

BIOLOGY OF THE ECONOMICALLY IMPORTANT INDIAN SEaweEDS—A REVIEW

V.S.K. Chennubhotla, N. Kaliaperumal¹, S. Kalimuthu² and P.V.R. Nair

Central Marine Fisheries Research Institute, Cochin-682 031, Kerala (India).

Abstract

Studies on the biological aspects of economically important Indian seaweeds are reviewed in this paper. These include the taxonomy and ecological studies at different localities along the Indian coast. The growth pattern, periods of maximum growth, fruiting seasons for plants such as *Cystoseira indica*, *Sargassum*, *Turbinaria*, *Gracilaria verrucosa* and *Gelidiella acerosa* have been studied. Commercial harvesting is suggested during peak growth periods to obtain larger quantity of raw materials and better yield of finished products. Spore shedding and the period of maximum sporulation which vary from one seaweed to another has been studied by estimation of spore output and observations on the liberation of spores. Information is available on the germination of spores, survival rate of germlings, culture of germlings and life history studies.

Introduction

Seaweeds form one of the important marine living resources. They are used as human food, live stock feed and fertilizer. Phyco-colloids such as agar-agar and algin extracted from red and brown seaweeds respectively are put to use in many industries such as food, confectionary, pharmaceutical, textile and paint and varnish industries, mostly as gelling, stabilizing and thickening agents. Agar is of great value as culture medium

in microbiological studies. Some seaweeds like *Ulva*, *Enteromorpha*, *Caulerpa*, *Porphyra*, *Gracilaria* and *Acanthophora* are consumed as vegetables in salads, soups, porridge and pickles. In view of the above facts and establishment of several agar and algin industries in India, a great deal of work has been done on biology, chemistry, survey and culture of seaweeds. Studies made so far by various workers on biological aspects of economically important Indian seaweeds are reviewed in this paper.

Taxonomy

Our knowledge of the marine algal flora of India is mainly due to papers published by Boergesen (1930, 1931, 1932 *a, b*; 1933 *a, b*; 1934 *a, b*; 1935, 1937 *a, b*, and 1938). Since then considerable work has been done on the taxonomy of Indian marine algae during the last 4 decades (Biswas, 1945; Srinivasan, 1946, 1960, 1966; Parija and Parija, 1946; Chacko *et al.*, 1955; Varma, 1960; Taylor, 1964; Umamaheswara Rao, 1969 *a*, 1972 *a, b*; Sreenivasa Rao and Kale, 1969; Gopalakrishnan, 1969, 1970; Umamaheswara Rao and Sreeramulu, 1970 *a*; Srinivasa Rao, 1970; Joshi and Krishnamurthy, 1971; Agadi and Untawale, 1978; Qasim and Wafar, 1979; Krishnamurthy, 1980; Balakrishnan and Kinker, 1981 and Balakrishnan Nair *et al.*, 1982).

Krishnamurthy and Joshi (1970) and Untawale *et al.*, (1983) have prepared check

^{1, 2} Regional Centre of Central Marine Fisheries Research Institute, Marine Fisheries-623 520 Tamilnadu, India.

lists of Indian marine algae. If these lists are updated, there will be a total of 681 species of marine algae on the Indian coasts.

Ecology

Ecological studies have been carried out on the marine algal vegetation of the Mahabalipuram coast (Srinivasan, 1946), salt marshes at Madras (Krishnamurthy, 1954), Chilka Lake (Parija and Parija, 1946), Okha, Porbandar, Veraval and Bombay areas (Misra, 1960), Visakhapatnam coast (Umamaheswara Rao and Sreeramulu, 1964) and Okha (Gopalakrishnan, 1970 and Murthy *et al.*, 1978). Umamaheswara Rao and Sreeramulu (1963) studied the vertical zonation and seasonal variation in the growth of *Porphyra* on Visakhapatnam coast. The role of critical tide factor in the vertical distribution of *Hypnea musciformis* was studied by Rama Rao (1972). The distribution pattern of marine algae on the shore of Pamban was given by Subbaramaiah *et al.* (1977). Many of these ecological investigations provided data on the seasonal changes and zonation of the algae and on the environmental conditions existing in those areas. The changes on the tidal emergence and submergence, topography of the coast, surf action, levels at which the plants grow contribute much to the fluctuations in the growth behaviour of the algae.

Umamaheswara Rao (1972 *c*) made observations on zonation and seasonal changes of some intertidal algae growing in the Gulf of Mannar and Palk Bay side for a period of two and a half years and the data were given together with the changes observed in the tidal behaviour and other environmental conditions. The relationship between the variations in the periods of submergence and emergence caused by tides and seasonal changes in the algal growth were shown. It is also pointed in this study that local environmental conditions influence the growth cycles of algae to a large extent. Certain variations were noticed in the maximum growth periods of *Enteromorpha* and *Sargassum* in the Gulf of Mannar and Palk Bay side.

