THE VERTICAL DISTRIBUTIONS OF SOME COPEPODS AND A MYSID IN A NEAR-SHORE WATER OF TANABE BAY[1)]

ALESSANDRO VALBONESI[2)] and EIJI HARADA

Seto Marine Biological Laboratory

With Text-figures 1–2 and Table 1

The vertical pattern in the distribution and abundance of the plankton has been investigated extensively in various sea areas, particularly since the work of Russell (1925), as well as in varied inland waters, and it appears to have become a classical subject of plankton study. It has provided a basis for the analysis of migratory behaviours of different plankton organisms, and the ecological importance of vertical distribution and migration has been considered in different ways. The detailed observations on spatial distributions of plankton have evoked much interest in heterogeneity and variability in plankton, leading to the concept of patch structure or patchiness of the plankton (Barnes & Marshall, 1951; Cushing & Tungate, 1963). The small-scale pattern in space and microdistribution have also been attached wide concern, together with theoretical studies on the processes generating spatial structure (Cassie, 1959b, 1963; Richerson, Powell, Leigh-Abbott & Coil, 1978; Haury, McGowan & Wiebe, 1978). However, the vertical profiles have been obtained mostly for the plankton in the upper layers of the waters of ample depths.

It has been widely noticed that in a very shallow water few animal species are represented in the daytime plankton samples. This is suspected, in one way, to be a reflection of their escape from the tows by staying close to the bottom surface. Indeed, this has been demonstrated by a considerable amount of the zooplankton caught by a epibenthic trawl from the layer of 0–20 cm above the sea bottom, that "would not have been adequately sampled with the usual vertical or oblique net tow" (Bieri & Tokioka, 1968). It seems, however, that the vertical distribution of plankton animals in a very shallow water has not been paid much attention, where the water is not deep enough to allow them to complete such extensive vertical migration as has frequently been reported. Thus, most of the investigations on shallow-water plankton have resulted to show horizontal variations in composition and abundance.

The primary object of this study was to examine the vertical distribution of

---

1) Contributions from the Seto Marine Biological Laboratory, No. 666.

2) Present address: Via Nicola Farnesi No. 2, 55100 Lucca, Italy.

Publ. Seto Mar. Biol. Lab., XXV (5/6), 445–460. (Article 27)

plankton animals inhabiting the near-shore water shallower than 10 m in depth. In this paper, we are particularly concerned with the diurnal and seasonal changes in the vertical pattern in the distribution and abundance of dominant species in the studied area, i.e. three copepod species, *Oithona ocellata, Pseudodiaptomus marinus* and *Acarticia steweri,* and one mysid species, *Anisomysis aikawai,* focusing the attention to their occurrence in the hypoplankton.

We wish to thank our colleagues at the Seto Marine Biological Laboratory for their help in collecting the materials and for much discussion. We are also indebted to Dr. M. Murano and Mr. T. Ueda for identifying mysids and copepods respectively. One of us (A. V.) would like to acknowledge his gratitude for the grant from the Japan Ministry of Education for giving him the opportunity to study at the Seto Marine Biological Laboratory.

Materials and Methods

The series of stratified plankton samples were collected at two sites in the near-shore shallow water over the sandy flat bottom along the north beach of the Seto Marine Biological Laboratory. The sampling sites were intended to be in the similar environmental conditions and were about 200 m apart from each other, about 300 m off the shore and more than 100 m from the nearest rocky reefs, with depths ranging from 7 to 10 m with tide. According to the daily hydrographical records of surface water taken by the Laboratory on the north shore in the past several years, surface temperatures fluctuated from about 10°C in winter to 28°C in summer and surface salinities rarely fell down below 30‰. Remarkable daily fluctuations and vertical variations in water temperature have not been noticed in the shallow water studied.

A bottom plankton net was designed, which was much the same to the multilevel net (Fager *et al.*, 1966) or the epibenthic dredge (Gunter, 1957) or the dragonet II (Bieri & Tokioka, 1968) in the principal construction and function. The square mouth opening was 50 cm wide and 20 cm high and was divided into three horizontal sections, 5, 5 and 10 cm high respectively from bottom to top, to the metal frame of each section of which the net made of GG72 gauze with mesh opening of 222 μ was separately attached, so as to collect the stratified samples of hypoplankton simultaneously. This net, fitted with sledges on both sides just beneath the lower edge of the mouth opening, was pushed underwater along the sea bottom over a distance of 10 m with the aid of the scuba diving techniques. A standard conical net with same mesh opening was also employed and hauled vertically from a small boat from about 50 cm above the sea bottom to the sea surface. The zone of 20–50 cm from the sea bottom was not sampled, so it should be remembered that the results and discussions given in the present paper are relevant only to the layers of 0–5 cm, 5–10 cm, 10–20 cm and 50 cm-surface.

The collections were made in July, August and October 1978 and January and April 1979. Each site was sampled twice a day in day and at night, and four repeated hauls with each net were obtained at each site at each time of collection.

The hauls were counted in the laboratory and the sample means and standard deviations of the densities per m^3 of water were calculated. Only the adults were counted for the copepod species. *Anisomysis aikawai* were separated into five groupings by developmental stage as follows and were counted separately.

Stage I: young juvenile, length (from the apex of rostrum to the tip of telson) up to 1.5 mm; telson with 3 spines on lateral margins and 4 spines on each apical lobe; secondary sexual characteristics not developed.

Stage II: young juvenile, length up to 2.5 mm; telson with 3–4 spines on lateral margins and 5 spines on each apical lobe; pleopods not fully developed; appendix masculina in male very small and round, without sensory bristles; marsupium not developed in female.

Stage III: advanced juvenile, length up to 3.2 mm; telson with 4 spines on lateral margins and 6 spines on each apical lobe; male 4th pleopod extending to the half length of 5th abdominal somite, with 3-jointed exopod; appendix masculina conical in shape, without sensory bristles; marsupium being formed.

Stage IV: immature male and female, length up to 3.8 mm; telson similar to that in the previous stage; male 4th pleopod extending to the end of 5th abdominal somite; appendix masculina of typical adult shape, bearing two tufts of a few sensory bristles; marsupium developed.

Stage V: mature male and female, length up to 5.2 mm; telson with 6–7 spines on each apical lobe; appendix masculina well developed, with many sensory bristles; eggs or youngs present in female marsupium.

The size at which the secondary sexual characteristics develop differs evidently between different seasons. The elongation of the fourth pleopod in male and the development of the marsupium in female are noticeable in the specimens of 3.6 mm in length in July, August and October, whereas they are not detectable in the specimens less than 4.2 mm in length in January.

Results

Population Compositions and Variations

Mean densities and standard deviations, calculated from the counts of the hauls, are given in Table 1. Variations in the calculated density among the replicate hauls are generally fairly large, but differences between layers, between day and night, between months and between species are far more evident and larger.

