

SHORT COMMUNICATIONS

to methyl red and oxidized with bromine water. The excess bromine was expelled by boiling the solution. KI was added and the liberated iodine was titrated against 0.001N Na₂S₂O₃ using starch as indicator. For each experiment, 5-10 g of the dried weed was used. The results of the analysis carried out in triplicate are given in Table 1.

Iodine content is generally low (Table 1) in the brown algae, intermediate in green algae and high in red algae. Earlier report¹⁰ indicates that it varies in the order Phaeophyceae > Rodophyceae > Chlorophyceae. Further, practically no information is available on the iodine content of most of the species analysed here except *Ulva fasciata*, *Gracilaria corticata*, *Sargassum tenerrimum*, *Colpomenia sinuosa* and *Acanthophora specifera*. The values obtained for the first 3 algae are much higher than those reported by Dave¹² for the same species from Gujarat coast. *Hypnea musciformis* from Mandapam⁹ contains as much as 0.1% of iodine (dry weight basis), while the same species from Saurashtra coast contains only 0.01% of iodine¹². The present study indicates an intermediate level of iodine content (0.07%) in the same species from the Goa coast. These variations are to be expected because the iodine content of fresh weeds varies in different seasons of the year and with locality. The analytical results also depend on the relative proportions of fronds and stipes in the sample and whether the plant is fruiting or it is sterile. It is also likely that the presence of epiphytes (e.g. in Rodophyceae) may affect the results. Similarly the iodine available is also affected by its concentration in sea water of a particular region, wave action, variation in temperature, etc. The actual escape of free iodine is due to the action of iodide oxidase acting in the presence of oxygen.

Though the iodine content of red seaweeds is the highest, it is unlikely that these seaweeds will shortly be used as a source of iodine for industrial purposes in view of the scarcity of most of these algae except *Gracilaria corticata* and *Hypnea musciformis*, which

though available in comparatively larger quantities, have lower iodine contents.

The most common species of chlorophyceae along the Goa coast are *Ulva fasciata* and *Chaetomorpha antennina*—the former being abundant and the latter available only in the monsoon. Thus the seasonal availability of the second species restricts its use as a raw material due to difficulty in collection. The only group of algae left for commercial exploitation is the brown algae in which although the iodine content is lowest they are readily available as a raw material in view of their greater abundance.

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Properties of Phycocolloid Extracts from Seaweeds of Goa

A. G. UNTAWALE, N. B. BHOSLE & V. K. DHARGALKAR
National Institute of Oceanography
Dona Paula 403004, Goa

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Phycocolloid extracts from 3 algal species (*Hypnea musciformis*, *Gracilaria corticata* and *Gelidiella* sp.) and their mixtures were studied for gel strength, gelling temperature and melting point. Total yield varied from 20 to 30% dry weight of the seaweed. Addition of an electrolyte such as KCl (0.5%) increased the yield and improved gel strength.

SEAWEEDS are the main source of 2 industrially important phycocolloids, agar agar and alginates. Number of reports on the extraction, preparation and uses of agar agar are available¹⁻⁴. However, no information is available on seaweeds from the Goa region. In India presently, only certain seaweeds like *Gelidiella* sp., *Gracilaria* sp., etc., are being utilized for the extraction of agar agar. As the quantity of these species along the Indian coastline is not sufficient for the seaweed industries,

TABLE 1 — IODINE CONTENT OF MARINE ALGAE

Species	mg iodine/100 g dry weed	Species	mg iodine/100 g dry weed
PHAEOPHYCEAE		RODOPHYCEAE	
<i>Dictyota bartayresii</i>	54.4	<i>Laurencia obtusa</i>	143.5
<i>Padina tetrastomatica</i>	61.2	<i>Chondrus</i> sp.	740
<i>Spatoglossum asperum</i>	85.1	<i>Chondrococcus</i> sp.	14.1
<i>Dictyota dumosa</i>	54.82	CHLOROPHYCEAE	
<i>Colpomenia sinuosa</i>	167.9	<i>Cladophora pinnulata</i>	488.5
<i>Sargassum tenerrimum</i>	129.4	<i>Corallina</i> sp.	127.7
RODOPHYCEAE		<i>Chaetomorpha</i> sp.	36.2
<i>Gracilaria corticata</i>	136	<i>Ulva fasciata</i>	119.4
<i>Hypnea musciformis</i>	74.2	<i>Enteromorpha</i> sp.	117.7
<i>Acanthophora specifera</i>	123	<i>Caulerpa sertularioides</i>	31.2
<i>Gracilaria</i> sp.	365.4	<i>Chaetomorpha antennina</i>	112.4

there is an urgent need to locate non-conventional resources.

Properties of agar agar from a single species of seaweed have been studied⁴⁻⁷. But mixed agar from 2 different species has not received much attention. In the present paper, properties of agar from a mixture of *Hypnea musciformis*, *Gracilaria corticata* and *Gelidiella* sp. have been reported in addition to agar from single species.

