

## Energy Pathways in the Laccadive Sea (Lakshadweep)

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Energy components of the Laccadive Sea include phytoplankton, zooplankton and detritus. Of these, the detritus contributes most of the energy (97%). Large quantities of detritus, many times greater than phytoplankton and zooplankton in the upper 250 m layer, include microbial flakes, organic aggregates, remains of phytoplankton and zooplankton and faecal pellets. Caloric content of suspended detritus is fairly high and similar to that of other water masses. Annual harvestable yield of the Laccadive Sea has been estimated from the total energy contributed by phytoplankton and zooplankton and it is concluded that Laccadive Sea can support fishery many times greater than what is exploited.

It has often been thought that in the open ocean, the basic sources of food or energy are largely phytoplankton and zooplankton. The alternate pathways of energy from detritus and bacteria have seldom been worked out in detail. During the 31st cruise of *R V Gaveshani* to the Laccadive Sea, during March-April 1978, different pathways of energy from living and non-living materials in the sea have been studied.

### Materials and Methods

For drawing the energy pathways, 12 stations (Fig. 1) were worked. From each station, water samples were collected using van Dorn samplers. The depth investigated were 0, 60 or 80, 100 and 200 or 250 m. From each depth, total suspended matter, chlorophyll (chl) *a* and detritus were measured by filtering 4 to 9 l of water through GF/C Whatman glass filter pads. The pads were dried to constant weight in an oven at 70°C. The difference in weight before and after the filtration gave the measure of total suspended matter in terms of dry weight. Chl *a* was measured fluorometrically on shipboard. From the chlorophyll content, total phytoplankton component in terms of carbon was determined using the conversion factor 1 mg chlorophyll = 50 mg carbon<sup>1</sup> and in terms of dry weight using the conversion factor 1 mg carbon = 3.3 mg dry weight of phytoplankton<sup>2</sup>.

For microscopic analysis, 1 litre of water was fixed with 5% formalin on shipboard and allowed to settle. The settled material was made up to 25 ml. From this, aliquots of 1 ml were pipetted out and examined under a microscope. Zooplankton biomass values available as displacement volume obtained by IOSN<sup>3</sup> during this cruise were converted to wet and dry weights following the conversion factors of Cushing<sup>4</sup> and

Cushing *et al.*<sup>2</sup> respectively and finally to carbon using the conversion factor given by Tranter<sup>1</sup>. The quantity of detritus inclusive of bacteria was determined as the difference between the total dry weights of the suspended matter and the dry weights of phyto and zooplankton.

Carbon values of phytoplankton were converted to calories using the conversion factor 1 mg carbon = 11.4

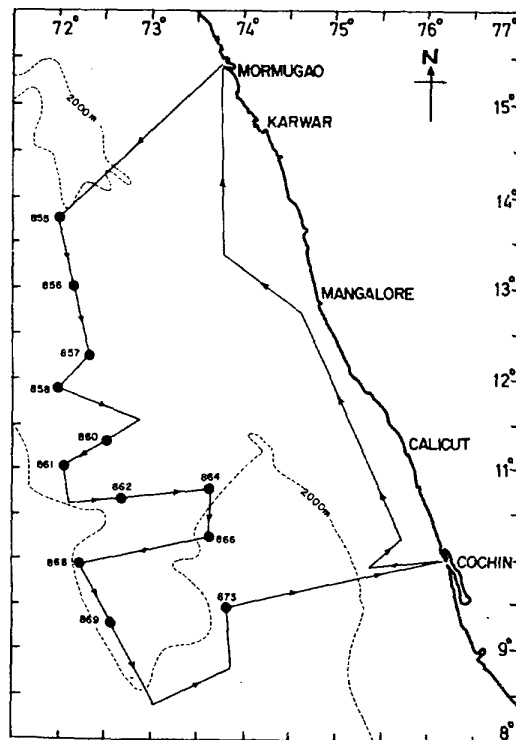


Fig. 1—Stations covered in the present study

calories<sup>5</sup>. Zooplankton calories were derived from carbon values following the factor 1 mg carbon = 10 calories<sup>6</sup>. The total suspended matter after drying was reduced to fine powder. It was then pelleted and combusted in an adiabatic microbomb calorimeter (Parr 1200). Detrital calories were obtained by subtracting the phyto and zooplankton calories from the caloric content of the total suspended matter.