Oithona ocellata

This species occurred in most of the layers of both sampling sites throughout the year. Maximum densities were attained in August, whereas the densities remained low in January to April.

Pseudodiaptomus marinus

The populations were comparatively small in this species and there was a complete disappearance of them in January. They increased and attained their maxima in April.

Table 1-1. Mean densities ($\bar{x}$, numbers per m^3) and standard deviations (s) of three copepods and one mysid, calculated from the counts of four replicate hauls, on 14 July 1978.

Species			*Oithona ocellata*		*Pseudo-diaptomus marinus*		*Acartia steweri*		*Anisomysis aikawai* Stage I		Stage II		Stage III		Stage IV		Stage V	
Site	Time	Layer	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
A	Day	50cm-surface	0	—	0	—	0.1	0.1	0	—	0	—	0	—	0	—	0	—
		10–20cm	165	204	17	7	7	3	2	2	8	4	0	—	0	—	0	—
		5–10cm	1469	830	53	25	30	12	11	5	8	9	1	2	0	—	0	—
		0–5cm	13370	4610	1412	555	428	298	60	31	91	29	20	4	7	4	5	2
	Night	50cm-surface	0.9	0.4	49	12	3	1	0.7	0.1	0.9	0.4	0.2	0.1	0.3	0.1	0.2	0.2
		10–20cm	184	45	20	10	1	2	14	8	4	4	0.5	1	2	2	5	6
		5–10cm	404	118	20	4	0	—	6	7	0	—	2	2	6	4	11	9
		0–5cm	686	255	27	28	0	—	11	16	0	—	2	4	7	8	18	33
B	Day	50cm-surface	0	—	0	—	0.1	0.1	0	—	0	—	0	—	0	—	0	—
		10–20cm	359	582	13	5	4	3	4	3	7	2	1	1	0	—	0	—
		5–10cm	1373	1097	60	23	5	2	32	31	104	44	3	4	0	—	0	—
		0–5cm	1806	1344	426	32	15	5	82	48	305	52	61	20	14	7	13	10
	Night	50cm-surface	0.2	0.2	31	6	0.7	0.1	0.4	0.3	2	1	0.1	0.1	0.1	0.1	0.3	0.3
		10–20cm	285	222	23	7	10	6	10	5	9	2	1	1	4	3	5	2
		5–10cm	616	409	33	17	3	6	6	2	11	8	1	2	7	4	11	8
		0–5cm	1288	1194	31	12	4	8	6	2	1	2	2	2	4	4	12	3

Table 1-2. Mean densities ($\bar{x}$, numbers per m^3) and standard deviations (s) of three copepods and one mysid, calculated from the counts of four replicate hauls, on 4 August 1978.

Species			*Oithona ocellata*		*Pseudo-diaptomus marinus*		*Acartia steweri*		*Anisomysis akiawai* Stage I		Stage II		Stage III		Stage IV		Stage V	
Site	Time	Layer	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
A	Day	50cm-surface	0.5	0.1	0	—	0.6	0.2	0	—	0	—	0	—	0	—	0	—
		10–20cm	29	14	20	14	399	242	14	12	25	26	1	2	0	—	0	—
		5–10cm	534	439	119	96	288	240	171	100	390	294	31	31	6	4	5	4
		0–5cm	14161	2913	930	327	338	195	783	267	1648	468	211	83	39	13	50	19
	Night	50cm-surface	0.5	0.4	4	1	8	3	1	1	9	4	2	1	0.4	0.2	0.7	0.2
		10–20cm	473	356	16	10	19	22	24	22	33	23	5	4	5	3	8	6
		5–10cm	1136	748	22	10	11	3	21	12	33	16	4	3	9	3	17	6
		0–5cm	961	929	24	13	9	8	3	2	23	13	9	3	8	0	7	2
B	Day	50cm-surface	0.2	0.4	0.5	0.6	0.1	0.2	0	—	0	—	0	—	0	—	0	—
		10–20cm	523	694	6	5	37	21	56	37	81	50	11	10	4	3	3	3
		5–10cm	2588	966	58	4	56	41	402	224	876	205	111	73	34	10	36	11
		0–5cm	5966	2069	221	134	9	6	382	190	758	439	232	115	57	53	81	56
	Night	50cm-surface	0.3	0.3	3	1	1	1	0.6	0.2	0.5	0.6	0.8	0.5	0.5	0.1	0.5	0.2
		10–20cm	473	112	28	11	30	19	37	23	114	47	17	3	23	5	46	22
		5–10cm	758	278	40	13	20	16	53	29	45	15	16	7	33	13	69	29
		0–5cm	1940	825	47	27	25	16	26	32	23	22	9	3	19	12	40	36

Table 1-3. Mean densities ($\bar{x}$, numbers per m^3) and standard deviations (s) of three copepods and one mysid, calculated from the counts of four replicate hauls, on 14 October 1978.

Species			*Oithona ocellata*		*Pseudo-diaptomus marinus*		*Acartia steweri*		*Anisomysis aikawai*									
									Stage I		Stage II		Stage III		Stage IV		Stage V	
Site	Time	Layer	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
A	Day	50cm-surface	0.2	0.2	0.1	0.1	0.2	0.2	0	—	0	—	0	—	0	—	0	—
		10–20cm	37	49	1	1	475	204	4	3	0	—	0.5	1.0	0	—	0	—
		5–10cm	641	917	1	2	702	223	36	33	7	3	0	—	0	—	0	—
		0–5cm	556	601	49	6	230	170	43	22	5	6	0	—	0	—	0	—
	Night	50cm-surface	0.2	0.2	0.6	0.3	16	4	0.1	0.2	0.1	0.2	0	—	0	—	0.2	0.2
		10-20cm	11	2	2	2	65	24	4	1	1	1	0	—	0	—	0	—
		5–10cm	29	16	3	4	73	39	5	6	4	6	0	—	0	—	3	4
		0–5cm	48	43	0	—	11	11	1	2	3	4	0	—	0	—	0	—
B	Day	50cm-surface	0	—	0	—	0.2	0.2	0	—	0	—	0	—	0	—	0	—
		10–20cm	349	314	2	3	1045	1296	7	9	1	1	1	1	0	—	0	—
		5–10cm	1818	1274	34	26	954	1126	28	10	3	4	1	2	0	—	1	2
		0–5cm	259	102	59	40	101	76	8	7	1	2	0	—	0	—	0	—
	Night	50cm-surface	0.2	0.2	0.3	0.2	6	7	0.1	0.1	0	—	0	—	0	—	0.1	0.2
		10–20cm	990	630	8	5	58	47	7	8	0	—	0	—	0	—	0	—
		5–10cm	4890	5330	25	27	91	110	41	56	14	25	0	—	0	—	3	4
		0–5cm	12940	6710	19	15	46	42	35	30	9	6	0	—	0	—	2	4

Table 1-4. Mean densities ($\bar{x}$, numbers per m^3) and standard deviations (s) of three copepods and one mysid, calculated from the counts of four replicate hauls, on 9 January 1979.

