

## Biological Characteristics of the Laccadive Sea (Lakshadweep)

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Primary productivity, chlorophyll *a*, phaeopigments and particulate organic carbon were studied in the Laccadive Sea during March-April 1978. Column primary productivity, chlorophyll *a* and phaeopigments ranged from 254 to 830 mg C/m<sup>2</sup>/day (av. 372), 1.4 to 15.4 mg/m<sup>2</sup> (av. 4.9) and 1.16 to 17.2 mg/m<sup>2</sup> (av. 4.6) respectively. Pigments from nannoplankton were 22 to 100% of the total phytoplankton pigments. Particulate organic carbon values ranged from 1.55 to 6.16 g/m<sup>2</sup> (av. 3.61). *Trichodesmium erythraeum* and *T. thiebautii* were present at all the stations. *Gymnodinium* sp. was mostly present near the islands. Attenuation coefficient varied from 0.061 to 0.113. On an average the detrital carbon was 81% of the particulate organic carbon.

Information on biological characteristics of the Laccadive Sea is confined to areas near some of the islands<sup>1-4</sup>. In order to understand the biological features over larger areas of the Laccadive Sea, a series of cruises have been undertaken on *R V Gaveshani*. The present paper gives some data on carbon assimilation by phytoplankton, chlorophyll (chl) *a*, phaeopigments, particulate organic carbon (POC), nannoplankton pigments, phytoplankton cell counts and attenuation coefficient, obtained during the 31st cruise (March-April 1978). Apart from these, data obtained from the 10th and 13th cruises (October and December 1976) are also presented for comparison<sup>5</sup>.

### Materials and Methods

Water sampling was done at different stations (Fig. 1) from surface and 4 other depths using a van Dorn sampler. The sampling depths were decided from the attenuation coefficient calculated from Secchi disc measurements such that light levels at the depths were 60, 30, 16 and 1% of the surface. Duplicate water samples (~125 ml) were inoculated with <sup>14</sup>C (4 μCi) and incubated by simulated *in situ* technique using neutral density filters to adjust the light levels<sup>6</sup>. Dark bottle samples were immediately filtered and light bottle samples were incubated for 24 hr. Samples were filtered through Sartorius membrane filters (0.45 μm pore size), exposed to acid fumes<sup>6</sup>, dried and counted in a scintillation counting system using 15 ml liquid scintillation cocktail (NE 220). Pigment estimations were made by fluorometry after filtering the samples through GF/D pads and extracting in 90% acetone<sup>7</sup>. Contribution of nannoplankton to the total phytoplankton pigment was estimated by passing the samples through 20 μm Nybolt net before filtration for

extraction of pigments. POC was measured by the wet acid digestion and spectrophotometry<sup>7</sup>.

### Results

Primary production, chl *a*, phaeophytin and POC values at surface and column are given in Table 1. Higher rates of production were obtained from the shelf region and lower values from the open sea stations.

Phytoplankton counts ranged from 1900 to 8200 cell/litre in the open sea. Stations situated near the islands (Fig. 1) showed lower counts of phytoplankton

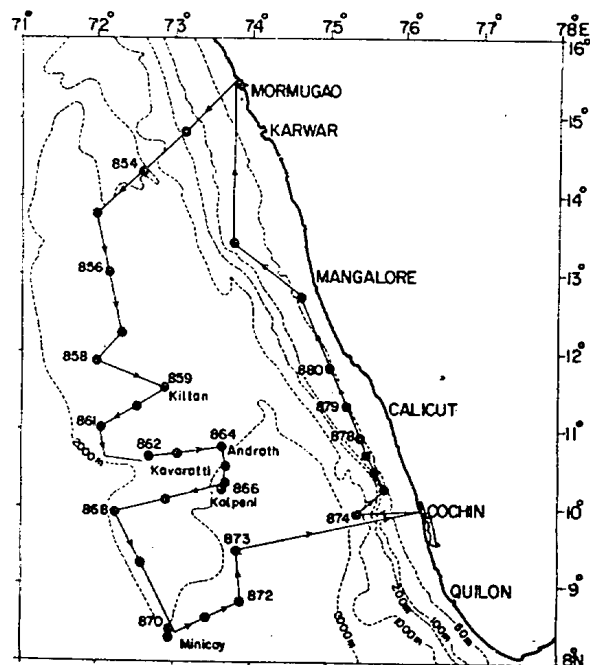


Fig. 1—Station positions (observations were carried out only at the numbered stations)

Table 1—Biological Characteristics of the Lakshadweep Sea during March-April 1978

