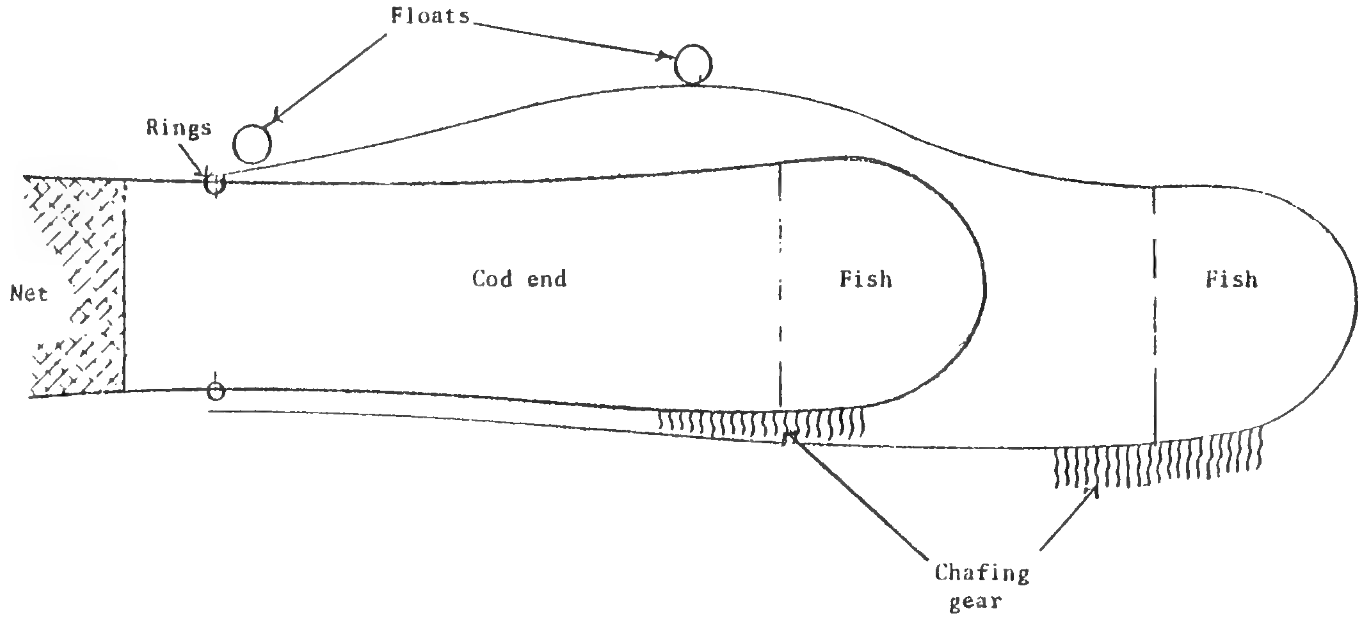
	VALKYRIE	PATTON
Trawl	- 114 mm (4.5 inches) average mesh size; 3-mm polypropylene twine.	
Cod ends	- Type 1: 107 mm average mesh size; 80 meshes around x 50 deep; #102 braided nylon twine; machine-made.	
	- Type 2: 131 mm average mesh size; 80 meshes around x 35 deep; #102 braided nylon twine; handmade.	
Cover (when used)	- 45 mm average mesh size; 270 meshes around x 150 deep; polypropylene.	
Headrope	- 23.2 m (76 ft) of 1-inch combination rope.	
Footrope (sweeps)	- 29.3 m (96 ft) of 5/8-inch chain with heavy rollers and bobbins wing-to-wing.	
Floats	- 45 (8-inch aluminum).	24 on wings, 14 on belly (galvanized).
Chafing gear	- Mat of polyethylene strands covering aft half (and underside only) of cod end and cover.	
Doors	- Slotted semi-oval steel doors (made in Portugal).	
	3.1 m (10 ft) long x 2.1 m (7 ft) wide; 650 kg.	2.7 m (8.8 ft) long x 1.4 m (4.7 ft) wide; 500 kg.
Backstraps	- Two 2.4-m (8-ft) lengths of 5/8-inch chain.	
Bridle wires (legs)	- 9.1 m (30 ft). Top of 5/8-inch wire; bottom of 7/8-inch wire.	Top 9.1 m (30 ft) of 1/2-inch wire; bottom 9.4 m (31 ft) of 3/4-inch wire.
Trawl warp	- 1-inch wire.	7/8-inch wire.
Ground cables	- 5.2 m (17 ft) of 7/8-inch wire.	4.3 m (14 ft) of 3/4-inch wire.



Trawl Diagram
VALKYRIE and PATTON*

*PATTON (where different)

COVER RIGGING



APPENDIX C

MESH MEASUREMENT STATISTICS

	Trawl Stations						
	1	2	5	6	9	11	Overall
	JOSEPH & LUCIA III						
	A. Small Cod End						
$\bar{x}$ =	105.80	109.83	109.70	109.03	111.97	111.47	109.6
S_x =	3.30	3.01	3.25	4.25	3.48	3.40	3.45
$S_{\bar{x}}$ =	0.60	0.55	0.59	0.78	0.64	0.62	0.63

	Trawl Stations						
	3	4	7	8	9	11	Overall
	JOSEPH & LUCIA II						
	B. Large Cod End						
$\bar{x}$ =	140.90	137.77	134.20	135.63	133.40	133.50	135.9
S_x =	5.27	3.37	4.08	3.96	3.23	3.09	3.84
$S_{\bar{x}}$ =	0.96	0.62	0.74	0.72	0.59	0.56	0.70

	Trawl Stations						
	3	4	7	8	10	12	Overall
	JOSEPH & LUCIA III						
	B. Large Cod End						
$\bar{x}$ =	140.97	141.73	138.90	138.50	143.30	141.83	140.8
S_x =	3.96	3.75	5.59	4.12	4.56	4.33	4.39
$S_{\bar{x}}$ =	0.72	0.68	1.02	0.75	0.83	0.79	0.80

	Trawl Stations								
	1	2	7	8	9	10	15	16	Overall
	VALKYRIE								
	A. Small Cod End								
$\bar{x}$ =	107.4	108.8	112.5	106.3	105.3	111.1	107.4	107.3	108.3
S_x =	3.67	3.38	5.95	3.27	3.71	3.66	4.12	5.25	4.13
$S_{\bar{x}}$ =	0.67	0.62	1.09	0.60	0.68	0.67	0.75	0.96	0.76
	PATTON								
	A. Small Cod End								
$\bar{x}$ =	105.8	105.4	105.6	105.1	106.7	106.1	106.7	106.6	106.0
S_x =	3.57	4.09	3.61	3.54	2.71	3.14	3.81	3.64	3.51
$S_{\bar{x}}$ =	0.65	0.75	0.66	0.65	0.49	0.57	0.70	0.67	0.64

	Trawl Stations								
	3	4	5	6	11	12	13	14	Overall
	VALKYRIE								
	B. Large Cod End								
$\bar{x}$ =	127.2	125.2	128.0	126.1	128.5	128.3	127.9	127.7	127.4
S_x =	4.11	3.46	4.78	4.46	8.05	5.26	5.34	6.77	5.28
$S_{\bar{x}}$ =	0.75	0.63	0.87	0.81	1.47	0.96	0.97	1.24	0.96
	PATTON								
	B. Large Cod End								
$\bar{x}$ =	132.7	133.9	137.4	132.8	135.2	134.0	136.2	134.8	134.6
S_x =	5.92	5.97	6.00	4.16	7.76	5.34	7.65	4.42	5.90
$S_{\bar{x}}$ =	1.08	1.09	1.10	0.76	1.42	0.98	1.40	0.81	1.08

APPENDIX C

MESH MEASUREMENT STATISTICS

	Trawl Stations									
	5	6	9	12	Overall	7	8	10	11	Overall
CHRISTOPHER ANDREW										
	A. Small Cod End					B. Large Cod End				
$\bar{x}$ =	140.00	107.50	103.92	104.33	104.90	140.00	143.40	140.00	138.00	140.35
Sx =	3.20	3.28	2.55	2.97	2.98	4.23	4.45	4.14	3.61	4.11
S$\bar{x}$ =					0.272					0.375
FRANCES ELIZABETH										
	A. Small Cod End					B. Large Cod End				
$\bar{x}$ =	109.23	106.37	106.53	104.97	106.80	141.00	138.23	133.83	134.33	136.80
Sx =	3.99	4.07	2.64	4.47	3.79	3.70	4.66	3.90	5.20	4.37
S$\bar{x}$ =					0.346					0.398

	Trawl Stations								
	1	2	7	8	9	10	15	16	Overall
LINDA B									
	A. Small Cod End						A. Small Cod End		
$\bar{x}$ =	98.23	98.67	100.13	99.73	98.87	98.87	100.10	99.50	99.26
Sx =	4.10	2.38	2.61	2.59	2.24	2.70	2.37	2.93	2.74
S$\bar{x}$ =	0.75	0.44	0.48	0.47	0.41	0.49	0.43	0.54	0.177
METACOMET									
	A. Small Cod End						A. Small Cod End		
$\bar{x}$ =	101.60	96.60	98.40	97.90	97.70	98.70	98.80	98.50	98.53
Sx =	4.00	3.50	4.10	3.10	2.90	3.60	3.60	3.40	3.53
S$\bar{x}$ =	0.70	0.60	0.80	0.60	0.50	0.70	0.70	0.60	0.228

	Trawl Stations								
	3	4	5	6	11	12	13	14	Overall
LINDA B									
	B. Large Cod End						B. Large Cod End		
$\bar{x}$ =	127.60	127.27	128.57	129.23	130.43	128.83	128.53	129.17	128.70
Sx =	3.87	3.37	3.45	3.26	3.92	3.02	3.5164	2.48	3.36
S$\bar{x}$ =	0.71	0.62	0.63	0.59	0.72	0.55	0.64	0.45	0.217
METACOMET									
	B. Large Cod End						B. Large Cod End		
$\bar{x}$ =	133.30	135.30	134.80	134.30	133.90	132.90	132.90	134.40	133.98
Sx =	3.20	5.60	3.70	4.10	3.50	4.90	3.30	5.10	4.18
S$\bar{x}$ =	0.60	1.00	0.70	0.08	0.60	0.90	0.60	0.90	0.270

	Trawl Stations						
	1	2	5	6	10	12	Overall
JOSEPH & LUCIA II							
	A. Small Cod End						A. Small Cod End
$\bar{x}$ =	102.30	101.50	104.17	103.70	106.57	103.97	103.7
Sx =	3.16	3.69	3.77	4.45	3.52	3.75	3.72
S$\bar{x}$ =	0.58	0.67	0.69	0.81	0.64	0.63	0.67

$\bar{x}$ = average (mean) size of meshes (mm). Sample size at each station was 30 meshes.
Sx = standard deviation indicating variation in mesh sizes. Two times Sx, added to and subtracted from $\bar{x}$, gives the size limits between which 95% of the meshes fall.
S$\bar{x}$ = standard error which is a measure of the preciseness of the mean. Two times S$\bar{x}$, added to and subtracted from $\bar{x}$, gives the 95% confidence limits of $\bar{x}$ shown in this table.

APPENDIX D

TOW DATA

Tow data (all tows 1 hr from set to haulback).

A. 12 December 1977. 10 kilometers east of Scituate, Massachusetts. Bottom type: sand and mud.

	FRANCES ELIZABETH	CHRISTOPHER ANDREW
Tow 1		
Cod end:	Large mesh uncovered	
Wire out:	128 meters	137 meters
Course:	170°	155°
Start time:	1110	1056
Avg. depth:	45 meters	45 meters
Weather:	Overcast; wind NNW at 15 knots; seas 1-2 meters; temp. -6°C	
Tow 2		
Cod end:	Large mesh covered	
Wire out:	128 meters	137 meters
Course:	170°	165°
Start time:	1305	1255
Avg. depth:	45 meters	45 meters
Weather:	Overcast; wind NW at 10 knots; seas 1-1.5 meters; temp. -6°C.	

	FRANCES ELIZABETH	CHRISTOPHER ANDREW
Tow 3		
Cod end:	Small mesh covered	
Wire out:	128 meters	137 meters
Course:	170°	170°
Start time:	1510	1434
Avg. depth:	41 meters	41 meters
Weather:	Overcast; wind NW at 10 knots; seas 1-1.5 meters; temp. -6°C	
Tow 4		
Cod end:	----------	Small mesh uncovered
Wire out:	----------	137 meters
Course:	----------	330°
Start time:	----------	1615
Avg. depth:	----------	41 meters
Weather:	Overcase; wind NW at 10 knots; seas 1-1.5 meters; temp. -6°C	

B. 13 December 1977. 11 kilometers ENE of Scituate, Massachusetts. Bottom type: Mud.

	FRANCES ELIZABETH	CHRISTOPHER ANDREW
Tow 5		
Cod end:	Small mesh uncovered	
Wire out:	137 meters	137 meters
Course:	000°	350°
Start time:	0805	0750
Avg. depth:	50 meters	47 meters
Weather:	Overcast; wind north at 10 knots; seas 1 meter; temp. -6°C.	
Tow 6		
Cod end:	Small mesh covered	
Wire out:	137 meters	137 meters
Course:	160°	125°
Start time:	0955	0929
Avg. depth:	50 meters	50 meters
Weather:	Overcast; wind NNE at 15 knots; seas 1 meter; temp. -3°C.	

	FRANCES ELIZABETH	CHRISTOPHER ANDREW
Tow 7		
Cod end:	Large mesh uncovered	
Wire out:	137 meters	137 meters
Course:	350°	350°
Start time:	1140	1130
Avg. depth:	51 meters	51 meters
Weather:	Overcast; wind NE at 15 knots; seas 1 meter; temp. 0°C.	
Tow 8		
Cod end:	Large mesh covered	
Wire out:	137 meters	137 meters
Course:	170°	170°
Start time:	1320	1307
Avg. depth:	51 meters	51 meters
Weather:	Overcast; wind NE at 15 knots; seas 1 meter; temp. 0°C.	

APPENDIX D

TOW DATA (cont'd)

Tow data (all tows 1 hr from set to haulback).

A. 22 March 1978. Between Long Beach and Eastern Point, Gloucester, Massachusetts. Bottom type: sand and mud.

Tow 1

	LINDA B	METACOMET
Cod end:	Small mesh uncovered	
Wire out:	100 fms (182.9 m)	100 fms (182.9 m)
Course:	East	East
Start time:	0640	0640
Avg. depth:	24 fms (43.9 m)	24 fms (43.9 m)
Weather:	Wind WSW at 20 knots; seas 4 ft; overcast.	

Tow 2

	LINDA B	METACOMET
Cod end:	Small mesh covered	
Wire out:	100 fms (182.9 m)	100 fms (182.9 m)
Course:	East	East
Start time:	0830	0826
Avg. depth:	25 fms (45.7 m)	25 fms (45.7 m)
Weather:	Wind West at 25 knots; seas 4 ft; partly cloudy.	

Tow 3

	LINDA B	METACOMET
Cod end:	Large mesh uncovered	
Wire out:	100 fms (182.9 m)	100 fms (182.9 m)
Course:	West	West
Start time:	1015	1015
Avg. depth:	27 fms (49.3 m)	27 fms (49.3 m)
Weather:	Wind West at 30 knots; seas 4 ft; cloudy.	

Tow 4

	LINDA B	METACOMET
Cod end:	Large mesh covered	
Wire out:	100 fms (182.9 m)	100 fms (182.9 m)
Course:	West	West
Start time:	1150	1200
Avg. depth:	25 fms (45.7 m)	25 fms (45.7 m)
Weather:	Wind WNW at 30 knots; seas 4 ft; partly cloudy.	

B. 23 March 1978. East of Thatcher's Island, Gloucester, Massachusetts. Bottom type: sand and mud.

Tow 5

	LINDA B	METACOMET
Cod end:	Large mesh covered	
Wire out:	100 fms (182.9 m)	100 fms (182.9 m)
Course:	East	East
Start time:	0600	0615
Avg. depth:	28 fms (51.2 m)	28 fms (51.2 m)
Weather:	Wind SSE at 15 knots; seas 3 ft; overcast.	

Tow 6

	LINDA B	METACOMET
Cod end:	Large mesh uncovered	
Wire out:	100 fms (182.9 m)	100 fms (182.9 m)
Course:	North	North
Start time:	0730	0755
Avg. depth:	30 fms (54.8 m)	30 fms (54.8 m)
Weather:	Wind SSE at 15 knots; seas 3 ft; partly cloudy.	

Tow 7

	LINDA B	METACOMET
Cod end:	Small mesh covered	
Wire out:	100 fms (182.9 m)	125 fms (228.5 m)
Course:	North	North
Start time:	0915	0945
Avg. depth:	40 fms (73.1 m)	35 fms (64.0 m)
Weather:	Wind SSE at 10 knots; seas 2 ft; partly cloudy.	

Tow 8

	LINDA B	METACOMET
Cod end:	Small mesh uncovered	
Wire out:	100 fms (182.9 m)	125 fms (228.5 m)
Course:	SW	SW
Start time:	1050	1050
Avg. depth:	40 fms (73.1 m)	40 fms (73.1 m)
Weather:	Wind South at 5 knots; seas 1 ft; partly cloudy.	

APPENDIX D

TOW DATA (cont'd)

Tow data (all tows 1 hr from set to haulback).

C. 25 March 1978. Off Long Beach, Gloucester, Massachusetts. Bottom type: sand and mud.

Tow 9	LINDA B	METACOMET
Cod end:	Small mesh covered	
Wire out:	100 fms (182.9 m)	100 fms (182.9 m)
Course:	NE	NE
Start time:	0630	0630
Avg. depth:	22 fms (40.2 m)	22 fms (40.2 m)
Weather:	Wind NE at 10 knots; seas 1 ft; clear.	

Tow 10	LINDA B	METACOMET
Cod end:	Small mesh uncovered	
Wire out:	100 fms (182.9 m)	100 fms (182.9 m)
Course:	SE	SE
Start time:	0755	0810
Avg. depth:	21 fms (38.5 m)	21 fms (38.4 m)
Weather:	Wind NE at 10 knots; seas 1 ft; clear.	

Tow 11	LINDA B	METACOMET
Cod end:	Large mesh covered	
Wire out:	100 fms (182.9 m)	100 fms (182.9 m)
Course:	SW	SW
Start time:	0945	0950
Avg. depth:	24 fms (43.9 m)	24 fms (43.9 m)
Weather:	Wind North at 10 knots; seas 1 ft; clear.	

Tow 12	LINDA B	METACOMET
Cod end:	Large mesh uncovered	
Wire out:	100 fms (182.9 m)	100 fms (182.9 m)
Course:	NE	NE
Start time:	1115	1130
Avg. depth:	21 fms (38.4 m)	21 fms (38.4 m)
Weather:	Wind North at 5 knots; seas calm; clear.	

D. 28 March 1978. Vicinity of Thatchers Island, Gloucester, Massachusetts. Bottom type: sand and mud.

Tow 13	LINDA B	METACOMET
Cod end:	Large mesh uncovered	
Wire out:	100 fms (182.9 m)	125 fms (228.5 m)
Course:	North	North
Start time:	0600	0610
Avg. depth:	32 fms (58.5 m)	38 fms (69.5 m)
Weather:	Wind WSW at 15 knots; seas 3 ft; partly cloudy.	

Tow 14	LINDA B	METACOMET
Cod end:	Large mesh covered	
Wire out:	100 fms (182.9 m)	125 fms (228.5 m)
Course:	SW	SW
Start time:	0730	0730
Avg. depth:	37 fms (67.6 m)	44 fms (80.4 m)
Weather:	Wind WSW at 15 knots; seas 3 ft; partly cloudy.	

Tow 15	LINDA B	METACOMET
Cod end:	Small mesh uncovered	
Wire out:	100 fms (182.9 m)	100 fms (182.9 m)
Course:	SW	SW
Start time:	1100	1030
Avg. depth:	24 fms (43.9 m)	24 fms (43.9 m)
Weather:	Wind WSW at 20 knots; seas 4 ft; partly cloudy.	

Tow 16	LINDA B	METACOMET
Cod end:	Small mesh covered	
Wire out:	100 fms (182.9 m)	100 fms (182.9 m)
Course:	West	West
Start time:	1100	1030
Avg. depth:	24 fms (43.9 m)	24 fms (43.9 m)
Weather:	Wind WSW at 20 knots; seas 4 ft; partly cloudy.	

APPENDIX D

TOW DATA (cont'd)

Tow data (all tows 1 hr from set to haulback). Bottom type: mud and rock.

A. 13 August 1978.

Tow 1

	JOSEPH & LUCIA II	JOSEPH & LUCIA III
Cod end:	Small mesh covered.	
Wire out:	225 fms	225 fms
Course:	NNW	320
Start time:	0540	0542
Avg. depth:	92 fms	85 fms
Weather:	Wind calm; 68°; overcast. Seas 1 ft; fog.	

Tow 2

	JOSEPH & LUCIA II	JOSEPH & LUCIA III
Cod end:	Small mesh uncovered.	
Wire out:	225 fms	225 fms
Course:	SW	270
Start time:	0718	0728
Avg. depth:	93 fms	90 fms
Weather:	Wind calm; 68°; overcast. Seas 1 ft; fog.	

Tow 3

	JOSEPH & LUCIA II	JOSEPH & LUCIA III
Cod end:	Large mesh covered.	
Wire out:	225 fms	200 fms
Course:	W	200
Start time:	1303	1300
Avg. depth:	74 fms	70 fms
Weather:	Wind calm; overcast.	Fog.

Tow 4

	JOSEPH & LUCIA II	JOSEPH & LUCIA III
Cod end:	Large mesh uncovered.	
Wire out:	225 fms	200 fms
Course:	E	110
Start time:	1445	1453
Avg. depth:	74 fms	70 fms
Weather:	Wind calm; overcast.	Seas 1 ft; fog.

B. 14 August 1978.

Tow 5

	JOSEPH & LUCIA II	JOSEPH & LUCIA III
Cod end:	Small mesh uncovered.	
Wire out:	225 fms	200 fms
Course:	E	260
Start time:	0810	0758
Avg. depth:	81 fms	72 fms
Weather:	Wind calm; overcast.	Seas 3 ft.

Tow 6

	JOSEPH & LUCIA II	JOSEPH & LUCIA III
Cod end:	Small mesh covered.	
Wire out:	225 fms	200 fms
Course:	W	270
Start time:	0953	950
Avg. depth:	81 fms	78 fms
Weather:	Wind calm; overcast.	Seas 3 ft; fog.

Tow 7

	JOSEPH & LUCIA II	JOSEPH & LUCIA III
Cod end:	Large mesh uncovered.	
Wire out:	225 fms	200 fms
Course:	E	120
Start time:	1158	1145
Avg. depth:	81 fms	78 fms
Weather:	Wind calm; overcast.	Seas 2 ft; fog.

Tow 8

	JOSEPH & LUCIA II	JOSEPH & LUCIA III
Cod end:	Large mesh covered.	
Wire out:	225 fms	200 fms
Course:	W	270
Start time:	1345	1350
Avg. depth:	83 fms	79 fms
Weather:	Wind calm, overcast.	Seas 2 ft; fog.

C. 15 August 1978.

Tow 9

	JOSEPH & LUCIA II	JOSEPH & LUCIA III
Cod end:	Large mesh uncovered.	Small mesh uncovered.
Wire out:	225 fms	200 fms
Course:	N	335
Start time:	0830	0835
Avg. depth:	85 fms	84 fms
Weather:	Wind calm; overcast, fog. Seas 2-3 ft.	

Tow 10

	JOSEPH & LUCIA II	JOSEPH & LUCIA III
Cod end:	Small mesh uncovered.	Large mesh uncovered.
Wire out:	225 fms	200 fms
Course:	S	040
Start time:	1015	1015
Avg. depth:	84 fms	82 fms
Weather:	Wind calm; overcast.	Seas 1-2 ft; fog.

Tow 11

	JOSEPH & LUCIA II	JOSEPH & LUCIA III
Cod end:	Large mesh uncovered.	Small mesh uncovered.
Wire out:	225 fms	200 fms
Course:	S	180
Start time:	1155	1155
Avg. depth:	84 fms	82 fms
Weather:	Wind calm; overcast.	Seas 1-2 ft, fog.

Tow 12

	JOSEPH & LUCIA II	JOSEPH & LUCIA III
Cod end:	Small mesh uncovered.	Large mesh uncovered.
Wire out:	225 fms	200 fms
Course:	N	350
Start time:	1340	1350
Avg. depth:	85 fms	82 fms
Weather:	Wind calm; overcast.	Seas calm; fog.

APPENDIX D

TOW DATA (cont'd)

Tow data. Bottom type: sand.

A. 8 October 1978.

Tow 1

	VALKYRIE	PATTON
Cod end:	Small mesh uncovered.	
Wire out:	60 fms	60 fms
Course:	S	175°
Start time:	0745	0740
Avg. depth:	22 fms	25 fms
Weather:	50°; clear. Seas 2-3 ft.	

Tow 2

	VALKYRIE	PATTON
Cod end:	Small mesh covered.	
Wire out:	150 fms	150 fms
Course:	S	140°-360°
Start time:	0935	0940
Avg. depth:	52 fms	56 fms
Weather:	51°; clear. Seas 2-3 ft.	

Tow 3

	VALKYRIE	PATTON
Cod end:	Large mesh uncovered.	
Wire out:	130 fms	120 fms
Course:	N	345°
Start time:	1130	1125
Avg. depth:	45 fms	40 fms
Weather:	59°; clear. Seas 3-4 ft.	

Tow 4

	VALKYRIE	PATTON
Cod end:	Large mesh covered.	
Wire out:	150 fms	150 fms
Course:	N	340°
Start time:	1405	1407
Avg. depth:	52 fms	56 fms
Weather:	60°; partly cloudy. Seas 1-4 ft.	

B. 9 October 1978.

Tow 5

	VALKYRIE	PATTON
Cod end:	Large mesh covered.	
Wire out:	60 fms	55 fms
Course:	N	345°
Start time:	0730	0730
Avg. depth:	20 fms	20 fms
Weather:	52°; partly cloudy. Seas 3-5 ft.	

Tow 6

	VALKYRIE	PATTON
Cod end:	Large mesh uncovered.	
Wire out:	60 fms	55 fms
Course:	N	360°
Start time:	0855	0855
Avg. depth:	18 fms	18 fms
Weather:	50°; partly cloudy. Seas 3-6 ft.	

Tow 7

	VALKYRIE	PATTON
Cod end:	Small mesh covered.	
Wire out:	60 fms	55 fms
Course:	E	120°
Start time:	1050	1055
Avg. depth:	29 fms	31 fms
Weather:	46°; partly cloudy. Seas 3-6 ft.	

Tow 8

	VALKYRIE	PATTON
Cod end:	Small mesh uncovered.	
Wire out:	100 fms	120 fms
Course:	W	260°
Start time:	1230	1230
Avg. depth:	40 fms	41 fms
Weather:	52°; partly cloudy. Seas 3-6 ft.	

APPENDIX D

TOW DATA (cont'd)

Tow data. Bottom type: sand.

C. 10 October 1978.

Tow 9	VALKYRIE	PATTON
Cod end:	Small mesh covered.	
Wire out:	70 fms	80 fms
Course:	N	010°
Start time:	0715	0715
Avg. depth:	26 fms	23 fms
Weather:	58°; clear. Seas 2-5 ft.	

Tow 10	VALKYRIE	PATTON
Cod end:	Small mesh uncovered.	
Wire out:	70 fms	70 fms
Course:	S	170°
Start time:	0905	0905
Avg. depth:	25 fms	25 fms
Weather:	60°; clear. Seas 3-6 ft.	

Tow 11	VALKYRIE	PATTON
Cod end:	Large mesh covered.	
Wire out:	120 fms	120 fms
Course:	N	340°
Start time:	1055	1100
Avg. depth:	43 fms	44 fms
Weather:	60°; clear. Seas 3-7 ft.	

Tow 12	VALKYRIE	PATTON
Cod end:	Large mesh uncovered.	
Wire out:	110 fms	120 fms
Course:	W	270°
Start time:	1230	1235
Avg. depth:	38 fms	37 fms
Weather:	62°; clear. Seas 3-7 ft.	

D. 11 October 1978.

Tow 13	VALKYRIE	PATTON
Cod end:	Large mesh uncovered.	
Wire out:	90 fms	90 fms
Course:	N	180°
Start time:	0735	0735
Avg. depth:	30 fms	31 fms
Weather:	60°; partly cloudy. Seas 2-3 ft.	

Tow 14	VALKYRIE	PATTON
Cod end:	Large mesh covered.	
Wire out:	90 fms	90 fms
Course:	N	360°
Start time:	0905	0910
Avg. depth:	35 fms	30 fms
Weather:	71°; clear. Seas 2-3 ft.	

Tow 15	VALKYRIE	PATTON
Cod end:	Small mesh uncovered.	
Wire out:	90 fms	90 fms
Course:	N	350°
Start time:	1045	1240
Avg. depth:	30 fms	30 fms
Weather:	70°; partly cloudy. Seas 2-3 ft.	

Tow 16	VALKYRIE	PATTON
Cod end:	Small mesh covered.	
Wire out:	90 fms	90 fms
Course:	N	360°
Start time:	1215	1415
Avg. depth:	30 fms	31 fms
Weather:	70°; clear. Seas 1-2 ft.	

APPENDIX E

Catch Weight Data (in kilograms)

	FRANCES ELIZABETH	CHRISTOPHER ANDREW
Tow 1	Yellowtail - 45.8	Yellowtail - 157.0
139 Cod end	Flounders - 13.4	Flounders - 14.0
	Cod (1) - 11.0	Cod - 27.0
	Whiting - 5.0	Ocean pout - 33.4
	Ocean pout - 15.4	Other - 19.0
	Other - 18.4	
	Total 109.0	Total - 250.4
Tow 2	Yellowtail -101.0	Yellowtail - 121.0
139 Cod end	Flounders - 15.4	Flounders - 26.0
	Cod (2) - 6.0	Cod - 9.5
	Whiting - 8.4	Ocean pout - 107.0
	Ocean pout - 73.5	Other - 24.0
	Other - 25.5	
	Total 229.8	Total - 287.5
Tow 2	Loose knot	Yellowtail - 53.5
Cover	no weights taken	Flounders - 11.0
		Cod - 11.0
		Ocean pout - 183.0
		Other - 20.0
		Total - 278.5
Tow 3	No good	Yellowtail - 39.0
106 Cod end		Flounders - 24.6
	(net caught something	Cod - 16.0
	heavy; caused door	Ocean pout - 126.5
	to capsize)	Other - 57.0
		Total - 263.1
Tow 3	No good	Yellowtail - 6.0
Cover		Ocean pout - 32.5
		Other - 11.0
		Total - 49.5

APPENDIX E

Catch Weight Data (in kilograms) (cont'd)

	FRANCES ELIZABETH		CHRISTOPHER ANDREW	
Tow 4			Yellowtail	83.5
106 Cod end	Did not tow		Flounders	36.5
	(darkness)		Cod	62.5
			Ocean pout	68.5
			Other	37.5
			Total	288.5
Tow 5	Yellowtail	47.0	Yellowtail	126.5
106 Cod end	Flounders	16.0	Flounders	30.5
	Cod	34.0	Cod	27.5
	Whiting	5.5	Whiting	9.5
	Ocean pout	11.0	Ocean pout	29.0
	Haddock	4.5	Haddock	3.0
	Other	50.0	Pollock(1)	7.0
			Other	27.0
	Total	168.0	Total	260.0
Tow 6	Yellowtail	14.5	Yellowtail	74.5
106 Cod end	Flounders	15.0	Flounders	37.5
	Cod	39.0	Cod	46.0
	Ocean pout	13.5	Whiting	18.0
	Other	36.0	Ocean pout	39.0
			Other	42.5
	Total	118.0	Total	257.5
Tow 6	Flounders	8.5	Yellowtail	2.5
Cover	Cod	5.5	Flounders	19.0
	Whiting	4.5	Cod, haddock, and pollock	4.5
	Ocean pout	18.5	Whiting	22.0
			Ocean pout	49.0
			Other	44.0
	Total	37.0	Total	141.0
Tow 7	Yellowtail	33.5	Yellowtail	64.0
139 Cod end	Flounders	15.0	Flounders	32.0
	Cod	55.0	Cod	47.0
	Other	49.0	Whiting	7.5
			Pollock(1)	11.5
			Other	18.5
	Total	152.5	Total	180.5

APPENDIX E

Catch Weight Data (in kilograms) (cont'd)

	FRANCES ELIZABETH		CHRISTOPHER ANDREW	
Tow 8 139 Cod end	Yellowtail	14.5	Yellowtail	33.0
	Flounders	12.0	Flounders	17.0
	Cod	18.5	Cod	24.5
	Other	12.5	Pollock(1)	3.5
			Whiting	4.5
			Ocean pout	14.0
			Other	14.5
	Total	57.5	Total	111.0
Tow 8 Cover	Yellowtail	4.5	Yellowtail	12.0
	Flounders	13.0	Flounders	10.0
	Cod	6.5	Cod	14.5
	Whiting	25.5	Whiting	19.5
	Hakes	51.0	Hakes	33.0
	Haddock	18.5	Haddock	3.0
	Ocean pout	18.5	Ocean pout	30.0
	Total	137.5	Total	122.0
Tow 9 106 Cod end	Yellowtail	72.5	Yellowtail	138.0
	Flounders	26.5	Flounders	16.0
	Cod	37.0	Cod	46.5
	Ocean pout	87.5	Ocean pout	128.5
	Other	45.0	Other	16.5
	Total	268.5	Total	345.5
Tow 10 139 Cod end	Yellowtail	47.0	Yellowtail	59.5
	Flounders	27.5	Flounders	22.5
	Cod	26.5	Cod	14.0
	Ocean pout	30.5	Ocean pout	32.0
	Other	32.0	Other	23.5
	Total	163.5	Total	151.5
Tow 10 Cover	Yellowtail	28.5	Yellowtail	54.0
	Flounders	12.5	Flounders	17.0
	Cod	28.5	Cod	25.5
	Ocean pout	42.0	Whiting	2.5
	Other	13.5	Ocean pout	36.5
			Other	10.0
	Total	125.0	Total	145.5

APPENDIX E

Catch Weight Data (in kilograms) (cont'd)

		FRANCES ELIZABETH	CHRISTOPHER ANDREW
Tow 11 139 Cod end	Yellowtail	35.5	32.0
	Flounders	23.5	18.0
	Cod	22.5	33.0
	Ocean pout	63.0	98.5
	Other	21.5	22.5
	Total	166.0	204.5
Tow 12 106 Cod end	Yellowtail	55.5	36.0
	Flounders	15.5	7.5
	Cod	53.0	38.0
	Ocean pout	54.0	20.5
	Other	42.0	18.0
	Total	220.0	120.0
Tow 12 Cover	Yellowtail	19.5	26.0
	Flounders	1.0	3.5
	Cod	6.5	7.0
	Ocean pout	18.5	14.0
	Other	5.5	7.5
	Total	51.0	58.0

APPENDIX E

Catch Weight Data (cont'd)

		LINDA B		METACOMET	
		kg	lb	kg	lb
Tow 1	Cod -	6.1	13.4	18.2	40.0
Small cod end	Yellowtail -	138.9	305.6	127.1	279.6
	Blackback -	37.4	82.3	24.6	56.3
	Dabs -	12.4	27.3	10.6	23.3
	Ocean pout -	40.0	88.0	117.4	258.3
	Other -	55.0	121.0		
	Total -	289.8	637.6	297.9	657.5
Tow 2	Cod -	16.1	35.4	1.3	2.9
Small Cod end	Yellowtail -	92.4	203.3	80.4	176.9
	Blackback -	31.5	69.3	25.5	56.1
	Dabs -	8.8	19.4	9.3	20.5
	Ocean pout -	80.0	176.0	59.1	130.0
	Other -	48.0	105.6		
	Total -	276.8	609.0	175.6	386.3
Tow 3	Cod -	0.6	1.3	0.7	1.5
Cover	Yellowtail -	0.6	1.3	0.8	1.8
	Blackback -	0.3	0.7	0.4	0.9
	Dabs -	0.2	0.4	1.6	3.5
	Ocean pout -	8.0	17.6	4.0	8.8
	Other -	0.6	1.3		
	Total -	10.3	22.6	7.5	16.5
Tow 3	Cod -	14.0	30.8	1.6	3.5
Large cod end	Yellowtail -	101.5	223.3	68.1	149.8
	Blackback -	18.0	39.6	14.3	31.5
	Dabs -	7.6	16.7	2.5	5.5
	Ocean pout -	80.0	176.0	38.9	85.6
	Other -	23.0	50.6		
	Total -	244.1	537.0	125.4	275.9
Tow 4	Cod -	20.8	45.8	2.0	4.4
Large cod end	Yellowtail -	94.3	207.5	85.1	187.2
	Blackjack -	25.2	55.4	35.3	77.7
	Dabs -	8.8	19.4	18.7	41.1
	Ocean pout -	44.0	96.8	34.3	75.5
	Other -	20.0	44.0		
	Total -	213.1	468.9	175.4	385.9

APPENDIX E

Catch Weight Data (cont'd)

		LINDA B		METACOMET	
		kg	lb	kg	lb
Tow 4 Cover	Cod -	0.9	2.0	4.8	10.6
	Yellowtail -	4.0	8.8	10.6	23.3
	Blackback -	3.9	8.6	20.9	46.0
	Dabs -	3.5	7.7	13.1	28.8
	Ocean pout -	30.0	66.0	100.0	220.0
	Other -	5.0	11.0		
	Total -	47.3	104.1	149.4	328.7
Tow 5 Large cod end	Cod -	3.0	6.6	3.4	7.5
	Yellowtail -	53.0	116.6	38.5	84.7
	Blackback -	11.5	25.3	5.2	11.4
	Dabs -	13.4	29.5	4.7	10.3
	Ocean pout -	55.0	121.0	16.0	33.2
	Other -	45.0	99.0		
	Total -	180.9	398.0	67.8	147.1
Tow 5 Cover	Cod -	1.2	2.6	1.5	3.3
	Yellowtail -	9.3	20.5	15.3	33.7
	Blackback -	4.2	9.2	10.1	22.2
	Dabs -	24.0	52.8	14.7	32.3
	Ocean pout -	10.0	22.0	30.0	66.0
	Other -	2.5	5.5		
	Total -	51.2	112.6	71.6	157.5
Tow 6 Large cod end	Cod -	76.6	168.5	38.5	84.7
	Yellowtail -	60.1	132.2	41.2	90.6
	Blackback -	21.7	47.7	17.5	38.5
	Dabs -	18.5	40.7	13.8	30.4
	Ocean pout -	67.5	148.5	53.4	117.5
	Other -	35.0	77.0		
	Total -	279.4	614.6	164.4	361.7
Tow 7 Small cod end	Cod -	711.3	1364.9	221.1	486.4
	Yellowtail -	238.2	524.0	153.4	337.5
	Blackback -	40.1	88.2	26.4	58.1
	Dabs -	58.6	128.9	37.4	82.3
	Ocean pout -	50.0	110.0	55.5	122.1
	Other -	100.0	220.0		
	Total -	1198.2	2436.0	493.8	1086.4
Tow 7 Cover	Cod -	55.5	122.1	37.2	81.8
	Yellowtail -	1.5	3.3	3.3	7.3
	Blackback -	0.8	1.8	0.5	1.1
	Dabs -	12.6	27.7	10.9	24.0
	Ocean pout -	7.0	15.4	13.5	29.7
	Other -	5.0	11.0		
	Total -	82.4	181.3	65.4	143.9

APPENDIX E

Catch weight data (cont'd)

		LINDA B		METACOMET	
		kg	lb	kg	lb
Tow 12 Large cod end	Cod	2.6	5.7	4.7	10.3
	Yellowtail -	110.9	244.0	227.7	500.9
	Blackback -	17.8	39.2	24.2	53.2
	Dabs -	1.9	4.2	0.3	0.7
	Ocean pout -	7.5	16.5	25.5	56.1
	Other -	21.0	46.2		
	Total -	161.7	355.8	282.4	621.2
Tow 13 Large cod end	Cod -	48.0	105.6	38.9	85.6
	Yellowtail -	103.6	227.9	52.7	115.9
	Blackback -	14.5	31.9	12.0	26.4
	Dabs -	50.7	111.5	26.0	57.2
	Ocean pout -	35.0	77.0	48.0	105.6
	Other -	65.5	144.1		
	Total -	317.3	698.0	177.6	390.7
Tow 14 Large cod end	Cod -	24.7	54.3	17.0	37.4
	Yellowtail -	75.7	166.5	59.0	129.8
	Blackback -	12.1	26.6	6.5	14.3
	Dabs -	54.0	118.8	18.6	40.9
	Ocean pout -	8.5	18.7	72.5	159.3
	Other -	63.0	138.6		
	Total -	238.0	523.5	173.6	381.7
Tow 14 Cover	Cod -	21.3	46.9	30.6	67.3
	Yellowtail -	6.4	14.1	14.7	32.3
	Blackback -	3.4	7.5	2.6	5.7
	Dabs -	26.0	57.2	16.1	35.4
	Ocean pout -	24.5	53.9	31.0	68.2
	Other -	20.5	45.1		
	Total -	102.1	224.7	95.0	208.9
Tow 15 Small cod end	Cod -	21.6	47.5	14.6	32.1
	Yellowtail -	111.4	245.1	70.1	154.2
	Blackback -	26.1	57.4	31.4	69.1
	Dabs -	8.9	19.6	20.8	45.8
	Ocean pout -	31.5	69.3	74.0	162.8
	Other -	49.5	108.9		
	Total -	249.0	547.8	210.9	464.0

APPENDIX E

Catch weight data (cont'd)

			LINDA B		METACOMET	
			kg	lb	kg	lb
Tow 8	Cod	-	195.1	429.2	157.9	303.4
Small cod end	Yellowtail	-	117.6	258.7	89.2	196.2
	Blackback	-	36.7	80.7	23.4	51.5
	Dabs	-	59.5	130.9	42.5	93.5
	Ocean pout	-	18.0	39.6	50.0	110.0
	Other	-	54.0	118.8		
	Total	-	480.9	1057.9	363.0	754.6
Tow 9	Cod	-	9.1	20.0	5.3	11.7
Small cod end	Yellowtail	-	164.5	361.9	133.5	293.7
	Blackback	-	39.3	86.5	44.5	97.9
	Dabs	-	1.0	2.2	6.1	13.4
	Ocean pout	-	12.5	27.5	56.0	123.2
	Other	-	43.0	94.6		
	Total	-	269.4	592.7	245.4	539.9
Tow 9	Cod	-	0	0	2.0	4.4
Cover	Yellowtail	-	0	0	1.5	3.3
	Blackback	-	0	0	3.4	7.5
	Dabs	-	0	0	3.0	6.6
	Ocean pout	-	0	0	3.0	6.6
	Other	-				
	Total	-	0	0	12.9	28.4
Tow 10	Cod	-	6.3	13.9	20.6	45.3
Small cod end	Yellowtail	-	176.3	387.9	155.9	343.0
	Blackback	-	53.7	118.1	34.8	76.6
	Dabs	-	9.3	20.5	1.6	3.5
	Ocean pout	-	88.5	194.7	45.0	99.0
	Other	-	40.0	88.0		
	Total	-	374.1	823.1	257.9	567.4
Tow 11	Cod	-	13.3	29.3	13.5	29.7
Large cod end	Yellowtail	-	192.3	423.1	81.2	178.6
	Blackback	-	38.2	84.0	24.7	54.3
	Dabs	-	4.0	8.8	4.0	8.8
	Ocean pout	-	26.5	58.3	37.0	81.4
	Other	-	16.5	36.3		
	Total	-	290.8	639.8	160.4	352.8
Tow 11	Cod	-	9.1	20.0	31.4	69.1
Cover	Yellowtail	-	11.0	24.2	10.4	22.9
	Blackback	-	15.1	33.2	9.9	21.8
	Dabs	-	9.7	21.3	10.1	22.2
	Ocean pout	-	20.5	45.1	42.0	92.4
	Other	-	13.5	29.7		
	Total	-	78.9	173.5	103.8	228.4

APPENDIX E

Catch weight data (cont'd)

		LINDA B		METACOMET	
		kg	lb	kg	lb
Tow 16 Small cod end	Cod -	19.9	43.8	18.0	39.6
	Yellowtail -	134.9	296.8	85.7	188.5
	Blackback -	27.3	60.1	13.3	29.3
	Dabs -	11.0	24.2	5.9	13.0
	Ocean pout -	16.5	36.3	35.0	77.0
	Other -	36.0	79.2		
	Total -	245.6	540.4	157.9	347.4
Tow 16 Cover	Cod -	3.6	7.9	0.7	1.5
	Yellowtail -	1.1	2.4	1.4	3.1
	Blackback -	0.9	2.0	1.1	2.4
	Dabs -	7.5	16.5	4.8	10.6
	Ocean pout -	8.5	18.7	4.5	9.9
	Other -	5.5	12.1		
	Total -	27.1	59.6	12.5	27.5

APPENDIX E

Catch weight data (cont'd)

		JOSEPH & LUCIA II		JOSEPH & LUCIA III	
		kg	lb	kg	lb
Tow 1 Small cod end	Haddock -	33.4	73.5	36.7	80.7
	Pollock -	32.8	72.2	26.6	58.5
	Cod -	102.7	225.9	168.2	370.0
	Redfish -	3.7	8.1	4.4	9.7
	Whiting -	1.9	4.2	0.5	1.1
	Dabs -	32.8	72.2	13.7	30.1
	Ling -	12.5	27.5	17.0	37.4
	Total -	219.8	483.6	267.1	587.5
Tow 1 Cover	Haddock -	0.3	0.7		
	Pollock -	0.6	1.3		
	Cod -			1.7	3.7
	Whiting -	0.2	0.4		
	Dabs -	0.4	0.9	0.4	0.9
	Ling -	5.8	12.8		
	Total -	7.3	16.1	2.1	4.6
Tow 2 Small cod end	Haddock -	71.2	156.6	84.7	186.3
	Pollock -	8.1	17.8	46.6	102.5
	Cod -	12.7	27.9	48.6	106.9
	Redfish -	2.4	5.3	7.1	15.6
	Whiting -	2.3	5.1	0.9	2.0
	Dabs -	21.5	47.3	29.3	64.5
	Ling -	17.1	37.6	26.1	57.4
	Total -	135.3	297.6	243.3	535.2
Tow 3 Large cod end	Haddock -	424.0	932.8	494.2	1,087.2
	Pollock -	262.7	577.9	364.3	801.5
	Cod -	93.0	204.6	44.8	98.6
	Redfish -	10.4	22.9	6.0	13.2
	Whiting -	4.0	8.8	2.3	5.1
	Dabs -	2.9	6.4	0.3	0.7
	Ling -	0.8	1.8		
	Total -	797.8	1,755.2	911.9	2,006.3
Tow 3 Cover	Haddock -	31.1	68.4	47.7	104.9
	Pollock -	39.2	86.2	127.1	279.6
	Cod -	1.2	2.6	1.0	2.4
	Redfish -	21.9	48.2	35.6	78.3
	Whiting -	4.1	9.0		
	Dabs -			2.1	4.6
	Ling -	1.2	2.6	0.5	1.1
	Total -	98.7	217.0	214.0	470.9

APPENDIX E

Catch weight data (cont'd)

		JOSEPH & LUCIA II		JOSEPH & LUCIA III	
		kg	lb	kg	lb
Tow 4 Large cod end	Haddock -	246.7	542.7	371.3	816.9
	Pollock -	237.7	522.9	372.9	820.4
	Cod -	52.8	116.2	179.4	394.7
	Redfish -	7.3	16.1		
	Whiting -			0.7	1.5
	Dabs -	3.4	7.5	1.9	4.2
	Total -	547.9	1,205.4	926.2	2,037.7
Tow 5 Small cod end	Haddock -	170.0	374.0	222.3	489.1
	Pollock -	74.8	164.6	139.3	306.5
	Cod -	54.4	119.7	35.0	77.0
	Redfish -	95.6	210.3	22.4	49.3
	Whiting -	3.0	6.6		
	Dabs -			13.8	30.4
	Total -	397.8	875.2	432.8	952.3
Tow 6 Small cod end	Haddock -	411.7	905.7	389.4	856.7
	Pollock -	30.5	67.1	38.1	83.8
	Cod -	210.3	462.7	119.4	262.7
	Redfish -	3.9	8.6	7.5	16.5
	Whiting -	9.0	19.8	12.6	27.7
	Dabs -	6.1	13.4	8.7	19.1
	Ling -	0.8	1.8	1.0	2.2
	Total -	672.3	1,479.1	576.7	1,268.7
Tow 6 Cover	Haddock -	2.2	4.8	2.9	6.4
	Pollock -	0.4	0.9	2.6	5.7
	Redfish -	2.5	5.5	14.8	32.6
	Whiting -	9.1	20.0	11.3	24.9
	Dabs -	0.4	0.9	1.4	3.1
	Ling -	2.1	4.6	0.8	1.8
	Total -	16.7	36.7	33.8	74.5
Tow 7 Large cod end	Haddock -	296.8	653.0	353.0	776.6
	Pollock -	77.8	171.2	53.0	116.6
	Cod -	158.5	348.7	48.6	106.9
	Redfish -			1.3	2.9
	Whiting -	2.6	5.7	1.4	3.1
	Dabs -	10.1	22.2	2.8	6.2
	Ling -	2.8	6.2		
	Total -	548.6	1,207.0	460.1	1,012.3

APPENDIX E

Catch weight data (cont'd)

		JOSEPH & LUCIA II		JOSEPH & LUCIA III	
		kg	lb	kg	lb
Tow 8 Large cod end	Haddock -	317.6	698.7	319.2	702.2
	Pollock -	42.3	93.1	42.1	92.6
	Cod -	128.7	283.1	134.3	295.5
	Redfish -	6.2	13.6	13.1	28.8
	Whiting -	4.4	9.7	5.0	11.0
	Dabs -	3.4	7.5	5.0	11.0
	Ling -	2.4	5.3	1.6	3.5
	Total -	505.0	1,111.0	520.3	1,144.6
Tow 8 Cover	Haddock -	11.1	24.4	11.0	24.2
	Pollock -	11.2	24.6	1.7	3.7
	Cod -	1.4	3.1	2.3	5.1
	Redfish -	1.4	3.1	1.3	2.9
	Whiting -	3.1	6.8	2.2	4.8
	Dabs -	0.5	1.1	0.2	0.4
	Total -	28.7	63.1	18.7	41.1
		Large cod end		Small cod end	
Tow 9	Haddock -	581.2	1,278.6	569.8	1,253.6
	Pollock -	2.3	5.1	4.8	10.6
	Cod -	183.9	404.6	92.6	203.7
	Redfish -	2.9	6.4	13.2	29.0
	Whiting -	3.1	6.8	5.9	13.0
	Dabs -	5.7	12.5		
	Ling -			2.4	5.3
	Total -	779.1	1,714.0	688.7	1,515.2
		Small cod end		Large cod end	
Tow 10	Haddock -	575.0	1,265.0	527.2	1,159.8
	Pollock -	67.0	147.4	30.8	67.8
	Cod -	68.9	151.6	128.6	282.9
	Redfish -	8.8	19.4		
	Whiting -	20.3	44.7	3.3	7.3
	Dabs -	1.9	4.2	5.7	12.5
	Ling -	2.0	4.4	2.0	4.4
	Total -	743.9	1,636.7	697.6	1,534.7

APPENDIX E

Catch weight data (cont'd)

		JOSEPH & LUCIA II		JOSEPH & LUCIA III	
		kg	lb	kg	lb
		Large cod end		Small cod end	
Tow 11	Haddock -	181.2	398.6	85.5	188.1
	Pollock -	6.2	13.6		
	Cod -	140.2	308.4	72.7	159.9
	Redfish -	26.4	58.1	75.1	165.2
	Whiting -	0.5	1.1		
	Dabs -	0.7	1.5	1.5	3.3
	Total -	355.2	781.3	234.8	516.5
		Small cod end		Large cod end	
Tow 12	Haddock -	493.1	1,084.8	212.0	466.4
	Pollock -	4.5	9.9	4.7	10.3
	Cod -	119.8	263.6	75.6	166.3
	Redfish -	19.2	42.2	1.5	3.3
	Whiting -	6.1	13.4	0.3	0.7
	Dabs -	3.2	7.0	1.4	3.1
	Ling -	10.9	24.0	3.2	7.0
	Total -	656.8	1,444.9	298.7	657.1

APPENDIX E

Catch weight data (cont'd)

		VALKYRIE		PATTON	
		kg	lb	kg	lb
Tow 1 Small cod end	Cod -	16.2	35.6	68.9	151.6
	Yellowtail -	11.5	25.3	8.6	18.9
	Winter flounder -	6.1	13.4		
	Spiny dogfish -	8.3	18.3		
	Total -	42.1	92.6	77.5	170.5
Tow 2 Small cod end	Haddock -	35.6	78.3	27.6	60.7
	Cod -	74.5	163.9	40.9	90.0
	Yellowtail -	6.0	13.2	4.3	9.5
	American plaice -	17.4	38.3	9.0	19.8
	Winter flounder -			0.9	2.0
	Whiting (silver hake) -	9.4	20.7		
	Spiny dogfish -	9.1	20.0		
	Total -	152.0	334.4	82.7	182.0
Tow 2 Cover	Haddock -	9.6	21.1	4.0	8.8
	Cod -	2.3	5.1	14.5	31.9
	Yellowtail -			0.6	1.3
	American plaice -	3.6	7.9	0.8	1.8
	Whiting (silver hake) -	21.6	47.5		
	Spiny dogfish -	3.2	7.0		
	Total -	40.3	88.6	19.9	43.8
Tow 3 Large cod end	Haddock -	14.2	31.2	10.3*	22.7
	Cod -	32.8	72.2	9.1	20.0
	Yellowtail -	3.0	6.6		
	American plaice -	5.0	11.0	*	
	Winter flounder -	1.1	2.4		
	Whiting (silver hake) -	1.2	2.6		
	Spiny dogfish -	2.2	4.8		
	Total -	59.5	130.8	19.4	42.7
Tow 4 Large cod end	Haddock -	28.1	61.8	50.3	110.7
	Cod -	53.0	116.6	73.0	160.6
	Yellowtail -	1.1	2.4		
	American plaice -	5.2	11.4		
	Whiting (silver hake) -	2.7	5.9		
	Total -	90.1	198.1	123.3	271.3

*Cod end torn up.

APPENDIX E

Catch weight data (cont'd)

			VALKYRIE		PATTON	
			kg	lb	kg	lb
Tow 4 Cover	Haddock	-	6.5	14.3	16.2	35.6
	Cod	-	5.9	13.0	18.8	41.4
	American plaice	-	3.1	6.8		
	Whiting (silver hake)	-	2.9	6.4		
	Spiny dogfish	-	2.8	6.2		
	Total	-	21.2	46.7	35.0	77.0
Tow 5 Large cod end	Cod	-	478.5	1,052.7	1.0	2.2
	Yellowtail	-	5.3	11.7	6.7	14.7
	Winter flounder	-	10.5	23.1		
	Spiny dogfish	-	16.0	35.2		
	Total	-	510.3	1,122.7	7.7	16.9
Tow 5 Cover	Yellowtail	-	3.0	6.6		
	Winter flounder	-	4.4	9.7		
	Whiting (silver hake)	-	0.3	0.7		
	Spiny dogfish	-	13.7	30.1		
	Total	-	21.4	47.1		
Tow 6 Large cod end	Cod	-	24.4	53.7	63.1	138.8
	Yellowtail	-	2.5	5.5	1.3	2.9
	Winter flounder	-	73.5	161.7	41.8	92.0
	Spiny dogfish	-	107.7	236.9		
	Total	-	208.1	457.8	106.2	233.7
Tow 7 Small cod end	Cod	-	1,443.6	3,175.9	*	
	Yellowtail	-	7.9	17.4	1.4	3.1
	Winter flounder	-	9.9	21.8	0.9	2.0
	Spiny dogfish	-	4.1	9.0		
	Total	-	1,465.5	3,224.1	2.3	5.1
Tow 7 Cover	Yellowtail	-	0.1	0.2		
	Spiny dogfish	-	0.8	1.8		
	Total	-	0.9	2.0		

*Trawl apparently wasn't fishing.

APPENDIX E

Catch weight data (cont'd)

			VALKYRIE		PATTON	
			kg	lb	kg	lb
Tow 8 Small cod end	Haddock	-	1.6	3.5	0.4	0.9
	Cod	-	40.8	89.8	15.5	34.1
	Yellowtail	-	5.4	11.9	7.5	16.5
	Winter flounder	-	11.9	26.2	8.5	18.7
	Spiny dogfish	-	0.6	1.3		
	Total	-	60.3	132.7	31.9	70.2
Tow 9 Small cod end	Cod	-	79.1	174.0	26.7	58.7
	Yellowtail	-	10.7	23.5	7.3	16.1
	Winter flounder	-	11.7	25.7	2.2	4.8
	Spiny dogfish	-	308.4	678.5		
	Total	-	409.9	901.7	36.2	79.6
Tow 9 Cover	Cod	-	2.6	5.7		
	Yellowtail	-	0.1	0.2		
	Spiny dogfish	-	72.3	159.1		
	Total	-	75.0	165.0		
Tow 10 Small cod end	Cod	-	499.8	1,099.6	422.5	929.5
	Yellowtail	-	16.2	35.6	7.0	15.4
	Winter flounder	-	12.1	26.6	6.7	14.7
	Spiny dogfish	-	27.8	61.2		
	Total	-	555.9	1,223.0	436.2	959.6
Tow 11 Large cod end	Haddock	-	18.4	40.5	3.8	8.4
	Cod	-	178.4	392.5	274.2	603.2
	Yellowtail	-	1.8	4.0	3.9	8.6
	Winter flounder	-	49.1	108.0	35.8	78.8
	Whiting(silver hake)	-	0.4	0.9		
	Total	-	248.1	545.9	317.7	699.0
Tow 11 Cover	Haddock	-	14.1	31.0	13.7	30.1
	Cod	-	4.2	9.2	19.4	42.7
	Yellowtail	-	0.4	0.9	0.7	1.5
	Winter flounder	-	0.6	1.3	0.9	2.0
	Spiny dogfish	-	0.6	1.3		
	Total	-	19.9	43.7	34.7	76.3

APPENDIX E

Catch weight data (cont'd)

			VALKYRIE		PATTON	
			kg	lb	kg	lb
Tow 12 Large cod end	Haddock	-	3.9	8.6	7.3	16.1
	Cod	-	599.5	1,318.9	730.8	1,607.8
	Yellowtail	-	5.3	11.7	4.7	10.3
	Winter flounder	-	60.0	132.0	67.7	148.9
	Spiny dogfish	-	3.7	8.1		
	Total	-	672.4	1,479.3	810.5	1,783.1
Tow 13 Large cod end	Haddock	-	1.9	4.2		
	Cod	-	256.4	564.1	173.3	381.3
	Yellowtail	-	6.6	14.5	2.7	5.9
	Winter flounder	-	87.9	193.4	66.8	147.0
	Total	-	352.8	776.2	242.8	534.2
Tow 14 Large cod end	Cod	-	807.6	1,776.7	12.8*	28.2
	Yellowtail	-	8.2	18.0		
	Winter flounder	-	110.0	242.0	1.9	4.2
	Spiny dogfish	-			5.5	12.1
	Total	-	925.8	2,036.7	20.2	44.5
Tow 14 Cover	Cod	-	**		2.1	4.6
	Total	-			2.1	4.6
Tow 15 Small cod end	Cod	-	285.6	628.3	125.3	275.7
	Yellowtail	-	3.2	7.0	2.9	6.4
	Winter flounder	-	112.0	246.4	73.8	162.4
	Total	-	400.8	881.7	202.0	444.5
Tow 16 Small cod end	Cod	-	572.8	1,260.2	137.8	303.2
	Yellowtail	-	6.2	13.6	3.3	7.3
	Winter flounder	-	96.2	211.6	60.0	132.0
	Total	-	675.2	1,485.4	201.1	442.5
Tow 16 Cover	Haddock	-	0.1	0.2		
	Cod	-	2.8	6.2	1.5	3.3
	Yellowtail	-	0.1	0.1	0.1	0.2
	Whiting(silver hake)	-	0.1	0.2		
	Total	-	3.1	6.7	1.6	3.5

*Large tear in belly.
**Cover torn up.

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NOAA Technical Report NMFS SSRF—772

Results of a Tagging Program to Determine Migration Rates and Patterns for Black Marlin, *Makaira indica*, in the Southwest Pacific Ocean

James L. Squire, Jr. and Daphne V. Nielsen

July 1983

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James L. Squire, Jr. and Daphne V. Nielsen

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Results of a Tagging Program to Determine Migration Rates and Patterns for Black Marlin, *Makaira indica*, in the Southwest Pacific Ocean

JAMES L. SQUIRE, JR.[1] and DAPHNE V. NIELSEN[2]

ABSTRACT

Marine game fish anglers reported tagging a total of 2,576 black marlin, *Makaira indica*, from 1968 through 1978 near the Great Barrier Reef, north Queensland, Australia, as part of the National Marine Fisheries Service Cooperative Marine Game Fish Tagging Program—Pacific Area. Sixty tagged black marlin were recaptured during an 11-year period for a recapture rate of 2.3%. Average weight of black marlin tagged was estimated to be 175 kg (385 lb). Anglers tend to overestimate weight at time of tagging and short-term recaptures (0-60 days) indicate an average angler overestimate of 16 kg (35 lb) per marlin.

Sex was determined for 28 recaptures; 25 (89%) were reported as males and 3 (11%) reported as females. Average weight of males at recapture was 91 kg (195 lb), for females, 221 kg (488 lb).

Vector analysis of time, distance, and direction data for tag recovery locations indicated migration direction (vector mean bearing) and distance (vector mean distance from point of tagging) by periods of release time: 0-60 days, 121°/72 nmi, 61-120 days, 134°/446 nmi, 121-240 days, 097°/1,256 nmi.

The greatest distance (2,100 nmi) recorded from the point of tagging was for a black marlin recaptured northeast of New Zealand, 235 days after tagging. Black marlin tagged early in the north Queensland fishing season (September) tended to migrate away from the area of tagging at a lower rate for the first 0-60 day period than black marlin tagged in October, November, or later in the fishing season.

Tag recoveries were made near the tagging location 1, 2, and 4 years after tagging. Locations of recapture for these black marlin were calculated to be a vector mean distance of 58.3 nmi from the point of tagging. Longline high catch rate areas for black marlin indicate a monthly movement for the first 240 days of release time not unlike that observed by tagging. In the summer the centers of high catch rate show a south to southeast movement off the east coast of Australia from the tagging area, then a northward movement in the winter and spring to the New Guinea-Bismark Archipelago-Solomon Islands area. The amount of interchange with the Indo-Pacific and areas to the north is unclear, although emigration from the tagging area to north of New Guinea was recorded.

INTRODUCTION

Little is known about the migratory patterns for oceanic pelagic species such as tunas and billfish in the Pacific Ocean. Only a few species of tuna, such as yellowfin tuna, *Thunnus albacares*; albacore, *Thunnus alalunga*; bluefin tuna, *Thunnus thynnus*; and skipjack tuna, *Euthynnus pelamis*, have been tagged in sufficient numbers, usually by commercial methods (trolling, live-bait, or purse seining), to determine patterns and rates of migration. Billfish have a high economic value to the commercial longline fishery but are not caught at any one time in large numbers like the tunas. Therefore, the opportunity to tag and release these fishes is more limited.

The concept of using anglers to tag and release billfish, tunas, and other pelagic marine game species, was first developed by Frank J. Mather III of the Woods Hole Oceanographic Institution, Woods Hole, Mass. (WHOI). The "Cooperative Marine Game Fish Tagging Program" was first established by WHOI with a grant from the National Science Foundation for studies in the Atlantic Ocean. Since marine anglers frequently travel worldwide to fish for billfish, some tags issued for studies in the Atlantic were being used in the Pacific starting in 1954 to tag black marlin, *Makaira indica*, blue marlin, *Makaira nigricans*, striped marlin, *Tetrapturus audax,* sailfish, *Istiophorus platypterus*, shortbill spearfish, *Tetrapturus angustirostris*, and swordfish, *Xiphias gladius*. In 1961, the senior author made a cooperative agreement with Mather to support Pacific area tagging on behalf of the U.S. Fish and Wildlife Service, Pacific Marine Game Fish Research Center/Tiburon Marine Laboratory, Tiburon, Calif., later to become a laboratory of the National Marine Fisheries Service (NMFS). The Service then assumed responsibility for the Pacific program and has continued since that time to support the tagging efforts of marine game fish anglers for billfish and other pelagic game fish species.

The tagging results discussed in this paper are for tags furnished through 1978 by the NMFS and the WHOI. Beginning in 1976, increasing numbers of black marlin have been tagged with tags furnished by New South Wales State Fisheries, Sydney, Australia, and this agency has now assumed the primary role in support of the tagging program for black marlin off north Queensland, Australia. These records are not included in the analysis portion of this paper, with the exception that data for four recoveries (6.3% of the tag recoveries reported upon) of New South Wales State Fisheries (NSWF) tags have been used in the computation of mean vector bearing and distances, sex ratios, and estimated weight data.

TAGGING AND RECOVERY

The tagging data base of this study is that portion of the black marlin catch tagged and released by anglers off the northeast coast of Australia adjacent to the Great Barrier Reef, between lat.

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[1] Southwest Fisheries Center La Jolla Laboratory, National Marine Fisheries Service, NOAA, La Jolla, CA 92038.

[2] Cairns Game Fishing Club, Cairns, Queensland, 4870, Australia.

14° and 18°S. The major source for recoveries is the Pacific-wide Japanese and Korean commercial longline fishery catch, and, to a minor extent, the catch of Australian and New Zealand commercial and recreational fisheries. Few recoveries could be expected from the billfish recreational fishery since the numbers of billfish taken are small compared with the catch of the commercial longline fishery (avg. 9,100 fish, 1969-78, Japanese longline data). The recreational fishery operates in a relatively restricted seasonal and geographical area near the edge of the Great Barrier Reef where the resource is available and catchable, and high rod-and-reel catch rates can be obtained. Potential recovery areas by anglers are generally restricted to the major tagging areas. The longline fishery, however, samples over a large area of the ocean and it is possible that recoveries could be made throughout the year, sometimes at considerable distances from the location of tagging. The extensive Japanese longline fishery recovers the most tagged marlin.

Black marlin are distributed widely throughout the Pacific and Indian Oceans with some catches reported in the South Atlantic Ocean. Some of the better longline fishing areas for black marlin are in the east China Sea near Taiwan, off northwest Australia, the Arafura Sea, Sulu Sea, Celebes Sea, and the Coral Sea off northeast Australia. Of interest to this migration study is that no longline effort or catches of black marlin are reported north of Australia in the eastern Arafura Sea. Between Cape York, Australia, and Papua lies the Torres Strait, a large area having a water depth of < 20 m. This shallow area may inhibit the migration of black marlin between the Coral and Arafura Seas. The distribution of black marlin as inferred from catch rates from the Japanese longline fishery in the Pacific, Indian, and South Atlantic Oceans is given in Figure 1.

Black marlin have been an important resource to the Japanese commercial longline fishery in the western Pacific since the early 1950's. Catch levels of all fleets in the western Pacific are currently about 3,000 t (metric tons), approximately one-half the peak catch in 1957, with about 59% of the southwestern Pacific black marlin catch being taken in 1976 by Japanese longliners (FAO 1979).

While the longline fishery generally targets on the tunas, in certain areas of the Pacific they may target upon marlin, sailfish, swordfish, or both tunas and billfish. Billfish comprise about 18% of the total longline catch in the Pacific (Ueyanagi 1974). However, the ex-vessel value of some species of billfish, such as striped, blue, and black marlin, may be two or more times that of some tunas, making the fraction of billfish an important factor in determining the location of fishing effort. Black marlin appears to be a target species in the western Coral Sea near the tagging area during the spring and early summer months of September through January. The distribution of longline fishing effort and catch rates obtained in the areas to the south, west, and north of the tagging area, in months subsequent to tagging, is an important factor in evaluating tag recovery data.

METHODS AND EQUIPMENT

All black marlin tagged in the Pacific under the auspices of the Cooperative Marine Game Fish Tagging Program were caught by anglers using rod-and-reel, and were tagged and released by the angler or a member of the charter boat crew. Several types of tags were used in the 1960's, the principal type being the double barbed, all-plastic FM67 tag (Fig. 2). Other tags used in small numbers included the Type "A" tag, a metal-tipped tag similar to the "H" tag, and type "B" tag, a small, single-barbed plastic tag similar to tags currently being used for tunas (Fig. 2). Since 1970, the tag distributed has been the stainless steel dart tag ("H" type). This tag has a nylon monofilament line extending from the stainless steel barb, with a yellow polyvinyl tubing sleeve over the monofilament for printed information. Numbers and letters on the yellow polyvinyl sleeve are heat embossed in black, giving the tag's serial number and return and reward information. All tags furnished by the National Marine Fisheries Service were manufactured by the Floy Tag and Manufacturing Company, Seattle, Wash.

Each tag is attached to a postcard having the tag's serial number printed on it. After tagging a fish, the angler completes the information requested on the postcard such as tagging date,

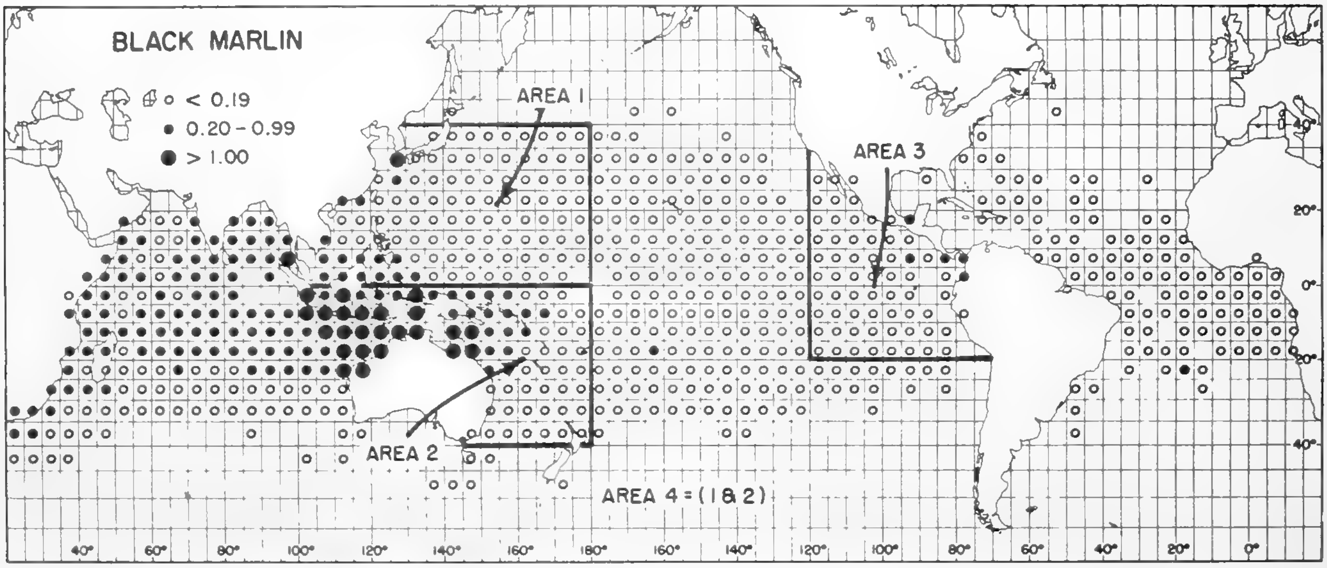


Figure 1.—Distribution of longline catch rates for black marlin in the Pacific Ocean as an indicator of resource distribution. Circles indicate mean catch rates (number of black marlin/1,000 hooks). Also shown are the boundaries of suggested black marlin stocks. From Shomura (1980).

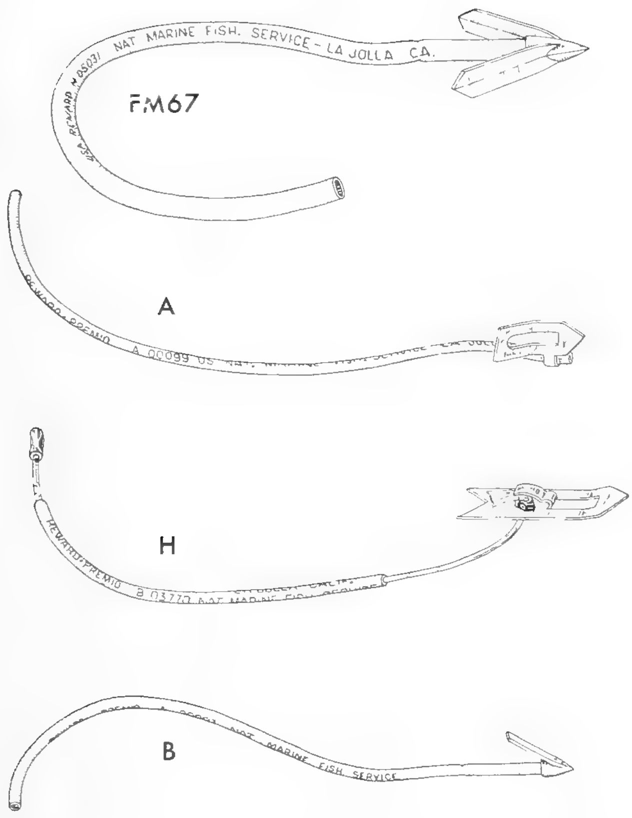


Figure 2.—Four types of dart tags used in the Pacific Ocean by the Cooperative Marine Game Fish Tagging Program.

location of tagging, species, estimate of fish's weight, tagger's name and address and returns it to the organization issuing the tag. Anglers who indicated a willingness to tag and release billfish were issued tagging equipment which consisted of a stainless steel applicator tip which must be mounted in a tagging pole, tags, instructions, and tagging flags for recognition of a billfish tagged and released. There was no charge for the tagging equipment.

When billfish are recovered, the recoverer receives a monetary reward upon sending in information on the tag number, species, date, and location of recovery. The recoverer sometimes adds information on water temperature at the time of recapture, length and weight measurements, sex, and gonad weight data.

RELEASE DATA

Cooperating marine game fish anglers and charter boat captains have tagged and released 2,885 black marlin in the Pacific Ocean using NMFS and WHOI tags since 1961. Of this number, 2,576 black marlin (89%) were tagged along the Great Barrier Reef off the north Queensland coast of Australia. The coordination of tagging for black marlin in this area was by the Cairns Game Fish Club, Cairns, Australia. Other locations in the Pacific where black marlin were reported to have been tagged were off the coasts of Panama and Hawaii, and near the southern tip of Baja California, Mexico.

The numbers of black marlin tagged in the north Queensland area are listed in Table 1 by year and tag type. Of the 2,576 black marlin tagged, 2,276 (88.0%) were tagged with "H" type tags and 305 (11.8%) with FM67 type tags. The remainder were tagged with "A" or "B" type tags.

Table 1.—Black marlin tagging off north Queensland, Australia, by year tagged and tag type, 1968-78.

Year	Number tagged	Tag types A	H	FM67	B
1968	26			26	
1969	51			51	
1970	110			110	
1971	184		127	57	
1972	288		287	1	
1973	438		378	60	
1974	337	1	335		1
1975	411	1	409		1
1976	501		501		
1977	170		170		
1978	60		60		
Total	2,576	2	2,267	305	2

Figure 3 shows the distribution of tagging effort by year and average estimated weights as given by the angler, in relation to tagging locations along the outer islands and reefs of the Great Barrier Reef. September, October, and November are the major months for tagging black marlin, with percentages of 21.6, 49.0, and 24.1, respectively. The geographical area where the most black marlin were tagged was along the Great Barrier Reef from lat. 16°00′ to 16°30′S. This area includes the reefs known as Hope, Nicholas, Onyx, Spur, Opal, St. Crispin, Linden Bank, and Agincourt Reefs No. 1 and 2. Data given in Figure 3 indicate that from 1972 to 1974 tagging effort shifted northward off the Queensland area. This was probably due to the development near the outer reefs of floating or island facilities for the angler, allowing him easier access to waters distant from Cairns, Queensland.

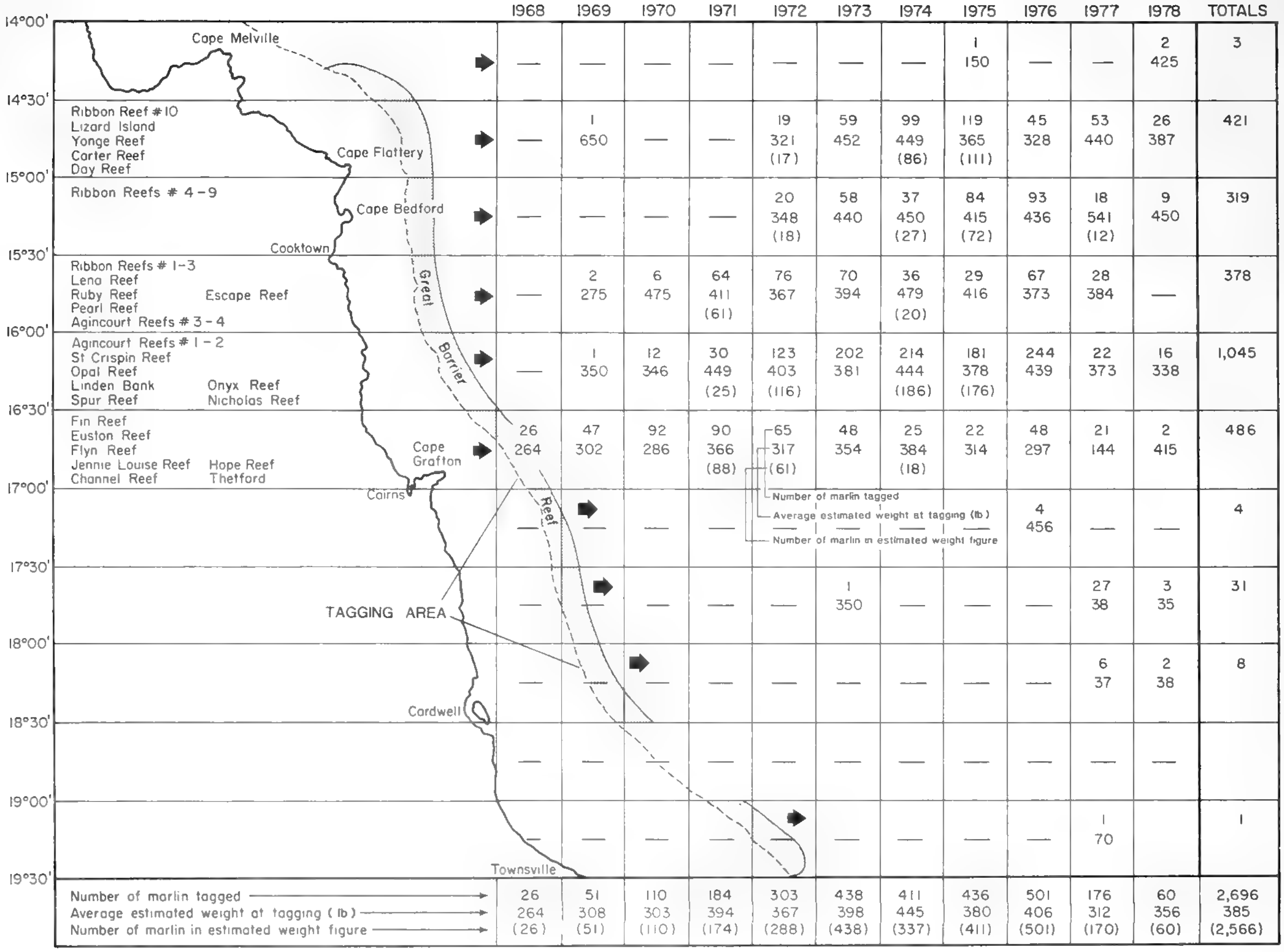
RECOVERIES

Of the 59 recaptures reported for black marlin tagged during the years 1968-78, 52 (88%) were recaptured by Japanese and Korean commercial longline fishing vessels, 4 (7%) by marine anglers, and 2 (3%) by Australian commercial fishermen (trawlers or netters); 1 (2%) was a beached marlin. Table 2 gives black marlin release, recapture, and biological data for those tagged with NMFS or WHOI tags. Data from four New South Wales State recoveries used elsewhere in the analysis are not listed in Table 2. Of the 59 returns, one return could not be matched to a tag report card.

RECOVERY RATES

A total of 2,576 black marlin was tagged off Queensland: 2,267 with the "H" type tags, 305 with the FM67, 2 with the "A" type, and 2 with the "B" type. Of these, 1.3% of the FM67 tags and 2.4% of the "H" tags were recovered, with an overall recovery rate of 2.3%. A breakdown of recovery rates for this area by year and by type of tag is given in Table 3.

Of the total of 189 black marlin reported tagged in other areas of the Pacific, 70 were tagged with FM67 type tags and 119 with "H" type tags. None has been reported recovered.



	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	TOTALS
	—	—	—	—	—	—	—	1 150	—	—	2 425	3
Ribbon Reef #10 Lizard Island Yonge Reef Carter Reef Day Reef	—	1 650	—	—	19 321 (17)	59 452	99 449 (86)	119 365 (111)	45 328	53 440	26 387	421
Ribbon Reefs # 4–9	—	—	—	—	20 348 (18)	58 440	37 450 (27)	84 415 (72)	93 436	18 541 (12)	9 450	319
Ribbon Reefs # 1–3 Lena Reef Ruby Reef Pearl Reef Agincourt Reefs # 3–4 Escape Reef	—	2 275	6 475	64 411 (61)	76 367	70 394	36 479 (20)	29 416	67 373	28 384	—	378
Agincourt Reefs # 1–2 St Crispin Reef Opal Reef Linden Bank Spur Reef Onyx Reef Nicholas Reef	—	1 350	12 346	30 449 (25)	123 403 (116)	202 381	214 444 (186)	181 378 (176)	244 439	22 373	16 338	1,045
Fin Reef Euston Reef Flyn Reef Jennie Louise Reef Channel Reef Hope Reef Thetford	26 264	47 302	92 286	90 366 (88)	65 317 (61)	48 354	25 384 (18)	22 314	48 297	21 144	2 415	486
	—	—	—	—	—	—	—	—	4 456	—	—	4
	—	—	—	—	—	1 350	—	—	—	27 38	3 35	31
	—	—	—	—	—	—	—	—	—	6 37	2 38	8
	—	—	—	—	—	—	—	—	—	—	—	
	—	—	—	—	—	—	—	—	—	1 70		1
Number of marlin tagged Average estimated weight at tagging (lb) Number of marlin in estimated weight figure	26 264 (26)	51 308 (51)	110 303 (110)	184 394 (174)	303 367 (288)	438 398 (438)	411 445 (337)	436 380 (411)	501 406 (501)	176 312 (170)	60 356 (60)	2,696 385 (2,566)

Figure 3.—Locations of black marlin tagging immediate to the Great Barrier Reef off north Queensland, Australia, by 30° latitude areas, by year and number of black marlin tagged, and average estimated weight by anglers at time of tagging. Note—estimated weight may vary from actual weight, see text. (For conversion of pounds to kilograms, lb × 0.4536 = kg).

TAGGING AND RECOVERY WEIGHT DATA

Upon tagging a black marlin, one of the items requested from the angler was an estimate of the marlin's weight. The average weight estimated by angler at the time of tagging, for 2,566 marlin having weight data reported, was 175 kg (385 lb). Average estimated weights by year and by 30° latitude area off north Queensland are given on Figure 3. The largest recorded average weight by year was 202 kg (445 lb) in 1974. The largest number of marlin tagged, and the largest average weight of 186 kg (410 lb), occured at lat. 16°00′ to 16°30′S. This area includes Agincourt Reefs #1 and #2, Linden Bank, and St. Crispan, Opal, Spur, Onyx, and Nicholas Reefs.

Estimated tagging weight varied greatly with landing weight as seen by catches recorded at Cairns and Lizard Island weighing stations from 1 September to 31 December 1970-78 (Table 4). The average weight of black marlin from the landing records is 346 kg (762 lb). Estimates of weight at time of tagging averaged 175 kg (385 lb) or 171 kg (377 lb) less than the weights recorded at the weighing station.

The weight data on recaptured marlin were sometimes submitted with additional information on the recovery. In the case of the commercial longline fishery the weights were with the bill and a portion of the head removed at about the area of the eye orbit. The reported weight must therefore be increased by a factor of 1.1 (Ueyanagi[1]) to give the approximate "round weight" of the fish.

Fifty-one marlin had weight and/or length data accompanying information on the geographical location and time of recapture. Upon examination of the weight and length data for the recaptures, it was determined that for five marlin the data were inadequate to determine total weight. Of 46 black marlin recaptured by the commercial longline fishery, having angler estimated weight data at tagging, 30 were recaptured at total weight less than estimated by the angler, 15 at weights greater than estimated, and 1 at the same weight. The average angler overestimate of black marlin recaptured at tagging, when compared with the recapture

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[1] Shoji Ueyanagi, Far Seas Fisheries Research Laboratory, Japan Fisheries Agency, 1000 Orido, Shimizu, 424, Japan, pers. commun.

Table 2.—Black marlin release and recapture data, 1968-1978. Angler's Country - (U.S.) United States, (NZ) New Zealand, (A) Australia. Others as given.

Releases				Recaptures					Biological data			
Year	Date (SWFC No.)	Location	Tagger/Captain	Date	Location	Recovered by	Distance from point of tagging	Days at large	Estimated weight at release	Weight at recapture	Length	Sex
1968	3 Oct. (74)	Euston Reef	Mrs. B. Dyer/(A) C. Chambers	Jan. 1969	Narlinga Beach 20 mi. S. of Innisfail, Aust.	J. Giddins Innisfail, Aust.	55	95 (est.)	----	----	----	-
1969	2 Nov. (102)	Hope Reef	Bob Dyer/(A) C. Chambers	Oct. 1970	Lat. 15°30'S Long. 145°55'E	*Kompira maru* No. 28 (Japan)	60 N	364	84 kg (158 lbs)	60 kg[1] (132 lbs)	----	-
1971	11 Oct. (120)	Escape Reef	P. Van Vleck/(U.S.) P. Bristow	Apr. 17, 1972	Lat. 03°33 S Long. 166°03'E	*Jinam* No. 26 (Korea)	1,440 NE	180	23 kg (50 lbs)	42 kg[1] (92 lbs)	104.6 cm[2]	-
1972	31 Aug. (134)	Hope Reef	H. Henze/(U.S.) P. Bristow	Oct. 31, 1972	Lat. 15°42'S Long. 146°06'E	*Tsurugi maru* (Japan)	50 E	61	91 kg (200 lbs)	----	173.0 cm[2]	M
1972	10 Oct.) (135)	Linden Bank	V. Price/(U.S.) T. Curran	Nov. 10, 1972	Lat. 16°00'S Long. 146°00'E	*Kompira maru* No. 28 (Japan)	17 N	31	136 kg (300 lbs)	30 kg (68 lbs)	----	-
1970	13 Oct. (136)	Off Cairns, Aust.	P. Gay/(A) D. Wallace	Nov. 17, 1971	Lat. 15°30'S Long. 146°15'E	*Kompira maru* No. 28 (Japan)	83 NW	400	----	70 kg (154 lbs)	----	-
1972	10 Oct. (140)	Off Cairns, Aust.	D. Lyall/(A) K. Lyall	Nov. 10, 1972	Lat. 18°32'S Long. 148°36'E	*Genyō maru* (Japan)	145 SE	31	91 kg (200 lbs)	43 kg (95 lbs)	157 cm[2]	M
1972	11 Sept. (141)	Near Ribbon Reefs	C. Simms/(U.S.) P. Bristow	Oct. 18, 1972	Lat. 14°45'S Long. 145°55'E	*Seiho maru* No. 58 (Japan)	15 N	37	68 kg (150 lbs)	68 kg (Est 150 lbs)	----	-
1972	25 Sept. (142)	Opal Reef	R. Schubot/(U.S.) D. Wallace	Nov. 22, 1972	Lat. 16°00'S Long. 146°12'E	*Seiwa maru* (Japan)	22 NE	58	68 kg (150 lbs)	----	172 cm[2]	M
1972	19 Oct. (144)	Agincourt Reef	G. Bos/(U.S.) P. Wright	Mar. 9, 1973	Lat. 03°00'S Long. 144°00'E	*Fuku maru* No. 11 (Japan)	1,080 N	141	273 kg (600 lbs)	280 kg (616 lbs)	----	-
1973	3 Oct. (160)	Ruby Reef	J. Del Guericio/(U.S.) P. Bristow	Oct. 22, 1973	Lat. 18°09'S Long. 148°03'E	*Genyō maru* (Japan)	197 SE	19	91 kg (200 lbs)	62 kg (136 lbs)	175 cm	M
1973	6 Oct. (162)	Lena Reef	J. Del Guercio/(U.S) P. Bristow	Nov. 11, 1973	Lat. 15°28'S Long. 145°59'E	*Satsuma Seium maru* No. 2 (Japan)	13 NE	35	91 kg (200 lbs)	----	191 cm[2]	-
1973	11 Oct. (163A)	Agincourt Reef	R. Vincent/(A) V. Vlassof	Nov. 1, 1973	Lat. 16°07'S Long. 146°16'E	*Fukushime maru* (Japan)	33 SE	21	182 kg (400 lbs)	84 kg (185 lbs)	192 cm[2]	M
1973	4 Oct. (174)	Off Cairns	----	Nov. 12, 1973	Lat. 15°05'S Long. 146°10'E	*Haybusa maru* No. 3 (Japan)	90 N (est.)	39 (est.)	----	Est 50 kg (110 lbs)	Est 2 m	-
1974	10 Oct. (176)	Opal Reef	J. Gay/(A) D. Wallace	Nov. 24, 1974	Lat. 14°26'S Long. 145°44'E	Yakushi maru No. 38 (Japan)	120 N	35	68 kg (150 lbs)	63 kg (139 lbs)	235 cm	-
1973	5 Nov. (177)	Agincourt Reef #2	E. Gould/(U.S.) P. Bristow	Nov. 4, 1974	Lat. 17°23'S Long. 147°05'E	*Kana maru* (Japan)	110 SE	364	182 kg (400 lbs)	88 kg[1] (194 lbs)	192 cm[2]	M 1,400 g[3]

Table [illegible].—Continued.