Species			*Oithona ocellata*		*Pseudo-diaptomus marinus*		*Acartia stcweri*		*Anisomysis aikawai*									
									Stage I		Stage II		Stage III		Stage IV		Stage V	
Site	Time	Layer	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
A	Day	50cm-surface	0.1	0.2	0	—	0.1	0.1	0	—	0	—	0	—	0	—	0	—
		10–20cm	0.5	1.0	0	—	2	2	0	—	0	—	0.5	1.0	0.5	1.0	4	4
		5-10cm	9	11	0	—	3	4	0	—	0	—	4	5	13	14	56	29
		0–5cm	4	3	0	—	0	—	0	—	0	—	3	6	17	12	90	88
	Night	50cm-surface	0.1	0.2	0	—	4	2	0	—	0	—	0.1	0.2	0.1	0.1	0.4	0.4
		10–20cm	200	56	0	—	12	9	0.5	1.0	0.5	1.0	0.5	1.0	0	—	0.5	1.0
		5–10cm	590	45	0	—	22	9	1	2	4	3	0	—	1	2	0	—
		0–5cm	712	421	0	—	12	11	0	—	0	—	0	—	2	2	0	—
B	Day	50cm-surface	0	—	0	—	0.2	0.3	0	—	0	—	0	—	0	—	0	—
		10–20cm	75	134	0	—	0.2	0.3	3	7	10	12	9	12	9	10	24	13
		5–10cm	42	24	0	—	0	—	10	9	43	68	62	61	85	57	148	85
		0–5cm	26	19	0	—	0	—	7	11	38	40	72	54	72	57	178	133
	Night	50cm-surface	0	—	0	—	0.5	0.6	0	—	0.1	0.1	0.2	0.2	0.2	0.1	1	1
		10–20cm	25	13	0	—	0.5	1.0	0.5	1.0	0	—	0.5	1.0	2	1	2	2
		5–10cm	152	55	0	—	1	2	0	—	4	8	0	—	2	2	4	3
		0–5cm	488	280	0	—	0	—	1	2	1	2	0	—	3	2	2	2

Table 1-5. Mean densities ($\bar{x}$, numbers per m^3) and standard deviations (s) of three copepods and one mysid, calculated from the counts of four replicate hauls, on 7 April 1979.

Species			*Oithona ocellata*		*Pseudo-diaptomus marinus*		*Acartia steweri*		*Anisomysis aikawai*									
									Stage I		Stage II		Stage III		Stage IV		Stage V	
Site	Time	Layer	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
A	Day	50cm-surface	0.1	0.1	17	3	0.1	0.2	0	—	0	—	0	—	0	—	0	—
		10–20cm	100	90	110	120	1010	780	120	20	740	250	350	70	200	110	70	40
		5–10cm	100	90	180	70	2610	870	350	270	1640	280	1140	90	730	600	250	180
		0–5cm	80	30	1480	260	2020	680	120	50	710	340	430	220	320	280	180	140
	Night	50cm-surface	0	—	15	5	15	5	0	—	0.1	0.1	0.3	0.2	0.2	0.2	0.3	0.2
		10–20cm	60	80	40	20	1070	260	60	80	100	70	140	110	430	220	560	260
		5–10cm	160	150	120	80	2830	1260	130	150	520	360	740	360	1740	420	2110	620
		0–5cm	670	530	350	170	1560	750	140	60	290	120	480	90	930	270	1070	320
B	Day	50cm-surface	0	—	18	3	0.1	0.1	0	—	0	—	0	—	0	—	0	—
		10–20cm	230	150	140	120	3160	3280	160	80	1410	1150	470	250	210	100	70	20
		5–10cm	80	70	760	480	3680	1060	410	300	3700	3070	2100	1370	1130	630	320	220
		0–5cm	60	50	1860	1080	1070	710	110	50	1010	630	550	270	420	350	230	180
	Night	50cm-surface	0	—	43	16	48	28	0.2	0.2	0.3	0.2	0.4	0.3	0.2	0.3	0	—
		10–20cm	120	80	1380	620	5440	2090	70	30	290	90	310	180	390	160	400	140
		5–10cm	200	140	730	120	11140	4270	160	140	230	170	640	420	1050	350	1100	760
		0–5cm	2250	730	480	120	10700	1590	140	80	810	350	1150	180	2720	1220	2470	1030

Acartia steweri

This species occurred in most of the layers throughout the year, but the seasonal fluctuations in density and population size were remarkable. Although the densities increased slightly in October, the populations were rather small during summer through winter and showed a sudden, considerable increase in April.

Anisomysis aikawai

The populations in July consisted mainly of juveniles with a few mature breeding adults. The population increased in August and decreased in October, though the compositions were not much different from that in July. The populations were still at low level in January, but the breeding adults increased relatively in number. The maximum densities were attained in April for nearly all stages.

Although the mature adults of stage IV were completely absent from the October hauls, and the breeding adults were few, the breeding adults occurred in the hauls of all months, indicating that breeding continued throughout the year with the spring intensive period.

Vertical Distribution Patterns

In order to figure and compare the patterns in depth distribution, the percentage of total of the calculated number of individuals in each layer of vertical column of water was calculated from the density. The results were shown in Figs. 1 and 2.