Krishnamurthy (1967) postulated a new set of principles governing zonation of marine algae on the Indian coasts and showed the marine algae in these coasts are essentially subtidal and many form a subtidal fringe at the lower intertidal. Balasundaram (1985) showed that the marine algae at Tiruchendur occupied the lower part of the intertidal and below and could be distinguished into an upper limit of the algal zone, a mid-algal zone which can be termed an algal mosaic, the lower intertidal zone and the subtidal zone. The algal mosaic is characterised by a number of algal species occurring intermingled and showing a continuous and dynamic change in number and cover area through time and space.

The colonization of marine algae on a fresh substratum was studied by Varma (1959) by suspending a concrete block in the Palk Bay and data were collected on settlement of spores and further development in several algal species. Recolonization studies were also made by Umamaheswara Rao and Sreeramulu (1968) on Visakhapatnam coast by clearing areas of 0.5 m² in the *Gracilaria corticata* belt. The sequence of colonization was followed for a period of five months. *Ulva* and *Enteromorpha* were seen as first colonizers and fresh germlings of *Gracilaria corticata* reappeared in the denuded areas after a few months.

Raju and Venugopal (1971) made an attempt to allow the oospores of *Sargassum plagiophyllum* to settle on a concrete substratum with a view to finding out the time required for the appearance of germlings and their growth to adult plants. The concrete cylinders were lowered in *Sargassum* beds. Observations revealed that the appearance of *Sargassum* germlings on the cylinders took 10 months and it took another 8 months to grow to maturity. Observations after one more year revealed that there were a number of new plants which had germinated from spores within the year and some had regenerated from persisting holdfasts. The potentiality for regeneration for a third year in a few plants was also found.

Growth cycle

Data on the annual growth variations of *Ulva fasciata*, *Enteromorpha compressa*, *Caulerpa fastigiata*, *C. racemosa*, *C. sertularioides*, *C. taxifolia*, *Padina tetrastromatica*, *Dictyota* sp., *Sargassum ilicifolium*, *S. tenerrium*, *S. turneri*, *S. vulgare*, *Gelidium* spp, *Gracilaria* sp., *Gelidiopsis variabilis* *Hypnea* sp., *Acanthophora spicifera* and *Porphyra vietnamensis* growing at Visakhapatnam coast were collected by Umamaheswara Rao and Sreeramulu (1964 and 1974). Similarly annual changes were observed in the growth of *Sargassum swartzii* (Chauhan and Krishnamurthy, 1971) and *Cystoseira indica* (Mairh, 1979) occurring at Port Okha. The growth behaviour of *Ulva fasciata* (Subbaramaiah *et al.*, 1967), *Hypnea musciformis* (Rama Rao, 1970) and *Gelidiella acerosa* (Sreenivasa Rao, 1974) growing at Veraval were studied.

Results obtained on the growth cycles of *Enteromorpha compressa* and *Gracilaria corticata* (Umamaheswara Rao, 1972 c), *Padina gymnospora* (Chennubhotla *et al.*, 1977), *Stoechospermum marginatum* (Kalimuthu *et al.*, 1980), *Sargassum wightii* (Umamaheswara Rao, 1969 b), *S. ilicifolium* (Chennubhotla *et al.*, 1982), *S. myriocystum* (Kalimuthu, 1980 and Chennubhotla *et al.*, 1982), *Turbinaria conoides* (Umamaheswara Rao, 1969 b and Chennubhotla *et al.*, 1978), *T. decurrens* (Kaliaperumal and Umamaheswara Rao, 1975 and Kaliaperumal and Kalimuthu, 1976), *T. ornata* (Umamaheswara Rao and Kalimuthu, 1972 and Kaliaperumal *et al.*, 1977), *Gelidiella acerosa* (Umamaheswara Rao, 1973 a, Thomas *et al.*, 1975 a, b and Chennubhotla *et al.*, 1986 a), *Gracilaria arcuata* var. *arcuata* and *G. corticata* var. *cylindrica* (Kaliaperumal *et al.*, 1986), *G. edulis* (Umamaheswara Rao, 1973 b and Chennubhotla *et al.*, 1986 a), *G. foliifera* and *Gracilariopsis sjoestedtii* (Umamaheswara Rao, 1973 b and Chennubhotla *et al.*, 1986 b) growing around Mandapam area were published. The growth pattern and period of maximum growth for these seaweeds together with the locality and authors are given in Table 1.