**Results and Discussion**

*Energy components*—Microscopic examination of the suspended matter showed that it is composed of phytoplankton cells (diatoms, dinoflagellates, a few blue green algae), intact zooplankton consisting of copepods, nauplii, a few ostracods and colonies of flagellates. The detrital part of the suspended matter included organic aggregates, microbial flakes, decaying algal cells, diatom frustules, appendages of adult copepods and nauplii, moults of crustaceans, faecal pellets and particles of silt constituting the inorganic fraction.

Integrated values of phytoplankton energy along with energy values for zooplankton, suspended matter

and detritus for the column of water are given in Table 1. Maximum values were recorded at st 856 and minimum at st 855. The average chlorophyll value in the Laccadive Sea was 4.27 mg/m<sup>2</sup>, average carbon value 213.35 mg/m<sup>2</sup> and the phytoplankton energy 2.43 kcal/m<sup>2</sup>. The average value for zooplankton dry weight in the Laccadive Sea (0-200 m column) was 3.0 g/m<sup>2</sup> which will be equivalent to 4.50 kcal/m<sup>2</sup>.

Total suspended matter in terms of dry weight and energy units varied from 14.96 to 677.43 g dry weight/m<sup>2</sup> or 67 to 501 kcal/m<sup>2</sup> respectively. Detrital energy varied from 64.14 to 493.68 kcal/m<sup>2</sup> with an average value of 226.41 kcal/m<sup>2</sup>. On unit weight basis, the detrital energy varied from 0.73 to 4.80 kcal/g dry weight with an average value of 3.85 kcal/g dry weight.

Percentage contribution of energy by living (phyto and zooplankton) and non-living (detritus) components in the total suspended matter is given in Table 2. Of the 3 components, the detrital contribution was the largest (97%) and zooplankton the lowest (1%).

Distribution of phytoplankton, zooplankton and detrital energy in relation to latitudes is shown in Fig. 2. Phytoplankton energy was maximum at lat. 13°

Table 1—Integrated Values of Chlorophyll *a*, Phytoplankton Carbon and Phytoplankton Energy from 0-100 m Column of Water; Zooplankton Weight and Energy from 0-200m Column of Water and Total Suspended Matter, Detrital Weight and Their Energies from 0-250 m Column of Water at Different Stations of the Laccadive Sea

St No.	Chl. <i>a</i> (mg/m <sup>2</sup> )	Phytoplankton carbon (mg/m <sup>2</sup> )	Phytoplankton energy (kcal/m <sup>2</sup> )	Zooplankton dry wt (g/m <sup>2</sup> )	Zooplankton energy (kcal/m <sup>2</sup> )	Total suspended matter (g dry wt/m <sup>2</sup> )	Total energy in suspended matter (kcal/m <sup>2</sup> )	Detritus (g dry wt/m <sup>2</sup> )	Detrital energy (kcal/m <sup>2</sup> )
855 N	1.13	56.5	0.64	5	7.5	79.43	221.44	74.24	213.3
856 D	15.4	770	8.78	4	6	93.43	396.85	86.88	382.07
857 D	3.86	193	2.20	2.6	3.9	64.74	223.73	61.5	217.63
858 D	7.51	375.5	4.28	2	3	677.43	500.96	674.2	493.68
860 D	1.61	80.5	0.92	1.2	1.8	14.96	66.86	13.49	64.14
861 N	2.06	103	1.17	2.8	4.2	108.53	499.01	105.39	493.64
862 N	7.26	363	4.14	3.5	5.25	57.44	227.26	52.75	217.87
864 D	1.43	71.5	0.82	2.2	3.3	23.95	96.22	21.51	92.10
866 N	3.88	194	2.21	3.9	5.85	39.15	111.71	34.61	103.65
868 D	2.31	115.6	1.32	1.5	2.25	27.56	126.9	25.67	123.33
869 N	2.4	120.2	1.37	4.3	6.45	55.79	221.68	50.79	213.86
873 D	2.35	117.5	1.34	—	—	21.55	102.94	21.16	101.60
Av.	4.27	213.35	2.43	3.0	4.5	105.33	232.96	101.85	226.41

N = Night stations; D = Day stations

Table 2—Percentage Contribution of Energy by Different Components in the Laccadive Sea

