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THE DISTRIBUTION OF THE STANDING CROP OF ZOOPLANKTON IN THE EASTERN SECTOR OF THE INDIAN OCEAN DURING JULY-SEPTEMBER, 1962

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INTRODUCTION

THE variations in the standing crop of zooplankton in the coastal and offshore waters are known in great detail (Raymont, 1963). In the tropical region of the Indian Ocean, the only available references are (i) the results of the John Murray Expedition (Sewell, 1948), (ii) observations at seven stations by R.R.S. ' Discovery ' (Foxton, 1957), (iii) certain peculiarities of plankton biomass distribution of surface waters (Bogorov and Vinogradov, 1961) and (iv) distribution of zooplankton biomass in the waters of Arabian Sea and Bengalian gulf (Ponomareva and Naumov, 1962).

During the 35th cruise of the U.S.S.R. Research Vessel *VITYAZ* from Djakarta to Madras *via* Freemantle from 15th July to 21st September 1962, opportunity was availed of for estimating the standing crop of zooplankton, from 500-0 metres at 36 stations. This paper summarises these observations.

MATERIAL AND METHODS

Material was collected with Juday pattern (80/113, 38 meshes per cm.) vertical closing net, hauled vertically at a speed of one metre/second over a davit, at depths of 25-0 m., 50-25 m., 100-50 m., 200-100 m., and 500-200 m., at 72 stations during the 35th cruise of the R.V. *VITYAZ*. The samples were taken from 5 depths (*vide supra*) at 29 stations, in 2, 3-4 stages at 5 stations (5197, 5217, 5218, 5221 and 5223) and upto 200 metre depth at 5199 and 5209. Each sample was transferred to glass trough and the large animals measuring above 20 mm., were removed, before measuring volumetrically. Foxton (1957) gives details of the technique. The data along with a part of the material were analysed in detail by the authors in the laboratories of the Zoological Survey of India. Data on temperature and salinity made available by the scientists of the R.V. *VITYAZ* were compared in relation to the standing crop of zooplankton. Block diagrams were prepared from the results of the volumetric analyses, following Foxton (1957). The total standing crop of zooplankton in the whole water column sampled, i.e., 500-0 metres, has been arrived at for 34 stations, by adding up the corrected displacement volumes of hauls made from the five different depths. Table 1 gives details of the various stations sampled.

OBSERVATIONS

The vertical distribution of standing crop of zooplankton at 5 stratified depths from 0-500 metres at 36 stations are represented in Figures 1, 2 and 3. The variations of temperature and salinity with depth are also presented. Data on lati-

tudinal and longitudinal position of each station, date and time of haul and depth of maximum amount of biomass are indicated in Table 1. In drawing conclusions, it should be remembered that only large scale variations are being considered.

TABLE I

Station	Date 1962	Time	Latitude	Longitude E	Depth (m.) of max. amount of biomass
5168	16. VII	15.30—17.30	8° 00′ 2″ S	105° 24′ 6″	0—25
5170	17	05.25—07.50	10° 02′ 4″ S	105° 23′ 3″	25—50
5173	19	08.30—11.30	13° 32′ 4″ S	105° 04′ 3″	0—25
5174	21	04.00—06.00	15° 00′ 1″ S	106° 46′ 0″	0—25
5175	21	17.30—19.25	16° 11′ 7″ S	107° 52′ 2″	0—25
5176	22	07.20—09.40	17° 34′ 2″ S	109° 14′ 3″	50—100
5177	23	11.30—13.00	18° 44′ 1″ S	110° 33′ 8″	50—100
5178	24	09.50—10.40	20° 07′ 9″ S	112° 08′ 7″	0—25
5182	25	16.30—17.10	21° 47′ 0″ S	112° 52′ 5″	0—25
5183	26	04.50—07.10	21° 45′ 9″ S	110° 50′ 4″	0—25
5184	26/27	23.37—01.40	21° 45′ 2″ S	108° 25′ 3″	0—25
5185	27	19.20—21.00	24° 34′ 3″ S	108° 20′ 9″	0—25
5186	28	10.15—12.10	26° 52′ 0″ S	108° 20′ 4″	0—25
5193	17.VIII	14.00—16.20	32° 48′ 9″ S	103° 58′ 2″	0—25
5196	20	13.45—15.15	32′ 34′ 7″ S	94° 14′ 7″	25—50
5197	22	04.55—05.20	29° 50′ 5″ S	91° 25′ 8″	0—25
5198	22	17.00—20.00	28° 01′ 0″ S	91° 26′ 5″	0—25
5199	23	10.15—10.50	26° 02′ 4″ S	91° 38′ 3″	100—200
5200	24	17.45—20.10	23° 58′ 7″ S	91° 40′ 3″	0—25
5201	25	10.05—12.55	22° 29′ 0″ S	91° 40′ 3″	0—25
5205	28	15.30—17.40	13° 10′ 9″ S	91° 44′ 0″	100—200
5207	29	17.42—18.40	9° 57′ 8″ S	91° 32′ 2″	0—25
5208	30	06.00—08.00	9° 16′ 0″ S	91° 27″ 2′	0—25
5209	31	18.35—20.30	8° 10′ 9″ S	91° 27′ 3″	100—200 (0-25)
5212	2/3.IX	23.10—01.10	5° 11′ 4″ S	91° 17′ 0″	50—100
5216	5	12.05—12.45	2° 03′ 2″ S	91° 27′ 9″	0—25
5217	7	14.00—16.15	1° 27′ 0″ S	91° 34′ 9″	0—100 (0-25)
5218	7	17.50—19.25	0′ 58′ 7″ S	91° 40′ 8″	0—50 (0-25)
5219	8	01.20—03.00	0° 30′ 6″ S	91° 37′ 8″	50—100
5220	8	12.50—14.30	0° 00′ 8″ N	91° 43′ 5″	100—200
5221	9/10	23.05—00.22	0° 28′ 0″ N	91° 32′ 2″	50—100
5222	10	04.00—06.10	01° 00′ 0″ N	91° 30′ 0″	50—100
5223	10	12.00—14.00	01° 40′ 0″ N	91° 45′ 3″	0—50 (0—25)
5224	10	16.15—17.30	02° 00′ 0″ N	91° 33′ 0″	0—25
5225	12	04.15—07.30	03° 06′ 0″ N	91° 34′ 0″	25—50
5227	13	05.50—07.30	05° 03′ 0″ N	91° 32′ 0″	25—50