From the information obtained on the variation in growth of the above algae growing in different localities along Indian coast, it may be mentioned that the life span of many seaweeds is limited to one year or for a short period of the year. Every year fresh plants develop from the reproductive bodies liberated by the plants of the previous generation or from the perennial basal portions of the old plants. The periods of regeneration, maximum growth and decline vary from species to species and also from one locality to the other. In some seaweeds such as *Cystoseira indica*, *Gracilaria edulis*, *G. corticata*, *G. foliifera* and *Gracilariopsis sjoestedtii*, two peak growth periods with a half yearly growth cycle was observed while in other seaweeds only a single peak growth period was observed. In general, maximum growth was observed in many seaweeds in two seasons of the year, one from June to August and the other from November to January. However, in certain seaweeds like *Porphyra vietnamensis* peak growth was found during the period from January to March/April (Umamaheswara Rao and Sreeramulu, 1963 and 1964). The economically useful seaweeds should be collected only during peak growth periods in order to get more quantity of raw material and better yield of finished products.

Fruiting behaviour

Studies were made on the fruiting periods and relative preponderance of vegetative and reproductive plants of *Ulva fasciata* (Subbaramaiah, 1970), *Sargassum wightii* (Umamaheswara Rao and Kaliaperumal, 1976), species of *Turbinaria* (Umamaheswara Rao and Kalimuthu, 1972 ; Kaliaperumal and Umamaheswara Rao, 1975 ; Kaliaperumal and Kalimuthu, 1976 ; Kaliaperumal *et al.*, 1977 and Chennubhotla *et al.*, 1978), *Cystoseira indica* (Mairh, 1967 and 1980), *Padina tetrastromatica* and *Dictyota dichotoma*

Table 1. Growth pattern of various economically important Indian seaweeds.

Species	Locality	Growth period	Period of maximum growth	Author
CHLOROPHYTA				
<i>Ulva fasciata</i>	Veraval	—	October-December	Subbaramaiah <i>et al.</i> , 1967
-do-	Visakhapatnam	Throughout the year	June-August	Umamaheswara Rao and Sreeramulu, 1964
<i>Caulerpa</i> spp	-do-	-do-	-do-	-do-
<i>Enteromorpha compressa</i>	-do-	Part of the year	November-December	-do-
-do-	Mandapam (Gulf of Mannar)	Most part of the year	June-August and November-December	Umamaheswara Rao, 1972 <i>c</i>
-do-	Mandapam (Palk Bay)	5-6 months in the year	November-December	-do-
PHAEOPHYTA				
<i>Padina gymnospora</i>	Pudumadam	Throughout the year	November-Jan./Feb.	Chennubhotla <i>et al.</i> , 1977
<i>P. tetrastromatica</i>	Visakhapatnam	Part of the year	November-December	Umamaheswara Rao and Sreeramulu, 1964
<i>Dictyota</i> sp.	-do-	Throughout the year	October-December	-do-
<i>Stoechospermum marginatum</i>	Pudumadam	-do-	January-March	Kalimuthu <i>et al.</i> , 1980
<i>Sargassum swartzii</i>	Port Okha	August-March	November-January	Chauhan and Krishnamurthy, 1971
<i>S. wightii</i>	Mandapam (Gulf of Mannar)	-do-	October-Dec./Jan.	Umamaheswara Rao, 1969 <i>b</i>
<i>S. vulgare</i>	Visakhapatnam	Throughout the year	October-December	Umamaheswara Rao and Sreeramulu, 1964
<i>S. turneri</i>	-do-	-do-	-do-	-do-
<i>S. tenerrimum</i>	-do-	-do-	-do-	-do-
<i>S. ilicifolium</i>	-do-	-do-	-do-	-do-
-do-	Mandapam	-do-	November-January	Chennubhotla <i>et al.</i> , 1982
<i>S. myriocystum</i>	Pamban	-do-	October-November	-do-
-do-	Pudumadam	-do-	May-August	Kalimuthu, 1980
<i>Turbinaria conoides</i>	Mandapam (Gulf of Mannar)	-do-	October-Dec./Jan.	Umamaheswara Rao, 1969 <i>b</i>
-do-	-do-	-do-	October-December	Chennubhotla <i>et al.</i> , 1978
<i>T. decurrens</i>	-do-	-do-	December-February	Kaliaperumal and Umamaheswara Rao, 1975
-do-	-do-	-do-	-do-	Kaliaperumal and Kalimuthu, 1976
<i>T. ornata</i>	Mandapam (Palk Bay)	-do-	October-December	Umamaheswara Rao and Kalimuthu, 1972
-do-	-do-	-do-	-do-	Kaliaperumal <i>et al.</i> , 1977
<i>Cystoseira indica</i>	Port Okha	-do-	May-June and November-December	Mairh, 1979