Fresh seaweeds collected from the coastal regions of Goa were washed thoroughly with seawater and then with running tap water. These were dried in an oven at 50°C to constant weight and then powdered. During drying, water was sprinkled periodically over the seaweeds to obtain proper bleaching. The method described by Chapman⁸ was followed for the extraction of agar.

Mixtures of 2 different species were prepared by taking equal amounts of each seaweed powder. The terminology for these mixtures was developed from first few letters of generic name (*Hyp-Gra* = *Hypnea* and *Gracilaria*).

Gel strength—Agar-gel extracts of 1, 1.5 and 2% (wt/vol.) conc. from the species of *Hypnea*, *Gracilaria*, *Gelidiella*, *Hyp-Gel*, *Hyp-Gna* and *Gra-Gel* were prepared adding 100 ml distilled water. After heating over a water bath, the extracts were cooled and allowed to stand for about 12 hr to form gel. Gel strength was determined by a penetrometer. The instrument consists of a glass vessel drawn into a tube of 0.6 mm diam. Weight of mercury required to penetrate the tube into the gel was taken as gel strength (g/cm²) of the extractive.

$$\text{Gel strength} = \frac{\text{wt of penetrometer} + \text{wt of Hg}}{22/7 \times (\text{diameter}/2)^2}$$

Centron (India) agar was used as a standard for comparison with *Hypnea*, *Gracilaria*, *Gelidiella*, *Hyp-Gra*, *Hyp-Gel* and *Gra-Gel* extractives.

Gelling and melting temperature—Extracts of 1, 1.5 and 2% (wt/vol.) conc. were prepared from oven dried flakes of agar from the species under investigation. Gelling temperature was recorded directly by inserting a thermometer into the extract. The temperature at which the incipient gel formation started was recorded. The extract was then cooled and allowed to stand for 12 hr to gel completely. The beakers containing extracts were placed on the water bath after taking the gel strength. A brass piece weighing 10 g was placed on the surface of the gel and the temperature at which the weight sank into the gel was taken as the melting point of the extract of that particular concentration.

Hypnea, *Hyp-Gel* and *Gra-Gel* extracts did not form the gel at 1% concentration (Table 1). However, at 2% conc. they formed gels of good strength. All the extracts from the 3 different species of algae and their mixtures formed gels of high strength in comparison with standard agar. Gelling and melting temperatures of different extracts were somewhat lower than those of standard agar. However, in higher concentration, these algal extracts show values comparable to those of the standards.

Effect of KCl on gel strength—Extracts of 1% conc. from *Hypnea* and *Gracilaria* did not form

TABLE 1—GELLING AND MELTING TEMPERATURE AND GEL STRENGTH OF 3 SPECIES OF ALGAE WITH AND WITHOUT POTASSIUM CHLORIDE

Agar source	Conc. of extract, % (wt/vol.)	Gelling temp. °C	Melting point °C	Gel strength g/cm ²
WITHOUT KCl				
<i>Hypnea musciformis</i>	1	20	—	—
	1.5	26	58	199
<i>Gracilaria corticata</i>	2	35	60	574
	1	42.5	—	65
<i>Gelidiella</i> sp.	1.5	45.5	54.5	88
	2	55	74.5	100
<i>Hyp-Gra</i> mixture	1	56	67	65
	1.5	66	67.1	103
<i>Hyp-Gel</i> mixture	2	69	79.5	122
	1	28	48	180
<i>Gra-Gel</i> mixture	1.5	58	58	352
	2	65	68	576
Centron (India)	1	46	29	—
	1.5	50	55	363
	2	55	61.5	410
	1	45.5	30	—
	1.5	53.6	38.5	82
	2	62	57.5	108
	1	50	73	160
	1.5	53	75	349
	2	53.5	78	418
WITH KCl (0.5%)				
<i>Hypnea musciformis</i>	1	36	50	164
	1.5	45	62	392
<i>Gracilaria corticata</i>	2	55	67	865
	1	52.4	42	65
<i>Gelidiella</i> sp.	1.5	52	63.5	175
	2	55	67	200
<i>Hyp-Gra</i> mixture	1	46	42.5	99
	1.5	55	66.5	199
<i>Hyp-Gel</i> mixture	2	58	69	247
	1	42	32	156
<i>Gra-Gel</i> mixture	1.5	55	65	529
	2	59	68	750
	1	40	40	165
	1.5	55.5	43	423
	2	62.5	63.5	561
	1	55.5	53	65
	1.5	64.5	58	160
	2	66	72.5	199

gels. However, gel strength was enhanced after the addition of 0.5% KCl which also increased the gel strength of 1.5 and 2% extracts. Similarly, there was an increase in the gel strength of the mixture of agar from different seaweeds, as compared to the agar without KCl.

Chapman⁸ has given a detailed account of physical properties of agar from Cuba. Ramarao and Krishnamurthy⁴ indicated the gelling point, melting temperature and gel strength of *Hypnea* sp. Rao and Bekheeti⁹ have studied various aspects of the extraction and other physical properties of agar from *Pterocladia capillacea*. They have observed maximum gel strength of 1350 g/cm² in 1.5% solution. The results obtained during present investigation confirm these findings. However, the values of gel strength were found to be somewhat higher, in *Hypnea* sp. and *Hyp-Gra*. These variations can be attributed to the different environmental conditions present in the Goa waters, as well as the maturity of the plants.

The importance of the addition of electrolytes like, KCl, NH_4Cl and KNO_3 has already been shown⁸. The gel strength can be increased by 5 to 15% with the addition of KCl (Table 1) which not only enhances gel strength but also controls gelation temperature (Table 1), as indicated earlier⁸.

From the present study, it seems that *Hypnea*, *Gracilaria*, *Gelidiella* and their mixtures can be used as a source of agar. However, to get the desired gel strength, KCl should be added before filtering the hot extract. But the addition of an electrolyte to increase the gel strength of the final product may not be desirable when agar is to be used for bacteriological investigations.

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A Model for the Prediction of Zooplankton Abundance in an Estuary

M. MADHUPRATAP, T. S. S. RAO & H. KRISHNA IYER
National Institute of Oceanography, Regional Centre
Cochin 682018

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Regression model for the prediction of zooplankton abundance correlating total numbers of zooplankton with salinity, temperature and oxygen from Cochin backwaters is presented. The variability explained by the parameters is 73.5% when the whole estuary is considered and 88.7% and 52.2% at 2 individual stations, viz. Aroor and Barmouth respectively. Salinity is the predominant factor controlling zooplankton abundance followed by oxygen and temperature.

ESTUARIES are dynamic systems where environmental parameters and populations may change in magnitude over very short periods. Estuarine zooplankton, in addition to the true estuarine species comprise opportunist species, which blossom into brief blooms when conditions become ideal, euryhaline marine species and also accidental immigrants from both marine and limnetic regions.

A model for the prediction of zooplankton abundance using multiple regression is presented in the

present paper from 2 sets of data (i) monthly collections from Cochin to Alleppey during 1972 and (ii) monthly collections at 2 stations, viz. Barmouth (Cochin) and Aroor (about 14 km south of mouth) from Nov. 1971 to Oct. 1972. Zooplankton collections and measurements of the environmental parameters (salinity, temperature and oxygen) were made as reported earlier^{1,2}.

Correlation coefficients were calculated between total numbers of zooplankton, salinity, temperature and oxygen. All the correlation coefficients being found significant, they were connected by a multiple regression model. The regression model fitted to the data was $Y = b_0 + b_1^X + b_2^X + b_3^X$, where Y stands for total numbers, X_1 for salinity, X_2 for temperature and X_3 for oxygen. The regression was fitted by the method of least squares and the normal equations were solved using matrix inversion. Significance of the regression coefficients was tested by analysis of variance and the relative importance of environmental parameters was estimated using

the formula: $b_i \sqrt{\frac{\sum x_i^2}{\sum y^2}}$ (ref. 3).

The equation derived for the whole estuary (series 1) was $\hat{Y} = -17.4733 - 0.0201X_1 + 0.8118X_2 - 1.2685X_3$. It was $\hat{Y} = 4.1574 + 0.0643X_1 - 0.0438X_2 - 0.2801X_3$ at Aroor and $\hat{Y} = 5.4335 + 0.0559X_1 - 0.1532X_2 + 0.2877X_3$ at Barmouth.

The test of significance for regression coefficients (Table 1) showed that in series 1 and at Aroor, the fitted regressions were highly significant ($P < 0.001$) while at Barmouth it was significant at a lesser level ($P < 0.05$). The variability explained by the fitted regression was 73.5% in series 1, 88.7% at Aroor and 52.2% at Barmouth.

Proximity to the mouth results in an early recovery of salinity after the monsoon season enhancing a longer duration of typical estuarine conditions at Aroor. During the monsoonal period salinity and zooplankton population are very low at this station. Hence the parameters considered accounted a higher percentage of variability at Aroor. But Barmouth is subjected to greater turbulence even during premonsoon period resulting in greater variations in environmental parameters and fauna. During the monsoonal period also the salinity values ranged from near zero values during low tide to 35.5‰ at the bottom during high tide. This indicates that other factors such as turbidity, currents and tidal dispersion, food, extent of pollution, etc. may have to be considered to explain the total variability occurring in the environment. Organisation of communities is influenced by multiple environmental stresses and organisms increase or decrease in response to these.

Relative importance of the 3 parameters in the equation are given in Table 2. In all cases salinity is the most prominent factor controlling zooplankton abundance followed by oxygen and temperature. Being a tropical estuary, fluctuations in temperature are of low magnitude to affect the organisms drastically. But sharp variations in salinity occur in the estuary and zooplankton population is very low