Release				Recaptures					Biological data			
Year	Date (SWFC No.)	Location	Tagger/Captain	Date	Location	Recovered by	Distance from point of tagging	Days at large	Estimated weight at release	Weight at recapture	Length	Sex
1974	4 Nov. (178)	Linden Bank	[illegible] Evans/(A) [illegible] Vlassof	Nov. 16, 1974	Lat. 17°11'S Long. 147°99'E	Kana maru [illegible]	[illegible] SE	12	91 kg (200 lbs)	98 kg (216 lbs)	193 cm[2]	M 2,100 g[3]
1974	12 Sept. (179)	Linden Bank	M. Florence/(A) [illegible]	Nov. 6, 1974	Lat. 13°55'S Long. 145°11'E	[illegible]	[illegible]	55	----	82 kg[1] (180 lbs)	197 cm[2]	M
1973	8 Oct. (180)	No. 10 Ribbon Reef	J. Del Guercio/(U.S.) [illegible] Bristow	Oct. 8, 1974	Lat. 16°01'S Long. [illegible]	[illegible] maru (Japan)	95 SE	364	136 kg (300 lbs)	94 kg[1] (185 lbs)	184 cm[2]	M
1974	[illegible] (1[illegible]1)	[illegible] Reef	H. Nordaas/(U.S.) [illegible]	Oct. 26, 1974	Lat. 15°01'S Long. 145°57'E	[illegible]	65 N	21	----	64 kg[1] (141 lbs)	180 cm[2]	M
1974	4 Oct. (182)	No. 9 Ribbon Reef	[illegible] Inscho/(U.S.) [illegible] Wright	Oct. 28, 1974	[illegible] Long. 145°45'E	[illegible] (Japan)	7[illegible] N	24	68 kg (150 lbs)	60 kg (132 lbs)	174 cm[2]	-
1974	25 Sept. (183)	Agincourt Reef	H. Nordass/(U.S.) [illegible] Klaproth	Dec. 26, 1974	Lat. 33°45'S Long. 151°22'E	[illegible] near Long Reef, Sydney, Aust.	1,290 S	92	136 kg (300 lbs)	77 kg (169 lbs)	----	-
1974	14 Sept. (184)	No. 10 Ribbon Reef	[illegible] Zuckerman/U.S.) [illegible]	Nov. 18, 1974	Lat. 18°45'S Long. 150°10'E	Genyō maru [illegible]	[illegible] SE	65	----	116 kg[1] (255 lbs)	206 cm[2]	M
1973	2 Sept. (185)	No. 2 Ribbon Reef	[illegible] Meyer/(A) [illegible] Bristow	Oct. 6, 1973	Lat. 16°18'S Long. 146°30'E	Funakawa maru (Japan)	7[illegible] SE	34	136 kg (300 lbs)	----	170 cm	-
1974	8 Oct. (203)	No. 10 Ribbon Reef	D. Phipps/(U.S.) [illegible] Woodbridge	Nov. 7, 1974	Lat. [illegible] Long. 154°33'E	Longliner (name unknown, Japan)	670 SE	30	45 kg (100 lbs)	52 kg (114 lbs)	----	-
1972	13 Sept. (204)	Off Cairns	M. Johnson (U.S.) [illegible] Wallace	Apr. 30, 1975	Elizabeth Reef near [illegible], New Zealand	[illegible] S. Pritchard, Capt.	1,[illegible]75 SE	959	159 kg (350 lbs)	147 kg (325 lbs)	108 cm[4]	-
1974	14 Sept. (205)	No. 6 Ribbon Reef	B. May (U.S.) D. Wallace	[illegible], 1974	Lat. [illegible] Long. 14[illegible]	Etsuzan maru (Japan)	32 SE	29	114 kg (250 lbs)	60 kg[1] (132 lbs)	170 cm[2]	M
1973	19 Sept. (206)	Escape Reef	G. Matthews/(U.S.) P. Bristow	Oct. [illegible], 1974	Lat. 16°30'S Long. 14[illegible]	Etsuzan maru (Japan)	60 SE	404	91 kg (250 lbs)	73 kg[1] (161 lbs)	184 cm[2]	M 650 g[3]
1974	2 Oct. (207)	No. 10 Ribbon Reef	R. Schubot/(U.S.) D. Wallace	Feb. [illegible]4, 197[illegible]	Lat. 31°03'S Long. [illegible] near Korogora Pt. north of Sidney, Aust.	V. Jordan Hat Head, NSW, Aust.	1,200 S	145	114 kg (250 lbs)	76.2 kg (168 lbs)	2.58 m	-
1974	17 Oct. (208)	Thetford Reef	R. Griffin/(N.Z.) J. Crump	Jun. 9, 1975	Lat. 34°03'S Long. 175°56'W	Lein Ho No. 1 (Korea)	2,100 SE	235	36 kg (80 lbs)	45 kg (100 lbs)	----	F
1976	22 Sept. (219)	No. 10 Ribbon Reef	R. Schubot/(U.S.) D. Wallace	Oct. 15, 1976	No. 5 Ribbon Reef	[illegible] Palmar, Angler P. Wright, Capt.	30 S	23	148 kg (325 lbs)	----	----	-

Table 2.—Continued.

Releases				Recaptures					Biological data			
Year	Date (SWFC No.)	Location	Tagger/Captain	Date	Location	Recovered by	Distance from point of tagging	Days at large	Estimated weight at release	Weight at recapture	Length	Sex
1975	5 Oct. (220)	No. 10 Ribbon Reef	J. Del Guerico/(U.S.) P. Bristow	Oct. 10, 1976	Linden Band	M. Mather, Angler G. Mills, Capt.	87 S	370	136 kg (300 lbs)	Est 68 kg (150 lbs)	----	-
1974	10 Oct. (227)	Carter Reef	O. Phipps/(U.S.) L. Woodbridge	Nov. 10, 1974	Lat. 14°33'S Long. 145°48'E	Yakushi maru (Japan)	6 E	41	----	340 kg (749 lbs)	410 cm	-
1975	14 Sept. (228)	No. 10 Ribbon Reef	M. Cohn/(U.S.) P. Bristow	Oct. 8, 1975	Lat. 16°01'S Long. 146°16'E	Oyama maru (Japan)	78 S	24	68 kg (150 lbs)	----	177 cm	-
1975	13 Sept. (231)	No. 3 Ribbon Reef	I. Marr/(A) D. Hayes	Nov. 1, 1975	Lat. 17°12'S Long. 147 °02'E	Kaiei maru (Japan)	25 SE	49	114 kg (250 lbs)	89 kg (196 lbs)	----	-
1975	9 Oct. (233)	Jenny Louise	K. Klaproth/(A) M. Klaproth	Feb 6, 1976	Off Inyadde Pt. South of Jervis NSW Aust.	T & C Puglisi Ulladulla, NSW Aust.	1,320 S	120	114 kg (250 lbs)	67 kg (148 lbs)	2,660 mm[5] 2,380 mm[6]	-
1974	14 Nov. (234)	Linden Bank	D. Roux/(S. Africa) P. Wright	Oct. 20, 1975	Lat. 14°46'S Long. 146°03'E	Oyama maru (Japan)	100 N	349	176 kg (80 lbs)	----	163 cm	-
1974	18 Sept. (235)	No. 10 Ribbon Reef	F. Rice/(U.S.) D. Wallace	Oct. 31, 1975	Lat. --°13'S Long. 144°50'E	Oyama maru (Japan)	95 NW	408	125 kg (275 lbs)	----	184 cm	-
1974	27 Sept. (236)	Agincourt Reef	P. Furnell/(A) G. White	Dec. 5, 1975	Lat. 21°30'S Long. 155°19'E	Sagami maru (Japan)	665 SE	434	91 kg (200 lbs)	----	191 cm	F 1,100 g[3]
1975	6 Sept. (237)	No. 10 Ribbon Reef	D. Etheridge/(-) P. Wright	Oct. 12, 1976	Lat. 17°58'S Long. 147°30'E	Etsuzan maru (Japan)	220 SE	402	114 kg (250 lbs)	89 kg (196 lbs)	188 cm[2]	M
1975	30 Oct. (238)	No. 10 Ribbon Reef	E. Gould/(U.S.) G. Hallam	Oct. 31, 1976	Lat. 13°44'S Long. 144°44'E	Etsuzan maru (Japan)	90 NW	367	91 kg (200 lbs)	82 kg (180 lbs)	186 cm[2]	M
1974	11 Nov. (239)	Opal Reef	S. Lindsay, Jr./(U.S.) K. Klaproth	Nov. 31 1976	Lat. 13°38'S Long. 145°02'E	Etsuzan maru (Japan)	162 NW	733	136 kg (300 lbs)	82 kg (180 lbs)	185 cm[2]	M
1975	9 Oct. (240)	No. 10 Ribbon Reef	J. Del Guerico/(U.S.) P. Bristow	Nov. 10, 1976	Lat. 14°05'S Long. 145°21'E	Etsuzan maru (Japan)	49 NW	397	136 kg (300 lbs)	64 kg (141 lbs)	174 cm[2]	M 3,020 g[3]
1974	18 Nov. (241)	Opal Reef	H. Samuels/(A) D. Wallace	Nov. 10, 1976	Lat. 14°05'S Long. 145°21'E	Etsuzan maru (Japan)	126 NW	723	114 kg (250 lbs)	64 kg (141 lbs)	174 cm[2]	M 1,200 g[3]
1976	11 Nov. (242)	Linden Bank	A. Virsakis/(-) D. Wallace	Dec. 20, 1976	Lat. 20°00'S Long. 153°44'E	Sagami maru (Japan)	500 SE	45	91 kg (200 lbs)	----	177 cm	-
1976	21 Sept. (243)	No. 9 Ribbon Reef	H. Breyer/(J.S.) P. Bristow	Nov. 28, 1976	Lat. 16°50'S Long. 147°05'E	Kompira maru No. 8 (Japan)	138 SE	68	114 kg (250 lbs)	80 kg (176 lbs)	236 cm (TL,)	-
1975	26 Nov. (244)	Euston Reef	P. Whelan/(A) B. Apnicn	Nov. 6, 1975	Lat. 13°58'S Long. 145°03'E	Kaiyo maru (Japan)	180 NE	346	102 kg (225 lbs)	87 kg (191 lbs)	188 cm[2]	M 2,500 g[3]

Table 2.—Continued.

Release				Recaptures					Biological data			
Year	Date (SWFC No.)	Location	Tagger/Captain	Date	Location	Recovered by	Distance from point of tagging	Days at large	Estimated weight at release	Weight at recapture	Length	Sex
1976	4 Nov. (245)	Opal Reef	J. Pilkington/(A) N. Jackson	Nov. 7, 1976	Lat. 15°38'S Long. 146°10'E	Yakusi maru No. 38 (Japan)	36 NE	3	227 kg (500 lbs)	65 kg (143 lbs)	215 cm	-
1976	15 Sept. (246)	No. 7 Ribbon Reef	D. Sheperdson/(A) P. Wright	Nov. 10, 1976	Lat. 16°37'S Long. 146°40'E	Yakushi maru No. 38 (Japan)	98 SE	56	112 kg (247 lbs)	95 kg (209 lbs)	305 cm	-
1976	22 Oct. (255)	No. 3 Ribbon Reef	C. Phipps/(U.S.) L. Woodbridge	Dec. 9, 1977	Lat. 18°35'S Long. 148°07'E	Kompira maru No. 8 (Japan)	200 SE	413	91 kg (200 lbs)	----	----	-
1976	6 Dec. (256)	Linden Bank	H. Nordass/(U.S.) K. Klaproth	Oct. 16, 1977	Lat. 15°35'S Long. 146°04'E	Kompira maru No. 8 (Japan)	38 NW	416	----	102 kg (224 lbs)	275 cm	-
--	Tag #18030 (257)	----	----	Oct. 23, 1977	Lat. 16°05'S Long. 146°40'E	Aomori maru	----	----	----	138 kg[1] (304 lbs)	220 cm	M
1976	15 Oct. (258)	Opal Reef	R. Mulholland/(-) D. Hayes	Oct. 17, 1977	Lat. 16°03'S Long. 146°13'E	Funakawa maru (Japan)	18 NE	367	91 kg (200 lbs)	----	183 cm	M
1976	28 Sept. (259)	No. 2 Ribbon Reef	D. Schubot/(U.S.) D. Wallace	Nov. 5, 1977	Lat. 15°35'S Long. 146°18'E	Ashu maru (Japan)	32 NE	327	80 kg (175 lbs)	72 kg[1] (158 lbs)	178 cm	M
1975	7 Nov. (260)	Opal Reef	P. Marvin/(U.S.) D. Wallace	Nov. 24, 1977	Lat. 17°43'S Long. 147°26'E	Fukuyoshi maru No. 25 (Japan)	128 SE	747	91 kg (200 lbs)	Est 75 kg (165 lbs)	----	-
1973	29 Oct. (261)	No. 10 Ribbon Reef	E. Gould/(U.S.) P. Bristow	Oct. 22, 1977	Lat. 14°21'S Long. 145°46'E	Oyama maru (Japan)	25 N	1,453	136 kg (300 lbs)	----	205 cm	M
1977	20 Sept. (269)	No. 1 Ribbon Reef	R. Estrada/(Ecuador) P. Bristow	Oct. 9, 1977	Lat. 15°28'S Long. 146°05'E	Fukuichi maru (Japan)	20 NW	19	68 kg (150 lbs)	60 kg (132 lbs)	205 cm	-
1976	3 Oct. (281)	No. 5 Ribbon Reef	A. Remley/(A) G. Hallam	Oct. 31, 1978	Lat. 16°31'S Long. 146°50'E	Yakushi maru No. 7 (Japan)	90 SE	758	250 kg (550 lbs)	115 kg (253 lbs)	2.5 m	-
1977	29 Sept. (282)	Linden Bank	C. Edwards/(A) W. Edwards	Nov. 6 , 1978	Lat. 17°00'S Long. 147°30'E	Yakushi maru No. 7 (Japan)	91 SE	403	136 kg (300 lbs)	120 kg (264 lbs)	2.5 m	-

[1] Gilled and gutted.
[2] Eye orbit (posterior) to fork.
[3] Gonad weight.
[4] Fork to anterior portion of jaw (lower).
[5] Bill tip to fork.
[6] Lower jaw tip to fork.

Table 3.—Tag return rates by year and tag type for black marlin tagged off north Queensland, Australia, as part of the Cooperative Marine Game Fish Tagging Program—Pacific Area (NMFS/WHOI). (For tagging 1968-78.) Total tag recovery rate (%): FM67 305T/4R = 1.3%; H 2,267T/56R = 2.4% (1 H tag recovered, tagging date unknown); no recoveries for either A or B tags.

Year	Type	No. tagged	No. recovered	Recovery rate (%)
1968	FM67	26	1	3.8
	H	0		
	A	0		
	B	0		
1969	FM67	51	1	1.9
	H	0		
	A	0		
	B	0		
1970	FM67	110	1	0.9
	H	0		
	A	0		
	B	0		
1971	FM67	57	1	1.7
	H	127	1	0.8
	A	0		
	B	0		
1972	FM67	1	0	0.0
	H	287	7	2.4
	A	0		
	B	0		
1973	FM67	60	0	0.0
	H	378	9	2.4
	A	0		
	B	0		
1974	FM67	0		
	H	335	17	5.1
	A	1	0	0.0
	B	1	0	0.0
1975	FM67	0		
	H	409	9	2.2
	A	1	0	0.0
	B	1	0	0.0
1976	FM67	0		
	H	501	10	2.0
	A	0		
	B	0		
1977	FM67	0		
	H	170	2	1.2
	A	0		
	B	0		
1978	FM67	0		
	H	60	0	0.0
	A	0		
	B	0		
		2,576	59	

Table 4.—Black marlin weights as recorded by year, 1 September through 31 December 1970-78, at Cairns and Lizard Island, Queensland, Australia.

Year	Number marlin	Total weight kg	Total weight lb	Average kg	Average lb	Heaviest kg	Heaviest lb	Lightest kg	Lightest lb
1970	47	12,271	27,053	261	575	558	1,231	35	77
1971	69	21,078	46,468	305	673	514	1,133	40	89
1972	107	34,177	75,346	319	704	576	1,271	78	172
1973	134	46,000	101,411	343	756	654	1,442	20	45
1974	64	22,775	50,210	356	784	535	1,180	98	215
1975	78	28,023	61,778	359	792	620	1,367	99	218
1976	59	22,043	48,596	373	823	583	1,286	84	186
1977	49	21,273	46,899	434	957	600	1,323	110	243
1978	37	15,036	33,149	406	896	616	1,358	118	261
Total	644	222,676	490,910						
	= 346 kg (762 lb) average								

weight for a release time of 0-60 d, was 16 kg (35 lb). For recaptures made 61-120 d after release, the average angler overestimate at tagging was 21 kg (46 lb). Estimated weights at tagging and recapture were compared within release time periods, and the results listed in Table 5. These calculations assume no growth, therefore an increase in recapture weight vs. weight at tagging would be expected as time progressed. However, the average recaptured weight decreased when compared with estimated weight at tagging during periods 0-60 and 61-120 d after release.

Table 5.—Average weights of black marlin as estimated by the angler at time of tagging and compared with weights reported upon recovery: estimated tagging weight vs. recorded weights by time periods.

Period	No. of fish	Average weight kg	Average weight lb
0-60 d	16	[1]+20.6	[1]+45.5
61-120 d	4	[1]+41.9	[1]+92.5
121-240 d	5	[2]−2.7	[2]−6.0
241-365 d	7	[2]−3.8	[2]−8.4
366d-2 yr	9	[1]+19.5	[1]+43.0
2-3 yr	3	[1]+14.3	[1]+31.6
3-4 yr	1	[1]+36.2	[2]−80.0

[1] Overestimate (+), fish recovered at weights < reported tagged.

[2] Underestimate (−), fish recovered at weights > reported tagged.

SEX RATIO OF RECAPTURED MARLIN

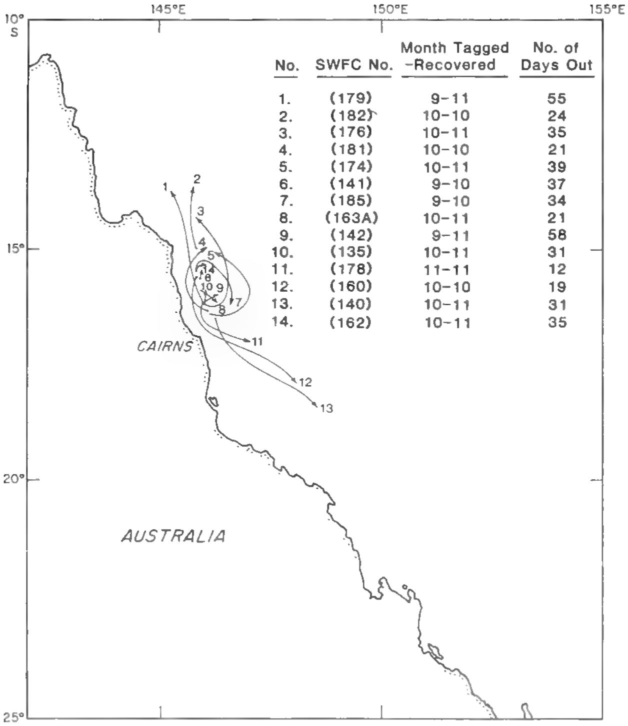
Some longline vessel crews recorded the sex of tagged black marlin upon recapture. One angler also gave this information on a recaptured marlin. Sex information was given for 28 recoveries including two recaptures from black marlin tagged with NSWF tags, and of this number, 25 (89%) were reported as males and 3 (11%) as females. The average weight of the 25 males recovered was 91 kg (193 lb), and 221 kg (449 lb) for the three females. The average weight for the small sample of females recovered was determined from black marlin weighing 45 kg (100 lb), 95 kg (209 lb), and 479 kg (1,056 lb).

MIGRATORY PATTERNS AND RATES

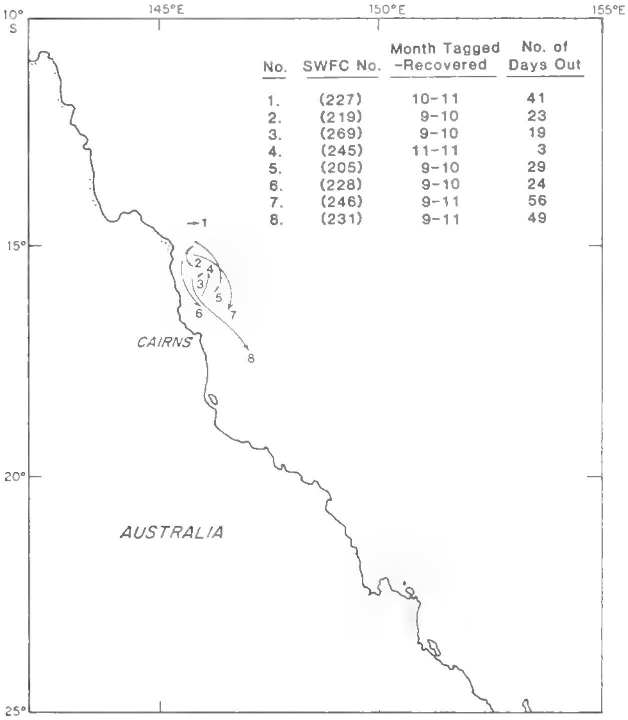
Black marlin occur throughout the Pacific Ocean between about lat. 40°N and 45°S, but their population density, as measured by the Japanese longline catch rate data, is low except in certain geographical areas. The stock structure of black marlin is not fully understood. Isolated high catch-rate areas are observed in the western and eastern Pacific. It has been suggested that two stocks (eastern/western) or three stocks (eastern/northwestern/northeastern) may be present (Shomura 1980). There is a strong possibility of mixing between black marlin stocks in the Indian Ocean, Indo-Pacific, and the western Pacific.

Figures 4-8 show plots of black marlin tag and recovery locations, grouped by release time periods. All recoveries >500 nmi from the tagging location off the Great Barrier Reef, Queensland, Australia, regardless of release time period, are shown in Figure 9. Information on recovery number, month of tagging, and number of days from release to recovery are included in these figures and lines connecting the tagging and recapture points do not indicate the exact migratory path of the tagged fish.

When these recovery distances over time (as measured by days from release to recapture) are presented, it can be seen that

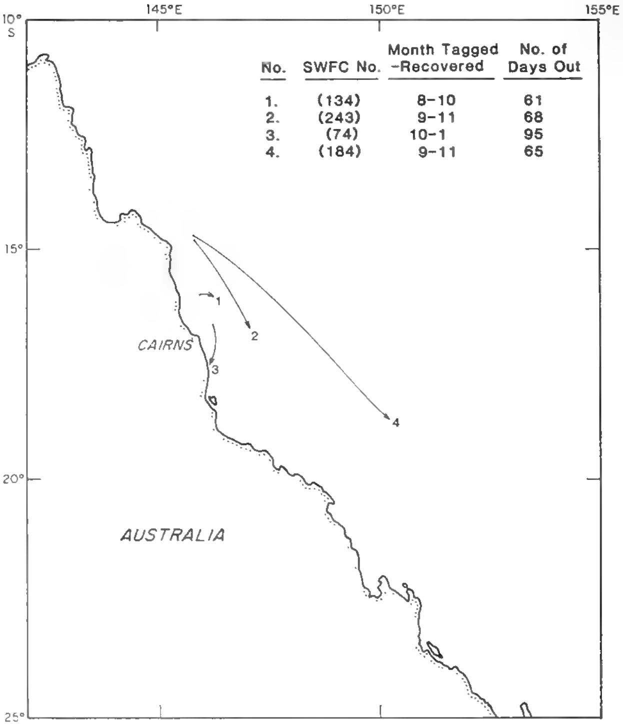


No.	SWFC No.	Month Tagged -Recovered	No. of Days Out
1.	(179)	9-11	55
2.	(182)	10-10	24
3.	(176)	10-11	35
4.	(181)	10-10	21
5.	(174)	10-11	39
6.	(141)	9-10	37
7.	(185)	9-10	34
8.	(163A)	10-11	21
9.	(142)	9-11	58
10.	(135)	10-11	31
11.	(178)	11-11	12
12.	(160)	10-10	19
13.	(140)	10-11	31
14.	(162)	10-11	35



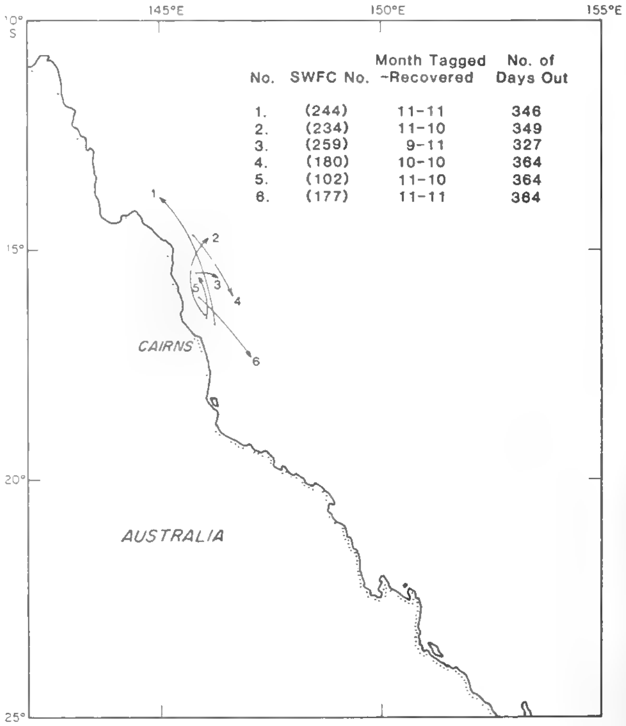
No.	SWFC No.	Month Tagged -Recovered	No. of Days Out
1.	(227)	10-11	41
2.	(219)	9-10	23
3.	(269)	9-10	19
4.	(245)	11-11	3
5.	(205)	9-10	29
6.	(228)	9-10	24
7.	(246)	9-11	56
8.	(231)	9-11	49

Figure 4.—Tag and recovery locations, 0-60 d time at large. Lines indicate point of tagging and recovery only.



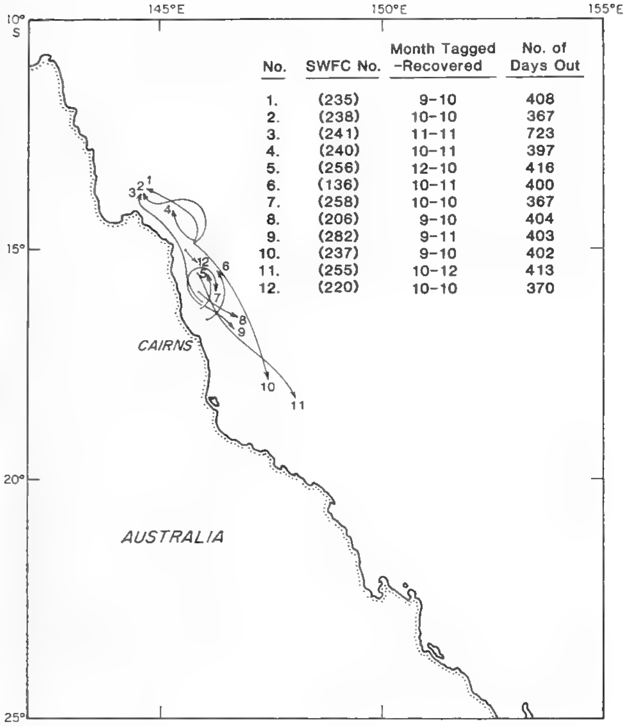
No.	SWFC No.	Month Tagged -Recovered	No. of Days Out
1.	(134)	8-10	61
2.	(243)	9-11	68
3.	(74)	10-1	95
4.	(184)	9-11	65

Figure 5.—Tag and recovery locations, 61-120 d time at large. Lines indicate point of tagging and recovery only.



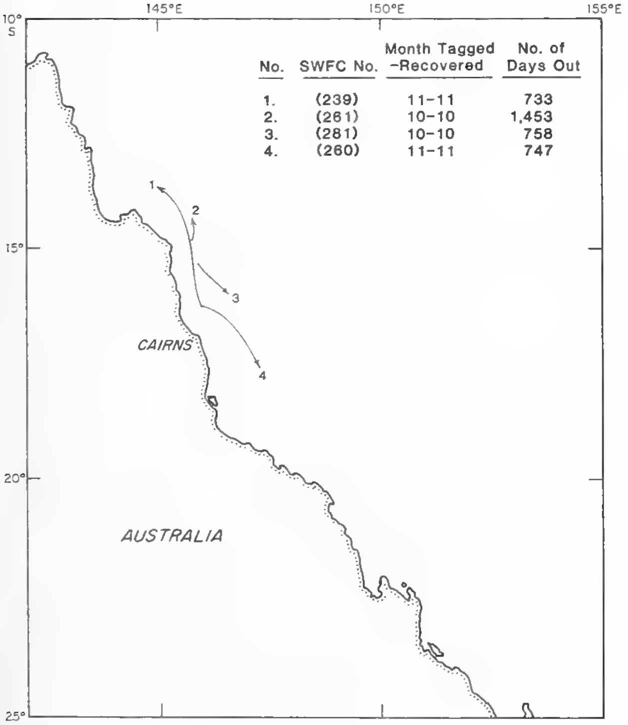
No.	SWFC No.	Month Tagged -Recovered	No. of Days Out
1.	(244)	11-11	346
2.	(234)	11-10	349
3.	(259)	9-11	327
4.	(180)	10-10	364
5.	(102)	11-10	364
6.	(177)	11-11	364

Figure 6.—Tag and recovery locations, 241-365 d time at large. Lines indicate point of tagging and recovery only.



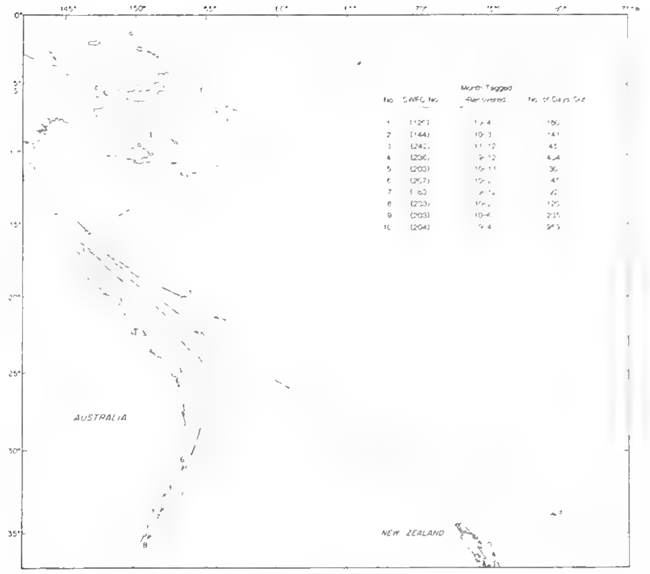
No.	SWFC No.	Month Tagged -Recovered	No. of Days Out
1.	(235)	9-10	408
2.	(238)	10-10	367
3.	(241)	11-11	723
4.	(240)	10-11	397
5.	(256)	12-10	416
6.	(136)	10-11	400
7.	(258)	10-10	367
8.	(206)	9-10	404
9.	(282)	9-11	403
10.	(237)	9-10	402
11.	(255)	10-12	413
12.	(220)	10-10	370

Figure 7.—Tag and recovery locations, 366d-2 yr time at large. Lines indicate point of tagging and recovery only.



No.	SWFC No.	Month Tagged -Recovered	No. of Days Out
1.	(239)	11-11	733
2.	(261)	10-10	1,453
3.	(281)	10-10	758
4.	(260)	11-11	747

Figure 8.—Tag and recovery locations, 2 to 3 yr and 3 to 4 yr time at large. Lines indicate point of tagging and recovery only.



No.	SWFC No.	Month Tagged -Recovered	No. of Days Out
1	[illegible]	[illegible]	[illegible]
2	(144)	[illegible]	[illegible]
3	[illegible]	11-12	[illegible]
4	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]
10	(204)	[illegible]	[illegible]

Figure 9.—All recoveries 500 nmi or greater from location of tagging. Lines indicate point of tagging and recovery only.

average distances of tagging to recapture points increase from time of tagging for at least the first 180 d of time at large. A regression was calculated for recaptures made within the first 235 d from time of release. Recapture distances by number of days from release are given in Figure 10. The greatest recorded distance between tagging and recapture was 2,100 nmi, 235 d after release. Recaptures made near the tagging area (within 210 nmi) were common 1 and 2 yr after tagging (17 at 1 yr, 4 at 2 yr) and one recapture at nearly 4 yr after release (1,453 d or 3.98 yr).

The average migration rate in nautical miles per day (nmi/d) away from the location of tagging, for selected time periods subsequent to tagging, was calculated using two methods from data derived from time, straight line distance, and true bearing angle measurements from the tagging point to the recapture point. Of particular interest are the data obtained from recaptures within the first three time periods selected (0-60, 61-120, and 121-240 d) since these data may better define the average migration rate of black marlin away from a high population density (as reflected in CPUE) and reported spawning area. The greatest observed migration rate for any black marlin recaptured was 22.3 nmi/d, an average attained during a release time of 30 d. Average movement was calculated in nautical miles per day for the first three time periods, then multiplied by the average number of days within the period in relation to zero day, or start of the first time period, to obtain the approximate average distance of migration:

Days	*Midpoint in time*	*Avg. nmi/d*	*To period midpoint*
0-60	30	3.65	109.5 nmi
61-120	40	6.08	547.2 nmi
121-240	180	7.70	1,386.0 nmi

The percentage of recaptures by month of tagging was August 30%, September 30%, October 49%, November 17%, and December 2%. Recaptures made within the first period (0-60 d) were examined to determine the migration rate for black marlin tagged in September (9 fish recaptured), October (13 fish recaptured), and November (3 fish recaptured). No black marlin tagged in

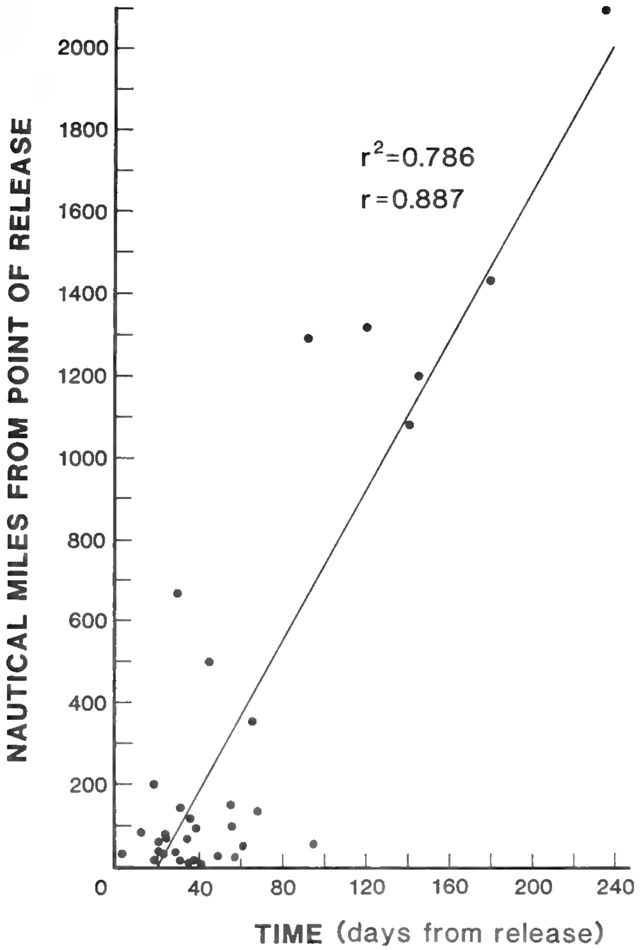


Figure 10.—Regression plot of black marlin recovery distances, by number of days at large.

August or December were recaptured within the first 60 d from release. The average rate of movement during the first 60 d from release for black marlin tagged in September was 1.46 nmi/d; October, 4.58 nmi/d; and November, 10.06 nmi/d. The average rate increased 3.1 times from September to October, and 2.2 times from October to November, with the November rate being 6.9 times that recorded for September. An increasing average rate of movement (nmi/d) was shown for black marlin tagged during the later part of the season. This may indicate that black marlin frequenting the general area of tagging early in the season may not migrate out of the area as rapidly as those black marlin tagged later in the season.

Vector analysis used distance and directional data determined by examination of tagging and recovery locations (straight-line distance), time of release (number of days), and direction (number of degrees, true bearing) from tagging point to recovery point. Vector mean bearings and distances were calculated 0-730 d in five time periods as shown in Figure 11. This analysis indicated a reduced rate of movement for the first time period after tagging (0-60 d) compared with the two following time periods (61-120 and 121-240 d). For the second period an acceleration of movement of 6.2 times the first period was noted. A reduced rate of movement of mean vector distance of 2.8 times the second period was observed for the third period (121-240 d).

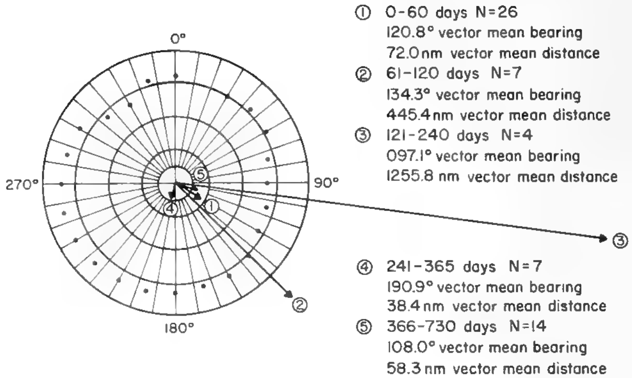


Figure 11.—Vector mean bearings and distances for five recovery periods: 0-60 d, 61-120 d, 121-240 d, 241-365 d, and 366-730 d.

Arcs showing mileage limits were plotted, using both the average distance traveled from tagging to recovery per day by period, times the midpoint for each time period; the vector mean distance for each period is given in Figure 12. The differences between the plots of average nautical miles per day and the vector mean distance are relatively small. Vector mileage arcs are smaller due to the method of calculation. The black marlin covering the most distance from the point of tagging (2,100 nmi in 235 d) to the recapture site northeast of New Zealand (see Fig. 12) had an average daily rate of travel of 8.94 nmi.

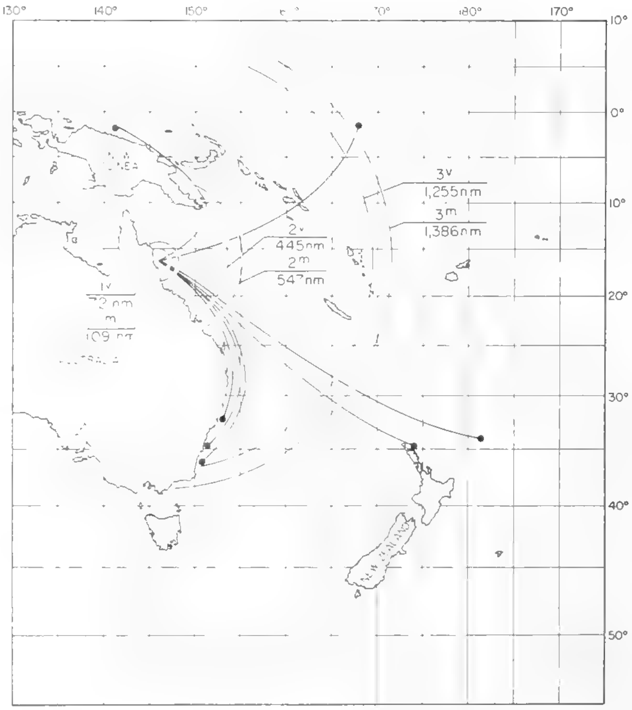


Figure 12.—Nautical mile arcs for average distance traveled from tagging to recovery by time periods, (1 = 0-60 d, avg. 30 d; 2 = 61-120 d, avg. 90 d; 3 = 121-240 d, avg. 180 d). V is the vector mean distance for each period, m is the measured distance. Only long distance recoveries (< 500 nmi) are also shown.

Studies by Ueyanagi (1960) indicate that a black marlin may spawn in the northwestern Coral Sea in early summer (November). Recaptures are reported in the spring and early summer near the point of tagging about 1, 2, 3, and 4 yr after tagging. This would indicate that at least some of these black marlin tagged show a returning migration trend toward a suspected spawning area.

Geographical areas fished by commercial longline gear vary in amount of fishing effort expended and changes in longline effort may affect the number of recoveries and recovery location. From 1965 to 1975, black marlin catch rates from the Japanese longline fishery in many areas of the southwest Pacific averaged 2.1-5.1+ and >5.1 fish/1,000 hooks effective hooking effort (Suzuki and Honma 1977); peak hooking rates were recorded near the tagging area off north Queensland from October through December. The distribution of longline effort and CPUE should be reflected in the distribution of recovery locations for black marlin tagged in the western Coral Sea. The effective effort for black marlin fished in the Coral Sea is high. The effectiveness index (*E*) of the effort on black marlin (effective hook/nominal hooks) exceeds 1.0 in 19 of 24 yr (1952-75) as reported by Suzuki and Honma (1977).

Figure 13 outlines the 10-yr average level of Japanese longline fishing effort by 5° longitude and 5° latitude for the Coral Sea and adjacent areas from 1968 to 1977 (Anonymous 1970-79). Extensive longline fishing effort is evident north of the Solomon Islands, east of Queensland, and off the southeast coast of Victoria, Australia, and off the eastern coast of New Zealand. A substantial amount of longline effort was expended off the Great Barrier Reef area (north Queensland) from lat. 20°S northward. No longline effort is reported in the eastern Arafura Sea and Torres Strait between Cape York and Papua. Fishing effort isolines also indicate an area of reduced effort extending from near New Caledonia eastward, centering on about lat. 20°S. The effort levels for the 5° areas given in Figure 13 for the period 1968-77 are indicated by numbers of hooks fished × 10^4. The strata of hook effort, levels 1-3, representing 9-99, 100-199, and 200 or greater × 10^4, respectively, were averaged for the 1968-77 period.

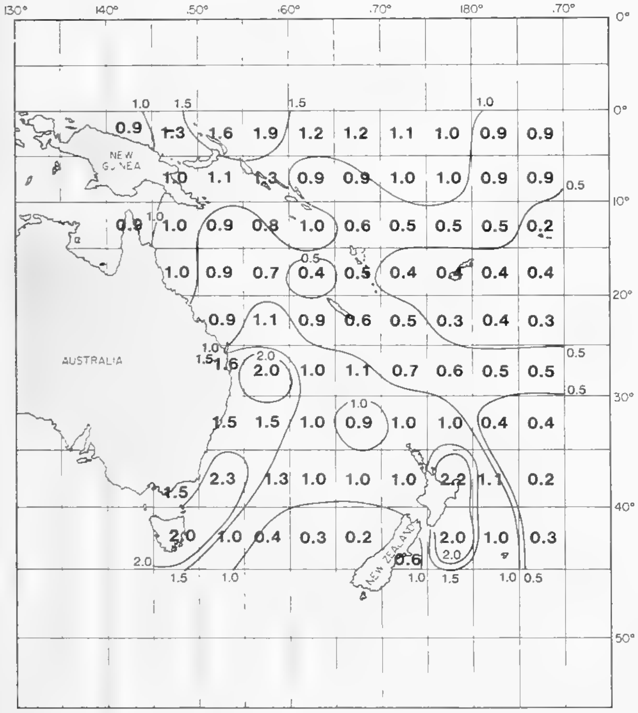


Figure 13.—Average distribution of Japanese longline fishing effort for 1968-77 by 5° longitude × latitude areas from Japanese Fishery Agency data. Effort levels for the 10-yr period were determined by averaging effort level 0-99, 100-199, 200 or greater × 10^4 hooks in terms of 1 = 0-99, 2 = 100-199, and 3 = 200 or greater × 10^4 hooks.

The distributions of longline fishing CPUE for black marlin as a measure of apparent abundance in the area from near northern New Zealand, and near the New Guinea-Solomon Islands are shown in Figure 14a, b, c (from Suzuki and Honma 1977).

A review of CPUE for June-August (Fig. 14a) shows CPUE levels of 0.6-2.0 black marlin/1,000 hooks are common in the New Guinea-Bismark Archipelago-Solomon Islands area throughout the winter months. Average effort levels are high in this area, 100-199 hooks × 10^4 per 5° longitude × 5° latitude area. In September-November (Fig. 14a, b) the tagging area has a high CPUE. The first indications of a poleward shift of high CPUE areas for black marlin, in the range of 0.6-2.0 fish/1,000 hooks along the western coast of the Coral Sea, occurs during September. By examining the changes in CPUE for the area off north Queensland during and after the months of September, October, and November, some insight into the shift of high black marlin CPUE away from the tagging areas can be observed. High catch rates ($\geq$5.1 black marlin/1,000 hooks) are common in the western Coral Sea from lat. 10° to 20°S in October and November. The high CPUE areas for September-November are near long. 150°E × lat. 15°S and have a hook effort of <99 hooks × 10^4 per 5° longitude × 5° latitude area. In December (Fig. 14b), increasing catch rates are observed south to about lat. 25°S. These higher catch rates are observed to the west within a latitudinal band of lat. 15° to 20°S. Longline hook effort level is <99 hooks × 10^4 per 5° longitude × 5° latitude area. In January (Fig. 14b), catch rates increase along the Australian coast to about lat. 35°S. Catch rates per 5° square are lower than those observed previously off the north Queensland area (lat. 10° to 20°S), but remain in the range of 2.1-5.0 black marlin/1,000 hooks. The center of high black marlin CPUE is in an area having an effort level of <99 hooks × 10^4 per 5° longitude × 5° latitude. By February (Fig. 14c), black marlin CPUE in the lat. 15° to 20°S area has decreased to 0.5 black marlin/1,000 hooks. The high CPUE areas continue to be off the Queensland and New South Wales coast, from lat. 20° to 35°S. Average effort levels in the high CPUE areas for February are at a higher level than during the previous months, $\geq$100 hooks per 5° longitude × 5° latitude area but <199 hooks × 10^4 per 5° area. CPUE patterns for March (Fig. 14c) change considerably, with higher CPUE areas noted north of lat. 15°S, and reduction in high CPUE areas to the south. Catch rates averaged 0.6-2.0 black marlin/1,000 hooks per 5° longitude × 5° latitude area. Effort levels in the higher CPUE areas are less than averages observed for high CPUE areas in February, and average $\leq$99 hooks × 10^4 per 5° longitude × 5° latitude area. Most catches in April (Fig. 14c) are being made north of lat. 20°S. Catches average 0.6-2.0 fish/hooks per 5° longitude × 5° latitude area. A further retraction of high CPUE areas from latitudes south of 15°S is evident in May (Fig. 14c). Some catches at levels of 0.6-2.0 black marlin/1,000 hooks are observed for areas east of the Queensland coast, but the center area of high CPUE is in the New Guinea-Bismark Archipelago-Solomon Islands area. Average effort levels are higher in this area and are between 100 and 199 hooks × 10^4 per 5° longitude × 5° latitude square.

a

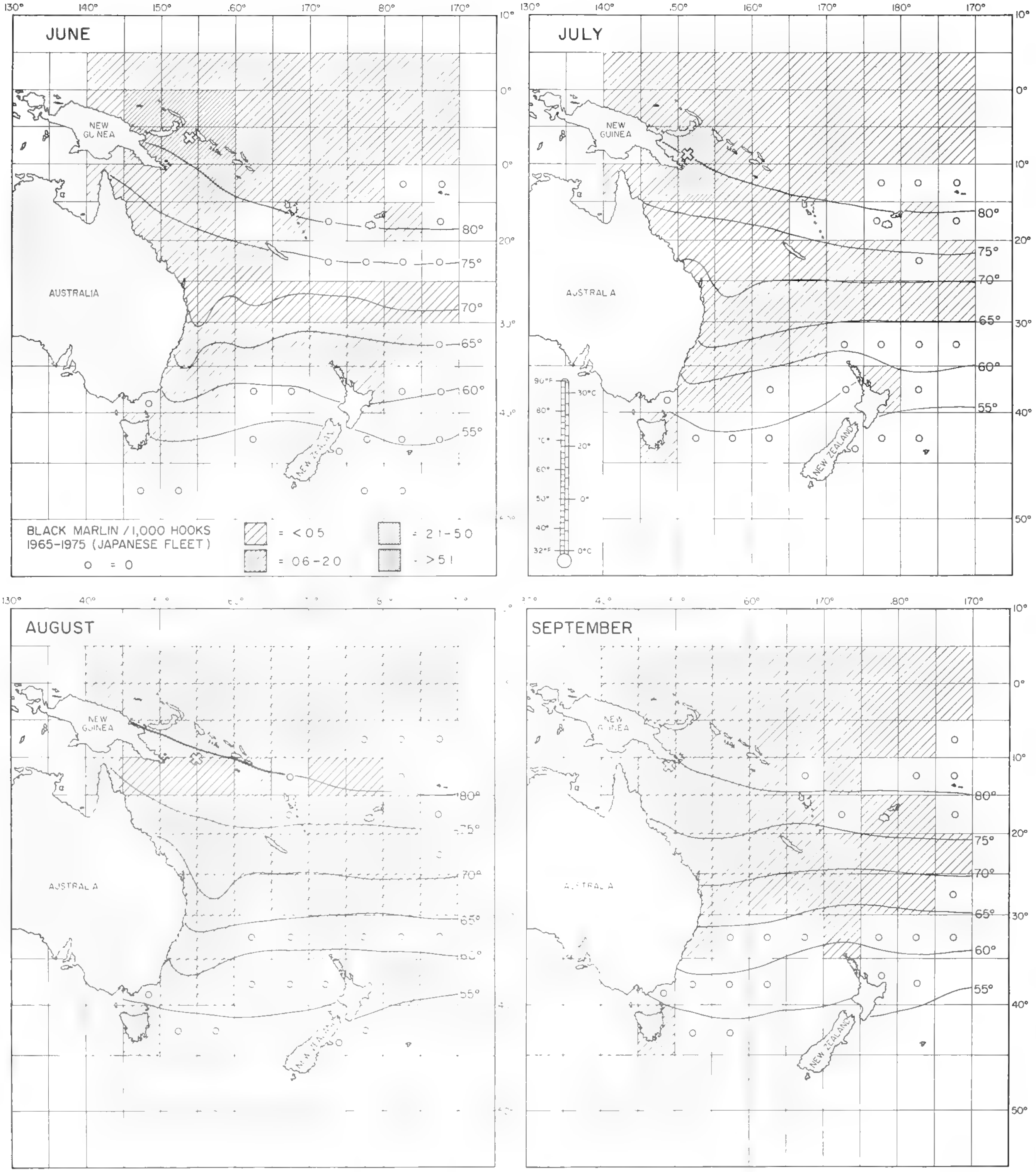


Figure 14.—Distribution of average hook rates for black marlin per 1,000 hooks effective effort (from Suzuki and Honma 1977): a. June-September. b. October-January. c. February-May.

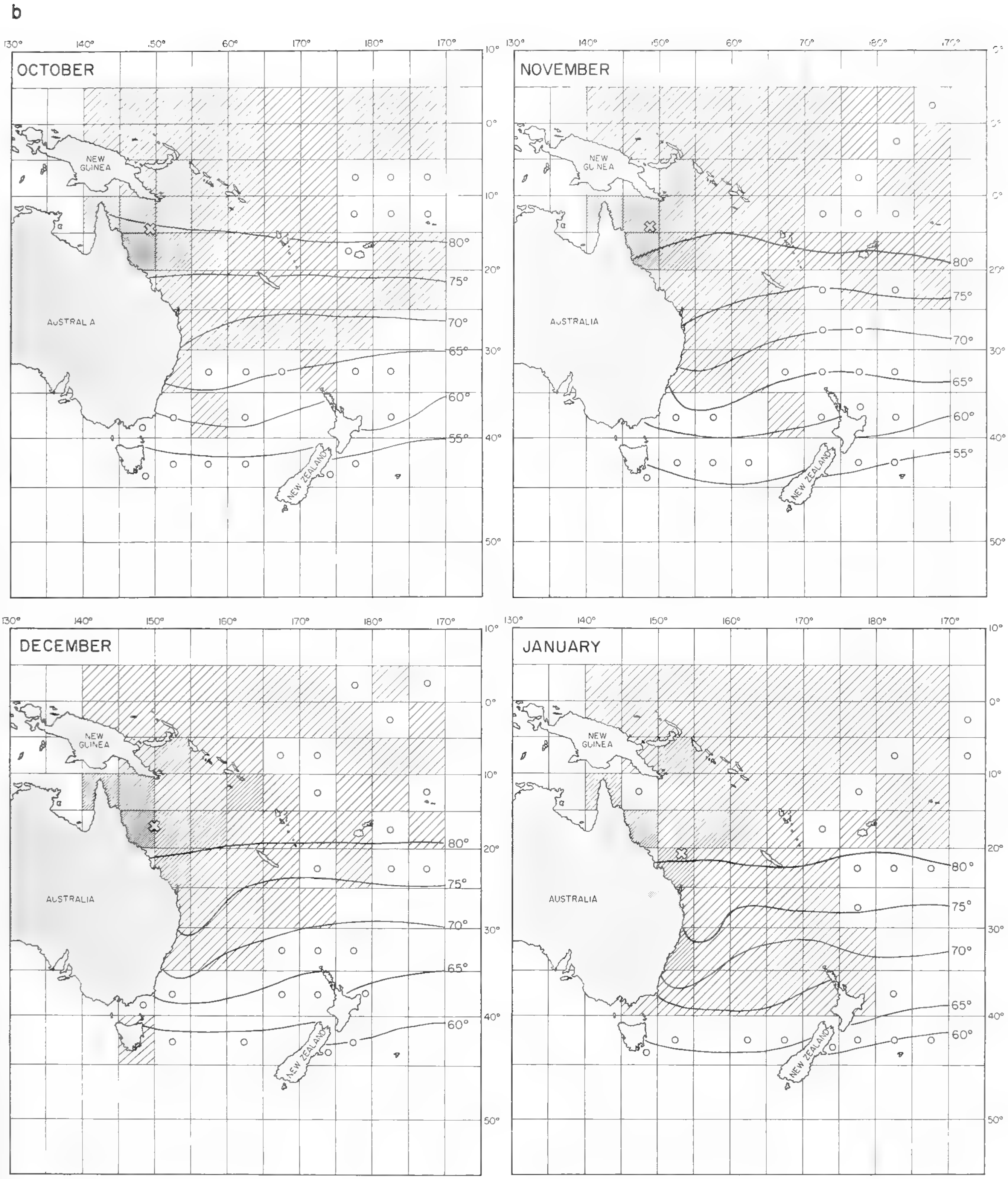


Figure 14.—Continued.

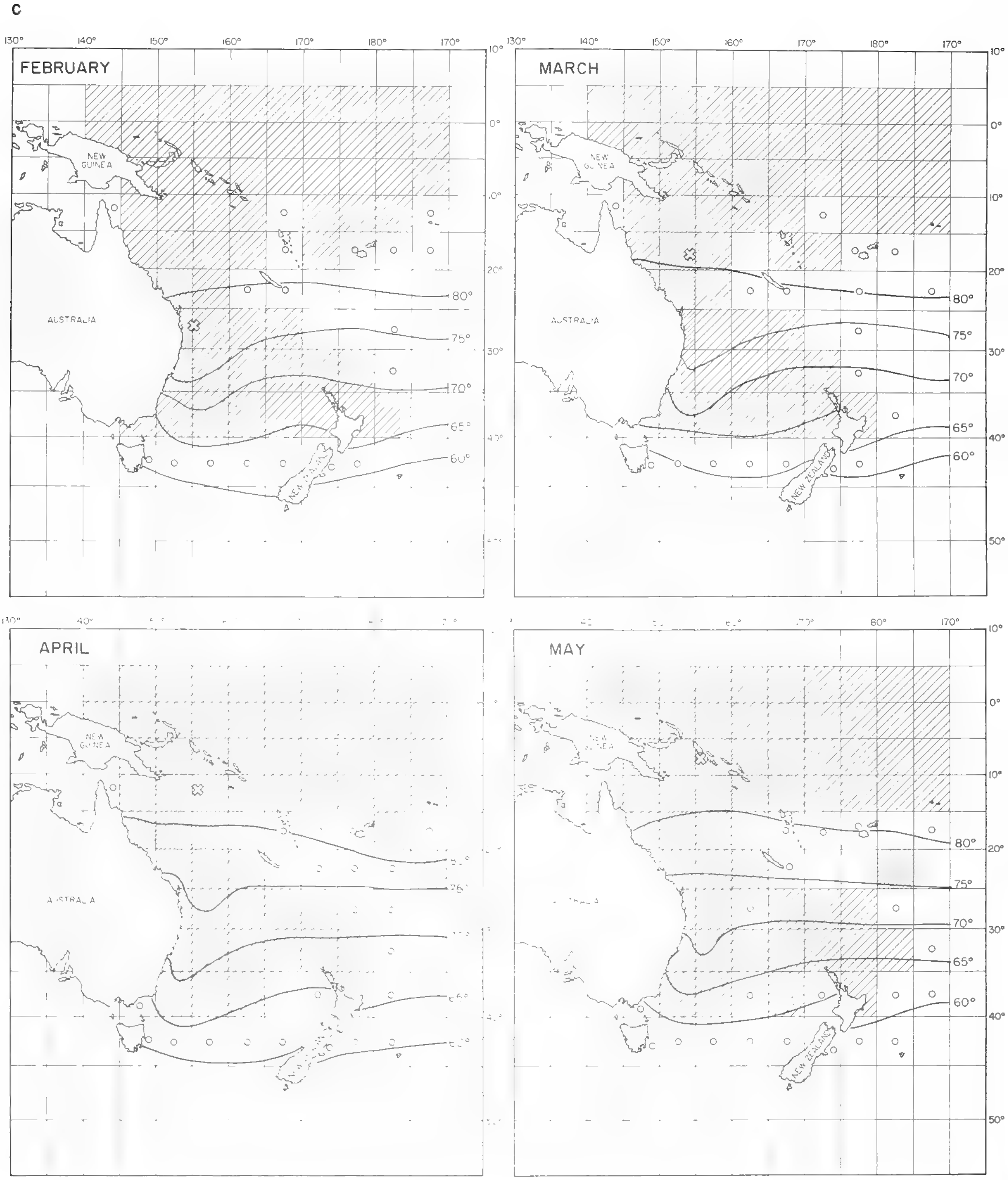


Figure 14.—*Continued.*

Low CPUE levels of black marlin, < 0.5 marlin/1,000 hooks, are common throughout most of the southwest Pacific from lat. 30°S northward during every month of the year. The southerly limit in the summer through fall (January-May) is about lat. 40°S. The only area commonly showing a low CPUE level throughout the year is the area from New Caledonia east, in a latitudinal band of lat. 10° to 20°S. A retraction of the low CPUE levels to the northwest from the New Zealand area is observed in October through December. CPUE data indicate that minor catches of black marlin could be expected in many areas of the southwest Pacific in most months.

To better define the changes in areas of high CPUE, the approximate center of high CPUE was estimated and its geographical position by month is given in Figure 15. A progressive southward movement of high CPUE areas from the tagging area is observed for December and January, reaching its southern-most limit by February. A substantial geographical shift in high CPUE center from about lat. 28° to 18°S has occured. In April, the shift is northeastward to the Solomon Islands area (lat. 10°S). CPUE center moves northwestward to about lat. 5°S in May and June. The southward movement is again evident in July-September, shifting the high CPUE center from lat. 5°S to about lat. 10° to 11°S between New Guinea and the Solomon Islands.

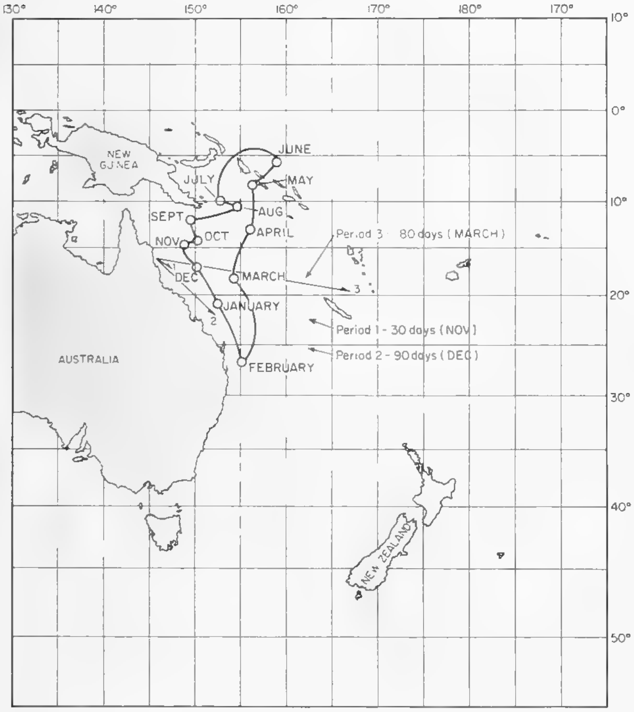


Figure 15.—Monthly movements of the approximate center (as determined by eye-fit) of high longline CPUE for black marlin as observed in Figure 14a, b, c.

DISCUSSION AND SUMMARY

The north Queensland, Australia, area is one of the most productive locations in the Pacific for anglers using rod-and-reel to catch black marlin. The excellent fishing attracts anglers from about the world, as indicated by the several countries represented in the tag recovery summary (see Table 2). An important factor was that many of the anglers and charterboat operators in this area were willing to tag and release black marlin. The number of black marlin tagged off north Queensland (2,576) is the sum of tag report forms returned by cooperating anglers. This represents a minimum number of fish tagged, since some report forms are not returned to the tagging agency (Squire 1974). The extent of nonreporting of releases is assumed to be minimal in this area because of the excellent management of the tagging effort by the Cairns Game Fishing Club which distributed the tagging equipment and maintained accurate records.

Of the black marlin reported tagged during 1968-78, 60 tags were returned for an overall return rate of 2.3%. The maximum return rate was observed in 1974, 5.1% for 335 marlin tagged with H-type tags. This is a greater return rate than the 0.9% rate experienced for striped marlin tagged by anglers in the northeastern Pacific (Squire 1974). For recapture data having information on sex, 89% were reported to be males.

The average weight of black marlin, as estimated at the time of tagging, was approximately 175 kg (385 lb) each. Table 5 indicates that substantial overestimates of black marlin weight at tagging were recorded. The ability of an angler to estimate accurately the weight of a large fish such as a black marlin actively swimming in the water is subject to considerable error. The data presented indicate that a reasonable level of accuracy (one that might produce growth rate data or allow estimates of annual average size) is not possible without the application of correction values. Estimated weight data, given by average weight per year (Fig. 3), indicate that estimated weights peaked in 1974 at 201 kg (445 lb)/fish. Average shoreside landing weights, as recorded by the Cairns Game Fishing Club, are about twice the estimated average weight of tagged fish (Table 4). This would indicate that the fish being landed for weighing are the large ones, and are not representative of the average weight of all marlin caught. Landing larger marlin, rather than tagging and releasing them, would tend to bias the average estimated tagging weight lower. Figure 3 also shows an increase in tagging effort northward along the Great Barrier Reef to latitudes < 15°30′S from the area immediate to Cairns, Australia (lat. 17°S). This increase in tagging is evident in the latitudinal band 15°30′ to 14°30′S, beginning in 1972.

The fish recaptured at 1, 2, and 3 yr after tagging, were recaptured relatively close to the point of tagging. Fish released about 1 yr earlier were recovered a mean distance of 38.4 nmi, and 2 yr earlier, at 58.3 nmi, from the point of tagging. The recovery of tagged fish at annual increments near the tagging location indicates that there is a tendency for at least some tagged black marlin to return to the northwestern Coral Sea.

To better define seasonal migratory patterns, tagging effort should be distributed throughout the species range. In most cases where tagging of oceanic species is conducted, the ideal distribution is not achieved. The tagging effort reported on in this paper is from one portion of the black marlin distributional range in the western Pacific and the associated Indo-Pacific area (Fig. 1). Black marlin are presumed to spawn in the Coral Sea between October and December (Ueyanagi 1960), and tagging takes place at this time at or near the spawning area. Black marlin are usually caught by anglers in proximity to the outer edge of the Great Barrier Reef, and most tagging takes place in this area. The commercial longline fishing operations take place offshore from the tagging area. The tagging area is within the high black marlin CPUE area for commercial longline gear during the September-December period (see Fig. 14a, b, c) and is also within an area of moderately high longline effort (see Fig. 13). Because of the commercial longline effort in this area, a number of short-term (0-60 d) recoveries were obtained. Of importance in evaluating the tag return data for migratory patterns is the relationship between a shift of the high CPUE areas and the frequency of recoveries in these areas. Recoveries about 6 mo, and 1 or more years after tagging, are most important, if one is to assume a seasonal migratory pattern exists.

Most of the tag and recovery geographical plots given in Figures 5 to 10 tend to give the impression that all migration is radiating outward from a geographically localized point of tagging, and that the tagging location is the "center" of distribution; this is not the case. Black marlin are tagged in an area as they migrate through it at varying rates and directions.

Emigration from the area of tagging during the first few months appears, for most recoveries, to be toward the south-southeast. An overall mid-point average for the first 0-60 d of release ($\bar{x}$ = 30 d) was 109 nmi; for period 2, 61-120 d ($\bar{x}$ = 90 d), 547 nmi; and for period 3, 121-240 d ($\bar{x}$ = 180 d), 1,386 nmi. Arc distances given in Figure 12 show that, based on average distance/time (180 d and 1,386 nmi), the average distance of migration would be from about southern New South Wales, just east of the New Hebrides, northeast to midway between Solomon Island and the Gilbert Islands to the Equator. The longest distance recorded was to the southeast of the tagging area, east of New Zealand (2,100 nmi, or 8.9 nmi/d). For black marlin recovered 121-240 d after tagging, the average rate was 7.7 nmi/d and in the time period of 180 d the average distance traveled at that rate would be 1,386 nmi. However, this sample, having a release time of 0-240 d, represents only 13.5% of the total recoveries. Based on average migration rate data, black marlin tagged early in the season (September) tended to migrate away from the point of tagging at a lower average rate for the first time period (0-60 d) than black marlin tagged in October, November, or later in the fishing season. This may be because the tagging areas are in or near the spawning area, and the behavior of black marlin in this area earlier in the spawning season may be different from those entering later in the season.

Data obtained from this study indicate that black marlin tagged in the western Coral Sea do not undergo short-term trans-Pacific migrations, although some interchange over time with the eastern Pacific is possible. The degree of interchange with the Indo-Pacific is unclear. Emigration from the tagging area to north of New Guinea was recorded; however, no recoveries were recorded to the east in the Arafura, Banda, or Timor Seas or the eastern Indian Ocean.

Some tentative estimate of the central tendency of migration direction and rate can be made using the vector analysis (Fig. 11), the graphic plots of tag and recovery points (Figs. 4 to 9), and movements of high CPUE areas over time (Fig. 14a, b, c), in relation to the geographical distribution of longline effort levels in the southwest Pacific (Fig. 13). Figure 15 gives the approximate geographical centers of high longline CPUE by month as observed in data presented in Figure 14a, b, c. Inspection of the longline CPUE rates for the 5° areas and plots of geographical location indicate south or southeast movement from the tagging area in the summer and then a northward movement of high CPUE areas to the New Guinea-Bismark Archipelago-Solomon Islands area in the winter. Vector mean bearing and distance data from tag results were plotted in Figure 11 and indicate direction and distance of migration away from the tagging area for 30, 90, and 180 d from October, the month having the most tagging activity (49%).

Monthly average sea surface temperature isotherms are shown in Figure 14a, b, c. High longline CPUE areas for black marlin are located in close relation to the 26.7°C (80°F) average isotherm during most months of the year. High CPUE areas are related to lower temperatures and are found between the 23.9°C (75°F) and 26.7°C (80°F) isotherms only in February off the Queensland and New South Wales coasts. Latitudinal warming and cooling as reflected in sea surface temperature may be a measure of other physical or biological environmental parameters that may be important to black marlin distribution.

From the results of tagging (emigration rates and directions), inspection of average longline effort, and CPUE, a diagramatic description of black marlin migration in the southwestern Pacific can be hypothesized (Fig. 16). The tagging results indicate that the migratory rates and patterns of black marlin are highly variable. There is, however, a central tendency of movement of tagged fish not unlike that expected from observations of the movements of CPUE trends. Black marlin were observed to move southward from the tagging area toward southeastern Australia and New Zealand in late summer, then northeast toward the Gilbert Islands, and to northeast of New Guinea in the winter, returning to the western Coral Sea in the spring and early summer. The interchange rate of the population found in the Coral Sea, with the population of the Indo-Pacific area, is unclear. The relationship of the Coral Sea population to that in the central Pacific and other areas in the western Pacific is also not defined. Though no recoveries have been made in these areas, some population interchange could be expected.

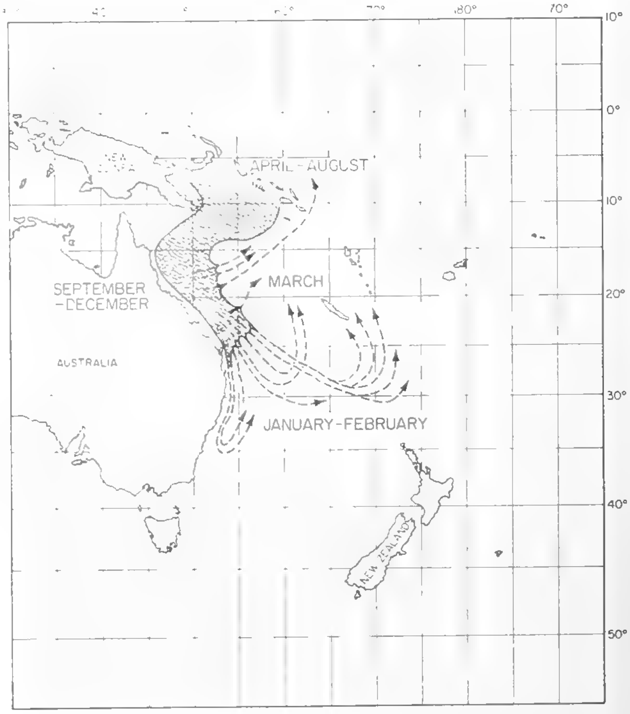


Figure 16.—A hypothetical description of black marlin migration in the southwest Pacific Ocean.

ACKNOWLEDGMENTS

The cooperation of the marine anglers who caught, tagged, and released black marlin made this study possible. We wish to convey our appreciation to the marine anglers, and to the Japanese and Korean commercial longline fleet captains and crews who recaptured tagged marlin and returned the tags.

Many of the recoveries were returned through either the Far Seas Fisheries Research Laboratory, Shimizu, Japan, or the Kanagawa Prefectural Fisheries Experimental Station, Joga Shima, Kanagawa Prefecture, Japan. We are grateful to scientists Eiji Hanamoto of the Kanagawa Fisheries Experimental Station, and Shoji Ueyanagi, Susumu Kume, and Shoji Kikawa of the Far Seas Fisheries Research Laboratory for their assistance in return of marlin tags and information used in the analysis. The interest of the charterboat captain in learning more about the resource on which he fishes often results in the marlin being tagged, although the anglers are credited for tagging and releasing the marlin. To the charterboat fleet off Cairns and nearby areas, our sincerest appreciation.

The Cairns Game Fishing Club provided excellent control of tagging equipment and maintained complete and accurate records of tagged fish throughout the years, thereby making the tagging analysis more accurate. Their precision handling of the program is appreciated.

To Julian Pepperell of New South Wales State Fisheries, who furnished a portion of the data used in this analysis, our sincere appreciation. The efforts of Norman Bartoo and Richard Evans (SWFC) in statistical analysis of the data are acknowledged. To others such as the International Game Fish Association and marine game fish anglers throughout the world who gave their support, we thank you.

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Food Habits and Trophic Relationships of a Community of Fishes on the Outer Continental Shelf

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Food Habits and Trophic Relationships of a Community of Fishes on the Outer Continental Shelf

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U.S. DEPARTMENT OF COMMERCE
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Food Habits and Trophic Relationships of a Community of Fishes on the Outer Continental Shelf[1]

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ABSTRACT

The demersal fish community of the Outer Continental Shelf in the Middle Atlantic Bight consists of resident species (*Lophius americanus*, *Citharichthys arctifrons*, *Paralichthys oblongus*), seasonal species with boreal affinities (*Raja erinacea*, *Urophycis chuss*, *Merluccius bilinearis*, *Macrozoarces americanus*), and seasonal species with warm-temperate affinities (*Urophycis regia*, *Stenotomus chrysops*). Although most dominant demersal fishes of the Outer Continental Shelf feed primarily on dense, stable macrobenthic invertebrate communities, some feed on fishes, cephalopods, and planktonic invertebrates. In addition to seasonal changes in prey species preference, food habits change considerably with fish size. Most predator species share many prey species. Overlap in diet among predators varies seasonally, with overlap relationships changing as species and size-class composition of the predators changes. Intraspecific diet overlap between size classes is low, but higher interspecific overlap occurs between species of similar size. Dietary overlap is lowest in the spring, when planktonic and nektonic organisms are consumed by most size classes of dominant predators. Although many important prey species are consumed by several predators, some are selectively consumed by only a few predators, so that there is never complete dietary overlap between two species.

INTRODUCTION

Studies of the food habits of fishes are essential to a complete understanding of the functional role of fishes in aquatic ecosystems. Research in this field has resulted in an abundance of papers dealing with the food habits of individual species, but fewer studies have related food habits to community structure, including patterns of competition, resource partitioning, or prey selectivity. Some experimental and field studies have focused on resource partitioning, including food subdivision in closely related species (McEachran et al. 1976; Werner and Hall 1976; Chao and Musick 1977; Ross 1977; Langton and Bowman 1980). Fewer studies have dealt with the feeding ecology of entire marine fish communities (Tyler 1972; Gatz 1979). Study of diet overlap is essential to understanding competitive coexistence and species diversity (Pyke et al. 1977) and hence community structure.

The continental shelf areas of the Middle Atlantic Bight have been a focus of benthic biological research in recent years (Boesch 1972; Pratt 1973; Steimle and Stone 1973; Pearce et al. 1976), and distribution and abundance of fishes have also been examined (Tyler 1971; Musick 1974; McEachran and Musick 1975; Clark and Brown 1977; Musick and Mercer 1977; Musick et al. 1979). The fish fauna on the continental shelf of the Middle Atlantic Bight consists of a highly migratory component of boreal and warm-temperate species and a small resident component (Tyler 1971; Musick et al. 1979). Stomach contents of some of the dominant species on the Middle Atlantic Outer Continental Shelf have been reported in faunal and taxonomic works and in life history studies (Bigelow and Welsh 1925; Nichols and Breder 1927; Olsen and Merriman 1946; Bigelow and Schroeder 1953; Fitz and Daiber 1963; Richards et al. 1963; Barans 1969), and some food habits studies have been done (Jensen and Fritz 1960; Sikora et al. 1972; Vinogradov 1972; McEachran et al. 1976; Langton and Bowman 1980, 1981).

The purposes of this report are to describe the food habits of dominant demersal fishes on the Middle Atlantic Outer Continental Shelf, to describe diet overlap patterns, and to relate these patterns to predator size and seasonality and to seasonal prey abundance.

METHODS

Two areas were selected for intensive fish sampling: Area B (approximately 735 km^2) off Atlantic City, N.J.; and Area E (approximately 540 km^2) off Delaware Bay (Fig. 1). These areas were chosen for the great habitat variety of their complex topography. The bottom of both areas is characterized by a series of ridges, swales, scarps, and flats which support different benthic invertebrate assemblages (Boesch 1978), and an attempt was made to sample each bottom type. Both study areas were divided into 11 strata, based mainly on depth data taken from U.S. Geological Survey charts and also on available data on the distribution of bottom sediments and previous sampling of macrobenthos.

Sampling for fishes consisted of tows of 15-min duration (at about 6.5 km/h) with a lined, semiballoon otter trawl having a 13.7 m (45 ft) headrope and the following stretch-mesh dimensions: 4.45 cm in the wings, 3.81 cm in the body, 3.96 cm in the cod end, and 1.27 cm in the cod end liner. Six stations, three day and three night, were randomly selected in each stratum for each cruise. Samples were collected seasonally on four cruises, utilizing the RV *Cape Henlopen* (fall 1976, spring and summer 1977) and the RV *James M. Gilliss* (winter 1977).

All fishes captured were identified, measured to the nearest millimeter, and weighed. Standard length (SL) was taken on all dominant species with the exception of *Raja erinacea* (disc width = DW) and *Macrozoarces americanus* (total length = TL). Each fish was dissected and its stomach excised if not conspicuously empty.

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On large catches of some dominant species, random subsamples (at least 30 specimens) were dissected. Each stomach was labeled, individually wrapped in cheesecloth, and fixed in 10% seawater Formalin.

After proper fixation, stomachs were soaked in water and transferred to either 40% isopropanol or 70% ethanol. For analysis, each stomach was cut open and its contents sorted by taxon and counted. Fragments such as crustacean parts, polychaete setae, or fish bones were counted as one animal, unless abundance could be estimated by counting pairs of eyes (crustaceans), otoliths (fishes), or other parts.

Volume displacement of food items was measured by using either a graduated cylinder (Windell 1971) or a calibrated vial and buret (McEachran et al. 1976). Displacement of small species was estimated by using a 0.1 cm^2 grid (Windell 1971).

Since methods of food habits analysis are variously biased (Hynes 1950; Pinkas et al. 1971; Windell 1971), the relative contribution of different food items to the total diet was determined using three methods: 1) The number of stomachs in which a food item occurred was expressed as a percentage of the total number of stomachs of a series containing food (percent frequency of occurrence); 2) the number of individuals of each type of food was expressed as a percentage of the total number of food items from all stomachs for a series (percent numerical abundance); 3) the volume displacement of food items was expressed as a percentage of the total volume of food from all stomachs examined of a series (percent volume displacement).

From these three measurements an index of relative importance, IRI (Pinkas et al. 1971), was calculated for each prey species and each higher taxon as follows:

$$\mathrm{IRI} = (N + V)\,F$$

where: IRI = index of relative importance,
N = numerical percentage,
V = volumetric percentage, and
F = frequency of occurrence percentage.

This index has been useful in evaluating the relative importance of different food items found in fish stomachs (Pinkas et al. 1971; McEachran et al. 1976; Sedberry and Musick 1978). The IRI was used in the present study to describe the food habits of each species and to determine seasonal and predator size differences in the relative importance of food items.

Overlap in diet among dominant predators was measured using cluster analysis. Stomachs of predators were treated as collections and were subjected to normal cluster analysis on the basis of prey similarity, using percent standardized numerical abundance (Clifford and Stephenson 1975), because sample sizes were unequal. Flexible sorting (Lance and Williams 1967; Clifford and Stephenson 1975), with $\beta = -0.25$, was used, based on resemblance measured by the Bray-Curtis similarity index (Bray and Curtis 1957), expressed as follows:

$$S_{jk} = 1 - \frac{\sum_i |X_{ij} - X_{ik}|}{\sum_i (X_{ij} + X_{ik})}$$

where S_{jk} is the similarity in diet between the predator species j and k; X_{ij} is the abundance of the ith prey species for predator j; and X_{ik} is the abundance of the ith prey species for predator k.

RESULTS

Food Habits Analysis

Over 12,500 individual fish were dissected in the field for stomach analysis. A total of 6,087 stomachs representing the nine dominant species was examined in the laboratory. Initially, only seven species were to be examined: *Raja erinacea* Mitchill, *Lophius americanus* Valenciennes, *Urophycis chuss* (Walbaum), *Merluccius bilinearis* (Mitchill), *Stenotomus chrysops* (Linnaeus), *Citharichthys arctifrons* Goode, and *Paralichthys oblongus* (Mitchill). *Urophycis regia* (Walbaum) and *Marcrozoarces americanus* (Schneider) were added to this list because they were dominant species in the catches in summer 1977 (Table 1).

Raja erinacea.—The little skate was abundant in the study area at all times of the year (see Table 1), feeding mainly on amphipods, decapods, cumaceans, and polychaetes (Fig. 2, Table 2). Pelecypods, fishes, and isopods were also consumed. The relative importance of these major taxa of food remained fairly constant seasonally, although juvenile fishes were somewhat more important and cumaceans less important in fall samples. Juvenile fishes were also important in the diet of *R. erinacea* in the summer. Although the relative importance of the major taxa was nearly constant seasonally, the species composition of these taxa in the diet changed somewhat seasonally (Table 2).

The food habits of *Raja erinacea* varied greatly with size (Fig. 3). Smaller skates fed more on amphipods and cumaceans, whereas larger skates fed more on decapods and polychaetes. The smallest skates (1–100 mm DW) fed on numerous small food items (Fig. 4), and fed on these in increasing numbers up to 200 mm DW. At about 200 mm DW, *R. erinacea* showed the most pronounced change in food habits and feeding strategies, switching to fewer, larger food items (primarily decapods).

Lophius americanus.—The goosefish, though not as abundant as many other fishes on the outer shelf, was common and composed a considerable portion of the biomass of fishes in the study areas because of its large size (Table 1). Goosefish fed mainly on fishes and to a lesser extent on benthic invertebrates during all seasons (Fig. 5, Table 3). Decapods and cephalopods were less important as food, and polychaetes, amphipods, asteroids, and chaetognaths were only occasionally found in stomachs. Fishes were the most important food for all sizes of *L. americanus* (Fig. 6), although larger fish were eaten by larger *L. americanus* (Fig. 7).

Urophycis chuss.—Although red hake were abundant during this study, size composition of the population varied seasonally. Juveniles predominated in fall ($\bar{x}$ SL = 49 mm) and summer ($\bar{x}$ SL = 147 mm), but were rare in winter and spring, when larger fish moved into the area ($\bar{x}$ SL = 251 and 238 mm, respectively). This was reflected in the much smaller contribution of this species to the biomass of fishes during the fall and summer (Table 1).

Red hake fed primarily on amphipods, which were important as food at all times of the year, especially in fall. During this season they made up most of the diet (Fig. 8, Table 4). Decapods and polychaetes were also dominant prey taxa, and copepods were important in fall and winter. Chaetognaths, absent from the diet in fall and winter, were commonly consumed during the spring and summer. Much seasonal variation was observed in the diet at the species level within these higher taxa (Table 4), particularly within the Amphipoda.

Small red hake ate amphipods (mainly planktonic hyperiids) and copepods (Fig. 9), whereas decapods and polychaetes were important dietary items for larger *U. chuss*. Chaetognaths were ingested by all size classes. Red hake fed on increasing numbers of increasingly larger prey items up to a length of about 300-350 mm SL (Fig. 10), where the feeding strategy of *U. chuss* changed, with fewer prey items of much larger size being consumed.

Urophycis regia.—Spotted hake were common in the study area in fall but were more abundant in summer. They were rare in the colder months, and only two were captured in winter.

Decapod crustaceans were the most important food for spotted hake based on seasons for which adequate data were available (Fig. 11, Table 5). Fishes and amphipods were next in importance in fall and summer, and the relative importance of these and other taxa of food was similar during these seasons. The relative importance of these taxa was different in spring samples, but this may reflect the small sample size.

Spotted hake fed on increasing numbers of decapods with increasing size of the fish (Fig. 12). Numbers of fishes consumed by *U. regia* decreased in relative abundance; however, the percent volume increased, indicating that larger *U. regia* fed on larger fishes. Amphipods decreased numerically in larger fish, and cephalopods, while remaining constant in relative abundance, became volumetrically important in the largest *U. regia*. Spotted hake demonstrated a distinct change in feeding strategy at about 250 mm SL (Fig. 13). The size of individual prey items increased by an order of magnitude, and fewer were consumed.

Merluccius bilinearis.—Silver hake were abundant in the study area at all times of the year but less so in spring. Juvenile fish (<100 mm SL) dominated the catches in fall and summer. Food habits of this species varied greatly with season (Fig. 14, Table 6). Amphipods were the primary food in fall, winter, and summer. Fishes were second in importance in winter and summer and were relatively unimportant in fall and spring. Cephalopods replaced fishes as the second most important prey in spring and were also quite important in fall. Decapods were third in importance in winter and summer, whereas copepods and amphipods were third in fall and spring, respectively. Chaetognaths were absent in the diet in fall, were infrequent in winter, but were the most important prey taxon in spring. They were also consumed in summer.

The food habits of *M. bilinearis* changed with size (Fig. 15). Amphipods were relatively numerous in all size classes except the largest, but they steadily decreased in relative volume in larger fish. Fishes and cephalopods were numerically dominant in larger fishes and made up the bulk of food in larger silver hakes. Decapods had the highest IRI in small and medium-sized fish (101–200 mm SL) and chaetognaths were important for medium-sized fish.

Silver hake fed on small food items up to a fish length of about 350 mm SL (Fig. 16). Average prey size increased at 351-400 mm SL, and continued a sharp increase in size up to the largest fish sampled. Average number of prey per stomach fluctuated, but reached a maximum at fish lengths of 251-300 mm SL.

Macrozoarces americanus.—The ocean pout varied greatly in its relative abundance, but at times made up a significant portion of the catch (Table 1). Abundances were low in fall (23 individuals), winter (46 individuals), and spring (84 individuals). In summer, however, juvenile ocean pout were common (397 individuals).

Ocean pout fed mainly on amphipods and decapods (Fig. 17, Table 7), which made up a large proportion of the diet at all seasons of the year except fall when all stomachs were empty. Polychaetes were important in the diet in winter and spring but were rarely consumed in summer. Cumaceans and pelecypods were eaten in small amounts during most seasons, and echinoids were important in winter.

Smaller ocean pout consumed more amphipods than decapods, and amphipods made up a large volume of the food eaten (Fig. 18). Larger ocean pout fed more heavily on decapods, which made up the greatest volume of food for larger fish. Although the total volume of food consumed did increase regularly from small to large fish, the mean volume of each prey item fluctuated, as did the number of prey consumed (Fig. 19).

Of the 23 ocean pout captured on the fall cruise, none had food in their stomachs. Olsen and Merriman (1946) also noted a high percentage (36–75%) of empty stomachs among their fall samples. They suggested that this may indicate a tendency to stop feeding either during spawning or movement into rocky winter habitats.

Stenotomus chrysops.—Scup were abundant in the study area in the fall, with only a few individuals taken on other cruises (Table 1). Food habits analysis was limited to fall samples.

Scup fed mainly on amphipods and polychaetes, and polychaetes made up the largest volume of food (Fig. 20, Table 8). Decapods, copepods, gastropods, and cumaceans were of lesser importance. Numerous other taxa were infrequently consumed (Table 8).

The food habits of scup changed with increasing fish size (Fig. 21). Amphipods decreased in relative abundance in larger fish, and gammarideans replaced hyperideans in the diet of larger scup. Polychaetes, especially the larger species (e.g., *C. infundibuliformis*), increased in abundance and became the most important food in the largest fish. Copepods were mainly consumed by small scup, and decapods were slightly important for all size classes. The smallest scup ate large numbers of small prey, mainly amphipods and copepods (Fig. 22), but scup of 101–150 mm SL fed on fewer, but larger, items. Mean volume per prey item remained relatively constant for fish larger than 150 mm SL, and larger scup again fed on increasing numbers of food items, thus increasing the total volume of food consumed.

Citharichthys arctifrons.—The Gulf Stream flounder was abundant at all times of the year, especially summer (Table 1). Amphipods and polychaetes were the most important prey taxa consumed by this species during all seasons; however, polychaetes exceeded amphipods in relative importance in the spring and were second during other seasons (Fig. 23, Table 9). Several other groups were consumed seasonally. Larvaceans and cumaceans were important in the diet in spring. Fishes were very important in summer, and copepods and ostracods were of minor importance in the fall.

Amphipods had the highest IRI in all size classes of *C. arctifrons* (Fig. 24). Polychaetes increased in importance in the diet of larger fish, and made up the greatest volume of prey in the largest size class. Copepods were important for smaller fish, whereas larger fish consumed more cumaceans. Small fishes were consumed by intermediate sized *C. arctifrons*.

Gulf Stream flounder demonstrated a more gradual change in feeding habits with size (Fig. 25). Average stomach volume, the mean prey number per stomach, and mean volume per prey item increased almost linearly with increasing fish length. In Gulf Stream flounder there was no sudden decrease in the number of prey per stomach with a corresponding large increase in average prey size. Small food items (i.e., amphipods) remain the most important food for all size classes of *C. arctifrons*.

Paralichthys oblongus.—Fourspot flounder were common in the study area on all cruises (Table 1). Decapods were the most important prey at all times of the year (Fig. 26, Table 10). Amphipods were very important in winter and spring, but fishes apparently replaced amphipods in the diet in fall and summer. This seasonal shift from amphipods to fishes reflected the seasonal abundance of small fishes in the study area and also seasonal differences in the size composition of the predator population. Fourspot flounder captured in winter and spring were slightly smaller ($\bar{x}$ SL = 196 and 180 mm, respectively) than those taken in fall and summer ($\bar{x}$ SL = 214 and 221 mm, respectively) and fed more on smaller prey items such as amphipods. Cephalopods were frequently consumed in the fall.

