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YALE UNIVERSITY

VOLUME XV

OCEANOGRAPHY OF
LONG ISLAND SOUND, 1952-1954

By

GORDON A. RILEY
SHIRLEY A. M. CONOVER
GEORGIANA B. DEEVEY
ROBERT J. CONOVER
SARAH B. WHEATLAND
EUGENE HARRIS
HOWARD L. SANDERS

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OCEANOGRAPHY OF LONG ISLAND SOUND, 1952-1954

V. ZOOPLANKTON

By

GEORGIANA BAXTER DEEVEY

Bingham Oceanographic Laboratory

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ABSTRACT

Zooplankton samples were collected by oblique hauls with a Clarke-Bumpus sampler, using both No. 2 and No. 10 silk nets, at weekly intervals at four stations from March 1952 to March 1954. Quantitative counts have been made on only those samples obtained from March 5, 1952 to June 1, 1953, but determinations of total displacement volumes are available for the entire two year period.

The seasonal cycle in total numbers of organisms from the No. 10 net samples showed maxima in late spring and late summer, with numbers increasing in the spring and decreasing during the fall to the midwinter minimum. The largest mean total number, over 200,000/m³, was recorded in late May 1952. The No. 2 net samples revealed maximal numbers of the larger forms in April and from August to September 1952: minimal numbers were found in October and November. The mean displacement volumes obtained for the two year period were 0.95 cc/m³ for the No. 10 net hauls and 0.29 cc/m³ for the No. 2 net samples. Mean No. 10 net displacement volumes recorded for the total water column varied from 8.1 cc/m² at St. 1 to 19.8 cc/m² at St. 2.

The copepods were the major group found in the zooplankton. The larvae of bottom invertebrates were second in numbers, while several species of Cladocera and a few other forms were fairly abundant seasonally. The total number of species is limited, since most neritic forms are excluded from the Sound by the lower salinities. The important species were *Acartia clausi*, *A. tonsa*, *Temora longicornis*, *Pseudocalanus minutus*, *Paracalanus crassirostris*, and *Oithona* spp.

A comparison of displacement volumes and total numbers of organisms recorded from Georges Bank, Block Island Sound and Long Island Sound shows a tremendous increase in total numbers and a concomitant decrease in mean size of individuals in passing from offshore neritic waters to inshore neritic and then to more enclosed, less saline waters. The lower salinity of Long Island Sound favors the development of an abundant zooplankton population composed largely of small species, which furnish adequate food only for the young of various fish and for those plankton-feeding fish which are efficient filter feeders. Thus, despite the high total numbers and the relatively high volumes of zooplankton present, Long Island Sound does not support any important commercial fisheries but acts as a spawning ground and nursery for young fish.

INTRODUCTION

The collection of zooplankton samples at certain stations and at weekly intervals has been part of the program of research on the hydrography and biology of Long Island Sound. Determinations of the displacement volumes have been completed for the two years, but the material has been examined and quantitative counts have been made only for the period March 5, 1952 to June 1, 1953.

The zooplankton organisms are all euryhaline species. The range in salinity is not great, usually varying between 25 and 28‰ during the year. Although occasional specimens of the neritic species common in the open coastal waters are carried into the Sound from Block Island Sound, observations of such occurrences have been relatively rare, since these forms are unable to survive at the lower salinities. The pertinent temperature and salinity data are presented in Fig. 1 of Riley's report, PHYSICAL OCEANOGRAPHY, in this volume.

Two other investigations have also been made on the zooplankton

material, both of which are reported in this volume. Wheatland has made an intensive examination of the fish eggs and larvae obtained in these hauls, and R. J. Conover has made a special study, using both live and preserved material, of *Acartia clausi* and *A. tonsa*, the most important copepods. The present report is a general survey of the species composition and quantity of the zooplankton.

ACKNOWLEDGMENTS

The samples were collected by Gordon Riley, assisted by Shirley and Robert Conover and Howard Sanders, to all of whom it is a pleasure to express my thanks. Also, I am most grateful to Gordon Riley for determinations of the displacement volumes, but I am especially indebted to him for his considered advice, cheerfully given at any time, and for sharing with me his knowledge of oceanographic problems in general.

METHODS

The samples were obtained by oblique tows with a Clarke-Bumpus sampler, using both No. 2 and No. 10 silk nets. The hauls were made from near bottom to the surface. The weight, attached about one meter below the sampler, could be lowered to the bottom, thus avoiding contamination of the sample with bottom material. However, at the deeper stations and at St. 8 where the depth was especially irregular, it was not always feasible to fish the whole water column.

Sts. 1, 2, 5, and 8 were visited regularly. As a rule, samples were collected at Sts. 1 and 2 every week and at 5 and 8 on alternate weeks, since the distances involved were too great to visit all four stations in a day's cruise. Thus hauls were made at Sts. 1, 2, and 5 in one week and at 1, 2, and 8 the next. Usually five samples were obtained each week; No. 2 and No. 10 net tows were made at two stations and a No. 10 net haul at the third.

All the stations studied are in the central portion of Long Island Sound (see Fig. 1 in Riley's INTRODUCTION). St. 2 is approximately in the center of the Sound, while 1 is off Milford, 8 is off the Thimble Islands, and 5 is off the north shore of Long Island. Sts. 1 and 8 are inshore and 2 and 5 are offshore stations.

During cruises to the eastern and western parts of the Sound in the spring and fall of 1952 and in spring of 1953, the No. 2 net was

used for most of the zooplankton hauls, although a few No. 10 net samples were collected.

The usual procedure has been followed in making quantitative counts. A sample was diluted to a known volume and stirred thoroughly, after which 5 or 10 cc, or more, were removed to the counting chamber. The number per cubic meter was obtained by dividing the total number of organisms in the sample by the volume of water strained when the sample was collected. All of the species have not yet been identified; the species of *Oithona*, for example, were not differentiated when the counts were made, and no attempt has been made to identify many of the larvae of bottom invertebrates, such as lamellibranch veligers, polychaete larvae, etc.

The total displacement volumes were obtained by straining the samples on a filter of No. 20 bolting silk, washing them several times with tap water, and removing the excess water by placing the silk on filter paper or some other absorbent surface for several minutes. The organisms were then removed from the silk with a thin spatula and put into a measured volume of water to obtain the displacement volume. Such determinations were made on all of the samples, except for some collected during February and March in 1953 and 1954 when too much phytoplankton was present to allow accurate determinations to be made.

THE ZOOPLANKTON

THE TOTAL ZOOPLANKTON

The mean total numbers of zooplankton organisms per cubic meter taken with the No. 2 and No. 10 nets from March 5, 1952 to June 1, 1953 are shown in Fig. 1. It is immediately apparent how small a proportion of the total population was sampled by the No. 2 net. Only in April 1952 did the numbers of No. 2 net organisms exceed 20,000/m³, while numbers of over 200,000/m³ were obtained by the No. 10 net hauls in late May 1952; mean total numbers of over 100,000/m³ were found during most of the period from late May through mid-September.

Comparison of the No. 10 net data for individual stations showed that total numbers of over 200,000/m³ were recorded only at Sts. 1 and 2. At St. 2 the maximal number of 213,000/m³ was obtained in mid-August, while at St. 1 total numbers of 258,000/m³, the highest re-

corded thus far in this survey, were found in early September. Nevertheless, the late summer maximum is not shown as strikingly in Fig. 1 as the late spring maximum. This is because a great increase took place simultaneously at all four stations in late May and early June, whereas the time of occurrence of the late summer maximum varied from station to station. The data obtained for St. 8 differed from those recorded for the other stations in that there was no marked increase in total numbers during the late summer; the numbers

TABLE I. MEAN MONTHLY TOTAL NUMBERS OF ZOOPLANKTON PER CUBIC METER AND PER SQUARE METER IN LONG ISLAND SOUND, 1952-1953.

	Mean Total Numbers per Cubic Meter				Mean of All Stations	
	Station 1	Station 2	Station 5	Station 8	Total No. per M ³	Total No. per M ²
March	11,750	25,875	41,730	21,000	25,675	475,950
April	43,980	65,300	25,600	31,750	44,255	725,000
May	110,920	111,510	104,500	115,600	111,200	1,729,800
June	210,900	142,500	111,600	100,400	161,385	2,230,330
July	70,275	83,840	76,615	77,070	77,000	1,230,540
August	107,555	152,070	108,700	84,025	114,715	1,890,220
September	145,680	80,575	85,400	40,200	105,140	1,507,970
October	27,730	19,290	65,750	36,900	31,180	507,405
November	29,655	32,735	38,800	24,000	31,350	529,800
December	11,840	15,090	23,600	8,870	14,325	238,060
January	8,530	10,530	15,575	9,500	10,635	189,365
February	16,475	14,665	26,900	28,800	19,560	347,000
March	15,400	44,400	61,975	—	45,940	1,093,310
April	49,300	72,000	68,900	8,050	53,430	1,140,180
May	97,370	83,135	64,000	43,150	76,870	1,153,400

increased abruptly to nearly 200,000/m³ in late May and then declined gradually to the seasonal minimum in late December.

Table I gives the mean monthly total numbers of the No. 10 net samples for Sts. 1, 2, 5, and 8; also given are the mean monthly numbers per cubic meter and per square meter of sea surface obtained by averaging the data from all No. 10 net hauls. At all stations the total numbers increased abruptly from April to May and remained high during June. High numbers were recorded during August at Sts. 2 and 5 and in August and September at St. 1. The decrease from September to October was particularly marked at Sts. 1 and 2. Minimal numbers were found in December and January, but through-

out the fall and winter the mean monthly numbers were somewhat greater at St. 5 than at the shallower stations. The yearly cycle, as revealed by the No. 10 net samples of 1952 to 1953, showed essentially a single maximum during the warmer months, the numbers increasing in the spring and decreasing in the fall to the mid-winter minimum.

The data for Sts. 1 and 2 at depths of 9 and 20 m respectively may be used to compare the total numbers of organisms per square meter of sea surface in the inshore and offshore waters. As expected, the numbers were approximately twice as large at the deeper station, where over 4,000,000/m² were found in August. Even at St. 1, over 2,000,000/m² were recorded in late spring and late summer. These figures are high when compared with those obtained for Block Island Sound (Deevey, 1952a) where the mean depth is 30 m; the highest numbers there did not exceed 1,000,000/m² of sea surface.

The No. 2 net samples (see Fig. 1) showed that maximal numbers of the larger forms were found during April and from mid-August to mid-September. Only in April 1952 did the numbers taken in the No. 2 net hauls exceed by a few hundred those obtained in the No. 10 net samples. The highest mean number, recorded in April 1952, was a little over 30,000/m³, twice the highest number found in April 1953. During October and November minimal numbers were present; from December onwards the totals increased gradually to the April maximum.

The mean total zooplankton displacement volumes obtained for the No. 2 and No. 10 net samples from March 1952 to March 1954 are shown in Fig. 2. For a comparison of the seasonal cycles of phosphate, nitrate, chlorophyll, and the No. 10 net volumes from the inshore and offshore stations, see Riley and Conover's accompanying report, CHEMICAL OCEANOGRAPHY. The quantity of zooplankton was considerably greater in 1952 than in 1953. It is probable, however, that such fluctuations in quantity occur from year to year in these waters.

