

Fig. 1—Station locations

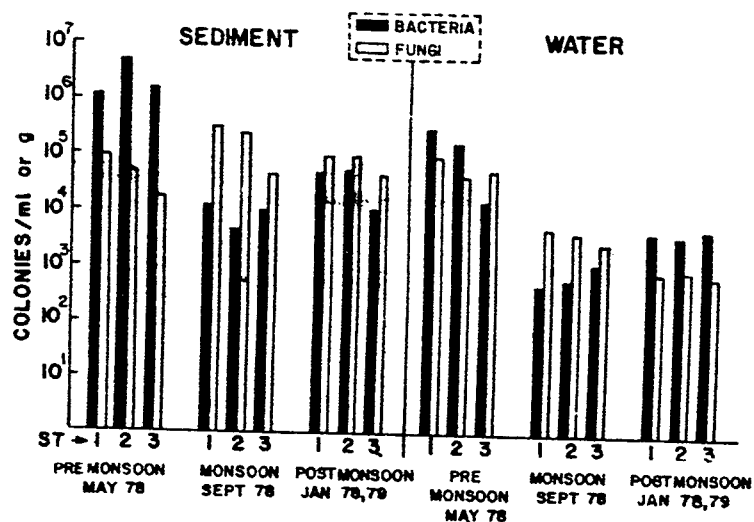


Fig. 2—Seasonal distribution of micro-organisms in mangrove swamps

Table 1—Physico-chemical Parameters of Water Samples from Selected Stations of Mangrove Swamps

	pH	Salinity ‰	Dissolved oxygen ml/litre
May	7 -7.3	28 -34.3	3.9-5.3
September	6.8-7	0.88- 3.8	5 -6.8
January	6.9-8	24 -28.5	4 -5.5

water<sup>9</sup>. Bacterial colonies were counted after 24 and 48 hr incubation and fungal colonies after 3-4 days incubation. Physico-chemical parameters were analysed using standard methods<sup>10</sup>.

Mangrove ecosystem harbours a large number of heterotrophic bacteria and fungi (Fig. 2). In the monsoon, the heavy rainfall leads to considerable reduction in salinity (Table 1) and low values of nutrients due to continuous washout and dilution of the estuarine waters<sup>11</sup>. This leads to low counts of bacteria, observed during September. However, the heavy leaf fall<sup>12</sup> on the water provides a very good medium for the growth of degradative fungi<sup>5</sup>, resulting in their high counts.

After monsoon the salinity normalizes<sup>11</sup> (Table 1) and the accumulation of degraded foliage with particulate matter, utilizable by the heterotrophic bacteria<sup>5</sup>, leads to increase in bacterial counts in January and May.

The ecological changes in the environment reflect on the seasonal variations in the microflora and turnover of the nutrients. Further work on the contribution of individual type of organisms on the decomposition process is necessary as the detritus formation finally affects the productivity of the ecosystem<sup>2</sup>.

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### Biochemical Changes & Energy Content of the Mangrove, *Rhizophora mucronata*, Leaves during Decomposition

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Decomposition of *R. mucronata* leaves both in the laboratory and in the field resulted in the loss of organic carbon and ash and increase in total nitrogen, organic matter, protein and caloric content. In the decomposed leaves, relatively high values of combustible organic matter were recorded (97.07% in the field and 88.4% in the laboratory).

## SHORT COMMUNICATIONS

Importance of mangrove detritus to estuarine fauna has been indicated<sup>1,2</sup>. In the estuaries of Goa, large quantities of detritus originate from the mangrove swamps<sup>3</sup> dominated by *Rhizophora mucronata* Lamk, *Avicennia officinalis* Linn, *Sonneratia alba* J. Sm in Rees and *Bruguiera gymnorrhiza* (L.) Lamk. Changes in organic constituents during growth and decomposition of *R. mucronata* and *A. officinalis* have been studied<sup>4</sup>. Shrimps fed on decomposed leaves of *R. mucronata* have shown good growth rate and high food conversion efficiency<sup>5,6</sup>. These are attributed to changes in the chemical composition of decomposing leaves. Such deductions have prompted this investigation on the biochemical changes in *R. mucronata* leaves during their decomposition in greater detail.