Amphipods were the most abundant food for smaller fourspot flounder, although decapods contributed most to the volume of food for all size classes (Fig. 27). Amphipods steadily decreased in relative abundance in larger fishes, when decapods became the most abundant food. Fishes, polychaetes, and cephalopods contributed more to the diet of larger *P. oblongus*.

Mean prey number per stomach remained relatively constant for all size classes of *P. oblongus* (Fig. 28). However, as larger fish switched to larger prey items, mean total volume of stomach contents increased.

Overlap in Diet

Overlap in diet varied seasonally with changes in species and size composition of the predator community (Fig. 29). *Merluccius bilinearis* and *U. chuss* showed the greatest similarity in diet in fall (Fig. 29A), when smaller individuals ($\bar{x}$ SL = 127 and 51 mm, respectively) dominated in the study area and fed mainly on small planktonic crustaceans such as *Parathemisto gaudichaudi* and *Centropages typicus*. *Stenotomus chrysops* also fed heavily on these two species and was classified with this group. *Raja erinacea* and *C. arctifrons*, both of which fed heavily on *Unciola irrorata*, *Byblis serrata*, and *Ampelisca vadorum*, were grouped together. *Paralichthys oblongus* and *U. regia* were more similar to each other in their diets than to other fishes in fall. Decapods and fish were the two most important food taxa for these species in fall, and amphipods were also important for both species. *Lophius americanus*, being primarily piscivorous, had little similarity in diet to other species but was classified with *P. oblongus* and *U. regia* which also ate fish.

In winter, predator groups changed for several reasons (Fig. 29B). First, *S. chrysops* was absent from the study area, and *M. americanus* became common and was included in the classification. Also larger *U. chuss* ($\bar{x}$ SL = 250 mm) and *M. bilinearis* ($\bar{x}$ SL = 282 mm) were present. *Unciola irrorata* and *Erichthonius rubricornis* were the most abundant food items for *P. oblongus*, *M. americanus*, *R. erinacea*, *C. arctifrons*, and *U. chuss*, and all of these species formed a group with high similarity. The one *U. regia* captured had eaten fish and was classified with *L. americanus*. *Merluccius bilinearis*, which fed mainly on hyperiids, copepods, *Dichelopandalus leptocerus*, and chaetognaths, differed in its diet from all other species. However, since *M. bilinearis* consumed fish, it was joined to this latter group at a lower level of similarity. The larger *M. bilinearis* present in the winter fed on different prey than smaller *M. bilinearis* and cooccurring larger *U. chuss*. Although *M. bilinearis* and *U. chuss* had similar diets in fall as juveniles, their adult diets were quite dissimilar in winter, when large *U. chuss* ate more benthic prey and *M. bilinearis* continued to feed on planktonic species. Also in winter, *P. oblongus* fed on more amphipods than decapods and fishes, and was grouped with other amphipod feeders.

In spring (Fig. 29C), as in winter, the corophiid amphipods *U. irrorata* and *E. rubricornis* were the most important food for several predators, and the classification was similar to winter, although similarity values between predators were lower. *Paralichthys oblongus* and *R. erinacea* fed heavily on *U. irrorata*, *E. rubricornis*, and *B. serrata* and showed the highest similarity of any predator pair. *Urophycis chuss*, *C. arctifrons*, and *M. americanus* also fed heavily on *U. irrorata* and *E. rubricornis*. They were included in this group, although they also fed heavily on other species. *Lophius americanus*, *U. regia*, and *M. bilinearis*, though somewhat dissimilar in diet, were more dissimilar to other predators and formed a separate group because all three species consumed fishes.

In summer, *C. arctifrons* and *M. americanus* displayed the greatest similarity in diet, when *C. arctifrons* again fed heavily on amphipods and *E. rubricornis* and *U. irrorata* were the most abundant species consumed by both predators (Fig. 29D). *Raja erinacea* and *U. chuss* again fed heavily on both these species during summer and were included in this group, but *R. erinacea* also fed heavily on ampeliscid amphipods, whereas *U. chuss* consumed many *Sagitta elegans* and *P. gaudichaudi*. *Parathemisto gaudichaudi* and *D. leptocerus* were the most abundant species consumed by *M. bilinearis* and *U. regia*, both of which also fed on fishes. *Paralichthys oblongus* switched to a fish and decapod diet in summer and was classified with *L. americanus* since both fed heavily on fish, primarily *M. bilinearis*. *Dichelopandalus leptocerus* was consumed by both species, so they were joined to *M. bilinearis* and *U. regia*.

A classification of predators from all seasons indicated two major groups of similar feeders (Fig. 30). One group (Group I, Fig. 30) fed mainly on benthic amphipods, primarily *U. irrorata*, *E. rubricornis*, *B. serrata*, and *A. vadorum*, and brachyuran decapods (primarily *C. irroratus*). A second major group (Group II, Fig. 30) fed mainly on hyperiids, copepods, fishes, and caridean decapods (primarily *D. leptocerus*). While some fishes consistently fed similarly during all seasons (e.g., *R. erinacea*), several predators belonged to both groups, switching at various seasons. Thus *U. chuss* fed mainly on hyperiids and copepods in the fall at which time it was classified in Group II; during other seasons red hake were included in Group I. *Urophycis regia* also fed differently in the fall from other seasons and was classified in Group I in the fall. *Paralichthys oblongus* fed preferentially on small fish in summer and fall, the period of their greatest abundance, but fed more on amphipods in winter and spring.

Although the food habits of some species appeared to change seasonally, this phenomenon may be attributed to seasonal changes in size-class composition of the predators in the study area. The food habits of most predators changed dramatically with size. Thus, diet overlap between species could be greater than that between different-sized fishes of the same species. To resolve such differences, each size class within a species was treated as an entity in the normal classification for each season (Figs. 31–34).

In fall, four major groups appeared in the classification (Fig. 31). The first (Group I, Fig. 31) was composed of small-to-medium skates, medium spotted hake, large fourspot flounder, small red hake, and medium-to-large scup. These fishes fed mainly on corophiid and ampeliscid amphipods and caridean decapods. Group II consisted mainly of piscivores, such as *L. americanus* and large *M. bilinearis*, and other fishes which had prey in common. Group III consisted of large fishes having *C. irroratus* as their most abundant food item. Finally, Group IV consisted of small *U. chuss* and *S. chrysops* and small-to-medium *M. bilinearis*, all of which fed heavily on hyperiid amphipods while consuming copepods and caridean decapods as well.

Small *R. erinacea* overlapped incompletely with other amphipod consumers, especially medium *U. chuss*, small *U. regia*, and large *P. oblongus* (Group I, Fig. 31). Medium-to-large *R. erinacea* also showed a very high similarity in diet to these three species (Group III, Fig. 31), but their prey (mainly *C. irroratus*) were quite different at this size. Thus, interspecific diet overlap, rather than intraspecific, was greater for these species. Small *S. chrysops* were very similar in diet to small *U. chuss* and *M. bilinearis* (Group IV), but were different from larger *S. chrysops*, which shared food items with medium *U. chuss* and *C. arctifrons*. Other examples of higher interspecific vs. intraspecific diet overlap were also evident (Fig. 31).

In winter, three major groups of similar feeders were classified (Fig. 32). Group I was composed of those fishes (Subgroup I-A) such as *L. americanus* and large *M. bilinearis* which fed largely on fishes (primarily *U. chuss*) and a few carideans (*D. leptocerus*); and those fishes (Subgroup I-B) which fed on hyperiids and carideans as well as fishes. As in fall, small *M. bilinearis* and *U. chuss* had similar diets and constituted a group (Group II) with high similarity. Group III (Fig. 32) was comprised of five species in several size classes; all fed primarily on corophiid amphipods (*U. irrorata* and *E. rubricornis*). Two subgroups were present: Subgroup III-A was comprised of small *P. oblongus*, *R. erinacea*, *C. arctifrons*, and large *M. americanus*, all of which had *E. rubricornis* as the most abundant food item. Subgroup III-B consisted of larger *P. oblongus*, *U. chuss*, *C. arctifrons*, *R. erinacea*, and small-to-medium *M. americanus*. With the exception of the largest *H. oblonga*, all size-classes of these species fed primarily on *U. irrorata* (the second most important food for large *H. oblonga*). *Erichthonius rubricornis* was the second most abundant food for most of these entities. Further subgroups (1 and 2) were distinguished by a secondary preference for other amphipods or alternatively for decapods. A multispecies group of large fishes which fed mainly on *C. irroratus* was absent in winter.

In winter, as in fall, different size classes within a species of predator were classified in different groups. Small *R. erinacea* fed mainly on *E. rubricornis* and overlapped with *M. americanus*, small *P. oblongus*, and small *C. arctifrons*. Medium *R. erinacea* fed mainly on *U. irrorata*, *E. rubricornis*, *D. sculpta*, and *B. serrata*, overlapping with large *U. chuss*, *M. americanus*, and again with larger *P. oblongus*. The largest class of skates also fed heavily on *U. irrorata*. Again, as in the fall, small *U. chuss* overlapped in diet most closely with small *M. bilinearis*. However, larger *U. chuss* fed more on gammarideans and decapods and were classified with similar feeders (Subgroup III-B). Large and medium *M. bilinearis* fed on fishes and were grouped with other piscivores, but small individuals fed on items similar to those taken by small *U. chuss*. All *M. americanus* fed primarily on gammarideans and were included in Group III. Small *C. arctifrons* and *H. oblonga* were similar in diet (Subgroup III-A), and larger individuals of these species were grouped with other gammaridean feeders (Subgroup III-B).

In spring (Fig. 33), the classification of predator entities resulted in several small groups, each characterized by high intragroup diet similarity. These groups were in turn joined together at lower levels of similarity. An additional large multispecies group consisted of several loosely joined entities (Group I). This group consisted mainly of piscivores such as *L. americanus*, large *U. chuss*, and small *U. regia*. These last two species also ate *C. irroratus*, in addition to fishes, and were joined with other decapod consumers (*M. americanus*, large *U. regia*, and large *H. oblonga*). The largest sizes of *M. bilinearis* consumed cephalopods (*I. illecebrosus*) and fishes (*C. arctifrons*) and were included in this rather dissimilar group.

The smaller, more similar groupings present in spring (e.g., Group II) were monospecific in many cases, indicating more specialization in the diet within each species, and less interspecific overlap in food in the spring. Thus, small and medium *M. bilinearis* (Group II) consumed predominantly *S. elegans* and were grouped together. Larvaceans were the most abundant prey for all sizes of *C. arctifrons*, and all sizes of this predator clustered together. Most size-classes of *M. americanus* clustered with small *R. erinacea*. Both species fed mainly on *E. rubricornis* and *U. irrorata*. All sizes of *U. chuss* (except the two largest individuals) were included in a single group of high similarity in spring. In fall and winter, small *U. chuss* fed quite differently from large ones and were classified separately with smaller individuals of other species, such as *C. arctifrons*, *S. chrysops*, and *M. bilinearis*. In spring, however, all *U. chuss* except the two largest individuals (451 and 500 mm SL) formed a distinct group. This group of *U. chuss* was joined with another group consisting of larger *P. oblongus* and *R. erinacea*, for which *U. irrorata* was the most abundant prey but which also fed heavily on decapods.

In summer (Fig. 34) interspecific overlap in diet again increased. A rather large group (Group I, Fig. 34) included the many species which consumed fishes during the summer and those species that fed primarily on planktonic invertebrates. Small *U. chuss* and *M. bilinearis* fed similarly, as in fall and winter, and were grouped together (Subgroup I-A, Fig. 34). They had consumed primarily *S. elegans*, *P. gaudichaudi*, and some gammarideans. A single small goosefish which had consumed chaetognaths (*S. elegans*) was included. The remainder of Group I consisted of those entities which had eaten fishes. Group II consisted of fishes for which *C. irroratus* was the most abundant food, followed by amphipods, other decapods, and fishes. This group consisted of large predators of decapods, such as *M. americanus*, *R. erinacea*, *P. oblongus*, and *U. regia*.

Group III consisted of amphipod eaters. *Erichthonius rubricornis* and *U. irrorata* were the two most abundant prey for all fishes in Subgroup III-A, and these two amphipods were also abundant in the diets of other Group III fishes. Other amphipods were also taken by Group III fishes.

In summer, as in most other seasons, different sizes of most predator species were included in different feeding groups. Thus, small *R. erinacea* clustered with other amphipod feeders, and large skates were included with larger individuals of other species which fed on decapods (primarily brachyurans such as *C. irroratus*). Large *U. regia* and *P. oblongus* fed on brachyuran decapods, whereas smaller individuals of both species fed more on fishes and caridean decapods. As in all other seasons except spring, small *M. bilinearis* and *U. chuss* were grouped together. However, larger *M. bilinearis* (151–400 mm SL) were included in a single assemblage which fed more on carideans and fishes. *Urophycis chuss* was associated with three separate groups. The smallest (1–100 mm SL) red hake fed on *S. elegans* and *P. gaudichaudi* and were associated with Group I-A. Intermediate-sized fish (101–300 mm SL) fed on gammarideans (*U. irrorata* and *E. rubricornis*), decapods, and *S. elegans*, and belonged to Group III. Large red hake (>300 mm SL) fed primarily on fishes (*C. arctifrons*) and *C. irroratus*. *Macrozoarces americanus* was associated with two groups: Small ocean pout fed mainly on amphipods (*E. rubricornis*, *U. irrorata*, and *A. vadorum*), and larger fish fed mainly on *C. irroratus*. *Lophius americanus* was primarily piscivorous and all sizes were included in Group I. *Citharichthys arctifrons* fed mainly on corophiid amphipods, and all sizes were included in Group III.

DISCUSSION

Comparison of present results with previous studies indicates that although fishes select a certain type of prey, depending on their size and habitat, the prey species consumed is dependent upon prey availability and prey community structure. Generally, the important higher prey taxa, e.g., polychaetes, amphipods, decapods, etc., are important in the diet of shelf fishes throughout their range, but the species consumed reflect availability of these prey items. *Raja erinacea* fed mainly on amphipods and decapods in the waters around Long Island (Smith 1950; Richards et al. 1963), a finding duplicated by the present study. The amphipod *Leptocheirus pinguis* was the most abundant species in the diet in Long Island waters, and Smith (1950) reported that this amphipod was a dominant species in the benthos. Although locally common in muddier habitats on the outer shelf, *L. pinguis* is seldom abundant in the present study area (Boesch 1978) and was not abundant in the diet of the little skate. McEachran et al. (1976) found no significant differences in the higher taxonomic composition of the diet of *R. erinacea* from four areas, including the Middle Atlantic Bight, Georges Bank, the Gulf of Maine, and the Nova Scotian shelf. However, species composition of the most important prey changed from north to south, probably reflecting changes in the benthic fauna. Previous reports of stomach contents of the other dominant species from other localities show similar results (Hildebrand and Schroeder 1927; Olsen and Merriman 1946; Bigelow and Schroeder 1953; Jensen and Fritz 1960; Richards 1963; Barans 1969; Sikora et al. 1972; Vinogradov 1972; Langton and Bowman 1980, 1981).

Diversity and Seasonality of Prey Availability

The diets of several outer shelf fishes were quite diverse. *Raja erinacea* fed on at least 107 species, *U. chuss* fed on about 130 species, *S. chrysops* fed on 106 species, and *C. arctifrons* fed on about 70 prey species. Other predators were more specialized in diet, such as *U. regia* (45 species of prey), *M. bilinearis* (51 species), *M. americanus* (39 species), and *P. oblongus* (34 species). *Lophius americanus* was the most specialized predator, feeding on only 24 prey species, mostly fishes.

Although many species of prey were consumed by the fish community, only a few species predominated in the diet of each predator. Most species important in the diet of any one predator were also important for other predators as well. These species include the amphipods *Ampelisca vadorum*, *Byblis serrata*, *Erichthonius rubricornis*, and *Unciola irrorata*. Other important prey species were *Cancer irroratus*, *Crangon septemspinosa*, *Dichelopandalus leptocerus*, and *Diastylis bispinosa*.

Predation can be an important factor controlling the structure of benthic communities (Virnstein 1977, 1979; Peterson 1979). Selective predation on prolific prey species keeps the population levels of these species low, allowing more species to coexist in the same habitat (Dayton and Hessler 1972). The heavy predation mortality exerted through selective predation by demersal shelf fishes on ampeliscid and, especially, corophiid amphipods may keep populations of these prolific species from completely dominating the benthic community, thus contributing to the high diversity (Boesch et al. 1977; Boesch 1978) in macrobenthic communities on the outer shelf.

In addition to those prey species that were important for many predators, some prey species were important to only a few predators. These included such species as *Ensis directus* (preyed on mainly by *R. erinacea*), *Clymenura* sp. A (prey for *C. arctifrons*), *Chone infundibuliformis* (prey for *S. chrysops* and *C. arctifrons*), *Ampelisca agassizi* (preyed on mainly by *S. chrysops*), fishes (fed on by *L. americanus* and seasonally important for *U. regia*, *H. oblonga*, and *M. bilinearis*), and cephalopods (important for *U. regia*, *M. bilinearis*, and *H. oblonga*).

Many prey species, mostly planktonic invertebrates, were only seasonally important in the diet of some predators. These included the copepods *Centropages typicus* and *Paracalanus* spp., hyperiid amphipods, decapod larvae, chaetognaths, larvaceans, and juvenile fishes. Seasonally important benthic invertebrates included *Diastylis sculpta*, *Cirolana polita*, *Trichophoxus epistomus*, *Monoculodes edwardsi*, *Dichelopandalus leptocerus*, and *Crangon septemspinosa*. However, most benthic food items were equally important in the diet of the predators during all seasons, reflecting the temporal persistence (Boesch 1978) of populations of macrobenthos on the shelf. The seasonal importance of planktonic prey in the diet is related to two factors. The first is the size class composition of the predators. Smaller red and silver hake present in the fall and summer consumed more copepods and hyperiids. Secondly, seasonal importance of pelagic food items is related to abundance of these taxa in the nearbottom plankton community. Chaetognaths were probably concentrated near the bottom in winter and spring, when they were important food for many demersal fishes. Larval stages of decapods were also seasonally important; this is related to the seasonal abundance of these stages in the plankton (Grant 1977).

Seasonal prey switching (Murdoch et al. 1975; Love and Ebeling 1978) was evident for some predators. For example, *S. elegans* was rare in the diet of large silver hake present in the study area in winter. In spring, however, *S. elegans* was the most abundant prey species consumed by silver hake. This probably represents an opportunistic switching in silver hake as chaetognaths become abundant in the nearbottom plankton. This switching was independent of predator size, i.e., larger silver hake present in winter and spring switched from a diet dominated by amphipods in the winter to a diet dominated by chaetognaths in the spring. Other predators switched seasonally between benthic and planktonic prey. *Urophycis chuss* demonstrated a similar switching to chaetognaths, and *C. arctifrons* switched to planktonic larvaceans in the spring. Love and Ebeling (1978) noted that fishes they studied switched to a more planktonic diet in winter and spring, when plankton volumes were high in their study area or when other food may have been relatively scarce. There were similar increases in plankton in spring in the Middle Atlantic Bight. Increased feeding on *S. elegans* in spring is related to an appearance of boreal zooplankton, which were abundant following the severe winter of 1977 (Grant 1979, 1980[3]). As concluded by Love and Ebeling (1978), seasonal switching in prey selectivity, in this case to different prey types—i.e., benthic to pelagic—probably reflects an increased relative abundance or availability of these prey species. Since benthic populations remain relatively constant (Boesch et al. 1977; Boesch 1978), this is probably due to an increase in nearbottom zooplankton, especially chaetognaths and larvaceans. Increased importance

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[3] G. C. Grant, Acting Assistant Director, Virginia Institute of Marine Science, Gloucester Pt., VA 23062, pers. commun. 20 April 1980.

of decapod larvae in the diet of many fishes (*R. erinacea*, *U. chuss*, *M. bilinearis*, *M. americanus*) in the summer may also reflect this phenomenon.

Predator Size and Feeding Strategy

The food habits of dominant shelf fishes changed considerably with size, as noted in other fishes (Tyler 1972; Ross 1978; Werner 1979). For most predators this change was a switch to different, larger, prey taxa. Many predators (*R. erinacea*, *U. chuss*, *U. regia*, and *M. bilinearis*) fed on increasing numbers of similarly sized, small food items, up to a certain length. At this point, there was a rapid increase in mean prey size for larger predators, with a concomitant decrease in the number of prey consumed. Total volume of food increased with increasing fish length. Ross (1978) noted a similar progression in food habits with increasing size and suggested this strategy should maximize energy intake at the onset of reproduction, a time of increased energy demand.

Schoener (1971) predicted, from optimal foraging models, that food size should decrease with decreasing predator size, and should do so asymptotically. Numerous examples demonstrate the trend of his prediction, but evidence for an asymptote has been sparse, and one study indicated it did not occur (Schoener 1971). Most shelf fishes studied (Figs. 4, 7, 10, 13, 16, 25, 28) demonstrate this phenomenon, but there are exceptions. *Macrozoarces americanus* (Fig. 19) fed heavily on small food items throughout the size-range examined, with larger fish retaining small prey in the diet, while broadening their feeding to include larger prey items. *Stenotomus chrysops* underwent a marked change in prey-size preference between 100 and 150 mm standard length (Fig. 22), but then prey size remained relatively constant. There is no asymptote at the lower end of the length range for *S. chrysops*.

Larger predators should take a greater size range of food, and food diversity (i.e., number of prey types or species) should be greater in large animals, unless available small prey are sufficiently more diverse (Schoener 1971). In those predators for which benthic prey dominated (all except *L. americanus* and *M. bilinearis*), such a relationship is evident for prey types. Although amphipods, the dominant prey for smaller predators, decrease in abundance, they remain relatively common in the diet of large fish even as other larger prey items are added. However, large prey items include the much less diverse decapods and larger polychaetes. The high diversity of available small prey (amphipods, isopods, cumaceans) result in smaller fishes having a more diverse diet at the species level.

Overlap in Diet

Most predator species were selective on the macrobenthos, particularly on corophiid and ampeliscid amphipods and decapods. These crustaceans were important food for these predators, resulting in considerable overlap in diet.

Cluster analysis of predator species and size-classes based on prey similarity indicates that intraspecific and interspecific diet-overlap relationships change considerably with season and with fish size. Although there was considerable interspecific overlap in diet, there is evidence for intraspecific food-resource partitioning. Small fishes overlapped in diet intraspecifically as well as with small fishes of other species. The larger fishes of these species also exhibited interspecific dietary overlap, but fed quite differently from the juveniles. These differences in diet overlap with size were correlated with changes in feeding strategy with increased fish length. For example, in fall (Fig. 31), all *R. erinacea* ranging between 51 and 250 mm DW fed similarly and were grouped together within a larger group of similar feeders. However, skates larger than 250 mm DW fed differently and were grouped together with other large decapod feeders. *Raja erinacea* demonstrated a marked change in food habits at 250 mm DW (Fig. 4) where this shift in food-overlap relationships occurred. The other species that grouped with *R. erinacea* also demonstrated a parallel change in feeding strategy with increased size. Thus, although intraspecific changes in diet with increased size may prevent intraspecific overlap in diet, considerable interspecific overlap occurred. Although intraspecific and interspecific diet-overlap relationships changed seasonally, it is apparent that intraspecific differences in feeding are as important as interspecific differences in structuring the predator community.

Several reasons may account for the considerable amount of interspecific overlap in diet exhibited by shelf fishes. Optimal foraging theory predicts that as food becomes scarce, predators will take a wide variety of food and similar predators occupying the same habitat will converge in diet (Pyke et al. 1977). Alternatively, some authors have hypothesized that as food density lowers, coexisting predators will specialize on different prey and food overlap will decrease. Considerable food overlap would only be expected if food were abundant (Jones 1978). Some field studies support this latter hypothesis, although this may be due to a lack of measurement of actual resource availability. Thus, Keast (1965) and Zaret and Rand (1971) found that fishes specialized in diet and that interspecific overlap was at a minimum during the food-impoverished season. Maximum food overlap occurred when food levels were high [see also Ross (1977) and Townsend and Hildrew (1979)]. Tyler (1972) reported little overlap in the diets of northern marine demersal fishes and concluded that food limitation led to specialization and food-resource partitioning. The present results indicate that shelf fishes are selective in their feeding, but that considerable interspecific overlap occurs in diet. The question remains whether this overlap is due to a food shortage (Pianka 1976; Pyke et al. 1977) or a food abundance (Zaret and Rand 1971; Ross 1977; Jones 1978). Boesch et al. (1977) and Boesch (1978) reported that density and abundance of macrobenthos on the outer shelf were generally high and persistent year-round. Walsh et al. (1978) reported an increase in plankton productivity in the early spring and suggested most of this productivity was transferred to the bottom. This could lead to a superabundance of food near and on the bottom in the spring. It is noteworthy that food overlap among shelf fishes was lowest in spring, and that some of this was due to normally benthic predators (e.g., *U. chuss* and *C. arctifrons*) switching to planktonic prey. It appears that minimal overlap in diet of shelf fishes in the present study is associated with a superabundance of prey in the spring, supporting the hypothesis of optimal foraging (Pianka 1976; Pyke et al. 1977).

The question also remains to be answered as to whether there is competition for food among shelf fishes. Although there was much interspecific diet overlap among shelf fishes, overlap need not necessarily lead to competition unless resources are in short supply (Pianka 1976). Extensive niche overlap may actually be correlated with reduced competition (Pianka 1974, 1976; Jones 1978). Most shelf fishes exhibited extensive overlap in habitat and food, but it is not known if these resources are in short supply. Predator exclusion experiments on the outer shelf indicate that the macrobenthic community is, in part, predator controlled (Boesch 1978) and that populations of certain species, including those important as prey to fishes (e.g., corophiid amphipods), may be kept below carrying capacity by fish predation. Whether this predation pressure keeps potential prey in short supply is unknown.

Seasonal intrusions of abundant predators could also result in food resource limitation and competition. Tyler (1972) reported that seasonally abundant species did not, as a group, feed on a unique set of prey species. In the present study *S. chrysops*, a seasonal species, was similar in diet to *U. chuss* and *M. bilinearis*. Ocean pout were only abundant seasonally (in summer), but fed on common prey species shared with other predators. Apparently seasonal intrusions of abundant predators do not affect food availability on the Middle Atlantic Shelf.

Overlap in diet between closely related species is generally lower than that for unrelated species, suggesting food resource partitioning among closely related species. Thus the congeners *U. chuss* and *U. regia* show a low similarity in prey species and prey size (Fig. 29). Seasonally, the bothids *Citharichthys arctifrons* and *Hippoglossina oblonga* were also quite dissimilar in diet. Still, no predator monopolized any trophic resource. This apparent food resource partitioning among closely related species may be due, not to present limited food resources, but to environmental factors and predator community structure during the evolutionary history of these species.

Although predators demonstrated considerable diet overlap, each predator had a diverse diet and fed selectively on some prey items that were not as important in the diets of other predators. Perhaps each predator has a food refuge in these prey species if competition for food becomes intense. Due to overexploitation by fishing vessels, populations of fishes on the outer shelf may be below carrying capacity (Edwards 1976; Clark and Brown 1977; Edwards and Bowman 1979), allowing several dominant species to coexist on similar food resources. At higher population levels, food resources may become a limiting factor and the high level of diet overlap could lead to competition. With reduced fishing pressure due to extended jurisdiction by the United States, fish populations on the outer shelf may increase, and food competition may become intense.

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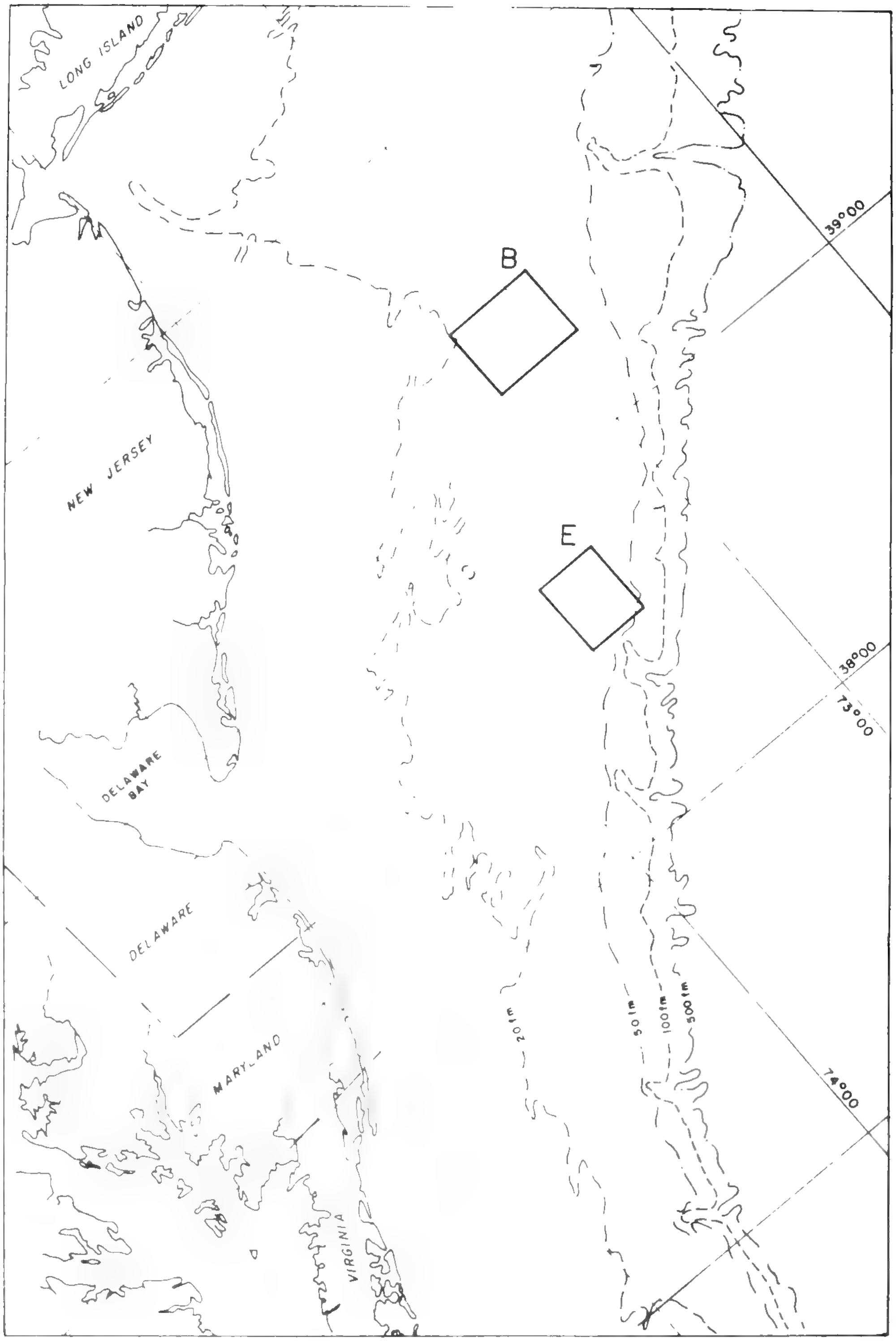


Figure 1.—Location of sample areas B and E.

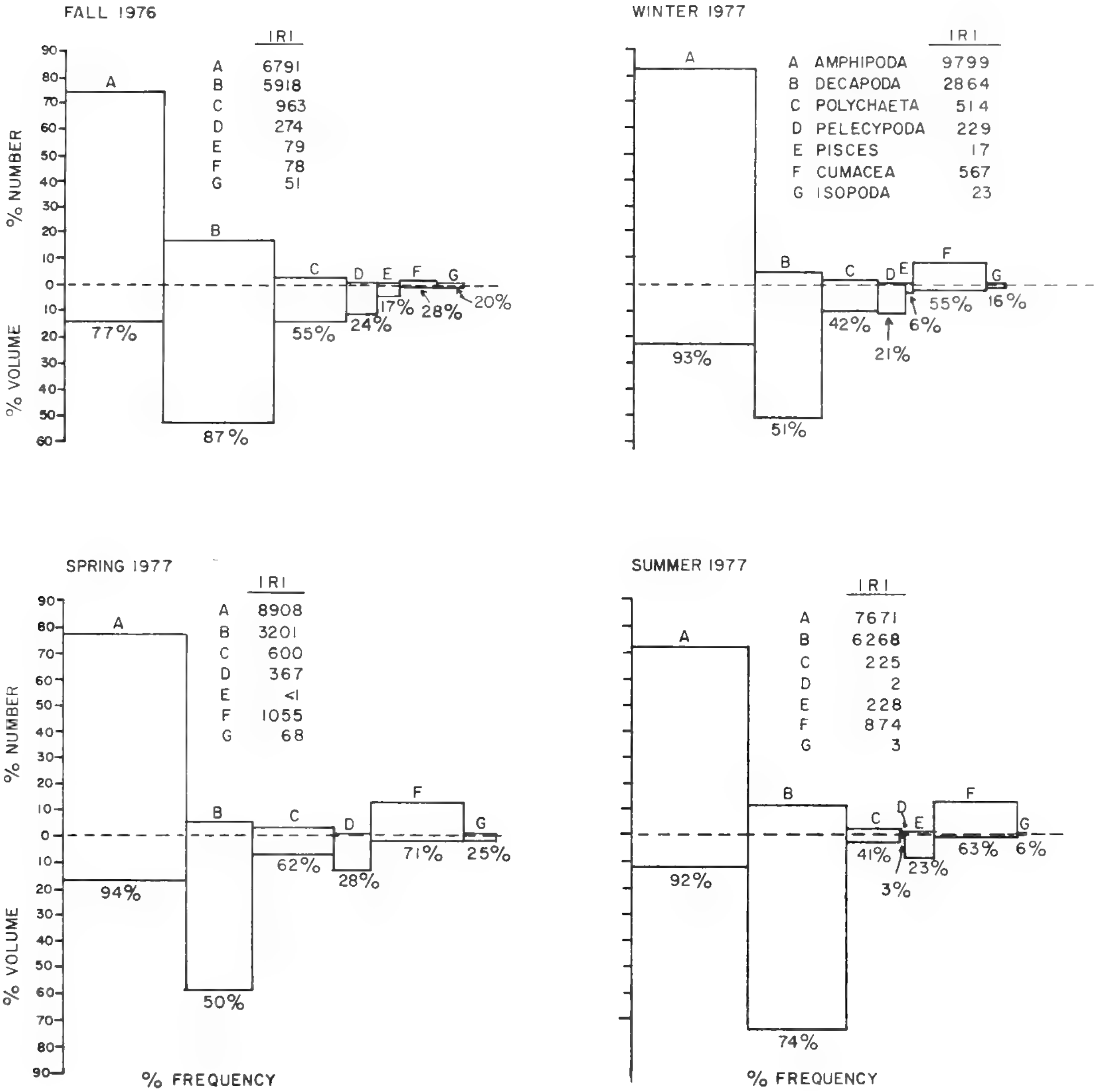
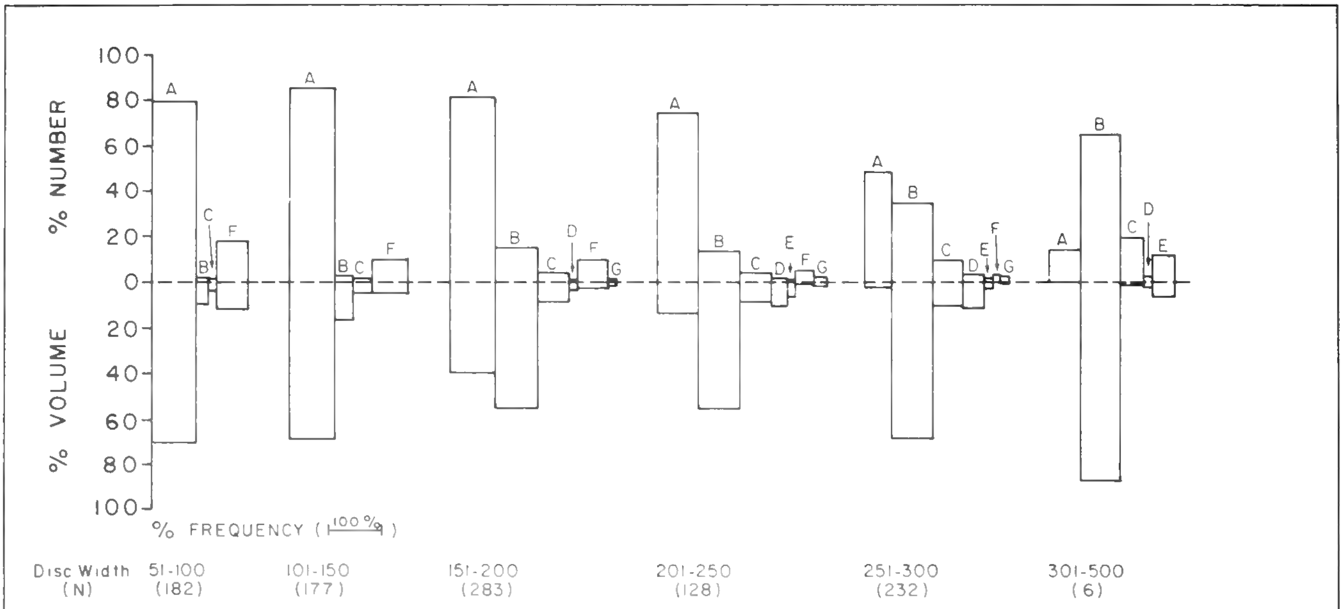


Figure 2.—Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food in the diet of *Raja erinacea*, by seasonal cruise.



IRI

	51-100	101-150	151-200	201-250	251-300	301-500	
A)	14861	15376	11850	7993	3147	960	AMPHIPODA
B)	284	849	3379	5997	9423	12662	DECAPODA
C)	54	259	564	321	1225	550	POLYCHAETA
D)	6	1	69	577	686	72	PELECYPODA
E)	7	16	13	121	70	915	PISCES
F)	2082	1173	443	227	48	0	CUMACEA
G)	1	25	24	44	72	0	ISOPODA

Figure 3.—Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food for size intervals (mm) of *Raja erinacea*.

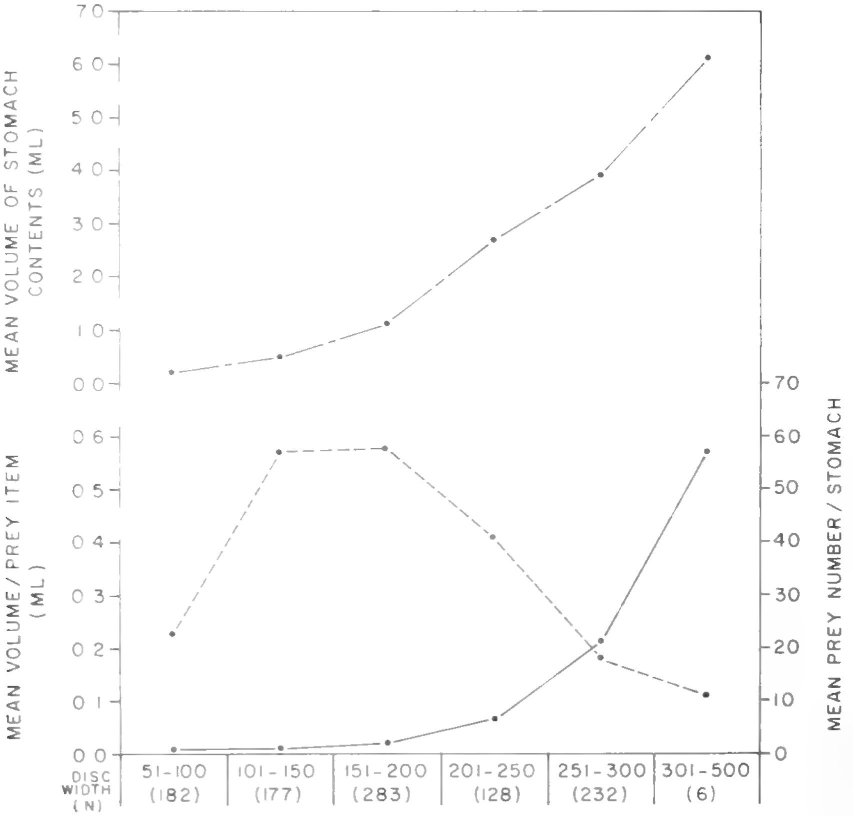


Figure 4.—Relationship between size of *Raja erinacea* and volume of food consumed (broken line), mean prey volume (solid line), and prey number per stomach (dashed line).

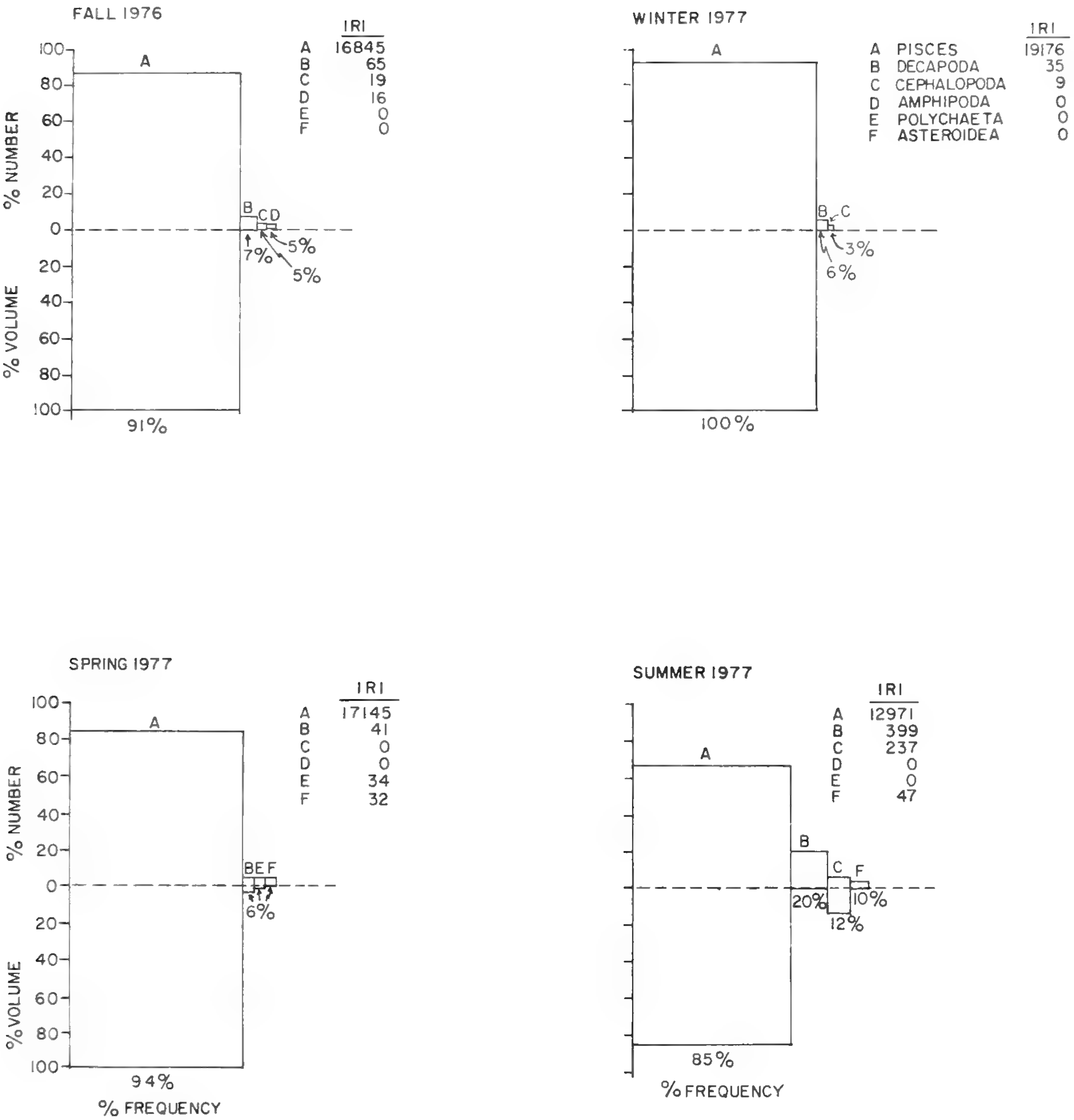
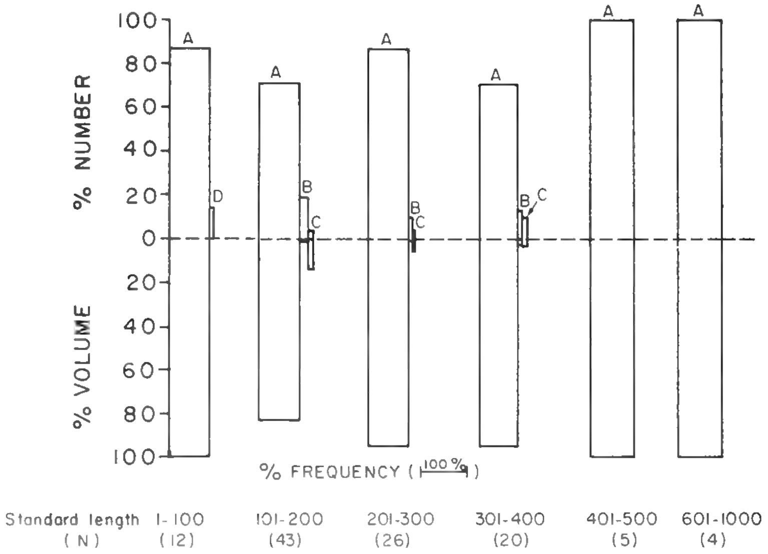


Figure 5.—Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food in the diet of *Lophius americanus*, by seasonal cruise.



IRI

A)	17080	14394	16763	14122	20000	20000	PISCES
B)	0	373	118	145	0	0	DECAPODA
C)	0	125	31	188	0	0	CEPHALOPODA
D)	114	0	0	0	0	0	CHAETOGNATHA

Figure 6.—Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food and size intervals (mm) of *Lophius americanus*.

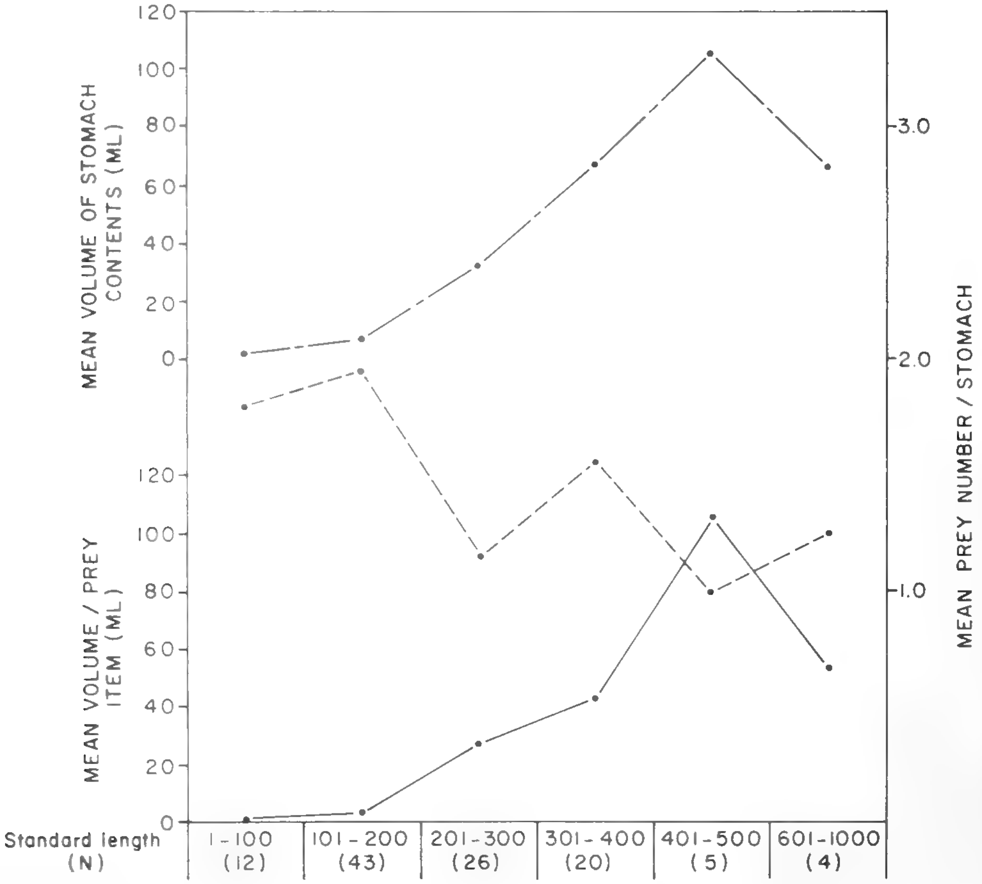


Figure 7.—Relationship between size of *Lophius americanus* and volume of food consumed (broken line), mean prey volume (solid line), and prey number per stomach (dashed line).

Urophycis chuss

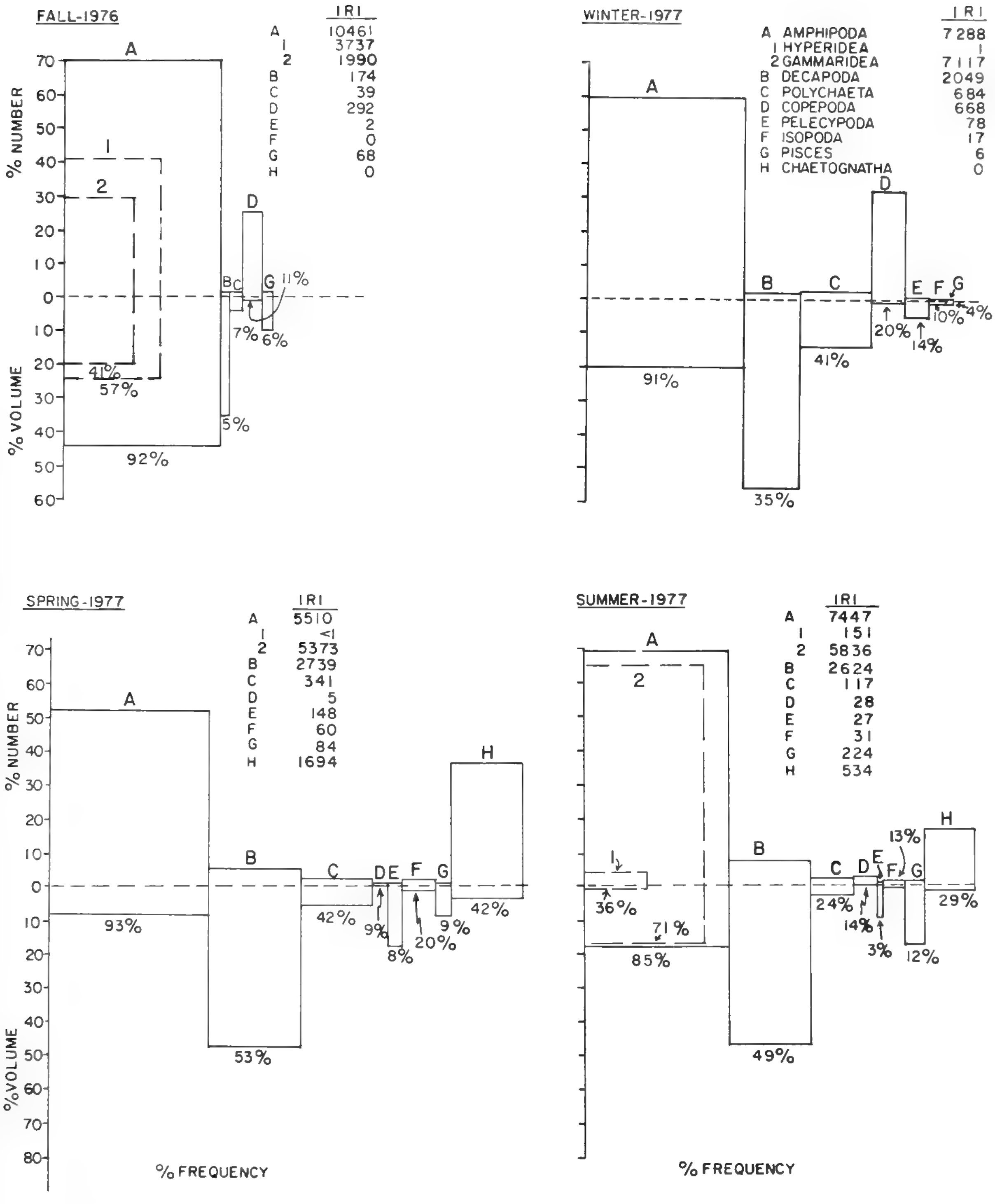
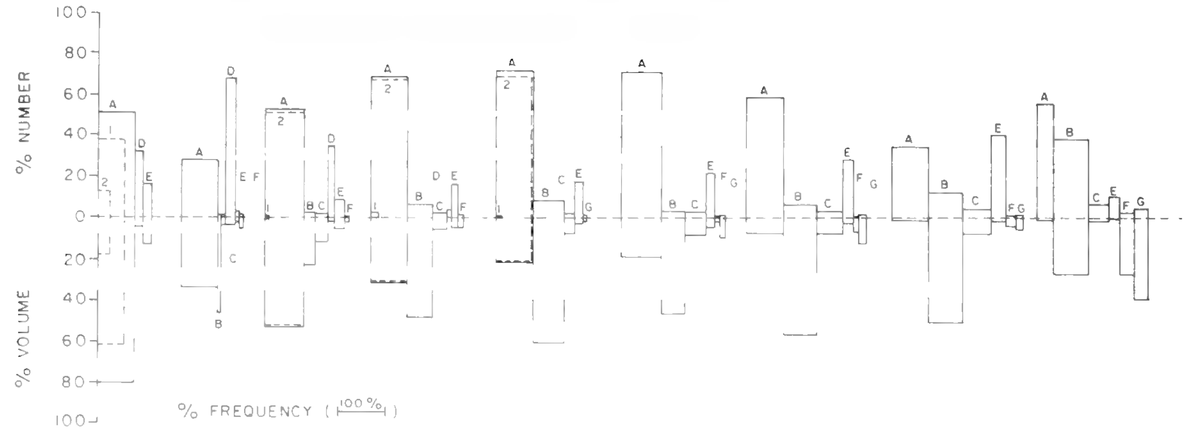


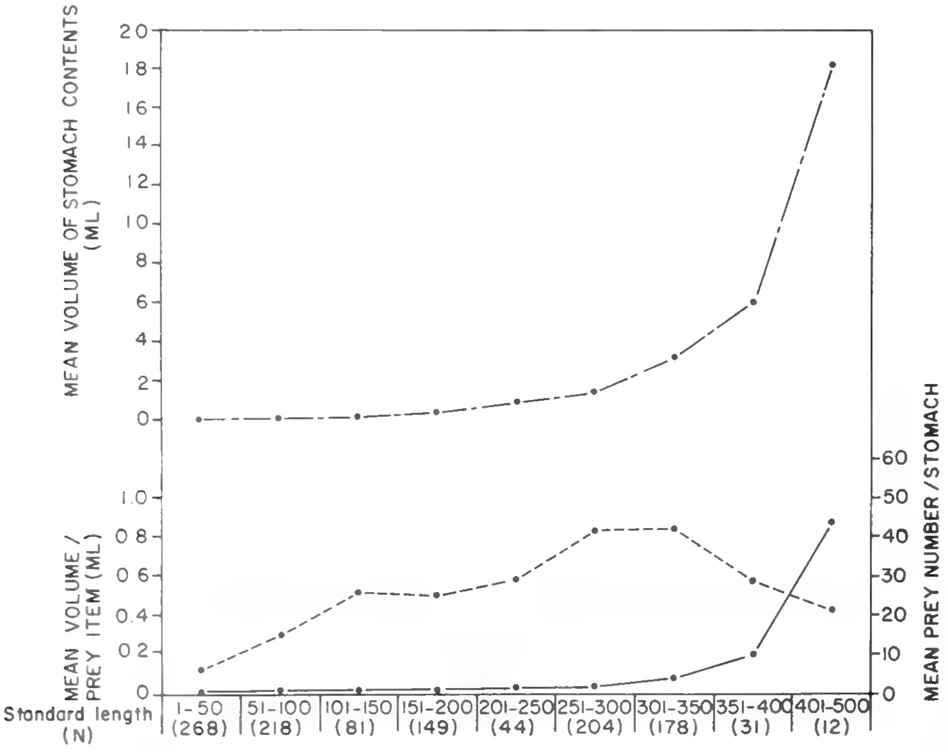
Figure 8.—Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food in the diet of *Urophycis chuss*, by seasonal cruise.



STANDARD LENGTH (N)	1-50 (268)	51-100 (218)	101-150 (81)	151-200 (149)	201-250 (44)	251-300 (204)	301-350 (178)	351-400 (31)	401-500 (12)	
IRI										
A)	11409	5703	9967	9248	5460	8466	5871	3210	2329	AMPHIPODA
1)	6466	1	7	47	23	1	1	0	0	HYPERIDEA
2)	679	5514	9567	6856	8017	3224	5736	3189	2176	GAMMARIDEA
B)	1	151	643	5383	5209	2962	4982	5134	3824	DECAPODA
C)	7	52	574	257	240	598	706	818	432	POLYCHAETA
D)	748	1766	488	25	1	2	1	3	0	COPEPODA
E)	628	68	551	541	400	533	743	1491	263	CHAETOGNATHA
F)	1	38	25	42	2	22	80	128	1006	PISCES
G)	0	1	2	3	20	142	312	83	1462	PELECYPODA

Figure 9.—Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food for size intervals (mm) of *Urophycis chuss*.

Figure 10.—Relationship between size of *Urophycis chuss* and volume of food consumed (broken line), mean prey volume (solid line), and prey number per stomach (dashed line).



Urophycis regia

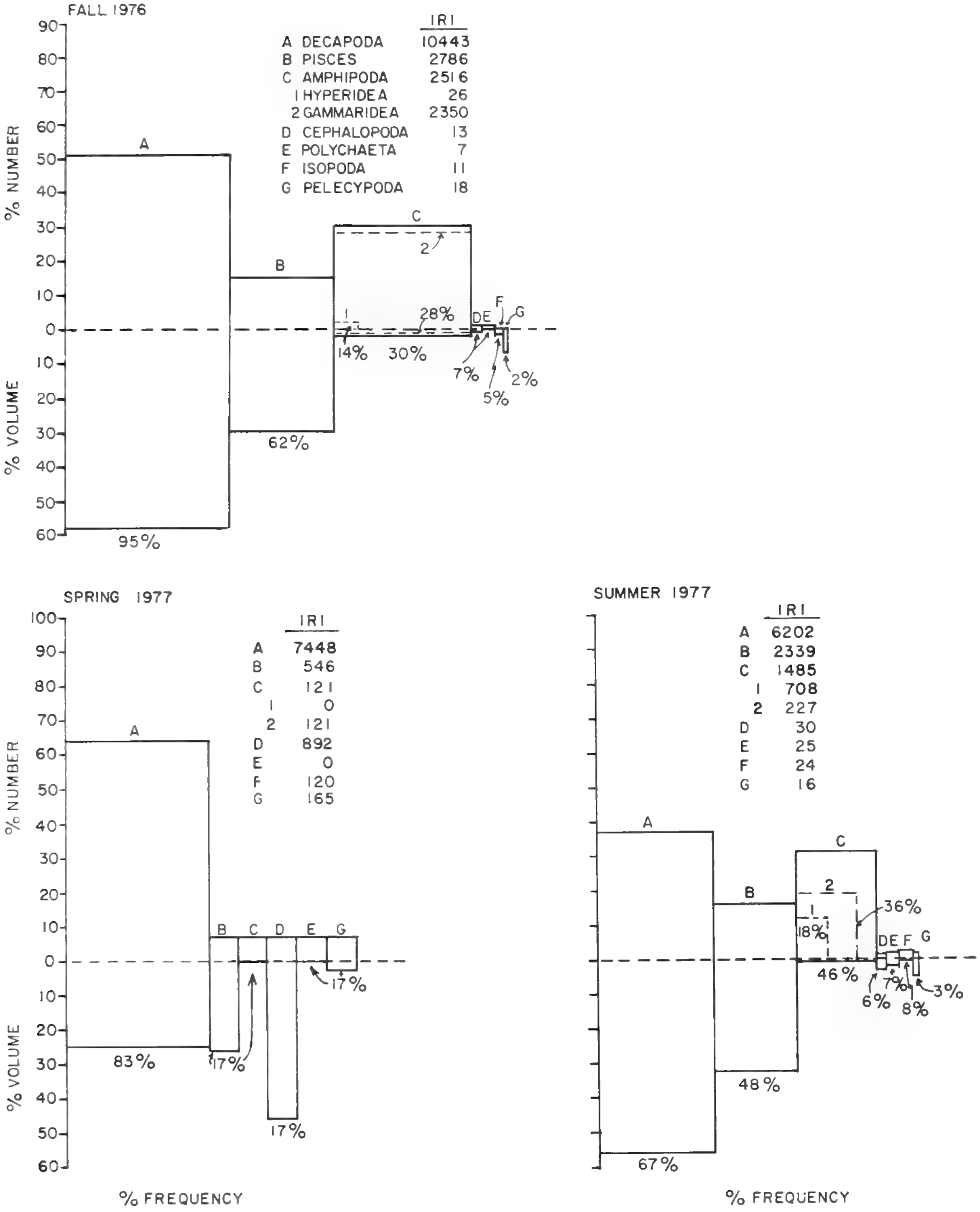


Figure 11.—Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food in the diet of *Urophycis regia*, by seasonal cruise.

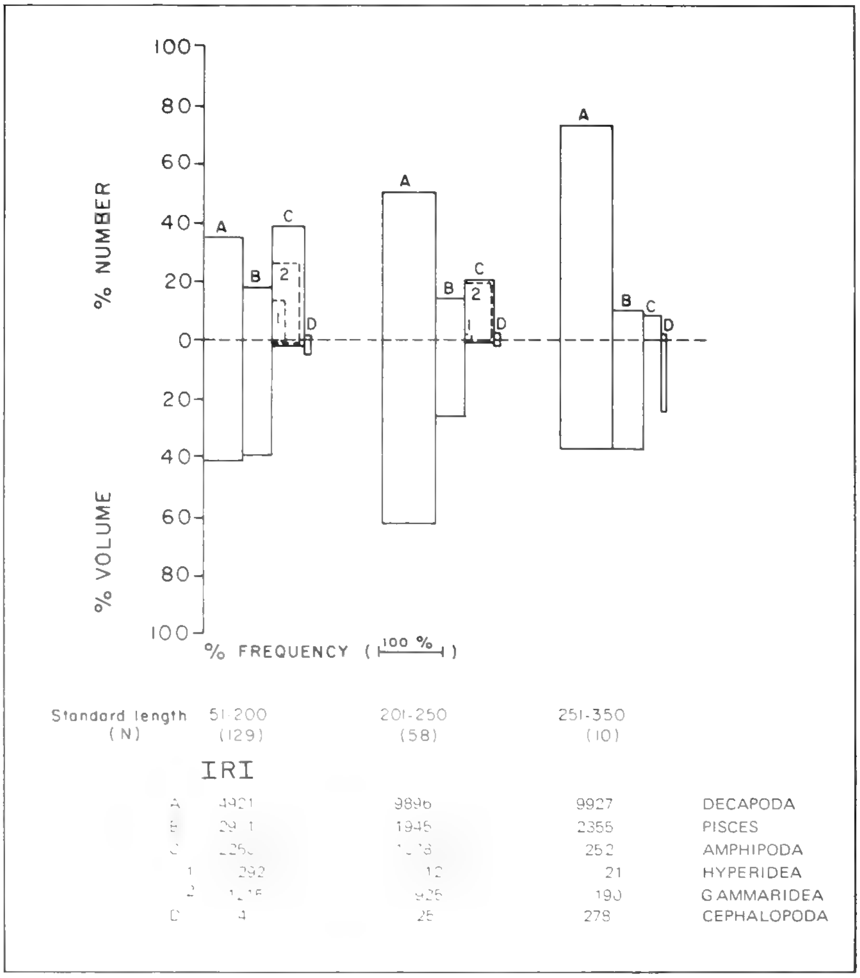


Figure 12.—Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food for size intervals (mm) of *Urophycis regia*.

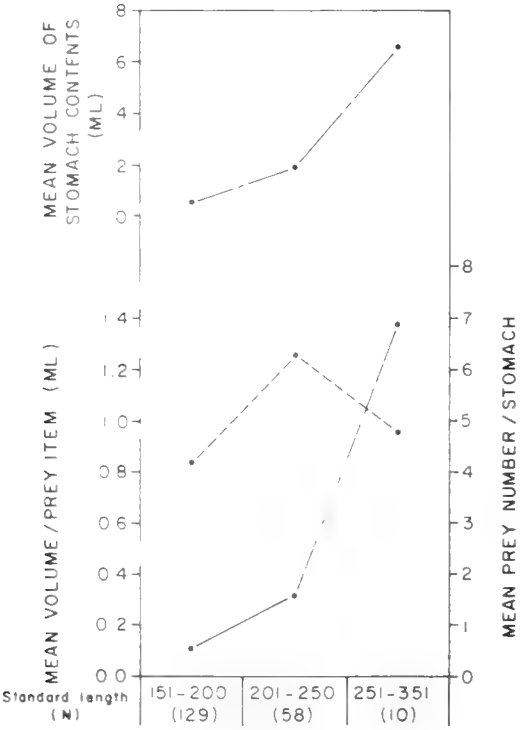


Figure 13.—Relationship between size of *Urophycis regia* and volume of food consumed (broken line), mean prey volume (solid line), and prey number per stomach (dashed line).

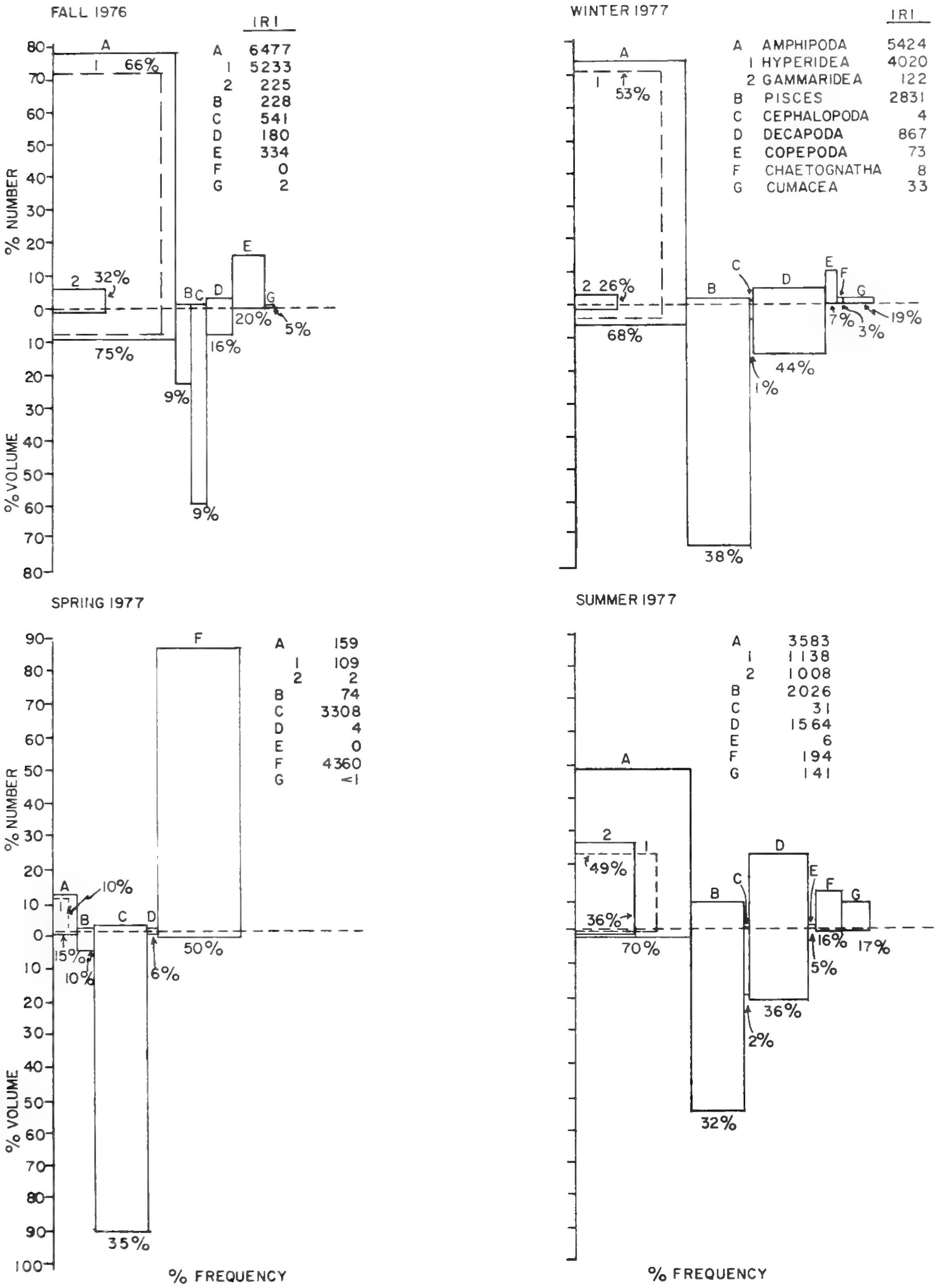
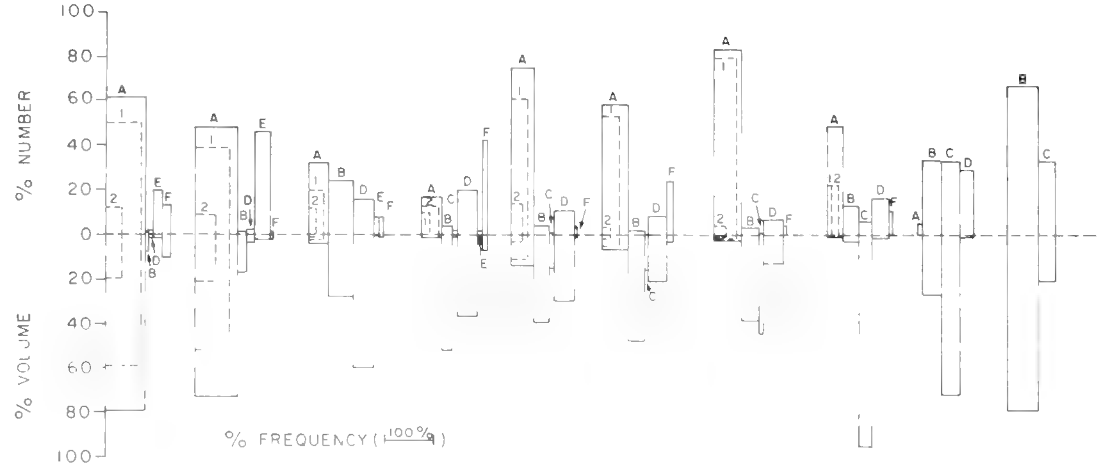


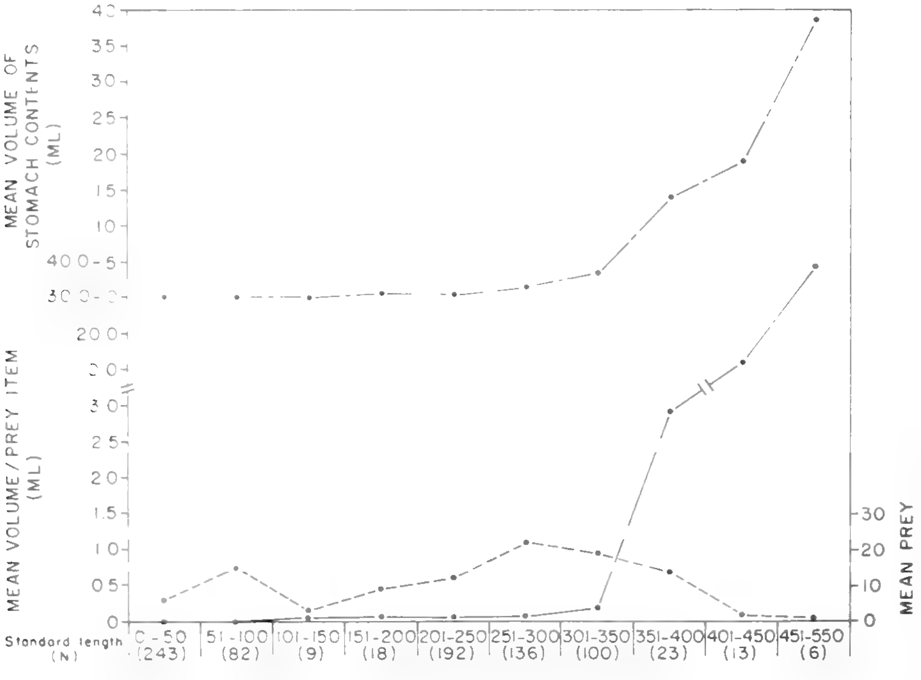
Figure 14.—Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food in the diet of *Merluccius bilinearis*, by seasonal cruise.



STANDARD LENGTH (N)	1-50 (243)	51-100 (82)	101-150 (9)	151-200 (18)	201-250 (192)	251-300 (136)	301-350 (100)	351-400 (23)	401-450 (13)	451-550 (6)	
IRI											
A)	12822	11321	1588	801	4631	3783	5008	1699	37	0	AMPHIPODA
1)	8526	6696	741	106	2564	2507	4007	236	0	0	HYPERIDEA
2)	1128	1346	300	515	429	156	105	567	37	0	GAMMARADEA
B)	43	341	2867	1869	1386	1715	1737	542	2782	9685	PISCES
C)	0	0	0	9	95	81	538	3079	4067	1825	CEPHALOPODA
D)	23	98	3365	2535	1840	1265	963	678	900	0	DECAPODA
E)	411	1571	89	3	4	1	1	0	0	0	COPEPODA
F)	490	14	97	285	15	384	12	51	0	0	CHAETOGNATHA

Figure 15.—Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food for size intervals (mm) of *Merluccius bilinearis*.

Figure 16.—Relationship between size of *Merluccius bilinearis* and volume of food consumed (broken line), mean prey volume (solid line), and prey number per stomach (dashed line).



Macrozoarces americanus

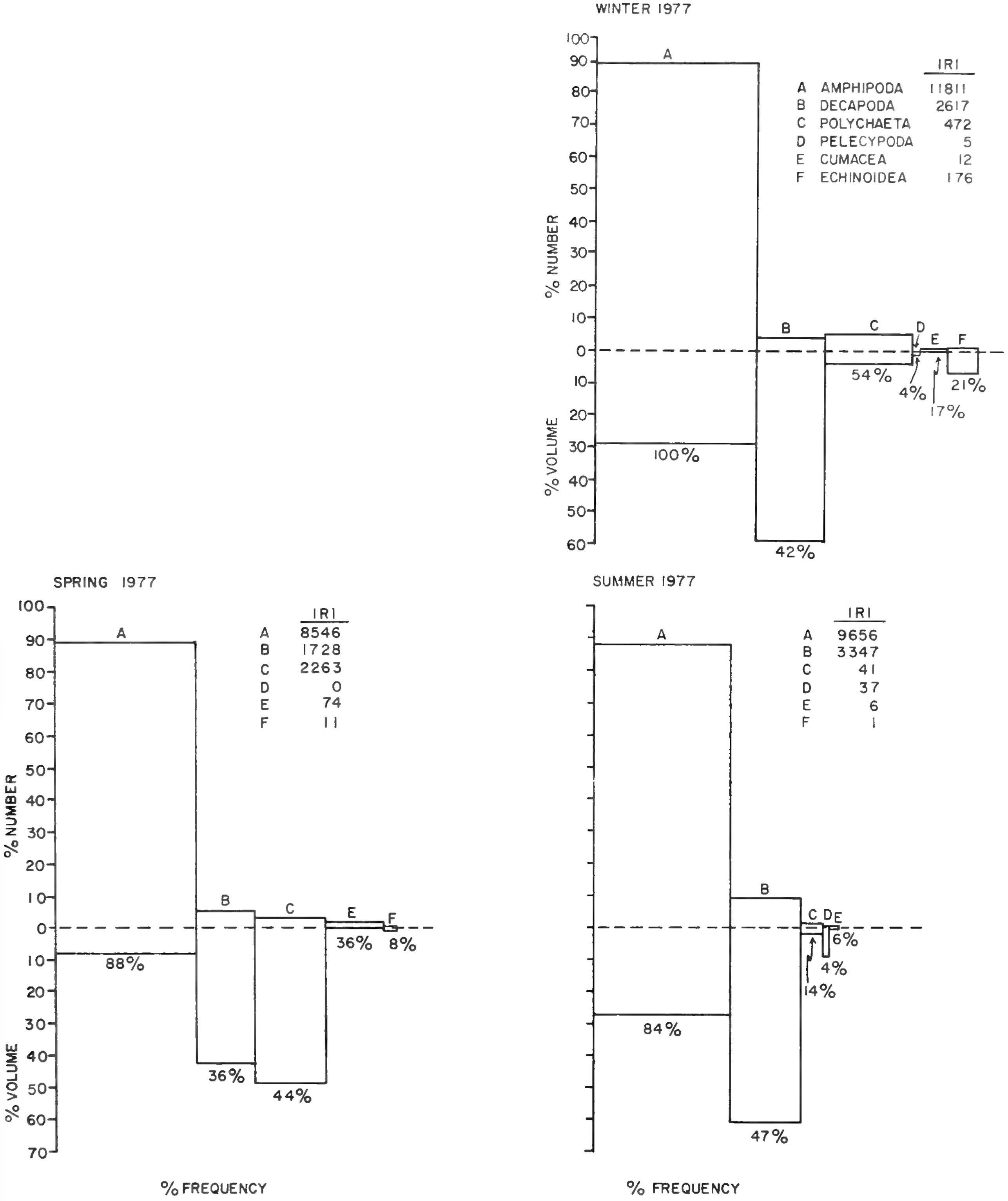
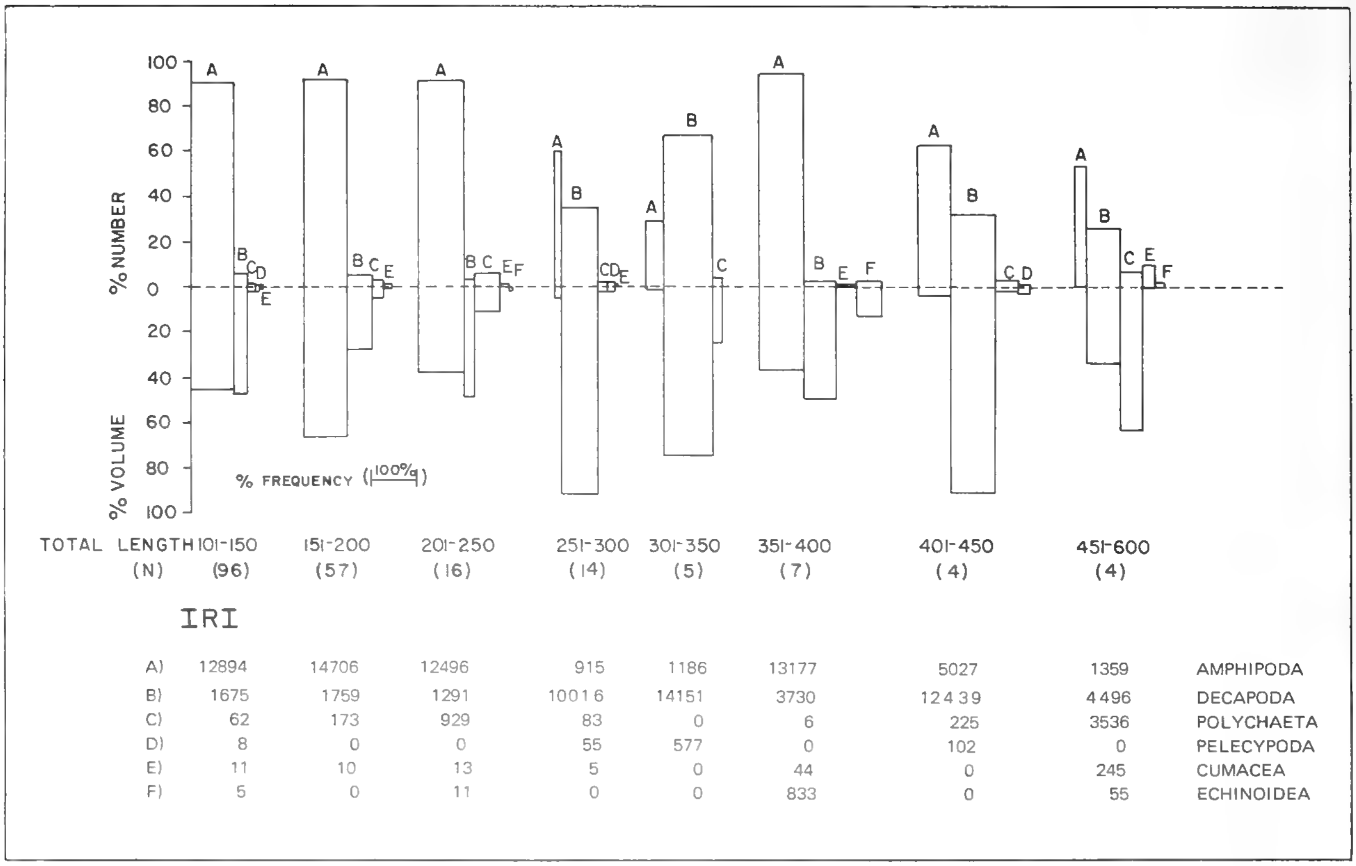


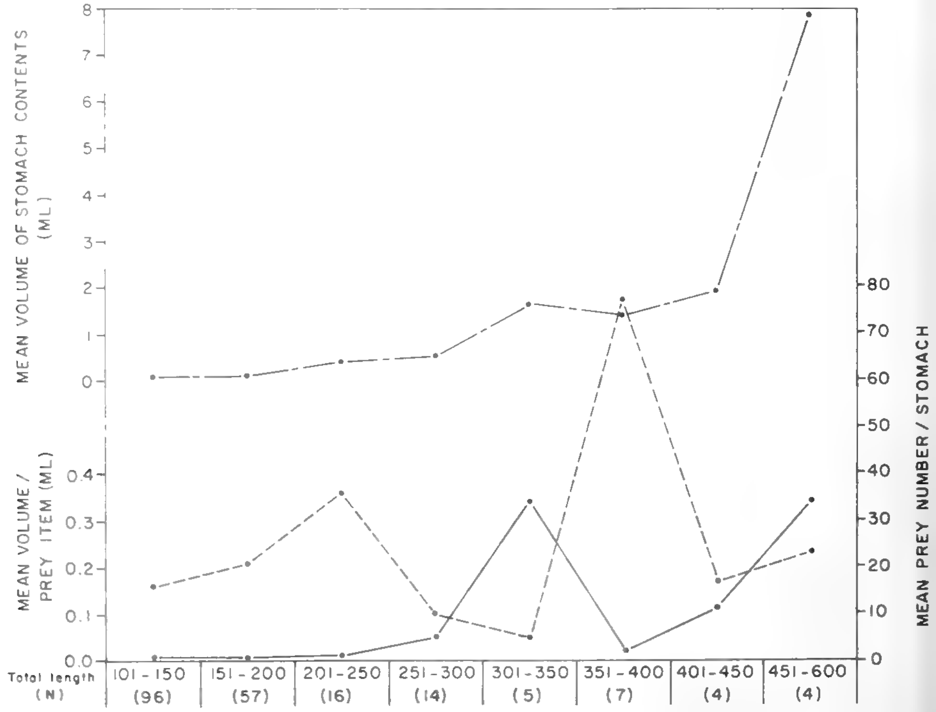
Figure 17.—Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food in the diet of *Macrozoarces americanus*, by seasonal cruise.

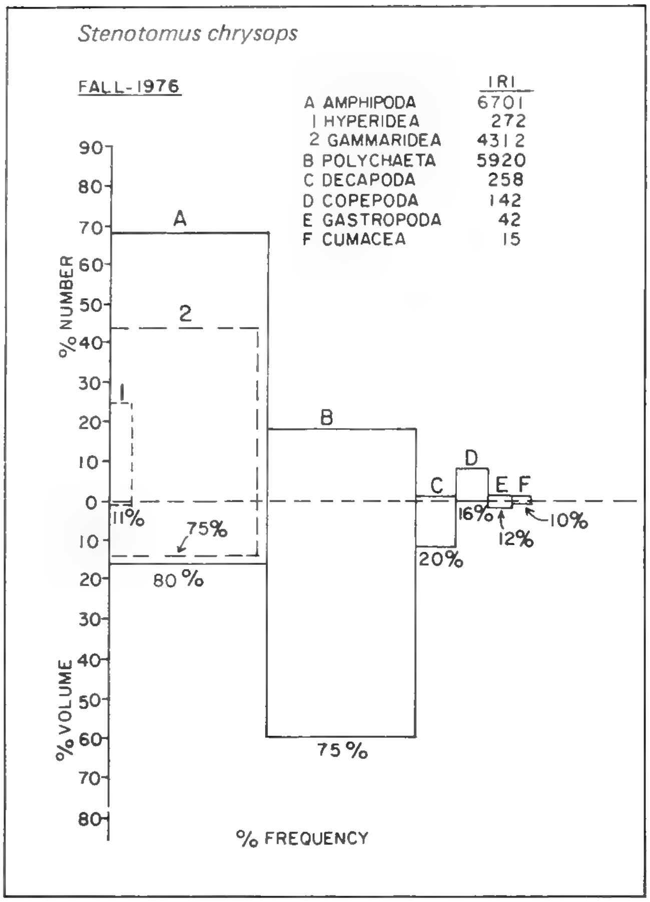


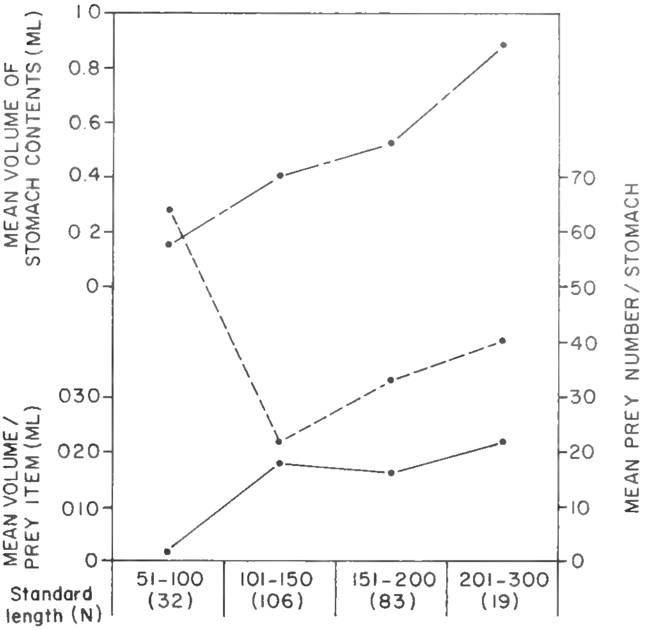
	101-150	151-200	201-250	251-300	301-350	351-400	401-450	451-600	
A)	12894	14706	12496	915	1186	13177	5027	1359	AMPHIPODA
B)	1675	1759	1291	10016	14151	3730	12439	4496	DECAPODA
C)	62	173	929	83	0	6	225	3536	POLYCHAETA
D)	8	0	0	55	577	0	102	0	PELECYPODA
E)	11	10	13	5	0	44	0	245	CUMACEA
F)	5	0	11	0	0	833	0	55	ECHINOIDEA

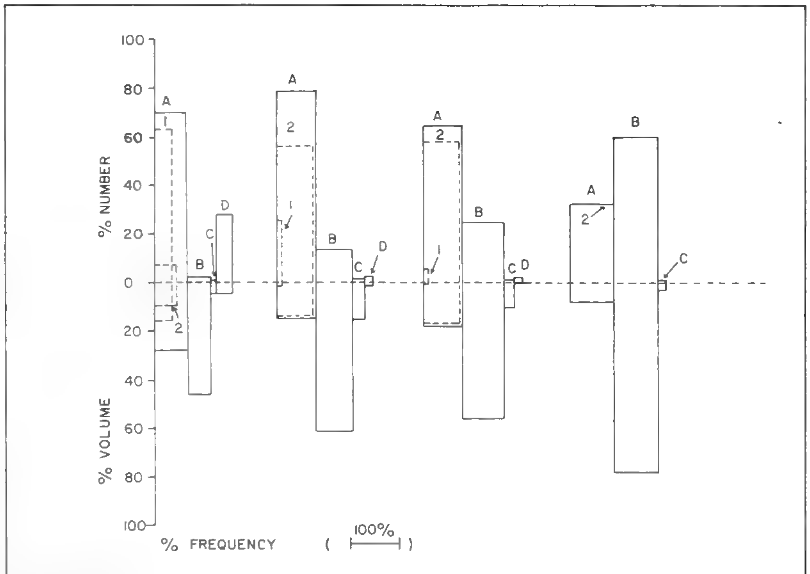
Figure 18.—Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food for size intervals (mm) of *Macrozoarces americanus*.

Figure 19.—Relationship between size of *Macrozoarces americanus* and volume of food consumed (broken line), mean prey volume (solid line), and prey number per stomach (dashed line).