Species	Locality	Growth period	Period of maximum growth	Author
RHODOPHYTA				
<i>Gelidiella acerosa</i>	Mandapam	-do-	July-August and December-April	Umamaheswara Rao, 1973 a
-do-	Krusadi Island	-do-	March-May and July-September	Chennubhotla et al., 1986 a
-do-	Kilakkarai	-do-	July and November	Thomas et al., 1975 a
-do-	-do-	-do-	March-May and November-January	Chennubhotla et al., 1986 a
-do-	Veraval	-do-	October-March	Sreenivasa Rao, 1974
<i>Gelidium</i> spp	Visakhapatnam	-do-	June-September	Umamaheswara Rao and Sreeramulu, 1964
<i>Gracilaria</i> sp.	-do-	-do-	October-December	-do-
<i>Gracilaria arcuata</i> var. <i>arcuata</i>	Kilakkarai	October-May	January-April	Kaliaperumal et al., 1986
<i>G. corticata</i>	Mandapam (Gulf of Mannar)	Throughout the year	June-September and November-December	Umamaheswara Rao, 1972 c
<i>G. corticata</i> var. <i>cylindrica</i>	Kilakkarai	-do-	November-February	Kaliaperumal et al., 1986
<i>G. edulis</i>	Rameswaram	-do-	January-April and August-September	Umamaheswara Rao, 1973 b
-do-	Krusadai Island	-do-	January-March and August-October	Chennubhotla et al., 1986 a
<i>G. foliifera</i>	Rameswaram	-do-	January-April and August-September	Umamaheswara Rao, 1972 c
-do-	-do-	February-June	April	Chennubhotla et al., 1986 b
<i>Gracilariopsis sjoestedtii</i>	Rameswaram	Throughout the year	November-Feb./March and July-September	Umamaheswara Rao, 1973 b
-do-	Pamban	June-September and December-March	September, January-March	Chennubhotla et al., 1986 b
-do-	Kilakkarai	May, Dec.-April	January-March	-do-
<i>Gelidiopsis variabilis</i>	Visakhapatnam	Throughout the year	October-Jan./Feb.	Kaliaperumal and Umamaheswara Rao, 1982
<i>Hypnea</i> sp.	-do-	-do-	October-December	Umamaheswara Rao and Sreeramulu, 1964
<i>Hypnea musciformis</i>	Veraval	October-June	December-February	Rama Rao, 1970
<i>Acanthophora spicifera</i>	Visakhapatnam	April-December	April	Umamaheswara Rao and Sreeramulu, 1974
<i>Porphyra vietnamensis</i>	-do-	Part of the year	January-March/April	Umamaheswara Rao and Sreeramulu, 1964

Umamaheswara Rao and Sreeramulu, 1970 b), *Gelidiella acerosa* (Umamaheswara Rao, 1973 a and 1974; Sreenivasa Rao, 1969 and Rama Rao *et al.*, 1976), species of *Gracilaria* and *Gracilariopsis* (Ahmed, 1966; Umamaheswara Rao, 1973 b; Kaliaperumal *et al.*, 1986 and Chennubhotla *et al.*, 1986 b), *Gelidiopsis variabilis* (Kaliaperumal and Umamaheswara Rao, 1982) and *Hypnea* spp (Rama Rao, 1977). All these studies conducted on the periods of reproduction show that the fruiting behaviour varies in different seaweeds growing along the Indian coast. Though reproduction was observed throughout the year, in many cases two fruiting seasons were seen in a year for plants like *Cystoseira indica*, *Gelidiella acerosa* and one fruiting season for *Sargassum wightii*, *Turbinaria* spp, *Gracilaria verrucosa*.

Spore output

Some information has been collected on the spore output from economically important algae. The estimation of spore output made in different seaweeds by various workers is given in Table 2. As the number of spores produced by an alga is found to be enormous they can be successfully raised into germlings in the laboratory or nursery and then into harvestable size plants by transplantation. Periodicity or rhythmic liberation of spores was observed in *Ulva fasciata*, *Cystoseira indica*, *Sargassum swartzii*, *Gracilaria edulis* and *Gracilaria verrucosa*, but there was no such periodicity in the shedding of spores in plants like *Sargassum wightii*, *Turbinaria* spp, *Gelidiella acerosa* and *Gelidiopsis variabilis*. The spore output season and also the period of maximum sporulation varied from species to species.

Table 2. Spore output in Indian marine algae.