St No.	Surface					Column					Atten- uation coeff.		
	*pp mgC/m <sup>3</sup> / day	Chl <i>a</i> mg/m <sup>3</sup>	Phaeo- pigments mg/m <sup>3</sup>	Nannoplankton		POC mg/m <sup>3</sup>	*pp mgC/m <sup>2</sup> / day	Chl <i>a</i> mg/m <sup>2</sup>	Phaeo- pigments mg/m <sup>2</sup>	Nannoplankton		POC g/m <sup>2</sup>	
				Chl <i>a</i> mg/m <sup>3</sup>	Phaeo- pigments mg/m <sup>3</sup>					Chl <i>a</i> mg/m <sup>2</sup>			Phaeo- pigments mg/m <sup>2</sup>
854	2.80	0.13	0.05	—	—	52	829.5	9.05	6.24	—	—	2.81	0.074
856	5.02	0.09	0.06	—	—	20	532.2	15.40	17.22	—	—	5.05	0.085
858	4.00	0.05	0.02	0.01	0.05	44	461.2	7.51	6.36	1.63	3.47	2.46	0.081
859	6.50	0.01	0.01	0.01	0.03	32	330.8	8.05	7.07	5.48	2.95	2.58	0.081
861	4.36	0.02	0.02	—	—	20	264.9	1.61	1.58	1.09	1.77	1.95	—
862	2.37	0.01	0.04	0.01	0.02	41	269.7	2.06	6.71	1.47	3.86	4.15	—
864	2.98	0.10	0.01	0.04	0.01	81	293.5	7.26	4.13	2.74	2.65	4.75	0.074
866	4.40	0	0	—	—	78	456.3	1.43	1.16	—	—	—	—
868	1.44	0.04	0	0.04	0.01	76	423.7	3.88	2.39	3.88	1.02	5.33	0.077
870	3.91	0.15	0.06	—	—	80	270.5	1.65	1.41	—	—	5.36	0.061
872	7.48	—	—	—	—	109	388.2	3.73	1.64	—	—	6.16	—
873	4.89	0.04	0.01	0.02	0.02	98	259.7	2.35	2.34	1.99	2.98	4.50	0.065
874	5.05	0.06	0.05	0.03	0.02	100	257.3	3.27	5.73	1.07	2.66	2.77	0.077
878	30.23	0.08	0.03	0.04	0.14	50	367.0	2.88	2.86	2.44	1.95	1.66	0.094
879	4.62	0.20	0.04	0.08	0.02	62	285.8	5.37	4.01	3.84	1.37	3.03	0.113
880	8.73	0.15	0.04	0.06	0.04	19	253.6	2.23	2.42	2.23	2.95	1.55	0.100
Av.	6.2	0.08	0.03	0.03	0.04	60	371.5	4.86	4.58	2.53	2.51	3.61	0.082
SD	6.7	0.06	0.02	0.02	0.04	30	150.6	3.8	4	1.4	0.88	1.5	—

\*pp=primary production

(2000-4000 cell/litre). *Trichodesmium erythraeum*, *T. thiebautii* and flagellates were present practically at all stations. The common phytoplankters such as *Navicula*, *Nitzschia*, *Chaetoceros*, *Rhizosolenia*, *Leptocylindrus* and flagellates were mainly present at the coastal stations. Dinoflagellates (*Peridinium* and *Prorocentrum*) were less represented than diatoms at majority of stations. *Gymnodinium* was mostly present at stations near the islands. Zooplankton biomass varied from 2 to 33 ml/100 m<sup>3</sup>.

### Discussion

Although there are wide fluctuations in the values of different parameters from station to station during March-April 1978, October and December 1976 (Tables 1 and 2) the average values for the 3 periods will provide information on the concentration of the parameters under consideration. The average surface primary production was higher during December as compared to other periods. The higher SD value for primary production during December was because of comparatively higher surface production at sts 220, 222 and 228 (Table 2). The pigment concentration was also high at these 3 stations (Table 2). The difference in the average values of surface production during March-April and October was highly insignificant ( $P > 0.7$ ) while those during March-April and Dec. and Oct. and December were significant at  $P = 0.4$  only. The column production during March-April was higher

than that during October and December. The high SD value during December was again due to higher production at sts 220, 222 and 228. However, the difference in the column production of March-April and October was highly significant ( $P < 0.001$ ) while that between March-April and December was highly insignificant ( $P > 0.8$ ). The difference of the values in October and December was significant ( $P = 0.025$ ).

