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Observations on the Distribution of Plankton at six Inshore Stations in the Gulf of Manaar.

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Observations on the Distribution of Plankton at six Inshore Stations in the Gulf of Manaar*

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With 2 Text-figures and 9 Tables

CONTENTS

I—Introduction

It has long been recognised that the distribution of plankton may be very patchy, especially in the coastal regions because near the land the sea may be frequently disturbed over small areas by the mixing of coastal and oceanic waters, tidal streams and the upwelling of the lower layers of water against coastal banks. This is further complicated by the sporadic outbursts of larval forms from the littoral fauna and the shallow water benthos. This patchiness in distribution of plankton, if it exists in an area surveyed, raises the important question regarding the extent of the area over which each haul may be taken as representative. In a study of the distribution of plankton it is essential to know whether the samples collected from any particular station in a survey are fairly representative of the quantities as well as the types of different organisms in the surrounding waters or whether the unevenness in the distribution of the various organisms may not make the sample unrepresentative. Hardy (1936) and Hardy and Gunther (1936) have emphasised the unevenness in the distribution of plankton. Hardy (1939) has said: "A realization of the frequently patchy nature of the plankton led to the first experiments with the continuous recorder ....." Bigelow and Sears (1939) have noticed that "The most striking feature of volumetric distribution throughout has been the irregularity from station to station, often with volumes differring up to hundred fold, between localities only a few miles apart." Such variability in the volume and type of plankton has been observed by Clarke (1940 and 1948), Lucas (1940) and others. Clarke (1940) has remarked that: "Previous studies have shown that the dispersal pattern of the population in each situation must be investigated individually." and has suggested "In view of this far reaching ir-

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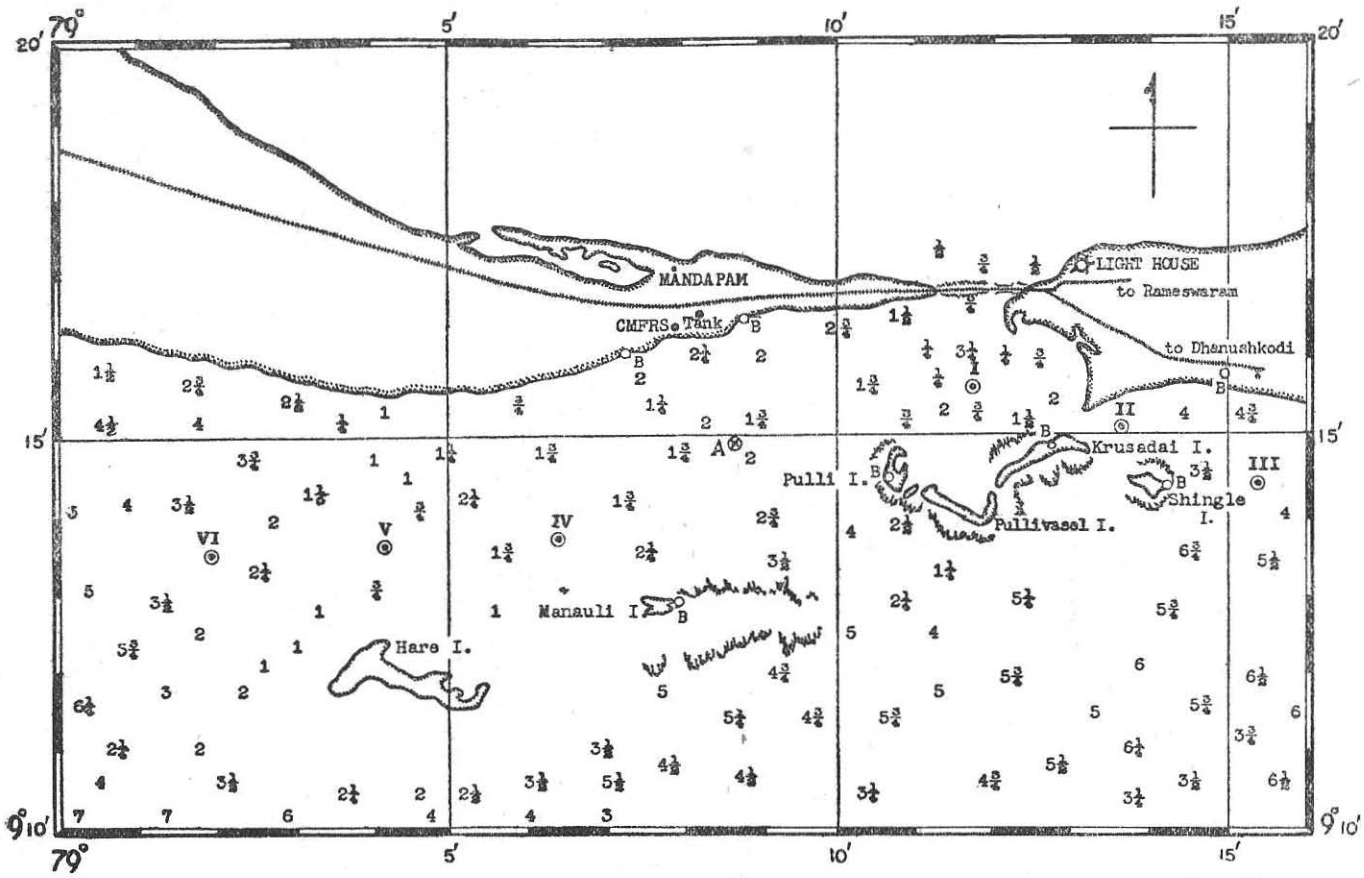