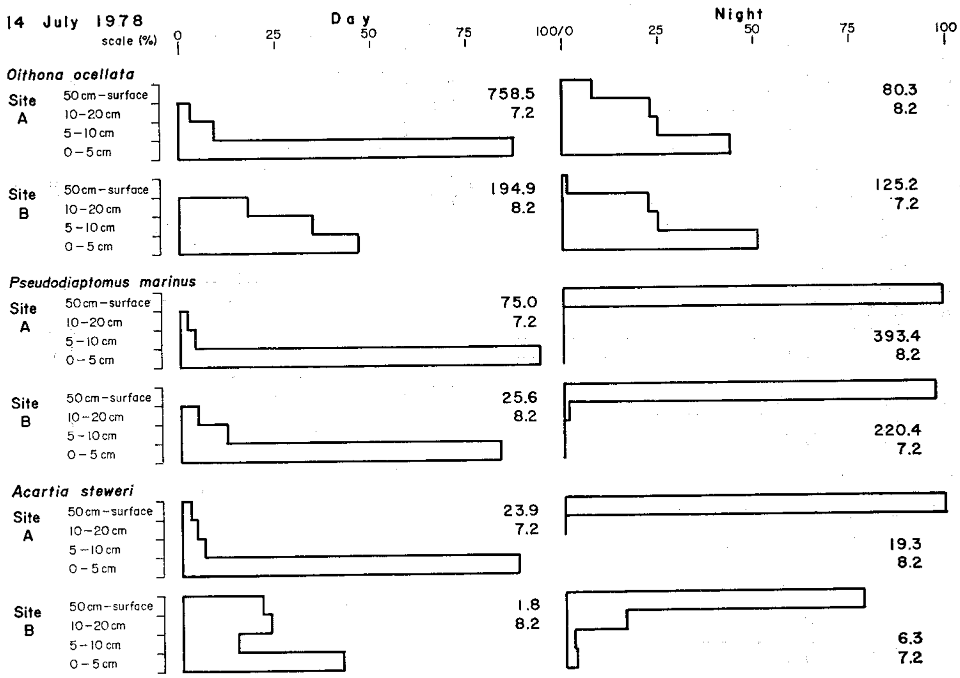
14 July 1978
Day
Night
scale (%)
0
25
50
75
100/0
25
50
75
100
Oithona ocellata
Site A
Site B
50 cm–surface
10–20 cm
5–10 cm
0–5 cm
758.5
7.2
80.3
8.2
194.9
8.2
125.2
7.2
Pseudodiaptomus marinus
75.0
7.2
393.4
8.2
25.6
8.2
220.4
7.2
Acartia steweri
23.9
7.2
19.3
8.2
1.8
8.2
6.3
7.2

Fig. 1–1.

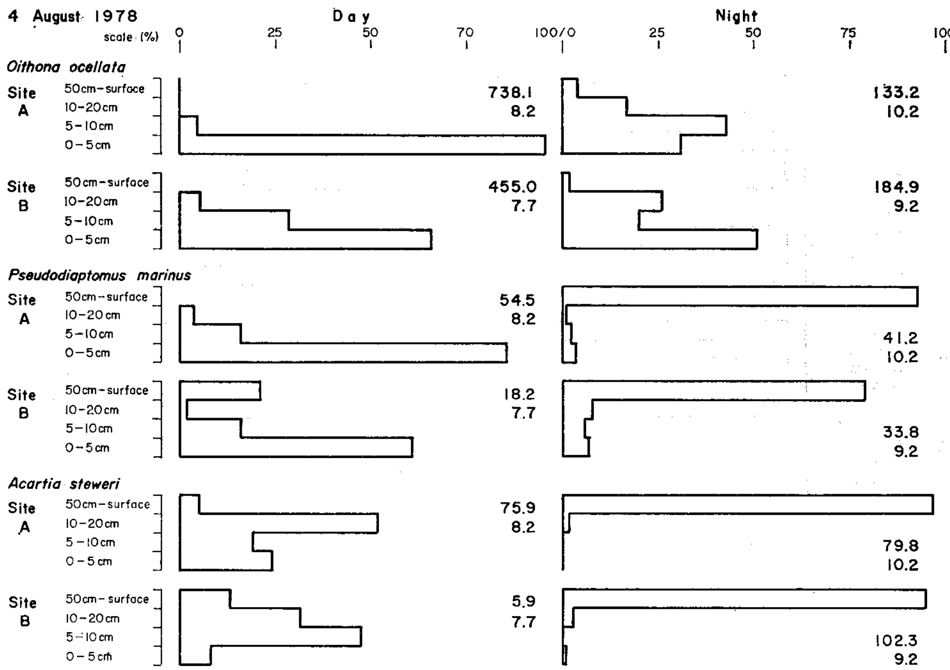
4 August 1978
Day
Night
scale (%)
0
25
50
70
100/0
25
50
75
100
Oithona ocellata
Site A
Site B
50cm–surface
10–20cm
5–10cm
0–5cm
738.1
8.2
133.2
10.2
455.0
7.7
184.9
9.2
Pseudodiaptomus marinus
54.5
8.2
41.2
10.2
18.2
7.7
33.8
9.2
Acartia steweri
75.9
8.2
79.8
10.2
5.9
7.7
102.3
9.2

Fig. 1–2.

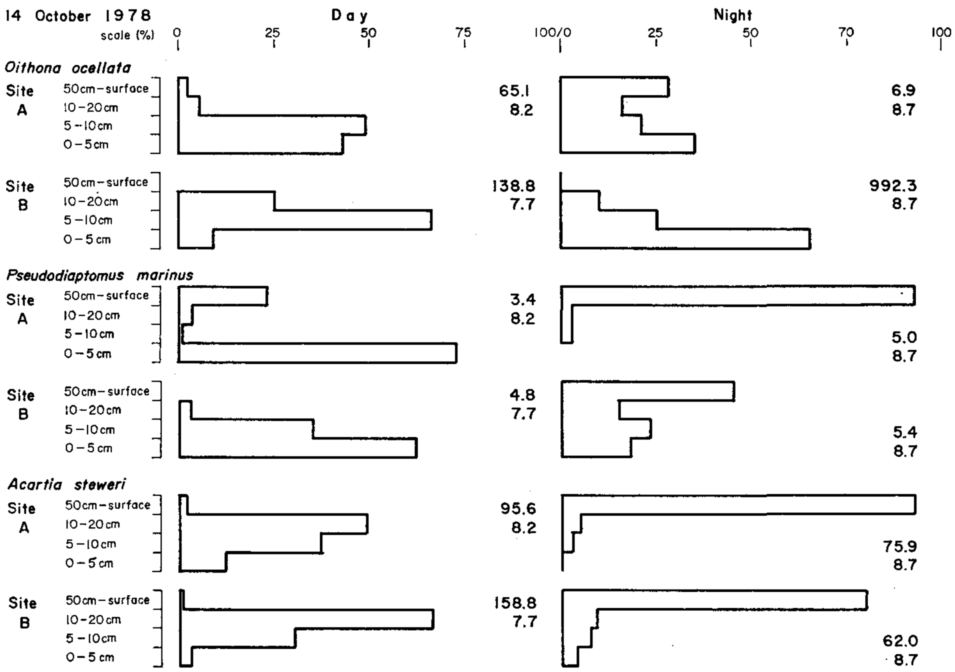
14 October 1978
Day
Night
scale (%)
0
25
50
75
100/0
25
50
70
100
Oithona ocellata
Site A
50cm–surface
10–20cm
5–10cm
0–5cm
65.1
8.2
6.9
8.7
Site B
138.8
7.7
992.3
8.7
Pseudodiaptomus marinus
3.4
8.2
5.0
8.7
4.8
7.7
5.4
8.7
Acartia steweri
95.6
8.2
75.9
8.7
158.8
7.7
62.0
8.7

Fig. 1-3.