St No.	Phytoplankton energy	Zooplankton energy	Detrital energy
855	0.29	3.39	96.32
856	2.21	1.51	96.28
857	0.98	1.74	97.28
858	0.85	0.6	98.55
860	1.38	2.69	95.93
861	0.23	0.84	98.93
862	1.82	2.31	95.87
864	0.85	3.43	95.72
866	1.98	5.24	92.78
868	1.04	1.77	97.19
869	0.62	2.91	96.47
873	1.30	—	98.70

and minimum at 14°, while zooplankton energy was highest at lat. 14° and lowest at 12°. Detrital energy was found to be maximum at lat. 13° and minimum at 10° (Fig. 2).

Taking the total area of the Laccadive Sea as  $2.3 \times 10^5 \text{ km}^2$ , the phytoplankton, zooplankton and detrital energy was respectively  $5.6 \times 10^{11}$ ,  $10.35 \times 10^{11}$  and  $520.74 \times 10^{11}$  kcal.

These figures indicate that phytoplankton and zooplankton constitute only a small fraction of the total particulate matter present in the sea and that the rest of the organic matter appears to exist in the form of detritus.

The question which has often been asked is what is the source of such large quantities of detritus in the sea and in what form does it exist? In the estuaries and inshore waters, according to Darnell<sup>7</sup>, the sources of detritus could be both autochthonous and allochthonous. However, in the open ocean, no outside source is possible and that almost the entire quantity of detritus must come from within the sea. According to Steele<sup>8</sup>, to assume a 'spontaneous creation' of detritus in the sea, many times greater than the living matter, is not possible.

In recent years, our knowledge of the total organic matter in the sea has advanced considerably and there is much evidence available to indicate that enormous reserves of dissolved and particulate matter exist in the sea in the form of 'organic pool'. This pool is far greater than the total stock of living organisms. Unfortunately, our present scheme of production process in the sea is based on the relationship of plants, herbivores and carnivores, which, without taking into account the detritus part, appears to be unrealistic.

Parsons<sup>9</sup> gives the following proportions of organic matter present in the sea: dissolved organic matter 100; particulate matter including microorganisms 10;

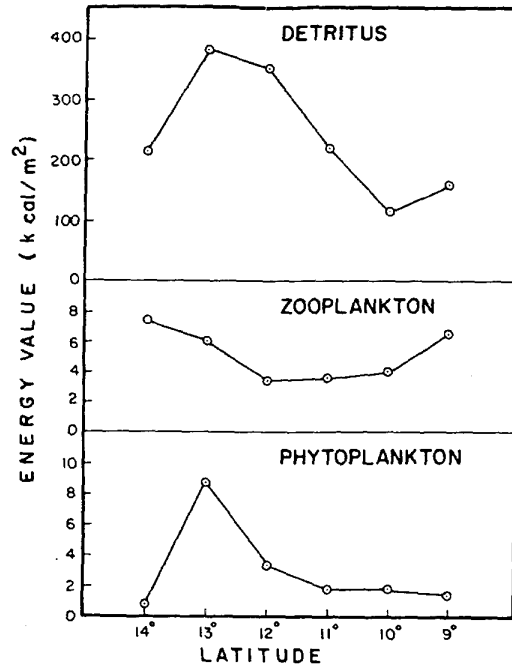
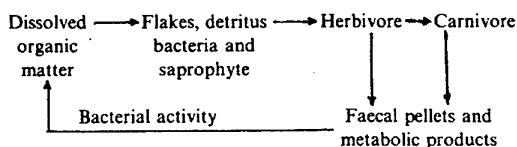


Fig. 2—Caloric values (average) of phytoplankton, zooplankton and detritus in relation to latitudes

phytoplankton 2; zooplankton 0.2; fish 0.002. This would mean that the lowest trophic level in the sea starts from heterotrophic bacteria, nannoplankton, ultraplankton and other microorganisms. Thus, the total quantity of organic matter present in the sea would be many times greater than that contributed by phytoplankton<sup>10</sup>. The presence of inert material in suspension increases the colonization of microorganism which, in turn, continues to enhance the total organic matter<sup>11</sup>. Detailed microscopic study conducted on the aggregates and detritus indicates that from the dissolved organic matter, plate-like flakes and flocculant particles (flocs) are continuously formed in the sea which increase the detrital load<sup>12</sup>. Measurements of adenosine triphosphate (ATP) have given some insight into the problem of quantification of bacterial biomass<sup>13</sup>, but the total quantity of non-living material produced in the sea is yet to be determined.