The No. 10 net volumes showed a pronounced maximum in August and September 1952, similar to that recorded for the total numbers. This was the period when *Acartia tonsa* was most abundant and when a variety of crustacean larvae were present. Nevertheless, it is not clear, from the composition of the population, why the late summer volumes should have been so much greater than those obtained

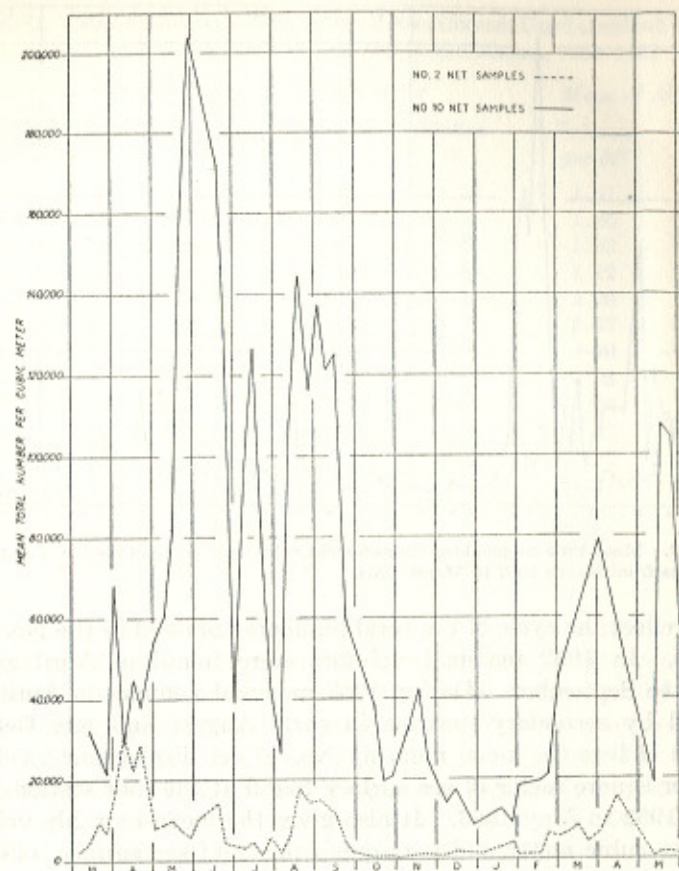


Figure 1. Mean total numbers of zooplankton per cubic meter taken with the No. 2 and No. 10 nets from March 5, 1952 to June 1, 1953.

earlier in the summer of 1952. The maximum in May 1952 may reflect, at least in part, the greater number of late-stage copepods present at this time which were responsible for the bursts of nauplii in early June. In 1953 a maximum in both numbers and volumes was found in early April. Since the samples obtained after June 1, 1953 have not been studied, it is not possible to compare total numbers with the much smaller volumes found in August and September 1953.

The seasonal cycle of the No. 2 net volumes (see Fig. 2) more

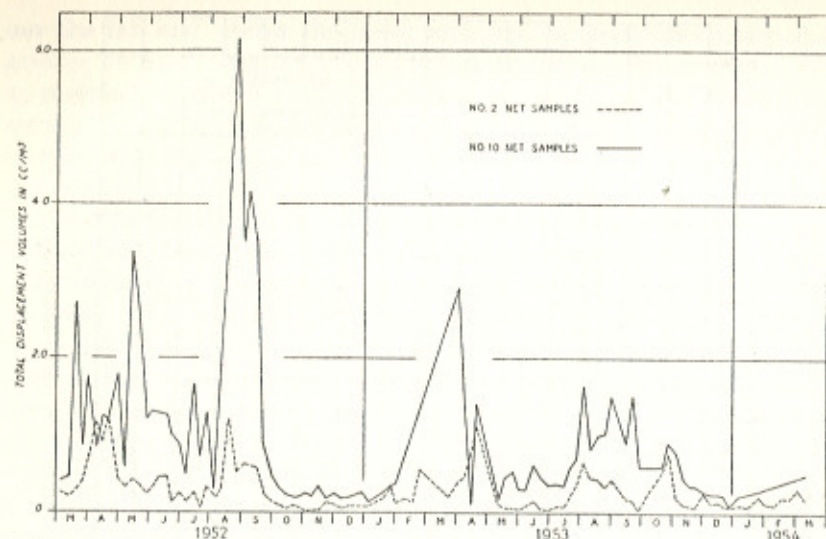


Figure 2. Mean total zooplankton displacement volumes in cc/m^3 of the No. 2 and No. 10 net samples from March 1952 to March 1954.

nearly reflect the cycle of the total numbers obtained in the No. 2 net samples. In 1952 maximal volumes were found in April and in August to September. During 1953 maximal volumes in April were followed by secondary maxima in early August and late October.

Table II lists the mean monthly No. 10 net displacement volumes in cc per square meter of sea surface found at the four stations from March 1952 to May 1953. It also gives the mean monthly volumes in cc per cubic meter and per square meter of sea surface, obtained by averaging all the No. 10 net data for this period. The individual station data can be converted into volumes per cubic meter by dividing by the station depths: 9 m for St. 1, 20 m for St. 2, 27 m for St. 5, and 12 m for St. 8. Presenting the station volumes as cc per square meter of sea surface makes it possible to compare quickly the total quantities found at the four stations during the year. At St. 1 the mean monthly volumes did not exceed $30 \text{ cc}/\text{m}^2$, but on several occasions at St. 8 exceptionally high volumes were obtained in 1952. Since considerable phytoplankton was present at St. 8 during the months in question, this may have contributed to the higher volumes. At the deeper stations, monthly volumes greater than $40 \text{ cc}/\text{m}^2$ were found only during August and September.

TABLE II. MEAN MONTHLY NO. 10 NET ZOOPLANKTON DISPLACEMENT VOLUMES IN CC PER SQUARE METER AND PER CUBIC METER, 1952-1953

	Mean Volumes per Square Meter				Mean of All Stations	
	Station 1	Station 2	Station 5	Station 8	Volumes per M^2	Volumes per M^3
March	6.30	12.20	16.88	55.20	1.21	17.99
April	13.20	33.60	16.07	11.52	1.26	19.56
May	10.73	36.64	23.67	47.44	1.92	28.45
June	11.40	21.30	26.19	10.92	1.12	16.27
July	7.47	13.84	11.20	26.40	1.00	13.88
August	28.87	86.00	41.58	49.80	3.37	50.57
September	23.87	59.50	93.15	3.96	2.70	45.63
October	1.89	4.00	11.07	2.58	0.23	3.77
November	2.12	5.25	7.16	2.04	0.24	3.99
December	1.71	2.87	6.48	3.60	0.21	3.33
January	1.73	8.10	5.80	4.20	0.26	4.33
February	—	9.40	7.29	—	0.37	8.35
March	—	—	—	—	—	—
April	11.70	5.80	40.50	1.44	0.80	14.86
May	3.30	9.20	12.42	3.18	0.39	6.25

The total volumes recorded for the No. 10 net samples yielded a mean annual concentration of $1.25 \text{ cc}/\text{m}^3$ for the period from March 1952 to March 1953. This is twice the mean volume of $0.61 \text{ cc}/\text{m}^3$ obtained from March 1953 to March 1954. For the two years, 235 determinations gave a mean concentration of $0.95 \text{ cc}/\text{m}^3$ for the No. 10 net samples. The No. 2 net zooplankton yielded a mean volume of $0.32 \text{ cc}/\text{m}^3$ for 1952 to 1953 and of $0.26 \text{ cc}/\text{m}^3$ for 1953 to 1954. The mean concentration obtained from 225 No. 2 net samples was $0.29 \text{ cc}/\text{m}^3$ for the two year period.

Table III summarizes the mean annual volumes recorded for the four stations. At each station the mean volumes obtained in 1953 to 1954 were smaller than those found during the first year. The volumes recorded for Sts. 1 and 2 are fairly similar. The smallest means were usually found at St. 5; also, at this station the difference between the two years was not as great. As previously noted, exceptionally large volumes were noted on several occasions in 1952 at St. 8; as a result the largest mean volume for 1952 to 1953 was obtained at this station. For the two year period, the No. 2 net volumes recorded for Sts. 1, 2, and 5 were one third as great as the No. 10 net volumes.

TABLE III. THE MEAN TOTAL ZOOPLANKTON DISPLACEMENT VOLUMES, IN CC/M³, AND THE ESTIMATED TOTAL ZOOPLANKTON CROP IN CC/M³ OF SEA SURFACE AT STATIONS 1, 2, 5 AND 8 IN LONG ISLAND SOUND, 1952-1954

	Mean Displacement Volumes in CC/M ³			Mean Zooplankton Crop in CC/M ³
	1952-1953	1953-1954	1952-1954	
Station 1				
No. 2 net	0.38	0.20	0.30	2.70
No. 10 net	1.16	0.59	0.90	8.10
Station 2				
No. 2 net	0.35	0.25	0.30	6.00
No. 10 net	1.33	0.62	0.99	19.80
Station 5				
No. 2 net	0.27	0.22	0.24	6.48
No. 10 net	0.86	0.56	0.72	19.44
Station 8				
No. 2 net	0.34	0.28	0.31	3.72
No. 10 net	1.95	0.52	1.24	14.88

When estimates are made of the mean zooplankton crops produced at the several stations during the two years, the results vary considerably due to the range of station depths (see Table III). Thus St. 1 yielded a mean volume of 8.1 cc/m³ for the No. 10 net samples, while the volumes recorded for Sts. 2 and 5 were 19.8 and 19.4 cc/m³, respectively. The mean volumes obtained for the No. 2 net samples varied from 2.7 at St. 1 to 6.5 cc/m³ at St. 5. When these figures are compared with those obtained from Block Island Sound¹ (Deevey, 1952a), it is apparent that the mean crop produced in Long Island Sound is probably no greater than that of Block Island Sound. This is rather surprising, since the highest number taken by the No. 10 net in Block Island Sound scarcely exceeded 30,000/m³, approximately the highest number retained by the No. 2 net in Long Island Sound. This excessive difference in total numbers coupled with similar displacement volumes indicates that the mean size of the organisms of Long Island Sound is considerably smaller than that of the zooplankton of Block Island Sound.

¹ Mean displacement volumes from Block Island Sound were: 0.68 cc/m³ and 20.4 cc/m³ for No. 10 net samples; 0.21 cc/m³ and 6.4 cc/m³ for No. 2 net samples.

THE COMPOSITION OF THE ZOOPLANKTON

The copepods were by far the dominant organisms. Only during May, June, July and September were appreciable quantities of other forms present. As a group, the larvae of bottom invertebrates ranked next in numbers; Cladocera were also important at all the stations. As previously noted, the dominant copepods were *Acartia clausi* and *A. tonsa*. *Temora longicornis*, *Pseudocalanus minutus*, *Paracalanus crassirostris*, and *Oithona* spp. also occurred in numbers during the year in both the No. 2 and No. 10 net hauls, while *Centropages hamatus*, *Labidocera aestiva* and *Pseudodiaptomus coronatus* constituted 5% or more of at least one of the No. 2 net samples. Three species of Cladocera, *Podon polyphemoides*, *Evadne nordmanni*, and *Penilia avirostris*, were obtained in numbers in the No. 2 and No. 10 net tows. The following types of larvae of bottom invertebrates made up 5% or more of at least one No. 2 or No. 10 net sample: barnacle nauplii, *Balanus balanoides* cyprids, lamellibranch veligers, gastropod veligers, echinoderm larvae, polychaete larvae, and mysid larvae. Aside from these forms, *Oikopleura dioica* and rotifers were the only other organisms that were fairly abundant seasonally.