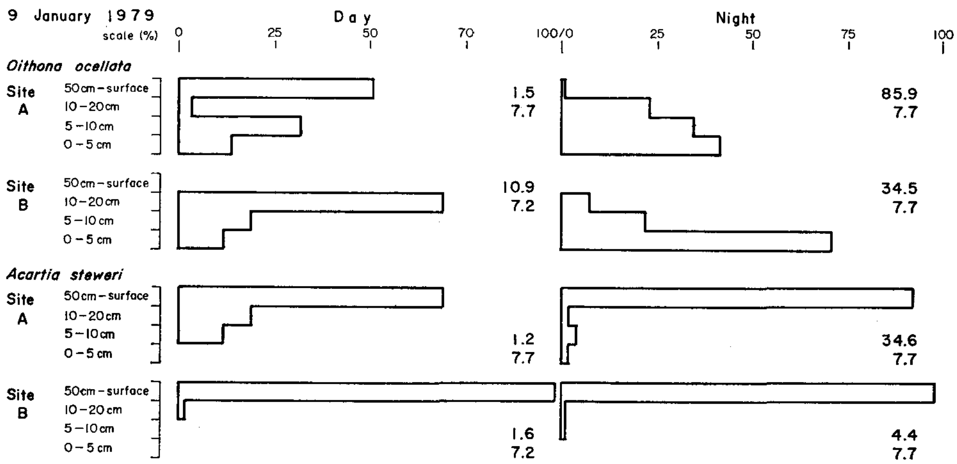
9 January 1979
Day
Night
scale (%)
0
25
50
70
100/0
25
50
75
100
Oithona ocellata
Site A
50cm–surface
10–20cm
5–10cm
0–5cm
1.5
7.7
85.9
7.7
Site B
10.9
7.2
34.5
7.7
Acartia steweri
1.2
7.7
34.6
7.7
1.6
7.2
4.4
7.7

Fig. 1-4.

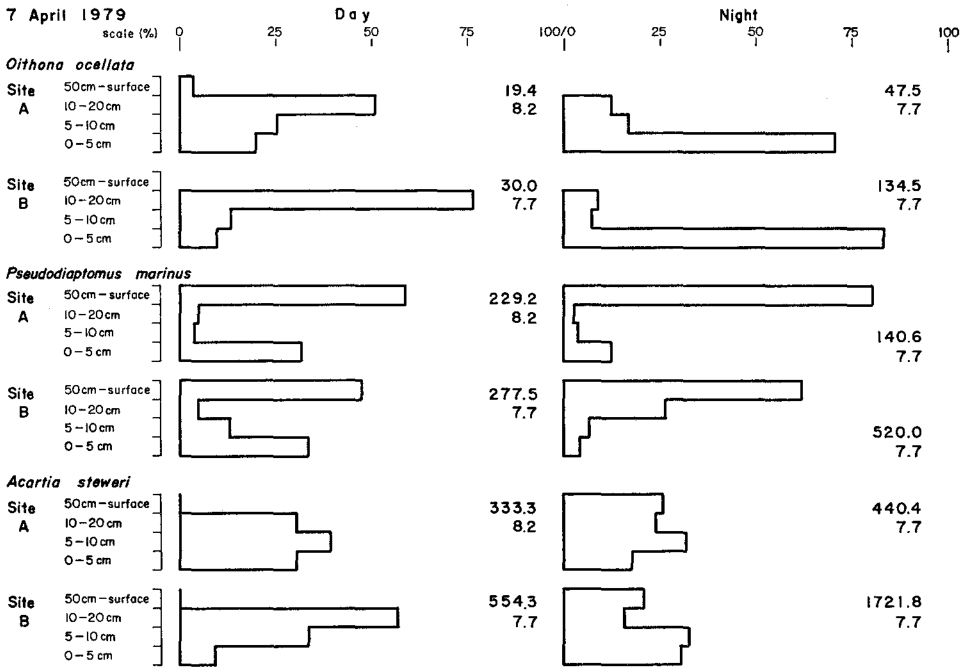

Fig. 1-5.

Fig. 1. Vertical patterns in percentage distribution of three copepods, *Oithona ocellata, Pseudodiaptomus marinus* and *Acartia steweri,* except for 20–50 cm zone. The figures for each vertical series show the calculated total numbers of individuals in a water column, except 20–50 cm zone, above m² of the sea floor (above) and the volume in m³, or the depth in m, of the water column (below).

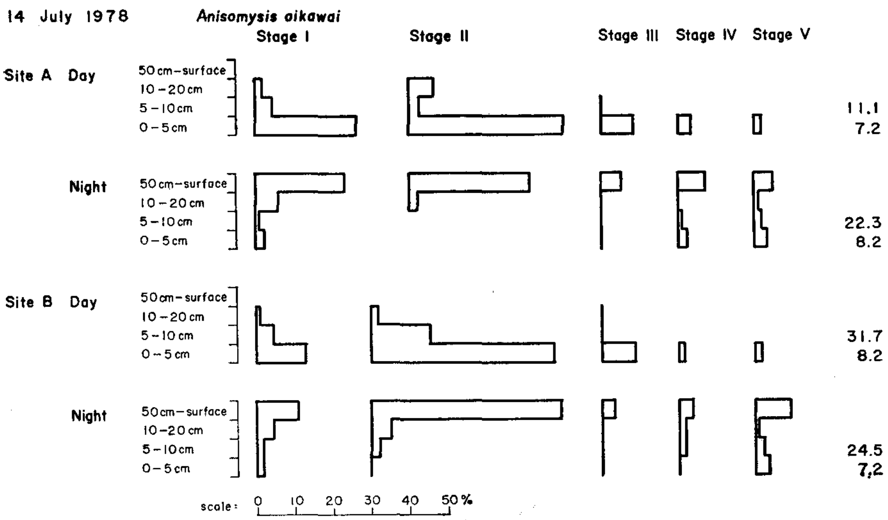

Fig. 2-1.