Withered leaves of *R. mucronata* collected from the mangrove bordered estuaries of Goa were cut into small pieces (1 cm) and used. In the laboratory the leaves (5 g fresh weight) were allowed to decompose in 10 glass aquaria (40 × 20 × 20 cm) containing 10 l water from mangrove swamps (sal. 20-22‰ and temp. 27 ± 1°C), filtered through No. 25 bolting nylon to remove zoo and phytoplankton and kept in the dark to prevent the growth of nannoplankton. Membrane-filtered water was not used to eliminate nan-

noplankton as the process would remove the native microbial flora which are important for decomposition.

*In situ* decomposition was studied by enclosing 25 g (fresh weight) of leaves in 10 perspex cylindrical tubes (30 cm length and 4.5 cm diam.). The tubes were provided with lids on either side with 250 μ netting and these were kept suspended horizontally in running water in the field. Care was exercised to ensure that they remained immersed in water even during the low tide.

At weekly and biweekly intervals, samples of leaves were withdrawn and allowed to stand in distilled water for 10 min to remove salt. These were then dried to constant weight. Biochemical constituents were determined following the standard methods<sup>7-9</sup>. Organic carbon<sup>10</sup>, total nitrogen<sup>11</sup> and total phosphorus<sup>12</sup> were estimated. Caloric values were determined in a Parr adiabatic calorimeter. Changes in the above parameters were followed for 11 weeks in the field and 13 weeks in the laboratory and the results presented in Table 1.

*In situ decomposition*—Between 1st and the 4th week, carbohydrate level decreased to 44% of the initial value, followed by a reduction up to 83% during the 5th week. Thereafter it did not vary much and towards the

Table 1—Changes in Biochemical Constituents, Organic Carbon, Total Nitrogen, Total Phosphorus and C:N and ΔN:P Ratios in Decomposing Leaves of *R. mucronata* under *in situ* and Laboratory Conditions

Time weeks	Carbo- hydrate %	Lipid %	Protein %	Ash %	Energy value kcal/g dry wt	Organic carbon %	Total nitrogen %	Total phosphorus μg/g dry wt	C:N ratio	ΔN:P ratio
<i>In situ</i>										
0	25.8	13.86	44.59	11.68	4.23	43.90	7.13	769	6.16	205
1	12.9	14.86	54.82	15.36	4.25	41.41	8.77	654	4.72	297
2	12.34	13.71	57.93	17.23	4.26	42.39	9.27	508	4.57	404
3	12.52	14.5	58.21	18.08	4.23	40.05	9.31	435	4.3	472
4	11.4	14.69	64.54	8.55	4.45	41.12	10.3	435	3.99	544
5	4.34	12.74	73.13	8.16	4.58	39.75	11.7	721	3.4	359
6	5.17	14.8	74.57	7.44	4.6	40.29	11.9	677	3.39	389
7	6.2	12.1	76.19	5.85	4.61	39.0	12.2	676	3.2	398
9	6.2	12.85	75.82	4.26	4.64	38.13	12.1	338	3.15	795
10	5.81	13.61	74.75	3.55	4.66	36.53	11.96	432	3.05	612
11	5.81	13.33	76.35	2.93	4.73	34.86	12.2	620	2.86	436
<i>Laboratory</i>										
0	33.0	12.4	43.97	12.73	3.88	41.34	7.04	871	5.88	179
1	14.34	12.94	57.52	16.28	4.08	47.29	9.14	610	5.17	331
2	10.57	13.52	62.49	11.38	4.14	47.24	9.8	485	4.82	474
3	10.4	12.33	64.81	15.56	4.16	46.01	10.1	347	4.56	641
4	10.0	13.26	59.17	23.53	4.18	39.72	9.85	338	4.03	644
5	10.33	14.81	53.52	22.46	4.09	40.0	8.77	410	4.56	473
6	10.64	9.42	60.51	17.01	4.13	40.19	9.26	431	4.34	475
8	4.32	9.12	73.79	11.56	4.14	43.05	10.3	469	4.25	478
10	4.43	9.13	74.93	13.81	4.20	34.98	11.0	448	3.18	542
12	3.3	8.3	72.63	12.02	4.21	29.85	12.32	654	2.42	417
13	4.68	8.73	73.18	11.59	4.32	26.12	12.55	721	2.08	385