The difference in chl *a* between March-April and October was not significant (av. values are equal) while those between March-April and Dec. and Oct. and December were significant ( $P = 0.05$  and  $P = 0.025$  respectively). The higher SD value during December was due to appreciably higher values of chl *a* at some stations (Table 2). The difference in the concentration of chl *a* in the column during March-April and October and October and December was significant ( $P = 0.2$  and  $P = 0.025$  respectively). During March-April and December the difference in the column pigment concentration was highly significant ( $P < 0.001$ ).

The differences in the concentration of POC of the surface between March-April and October, March-April and December and October and December were significant ( $P = 0.05$ , 0.01 and 0.05 respectively). The column POC values were found to vary much. The differences in the values during March-April and October and October and December were highly significant ( $P < 0.001$ ) while the difference between March-April and December was significant ( $P = 0.01$ ).

Table 2—Biological Characteristics of the Lakshadweep Sea during October and December 1976

St No.	Surface				Column			
	*pp mgC/m <sup>3</sup> /day	Chl <i>a</i> mg/m <sup>3</sup>	Phaeopigments mg/m <sup>3</sup>	POC mg/m <sup>3</sup>	*pp mgC/m <sup>2</sup> /day	Chl <i>a</i> mg/m <sup>2</sup>	Phaeopigments mg/m <sup>2</sup>	POC g/m <sup>2</sup>
October								
129	13.29	0.08	0.04	205	358.8	12.00	10.89	33.21
134	14.67	0.12	0.05	709	190.3	8.86	4.24	35.80
137	6.01	0.12	0.05	142	175.9	4.41	8.45	17.30
138A	2.48	0.07	0.05	173	23.0	0.89	0.26	2.04
139	14.03	—	—	142	202.1	—	—	13.50
140	7.91	0.07	0.03	205	92.0	6.61	1.54	18.32
141	5.85	0.13	0.05	79	95.9	7.20	3.79	11.18
143	2.72	0.16	0.05	551	135.3	8.67	3.93	21.91
147	3.54	0.10	0.03	—	177.9	4.09	1.86	—
150	0.53	0.08	0.05	142	21.8	5.39	1.15	13.68
151	0.79	0.02	0.03	173	53.2	3.85	2.70	24.26
153	0.33	0.05	0.03	79	29.5	6.54	6.40	9.39
154	1.94	0.03	0.05	110	98.7	7.23	7.74	19.63
157	1.93	0.05	0.04	173	222.5	7.85	7.22	17.20
Av.	5.43	0.08	0.04	222	134	6.44	4.63	18.26
SD	5.14	0.04	0.01	188	94.7	2.8	3.25	9.2
December								
212	1.65	0.04	0.03	213	85.0	4.40	3.04	14.30
214	2.96	0.09	0.03	100	110.9	3.84	5.29	6.16
215	3.61	0.15	0.03	246	164.4	16.72	6.75	8.23
217	3.23	0.10	0.01	75	190.2	12.90	6.37	2.00
219A	8.17	0.22	0.04	125	635.6	11.91	4.83	14.75
220	32.89	0.58	0.20	94	578.7	18.86	7.45	11.68
222	28.32	0.17	0.06	150	676.1	16.89	11.49	10.75
225	2.30	0.10	0.03	63	199.9	7.75	15.98	3.62
227	2.96	0.15	0.04	175	115.5	3.98	1.35	8.82
228	42.23	0.33	0.09	50	1166.6	16.55	7.48	3.25
230	3.84	0.10	0.32	50	170.7	9.38	11.35	10.07
233	0.67	0.08	0.06	88	263.9	3.87	7.76	2.63
235	3.55	0.10	0.05	75	44.6	7.08	4.38	1.97
236	4.65	0.11	0.06	50	608.8	7.19	9.49	2.50
Av.	10.07	0.17	0.08	111	357.9	10.60	7.36	7.20
SD	13.62	0.14	0.08	63	324.7	5.0	3.80	4.6

\*pp = primary production

Comparison of productivity, chl *a* and POC values indicated how widely they fluctuated during the 3 periods of study. However, the production was maximum during March-April. It was much less than that of Northern Arabian Sea (698 mgC/m<sup>2</sup>/day) during December 1973 to May 1974<sup>8</sup>. But it was higher than the values of Northeastern Arabian Sea (216 mgC/m<sup>2</sup>/day) during November 1976<sup>9</sup>. The surface chl *a* value was less than half of that of the Northeastern Arabian Sea<sup>9</sup>. The column chl *a* value was low except in December when it was almost equal to that of Northeastern Arabian Sea. The surface and column POC values during March-April were also less than those of the Northeastern Arabian Sea.