TEXT-FIG. 1—The location of stations I to VI and A in the Gulf of Manaar. The numbers in the figure indicate the depth in fathoms. CMFRS stands for the Central Marine Fisheries Research Station.

regularity in distribution, it is essential that the number of stations occupied be as large as possible and that all hauls within each area be combined in suitable ways before any conclusions be attempted in regard to relative richness." The considerable changes observed in the volume as well as the composition of plankton at neighbouring stations raise the question of the reliability of single hauls. A statistical study of the variation in the catch of plankton for different types of nets has been made by Winsor and Clarke (1940).

A study of the plankton, both quantitative and qualitative, of the inshore waters off Mandapam was started in 1950. In the beginning a station 'A' approximately 2 miles from the shore (Text-fig. 1) was fixed and regular collections were made from this station. However, occasional samples collected from the neighbouring areas showed considerable differences in the quality as well as the quantity of the plankton. It was then thought that there may be marked differences in the distribution of plankton in this area, but as the methods of collection were not identical it was not possible to compare the data and decide whether the differences were due to the patterns of distribution or merely due to differences in the method of collection. In order to check this a series of plankton samples were collected from six stations (Text-fig. 1) from January to March 1951. The distance between the stations III to VI was about 14 miles. With the exception of stations I and IV the others are located approximately two miles apart. The area investigated is a region of shallow water with extensive coral reef formation as can be seen from Text-fig. 1.

This work is intended only as a preliminary investigation to ascertain whether there are marked differences in the distribution of plankton between the six stations distributed over a distance of about fourteen miles. No high degree of accuracy is claimed for the results of this investigation because in addition to the analytical and sampling errors, there exist the errors of unknown magnitude resulting from the exclusion of current transport, lateral mixing and other factors.

The authors wish to thank Mr. S. K. Banerjee for valuable suggestions on the statistical part of the paper.

II—Material and Methods

The material for the study includes 48 samples of plankton collected at six stations from January to March 1951. These months were selected because almost stable conditions are established in this area after the turbulent conditions that prevail during May to October. From the hydrological point of view also Mr. R. Jayaraman reports (personal communication) that this period shows comparatively little fluctuations. Further, this is a period when the phytoplankton production is at a low level thus considerably reducing clogging of meshes of

the plankton net by diatoms resulting in a reduction of the filtering efficiency. The possibility that the present observations may be vitiated by the effect of animal exclusion can be overruled because of the conditions under which these observations were made and the variety of organisms included in the study.

In order to minimise any possible effects of vertical migration of the zooplankters, the collections were made between 06 00 and 08 00 hours. A half-meter net made out of Organdie cloth (36 strands/cm) was used throughout from a motor launch the speed of which was kept as constant as possible during the time of hauls. All were 15 minute horizontal surface hauls. The samples were preserved in 5 per cent formaldehyde and the net-plankton volumes were estimated by the method suggested by Sheard (1947). The organisms have been expressed as numbers per cc. The method adopted was to add sufficient formaldehyde to make the samples up to 250 cc. and from this a 1 cc. sub-sample was taken after thoroughly mixing the sample. This is then spread uniformly over a slide marked into 100 equal squares and the various organisms counted under a binocular microscope. A slightly different procedure was adopted for the enumeration of diatoms when they occur in large numbers. Counting was restricted to 20 squars and from the average the total number per cc. was calculated. This method of expressing the various components had to be adopted in the absence of any other facilities to estimate the actual quantity of water strained by the net during each haul.