end it had decreased to 77.5% of the initial value. Lipid content did not show any definite pattern of variation. Protein level showed a gradual increase up to 7th week and for the rest of the period it did not vary much. An increment of 55% of the initial value was recorded for ash content up to the 3rd week. Between 3rd and 4th weeks, a sudden decline (27%) from the initial value was recorded. Thereafter, ash content declined and a loss of 75% from the initial level occurred at the end. Caloric content on dry weight basis during the 1st 3 weeks did not vary much but increased thereafter till the end of the experiment (11.8% increase over initial value). On an ash-free dry weight basis the increase towards the end was 2.21% from the initial level.

Organic carbon recorded a gradual decline with a loss of 21% at the end. Variations in the total nitrogen content were similar to those of protein. The gain in total nitrogen was 71.11% of the initial value. The total phosphorus recorded a gradual drop up to the 4th week and then increased up to the 7th week. Thereafter, the pattern became irregular. C:N ratio was much lower (54%) than that of the withered leaves.

*Decomposition in the laboratory*—Carbohydrate content decreased by 57% of initial value during the 1st week. From 2nd to 6th week the values remained constant after which they decreased. Lipid did not vary much up to the 5th week but thereafter declined. The loss at the end was 30%. Protein content increased up to the 10th week. A gain of 66.43% was recorded at the end. Ash content increased up to the 4th week and then decreased. Caloric value on dry weight basis increased till the end and gain was 11.34% and on ash-free dry weight basis the gain amounted to 10%.

Organic carbon during the 1st to 3rd week increased by 12% from the initial value. Between 4-6 weeks the values did not vary much and a loss of 36.82% occurred at the end (Table 1). Total nitrogen increased till the end, except for a slight decrease between 4-6 weeks. The gain was 78.3%. Total phosphorus decreased up to the 4th week and then gradually increased. However, the increase recorded was lower by 17.22% of the initial level. C:N ratio declined till the end with a loss of 64.6% from the initial.

Decomposition of *R. mucronata* leaves both in the laboratory and in the field resulted in the loss of organic carbon and ash and increase in total nitrogen, organic matter, protein and caloric content. In the decomposed leaves, relatively high values of combustible organic matter were recorded (97.07% in the field and 88.4% in the laboratory). This agrees with earlier findings<sup>13,14</sup>.

During decomposition, caloric content increased from 4230 to 4730 cal/g dry weight in the field and 3880 to 4320 cal/g dry weight in the laboratory. Gosselink and Kirby<sup>15</sup> reported similar values in *Spartina*

*alterniflora* Loisel, while Odum and Heald<sup>2</sup> observed an increase of 600 calories in the decomposing *Rhizophora mangle* L. in 6 months. Such an increase in calories is associated with the increase in protein during decomposition. The increase in protein recorded in the present study may be due to colonization of microbial flora<sup>14,15</sup>. Heald<sup>1</sup> reported 22% increase in protein in *R. mangle* while De la Cruz<sup>14</sup> recorded an increase of 96% in *S. americanus*, 99% in *S. cynosuroides* and 300% in *D. spicata*. Odum and Heald<sup>2</sup> reported an increase from 5 to 21% in *R. mangle*. Untawale *et al.*<sup>4</sup> also recorded the increase in protein content during decomposition.

Decrease in carbohydrate during decomposition may account for the loss in organic carbon. Reduction in C:N ratio in decomposing mangrove leaves and the eel grass has been reported<sup>4,16,17</sup>. In the present study, the ash content increased during the early phase of decomposition and declined later. This indicates that initially the loss in the inorganic matter was lower than the organic loss. The decline in ash content indicates a greater loss of inorganic matter.