Fig. 3 shows the total numbers of the several groups of organisms taken with the No. 10 net at St. 2. The relative proportions of the groups were similar at all stations. During most of the year, the copepods (including nauplii) constituted at least 80% of the population. Bottom larvae were abundant in May, June, July and September, while Cladocera were most numerous at the beginning of summer and again in September. Rotifers were largely responsible for the early April 1953 maximum of miscellaneous organisms. The composition of the No. 2 net zooplankton at St. 2 is shown in Fig. 4. Copepods constituted an even higher percentage of the No. 2 net hauls. Bottom larvae were not taken in quantity, and Cladocera were most numerous in June. The variety of zooplankton organisms is obviously not great.

The percentage composition of the copepod population found in the No. 10 net hauls at St. 2 is presented in Fig. 5, where the sequence of the important species during the year is clearly illustrated. *Acartia clausi*, *Temora longicornis*, and *Pseudocalanus minutus* occurred during the winter and spring. In July there was an abrupt change in the species composition as *Acartia tonsa*, *Paracalanus crassirostris*, and

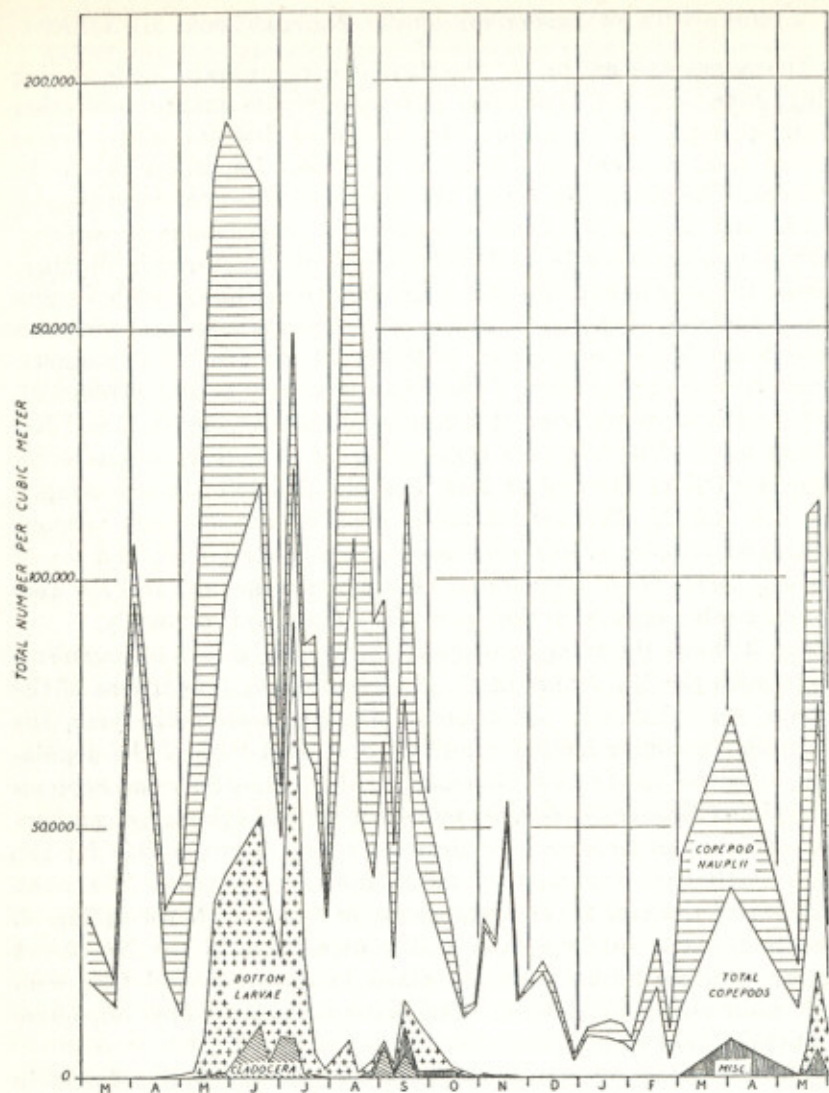


Figure 3. Total numbers per cubic meter of the different groups of organisms obtained in the No. 10 net hauls at St. 2 from March 1952 to June 1, 1953. The numbers of the groups are cumulative, the top line representing total numbers of zooplankton.

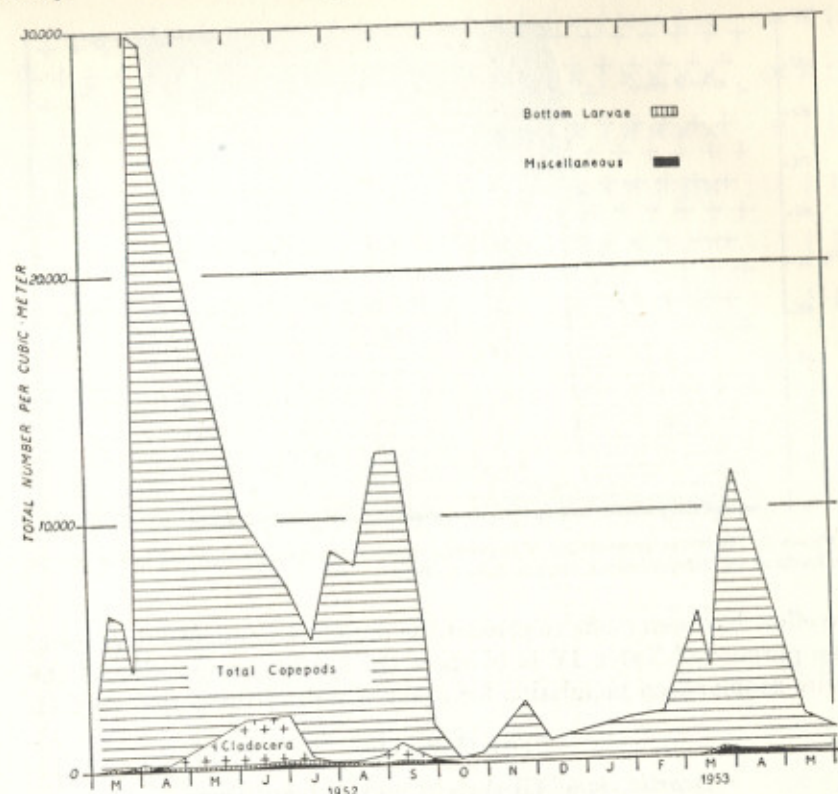


Figure 4. Total numbers per cubic meter of the different groups of organisms taken in the No. 2 net samples at St. 2 from March 1952 to June 1, 1953. The numbers of the groups are cumulative, as in Fig. 3.

Oithona spp. appeared and rapidly increased in numbers while the earlier species disappeared. In December the winter to spring species reappeared and began slowly to increase in abundance, while the summer and fall species dwindled in numbers during the winter months. Thus the winter change-over in species was much more gradual than the one that occurred in July. All of the other species of copepods combined, included in Fig. 5 as "Miscellaneous," were never of numerical importance.

Table IV gives a checklist of the species found in Long Island Sound. If a single specimen of a species was found in one sample at one station during the month, a check indicates its presence at that time.

TABLE IV. (Continued)

	1952										1953					
	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
CLADOCERA (Continued)																
<i>P. intermedius</i>	—	—	—	×	×	—	—	×	—	—	—	—	—	—	—	—
<i>Penilia avirostris</i>	—	—	—	—	×	×	×	×	—	—	—	—	—	—	—	—
<i>Bosmina</i> sp.	—	—	—	×	—	—	×	×	—	—	×	—	—	—	×	×
<i>Daphnia</i> sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×
CRUSTACEAN LARVAE																
<i>Balanus balanoides</i> nauplii	×	×	—	—	—	—	—	—	—	—	×	×	×	×	—	—
<i>B. balanoides</i> cyprids	×	×	×	—	—	—	—	—	—	—	×	×	×	×	×	—
Other barnacle larvae	—	—	×	×	×	×	×	×	—	—	×	×	×	×	×	—
Mysid larvae	×	×	×	×	×	—	×	×	×	×	×	×	×	×	×	—
Cumacean larvae	—	—	—	—	—	—	—	—	—	—	×	×	×	×	×	—
<i>Squilla</i> pseudozoeae	—	—	—	—	×	×	×	×	—	—	—	—	—	—	—	—
Microniscus larvae	—	—	—	—	—	—	×	×	—	—	—	—	—	—	—	—
Larval gammarids	—	—	×	—	×	—	×	×	×	—	—	—	—	—	—	—
Caprellids	—	—	—	—	—	—	×	×	—	—	—	—	—	—	—	—
Hyperiid amphipods	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Larval <i>Crago</i>	×	×	×	×	×	×	×	×	×	×	—	—	—	—	—	—
<i>Hippolyte</i> larvae	—	—	—	×	×	—	—	—	—	—	—	—	—	—	—	—
<i>Upogebia</i> larvae	—	—	—	—	×	×	×	×	—	—	—	—	—	—	—	—
<i>Eupagurus</i> larvae	—	—	—	×	×	×	×	×	×	—	—	—	—	—	—	—
Porcellanid larvae	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cancer irroratus</i> zoeae	—	—	×	×	×	×	—	×	—	—	—	—	—	—	×	×
<i>Callinectes sapidus</i> zoeae	—	—	—	×	×	×	×	×	—	—	—	—	—	—	×	×
<i>Pinnixa</i> sp. zoeae	—	—	—	—	×	×	×	×	—	—	—	—	—	—	—	—
<i>Libinia</i> sp. zoeae	—	—	—	—	×	×	×	×	—	—	—	—	—	—	—	—
<i>Neopanope texana sayi</i> zoeae	—	—	—	—	×	×	×	×	—	—	—	—	—	—	—	—
<i>Pelia mutica</i> zoeae	—	—	—	—	—	—	×	×	—	—	—	—	—	—	—	—

TABLE IV. (Continued)

	1952										1953					
	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
CRUSTACEAN LARVAE (Cont.)																
<i>Pinnotheres maculatus</i> zoeae	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—
Post-larval <i>Pinnotheres</i> sp.	—	—	—	—	—	×	—	×	—	—	—	—	—	—	—	—
Megalops larvae	—	—	—	—	—	×	×	×	—	—	—	—	—	—	—	—
OTHER LARVAL FORMS																
Echinoderm larvae	—	—	—	×	×	×	×	—	—	—	—	—	—	—	—	—
Cyphonautes larvae	×	×	—	×	—	×	×	×	—	—	—	—	—	×	—	—
Gastropod veligers	—	×	×	×	×	×	×	×	×	×	×	—	—	—	—	×
Lamellibranch veligers	×	×	×	×	×	×	×	×	×	—	—	×	×	×	×	×
Squid larvae	—	—	—	—	—	×	×	×	—	—	—	—	—	—	—	—
POLYCHAETES																
Polychaete larvae	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
<i>Autolytus</i> sp.	×	—	×	×	—	—	×	×	—	—	—	—	—	×	×	×
<i>Tomopteris</i> sp.	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—
COELENTERATES																
Hydromedusae	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Actinuli	—	—	—	—	—	—	×	×	—	×	—	—	×	×	—	—
Siphonophores	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—
OTHER FORMS																
<i>Sagitta elegans</i>	×	×	×	×	×	—	—	×	×	×	×	×	×	×	×	—
<i>Oikopleura dioica</i>	—	—	—	—	—	×	×	×	×	—	—	—	—	—	—	—
<i>Fritillaria</i> sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—
Rotifers	×	×	×	—	—	—	—	—	×	—	—	×	×	×	×	×
Nematodes	—	—	—	—	—	—	×	×	—	—	—	—	—	×	×	×
Fish eggs	×	×	×	×	×	×	×	×	—	—	—	—	×	×	×	×
Fish larvae	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	—