(a) *General depth distribution pattern of zooplankton*

A perusal of these Figures show that the standing crop of zooplankton is maximal in the surface layer of 0-25 metres at 22 stations, i.e., 5168, 5173, 5174, 5178, 5182, 5184, 5185, 5186, 5193, 5197, 5207, 5216, 5217 & 5175, 5183, 5198, 5200, 5201, 5208, 5218, 5223 and 5224. The biomass gradually decreases with increasing depth at the first 13 stations, i.e., 5168 to 5217. The gradual decrease of standing crop of zooplankton is interrupted by a slightly lower concentration at the 25-50 metre depth region at 4 stations, i.e., 5200, 5201, 5208, and 5224. This low concentration of biomass descends to the 50-100 metre depth at 5198, 5218 and 5223. At stations 5175 and 5183, the lowest concentration is further down at 100-200 metre depth region. The peak density occurs at 25-50 metre depth at 4 stations

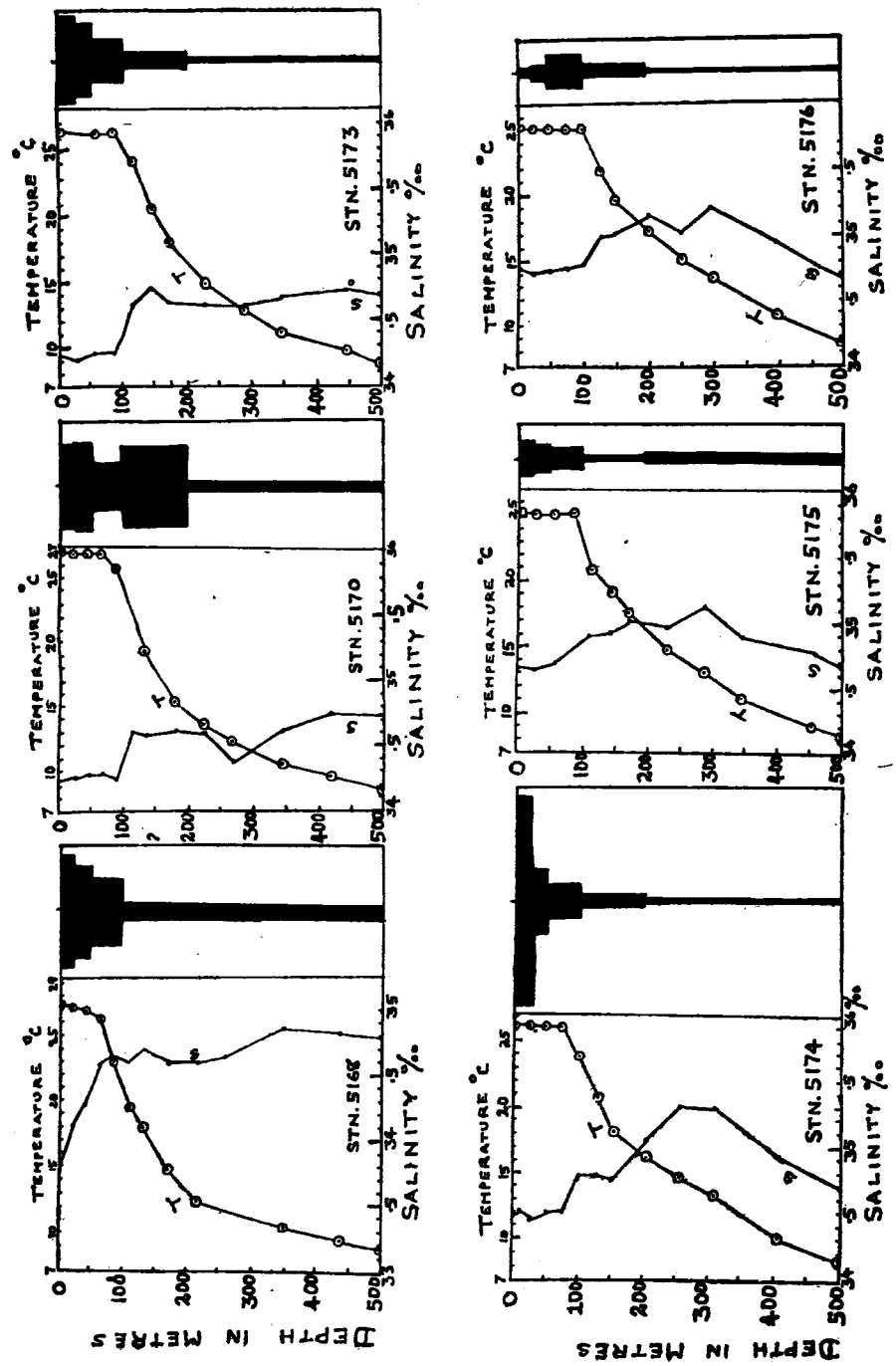

STN. 5168
STN. 5170
STN. 5173
STN. 5174
STN. 5175
STN. 5176
TEMPERATURE °C
SALINITY ‰
DEPTH IN METRES
T
S

FIG. 1

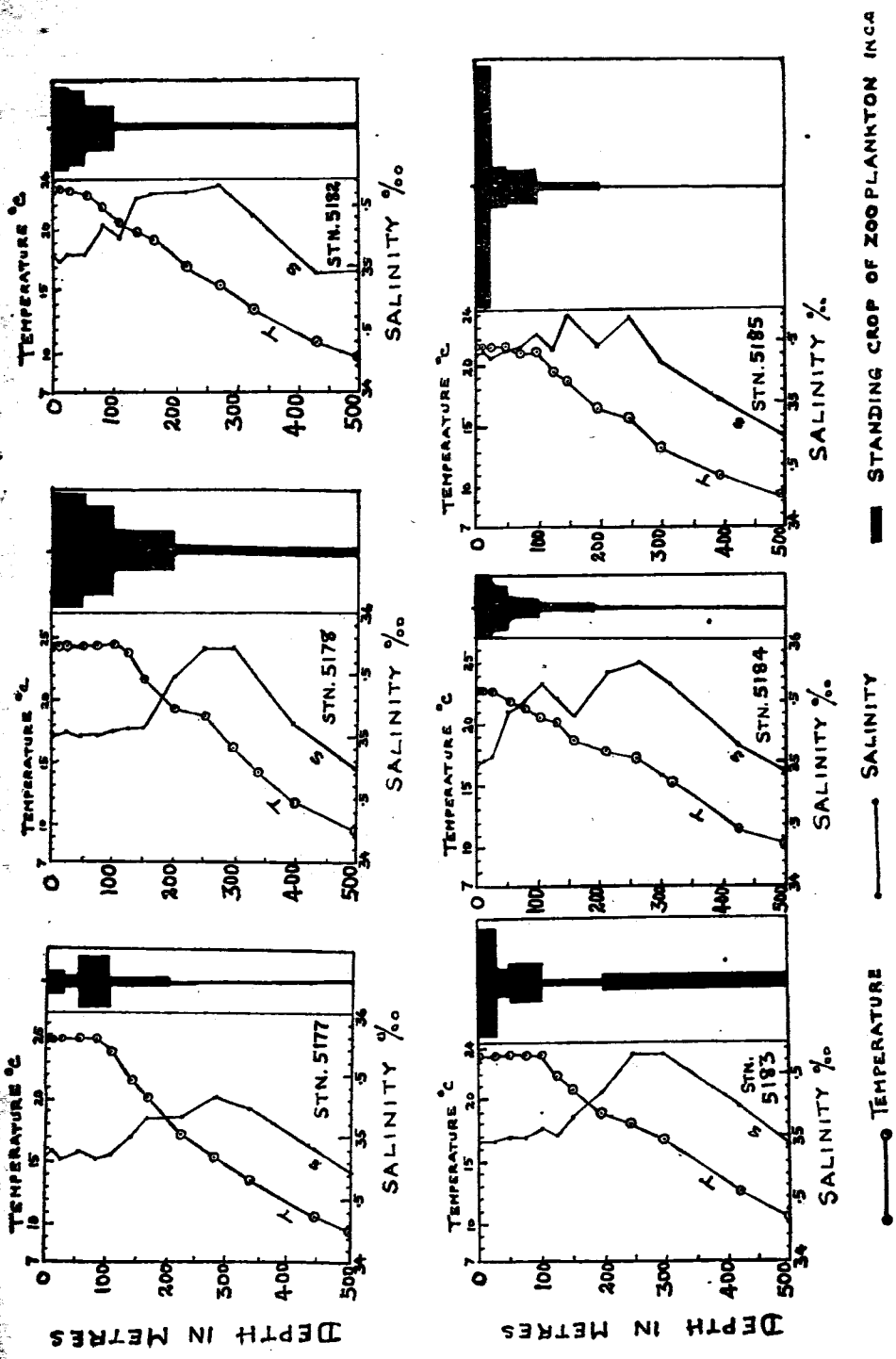


FIG. 1. Showing the vertical distribution of standing crop of zooplankton at 5 stratified depths from 0-500 metres and the variations of temperature and salinity with depth