STANDARD LENGTH (N)	51-100 (32)	101-150 (106)	151-200 (83)	201-300 (19)	
IRI					
A)	7091	7275	6477	3701	AMPHIPODA
1)	2728	177	64	1	HYPERIDEA
2)	773	5088	5615	3678	GAMMARIDEA
B)	2096	5793	6681	12 378	POLYCHAETA
C)	17	414	243	49	DECAPODA
D)	1212	39	45	5	COPEPODA

Figure 20 (upper left).—Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food in the diet of *Stenotomus chrysops* in the fall.

Figure 21 (lower left).—Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food for size intervals (mm) of *Stenotomus chrysops*.

Figure 22 (upper right).—Relationship between size of *Stenotomus chrysops* and volume of food consumed (broken line), mean prey volume (solid line), and prey number per stomach (dashed line).

Citharichthys arctifrons

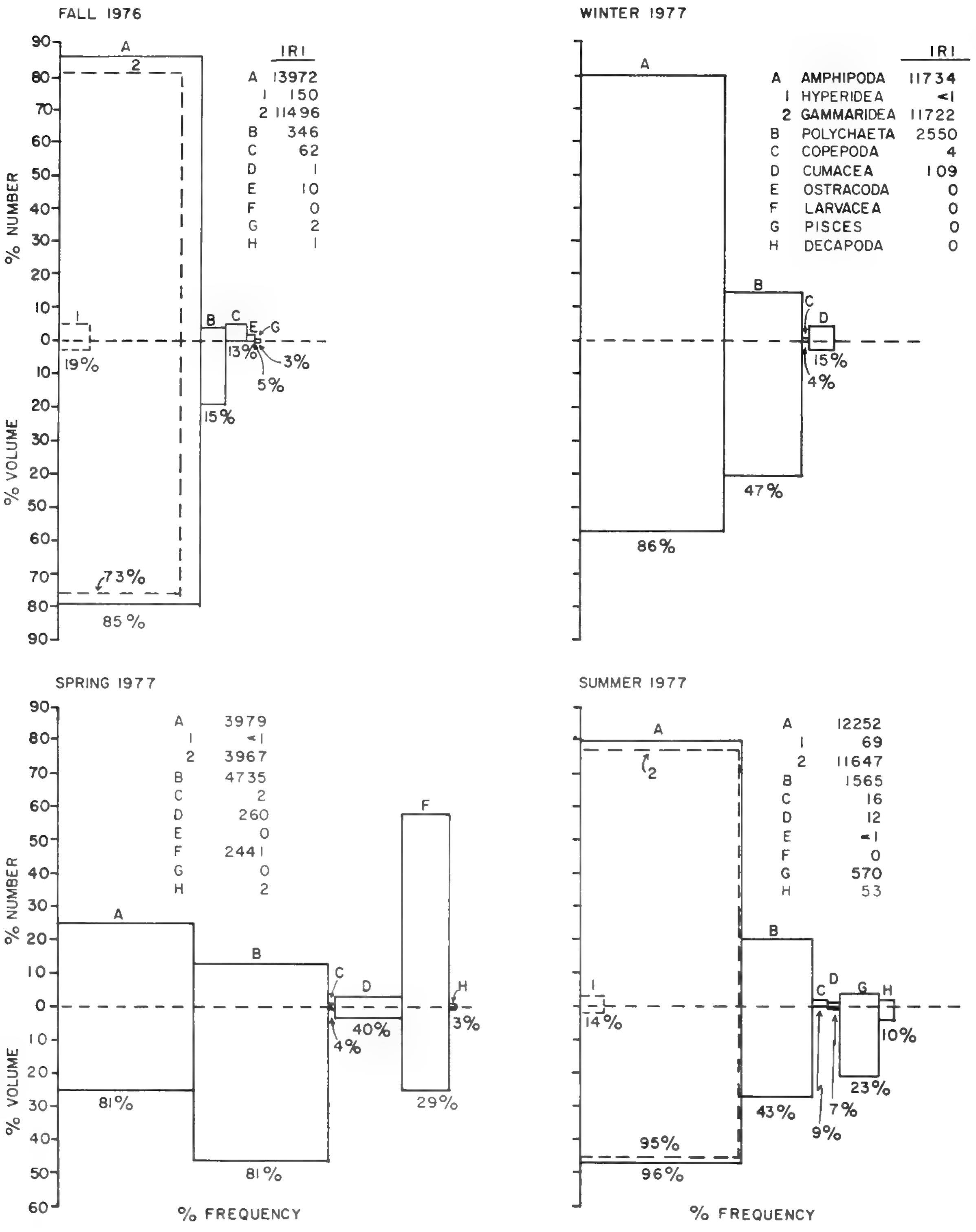
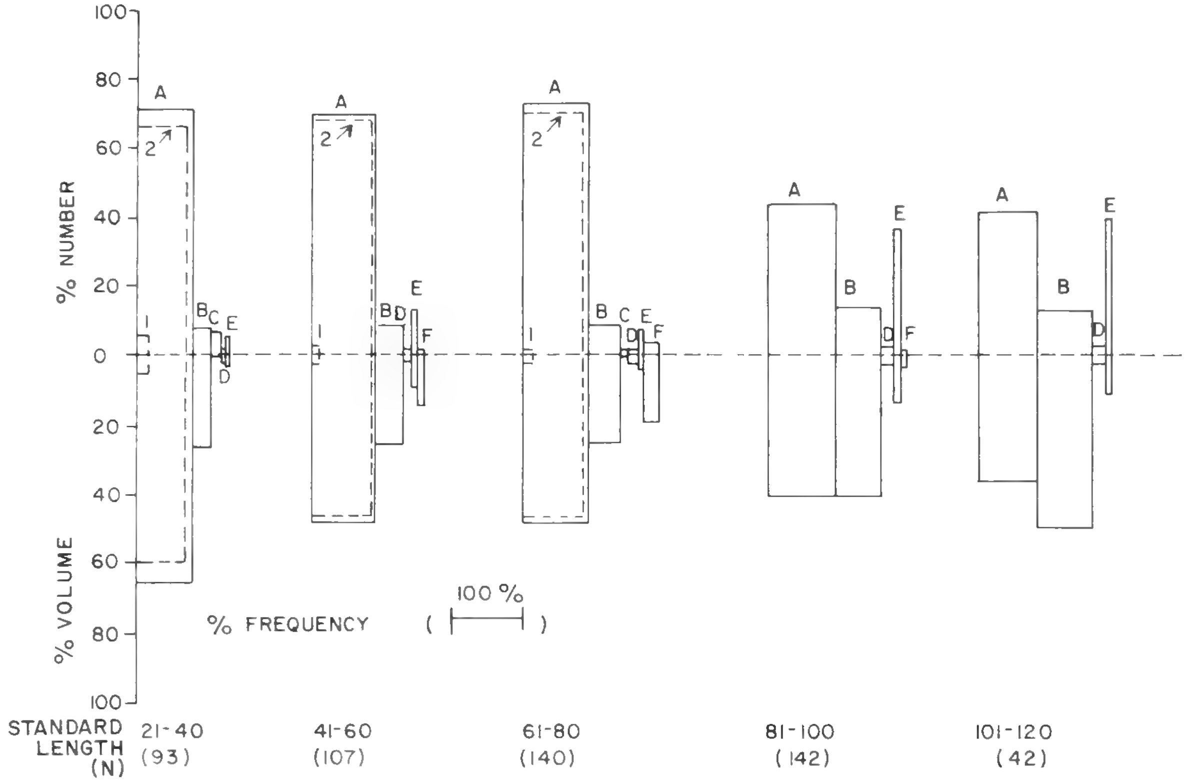


Figure 23.—Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food in the diet of *Citharichthys arctifrons*, by seasonal cruise.



IRI						
A)	10521	10544	11512	7983	6739	AMPHIPODA
1)	154	49	60	1	1	HYPERIDEA
2)	8727	9979	10965	7952	6707	GAMMARIDEA
B)	811	1279	1528	3570	4896	POLYCHAETA
C)	87	6	19	3	1	COPEPODA
D)	23	28	61	101	100	CUMACEA
E)	40	88	27	426	240	LARVACEA
F)	1	187	571	21	6	PISCES

Figure 24.—Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food for size intervals (mm) of *Citharichthys arctifrons*.

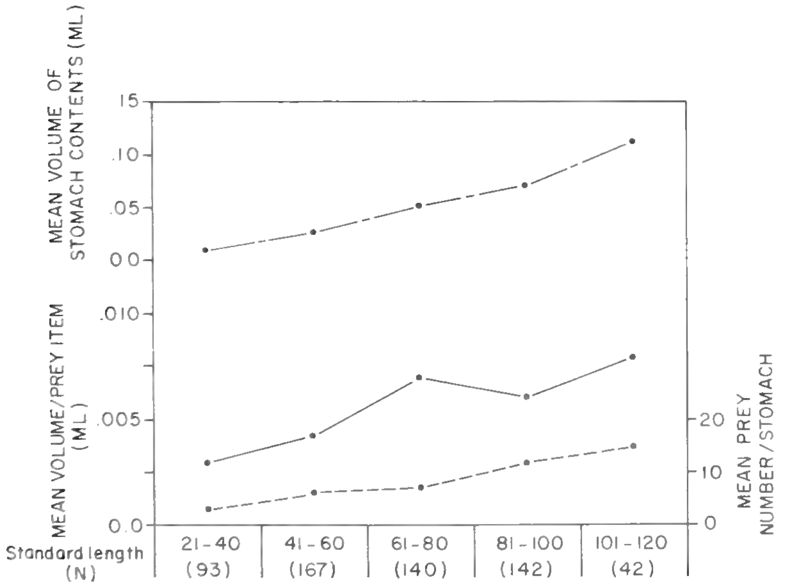


Figure 25.—Relationship between size of *Citharichthys arctifrons* and volume of food consumed (broken line), mean prey volume (solid line), and prey number per stomach (dashed line).

Paralichthys oblongus

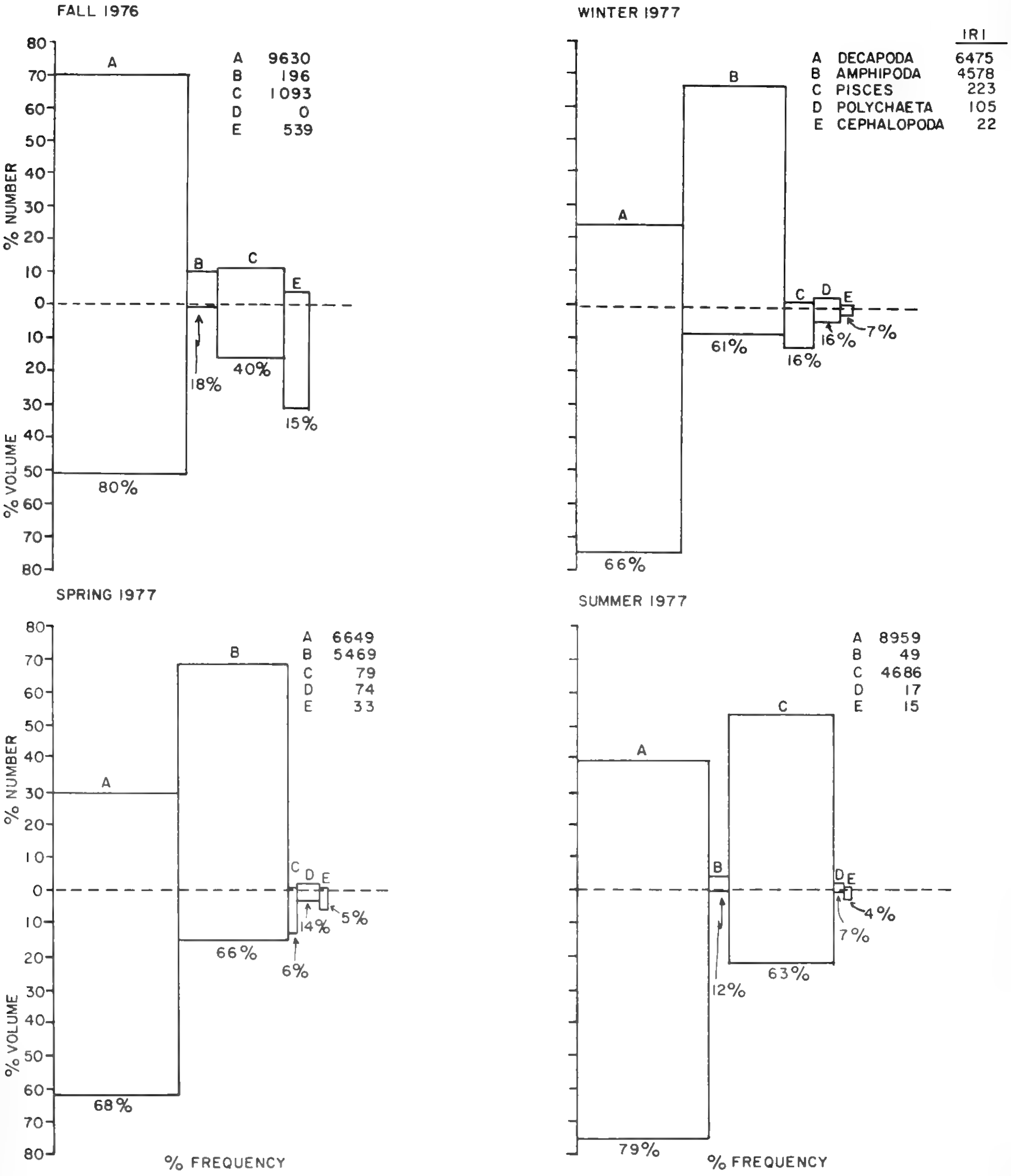
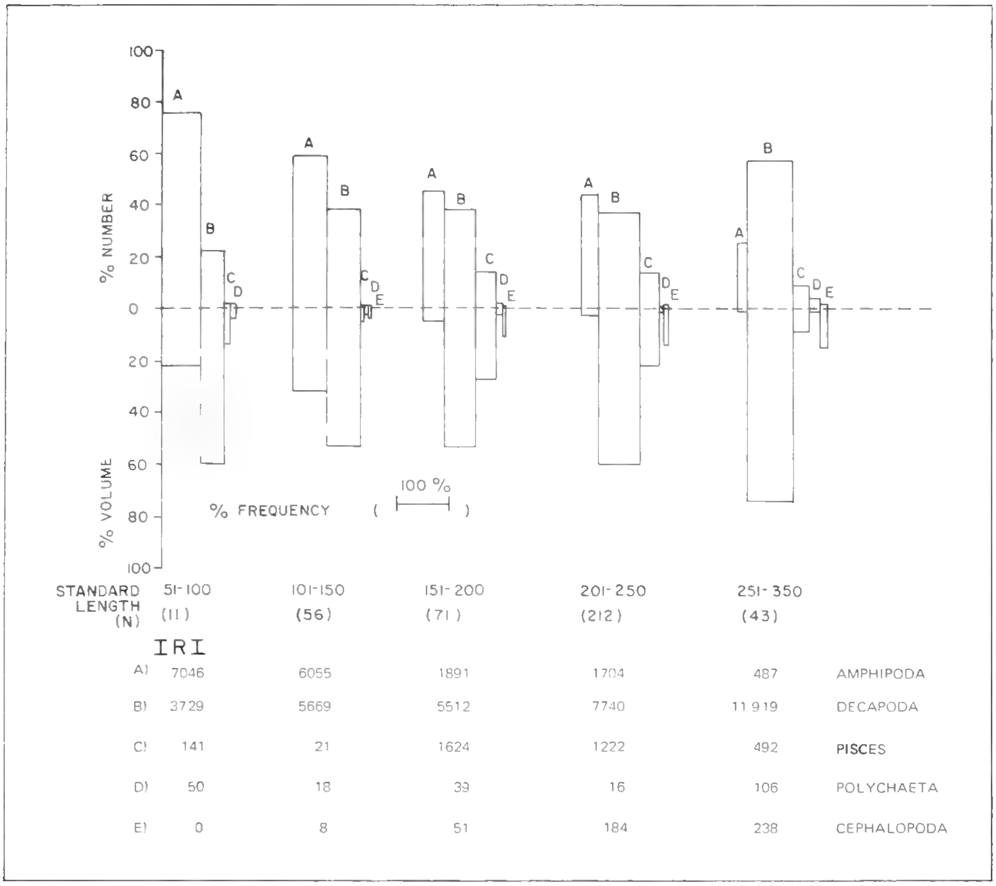


Figure 26.—Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food in the diet of *Paralichthys oblongus*, by seasonal cruise.



IRI	51-100	101-150	151-200	201-250	251-350	
A)	7046	6055	1891	1704	487	AMPHIPODA
B)	3729	5669	5512	7740	11 919	DECAPODA
C)	141	21	1624	1222	492	PISCES
D)	50	18	39	16	106	POLYCHAETA
E)	0	8	51	184	238	CEPHALOPODA

Figure 27.—Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food for size intervals (mm) of *Paralichthys oblongus*.

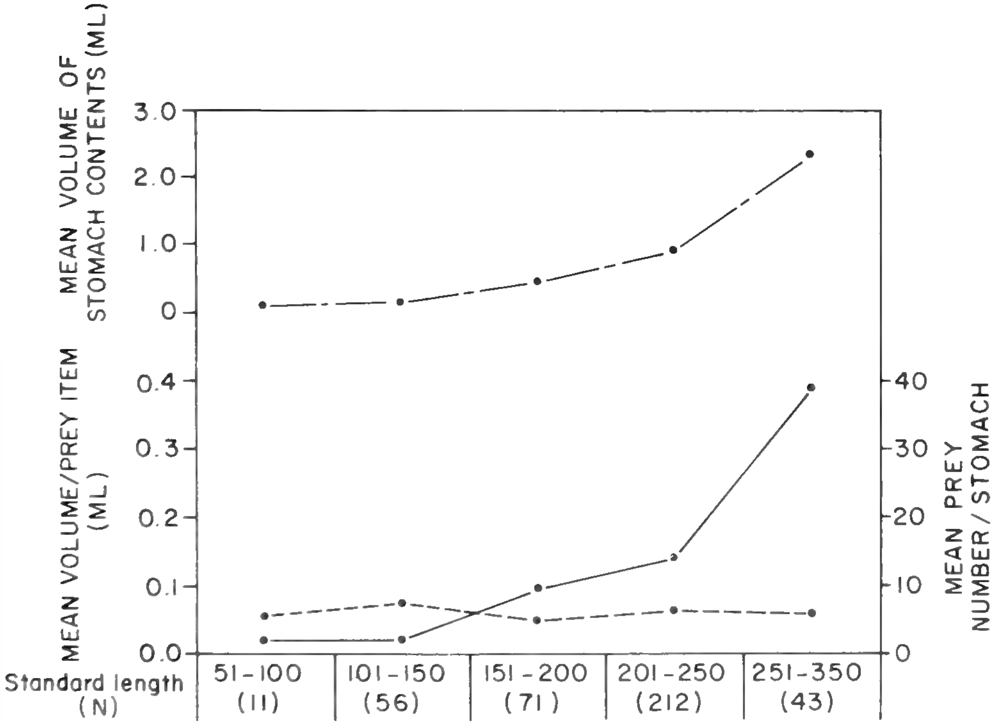


Figure 28.—Relationship between size of *Paralichthys oblongus* and volume of food consumed (broken line), mean prey volume (solid line), and prey number per stomach (dashed line).

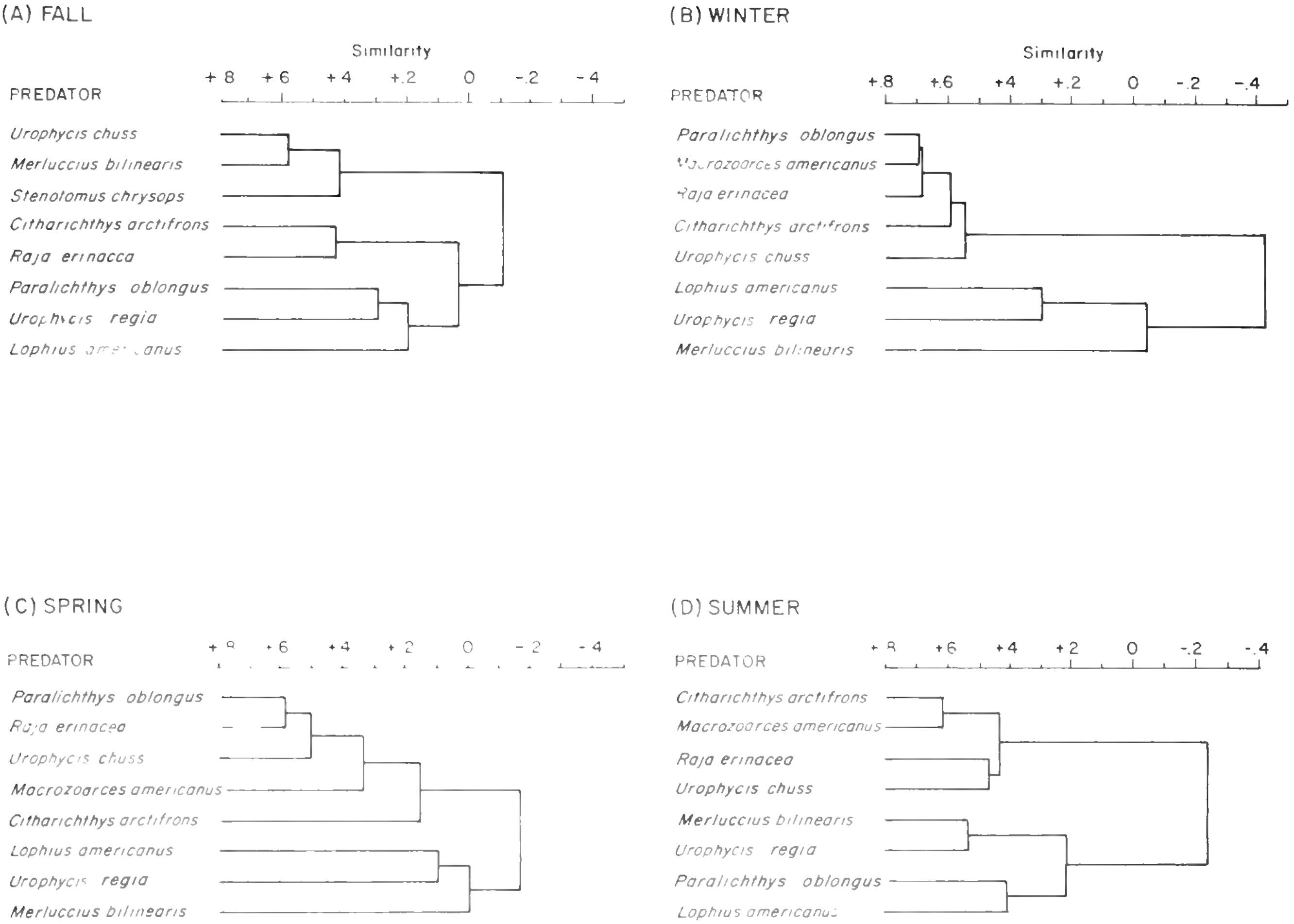


Figure 29.—Dendrograms depicting diet similarity (Bray-Curtis similarity index) among dominant predators, within each season.

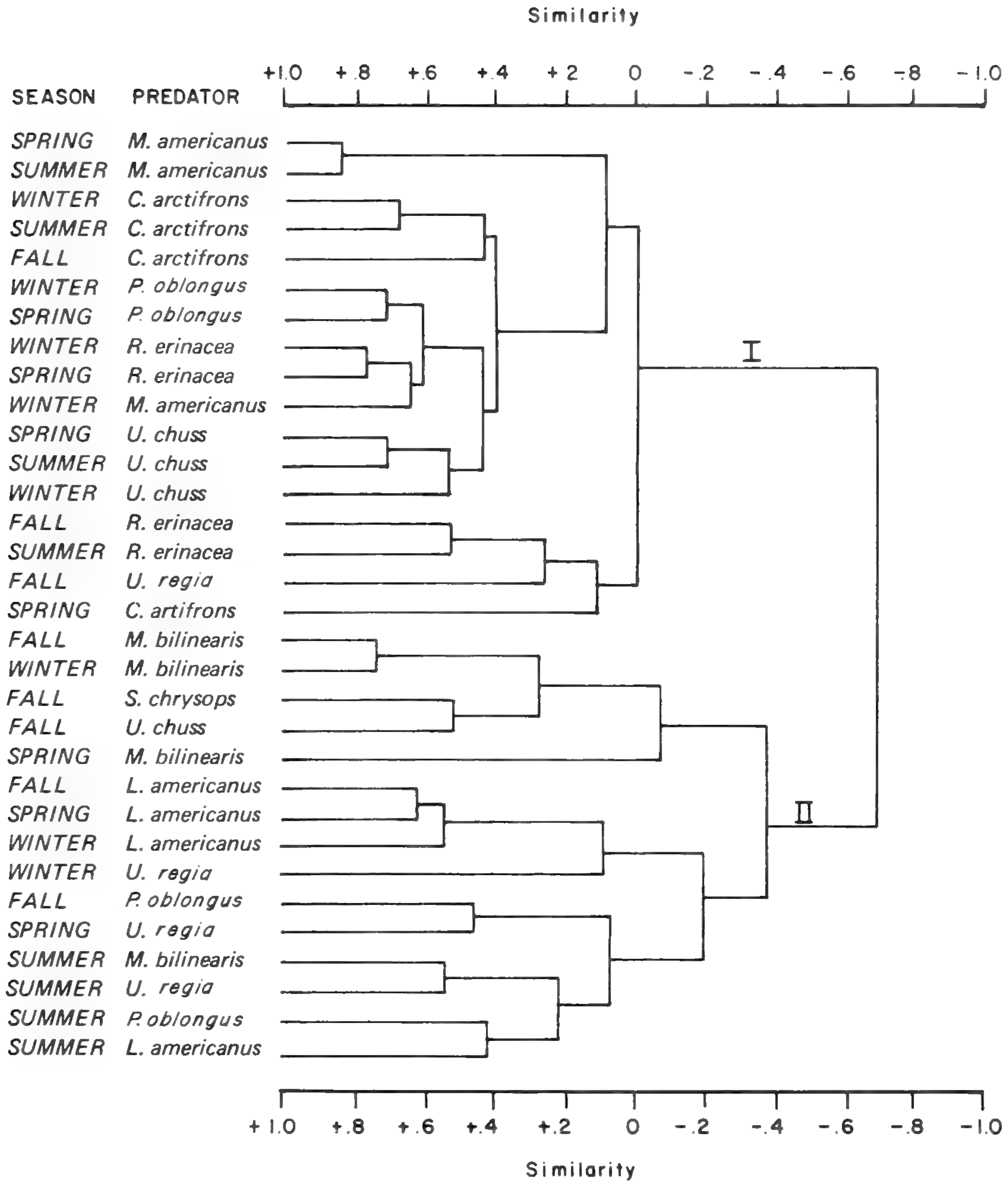


Figure 30.—Dendrogram depicting diet similarity (Bray-Curtis similarity index) among predators, by season. Roman numerals indicate groups referred to in the text.

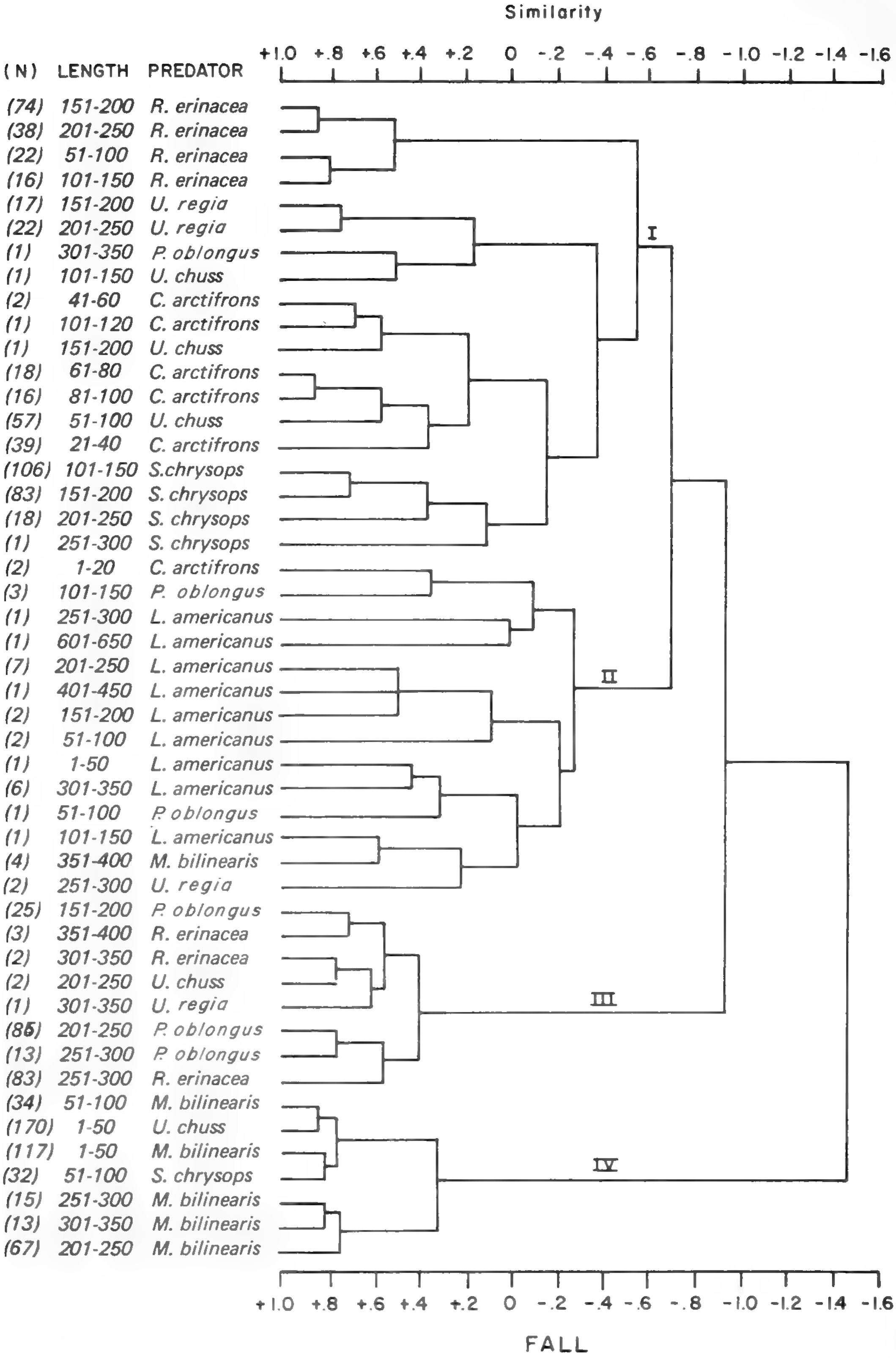


Figure 31.—Dendrogram depicting diet similarity (Bray-Curtis similarity index) among size groups of predators in the fall. Roman numerals indicate groups referred to in the text.

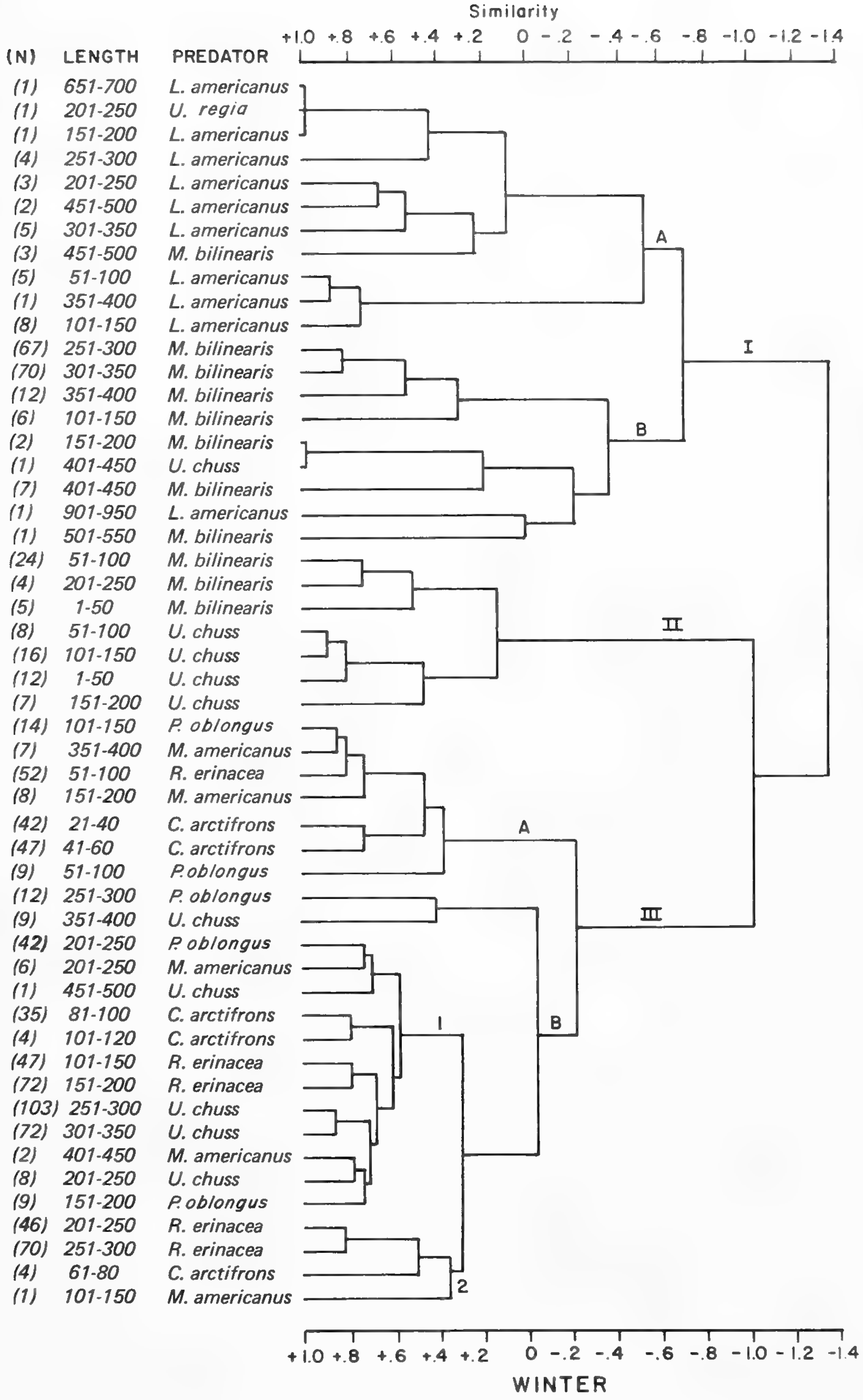


Figure 32.—Dendrogram depicting diet similarity (Bray-Curtis similarity index) among size groups of predators in winter. Roman numerals, letters and arabic numbers indicate groups and subgroups referred to in the text.

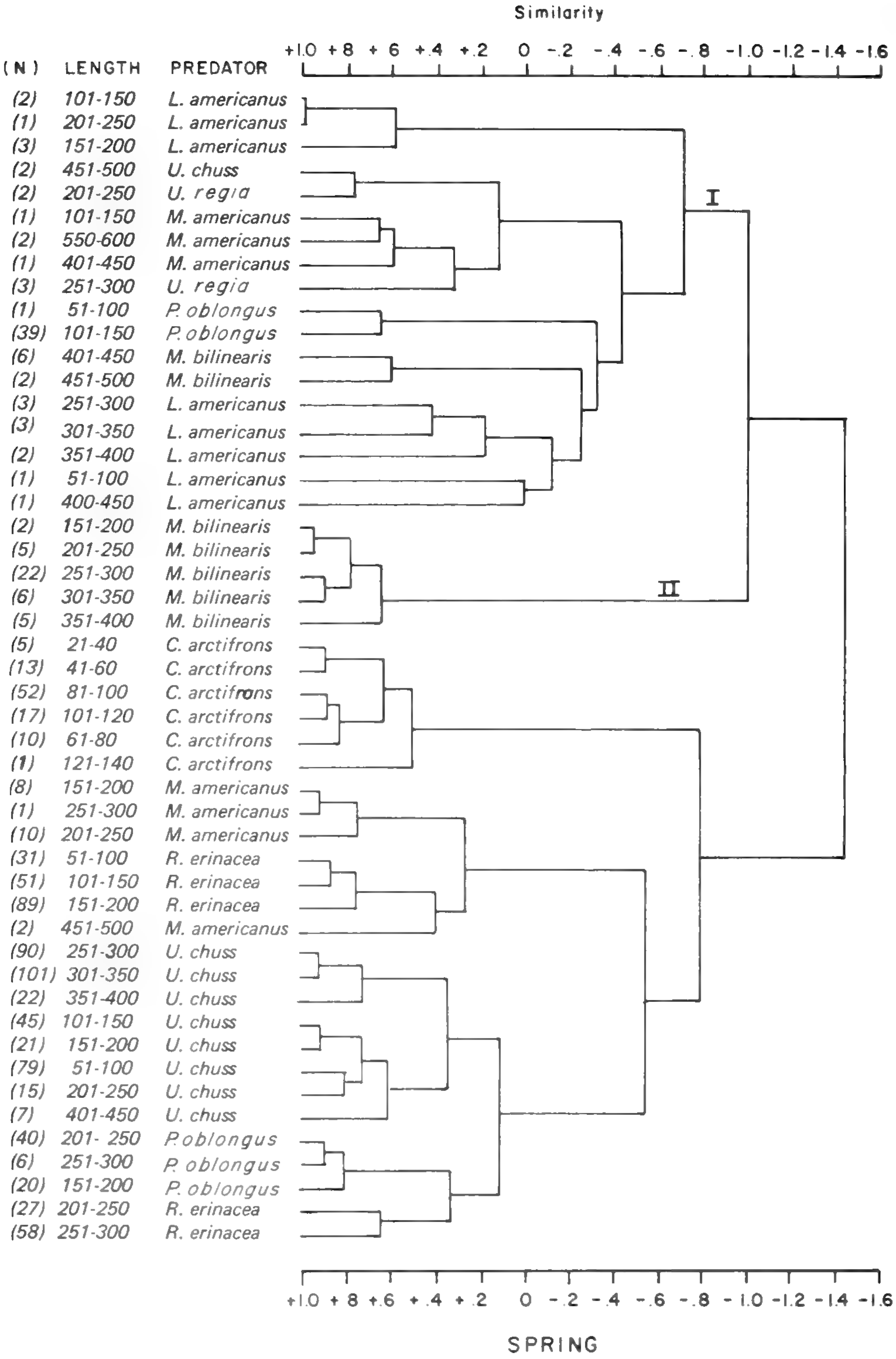


Figure 33.—Dendrogram depicting diet similarity (Bray-Curtis similarity index) among size groups of predators in spring. Roman numerals indicate groups referred to in the text.

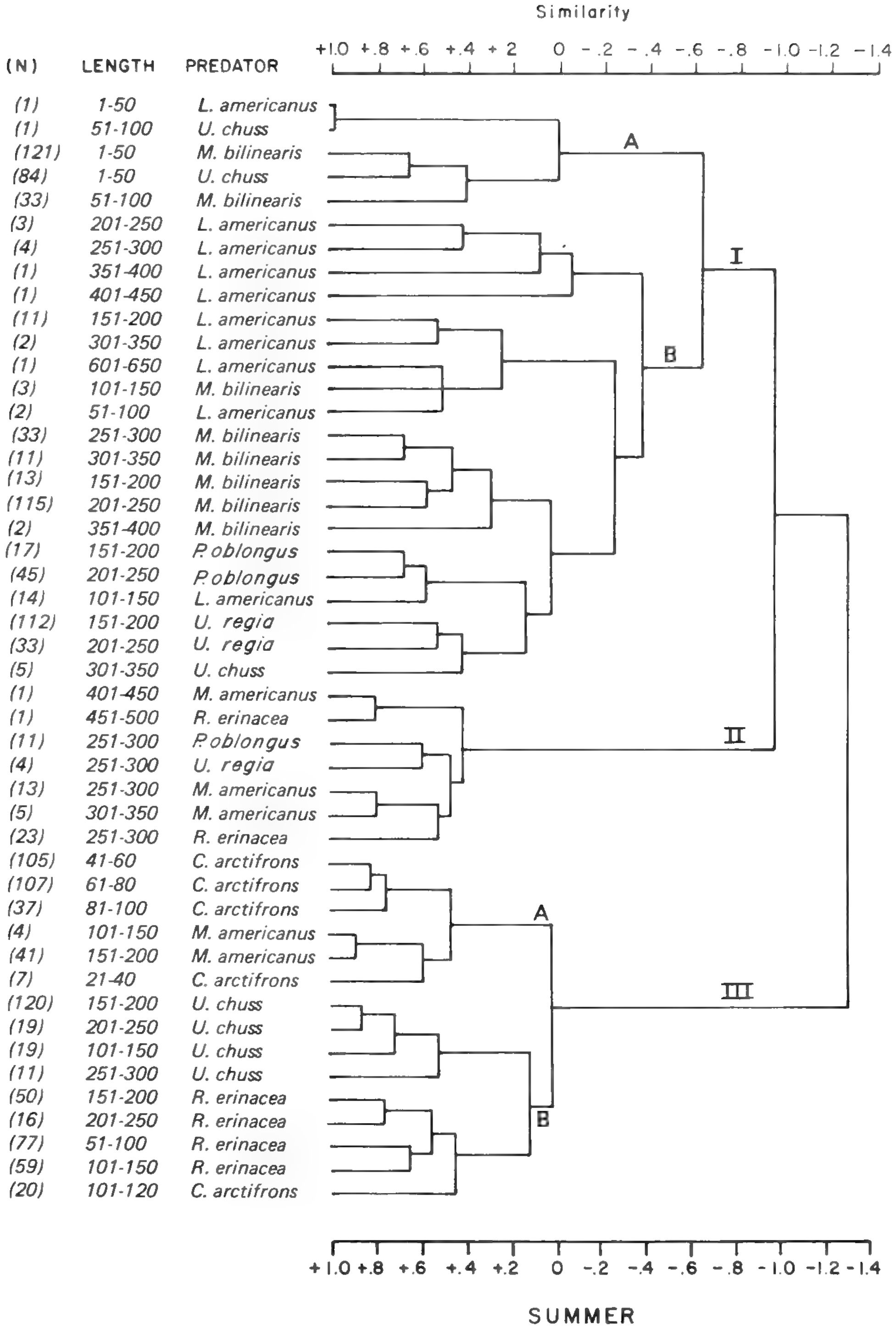


Figure 34.—Dendrogram depicting diet similarity (Bray-Curtis similarity index) among size groups of predators in summer. Roman numerals and letters indicate groups and subgroups referred to in the text.

Table 1.--Fishes selected for food habits analysis, and percentage of the total catch by number (N) and weight (W) comprised by each species, for each cruise.

Species	Fall 1976		Winter 1977		Spring 1977		Summer 1977	
	N	W	N	W	N	W	N	W
Rajidae								
Raja erinacea	6.7	21.2	13.4	14.7	24.2	28.6	5.2	15.6
Lophiidae								
Lophius americanus	1.5	18.3	2.8	11.5	3.3	12.7	1.2	10.5
Gadidae								
Urophycis chuss	25.0	0.3	39.8	33.4	36.6	33.6	17.3	15.4
Urophycis regia	1.2	1.4	0.1	0.1	0.6	0.9	7.2	12.0
Merluccius bilinearis	16.7	5.1	22.8	25.3	10.2	14.1	27.0	32.1
Zoarcidae								
Macrozoarces americanus	0.5	0.4	1.8	0.9	5.3	3.8	8.2	2.7
Sparidae								
Stenotomus chrysops	26.7	25.9	0.1	0.1	0.4	0.2	0.0	0.0
Bothidae								
Citharichthys arctifrons	11.7	0.1	7.9	0.1	7.1	0.3	26.9	1.8
Paralichthys oblongus	5.2	7.1	5.0	2.8	9.2	4.2	1.9	5.3
TOTAL	95.2	79.8	93.7	88.9	96.9	98.4	94.9	95.4

Table 2.--Percent frequency occurrence (F), percent number (N), percent volume (V) and index of relative importance (IRI) of food items in <u>Raja erinacea</u> stomachs, by cruise.

Taxon	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
Food Item	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Cnidaria																
Hydrozoa																
<u>Eudendrium</u> spp.	-	-	-	-	.35	.01	.00	<1	-	-	-	-	-	-	-	-
Anthozoa																
Unidentified	-	-	-	-	-	-	-	-	1.13	.03	.36	<1	-	-	-	-
Annelida																
Polychaeta																
<u>Aphrodita hastata</u>	3.67	.12	1.63	6	2.08	.07	1.90	4	1.13	.03	.52	1	-	-	-	-
<u>Harmothoe extenuata</u>	.41	.01	.25	<1	.70	.03	.03	<1	10.94	.38	.22	7	7.05	.30	.13	3
<u>Sthenelais limicola</u>	3.67	.17	.17	1	7.29	.48	1.28	13	17.36	.67	1.89	44	4.41	.15	.26	2
Phyllodocidae	-	-	-	-	-	-	-	-	.35	.01	.01	<1	.88	.03	.02	<1
Nereidae	.41	.01	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
<u>Nereis</u>	.41	.01	.00	<1	-	-	-	-	.38	.01	.00	<1	4.41	.18	.20	2
<u>N. grayi</u>	.41	.01	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
Nephtyidae	-	-	-	-	-	-	-	-	1.13	.03	.15	<1	-	-	-	-
<u>Aglaophamus circinata</u>	4.10	.11	.86	4	1.73	.04	.72	1	.75	.02	.03	<1	1.32	.04	.08	<1
<u>Nephtys</u>	-	-	-	-	-	-	-	-	.75	.02	.23	<1	-	-	-	-
<u>N. bucera</u>	-	-	-	-	-	-	-	-	.38	.01	.04	<1	-	-	-	-
<u>N. incisa</u>	.41	.01	.83	<1	-	-	-	-	-	-	-	-	-	-	-	-
<u>Glycera</u> spp.	2.86	.08	.24	1	2.78	.06	.10	<1	.75	.02	.05	<1	.88	.03	.08	<1
<u>G. dibranchiata</u>	6.53	.20	.81	7	-	-	-	-	12.08	.31	1.30	19	3.08	.09	.56	2
<u>Godiada norvegica</u>	.41	.03	.69	<1	11.46	.31	2.29	30	-	-	-	-	-	-	-	-
<u>G. brunnea</u>	-	-	-	-	.35	.01	.26	<1	-	-	-	-	-	-	-	-
<u>Scalibregma inflatum</u>	.41	.01	.01	<1	.69	.02	.01	<1	6.42	.14	.25	3	3.96	.11	.14	1
<u>Ophelia denticulata</u>	1.22	.03	.23	<1	.69	.02	.04	<1	.38	.01	.08	<1	-	-	-	-
<u>Ophelina</u> spp.	4.08	.75	.51	5	.35	.01	.02	<1	.75	.04	.04	<1	8.81	.76	.61	12
Maldanidae	.81	.02	.02	<1	1.04	.03	.13	<1	.38	.01	.01	<1	5.73	.16	.22	2
<u>Clymenella torquata</u>	.41	.01	.02	<1	.35	.01	.02	<1	.38	.01	.01	<1	.88	.03	.04	<1
<u>Euclymene collaris</u>	.41	.01	.02	<1	-	-	-	-	-	-	-	-	-	-	-	-
<u>Clymenura</u> sp. A	8.57	.24	.58	7	8.67	.22	.96	10	10.19	.23	.67	9	1.32	.04	.05	<1
Spionidae	.41	.01	.03	<1	-	-	-	-	.75	.02	.02	<1	.44	.01	.00	<1
<u>Spiophanes bombyx</u>	-	-	-	-	-	-	-	-	-	-	-	-	.44	.01	.00	<1
<u>Onuphis pallidula</u>	-	-	-	-	-	-	-	-	.38	.01	.01	<1	-	-	-	-
<u>Marphysa</u> spp.	-	-	-	-	-	-	-	-	.75	.02	.01	<1	.44	.01	.03	<1
<u>Lumbrineris fragilis</u>	2.45	.07	.76	2	1.39	.03	.22	<1	1.51	.03	.12	<1	.44	.01	.07	<1
<u>Ampharete arctica</u>	1.22	.03	.02	<1	7.98	.23	.37	5	3.77	.10	.15	1	1.32	.04	.01	<1
<u>Pherusa affinis</u>	2.04	.11	.56	1	2.08	.08	.28	1	1.51	.08	.42	1	-	-	-	-
Sabellidae	1.22	.06	.94	1	-	-	-	-	-	-	-	-	.88	.03	.39	<1
<u>Chone infundibuliformis</u>	4.90	.20	.77	5	3.47	.08	.16	1	3.02	.07	.18	1	.44	.01	.00	<1
<u>Filograma implexa</u>	.41	.01	.50	<1	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified	29.80	.97	3.83	143	14.93	.37	1.26	24	20.38	.47	.60	22	10.13	.31	.30	6
Total Polychaeta	54.69	3.32	14.28	963	42.31	2.08	10.07	515	61.51	2.73	7.03	600	40.53	2.34	3.20	225
Mollusca																
Scaphopoda																
Unidentified	.41	.01	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
Gastropoda																
Unidentified	.41	.01	.08	<1	.35	.01	.00	<1	-	-	-	-	-	-	-	-
Pelecypoda																
<u>Ensis directus</u>	10.61	.29	3.10	36	20.48	.51	10.30	221	27.17	.63	12.61	360	3.08	.10	.62	2
Unidentified	13.47	.37	7.61	108	.69	.02	.19	<1	.38	.01	.00	<1	-	-	-	-
Total Pelecypoda	24.08	.67	10.71	274	20.83	.52	10.49	229	27.55	.64	12.62	365	3.08	.10	.62	2
Cephalopoda																
<u>Loligo pealei</u>	.41	.01	1.25	1	-	-	-	-	-	-	-	-	-	-	-	-
<u>Rossia tenera</u>	.82	.02	.01	<1	-	-	-	-	.38	.01	.00	<1	.44	.01	.20	<1
<u>Octopus vulgaris</u>	-	-	-	-	-	-	-	-	-	-	-	-	.88	.03	.08	<1
Unidentified	-	-	-	-	-	-	-	-	.38	.01	.00	<1	-	-	-	-
Total Cephalopoda	1.22	.03	1.26	2	-	-	-	-	.75	.02	.00	<1	1.32	.04	.28	<1
Total Mollusca	25.71	.72	12.06	329	21.18	.53	10.49	233	28.30	.66	12.62	376	4.41	.14	.90	5

Table 2.--Continued.

Taxon Food Item	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Crustacea																
Copepoda																
Calanus finmarchicus	-	-	-	-	-	-	-	-	1.51	.04	.00	<1	3.08	.10	.00	<1
Paracalanus spp.	-	-	-	-	1.39	.08	.00	<1	-	-	-	-	-	-	-	-
Centropages typicus	-	-	-	-	1.73	.05	.00	<1	-	-	-	-	.44	.01	.00	<1
Candacia armata	-	-	-	-	-	-	-	-	-	-	-	-	13.22	.47	.01	6
Metridia lucens	-	-	-	-	.35	.01	.00	<1	1.51	.03	.00	<1	.44	.01	.00	<1
Caligus spp.	-	-	-	-	-	-	-	-	-	-	-	-	.44	.01	.00	<1
Unidentified	.41	.01	.00	<1	.69	.02	.00	<1	.75	.02	.00	<1	-	-	-	-
Total Copepoda	.41	.01	.00	<1	3.82	.16	.00	1	3.40	.09	.00	<1	15.42	.60	.01	7
Stomatopoda																
Unidentified	-	-	-	-	-	-	-	-	-	-	-	-	1.32	.04	.05	<1
Mysidacea																
Heteromysis formosa	.41	.01	.00	<1	.69	.02	.00	<1	.75	.02	.01	<1	.88	.03	.01	<1
Erythrops erythropthalma	-	-	-	-	-	-	-	-	.75	.02	.00	<1	.88	.03	.00	<1
Total Mysidacea	.41	.01	.00	<1	.69	.02	.00	<1	1.50	.03	.02	<1	1.76	.05	.01	<1
Cumacea																
Eudorella spp.	-	-	-	-	.35	.01	.00	<1	2.26	.05	.00	<1	.44	.01	.00	<1
E. hispida	-	-	-	-	.69	.02	.00	<1	1.13	.03	.00	<1	-	-	-	-
Diastylis spp.	2.45	.17	.02	<1	3.13	.26	.02	1	.38	.01	.00	<1	.44	.01	.00	<1
D. sculpta	.41	.01	.00	<1	33.68	4.26	.53	161	60.75	8.65	1.21	594	42.73	6.97	.60	323
D. bispinosa	22.04	1.84	.36	49	35.76	4.10	1.00	182	42.26	4.29	.56	205	48.46	5.39	.71	296
D. polita	-	-	-	-	-	-	-	-	.38	.01	.00	<1	-	-	-	-
Nannastacidae	-	-	-	-	.35	.01	.00	<1	-	-	-	-	-	-	-	-
Petalosarsia declivis	-	-	-	-	1.39	.05	.00	<1	1.51	.07	.00	<1	2.64	.08	.00	<1
Unidentified	6.53	.32	.04	2	2.43	.06	.01	<1	-	-	-	-	.44	.01	.00	<1
Total Cumacea	28.16	2.34	.43	78	54.86	8.77	1.56	567	70.94	13.09	1.77	1055	63.44	12.47	1.31	874
Isopoda																
Chirodotea spp.	.41	.01	.00	<1	.35	.01	.00	<1	.38	.02	.00	<1	.44	.03	.00	<1
C. tuftsi	2.04	.07	.01	<1	.35	.01	.00	<1	1.38	.01	.00	<1	.88	.04	.01	<1
C. arenicola	-	-	-	-	-	-	-	-	1.51	.07	.02	<1	.44	.01	.00	<1
Edotea triloba	.41	.01	.00	<1	2.43	.05	.01	<1	12.83	.54	.09	8	.88	.04	.01	<1
Cirolana spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C. polita	18.78	1.10	1.27	44	13.19	.36	.93	17	11.32	.59	1.38	22	3.08	.10	.22	1
Janira alta	-	-	-	-	-	-	-	-	.38	.01	.00	<1	.44	.01	.00	<1
Unidentified	.41	.01	.00	<1	.69	.02	.02	<1	-	-	-	-	-	-	-	-
Total Isopoda	20.40	1.20	1.28	51	15.97	.44	.97	23	24.91	1.24	1.51	68	6.17	.21	.24	3
Amphipoda																
Ampelisca spp.	4.08	.32	.02	1	1.39	.05	.01	<1	.75	.02	.00	1	.44	.01	.00	<1
A. vadorum	38.78	9.46	1.74	436	22.92	1.20	.34	34	22.26	.94	.26	34	42.29	9.31	1.53	458
A. macrocephala	.41	.02	.01	<1	.69	.02	.01	<1	.38	.01	.00	<1	-	-	-	-
A. agassizi	2.86	.10	.03	<1	1.73	.04	.01	<1	3.40	.13	.01	<1	5.73	.19	.03	1
Byblis serrata	62.45	49.82	9.32	3694	57.64	9.43	2.64	696	67.55	11.26	3.04	966	69.16	19.49	4.06	1629
Leptocheirus pinguis	8.57	.67	.33	9	18.05	2.05	1.17	58	14.34	.85	.45	19	8.81	.37	.16	5
Argissa hamatipes	-	-	-	-	4.17	.16	.02	1	.75	.02	.00	<1	2.20	.06	.00	<1
Corophium spp.	.41	.01	.00	<1	.35	.01	.00	<1	-	-	-	-	-	-	-	-
Erichthonius rubricornis	26.53	1.84	.18	53	66.67	17.64	1.89	1302	74.34	28.30	3.69	2379	71.37	14.98	1.14	1152
Unciola spp.	-	-	-	-	-	-	-	-	-	-	-	-	.44	.01	.00	1
U. irrorata	51.43	8.06	1.50	491	87.15	50.65	15.86	5797	87.92	33.91	9.28	3798	77.09	15.51	3.24	1446
Pseudunicola obliquua	-	-	-	-	-	-	-	-	.38	.01	.00	<1	-	-	-	-
Siphonoectes smithianus	.41	.01	.00	<1	-	-	-	-	-	-	-	-	1.76	.08	.01	<1
Melita dentata	.41	.01	.00	<1	1.39	.04	.02	<1	.38	.02	.02	<1	.44	.01	.00	<1
Casco bigelowi	1.22	.03	.03	<1	.69	.02	.01	<1	2.64	.06	.02	<1	3.96	.14	.08	1
Jerbarnia sp. A	-	-	-	-	.35	.01	.00	<1	1.13	.10	101	<1	-	-	-	-
Protohaustorius wigleyi	1.63	.05	.01	<1	3.47	.10	.02	<1	1.89	.12	.01	<1	2.64	.08	.00	<1
Photis spp.	-	-	-	-	.35	.01	.00	<1	-	-	-	-	.88	.03	.00	<1
Photis dentata	-	-	-	-	-	-	-	-	.38	.01	.00	<1	.44	.01	.00	<1
Protomedia fasciata	-	-	-	-	-	-	-	-	3.02	.09	.01	<1	-	-	-	-
Hippomedan serratus	4.49	.15	.06	<1	2.78	.06	.06	<1	3.02	.08	.09	<1	1.32	.04	.01	<1
Anonyx sarsi	1.22	.03	.02	<1	.35	.01	.02	<1	2.64	.06	.17	1	-	-	-	-
A. lilljeborgi	.41	.01	.00	<1	.35	.01	.01	<1	-	-	-	-	-	-	-	-
Oedicerotidae	.41	.01	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
Monoculodes spp.	.41	.01	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
Monoculodes edwardsi	2.04	.08	.01	<1	4.17	.29	.07	1	1.13	.03	.00	<1	54.63	9.08	1.19	561

Table 2.--Continued.

Taxon Food Item	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Synchelidium americanum	.82	.02	.00	<1	-	-	-	-	.38	.01	.00	<1	-	-	-	-
Phoxocephalus holbolli	.41	.01	.00	<1	1.04	.02	.00	<1	2.64	.06	.01	<1	4.85	.20	.02	1
Trichophoxus epistomus	21.63	2.20	.32	55	4.86	.12	.02	1	7.92	.23	.05	2	6.17	.19	.03	1
Harpinia propinqua	1.22	.03	.00	<1	-	-	-	-	.38	.01	.00	<1	.44	.01	.00	<1
Stenopleustis inermis	.82	.02	.00	<1	2.78	.06	.00	<1	6.79	.25	.01	2	11.01	.38	.00	4
Hyperiidae	1.63	.05	.01	<1	-	-	-	-	-	-	-	-	-	-	-	-
Parathemisto gaudichaudi	6.12	.20	.02	1	1.39	.03	.00	<1	.75	.02	.00	<1	29.07	1.54	.12	46
Caprellidae	-	-	-	-	.35	.01	.00	<1	-	-	-	-	-	-	-	-
Aeginina longicornis	.82	.02	.00	<1	15.63	.67	.31	15	16.98	.75	.21	16	7.05	.30	.07	3
Unidentified	16.33	.94	.24	19	2.43	.07	.03	<1	3.02	.13	.01	<1	.88	.03	.00	<1
Total Amphipoda	77.14	74.20	13.83	6791	93.06	82.79	22.52	9800	93.96	77.45	17.35	8908	91.63	72.02	11.70	7671
Euphausiacea																
Euphausiidae	-	-	-	-	-	-	-	-	-	-	-	-	.44	.01	.00	<1
Decapoda																
Leptochela bermudensis	1.22	.03	.02	<1	-	-	-	-	-	-	-	-	1.32	.05	.02	<1
Dichelopandalus leptocerus	6.94	.28	1.78	14	1.73	.05	.24	1	4.53	.10	.02	1	18.06	.74	1.43	39
Crangonidae	.82	.02	.00	<1	-	-	-	-	-	-	-	-	.44	.01	.00	<1
Crangon septemspinosa	28.98	1.27	2.09	97	12.15	.82	.54	17	7.17	.21	.28	4	44.05	3.06	1.77	213
Munida iris	-	-	-	-	.35	.01	.04	<1	-	-	-	-	-	-	-	-
Axius serrata	.82	.02	.36	<1	-	-	-	-	-	-	-	-	-	-	-	-
Pagurus spp.	.41	.01	.01	<1	.69	.02	.06	<1	-	-	-	-	1.32	.04	.01	<1
P. arcuatus	.41	.01	.03	<1	-	-	-	-	.38	.01	.10	<1	-	-	-	-
P. acadianus	-	-	-	-	1.39	.03	.14	<1	.38	.01	.02	<1	.44	.01	.03	<1
Albunea spp. megalopae	-	-	-	-	-	-	-	-	-	-	-	-	.44	.01	.00	<1
Calappidae spp. megalopae	-	-	-	-	-	-	-	-	-	-	-	-	.88	.03	.00	<1
Callinectes spp. zoea	-	-	-	-	-	-	-	-	-	-	-	-	.44	.01	.00	<1
Cancer spp.	8.16	.59	.36	8	2.08	.05	.09	<1	.38	.02	.01	<1	-	-	-	-
C. borealis	11.02	.50	1.31	20	3.13	.10	.58	2	3.02	.11	1.49	5	3.96	.20	5.88	24
C. irroratus	72.65	13.29	45.57	4284	42.71	3.86	49.77	2290	43.77	4.12	57.28	2688	53.30	7.05	64.30	3803
Unidentified	11.43	1.05	1.68	31	1.04	.02	.07	<1	-	-	-	-	.44	.01	.00	<1
Total Decapoda	83.08	17.18	53.21	5918	50.69	4.95	51.54	2864	50.19	4.57	59.21	3201	74.01	11.24	73.46	6268
Unidentified Crustacea	9.80	.36	.84	12	3.13	.09	.05	1	1.51	.03	.00	<1	1.32	.04	.01	<1
Total Crustacea	99.59	95.30	69.59	16421	100.00	97.22	76.63	17386	100.00	96.52	79.85	17636	100.00	96.69	86.79	18348
Nemertea																
Phascolion strombi	-	-	-	-	.35	.01	.00	<1	-	-	-	-	-	-	-	-
Ectoprocta																
Unidentified	-	-	-	-	.35	.01	.00	<1	-	-	-	-	-	-	-	-
Echino dermata																
Echinoidea																
Echinarachnius parma	.82	.02	.00	<1	.35	.01	.01	<1	-	-	-	-	-	-	-	-
Asteroidea																
Unidentified	.41	.01	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
Total Echinodermata	1.22	.03	.01	<1	.35	.01	.01	<1	-	-	-	-	-	-	-	-
Chaetognatha																
Sagitta elegans	-	-	-	-	-	-	-	-	.75	.02	.00	<1	-	-	-	-
Chordata																
Pisces																
Teleostei	11.02	.36	1.65	22	2.78	.06	1.57	5	.75	.02	.01	<1	10.57	.31	1.02	14
Urophycis chuss	4.08	.18	.43	3	1.39	.03	.84	1	-	-	-	-	2.20	.06	7.12	16
Merluccius bilinearis	.41	.01	.08	<1	.35	.01	.21	<1	-	-	-	-	1.32	.08	.20	<1
Lepophidium cervinum	.41	.02	1.83	1	.69	.02	.13	<1	.38	.02	.12	<1	-	-	-	-
Liparis inquilinus	-	-	-	-	-	-	-	-	.38	.01	.00	<1	.88	.02	.03	<1
Ammodytes spp.	-	-	-	-	.69	.02	.04	<1	.38	.01	.02	<1	-	-	-	-
Citharichthys arctifrons	1.22	.05	.08	<1	-	-	-	-	-	-	-	-	3.52	.16	.25	1
Limanda ferruginea	-	-	-	-	-	-	-	-	-	-	-	-	4.85	.19	.49	3
Total Pisces	16.73	.62	4.08	79	5.90	.13	2.80	17	1.89	.05	.15	<1	22.91	.83	9.12	228
Total number of stomachs examined:		249				296				272				233		
Examined stomachs with food:		245				288				265				227		

Table 3.--Percent frequency occurrence (F), percent number (N), percent volume (V) and index of relative importance (IRI) of food items in *Lophius americanus* stomachs, by cruise.

Taxon	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
Food Item	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Annelida																
Polychaeta																
Aphrodita hastata	-	-	-	-	-	-	-	-	6.25	5.00	.41	34	-	-	-	-
Mollusca																
Cephalopoda																
Loligo pealeii	4.54	3.45	.69	19	-	-	-	-	-	-	-	-	7.32	3.33	11.47	108
Rossia tenera	-	-	-	-	3.23	2.63	.19	9	-	-	-	-	2.44	1.11	.02	3
unidentified	-	-	-	-	-	-	-	-	-	-	-	-	2.44	1.11	2.39	9
Total Cephalopoda	4.54	3.45	.69	19	3.23	2.63	.19	9	-	-	-	-	12.20	5.56	13.89	237
Crustacea																
Amphipoda																
Byblis serrata	4.54	3.45	.00	16	-	-	-	-	-	-	-	-	-	-	-	-
Decapoda																
Dichelopandalus leptocerus	9.09	6.90	.22	65	6.45	5.26	.16	35	-	-	-	-	17.07	16.67	.36	291
Crangon septemspinosa	-	-	-	-	-	-	-	-	-	-	-	-	2.44	1.11	.02	3
Cancer borealis	-	-	-	-	-	-	-	-	6.25	5.00	1.63	41	-	-	-	-
C. irroratus	-	-	-	-	-	-	-	-	-	-	-	-	4.88	2.22	.05	11
Total Decapoda	9.09	6.90	.22	65	6.45	5.26	.16	35	6.25	5.00	1.63	41	19.51	20.00	.43	399
Echinodermata																
Asteroidea																
Asterias vulgaris	-	-	-	-	-	-	-	-	6.25	5.00	.08	32	7.32	3.33	.28	26
Astropecten americanus	-	-	-	-	-	-	-	-	-	-	-	-	2.44	1.11	.12	3
Total Asteroidea	-	-	-	-	-	-	-	-	6.25	5.00	.08	32	9.76	4.44	.40	47
Chaetognatha																
Sagitta elegans	-	-	-	-	-	-	-	-	-	-	-	-	2.44	3.33	.00	8
Chordata																
Pisces																
Squalus acanthias	-	-	-	-	6.45	5.26	.97	40	-	-	-	-	-	-	-	-
Raja spp.	-	-	-	-	3.23	2.63	.23	9	-	-	-	-	-	-	-	-
Teleostei	27.27	20.69	10.69	856	35.48	28.95	40.20	2454	25.00	20.00	12.96	824	29.27	15.55	25.46	1200
Lophius americanus	-	-	-	-	-	-	-	-	6.25	5.00	.24	33	-	-	-	-
Urophycis chuss	27.27	24.14	6.20	827	48.39	50.00	54.75	5068	43.75	35.00	33.21	2984	24.39	11.11	25.36	890
U. regius	-	-	-	-	-	-	-	-	-	-	-	-	2.44	1.11	8.37	23
Merluccius bilinearis	4.54	3.45	.24	17	-	-	-	-	6.25	5.00	26.89	199	7.32	18.89	.65	143
Lepophidium cervinum	13.64	10.34	8.33	255	3.23	2.63	2.03	15	6.25	5.00	1.63	41	12.19	5.55	5.68	137
Liparis inquilinus	-	-	-	-	-	-	-	-	-	-	-	-	4.88	2.22	.02	11
Stenotomus chrysops	9.09	10.34	70.76	737	-	-	-	-	6.25	5.00	4.89	62	-	-	-	-
Scombridae	-	-	-	-	-	-	-	-	6.25	5.00	17.93	143	-	-	-	-
Citharichthys arctifrons	4.54	13.79	.19	64	-	-	-	-	6.25	5.00	.12	32	17.07	10.00	4.20	242
Pseudopleuronectes americanus	-	-	-	-	-	-	-	-	-	-	-	-	2.44	1.11	13.15	35
Limanda ferruginea	-	-	-	-	-	-	-	-	-	-	-	-	2.44	1.11	2.39	9
Total Pisces	90.91	86.21	99.08	16845	100.00	92.11	99.65	19176	93.75	85.00	97.88	17145	85.35	66.67	85.28	12971
Total number of stomachs examined		37				40				18				45		
Examined stomachs with food:		22				31				16				41		

Table 4.--Percent frequency occurrence (F), percent number (N), percent volume (V) and index of relative importance (IRI) of food items in *Urophycis chuss* stomachs, by cruise.

Taxon	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
Food Item	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	V	N	IRI
Plant																
Sargassum spp.	–	–	–	–	–	–	–	–	–	–	–	–	.38	.02	.01	<1
Poacea	–	–	–	–	.32	.01	.16	<1	–	–	–	–	–	–	–	–
Cnidaria																
Hydrozoa																
Unidentified	–	–	–	–	–	–	–	–	1.04	.03	.00	<1	–	–	–	–
Anthozoa																
Unidentified	–	–	–	–	.32	.01	.05	<1	.26	.01	.00	<1	–	–	–	–
Rhynchocoela																
Anopla																
Carinomella lactea	–	–	–	–	.32	.01	.08	<1	–	–	–	–	–	–	–	–
Annelida																
Polychaeta																
Aphrodita hastata	–	–	–	–	2.22	.07	2.55	6	8.33	.27	3.84	34	–	–	–	–
Harmothoe spp.	–	–	–	–	.32	.01	.07	<1	–	–	–	–	–	–	–	–
H. extenuata	–	–	–	–	3.49	.14	.11	1	3.13	.11	.05	<1	1.53	.08	.04	<1
Sthenalais limicola	–	–	–	–	1.90	.06	.27	1	4.17	.14	.12	1	2.30	.11	.28	1
Phyllodoce spp.	–	–	–	–	.32	.01	.02	<1	.26	.01	.00	<1	–	–	–	–
P. mucosa	–	–	–	–	.32	.01	.00	<1	–	–	–	–	–	–	–	–
Syllis spp.	–	–	–	–	–	–	–	–	.52	.02	.00	<1	–	–	–	–
Nereis spp.	–	–	–	–	–	–	–	–	.52	.02	.00	<1	–	–	–	–
N. grayi	–	–	–	–	–	–	–	–	.26	.01	.01	<1	–	–	–	–
Nephtyidae	–	–	–	–	–	–	–	–	–	–	–	–	1.53	.08	.08	<1
Aglaophamus circinata	–	–	–	–	–	–	–	–	1.82	.05	.03	<1	–	–	–	–
Glycera dibranchiata	–	–	–	–	–	–	–	–	.52	.02	.01	<1	–	–	–	–
Goniada spp.	–	–	–	–	–	–	–	–	.26	.01	.00	<1	–	–	–	–
G. brunnea	–	–	–	–	.32	.01	.04	<1	–	–	–	–	–	–	–	–
Scalibregma inflatum	–	–	–	–	–	–	–	–	.26	.01	.01	<1	–	–	–	–
Ophelina spp.	–	–	–	–	–	–	–	–	–	–	–	–	1.53	.08	.05	<1
Maldanidae	–	–	–	–	–	–	–	–	1.04	.03	.02	<1	1.91	.12	.07	<1
Euclymene collaris	–	–	–	–	–	–	–	–	.26	.01	.00	<1	–	–	–	–
Clymenura sp. A	.43	.08	.73	<1	7.30	.24	.74	7	5.47	.18	.18	2	4.20	.23	.35	2
Praxillura longissima	–	–	–	–	–	–	–	–	.26	.01	.02	<1	–	–	–	–
Spionidae	–	–	–	–	.32	.01	.00	<1	.26	.01	.00	<1	–	–	–	–
Spiophanes bombyx	–	–	–	–	–	–	–	–	.26	.01	.00	<1	–	–	–	–
Onuphis pallidula	–	–	–	–	–	–	–	–	2.34	.11	.05	<1	–	–	–	–
Marphysa spp.	–	–	–	–	1.27	.04	.50	1	–	–	–	–	.38	.02	.22	<1
M. sanguinea	–	–	–	–	1.27	.05	1.06	1	–	–	–	–	–	–	–	–
M. bellii	–	–	–	–	.63	.02	.04	<1	–	–	–	–	–	–	–	–
Lumbrineris spp.	.43	.08	.00	<1	–	–	–	–	–	–	–	–	–	–	–	–
L. fragilis	–	–	–	–	6.35	.23	2.81	19	3.65	.13	.22	1	1.91	.09	.66	1
L. cruzensis	–	–	–	–	.63	.03	.02	<1	–	–	–	–	.38	.02	.01	<1
L. impatiens	–	–	–	–	–	–	–	–	–	–	–	–	.76	.04	.01	<1
L. albidentata	–	–	–	–	.32	.01	.03	<1	.26	.01	.00	<1	–	–	–	–
Lumbrinerides spp.	–	–	–	–	.32	.01	.02	<1	–	–	–	–	–	–	–	–
Arabella iricolor	–	–	–	–	.32	.07	1.10	<1	.52	.05	.13	<1	–	–	–	–
Driloneris longa	–	–	–	–	–	–	–	–	.26	.02	.02	<1	–	–	–	–
D. magna	–	–	–	–	.63	.02	.19	<1	–	–	–	–	.38	.02	.04	<1
Cirratulidae	–	–	–	–	.32	.01	.01	<1	1.82	.05	.10	<1	.38	.02	.07	<1
Tharyx spp.	–	–	–	–	.32	.01	.04	<1	–	–	–	–	–	–	–	–
T. acuta	–	–	–	–	1.59	.06	.22	<1	–	–	–	–	–	–	–	–
Ampharete arctica	–	–	–	–	8.25	.57	.94	12	1.30	.05	.03	<1	–	–	–	–
Terebellidae spp.	–	–	–	–	–	–	–	–	.26	.01	.03	<1	–	–	–	–
Nicolea venustula	–	–	–	–	.32	.01	.02	<1	–	–	–	–	–	–	–	–
Terebellides stroemi	–	–	–	–	.32	.01	.04	<1	–	–	–	–	–	–	–	–
Pherusa affinis	–	–	–	–	.95	.03	.13	<1	2.86	.10	.31	1	1.15	.10	.27	<1
Chone infundibuliformis	–	–	–	–	4.13	.23	.25	2	5.21	.19	.33	3	1.91	.10	.30	1
Unidentified	6.44	1.18	3.28	29	17.78	.68	2.68	60	16.67	.57	.44	17	8.78	.48	.73	11
Total Polychaeta	7.30	1.34	4.01	39	41.27	2.68	13.90	684	41.93	2.17	5.96	341	24.43	1.58	3.20	117
Mollusca																
Gastropoda																
Lunatia heros	–	–	–	–	–	–	–	–	.26	.01	1.99	1	–	–	–	–
Mitrella spp.	–	–	–	–	.95	.03	.01	<1	.26	.01	.00	<1	–	–	–	–
Pyramidellidae	–	–	–	–	.95	.03	.01	<1	–	–	–	–	–	–	–	–
Odostomia spp.	–	–	–	–	.32	.01	.00	<1	–	–	–	–	–	–	–	–
Unidentified	–	–	–	–	.63	.02	.00	<1	–	–	–	–	–	–	–	–
Total Gastropoda	–	–	–	–	2.54	.09	.02	<1	.52	.02	2.00	1	–	–	–	–

Table 4.—Continued.

Taxon Food Item	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Pelecypoda																
Placopecten magellanicus	-	-	-	-	1.90	.07	2.88	6	3.65	.15	16.83	62	1.15	.06	8.97	10
Astarte spp.	-	-	-	-	.32	.01	.00	<1	.26	.01	.00	1	-	-	-	-
A. undata	-	-	-	-	.159	.05	.16	<1	.26	.01	.00	1	-	-	-	-
Cyclocardia borealis	-	-	-	-	.95	.04	.13	<1	.26	.01	.00	1	.76	.04	.00	<1
Ensis directus	-	-	-	-	6.98	.29	.50	5	3.13	.09	.23	1	.38	.02	.75	<1
Unidentified	.86	.16	2.48	2	4.76	.21	1.21	7	1.04	.03	.95	1	.38	.02	.26	<1
Total Pelecypoda	.86	.16	2.48	2	13.97	.67	4.88	78	8.07	.29	18.02	148	2.67	.13	9.97	27
Cephalopoda																
Rossia spp.	-	-	-	-	-	-	-	-	1.56	.05	.01	<1	-	-	-	-
Illex illecebrosus	-	-	-	-	-	-	-	-	1.82	.05	4.70	9	-	-	-	-
Unidentified	-	-	-	-	.32	.01	.04	<1	1.30	.04	.45	1	-	-	-	-
Total Cephalopoda	-	-	-	-	.32	.01	.04	<1	4.43	.15	5.16	23	-	-	-	-
Unidentified Mollusca	.43	.08	.07	<1	.63	.02	.01	<1	-	-	-	-	-	-	-	-
Total Mollusca	1.29	.24	2.55	4	16.82	.80	4.94	97	12.50	.45	25.17	324	2.67	.13	9.97	27
Arthropoda																
Ostracoda																
Unidentified	-	-	-	-	-	-	-	-	.26	.01	.00	<1	-	-	-	-
Copepoda																
Calanus finmarchicus	-	-	-	-	-	-	-	-	4.43	.19	.00	1	1.53	.08	.00	<1
Rhincalanus nasutus	-	-	-	-	.32	.01	.00	<1	-	-	-	-	-	-	-	-
Nannocalanus minor	.43	.24	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
Paracalanus spp.	-	-	-	-	10.48	15.67	.27	167	3.65	.16	.00	1	.76	.08	.00	<1
Pseudocalanus spp.	.43	.08	.00	<1	.32	.03	.00	<1	-	-	-	-	-	-	-	-
Temora longicornis	-	-	-	-	2.54	.18	.00	<1	.26	.02	.00	<1	.38	.02	.00	<1
Centropages typicus	9.01	24.49	.88	229	9.21	.73	.01	7	.78	.05	.00	1	2.29	.56	.02	1
Candacia armata	-	-	-	-	-	-	-	-	-	-	-	-	4.20	.27	.01	1
Metridia lucens	.43	.08	.00	<1	-	-	-	-	-	-	-	-	4.58	.81	.01	4
Euchaeta marina	-	-	-	-	-	-	-	-	-	-	-	-	.38	.02	.00	<1
Harpacticoida	-	-	-	-	-	-	-	-	.26	.01	.00	<1	-	-	-	-
Microsetella norvegica	-	-	-	-	.63	.02	.00	<1	-	-	-	-	-	-	-	-
Caligus spp.	-	-	-	-	-	-	-	-	.26	.01	.00	<1	-	-	-	-
Unidentified	1.72	.39	.00	1	10.48	15.65	.28	167	1.56	.05	.00	<1	1.91	.11	.00	<1
Total Copepoda	11.16	25.28	.88	292	20.32	32.30	.57	668	9.38	.50	.00	5	14.12	1.94	.05	28
Stomatopoda																
Unidentified (larvae)	-	-	-	-	-	-	-	-	.26	.01	.00	<1	.38	.02	.00	<1
Mysidacea																
Heteromysis formosa	-	-	-	-	.63	.02	.01	<1	.52	.02	.00	<1	1.14	.06	.02	<1
Cumacea																
Eudorella spp.	-	-	-	-	-	-	-	-	.78	.02	.00	<1	-	-	-	-
E. hispida	-	-	-	-	1.27	.06	.01	<1	2.34	.08	.00	<1	-	-	-	-
Petalosarsia declivis	-	-	-	-	-	-	-	-	6.25	.73	.02	5	-	-	-	-
Diastylis spp.	-	-	-	-	.95	.03	.00	<1	1.56	.07	.00	<1	-	-	-	-
D. scupta	-	-	-	-	2.22	.09	.01	<1	10.94	.67	.04	8	2.67	.17	.02	1
D. bispinosa	-	-	-	-	4.44	.20	.05	1	13.28	.66	.04	9	12.60	1.52	.37	24
Unidentified	.43	.08	.07	<1	1.27	.08	.01	<1	1.04	.03	.00	<1	-	-	-	-
Total Cumacea	.43	.08	.07	<1	9.52	.47	.09	5	28.13	2.25	.10	66	13.36	1.69	.40	28
Tanaidacea																
Tanaissus lilljeborgi	-	-	-	-	.32	.01	.00	<1	.26	.01	.00	<1	-	-	-	-
Isopoda																
Chiridotea spp.	-	-	-	-	.32	.02	.00	<1	.52	.02	.00	<1	-	-	-	-
C. tuftsi	-	-	-	-	.63	.02	.01	<1	.26	.01	.00	<1	-	-	-	-
C. arenicola	-	-	-	-	.32	.01	.00	<1	.26	.01	.00	<1	-	-	-	-
Edotea triloba	-	-	-	-	.32	.02	.00	<1	1.30	.05	.00	<1	2.29	.13	.04	<1
Ptilanthura tricarina	-	-	-	-	.63	.02	.00	<1	.26	.01	.00	<1	1.53	.31	.04	1
Cirolana spp.	-	-	-	-	.32	.01	.01	<1	.26	.01	.00	<1	-	-	-	-
C. polita	-	-	-	-	6.67	.37	1.11	10	16.67	1.33	1.51	47	10.31	.67	1.11	18
Janira alta	-	-	-	-	.32	.01	.00	<1	.52	.02	.00	<1	.38	.02	.00	<1
Unidentified	-	-	-	-	.95	.04	.09	<1	.52	.02	.00	<1	-	-	-	-
Total Isopoda	-	-	-	-	9.52	.53	1.24	17	20.05	1.46	1.52	60	13.36	1.13	1.19	31
Amphipoda																
Ampelisca spp.	.86	.16	.00	<1	2.22	.16	.02	<1	-	-	-	-	-	-	-	-
A. vadorum	3.43	.71	.58	4	16.82	1.39	.29	28	9.11	.39	.04	4	10.69	1.08	.31	15
A. macrocephala	-	-	-	-	-	-	-	-	-	-	-	-	.38	.02	.00	<1

Table 4.—Continued.

Taxon Food Item	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
A. agassizi	.43	.08	.07	<1	5.08	1.88	.30	11	4.69	.44	.02	2	5.73	.77	.13	5
Byblis serrata	7.30	2.84	2.85	42	10.79	.41	.14	6	15.63	.97	.10	17	20.61	2.50	.87	69
Ampithoidae	-	-	-	-	-	-	-	-	.26	.01	.00	<1	-	-	-	-
Aoridae	-	-	-	-	-	-	-	-	.26	.01	.01	<1	-	-	-	-
Leptocheirus pinguis	.43	.08	.22	<1	6.67	.29	.36	4	4.43	.14	.05	1	1.91	.13	.13	1
Argissa hamatipes	-	-	-	-	2.86	.14	.04	1	1.30	.04	.00	<1	-	-	-	-
Erichthonius rubricornis	14.16	5.45	1.82	103	70.48	16.69	3.82	1446	67.97	13.58	.97	988	45.42	16.11	2.08	826
Unciola spp.	.86	.24	.07	<1	-	-	-	-	-	-	-	-	-	-	-	-
U. irrorata	27.90	16.74	12.48	815	77.78	33.93	13.56	3694	85.16	31.18	5.28	3105	46.56	39.58	12.85	2441
U. serrata (?)	.43	.08	.07	<1	-	-	-	-	-	-	-	-	-	-	-	-
Pseudunciola obliquua	-	-	-	-	-	-	-	-	.26	.01	.00	<1	-	-	-	-
Siphonoecetes smithianus	1.29	.24	.00	<1	.95	.03	.00	<1	.26	.01	.00	<1	.76	.04	.00	<1
Rhachotropis oculata	.43	.08	.07	<1	-	-	-	-	-	-	-	-	-	-	-	-
Gammaridae	-	-	-	-	.95	.04	.01	<1	-	-	-	-	-	-	-	-
Melita dentata	.86	.16	.15	<1	13.33	.82	.62	19	9.38	.45	.08	5	2.67	.13	.06	1
Maera danae	-	-	-	-	.95	.03	.02	<1	.26	.02	.01	<1	-	-	-	-
Casco bigelowi	-	-	-	-	-	-	-	-	1.56	.05	.02	<1	2.29	.13	.12	1
Jerbarnia sp. A	-	-	-	-	.63	.05	.01	<1	-	-	-	-	.38	.02	.00	<1
Protohaustorius wigleyi	-	-	-	-	-	-	-	-	.26	.01	.00	<1	-	-	-	-
Photis spp.	-	-	-	-	.32	.01	.00	<1	.78	.02	.00	<1	-	-	-	-
P. dentata	-	-	-	-	2.86	.23	.02	1	4.43	.18	.01	1	1.14	.06	.00	<1
P. macrocoxa	-	-	-	-	-	-	-	-	.52	.02	.00	<1	.38	.02	.00	<1
Lysianassidae	-	-	-	-	-	-	-	-	.26	.01	.00	<1	-	-	-	-
Orchomenella pinguis	-	-	-	-	-	-	-	-	.52	.02	.00	<1	-	-	-	-
Hippomedon serratus	-	-	-	-	.95	.03	.02	<1	11.20	.45	.16	7	2.29	.13	.04	<1
Anonyx lilljeborgi	-	-	-	-	.32	.02	.02	<1	-	-	-	-	.38	.02	.01	<1
A. sarsi	-	-	-	-	-	-	-	-	1.30	.05	.06	<1	.76	.04	.01	<1
Monoculodes edwardsi	.43	.08	.00	<1	2.86	.14	.04	1	2.34	.07	.01	<1	22.14	2.77	.61	75
Phoxocephalus holbolli	-	-	-	-	6.03	.28	.05	2	22.14	1.72	.11	40	9.92	.67	.05	7
Trichophoxus epistomus	1.29	.24	.07	<1	15.87	1.24	.30	24	8.07	.35	.04	3	9.54	.69	.17	8
Harpinia propinqua	-	-	-	-	2.54	.10	.02	<1	.52	.02	.00	<1	.38	.02	.00	<1
Stenopleustes gracilis	-	-	-	-	.32	.01	.00	<1	1.30	.07	.00	<1	.38	.02	.00	<1
S. inermis	-	-	-	-	-	-	-	-	1.30	.04	.00	<1	1.14	.06	.00	<1
Dulichia porrecta	-	-	-	-	.95	.03	.00	<1	-	-	-	-	-	-	-	-
Stenothoidae	-	-	-	-	-	-	-	-	.78	.02	.00	<1	-	-	-	-
Hyperiidae	19.74	6.24	3.36	189	.95	.03	.01	<1	.26	.01	.00	<1	-	-	-	-
Parathemisto gaudichaudi	46.78	34.44	20.95	2591	.32	.01	.00	<1	.26	.01	.00	<1	35.88	3.75	.48	152
Aeginina longicornis	1.29	.32	.29	1	8.25	.51	.21	6	20.83	1.23	.22	30	4.58	.50	.11	3
Unidentified	6.44	1.50	1.17	17	22.54	.92	.62	35	4.17	.16	.00	1	1.91	.17	.01	<1
Total Amphipoda	91.85	69.67	44.23	10461	91.11	59.46	20.53	7288	93.49	51.73	7.21	5510	88.11	69.43	18.06	7447
Euphausiacea																
Euphausiidae	-	-	-	-	.32	.01	.01	<1	-	-	-	-	-	-	-	-
Decapoda																
Eualus pusiolus	-	-	-	-	-	-	-	-	.26	.01	.00	<1	.38	.02	.04	<1
Dichelopandalus leptocerus	.43	.08	1.31	1	2.86	.30	5.26	16	4.17	.16	.83	4	24.05	3.36	11.52	358
Carngon septemspinosa	2.15	.55	4.31	10	4.76	.20	.68	4	8.07	.32	.33	5	8.78	.73	1.10	16
Axius serrata	-	-	-	-	1.27	.04	.92	1	.52	.02	.03	<1	-	-	-	-
Munida iris	-	-	-	-	5.40	.28	1.88	12	1.04	.04	.13	<1	.38	.02	1.57	1
Pagurus spp.	-	-	-	-	.63	.03	.38	<1	.52	.02	.03	<1	.76	.04	.01	<1
P. acadianus	-	-	-	-	.63	.02	.24	<1	1.30	.04	.86	1	-	-	-	-
P. arcuatus	-	-	-	-	.63	.02	.16	<1	-	-	-	-	-	-	-	-
Calappidae megalopae	-	-	-	-	-	-	-	-	-	-	-	-	.76	.06	.03	<1
Cancer spp.	-	-	-	-	1.59	.05	.56	1	.52	.02	.01	<1	1.53	.13	.98	2
C. borealis	-	-	-	-	8.25	.48	14.91	127	7.29	.44	5.99	47	1.53	.08	.45	1
C. irroratus	.86	.55	29.42	26	21.59	1.47	28.54	648	43.75	3.45	38.84	1850	31.68	2.29	31.17	1060
Unidentified	1.72	.32	.29	1	3.49	.16	2.65	10	.26	.01	.00	<1	.76	.04	.09	<1
Total Decapoda	4.72	1.50	35.33	174	34.60	3.05	56.18	2049	53.13	4.51	47.06	2731	48.85	6.77	46.95	2624
Unidentified Crustacea	2.15	.39	2.41	6	4.76	.16	.32	2	1.04	.04	.01	<1	.76	.04	.01	<1
Total Crustacea	95.71	96.92	82.92	17212	96.82	96.01	78.95	16940	98.70	60.52	55.91	11491	93.66	81.08	66.69	13987
Insecta																
Unidentified	-	-	-	-	-	-	-	-	.26	.01	.00	<1	-	-	-	-
Nemertea																
Phascolion strombi	-	-	-	-	-	-	-	-	.26	.01	.00	<1	-	-	-	-
Ectoprocta																
Unidentified	-	-	-	-	.95	.03	.01	<1	1.30	.04	.00	<1	.76	.04	.01	<1

Table 4.—Continued.