An attempt has also been made to determine the contribution of detrital carbon to POC. Table 3 gives the ranges in POC, phytoplankton carbon, zooplankton carbon and detrital carbon during the 3 periods. Only those stations from where all the 3 parameters are obtained have been included for the analysis. Information on the carbon content of microzooplankton is not available and hence it is not included along with the zooplankton carbon. The conversion factors used in the computation have been taken from Tranter<sup>10</sup>.

The contribution of detrital carbon was lowest during March-April and highest during October (Table 3). The average percentage of detrital carbon to POC was 81, 96 and 87 during March-April, October

Table 3—Ranges in POC, Phytoplankton Carbon, Zooplankton Carbon and Detrital Carbon in the Lakshadweep Sea during Different Months

[Values are expressed in mg/m<sup>2</sup>. Average values are given in parentheses]

	POC	Phyto- plankton carbon	Zoo- plankton carbon	Detrital carbon
March/April 1978	1546 to 6155 (3603)	83 to 770 (303)	75 to 672 (368)	984 to 5704 (2932)
October 1976	2045 to 33200 (17425)	45 to 605 (308)	104 to 871 (365)	1900 to 32400 (16752)
December 1976	1969 to 14754 (7194)	192 to 943 (530)	60 to 2040 (376)	1145 to 13945 (6288)

and December. The higher values obtained in October could probably be due to the land run off during southwest monsoon. The range in detrital carbon was least during March-April and highest during October. The detrital carbon was 1 to 56 (av. 10) times the phytoplankton carbon in March-April. The corresponding values ranged from 18 to 122 (av. 55) and from 2 to 63 (av. 12) during October and December respectively. Evidently, there was a decrease in the ratio of detrital carbon to phytoplankton carbon from October to March-April. A similar computation for the Northeastern Arabian Sea (November 1976) gave high ratio of detrital carbon to phytoplankton carbon.

Parsons<sup>11</sup> recorded the average ratio of detrital carbon to phytoplankton carbon to be 5. Ryther and Menzel<sup>12</sup> pointed out that the ratio will be as high as 10 in the upwelling areas. But in the present case, the ratio was quite high (av. 55) especially during October. While discussing this aspect, the influence of monsoon will have to be considered. Tranter<sup>10</sup> while working along meridian 110°E found the detrital carbon on an annual basis to be 2 to 3 times the phytoplankton carbon. Therefore, compared to many of the values reported earlier, the Laccadive Sea contained more detrital carbon.

Zooplankton when considered as a percentage of phytoplankton carbon showed large variations. During March-April, October and December, these values (%) varied from 52 to 824 (av. 252), 29 to 233 (av. 142) and 18 to 342 (av. 81) respectively. The range in the zooplankton carbon computed for the region along 110°E was 17 to 73% of the phytoplankton carbon<sup>10</sup>. In Sargasso Sea, it was 15% of the phytoplankton carbon<sup>13</sup>. In comparison to Sargasso Sea and region along 110°E meridian, the per cent ratio of zooplankton carbon to phytoplankton carbon was much higher in the Laccadive Sea.

The time required (in days) for the complete turn over (i.e. the time needed to produce its own weight of carbon) of phytoplankton at all the stations ranged

from 0.2 to 3 (av. 0.8), 1 to 12 (av. 4) and from 0.6 to 8 days (av. 3) during March-April, October and December respectively. Thus, the time required for complete turn over was much shorter in March-April than in October and December and this was partially evident from the highest production in March-April. In the tropical zone along 110°E, the time required for this turn over varied from 3 to 10 days<sup>10</sup>.

From the foregoing account, it can be seen that the biological characteristics of the Laccadive Sea are somewhat different in March-April from those of October or December. This difference may be due to the difference in the physical and chemical characteristics observed during the different periods.

In general, during March-April the temperature at the surface decreases from coast to offshore and from south to north<sup>14</sup>. The top 50m is isothermal. Thermocline is between 80 and 125m. There are indications of the 'rising' of the subsurface waters. During October, the mixed layer thickness varies between 50 and 60m in the open sea. In shallow seas, the water column is homogeneous up to almost the bottom. During December, the mixed layer thickness is between 50 and 60m. The vertical structure of temperature during December is similar to that of October. The water masses present in the Laccadive Sea during March-April, October and December exhibited different physical characteristics. Thus, October is the period when upwelling ceases and is expected to be less fertile. The surface layer especially on the continental shelf (top 100m) is occupied by Arabian Sea upper subsurface waters<sup>15,16</sup>. The  $\sigma_t$  values in the upper 100m are between 23 and 24. But during November-December the low saline Bay of Bengal water enters the Arabian Sea and spreads in a northwest direction and enters the Laccadive region<sup>17,18</sup>. The  $\sigma_t$  values during December is approximately 22 in the upper 100m water column. By March the Bay of Bengal water has spread quite extensively into the Arabian Sea (see Wyrski<sup>18</sup>, plates 50, 51 and 52). During this month the surface layer (top 100m) is found to have  $\sigma_t$  between 22 and 23 in a section along Androth and Kalpeni islands. In another section along Androth and Kavaratti  $\sigma_t$  ranges from 22 to 23.5 in the upper 100m. The  $\sigma_t$  is between 22.5 and 23.5 along north-south section between 13°45'N and 8°30'N (sts 855 to 871)<sup>19</sup>. The above account gives briefly the physical features of the Laccadive Sea during the 3 months.