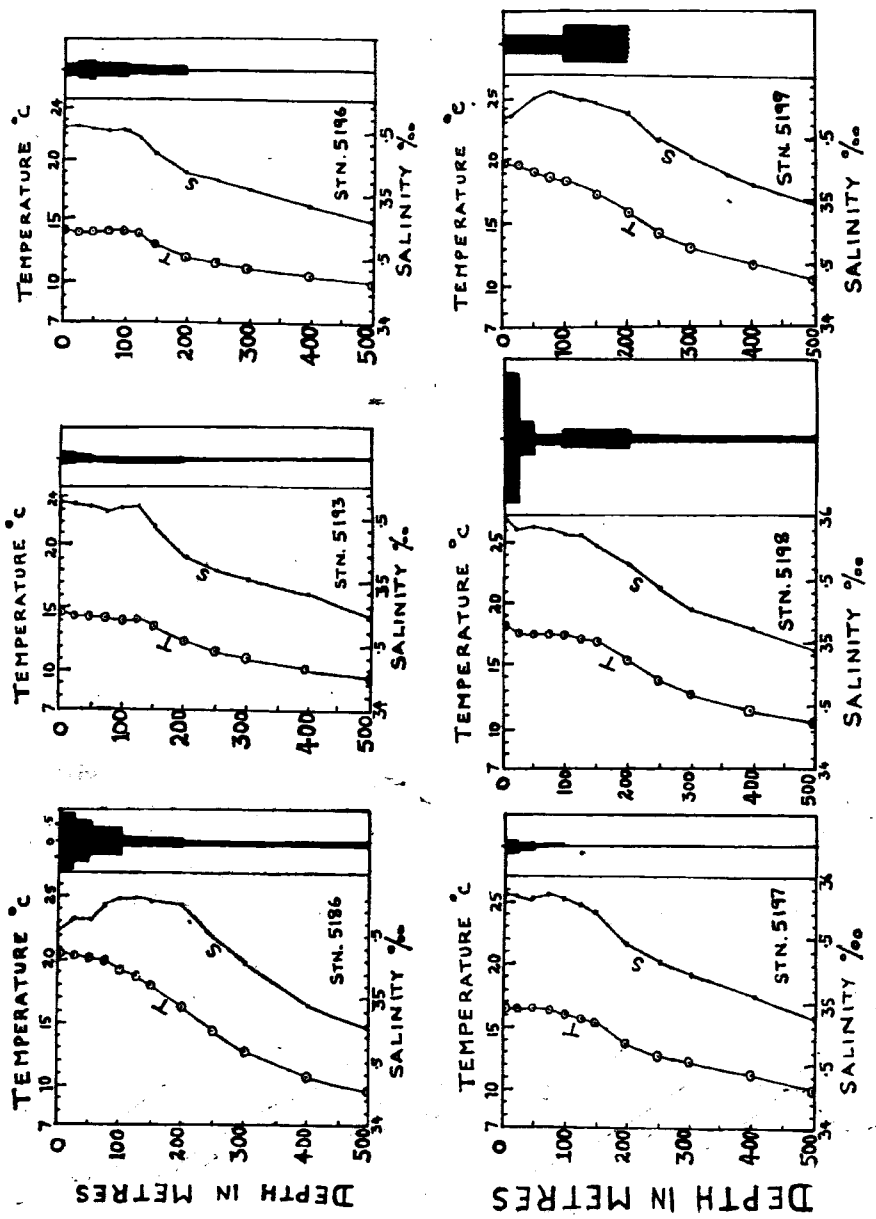

TEMPERATURE °C
SALINITY ‰
STN. 5196
STN. 5199
STN. 5193
STN. 5198
STN. 5186
STN. 5197
DEPTH IN METRES
DEPTH IN METRES

FIG. 2

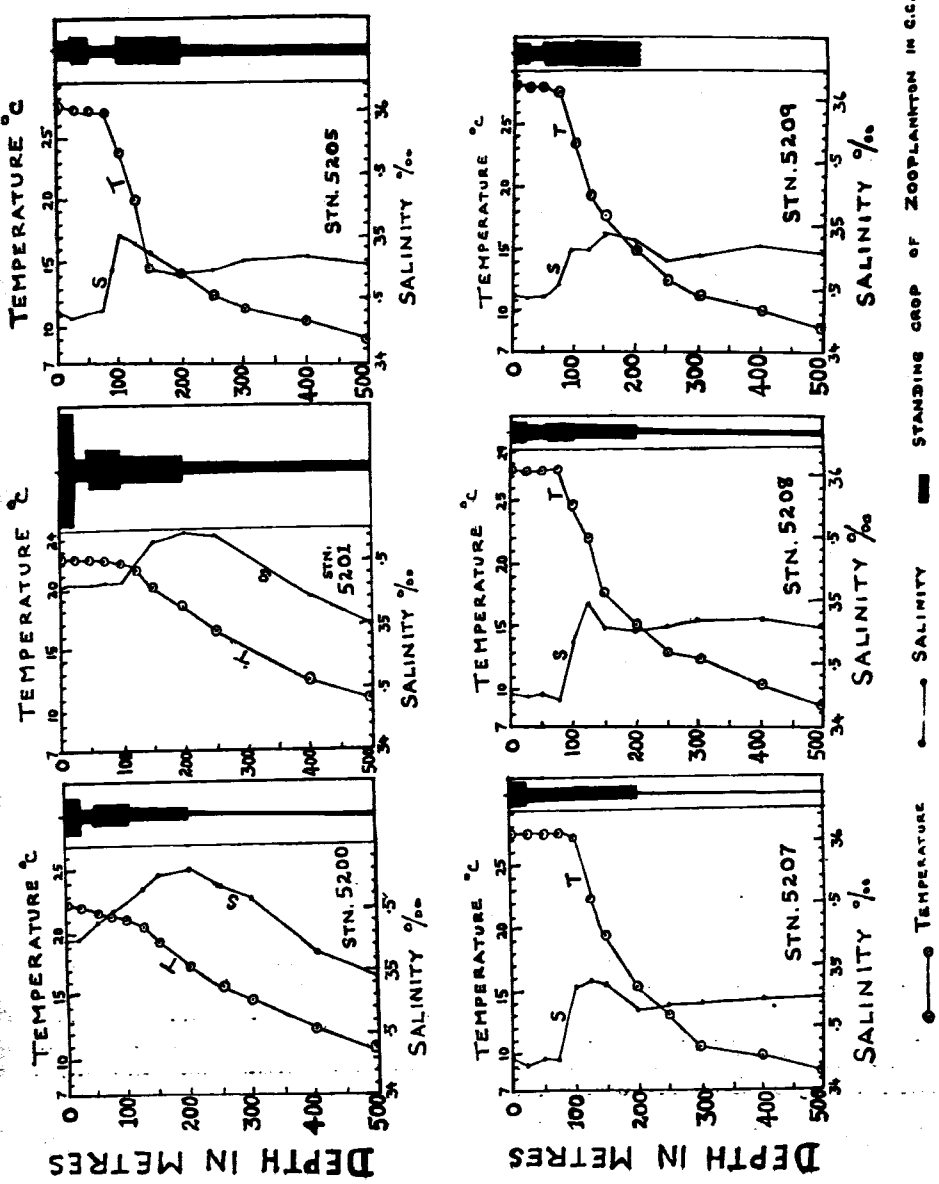


FIG. 2. Showing the vertical distribution of standing crop of zooplankton at 5 stratified depths from 0-500 metres and the variations of temperature and salinity with depth

(5170, 5196, 5225 and 5227), the surface waters being only slightly less dense. While in stations 5196, 5225 and 5227, the standing crop gradually decreases with depth from the 50 metre level, at station 5170 there is a secondary peak at 100-200 metre depth region.

At 6 stations (5176, 5177, 5212, 5219, 5221 and 5222), the maximum concentration is at 50-100 metre depth, gradually decreasing towards surface and greater depth, excepting at station 5177 where the 0-25 metre region bears denser plankton than the 25-50 metre region. The peak densities at stations 5205 and 5220 occur at 25-50 metre and 100-200 metre depths, the surface region being only slightly less dense. At 2 stations (5199 and 5209) data are incomplete, as the values are available only up to 200 metre depth. At both these stations, the maximum density appears to be at the 100-200 metre depth region.

The region between 200-500 metre depth is usually poor in the standing crop of zooplankton. However, at 12 stations, i.e., 5168, 5170, 5175, 5183, 5201, 5205, 5219, 5220, 5222, 5224, 5225 and 5227, the occurrence of comparatively denser zooplankton is a noteworthy feature.

(b) *Relation of depth distribution of plankton with day and night*

In Table 1, details of the 36 stations are presented. A perusal of the table reveals that 22 stations at which the standing crop of zooplankton was maximal at the surface (0-25 metres), were established during different periods of the day and night. Even the 4 stations (5170, 5196, 5225 and 5227) at which the peak density occurred at 25-50 m. were established in morning, midday, evening or night. Therefore, there appears to be no distinct correlation between the depth distribution pattern of the standing crop and day-night periods. However, the stations where the richest standing crop of zooplankton occurred at the surface were established during the hours of fading light, i.e., day