Taxon Food Item	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Echinodermata																
Asteroidea																
Asterias vulgaris	-	-	-	-	.32	.01	.04	<1	-	-	-	-	-	-	-	-
Echinoidea																
Echinarachnius parma	.43	.08	.58	<1	4.13	.13	.12	1	-	-	-	-	-	-	-	-
Holothuroidea																
Stereoderma unisemita	-	-	-	-	-	-	-	-	.26	.01	.02	<1	-	-	-	-
Havelockia scabra	-	-	-	-	.95	.03	.65	1	-	-	-	-	-	-	-	-
Total Echinodermata	.43	.08	.58	<1	5.08	.18	.81	5	.26	.01	.02	<1	-	-	-	-
Chaetognatha																
Sagitta elegans	-	-	-	-	-	-	-	-	42.19	36.44	3.71	1694	29.39	16.13	2.03	534
Chordata																
Larvacea																
Unidentified	-	-	-	-	-	-	-	-	-	-	-	-	.38	.13	.01	<1
Pisces																
Raja erinacea	-	-	-	-	-	-	-	-	.26	.01	.16	<1	-	-	-	-
Teleostei	1.29	.24	.88	1	1.27	.05	.28	<1	3.39	.11	5.87	20	6.11	.31	1.01	8
Urophycis chuss	.86	.16	1.46	1	.63	.02	.01	<1	2.34	.07	1.60	4	1.91	.10	.57	1
Merluccius bilinearis	-	-	-	-	.63	.02	.07	<1	.26	.01	.01	<1	.76	.15	.90	1
Lepophidium cervinum	.43	.08	.73	<1	1.27	.15	.61	1	.78	.03	.20	<1	.38	.02	.07	<1
Liparis inquilinus	-	-	-	-	-	-	-	-	.52	.02	.00	<1	-	-	-	-
Ammodytes spp.	-	-	-	-	.32	.01	.01	<1	.52	.02	.02	<1	-	-	-	-
Citharichthys arctifrons	4.72	.95	6.86	37	.32	.01	[illegible]	[illegible]	1.82	.05	1.35	3	3.05	.31	15.54	48
Total Pisces	6.01	1.42	9.93	68	4.44	.27	1.05	6	8.85	.31	9.22	84	11.83	.88	18.09	224
Aves (unidentified feathers)	-	-	-	-	-	-	-	-	.26	.01	.00	<1	-	-	-	-
Total number of stomachs examined:		295				352				418				284		
Examined stomachs with food:		233				315				384				262		

Table 5.--Percent frequency occurrence (F), percent number (N), percent volume (V) and index of relative importance (IRI) of food items in *Urophycis regia* stomachs, by cruise.

Taxon	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
Food Item	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Annelida																
Polychaeta																
Harmothoe extenuata	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	.03	<1
Sthenelais limicola	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	.19	<1
Nephtyidae	2.38	.28	.07	1	-	-	-	-	-	-	-	-	-	-	-	-
Aglaophamus circinata	2.38	.28	.07	1	-	-	-	-	-	-	-	-	-	-	-	-
Onuphis pallidula	-	-	-	-	-	-	-	-	-	-	-	-	2.01	.51	.06	1
Eunicidae	-	-	-	-	-	-	-	-	-	-	-	-	1.34	.34	1.50	2
Unidentified	2.38	.28	.00	1	-	-	-	-	-	-	-	-	2.68	.68	.07	2
Total Polychaeta	7.14	.85	.14	7	-	-	-	-	-	-	-	-	6.71	1.88	1.85	25
Mollusca																
Pelecypoda																
Placopecten magellanicus	2.38	.28	7.15	18	-	-	-	-	16.67	7.14	2.73	164	2.01	.51	5.39	12
Ensis directus	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	.03	<1
Unidentified	-	-	-	-	-	-	-	-	-	-	-	-	2.68	.68	5.42	16
Total Pelecypoda	2.38	.28	7.15	18	-	-	-	-	16.67	7.14	2.73	165	-	-	-	-
Cephalopoda																
Illex illecebrosus	-	-	-	-	-	-	-	-	16.67	7.14	46.36	892	-	-	-	-
Rossia tenera	7.14	.85	.95	13	-	-	-	-	-	-	-	-	5.37	1.37	3.30	25
Unidentified	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	.06	<1
Total Cephalopoda	7.14	.85	.95	13	-	-	-	-	16.67	7.14	46.36	892	6.04	1.54	3.36	30
Total Mollusca	9.52	1.14	8.11	88	-	-	-	-	33.33	14.29	49.09	2112	8.05	2.22	8.78	89
Crustacea																
Copepoda																
Calanus finmarchicus	-	-	-	-	-	-	-	-	-	-	-	-	1.34	.34	.00	<1
Centropages typicus	2.38	.57	.00	1	-	-	-	-	-	-	-	-	-	-	-	-
Candacia armata	2.38	.28	.00	1	-	-	-	-	-	-	-	-	.67	.17	.00	<1
Unidentified	-	-	-	-	-	-	-	-	-	-	-	-	2.01	.68	.00	1
Total Copepoda	2.38	.85	.00	2	-	-	-	-	-	-	-	-	4.03	1.20	.00	5
Stomatopoda																
Unidentified	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	.03	<1
Cumecea																
Eudorella spp.	-	-	-	-	-	-	-	-	-	-	-	-	1.34	.34	.00	<1
Isopoda																
Cirolana polita	4.76	.57	1.67	11	-	-	-	-	16.67	7.14	.05	120	7.38	2.39	.46	21
Janira alta	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	.01	<1
Total Isopoda	4.76	.57	1.67	11	-	-	-	-	16.67	7.14	.05	120	8.05	2.56	.47	24
Amphipoda																
Ampelisca spp.	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	.00	<1

Table 5.--Continued.

Taxon	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
Food Item	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
A. vadorum	2.38	1.42	.12	4	-	-	-	-	-	-	-	-	4.03	1.20	.03	5
A. agassizi	4.76	.85	.07	4	-	-	-	-	-	-	-	-	3.36	1.37	.01	5
Bybis serrata	14.29	1.70	.00	24	-	-	-	-	-	-	-	-	.67	.17	.00	<1
Leptocheirus pinguis	2.38	.28	.24	1	-	-	-	-	-	-	-	-	-	-	-	-
Erichthonius rubricornis	14.29	1.99	.02	29	-	-	-	-	--	-	-	-	4.03	1.37	.01	6
Unciola irrorata	59.52	20.45	1.50	1307	-	-	-	-	-	-	-	-	14.76	9.74	.26	148
Rhachotropis oculata	2.38	.57	.00	1	-	-	-	-	-	-	-	-	-	-	-	-
Melita dentata	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	.02	<1
Protohaustorius wigleyi	-	-	-	-	-	-	-	-	-	-	-	-	1.34	.34	.00	<1
Hippomedan serratus	-	-	-	-	-	-	-	-	16.67	7.14	.14	121	1.34	.34	.01	<1
Anonyx sarsi	2.38	.28	.12	1	-	-	-	-	-	-	-	-	1.34	.34	.00	<1
Monoculodes edwardsi	-	-	-	-	-	-	-	-	-	-	-	-	2.68	.85	.01	2
Phoxocephalus holbolli	-	-	-	-	-	-	-	-	-	-	-	-	2.01	.51	.00	1
Trichophoxus epistomus	2.38	.28	.00	1	-	-	-	-	-	-	-	-	8.05	2.56	.06	21
Parathemisto gaudichaudi	14.29	1.70	.10	26	-	-	-	-	-	-	-	-	18.12	12.31	.22	227
Aeginina longicornis	2.38	.28	.02	1	-	-	-	-	-	-	-	-	-	-	-	-
Total Amphipoda	78.57	29.83	2.19	2516	-	-	-	-	16.67	7.14	.14	121	46.31	31.45	.62	1485
Euphausiacea																
Thysanoessa inermis	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	.00	<1
Decapoda																
Dichelopandalus leptocerus	19.05	5.40	12.57	342	-	-	-	-	-	-	-	-	44.67	27.01	14.05	1846
Crangon septemspinosa	85.71	32.10	25.54	4940	-	-	-	-	16.67	14.29	.55	247	3.36	1.03	.23	4
Munida iris	9.52	1.42	.33	17	-	-	-	-	-	-	-	-	2.68	.68	1.63	6
Cancer spp.	2.38	.57	.12	2	-	-	-	-	-	-	-	-	-	-	-	-
C. borealis	7.14	3.41	5.96	67	-	-	-	-	16.67	14.29	4.91	320	1.34	.34	.13	1
C. irroratus	26.19	8.24	13.71	575	-	-	-	-	83.33	35.71	19.63	4612	24.16	7.52	39.56	1137
Unidentified	2.38	.28	.00	1	-	-	-	-	-	-	-	-	.67	.17	.06	<1
Total Decapoda	95.24	51.42	58.23	10443	-	-	-	-	83.33	64.29	25.09	7448	67.11	36.75	55.66	6202
Unidentified Crustacea	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	.01	<1
Total Crustacea	95.24	82.67	62.09	13787	-	-	-	-	83.33	78.57	25.28	8654	86.58	72.82	56.79	11222
Sipuncula																
Phascolion strombi	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	.00	1
Chaetognatha																
Sagitta elegans	-	-	-	-	-	-	-	-	-	-	-	-	.67	6.32	.06	4
Chordata																
Pisces																
Teleostei	2.38	.28	.02	1	100	100	100	20000	16.67	7.14	25.63	546	22.15	5.64	4.21	218
Etrumeus teres	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	5.01	3
Urophycis chuss	7.14	.85	3.93	34	-	-	-	-	-	-	-	-	3.36	.85	9.68	35
Merluccius bilinearis	2.38	.28	1.91	5	-	-	-	-	-	-	-	-	6.04	4.27	5.33	58
Lepophidium cervinum	14.29	1.99	5.72	110	-	-	-	-	-	-	-	-	.67	.17	.06	<1
Liparis inquilinus	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	.06	<1
Citharichthys arctifrons	50.00	11.93	18.07	1500	-	-	-	-	-	-	-	-	16.11	5.30	7.85	212
Total Pisces	61.90	15.34	29.66	2786	100	100	100	20000	16.67	7.14	.26	546	47.65	16.58	32.51	2339
Number of stomachs examined:		45				2				7				180		
Examined stomachs with food:		42				1				6				149		

Table 6.--Percent frequency occurrence (F), percent number (N), percent volume (V) and index of relative importance (IRI) of food items in Merluccius bilinearis stomachs, by cruise.

Taxon Food Item	Fall 1976 F	Fall 1976 N	Fall 1976 V	Fall 1976 IRI	Winter 1977 F	Winter 1977 N	Winter 1977 V	Winter 1977 IRI	Spring 1977 F	Spring 1977 N	Spring 1977 V	Spring 1977 IRI	Summer 1977 F	Summer 1977 N	Summer 1977 V	Summer 1977 IRI
Cnidaria																
Hydrozoa																
Unidentified	-	-	-	-	.50	.02	.00	<1	-	-	-	-	-	-	-	-
Annelida																
Polychaeta																
Harmothoe extenuata	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.02	<1
Nereis spp.	-	-	-	-	-	-	-	-	-	-	-	-	.60	.11	.08	<1
Nephtyidae	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.02	<1
Aglaophamus circinata	-	-	-	-	.50	.05	.00	<1	-	-	-	-	-	-	-	-
Ophelina spp.	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.00	<1
Clymenella torquata	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.04	<1
Unidentified	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.04	<1
Total Polychaeta	-	-	-	-	.50	.05	.00	<1	-	-	-	-	2.11	.38	.21	1
Mollusca																
Cephalopoda																
Loliginidae	3.28	.31	29.45	98	.50	.02	3.40	2	-	-	-	-	-	-	-	-
Loligo pealei	3.69	.40	28.21	106	-	-	-	-	2.08	.10	8.46	18	.30	.05	16.10	5
Rossia spp.	-	-	-	-	-	-	-	-	2.08	.20	.01	<1	-	-	-	-
R. tenera	.82	.06	.40	<1	.50	.02	.15	<1	4.17	.30	.41	3	.90	.16	3.78	4
Illex illecebrosus	-	-	-	-	-	-	-	-	25.00	1.40	80.72	2053	-	-	-	-
Unidentified	1.64	.12	.99	2	-	-	-	-	2.08	.10	1.69	4	.30	.05	.12	<1
Total Cephalopoda	9.02	.89	59.06	541	1.00	.05	3.55	4	35.42	2.10	91.29	3308	1.51	.27	20.01	31
Arthropoda																
Copepoda																
Calanus finmarchicus	-	-	-	-	1.00	.05	.00	<1	-	-	-	-	.90	.33	.01	<1
Paracalanus spp.	-	-	-	-	5.97	9.01	.02	54	-	-	-	-	-	-	-	-
Rhincalanus nasutus	2.05	.22	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
Nannocalanus minor	2.46	.34	.00	1	-	-	-	-	-	-	-	-	-	-	-	-
Centropages typicus	18.03	14.90	.02	269	1.49	.68	.00	1	-	-	-	-	.30	.05	.00	<1
Candacia armata	-	-	-	-	-	-	-	-	-	-	-	-	2.41	.44	.00	1
Metridia lucens	.82	.12	.00	<1	-	-	-	-	-	-	-	-	.60	.11	.00	<1
Caligus spp.	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.00	<1
Unidentified	4.10	.71	.00	3	1.00	.05	.00	<1	-	-	-	-	.60	.11	.00	<1
Total Copepoda	20.49	16.29	.02	334	7.46	9.78	.02	73	-	-	-	-	5.12	1.10	.02	6
Cumacea																
Eudorella spp.	-	-	-	-	-	-	-	-	-	-	-	-	.90	.22	.01	<1
E. emarginata	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.00	<1
E. hispida	-	-	-	-	1.00	.05	.00	<1	-	-	-	-	.60	.27	.01	<1
Diastylis spp.	-	-	-	-	1.99	.22	.01	<1	-	-	-	-	-	-	-	-
D. sculpta	-	-	-	-	14.43	1.28	.07	19	2.08	.10	.00	<1	3.01	.66	.01	2
D. bispinosa	2.46	.28	.03	1	1.00	.07	.00	<1	-	-	-	-	12.65	6.43	.32	85
Unidentified	2.05	.19	.01	<1	.50	.02	.00	<1	-	-	-	-	.60	.11	.00	<1
Total Cumacea	4.51	.46	.04	2	18.91	1.65	.08	33	2.08	.10	.00	<1	17.47	7.75	.34	141
Isopoda																
Unidentified	.41	.03	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
Cirolana polita	.41	.03	.04	<1	-	-	-	-	-	-	-	-	-	-	-	-
Total Isopoda	.82	.06	.04	1	-	-	-	-	-	-	-	-	-	-	-	-
Amphipoda																
Ampelisca spp.	.82	.06	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
A. vadorum	19.67	2.34	.32	52	2.49	.15	.70	2	-	-	-	-	4.52	1.59	.11	8
A. macrocephala	.41	.03	.01	<1	.50	.02	.00	<1	-	-	-	-	-	-	-	-
A. agassizi	1.64	.22	.02	<1	.50	.02	.00	<1	-	-	-	-	5.42	2.75	.14	16
Byblis serrata	12.70	3.21	.44	46	1.49	.10	.01	<1	2.08	.10	.00	<1	20.48	14.90	1.23	330
Argissa hamatipes	-	-	-	-	4.48	.34	.02	2	-	-	-	-	-	-	-	-
Erichthonius rubricornis	.82	.06	.00	<1	-	-	-	-	-	-	-	-	4.82	1.21	.02	6
Unciola irrorata	.41	.06	.00	<1	4.48	.36	.05	2	-	-	-	-	1.81	.33	.02	1
Haustoriidae	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.00	<1
Photis dentata	-	-	-	-	-	-	-	-	-	-	-	-	.30	.22	.00	<1
Orchomenella minuta	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.00	<1
O. pinguis	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.00	<1
Hippomedon serratus	-	-	-	-	7.46	1.09	.24	10	2.08	.30	.01	1	.06	.11	.04	<1
Anonyx sarsi	-	-	-	-	1.49	.61	.30	1	-	-	-	-	-	-	-	-
Monoculodes spp.	-	-	-	-	.50	.02	.00	<1	-	-	-	-	-	-	-	-
M. edwardsi	-	-	-	-	4.98	.31	.02	2	-	-	-	-	5.72	1.59	.04	9
Harpinia propinqua	.41	.03	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-

Table 6.--Continued.

Taxon Food Item	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Phoxocephalus holbolli	-	-	-	-	-	-	-	-	-	-	-	-	1.81	.93	.02	2
Trichophoxus epistomus	-	-	-	-	-	-	-	-	-	-	-	-	5.12	2.31	.08	12
Stenopleustes inermis	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.00	<1
Hyperiidae	9.84	2.09	.42	23	1.99	.73	.10	2	-	-	-	-	-	-	-	-
Parathemisto gaudichaudi	61.89	69.42	7.87	4784	52.24	70.43	4.27	3902	10.42	10.42	.06	109	49.10	22.43	.75	1138
Aeginina longicornis	-	-	-	-	.50	.02	.00	<1	-	-	-	-	-	-	-	-
Unidentified	2.05	.19	.03	<1	2.99	.19	.03	1	-	-	-	-	-	-	-	-
Total Amphipoda	74.59	77.72	9.12	6477	67.66	74.40	5.76	5424	14.58	10.82	.07	159	70.18	48.60	2.46	3583
Euphausiacea																
Euphausiidae	-	-	-	-	.50	1.84	.91	1	-	-	-	-	-	-	-	-
Thysanoessa raschii	.41	.06	.00	<1	.50	2.35	1.06	2	-	-	-	-	-	-	-	-
T. inermis	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.01	<1
Total Euphausiacea	.41	.06	.00	<1	1.00	4.19	1.97	6	-	-	-	-	.30	.05	.01	<1
Decapoda																
Dichelopandalus leptocerus	5.74	1.54	7.81	54	23.88	2.88	11.66	347	6.25	.50	.17	4	28.92	18.14	19.10	1077
Crangonidae	-	-	-	-	1.49	.10	.03	<1	-	-	-	-	.30	.05	.00	<1
Crangon septemspinosa	2.87	.28	.30	2	25.87	1.94	2.74	121	-	-	-	-	13.25	4.12	2.35	86
Calappidae spp. megalopae	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.00	<1
Callinectes spp. megalopae	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.00	<1
Geryon quinquedens megalopae	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.00	<1
Cancer spp. zoea & megalopae	5.74	1.30	.00	7	-	-	-	-	-	-	-	-	.30	.05	.00	<1
Cancer irroratus	-	-	-	-	.50	.02	.33	<1	-	-	-	-	-	-	-	-
Unidentified	2.46	.22	.08	1	1.00	.05	.05	<1	-	-	-	-	-	-	-	-
Total Decapoda	15.57	3.33	8.20	180	43.78	4.99	14.81	867	6.25	.50	.17	4	35.54	22.54	21.46	1564
Unidentified Crustacea	2.87	.31	.06	1	3.48	.17	.05	1	-	-	-	-	-	-	-	-
Total Crustacea	78.69	98.24	17.48	9106	87.06	95.18	22.69	10762	18.75	11.42	.24	219	85.84	80.04	24.29	8956
Echinodermata																
Asteroidea																
Asterias vulgaris	-	-	-	-	.50	.02	.14	<1	2.08	.10	.05	<1	-	-	-	-
Astropecten americanus	.41	.03	.06	<1	-	-	-	-	-	-	-	-	-	-	-	-
Total Asteroidea	.41	.03	.06	<1	.50	.02	.14	<1	2.08	.10	.05	<1	-	-	-	-
Echinoidea																
Echinarachnius parma	-	-	-	-	1.99	.10	.77	2	4.17	.20	.34	2	-	-	-	-
Total Echinodermata	.41	.03	.06	<1	2.49	.12	.90	3	6.25	.30	.39	4	-	-	-	-
Chaetognatha																
Sagitta elegans	-	-	-	-	2.99	2.40	.15	8	50.00	85.57	1.62	4360	16.27	11.60	.33	194
Chordata																
Pisces																
Teleostei	2.05	.15	2.61	6	19.40	.94	13.03	271	4.17	.20	.11	1	13.55	2.64	10.42	177
Clupeidae	-	-	-	-	1.49	.07	14.29	21	-	-	-	-	-	-	-	-
Etrumeus teres	.82	.06	19.10	16	1.00	.05	30.82	31	-	-	-	-	.30	.05	2.21	1
Urophycis chuss	3.28	.25	.77	3	1.99	.15	5.56	11	-	-	-	-	3.92	.77	22.86	93
Merluccius bilinearis	1.23	.09	.51	1	10.45	.53	8.69	96	-	-	-	-	12.05	3.19	4.92	98
Ammodytes spp.	-	-	-	-	3.98	.44	.30	3	-	-	-	-	1.80	.55	11.64	22
Peprilus triacanthus	-	-	-	-	-	-	-	-	2.08	.20	4.23	9	-	-	-	-
Citharichthys arctifrons	2.46	.28	.41	2	-	-	-	-	4.17	.20	2.12	10	2.41	.49	3.12	9
Total Pisces	9.43	.83	23.40	229	37.81	2.18	72.71	2831	10.42	.60	6.46	74	31.23	7.70	55.17	2026
Total number of stomachs examined:		272				282				109				385		
Examined stomachs with food:		244				201				48				332		

Table 7.--Percent frequency occurrence (F), percent number (N), percent volume (V) and index of relative importance (IRI) of food items in *Macrozoarces americanus* stomachs, by cruise.

Taxon Food Item	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Annelida																
Polychaeta																
Aphrodita hastata	-	-	-	-	-	-	-	-	4.00	.33	47.44	191	-	-	-	-
Harmothoe extenuata	-	-	-	-	25.00	1.11	1.57	67	28.00	1.11	.33	40	4.55	.31	.85	5
Pholoe minuta	-	-	-	-	-	-	-	-	-	-	-	-	.65	.04	.08	<1
Scalibregma inflatum	-	-	-	-	-	-	-	-	4.00	.11	.05	1	-	-	-	-
Maldanidae	-	-	-	-	4.17	.11	.27	2	-	-	-	-	.65	.04	.04	<1
Clymenura sp. A	-	-	-	-	-	-	-	-	4.00	.11	.02	1	.65	.04	.04	<1
Lumbrineris fragilis	-	-	-	-	4.17	.11	.05	1	-	-	-	-	-	-	-	-
Ampharete arctica	-	-	-	-	16.67	1.22	1.41	44	-	-	-	-	-	-	-	-
Flabelligeridae sp. A	-	-	-	-	-	-	-	-	4.00	.22	.19	2	-	-	-	-
Brada spp.	-	-	-	-	4.17	1.11	.27	6	-	-	-	-	-	-	-	-
Euchone spp.	-	-	-	-	8.33	.88	.22	9	-	-	-	-	-	-	-	-
Chone infundibuliformis	-	-	-	-	-	-	-	-	12.00	1.11	.40	18	3.25	.52	.19	2
Unidentified	-	-	-	-	8.33	.22	.16	3	-	-	-	-	4.55	.31	.58	4
Total Polychaeta	-	-	-	-	54.17	4.76	3.95	472	44.00	2.99	48.43	2263	13.64	1.27	1.78	41
Mollusca																
Pelecypoda																
Placopecten magellanicus	-	-	-	-	-	-	-	-	-	-	-	-	2.60	.22	8.57	23
Cyclocardia borealis	-	-	-	-	-	-	-	-	-	-	-	-	.65	.22	.19	<1
Ensis directus	-	-	-	-	4.17	.11	1.08	5	-	-	-	-	1.30	.13	.23	<1
Total Pelecypoda	-	-	-	-	4.17	.11	1.08	5	-	-	-	-	3.90	.57	8.99	37
Crustacea																
Copepoda																
Candacia armata	-	-	-	-	-	-	-	-	-	-	-	-	.65	.04	.00	<1
Cumacea																
Eudorella hispida	-	-	-	-	-	-	-	-	4.00	.11	.00	1	-	-	-	-
Diastylis sculpta	-	-	-	-	12.50	.44	.00	6	32.00	1.33	.07	45	3.25	.26	.08	1
D. bispinosa	-	-	-	-	4.17	.22	.05	1	12.00	.55	.00	7	3.25	.39	.15	2
Total Cumacea	-	-	-	-	16.67	.66	.05	12	36.00	1.99	.07	74	6.49	.65	.23	6
Isopoda																
Janira alta	-	-	-	-	-	-	-	-	-	-	-	-	.65	.04	.00	<1
Amphipoda																
Ampelisca spp.	-	-	-	-	-	-	-	-	-	-	-	-	.65	.26	.12	<1
A. vadorum	-	-	-	-	4.17	.11	.00	1	16.00	1.22	.14	22	11.69	2.40	1.08	4
A. agassizi	-	-	-	-	-	-	-	-	4.00	.88	.12	4	-	-	-	-
Byblis serrata	-	-	-	-	4.17	.11	.05	1	4.00	.11	.00	<1	1.95	.13	.04	<1
Leptocheirus pinguis	-	-	-	-	-	-	-	-	4.00	.11	.12	1	.65	.04	.04	<1
Erichthonius rubricornis	-	-	-	-	70.83	43.69	6.11	3528	84.00	71.90	5.79	6526	72.08	63.74	13.20	5546
Unciola irrorata	-	-	-	-	100.00	44.91	22.84	6775	72.00	13.50	1.85	1105	63.64	21.25	12.54	2150
Melita dentata	-	-	-	-	-	-	-	-	8.00	.22	.00	2	-	-	-	-
Photis dentata	-	-	-	-	-	-	-	-	8.00	.44	.02	4	.65	.04	.00	<1
Monoculodes edwardsi	-	-	-	-	-	-	-	-	-	-	-	-	.65	.04	.00	<1
Phoxocephalus holbolli	-	-	-	-	4.17	.11	.00	1	4.00	.11	.00	1	.65	.04	.00	<1
Stenopleustes inermis	-	-	-	-	-	-	-	-	8.00	.33	.00	3	-	-	-	-
Parathemisto gaudichaudi	-	-	-	-	-	-	-	-	-	-	-	-	1.30	.09	.00	<1
Aeginina longicornis	-	-	-	-	4.17	.11	.05	1	8.00	.22	.02	2	2.60	.17	.04	<1
Total Amphipoda	-	-	-	-	100.00	89.05	29.06	11811	88.00	89.05	8.06	8546	83.77	88.22	27.06	9656
Decapoda																
Crangon septemspinosa	-	-	-	-	-	-	-	-	-	-	-	-	.65	.04	.39	<1
Calappidae spp. megalopae	-	-	-	-	-	-	-	-	-	-	-	-	.65	.04	.00	<1
Cancer spp.	-	-	-	-	-	-	-	-	-	-	-	--	.65	.04	.12	<1
C. borealis	-	-	-	-	4.17	.11	1.08	5	4.00	.33	1.07	6	4.55	.31	6.10	29
C. irroratus	-	-	-	-	41.67	3.98	57.63	2567	36.00	5.20	41.39	1677	44.16	8.64	54.92	2806
Total Decapoda	-	-	-	-	41.67	4.09	58.71	2617	36.00	5.53	42.46	1728	47.40	9.08	61.52	3347
Total Crustacea	-	-	-	-	100.00	93.81	87.93	18163	100.00	96.57	50.59	14716	96.10	98.04	88.81	17957
Echinodermata																
Echinoidea																
Echinarachnius parma	-	-	-	-	20.83	1.33	7.14	176	8.00	.33	.95	10	1.30	.09	.23	<1
Ophiuroidea																
Amphioplus macilentus	-	-	-	-	-	-	-	-	4.00	.11	.02	1	-	-	-	-
Total Echinodermata	-	-	-	-	20.83	1.33	7.14	176	8.00	.44	.97	11	-	-	-	-
Chordata																
Pisces																
Teleostei	-	-	-	-	-	-	-	-	-	-	-	-	.65	.04	.19	<1
Number of stomachs examined:		7				27				31				359		
Examined stomachs with food:		0				24				25				154		

Table 8.--Percent frequency occurrence (F), percent number (N), percent volume (V) and index of relative importance (IRI) of food items in *Stenotomus chrysops* from fall samples.

Taxon Food Item	F	N	V	IRI
Cnidaria				
Anthozoa				
Unidentified	1.51	.19	.18	1
Nematoda				
Unidentified	.75	.04	.00	<1
Annelida				
Polychaeta				
Aphrodita spp.	.38	.01	.43	<1
A. hastata	.75	.04	.64	1
Harmothoe extenuata	.38	.01	.01	<1
Sthenelais limicola	2.64	.10	.77	2
Phyllodocidae	.38	.01	.01	<1
Paranaitis speciosa	.75	.02	.02	<1
Phyllodoce spp.	1.51	.25	.27	1
P. mucosa	.38	.01	.03	<1
P. groenlandica	12.83	1.19	1.08	29
Eulalia bilineata	.75	.02	.09	<1
Syllis sp.	.38	.01	.01	<1
Nereis grayi	3.02	.12	.14	1
N. zonata	.38	.01	.04	<1
N. riisei	.38	.01	.04	<1
Nephtyidae	.38	.01	.01	<1
Aglaophamus circinata	8.30	.45	3.01	29
Glycera spp.	1.13	.04	.59	1
G. dibranchiata	6.79	.21	4.85	34
G. robusta	.38	.01	.26	<1
Goniada norvegica	.75	.04	.61	<1
Scalibregma inflatum	4.91	.15	1.31	7
Ophelina spp.	4.15	.25	.85	5
Maldanidae	1.51	.07	.19	<1
Clymenella torquata	1.13	.06	.13	<1
Euclymene collaris	6.04	.46	.28	4
Clymenura sp. A	12.83	.76	1.89	34
Aricidea neosuecia	1.89	.07	.04	<1
Spio spp.	.75	.02	.07	<1
Onuphis pallidula	3.77	1.32	2.37	14
Marphysa spp.	2.26	.10	1.61	4
Marphysa bellii	.38	.01	.01	1
Lumbrineridae	.38	.01	.01	<1
Lumbrineris spp.	13.20	.78	.92	21
L. fragilis	3.02	.10	.48	2
L. impatiens	1.13	.04	.03	<1

Table 8.--Continued.

Taxon Food Item	F	N	V	IRI
L. albidentata	2.64	.17	.32	1
Ninoe nigripes	2.26	.08	.61	2
Drilonereis spp.	3.02	.10	.17	1
D. longa	.38	.01	.03	<1
D. magna	3.02	.13	.67	2
Cirratulidae	.75	.07	.09	<1
Tharyx spp.	1.51	.05	.23	<1
T. acutus	7.92	.87	.49	11
Oweniidae	.38	.01	.02	<1
Melinna cristata	1.13	.04	.15	<1
Ampharete arctica	6.41	.32	.52	5
Terebellidae	.75	.02	.30	<1
Pista maculata	.38	.01	.69	<1
Nicolea venustula	15.85	2.43	2.27	74
Terebellides stroemi	3.77	.19	.43	2
Pherusa affinis	2.26	.08	.84	2
P. plumosa	.75	.02	.26	<1
Sabellidae	1.51	.06	1.43	2
Potamilla reniformis	1.89	.06	.20	<1
Chone infundibuliformes	22.64	5.28	13.48	425
Unidentified	37.36	1.65	14.11	589
Total Polychaeta	75.09	18.43	60.41	5920
Mollusca				
Scaphopoda				
Unidentified	.38	.01	.04	<1
Gastropoda				
Mitrella spp.	6.42	1.00	.69	11
Nassarius trivittatus	.38	.01	.00	<1
Pleurobranchaea tarda	6.42	.40	1.35	11
Unidentified	1.51	.05	.10	<1
Total Gastropoda	11.70	1.46	2.14	42
Pelecypoda				
Placopecten magellanicus	.38	.01	.74	<1
Unidentified	.38	.01	.09	<1
Total Pelecypoda	.75	.02	.82	1
Cephalopoda				
Unidentified	.75	.02	.10	<1
Total Mollusca	13.21	1.52	3.10	61
Crustacea				
Copepoda				
Eucalanus spp.	.38	.01	.00	1

Table 8.--Continued.

Taxon Food Item	F	N	V	IRI
Nannocalanus minor	.75	.02	.01	<1
Temora longicornis	.38	.01	.00	<1
Centropages typicus	15.85	8.25	.41	137
Xanthocalanus spp.	.38	.01	.00	<1
Unidentified	.38	.02	.00	<1
Total Copepoda	16.23	8.32	.42	142
Cumacea				
Eudorella hispida	.38	.01	.00	<1
Diastylis spp.	1.89	.14	.17	1
D. sculpta	.38	.01	.01	<1
D. bispinosa	4.91	.31	.34	3
Unidentified	3.40	.20	.24	2
Total Cumacea	10.19	.68	.76	15
Tanaidacea				
Tanaissus lilljeborgi	.38	.01	.00	<1
Isopoda				
Edotea acuta	.38	.01	.04	<1
E. triloba	.38	.02	.04	<1
Ptilanthura tricarina	4.53	.26	.08	2
Cirolana polita	1.51	.05	.25	<1
Total Isopoda	6.79	.34	.42	5
Amphipoda				
Ampeliscidae	.75	.02	.04	<1
Ampelisca spp.	5.66	.44	.21	4
A. vadorum	20.00	1.88	.87	55
A. agassizi	25.28	4.17	1.63	147
Byblis serrata	18.49	1.07	.50	29
Aoridae	.38	.01	.00	<1
Leptocheirus pinguis	3.40	.12	.09	1
Argissa hamatipes	1.51	.05	.02	<1
Corophium spp.	.75	.04	.04	<1
C. crassicorne	.38	.02	.01	<1
Erichthonius spp.	.75	.08	.03	<1
E. rubricornis	61.13	25.81	5.44	1910
Unciola irrorata	44.53	6.48	3.68	452
Siphonoecetes smithianus	3.02	.10	.05	<1
Rachotropis inflata	.38	.01	.01	<1
Gammarus spp.	.38	.01	.01	<1
Melita dentata	1.89	.14	.05	<1
Casco bigelowi	.75	.02	.13	<1
Protohaustorius wigleyi	.38	.01	.00	<1
Photis spp.	.75	.02	.01	<1

Table 8.--Continued.

Taxon Food Item	F	N	V	IRI
P. dentata	1.51	.07	.03	<1
P. macrocoxa	.38	.01	.00	<1
Podoceropsis nitida	.75	.02	.02	<1
Anonyx sarsi	.38	.01	.02	<1
Melphidippidae	.38	.01	.03	<1
Monoculodes spp.	.38	.01	.01	<1
M. edwardsi	.75	.02	.03	<1
Phoxocephalidae	.38	.01	.00	<1
Phoxocephalus holbolli	21.51	1.39	.49	41
Trichophoxus epistomus	4.15	.19	.05	1
Harpinia propinqua	5.28	.39	.41	4
H. truncata	.38	.02	.01	<1
Stenopleustes gracilis	.38	.01	.00	<1
S. inermis	3.40	.13	.01	<1
Hyperiidae	.75	.05	.01	<1
Parathemisto gaudichaudi	9.81	24.72	.94	252
Caprellidae	.38	.01	.02	<1
Aeginina longicornis	7.17	.31	.37	5
Unidentified	11.32	.69	.28	11
Total Amphipoda	79.62	68.63	15.53	6701
Euphausiacea				
Euphausiidae	.38	.01	.00	<1
Decapoda				
Dichelopandalus leptocerus	2.64	.13	3.05	8
Crangon septemspinosa	.75	.02	.35	<1
Axius serrata	.75	.02	.03	<1
Pagurus spp.	.75	.02	1.04	1
Cancer spp.	3.02	.12	.74	3
C. borealis	2.26	.08	.48	1
C. irroratus	10.19	.42	5.53	61
Unidentified	1.89	.06	.57	1
Total Decapoda	20.38	.88	11.79	258
Unidentified Crustacea	7.92	.38	4.70	40
Total Crustacea	86.79	79.27	33.61	9797
Priapulida				
Priapulus caudata	.75	.02	.53	<1
Ectoprocta				
Unidentified	.38	.01	.00	<1
Echinodermata				
Asteroidea				
Asterias vulgaris	.38	.01	.01	<1

Table 8.--Continued.

Taxon Food Item	F	N	V	IRI
Unidentified	.38	.02	.00	<1
Total Asteroidea	.75	.04	.01	<1
Echinoidea				
Echinarachnius parma	4.53	.15	.52	3
Ophiuroidea				
Amphioplus macilentus	1.13	.08	.22	<1
Axiognathus squamata	2.64	.11	.08	<1
Unidentified	.38	.01	.00	<1
Total Ophiuroidea	4.15	.20	.29	2
Total Echinodermata	9.06	.39	.82	11
Chordata				
Ascideacea				
Unidentified	.38	.01	.05	<1
Pisces				
Teleostei	1.51	.05	.74	1
Urophycis chuss	.75	.02	.56	<1
Gobiidae spp. larvae	.38	.04	.00	<1
Total Pisces	2.64	.11	1.30	4
Total number of stomachs examined:		563		
Number of examined stomachs with food:		265		

Table 9.--Percent frequency occurrence (F), percent number (N), percent volume (V) and index of relative importance (IRI) of food items in *Citharichthys arctifrons* stomachs, by cruise.

Taxon Food Item	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Annelida																
Polychaeta																
Harmothoe extenuata	1.28	.28	.39	1	-	-	-	-	10.68	.76	1.26	22	2.17	.40	1.36	4
Sthenelais limicola	-	-	-	-	2.16	.44	2.93	7	9.71	.71	8.03	85	5.79	1.03	5.96	40
Phyllodoce spp.	-	-	-	-	-	-	-	-	-	-	-	-	.72	.11	.09	<1
Nephytidae	-	-	-	-	-	-	-	-	.97	.05	.19	1	.36	.06	.45	<1
Aglaophamus circinata	-	-	-	-	1.44	.29	2.13	3	10.68	.76	5.13	63	2.89	.46	3.25	11
Opheliidae	-	-	-	-	-	-	-	-	-	-	-	-	.36	.06	.09	<1
Ophelia denticulata	-	-	-	-	-	-	-	-	-	-	-	-	.36	.06	.00	<1
Ophelina spp.	-	-	-	-	-	-	-	-	-	-	-	-	.36	.06	.09	<1
Maldanidae	1.28	.28	.77	1	.72	.15	.27	<1	4.85	.25	1.06	6	2.53	.40	1.08	4
Clymenella torquata	-	-	-	-	-	-	-	-	.97	.05	.00	<1	-	-	-	-
Clymenura sp. A	6.41	1.42	13.51	96	5.75	1.76	10.67	72	21.36	1.58	8.03	205	6.86	1.49	4.25	39
Paraonidae	-	-	-	-	-	-	-	-	1.94	.25	.68	2	-	-	-	-
Spionidae	-	-	-	-	1.44	.29	.00	<1	1.94	.15	.19	1	.36	.06	.90	<1
Spiophanes bombyx	-	-	-	-	-	-	-	-	1.94	.20	.58	2	1.08	.17	.18	<1
Onuphis pallidula	-	-	-	-	1.44	.73	2.40	5	6.79	.76	3.68	30	.72	.11	.18	<1
Lumbrineris spp.	-	-	-	-	.72	.15	.27	<1	.97	.05	.00	<1	.36	.06	.09	<1
L. fragilis	-	-	-	-	-	-	-	-	2.91	.15	1.55	5	.36	.06	.45	<1
L. cruzensis	-	-	-	-	4.32	.88	1.33	10	2.91	.15	.48	2	1.80	.29	.45	1
L. impatiens	-	-	-	-	1.44	.29	.53	1	-	-	-	-	.72	.11	.09	<1
Drilonereis spp.	-	-	-	-	.72	.15	.00	<1	-	-	-	-	.36	.06	.00	<1
Ampharete arctica	-	-	-	-	8.63	2.20	6.13	72	13.59	.76	1.84	35	1.80	.29	1.36	3
Pherusa affinis	-	-	-	-	-	-	-	-	-	-	-	-	.36	.06	.00	<1
Sabellidae	-	-	-	-	.72	.15	.27	<1	-	-	-	-	-	-	-	-
Euchone spp.	-	-	-	-	-	-	-	-	.97	.05	.10	<1	-	-	-	-
Chone infundibuliformis	-	-	-	-	3.60	2.20	2.40	17	38.83	5.65	9.67	595	9.02	2.46	2.17	42
Unidentified	8.97	1.99	3.86	53	22.30	4.84	10.67	346	10.68	.56	3.38	42	13.00	2.29	3.79	79
Total Polychaeta	15.38	3.98	18.53	346	46.76	14.54	40.00	2550	80.58	12.92	45.84	4735	42.96	10.14	26.29	1565
Mollusca																
Gastropoda																
Unidentified	-	-	-	-	.72	.15	.00	<1	-	-	-	-	-	-	-	-
Pelecypoda																
Unidentified	-	-	-	-	-	-	-	-	-	-	-	-	.36	.06	.00	<1
Crustacea																
Ostracoda																
Unidentified	5.13	1.99	.00	10	-	-	-	-	-	-	-	-	.36	.06	.00	<1
Copepoda																
Calanus finmarchicus	-	-	-	-	-	-	-	-	3.88	.36	.10	2	2.17	.57	.09	1
Paracalanus spp.	1.28	.28	.00	<1	.72	.15	.00	<1	-	-	-	-	-	-	-	-
Centropages typicus	2.56	.85	.00	2	2.88	.73	.00	2	-	-	-	-	-	-	-	-
Candacia armata	-	-	-	-	-	-	-	-	-	-	-	-	5.41	.97	.00	5
Metridia lucens	-	-	-	-	-	-	-	-	-	-	-	-	.36	.06	.00	<1
Harpacticoid	2.56	1.14	.00	3	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified	6.41	2.56	.00	16	.72	.15	.00	<1	-	-	-	-	.72	.17	.00	<1
Total Copepoda	12.82	4.83	.00	62	4.32	1.03	.00	4	3.88	.36	.10	2	8.66	1.78	.09	16
Cumacea																
Eudorella spp.	-	-	-	-	-	-	-	-	.97	.05	.00	<1	.36	.06	.00	<1
E. hispida	-	-	-	-	1.44	.29	.00	1	.97	.05	.00	<1	-	-	-	-
Diastylis spp.	-	-	-	-	1.49	.44	.00	1	.97	.05	.00	<1	-	-	-	-
D. sculpta	-	-	-	-	5.04	1.03	1.33	12	16.50	1.22	1.45	44	2.89	.57	.36	3
D. bispinosa	-	-	-	-	3.60	1.03	.53	6	24.27	1.83	1.84	89	2.89	.46	.36	2
Petalosarsia declivis	-	-	-	-	3.60	1.47	.80	8	.97	.05	.00	<1	.36	.06	.00	<1
Unidentified	1.28	.28	.39	1	1.44	.29	.00	1	-	-	-	-	-	-	-	-
Total Cumacea	1.78	.28	.39	1	15.11	4.55	2.67	109	39.81	3.26	3.29	260	6.50	1.15	.72	12
Tanaidacea																
Tanaissus lilljeborgia	1.28	.28	.00	1	-	-	-	-	.97	.05	.00	1	-	-	-	-
Isopoda																
Edotea triloba	-	-	-	-	-	-	-	-	-	-	-	-	1.44	.23	.36	1
Janira alta	-	-	-	-	-	-	-	-	.97	.05	.00	1	2.53	.46	.36	2
Total Isopoda	-	-	-	-	-	-	-	-	.97	.05	.00	1	3.97	.69	.72	6

Table 9.--Continued.

Taxon Food Item	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Amphipoda																
Ampelisca spp.	2.56	.85	.39	3	1.44	.29	.00	<1	.97	.05	.00	<1	.72	.11	.00	<1
A. macrocephala	-	-	-	-	-	-	-	-	-	-	-	-	.36	.06	.45	<1
A. vadorum	14.10	7.95	3.86	167	12.23	4.70	4.27	110	11.65	.66	.87	18	30.69	8.76	7.05	485
A. agassizi	3.85	1.14	1.16	9	4.32	1.03	1.33	10	2.91	.20	.19	1	1.08	.17	.09	<1
Byblis serrata	32.05	17.90	26.25	1415	7.19	2.94	3.20	44	13.59	1.17	2.32	47	15.88	4.81	6.05	172
Leptocheirus pinguis	-	-	-	-	-	-	-	-	.97	.05	.00	<1	-	-	-	-
Argissa hamatipes	-	-	-	-	-	-	-	-	.97	.05	.19	<1	-	-	-	-
Erichthonius spp.	1.28	.28	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
E. rubricornis	21.79	7.39	1.93	203	48.20	25.70	18.93	2151	42.72	8.24	8.32	707	61.37	35.22	11.02	2838
Unciola irrorata	58.97	35.79	30.89	3932	56.11	34.95	27.73	3517	58.25	10.58	11.51	1287	63.18	23.42	17.80	2604
Siphonoecetes smithianus	1.28	.28	.39	1	-	-	-	-	-	-	-	-	-	-	-	-
Melita dentata	1.28	.28	.39	1	-	-	-	-	3.88	.20	.10	1	2.89	.57	.54	3
Casco bigelowi	-	-	-	-	1.44	.29	.27	1	.97	.05	.10	<1	.72	.11	.18	<1
Jerbarnia spp.	-	-	-	-	-	-	-	-	.97	.05	.00	<1	-	-	-	-
Photis spp.	-	-	-	-	.72	.15	.00	<1	-	-	-	-	-	-	-	-
P. dentata	1.28	.28	.39	1	4.32	1.17	.53	7	5.82	.46	.19	4	1.44	.29	.09	1
P. macrocoxa	-	-	-	-	1.44	.73	.00	1	1.94	.15	.00	<1	-	-	-	-
Podoceropsis nitida	-	-	-	-	-	-	-	-	-	-	-	-	.36	.06	.09	<1
Orchomonella pinguis	-	-	-	-	-	-	-	-	.97	.05	.10	<1	-	-	-	-
Monoculodes spp.	-	-	-	-	.72	.44	.00	<1	-	-	-	-	-	-	-	--
M. edwardsi	-	-	-	-	.72	.15	.27	<1	-	-	-	-	10.83	2.29	2.08	47
Phoxocephalus holbolli	1.28	.28	.39	1	2.16	.44	.00	1	1.94	.10	.10	<1	2.17	.34	.00	1
Trichophoxus epistomus	6.41	1.70	.39	13	2.16	.44	.00	1	4.85	.25	.39	3	2.17	.34	.09	1
Stenopleustes gracilis	-	-	-	-	-	-	-	-	2.91	.20	.00	1	-	-	-	-
S. inermis	-	-	-	-	8.63	3.08	.00	27	15.53	1.93	.29	35	.72	.11	.00	1
Stenothoidae	1.28	.28	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
Hyperiidae	8.97	1.99	.77	25	.72	.15	.00	<1	-	-	-	-	-	-	-	-
Parathemisto gaudichaudi	10.26	3.13	1.93	52	-	-	-	-	1.94	.10	.00	<1	14.08	2.92	1.99	69
Aeginina longicornis	-	-	-	-	-	-	-	-	.97	.05	.00	<1	-	-	-	-
Unidentified	29.49	6.82	9.65	486	9.35	3.08	.80	36	1.94	.10	.00	<1	2.89	.46	.00	1
Total Amphipoda	84.62	86.36	78.76	13972	85.61	79.74	57.33	11735	80.58	24.72	24.66	3979	96.03	80.07	47.52	12252
Decapoda																
Leptochela bermudensis	-	-	-	-	-	-	-	-	-	-	-	-	.72	.11	.27	<1
Dichelopandalus leptoceras	-	-	-	-	-	-	-	-	2.91	.15	.48	2	3.97	.63	.90	6
Crangon septemspinosa	-	-	-	-	-	-	-	-	-	-	-	-	2.89	.51	1.72	6
Cancer spp.	-	-	-	-	-	-	-	-	-	-	-	-	.72	.11	.09	<1
C. borealis	-	-	-	-	-	-	-	-	-	-	-	-	.36	.11	.18	<1
C. irroratus	-	-	-	-	-	-	-	-	-	-	-	-	1.44	.23	.45	1
Unidentified	1.28	.28	.39	1	-	-	-	-	-	-	-	-	.36	.06	.09	<1
Total Decapoda	1.28	.28	.39	1	-	-	-	-	2.91	.15	.48	2	9.75	1.78	3.70	53
Unidentified Crustacea	6.41	1.42	1.54	19	-	-	-	-	-	-	-	-	.72	.11	.09	<1
Total Crustacea	93.59	95.45	81.08	16522	86.33	85.32	60.00	12545	86.41	28.59	28.63	4943	97.11	85.62	52.85	13447
Sipuncula																
Phascolion strombi	-	-	-	-	-	-	-	-	.97	.05	.00	<1	-	-	-	-
Echinodermata																
Ophiuroidea																
Axiognathus squamata	-	-	-	-	-	-	-	-	-	-	-	-	.36	.06	.09	<1
Chaetognatha																
Sagitta elegans	-	-	-	-	-	-	-	-	.97	.05	.10	<1	1.44	.23	.00	<1
Chordata																
Larvacea																
Unidentified	-	-	-	-	-	-	-	-	29.13	58.39	25.44	2442	-	-	-	-
Pisces																
Teleostei spp.	2.56	.57	.39	2	-	-	-	-	-	-	-	-	17.33	2.81	12.92	272
Merluccius bilinearis	-	-	-	-	-	-	-	-	-	-	-	-	4.69	.92	7.05	37
Ammodytes spp.	-	-	-	-	-	-	-	-	-	-	-	-	.36	.06	.45	<1
Citharichthys arctifrons	-	-	-	-	-	-	-	-	-	-	-	-	.72	.11	.36	<1
Total Pisces	2.56	.57	.39	2	-	-	-	-	-	-	-	-	23.10	3.89	20.78	570
Total number of stomachs examined:		195				189				110				315		
Examined stomachs with food:		78				139				103				277		

Table 10.--Percent frequency occurrence (F), percent number (N), percent volume (V) and index of relative importance (IRI) of food items in *Paralichthys oblongus* stomachs, by cruise.

Taxon Food Item	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Cnidaria																
Hydrozoa																
Eudendrium spp.	.77	.17	.08	<1	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified	-	-	-	-	-	-	-	-	.94	.10	.00	<1	-	-	-	-
Annelida																
Polychaeta																
Harmothoe extenuata	-	-	-	-	1.11	.18	.11	<1	.94	.10	.02	<1	1.33	.29	.04	<1
Sthenelais limicola	-	-	-	-	2.22	.35	.80	3	4.72	.52	.68	6	2.67	.57	.09	2
Maldanidae	-	-	-	-	-	-	-	-	.94	.10	.28	<1	1.33	.29	.04	<1
Clymenura sp. A	-	-	-	-	1.11	.18	.92	1	1.89	.21	.22	1	-	-	-	-
Spionidae	-	-	-	-	1.11	.18	.05	1	-	-	-	-	-	-	-	-
Ampharete arctica	-	-	-	-	1.11	.18	.11	<1	-	-	-	-	-	-	-	-
Chone infundibuliformis	-	-	-	-	5.55	.88	1.95	16	6.60	.93	2.04	20	1.33	.29	.16	1
Unidentified	-	-	-	-	4.44	.70	.14	4	.94	.10	.02	<1	2.67	.57	.17	2
Total Polychaeta	-	-	-	-	15.56	2.65	4.08	105	14.15	1.96	3.26	74	6.67	2.01	.51	17
Mollusca																
Pelecypoda																
Placopecten magellanicus	.77	.17	.01	<1	-	-	-	-	-	-	-	-	-	-	-	-
Cyclocardia borealis	.77	.17	.01	<1	1.11	.18	.11	<1	-	-	-	-	-	-	-	-
Ensis directus	.77	.17	.08	<1	-	-	-	-	.94	.10	.02	<1	-	-	-	-
Unidentified	2.31	.68	.21	2	-	-	-	-	-	-	-	-	-	-	-	-
Total Pelecypoda	4.62	1.19	.31	7	1.11	.18	.11	<1	.94	.10	.02	<1	-	-	-	-
Cephalopoda																
Loliginidae	2.31	.51	9.91	24	-	-	-	-	1.89	.31	4.07	8	1.33	.29	1.31	2
Loligo pealei	3.08	.85	18.49	60	-	-	-	-	-	-	-	-	-	-	-	-
Rossia spp.	3.85	.85	.62	6	5.55	.88	2.11	17	1.89	.21	.09	1	1.33	.29	.00	<1
R. tenera	2.31	.51	1.66	5	1.11	.35	.00	<1	.94	.10	2.22	2	1.33	.29	1.64	3
Unidentified	3.85	1.02	.60	6	-	-	-	-	-	-	-	-	-	-	-	-
Total Cephalopoda	15.38	3.74	31.28	539	6.67	1.23	2.11	22	-	-	-	-	4.00	.86	2.95	15
Unidentified Mollusca	5.38	1.70	.32	11	-	-	-	-	4.72	.62	6.38	33	-	-	-	-
Total Mollusca	22.31	6.62	31.90	859	7.78	1.41	2.23	28	5.66	.73	6.40	40	4.00	.86	2.95	15
Crustacea																
Copepoda																
Centropages typicus	-	-	-	-	1.11	.35	.00	<1	-	-	-	-	-	-	-	-
Candacia armata	-	-	-	-	-	-	-	-	-	-	-	-	2.67	.57	.00	2
Total Copepoda	-	-	-	-	1.11	.35	.00	<1	-	-	-	-	2.67	.57	.00	2
Stomatopoda																
Unidentified	-	-	-	-	-	-	-	-	.94	.10	.09	<1	-	-	-	-
Mysidacea																
Neomysis americana	-	-	-	-	-	-	-	-	.94	.10	.02	<1	-	-	-	-
Cumacea																
Diastylis sculpta	-	-	-	-	-	-	-	-	.94	.10	.00	<1	-	-	-	-

Table 10.--Continued.

Taxon Food Item	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Amphipoda																
Ampelisca spp.	.77	.17	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
A. vadorum	.77	.17	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
A. agassizi	.77	.17	.01	<1	-	-	-	-	.94	.10	.00	<1	-	-	-	-
Byblis serrata	6.15	3.40	.19	22	5.55	2.29	.39	15	18.87	7.48	2.53	189	-	-	-	-
Leptocheirus pinguis	-	-	-	-	-	-	-	-	.94	.10	.09	<1	-	-	-	-
Erichthonius rubricornis	2.31	.68	.01	2	38.89	21.69	1.74	911	24.53	9.24	1.33	259	1.33	.29	.00	<1
Unciola irrorata	10.77	3.23	.19	37	53.33	42.33	5.55	2554	51.89	50.57	11.25	3208	6.67	2.58	.10	18
Trichophoxus epistomus	1.54	.34	.01	1	-	-	-	-	-	-	-	-	-	-	-	-
Hyperiidae	2.31	.68	.01	2	-	-	-	-	-	-	-	-	-	-	-	-
Parathemisto gaudichaudi	2.31	1.02	.02	2	1.11	.70	.02	1	.94	.10	.00	<1	4.00	1.15	.00	5
Unidentified	1.54	.34	.01	1	1.11	.18	.00	<1	-	-	-	-	-	-	-	-
Total Amphipoda	18.46	10.19	.44	196	61.11	67.20	7.71	4578	66.04	67.60	15.21	5469	12.00	4.01	.10	49
Decapoda																
Dichelopandalus leptocerus	7.69	4.75	8.15	99	7.78	1.59	6.72	65	38.68	16.51	14.51	1200	25.33	10.31	3.71	355
Crangonidae	-	-	-	-	-	-	-	-	94	.10	.02	<1	-	-	-	-
Crangon septemspinosa	11.54	3.56	2.34	65	12.22	3.53	4.89	103	25.47	5.50	6.62	309	22.67	8.60	2.22	245
Scyllarus spp.	-	-	-	-	-	-	-	-	.94	.10	.46	1	-	-	-	-
Munida iris	-	-	-	-	7.78	2.12	4.93	55	.94	.10	.46	1	-	-	-	-
Cancer spp.	10.00	5.09	1.82	69	2.22	.53	.44	2	1.89	.21	.31	1	-	-	-	-
C. borealis	3.85	1.02	.47	6	3.33	1.23	6.54	26	.94	.10	.09	<1	-	-	-	-
C. irroratus	61.54	42.61	31.70	4573	44.44	16.05	49.91	2931	28.30	5.92	39.13	1275	46.67	20.34	68.71	4156
Collodes robustus	-	-	-	-	1.11	.18	.11	<1	-	-	-	-	-	-	-	-
Unidentified	25.38	12.73	6.09	478	-	-	-	-	.94	.10	.09	1	-	-	-	-
Total Decapoda	80.00	69.78	50.60	9630	65.56	25.22	73.54	6475	73.58	28.66	61.70	6649	78.67	39.26	74.63	8959
Unidentified Crustacea	2.31	.68	.35	2	3.33	.53	.76	4	-	-	-	-	-	-	-	-
Total Crustacea	86.92	80.65	51.39	11477	93.33	93.30	82.01	16362	95.28	96.57	77.02	16541	81.33	43.84	74 73	9644
Echinodermata																
Echinoidea																
Echinarachnius parma	6.92	1.53	.34	13	-	-	-	-	-	-	-	-	1.33	.29	.04	<1
Chordata																
Pisces																
Teleostei spp.	22.31	5.26	8.28	302	10.00	1.59	4.54	61	1.89	.21	3.70	7	24.00	8.60	3.35	287
Urophycis chuss	9.23	3.56	6.04	89	1.11	.18	1.84	2	1.89	.21	8.88	17	1.33	.29	.08	<1
Merluccius bilinearis	5.38	1.36	1.37	15	3.33	.53	3.67	14	.94	.10	.56	1	40.00	44.13	18.34	2498
Citharichthys arctifrons	3.85	.85	.60	6	2.22	.35	1.63	4	.94	.10	.19	<1	-	-	-	-
Total Pisces	40.00	11.04	16.29	1093	15.56	2.65	11.68	223	5.66	.62	13.32	79	62.67	53.01	21.77	4686
Total number of stomachs examined		169				101				125				75		
Examined stomachs with food:		130				90				106				75		

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Mayo H. Judy and Robert M. Lewis

October 1983

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

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U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary
National Oceanic and Atmospheric Administration
John V. Byrne, Administrator
National Marine Fisheries Service
William G. Gordon, Assistant Administrator for Fisheries

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

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

ABSTRACT

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

INTRODUCTION

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

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

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

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

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

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

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

RESULTS AND DISCUSSION

Temporal and Geographical Collections of Eggs

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

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

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

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

Temporal and Geographical Collections of Larvae

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

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

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

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

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

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

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

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

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

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

TEMPORAL AND GEOGRAPHIC NORMS OF SPAWNING

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

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

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

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

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

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

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

Table 2.—*Continued.*

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

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

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

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

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

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

CONCLUSIONS

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

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APPENDIX I

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

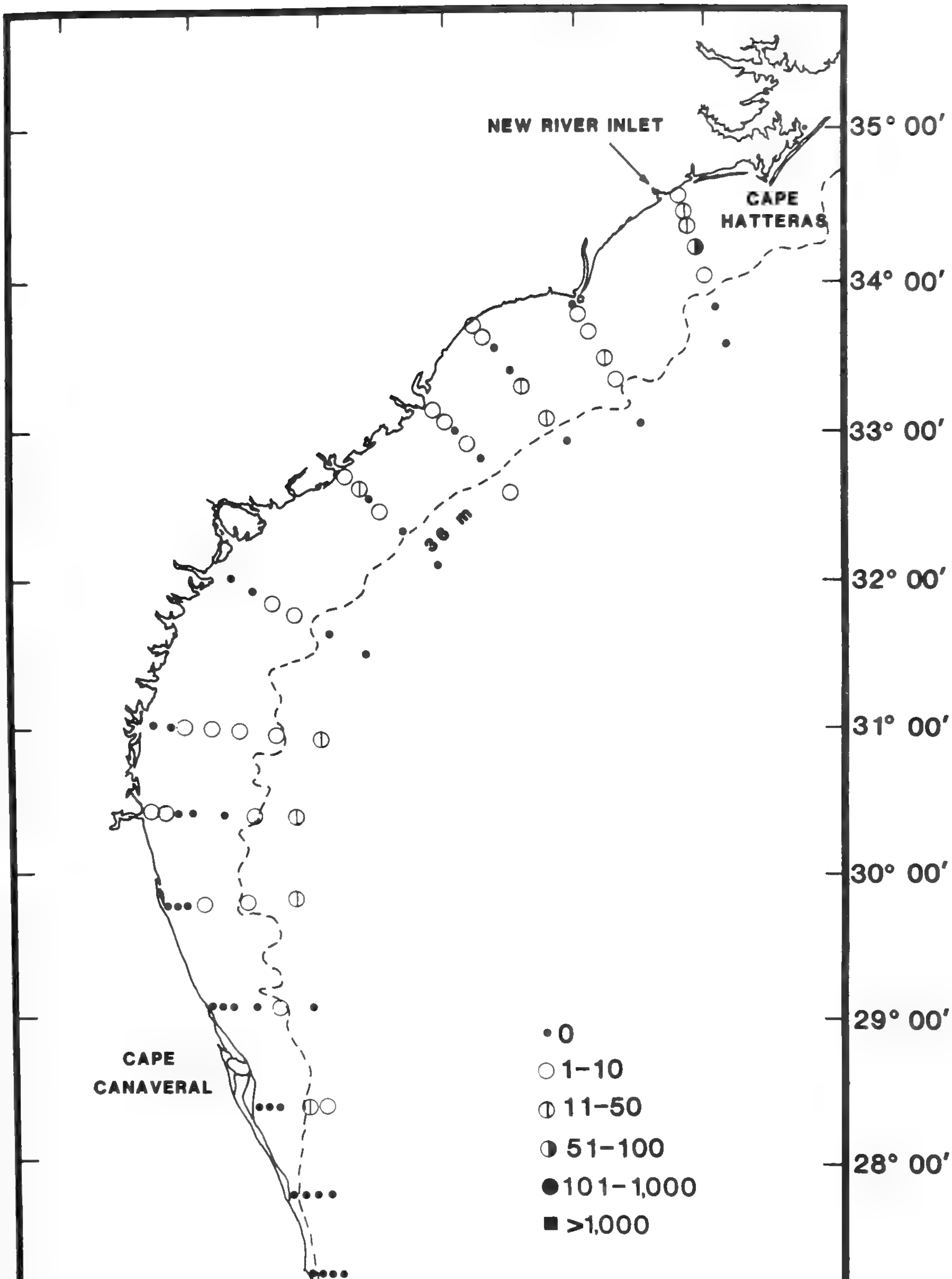

Figure 1.—RV *Dolphin* cruises D-68-1, January and February 1968. Number of Atlantic menhaden larvae by category and station locations.

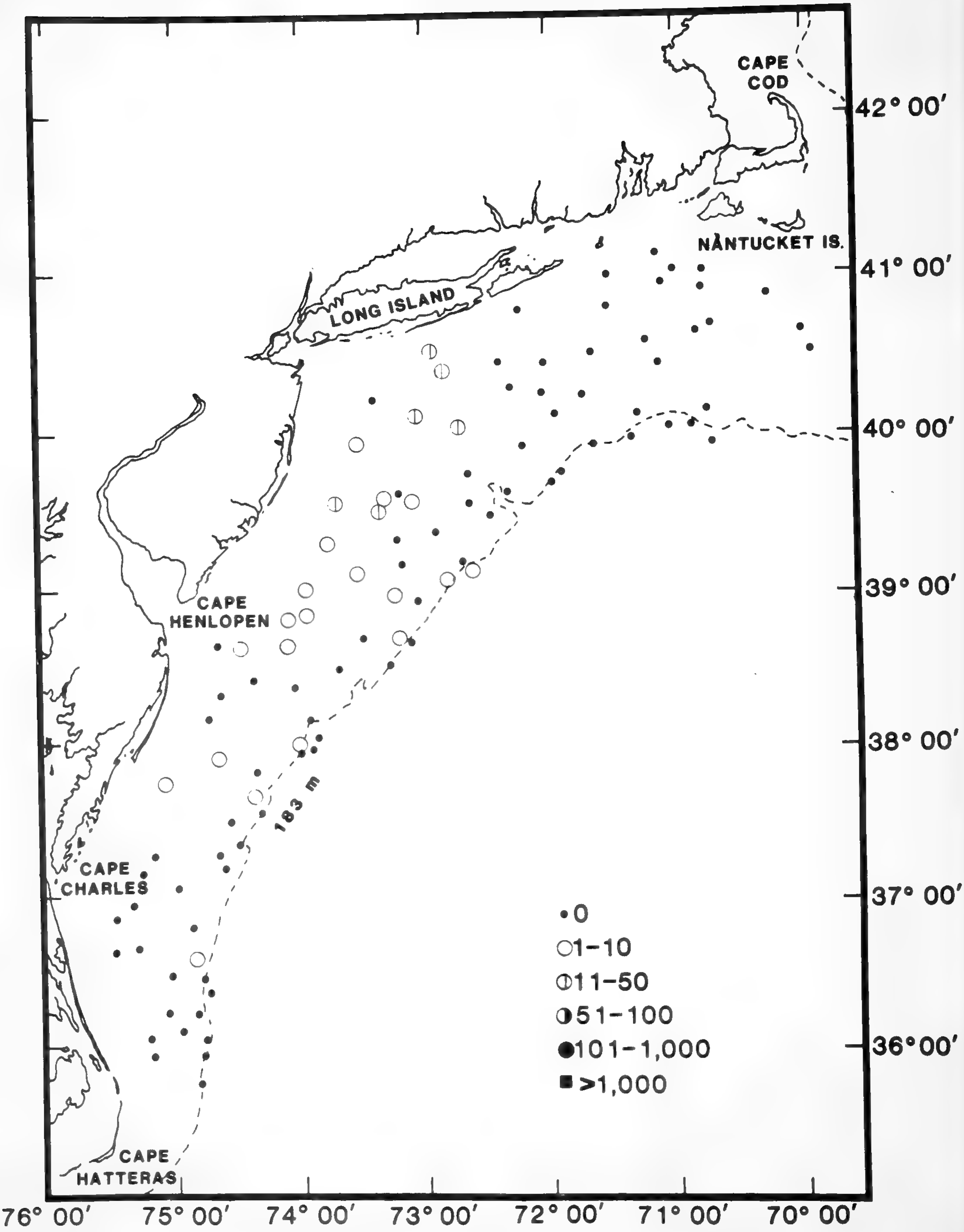

Figure 2.—RV *Albatross IV* cruise 68-17, October 1968. Number of Atlantic menhaden larvae by category and station locations.

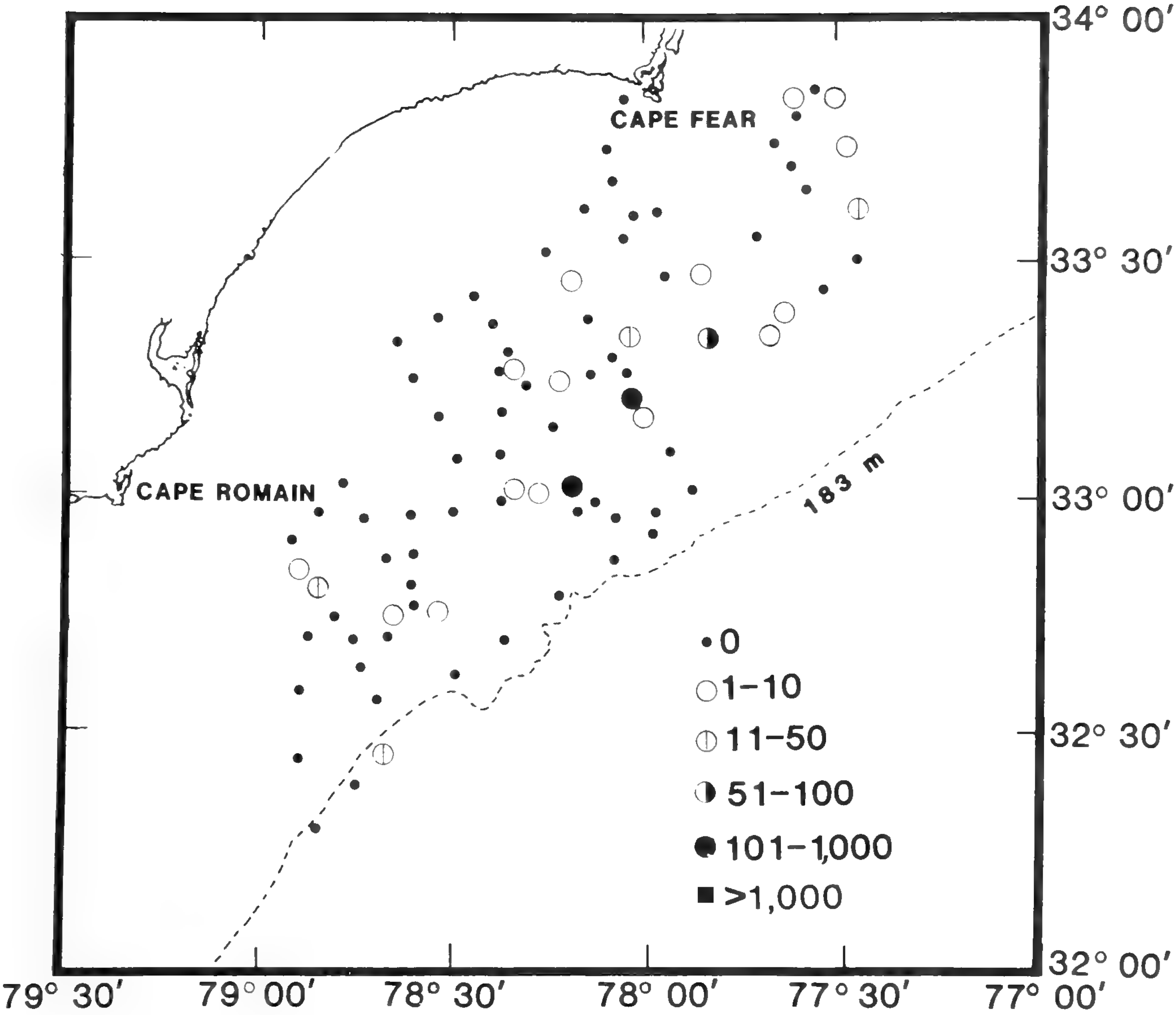

Figure 3.—RV *Advance II* cruise 4, January 1969. Number of Atlantic menhaden larvae by category and station locations.

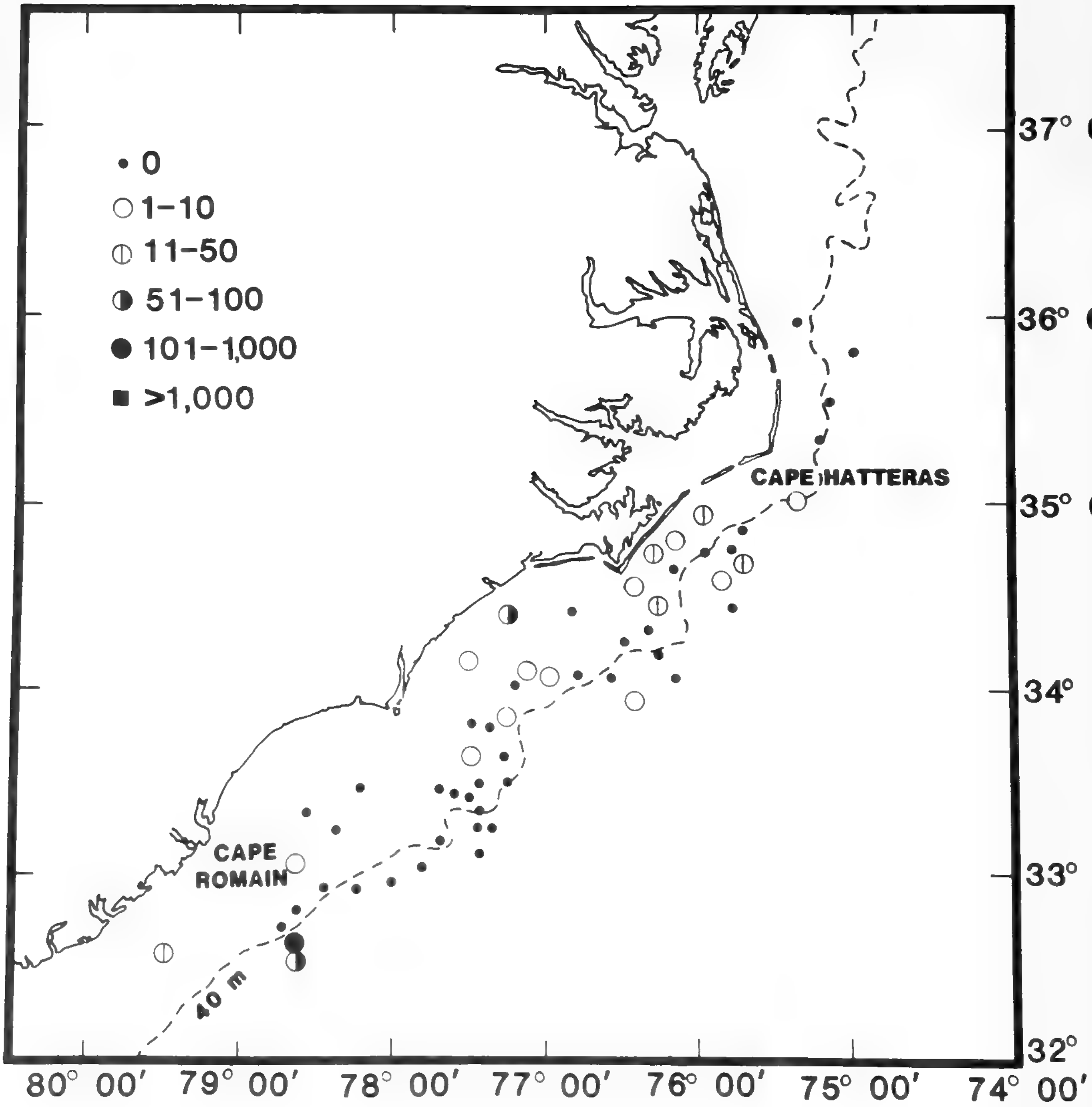

Figure 4.—USCG Cutter *Chilula* and NASA *Range Recoverer*, March 1969. Number of Atlantic menhaden larvae by category and station locations.

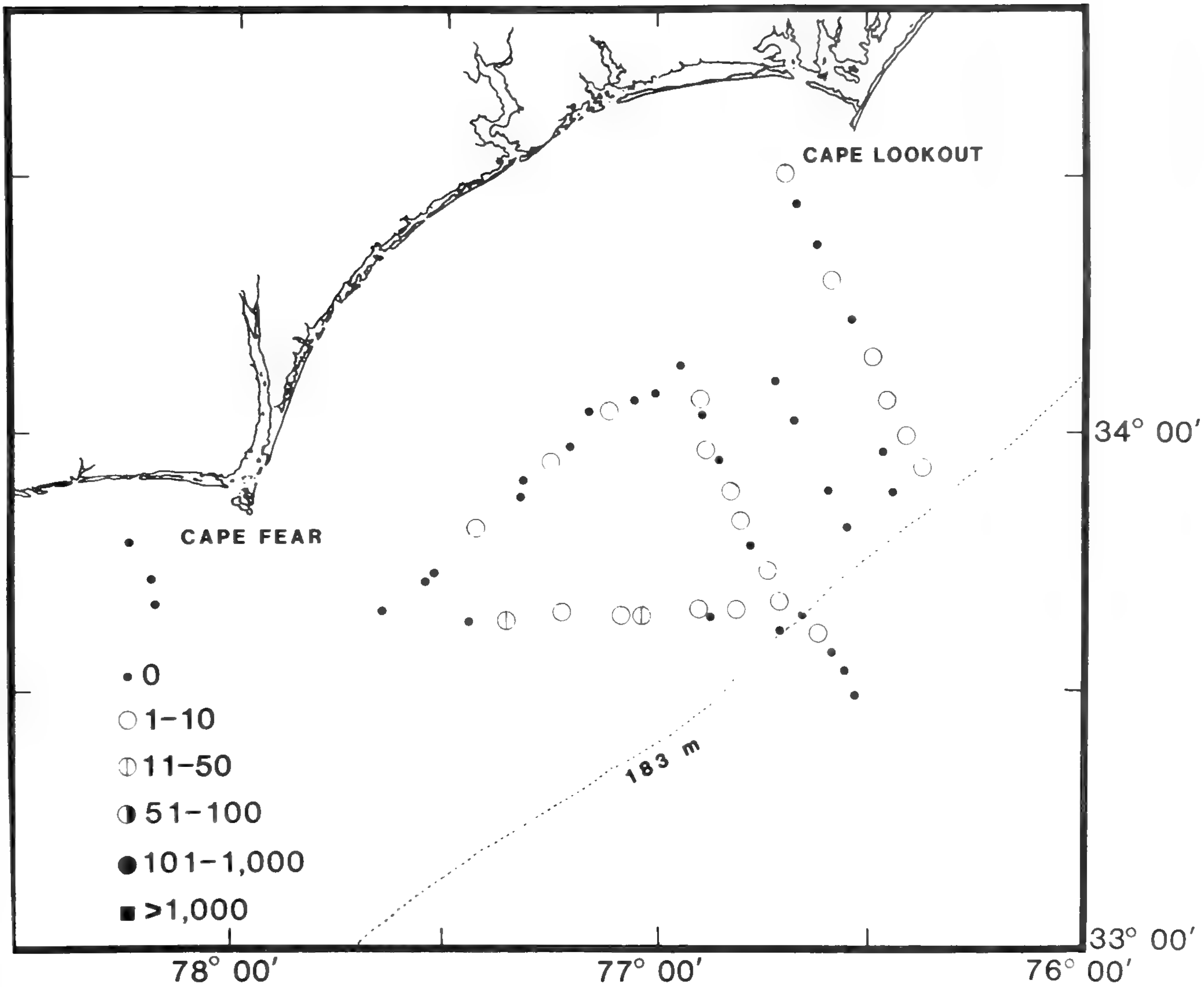

Figure 5.—RV *Undaunted* cruises, December 1970 and January 1971. Number of Atlantic menhaden larvae by category and station locations.

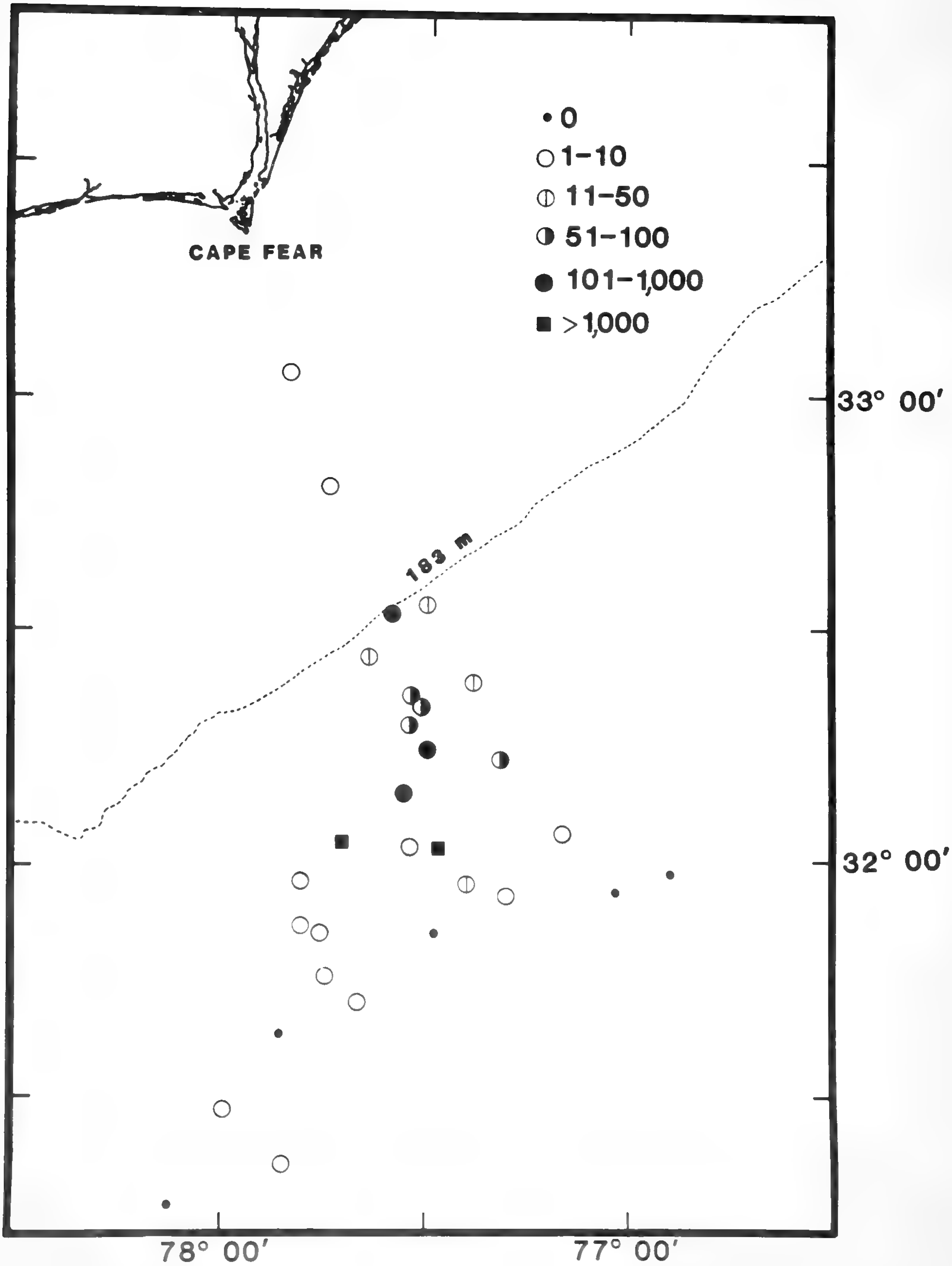

Figure 6.—RV *Undaunted* cruises, February and March 1971. Number of Atlantic menhaden larvae by category and station locations.

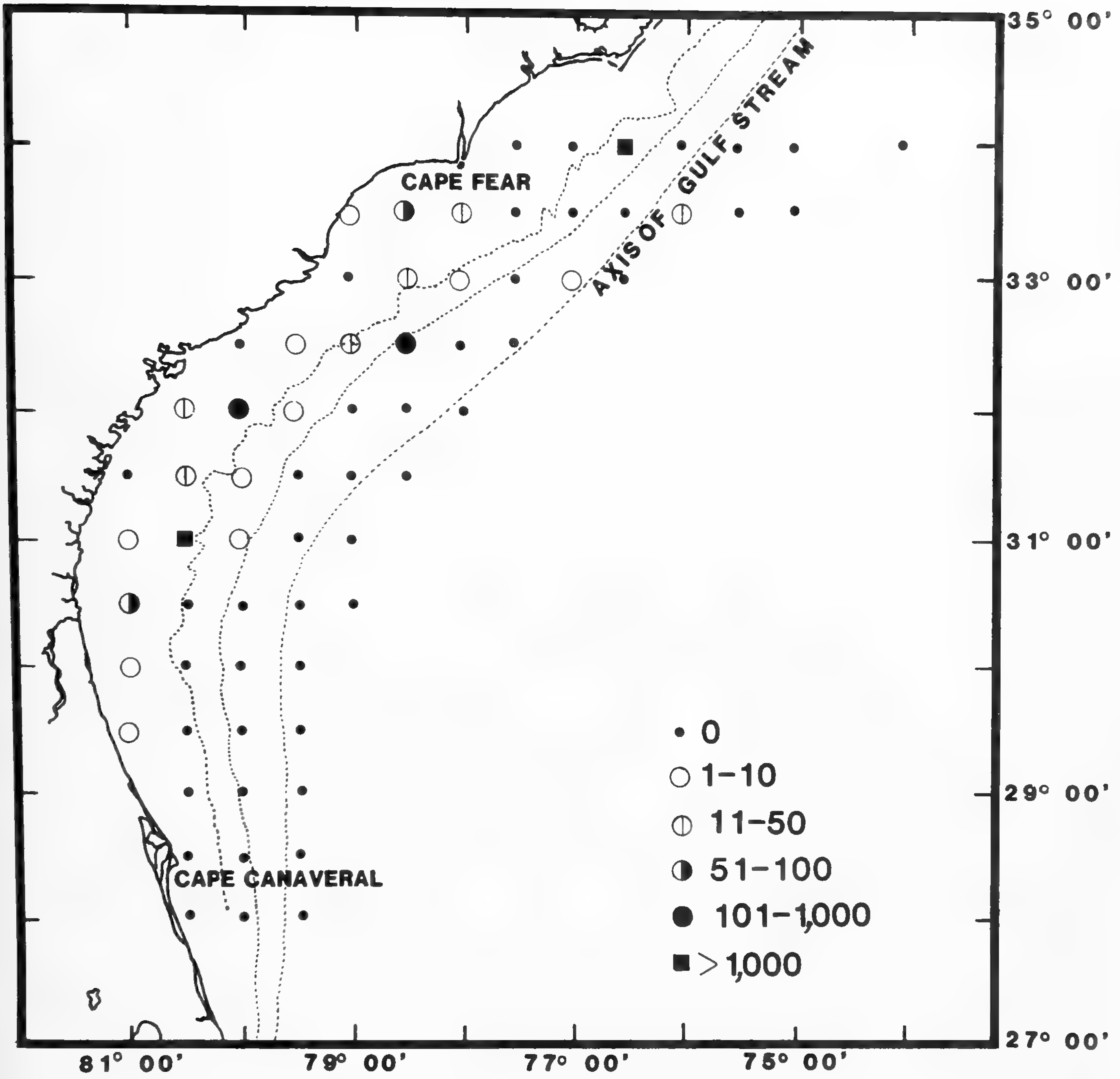

Figure 7.—RV *Dolphin* cruise D2-73, February and March 1973. Number of Atlantic menhaden larvae by category and station locations.

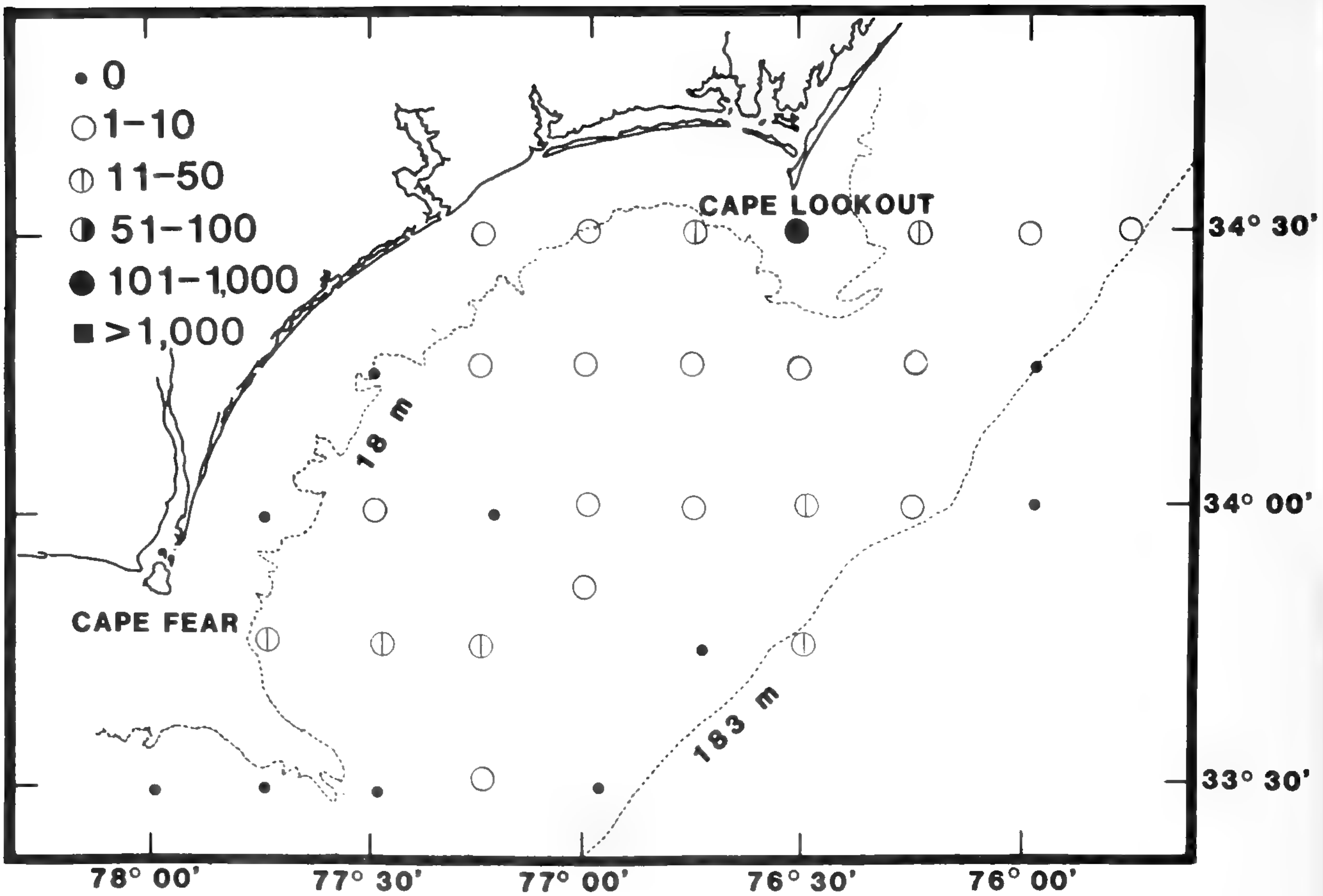

Figure 8.—RV *Dolphin* cruise D1-74, January 1974. Number of Atlantic menhaden larvae, by category and station locations, for the 60 cm bongos (0.333 and 0.505 mm mesh combined).