However, besides the continuous regeneration of detritus in the sea, the more important problem is its removal from the system by such mechanism as grazing. Lenz<sup>14</sup> has suggested both direct utilization of detritus by filter feeders and indirect utilization by bacteria and saprophytes and in turn its consumption by filter feeders and herbivores. The second pathway allows recycling of dissolved organic matter and its re-entry into the food chain.

In the light of some of the evidences summarized above, the generalized pathway of energy in the Laccadive Sea seems to be:



The average caloric value of detritus from the Laccadive Sea was found to be fairly high. Table 3 gives the energy levels of detritus from different water masses. The average caloric value of suspended detritus from the Laccadive Sea seems to be close to that of the other marine environments. This is largely because the suspended matter from the open ocean contains little inorganic material. However, at stations close to the atolls, fine silt, mainly containing calcium carbonate particles, largely seems to come from coral reefs.

**Primary production**—Of the 12 stations investigated, only 7 were day stations (Table 1). Chlorophyll values from these stations were used for calculating the rate of primary production. The integrated values of chl *a* up to 100 m depth were converted to carbon assimilation from the method of Ryther and Yentsch<sup>15</sup>. Average solar radiation values were taken from Mani *et al.*<sup>16</sup> and the assimilation number was taken as 6.8 deduced earlier for the coastal waters of the Arabian Sea<sup>17</sup>. The average primary production for the Laccadive Sea was found to be 382.5 mgC/m<sup>2</sup>/d or 3.21 × 10<sup>7</sup> tonnes carbon/yr.

**Secondary production**—For calculating the secondary production, zooplankton carbon values from the corresponding 7 stations taken for the estimation of primary production, were converted to calories using the conversion factor given by Crisp<sup>6</sup>. Since the copepods were found to be the most abundant organisms in the zooplankton samples, their generation time was worked out using the procedure given by Cushing<sup>18</sup>. Thus, the secondary production was found to be 2.7 × 10<sup>7</sup> tonnes carbon/yr.

The total energy from primary production for the entire Laccadive Sea would be about 366.29 × 10<sup>15</sup> calories and from the secondary production it would be 276.6 × 10<sup>15</sup> calories.

**Tertiary production**—For computing tertiary production, energy values obtained from primary and secondary production rates were converted to live weight according to the factor given by Qasim *et al.*<sup>17</sup>. Then 0.1% of primary production and 1% of secondary production values were taken and the mean of the 2 was determined. This gave the potential fish yield of the

Table 3—Caloric Values of Detritus from Different Environments Reported by Earlier Authors

[Values represent cal/g dry wt]

Area	Range	Mean
Red Sea <sup>19</sup>	2170-3660	3010
Gulf of Aden <sup>19</sup>	3600-4240	4050
Equatorial Atlantic <sup>19</sup>	3100-4320	3910
Gulf of Mexico <sup>19</sup>	3600-5100	4400
Menai Straits <sup>20</sup>	1076-5542	3263
(Suspended detritus)		
Cochin Backwaters <sup>21</sup>	228-500	358
(Sedimented detritus)		
Zuari estuary <sup>22</sup>	173-6057	1463
(Suspended detritus)		
Laccadive Sea*	732-4804	3850
(Suspended detritus)		

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Laccadive Sea as 156.62 × 10<sup>13</sup> calories or 1659754 tonnes of live weight (see Qasim *et al.*<sup>17</sup>). Since secondary carnivores such as tuna and bill-fishes form the major fisheries which are the long-lived forms, 25% of the potential yield was taken as the harvestable stock. This would amount to 414939 tonnes of fish. According to the catch data collected by the Central Marine Fisheries Research Institute, Cochin for the years 1974 and 1976, the average fish catch for the Laccadive Sea is 2402 tonnes. Thus, a surplus of 4.1 × 10<sup>5</sup> tonnes of fish seems to be available. The ratio of harvestable yield to exploited yield was found to be 173. This indicates that the present level of fishery exploitation in the Laccadive Sea is rather low and there is sufficient scope to increase the catch.

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