break or dusk. For example, station 5198 was established between 17.00-20.00 hours ; station 5185 between 19.20-21.00 hours ; and stations 5174, 5183 and 5227 in the early hours of the morning at day break between 4.00 a.m. and 7.30 a.m. Further, at 5 stations (5176, 5177, 5212, 5219 and 5221) wherein the surface region exhibited poor plankton density were established either during bright day periods or at midnight.

(c) *Relation of depth distribution of plankton to temperature and salinity*

A perusal of Figures 1, 2 and 3 shows that the depth distribution of the standing crop of zooplankton is influenced by the thermohaline discontinuity layers at 20 stations. The standing crop of zooplankton is relatively dense within the thermocline at stations 5170, 5199, 5205, 5209, 5218, 5220 and 5223. At stations 5208, 5212, 5219, 5221, 5222 and 5224, dense zooplankton occurs within the thermocline but is confined to the upper margin. At stations 5176, 5177, 5201, 5225 and 5227, there is a concentration of zooplankton just above the thermocline. At 2 stations (5175 and 5183) very poor zooplankton occurs within the thermocline and denser biomass is seen just above the thermocline.

The region of increased salinity corresponds with the thermocline at all the stations.

(d) *Regional distribution of the total standing crop of zooplankton*

In Figure 4, the total standing crop of zooplankton in the whole water column sampled, i.e., 0-500 metres, at 34 stations is shown. As stated earlier, these values have been arrived at by adding the volume of hauls made from 25-0 m., 50-

25 m., 100-50 m., 200-100 m. and 500-200 m. Although for a thorough comparison of the relative quantity of zooplankton in 0-500 m. layer, it would have been ideal to take a single haul, no complete set of observations were made and hence this combined data are presented to give a general idea of the regional variations in the standing crop of zooplankton.

The standing crop was extremely abundant at stations 5168, 5170, 5178 and 5227, where the displacement values were 18.06 c.c., 21.80 c.c., 20.56 c.c. and 29.59 c.c. respectively. It is probable that these stations being located near the continental landmasses, have been influenced to a great extent by the presence of neritic species.

At stations 5173, 5174, 5182, 5183, 5185, 5201, 5212, 5219, 5220, 5222, 5223, 5224 and 5225, the standing crop of zooplankton is moderately rich ranging from 10.2 c.c.-16.75 c.c. Stations 5175, 5177, 5184, 5186, 5198, 5205, 5216, 5218, and 5221 show low concentrations of standing crop ranging from 6.2 c.c.-9 c.c. At stations 5176, 5200, 5207, 5208 and 5217, the waters are poor in zooplankton ranging from 3.1 c.c.-4.8 c.c. The standing crop of zooplankton at stations 5193, 5196 and 5197 is extremely low, the displacement values being 1.55 c.c., 2.64 c.c. and 0.74 c.c. respectively. It is probable that this region is biologically poor. It appears that the crop of zooplankton fluctuates considerably from station to station and that during the period of the investigation there is no definite distribution pattern which could be correlated with latitudinal changes.

Discussion

Although the variations in the standing crop of zooplankton in the open ocean of the Atlantic, Pacific and Antarctic are known, comparison of these results is difficult since there is much diversity in the gear used and methods adopted to capture and measure the quantity of plankton. The present observations show that there is a maximum zooplankton biomass in the surface layers of 0-25 m. extending to 100 m. approximately in most of the areas, and upto 200 m. occasionally, with a marked falling off in the standing crop in the 200-500 m. depth region. These findings link up well with those of Zenkervitch and Birstein (1956).

In the present study, there appears to be no distinct correlation between the depth distribution pattern of the standing crop of zooplankton and day-night periods at 22 stations lending support to the observations of Banse (1957), Bekelemishev (1957) and Heinrich (1961). However, the richest crop of surface zooplankton occurring at stations which were established during the hours of fading light and the availability of poor plankton at the surface at stations established either during bright day periods or at mid-night show that downward migration or sinking takes place during the bright day light hours and mid-night. Due probably to the reactions of the organisms to low intensities of light, these migrate upwards during the hours of fading light, showing that light as a factor influencing diurnal migration cannot be ignored.

Many factors such as changes in pH, oxygen tension, temperature, salinity, illumination (light), bioluminiscence, pressure, watermass movement, various known and unknown features of the animal's physiological state, presence of phytoplankton and gravitational force, have been suggested as factors influencing the vertical distribution of plankton (Raymont, 1963 and Banse, 1964). In the present study, data on temperature, salinity and day-night periods only are available for correlation with the distribution of the plankton.