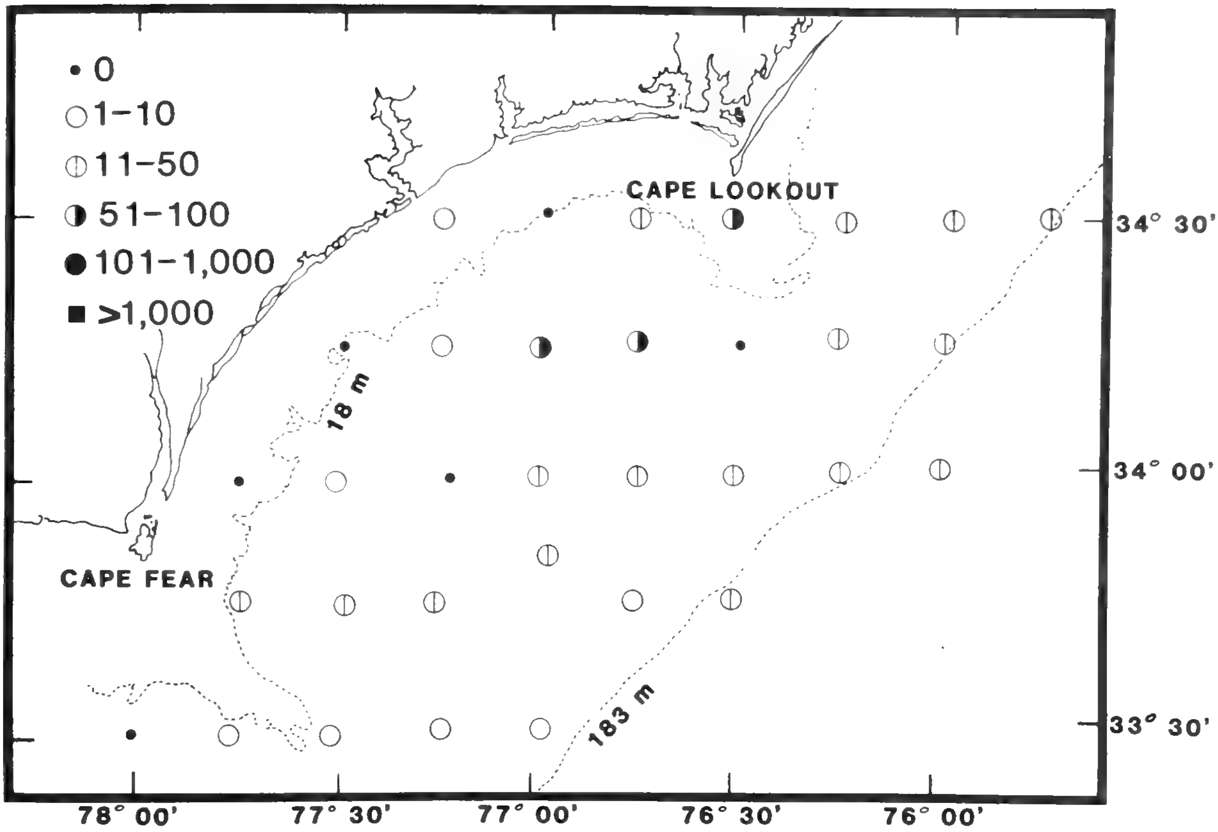

Figure 9.—RV *Dolphin* cruise D1-74, January 1974. Number of Atlantic menhaden larvae, by category and station locations, for the 1 X 2 m neuston (0.947 mm mesh).

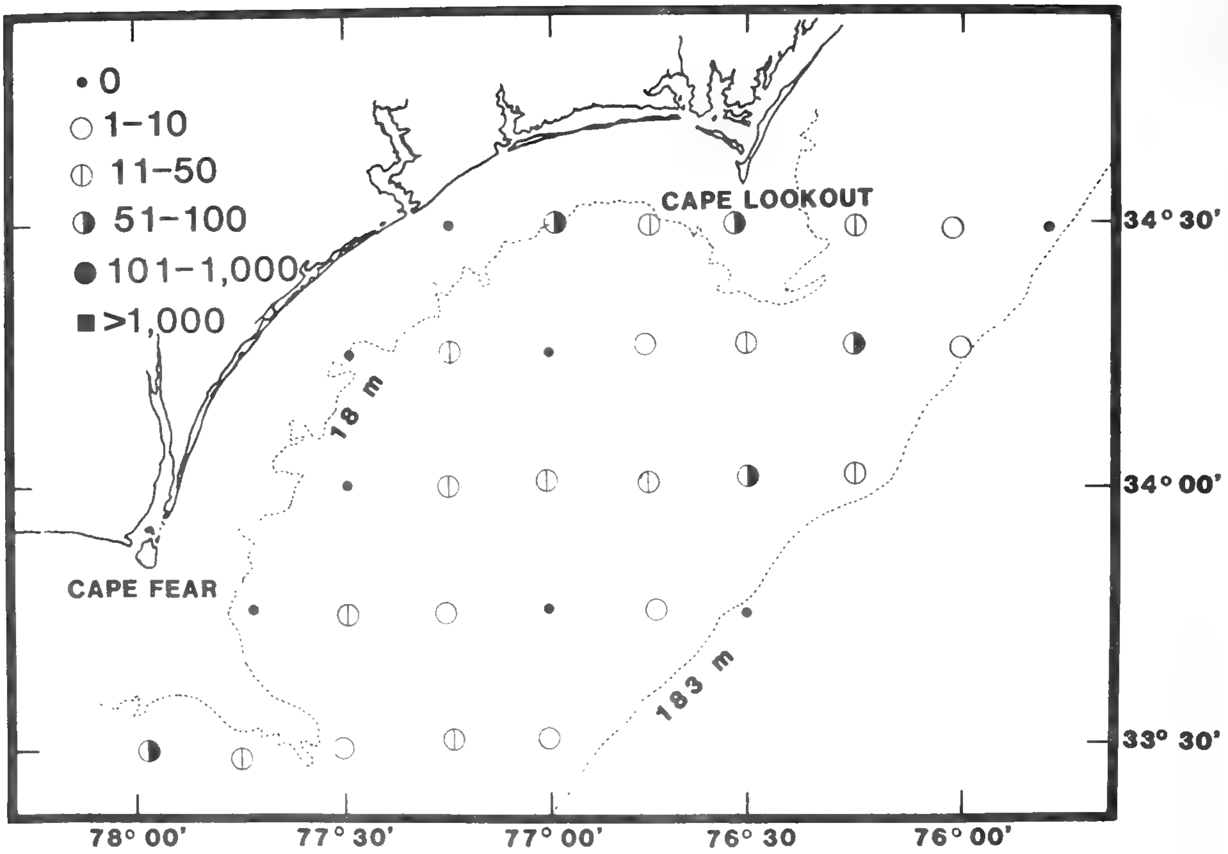

Figure 10.—RV *Dolphin* cruise D1-75, January 1975. Number of Atlantic menhaden larvae, by category and station locations, for the 60 mm bongos (0.333 and 0.505 mm mesh combined).

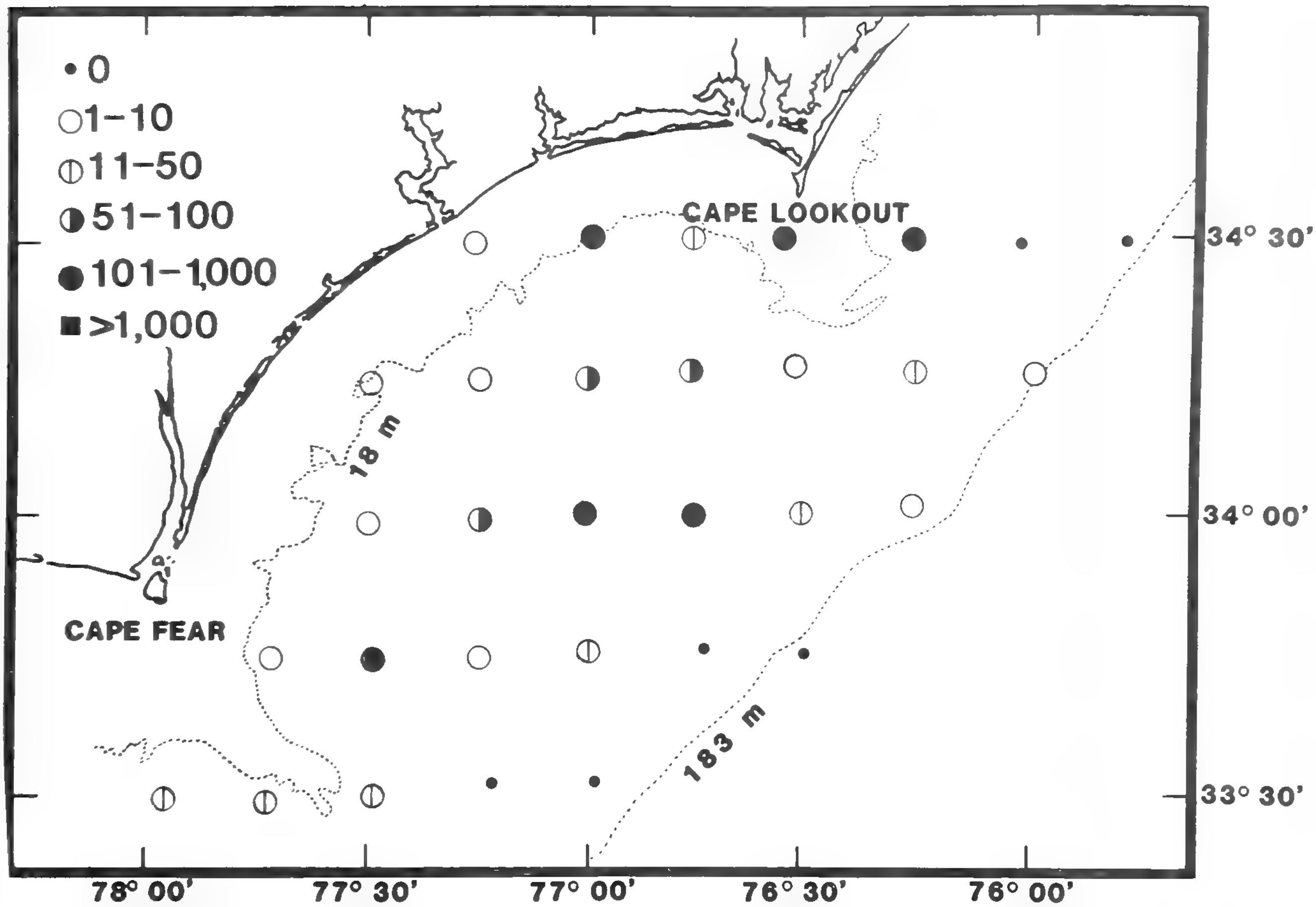

Figure 11.—RV *Dolphin* cruise D1-75, January 1975. Number of Atlantic menhaden larvae, by category and station locations, for the 1 X 2 m neuston (0.947 mm mesh).

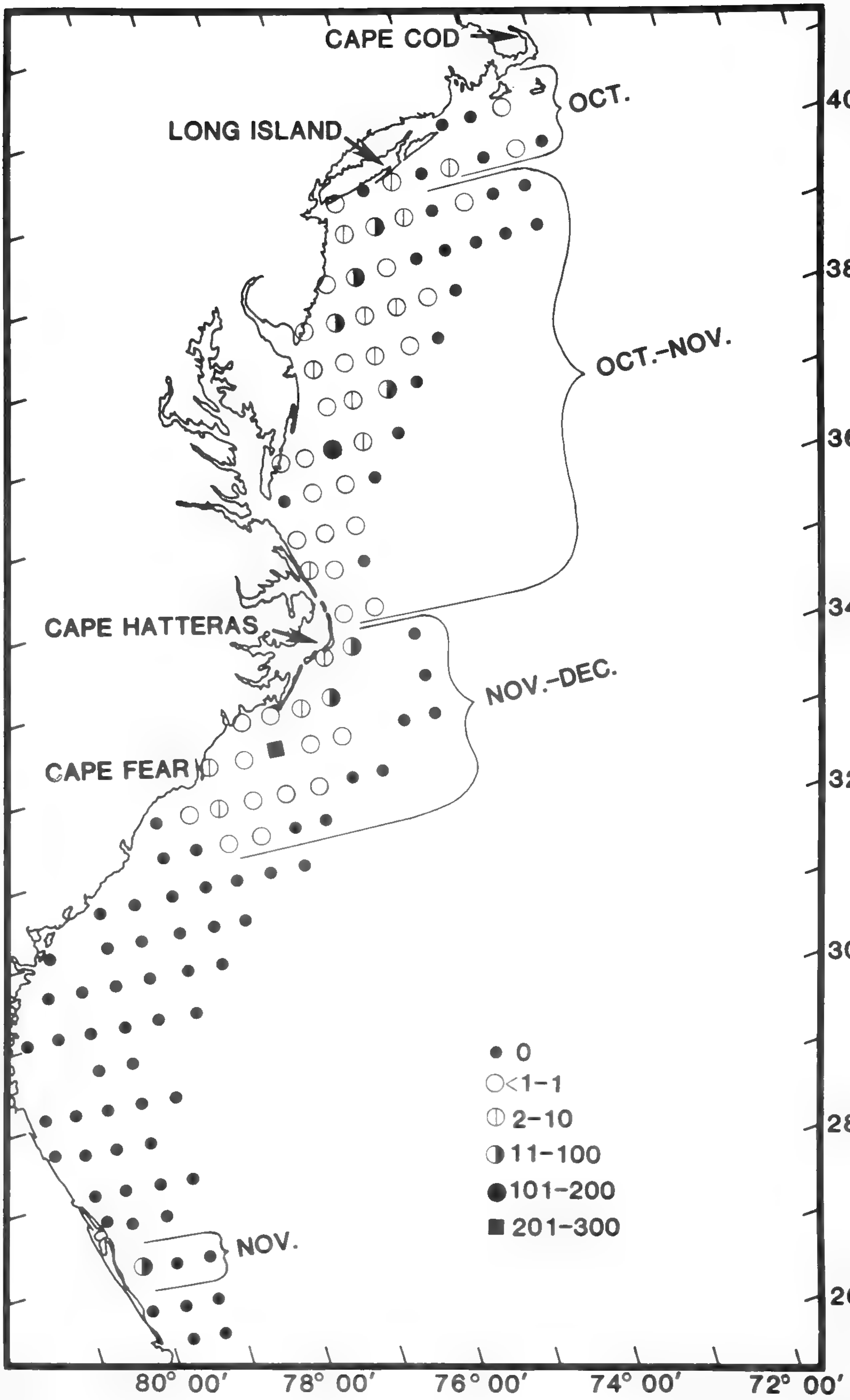

Figure 12.—Mean number of Atlantic menhaden larvae, by category, shown by symbols representing areas of 15′00″ latitude and 15′00″ longitude, October - December, 1953-75.

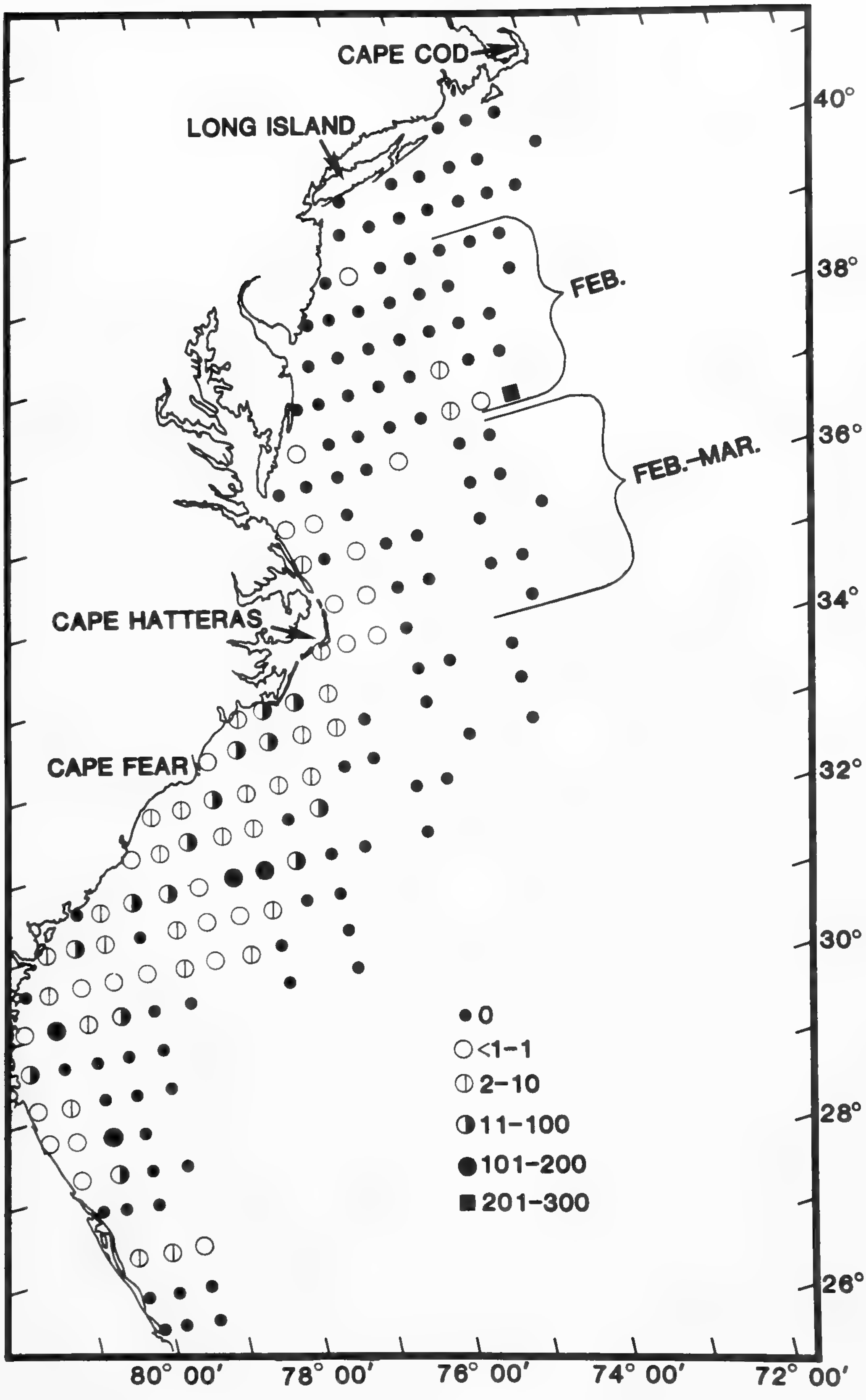

Figure 13.—Mean number of Atlantic menhaden larvae, by category, shown by symbols representing areas of 15 '00" latitude and 15 '00" longitude, January-March, 1953-75.

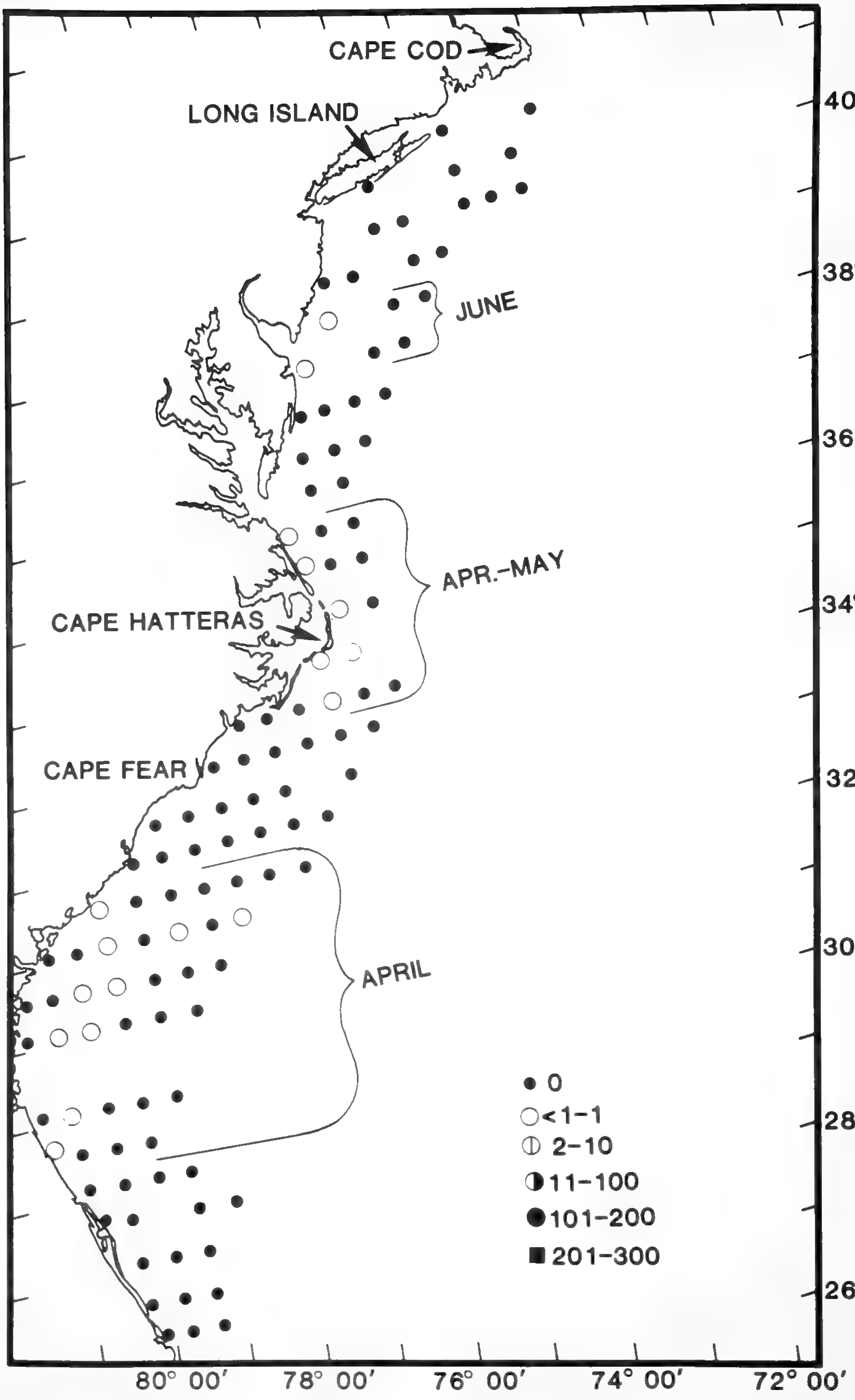

Figure 14.—Mean number of Atlantic menhaden larvae, by category, shown by symbols representing areas of 15′00″ latitude and 15′00″ longitude, April-June, 1953-75.

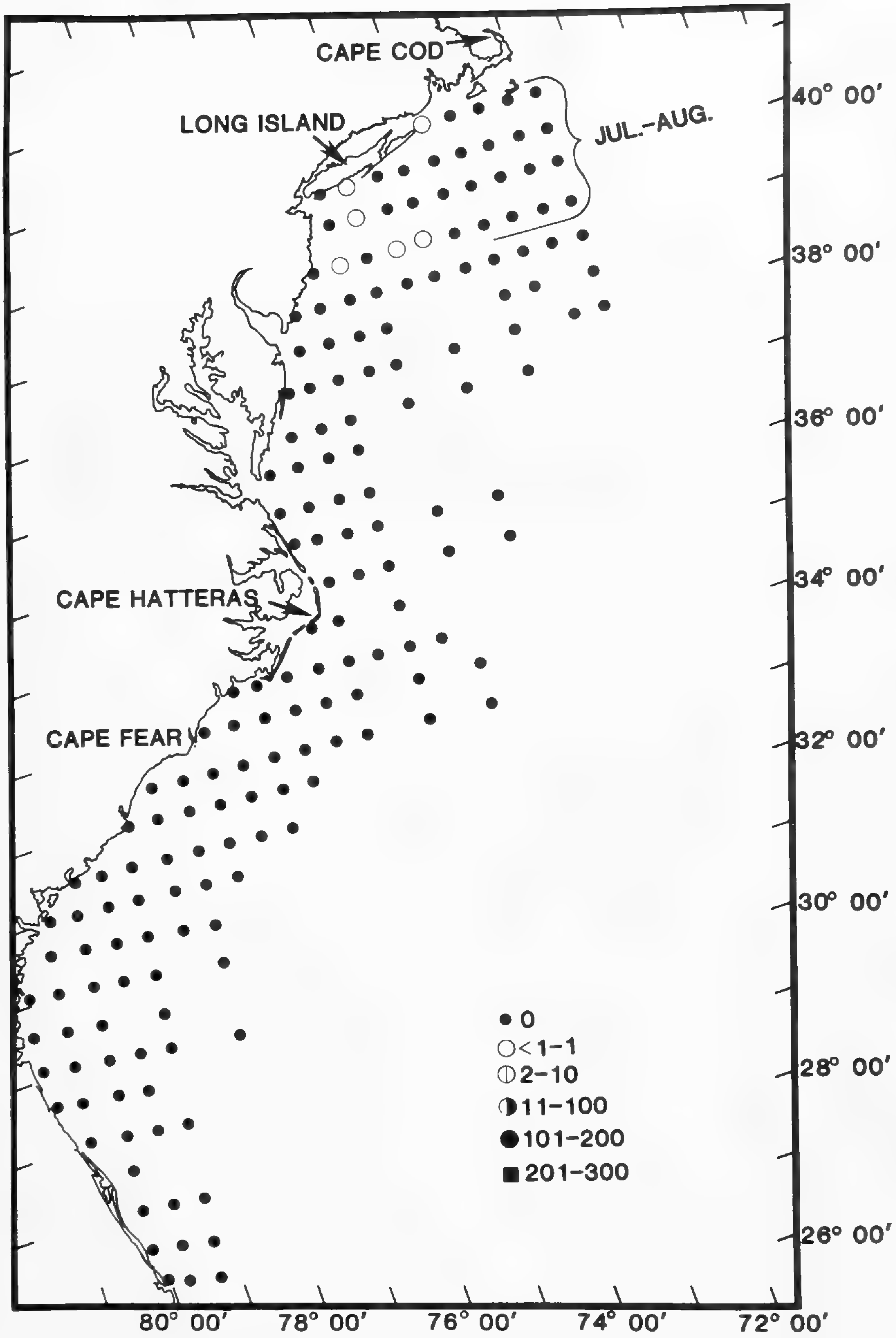

Figure 15.—Mean number of Atlantic menhaden larvae, by category, shown by symbols representing areas of 15′00″ latitude and 15′00″ longitude, July-September, 1953-75.

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September 1983

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National Oceanic and Atmospheric Administration
National Marine Fisheries Service

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NOAA Technical Report NMFS SSRF-775

Distribution and Relative Abundance of American Lobster, *Homarus americanus*, Larvae: New England Investigations During 1974-79

Michael J. Fogarty (editor)

September 1983

U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary
National Oceanic and Atmospheric Administration
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William G. Gordon, Assistant Administrator for Fisheries

PREFACE

In this volume, surveys of the distribution and relative abundance of American lobster, *Homarus americanus*, larvae conducted in New England during 1974-79 are described. The results of eight individual investigations, ranging from 1 to 4 yr in duration, conducted by members of an Ad Hoc Larval Lobster Working Group are provided. In addition, the relative sampling efficiency of neuston nets and Tucker trawls with respect to lobster larvae is examined.

As an introduction to this volume, factors influencing the diurnal, vertical, and spatial distribution of lobster larvae are reviewed, providing background for interpretation of the results of our investigations and obviating the need for extensive reviews within each paper. The results of these studies are then synthesized in an overview paper which precedes the individual research reports in this volume.

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Distribution and Relative Abundance of American Lobster, *Homarus americanus*, Larvae: New England Investigations During 1974-79

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Distribution and Relative Abundance of American Lobster, *Homarus americanus*, Larvae: A Review

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INTRODUCTION

The American lobster, *Homarus americanus*, is among the most valuable fishery resources of the east coast of the United States. Preliminary U.S. landings of American lobster in 1980 were 16,800 metric tons (t) with an estimated ex-vessel value of $75 million (National Marine Fisheries Service 1980). Intensive exploitation of this valuable resource has resulted in concern over possible impacts of increasing fishing mortality rates on yield and reproductive potential of inshore populations (Anthony and Caddy 1980). Despite large-scale research efforts to define the population dynamics of the American lobster, relatively little is known about the determinants of larval production, survival, and subsequent recruitment to the fisheries. Observations on the occurrence of larval American lobsters have been documented since the latter part of the 19th century (Smith 1873; Herrick 1896); however, quantitative sampling programs have been undertaken only within the last 30 yr.

Larval development of the American lobster is characterized by four pelagic instars. A brief prezoeal stage precedes the first larval stage (Davis 1964). Hatching primarily occurs during late May-early June in New England (Hughes and Matthiessen 1962) after a 10-11 mo incubation period. Larvae typically occur in the plankton from late May to early September depending on location. The larval phase is normally completed in 25-35 d although stage duration is temperature dependent (Templeman 1936). Settlement occurs during the fourth larval stage (Scarratt 1973) and the postlarvae are benthic.

In this review, the distribution and relative abundance of larval lobsters in relation to depth, hydrographic factors, and environmental variables are summariezed and additional information on survival rates and stock-recruitment relationships examined. Phillips and Sastry (1980) reviewed aspects of larval lobster behavior, physiology, nutritional requirements, and ecology. Stasko (1980) and Fair (1980) provided summaries of Canadian and U.S. investigations on the distribution of larval American lobsters in the northwest Atlantic.

VERTICAL DISTRIBUTION

Several studies have indicated that lobster larvae are concentrated at the surface during daylight. Templeman (1937) reported that daytime catch rates at the surface were six-fold greater than at 0.2-4.5 m depth and no lobster larvae were obtained at 5.5-11 m. Smith (1937 cited by Stasko 1980) reported catch rates of 10.0 larvae/tow in surface samples and 0.9 larvae/tow at subsurface depths; larvae in subsurface hauls were primarily collected at night or at dawn. Templeman and Tibbo (1945) concluded that larvae were primarily neustonic in the Gulf of St. Lawrence, however, ambient light levels were found to affect depth distribution and this effect varied with larval stage. In the Gulf of Maine, Sherman and Lewis (1967) reported that catches in surface tows exceeded those in oblique hauls (0-20 m) by a factor of 2.4. Scarratt (1973) noted sharp differences in daytime catch rates between neuston and subsurface nets suspended at 0.6-1.2 m depth; in two series of hauls (34 tows), 876 larvae were obtained in the upper net and 95 in the lower. Further samples taken at 4-18 m depth (13 tows) yielded 14 larvae and no larvae were obtained in tows with the net held 10 cm from the bottom. Stasko[2] reported that few lobster larvae were taken in subsurface collections on the Scotian shelf. Harding et al. (1982) sampled the upper 110 cm of the water column with a three compartment net; 81.4, 14.1, and 4.5% of the larvae obtained were within the 0-30, 30-70, and 70-110 cm depth strata, respectively.

LIGHT INTENSITY

Ambient light intensity has been demonstrated to influence the vertical distribution of lobster larvae. Templeman (1937) concluded on the basis of field observations that first and second stage larvae react positively to low intensity light but respond negatively to increased light intensity. Templeman and Tibbo (1945) noted that third and fourth stage larvae are less sensitive to light levels than earlier stages. Diurnal vertical distribution was apparently related to light intensity and larvae tended to disperse from surface waters during night except under bright moonlight (Templeman 1939). Scarratt (1973) demonstrated significantly higher catch rates at the surface for stage I larvae during daylight, however, no significant differences between day and night samples were observed for second stage larvae. Positive phototaxis was noted for first and second stage larvae under experimental conditions, however, sustained phototactic behavior was not observed and later stage larvae were less responsive to changes in light intensity (Ennis 1975). Harding et al. (1982) noted a dispersal from surface (0-30 cm) waters during bright sunlight, confirming the observations of Templeman and Tibbo (1945).

Early observations under laboratory conditions indicated that phototactic responses differed among larval stages and,

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[2] Stasko, A. B. 1977. Lobster larvae on the Scotian Shelf. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 77/31, 10 p.

to a lesser extent, within each larval stage (Hadley 1905, 1908). First and fourth stage larvae were initially positively phototactic but reversed phototactic responses late in each stage. Second and third stage larvae tended to be negatively phototactic, however, response patterns were highly variable. Huntsman (1924) indicated that direct exposure to sunlight under experimental conditions could be lethal to first stage larvae. Templeman (1936) reported increased survival and growth rates for larvae cultured in darkness. These field and laboratory observations indicate that ambient light levels may directly affect availability of larval lobsters to neuston nets, potentially affecting estimates of relative abundance and survival.

Field investigations demonstrate a predominance of stage I larvae in daylight surface collections (Table 1). The progressive decline in successive stage densities is presumably due to the effects of mortality and behavioral factors, notably phototaxis, which affect availability and catchability of larvae.

TEMPERATURE

Scarratt (1964) found no relationship between surface water temperature and production, relative abundance, and survival of larvae in Northumberland Strait during 1949-61. The period of larval production was, however, extended in cool years. Scarratt suggested that larvae produced in the latter part of the season may be unable to successfully molt into fourth stage before winter. Caddy (1979) concluded that the cumulative temperature sum (degree-days) required for completion of the pelagic phase increases with decreasing water temperature and further suggested that larvae produced in the later part of the season (mid-late August) may not successfully molt if water temperatures decline more rapidly than the accretion of necessary degree-days. An apparent relationship between survival and mean surface water temperature from April through August inclusive was also indicated. Sherman and Lewis (1967) reported mean surface water temperatures of 13.7°-15.0°C

Table 1.—Summary of published accounts of larval American lobster sampling programs conducted from southern New England to Newfoundland in daylight surface tows. (Only daylight tows with complete catch composition data are included.)

Year	Location	Sample period	Percent stage composition I	II	III	IV	Total no. larvae	No. tows	Tow speed (km hr)	Tow duration (min)	Gear	Source
1936	Nova Scotia	July-Aug.	95.8	3.0	0.6	0.6	324	—	—	60	1 m plankton	Templeman 1937
1936	Northumberland Strait	July-Aug.	98.1	1.6	0.3	0	322	50	—	—	1 m plankton	Smith 1937 (cited by Stasko 1980)
1938-40	Newfoundland	June-Sept.	54.4	13.6	18.9	13.1	5,037	—	—	—	1 m plankton	Templeman and Tibbo 1945
1948-61	Northumberland Strait	June-Sept.	77.9	13.8	4.7	3.6	298,872	—	1.8	30	3.7 × 0.9 m neuston	Scarratt 1964
1962-63	Northumberland Strait	June-Sept.	88.8	8.6	2.1	0.5	11,955	448	1.8	30	3.7 × 0.9 m neuston	Scarratt 1973
1965-66	Gulf of Maine	June-Sept	80.4	1.9	0.3	17.4	368	218	7.4-11.1	10-30	1 m plankton 2 × 1 m neuston 1 × 0.5 m neuston	Sherman and Lewis 1967
1966-67	Offshore S. New England	June-Aug.	47.9	14.3	28.6	9.2	119	96	5.6-6.5	30	1.5 m plankton	Lund and Stewart 1970
1968	Long Island Sound	June-Aug.	34.7	23.8	23.6	17.9	1,367	145	5.6-6.5	30	1.5 m plankton	Lund and Stewart 1970
1966	Nova Scotia	July-Aug.	94.9	4.4	0.4	0.3	1,984	100	1.8	30	3.7 × 0.9 m neuston	Scarratt 1968
1968	Nova Scotia	July-Aug.	90.2	2.0	0.4	7.4	746	100	1.8	30	3.6 × 0.9 m neuston	Scarratt 1969
1975	Nova Scotia	June-Aug.	91.7	7.8	0.5	0	193	—	7.4	15	0.4 × 0.4 m neuston	Harding et al. 1979
1976	Scotian Shelf	Aug.	8.5	8.5	19.7	63.4	142	—	4.6-9.3	15-30	1 m neuston 1 m plankton Issacs-Kidd Trawl	Stasko (see text footnote 2)
1978	Nova Scotia	June-Aug.	[1]69.6	[1]22.6	[1]6.1	[1]1.7	925	81	5.4-7.2	15-20	0.4 × 1.1 m partitioned neuston	Harding et al. (1982)

[1] Based on production estimates.

at Boothbay Harbor during the period of peak larval density in the Gulf of Maine. Larvae were collected at water temperatures ranging from 12.5° to 28.5°C in Long Island Sound with peak hatching occurring at approximately 20°C (Lund and Stewart 1970).

Hughes and Matthiessen (1962) reported intensive hatching activity at approximately 15°C at a culture facility supplied with ambient running seawater. Hatching occurred at temperatures as low as 9.4°C and peak hatching was noted at 20°C. The time required to reach the fourth larval stage varied inversely with water temperature, ranging from 9 to 33 d at mean water temperatures of 22.3°-16.1°C.

Templeman (1936) reported the cumulative time required to reach successive larval stages (I-V) at temperatures ranging from 7° to 24°C. At 15°C approximately 25 d were needed to reach the fourth larval stage while an increase to 20°C reduced the time required to reach stage IV to 13 d. These data are extremely useful in correcting density estimates for intermolt duration (Scarratt 1964, 1973). The graphical presentation of Templeman (1936) was therefore converted to a series of of power curves relating intermolt period to water temperature for each larval stage (Table 2).

Table 2.—Parameter estimates and degree of fit index for the relationship $D = aT^b$ where D and T represent stage duration (days) and temperature (°C), respectively. Equations derived from the graphical presentation of Templeman (1936) by calculating the difference between the cumulative times required to reach successive larval stages and regressing on temperature.

	Larval stage			
Parameter	I	II	III	IV
a	1,123.542	2,510.476	2,745.043	7,492.117
b	−1.91255	−2.16334	−2.07060	−2.11708
R^2	.968	.967	.970	.958

SALINITY

Scarratt (1968, 1969) noted a distinct onshore-offshore salinity gradient during July-August off Nova Scotia; larval lobster densities tended to be greater at higher salinity sampling locations. Scarratt and Raine (1967) reported that first stage larvae avoided salinities of < 21.4 ppt in laboratory experiments. Templeman (1936) had earlier noted that survival rates were adversely affected at salinities below 20 ppt. Above this level, neither survival nor time required to reach fourth stage was significantly affected.

SURFACE CIRCULATION

Vertical distribution studies indicating low concentrations of lobster larvae in subsurface waters have led to speculation that wind-induced surface circulation patterns may influence larval distribution. Templeman (1937) concluded that offshore winds result in dispersal of larvae in surface waters. Templeman and Tibbo (1945) integrated the results of drift bottle investigations, wind pattern observations, and larval lobster distribution studies and suggested that surface hydrography determined the spatial distribution of larvae. Scarratt (1964) considered surface circulation to be a primary determinant of larval lobster distribution and inferred that passive transport may affect catch rates of later stage larvae. However, in an analysis of the same data, Caddy (1979) computed centers of density for each stage within the survey area and concluded that larvae may move against the prevailing surface drift, presumably by vertical migration and transport by subsurface countercurrents. Scarratt (1968, 1969) reported predominately onshore southwesterly winds off Nova Scotia during the period of larval occurrence and suggested that larvae may be concentrated along windward coastal locations by onshore winds. Rogers et al. (1968) noted higher levels of stage I larvae in offshore stations in southern New England while stage IV lobsters dominated inshore stations, implying an onshore drift with time. Coastward surface drift rates of up to 6.4 km/d during the larval period were cited. Evidence for retention of larvae within circulation gyres in western Long Island Sound was presented by Lund and Stewart (1970). Squires (1970) acknowledged the possibility of larval transport in surface waters but postulated that larvae may maintain position during strong winds by descending in the water column. Ennis (1975) indicated that lobster larvae were more sensitive to hydrostatic pressure than light intensity and were capable of depth regulation within broadly defined limits. There was considerable diminution of sensitivity to pressure changes in stage III and IV larvae. Harding et al. (1979) reported that higher densities of larvae in central and eastern St. Georges Bay, Nova Scotia, were due to prevailing southwesterly winds in summer. Stasko (footnote 2) postulated that surface circulation patterns would result in advection of larvae from Georges Bank and Browns Bank toward southwest Nova Scotia. Harding et al. (1982) further proposed that creation of convergent zones through Langmuir circulation may result in concentrations of larvae, explaining the generally observed contagious distribution patterns.

SURVIVAL

Estimates of survival between stages I and IV were derived by Scarratt (1964, 1973) after standardizing larval density estimates for stage duration at prevailing water temperatures. Estimated survival rates ranged from 0.79% to 2.39% during 1949-61 and averaged 1.12%. Harding et al. (1982) estimated a survival rate of 1.0% through the pelagic phase after adjustment for stage duration in St. Georges Bay, Nova Scotia, during 1978. Considerably higher estimates of survival (>50%) were calculated by Lund and Stewart (1970) in Long Island Sound; however, no attempt was made to adjust for increased stage duration and availability with successive larval stages. Ennis (1975) cautioned that differential response of the larval stages to varying light levels may bias estimates of survival based on surface plankton hauls. Correction for stage-specific larval response to ambient light levels should allow increased precision in estimates of larval lobster density and survival rates, however, the confounding influence of within-stage variability in phototactic responses (Hadley 1908) greatly complicates development of an appropriate adjustment factor. Estimates of survival based on surface samples should be considered preliminary until further information on the effects of light intensity, wind direction and velocity, and other environmental variables on larval lobster distribution (vertical and horizontal) are quantified.

STAGE IV PRODUCTION AND SUBSEQUENT STOCK

In an extensive series of observations, Scarratt (1964, 1973) examined the relationship between stage IV production in Northumberland Strait and subsequent stock size. Stock size was lagged by 6 yr to account for the delay between spawning and recruitment (Wilder 1953). Stock estimates were based on tagging studies conducted off Miminigash, P.E.I. Wide variability in growth rates may result in a single cohort recruiting to the fishery over a 2-3 yr period (Wilder 1953); accordingly, Scarratt (1973) related 3-yr running averages of stage IV larval production and stock size. Scarratt concluded that sampling variability prevented accurate prediction of stock size based on larval production estimates.

Scarratt (1964, 1973) restricted consideration to a linear relationship between larval production and subsequent stock size. However, density (stock) dependent effects may result in a nonlinear functional relationship between larval production and subsequent stock. To further examine this possibility, a modification of the Ricker stock-recruitment model (Saila and Lorda in press) was used to evaluate the relationship between 3-yr running averages of stage IV production (P) and stock size (S) lagged by 6 yr. The generalized model of Saila and Lorda (in press):

$$S = \alpha P^{\beta} e^{-\delta P}$$

was employed in this analysis. The derived curve provided a reasonable representation (r = 0.87; df = 12) of the stage IV production-recruitment observations (Fig. 1). This model may assume either a nearly asymptotic or convex form and therefore retains great flexibility in evaluating stock-recruitment relationships.

Although the many sources of variability in estimating stage IV density and stock size must be recognized, this analysis does provide an indication of a relationship between stage IV production and stock size which merits further investigation.

Stock recruitment relationships have proven difficult to conclusively demonstrate for marine species. Variable survival rates for egg and larval stages caused by variability in critical environmental factors tend to obscure any underlying parental stock effect. During the lengthy incubation period typical of many crustacean species, however, the protection afforded to the eggs by brooding behavior of the female reduces mortality and variability in survival rates. Perkins (1971) estimated an average egg loss rate of 36% during incubation for the American lobster; egg mortality would undoubtedly be considerably higher if the eggs remained unprotected.

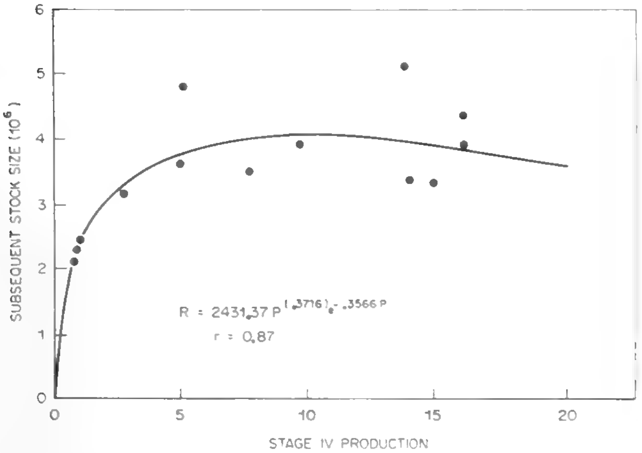

Figure 1.—Relationship between stage IV production (no 3,430 m^2) and subsequent stock size (10^6) 6 yr later. Three-year moving average employed for both variables.

Although adequate time series of stock and recruitment estimates are not widely available for crustacean stocks (Hancock 1973), recent studies provide evidence for stock-recruitment relationships in two species. Boddeke (1981) demonstrated asymptotic relationships between egg production and subsequent harvestable stock of the European brown shrimp, *Crangon crangon*, in four areas off the Netherlands and Belgium. Morgan et al. (1982) reported an asymptotic relationship between puerulus settlement and recruitment for spiny lobster, *Panulius cygnus*, off Western Australia.

The asymptotic form noted in each of the above investigations indicates that recruitment in crustacean stocks may be relatively stable over a wide range of parental stock sizes. Recruitment curves of this type further imply that the primary population regulatory mechanism is limitation of available resources (e.g., food or habitat). Boddeke (1981) suggested that spatial limitations on the nursery grounds may limit population size. Morgan et al. (1982) cited limitations on food and shelter sites as possible regulatory factors. Although there is no convincing evidence of food resource limitation on American lobster populations, shelter availability is an important feature of lobster habitat (Cobb 1971) and shelter may be a limiting resource, particularly for juvenile lobsters, which are more vulnerable to predation.

CONCLUSIONS

American lobster larvae have been collected most consistently at the surface during daylight. Abundance apparently declines with increasing depth. Although laboratory observations have indicated clear photonegative responses during portions of several larval stages, few larvae have been obtained in subsurface collections. The limited number of samples collected at night do not permit definitive conclusions but do suggest some dispersal from surface waters.

Transport of larvae in surface currents has been widely assumed (Templeman 1937, 1939; Templeman and Tibbo 1945; Scarratt 1964, 1968, 1969, 1973; Rogers et al. 1967; Lund and Stewart 1970; Harding et al. 1979) and higher larval densities along windward coasts tend to support this inference. Vertical migration has been implicated in position-keeping in response to wind-induced turbulence and surface drift (Squires 1970; Caddy 1979), however direct evidence of a behavioral mechanism of this type has not been observed.

Prevailing southwesterly winds along much of the northeastern coast of the United States may result in transport of larvae from offshore locations to coastal sites. Rogers et al. (1968) cited a coastward transport of up to 6.4 km/d off southern New England, implying a possible dispersal range of approximately 100-150 km during a 20-25 d developmental period. Larval transport from offshore areas (which have only recently been exploited) may provide some degree of larval recruitment to coastal populations. Fishing mortality rates in coastal areas are extremely high and current minimum size limits are below the mean size at maturity for many areas (Anthony and Caddy 1980), suggesting that recruitment from less heavily exploited areas may play an important role in sustaining coastal fisheries.

A 15-yr study of stage IV density and subsequent stock size indicated a relationship between larval production and stock size 6 yr later. The derived function is similar in form to stock-recruitment relationships developed for European brown shrimp (Boddeke 1981) and spiny lobster (Morgan et al. 1982), possibly indicating a similarity in population regulatory mechanisms among these crustacean species.

In the context of extremely high levels of fishing mortality for this species (Anthony and Caddy 1980), protection of brood stock by setting minimum size limits to the vicinity of mean size at maturity and prohibition on harvesting ovigerous females would appear prudent. Increases in minimum size limits and reduction in fishing mortality rates would also result in increased yield per recruit (Ennis 1980; Fogarty 1980), providing further incentive for increasing legal size limits.

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An Overview of Larval American Lobster, *Homarus americanus*, Sampling Programs in New England During 1974-79

MICHAEL J. FOGARTY[1] and ROBERT LAWTON[2]

INTRODUCTION

The American lobster, *Homarus americanus*, has long generated intense interest, both for its significance to the fisheries of the coastal New England States and Canadian Maritime Provinces, and its importance in the structure of benthic communities in the northwest Atlantic (Cobb and Wang in press).

Concern over the potential impact of proposed or operating power plants on lobster populations in coastal locations in New England led to several investigations of larval lobster distribution during the last decade. In addition, general studies on lobster population dynamics were undertaken during this period in support of development of a coastwide fishery management program. A lack of adequate knowledge of the distribution of lobster larvae, factors affecting larval production, and annual variation in abundance were recognized as serious impediments to understanding lobster recruitment patterns and to estimating potential losses due to entrainment by power plants.

An ad hoc working group, comprised of scientists from both the private and public sectors, was formed during 1977 to discuss the results of ongoing larval lobster research programs and to provide guidance for the development of future studies. In this report, the results of larval lobster investigations in Maine, New Hampshire, Massachusetts, and Rhode Island by members of the working group are summarized. Aspects of the spatial and temporal distribution of larvae are described and additional information on the diurnal and vertical distribution of lobster larvae and annual variation in production is provided.

SAMPLING METHODS

Larval lobster sampling programs were initiated at several coastal locations throughout the New England region during 1974-79 (Fig. 1). Prior studies indicated that lobster larvae are concentrated in surface waters during daylight (Templeman 1937; Templeman and Tibbo 1945; Scarratt 1964, 1973). Accordingly, sampling effort was directed at the air-water interface using neuston gear (Table 1). An opening-closing Tucker trawl (Hopkins et al. 1973) was used for discrete depth sampling in several studies and for both surface and subsurface hauls in one program (Table 1). Comparison trials between 1 × 2 m neuston gear and a 2 × 2 m Tucker trawl towed at the surface indicated that both nets provided similar density estimates when expressed on an areal basis but neuston net density was approximately 2-4 times higher when expressed on a volumetric basis (Bibb et al. 1983b). These results suggest that larvae are concentrated in the upper 0.50-0.75 m of the water column and that the lower depth strata sampled by the Tucker trawl was nearly devoid of larvae.

Sampling was primarily conducted during daylight hours, however, night samples were occasionally collected in two studies and were consistently taken in Block Island Sound (Bibb et al. 1983a).

Tow speeds ranged from 1.8 to 5.6 km/h and were from 12 to 30 min in duration (Table 1). Tows were often abbreviated during periods of high ctenophore abundance when the filtration efficiency of the nets was reduced. Sampling periods spanned the known seasonal occurrence of larvae, ranging from May through October depending on year and area sampled (Table 1).

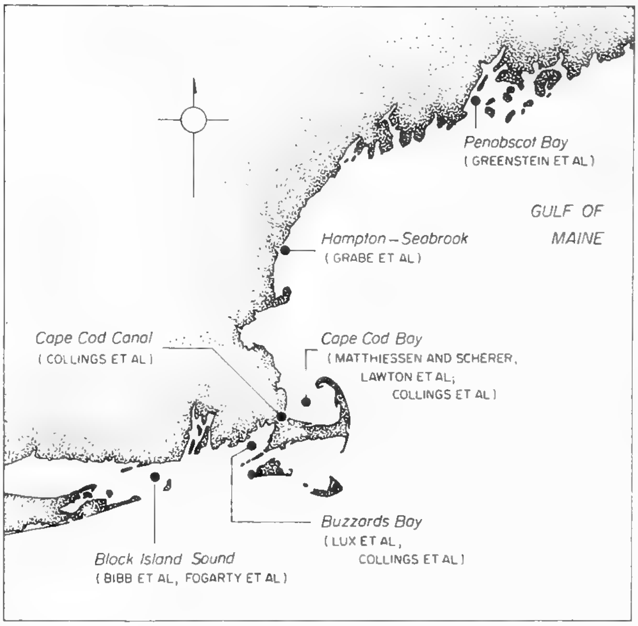

Figure 1.—Sampling locations for larval American lobster, *Homarus americanus*, in New England during 1974-79.

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Table 1.—Summary of larval lobster sampling protocol for New England investigations during 1974-79.

Area	Year	Sample period	Gear	Diurnal period	No. tows	Tow speed (km/h)	Tow duration (min)	Source
Maine Penobscot Bay	1976	May-Sept.	0.9 × 3.7 m Neuston	Day	213	1.8	30	Greenstein et al. (1983)
New Hampshire Hampton-Seabrook	1978	June-Oct.	1 × 2 m Neuston	Day	34	3.6	15-30	Grabe et al. (1983)
	1979	May-Sept.	1 × 2 m Neuston	Day	30	3.6	30	
Massachusetts Cape Cod Bay	1974	May-Aug.	1 × 2 m Neuston	Day	20	3.7	12	Lawton et al. (1983)
	1975	May-Aug.	1 × 1 m Neustn	Day	27	3.5-4.6	10-30	
	1976	June-Aug.	1 × 2 m Neuston	Day	60	4.6	30	
	1977	May-Aug.	1 × 2 m Neuston	Day	78	4.6	30	
		June-Aug.	1 × 1.5 m Tucker trawl	Day	48	5.6	20	
Cape Cod Bay	1974	June-Aug.	1 × 2 m Neuston	Day	58	4.0-5.5	30	Matthiessen and Scherer (1983)
	1975	June-Oct.	1 × 2 m Neuston	Day (some night)	145	4.0-5.5	30	
	1976	May-Sept.	1 × 2 m Neuston 2 × 2 m Tucker trawl	Day	325	.0-5.5	30	
Cape Cod Bay	1976	May-Aug.	1 × 2 m Neuston	Day	88	4.6-5.6	30	Collings et al. (1983)
Cape Cod Canal Buzzards Bay	1977	May-Aug.	1 × 2 m Neuston	Day	189	4.6-5.6	30	
			1 × 1.5 m Tucker trawl		66	6.5-7.4	20	
	1978	May-Oct.	1 × 2 m Neuston	Day	182	4.6-5.6	30	
Buzzards Bay	1976	May-Aug.	1 × 2 m Neuston	Day (some night)	50	4.6-5.6	30	Lux et al. (1983)
	1977	May-Aug.	1 × 2 m Neuston	Day	80	6.0	30	
	1978	May-Aug.	1 × 2 m Neuston	Day	62	6.0	30	
	1979	May-Aug.	1 × 2 m Neuston	Day	56	6.0	30	
Rhode Island Block Island Sound	1977	May-Aug.	2 × 2 m Tucker trawl	Day and night	107	3.6	12	Bibb et al. (1983a)
	1978	May-Aug.	2 × 2 m Tucker trawl	Day and night	132	3.6	12	
	1979	May-June[2]	1 × 2 m Neuston	Day	144	3.6	12	
Block Island Sound	1978	May-Sept.	1 × 2 m Neuston	Day	244	3.7	20	Fogarty et al. (1983)

[1] Samples collected by holding position into current.

[2] Sampling terminated.

RELATIVE ABUNDANCE

Distinctive differences in mean annual density of larvae were evident between the Gulf of Maine-Cape Cod Bay region and southern New England (Buzzards Bay-Block Island Sound). Consistently higher densities were recorded in southern New England (Table 2). Reduced density within the Cape Cod Bay-Gulf of Maine complex may reflect the influence of prevailing southwesterly winds during the period of larval occurrence. Prevailing winds during summer are onshore in

Table 2.—Summary of larval lobster relative abundance, seasonal occurrence, and stage composition for New England Investigations during 1974-79. Data obtained from reports in this volume and personal communication with investigators.

Area	Year	Total no. larvae	Period of peak abundance	Maximum density (no./1,000m³)	Mean annual density (no./1,000m³)	Temp. (°C) at 1st occurrence	Temp. (°C) at peak occurrence	Stage composition (percent)				Source
								I	II	III	IV	
Maine												
Penobscot Bay	1976	58	late June	2.9	0.2	[1]10.5	[1]13.5	89.7	1.7	0.0	8.6	Greenstein et al. (1983)
New Hampshire												
Hampton-Seabrook	1978	169	late Aug	53.8	4.3	[1]13.9	[1]13.3	12.5	0.0	1.1	86.4	Grabe et al. (1983)
	1979	120	late July	38.3	3.4	[1]7.9	[1]9.6	70.8	2.5	1.7	25.0	
Massachusetts												
Cape Cod Bay (Plymouth Area)	[2]1974	25	early Aug.	—	—	—	—	4.0	0.0	0.0	96.0	Lawton et al. (1983)
	1975	177	early July	19.8	2.0	[1]12.7	[1]14.1	59.9	23.7	8.1	8.3	
	1976	871	late July	34.9	4.4	[1]9.5	[1]16.0	25.5	19.7	29.6	25.2	
	1977	206	late July	11.2	1.3	[1]11.5	[1]8.5	55.2	16.9	5.3	22.6	
Cape Cod Bay	1974	608	July	7.3	1.6	[3]16.1	[3]20.8	21.0	19.0	25.0	35.0	Matthiessen and Scherer (1983)
	1975	931	June	40.5	2.0	[1]9.0	[3]14.7	56.0	23.0	12.0	8.0	
	1976	3,279	June	21.6	2.7	[3]10.5	[3]15.1	52.0	20.0	16.0	12.0	
Cape Cod Bay (Sandwich Area)	1976	47	late June	3.7	1.3	[3]10.3	[3]13.0	68.1	2.1	6.4	23.4	Collings et al. (1983)
	1977	672	late June	153.5	7.9	[3]11.5	[3]17.5	81.0	4.5	3.4	11.2	
	1978	115	early July	8.6	1.7	[3]13.5	[3]12.5	52.2	5.2	9.6	33.0	
Cape Cod Canal	1976	1,428	June	174.8	15.8	[1]12.5	[3]18.5	34.9	21.6	33.4	10.2	
	1977	654	June-July	47.6	7.4	[3]14.5	[3]14.5	47.4	13.6	9.2	29.8	
	1978	430	June	45.1	3.7	[1]12.5	[3]16.0	48.1	10.2	16.0	25.6	
Upper Buzzards Bay	1976	687	mid-June	79.0	8.6	[1]13.9	[1]16.5	56.6	16.0	17.9	9.5	
	1977	4,035	mid-June	266.2	15.9	[3]17.0	[3]20.0	28.8	22.0	25.8	23.4	
	1978	1,563	mid-June	91.8	10.1	[1]14.5	[3]19.5	36.8	15.2	14.9	33.1	
Lower Buzzards Bay	1976	1,284	late June	35.0	10.1	[3]13.0	[3]18.0	33.7	37.7	22.6	6.0	Lux et al. (1983)
	1977	3,461	late June	68.7	18.8	[1]11.0	[1]17.0	20.4	30.8	21.9	26.9	
	1978	1,631	late June	42.4	9.6	[1]11.0	[1]17.0	5.5	6.3	14.9	73.3	
	1979	10,303	late June	449.7	43.7	[3]15.0	[3]19.0	23.4	25.6	38.5	12.5	
Rhode Island												
Block Island Sound	1977	1,661	mid-June	[4]31.2	[4]9.0	[1]13.3	[1]14.0-16.6	59.0	24.0	13.0	4.0	Bibb et al. (1983a)
	1978	761	early July	[4]19.1	[4]4.5	[1]13.6	[1]12.8-14.8	23.0	14.0	11.0	52.0	
	[5]1979	1,335	early June	18.7	—	[1]12.6	—					
Block Island Sound	1978	1,030	late June	33.3	10.8	[3]13.0	[3]14.0-17.0	12.3	14.1	10.9	62.6	Fogarty et al. (1983)

[1] Bottom temperature (°C).

[2] Preliminary sampling program.

[3] Surface temperature (°C).

[4] Tucker trawl estimates multipled by a factor of 4 to approximate neuston net catches.

[5] Sampling terminated in June.

southern New England, but offshore in Cape Cod Bay, and offshore or alongshore in northern New England. Advection of lobster larvae in wind induced surface currents has been hypothesized as a passive transport mechanism (see review by Fogarty 1983) and dispersal of larvae during periods of offshore winds may result in reduced surface density. Increased catch rates during onshore winds were noted in several studies, lending support to the inference that lobster larvae are transported by surface water circulation. Grabe et al. (1983) reported that 67% of stage IV larvae were collected off New Hampshire when winds were on or alongshore. Similarly, Collings et al. (1983) collected 85% of larvae obtained in Buzzards Bay when winds were from the southwest while only 39% of the larvae collected in Cape Cod Bay were obtained during southwest winds. Lawton et al. (1983) noted that 82% of the larvae in their collections were observed when winds were onshore, however, most sampling (73%) was conducted when winds were onshore. In Block Island Sound, most sampling dates during the period of peak occurrence of larvae corresponded to periods of onshore winds and no significant wind direction effect could be demonstrated (Fogarty et al. 1983).

Mean size at maturity of female lobsters is considerably lower in the warmer waters of southern New England (Van Engle 1980; Aiken and Waddy 1980), resulting in an increased probability of spawning prior to capture. Templeman (1936a) noted an inverse relationship between size at sexual maturity and water temperature in the Canadian Maritime Provinces. Higher brood stock levels may therefore contribute to higher larval lobster density in southern New England waters. It should be noted, however, that the primary source of lobster landings off the northeastern United States is within the Gulf of Main, implying adequate larval production or transport from other areas.

An association between larval lobster abundance and the occurrence of cencentrations of detached macroalgae and marine vascular plants (primarily *spartina*) was observed off New Hampshire (Grabe et al. 1983). Larvae may avoid predators by seeking refuge in windrows of drifting vegetation. Wind speed and direction may indirectly influence larval lobster distribution by affecting the formation and distribution of windrows. Harding et al. (1982) reported a significant relationship between the occurrence of lobster larvae and floating vegetation in St. Georges Bay, Nova Scotia, Cobb and Wang (in press) have suggested the use of artificial seaweed collectors to monitor abundance of American lobster larvae.

ANNUAL VARIATION IN ABUNDANCE

Despite apparent differences between areas in the availability (catchability) of larvae, relative differences in mean annual density were generally consistent in years for which comparisons were possible (Fig. 2). Increased density in 1977 relative to 1976 and 1978 was noted by Collings et al.(1983) in Cape Cod Bay and Buzzards Bay and by Lux et al. (1983) in Buzzards Bay. Bibb et al. (1983a) reported decreased abundance in 1978 from 1977 density estimates. Matthiessen and Scherer (1983) and Lawton et al. (1983) reported increased relative abundance in 1976 over 1975 levels. Lux et al. (1983) observed a sharp increase in mean density in 1979, although this increase was primarily due to several large catches of stage I larvae. In contrast, Grabe et al. (1983) reported slightly reduced larval density in 1979 relative to the 1978 level, however, the number of larvae obtained was low, possibly obscuring trends in relative abundance.

A striking increase in the proportion of stage IV larvae was observed in 1978 (Table 2). This shift in stage composition was accompanied by generally reduced density levels (Table 2). Increased stage IV composition may reflect an increase in survival through the pelagic phase, accentuated by the longer intermolt duration of fourth stage larvae and hence greater vulnerability to capture (Scarratt 1964, 1973). Positive phototactic responses in early stage IV larvae (Hadley 1908; Templeman 1936b) may render this stage more accessible to capture by neuston gear. However, stage I larvae are also initially positively phototactic (Hadley 1908; Templeman 1937; Scarratt 1973). In addition, production estimates with explicit correction for stage duration still exhibited unexpectedly high stage IV densities (Bibb et al. 1983b; Fogarty et al. 1983). Transport of later stage (III and IV) larvae toward inshore locations in wind-induced surface currents and favorable sampling conditions may also have contributed to increased proportions of stage IV larvae in 1978.

In general, the proportion of stage IV larvae in our studies exceeded those reported by Scarratt (1964, 1973) for Northumberland Strait where the average percentage of fourth stage larvae (uncorrected for stage duration) during 1948-63 was <5%. It is possible that the higher towing speeds in many of the investigations in New England during 1974-79 resulted in the capture of proportionately more stage IV larvae. Increased development of swimming and escape responses in fourth stage larvae may allow avoidance of nets towed at low (<2 km/h) speed.

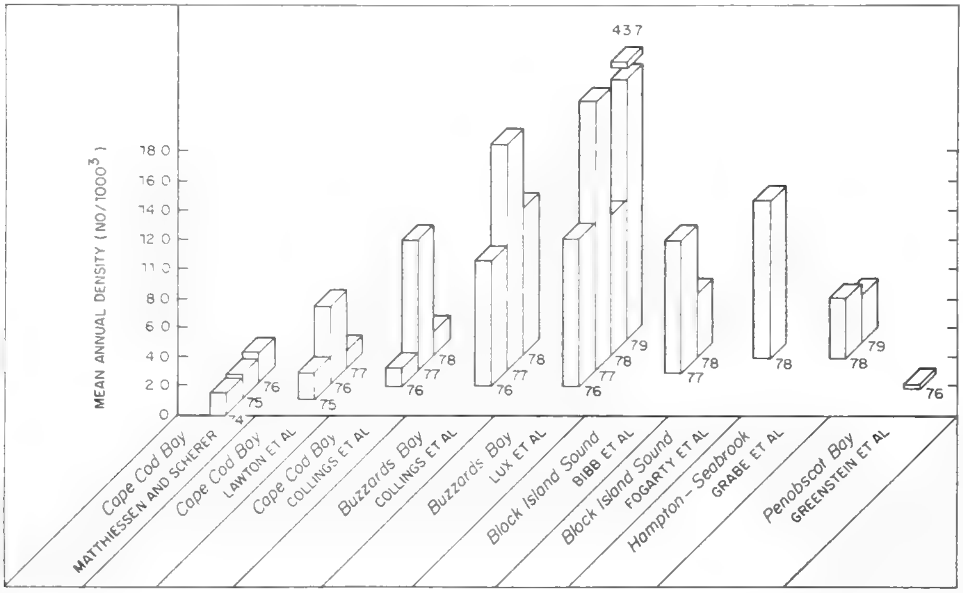

Figure 2.—Mean annual density (daytime surface tows) of American lobster larvae in New England studies during 1974-79. Years of sampling indicated at base. Cape Cod Canal estimates not included since unusual hydrographic features of the Canal may result in biased estimates of density.

TEMPERATURE

Marked differences in water temperature at first occurrence of larvae were noted between the Gulf of Maine and southern New England. Bottom water temperatures at hatching were as low as 8°-9°C in samples collected in northern New England but ranged from 11° to 13.6°C in Buzzards Bay and Block Island Sound (Table 2). Bottom water temperatures at peak larval densities were 8.5°-16.0°C in northern and 12.8°-17.0°C in southern areas (Table 2). Surface water temperatures during the period of highest density were approximately 15°-20°C depending on year and area sampled (Table 2). Hatching is presumably keyed to an increase in water temperature during late spring. Annual variation in water temperature during May-October may affect the onset and duration of hatching, intermolt duration, and survival of larvae.

VERTICAL DISTRIBUTION

Lobster larvae were consistently found in higher concentrations in surface collections in Block Island Sound and Cape Cod Bay (Bibb et al. 1983a; Collings et al. 1983; Lawton et al. 1983). Bibb et al. (1983a) reported significantly higher surface densities of larvae during daylight, however, occasional high larval densities were noted in near bottom samples. Lawton et al. (1983) obtained two larvae in 48 subsurface tows at depths ranging from 3.0 to 7.6 m in Cape Cod Bay in 1977. Significant depth related differences in larval density were observed in Cape Cod Bay with higher abundance at the surface (Collings et al. 1983). These results are consistent with the observations of Templeman (1937), Templeman and Tibbo (1945), and Scarratt (1973).

Discrete depth samples taken within the Cape Cod Canal showed no significant differences with depth (Collings et al. 1983); Matthiessen and Scherer (1983) reported significantly higher larval density at 3 m depth at the eastern end of the Canal. The turbulence and mixing effect of water flow through the Canal were cited as possible factors influencing vertical distribution within the Canal.

DIURNAL DISTRIBUTION

Bibb et al. (1983a) noted significantly higher density of larvae in daylight surface samples in Block Island Sound; however, substantial numbers of larvae were collected both at the surface and in near-bottom waters at night. Lux et al. (1983) reported decreased surface abundance during darkness. A shift in relative stage composition was also noted. First stage larvae were most abundant during daylight while stage III larvae were dominant in night collections. These observations are in accord with known differences in phototactic responses among larval stages (Hadley 1908; Templeman 1936b).

Reduced abundance of larvae in daylight surface samples was observed under completely overcast conditions (Lawton et al. 1983; Collings et al. 1983). Templeman and Tibbo (1945) speculated that some minimum light intensity was necessary to attract larvae to the surface. Greenstein et al. (1983) reported, however, that 84% of larvae collected in Penobscot Bay in 1976 were obtained with cloud cover greater than or equal to 50%; 62% of the larval catch was taken on completely overcast days. Harding et al. (1982) reported that most larvae (95%) were collected in the upper 30 cm of the water column during overcast conditions; during bright sunlight, 73.3% of the larvae obtained were within the 0-30 cm depth interval. Differences in turbidity may alter the effect of light intensity on vertical distribution of larvae among geographical locations (Templeman and Tibbo 1945), possibly explaining some of the discrepancies noted above.

SUMMARY

Larval stages of the American lobster were collected during May-October in New England investigations during 1974-79. Lobster larvae occurred earlier in the southern New England region than in the Gulf of Maine. Lobster larvae were more abundant in southern New England than in the Gulf of Maine (including Cape Cod Bay). Favorable conditions for production of larvae in southern New England (lower mean size at maturity), coupled with the effects of prevailing southwesterly winds which concentrate larvae along windward shores, undoubtedly contributed to higher density estimates in Buzzards Bay and Block Island Sound.

Unusually high proportions of stage IV larvae, accompanied by reduced densities, were observed in several studies during 1978. Increased density dependent survival through the pelagic phase may account, in part, for this result. Alternatively, transport of larvae from offshore locations may have resulted in increased stage IV representation in 1978.

Larvae were most abundant at the surface during daylight hours and some evidence for dispersal of larvae from surface waters during night was obtained. The diurnal and vertical distributions of lobster larvae are, of course, not independent; however, the apparent concentration of larvae in surface waters during daylight offers clear advantages for the development of an appropriate sampling design. Lobster larvae are seldom collected in dense concentrations and factors resulting in further dispersal of larvae should be considered in the development of sampling strategies.

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Distribution and Abundance of Lobster Larvae (*Homarus americanus*) in Block Island Sound

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ABSTRACT

The distribution and abundance of lobster larvae along a transect in Block Island Sound was studied in 1977 and 1978. We examined the seasonal, diel, and vertical distribution of lobster larvae. The study was expanded to four transects in 1979 to examine broader spatial patterns.

Lobster larvae were seasonally abundant, appearing in late May or early June and disappearing by late August. Larvae were generally more abundant at the surface than in near-bottom waters, but occasional high concentrations of larvae were observed near the bottom. Surface abundance tended to be higher in daylight than at night. Stage IV larvae were more abundant in 1978 than anticipated from abundance of stage I larvae, possibly suggesting recruitment from adjacent areas. In the 1979 study, stage I larvae were most abundant in the eastern section of the survey area.

INTRODUCTION

This paper describes an intensive study of the distribution and relative abundance of lobster larvae (*Homarus americanus* Milne-Edwards) in Block Island Sound during 1977-79. The objectives of the study were to provide information on diel variation, depth distribution, spatial differences, seasonal variation, and yearly variation of lobster larvae in Block Island Sound to examine potential impacts of a proposed nuclear power facility at Charlestown, R.I.

METHODS

The 1977 and 1978 surveys consisted of weekly sampling using a Tucker net at four stations along a transect off East Beach, Charlestown, R.I. (Fig. 1). Surface samples were taken day and night at four stations. Bottom samples were taken at two stations only, EB-B and EB-C. In 1977, stations EB-B, EB-C, EB-D, and EB-E were sampled. In 1978, stations EB-A, EB-B, EB-C, and EB-D were sampled. In 1979, the sampling area was expanded to 12 stations along four transects: off Weekapaug (WK), East Beach (EB), Nebraska Shoals (NS), and Point Judith (PJ). Surface samples were collected in daylight every 3 to 4 d using a neuston net along these transects.

In 1977 and 1978, preliminary sampling was carried out at stations EB-B and EB-C to determine when larvae first appeared. During the subsequent weeks, sampling was carried out at all stations and depths described above until no more larvae were observed. The period of sampling extended from May through August 1977 and 1978, and May through mid-June in 1979. Plankton sampling along the same transect was carried out through fall, winter, and spring of 1977 and 1978 and early 1979.

All 1977 and 1978 samples were collected using an opening and closing Tucker net (Hopkins et al. 1973), equipped with a 2 m × 2 m, 0.950 mm mesh, 8 m long net. The mouth of the net sampled at a 45° angle with a resultant 2 m × 2 m effective sampling area. Surface tows were taken with the upper bar of the Tucker net about 10 cm out of the water. Bottom tows were made with the center of the Tucker net about 3 m off the bottom. The net was towed between 0.77 and 1.29 m/s for approximately 12 min. Estimated sample volumes were generally between 2,000 and 4,000 m^3. Triplicate tows were made either in a westerly or easterly direction.

Samples in 1979 were taken with a neuston net having 1 m × 2 m mouth, length of 4 m, and 1 mm mesh. Simultaneous paired tows were made with approximately 10 cm of net out of the water. Sample volumes were generally 1,500 to 2,000 m^3. A paired-comparison of sampling efficiency using the Tucker and neuston nets was performed in 1979 (Bibb et al. 1983).

Samples were reduced in volume to 2 l and preserved in 10% buffered formaldehyde for analysis.

Temperature and salinity measurements were taken during plankton surveys at the surface and bottom at each station in 1977 and 1978 and at the surface in 1979 using a calibrated Beckman Model RS-5 salinometer[4]. The temperature output was calibrated using a NBS-traceable thermometer and the salinity output using standard seawater, and an appropriate correction factor derived. Continuous temperature data was recorded using Aanderaa thermistors deployed at stations EB-A and EB-B (Snooks and Jacobson[5]).

Data were analyzed using analyses of variance (ANOVA) on $\log_{10}(n+1)$ transformed data; the log transform was used to normalize the data and reduce the dependence of the sample mean and variance (Cassie 1968). Data from 1977 and 1978 from stations EB-B and EB-C were analysed by four-way

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[2] Raytheon Company, P.O. Box 360, Portsmouth, Rhode Island; present address: 124 North Road, Kingston, RI 02881.

[3] Yankee Atomic Electric Company, 1671 Worcester Road, Framingham, MA 01701.

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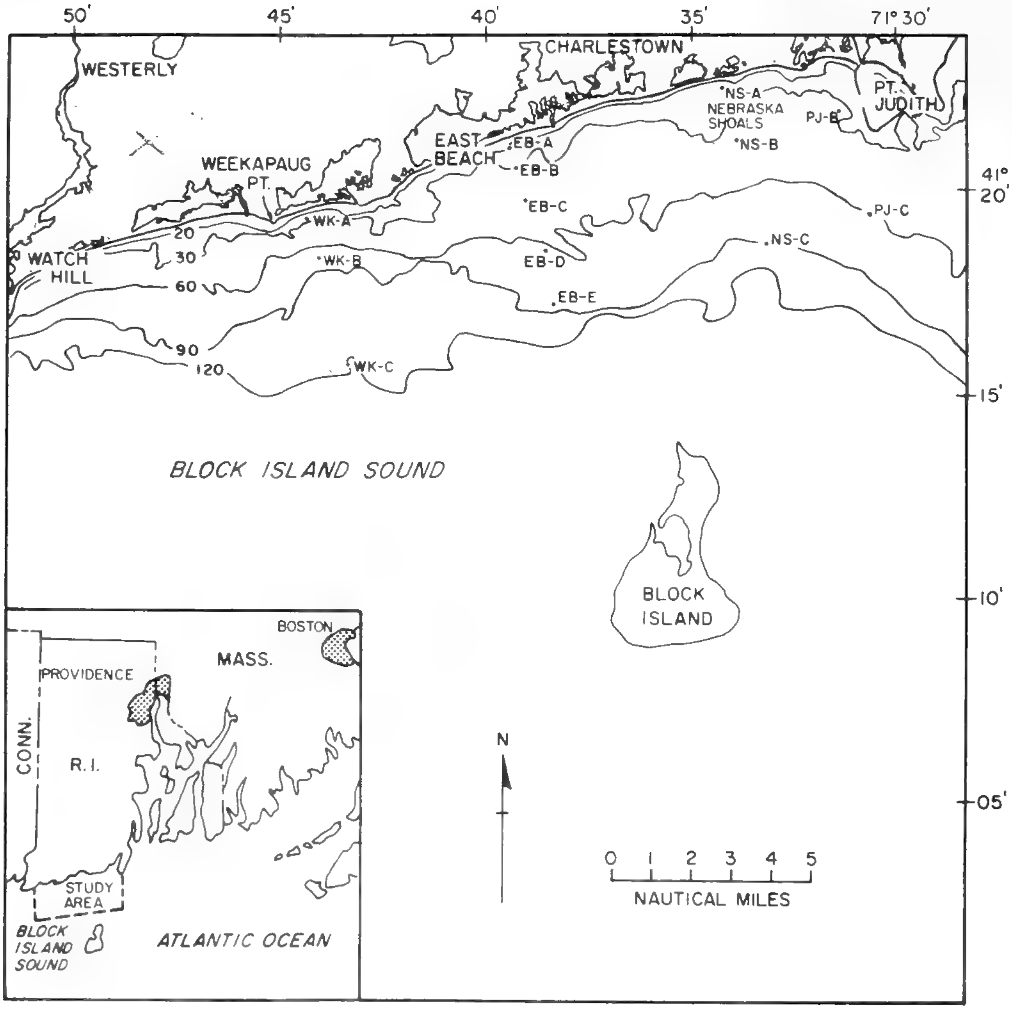

Figure 1.—Station locations in Block Island Sound.

ANOVA with depth, time of day, station, and sample date as main effects. A three-way classification ANOVA was performed on 1977 and 1978 surface data from four stations with station, sample date, and time of day as main effects. One-way ANOVA was performed on 1979 data with station location as the main effect.

RESULTS

Seasonal Abundance

In 1977, lobster larvae were first observed on 31 May, reached peak abundance in mid-June, and were no longer collected after 1 August (Fig. 2). In 1978, larvae were initially collected during the first week of June, and had disappeared by the end of August. In 1979, larvae were first observed on 23 May. Bottom temperatures at station EB-B when stage I larvae were first observed were 13.3°C, 13.6°C, and 12.6°C during 1977-79, respectively.

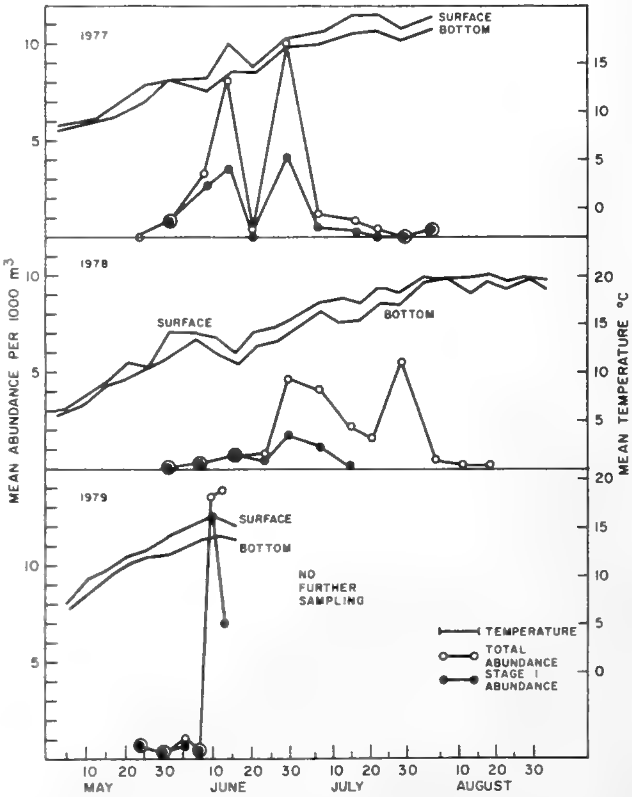

Figure 2.—Mean surface day abundance at stations EB-B and EB-C and mean surface bottom temperature at station EB-B in Block Island Sound. Samples collected in 1977 and 1978 by Tucker net, in 1979 by neuston net.

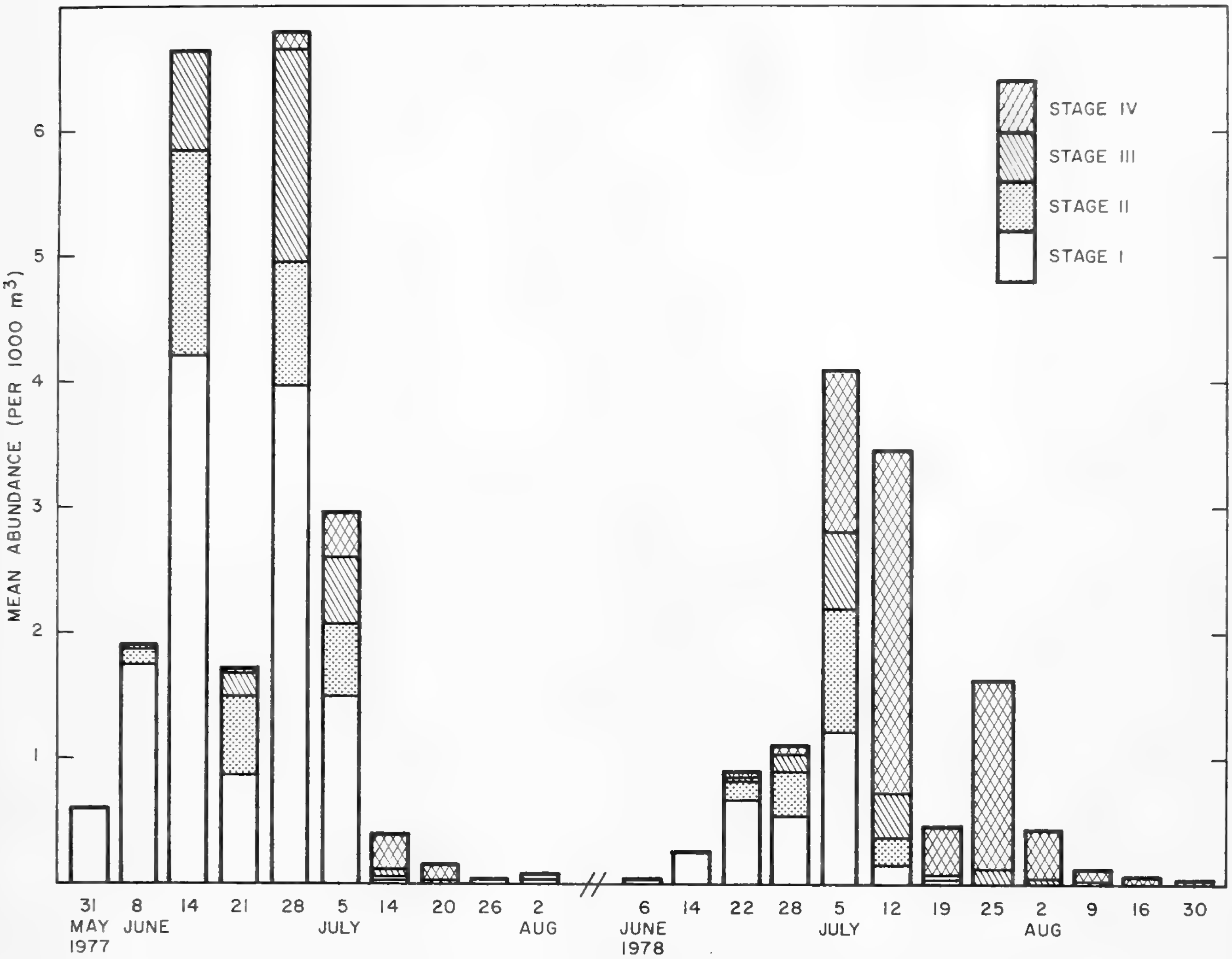

Figure 3.—Stage composition by survey. Mean of all stations, surface and near-bottom, day and night samples.

Stage I larvae were in the water column for a total of 10 wk in 1977 and 8 in 1978 (Fig. 2). In 1977, the maximum abundance of stage I larvae corresponded to maximum total abundance, approximately 3 to 5 wk following the first occurrence of larvae. During the period, mean daily surface and bottom temperatures at station EB-B ranged from 14.5° to 17.5°C and 14.0° to 16.6°C, respectively. In 1978, peak stage I abundance occurred over a 3-wk period from late June to early July. Mean daily surface and bottom temperatures at EB-B during this period ranged from 14.5° to 15.9°C and 12.8° to 14.8°C, respectively.

The appearance of later stage larvae in the water column varied annually (Fig. 3). Stage II larvae were typically found 1 to 2 wk after the first appearance of stage I larvae. Stage III and IV were first collected 2 to 4 wk later. Stage II and III were first found when the bottom temperature at EB-B was approximately 13°-14°C and stage IV at 14°-15°C.

Estimated larval density in 1977 samples declined with each successive stage. In 1978, stage IV larvae, however, were extremely abundant and were observed over a longer time period than in 1977. Stage IV larvae composed 52% of the season total in 1978, but only 4% of the 1977 total (Table 1).

Table 1.—Mean abundance (numbers per 1,000 m³ ± 95% confidence limits) and percent composition by stage of lobster larvae collected off East Beach, Block Island Sound.

	[1]1977		[2]1978	
Stage	Abundance	Percent of total	Abundance	Percent of total
I	1.33±0.54	59	0.26±0.13	23
II	0.53±0.26	24	0.16±0.10	14
III	0.30±0.14	13	0.12±0.07	11
IV	0.10±0.06	4	0.59±0.38	52
Total	2.26±0.83	100	1.13±0.48	100

[1] 107 sampling events 31 May - 2 August 1977).

[2] 132 sampling events (15 June - 30 August 1978).

Vertical and Diel Distribution

Four-way ANOVA indicated that mean surface density was significantly higher than near-bottom density at stations EB-B and EB-C in both 1977 and 1978 (Table 2). Relatively high

Table 2.—*F*-value and mean of larval densities for depth and time of day from four-way analysis of variance of lobster larvae data collected at stations EB-B and EB-C using $\log_{10}(n + 1)$ transformed abundance per 1,000 m³.

		Depth			Time of day		
			Mean			Mean	
Year	Stage	*F*-value	Surface	Bottom	*F*-value	Day	Night
[1]1977	I	26.41**	0.18	0.08	11.16**	0.09	0.17
	II	38.29**	0.09	0.02	19.53**	0.08	0.03
	III	31.09**	0.07	0.01	10.99**	0.57	0.03
	IV	26.75**	0.06	0.01	1.34	0.04	0.03
	Total	88.24**	0.28	0.11	1.80	0.19	0.21
[2]1978	I	4.28**	0.11	0.07	0.14	0.09	0.08
	II	1.08	0.05	0.04	4.95*	0.06	0.03
	III	4.98*	0.05	0.03	1.81	0.04	0.03
	IV	104.39**	0.20	0.03	12.83**	0.14	0.08
	Total	67.04**	0.34	0.12	6.50*	0.26	0.20

*Means significantly different at 95% level.

**Means significantly different at 99% level.

[1] 14 June through 2 August.

[2] 15 June through 17 August.

Table 3.—*F*-value and mean of larval densities for time of day from three-way analysis of variance using $\log_{10}(n+1)$ transformed abundance per 1,000 m³.

			Mean	
Year	Stage	*F*-value	Day	Night
[1]1977	I	2.18	0.26	0.23
	II	32.78**	0.19	0.11
	III	17.54**	0.13	0.08
	IV	1.10	0.06	0.05
	Total	17.01**	0.41	0.32
[2]1978	I	0.13	0.10	0.11
	II	4.02*	0.08	0.06
	III	0.03	0.06	0.06
	IV	23.19**	0.06	0.14
	Total	15.37**	0.39	0.28

*Means significantly different at 95% level.

**Means significantly different at 99% level.

[1] 14 June through 2 August.

[2] 15 June through 17 August.

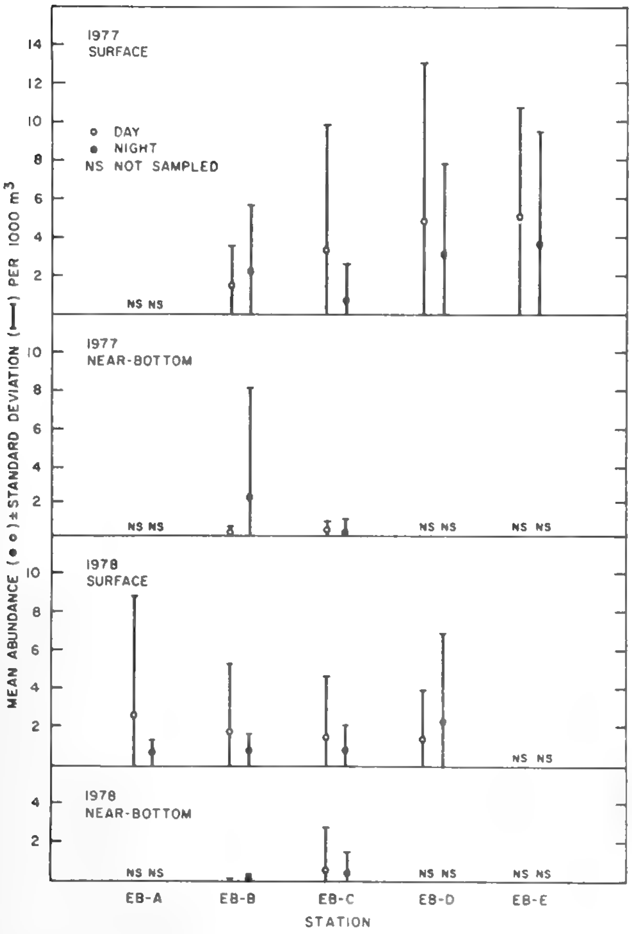

Figure 4.—Vertical and diel distribution of lobster larvae. Mean and standard deviation of all surveys by station, depth, and time of day.

larval densities were noted however in some near-bottom samples (Fig. 4). Day-night differences show no consistent pattern at these stations (Table 2).

When surface density at all four stations was compared using three-way ANOVA (Table 3), daytime density was significantly greater than night abundance for all stages combined. For the individual stages where significant differences were noted, day abundances were consistently higher (Table 3).