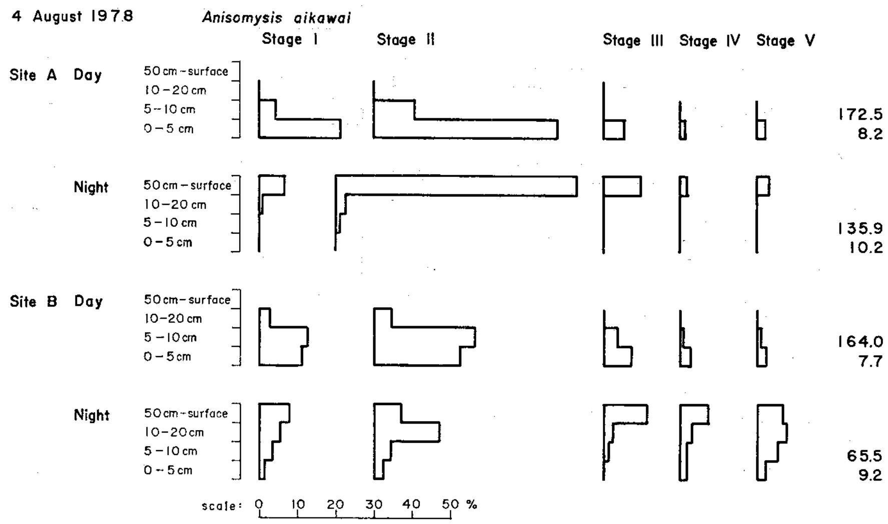
4 August 1978
Anisomysis aikawai
Stage I
Stage II
Stage III
Stage IV
Stage V
Site A Day
Night
Site B Day
Night
50 cm-surface
10-20 cm
5-10 cm
0-5 cm
172.5
8.2
135.9
10.2
164.0
7.7
65.5
9.2
scale: 0 10 20 30 40 50 %

Fig. 2–2.

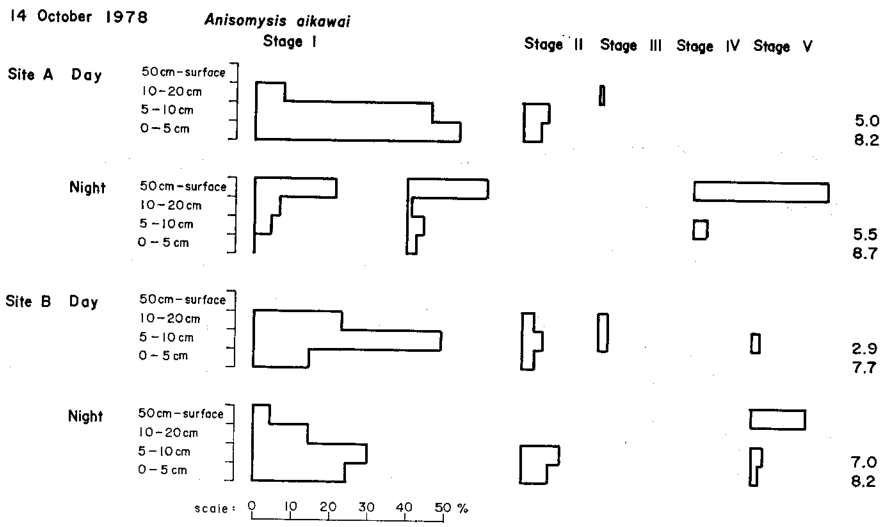
14 October 1978
Anisomysis aikawai
Stage I
Stage II
Stage III
Stage IV
Stage V
Site A Day
Night
Site B Day
Night
50 cm-surface
10-20 cm
5-10 cm
0-5 cm
5.0
8.2
5.5
8.7
2.9
7.7
7.0
8.2
scale: 0 10 20 30 40 50 %

Fig. 2–3.

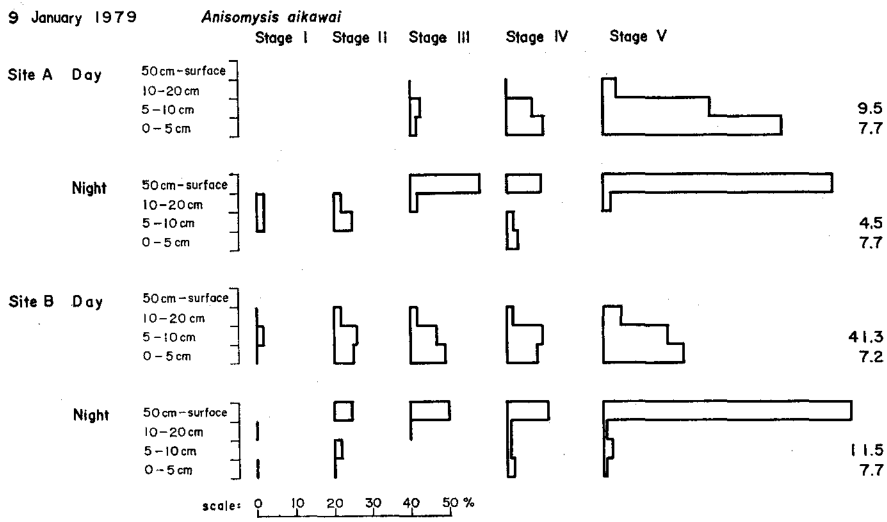

Fig. 2-4.

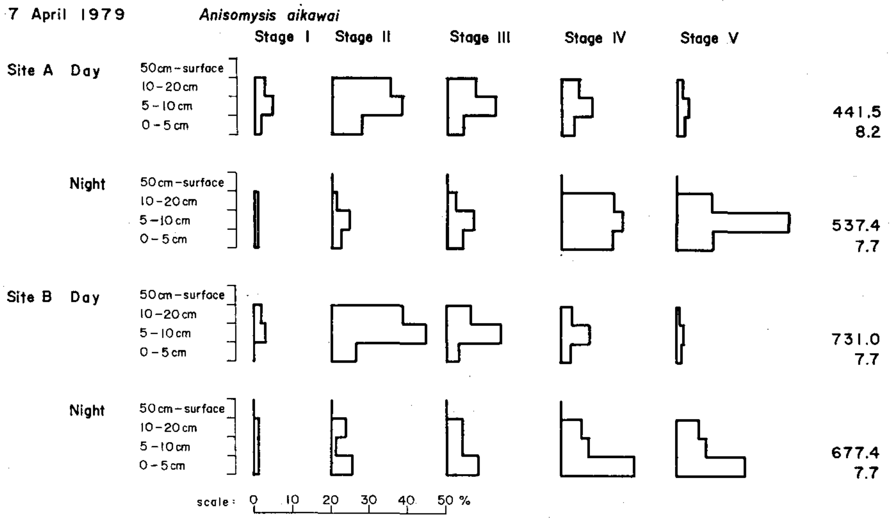

Fig. 2-5.

Fig. 2. Vertical patterns in percentage distribution of a mysid, *Anisomysis aikawai*, except for 20–50 cm zone. The figures for each vertical series show the calculated total numbers of individuals in a water column, except 20–50 cm zone, above m^2 of the sea floor (above) and the volume in m^3, or the depth in m, of the water column (below).

Oithona ocellata

The depth distributions obtained were generally similar, the majority of the population being found in the bottom layers both day and night throughout the year, with the sole exception at Site A in the daytime in January. Within the bottom layers, the difference in the vertical abundance gradient is noticeable. The greatest numbers were found in the 5 cm layer immediately above the sea bottom at night throughout the year and in the daytime in summer months, whereas in the daytime in October to April the abundance maxima were in the 5–10 cm or the 10–20 cm layer above the sea bottom.