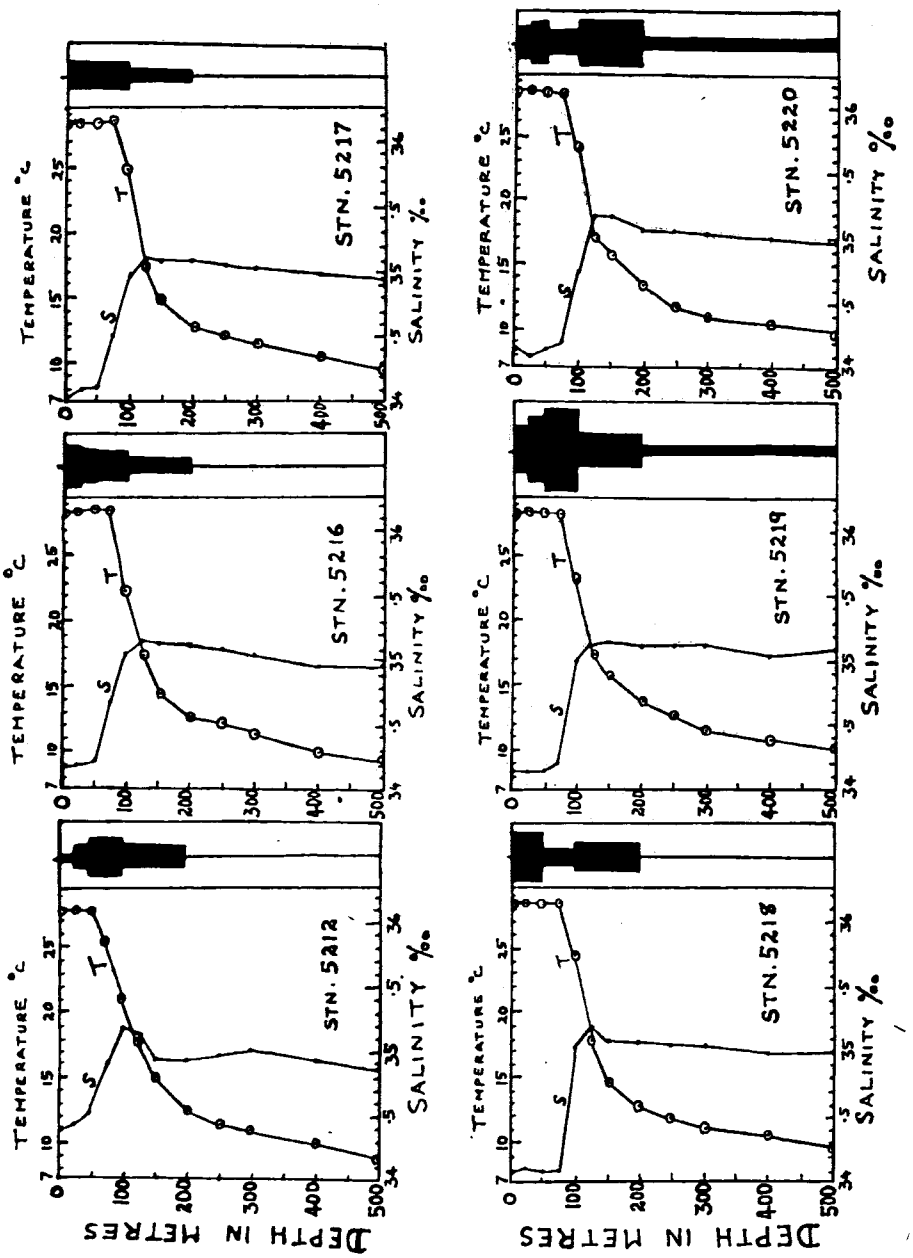

STN. 5212
STN. 5216
STN. 5217
STN. 5218
STN. 5219
STN. 5220
TEMPERATURE °C