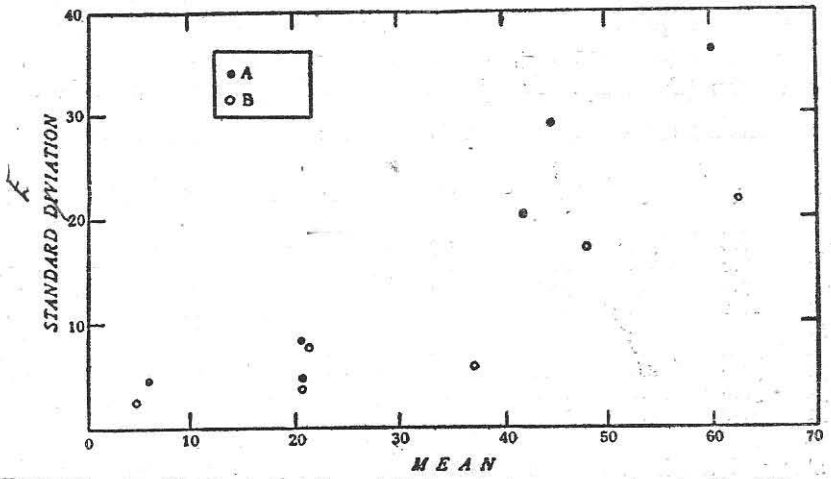
Except in a few instances in which the analysis was carried to species, usually the fluctuations are expressed in terms of numbers of particular genera or groups. It has been assumed that in comparing one station with another the errors in methodology are probably uniform since the technique adopted is the same.

In a study of this nature it is necessary to estimate the haul to haul variation in order to ascertain whether the observed differences can be explained by this factor.

Haul to haul variation.—A series of 7 horizontal surface hauls, each of 15 minutes duration was made at the same area between 06 00-08 00 hours making use of 2 half-meter Organdie nets (marked A and B) simultaneously. The nets were of identical diamensions and construction and were similar to the one used for making collections at the six stations. These nets were towed side by side, about three quarters of a meter apart, at the same level and the catches were kept separately for analysis.

Seven of the more important organisms viz., (1) fish eggs, (2) *Lucifer* sp., (3) Copepods, (4) Decapod larvae, (5) *Oikopleura* sp., (6) Chaetognaths and (7) Molluscan larvae were used for the study. In the case of these organisms it will be obvious that the variations will be different for the different groups but

it will be seen from Text-fig. 2 that their standard deviation increases almost linearly with the mean and so logarithms of the numbers were used instead of the actual numbers themselves.



TEXT-FIG. 2.—Standard deviation plotted against mean number for the different species of organisms studied from nets A and B.

The data were first analysed by maintaining the distinction between the samples collected by the nets A and B. But as the analysis showed no significant difference between the nets (as is to be expected) the data for the two nets were pooled together and the details of the analysis of variance are given in Table I.

TABLE I—ANALYSIS OF VARIANCE: ZOOPLANKTERS

Source of variation		Degrees of freedom	Sum of squares	Mean squares
Between samples (S)	...	... 13	0.6818	0.0524
Between animals (A)	...	... 6	34.3658	5.7276
Residual (AS)	...	... 78	2.5312	0.0324
	Total	... 97	37.5788	

It will be noticed from this table that the mean squares for interaction ~~between animals~~ (AS) and between samples do not differ significantly. Therefore it may be assumed the same populations are being sampled.

The analysis has been carried further to determine the haul to haul variations. Now the mean square for the residual (A x S) is an estimate of the quantity σ^2_{AS}. The mean square for samples 0.0524, is an estimate of the quantity $7\sigma^2_S + \sigma^2_{AS}$. From this we get $\sigma^2_S = 0.0028$ and, therefore, the logarithmic standard deviation will be 0.0529. This corresponds to a percentage standard deviation or coeffecient of variation of 12.9%. Thus the haul to haul variation itself will be 12.9%.