Laboratory and field experiments showed some differences in the chemical composition during decomposition (Table 2). These may probably be due to the controlled conditions in the laboratory and free passage of water and exchange of nutrients in the field experiments.

N:P ratios are of importance because of their significance on the productivity of natural ecosystems<sup>18</sup>. Generally in estuaries the available nitrogen seems to limit plant production<sup>19</sup>. Ramadhas<sup>20</sup> recorded high  $\Delta$ N:P ratio in mangrove waters and attributed it to the nitrogen enriched mangrove debris. Similar situation is observed in the present study which may contribute to the nutrient enrichment of mangrove waters.

C:N ratio is also important in assessing the dietary requirements<sup>21</sup>. In the present study it is observed that both non-decomposed and decomposed leaves had a low C:N ratios. In earlier studies<sup>6</sup> when decomposed

Table 2—Per cent Loss or Gain Per Day Recorded in the Proximate Composition, Organic Carbon, Total Nitrogen, Energy Content and C:N ratio Under Laboratory and *in situ* Conditions

	Laboratory	<i>In situ</i>
Carbohydrate	-0.95	-1.07
Protein	+0.74	+0.99
Ash	-0.04	-0.97
Organic carbon	-0.41	-0.27
Total nitrogen	+0.87	+0.92
Energy dry wt basis	+0.13	+0.15
Energy ash-free dry wt basis	+0.11	+0.02
C:N ratio	-0.72	-0.70

*R. mucronata* leaves with low C:N ratio were fed to shrimps, the rate of growth in the shrimp increased indicating that such a diet can give a satisfactory food value. In conclusion it can be stated that the decaying leaves of *R. mucronata* with their high caloric and protein content are a good food source for detritivorous organisms.

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## Conversion Efficiency in the Shrimp, *Metapenaeus monoceros* (Fabricius), Fed Decomposed Mangrove Leaves

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Feeding experiments were carried out with *M. monoceros* using mangrove leaves at different stages of decomposition, in combination with rice bran. Maximum conversion efficiency was found in shrimps fed completely decomposed mangrove leaves. Differences in the conversion efficiency obtained in the shrimps were attributed to biochemical composition of the feeds which varied as decomposition process proceeded.

Importance of mangrove detritus as food for estuarine and marine animals is known<sup>1-4</sup>. Withered leaves of *Rhizophora mucronata* in combination with rice bran, lead to low conversion efficiency in the shrimp, *M. monoceros*<sup>5</sup>. In this paper conversion efficiency in *M. monoceros* fed compounded diets prepared with partially and completely decomposed leaves of *R. mucronata* is reported.

*Preparation of test diet*—Withered yellow leaves (1 kg) of *R. mucronata*, collected from mangrove fringed estuaries of Goa, were cut into pieces (1 cm) and allowed to decompose in dark in 30 l aerated mangrove water (sal. 25-27‰) at room temperature (28 ± 1°C). Water was changed once in 3 days during the first 2 weeks to avoid heavy accumulation of organic matter. At the end of the 2nd week, half of the plant material which had undergone degradation due to leaching and microbial decomposition was used for compounding a test diet for the shrimps (group I). This diet, in combination with rice bran is referred as partially decomposed. The rest of the material was allowed to decompose further till the end of the 5th week. At this stage, the plant material had undergone decomposition to the level of 2-3 mm particles. This material, in combination with rice bran was used to prepare the test diet for the shrimps (group II) and is referred as completely decomposed. Decomposition beyond this stage was not attempted as it may lead to the formation of particles having primarily cellulose and lignins which would probably be of little food value<sup>2</sup>.

About 60% of partially and completely decomposed material was pulverised, mixed with 40% finely powdered rice bran, made into a paste with distilled water and passed through a surgical syringe and drawn in the form of pellets, which were air dried.

Mangrove leaves were used as the chief source of protein. Since carbohydrate content (both utilizable and non-utilizable) is generally lowered during decomposition<sup>1,3,6</sup>, this was supplemented with rice bran.