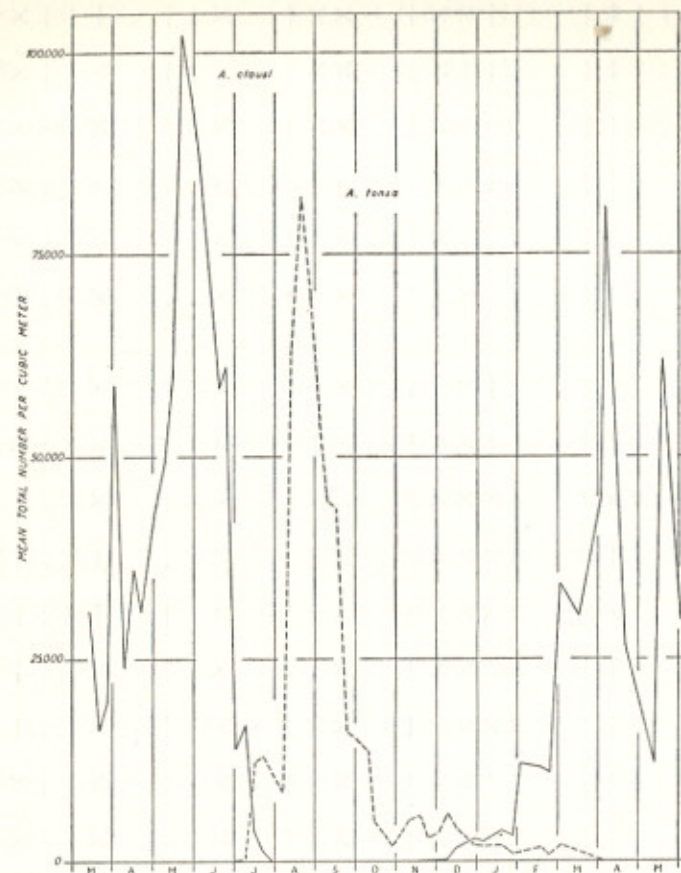


Figure 6. Mean total numbers of *Acartia clausi* and *A. tonsa* per cubic meter taken in the No. 10 net samples from March 1952 to June 1, 1953.

tually disappeared from the samples. In July the numbers began to increase and *A. tonsa* replaced *A. clausi* as the dominant species. The numbers of *A. tonsa* increased abruptly during August to their seasonal maximum, then declined rapidly in September. *A. tonsa* remained an important form during the fall, although it was exceeded in numbers by *Paracalanus crassirostris* and *Oithona* spp. (see Fig. 5). Late stages were present in small numbers throughout the winter and early spring months.

Judging from the total numbers recorded for the two species during

the year, *A. clausi* is better adapted to living in the waters of Long Island Sound than *A. tonsa*. An influx of ctenophores, appearing in early September 1952 and continuing during that month, may have been partially instrumental in lowering so drastically the numbers of *A. tonsa*, or it may be that *A. tonsa*, primarily an inhabitant of warmer waters, is incapable of reproducing in large numbers except during the warmest months at the northern limits of its range.

Temora longicornis (Müller)

This species ranked third in numbers. Its seasonal cycle, closely following that of *Acartia clausi*, was similar to that previously described (Deevey, 1952a) for Block Island Sound. However, it was more abundant in Long Island Sound. Fig. 7 shows the mean total numbers of *T. longicornis* recorded from the No. 10 net samples. In 1952 the numbers remained fairly low until mid-May, when there was an abrupt increase to a maximum in late May and June. The highest number obtained was approximately 100,000/m³ at St. 1 during the third week of June. Total numbers decreased sharply in late June, and by the beginning of August it had disappeared. It

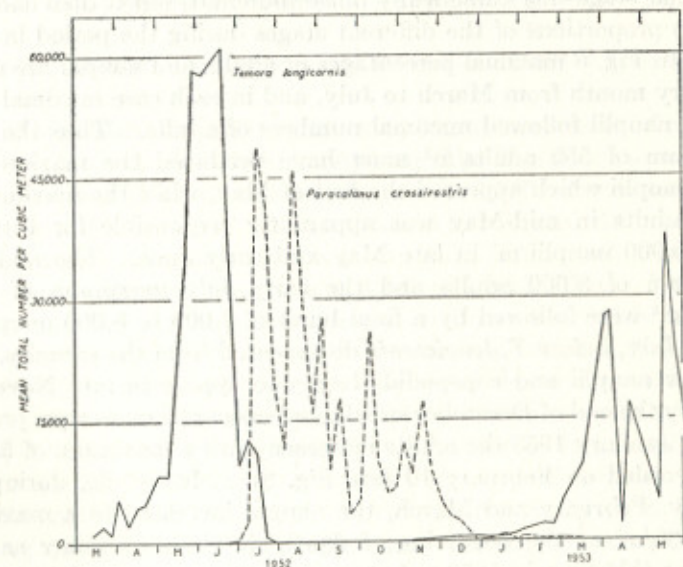


Figure 7. Mean total numbers per cubic meter of *Temora longicornis* and *Paracalanus crassirostris* taken in the No. 10 net samples from March 1952 to June 1, 1953.

reappeared in November and was present in small numbers until the end of February, but during March it began to increase and reached a maximum in early April. A second maximum occurred in mid-May, and then it declined in numbers up to the first of June. Obviously, both *T. longicornis* and *Acartia clausi* were similarly affected by whatever factors were responsible for the differences in total numbers observed between the springs of 1953 and 1952.

Since only portions of two seasonal cycles have been studied, and since the data for the two years varied considerably, it is difficult to determine the probable number of generations per year. From March to the end of July 1952, excepting July 1, nauplii constituted 40% or more of the total numbers, and reproduction probably occurred continuously during winter and spring until the population attained the high numbers recorded in late May and June. However, when the various developmental stages are plotted as percentages of the total number, as in Fig. 8, three and possibly four major maxima of nauplii are apparent between March and the end of July 1952. Such a graph is deceptive in that the time of occurrence of a higher percentage of a certain stage may not coincide with the date when that particular stage was numerically most abundant, but it does show the relative proportions of the different stages during the period in question. In Fig. 8 maximal percentages of adults and nauplii are shown for every month from March to July, and in each case maximal numbers of nauplii followed maximal numbers of adults. Thus the April maximum of 550 adults/m³ must have produced the maximum of 5,600 nauplii which appeared the first of May, while the maximum of 1,500 adults in mid-May was apparently responsible for totals of over 40,000 nauplii/m³ in late May and early June. The mid-June maximum of 3,000 adults and the early July maximum of 4,400 adults/m³ were followed by a final burst of 7,000 to 8,000 nauplii/m³ in mid-July, before *T. longicornis* disappeared from the samples.

A few nauplii and copepodids began to appear in late November 1952; by the end of December small numbers of all stages were present. During January 1953 the adults increased until a maximum of 550/m³ was recorded on February 10 (see Fig. 8). Meanwhile, during late January, February and March, the nauplii increased to a maximum of 22,000/m³ at the beginning of April, six times as many as were found at this time in 1952. A second adult maximum also occurred in late March and early April, although the numbers of nauplii were

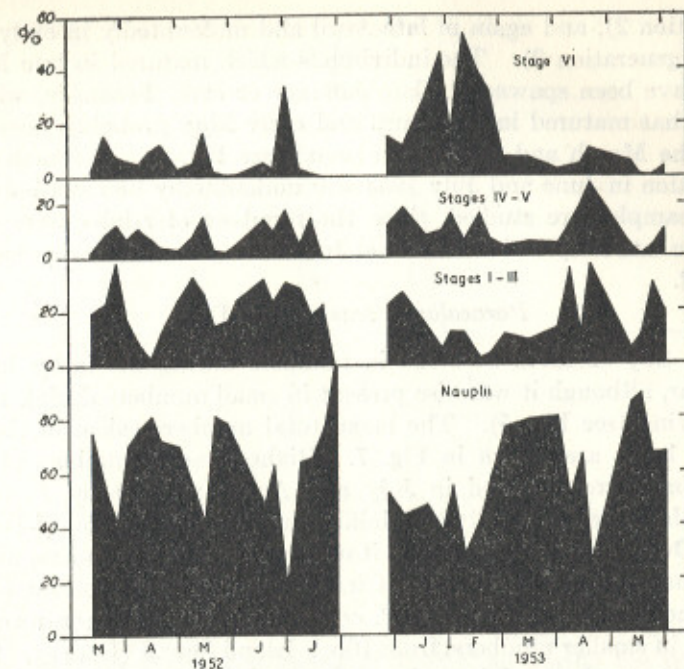


Figure 8. Relative percentages of nauplii and copepodid stages of *Temora longicornis*.

sufficiently high to obscure the early April maximum of stage VI *T. longicornis*. During April, many stage I to V individuals were present, and the highest number of adults, over 1,700/m³, was recorded on April 20. Unfortunately, no samples were collected during the next three weeks, when the ship was in drydock, but it is obvious that an adult maximum occurred in late April and early May. The second major maximum of over 33,000 nauplii/m³ was recorded in mid-May.

Several generations were produced during the months when *T. longicornis* was present, but the spacing of the broods and possibly the number may vary from year to year. In January and February 1953 the adult stock was gradually augmented to form adult generation 1 by the development of nauplii and copepodids which appeared in November and December. Spawning continued at a low level during midwinter, but in late February the nauplii had increased to approximately 1,000/m³ and by mid-March to nearly 8,000. Maximal numbers of adults also occurred in late March and early April (adult

generation 2), and again in late April and undoubtedly in early May (adult generation 3). The individuals which matured in late March may have been spawned in late January or early February, whereas those that matured in late April and early May probably developed from the March and early April brood (see Fig. 8). A fourth adult generation in June and July 1953 will undoubtedly be recorded when those samples are studied, since the numbers of adults were rising again in late May and since a final June-July generation was observed in 1952.

Paracalanus crassirostris Dahl

This tiny calanoid occurred in numbers during the latter half of the year, although it was also present in small numbers during winter and spring (see Fig. 5). The mean total numbers taken in the No. 10 net hauls are shown in Fig. 7. Highest mean numbers of over 45,000/m³ were obtained in July and August; thereafter *P. crassirostris* decreased gradually to minimal numbers by the end of December. During the spring of 1952 it occurred in small numbers, usually more than 100/m³, but in 1953 it was not found in the routine counts after the beginning of April. *P. crassirostris* has also been recorded, though in smaller numbers, from Block Island Sound (Deevey, 1952a) where it was observed from August to early February, with maxima in August and from October to December. In Long Island Sound it was found equally at all four stations, offshore as well as inshore. The highest total, 66,000/m³, was obtained at St. 2 in the center of the Sound in mid-August, while the next highest, 59,000, was noted in mid-July at St. 1. No attempt has been made to differentiate the developmental stages of this species. Only the numbers of the copepodid stages are plotted in Fig. 7.

Oithona spp.

The total numbers taken in the No. 10 net tows are presented in Fig. 9. The species have not been differentiated, but possibly three are included in these counts, *O. similis*, *O. brevicornis*, and *O. nana*. *Oithona* was found throughout the year (see Table IV). Minimal numbers were noted during the spring of 1952, but beginning in July and continuing in August the numbers increased to approximately 29,000/m³ in September. It then gradually decreased in quantity during the fall months, with relatively high numbers recorded in

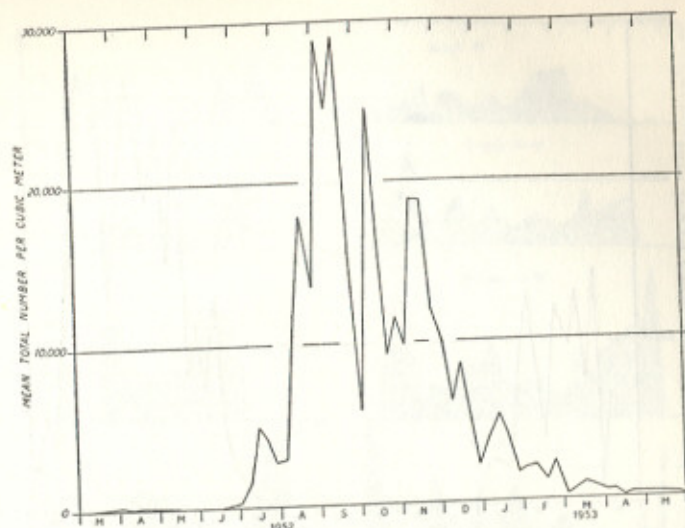


Figure 9. Mean total numbers of *Oithona* spp. per cubic meter obtained in the No. 10 net hauls.

October and again in November. *Oithona* occurred in appreciably larger numbers during the spring of 1953 than during the preceding spring. The species of *Oithona* thus exhibited a seasonal cycle similar to that of *Paracalanus crassirostris* (see Fig. 5). Maximal numbers were found at St. 1, the highest number being 46,000/m³ in early September, but it was also abundant at the other stations. During the fall months *Oithona* and *Paracalanus crassirostris* were of greater numerical importance than *Acartia tonsa*.

Pseudocalanus minutus (Krøyer)

This species occurred during winter and spring (see Fig. 5). Although its seasonal cycle resembled that of *Temora longicornis*, it was never as abundant. Fig. 10 shows the mean total numbers taken in the No. 10 net hauls. *P. minutus* was found in larger numbers in 1953 than in 1952. Maxima of nearly 3,000/m³ were noted in early April and of over 2,500/m³ in the latter part of May 1952. Small numbers were observed in June and it disappeared early in July. A few individuals were recorded in early December, and by the end of December all stages were present. The numbers increased during January 1953; in February, March and April maxima

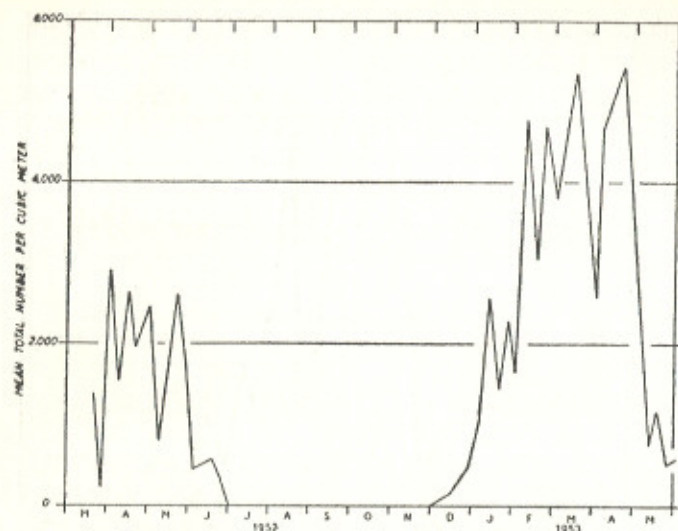


Figure 10. Mean total numbers of *Pseudocalanus minutus* per cubic meter taken in the No. 10 net samples.

of 4,500 to 5,500/m³ were found. However, the numbers decreased abruptly between late April and early May, so that *P. minutus* was not nearly as abundant in May 1953 as it had been in May 1952. As previously noted, this was also true of *Temora longicornis* and *Acartia clausi*.

Fig. 11 shows the percentage composition of the developmental stages in 1952 and 1953. Between March and July 1952, two major spawning periods are evident. The numbers of adults were low, the highest number (175/m³) occurring in mid-May, but judging from the relative percentages and the numbers of nauplii and of stages I to III, spawning occurred primarily during April and late May when nauplii were most abundant. Stages I to III were most numerous in early April and late May; none were observed after mid-June. Stages IV and V were also last recorded in mid-June, but a few females remained until the first of July. Nauplii were not numerous after the end of May. The mid-July maximum of nauplii shown in Fig. 11 is deceptive, since it represents only the small numbers that were found after the copepodid stages had disappeared.

By early December 1952 a few females, stage V copepodids and nauplii had appeared, in mid-December stages I and II were dominant,

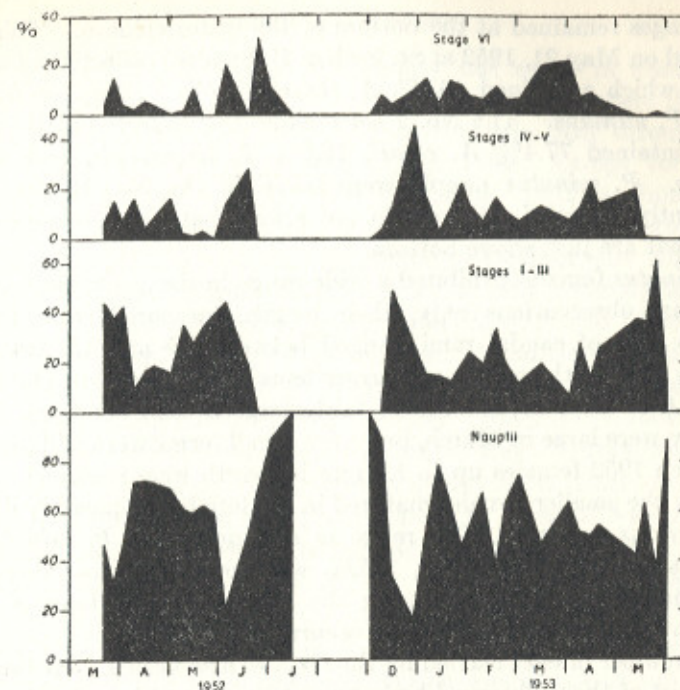


Figure 11. Relative percentages of nauplii and copepodid stages of *Pseudocalanus minutus*.

and by the end of the month all stages were present. From January to April 1953 spawning was continuous. The numbers of adults increased to approximately 350/m³ in late January and mid-February and reached maxima of over 1,000/m³ in mid-March. The first major burst of nauplii occurred in mid-January, when 2,000/m³ were recorded (see Fig. 11). During most of the period from February 10 to March 15 the numbers of nauplii remained around 3,000. Nauplii also appeared in comparable numbers in early and late April. Thereafter the total numbers of all stages decreased abruptly. During the latter half of May only stages I to III and nauplii were present. Possibly these developed into a last generation of adults in June, as in 1952.

Appreciable numbers of stage VI *P. minutus* were found only from January to April. Later in the spring, disproportionately low numbers of adults were taken. Possibly, as the temperature rose the

older stages remained at the bottom of the water column. This was observed on May 21, 1952 at St. 5 when H. Sanders collected a bottom sample which contained 46.5% *A. clausi*, 38.4% *T. longicornis*, and 16.4% *P. minutus*. The No. 2 net oblique tow collected at the same time contained 77.4% *A. clausi*, 19.3% *T. longicornis*, and no *P. minutus*. *P. minutus* nauplii were taken in the No. 10 net haul. Apparently, the oblique tows do not always sample adequately the forms that are just above bottom.

P. minutus females exhibited a wide range in size. On the basis of occasional observations only, their length, measured from top of head to base of caudal rami, ranged between 1.0 and 1.8 mm. In January 1953 both smaller and larger females were present, the range being 1.0 to 1.7 mm; most were fairly large in mid-February. The majority were large in March, but a few small forms were still present. In March 1952 females up to 1.8 mm in length were recorded. Presumably the smaller females matured in the late fall or possibly during the previous summer. The range in size noted for *P. minutus* in Block Island Sound (Deevey, 1952a) was not as extreme; there the small individuals matured during the summer, larger females were found in January, and the largest occurred in March.

The number of eggs carried by the females also varied. In January 1953 most of those observed had one or two eggs, although a few had up to 10 eggs. In mid-February, females approximately 1.7 mm in length carried up to 10 eggs, in March up to 16 eggs. In April occasional specimens carried large egg sacs, others only one egg. Evidently conditions in Long Island Sound were optimal for *P. minutus* during March. Marshall and Orr (1952) found that egg production in *Calanus* depends primarily on the quantity of food available, and Marshall (1949) noted a similar relationship between food and egg production in *Pseudocalanus*; in the latter, however, the largest females produced the greatest number of eggs. Since total numbers of diatoms were high in March (see S. A. M. Conover in this volume), it is not surprising that the largest *P. minutus* and also the greatest number of eggs per eggsac were observed at this time.

P. minutus was more numerous in Block Island Sound (Deevey, 1952a), where it was the dominant winter to spring species and where it occurred throughout the year, although in minimal numbers from September to December. Even though it is capable of maintaining itself in Long Island Sound at lowered salinities and over a wide range of temperature, it is primarily a neritic species.

OTHER COPEPODS

A few other species occurred regularly but never in abundance. *Centropages hamatus* (Lilljeborg) was found in small numbers throughout the spring and was most numerous from late May through July 1952. Fewer numbers were recorded in 1953. Except for April, it was present every month from November 1952 to June 1953. *Tortanus discaudatus* (Thompson and Scott) was most numerous from May to July 1952, but it was found also in October and November 1952 and in January, April, May, and June 1953. *Pseudodiaptomus coronatus* Williams occurred regularly from June 1952 to March 1953, in largest numbers from July to November. *Labidocera aestiva* Wheeler was noted from the end of June to the end of December 1952; it was most abundant in early September. Since these four species have a fairly wide salinity tolerance, one or more factors other than the lower salinity must have been responsible for their occurrence in limited numbers. In this general area, *C. hamatus* was observed in relative abundance only in the surface waters of Block Island Sound (Deevey, 1952b). The other species may prefer more specialized environments. *P. coronatus*, for example, was obtained in numbers on only one occasion, at St. 217 on September 30, 1952 when it constituted 83.5% of a night tow; this station was at one of the eastern entrances to the Sound in an area of rapid currents. Also it should be noted that, compared with the dominant species, except for *Pseudocalanus minutus*, these four species are relatively large. *T. discaudatus* is a carnivore, but the others are not, and possibly the particular forms that they prefer for food are not abundant in the Sound.

Harpacticoids were recorded every month except June 1952. Only three species were identified; *Alteutha depressa* Baird was found in January and April, but *Clytemnestra rostrata* (Brady) and *Microsetella norvegica* (Boeck) were noted only in April 1953. These species probably entered from Block Island Sound. An unidentified cyclopoid copepod occurred in April, May, June and August 1952 and in April and May 1953. *Eurytemora* sp., a brackish water calanoid, was found only in November 1952.

The several remaining species of copepods noted were stray specimens of neritic forms which were observed occasionally but which could not survive for any length of time in the Sound: *Centropages typicus* Krøyer, *Calanus finmarchicus* (Gunner), *Paracalanus parvus* (Claus), *Metridia lucens* Boeck, and *Candacia armata* (Boeck). Table

IV gives the records of their occurrence. These strays from neritic waters must have been carried into the Sound in the more saline bottom waters that enter from Block Island Sound.

CLADOCERA

Three species of Cladocera, *Evadne nordmanni* Loven, *Podon polyphemoides* (Leuckart), and *Penilia avirostris* Dana, were abundant seasonally, but several others were also present. *Podon leuckarti* Sars occurred at St. 2 in June 1952 and *P. intermedius* Lilljeborg was found at Sts. 2 and 5 in late June and July and at Sts. 219 and 220 in October 1952. *Bosmina* sp. was recorded in June, September and October 1952 and in January, May and June 1953. *Daphnia* sp. was noted at St. 2 on June 1, 1953, and *Daphnia ephippia* were observed at Sts. 1 and 2 in November 1952. The highest percentages of Cladocera were found at Sts. 1 and 5, but in all instances the total numbers of the several important species were highest at St. 1.

Fig. 12 shows the mean total numbers of *P. polyphemoides* collected in the No. 2 and No. 10 net samples in 1952. Only a small proportion of the *P. polyphemoides* population was retained by the No. 2 net. *P. polyphemoides* appeared at St. 1 during the latter part of May but not at the other stations until June. Two maxima were found in the No. 10 net hauls from Sts. 1 and 2, but by far the greater numbers occurred at St. 1, where approximately 15,000/m³ were recorded on June 19 and nearly 30,000/m³ on July 8. At St. 8 the highest numbers obtained were 1,000/m³ in June; at St. 5 it was not numerous until July. Two maxima of approximately 1,000/m³ were found in the No. 2 net samples, and it is of interest to note that the highest numbers of the larger specimens occurred in each case a week before the maxima recorded for the No. 10 net hauls. Although it has a wide salinity tolerance, *P. polyphemoides* apparently prefers waters of lower salinity. It was the only species of Cladocera observed in Tisbury Great Pond (Deevey, 1948), where it was found to be extremely euryhaline and moderately eurythermal, but it occurred in smaller numbers there than at St. 1. It was not found in Block Island Sound (Deevey, 1952a, 1952b). There this genus was represented by *P. leuckarti* and *P. intermedius*, species which did not occur in any quantity in Long Island Sound. *P. polyphemoides* was previously reported from Long Island Sound by Fish (1925).

Evadne nordmanni occurred from April to August 1952, with greatest

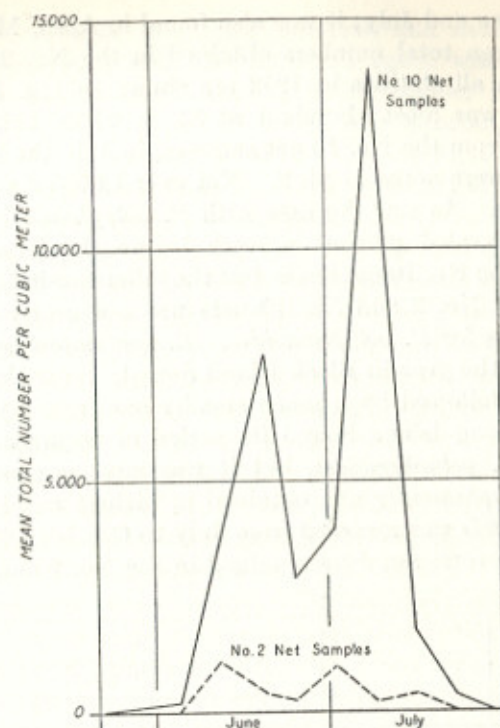


Figure 12. Mean total numbers of *Podon polyphemoides* per cubic meter obtained in the No. 10 and No. 2 net hauls in 1952.

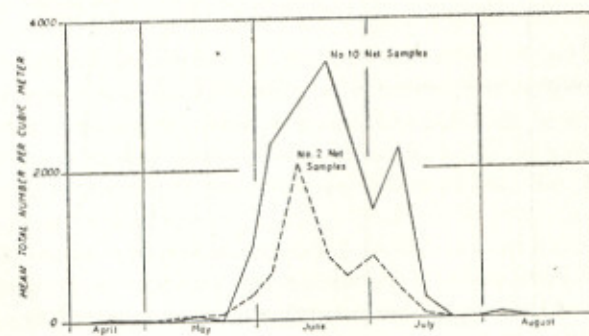


Figure 13. Mean total numbers of *Evadne nordmanni* per cubic meter taken in the No. 2 and No. 10 net hauls in 1952.

numbers in June and July; it was also found in April, May and June 1953. The mean total numbers obtained in the No. 2 and No. 10 net hauls from all stations in 1952 are shown in Fig. 13. In June *E. nordmanni* was most abundant at St. 1, where nearly 6,000/m³ were recorded from the No. 10 net samples; in July the highest numbers, 3,500/m³ were noted at St. 2. Not over 1,000/m³ were obtained at Sts. 5 and 8. As was the case with *P. polyphemoides*, the No. 2 net samples revealed maxima a week before the largest numbers were found in the No. 10 net hauls, but the difference in total numbers retained by the No. 2 and No. 10 nets was not nearly as great for *E. nordmanni* as for *P. polyphemoides*. *E. nordmanni* occurred for a greater part of the year in Block Island Sound, where the early June maximum was followed by a much smaller one from late August to October. In Long Island Sound its period of occurrence coincided with that of *P. polyphemoides*, but it was most numerous in June whereas *P. polyphemoides* was obtained in highest numbers in July.

Penilia avirostris was recorded from July to October 1952. Fig. 14 shows the mean total numbers obtained in the No. 2 and No. 10 net

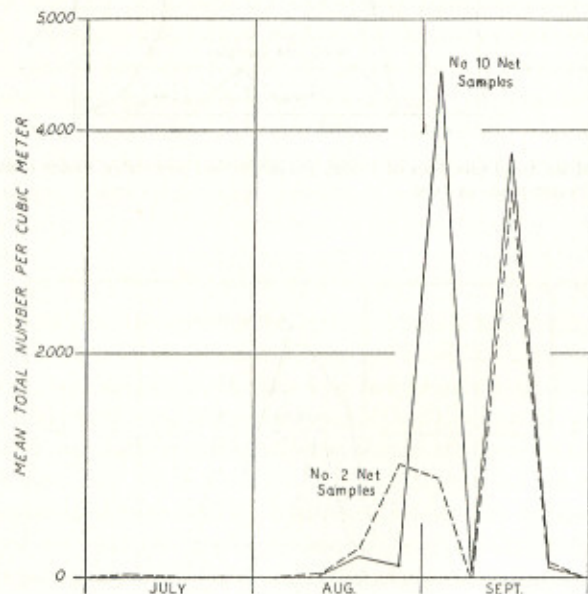


Figure 14. Mean total numbers of *Penilia avirostris* per cubic meter obtained in the No. 2 and No. 10 samples in 1952.

hauls. As in the case of *P. polyphemoides* and *Evadne nordmanni*, *P. avirostris* was most abundant at Sts. 1 and 2 where two maxima occurred, the first at the beginning of September and the second only two weeks later. At St. 2 the highest number, 6,000/m³, was recorded in early September, at which time 7,500/m³ were noted at St. 1; in mid-September nearly 11,000/m³ were found at St. 1. Only one maximum was recorded at Sts. 5 and 8; at St. 8 1,700/m³ were noted in late August, but at St. 5 it was not numerous until mid-September (4,000/m³). The No. 2 net samples showed a small early maximum in late August, but in mid-September almost as many were retained by the No. 2 as by the No. 10 net. In Block Island Sound in 1949 *P. avirostris* was also found from August to October. This species has not hitherto been considered a regular member of the zooplankton communities of the coastal waters of the northeastern Atlantic coast of the United States. Although it was noted seasonally in Block Island Sound (Deevey, 1952a, 1952b), it appeared together with the influx of warm water species in late summer and early fall. *P. avirostris* itself is primarily a warm water species. However, it may have extended its range recently. It was first observed at St. 1 in July, earlier than its usual time of appearance in Block Island Sound; it was also most abundant at St. 1. This may mean that it has now become acclimated to these waters and is an indigenous member of the plankton fauna. So far as is known, all of the other records for this species in these latitudes are from neritic waters. Its occurrence in numbers in waters of lower salinity may not have been reported previously.

THE LARVAE OF BOTTOM INVERTEBRATES

The periods of occurrence of the various larvae of bottom invertebrates are given in Table IV. Only lamellibranch veligers, gastropod veligers and polychaete larvae were obtained in numbers, but echinoderm larvae and barnacle larvae were fairly numerous seasonally. The total numbers of bottom larvae taken in the No. 10 net hauls at St. 2 are shown in Fig. 3.

Lamellibranch veligers constituted by far the greater part of the total numbers of bottom larvae recorded during the year. Fig. 15 presents the mean numbers taken in the No. 10 net samples. Maximal numbers were found from late May to mid-July 1952; a smaller maximum occurred in September. The highest number,

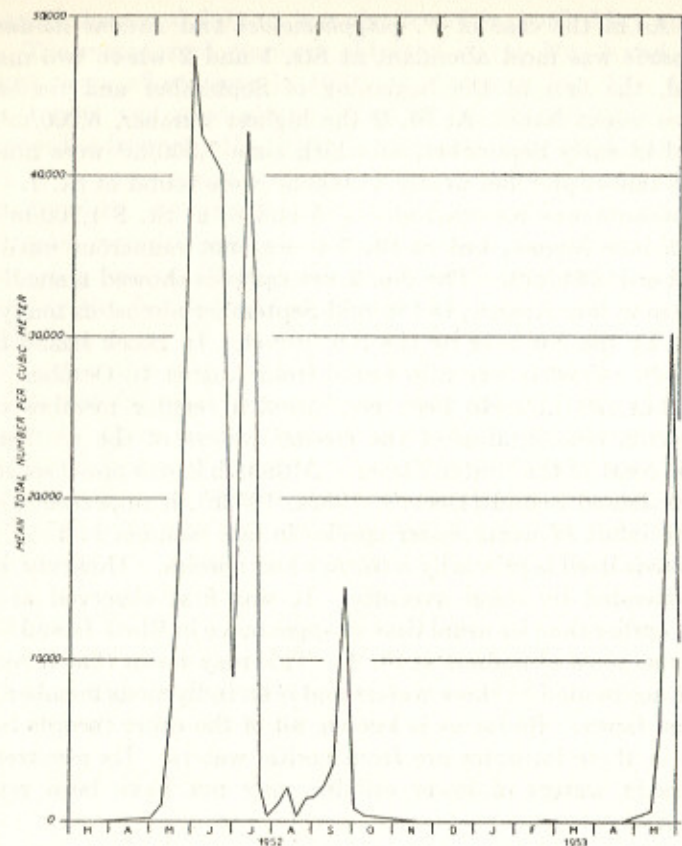


Figure 15. Mean total numbers of lamellibranch veligers per cubic meter taken in the No. 10 net samples from March 1952 to June 1, 1953.

81,300/m³, was noted at St. 2 on July 8. Few were present during the fall and none were recorded in December and January. In 1953, small numbers were found from late February to mid-May, when the numbers increased abruptly once more, although they had declined on June 1.

Gastropod veligers were numerous only during the summer of 1952, although small numbers or occasional specimens were recorded from April 1952 to January 1953 (see Table IV). They were not present during late winter and spring 1953. The mean numbers taken in the No. 10 net samples are shown in Fig. 16 together with those of the

polychaete larvae. The numbers increased in June, were maximal during July and August, and decreased by October. Relatively few gastropod veligers were obtained in the No. 2 net samples.

The only other molluscan larvae noted were occasional specimens of squid larvae at the offshore stations in August, September and October 1952.

Polychaete larvae were present every month from March 1952 to June 1953, but they were abundant only during July and to a lesser extent in August. The mean numbers from the No. 10 net samples

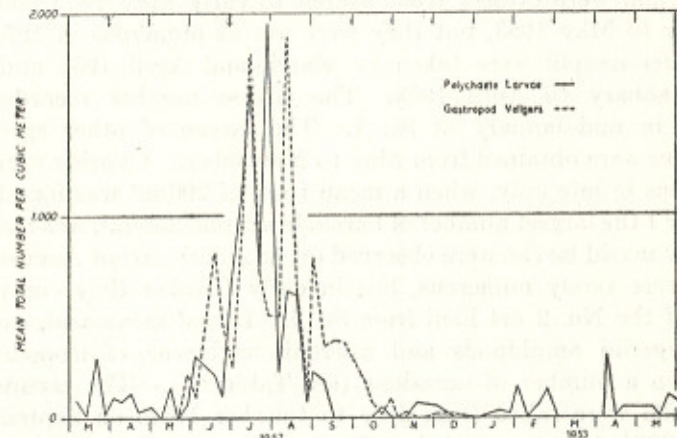


Figure 16. Mean total numbers per cubic meter of gastropod veligers and polychaete larvae obtained in the No. 10 net samples.

are presented in Fig. 16. Few were observed during late fall, small numbers were found during winter and spring, and large numbers occurred only in July.

Autolytus sp. was noted on a number of occasions (see Table IV), but *Tomopteris* sp. was found only in March 1953 at the offshore stations. *Tomopteris* is a pelagic polychaete, whereas *Autolytus* commonly appears in the plankton only at certain stages of its life history.

The cyphonautes larvae of Bryozoa were more numerous in Block Island Sound than in Long Island Sound, where a few were observed in the spring and from late summer to early fall (see Table IV). The highest numbers were found in samples collected on cruises to the eastern part of the Sound. Approximately 125/m³ were recorded

from the No. 2 net samples obtained on the June 1952 cruise and 165/m³ from No. 10 net samples collected on October 1, 1952.

Echinoderm larvae were present in appreciable numbers only in July and August 1952, although they also occurred in June and September. Highest numbers were found at St. 1, where 800/m³ were recorded on July 15 and 1,230/m³ on July 22. In August fewer than 200/m³ were noted.

Quite a variety of crustacean larvae was found (see Table IV). *Balanus balanoides* cyprids occurred in greater numbers than the nauplii and were present from March to early May 1952 and from January to May 1953, but they were not as numerous in 1953. *B. balanoides* nauplii were taken in March and April 1952 and from early January to April 1953. The largest number recorded was 500/m³ in mid-January at St. 1. The larvae of other species of barnacles were obtained from May to November. Cyprids were most numerous in late July, when a mean total of 200/m³ was found. On October 1 the largest number of barnacle nauplii, 355/m³, was recorded.

A few mysid larvae were observed every month except August 1952. They were rarely numerous, but in early October they constituted 9.4% of the No. 2 net haul from St. 5. Larval gammarid, caprellid and hyperiid amphipods and microniscus larvae of isopods were noted on a number of occasions (see Table IV). The pseudozoeae of *Squilla* were taken from July to October 1952; on September 9 nearly 200/m³ were recorded at St. 2. Cumacea were obtained only during the April 1953 cruise to the eastern end of the Sound.

Larval *Crago septemspinus* was found at most of the stations fairly continuously but in small numbers from mid-April to December 1952 and from April to June 1953. *Hippolyte* larvae were noted occasionally in spring and summer, whereas *Upogebia* and *Eupagurus* larvae were taken frequently during the summer and fall months (see Table IV). Porcellanid larvae were found only in the eastern part of the Sound in October 1952.

The remaining crustacean larvae belong to the Brachyura. The zoeae of *Libinia* sp., *Neopanope texana sayi*, *Pinnixa* sp., and *Calinectes sapidus* occurred continuously during the summer and early fall. *Cancer irroratus* zoeae were taken also in late spring (see Table IV), but the zoeae of *Pelid mutica* and *Pinnotheres maculatus* were observed only in the early fall. Zoeae were most numerous in August, the highest number recorded being 410/m³ at St. 8 on August 12.

Megalops larvae were found from August to October and young specimens of *Pinnotheres* sp. were taken in the zooplankton hauls in August and October.

OTHER FORMS

Of the remaining groups of organisms, the tunicates and rotifers (see Fig. 17) appeared seasonally in relatively large numbers. *Oikopleura dioica* Fol was the only tunicate that occurred in abundance, but *Fritillaria* sp. was found at St. 318 in the eastern part of the Sound in April 1953. *O. dioica* was present at most of the regular stations

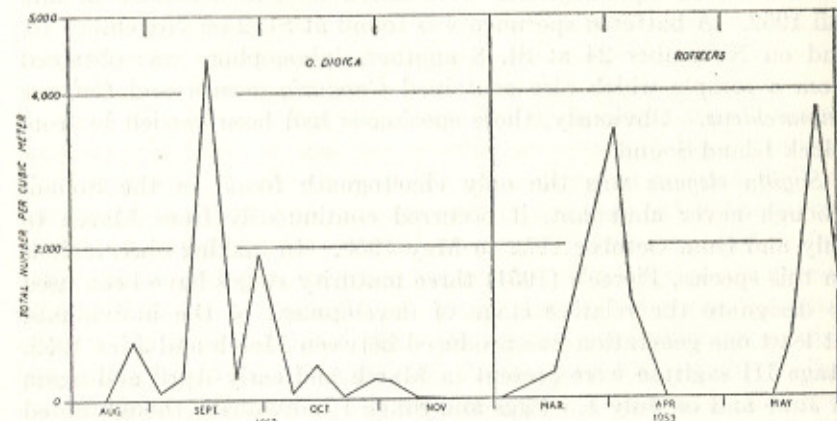


Figure 17. Mean total numbers per cubic meter of *Oikopleura dioica* and rotifers taken in the No. 10 net hauls.

from mid-August to mid-November 1952, with maximal numbers in mid-September, when about 5,500/m³ were recorded at St. 2, 4,800/m³ at St. 1, and 3,000/m³ at St. 5. At St. 8 maximal numbers of about 1,300/m³ were found in late August. In Block Island Sound this species occurred from July to September in comparable numbers (Deevey, 1952a).

Rotifers were found in March, April, May, and November 1952 and from February to June 1953. They were present in minimal numbers in 1952, but in 1953 they were fairly abundant in early April and late May (see Fig. 17). The highest number recorded was 7,000/m³ at St. 2 in early April. Only during the latter part of May were they observed at all of the regular stations.

Hydromedusae were found in small numbers throughout the

period studied. They were somewhat more numerous in April of each year, the highest number being 535/m² at St. 8 in 1952. As yet all of the species have not been identified. *Hybocodon prolifer* occurred in March and April 1952 and from January to April 1953, *Rathkea octopunctata* from March to May 1952 and from January to April 1953. *Sarsia mirabilis* was found in April, *Stomatoca dinema* in November, and *Nemopsis bachei* in December 1952. Several other species were also present. Actinuli (see Table IV) were recorded in the fall and spring.

Unidentified siphonophores were noted on two occasions in late fall 1952. A battered specimen was found at St. 2 on November 10, and on November 24 at St. 8 another siphonophore was obtained from a sample which also contained *Candacia armata* and *Calanus finmarchicus*. Obviously, these specimens had been carried in from Block Island Sound.

Sagitta elegans was the only chaetognath found in the Sound. Though never abundant, it occurred continuously from March to July and from October 1952 to May 1953. In making observations on this species, Pierce's (1951) three maturity stages have been used to designate the relative stage of development of the individuals. At least one generation was produced between March and June 1952. Stage III sagittae were present in March and early April and again in June and on July 1. Eggs and Stage I individuals, though noted every month from March to July, were more numerous in March and early April and in June and July. The sagittae disappeared the latter part of July.

Between fall 1952 and late May 1953 probably three generations were produced, but reproduction must have been fairly continuous during winter and spring, since eggs were present from December to late May. A few stage I individuals appeared in October, and these were followed by stage II sagittae in November and December 1952. Stage III individuals were present in January, March to early April, and mid-May 1953. Probably the sagittae which matured in January produced the generation that matured in March and early April, and these spawned the individuals that were beginning to mature by mid-May. The available data give no clue to the origin of the sagittae that appeared in the fall. In Block Island Sound, too, *Sagitta elegans* was not found in the zooplankton tows during late summer and early fall (Deevey, 1952b). Also, it is not known whether

Sagitta is indigenous to Long Island Sound or whether it is continually brought in from Block Island Sound in the deeper, more saline waters.

The other organisms taken in the zooplankton tows were nematodes and fish eggs and larvae. Nematodes were recorded only in September and October 1952 and in April and May 1953. Fish eggs and larvae were never found in numbers in the hauls, although fish larvae were noted every month from March 1952 to May 1953 and fish eggs were absent from the samples only from November through February. These forms have been studied in detail by Wheatland, whose report is given in an accompanying paper.

DISCUSSION

All of the zooplankton organisms living in Long Island Sound are euryhaline species that are adapted to waters of lower salinity. The copepods are the dominant group, comprising at least 80% of the population during the greater part of the year, while the larvae of bottom invertebrates, several species of Cladocera, and a few other forms are fairly abundant seasonally. Although a few species of copepods are exceedingly numerous during the year, the total number of species is limited, since the neritic forms which are carried into Long Island Sound from Block Island Sound are unable to live at the lower salinities. The zooplankton population is therefore more or less self contained. The dominant copepods are small species. For reasons not apparent at present, several larger copepods which might be expected to occur were found only in limited numbers, at least at the stations studied. The important species are *Acartia clausi*, *A. tonsa*, *Temora longicornis*, *Paracalanus crassirostris*, and *Oithona* spp.