III—Fluctuations in the net-plankton volume and some of the important zooplankters

Net-plankton volume.—The net-plankton volume has been taken as an index of the total quantity of the standing crop.[1] Considerable variations are observed in the net-plankton volume from day to day and on the same day from station to station (Table II). Asterisks in all tables indicate lack of data.

TABLE II—NET-PLANKTON VOLUMES: STATIONS I TO VI

Date	Volume (ml.) I	II	III	Mean	Date	Volume (ml.) IV	V	VI	Mean
16-1-51	1.0	5.0	10.0	5.3	20-1-51	6.5	5.5	*	6.0 x
23-1-51	6.0	13.0	81.0	33.3	25-1-51	6.0	8.0	*	7.0 x
30-1-51	7.0	3.5	34.0	14.8	3-2-51	11.0	9.5	22.0	14.1
6-2-51	12.0	28.0	63.0	34.3	10-2-51	11.0	12.0	8.5	10.5 x
13-2-51	18.0	15.0	36.0	23.0	17-2-51	38.0	21.0	15.0	24.6
20-2-51	32.0	21.0	42.0	31.6	24-2-51	9.0	21.0	*	15.0
27-2-51	36.0	6.0	16.0	19.3	3-3-51	14.0	11.0	32.0	19.0
13-3-51	36.0	14.0	10.0	20.0	17-3-51	70.0	21.0	44.0	45.0
20-3-51	32.0	4.0	6.0	14.0	...	...	...	...	...

A study of the haul to haul variation has shown that the standard deviation is about 13% of the mean. For this study a limit of two standard deviations (about 27.5%) in excess or defect of the mean may be considered. It will be obvious from the figures given in Table II that the fluctuations observed in volume from station to station on many days are real differences and are not due to errors of sampling (except for three days marked 'x' in the table when the range falls within that explainable by the haul to haul variation).

Copepods.—The total number of copepods of all species from the six stations were compared and the results are given in Table III. The catch composed mainly of calanoids and very few harpacticoids. It will be noticed that the oberved fluctuations on most of the days are real and that the distribution was not random except on January 30, February 6 and 13 at stations I to III and on the last two days in March at stations IV to VI.

TABLE III—NUMBER OF COPEPODS PER C.C. COLLECTED FROM STATIONS I TO VI

Date	Stations I	II	III	Mean	Date	Stations IV	V	VI	Mean
16-1-51	209	352	944	501.6	20-1-51	420	140	*	280.0
23-1-51	344	400	1415	719.6	25-1-51	955	649	*	802.0
30-1-51	440	475	604	506.3 x	3-2-51	264	213	352	276.3
6-2-51	780	764	907	817.0 x	10-2-51	477	766	476	573 0
13-2-51	613	421	572	535.3 x	17-2-51	1061	612	621	764.6
20-2-51	1550	664	2113	1442.3	24-2-51	404	200	*	302.0
27-2-51	1072	352	796	740.0	3-3-51	576	893	744	737.6 x
13-3-51	340	116	168	208.0	17-3-51	384	414	276	358.0 x
20-3-51	609	327	284	406.6	...	...	...	...	...

[1] The term 'standing crop' is used to mean the amount of organisms existing in the area at the time of observation as defined by Clarke (1946).

Lucifer sp.—Table IV shows the wide fluctuations in the numbers caught from different stations. Except for two days the variation from station to station exceeded the range of haul to haul variation indicating thereby the unevenness in distribution with sometimes complete absence of this species at one or even two stations.

TABLE IV—*LUCIFER* SP.

Date	Stations I	II	III	Mean	Date	Stations IV	V	VI	Mean
16-1-51	0	4	0	1.3	20-1-51	2	0	*	1.0
23-1-51	16	15	28	19.6	25-1-51	12	10	*	11.0 x
30-1-51	40	0	0	13.3	3-2-51	20	8	20	16.0
6-2-51	4	48	72	41.3	10-2-51	13	0	12	8.3
13-2-51	33	24	32	29.6 x	17-2-51	20	4	11	11.6
20-2-51	4	36	44	28.0	24-2-51	4	48	*	26.0
27-2-51	13	0	8	7.0	3-3-51	0	12	0	4.0
13-3-51	16	8	0	8.0	17-3-51	0	0	12	4.0
20-3-51	24	0	20	14.6					

Chaetognaths.—Just as in the case of *Lucifer* sp. chaetognaths were not randomly distributed on all days (Table V). At stations I to III there was an apparent evenness in distribution on February 6, and March 20.