Geographical Distribution

Average surface abundance in 1977 and 1978 was greatest at the offshore stations for stages I-III; and was approximately equal (1977) or greater (1978) at inshore stations for stage IV larvae as indicated by three-way ANOVA (Fig. 5). Distribution of stage IV larvae was patchy, with 41% of all stage IV larvae collected in two samples from EB-A and EB-B in 1978.

The 1979 study was designed to examine broader geographic distribution of lobster larvae in Block Island Sound. The mean abundance of stage I lobster larvae in this study was generally higher along the Point Judith transect and decreased successively along each of the western transects (Fig. 6, Table 4).

A one-way ANOVA indicated that mean density of stage I larvae was significantly different between stations at the 95% level ($F = 2.78$, df $= 11, 108$). Station abundance means were ranked and a Student-Newman-Keuls test performed to determine significant groups. Abundance of stage I larvae was significantly higher at stations in the eastern end of Block Island Sound and at the offshore station EB-E. From 1 to 11 June (the last sampling date) the proportion of later stage larvae steadily increased along all transects. Because sampling was terminated in 1979 before the later stages would normally peak, no further conclusions can be drawn with respect to their distribution. However, the proportion of older larvae was greater along western transects while the proportion of stage I larvae remained higher along the eastern transects (Table 4).

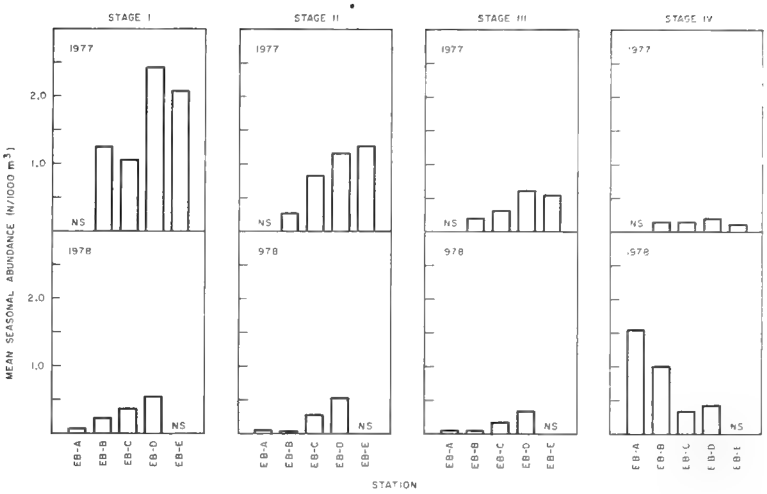

Figure 5.—Distribution of lobster larvae between stages by station in 1977 and 1978.

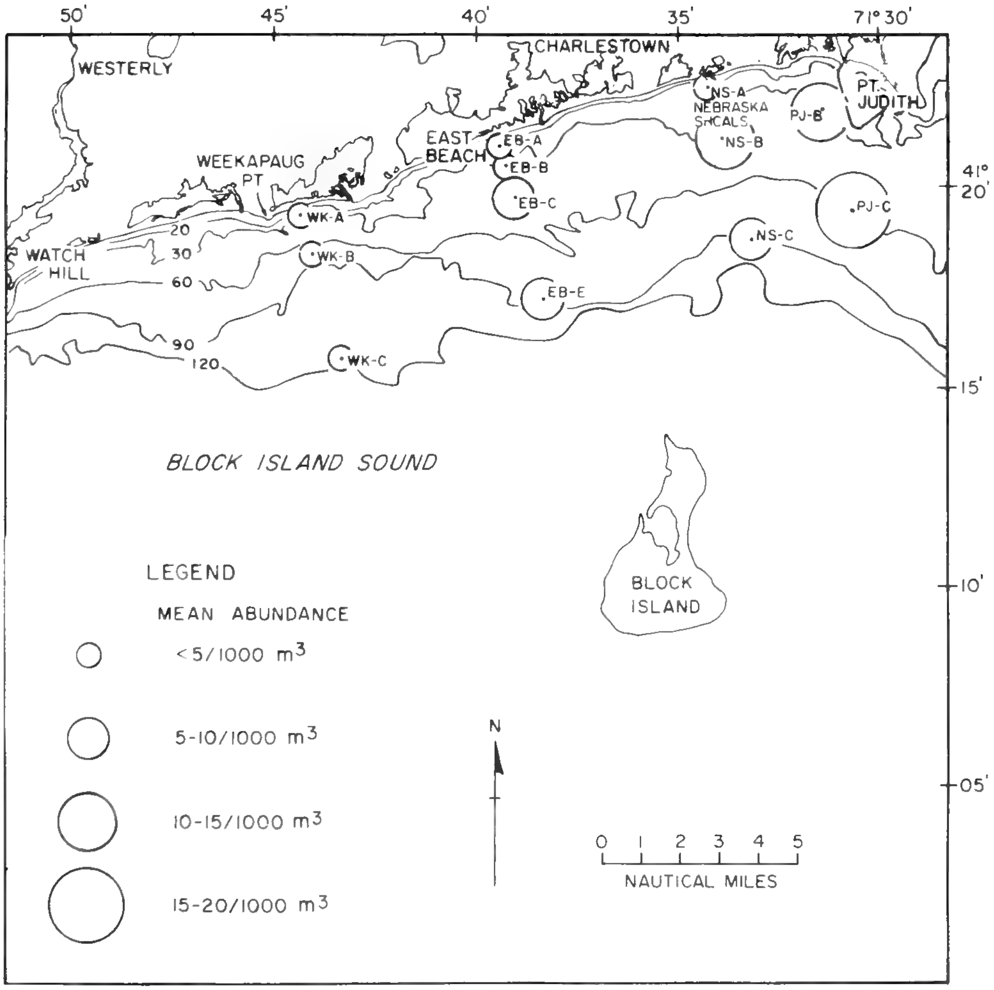

Figure 6.—Relative abundance of stage I lobster larvae by station in 1979.

Table 4.—Mean density and standard deviation per 1,000 m^3 of lobster larvae by stage collected along four transects in Block Island Sound during May and June 1979.

	Stage							
	I		II		III		IV	
Transect	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Weekapaug	2.9	3.3	1.5	2.2	0.1	0.3	0	0
East Beach	4.9	7.2	1.6	2.3	0.4	0.8	0	0
Nebraska Shoals	7.7	8.3	1.3	1.8	0.2	0.4	0	0
Point Judith	16.4	23.6	2.0	4.1	0.5	1.0	0	0

Observations on surface current patterns indicate westward surface currents from the Point Judith area (Fig. 7), suggesting transport of larvae to the west.

Production

Relative production for the 1977 and 1978 seasons was determined using the method of Scarratt (1964). Weekly production was divided by the time between molts (Templeman 1936) for each stage at the corresponding mean surface temperature for that week. Weekly production estimates were then summed to estimate relative seasonal production. The estimated seasonal production of lobster larvae in 1977 was threefold higher than the 1978 production estimate (Table 5). There was an exponential decrease in production from stages I and IV in 1977. Stage II abundance was 40% of stage I; stage II was 57% of II; and stage IV as 33% of III. A similar pattern was observed for stages I, II, and III in 1978. However, in 1978, stage IV production exceeded that of stages II and III.

DISCUSSION

Lobster larvae in Block Island Sound were abundant in the plankton for a relatively short period in June and July. Observation of stage I lobster larvae in late May or early June is an indication of recent hatching. Since the duration of stage I is approximately 1 to 5 d (Herrick 1911), first hatching occurred off East Beach in mid to late May during 1977-79. The duration of hatching activity was about 8 to 9 wk based on the occurrence of stage I larvae in the water column. Peak hatching apparently occurred in mid to late June in 1977-79.

Herrick (1911) observed that hatching was triggered by rising temperatures. The bottom temperature when larvae were first observed off East Beach was 13.3°C in 1977, 13.6°C in 1978, and 12.6°C in 1979. Peak abundance of stage I larvae occurred in early June in 1977 and 1979 and in early July in 1978. This reflects a later warming trend in 1978. In 1977 and 1979, bottom temperatures at EB-B had reached 12°C by about 20 May; in 1978, water temperatures did not reach this level until 30 May. Bottom temperatures during periods of apparent maximum hatching were approximately 14°-18°C. Peak occurrence of stage I larvae was observed at temperatures of 13°-15°C in Maine by Sherman and Lewis (1967). Intensive hatching was observed in Martha's Vineyard at temperatures of 15°-20°C by Hughes and Matthiessen (1962).

Hatching was apparently complete by early August in both 1977 and 1978. Stage IV larvae were observed from mid-June until the last week of August in 1978, but only from late June until the first week of August 1977.

Templeman (1939), Scarratt (1973), and Sherman and Lewis (1967) observed highest surface concentrations of lobster larvae during daylight. Our results generally confirm these observations. On occasion, considerable numbers of stage I larvae were caught in near-bottom waters during both day and night.

The distribution of lobster larvae observed in 1977 and 1978 suggests a hatching area near stations EB-C and EB-D. Larvae which hatch in this area may be transported westward and collected at stations EB-C and EB-D.

Currents in Block Island Sound are primarily tidal, with eccentric elliptic patterns generally parallel to the shore (east-west). Velocities are moderate to strong (0.15 to 0.30 m/s). Residual drift is strongly influenced by local winds with strong seasonal variability (Snooks and Jacobson footnote 5). Surface drifters released at stations off East Beach and other Block Island stations in July 1977 were all recovered along the mainland shore to the west of the release point except for those released just off Block Island; some of these were recovered off Block Island and Long Island (Fig. 7).

The 1979 study was designed to identify hatching sites in Block Island Sound and their potential contribution to lobster populations off East Beach. However, the 1979 results are of limited use in identifying hatching areas because the sampling period was abbreviated. Nevertheless, several factors point to a major hatching area near Point Judith. Surface drifters indicate transport to the west during summer. Stage I larvae were more abundant in this area (PJ and NS transects). The proportion of stage I larvae was highest along these transects, with higher proportions of stage II and III larvae observed at more westerly transects.

A summary of observations on lobster larvae for 1976 through 1979 off East Beach in Block Island Sound is presented in Table 6. The time of peak abundance was later in 1978, reflecting a slower rise in bottom temperature. Average surface abundance of larvae at its maximum showed considerable variability, even allowing a factor of two to four for total difference in abundance estimates between neuston and Tucker net samples (Bibb et al. 1983). Abundance of lobster larvae for all stages was higher at offshore stations in 1977. In 1978, stage I through III larvae maintained this pattern, but stage IV larvae were more abundant inshore. In 1976, all stages were more abundant at the inshore station. The high abundance of stage IV larvae in 1978 is perhaps the most remarkable difference among the years of observations, possibly resulting from transport from adjacent areas or differences in survival or sampling efficiency.

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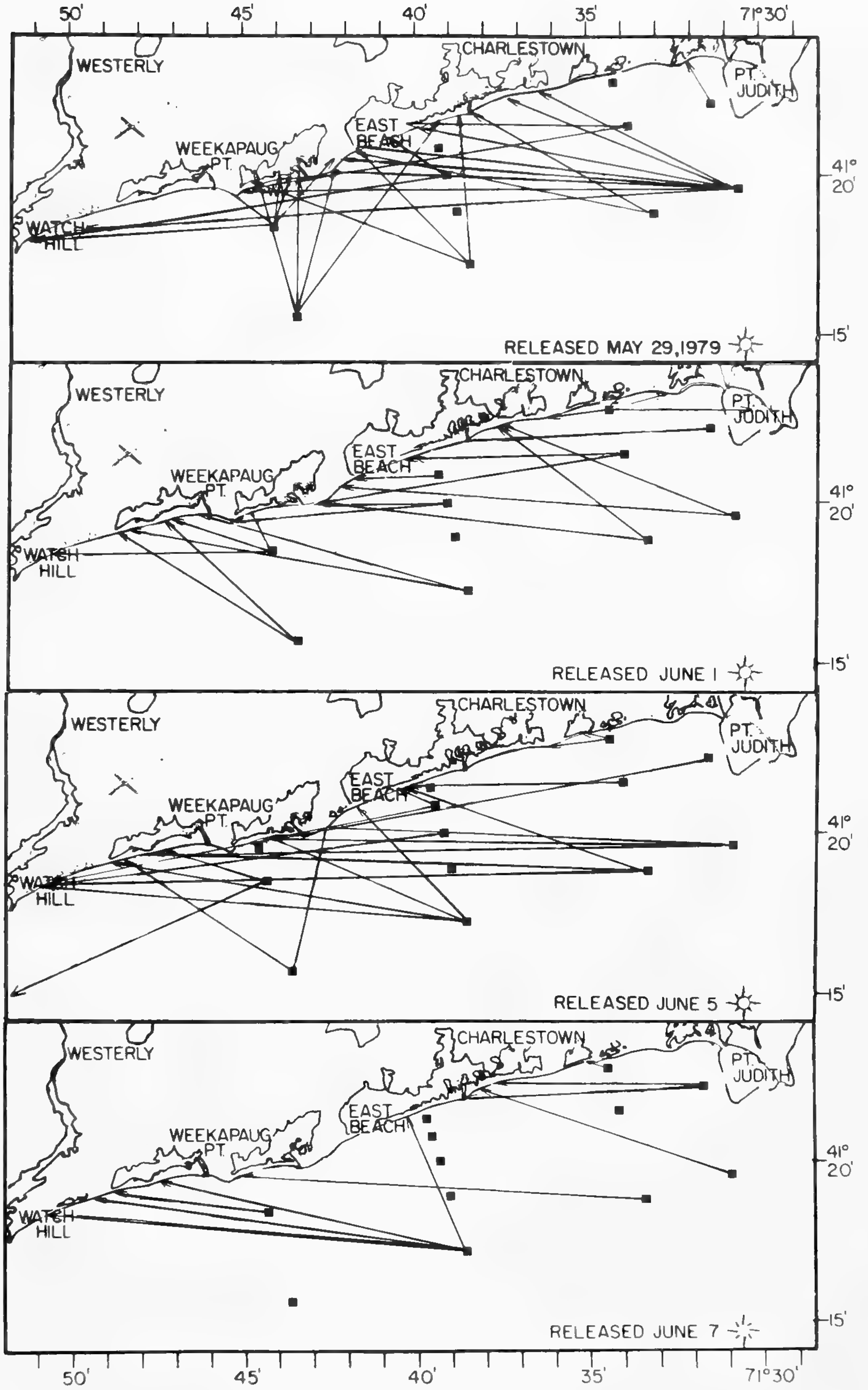

Figure 7.—Surface drifter release and recovery points in May and June 1979 in Block Island Sound.

Table 5.—Seasonal production (number per 1,000 m^3 per season) of lobster larvae collected off East Beach calculated using technique of Scarratt (1964).

	Year	
Stage	1977	1978
I	22.8	4.7
II	4.8	1.7
III	2.0	1.3
IV	0.4	2.3
Total	30.0	10.0

Table 6.—Comparison of lobster larvae observations from 1976 through 1979 along a transect in Block Island Sound.

Parameter	[1]1976	1977	1978	[2]1979
First larvae observed	27 May[3]	31 May	6 June	23 May
Highest station value observed (/1,000 m^3)	65.7	20.81	21.42	21.3
Peak larval abundance (/1,000 m^3) average of all stations, surface	37.2	7.79	4.78	18.7
Date of peak larval abundance	18 June[4]	14, 28 June	5, 12 July	
Relative abundance by stage (over season)	II > I > IV > III	I > II > III > IV	IV > I > II > III	I > II > III
Highest station				
I	nearshore	offshore	offshore	offshore
II	nearshore	offshore	offshore	offshore
III	nearshore	offshore	offshore	offshore
IV	nearshore	offshore	nearshore	not seen
Total	nearshore	offshore	offshore	offshore
Highest time of day	night	day	day	not sampled
Collection method	neuston	Tucker	Tucker	neuston

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[2] Sampling discontinued 11 June 1979.

[3] Observed in ichthyoplankton samples.

[4] First sampling date.

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Distribution, Relative Abundance, and Seasonal Production of American Lobster, *Homarus americanus*, Larvae in Block Island Sound in 1978

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and CLEMENT A. GRISCOM[4]

ABSTRACT

Neuston samples were collected at eight station sites in Block Island Sound at approximately weekly intervals from 3 May through 1 September 1978, and sorted for lobster (*Homarus americanus*) larvae. Larvae were collected between 1 June and 22 August. Fourth stage larvae were numerically dominant, comprising 63% of the 1,030 larvae collected in this survey. Total production of stage I larvae in Rhode Island Statistical Area 4 estimated from survey data was 2.514 × 10^6 larvae. A minimum estimate of potential stage I production in Area 4 based on population size determined by cohort analysis and relative population fecundity indicated that at least 3.232 *X* 10^7 larvae could have been produced. Stepwise multiple regression analysis of hydrographic and climatological variables on total larval density demonstrated that water temperature and wind velocity explained 61.5% of the observed variance.

INTRODUCTION

The American lobster, *Homarus americanus*, is among the most valuable commercially exploited species in Rhode Island. Preliminary commercial landings in 1980 were 1,100 t with an estimated value of $5.6 million. Due to the importance of this species to the economy of Rhode Island, investigations into several aspects of lobster population dynamics were initiated in 1974. These studies provided information on growth and mortality (Russell et al.[5]), local movements and migratory behavior (Fogarty et al. 1980), gear selectivity (Fogarty and Borden 1980), trawl induced injury and mortality (Ganz[6]), and commercial catch statistics (Simon[7]).

Despite the recent attention devoted to the behavior, ecology, and population biology of juvenile and adult American lobster, relatively little is known of the pelagic larval stages. The present study was designed to investigate the seasonal and spatial distribution of lobster larvae in Block Island Sound. We derived a preliminary estimate of larval production in the survey area using stage I density adjusted for development time and mortality. For comparsion, potential egg production was calculated using information on population structure, sex ratios, size at maturity (Russell et al. footnote 5), and relative population fecundity (Saila et al. 1969).

MATERIALS AND METHODS

Neuston samples were collected at approximately weekly intervals from 3 May through 1 September 1978 at eight stations in Block Island Sound (Fig. 1) and sorted for lobster larvae. Replicate samples were collected with paired neuston nets (1 m × 2 m opening; 0.946 mm mesh) deployed from two side booms aboard a 20 m research vessel. When sampling, the nets were positioned forward of the stern wake and outside of the bow wake to ensure an undisturbed sample. The position of the nets was adjusted to sample the upper 0.5 m of the water column. Standard tows were of 20 min duration at approximately 3.7 km/h. During periods of high ctenophore abundance, when the filtration efficiency of the nets was reduced,

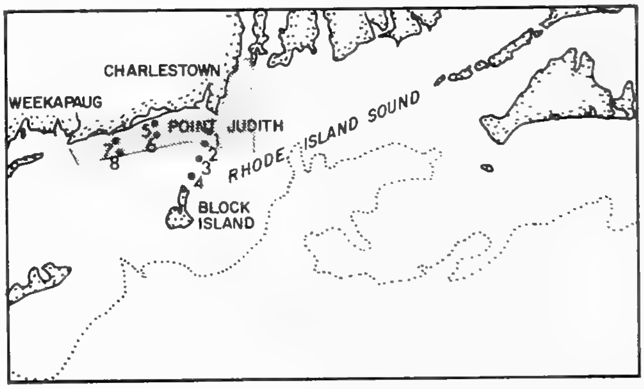

Figure 1.—Location of sample sites in Block Island Sound, 1978. Shaded area indicates Rhode Island Statistical Area 4.

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[5] Russell, H. J., D. V. D. Borden, and M. J. Fogarty. 1978. Management studies of inshore lobster resources. Final report. State-Federal Lobster Management Program Contract No. 03-4-043-360, 78 p.

[6] Ganz, A. R. 1979. Evaluation of otter trawl induced lobster damage. Final report. Commercial Fisheries Research and Development Act Contract No. 04-7-043-44041, 23 p.

[7] Simon, B. M. 1980. Lobster logbook and statistical analysis. Segment report. Commercial Fisheries Research and Development Act Contract 04-78-D01-R1B-B.

tows were shortened. All samples were collected during daylight between 0800 and 1600 h since previous investigations demonstrated that larval abundance is highest at the surface during daylight (Templeman 1937; Templeman and Tibbo 1945; Scarratt 1973). The distance covered by the vessel during each tow was determined from loran-C coordinates recorded to the nearest 0.1μs at the start and end of each tow. Surface water temperature was recorded at each station.

Nets were washed down with seawater after each tow to maintain a standard filtration efficiency. Samples were rinsed in seawater, strained using a 505 μ mesh screen, and placed in buffered 10% Formalin.[8] Samples were sorted for decapod larvae and fish eggs and larvae in the laboratory. All lobster larvae were removed and identified to stage (Herrick 1911) using a dissecting microscope equipped with an ocular micrometer. Since fourth and fifth stage larvae are best differentiated by size (Herrick 1911), larvae identified as fourth stage were measured (total length) to the nearest millimeter and compared with published records of length of stage IV larvae. Larval density estimates were derived using Δ-distribution theory (Aitchison 1955; Aitchison and Brown 1957), a technique in which survey data are classified into zero and non-zero catch values. The conditional distribution of the non-zero class is assumed to be log-normal. A minimum variance unbiased estimator of the sample mean (Aitchison 1955) is:

$$C = \frac{m}{n} e^{y} \psi_m(s^2/2)$$

where m is the number of non-zero observations, n is the total number of observations, y and s^2 are the mean and variance of the log transformed non-zero observations and ψm (Aitchison 1955) is given by:

$$\psi m = 1 + \frac{n-1}{n} t + \sum_{j=2}^{\infty} \frac{(n-1)^{2j-1}}{n^j (n+1)(n+3)\ldots(n+2j-3)} \cdot \frac{t^j}{j!} .$$

Density estimates for each stage were corrected for stage duration by dividing by development time at prevailing water temperatures (Templeman 1937) for each sample period. Daily production estimates were summed over the entire sampling season to provide an estimate of annual larval production per 1,000 m^3.

RESULTS AND DISCUSSION

Seasonal Distribution

Due to the relatively short duration of the first larval stage, the occurrence of stage I lobster larvae is indicative of recent hatching activity. We initially noted stage I larvae on 1 June and first stage larvae were observed through the beginning of August, indicating that the hatching period in 1978 spanned approximately 2 mo (Fig. 2). Peak abundance of first stage larvae occurred in late June at a mean density of 10.82 larvae/1,000 m^3. The mean seasonal density of stage I larvae was 1.98/1,000 m^3.

Second and third stage larvae were first observed in the 20 June collections and the highest densities for both stages were noted in samples collected in late June (Fig. 2). Stage II larvae were collected through the end of July while third stage larvae were observed through mid-August. The mean seasonal density was 3.11/1,000 m^3 and 1.80/1,000 m^3 for second and third stage larvae, respectively.

Fourth stage larvae were initially collected in the 27 June samples and were dominant for the remainder of the season. The highest mean weekly density of stage IV larvae (26.08/1,000 m^3) was noted in mid-July and fourth stage larvae were collected through the end of August (Fig. 2). Of the 1,030 larvae collected during this survey, 645 (62.6%) were fourth stage. In contrast, the first through third larval stages comprised 12.3%, 14.1%, and 10.9% of the samples, respectively. The dominance of fourth stage larvae is particularly striking since previous investigators observed relatively low densities for this stage (Templeman 1937; Templeman and Tibbo 1945; Scarratt 1964, 1973; Sherman and Lewis 1967). Bibb et al. (1983) also noted a high proportion (52%) of stage IV larvae in 1978 in Block Island Sound, in marked contrast to their 1977

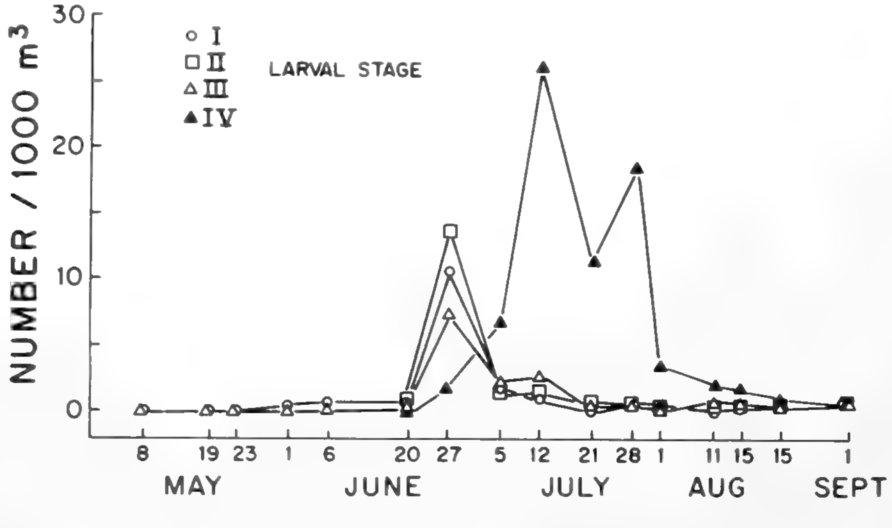

Figure 2.—Density (no./1,000 m^3) of stage I-IV lobster larvae during sampling period (8 May through 1 September).

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

collections in which stage IV larvae composed 4% of the total larvae obtained.

High stage IV densities may be due to transport into the study area or differential catchability. Phototropic responses differ among larval stages (Hadley 1908; Templeman and Tibbo 1945; Ennis 1975) with first and fourth stage larvae being most strongly phototactic, indicating that these stages may be more vulnerable to surface gear. Since previous researchers, using similar gear, obtained relatively low stage IV densities, it is unlikely that differences in catchability alone are sufficient to explain the high abundance of fourth stage larvae in our samples.

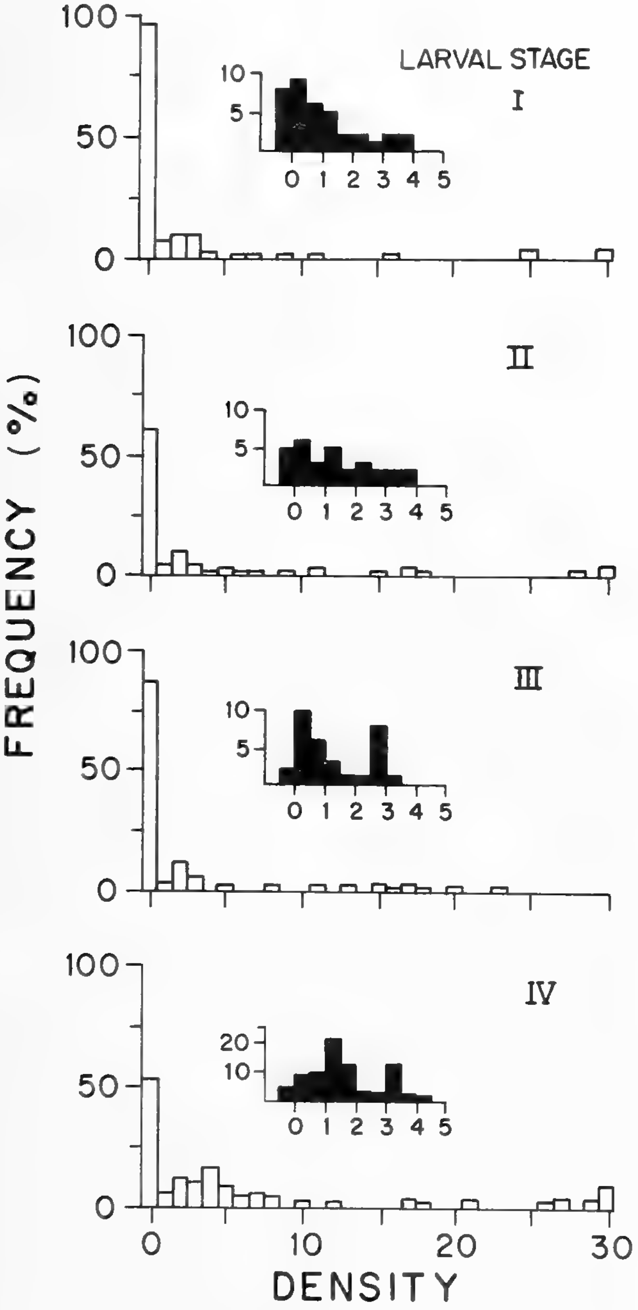

Figure 3.—Frequency distribution of lobster larval catch densities (no./1,000 m^3) and distribution of $\log_e$ transformed catch densities (zero catches excluded).

Conditional distribution of the non-zero catches was approximately log-normal for each larval stage (Fig. 3). Contagious distribution patterns have been consistly noted in larval lobster sampling programs (see reviews by Fair 1980 and Stasko 1980). Patch size dimensions are not generally known, however no significant differences in catch between paired neuston nets separated by ≅15 m were observed (Wilcoxon paired rank sum test; $P > 0.05$).

Comparisons between larval catches at each of the eight stations (Table 1) indicated no significant differences among stations for stages I-III (Kruskal-Wallis test; $P > 0.05$). The lack of significant differences in stage I densities between stations does not permit inference regarding possible spawning locations; however, the area surveyed was relatively small and transport of larvae with prevailing currents may have obscurred source areas. Significant differences ($P < 0.005$) were noted, however, between stations for stage IV larvae (Kruskal-Wallis test; $\chi^2 = 20.91$; df = 7). Stage IV densities tended to be highest in the western segment of the study area (Table 1), however, relatively high stage IV density was noted at station 1 in the eastern section of the survey area.

Table 1.—Mean larval densities (no./1,000 m^3) for stages I-IV over the entire sampling season.

	Larval stage			
Station	I	II	III	IV
1	2.208	4.197	2.560	9.852
2	1.071	2.456	1.995	2.242
3	0.559	0.938	0.331	0.891
4	3.585	9.339	2.099	0.699
5	3.383	5.857	1.035	12.990
6	1.231	1.633	3.957	12.166
7	0.207	0.560	1.533	10.816
8	0.310	1.540	0.790	1.969

Seasonal Production

Seasonal production curves were constructed based on standardized daily production estimates (Fig. 4); annual larval production was then determined by integration. Estimated annual production for stages I-IV was 22.72, 19.80, 12.20, and 32.33 larvae/1,000 m^3, respectively. The high production estimate for fourth stage larvae, despite correction for stage duration, is indicative of the unusually high abundance of stage IV larvae in 1978. The adjusted estimates of stage IV production are conservative since settlement occurs approximately midway through the fourth stage and the larvae are no longer vulnerable to the gear (Scarratt 1973). Scarratt (1964) provided stage I seasonal production values for Northumberland Strait which considerably exceeded our estimates.

Stage I density was expanded to provide an estimate of 2.514×10^6 stage I larvae produced in Rhode Island Statistical Area 4 (Fig. 1). The statistical area encompasses 165.01 km^2 and it was assumed that larvae were confined to the upper 0.5 m of the water column. The stage I total production estimate was corrected for an instantaneous daily mortality rate of $Z = 0.050$ derived by regressing $\log_e$ transformed production of stages I-III on the weighted mean duration (days) of each stage. Due to the many variables influencing the catchability

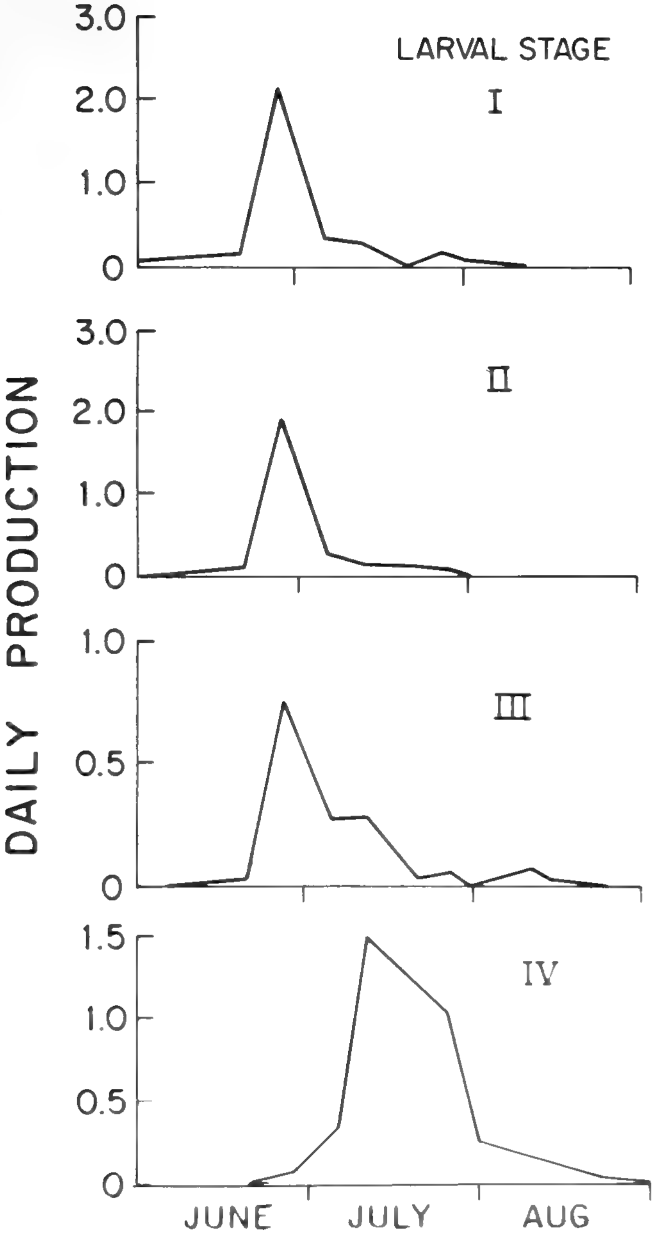

Figure 4.—Daily production (no./1,000 m^3) estimates of stage I-IV lobster larvae during period of larval occurrence (1 June-22 August).

of lobster larvae, this must be considered a preliminary estimate.

For comparative purposes, a minimum estimate of potential stage I production in Statistical Area 4 was derived using population size determined by cohort analysis (Jones 1974), size at sexual maturity (Russell et al. footnote 5), and fecundity (Saila et al. 1969). Commercial catch data (B. Simon[9]) for September 1977 to 30 July 1978 were employed in this analysis; this interval spans the egg bearing period for lobsters which would release larvae in 1978. It is implicitly assumed that the catchability of ovigerous females is not altered. Size groupings were arbitrarily defined based on molt increment data using the minimum legal size at the time of this study (78 mm carapace length) as a starting point. Terminal fishing mortality ($F_t = 1.2$) was determined from tag return data (Russell et al. footnote 5) adjusted for the seasonal pattern of catches. Fecundity for each molt class was calculated using the relationship

$$F = 0.02502\ \mathrm{CL}^{2.8647}$$

where F is fecundity and CL is the carapace length (mm) (Saila et al. 1969). Estimated potential egg production for Statistical Area 4 was 3.323×10^7 (Table 2). No estimate of the reproductive contribution of females <78 mm CL was made, however ovigerous females composed < 1% of the 68-77 mm CL female size class in research catches. The expanded survey estimate of stage I production apparently underestimated potential production by an order of magnitude. Nichols and Lawton (1978) noted discrepancies between estimated larval density of *H. gammarus* and potential production. Larvae are not entirely confined to the surface layer (Scarratt 1973) accounting, in part, for this discrepancy. The contagious distribution pattern and behavioral responses to environmental conditions (light intensity, wind factors, etc.) which alter availability compound the difficulty in estimating larval abundance.

Environmental Effects

The influence of several hydrographic and climatological factors on larval density was examined using stepwise multiple

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Table 2.—Arbitrary size classes (carapace length, mm); proportion of each size class, proportion female, and proportion ovigerous in research catches; estimated number of females in commercial catch from 1 September 1977 to 30 July 1978 in statistical area 4; population size of females based on cohort analysis; estimated numbers of ovigerous females in population; and average fecundity.

Size class	Proportion of catch[1]	Proportion female[1]	Proportion ovigerous[1]	Est. no. females in catch	Est. no. females in population[2]	No. spawners	Average fecundity[3]
78-87	0.823	0.529	0.073	24,421	33,683	2,459	7,581
88-99	.162	.522	.143	4,938	6,282	898	10,142
100-112	.011	.444	.375	285	658	247	14,866
>112	.004	.750	.333	175	266	89	20,473

[1] Russell et al. (text footnote 5).

[2] Parameters for cohort analyses by length groups (Jones 1974): $K = 0.0966$, $L_\infty = 184.58$, $M = 0.15$, $F_t = 1.2$ (Russell et al. text footnote 5).

[3] Average fecundity for each size class using mean carapace length of each group and fecundity relationship of Saila et al. (1969).

regression. Independent variables included mean weekly water temperature, mean wind speed and direction on the sampling date, and wind speed and direction averaged over the sampling date and the previous 2 d. Wind direction was treated as a categorical variable with two classes (onshore and offshore). Wind speed and direction data were obtained from the National Weather Service Station at Warwick, R.I. Larval density, water temperature, wind speed, and averaged wind speed were transformed to natural logarithms prior to analysis. Two variables, water temperature and wind speed on the sampling date, were sufficient to provide a significant regression equation (Table 3) with multiple correlation coefficient of R = 0.784. Examination of the squared multiple correlation coefficient indicated that 61.5% of the variance was explained by the derived equation. Inspection of the standardized residuals revealed no departure from the assumption of normality and a Durbin-Watson test (Neter and Wasserman 1974) indicated no significant autocorrelation in the residuals.

Table 3.—Coefficients and associated standard errors (SE), F ratios (df = 2,9), and multiple correlation coefficients (R) for stepwise regression model relating larval density to wind speed and temperature.

Variable	Coefficient	SE	F	R
Wind speed	3.0907	0.8507	13.199**	0.649
Temperature	5.4328	2.5675	4.477*	.783
(Constant)	−19.6808			

**Significant at $P<0.01$.
*Significant at $P<0.05$.

The lack of a significant wind direction effect was surprising since a positive relationship between onshore winds and larval abundance has been previously noted (Templeman and Tibbo 1945; Squires 1970; Stasko 1980). In the present study, the highest larval densities were generally obtained when winds were onshore. However, low larval densities at the beginning and end of the season, despite onshore winds, tended to obscure this relationship. A vector plot of surface transport was constructed for the period of high larval abundance, 20 June to 28 July, assuming surface drift to be 3.0% of the resultant wind speed and at an angle of 15° to the right of wind direction (Fig. 5). Prevailing winds for the period were southwesterly, however, variable offshore winds dominated from 27 June through 5 July, culminating in reduced larval catches on this date (Fig. 5). High larval densities on 12 July, despite 2 d of offshore winds, do not conform to the general pattern although the effects of strong onshore winds from 6 through 10 July may account, in part, for this result.

The inclusion of surface water temperature in the model reflects the increasing contribution of fourth stage larvae later in the season when water temperatures were also increasing. Lobster larvae were collected in surface water temperatures ranging from 13° to 25°C. Modal temperatures at peak larval densities for stages I and II were 14°-16°C and 17°C for third stage larvae (Fig. 6). Stage IV larvae were abundant at surface water temperatures over 17°C. Lund and Stewart (1970) collected lobster larvae in surface waters ranging from 12.5° to 28.5°C in Long Island Sound. Surface water temperatures ranged from 13.7° to 15°C during peak larval concentrations in the Gulf of Maine (Sherman and Lewis 1967).

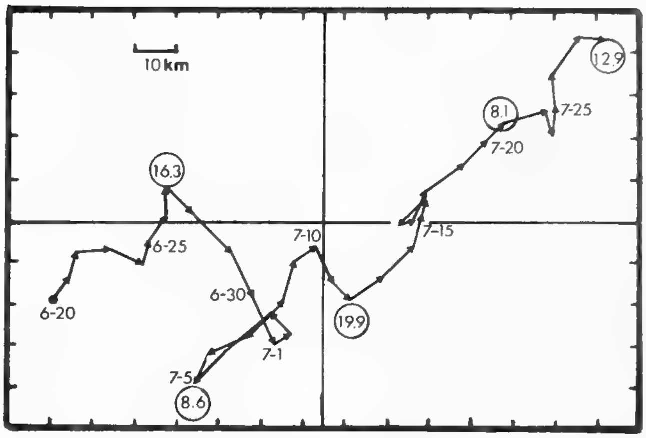

Figure 5.—Vector plot of wind-induced surface drift during 20 June-28 July 1978. Circled figures represent larval densities on sampling dates. Dates provided at 5-d intervals for reference.

The contribution of wind speed to the regression equation may reflect wind-induced advection currents which presumably served to transport larvae into the study area. Wind velocities on sample dates were relatively moderate and apparently did not reach levels at which surface turbulence would result in reduced densities (Squires 1970).

CONCLUSIONS

High fourth stage larval lobster densities were obtained in Block Island Sound in 1978. Adjustment for probability of capture based on developmental times for each larval stage did not eliminate the dominance of stage IV larvae in these collections. Although first and fourth stage larvae may be more vulnerable to surface gear (Templeman and Tibbo 1945), high mortality rates during the pelagic larval stages (Scarratt 1964, 1973) should result in relatively low numbers of stage IV larvae if recruitment is strictly localized. Prevailing winds during the period of larval occurrence are onshore, possibly resulting in a net transport of larvae from continental shelf waters. Larval recruitment from offshore locations may assume particular importance in maintaining inshore populations which are subjected to extremely high fishing mortality rates.

Stage I larval production in Rhode Island Statistical Area 4 was estimated to be 2.514 × 10^6 larvae based on expansion of corrected larval densities. A minimum estimate of hypothetical larval production based on population size determined by cohort analysis, sex ratio, maturity, and fecundity indicated that at least 3.323 × 10^7 larvae could have been produced. Nichols and Lawton (1978) reported similar underestimates of larval production of *Homarus americanus* based on neuston samples.

Larval density was significantly correlated with wind speed on the day of sampling and surface water temperature.

ACKNOWLEDGMENTS

We would like to express our appreciation to R. Wood, T. Lynch, A. Ganz, and J. Hoenig for assistance in the field and to J. Hoenig for sorting samples. We are grateful to M. Pennington for bringing the Delta distribution method to our atten-

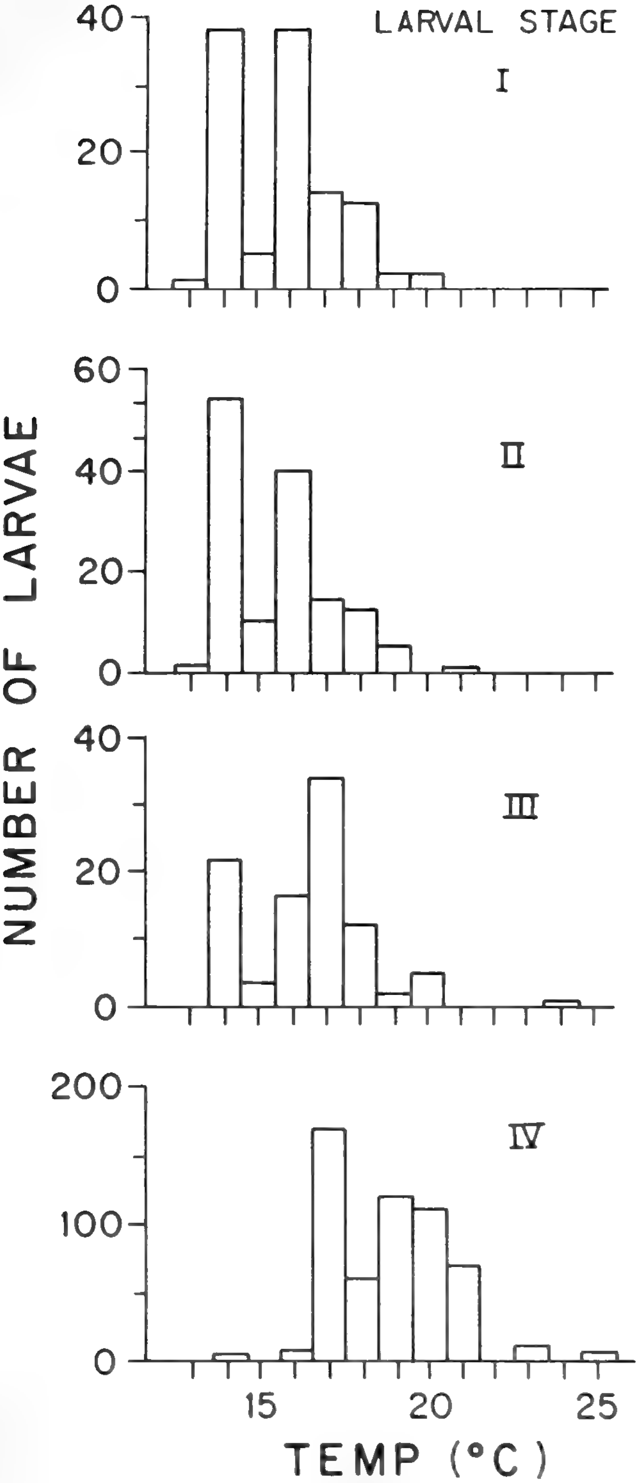

Figure 6.—Frequency distribution of stage I-IV lobster larvae collected at prevailing surface water temperatures.

tion. The critical reviews of M. Sissenwine and S. Saila were very helpful.

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Distribution and Abundance of Larval Lobsters (*Homarus americanus*) in Buzzards Bay, Massachusetts, During 1976-79

FRED E. LUX, GEORGE F. KELLY, and CHARLES L. WHEELER[1]

ABSTRACT

In 280 neuston tows during 1976-79 in Buzzards Bay, Mass., 16,679 larval lobsters (stages I-IV) were collected. The larvae began to appear in catches in late May in each year, reached peak numbers in mid-June, and disappeared from the plankton by early August. The bottom temperature was approximately 13°C when larvae first were caught and about 17°C at the peak of larval production. The mean number of larvae caught per 1,000 m^3 of water filtered ranged from 9.6 in 1978 to 43.7 in 1979. Largest catches were obtained on 18 June 1979 when 6,746 larvae were caught in five 0.5-h tows. The catch of late stage larvae was unusually high in 1978 when stage IV larvae were twice as numerous as the other stages combined. The sampling results indicated that Buzzards Bay is an area of high production of larval lobsters.

INTRODUCTION

The National Marine Fisheries Service (NMFS) at Woods Hole began sampling planktonic larval stages of lobsters (*Homarus americanus*) in Buzzards Bay, Mass., in May 1976. This effort has continued each year with sampling beginning in early May prior to the hatching of lobster eggs and ending in early August after the larvae have settled out of the plankton. The survey was begun as part of a joint study with the Massachusetts Division of Marine Fisheries of the distribution and abundance of lobster larvae in Cape Cod Bay, the Cape Cod Canal, and Buzzards Bay. We sampled the middle section of Buzzards Bay (Fig. 1). This paper reports the results from this work in 1976-79. A general summary of information on distribution and abundance of lobster larvae has been prepared by Fogarty (1983) and therefore is omitted here.

Buzzards Bay varies in depth from < 5 m at the Cape Cod Canal end to about 30 m at the bay mouth. Sediments consist largely of sand and silt, although there are numerous areas of rocky bottom and, along the northwest shore, rock ledge.

The bay, which lies entirely within Massachusetts territorial waters, is closed by State law to fishing with trawls or nets. There are, however, active commercial and recreational trap fisheries for lobsters from spring to late fall. Lobsters <81 mm carapace length and all ovigerous females must be returned to the water. Precise lobster landings from Buzzards Bay are not known, although catch reports filed to the State by lobster fishermen indicate that an estimated 500 tons may be landed per year (Beals et al.[2]).

METHODS

Numerous reports have demonstrated that planktonic lobster larvae are positively phototactic and are found at or near the water surface during daylight (Fogarty 1983). Therefore a neuston net (1 × 2 m mouth, 9 m length) with a mesh size of 0.97 mm was used for sampling. The net was towed from the end of a boom extending 2.5 m out from the starboard side of a 12 m research vessel. Tows were made in a straight line with the net approximately 20 m astern of the vessel and out of the wake; the net mouth was from one-half to two-thirds submerged. Towing speed in 1976, based on distance covered, was estimated at 4.6-5.6 km/h (2.5-3.0 kn) and

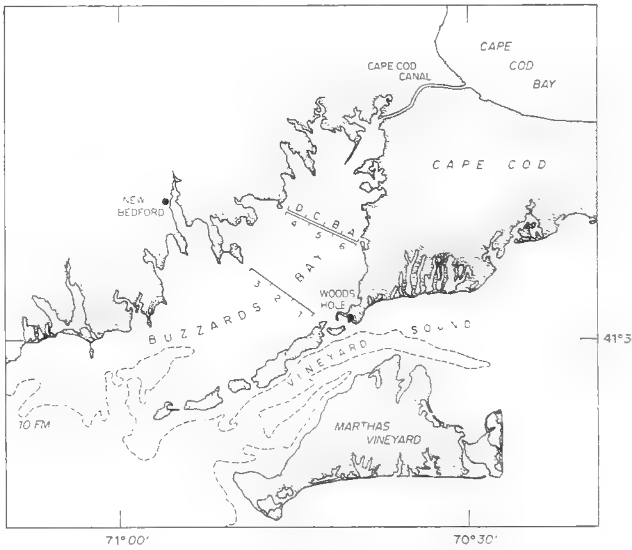

Figure 1.—Sampling stations for neuston tows in Buzzards Bay, Mass., 1976-79. In 1976, stations A-D (upper transect) were sampled; in 1977-79, stations 1-6 (lower and upper transects) were sampled.

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[1] Northeast Fisheries Center Woods Hole Laboratory, National Marine Fisheries Service, NOAA, Woods Hole, MA 02543.

[2] Beals, R. W., C. J. Kilbride, and G. M. Nash. 1978. 1977 Massachusetts coastal lobster fishery statistics. Mass. Div. Mar. Fish. Tech. Ser. 13, 19 p.

6.0 km/h (3.25 kn) as determined by electronic log during 1977-79.

Except where there was significant net clogging, the tows were 0.5 h in duration. At 6 km/h the estimated surface area sampled in a 0.5-h tow was 6,000 m^2, and the estimated volume of water filtered was 3,000 m^3, assuming that the net sampled a surface layer of water 0.5 m deep. At the lower towing speeds used in 1976 the estimated volume filtered in a 0.5 h tow ranged from 2,200 to 2,750 m^3. The volume actually filtered may vary considerably depending on depth of the net in the water, extent of clogging, and the amount of wind and wave action (Scarratt 1973). The water volumes filtered that we have used therefore must be considered approximate.

Where net clogging occurred due to algal blooms or concentrations of ctenophores the volume filtered was reduced. Tows in which clogging was apparent were abbreviated. Clogging often occurred from mid-July to early August, affecting approximately 10% of the tows in a season.

At the completion of each tow the catch was removed from the cod end and floating algae and eelgrass were rinsed free of organisms and discarded. The catch then was strained with a sieve, placed in jars, and preserved in 2% formaldehyde; lobster larvae were sorted in the laboratory.

Weather permitting, all stations were sampled once each week during May-August. In 1977-79 we sampled six stations in two transects, each of which was 9 km in length (Fig. 1). In 1976 we sampled only the easternmost transect, which we divided into four stations (Fig. 1). Sampling began at approximately 0800 h (EST) and was completed by about 1400 h. On one occasion, in 1976, we sampled during early evening hours and after dark.

Surface water temperature was recorded to the nearest 0.1°C at the beginning of each tow, using a mercury thermometer. Surface to bottom temperatures were obtained with an electronic probe in 1977 and part of 1978. Wind and cloud cover observations were noted on each tow log.

RESULTS

Over the 4 yr sampled, 16,679 larval lobsters were caught, averaging 23.3/1,000 m^3 of water filtered (Table 1). Numbers of larvae varied considerably from year to year with totals ranging from 1,284 in 1976, when there were fewer stations, to 10,303 in 1979.

There was a marked variation also in the composition of the catch by stage of development, both within and between years (Table 1). Stage II predominated in 1976 and 1977; stage IV, in 1978; and stage III, in 1979. The large numbers of stage IV larvae in most years seemed unusual, even though the longer duration of this stage increases the chance of capture. In 1978, when this was most pronounced, there were more than twice as many stage IV larvae as the other stages combined (Table 1).

Estimates of the abundance of larvae by sampling date for all stations combined in each year (Fig. 2) indicate that the larvae began to appear in the catch in the latter half of May, reached peak numbers in mid to late June, and had completed pelagic stages by early August. The surface water temperature when larvae first were caught was about 13°-15°C; the temperature at the bottom usually was 1° or 2° lower than at the surface (Fig. 2). The temperature at the peak of larval production was about 19°C at the surface and 17°C at the bottom. These temperatures for initiation of hatching and peak of larval production agree rather closely with the findings of Hughes and Matthiessen (1962). Water temperatures as high as about 24°C at the surface were recorded in July and early August (Fig. 2).

There was no consistent pattern in total abundance by station, although the largest catches generally were made at station 3 (Fig. 1). The water temperature was higher by about 1°-2°C at stations 4-6 (A-D), where the depth was 10-12 m, than at stations 1-3, where the depth was about 15 m, but it was not clear if these temperature or depth differences affected larval abundance.

The high numbers of larvae caught in 1979 were due largely to catches on one sampling date (18 June) when 6,746 larvae were caught in the five tows (Table 1). The mean total catch per 1,000 m^3 of water filtered for 18 June was 450 larvae (Fig. 2). The year 1979 was, however, one of generally high larval abundance in Buzzards Bay (Fig. 2).

The abundance of lobster larvae by developmental stage for each year and sampling date show the general progression of stages through the hatching season (Fig. 3). The abundance of stage I larvae usually peaked around mid-June and stage IV peaked in late June. Larvae were caught from late May to

Table 1.—Total numbers of tows, numbers of tows containing larval lobsters, total numbers of lobster larvae of each stage, mean total numbers per 1,000 m^3, and percentage frequency by stage (in parentheses) for Buzzards Bay neuston sampling in 1976-79 and all years combined.

Year	Number of tows: Total	Number of tows: With larvae	Numbers of larvae of each stage: I	II	III	IV	Total number	Number per 1,000 m^3
1976	50	32	433	484	290	77	1,284	10.1
			(33.7)	(37.7)	(22.6)	(6.0)	(100.0)	
1977	80	56	706	1,064	759	932	3,461	18.8
			(20.4)	(30.8)	(21.9)	(26.9)	(100.0)	
1978	62	41	90	103	243	1,195	1,631	9.6
			(5.5)	(6.3)	(14.9)	(73.3)	(100.0)	
1979	88	56	2,413	2,640	3,962	1,288	10,303	43.7
			(23.4)	(25.6)	(38.5)	(12.5)	(100.0)	
All years	280	185	3,642	4,291	5,254	3,492	16,679	23.3
			(21.8)	(25.7)	(31.5)	(21.0)	(100.0)	

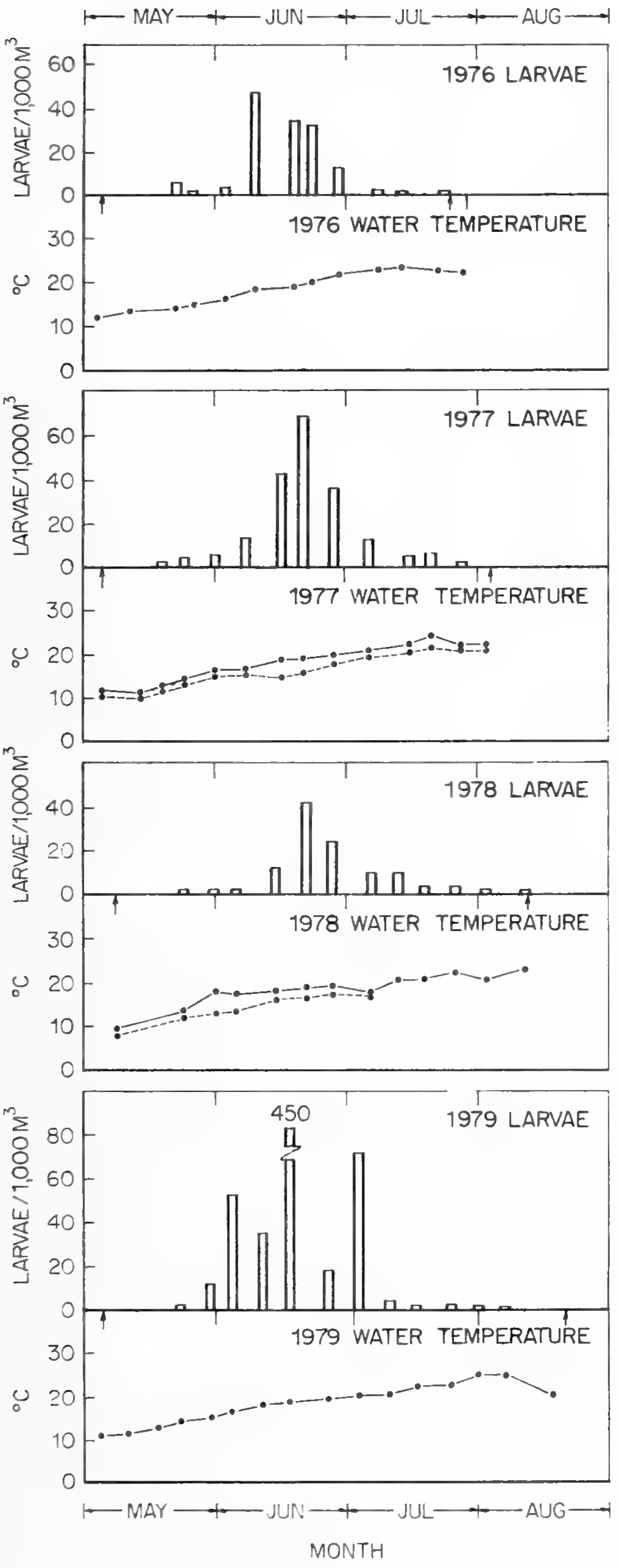

Figure 2.—Numbers of lobster larvae caught per 1,000 m^3 of water filtered and average water temperature for each sampling date in Buzzards Bay neuston sampling, 1976-79. Surface temperature (solid line); bottom temperature (broken line); vertical arrows indicate starting and ending dates for sampling in each year.

early August, encompassing a period of about 11 or 12 wk. Generally there was a small peak in abundance of stage I larvae in late May and well before the seasonal peak in mid-June (Fig. 3); this has been noted previously by Collings et al.[3] in the northeastern part of Buzzards Bay.

In 1976 the pattern of larval abundance by stage (Fig. 3) showed early stage larvae to be more abundant than later stages. In 1977 and, especially, in 1978 later stages were as abundant or more so than earlier stages. In 1979 the very high numbers of all stages caught on 18 June greatly altered the pattern of abundance for that year.

In order to examine day-night differences in the larval catch, we made three daylight and three night tows on the evening of 9 June 1976 at stations B, C, and D (Fig. 1). Only the first three larval stages were caught (Fig. 4). Station B, 1820-1850 h EST, yielded 257 larvae, the largest catch of the 1976 season. At station C, 1855-1925 h, 113 larvae were caught, and at station D, 1930-2000 h, 31 larvae were taken. These were the three daylight tows, although the light was fading through the last two of these. Sunset occurred at 1921 h. For the night tows the times and catches were: station D, 2025-2055 h, 45 larvae; station C, 2100-2130 h, 28 larvae; and station B, 2135-2205 h, 17 larvae. Catch dropped rapidly as the light level decreased. Further, the catch composition by stage changed greatly, with stage I larvae dominating during daylight and stage III larvae making up much of the catch after dark.

DISCUSSION

The results from this study and from those of Collings et al. (footnote 3), indicate that the numbers of lobster larvae caught in Buzzards Bay considerably exceed those caught in other New England areas, such as the Maine coast (Sherman and Lewis 1967), Cape Cod Bay (Anderson and Scotton[4]), Vineyard Sound (Herrick 1896), Block Island Sound (Bibb and Hersey[5]), and Long Island Sound (Lund and Steward 1970). Indeed, it appears, when Canadian studies are considered as well, that the larvae are at least as numerous here as in any other location.

The abundance of early stage larvae in an area depends in part on the numbers of ovigerous lobsters present. Collings et al. (footnote 3) indicated that Buzzards Bay lobsters matured at a smaller size than those in Cape Cod Bay, presumably due to higher water temperatures in the former area. This is consistent with the results of Templeman (1936) who found indications that lobsters matured at smaller sizes in the warmer water areas off Canada than in colder areas. Lobster fishermen also have reported a higher proportion of sublegal

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[3] Collings, W. S., C. C. Sheehan, S. C. Hughes, and J. L. Buckley. 1980. Biological investigations relative to the effects of a second electrical generating unit upon some of the marine resources of northern Buzzards Bay and the Cape Cod Canal. Unnumbered report, 423 p., append. Canal Electric Co., Sandwich, MA 02563.

[4] Anderson, R. D., and L. N. Scotton. 1978. Marine ecology studies related to operation of Pilgrim Station. Final Rept. July 1969-Dec. 1977, Vol. 1, 407 p., Vol. 2, 217 p. Boston Edison Co., 800 Boylston St., Boston, MA 02199.

[5] Bibb, B. G., and R. Hersey. 1979. Distribution and abundance of lobster larvae in Block Island Sound, 1978. 1978 Final Rept., Raytheon Environ. and Oceanogr. Serv., 89 p. New England Power Co., 20 Turnpike Rd., Westboro, MA 01581.

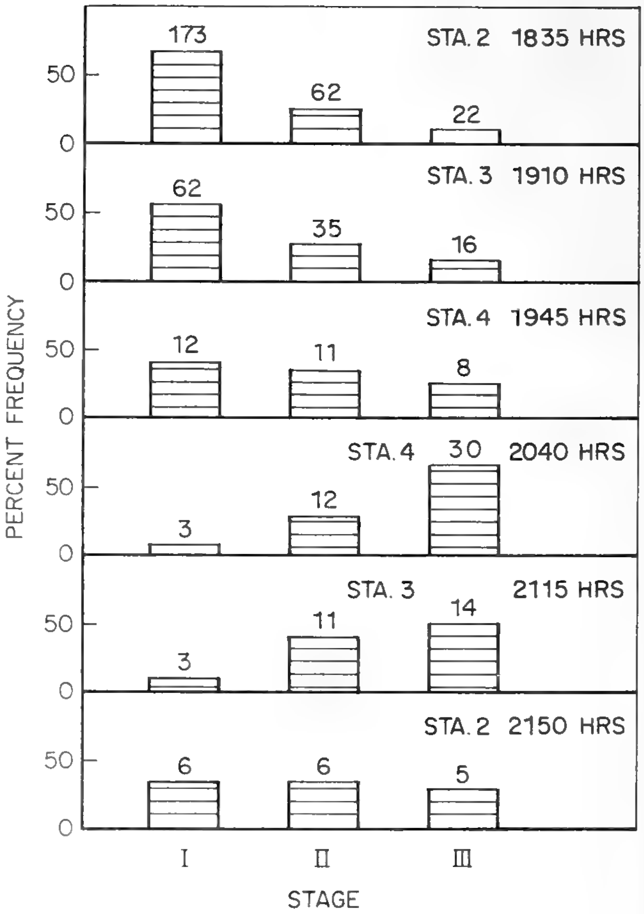

Figure 4.—Percent frequency distributions of lobster larval stages caught during six day-night neuston tows in Buzzards Bay, 9 June 1976. (The times given are EST at the tow midpoints; numbers above each graph are actual numbers of larvae caught; the top three graphs are for the daylight tows, the lower three for those after dark.)

ovigerous lobsters in Buzzards Bay than in surrounding waters, possibly increasing the larval production.

In Long Island Sound, where physical conditions are similar in many respects to Buzzards Bay, Lund et al.,[6] Smith,[7] and Briggs and Mushacke (1979) found that a high proportion of sublegal female lobsters were sexually mature, while in waters south of Long Island (Briggs and Mushacke 1980) this proportion was low. As Lund and Stewart (1970) reported, large numbers of larval lobsters are found in the sound and low numbers, south of Long Island.

All of the above suggests that conditions are more favorable in Buzzards Bay for the production of larvae than in adjacent waters. This bay, which is shallower than adjacent areas and has a slower flushing rate, is warmer from spring to fall

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[6] Lund, W. A., Jr., L. L. Stewart, and C. J. Rathbun. 1973. Investigation on the lobster. Completion Rept. for Connecticut Project 3-130-R Comm. Fish. Res. Devel. Act, 105 p. Univ. Conn., Noank, CT 06340.

[7] Smith, E. M. 1977. Long Island Sound lobster management. Completion Rept. for Connecticut Project 3-253-R-1 Comm. Fish. Res. Devel. Act, 97 p. Conn. Dept. Environ. Protect., State Office Bldg., Hartford, CT 06115.

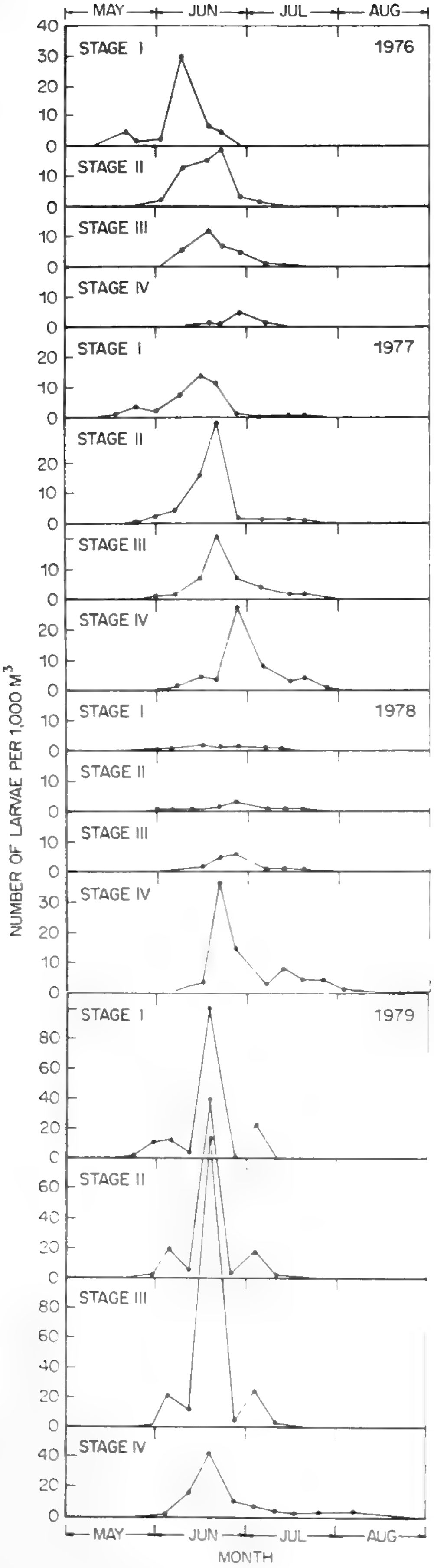

Figure 3.—Numbers, by development stage, of lobster larvae caught per 1,000 m³ of water filtered for each sampling date in each year, 1976-79.

(the season of rapid growth) than either Vineyard Sound (Sumner et al. 1911) or Cape Cod Bay (Collings et al. footnote 3). The high numbers of larvae caught in Buzzards Bay compared with the lower numbers in Vineyard Sound (Herrick 1896) and in Cape Cod Bay (Anderson and Scotton footnote 4) support this suggestion.

The results in several larval lobster studies have shown that stage I larvae dominated the catches (Templeman 1937; Templeman and Tibbo 1945; Scarratt 1964; Sherman and Lewis 1967; Lund and Stewart 1970; Scarratt 1973). The results from our sampling, however, showed stage II, III, and IV larvae dominating the catch in the 4 yr sampled (Table 1, Fig. 3), a pattern that was similar to that concurrently obtained by Collings et al. (footnote 3) in northeastern Buzzards Bay. Templeman and Tibbo (1945) found that under bright sunlight conditions stage I and II larvae moved from the surface layer. Scarratt (1973) also found considerable numbers of stage I larvae in depths of 0.6-1.2 m on sunny days in the Gulf of St. Lawrence.

Most of our sampling in Buzzards Bay was done under sunny conditions, and it is therefore possible that early stage larvae were missed due to vertical migration in response to light levels. Our data do not cover enough light conditions, however, to draw any conclusions in this regard.

Another possible factor may be the longer duration of the fourth larval stage. Herrick (1896) indicated that stages I and II molted within 5 d and stage III molted in 2-8 d. Stage IV larvae, however, did not molt for 10-19 d and thus were exposed to capture for a longer period.

Surface drift may also result in dispersal of larvae. Scarratt (1964) suggested that the levels of stage I abundance reflected the location of the parent stock. Drift of the larvae could result in a different distribution of stage I relative to stage IV.

High catches of larval lobsters in this study frequently coincided with high catches of zoea and megalops stages of crabs. Similar results were noted by Templeman (1937). Larvae of the rock crab, *Cancer irroratus*, predominated, however larvae of green crab, *Carcinus maenas*, and lady crab, *Ovalipes ocellatus*, also were frequent components of the catch. Larvae of porcellanid crabs were abundant through much of July and into early August.

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The Spatio-Temporal Distribution of American Lobster, *Homarus americanus*, Larvae in the Cape Cod Canal and Approaches

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SALLY C. HUGHES,[2] and JAMES L. BUCKLEY[1]

ABSTRACT

The spatial and temporal distribution of larval lobsters in northern Buzzards Bay, the Cape Cod Canal, and southwestern Cape Cod Bay was examined during 1976-78. Hatching generally began in late May when bottom water temperatures approximated 10°C. Most larvae had settled out of the water column by mid-August, but larvae were occasionally collected as late as October. Larvae were concentrated at nearshore stations by onshore winds in Buzzards Bay and Cape Cod Bay. A higher percentage (71%) of the total larvae were collected when cloud cover was 25% or less. Larvae were collected in water ranging in temperature from 10.3° to 25.5°C. Salinities ranged from 23.3 to 35.5‰. Percent stage composition was comparable with that found in southern Buzzards Bay. The density of lobster larvae in the Cape Cod Canal was similar at all depths, but larvae were associated with the surface water layer in Buzzards Bay and Cape Cod Bay. In 1976, 1977, and 1978, an estimated 13.5, 26.0, and 9.2 million larvae, respectively, were deposited from the Cape Cod Canal into Cape Cod Bay.

INTRODUCTION

Preliminary larval lobster distribution studies carried out in Cape Cod Bay by the Massachusetts Division of Marine Fisheries prior to 1974, and intensive efforts by both the Division and a private contractor (Marine Research, Inc.) from 1974 to 1977, revealed few larvae in Cape Cod Bay. A large commercial fishery exists in Cape Cod Bay and concentrations of egg-bearing female lobsters are occasionally observed in the Cape Cod Canal and Buzzards Bay; accordingly the possible importance of larval transport to Cape Cod Bay and the effects of an additional fossil-fueled electrical generating station on the Cape Cod Canal were investigated. A 3-yr study of the spatial and temporal distribution of larval lobsters in northern Buzzards Bay, the Cape Cod Canal, and southwestern Cape Cod Bay was initiated in the spring of 1976.

STUDY AREA

Buzzards Bay is a marine embayment approximately 46 km long by 19 km wide (Fig. 1) with a maximum depth of 41 m and an average depth of 11 m (Anraku 1964; Gilbert et al.[3]). In upper Buzzards Bay, the salinity varies from 26.0 to 35.5‰ with surface water temperatures ranging from −1° to 28.0°C and bottom temperatures from −1° to 25°C (Collings et al.[4]).

Cape Cod Bay is a nearly circular embayment of the Atlantic Ocean with water depths reaching 91.5 m but with an average depth of 25 m (Parsons 1918; Anraku 1964). Surface salinities range between 29.0 and 36.0‰, and while surface water temperatures can exceed 20°C in the summer, bottom temperatures rarely exceed 15°C. Currents in both bays are weak, seldom exceeding 1.1 km/h (Collings et al. footnote 4).

The Cape Cod Canal is a sea level passage connecting Cape Cod Bay with Buzzards Bay. With a mean tidal range in Cape Cod Bay of 2.8 m and of 1.2 m in Buzzards Bay, the difference in phase and amplitude of the tides produce changes in the slope of the water in the Canal. Consequently, there is a regular reversal in current at approximately 6 h intervals. Currents have an average speed of 6.5 km/h in midchannel, but during spring tides increase to about 7.4 km/h (Anraku 1964). Surface salinity varies from 28.0 to 34.0‰ (Collings et al. footnote 4), and water temperatures range from −1° to 25°C. The lack of thermal stratification in the Canal is due to the strong currents and turbulence (Fairbanks et al.[5]).

METHODS AND MATERIALS

Neuston samples were collected at 7 stations during 1976, 16 in 1977, and 10 in 1978 (Fig. 2). Stations were sampled on a weekly basis from the first week in May until lobster larvae were no longer obtained in neuston samples. Factors that prevented sampling were rough seas and high concentrations of ctenophores (*Mnemiopsis leidyi*) or crab larvae.

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[1] Commonwealth Energy, Canal Electric Company, Cranberry Highway, Wareham, MA 02571.

[2] Massachusetts Division of Marine Fisheries, 100 Cambridge Street, Boston, MA 02202.

[3] Gilbert, T., A. Clay, and A. Barker. 1973. Site selection and study of ecological effects of disposal of dredged materials in Buzzards Bay, Massachusetts. Prepared for Department of the Army, New England Division, Corps of Engineers by New England Aquarium under Purchase Order No. DACW 33, 73-C-0024, 70 p.

[4] Collings, W. S., C. C. Sheehan, S. C. Hughes, and J. L. Buckley. 1981. The effects of power generation on some of the living marine resources of the Cape Cod Canal and approaches. Massachusetts Department of Fisheries, Wildlife, and Recreational Vehicles, Div. Mar. Fish., 100 Cambridge Street, Boston, Mass., 212 p. + appendices.

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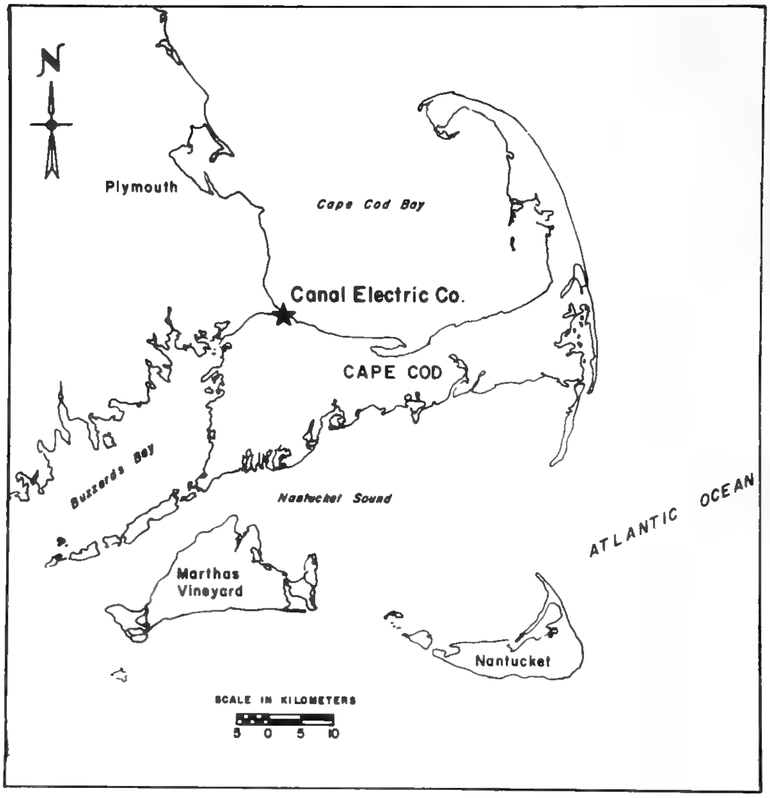
Figure 1.—Map of study area.



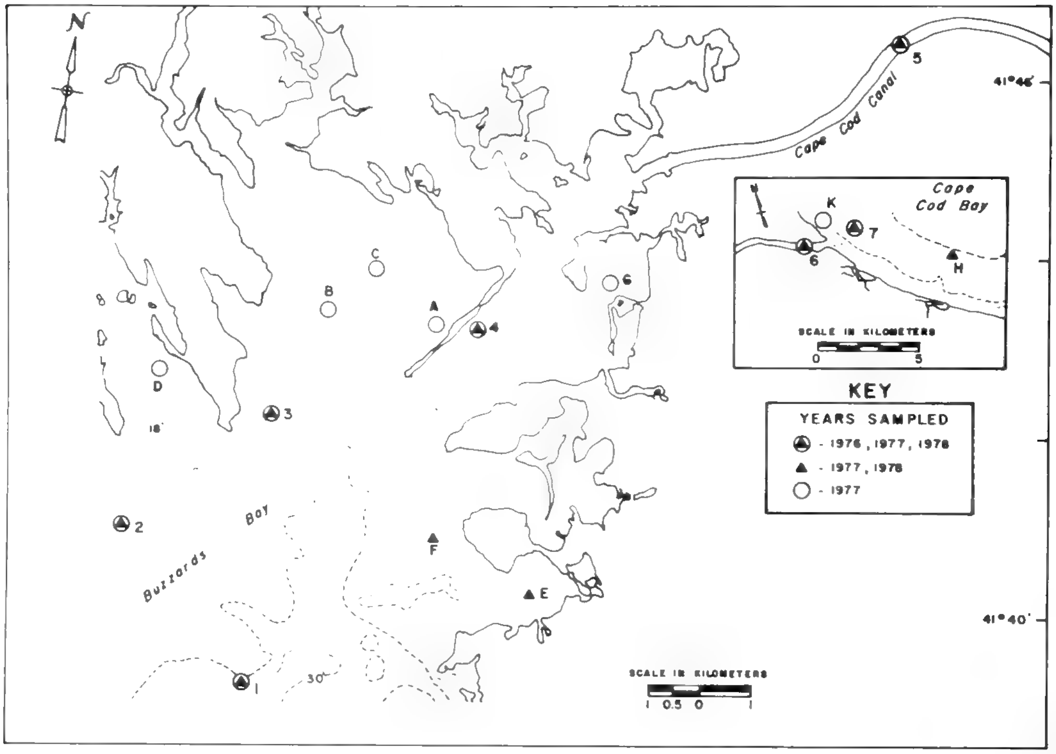


Figure 2.—Lobster larvae sampling locations, 1976-78.

Surface tows were made with a 1 × 2 m neuston net with a mesh size of 1.05 mm. All tows were made during daylight hours at a speed of 4.6-5.6 km/h with the top 20 cm of the net breaking the water surface. Tow duration was 30 min and volumetric measurements were calculated from flowmeter readings obtained from a General Oceanics[6] model S 2030 R flowmeter in the net mouth. The average volume of water strained per tow was 2,793 m³. This volume per tow decreased over the 3 yr as a result of high ctenophore and larval crab concentrations. The numbers of ctenophores and crab larvae increased rapidly and reached such high densities in 1976, it became impossible to tow for more than 5 min. By mid-August, sampling had to be terminated. While concentrations remained high enough in 1977 and 1978 to prevent full 30-min tows, shorter tows were possible at many stations.

A 1 × 1.5 m opening and closing Tucker trawl with 1.05 mm mesh similar in design to that described by Clark (1969) and Hopkins et al. (1973) was utilized for discrete depth sampling. The net was designed to be fished at a 45° wire angle, presenting an effective opening of 1 m². The net was towed at 5.6 km/h for 20 min.

After completion of a neuston or Tucker trawl tow, samples were washed into a pair of nesting sieves with mesh sizes of 1.05 mm and 6.35 mm. Sample concentrate was preserved in a 5% Formalin-95% seawater solution buffered with sodium borate ($Na_2B_4O_7 \bullet 10H_2O$). Samples were returned to the laboratory where all lobster larvae were removed and staged according to the descriptions of Herrick (1911).

RESULTS AND DISCUSSION

Neuston Tows

Four hundred fifty-nine tows were made during 1976-78; 9,631 larvae were collected for an average density of 9.9 larvae/1,000 m³ or water filtered (Table 1). The maximum number and density of larvae collected was 746 (266.2/1,000 m³) at Station F in Buzzards Bay on 21 June 1977. Mean annual densities were highest in Buzzards Bay during 1977 and 1978 and highest in the Cape Cod Canal during 1976 (Table 1). Highest mean density (12.8 larvae/1,000 m³) over all years was observed in Buzzards Bay.

Abundance and Temporal Distribution

Hatching in Buzzards Bay commenced during the third week in May and stage I larvae generally disappeared from the water column by mid-July. The peak of stage I abundance in mid-June corresponded to the peak of total larval abundance. An initial small peak of hatching was evident during the last week of May. This peak was consistently observed and may be due to earlier hatching of eggs extruded during summer; ova extruded during autumn appear to hatch later in the season (Perkins 1972). Second stage larvae first appeared in samples by the end of the third week in May and peaked in abundance in mid-June. Stage III larvae were usually found in samples by the first of June and peaked in mid-June. Fourth stage larvae were initially collected by the first week of June, peaked in abundance by 1 July, and could, as in 1978, continue to be collected into September.

Larval abundance patterns in the Cape Cod Canal were quite similar to those found in Buzzards Bay, although a bi-

Table 1.—Lobster larval tow data for three areas for 1976-78.

Area	Number of stations sampled	Total number of tows	Volume of water sampled (m³)	Number of tows with larvae	Average volume (m³)	Number larvae collected	Mean larval density (no./1,000 m³)
1978							
Buzzards Bay	5	90	154,858	40	2,561	1,563	10.1
Cape Cod Canal	3	58	115,972	30	2,686	430	3.7
Cape Cod Bay	2	34	69,085	17	2,442	115	1.7
	10	182	339,915	87	2,578	2,108	6.2
1977							
Buzzards Bay	10	103	257,264	68	2,714	4,035	15.9
Cape Cod Canal	3	50	88,272	23	2,883	654	7.4
Cape Cod Bay	3	36	84,988	23	2,717	672	7.9
	16	189	430,524	114	2,759	5,361	12.5
1976							
Buzzards Bay	3	31	80,137	15	3,343	687	8.6
Cape Cod Canal	3	43	90,353	22	3,170	1,428	15.8
Cape Cod Bay	1	14	35,468	8	3,698	47	1.3
	7	88	205,958	45	3,314	2,162	10.5
All years							
Buzzards Bay	10	224	492,259	123	2,739	6,285	12.8
Cape Cod Canal	3	151	294,597	75	2,889	2,512	8.5
Cape Cod Bay	3	84	189,541	49	2,769	834	4.4
	16	459	976,397	247	2,793	9,631	9.9

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

modal peak of stage I abundance was not as evident as in Buzzards Bay. The period of exact hatching in the Canal was possibly masked by advection of Buzzards Bay larvae into the Canal with reversal of the tidal cycle.

Cape Cod Bay larval abundance patterns were similar to those of Buzzards Bay, but occurred several weeks later. Stage I abundance was greatest by the last week of June and stages II, III, and IV were not collected until the second week of June. Larval occurrence extended into September in Cape Cod Bay and stage III and IV larvae were collected as late as October.

Percent stage composition of larval catches varied both annually and geographically (Table 2). We noted an increased percentage of fourth stage larvae over the 3-yr study period. Similar patterns in stage IV abundance during 1976-78 were noted by Bibb et al. (1983) and Lux et al. (1983). Ctenophore abundance was relatively high in 1976 and subsequently decreased over the next 2 yr. Lund and Stewart (1970) found that when ctenophore densities peaked, samples were almost devoid of fish or crustacean larvae.

The number of lobster larvae collected is dependent, in part, on the number of ovigerous females within the area. The mean carapace lengths (CL) of ovigerous females in Buzzards Bay and Cape Cod Bay were 81 mm and 97 mm, respectively, (Fair[7]) and the proportion of ovigerous females in research trap catches was higher in Buzzards Bay. Ovigerous females composed up to 14% of the catch in Buzzards Bay but < 1.0% in Cape Cod Bay. Higher larval densities in Buzzards Bay may reflect higher spawning stock levels. Templeman (1936a) suggested that the American lobster attains maturity at a size which varies inversely with temperature. Aiken and Waddy (1976) stated that female lobsters matured at a smaller size in the warmer Gulf of St. Lawrence than off southern Nova Scotia.

Effects of Surface Currents on Spatial Distribution

During the months of May-September, winds in the study area were generally southwest and monthly average speeds ranged from 17.7 to 24.1 km/h (11-15 mph) (U.S. Army Corps of Engineers[8]). Scarratt (1973) noted that winds in excess of 24.1-29.0 km/h (15-18 mph) tend to prevent efficient sampling. Our sampling trips were rescheduled if strong winds were forecast; exposed stations were not sampled if winds increased appreciably during any sampling day.

Wind records for the 24-h period prior to sampling revealed that 68.0% of all tows and 76.4% of the tows containing larvae in Buzzards Bay were made when winds were from the southwest. A total of 85.2% of the larvae was found in samples collected when winds were onshore.

In Cape Cod Bay, 72% of all tows and 73% of all tows containing larvae were made when winds were from the southwest quadrant, however, only 39% of the larvae were collected during offshore winds. When winds were from the northeast-northwest (on or alongshore) 56.8% of the larvae collected in Cape Cod Bay were obtained in 10 tows.

Throughout 1976, the continued occurrence of stage I larvae at Stations 3 and 5 suggests that these sites were primary hatching areas. Large numbers of late stage larvae collected at Stations 1, 2, E, and G were possibly due to larval trans-

Table 2.—Percent stage composition of lobster larvae for three areas for 1976-78.

Area	Stage I No.	Stage I Percent	Stage II No.	Stage II Percent	Stage III No.	Stage III Percent	Stage I No.	Stage I Percent	All stages
1978									
Buzzards Bay	575	36.8	237	15.2	233	14.9	518	33.1	1,563
Cape Cod Canal	207	48.1	44	10.2	69	16.0	110	25.6	430
Cape Cod Bay	60	52.2	6	5.2	11	9.6	38	33.0	115
	842	39.9	287	13.6	313	14.8	666	31.6	2,108
1977									
Buzzards Bay	1,161	28.8	888	22.0	1,040	25.8	946	23.4	4,035
Cape Cod Canal	310	47.4	89	13.6	60	9.2	195	29.8	654
Cape Cod Bay	544	81.0	30	4.5	23	3.4	75	11.2	672
	2,015	37.6	1,007	18.8	1,123	20.9	1,216	22.7	5,361
1976									
Buzzards Bay	389	56.6	110	16.0	123	17.9	65	9.5	687
Cape Cod Canal	498	34.9	308	21.6	477	33.4	145	10.2	1,428
Cape Cod Bay	32	68.1	1	2.1	3	6.4	11	23.4	47
	919	42.5	419	19.4	603	27.9	221	10.2	2,162
All years									
Buzzards Bay	2,125	33.8	1,235	19.6	1,396	22.2	1,529	24.3	6,285
Cape Cod Canal	1,015	40.4	441	17.6	606	24.1	450	17.9	2,512
Cape Cod Bay	636	76.2	37	4.4	37	4.4	124	14.9	834
	3,776	39.2	1,713	17.8	2,039	21.2	2,103	21.8	9,631

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[7] James J. Fair, Assistant Director, Massachusetts Division of Marine Fisheries, 100 Cambridge Street, Boston, MA 02202, pers. commun. 4 September 1978.

[8] U.S. Army Corps of Engineers Division, New England. 1973. Final environmental statement, addition of Unit No. 2, Canal Plant. 2.1, 12 p. U.S. Army Corps of Engineers, Trapello Road, Waltham, Mass.

port caused by wind driven currents and generally counterclockwise tidal currents in Buzzards Bay (Anraku 1964). The presence of both stage I and stage IV larvae at Station K was an indication of hatching in the vicinity of the entrance of the Canal and possible recruitment of larvae from an area north of the Canal.

It appeared that onshore winds concentrated lobster larvae at nearshore stations. This was substantiated by the higher densities of late stage larvae found in northern Buzzards Bay following southwest winds and at nearshore stations in Cape Cod Bay following northeast winds.

Effects of Cloud Cover

A total of 65.7% of our tows was made when cloud cover was 25% or less and 71% of the total larvae were collected when cloud cover was minimal (25% or less). The average density of larvae collected under clear skies, hazy, 25% cover, 50% cover, and 75% cover was 7.3, 8.2, 7.1, 10.5, and 8.4 larvae/1,000 m^3, respectively. Under completely overcast conditions, the average density decreased dramatically (2.8 larvae/1,000 m^3). Only 6.4% of the larvae collected were obtained when cloud cover was 100%.

Water Temperature, Larval Hatching, and Intermolt Periods

Stage I larvae were collected in Buzzards Bay waters ranging in temperature from 14.0° to 25.0°C. Stages II, III, and IV were collected at temperatures ranging from 16.5° to 25.5°C. Larvae collected in the Cape Cod Canal were found in water ranging in temperature from 12.5° to 23.5°C. First stage larvae were collected at 12.5°-22.0°C, second stage were collected at 14.5°-22.5°C, third stage at 16.5°-22.5°C, and fourth stage in temperatures ranging from 17.0° to 23.5°C. Larvae were collected in Cape Cod Bay at the following surface water temperatures: Stage I, 10.3°-21.1°C, stage II, 14.0°-20.0°C, stage III, 14.0°-20.0°C, and stage IV, 14.5°-20.5°C. The highest water temperature at which larvae were collected was 25.5°C and the lowest water temperature recorded when larvae were collected was 10.3°C.

Estimated average larval intermolt period was determined from the number of days between initial collection of a given stage and first collection of the succeeding stage. Buzzards Bay larvae took an average of 23.2 d to molt from stage I into stage IV in water temperatures ranging from 14.0° to 22.0°C. Templeman (1936b) reported development times of 11-26.5 d for larvae to molt into stage IV at this temperature range. Cape Cod Canal larvae required an average of 25 d to reach stage IV at temperatures ranging from 12.5° to 22.5°C. Based on Templeman's data it would take 10.5-78 d for larvae to complete their third molt when held at these temperatures. Cape Cod Bay larvae averaged 35 d to molt into stage IV at 10.3°-20°C; predicted development times under laboratory conditions were 12-49 d (Templeman 1936b).