Whereas most of the neritic species of the neighboring waters are barred from Long Island Sound by the lower salinities, nearly all of the forms found in abundance in the Sound are fairly numerous in Block Island Sound. *Acartia tonsa*, *Temora longicornis*, *Paracalanus crassirostris* and *Oithona* spp. are relatively abundant and contribute appreciably to the total numbers of the zooplankton population of Block Island Sound. Only *Acartia clausi*, the species most successfully adapted to living in Long Island Sound, is evidently incapable of maintaining itself in numbers in Block Island Sound. On the other hand, *Pseudocalanus minutus* is the only primarily

neritic copepod that is able to survive and reproduce successfully in Long Island Sound.

Of the other members of the plankton fauna, two of the important species of Cladocera, *Penilia avirostris* and *Evadne nordmanni*, occur in both Long Island Sound and Block Island Sound, although they were more numerous in the former. *Podon polyphemoides*, numerically the most abundant cladoceran in Long Island Sound, has not been recorded from Block Island Sound, where it is replaced by two other species of *Podon*. The higher salinities should not have barred *P. polyphemoides*, since, according to Baker (1938), it has a wide salinity tolerance and occurred throughout the year in Monterey Bay where salinities are higher than those of Block Island Sound. The two species of *Podon* found in Block Island Sound were not numerous in Long Island Sound.

Of all the groups and species of zooplankton organisms observed in Block Island Sound, few can tolerate the lower salinities of Long Island Sound. *Pseudocalanus minutus* and *Sagitta elegans* are the two forms living in Long Island Sound whose stock may be continually augmented by repeated incursions from Block Island Sound. Possibly *Oikopleura dioica* should be included with these species, since it occurs in comparable numbers in both Sounds. Presumably the hydromedusae, found equally in the two areas, are not affected by changes in salinity. Conversely, the majority of species which are abundant in Long Island Sound may be carried out in the less saline surface waters, thus increasing the variety of plankton in Block Island Sound.

Zooplankton displacement volumes have been found to be of the same order of magnitude throughout the coastal waters of the northeastern United States (Riley, *et al.*, 1949). A similar range of volumes has been noted in some European waters also (Wiborg, 1954). Over the continental shelf from Cape Cod to Chesapeake Bay, Bigelow and Sears (1939) found volumes of 0.4 to 0.8 cc/m³, while the zooplankton of Georges Bank (Riley and Bumpus, 1946) yielded a mean of 0.72 cc/m³. Redfield's (1941) data gave mean volumes varying between 0.3 and 0.53 cc/m³ for the different sectors of the Gulf of Maine. For Block Island Sound (Deevey, 1952a) the mean volumes obtained were 0.68 cc/m³ for the No. 10 net samples and 0.21 cc/m³ for the No. 2 net hauls. The mean concentrations recorded for 1952 to 1954 for Long Island Sound were 0.95 cc/m³ for the No. 10 net tows

and 0.29 cc/m³ from the No. 2 net samples. Apparently, in both Sounds the No. 2 net sampled only about a third of the total population. If the figure of 0.95 cc/m³ is accepted as representative of the quantity of zooplankton in Long Island Sound, it appears that these waters produce a slightly greater volume than the neritic areas investigated.

However, the Sound is a relatively shallow body of water, the depths varying from approximately 9 to 27 m at the stations studied, while the mean depths of Georges Bank and Block Island Sound are 65 and 30 m respectively. When estimates of the mean volumes beneath a square meter of sea surface are made, it is seen that at best the total crop produced in Long Island Sound is probably no greater than that of Block Island Sound. This is illustrated in Fig. 18, which compares the mean monthly volumes, in cc/m² of sea surface, recorded

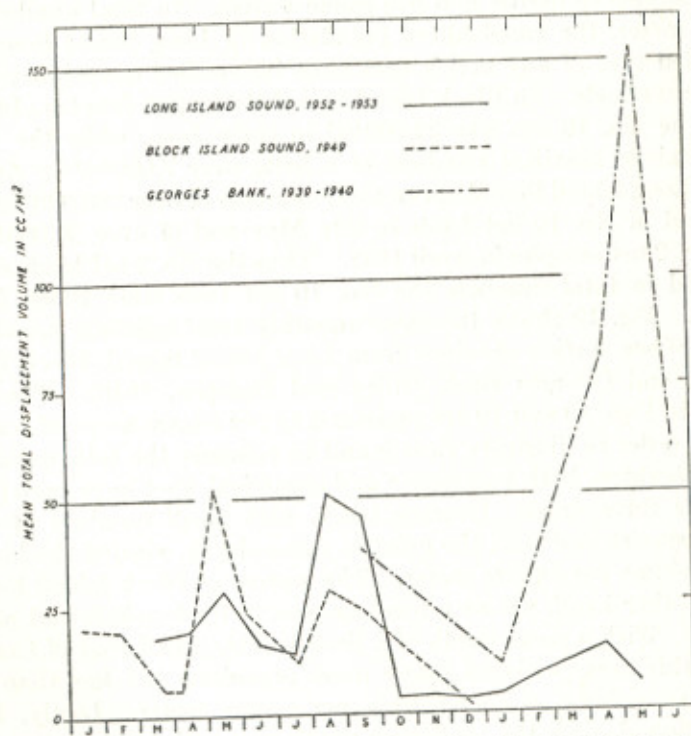


Figure 18. Mean monthly zooplankton displacement volumes, in cc/m² of sea surface, recorded from Long Island Sound, Block Island Sound and Georges Bank.

from Georges Bank, Block Island Sound and Long Island Sound. Fig. 18 also shows that maximal volumes were found in late spring and late summer in both Sounds, while the Georges Bank volumes were highest in May. The mean volumes obtained for the No. 10 net zooplankton from the four stations in Long Island Sound (see Table III) ranged from 8.1 at St. 1 to 19.8 cc/m² at St. 2. The mean volume recorded for Block Island Sound was 20.4 cc/m² of sea surface, while the estimated mean for Georges Bank, 48 cc/m², is more than twice as large. Therefore, although Long Island Sound yielded a relatively high volume of zooplankton per cubic meter, the total crop produced did not exceed that of Block Island Sound and was not half as large as the mean volume per square meter of sea surface recorded for Georges Bank.

It is also of interest to compare the difference in total numbers of organisms in neritic and less saline waters. In total numbers per cubic meter, the zooplankton population of Long Island Sound far exceeded that of any neritic area thus far studied quantitatively by similar methods. In Block Island Sound the largest number obtained with the No. 10 net was 32,000/m³ in early June, while the No. 2 net retained maximal numbers of a little over 7,000/m³ in August. From Long Island Sound, mean total numbers of over 200,000/m³ were recorded in No. 10 net hauls in late May and of over 30,000/m³ in the No. 2 net samples in April 1952. Thus the No. 2 net hauls almost equalled in total numbers the No. 10 net tows from Block Island Sound. Fig. 19 shows the mean monthly total numbers per square meter of sea surface obtained from Long Island Sound, Block Island Sound, and Georges Bank (Riley and Bumpus, 1946). The data shown in Figs. 18 and 19 are presented as per square meter of sea surface in order to illustrate clearly and to compare the total quantities of zooplankton, both volumetric and numerical, that have been found in these three areas. Georges Bank, with small numbers of large neritic species and with the greatest mean depth, yielded the highest total volume per square meter. The waters of Block Island Sound, on the other hand, act as a meeting ground for brackish and neritic species. With a mean depth of a little less than half that of Georges Bank, this area produced many more organisms but less than half the mean volume of zooplankton per square meter. Lastly, Long Island Sound, with the shallowest depth and with a population consisting almost entirely of small species, yielded volumes which were

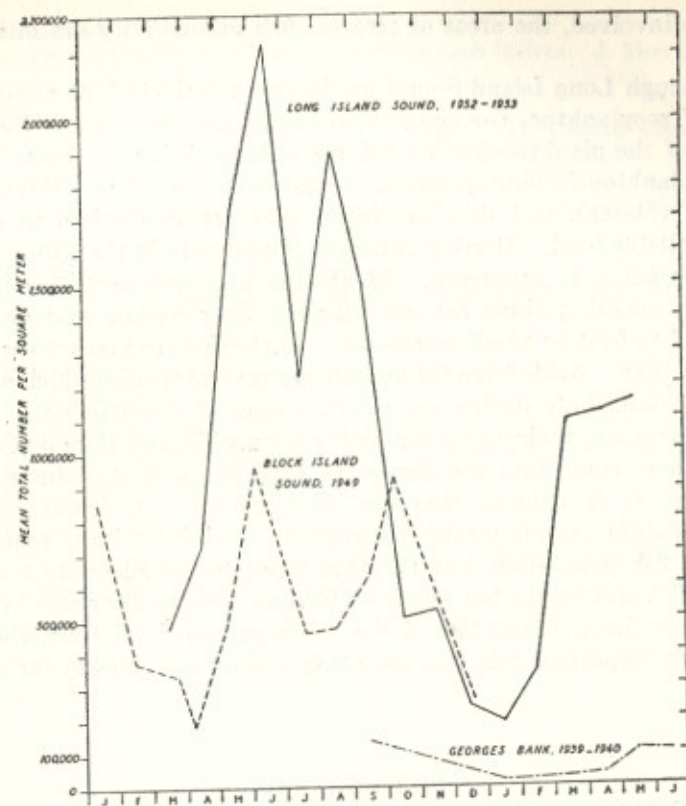


Figure 19. Mean monthly total numbers per square meter of sea surface recorded from Long Island Sound, Block Island Sound and Georges Bank.

comparable to those of Block Island Sound but produced at least twice as many organisms for the total water column. There is thus an extraordinary increase in total numbers of zooplankton in passing from offshore neritic areas to inshore neritic and then to more enclosed, less saline waters. Accompanying this there is evidently a tremendous decrease in the mean size of individuals, since the mean displacement volumes per cubic meter do not vary widely. Less saline waters favor the development of a zooplankton population composed chiefly of small organisms, if only by excluding the larger neritic species. This is undoubtedly of considerable import to the higher forms in the food chain, and it helps to explain why, aside from the other

factors involved, the areas of greatest fish productivity are in neritic waters.

Although Long Island Sound produces a relatively high concentration of zooplankton, the constituent organisms are so small that not many of the plankton-feeding fish are able to thrive on them. Only a few plankton-feeding species are found in the Sound (see Wheatland in this volume), and they are forms that are well suited to utilize the available food. Herring enter the Sound only in the winter when *Pseudocalanus* is numerous. Menhaden are abundant during the summer months; these fish are efficient filter feeders and are well adapted to feed on small organisms. Anchovies are present throughout the year. Aside from these there are several species which appear in the Sound only during their early stages of development. Some enter to spawn, their young remaining for a while and then departing, and others come into the Sound as juveniles and stay for several months. It is evident that the zooplankton organisms of Long Island Sound cannot furnish appropriate food for a large plankton-feeding fish population, but they are nevertheless adequate food for young fish and for the few species which are able to filter small forms. Therefore, Long Island Sound has no large commercial fisheries but serves an important role as a spawning ground and nursery for young fish.

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