TABLE V—CHAETOGNATHS

Date	Stations I	II	III	Mean	Date	Stations IV	V	VI	Mean
16-1-51	9	0	8	5.6	20-1-51	0	0	*	0
23-1-51	0	12	64	25.3	25-1-51	28	0	*	14.0
30-1-51	12	4	0	5.3	3-2-51	8	7	12	9.0
6-2-51	24	20	20	21.3 x	10-2-51	12	40	24	25.3
13-2-51	0	0	20	6.6	17-2-51	20	8	16	14.6
20-2-51	24	21	48	31.0	24-2-51	16	0	*	8.0
27-2-51	12	0	0	4.0	3-3-51	0	0	8	2.6
13-3-51	0	0	0	0	17-3-51	4	0	8	4.0
20-3-51	8	8	9	8.3 x					

But on several days chaetognaths were absent at one or two stations.

Oikopleura sp.—This species was well represented at stations III and IV and it will be noticed that the maximum number was present at station III. The distribution may be considered random on January 20, 25 and February 10 whereas on days like January 16, 23 and 30 show a marked clumping of these at station III.

TABLE VI—*OIKOPLEURA* SP.

Date	Stations I	II	III	Mean	Date	Stations IV	V	VI	Mean
16-1-51	0	0	85	28.3	20-1-51	12	16	*	14.0 x
23-1-51	9	0	88	32.3	25-1-51	25	20	*	22.5 x
30-1-51	8	0	87	31.6	3-2-51	16	0	0	5.3
6-2-51	0	72	8	26.6	10-2-51	8	13	12	11.0 x
13-2-51	32	40	19	30.3	17-2-51	8	0	9	5.6
20-2-51	0	8	8	5.3	24-2-51	0	0	*	0
27-2-51	12	8	4	8.0	3-3-51	13	8	28	16.3
13-3-51	4	0	0	1.3	17-3-51	0	0	0	0
20-3-51	0	4	12	5.3					

Decapod larvae.—Decapod larvae were present in all samples except one. The distribution of these is given in Table VII. On certain days there was considerable aggregation of the larvae at one station and on none of the days investigated the distribution was found to be random.

TABLE VII—DECAPOD LARVAE

Date	Stations I	II	III	Mean	Date	Stations IV	V	VI	Mean
16-1-51	16	75	36	42.3	20-1-51	23	12	*	17.5
23-1-51	32	204	88	108.0	25-1-51	44	80	*	62.0
30-1-51	140	40	12	64.0	3-2-51	32	44	240	105.3
6-2-51	168	124	221	171.0	10-2-51	145	136	80	120.3
13-2-51	104	48	16	56.0	17-2-51	140	160	232	177.3
20-2-51	64	588	140	264.0	24-2-51	96	318	*	207.0
27-2-51	160	72	0	77.3	3-3-51	16	64	124	68.0
13-3-51	308	116	44	156.0	17-3-51	111	28	280	139.6
20-3-51	140	80	53	91.0					

Molluscan larvae.—Another group of larvae which was present in appreciable numbers is molluscan larvae. They were present in all the samples, but in varying numbers (Table VIII). Maximum number of larvae were present at station I. On two days the distribution was fairly uniform.

TABLE VIII—MOLLUSCAN LARVAE

Date	Stations I	II	III	Mean	Date	Stations IV	V	VI	Mean
16-1-51	20	12	28	20.0	20-1-51	16	4	*	10.0
23-1-51	24	24	116	54.6	25-1-51	44	4	*	24.0
30-1-51	4	16	124	48.0	3-2-51	8	36	48	30.6
6-2-51	88	40	52	60.0	10-2-51	92	68	52	70.6
13-2-51	392	128	36	185.3	17-3-51	40	40	204	94.3
20-2-51	68	44	120	77.3	24-2-51	56	36	*	46.0 x
27-2-51	176	32	32	80.0	3-3-51	4	16	88	36.0
13-3-51	32	20	28	[26.6 x]	17-2-51	40	80	52	57.3
20-3-51	104	32	36	57.3					