Name of the alga	Type of spore	Number of spores liberated (maximum spore output)		Author
<i>Ulva fasciata</i>	Swarmer (Gametes)	1,15,34,400	Spores/Plant	Subbaramaiah <i>et al.</i> , 1967
<i>Cystoseira indica</i>	Oospores	5,11,251	-do-	Mairh and Krishnamurthy, 1968
<i>Sargassum swartzii</i>	-do-	5,53,331	-do-	Chauhan and Krishnamurthy, 1967
<i>S. wightii</i>	-do-	3,70,272	-do-	Umamaheswara Rao and Kaliaperumal, 1976
<i>Turbinaria conoides</i>	-do-	11,312	-do-	Chennubhotla <i>et al.</i> , 1978
<i>T. decurrens</i>	-do-	28,196	-do-	Kaliaperumal and Umamaheswara Rao, 1975
<i>T. ornata</i>	-do-	33,810	-do-	Kaliaperumal <i>et al.</i> , 1977
<i>Gelidiella acerosa</i>	Tetraspores	20,000	-do-	Sreenivasa Rao, 1969
-do-	-do-	10,000	Spores/g fr wt/day	Umamaheswara Rao, 1974
<i>Gelidiopsis variabilis</i>	-do-	2,60,940	-do-	Kaliaperumal and Umamaheswara Rao, 1982
<i>Gracilaria corticata</i>	-do-	3,98,000	-do-	Umamaheswara Rao, 1976
-do-	Carpospores	2,374	Spores/cystocarp/day	-do-
-do-	-do-	8,66,700	Spores/Plant	Mohan Joseph and Krishnamurthy 1977
<i>G. edulis</i>	-do-	6,49,873	-do-	Rama Rao and Thomas, 1974
<i>G. foliifera</i>	-do-	26,368	Spores/g fr wt/day	Chennubhotla <i>et al.</i> , 1986 b
-do-	Tetraspores	11,508	-do-	-do-
<i>G. millardetii</i>	-do-	68,520	Spores/Plant	Krishnamurthy, 1967
-do-	Carpospores	42,782	-do-	-do-
<i>G. verrucosa</i>	-do-	70,000	-do-	Oza and Krishnamurthy, 1968
<i>Gracilariopsis sjoestedtii</i>	Tetraspores	3,27,791	Spores/g fr wt/day	Chennubhotla <i>et al.</i> , 1986 b
-do-	Carpospores	2,52,151	-do-	-do-
<i>Hypnea valentiae</i>	-do-	7,01,607	Spores/Plant	Rama Rao, 1979
-do-	Tetraspores	3,14,914	-do-	-do-

Germination of spores, viability and culture of germilings

Data were collected on the development of oospores of *Sargassum swartzii* (Chauhan and Krishnamurthy, 1967 and 1971), *Cystoseira* (Krishnamurthy and Mairh, 1967 and Mairh and Krishnamurthy, 1968), tetraspores of *Gelidiella acerosa* (Umamaheswara Rao, 1974 and Sreenivasa Rao, 1971), carpospores of *Gracilaria verrucosa* (Oza and Krishnamurthy, 1967) and tetraspores and carpospores of *Gracilaria corticata* (Oza, 1975).

Some observations were made on the rate of spore germination and survival of germilings in certain seaweeds. Mairh and Krishnamurthy (1968) observed 100 % germination of oospores of *Cystoseira* and subsequently 94 % of their survival. The germilings not only survived but also grew into young healthy plants under experimental conditions. Chauhan and Krishnamurthy (1971) got cent per cent germination in *Sargassum swartzii* and all the germilings grew in healthy condition for more than eight months. Umamaheswara Rao and Kaliaperumal (1976) maintained the oospores of *Sargassum wightii* in a medium of sea-water enriched with agar and found that 47.6 % of germilings were in healthy condition at the end of 60 days.

In studies on the culture under controlled conditions in the laboratory and in the field, germilings of *Ulva fasciata* were kept growing in attached or in a free floating condition in petri dishes containing sterile sea-water which was changed once in a week (Subbaramaiah *et al.*, 1967). In two months the germilings differentiated into cylindrical plants with 2-3 branches arising from the basal cells. The floating plants were longer (1.25 to 1.75 mm) and branched, while the attached ones were shorter (0.75 to 0.83 mm) and unbranched. The growth of germilings did not advance beyond the cylindrical form

during the two months period. Subbaramaiah (1970) observed the settlement and growth of germilings of *Ulva fasciata* under laboratory conditions using a variety of artificial substrata like shells, stones, bamboo stems (entire and split), coir rope, nylon string and plain glass. The germilings attained a size of 5 mm in 100 days when they were raised on nylon string. The swarmer formation, liberation, settlement and growth of germilings of pre-prepared nets were also obtained in an experimental pond. The germilings attained an average length of 24.3 mm and breadth of 5.7 mm in two months. Kale and Krishnamurthy (1967) studied the growth of germilings of *Ulva lactuca* in plain sea-water, Erd-Schreiber and artificial sea-water.