SALINITY ‰
DEPTH IN METRES
T
S

FIG. 3

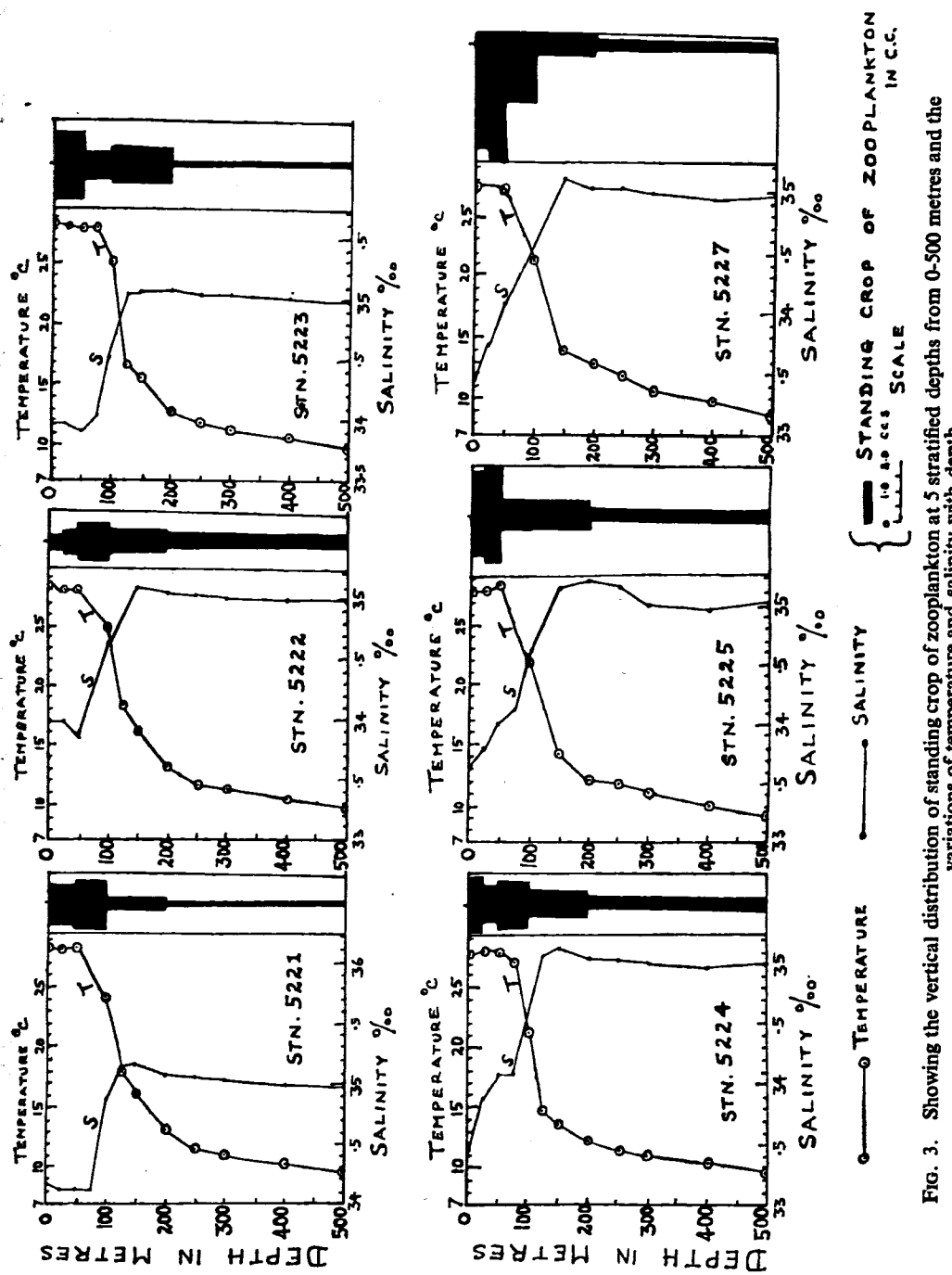
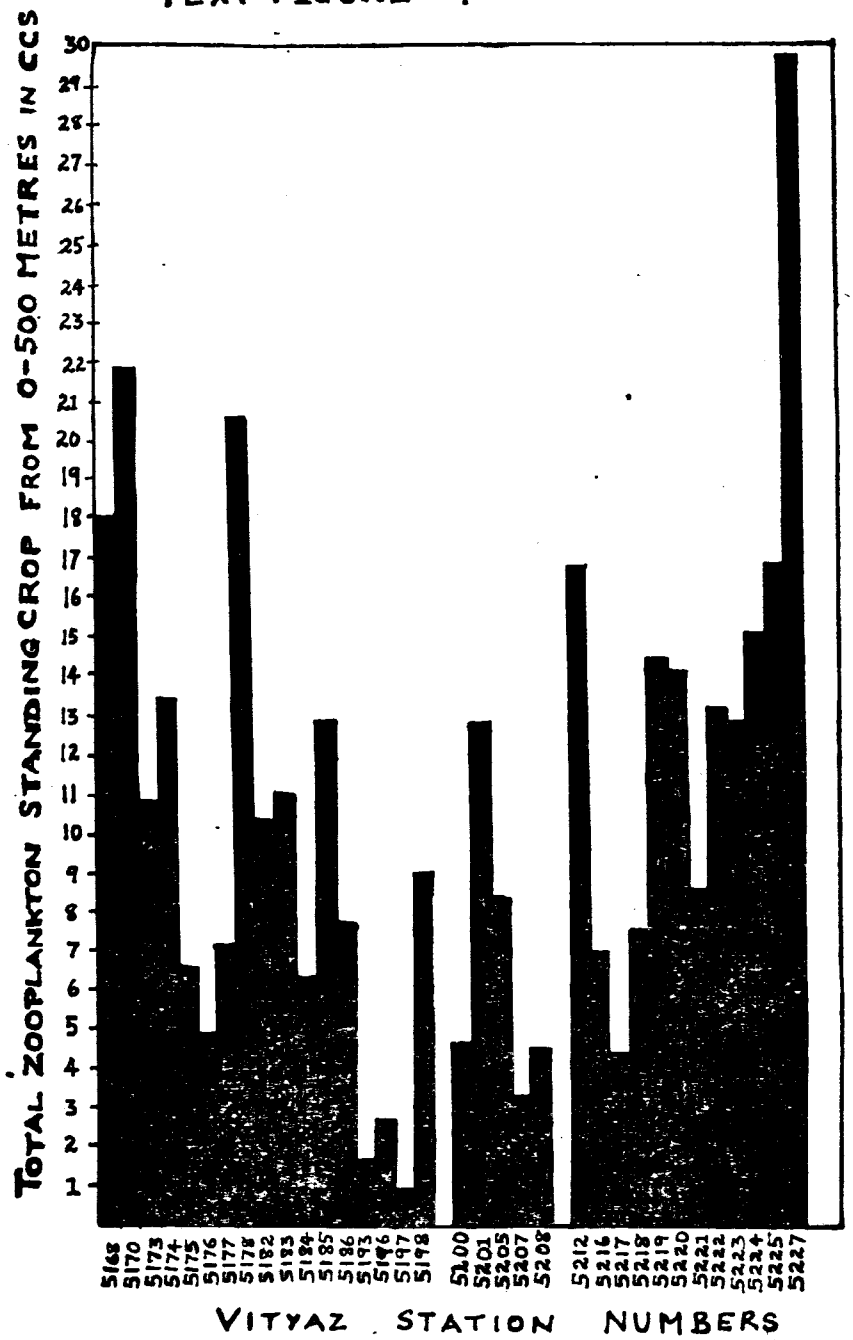