TABLE IX—THE IMPORTANT SPECIES OF DIATOMS AND THE TOTAL NUMBER OF DIATOM CELLS PER CC. OF THE SAMPLES

Date	*Coscinodiscus* spp.			*Rhizosolenia imbricata*			*Rhizosolenia alata*			*Biddulphia sinensis*			*Thalassionema nitzschioides*			*Hemidiscus hardmannianus*			Total diatoms		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
16-1-51 ...	0	32	60	0	8	12	0	0	16	0	12	24	12	68	12	0	0	12	96	268	136
23-1-51 ...	16	208	0	0	0	42	0	0	40	12	24	44	164	576	16	0	0	12	248	1160	214
30-1-51 ...	48	48	180	0	4800	400	0	0	40	0	400	12	0	0	104	0	0	0	424	5388	760
6-2-51 ...	408	0	0	4800	16000	8800	0	0	0	0	0	0	0	0	0	0	0	0	5248	16000	8800
13-2-51 ...	64	169	220	8000	4000	6000	1200	1200	1600	0	0	0	240	0	0	0	0	0	9504	5369	7820
20-2-51 ...	800	108	0	0	800	800	0	800	0	0	0	0	0	0	0	60	0	0	860	1708	800
27-2-51 ...	0	0	0	0	0	0	140	0	160	0	0	0	0	0	0	80	240	120	220	240	280
13-3-51 ...	0	0	0	0	0	160	400	120	0	0	0	0	0	0	0	280	640	920	1400	1336	1560
20-3-51 ...	0	0	0	0	0	40	120	190	120	0	0	0	0	0	0	1600	1600	32	2040	1740	192
	IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI
20-1-51 ...	28	0	*	0	1200	*	0	800	*	120	760	*	0	0	*	16	0	*	176	5204	*
25-1-51 ...	40	36	*	0	200	*	0	80	*	12	80	*	24	0	*	0	8	*	76	452	*
3-2-51 ...	52	88	0	24	8400	32	0	0	0	16	440	8	0	0	0	0	0	0	92	9096	40
10-2-51 ...	0	0	472	80	1200	2800	0	0	0	0	12	0	40	0	0	0	0	0	120	1212	3272
17-2-51 ...	0	36	0	1200	2400	2000	800	0	0	0	0	0	0	0	0	0	0	0	2000	2436	2000
24-2-51 ...	280	372	*	120	0	*	0	0	*	0	0	*	0	0	*	1040	40	*	400	372	*
3-3-51 ...	420	240	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1460	280	24
17-3-51 ...	0	0	0	0	0	0	120	0	80	0	0	0	0	0	0	400	8400	560	540	8400	640

From these data it may be safe to assume that in the area investigated the distribution of many of the animals was not random. The animals show a tendency to aggregate at certain places. A similar tendency of unevenness in distribution was also evident in phytoplankton. The number of cells per cc. of the predominant species which occurred at the time of investigation is given in Table IX. It will be noticed that on several days there was considerable clumping of a species at one station and practically no cells of the species at other stations indicating thereby the highly patchy nature of distribution.

Evidence of aggregation of organisms in freshwater plankton has been brought forth by Ricker (1937). He has pointed out that the variance is often greater than the mean and that it is an evidence of aggregation. Langford (1938) as a result of comparing the mean and variance of a number of hauls taken at one station as well as over an area in Lake Nipissing in Ontario found that while some organisms were clumped others could be considered randomly distributed. Barnes and Marshall (1951) as a result of detailed study have come to the conclusion that "Only at low population densities is there a close approach to a random distribution. As the population density increases there is a clear evidence of aggression, i.e. the chance of an organism being present is increased by the presence of an organism already there, so that the frequency distributions fit those of a contagious series."

As a result of the present study it has already been pointed out that in the area investigated most of the organisms were not randomly distributed. It was observed that while an organism may be present in fair numbers at one station it may be completely absent at the same time from the neighbouring station or stations. Further, in many cases it was also observed that the variance exceeded the mean indicating thereby the possibility of aggregation amongst the different organisms.

IV—Summary

1. A preliminary survey of the distribution of plankton at six inshore stations located over a distance of about 14 miles in the Gulf of Manaar has been made in order to ascertain whether there are marked differences in the distribution.

2. Studies made separately have shown that the standard deviation of haul to haul variation for horizontal hauls (using a half-meter Organdie net) is 12.9%.

3. The net-plankton volume and six of the important zooplankters have been selected for a detailed study of the distribution. An arbitrary range has been set up by taking two standard deviation of the haul to haul variation in excess or defect of the mean. It was found that in majority of cases the fluctuations in the number of organisms caught exceeded the range showing thereby an unevenness in their distribution in the area surveyed.

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