TABLE 2 — CORRELATION BETWEEN EXPECTED AND ESTIMATED ION-EXCHANGE CAPACITY OF THE SEAWEEDS

	Loss in wt of weed on conversion to H^+ form %	Alginic acid content %	meq/100 g air-dried weed in H^+ form				
			SO_4^{2-} contents of washed weed	Expected capacity due to			Fixed cation in washed weed	Estimated capacity*
				Alginic acid	Fucoidan	Total		
Cystoseira indica	45	31·01	38·65	139·9	40·5	180·4	174·1	232
Sargassum tenerrimum	47·4	35·79	89·77	160	49·92	209·9	258·1	276·5
Padina pavonica	48	32·44	49·59	184·3	44·65	229	249·7	258
Sargassum swartzii	50	37·6	67·48	213·6	69	282·6	269·94	295
Turbinaria conoides	39	36·03	83·53	208·8	39·96	248·8	297·5	305·5

*Determined in 1*N* calcium acetate solution; *p*H of equilibrated solution 5·7.

Cation-exchange capacity — About 1 g of air-dried H^+-weed was accurately weighed and equilibrated with 100 ml of *N* calcium acetate solution. Ca^{2+} ion concentration in the solution before and after equilibration was determined and uptake of Ca^{2+}/100 g air-dried H^+-weed was calculated.

Table 1 shows that in all raw weed samples potassium ion content is higher than that of sodium and in some cases (samples 1, 2 and 5) even higher than that of alkaline earth. In sea water, ratios (on equivalent basis) of sodium to alkaline earth metal ions and sodium to potassium are 4 and 46 respectively whereas in *Cystoseira indica* these are 0·31 and 0·229 respectively and in *Padina* which contains less alkali metal as compared to other weeds, these are respectively 0·059 and 1·053. Thus weeds accumulate potassium and alkaline earth in preference to sodium from seawater. This is in accordance with the observation reported by other workers[7].

Difference in the mineral content of the weeds before and after washing with hot water (Table 1) reveals that nearly 60 to 70% of the metallic ion are present as water soluble sorbed salts (mainly as chlorides). However, in *Padina*, containing large amount of calcareous ($CaCO_3$) materials[8], and *Turbinaria*, having more of 'fixed' alkali metal ions, the water soluble mineral contents are about 40% of the total minerals. Most of Mg^{2+} and Ca^{2+} and a fraction of the alkali metal ions which could not be washed out with water are leached out with dilute hydrochloric acid. This indicates that these acid soluble ions may either be present as insoluble salt (carbonate) or fixed with the ionogenic groups present in the weeds. This is clearly shown in Table 2 (column 9) wherein the fixed cation content of the washed weed (total cation minus adherent $CaCO_3$) is expressed on the basis of the weeds in H^+ form.

It is seen that some chloride is left on the weed even after thorough washing with hot water (Table 1). Hence this part of the chloride might be present as organically bound chloride in the weed.

In *Cystoseira indica, S. swartzii and Padina pavonica* the sulphate estimated in the washed weed is nearly equivalent to the fucoidan content of the weed in H^+ form, whereas in the *S. tenerrimum* and *Turbinaria conoides*, the sulphate in the washed samples was nearly 1·8 and 2·1 times the equivalent fucoidan content respectively (Table 2). This indicates that in the latter 2 samples, part of the sulphate remains probably as water insoluble sulphate ($CaSO_4$) which could be washed out with dilute hydrochloride acid.

Data in Table 2 further reveal that in all cases the ion-exchange capacity is higher than that can be accounted by the alginic acid and the fucoidan contents of the weed. Higher cation-exchange capacity and the fixed ionic content, therefore, indicate that over and above the alginic acid and the fucoidan content, weeds might be containing some other constituents with ionogenic groups which can fix and exchange the cations.

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Biochemical Composition of Mangrove Leaves from Goa

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Analysis of biochemical constituents shows that the leaves are rich in carbohydrates, lipids and proteins. They also have a high caloric content and hence they would form a source of nutrition to the animals feeding on decaying leaves of mangroves.

CHEMICAL composition of mangroves has been studied earlier[1-5]. To substantiate the data on the Indian mangroves, the leaves of 7 species of local mangroves were analysed for their biochemical composition.

Fresh leaves of *Sonneratia acida, Bruguiera gymnorhyza, B. parviflora, Avicennia officinalis, Rhizophora mucronata, Acanthus ilicifolius* and *Derris trifoliata* were collected and analysed for total carbohydrate, total lipid, total nitrogen, protein nitrogen, non-protein nitrogen, organic carbon, ash and water content.

After homogenization in distilled water, 1 ml homogenate was used for the determination of total sugars[6]. Total nitrogen was determined by microkjeldahl digestion followed by nesslerization[7], while protein nitrogen was estimated by the same method but after precipitation of proteins by freshly prepared cold 10% trichloro acetic acid. Difference between the total nitrogen and protein nitrogen was taken as the non-protein nitrogen.

Lipids were extracted according to the method of Bligh and Dyer[8] with some modification. A known amount of sample was homogenized in 2 ml distilled water to which 2 ml chloroform and 4 ml methanol were added. The mixture was centrifuged and then kept at 5°C for at least 10 min. After centrifugation for about 5 min at 2000 rpm, the supernatant was transferred to a dry test tube and 2 ml chloroform plus 2 ml distilled water were added. The contents of tubes were stirred again and centrifuged for about 10 min at 2000 rpm. The top layer was discarded and the lower layer containing lipids was concentrated at 50°C. It was dried in a vacuum desiccator and weighed to determine lipid per cent.

Organic carbon was estimated following the method of Wakeel and Riley[9].

Using appropriate calorific equivalents of 5·65 for protein (calculated as NX6·25), 4·15 for carbohydrate and 9·4 for lipid on ash free dry weight basis, the caloric values of mangrove leaves in terms of each fraction and total energy were calculated[10,11].

To determine the ash content, a weighed quantity of powdered leaves was burnt in a muffle furnace at 500°C for about 5 hr. Water content of leaves was determined by drying fresh leaves to constant weight in a hot air oven at 80°C.

In the present study large differences in the biochemical constituents have been recorded in different species. For example, species belonging to the same genus *Bruguiera* showed considerable differences in their biochemical composition (Table 1). *Derris trifoliata* showed relatively high con centration of total nitrogen and non-protein nitrogen and very low concentration of carbohydrate, ash and water.

Sidhu[4] analysed the ash and sodium content of 3 species of *Avicennia* and the present value of the ash content in *A. officinalis* agrees with his finding. Similarly, the water content in *R. mucronata* determined by us is similar to that reported earlier[5]. Chemical composition of *Rhizophora mangle* from Florida has already been reported[1,2] and the values recorded for *R. mucronata* in the present investigation compare favourably with the data from Florida.

Energy values of the leaves of all the species were found to be fairly high (Table 2). Maximum caloric value was obtained in *Sonneratia acida*, while *B. parviflora* showed the minimum value (Table 2). Similarly *S. acida* and *D. trifoliata* showed maximum

TABLE 1 — BIOCHEMICAL COMPOSITION OF MANGROVE LEAVES

(Results, expressed as per cent, are calculated on ash-free dry weight basis)

Species	Total carbohydrate	Lipid	Protein nitrogen	Non-protein nitrogen	Total nitrogen	Digestible organic carbon	Ash content	Water content
Sonneratia acida	27·9	13·72	2·515	0·354	2·869	34·5	10·4	78·07
Acanthus ilicifolius	20·95	13·55	1·871	0·241	2·112	39·3	12·2	78·24
Derris trifoliata	16·73	11·33	3·343	1·099	4·442	34·2	7·4	61·2
Bruguiera parviflora	25·4	11·31	1·027	0·55	1·577	44·55	13·4	78·17
B. gymnorhiza	43·37	7·76	1·028	0·484	1·512	37·55	12·4	75·55
Avicennia officinalis	46·87	9·72	0·856	0·613	1·469	44·1	13·6	73·2
Rhizophora mucronata	36·11	10·94	2·129	0·358	2·487	39·6	11·4	73·9

TABLE 2 — ENERGY VALUES FOR MANGROVE LEAVES

(Results expressed in cal/g ash-free dry weight)

Species	Protein	Carbohydrate	Lipid	Total caloric value	Caloric value calculated from organic carbon
Sonneratia acida	1013·1	1157·85	1289·68	3460·63	5017
Acanthus ilicifolius	745·8	869·42	1273·7	2888·92	5746·6
Derris trifoliata	1568·6	694·29	1065·02	3327·91	4971·4
Bruguiera parviflora	556·86	1054·1	1063·14	2674·1	6544·6
B. gymnorhiza	533·925	1799·85	729·44	3063·21	5480·6
Avicennia officinalis	518·52	1945·1	913·68	3377·3	6476·2
Rhizophora mucronata	878·23	1498·56	1028·36	3405·15	5792·2

value in terms of lipid and protein fraction respectively, whereas *A. officinalis* gave maximum caloric value for carbohydrate (Table 2). While studying the energy values of detrital matter from Cochin Backwater, it was observed that the detritus had a protein value ranging from 123·17 to 331·66 cal/g dry weight[11]. Mangrove foliage seems to have a low caloric value for proteins but considerably high values for carbohydrate and lipid (Table 2).

The caloric values of mangrove leaves were also calculated from its carbon content by using the equation given for zooplankton equivalent[12].

$$\text{Cal/g dry weight} = -227+152\ (\%\ \text{carbon})$$

Energy values calculated from organic carbon were consistently higher than those determined from the major metabolites (protein, carbohydrate and lipid). This indicates that the mangrove foliage may contain additional carbon from sources other than protein, carbohydrate and lipid. Evidently, the total particulate carbon seems to be the best single property for measuring the caloric value of mangrove foliage.

The production, consumption and distribution of organic detritus from mangrove has been studied and it was pointed out that many commercially important fishes and invertebrate flourish in the mangrove swamps[13,14]. Microorganisms convert the substances like cellulose and lignin present in the mangrove leaves into digestible matter which is utilized by the animal communities[14]. On the basis of the present analysis, the earlier assumption[15] that mangrove swamps are rich in food material which is readily consumed by estuarine animals, seems valid.

There is a strong possibility of using powdered leaves of mangroves as food for commercially important fishes and prawns in aquaculture, since the possibility of utilizing the mangrove leaves as cattle food has already been reported[16-18].

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Osmoregulation in the Sand Crab, *Emerita holthuisi*

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Ability of the sand crab to withstand osmotic stress was investigated by following salinity tolerance, changes in freezing point depression and changes in body weight in different salinities. Lower salinity tolerance was found to be in 17·2‰ while upper was in 32·5‰. *E. holthuisi* maintained its body fluid hypotonic to sea water of salinity 35·2‰ and hypertonic to 17·2‰ salinity and further dilutions. Isotonicity was maintained between 21·7 and 32·5‰ salinities. In 25·6‰ salinity within 64 hr and in 18·1‰ salinity within 112 hr the body weights were regained. However, in 12·8‰ salinity the sand crab did not regain its original body weight.

OSMOTIC and ionic regulation among aquatic decapod Crustacea have been extensively investigated[1,2]. There is, however, little information about the osmotic behaviour of anomuran Crustacea. Freezing point of blood has been determined for *Birgus latro*[3] and *Coenobita clypeatus*[4]. Gross[5] has shown that *B. latro* could control its blood concentration by selecting water of appropriate salinity. Gross and Halland[6] have reported similar behavioural mechanism in *Coenobita perlatus*. Sukumaran[7] has studied osmoregulation of *Clibanarius padavensis* under heterosmotic conditions.

The work reported here has been carried out to elucidate certain aspects of osmotic behaviour of the anomuran sand crab, *E. holthuisi* which occurs in abundance in beaches on the west coast of India.

E. holthuisi, collected from Mirya Bay, Ratnagiri, was kept in glass troughs filled with sea water (salinity 32·5‰) to a depth of 2 in. Only healthy and active crabs of both sexes were used for the experiments. All the specimens used in this investigation were mature, of same size and of intermoult stage.

Salinity tolerance — Solutions of different salinities (32·5, 25·6, 21·7 and 12·2‰) were made by diluting sea water with distilled water. In each salinity 5 healthy crabs of equal size were kept in finger bowls having 300 ml unfiltered sea water. The bowls were loosely covered to prevent excessive evaporation and the water was changed twice a day. Mortality was recorded for a period of 5 days (120 hr).

Freezing point depression — Osmotic pressure of the body fluid was determined by the comparative melting point method of Jones[8] and Gross[9] as