Pseudodiaptomus marinus

The depth layers of maximum concentration were 0–5 cm above the sea bottom in the daytime, except in April, and 50 cm–surface at night. The bimodal vertical pattern in percentage distribution was notable in the daytime in April, as well as in the daytime in August at Site B and at night in April at Site A, with two layers of concentration at 0–5 cm above the sea bottom and 50 cm–surface.

Acartia steweri

In the daytime, a large part of the population occurred in the bottom layers, at 0–5 cm above the sea bottom in July and at 5–20 cm in August, October and April, except in January when the majority of the population were found at 50 cm–surface. The main concentration at night was observed distinctly in the 50 cm–surface zone, except in April when the abundance peak was obscure.

Anisomysis aikawai

The day and night vertical distributions were evidently different, except in April when the densities were highest, but there was no significant difference in vertical pattern of distribution between sampling sites or developmental stages. By day, the majority of the population were found in the near-bottom layers, the layer of the abundance peak mostly being 0–5 cm above the sea bottom. The large part of the population occurred in the upper layer of 50 cm–surface occasionally at night, but the densities were smaller than that in the deeper layers. In April, although the densities found in the upper layer at night were not much different from that in other months, the majority of the population were concentrated in the deeper near-bottom layers both day and night.

Discussion

The high values for the standard deviations of the calculated densities among the replicate samples were recorded for all the species examined throughout the sampling period at both sampling sites. Although the replicate hauls were taken close each other only to cover 10 m in distance in hypoplankton collection or some 7 to 10 m in depth in ordinary vertical towing, the populations of these species can not be assumed to be uniform within this range of space. Cassie (1959b, 1963) has reviewed the approaches made to the microdistribution of a spatial scales of less than a metre and discussed the significance of microdistribution. The heterogeneity on this scale of the plankton community in density and composition has been demonstrated (Cassie, 1959a; Della Croce & Sertorio, 1959; Anraku, 1975) and the occurrence of patches of plankters on spatial scales of a few tens of metres or less has been shown or suggested (Emery, 1968; Clutter, 1969; Wiebe, 1970; Smith, Miller & Holton, 1976; Anraku, 1979, 1980). The variability in density of the present species may probably be associated with patchy distribution of small-sclae in them.

The difference between day and night percentage depth distributions is evidently shown in all the present species, with some seasonal differences in their patterns. There is general resemblance between these species, and the majority of the population stay mostly in the layers close to the sea bottom in the daytime, while large numbers appear in the upper zone at night, except for *Oithona ocellata,* suggesting the marked diurnal vertical migration in them. In *Oithona ocellata,* the majority of the population remain also in layers near the sea bottom at night, in any season of the year, that implies that this species is a typical hypoplankter in this region.

Seasonal changes are apparently discernible particularly for daytime distributions. The occurrence of a large part of the population in the upper layer in the daytime was recorded for *Oithona ocellata* and *Acartia steweri* in January and for *Pseudodiaptomus marinus* in October and April. Even within the layers within 20 cm off the sea bottom, larger numbers occurred exclusively in upper layers in *Oithona ocellata* in October, January and April and in *Acartia steweri* in August, October and April. Thus, the general trend of seasonal change in daytime vertical distribution is figured as the occurrence of larger numbers in upper layers in colder seasons and the restriction to the immediate bottom layer in warmer seasons. Since the populations are smallest in January and large in other months, this trend can not be explained on the basis of density effect or competition alone and better will be understood in relation to the seasonal aspects of their life and activities.

The vertical patterns of distribution in *Anisomysis aikawai* are not much different between the developmental stages. Although the majority of each stage generally occur in the upper layer at night in July to January, individuals of more advanced stages tend to remain in bottom layers in July, in contrast to that of younger stages in January. The daytime populations are concentrated in the layer immediately above the sea bottom in July and August, but tend to occur more in upper layers in October to April. In April, when the populations are largest, the vertical distribution patterns at night resemble those in the daytime, the majority remaining in the layers within 20 cm off the sea bottom. Clutter (1969) reports for *Metamysidopsis elongata* in La Jolla region that this species occur in layers of 5 cm to 1 m off the sea bottom during the day and largely remain there at night. He also states that the mysids caught at the sea surface at night were mostly juveniles, but, near the sea bottom, the vertical distributions of the various subgroups by developmental stage are not significantly different. His results accord well with the patterns of vertical distribution in April in the present species, *Anisomysis aikawai,* but not with those in other seasons. Since April is the intensive breeding season for this species, and if copulation occurs only at night and efficiently through social behaviour to result in aggregation, as Clutter (1969) has observed and discussed for *Metamysidopsis elongata,* in the present species as well, the concentration of the population in the layers near the sea bottom may be related to breeding activity, although the vertical pattern in January, when the populations comprise mainly breeding and immature adults, can not be explained on the same basis.

The pronounced concentration of the population to the defined layers near the sea bottom in the daytime, as well as in some cases at night, has been evidently demonstrated, and the differences in abundance even between the thin layer of 5 cm from the sea bottom and the next thin layers have been elucidated to occur in all species studied. The vertical pattern of microdistribution near the sea bottom may be taken as an indication of how the occurrence of a plankton species is related to the bottom—depth, substratum, configuration, etc. This implies that the horizontal distribution of a plankton species, particularly that which exhibits vertical migration and stays some time near the sea bottom, may also is some way be influenced or restricted by the bottom, the necessity of recognition of interdependence of vertical and horizontal distributions.

Summary

1. Four replicate stratified plankton hauls were obtained in day and at night at two sampling sites selected in a shallow near-shore water in Tanabe Bay during July 1978 to April 1979.
2. Densities of three copepods, *Oithona ocellata, Pseudodiaptomus marinus* and *Acartia steweri*, and one mysid, *Anisomysis aikawai*, were calculated from their counts and the vertical patterns of distribution were figured and compared.
3. Densities fluctuated considerably with season, attaining summer maxima in *Oithona ocellata* and spring maxima in the rest species.
4. The concentration of the population in the layers at 0–20 cm from the sea bottom in the daytime and the occurrence of a large part of the population in the 50 cm-surface zone at right were generally observed in the species, except *Oithona ocellata.* Vertical patterns in microdistribution near the sea bottom were elucidated.
5. Diurnal and seasonal changes in vertical distribution were compared between species and developmental stages, and their meanings were briefly discussed.