The chemical characteristics of the Laccadive waters during March-April, October and December also show some differences<sup>19</sup>. During March-April, nitrate-nitrogen is absent at almost all the stations from surface to 50-75m depth. The surface concentration of ammonia-nitrogen ranges from 0.5 to 5.5  $\mu\text{g-at/litre}$ .

The higher values are probably due to the enrichment caused by *Trichodesmium* bloom. The average PO<sub>4</sub>-P and NO<sub>3</sub>-N concentrations during March-April (top 100 m) are less than those found during December. March-April is the period when the oxygen (between 0 and 50 m) is supersaturated (104 to 112%) while during October the saturation ranges from 94 to 110%. The supersaturation of oxygen in the upper 50 m during March-April may be a result of higher primary production.

Laccadive Sea has been earlier described as an oligotrophic environment<sup>2</sup>. But present investigation shows that while certain areas of the region can be termed as oligotrophic during October, such situation is not found during other periods. In short, areas which are oligotrophic at certain times can as well be eutrophic at other times as found in the case of the Laccadive Sea.

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#### References

- 1 Qasim S Z, *Deep-Sea Res*, 17 (1970) 655.
- 2 Qasim S Z, Bhattathiri P M A & Reddy C V G, *Int Revue ges Hydrobiol*, 57 (1972) 207.
- 3 Tranter D J & George J, in *Proceedings of symposium on corals and coral reefs* (Marine Biological Association of India, Cochin) 1972, 239.
- 4 Goswami S C, *Proc Indian natn Sci Acad*, 39B (1973) 676.
- 5 Bhargava R M S, Bhattathiri P M A, Devassy V P & Radhakrishna K, *Indian J mar Sci*, 7 (1978) 267.
- 6 Vollenweider R A (editor), *A manual on methods for measuring primary production in aquatic environments*, IBP Handbook No. 12, second edition (Blackwell Scientific Publication, London) 1974, 225pp.
- 7 Strickland J D H & Parsons T R, *A practical handbook of seawater analysis: Bull Fish Res Bd Can*, 167 (1968) 311pp.
- 8 Radhakrishna K, Devassy V P, Bhargava R M S & Bhattathiri P M A, *Indian J mar Sci*, 7 (1978) 271.
- 9 Radhakrishna K, Devassy V P, Bhattathiri P M A & Bhargava R M S, *Indian J mar Sci*, 7 (1978) 137.
- 10 Tranter D J, in *The biology of the Indian Ocean*, Vol. 3, edited by B. Zeitschel (Springer-Verlag Berlin) 1973, 487.
- 11 Parsons T R, in *Progress in oceanography*, Vol. 1, edited by M. Sears (Pergamon Press, New York) 1963, 203.
- 12 Ryther J H & Menzel D W, *Deep-Sea Res*, 12 (1965) 199.
- 13 Beers J R, *Limnol Oceanogr*, 11 (1966) 520.
- 14 Varkey M J, Kesava Das V & Rama Raju D V, *Indian J mar Sci*, 8 (1979), 203.
- 15 Ramasastry A A, *J mar biol Ass India*, 1 (1959) 253.
- 16 Ryther J H, Hall J R, Pease A K, Bakun A & Jones N M, *Limnol Oceanogr*, 11(1966) 371.
- 17 Boisvert W E, *Ocean currents in the Arabian Sea and northwest Indian Ocean* (Special publication 92, US Naval Oceanographic Office, Washington, D.C.) 1966, 29pp.
- 18 Wyrki K, *Oceanographic atlas of the International Indian Ocean expedition* (National Science Foundation, Washington) 1971, 531pp.
- 19 Sen Gupta R, Moraes C, Kureishy T W, Sankaranarayanan V N, Jana T K, Naqvi S W A & Rajagopal M D, *Indian J mar Sci*, 8 (1979) 215.