FIG. 3. Showing the vertical distribution of standing crop of zooplankton at 5 stratified depths from 0-500 metres and the variations of temperature and salinity with depth

TEXT-FIGURE 4



A comparison of the temperature-salinity data with the standing crop of zooplankton shows that (i) the standing crop of zooplankton is concentrated within the thermocline at 7 stations, (ii) at 6 stations it is dense within the thermocline but is confined to the upper border, (iii) at 5 stations there is a concentration just above the thermocline, (iv) at 2 stations very low concentrations occur within the thermocline and denser biomass occurs just above the thermocline and (v) at 16 stations there is no distinct influence in the distribution of the standing crop. At all these stations, the region of increased salinity corresponds with the thermocline region.

These observations show that there is an obvious concentration of the population into narrow depth zones which are intrinsically related to the temperature-salinity changes of the waters (thermohaline stratification) supporting the views held by Conover (1956), Banse (1957, 1964) and Petipa *et al.* (1960).

It is probable that these plankton organisms primarily respond to changing intensities of illumination (Daniel, 1957 ; 1963 for barnacle larvae), and during their vertical migratory movements are prevented by the discontinuity layer as a result of sharp temperature-salinity changes, to continue their movements. Further sampling of zooplankton at hydrographically meaningful depths and detailed investigations of all the factors suggested as influencing their vertical distribution are required.

It is of interest to note that Sewell (1948) showed that in density of individuals and in number of species there is a maximum in the surface layer extending to approximately 100 metres depth in the Indian Ocean, while several authors have maintained that fairly extensive upward migrations of various species take place during the dark hours (Esterly, 1912 ; Murray and Hjort, 1912 ; Hardy and Gunther, 1936 ; Waterman *et al.*, 1939 ; Moore, 1949 ; Moore and O'Berry, 1957 ; Bogorov, 1958), and that sinking of plankton during the midnight period owing to negative geotaxis wherein, on a photokinesis theory, movement is negligible and animals may sink. Where sinking occurs and the plankton appears to become more or less evenly distributed at night, a rise towards the surface may follow at, or just before dawn (Kikuchi, 1930 ; Raymont, 1963 and Banse, 1964).

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