Riassunto

Due differenti stazioni di acque basse costiere sono state esaminate bella Baia di Tanabe (Giappone) compiendo due campionamenti di plancton, rispettivamente di giorno e di notte. Ogni campionamento era composto di quattro differenti repliche. I dati ottenuti hanno permesso di calcolare la densità di tre copepodi, *Oithona ocellata, Pseudodiaptomus marinus, Acartia steweri,* e di un misidiaceo *Anisomysis aikawai* e le modalità della loro distribuzione verticale. Le densità presentano notevoli fluttuazioni stagionali e raggiungono i massimi in estate per *Oithona ocellata* e in primavera per le altre specie. Tutte le specie mostrano una massima concentrazione durante il giorno negli strati posti da 0–20 cm dal fondo, mentre durante la notte gran parte delle popolazioni, tranne *Oithona ocellata* che non presenta rilevanti movimenti migratori, occupa la colonna d'acqua compresa tra la superficie e i 50 cm al di sopra del fondo. Le varie specie, inoltre, presentano differenti microdistribuzioni verticali che possono variare in rapporto alla densità delle specie e ai loro differenti stadi di sviluppo.

REFERENCES

Anraku, M. 1956. Some experiments on the variability of horizontal plankton hauls and on the horizontal distribution of plankton in a limited area. Bull. Fac. Fish., Hokkaido Univ., 7(1): 1–16.

————. 1975. Microdistribution of marine copepods in a small inlet. Marine Biology, 30(1): 79–87.

————. 1979. Notes on plankton investigation - (1) Microdistribution of zooplankton - historical background. Aquabiology (Kaiyo-to-Seibutsu), 1(5): 66–72. (in Japanese)

————. 1980. Notes on plankton investigation - (2) Microdistribution of zooplankton - cause and ecological implication. Ibid., 2(1): 47–51. (in Japanese)

Barnes, H. & Marshall, S. M. 1951. On the variability of replicate plankton samples and some applications of 'contagious' series to the statistical distribution of catches over restricted periods. J. mar. biol. Ass. U.K., 30(2): 233–263.

Bieri, R. & Tokioka, T. 1968. Dragonet II, an opening-closing quantitative trawl for the study of microvertical distribution of zooplankton and the meio-epibenthos. Publ. Seto Mar. Biol. Lab., 15(5): 373–390.

Boxshall, G.A. 1977. The depth distributions and community organization of the planktonic cyclopoids (Crustacea: Copepoda) of the Cape Verde Islands region. J. mar. biol. Ass. U.K., 57(2): 543–568.

Boyd, C.M. 1973. Small scale spatial patterns of marine zooplankton examined by an electronic in situ zooplankton detecting device. Netherl. J. Sea Res., 7, 7th European Symposium on Marine Biology: 103–111.

Cassie, R.M. 1959a. An experimental study on factors inducing aggregation in marine plankton. N.Z. J. Sci., 2: 339–365.

————. 1959b. Micro-distribution of plankton. Ibid., 2: 398–409.

————. 1962. Microdistribution and other error components of C^{14} primary production estimates. Limnol. Oceanogr., 7(2): 121–130.

————. 1963. Microdistribution of plankton. Oceanogr. Mar. Biol. Ann. Rev., 1: 223–232. H. Barnes, ed., Publ. George Allen & Unwin Ltd., London.

Clutter, R.I. 1967. Zonation of nearshore mysids. Ecology, 48: 200–208.

————. 1969. The microdistribution and social behavior of some pelagic mysid shrimps. J. exp. mar. Biol. Ecol., 3(2): 125–155.

Cushing, D.H. & Tungate, D.S. 1963. Studies of a *Calanus* patch. I. The identification of a *Calanus* patch. J. mar. biol. Ass. U.K., 43(2): 327–337.

Della Croce, N. 1962. Aspects of microdistribution of the zooplankton. Rapp. et Proc. Verb., Cons. Internat. Explor. de la Mer, 153: 149–151.

———— & Sertorio, T. 1959. Microdistribuzione dello zooplancton. Boll. Mus. Ist. Biol. Univ. Genova, 29: 5–28.

Emery, A.R. 1968. Preliminary observations on coral reef plankton. Limnol. Oceanogr., 13(3): 293–303.

Evans, G.T. 1978. Biological effects of vertical-horizontal interactions. *In*: J.H. Steele (ed.), Spatial Pattern in Plankton Communities, Plenum Press, New York, 157–179.

Fage, L. 1932. La migration verticale saisonniére des Mysidacés. C.R. Acad. Sci. Paris, 194: 313.

Fager, E.W. & Clutter, R.I. 1968. Parameters of a natural population of a hypopelagic marine mysid, *Metamysidopsis elongata* (Holmes). Physiol. Zoöl., 41: 257–267.

————, Flechsig, A.O., Ford, R.F., Clutter, R.I. & Ghelardi, R.J. 1966. Equipment for use in ecological studies using scuba. Limnol. Oceanogr., 11(4): 503–509.

Gunter, G. 1957. Dredges and trawls. *In* : W. Hedgpeth (ed.), Treatise on Marine Ecology and Paleoecology, Vol. 1, Ecology, Chapt. 4, Geological Society of America, New York, 73–78.

Haury, L.R., McGowan, J.A. & Wiebe, P.H. 1978. Patterns and processes in the time-space sacles of plankton distributions. *In*: J.H. Steele (ed.), Spatial Pattern in Plankton Communities, Plenum Press, New York, 277–327.

Holligan, P.M. 1978. Patchiness in subsurface phytoplankton populations on the northwest European continental shelf. *In*: J.H. Steele (ed.), Spatial Pattern in Plankton Communities, Plenum Press, New York, 221–238.

Mauchline, J. 1971. Seasonal occurrence of mysids (Crustacea) and evidence of social behaviour. J. mar. biol. Ass. U.K. 51(4): 809–825.

McAlice, B.J. 1970. Observations on the small-scale distribution of estuarine phytoplankton. Marine Biology, 7(2): 100–111.

Platt, T., Dickie, L.M. & Trites, R.W. 1970. Spatial heterogeneity of phytoplankton in a near-shore environment. J. Fish. Res. Bd. Canada, 27(8): 1453–1473.

Richerson, P.J., Powell, T.M., Leigh-Abbott, M.R. & Coil, J.A. 1978. Spatial heterogeneity in closed basins. *In*: J.H. Steele (ed.), Spatial Pattern in Plankton Communities, Plenum Press, New York, 239–276.

Russell, F.S. 1925. The vertical distribution of marine macroplankton. An observation on diurnal changes. J. mar. biol. Ass. U.K., N.S., 13(4): 769–809.

Smith, L.R., Miller, C.B. & Holton, R.L. 1976. Small-scale horizontal distribution of coastal copepods. J. exp. mar. Biol. Ecol., 23(3): 241–253.

Steele, J.H. 1978. Some comments on plankton patches. *In*: J.H. Steele (ed.), Spatial Pattern in Plankton Communities, Plenum Press, New York, 1–20.

Wiebe, P.H. 1970. Small-scale spatial distribution in oceanic zooplankton. Limnol. Oceanogr., 15(2): 205–217.