Salinity

Observed salinities of 23.3 to 35.5°/₀₀ were within the tolerance range of < 20°/₀₀ to 42.5°/₀₀ (Templeman 1936b; Scarratt and Raine 1967; McLeese 1956).

Discrete Depth Sampling

Sixty-six discrete depth tows were made at nine stations in 1977. Four depths (surface, 3, 6, and 9 m) were sampled. A two-way analysis of variance (ANOVA) (Snedecor and Cochran 1967) was performed on data grouped into two categories: Canal stations (4, 5, and 6) and open water stations (Stations 1, 2, 3, F, H, and K). Results showed that at the Canal stations there was no significant difference with depth at the 5% level ($F = 1.04$; df = 3, 9); the probability of capturing larvae was uniform at all depths due to mixing in the Canal (Collings et al. footnote 4). However, at open water stations, significantly higher surface densities were obtained ($F = 6.74$; df = 3, 9; $P < 0.05$).

Scarratt (1973) reported significatly higher catch rates for stage I larvae in surface waters. Bibb et al. (1983) obtained similar results in Block Island Sound in 1977 and 1978.

Larval Deposition in Cape Cod Bay

Tidal patterns in the study area result in transport of significant numbers of larvae hatched in Buzzards Bay and the Cape Cod Canal into Cape Cod Bay. It was conservatively estimated that canal water flows into Cape Cod Bay for 3 h per tidal cycle at a rate of 2,095.4 m^3/s. The average Cape Cod Canal larval density for each year was multiplied by the total volume of water flowing into Cape Cod Bay during each larval season. Estimates of the numbers of larvae entering Cape Cod Bay for the years 1976, 1977, and 1978 were 13.5 million, 26.0 million, and 9.2 million, respectively.

Matthiessen and Scherer (1983) calculated that approximately 7.3 million larvae were deposited in Cape Cod Bay during the period 7-20 June 1976. Our estimate for the same period was 9.2 million larvae.

ACKNOWLEDGMENTS

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Observations on the Seasonal Occurrence, Abundance, and Distribution of Larval Lobsters (*Homarus americanus*) in Cape Cod Bay

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ABSTRACT

The seasonal occurrence, abundance, and distribution of the larvae of the American lobster, *Homarus americanus*, in Cape Cod Bay were studied over a 3-yr period (1974-76). Although larvae were observed during the months of May-September, the great majority were found to occur during June, July, and August. In the neuston net collections, mean larval densities for these 3 mo averaged 3.1, 3.2, and 1.6 larvae/1,000 m^3, respectively. However, densities as high as 62.3 larvae/1,000 m^3 were observed in Tucker net collections near the east end of Cape Cod Canal.

The seasonal occurrence, pattern of distribution, and relative abundance of first-stage larvae near the east end of Cape Cod Canal during June suggest the likelihood that the Canal may contribute significant numbers of larvae to Cape Cod Bay.

INTRODUCTION

Despite the economic significance of the lobster (*Homarus americanus*) fishery in New England, very little is known of the origin and dispersal of larval lobsters and therefore of the primary sources of recruitment to localized stocks.

The increasing number of electric generating plants along the New England coast prompted a series of investigations of the seasonal abundance and distribution of larval lobsters during the 1970's. The primary objective of many of these investigations was to estimate the potential losses of larvae resulting from their entrainment in the power plant's cooling water, the relationship of the numbers of entrained larvae to the population as a whole, and the resultant potential impact upon the local or regional fishery.

The Pilgrim Nuclear Power Station, located in Plymouth, Mass., on the west side of Cape Cod Bay, draws its cooling water from an area that supports a valuable and intensive lobster fishery. The investigation described in this report was initiated to compare the numbers of larvae occurring in the vicinity of the station, and therefore potentially vulnerable to entrainment, with larval abundance in other areas of Cape Cod Bay, and to determine the seasonal occurrence and duration of the larval period in this area.

METHODS

Surface Sampling

Larval lobster were sampled at Stations I-VIII (Fig. 1) biweekly from 20 June through 19 August in 1974; weekly at Stations I-VIII from 5 June through 8 October in 1975; and weekly at Stations I-X from 4 May through 1 September 1976.

Sampling gear consisted of a 1 mm mesh neuston net measuring 1 m × 2 m at the mouth and 10 m in length. The top edge of the net was held just above the surface by large floats. Tows were made at 4-5.5 km/h for approximately 30 min off the side of 12 m (1975 and 1976) and 20 m (1974) vessels. Filtration volumes, estimated with a General Oceanics 2030[2] flowmeter mounted in the mouth of the net, averaged about 3,000 m^3/tow. Surface temperature and salinity were recorded at each station using a Beckman RS5-3 salinometer.

In 1974 duplicate tows were made irregularly at various stations as time and weather permitted. Single tows were taken at each station in 1975. In 1976 two vessels were used, towing in parallel, to collect duplicate tows at each station.

Vertical Sampling

In 1976 samples were taken at 0, 3, 6, 9, and 12 m (near bottom) at Station A located just off the easterly end of Cape Cod Canal (Fig. 1). Samples were taken on easterly tides by holding position into the current which averages about 6.5 or 7.4 km/h on spring tides (Anraku 1964). One sample was taken at each depth during daylight, and in most cases during darkness within the same 12-h period, on a weekly basis 7 June through 8 July.

Gear consisted of a messenger-operated 1 mm mesh Tucker net (Tucker 1951; Clarke 1969) with a mouth measuring 2 m × 2 m. Filtration volumes averaged 3,000-4,000 m^3.

All samples were preserved in 10% Formalin and returned to the laboratory for analysis. Lobster larvae were enumerated and staged following Herrick (1911).

RESULTS

Seasonal Occurrence and Distribution

During the 1974-76 sampling seasons, lobster larvae were found in Cape Cod Bay as early as 11 May (1976) and as late as 28 September (1975). Stage I larvae were found from 11 May

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[1] Marine Research, Inc., 141 Falmouth Heights Road, Falmouth, MA 02540.

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

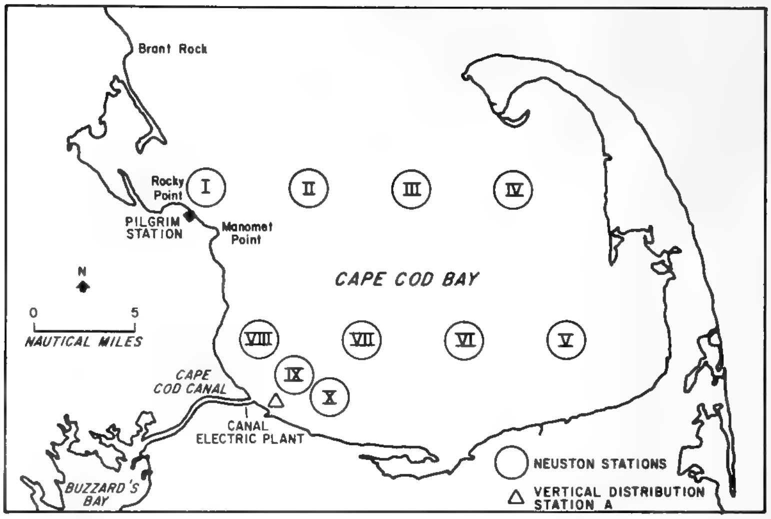

Figure 1.—Lobster larvae stations in Cape Cod Bay sampled in 1974-75 (Stations I-VIII) and 1976 (Stations I-X, vertical distribution Station A).

(1976) to 2 September (1976), stage II larvae from 3 June (1976) to 2 September (1976), stage III larvae from 3 June (1976) to 17 September (1975), and stage IV larvae from 18 June (1976) to 28 September (1975). Larvae were most abundant during the months of June, July, and August (Table 1). Surface water temperatures recorded when larvae were collected ranged between 10.5°C (May 1976) and 21.4°C (July 1974).

Early in the season, highest concentrations of lobster larvae were found in the southern section of Cape Cod Bay (Table 2). A highly significant difference ($P<0.01$) was found between mean densities at stations I-IV and stations V-VIII (X) over all June sampling dates based on a Mann-Whitney U test (Zar 1974). No significant difference ($P>0.05$) was detected for the months of July and August. Although collections were made in May of 1976, few larvae were taken during that period (Table 1). Those that were collected were found in both northern and southern areas of the Bay. Small numbers of larvae were also taken in September 1975 (Table 1); most were found in the northern section of the Bay.

Table 1.—Cape Cod Bay larval lobster collections by month, 1974-76.

Month	Year(s) sampled	Number of tows	Total larvae	Mean number of larvae per 1,000 m³	SD
May	1976	62	61	0.30	0.83
June	1974-76	142	2,005	3.68	5.67
July	1974-76	147	2,340	3.82	4.86
Aug.	1974-76	141	735	1.65	2.84
Sept.	1975, 1976	52	28	0.17	0.26

Table 2.—Mean larval lobster densities, per 1,000 m³ of water, over Stations I-IV (northern section) and V-VIII (or X in 1976) (southern section) by month and year.

		1974[1]			1975			1976		
	Stations	n[2]	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	s
June	I-IV	4	0.82	0.69	16	2.82	2.73	20	1.78	2.08
	V-VIII(X)	2	1.53	0.38	16	6.14	9.80	30	4.80	6.33
July	I-IV	8	2.60	2.09	20	1.09	2.30	16	7.10	5.95
	V-VIII(X)	8	2.39	1.93	20	2.66	5.16	30	3.85	4.30
Aug.	I-IV	8	0.87	0.90	16	1.17	1.82	16	1.55	1.79
	V-VIII(X)	8	1.01	0.81	16	2.31	3.29	24	2.03	3.54

[1] Although included, little data were available for June 1974 since sampling did not begin until 20 June and Stations VII and VIII were not sampled until July.

[2] n = number of samples not including replicate tows which were averaged within dates for each station.

Annual Variations in Abundance

Average larval densities were compared by month for each year, 1974-76, to determine if any clear differences in abundance occurred between years. To make this comparison more valid, stations IX and X, sampled only in 1976, were excluded. Comparisons were based on unadjusted mean densities and on mean densities calculated after dividing each density estimate by the temperature-related stage duration for each larval stage obtained from Templeman (1936). Both the unadjusted and adjusted mean densities suggested that larvae were less abundant in 1974 than in 1975 and 1976 (Table 3). The differences

Table 3.—Mean monthly densities of lobster larvae, per 1,000 m³ of water, over Stations I-VIII, for June, July, and August, 1974-76. Mean densities are also shown based on data adjusted for variations in stage duration (see text). Between-station standard deviation in parentheses.

		Month			
Year		June	July	August	June-August
1974	No. sampling periods	1	2	2	5
	Mean/1,000 m³	1.1(0.7)	2.4(1.4)	0.9(0.6)	1.5(1.2)
	Adjusted mean	0.2(0.1)	0.6(0.3)	0.1(0.04)	0.3(0.3)
1975	No. sampling periods	4	5	4	13
	Mean/1,000 m³	4.5(4.2)	1.9(1.3)	1.9(1.0)	2.7(2.8)
	Adjusted mean	0.8(0.6)	0.4(0.3)	0.3(0.2)	0.4(0.4)
1976	No. sampling periods	5	5	5	15
	Mean/1,000 m³	3.3(2.5)	5.8(3.6)	1.3(0.9)	3.5(3.1)
	Adjusted mean	0.5(0.4)	1.2(0.8)	0.3(0.2)	0.7(0.7)

may be exaggerated, however, by the fact that the Bay was sampled only once in June of 1974.

Distribution by Larval Stage

During the early part of the larval season, in both 1975 and 1976 the distribution of larval lobster in Cape Cod Bay appeared to be related to stage of development. Not only the highest densities of larvae but also the highest percentage of stage I larvae were found in the southwest section of the Bay (Fig. 2). A great percentage of larvae collected in the northwest section (Station I) early in the season were also stage I larvae; however, the numbers collected were low in comparison with the southwest collections.

No consistent distributional pattern could be detected among total larvae densities in July and August of each year. No pattern was apparent among stage II or stage IV larvae during these months. In 1974, stage III larvae were most abundant at Station IV on each sampling date of July and August except the last (19 August) when this station ranked second. In 1975 and 1976, however, no pattern among stage III larvae was apparent.

Paired Tows

During 1976, when two vessels, towing in parallel, collected simultaneous neuston samples at each station, a total of 164 paired samples were collected. The mean number of larvae per individual tow was 3.11/1,000 m^3, with a standard deviation of 5.21. The mean of the variation between tows was 1.44/1,000 m^3, with a standard deviation of 2.28. Comparing the catch of the two vessels by means of a Wilcoxon paired sample test indicated that no significant difference ($P>0.05$) occurred.

Vertical Distribution

Results of vertical sampling at the easterly end of Cape Cod Canal from 7 June to 8 July 1976 indicated that highest concentrations of larvae were generally found at a depth of 3 m (Table 4). An analysis of these data using Friedman's test (Zar 1974) indicated a highly significant difference ($P<0.01$) between depths of collection.

The data also indicate that the highest concentrations of larvae tend to occur during periods of darkness (Table 4). However, when the data for dates which included both day and night (1 h after sunset to 1 h before sunrise) sampling within a 24-h period were analyzed using the Mann-Whitney U test (Zar 1974), the results indicated no significant difference in larval density occurred between day and night.

Approximately 96% of the larvae captured in the Tucker net were stage I. This is consistent with the June 1976 data for the nearby neuston stations (Stations VIII, IX, and X) (Fig. 2).

DISCUSSION

It was concluded on the basis of 10 yr of records maintained at the Massachusetts State Lobster Hatchery that hatching of *Homarus americanus* eggs usually begins when water temperatures have risen to 15°C and is most intensive when temperatures approximate 20°C (Hughes and Matthiessen 1962). The lowest temperature at which hatching was recorded during 1951-61 was 12.2°C.[3] The occurrence of stage III and IV larvae in the 20 June 1974 collections was therefore somewhat surprising in relation to both the Massachusetts State Lobster Hatchery data and observations by Sherman and Lewis (1967) and Lund and Stewart (1970) relative to the onset of hatching at 13.7°-15.0°C and 14.0°C in Maine and Connecticut, respectively. Surface water temperatures averaged 16.1°C on 20 June 1974. At this temperature, the time required to reach the third and fourth larval stages is approximately 10 and 20 d, respectively (Templeman 1936). Bottom water temperatures in Cape Cod Bay 14 d prior to 20 June averaged only 7.7°C (based on 51 ichthyoplankton stations).[4]

In 1975 high concentrations of larvae were found in the collections on the first sampling date (5 June), primarily in the southwest sector of the Bay (Fig. 2). Although the great majority of these were stage I larvae (Fig. 2), bottom water temperatures in Cape Cod Bay at this time, gathered at 18 ichthyoplankton stations on 3-4 June (MRI[5]), averaged only 9°C. Despite these low temperatures, it was evident from the large numbers of stage I larvae, and moderate numbers of stage II, in the collections that hatching must have been well underway by 1 June.

Cape Cod Canal water temperature records maintained by the New England Gas and Electric Generating Station in Sandwich, Mass., indicate that water temperatures may vary by 5°C or more in the Canal during a tidal cycle, depending upon whether the water originates from Cape Cod Bay or from the much warmer Buzzards Bay. Stations IX and X and the Tucker net sampling station were added in 1976 for the purpose of establishing whether the large number of larvae found in the southwest area of the Bay in early June samples might originate from Cape Cod Canal, or perhaps Buzzards Bay, where temperatures at that time would be more conducive to hatching.

The June distribution of larvae in the Bay at Stations I-IX (Fig. 2) and the abundance of larvae at vertical sampling station A in 1976 (Table 4) raises the possibility that Cape Cod Canal may contribute large numbers of larvae during June. Data reported by the U.S. Army Corps of Engineers (1973) indicated that water enters Cape Cod Bay via Cape Cod Canal at an average rate of 2,060 m^3/s during an easterly tide, and that most of this water does not return to the Canal during the ebbing (westerly) tide. It is estimated, therefore, that an average of 95.8×10^6 m^3 of water flows into Cape Cod Bay from the Canal each day.

For the period 7-30 June 1976 the mean density of larvae in the water column at the mouth of the Canal was computed for each day of Tucker net sampling. Densities for replicate or day/night tows taken during the same 24-h period were averaged. The total number entering the Bay each sampling day was then estimated by multiplying mean larval density by daily flow. By plotting the numbers of larvae introduced into Cape Cod Bay on each sampling day against time, and computing

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[3] This information, in fact, was the basis for the decision not to initiate the 1974 sampling program until the latter part of June since the data collected during previous ichthyoplankton surveys of the Bay (MRI 1974; see footnote 4) indicated temperatures of Cape Cod Bay rarely exceeded 15°C before this time.

[4] MRI (Marine Research, Inc.). 1974. Cape Cod Bay Study Quarterly Progress Report, March-May 1974. 6 p. + appendix.

[5] MRI (Marine Research, Inc.). 1975. Cape Cod Bay Study Quarterly Progress Report, June-August 1975. 7 p. + appendix.

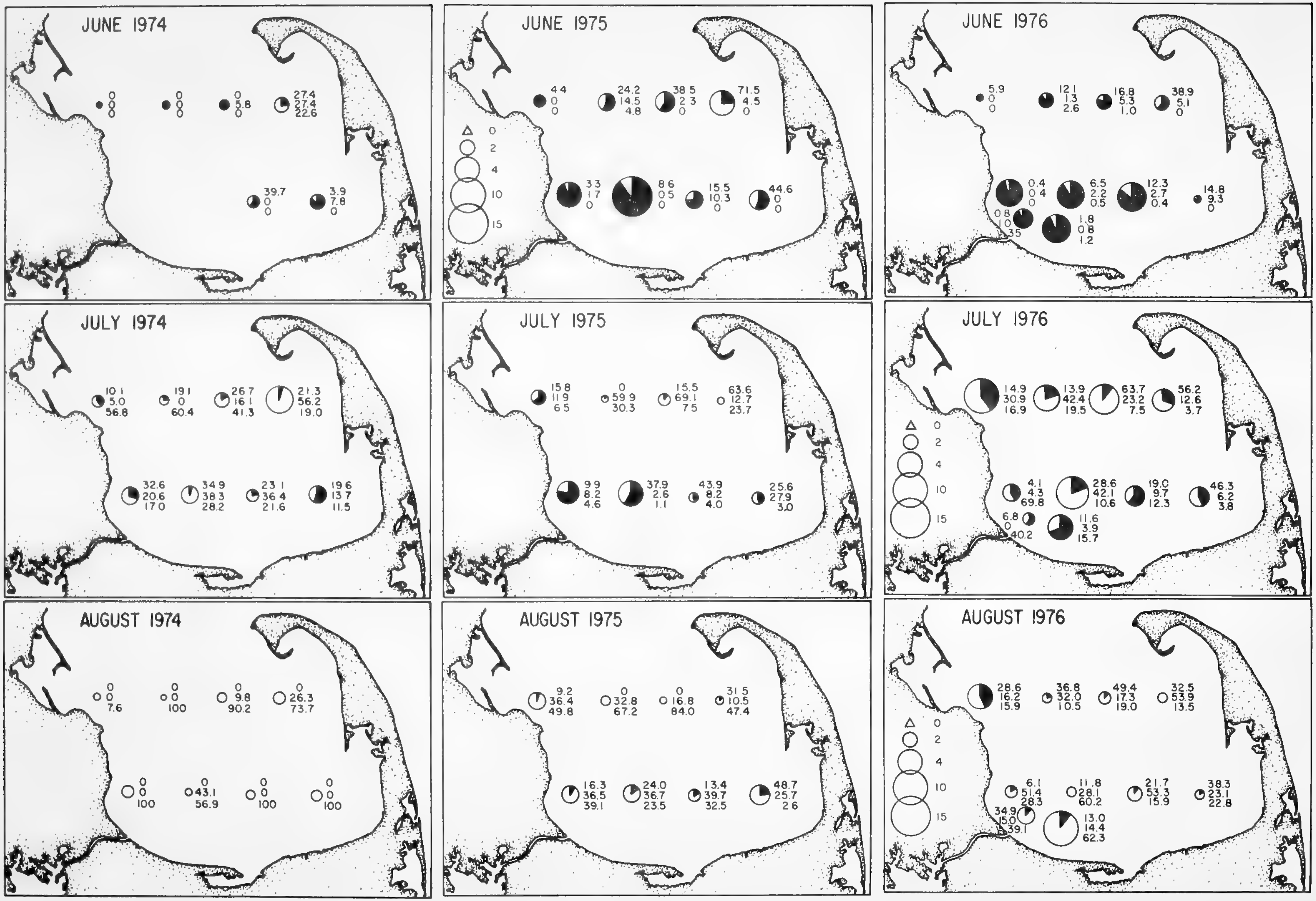

Figure 2.—Distribution of mean monthly larval lobster densities, per 1,000 m^3 of water, by station in Cape Cod Bay, 1974-76. Dark areas within each circle represent percent of the mean represented by stage I larvae. Numbers beside each circle indicate (from top to bottom) the percent stage II, III, and IV larvae.

Table 4.—Lobster larvae densities (number per 1,000 m³) in vertically stratified Tucker net samples.

Date	Time	Surface	Depth (m) 3	6	9	12	Mean
7 June	1437-1700	0	1.6	0	0	0	0.32
8 June	0055-0240	0.73	4.0	0.43	0	0	1.03
	0310-0500	9.99	27.13	12.30	2.36	3.01	10.96
10 June	1605-1750	0.34	0	0	0	0	0.07
	1810-2000	0.40	0.62	1.74	1.55	0.50	0.96
11 June	0425-0615	0.56	2.69	0.33	1.24	0	0.96
	0715-0850	0.84	18.50	0	0	0	3.87
19 June	2345-0100	49.49	62.29	10.88	0	0.93	24.72
	0135-0355	1.17	2.16	0.81	0.59	1.09	1.16
	1105-1240	0	0.87	0.41	3.30	0.33	0.98
	1330-1515	0	2.72	5.09	1.90	0.93	2.13
23 June	0215-0410	0	0.55	0.47	0.91	0.48	0.48
	0458-0645	2.27	7.95	2.71	3.35	2.21	3.70
	1430-1635	0.42	0	0.41	0	0	0.42
	1700-1835	0	0	0	0	0	0
30 June	0720-1020	0.76	0.79	0	1.03	0	0.52
	1050-1230	0.35	5.49	1.54	2.72	1.01	2.22
	1940-2135	0	0	0	0	0	0
	2155-2345	3.11	5.26	2.76	1.90	0	2.61
7 July	1355-1538	0	0.32	0.34	0	0	0.13
	1605-1740	0	0	0	0.73	0	0.15
8 July	0115-0255	0	0	0	0	0	0
	0320-0505	0	0	0	0	0	0
Mean		3.06	6.21	1.75	0.94	0.46	
SD		10.34	13.87	3.35	1.12	0.79	

the area under the curve by trapezoidal integration, it was estimated that approximately 7.3 million larvae entered the Bay from the Canal during this 24-d period alone.

Although the fate of these larvae upon entering the Bay is unknown, information on the hydrography of Cape Cod Bay combined with the available field data for 1974-76 suggest the possibility that many of these larvae entering from the Canal may eventually settle in the area of Provincetown or perhaps pass out of the Bay completely before terminating their pelagic period. Drift bottle studies described by Bigelow (1924) indicate a counterclockwise direction to the Bay surface currents, which, according to Ayers (1956), have an average speed of 1.9 n.mi./d. At this rate, it might require a period of 10 d for stage I larvae originating at the Canal mouth to arrive in the area of Provincetown. Although the duration of the larval period varies strongly and inversely with temperature (Templeman 1936; Hughes and Matthiessen 1962), the fact that 22 d may be required for a newly hatched larva to attain stage IV at 15 °C (Sherman and Lewis 1967) indicates that most of these larvae would not have settled out prior to reaching Provincetown.

Assuming a counterclockwise drift of the larvae, their projected path from the Canal mouth should pass near Stations VI and then IV prior to passage from the Bay or settlement in the vicinity of Provincetown. This route is suggested by the data in Figure 2 for 1975 and 1976, during which the percentage of stage I larvae in the samples steadily dropped in a northeasterly direction, i.e., between Stations X and VI and between Stations VI and IV. This might explain why stage III larvae were most abundant at Station IV in 1974.

There is some evidence from the 1976 data that a counterclockwise current as described by Bigelow (1924) may also serve to transport larvae from the northwest section of the Bay (Station I) into the southwest sector, notably during the month of July. Large concentrations of early stage larvae found at Station I in 1976 were followed by high concentrations of larvae of later stages at Station VII later during the month (Fig. 2).

The observed vertical distribution of larvae near the mouth of Cape Cod Canal is interesting since most previous efforts to sample larvae have generally relied upon neuston nets in the belief that larvae tend to concentrate at the surface (Lund and Stewart 1970; Scarratt 1973). We suspect, however, that the strong turbulence apparently characteristic of Cape Cod Canal may influence the vertical distribution of the larvae in this area.

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Distribution and Abundance of Larval American Lobsters, *Homarus americanus* Milne-Edwards, in the Western Inshore Region of Cape Cod Bay, Massachusetts

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ABSTRACT

Larval lobster (*Homarus americanus*) abundance and distribution in the western inshore region of Cape Cod Bay, Mass., from 1974 to 1977 are reported. Lobster hatching generally began in mid-June, and the period of larval occurrence ranged from 46 to 62 d over the time and area studied. Maximum densities of larvae were collected in surface waters in July. Considerably more stage IV than stage I larvae were collected. Densities of lobster larvae were similar to levels obtained in several other New England investigations with the notable exception of Buzzards Bay where hatching was substantially greater.

INTRODUCTION

The American lobster, *Homarus americanus* Milne-Edwards, is the most valuable commercial resource harvested in Massachusett's territorial waters. An intensive lobster fishery occurs off Plymouth (Fig. 1) from March to November. The lobster catch reported for Plymouth County amounted to 348 t and was valued at $1.1 million in 1974 (Beals and Phelan[4]). By 1980, landings increased to 918 t, valued at $4.0 million (Anderson et al.[5]).

Inshore lobstering in Plymouth is concentrated within a 5.6 km radius of Pilgrim Nuclear Power Station, located on the western shore of Cape Cod Bay (Fig. 1). Because of the economic value and proximity of this fishery to the power plant and lack of information on site-specific larval ecology, the Massachusetts Division of Marine Fisheries examined the temporal and spatial distribution of lobster larvae from 1974 to 1977. This undertaking was part of an overall ecological investigation to determine plant-related impact on marine resources in Cape Cod Bay.

Our objectives were to determine location of hatching areas, density, and distribution of lobster larvae in the vicinity of the power plant. Work conducted in 1974 was preliminary. We expanded our inquiry in 1975 to investigate effects of wind on larval distribution and to examine the occurrence and density of larvae in shallow water. In 1976, we increased sampling frequency and concentrated efforts from Rocky Point northward to Brant Rock (Fig. 1). Our intent in 1977 was to obtain information on distribution of larvae at depth and further definition of hatching and nursery areas.

METHODS

Study Area

Cape Cod Bay, located at the southern extremity of the Gulf of Maine, is a broad open water body bounded by the landform of the eastward and northward extension of Cape Cod. The substrate in the overall study area, which included stations from Brant Rock to Scorton Ledge (Fig. 1), is primarily smooth sand interrupted by submerged ledges. This habitat may support high lobster densities (Cobb 1971).

Hatching, distribution, and density of larvae are influenced by an interaction of water temperature, salinity, and current patterns. Annual surface and bottom water temperatures generally range from −1 °C in February to 23 °C in August and from −1 °C in February to 21 °C in September, respectively (Lawton et al.[6]). The water column is stratified from June to November with a thermocline evident between 5 and 10 m (Doret et al.[7]). Surface salinities, ranging primarily from 28 to 35‰, are influenced by both the ocean and, to a lesser degree, drainage from watersheds. The overall water move-

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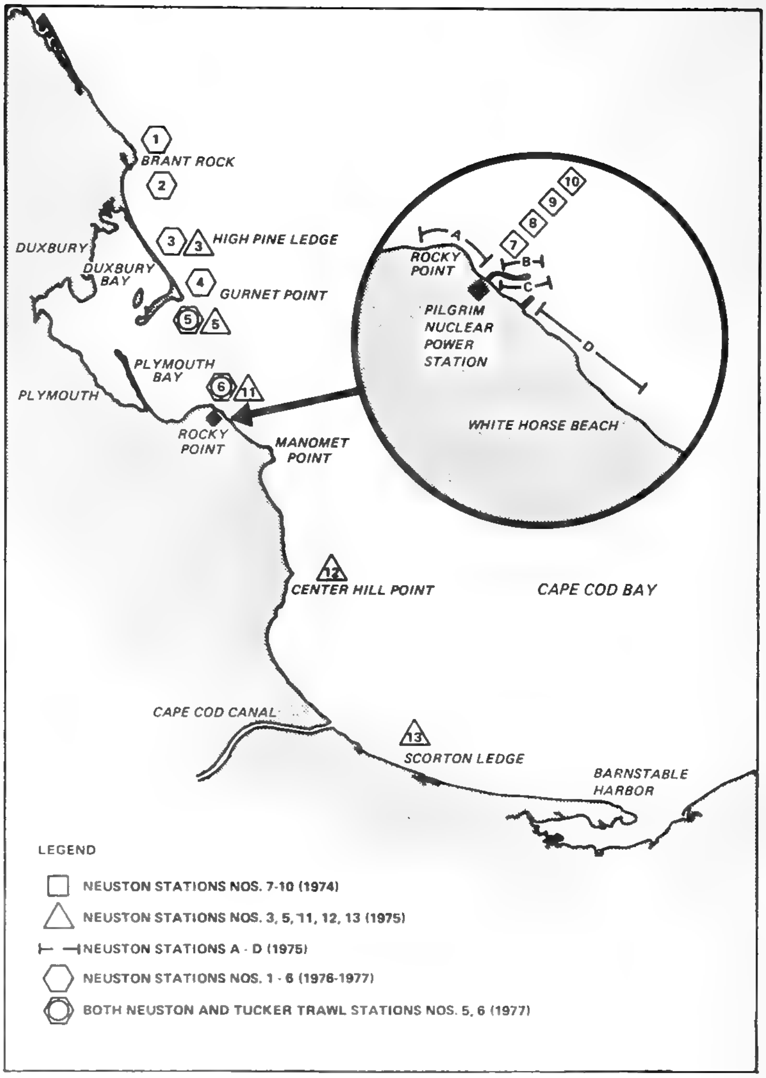

Figure 1.—Lobster larvae sampling stations in western Cape Cod Bay, 1974-77.

ment in Cape Cod Bay is a result of geostrophic, tidal, and longshore currents which have a net effect of producing a flow parallel to the coast toward the southeast (E G and G Environmental Consultants[8]). Movement of surface water nearshore is most influenced by wind-induced currents which are variable in direction (O'Hagan[9]).

Sampling Gear Specifications and Procedures

Division of Marine Fisheries research vessels, RV *F.C. Wilbour* and RV *J.J. Sullivan*, were employed for surface towing. Sampling gear consisted of a 1 m × 2 m neuston net, approximately 3 m in length and constructed of 1.05 mm nylon mesh. Net frame was constructed of 12.7 mm steel rod with four floats for buoyancy. Based on knowledge of diurnal lobster larvae distribution (Templeman and Tibbo 1945), we sampled only in the daytime and primarily at the surface from 1974 to 1977. In 1975, we also conducted surface tows at shoal stations employing two 1 m × 1 m neuston nets. These were suspended amidships from a horizontal boom on each side of a 5.5 m skiff to avoid propeller wash.

A General Oceanics Model S 2030 R flowmeter[10] attached to the mouth of the neuston net was used to determine the volumes of water sampled (Table 1). Overall, surface collections averaged 3,522 m^3 of water sampled per tow. We towed the neuston net breaking the water's surface. The vessel was maneuvered to keep the net out of the propeller wash.

In 1977, we conducted subsurface tows aboard the *F.C. Wilbour* using a 1 m × 1.5 m Tucker trawl, approximately 5 m long with 1.05 mm mesh as described by Clarke (1969) and Hopkins et al. (1973). The trawl fished at an angle of 45° producing a net opening of 1 m^2.

Upon completion of each surface and subsurface tow, net contents were washed into the cod end, emptied into a nested set of sieves (6.35 mm and 1.05 mm size mesh), and rinsed. Material retained in the 6.35 mm mesh sieve was rinsed again,

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[8] E G and G Environmental Consultants. 1975. Preliminary Phase II Final Report. *In* Forecasting Power Plant Effects on the Coastal Zone, 187 p. E G and G Environmental Consultants, 196 Beak Hill Road., Waltham, MA 02154.

[9] O'Hagan, R. M. 1974. Analysis of 1972-1973 ocean current measurements near Pilgrim Station. *In* Marine ecology studies related to operation of Pilgrim Station, Semi-Annual Report No. 4, sect. III, 38 p. Boston Edison Company, Boston, MA 02199.

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

Table 1.—Schedule, stations, gear type, and procedures for lobster larvae sampling in western Cape Cod Bay, 1974-77.

Year	Sampling dates	Station locations (Fig. 1)	Gear type	$\bar{x}$ Tow duration (min)	$\bar{x}$ Volume of water sampled (m^3)	$\bar{x}$ Tow speed (km/h)
1974	5/24-8/20	7-10	1 × 2 m neuston net	11.5	—	3.7
1975	5/23-8/5	3, 5, 11, 12, 13	1 × 2 m neuston net	30	3,774	4.6
	6/20-8/14	A-D	two 1 × 1 m neuston nets	10	1,400	3.5
1976	6/4 -8/11	1-6	1 × 2 m neuston net	30	3,271	4.6
1977	5/5 -8/10	1-6	1 × 2 m neuston net	30	3,001	4.6
	6/9 -8/1	5-6	1 × 1.5 m Tucker trawl	20	1,301	5.6

examined for larvae, and discarded. If large amounts of algae, and/or eelgrass, *Zostera marina*, were present, a third rinse was performed to assure complete removal of larvae. Contents washed into the 1.05 mm sieve were transferred into labeled 1 litre jars containing a preservative of 5% buffered Formalin-seawater solution. Samples were sorted in the laboratory, and lobster larvae were identified and enumerated by molt stage according to Herrick (1911).

Sampling Stations, Schedule, and Data Analysis

Location of sampling stations is presented in Figure 1. We conducted neuston sampling on a biweekly basis in 1974 and 1975 (Table 1). Weekly collections were made in 1976. Biweekly sampling in May and June 1977 was intensified to several days each week in July and August during peak hatching. In June 1977, we initiated biweekly subsurface towing at stations 5 and 6 at depths of 3.0 m, 5.5 m, and 7.6 m. In July and August, we increased the frequency of sampling to weekly intervals. We collected data until ctenophore abundance precluded successful net operations in early August.

The effect of local wind conditions on the concentration of lobster larvae was examined in 1975 and 1976. Mean weekly wind speed, direction, and duration at Pilgrim Station were determined from data provided by Boston Edison Company. Data were grouped into 16 wind directions and by 8.0 km/h wind speed increments.

Density estimates for each larval stage were corrected for stage duration according to Templeman (1936) for each sampling date. Differences in stage I and stage IV density (no./1,000 m^3) by station were examined by Kruskal-Wallis tests (Sokal and Rohlf 1969).

RESULTS

1974 Sampling

We collected only 25 lobster larvae in 1974 (Table 2) in the vicinity of the power plant (Fig. 1). Only nine tows contained larvae. The first larva was obtained on 2 July and was in the fourth stage. Only one first stage larva was found, with other collections consisting exclusively of stage IV individuals. The maximum number (7) captured in one tow was collected at station 7 on 7 August.

1975 Sampling

Expanded spatial coverage in 1975 yielded a total of 177 lobster larvae (excluding shoal water stations A-D). Larvae were first collected on 10 June at stations 12 and 13 (Fig. 1). All were first stage, indicating that hatching had just commenced. On this date, water temperatures in western Cape Cod Bay averaged 14.8°C at the surface and 12.7°C on the bottom (Fig. 2). As determined by the presence of stage I larvae in our catch, the hatching period extended from 10 June into the first week of August, or approximately 56 d. Densities of all stages peaked in early July when a total of 137 larvae (65% stages I and II) was captured on one sampling date. The largest number of larvae was collected at station 3 on 8 July.

Table 2.—Larval catch, mean densities, and percent composition for stages I-IV collected in neuston tows in western Cape Cod Bay, 1974-77.

Year	No. tows	Bottom temperature range (°C)	Percent catch composition by molt stage I	II	III	IV	Avg. density (No./1,000 m^3)	Total larval catch
1974	20	—	4.0			96.0	—	25
1975	27	7.7-14.8	59.9	23.7	8.1	8.3	2.05	177
1976	60	5.5-16.5	25.5	19.7	29.6	25.2	4.44	871
1977	78	5.5-15.0	55.2	16.9	5.3	22.6	1.26	206

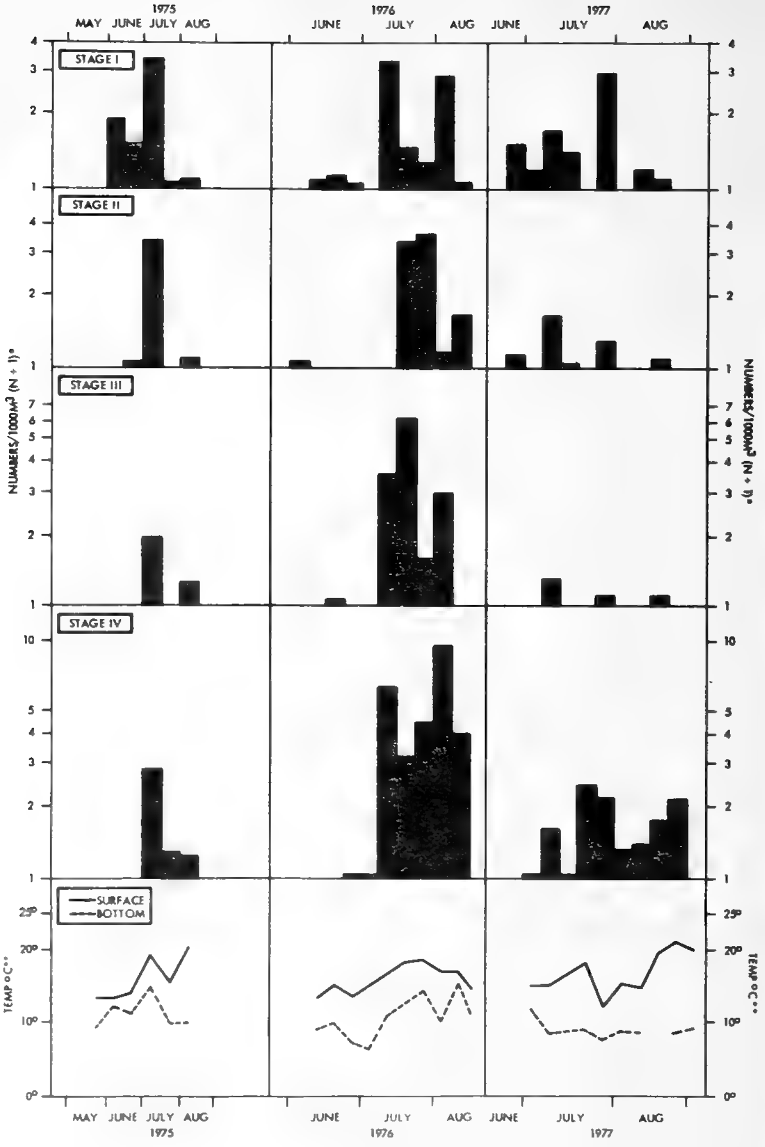

Figure 2.—Temporal distributions of mean lobster larvae pooled density (stations) by molt stage collected in neuston tows, and mean water temperatures in western Cape Cod Bay, 1975-77.

Average density per tow for combined molt stages over the study for all stations was 2.05 larvae/1,000 m³ (Table 2).

Percent composition of total larval catch for 1975 was: stage I - 59.9%, stage II - 23.7%, stage III - 8.1%, and stage IV - 8.3%. Catches at stations 3 and 13 were dominated by first stage larvae which composed 66% and 82%, respectively, of station totals.

At shoal water stations A-D (Fig. 1), we sampled on five dates but collected only eight larvae in 20 tows. Seven larvae were fourth stage, six of which were captured on 25 July.

1976 Sampling

The largest number of lobster larvae was collected in 1976, when we captured 871 larvae (Table 2). Hatching began in June and terminated in August (Fig. 2). Only one larva (stage II) was collected in the first week of June when water temperatures measured 13.7 °C at the surface and 9.5 °C on the bottom (Fig. 2). Ninety-two percent (801) of the total larval catch was taken from 14 July to 3 August at surface water temperatures ranging from 9.5° to 16.5 °C. Catch distribution was bimodal with peak densities occurring on 14 July and 3 August. By 11 August, with one exception, collections consisted exclusively of stage IV larvae. Percent composition of the season's total catch (pooled stations' data) by developmental stage was: stage I - 25.5%, II - 19.7%, III - 29.6%, and IV - 25.2% (Table 2). Catch at all stations contained relatively large numbers of late stage larvae. Mean density per tow was 4.44 larvae/1,000 m³.

Stations 5 and 6 ranked first and second, respectively, in total number of larval lobsters collected (Fig. 3). The combined catch of these stations was 451 larvae, or 52% of the total catch for 1976, consisting of 22.2% stage I, 23.2% stage II, 35.3% stage III, and 19.3% stage IV larvae. Station 1 ranked third in total catch (176 larvae), of which 23% were stage IV. Thirty percent (31 larvae) of all first stage larvae (105) were captured at station 1. Fifty first stage larvae, which constituted 48% of the total stage I individuals collected, were caught at stations 5 and 6 combined.

1977 Sampling

Despite substantially increased effort in 1977, only 206 lobster larvae were obtained (Table 2). We initiated sampling in early May but caught no lobster larvae until 14 June when first and second stage individuals were collected (Fig. 2). Water temperatures averaged 14 °C (surface) and 11.5 °C (bottom) on this date. Hatching apparently terminated in August. On the last sampling date (10 August), surface tows contained exclusively fourth stage larvae. Further sampling was prevented because of net fouling by an unidentified brown alga.

Seasonal catch distribution was bimodal with larval densities peaking on 11 and 29 July (Fig. 2). On 29 July, we collected 73 larval lobsters, consisting of 52% stage I and 29% stage IV individuals. Mean seasonal density (pooled station and molt stage data) was 1.26 larvae/1,000 m^3, well below the 1976 average density level (Table 2). Percent composition of the total catch for stages I-IV was: 55.2%, 16.9%, 5.3%, and 22.6%, respectively.

Stations 1 and 2, in the area of Brant Rock (Fig. 1), yielded the greatest numbers of larvae. At station 1, catch composition was dominated by stage I larvae (74%), while at station 2, first stage larvae comprised about 43% of the station total. Samples were dominated by first and fourth stage individuals (Fig. 3). Of the total first stage lobsters sampled, 49% were taken at station 1. Within the study area, catches of stage I larvae generally decreased from north to south. Only 9.0% and 6.4% of the total first stage larvae were collected at stations 5 and 6, respectively.

We made 48 subsurface tows from 9 June to 1 August 1977. Two larval lobsters were collected at station 6 on 23 June. One was a first molt stage individual collected at a depth of 7.6 m and the other a fourth stage larva captured 3.0 m below the surface.

Effect of Wind Conditions

Analysis of wind data for the spring and summer of 1975 and 1976 indicated that offshore winds from the southwest and south-southwest prevailed. However, an inspection of wind direction for respective sampling days revealed that during the period of peak larval abundance the majority of sampling trips coincided with onshore or alongshore winds. Seventy-three percent of the tows were made during onshore winds, and 82% of the larvae were collected when winds were onshore. Consequently, we could not statistically compare the effect of onshore-alongshore winds versus offshore winds on the dispersion and resultant concentration of lobster larvae in the study area.

Spatial and Temporal Distribution

Kruskal-Wallis tests indicated no significant difference ($P > 0.20$) in density of stage I larvae between stations sampled in 1976 and 1977. There was no significant difference ($P > 0.20$) in density of stage IV larvae between stations for the same 2 yr.

Temporal distribution of mean pooled lobster larvae densities by molt stage and water temperature data are given for 1975-77 in Figure 2. We estimated the period of occurrence of larvae in the water column ranged from 46 to 62 d over the time and area studied.

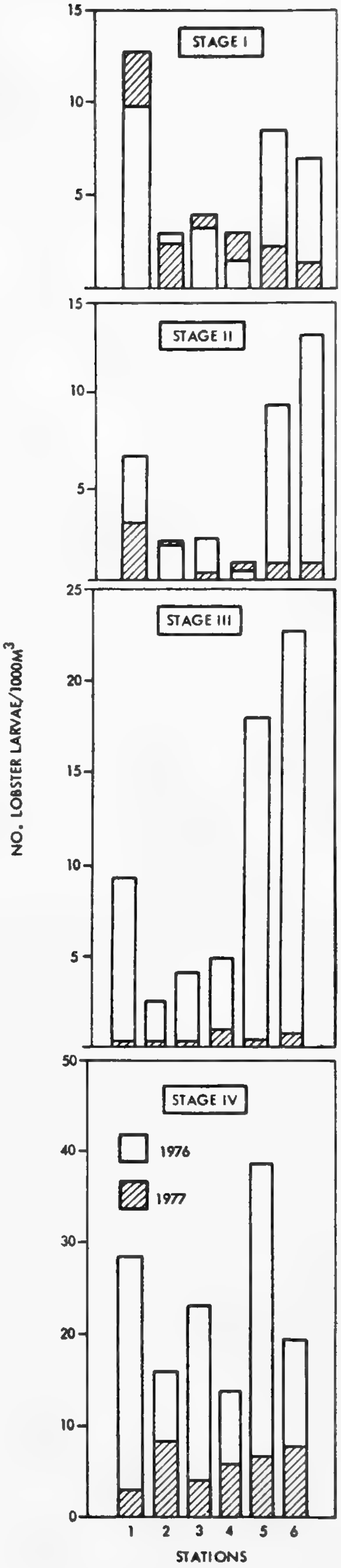

Figure 3.—Lobster larvae density by molt stage collected in neuston tows in western Cape Cod Bay, 1976-77.

DISCUSSION

According to Scarratt (1964), the period of lobster hatching and location of hatching areas may be determined by examining the temporal and spatial presence of stage I larvae. A comparison of station densities in 1975 revealed that substantially more stage I individuals were collected at stations 3 and 13. In 1976, stage I larval densities were relatively high at stations 1, 5, and 6. Our results agreed with those obtained by Marine Research, Inc.,[11] indicating peak larval densities in the environs of Rocky Point. Again in 1977, stage I larval density was highest at station 1. Forty-nine percent of the first stage larvae we collected that year were captured at this site. In contrast to our 1976 findings, the total catch of stage I larvae was less at stations 5 and 6 in 1977.

The relatively high percentage of fourth stage larvae obtained in our study may be due to differential availabilty to capture by molt stage (Herrick 1896; Templeman and Tibbo 1945; Scarratt 1973). Alternatively, high catches of fourth stage larvae may represent transport by currents from other hatching areas. With the existence of a net counterclockwise advection in Cape Cod Bay (O'Hagen footnote 9), late stage larvae may be recruited from areas north and offshore from those studied. In late July 1976, prevailing south-southwest winds with concomitant decline in surface water temperature probably produced an offshore movement of surface water with a possible transport of lobster larvae. A similar situation existed in 1977 during a period of reduced larval density.

Our limited sampling indicated there was minimal depth stratification of larvae during the daylight. Templeman (1937), Templeman and Tibbo (1945), Sherman and Lewis (1967), and Scarratt (1973) reported that the majority of lobster larvae during the daytime are collected at the surface.

Hatching initiated in mid-June at water temperatures of approximately 14°C (surface) and 8°-9°C (bottom) and terminated by mid-August. The period of occurrence of larvae in the water column ranged from 46 to 62 d. There was considerable variability between years in seasonal larval densities and percent composition of molt stages. Maximum abundance of lobster larvae in daytime occurred in surface waters in July. Sampling at shoal water stations yielded few larvae whereas the areas of Brant Rock (Stations 1 and 2), High Pine Ledge (Station 3), and from the mouth of Plymouth Bay to Rocky Point (Stations 5 and 6) produced greatest numbers of total larvae. Higher numbers of stage IV larvae were collected than were expected relative to the number of stage I larvae obtained and considering the expected mortality between stages I-IV.

Wind-generated currents may be an important transport mechanism affecting dispersion of lobster larvae and ultimate distribution in surface waters (Templeman 1937; Templeman and Tibbo 1945; Squires 1969; Caddy[12]). We observed on several occasions over the 4 yr that when a sampling trip was preceded by several consecutive days of offshore winds, e.g., from the southwest, we noted that our catch was comprised of atypically fewer lobster larvae, substantially less crab larvae, and abnormally large numbers of terrestrial flying insects.

ACKNOWLEDGMENTS

We extend special thanks to the following: Boston Edison Company (BECo) funded the study and provided wind data; the Pilgrim Administrative-Technical Advisory Committee for overseeing the investigation; Robert Anderson of BECo for his continued support throughout all aspects of the study; and to numerous Division staff: Shirley G. Mitchell, Lewis Emerald, James Fair, and Raymond Heintz for their assistance in field collections; Donald MacIsaac aided in computer programming; W. Stephen Collings for his helpful suggestions; Eleanor Bois who typed the manuscript; and W. Leigh Bridges, Christine Sheehan, and Susan Faria for editorial review of the text.

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New Hampshire Lobster Larvae Studies

STEPHEN A. GRABE,[1] JOHN W. SHIPMAN,[2] and WELDON S. BOSWORTH[2]

ABSTRACT

Lobster larvae, which were collected in coastal New Hampshire waters between mid-July and early October 1978 and early June through mid-August 1979, reached maximum abundance in late August in 1978 and late July in 1979. Stage composition was heavily weighted towards stage IV larvae in 1978, and stage I larvae in 1979. The sizes of larvae at all stages were generally larger than those reported in other studies.

INTRODUCTION

The only quantitative investigations of lobster larvae in New Hampshire waters have been conducted as part of the preoperational ecological studies for Seabrook Station (Public Service Co. of New Hampshire). Preliminary sampling was undertaken during the summer of 1973 (Normandeau Associates, Inc.[3]); formal preoperational studies, described below, were initiated during 1978. Primary questions concerned the seasonal distribution and abundance of lobster larvae in the vicinity of the offshore intake and discharge structures for Seabrook Station.

MATERIALS AND METHODS

A neuston net (1 m × 2 m × 8 m; 1.0 mm mesh) was towed during daylight hours along a north-south transect about 1,850 m offshore from Hampton Beach, N.H. (Fig. 1). Samples were collected from 9 June to 18 October 1978 and 15 May to 20 September 1979. Collections were made weekly until the first larvae were collected, twice-weekly when larvae were present, and weekly again for a few weeks after larvae were no longer collected. Thirty-four collections were made during 1978, 30 during 1979.

Tow duration was 15 min through 18 July 1978 and was increased to 30 min thereafter; tow speed was $\cong$ 1 m/s. Tows were made from the side of the boat outside of the wake. The net bottom was 0.5 m below the surface to give an effective sampling area of 1.0 m^2. Sample volumes, measured by a digital flowmeter, averaged 1,475 m^3 for 15-min tows and 1,868 m^3 for 30-min tows. If flowmeter readings were suspect (fouled with algae), the average volume calculated for similar tow characteristics (duration and net area) was applied.

Samples were sorted for all lobster larvae in the laboratory, staged after Herrick (1896) and Templeman (1948a), and measured (stage IV only during 1978).

Numerical classification (Boesch 1977) was used to compare the stage composition from New Hampshire with that of other New England areas. A similarity matrix, using percent similarity (Boesch 1977), was constructed for each combination of sites. Group average clustering (Boesch 1977) was then applied to organize these sites into larger groups based on the similarity of larval stage composition.

RESULTS

Seasonality and Abundance

Lobster larvae were first collected in neuston tows on 21 July 1978 and 8 June 1979. Stage I larvae were present from late July through mid-August 1978 and from early June through early August 1979 (Fig. 2). There was no distinct seasonal peak of stage I larvae during 1978; the collection of 53 individuals on 24 July 1979 was coincident with the collection of large amounts of macroalgae. Few stage II (n = 3) and III (n = 3) larvae were collected during 1978-79. Stage IV larvae were collected from 21 July to 3 October 1978 and 17 July to 10 August 1979 (Fig. 3). Peak densities of stage IV larvae

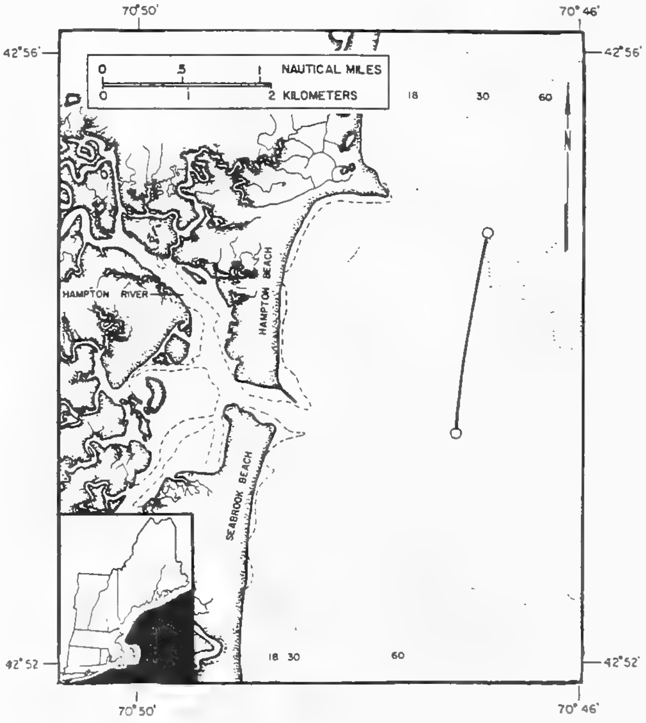

Figure 1.—Lobster larvae sampling station off Hampton, N.H.

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03102.

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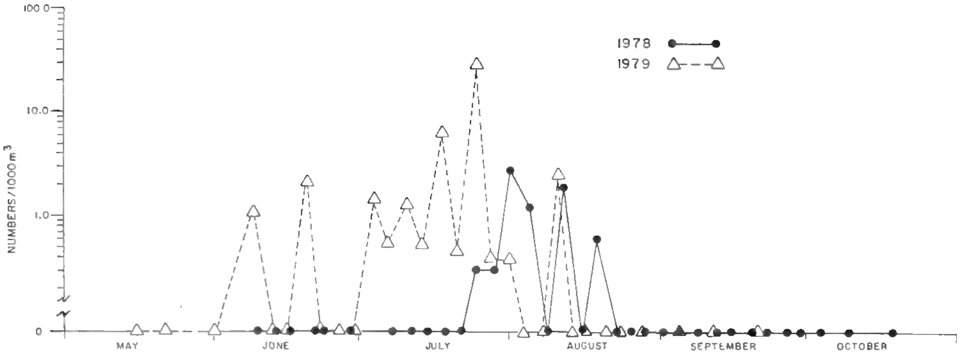

Figure 2.—Abundance of stage I lobster larvae in neuston collections off Hampton, N.H., 1978-79.

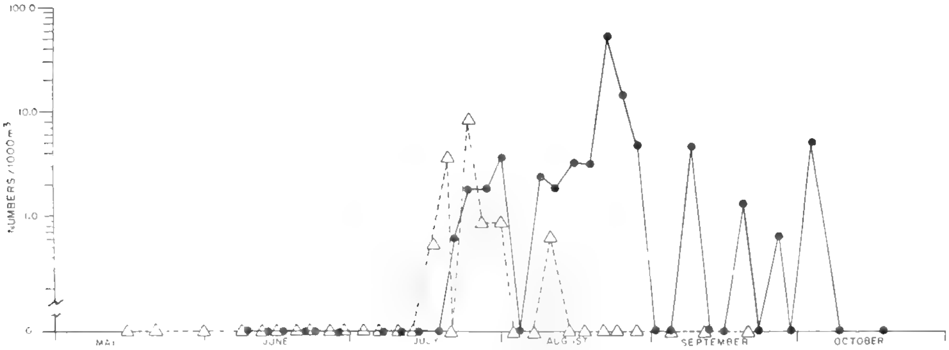

Figure 3.—Abundance of stage IV lobster larvae in neuston collections off Hampton, N.H., 1978-79.

occurred during late August 1978 and late July 1979 and were coincident with large quantities of macroalgae. During 1978, stage IV larvae were collected somewhat more frequently when winds were onshore (Table 1). A total of 169 (1978) and 120 (1979) larvae were collected.

Lobster larvae were also collected during discrete depth plankton sampling conducted in 1978 by Normandeau Assoc., Inc.[4] A third-stage larva was collected in a mid-depth tow on 7 July 1978 indicating that hatching considerably pre-dated the first occurrence of larvae in neuston tows.

Stage Composition

Stage IV larvae were dominant during 1978. Previous neuston sampling conducted off Hampton-Seabrook during 1973 also indicated a disproportionate number of stage IV larvae (Normandeau Assoc., Inc. footnote 3). Stage I larvae, however, were dominant during 1979; stage II and III composed <9% of the larvae collected.

Stage composition in the Hampton-Seabrook area during 1973 and 1978 was dissimilar to that of most other areas of New England for which data were available (Fig. 4). Five clusters were distinguished at varying similarities. Clusters A and B were dominated by stage I larvae, but differed in the contribution of stage II and III larvae (Fig. 4). Stage distribution was somewhat more evenly distributed in Cluster C. Clusters D and E (Hampton-Seabrook, 1973 and 1978) were characterized by stage IV dominance but differed in the contributions of stage II and III larvae.

Size of Lobster Larvae

Mean length of lobster larvae increased almost two-fold from stage I to stage IV (Table 2). At all stages, larvae from New Hampshire appeared to be larger than those reported from areas of Canada and southern New England, with the ex-

Table 1.—Frequency of wind directional vectors (°true) and the percent of stage IV lobster larvae, Hampton, N.H., 21 July-18 October 1978.

Wind direction	All dates	Dates stage IV larvae present in collections	Dates stage IV larvae absent from collections
Alongshore[1]	35.2	33.3	50.0
Offshore[2]	40.6	20.0	33.3
Onshore[3]	24.2	46.7	16.7
	n = 91	*n* = 15	*n* = 6

[1] Directional vectors 0°-30°, 150°-210°, 330°-360°.
[2] Directional vectors 30°-150°.
[3] Directional vectors 210°-330°.

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[4] Normandeau Associates, Inc., 1981. Plankton studies in the vicinity of Hampton Beach, New Hampshire. Tech. Rep. XI-3, 147 p. Prepared for Public Service Co. of New Hampshire.

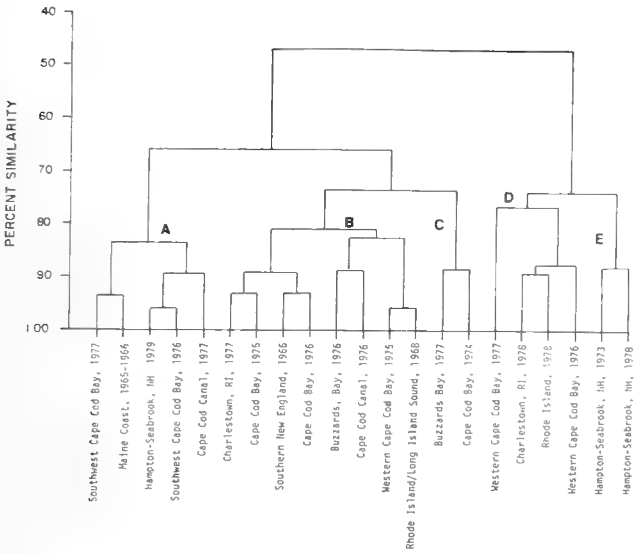

Figure 4.—Dendogram of stage composition in New England lobster larvae studies. Percent stage composition (clustered variable) obtained from reports in this volume and personal communication with investigators; additional data obtained from Sherman and Lewis (1967) and Lund and Stewart (1970).

ception of stage IV larvae from Charlestown, R.I. (Bibb and Hersey[5]).

Associated Species

In addition to lobster larvae, 15 invertebrate species and 12 fish species have been identified from summer neuston tows (Table 3). Although quantitative data are not available, *Cancer* spp. megalopa and the copepod *Calanus finmarchicus* appeared to be the most abundant invertebrates. Dominant larval and juvenile fish during 1979 were *Enchelyopus cimbrius*, *Urophycis* spp., *Ulvaria subbifurcata*, and *Tautogolabrus adspersus*.

DISCUSSION

The periods of occurrence of lobster larvae in the Hampton-Seabrook area generally agree with that reported elsewhere (Wilder 1953; Scarratt 1964, 1973; Lund and Stewart 1970; Sherman and Lewis 1967). Peak densities occurred between 1 and 2 mo later than that found in southern New England (Lund and Stewart 1970) but agreed with Canadian studies (Wilder 1953; Scarratt 1964, 1973).

Table 2.—Mean total length and range (mm) of lobster larvae from Hampton, N.H., compared with larvae from Canadian and southern New England waters.

Area	Stage I	Stage II	Stage III	Stage IV
Hampton, N.H. (this study)[1]	9.1 (7.6-10.7)	11.1	13.8 (13.5-14.0)	16.7 (13.6-22.0)
Northumberland Strait, Can. (Wilder 1953)	—[2]	—	—	14.4
Northumberland Strait, Can. (Wilder 1953; computed from Templeman 1936)	7.5	—	—	14.6
Woods Hole, Mass. (Herrick 1896)	7.8 (7.5-8.0)	9.2 (8.3-10.2)	11.1 (10-12)	12.6 (11-14)
Wickford, R.I. (Hadley 1906)	8.2	9.6	11.4	13.5
Southern New England (Rogers et al. 1968)				
Inshore	8.3	10.4	12.9	15.6
Offshore	8.6	10.8	13.1	15.9
Charlestown, R.I. (Bibb and Hersey 1979; see text footnote 4)	7.9 (6.5-10.0)	9.5 (8.0-11.0)	12.1 (10.5-14.0)	16.3 (14.0-19.5)

[1] Number measured by stage: 26(I), 1(II), 2(III), 162(IV); stages I-III, 1979 data only; stage IV, 1978-79.

[2] —Data not available.

Table 3.—Species associated with lobster larvae in neuston collections from the vicinity of Hampton, N.H.

- Cnidaria
  - Hydrozoa
    - *Bougainvillia* sp.
    - *Halitholus cirratus*
  - Scyphozoa
    - *Cyanea capillata*
- Arthropoda
  - Copepoda
    - *Anomalocera opalus*
    - *Calanus finmarchicus*
    - *Caligus* (*elongata*?)
  - Mysidacea
    - *Neomysis americana*
- Isopoda
    - *Idotea balthica*
- Amphipoda
    - *Calliopius laeviusculus*
    - *Gammarus lawrencianus*
    - *Parathemisto gaudichaudi*
- Decapoda
    - *Cancer* spp. (zoeae, megalopa)
    - *Carcinas maenas* (zoeae, megalopa)
    - *Pagurus arcuatus*? (zoeae)
    - *P. longicarpus*
- Chordata
  - Pisces
    - *Cyclopterus lumpus*
    - *Enchelyopus cimbrius*
    - *Gasterosteus aculeatus*
    - *Liparis* (*atlanticus*?)
    - *Peprilus triacanthus*
    - *Pseudopleuronectes americanus*
    - *Scomber scombrus*
    - *Scophthalmus aquosus*
    - *Syngnathus fuscus*
    - *Tautogolabrus adspersus*
    - *Ulvaria subbifurcata*
    - *Urophycis* sp(p).

Stage composition of lobster larvae in 1973 and 1978 was heavily weighted toward stage IV larvae with few intermediate stages present. Stage I larvae have been dominant in Canadian studies, composing between 72 and 95% of the larvae collected (Wilder 1953; Scarratt 1968, 1969, 1973). Stage IV larvae never composed more than 7.5% of total larval abundance in Canadian studies. The other New England studies described in this report generally showed higher percentages of stage II and III larvae or very high contributions by stage I larvae.

The 1973 and 1978 data suggest that recruitment of juvenile lobsters in the Hampton-Seabrook area may not be dependent upon a local spawning population. Three lines of evidence tend to support this contention: 1) Stage composition showed low proportions of stage I-III, relative to stage IV, indicating

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[5] Bibb, B. G., and R. Hersey. 1979. Distribution and abundance of lobster larvae in Block Island Sound, 1978. Raytheon Co., 88 p. Prepared for New England Power Co.

little contribution from resident spawning stock. 2) There was a tendency during 1978, for stage IV larvae to be collected when winds were onshore. Winds in the Hampton-Seabrook area tend to be from the west and southwest during summer months, but due to thermal differences between air and water, are more likely to be onshore during the day and offshore at night (Normandeau Associates, Inc.[6]). Tidal currents in the area average 0.05-0.1 m/s; these effects are more pronounced during summer months when wind velocities are somewhat below average. Net drift tended to be predominantly southward and was generally 1.8 to 3.8 km/d (Normandeau Associates, Inc. footnote 6). This suggests that larvae may be derived from a more northern spawning population, are moved by tidal currents into New Hampshire coastal waters, and are then transported onshore by winds. 3) Catch data for adult lobsters (Normandeau Associates, Inc. footnote 3) showed that during 1972 and 1973 ovigerous females never made up more than 1.5% of the monthly catch; Public Service Co. of New Hampshire (unpubl. data) found that ovigerous females never exceeded 2.4% of the monthly catch during 1974-78, even though females made up 60% of the catch. Also, fewer than 5% of the females in the nearby Piscataqua River were found to be ovigerous (Normandeau Associates, Inc.[7]).

Ennis (1980) and Squires (1970) found between 2.6-30.4% and 10-35% of females were ovigerous, respectively, in Newfoundland waters. Skud and Perkins (1969) reported that 22% of females collected were ovigerous in trawl catches from the continental shelf off New England. Ovigerous females, however, may not be as easily trapped as non-ovigerous females (Templeman and Tibbo 1945).

The association between large amounts of drift macroalgae and increased catch of larval lobsters requires further investigation. For example, virtually all of the stage I larvae collected during 1979 occurred in a single sample which contained a large amount of algae.

Stage IV larvae from the Hampton-Seabrook area appear to be considerably larger than those from Canadian and southern New England waters. Stage IV larvae in our collections were within the size range of Herrick's (1896) stage V-VIII larvae. However, both Herrick (1896) and Hadley (1906) reared their larvae in the laboratory. Templeman (1948b) noted that larvae collected in the warmer waters of Northumberland Strait were smaller than larvae collected from cooler waters, but did not provide temperature data. Wilder (1953) compared larval and juvenile growth in the cooler Bay of Fundy with that in the warmer Gulf of St. Lawrence, and made similar observations.

Species associated with lobster larvae in our collections may be categorized as true neuston species or as near-surface species which may be associated with floating macroalgae. *Anomalocera opalus* and *Enchelyopus cimbrius* are common neuston species in the Gulf of St. Lawrence (Pennell 1967). The majority of species, such as *Cancer* spp. larvae, the hydrozoans and their associated hyperiid amphipods, may be inhabitants of the near-surface waters for either a particular part of their life cycle or for a particular part of the day, but are not adapted for a neuston existence per se. The third assemblage, which lives among the floating algae, includes *Idotea balthica* (Schultz 1969) and larvae and juveniles of *Gasterosteus aculeatus*, *Cyclopterus lumpus*, *Liparis* spp., and *Sygnathus fuscus* (Bigelow and Schroeder 1953; Leim and Scott 1966).

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[6] Normandeau Associates, Inc., 1979. Annual summary report for 1976 hydrographic studies off Hampton Beach, New Hampshire. Tech. Rep. VIII-1, 184 p. Preoperational ecological monitoring studies for Seabrook Station. Prepared for Public Service Co. of New Hampshire.

[7] Normandeau Associates, Inc., 1979. Newington Generating Station, 316 Demonstration. Vol. 1, 398 p. Prepared for Public Service Co. of New Hampshire.

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Abundance and Distribution of Lobster Larvae (*Homarus americanus*) for Selected Locations in Penobscot Bay, Maine

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ABSTRACT

Larval lobster (*Homarus americanus*) abundance and distribution were compared at three locations in Penobscot Bay, Maine, from May through September 1976. For the areas in which larvae were found, abundance was low (0.30 larvae/1,000 m^3) during the hatching and development period (mid-June through July) when over 98% of the larvae were collected. Hatching initiated when bottom temperatures were as low as 10.5°C (Station 2). The abundance of lobster larvae decreased from the mouth to the head of the bay. The absence of larvae at the upper bay station was attributed to low salinity surface waters in the area. Almost all stage I larvae (92%) were found on days when cloud cover was 50% or greater.

INTRODUCTION

American lobster, *Homarus americanus*, larvae were collected in Penobscot Bay from May through September 1976 as part of a regional environmental survey related to a proposed power plant site in the upper bay. The principal objective of the study was to estimate the relative abundance and temporal distribution of lobster larvae at three locations in Penobscot Bay (Fig. 1). These stations, distributed over the length of the bay, had similar benthic topography. Furthermore, the lower bay station was selected as an area of relatively high lobster density (as indicated by lobster trap densities).

The study also provided a data base which would contribute to estimates of power plant entrainment impact.

MATERIALS AND METHODS

Lobster larvae were collected with a 1 mm mesh net similar to the type developed and used by Wilder (1953) and Scarratt (1964, 1968, 1973). The net measured 3.7 m × 0.9 m at the mouth, extending 7.6 m to a 0.4 m cod end, and was rigged and buoyed horizontally to expose the upper 0.15 m above the air-sea interface with the remaining 0.85 m underwater. A flowmeter was mounted in the mouth of the net. The net was towed 90 m astern of the boat to avoid towing in the propeller wash. Each tow was 30 min at approximately 1.8 km/h and filtered about 2,650 m^3 of water. Generally samples were collected 3 or 4 d per week. On sampling dates two or three tows were made at each of two stations on a rotating schedule. All samples were collected during the daylight hours.

RESULTS

Total Catch

A total of 58 lobster larvae was collected in 213 surface net tows (Fig. 2). Only 23 of the tows (11%) contained larvae. All

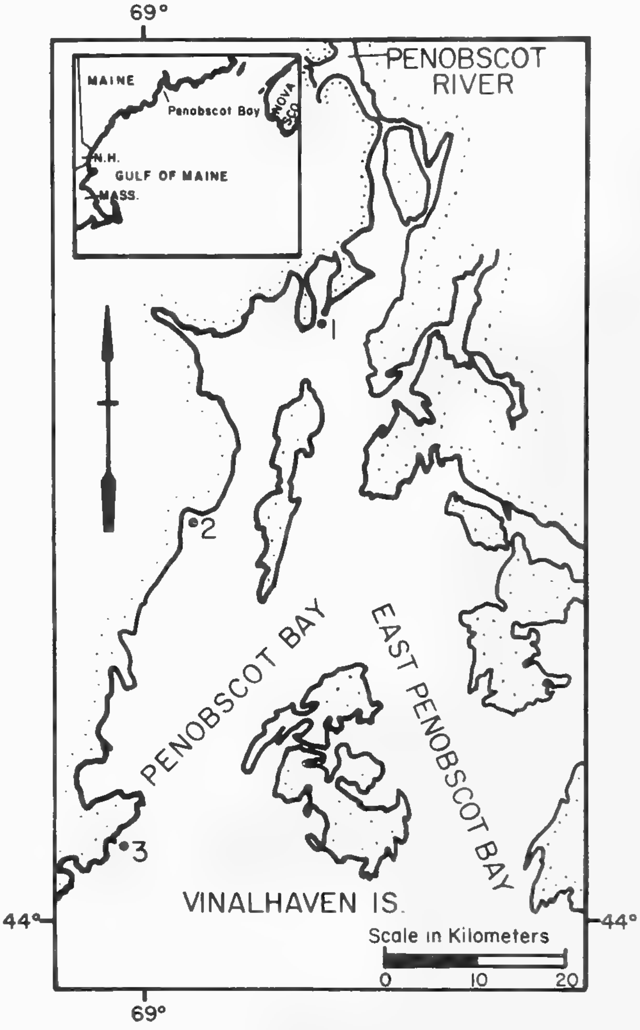

Figure 1.—Sampling stations for lobster larvae, Penobscot Bay, Maine.

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[1] Environmental Studies Department, Central Maine Power Company, P.O. Box 53, Yarmouth, ME 04096.

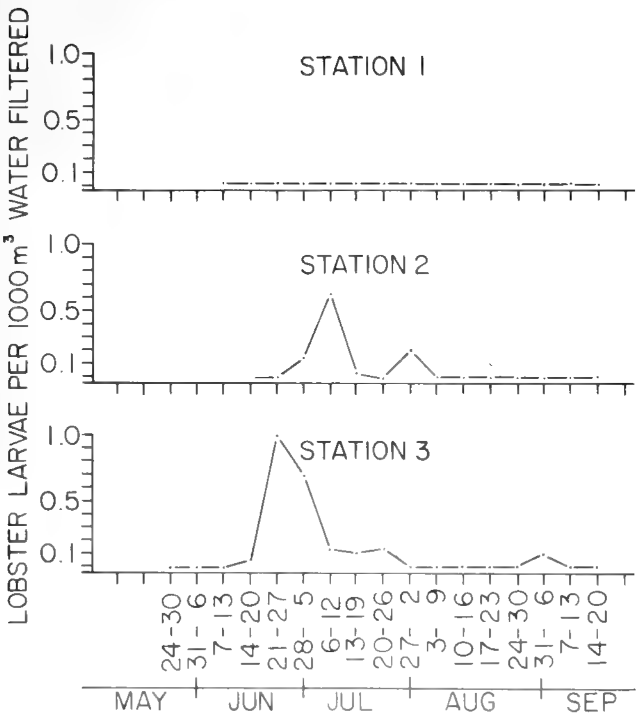

Figure 2.—Weekly lobster larval densities at Stations 1, 2, and 3 in Penobscot Bay, Maine, May-September 1976.

but one larva were collected from 16 June through 26 July. Stage I larvae dominated the catch, initially appearing at the southernmost station (No. 3) followed by their appearance at station 2, 2 wk later. Only one stage II larva and no stage III larvae were collected during the study. Stage IV larvae were initially found during the later part of July.

Catch by Station

Throughout the sampling period no larvae were found at station 1. At station 2, 17 larvae (14 stage I; 1 stage II; and 2 stage IV) were collected during 1 through 26 July. The 2 stage IV larvae were found in near-surface waters at the end of this period. A peak density of 1.62 larvae/1,000 m^3 occurred 8 d after the first occurrence of larvae in neuston samples.

Highest densities of larvae were recorded at station 3 where 38 stage I and 3 stage IV lobster larvae were collected. Stage I larvae were initially found on 16 June. Higher bottom temperatures were recorded at station 3 (Fig. 3), resulting in earlier hatching at this station than station 2. Hatching intensity, as reflected by the presence of stage I larvae, peaked at a density of 2.89 larvae/1,000 m^3, 9 d after the initial occurrence of larvae (bottom temperature = 11 °C). Hatching apparently ceased after 16 July, after which 2 stage IV larvae were found 1 wk later and 1 stage IV larva was collected on 31 August.

Relation to Cloud Cover

A relationship was noted between the number of larvae taken and the degree of cloud cover. Ninety-two percent of the stage I larvae were collected on days of cloud cover ≥50% while all stage IV larvae (n = 5) were taken on days of <50% cloud cover. For all larvae, 84% were collected when cloud cover was ≥50% and 62% of the larvae were obtained on completely overcast days. Approximately 45% of all tows were made on days when cloud cover was ≥50%.

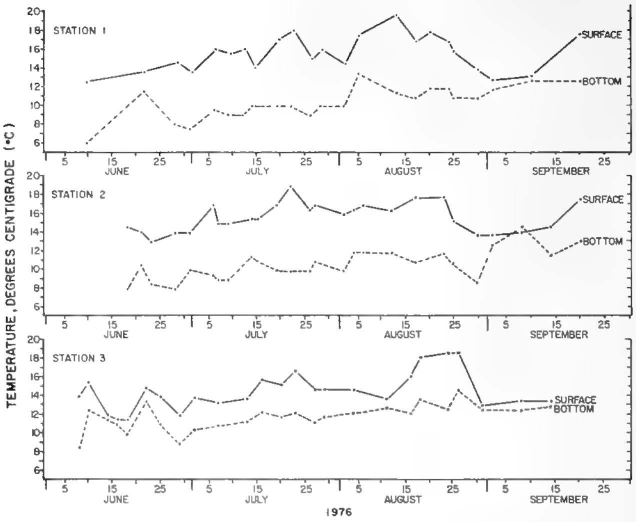

Figure 3.—Surface and bottom water temperatures at Stations 1, 2, and 3 in Penobscot Bay, Maine, June-September 1976.

DISCUSSION

Overall abundance of lobster larvae at the Penobscot Bay stations was low when compared with similar studies conducted in New England coastal waters (Sherman and Lewis 1967; Lund and Stewart 1970) and along the eastern Canadian coast (Scarratt 1964, 1968, 1973). We noted an average density of 0.30 larvae/1,000 m^3 of water for the observed hatching and development period (16 June-31 July) and 0.19 larvae/1,000 m^3 for the entire period of larval occurrence at stations 2 and 3. Based on the temporal distribution of larvae, it appears that the majority of lobsters in Penobscot Bay spawned from early to mid-June through July in 1976.

Stage I larvae from the lower bay (station 3) showed the earliest evidence of hatching (16 June) and the longest period during which larvae were found (16 June through 31 August). Scarratt (1964) suggested that stage I abundance is indicative of underlying parent stock size. Thus, the higher stage I larval abundance observed at station 3 possibly reflects a larger parent stock at this location.

An early warming of the Maine coastal waters in 1976 (Welch[2]) stimulated hatching in mid-June. During the previous year lobster larvae were first observed in Penobscot Bay during early July (Central Maine Power Company[3]). Hatching at station 3 apparently began within 6 d after bottom temperatures rose to 12.5 °C. Not until 21 June did the bottom temperature at station 2 exceed 10°C and become warm enough to stimulate hatching at this site. At station 2, stage IV larvae

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[2] W. R. Welch, Maine Department of Marine Resources, Fisheries Research Station, W. Boothbay Harbor, ME 04575, pers. commun. October 1976.

[3] Central Maine Power Company, Environmental Studies Department. 1976. Lobster larval distribution in Upper Penobscot Bay, Maine. Unpubl. rep., 4 p. Central Maine Power Company, Augusta, ME 04336.

appeared approximately 4 wk after the first stage I larvae was found, while at station 3 the corresponding development period lasted more than 5 wk possibly due to lower mean surface water temperature at this site. Average surface temperatures were 15.0°C and 16.2°C at stations 3 and 2, respectively, during the period of larval occurrence. At both stations the appearance of stage IV larvae accompanied by the absence of stage I larvae in late July, signaled the end of the spawning period. The single stage IV larva collected on 31 August was attributed to a random late hatch.

Salinities of 19.4‰ or less are unfavorable to larval growth (Templeman 1936). Scarratt and Raine (1967) have shown larval avoidance of salinities as low as 21.4‰. Station 1 was subjected to frequent periods of low salinity caused by freshwater runoff from the Penobscot River, possibly explaining the absence of larvae at this site. Larvae may have avoided lower salinity surface water at station 1 and were therefore not vulnerable to neuston gear.

It is well documented that early stage I lobster larvae exhibit positive phototaxis (Hadley 1908; Herrick 1911; Ennis 1973), concentrating in the near-surface waters during daylight. However, young larvae are subject to mortality from ultraviolet radiation (Huntsman 1924; Templeman 1936) and tend to move from surface waters during periods of bright sunlight (Templeman and Tibbo 1945). Based on cloud cover observation recorded during the present study it appeared that the larvae adjusted their depth in response to ambient light intensity. Larvae apparently moved to surface waters during partially to totally overcast days when sunlight intensity was reduced. During periods of high light intensity, lobster larvae may have descended to avoid possible harmful levels of ultraviolet radiation. During periods of intense sunlight, the larvae may have been below the net sampling depth, accounting for the capture of 92% of stage I larvae when cloud cover equaled or exceeded 50%. Stage IV larvae, which are not as susceptible to ultraviolet radiation, were found at the surface on days of <50% cloud cover although the number of stage IV larvae collected was low.

SUMMARY AND CONCLUSIONS

Data analysis from this program, designed to study American lobster larvae abundance and distribution at three locations in Penobscot Bay, Maine, from May through September 1976, revealed the following:

1) Abundance of American lobster larvae for the three areas of Penobscot Bay studied appeared to be relatively low compared with Canadian waters such as the Northumberland Strait and various New England areas.

2) The hatching period for the American lobster in Penobscot Bay extended over a 6-wk period from mid-June through late July in 1976 when coastal water temperatures rose more rapidly than in previous years, resulting in a correspondingly early hatching period.

3) Low average salinities as found in surface waters near station 1 in early summer may have been detrimental to larval development resulting in either the avoidance of the area by larvae or mortality of larvae.

4) Early planktonic stages which are more vulnerable to ultraviolet radiation than stage IV larvae were most abundant in the near-surface waters on cloudy days.

ACKNOWLEDGMENTS

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A Comparison of Lobster Larvae Sampling Using Neuston and Tucker Nets

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ABSTRACT

A series of paired surface tows with a 1 m × 2 m neuston net and a 2 m × 2 m Tucker net were made to compare sampling efficiency for lobster larvae. The neuston net collected two to four times more larvae per unit volume than the corresponding Tucker net. Both nets collected similar numbers of larvae if numbers are expressed per unit area. This indicates that larvae were concentrated in the upper 0.75 m of the water column.

INTRODUCTION

Both neuston and Tucker nets have been used to collect lobster larvae along the New England coast. Neuston nets were used in a study of geographic distribution of lobster larvae in Block Island Sound (Fogarty et al. 1983) and Tucker nets in a study of distribution and abundance off East Beach, R.I. (Bibb et al. 1983). Because of the different nets used, the results of these surveys are not directly comparable. This study was conducted to compare the sampling efficiency of the neuston net with that of the Tucker net to determine whether lobster larvae data collected using these two techniques are comparable.

METHODS

Paired tows were made with a neuston net off the port side and a Tucker net off the starboard side of the survey vessel. About 25 cm of the neuston net and 10 cm of the Tucker net were kept above the water's surface while towing. All tows were made into the current at 1 m/s for 15 min. Sample volume and boat speed were estimated with a calibrated General Oceanics Model 2030 flowmeter.[4] Volumes for each tow ranged from approximately 2,000 to 4,000 m^3 (Tucker) and 1,500 to 2,000 m^3 (neuston).

The neuston net had 1 m × 2 m opening and 4 m length with a 1 mm mesh (Fig. 1). The opening and closing Tucker net was 8 m long with a 0.950 mm mesh (Fig. 1). The mouth of the Tucker net was designed to sample at a 45° angle with a resultant 2 m × 2 m sampling area.

Samples were collected 14, 18, and 21 June 1979 at two stations in Block Island Sound, NS-B and PJ-C (Fig. 2). Triplicate paired tows were made at each station. Mean surface temperatures for each sampling date were 15.4°, 16.7°, and 16.1°C, respectively. During sampling, the sky was clear and seas were calm.

Data comparisons were made in two ways: Per unit volume (1,000 m^3) and per unit area (1,000 m^2). Abundance per unit volume was calculated using the volume filtered as indicated by the flowmeter. Abundance per unit area was calculated by dividing the flowmeter volume by the depth sampled by each net. These depths were 0.75 m for the neuston net and 1.9 m for the Tucker net.

RESULTS AND DISCUSSION

A comparison of the total number of lobster larvae collected in paired triplicate surface tows using neuston and Tucker nets is shown in Table 1. These results indicate that

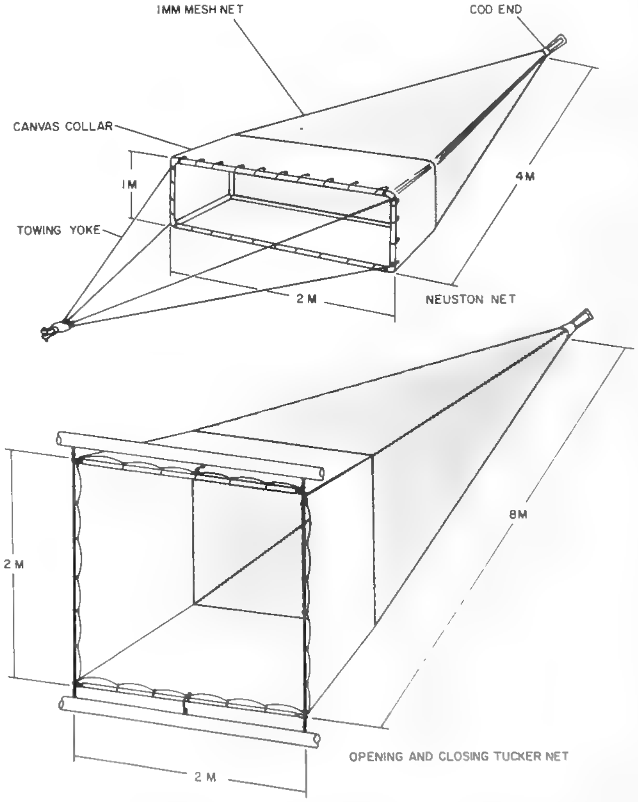

Figure 1.—Diagrammtic representation of neuston and Tucker nets.

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[1] Raytheon Company, P.O. Box 360, Portsmouth, RI 02871.

[2] Raytheon Company, P.O. Box 360, Portsmouth, R.I.; present address: 124 North Road, Kingston, RI 02881.

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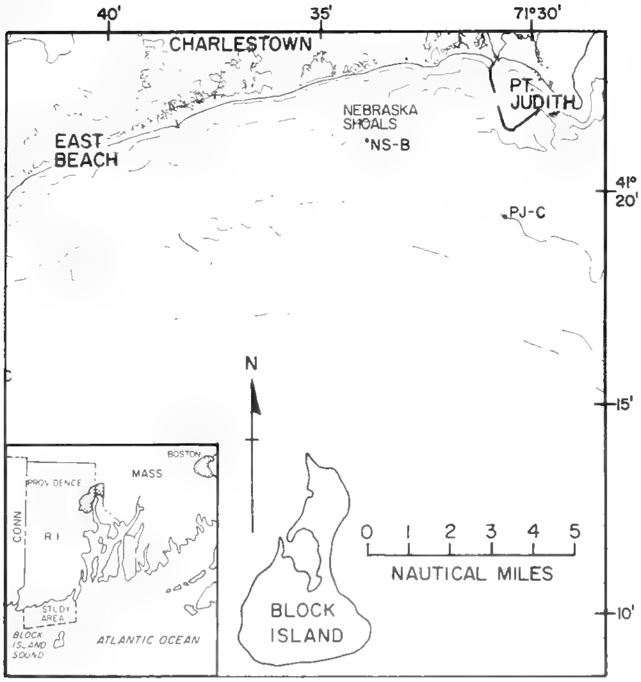

Figure 2.—Sampling locations for net comparison study.

Table 1.—Mean abundance ± standard deviation of lobster larvae (all stages) in paired triplicate surface tows using a 1 m × 2 m neuston net and 2 m × 2 m Tucker net.

		Abundance per 1,000 m^3		Abundance per 1,000 m^2	
Date	Station	Neuston net	Tucker net	Neuston net	Tucker net
6/14/79	NS-B	37.1 ± 44.1	14.4 ± 14.2	27.9 ± 33.0	28.8 ± 28.4
	PJ-C	34.6 ± 18.6	14.3 ± 15.7	25.9 ± 36.5	28.7 ± 26.8
6/18/79	NS-B	6.4 ± 4.1	1.4 ± 0.8	4.6 ± 3.0	2.9 ± 1.7
	PJ-C	177.3 ± 181.3	47.3 ± 33.7	133.0 ± 135.9	94.5 ± 67.3
6/21/79	NS-B	6.1 ± 5.2	3.2 ± 2.6	4.5 ± 3.8	6.5 ± 5.3
	PJ-C	6.2 ± 4.2	3.1 ± 0.8	4.7 ± 3.2	6.3 ± 1.5
Grand mean and standard deviation		44.6 ± 91.1	14.0 ± 21.3	33.4 ± 68.3	27.9 ± 42.5

when expressed on a volume basis (number per 1,000 m^3) the neuston net collected two to four times as many larvae as the Tucker net.

The sampling variance was high and proportional to the mean as is characteristic of lobster larvae data and most plankton data (Cassie 1968). Consequently, the data were normalized with a log $(n + 1)$ transformation and a paired t-test was performed on the complete data set. The mean difference of total larval abundance from neuston net samples versus Tucker net samples was significantly different ($t_S = 6.42$, $t_{.01(17)} = 2.90$).

When abundance is calculated over the area sampled (number per 1,000 m^2), the neuston and Tucker nets collected approximately equal numbers of larvae (Table 1). The mean difference in total abundance was not significantly different ($t_S = 0.93$; $t_{.05(17)} = 2.11$).

The Tucker net used in this study has a sampling volume approximately 2.7 times that of the neuston net. The observed ratio of abundance in Table 1 is approximately 2.9, indicating that larvae may be concentrated in the uppermost 0.75 m.

These observations indicate that densities of lobster larvae (per 1,000 m^3) estimated from Tucker net samples can be compared with neuston densities by considering ratios of volumes filtered. However, such a factor would be applicable only to samples collected under similar conditions. All samples in this study were taken on sunny days when seas were relatively calm (<1 m). Larval distribution in rough seas and on cloudy days may be more dispersed and differences observed would be smaller.

ACKNOWLEDGMENTS

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