Chauhan and Krishnamurthy (1967) cultured the oospores of *Sargassum swartzii* in petri dishes lined with filter paper. They developed into germilings and some of them grew for a period of five weeks. Experiments were also conducted using different substrata such as coral pieces, shells, granite stones, nylon threads and rough stones. Some of the oospores attached to the substrata and developed into healthy germilings, while a large number did not survive. Continuous illumination of the culture experiments with light intensity of 600-800 lux, 23-26° C temperature and circulation of thin stream of filtered sea-water were found favourable for healthy growth of germilings. Chauhan (1972) observed the survival of germilings in *Sargassum swartzii* for about six months under controlled laboratory conditions. Of the eight different substrata used, the cement concrete blocks, bricks and filter paper were found to be good substrata as they retained 84.55 %, 78.42 % and 62 % of the germilings respectively. The filtered sea-water and the sea-water with enrichment were found to be the most

suitable culture media for the growth of germlings. The use of culture media like ASP₆ and ASP₁₂ did not give good growth of germlings. Continuous illumination was more beneficial than restricted photo-period. Krishnamurthy *et al.* (1969) raised the germlings of *Gracilaria edulis* and *G. corticata* on a nylon fabric from carpospores under laboratory conditions. Then they were transferred to the sea. After four months young plants appeared and they took another four months to attain maturity and develop reproductive structures. An interesting observation in this experiment was that these plants were carposporic, thereby suggesting an aberrant life-cycle in these species.

Some attempts on the life-cycle of *Enteromorpha compressa* (Ramanathan, 1939), *Sargassum tenerrimum* (Prakasa Rao, 1946), *S. swartzii* (Chauhan and Krishnamurthy, 1971), *Cystoseira indica* (Mairh, 1967 and 1980), *Gelidiella acerosa* (Sreenivasa Rao, 1969 and 1974), *Gracilaria corticata* and *G. edulis* (Krishnamurthy *et al.*, 1969) and on the

conchocelis phase of *Porphyra vietnamensis* (Prakasa Rao, 1964) have also been studied.

Prospects of farming

The above information on the growth, fruiting behaviour and sporulation of many of the economically important seaweeds growing in different areas will help us to utilise the available resources in a rational way for cultivation and for economic exploitation.

Seaweed culture technology can be perfected further with the help of the knowledge gained so far on these vital aspects of seaweed research. Seaweed cultivation on commercial scale would augment the supply of seaweeds and provide employment opportunities to the coastal population which may improve their economic condition and thus help in the rural upliftment.

Acknowledgement

Our thanks are due to Dr. E.G. Silas, former Director, Central Marine Fisheries Research Institute, Cochin for his encouragement in preparing this paper.

LITERATURE CITED

- Agadi, V.V. and A.G. Untawale 1978 Marine algal flora of Goa coast *Seaweed Res. Utiln.*, 3 (1&2): 56-70
- Ahmed, M.K. 1966 Studies on *Gracilaria* Grev. of the Chilka lake, Orissa *Fish Res. Invest. Bull.*, 1: 46-53
- Balakrishnan, M.S. and V. N. Kinker 1981 A taxonomic account of Indian Ectocarpales and Rhodophyta *Seaweed Res. Utiln.*, 4 (2): 1-57
- Balakrishnan Nair, N., V. Shoba, and M. Arunachalam, 1982 Algae from southern Kerala coast *Indian J. mar. Sci.*, 11 (3): 266-269
- Balasundaram, A- 1985 Seasonal succession of algae in the mid-algal zone on the Thiruchendur shore In V. Krishnamurthy & A.G. Untawale (Eds). *Marine Plants*, pp. 179-190.
- Biswas, K. 1945 A general review of the marine algae of the western coast of India *J. Bombay nat. Hist. Soc.*, 45: 515-530
- Boergesen, F. 1930 Some Indian green and brown algae especially from the shores of the Presidency of Bombay *J. Indian bot. Soc.* 9: 151-174
- Boergesen, F. 1931 Some Indian Rhodophyceae especially from the shores of the Presidency of Bombay I *Kew Bull.*, 1: 1-24
- Boergesen, F. 1932 a Some Indian Rhodophyceae especially from the shores of the Presidency of Bombay II *Kew Bull.*, 2: 113-134
- Boergesen, F. 1932 b Some Indian green and brown algae especially from the Presidency of Bombay *J. Indian bot. Soc.*, 11: 51-70
- Boergesen, F. 1933 a Some Indian Rhodophyceae especially from the Presidency of Bombay III *Kew Bull.*, 3: 113-142
- Boergesen, F. 1933 b Some Indian green and brown algae from the Presidency of Bombay *J. Indian bot. Soc.*, 12: 1-16
- Boergesen, F. 1934 a Some Indian Rhodophyceae especially from the Presidency of Bombay IV *Kew Bull.*, 4: 1-30

- Boergesen, F. 1934 *b* Some marine algae from the northern part of the Arabian Sea with remarks on their geographical distribution *Kgl. Danske Vidensk. Selsk. Biol. Meddel.*, **10** : 1-72
- Boergesen, F. 1935 A list of marine algae from Bombay *Kgl. Danske Vidensk. Selsk. Biol. Meddel.*, **12** : 164
- Boergesen, F. 1937 *a* Contribution to a South Indian Marine algal flora I *J. Indian bot. Soc.*, **16** : 1-56
- Boergesen, F. 1937 *b* Contributions to a South Indian marine algal flora II *J. Indian bot. Soc.*, **16** : 311-357
- Boergesen, F. 1938 Contributions to a South Indian marine algal flora III *J. Indian bot. Soc.*, **17** : 205-242
- Chacko, P.I., S. Mahadevan and R. Ganesan 1955 A guide to the field study of the fauna and flora of Krusadai Island, Gulf of Mannar *Contr. mar. biol. St. Krusadai Island*, **3** : 1-16
- Chauhan, V.D. 1972 Physiological ecology of the early stages of *Sargassum swartzii* (Turner) C.Ag. *Bot. mar.*, **15** : 49-51
- Chauhan, V.D. and V. Krishnamurthy 1967 Observations on the output of oospores, their liberation, viability and germination in *Sargassum swartzii* (Turn.) C.Ag. *Proc. Sem. Sea Salt and Plants*, Bhavnagar, pp. 197-201
- Chauhan, V.D. and V. Krishnamurthy 1971 Ecology and seasonal succession of *Sargassum swartzii* (Turn.) C. Ag. in Indian waters *Phykos*, **10** : 1-11
- Chennubhotla, V.S.K., S. Kalimuthu, N. Kaliaperumal and J.R. Ramalingam 1977 Studies on the growth variation, alginic acid and mannitol contents in *Padina gymnospora* (Kuetzing) Vickers *Seaweed Res. Utiln.*, **2** : 91-94
- Chennubhotla, V.S.K., N. Kaliaperumal and S. Kalimuthu 1978 Seasonal changes in growth, fruiting cycle and oospore output in *Turbinaria conoides* (J. Ag.) Kuetzing *Bot. mar.*, **21** : 67-69
- Chennubhotla, V.S.K., N. Kaliaperumal, S. Kalimuthu, M. Selvaraj, J.R. Ramalingam and M. Najmuddin 1982 Seasonal changes in growth and alginic acid and mannitol contents in *Sargassum ilicifolium* (Turner) J. Agardh and *S. myriocystum* J. Agardh *Indian J. mar. Sci.*, **11** : 195-196
- Chennubhotla, V.S.K., S. Kalimuthu, M. Najmuddin, R. Panigrahy and M. Selvaraj 1986 *a* Changes in growth and phycocolloid content of *Gelidiella acerosa* and *Gracilaria edulis* *Seaweed Res. Utiln.*, **9** : (1 & 2) : 45-48
- Chennubhotla, V.S.K., N. Kaliaperumal, J.R. Ramalingam and S. Kalimuthu 1986 *b* Growth, reproduction and spore output in *Gracilaria foliifera* (Forsskal) Boergesen and *Gracilariopsis sjoestedtii* (Kylin) Dawson around Mandapam *Indian J. Fish.*, **33** (1) : 76-84
- Gopalakrishnan, P. 1969 Some marine algae from the Gulf of Kutch *Phykos*, **8** : 61-67
- Gopalakrishnan, P. 1970 Some observations on the shore ecology of Okha coast *J. mar. biol. Assn. India*, **12** : 15-34
- Joshi, H.V. and V. Krishnamurthy 1971 The species of *Enteromorpha* from India *Bot. J. Linn. Soc.*, **65** (1) : 119-128
- Kale, S.R. and V. Krishnamurthy 1967 Effect of different media on the germlings of *Ulva lactuca* var. *rigida* *Phykos*, **6** : 32-35
- Kaliaperumal, N. and M. Umamaheswara Rao 1975 Growth, fruiting cycle and cospore output in *Turbinaria decurrens* Bory *Indian J. Fish.*, **22** : 225-230
- Kaliaperumal, N. and S. Kalimuthu 1976 Changes in growth, reproduction, alginic acid and mannitol contents in *Turbinaria decurrens* Bory *Bot. mar.*, **19** : 157-159
- Kaliaperumal, N. and M. Umamaheswara Rao 1982 Seasonal growth and reproduction of *Gelidiopsis variabilis* (Greville) Schmitz *J. exp. mar. Biol. Ecol.*, **61** : 265-270
- Kaliaperumal, N., V.S.K. Chennubhotla and S. Kalimuthu, 1977 Growth, reproduction and liberation of oospores in *Turbinaria ornata* (Turner) J. Agardh *Indian J. mar. Sci.*, **6** : 178-179
- Kaliaperumal, N., V.S.K. Chennubhotla, S. Kalimuthu, and J.R. Ramalingam 1986 Growth, phenology and spore shedding in *Gracilaria arcuata* var. *arcuata* (Zanardini) Umamaheswara Rao and *G. corticata* var. *cylindrica* (J. Agardh) Umamaheswara Rao (Rhodophyta) *Indian J. mar. Sci.*, **15** : 107-110
- Kalimuthu, S. 1980 Variations in growth and mannitol and alginic acid contents of *Sargassum myriocystum* J. Agardh *Indian J. Fish.*, **27** : 265-266

- Kalimuthu, S., V.S.K. Chennubhotla, M. Selvaraj, M. Najmuddin and R. Panigrahy 1980 Alginic acid and mannitol contents in relation to growth in *Stoechospermum marginatum* (C. Agardh) Kuetzing *Indian J. Fish.*, **27** : 267-269
- Krishnamurthy, V. 1954 Ecology and seasonal succession of the algal flora of a salt marsh at Madras *J. Madras Univ. B.* **24** : 161-178
- Krishnamurthy, V. 1967 Marine algal cultivation, necessity, principles and problems. *Proc. Sem. Sea Salt and Plants*, Bhavnagar, pp. 327-333
- Krishnamurthy, V. 1980 The marine algae of Tiruchendur, South India *Seaweed Res. Utiln.*, **4** (1) : 49-58
- Krishnamurthy, V. and O.P. Mairh 1967 Some observations on the shedding of oospores, germination and germlings of *Cystoseira* *Proc. Sem. Sea Salt and Plants*, Bhavnagar, pp.190-196
- Krishnamurthy, V. and H.V. Joshi 1970 A check list of Indian marine algae, Bhavnagar, pp. 1-36
- Krishnamurthy, V., P.V. Raju and R. Venugopal 1969 An aberrant life history in *Gracilaria edulis* (Gmel.) Silva and *Gracilaria corticata* J. Ag. *Curr Sci.*, **38** : 343-344
- Mairh, O.P. 1967 Observation on the seasonal phenomena in the life cycle of *Cystoseira* occurring at Port Okha on the Gujarat coast *Phykos*, **6** : 78-83
- Mairh, O.P. 1979 Studies on the Cystoseiraceae of India *Salt Res. Ind.*, **15** : 49-50
- Mairh, O.P. 1980 Ecology of *Cystoseira indica* occurring at Port Okha : Environmental factors, seasonal phenomena and growth, recolonisation and life cycle *Seaweed Res. Utiln.*, **4** : 1-16
- Mairh, O.P. and V. Krishnamurthy 1968 Observation on the germination of spores and growth of germlings in a *Cystoseira* *J. Indian bot. Soc.* **47** : 256-263
- Misra, J.N. 1960 The ecology, distribution and seasonal succession of the littoral algae on the west coast of India *Proc. Symp. Algology*, New Delhi, pp. 187-203
- Mohan Joseph, M. and V. Krishnamurthy 1977 Studies on the shedding of carpospores in *Gracilaria corticata* J. Ag. *Seaweed Res. Utiln.*, **2** : 1-8
- Murthy, M.S., M. Bhattacharya and P. Radia 1978 Ecological studies on the intertidal algae at Okha, India *Bot. mar.*, **21** (6) : 381-386
- Oza, R.M. 1975 Studies on Indian *Gracilaria* I. Carpospore and tetraspore germination and early stages of development in *Gracilaria corticata* J. Ag. *Bot. mar.*, **18** : 97-99
- Oza, R.M. and V. Krishnamurthy 1967 Carpospore germination and early stages of development in *Gracilaria verrucosa* (Huds.) Papenf. *Phykos*, **6** : 84-86
- Oza, R.M. and V. Krishnamurthy 1968 Studies on carposporic rhythm of *Gracilaria verrucosa* (Huds.) Papenf. *Bot. mar.*, **11** : 118-121
- Parija, P. and P. Parija 1946 Algal succession on a rocky island named Charai guha in the Chilka Lake *J. Indian bot. Soc. (M.O.P. Iyengar Comm. Vol.)* pp. 375-379
- Prakasa Rao, C.S. 1946 A contribution to the morphology and life history of *Sargassum tenerrimum* J. Ag. *Proc. Indian. Acad. Sci.*, **23** : 39-51
- Prakasa Rao, C.S. 1964 Some observations on conchocelis phase from Visakhapatnam *Curr. Sci.*, **33** : 153
- Qasim, S.Z. and M.V.M. Wefar 1979 Occurrence of living corals at several places along the west coast of India *Mahasagar*, **12**(1) : 53-58
- Raju, P.V. and R. Venugopal 1971 Appearance and growth of *Sargassum plagiophyllum* (Mert.) C. Ag. on a fresh substratum *Bot. mar.*, **14** (1) : 36-38
- Ramanathan, K.R. 1939 The morphology, cytology and alternation of generation in *Enteromorpha compressa* (L.) