

21261

# Seaweed Utilization and its Present Status in India

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## Introduction

Marine algae are simple plants varying in size from microscopic single celled forms to giant macrophytes. The earliest knowledge of marine plants is from the exploratory voyages around India and collections made by the missionaries who then visited India. Boergesen (1930) published a series of reports based on his own and M.O.P. Iyengar's collections from some parts of the west coast of India. Subsequent work that followed dealt mainly with algal morphology and taxonomy (Dixit, 1933, 1940; Koshi & John, 1948; Srinivasan, 1946; Biswas, 1934, 1945).

During the last few decades, interest in seaweeds has increased considerably which resulted in the extensive survey of these natural resources. Along the east coast of India, work on algal ecology, distribution and enumeration of algal species has been documented (Srinivasan, 1946; Parija and Parija, 1946; Chacko *et al.* 1955; Varma and Krishnarao, 1961; Umamaheswara Rao, 1969, 1974). Systematic evaluation of seaweed resources of the Andhra coast was carried out by Umamaheswara Rao (1978) while Krishnamurthy (1957, 1960, 1966, 1977) reported many new algal species from South India.

The west coast of India has been extensively studied for taxonomical studies, resource evaluation, ecology, distribution, utilization and cultivation (Sreenivasa Rao *et al.*, 1964; Desai, 1967; Chauhan and Krishnamurthy, 1968; Chauhan and Mairh, 1978; Dixit, 1933; Untawale and Dhargalkar, 1978; Dhargalkar, 1981; Untawale *et al.*, 1981, 1983).

The importance of marine algae as food, feed, fertilizer, drugs and in industrial use is well recognized. Many studies have been carried out on chemical constituents of marine algae. Algal products such as agar, alginates and carrageenan are being used in textile, drugs, dairy and paper and pulp industries (Thomas and Krishnamurthy, 1975; Mehta and Baxi, 1976).

Marine algae as manure have been used since ancient times for paddy and fruit bearing plants. Recently, it was confirmed that seaweed manure is superior to the conventional organic manure (Black and Woodwards, 1957; Mehta *et al.*, 1967). Seaweed as a liquid fertilizer has been successfully tried in the laboratory (Bhosle *et al.*, 1978) and in the field (Bukhari and Untawale, 1979; Dhargalkar and Untawale, 1980).

The present paper briefly discusses the status of Indian seaweed, its exploitation for industrial purpose, management and effective measures to conserve this valuable marine living resource. It also describes application of recently developed techniques such as tissue culture, genetic engineering, molecular biology for improving yield and quality. Use of marine living resource on sustainable yield basis has also been discussed.

## Status of marine Algae in India

- a. **Species distribution**— Indian phycologists have conducted extensive research on morphology, taxonomy and distribution of Indian marine algae. According to Untawale *et al.* (1983), there are about 624 marine algal species of various groups. From station-wise distribution of seaweeds for different algal groups it seems that Tamil Nadu coast dominates in number of algal species (302),

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followed by Gujarat (202), Maharashtra (159) Lakshadweep group of islands (89), Goa (82), etc. The recorded algal species belong to 204 genera, 61 families and 15 orders (Table 1).

- b. **Resource survey**— It has been estimated that about 100,000 tonnes (wet wt.) of seaweeds can be harvested annually from the Indian coast (Table 2). Global seaweed potential is estimated to be about  $1821 \times 10^4$  tonnes wet wt. of which about 4.83% is being harvested from east and west Indian ocean (Michanek, 1975). Along the Indian coastline, Gulf of Kutch and Palk Bay are proven areas for luxuriant seaweed biomass and are being exploited for quite some time. At these localities some seaweed species such as *Sargassum*, *Gelidiella* and *Gracilaria* have been over exploited.

The methodology used for survey purpose differs widely and the estimates are uncomparable. A standard methodology for the proper and reliable estimation of the biomass is required to be followed.

The algal surveys conducted so far are mostly from the intertidal areas and for commonly and abundantly growing species. The subtidal areas have been neglected due to non-availability of equipments and trained manpower. Recently introduced new and effective techniques such as underwater diving, remote sensing such as satellite imageries and infra red as well as coloured aerial photography, if employed, could increase the present estimates.

- c. **Seaweed Utilization** — Utilization of seaweeds for industrial purposes in India dates back to the 2nd World War when soda ash, alginates and iodine were extracted from seaweeds. Increasing demand of agar and alginates lead to over exploitation of the phycocolloid yielding seaweeds. The major seaweeds that are used for the purpose are *Gelidium* spp., *Gelidiella* spp., *Gracilaria* spp. for agar and *Sargassum* and *Turbinaria* spp. for alginates. Agar and alginate contents in the seaweeds are given in Table 3. The estimated harvestable qualities of these economically important seaweeds found along the Indian coast is given in Table 4. Our seaweed industries produce about 60 tons of agar and 600 tons of alginates annually. Of this quantity, 50% of agar is in the form of bacteriological grade. Alginate production and its utilization in India is given in Table 5.

The quantity of alginates and agar produced cannot meet the present industrial demands. Hence fair amounts of these products are being purchased from other countries (Table 6). The demand for phycocolloid and their raw materials is estimated to increase by 10% annually and with available resources it will not be possible to cope up with the increasing trend, hence large scale cultivation of the economically important seaweeds is the only alternative we can think of at present.

- d. **Other uses of seaweeds**— Use of seaweeds as fodder is known from the ancient times. The coastal inhabitants use seaweeds to feed cattle, poultry, piggery, etc. Some of the green algae are used as fish food in aquaculture. Various minerals and vitamins are also extracted from the marine algae (Table 7). Uses of seaweeds as manure is increasing day by day. Organic fertilizers have been prepared from the seaweeds and effectively used (Bhosle *et al.*, 1975; Dhargalkar and Untawale, 1980). Large quantities of drifted seaweeds on beaches could be used for this purpose.

Use of seaweeds as human food is being practiced in South East Asian countries for a long time. However, it is not being used in India till now. Efforts have to be initiated to develop taste for seaweeds as part of the Indian diet to overcome protein, iodine and trace metal deficiency. Some of the seaweed species have shown biological activities (Table 8). About 50 marine algae have been screened for bioactive compounds. Results achieved so far are very encouraging.

### Seaweed cultivation

Although some indigenous technical know-how for the cultivation of different economically important seaweeds have been developed, it has not gained much attention for large scale cultivation. Technical know-how in this field has been demonstrated at Malwan (Untawale *et al.*, 1982), Okha (Ohno, *et al.*, 1981), Mandapam (Subbaramaiah *et al.*, 1978) to cultivate *Gelidiella* spp., *Gracilaria edulis*, *Hypnea musciformis*, *Monostroma* sp. and *Enteromorpha* sp. Most of the industries depend entirely on the natural resources of the Indian coast. It is high time to take up cultivation of these plants on larger scale in order to increase raw materials and production of these vital phycocolloids to meet growing demands.

To augment these resources further, techniques such as tissue culture, genetic engineering, molecular biology could be taken up to have desired strains and high quality yield of respective products. A few institutes and universities have initiated this programme in India. These techniques may be applied to obtain high yielding species for agar, alginates, carrageenan, proteins of any desired quality and may also be useful in producing a few kelp species like *Macrocystis* and *Laminaria* which can be grown in Indian waters. Intensive inbreeding and selection, X-ray induced mutants to produce new and improved strains are possible (Anonymous, 1976; T. Seng, 1981). Successful application of these techniques will open new vistas in seaweed research in the next century.

The ability of some algal species to tolerate sewage pollution has been recognized. Industrial complexes along the coast discharge effluents in the surrounding waters, and these have shown diverse effects on marine algae. Efforts are required to cultivate some of the seaweeds that can grow in these effluents to reclaim the area to some extent.

In view of future large scale seaweed farming, it would be necessary to know about the diseases caused by various marine organisms and also suitable remedies to control these diseases.

### Introduction of new algal species

One of the major aspects for the future development of seaweed industrial potential will be introduction of some economically important and high yielding marine algal species in suitable coastal waters. Algal species like *Eucheuma*, which is being cultivated in Philippines, Indonesia and USA on large scale is a good source of Kappa-Carrageenan, may be an ideal seaweed for Indian conditions. Some more high yielding algal species may be taken up. Although this aspect will increase the production, lot of research and development work is needed in this field so that species introduced will not outrage existing species, upsetting the ecological balance.

### Energy from biomass

Investigations have been carried out on the potential of seaweed as fuel through anaerobic digestion on methane. Ryther and Hanisak (1981) demonstrated the production of biogas from marine algae through biotechnology. It has been technically feasible to develop and cultivate a particular clone with specific characteristic through tissue culture. For instance a particular clone of *Gracilaria tikvahiae* has a capacity to propagate vegetatively for long periods without genetic change. Such seaweeds can be used as "energy crops" to meet present energy crises.

### Marine Taxonomy

Although vast literature is available on taxonomy of Indian seaweeds, it has been neglected for some or the other reasons. With a view of seaweed-utilization occupying forefront in the next century, it is necessary to have well organized marine algal taxonomical centres in India. Coastal Universities

can take up this programme and develop a chain of herbarium centres in India. Existing centres in the Universities and institutions are required to be strengthened and improved with adequate manpower and financial assistance.

### Constraints

1. Overexploitation and wrong harvesting techniques are being used as a result of which natural resources are damaged.
2. Proper management and utilization of marine algal resources are lacking.
3. Basic work like taxonomy, morphology, physiology, biology and opening herbarium centres should be centralized.
4. Appropriate legislation for the control of pollution is lacking.
5. Lack of monitoring the water quality of the seaweed rich coastal zone.
6. There is paucity of data on quality and quantity of subtidal algal species. Present knowledge is restricted only to the intertidal areas.
7. Uneconomical seaweeds to the tune of 60% of the total biomass are not utilized.
8. R & D efforts to utilize seaweeds in an organized way are lacking.
9. Lack in coordination among algologists, seaweed suppliers and industrialists.

### Recommendations

1. There is a vast potential for profitable use of uneconomic seaweeds and biotechnical research needs to be oriented accordingly.
2. Technology on the cultivation techniques of different species other than currently used should be developed at different locations.
3. Prospects of processing seaweeds within the region should be assessed and arrangements made for that.
4. Realistic demands for marketing various economic species may be worked out and regularly updated for effective management and execution.
5. Effective techniques, to use seaweeds as a source of energy for methane, methanol, hydrogen, biogas and seaweed liquid fertilizer should be developed.
6. Suitable areas rich in seaweeds may be protected and preserved for seed material and research which may form part of "Marine Park".
7. Introduction of new species may be undertaken judiciously and with conservation measures.
8. Hybridization of indigenous species using genetic engineering and tissue culture techniques are promising areas for future research.

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Table-1

## Distribution of marine algal species along the Indian coast

Sr. No.	State	No. of orders	No. of families	No. of Genera	No. of Species
1.	Gujarat	15	42	105	202
2.	Maharashtra	16	40	76	159
3.	Goa	13	29	48	82
4.	Karnataka	12	19	28	66
5.	Kerala	8	10	14	20
6.	Lakshadweep Islands	13	29	51	89
7.	Tamil Nadu	15	45	128	302
8.	Andhra Pradesh	14	29	51	79
9.	Orissa	-	-	-	-
10.	West Bengal	3	4	5	6
11.	Andaman and Nicobar Islands	8	15	23	34

Table-2

## Seaweed resources of the Indian coast

Sr. No.		Annual Yield in tons (fresh wt.)	Authors
I.	GUJARAT		
	(a) Gulf of Kutch	100,000	Desai (1967)
	" " "	19,000	Chauhan & Krishnamurthy
	(b) Hanumandandi to Vumani (Okha)	650	Bhanderi & Trivedi (1975)
	(c) Adatra Reef	60	Sreenivasa Rao <i>et al.</i> (1964)
	(d) Saurashtra Coast	282 to 608	Chauhan & Mairh (1978)
II.	MAHARASHTRA		
	(a) Entire Coast	315	Chauhan (1977)
	(b) " "	20,000	Untawale <i>et al.</i> (1979)
III.	GOA	2,000	Dhargalkar (1981)
IV.	KARNATAKA		
	(a) Entire Coast	Negligible	Untawale & Agadi (1981)
V.	KERALA	?	—
VI.	TAMIL NADU		
	(a) Cape Comorin-to-Colachel	5	Koshy & John (1948)
	(b) Calimare-to-Cape-Comorin	66,000	Chacko & Malu Pillai (1958)
	(c) Pamban	1,000	Varma & Rao (1964)
	(d) Palk Bay	900	Umamaheswara Rao (1968)
	(e) South East Coast	20,535	Subbaramaiah <i>et al.</i> (1977)
	(f) Entire Coast	22,044	Subbaramaiah <i>et al.</i> (1979)
VII.	ANDHRA PRADESH	?	—
VIII.	ORISSA		
	(a) Chilka Lake	5	Mitra (1946)
IX.	WEST BENGAL	?	—
X.	ANDAMAN & NICOBAR ISLAND	?	—
XI.	LAKSHADWEEP ISLANDS	3,645 to 7,598	Subbaramaiah <i>et al.</i> (1979)

Source : Untawale *et al.* 1981

Table-3

## Agar and algin contents in the Indian seaweeds

Species	Alginic acid %	Agar %	Gel strength gm/cm <sup>2</sup>
<b>PHAEOPHYTA</b>			
1. <i>Dictyota dumosa</i>	13.34	-	-
2. <i>D. bartayresiana</i>	22.94	-	-
3. <i>Spathoglossum asperum</i>	17.14	-	-
4. <i>Padina tetrastromatica</i>	8.48	-	-
5. <i>Colpomenia sinuosa</i>	16.65	-	-
6. <i>Sargassum tenerrimum</i>	15.16	-	-
7. <i>S. cinereum</i>	29.17	-	-
8. <i>S. swartzii</i>	15.54	-	-
9. <i>S. wightii</i>	32.00	-	-
10. <i>S. myriocystum</i>	24.70	-	-
11. <i>Turbinaria conoides</i>	36.00	-	-
12. <i>T. ornata</i>	32.18	-	-
13. <i>Cystophyllum muricatum</i>	15.63	-	-
14. <i>Hormophyra trigueta</i>	18.22	-	-
<b>RHODOPHYTA</b>			
1. <i>Gelidiella acerosa</i>	-	50	300
2. <i>Gracilaria lichenoides</i>	-	43	-
3. <i>G. edulis</i>	-	43	120
4. <i>G. crassa</i>	-	23	140
5. <i>G. corticata</i>	-	38	120
6. <i>G. verrucosa</i>	-	30	125

Source : Venkateshkumar, 1980

Table-4

Estimated quantity of industrially used seaweeds on Indian coasts  
(Quantity - Tonnes - wet weight)

Species	Gujarat	Maharashtra	Goa	Lakshadweep	Andhra Pradesh	Tamil Nadu	Total (round figure)
<i>Sargassum</i>	12400	8000	1200	0.30	220	9381	31200
<i>Turbinaria</i>	...	...	...	11	...	714	700
<i>Gelidiella</i>	4	...	...	945	...	74	1000
<i>Gracilaria</i>	19	800	400	420	422	974	3000
<i>Hypnea*</i>	...	500	200	33	53	798	1600
Total (round figures)	12400	9300	1800	1400	700	11900	375000

\* Not yet used. However it has got high potential for industrial use.

Table-5

Annual production & consumption of elginate in India  
(Quantity in Metric Tonnes)

Year	Indigenous production	Import	Apparent consumption
1973-74	137.0	745.8	882.0
1974-75	157.0	51.6	208.6
1975-76	395.5	28.9	424.4
1976-77	441.4	133.9	575.3
1977-78	676.4	186.0	862.4
1978-79	506.0	751.7	1257.7
1979-80	580.0	200.9	780.9
1980-81	546.0	154.3	700.4
1981-82	...	667.8	...

Table-6  
Import and export of agar, alginates and iodine in India

Q = Quantity in Metric Tonnes  
V = Value in lakhs of rupees

Year		Agar		Alginates <sup>++</sup> Import	Iodine <sup>++*</sup> Import
		Import	Export		
1976-77	Q	0.005	1.60	133.95 (100%)	9317.67 #
	V	0.81	1.28	45.52 (100%)	
1977-78	Q	...	1.00	186.83 (100%)	...
	V	...	0.44	49.15 (100%)	
1978-79	Q	0.38	0.08	751.67 (100%)	...
	V	0.46	0.12	56.32 (100%)	
1979-80	Q	1.13	100.15	200.87 (100%)	...
	V	1.65	5.17	69.77 (100%)	
1980-81	Q	5.75	1.45	154.33 (90.6%)	306.29
	V	6.37	0.04	42.58 (82.5%)	
1981-82	Q	11.61	15.10	667.80 (97.4%)	304.27
	V	12.10	1.85	209.84 (97.2%)	
1982-83	Q	3.80	...	240.00 (100%)	...
	V	5.17	...	77.94 (100%)	

\* Alginate and iodine are not exported

+ Includes alginic acid, its salts, esters & sodium alginates

Figures in parenthesis show the % of sodium alginate out of overall import.

++ Includes metallic, colloidal, sublimized, iodinated hydrocarbon.

# Quantity for colloidal iodine is not mentioned. However, value is mentioned in the literature.

Table-7

Average values of the mineral constituents of the Indian Seaweeds mg/100 g

Constituents	Chlorophyta	Phaeophyta	Rhodophyta
Sodium	3.35	1.3	1.32
Potassium	2.17	2.18	0.78
Calcium	0.60	0.14	0.44
Magnesium	0.56	0.11	0.26
Chloride	4.53	2.20	2.37
Nitrogen	0.38	0.60	1.14
Sulphate	6.11	1.72	2.53
Iron	138.12	162.87	26.6
Copper	1.23	1.18	1.16
Manganese	17.74	22.05	26.02
Boron	7.96	1.93	0.81
Zinc	2.26	2.16	6.82
Phosphorous	228.83	106.31	-
Cobalt	0.90	0.52	0.89
Nickel	2.03	0.86	1.40
Lead	1.40	1.5	1.17
Arsenic	0.26	0.81	0.34

\* Compiled from Published Reports

Table-8  
Biological screening of extracts of Indian seaweeds

Species	Activity
<b>CHLOROPHYCEAE</b>	
1. <i>Caulerpa racemosa</i>	Hypotensive
2. <i>C. sertularioides</i>	-
3. <i>Chaetomorpha media</i>	-
4. <i>Cladophora pinnulata</i>	toxic
5. <i>Codium elongatum</i>	Antiviral
6. <i>Enteromorpha intestinalis</i>	-
7. <i>Enteromorpha</i> sp.	Diuretic
8. <i>Ulva fasciata</i>	-
<b>PHAEOPHYCEAE</b>	
9. <i>Chonospora implexa</i>	-
10. <i>Dictyota bartayresiana</i>	-
11. <i>Stoechospermum marginatum</i>	Spasmolytic
12. <i>Padina tetrastratica</i>	Spasmogenic
13. <i>Sargassum tenerrimum</i>	CNS depressant
14. <i>Spathoglossum asperum</i>	-
<b>RHODOPHYCEAE</b>	
15. <i>Acanthophora spicifera</i>	Antifertility
16. <i>Chondria armata</i>	Hypotensive
17. <i>Gelidiella</i> sp.	-
18. <i>Gracilaria corticata</i>	-
19. <i>Hypnea musciformis</i>	Diuretic

Source : Naqvi *et al.* 1980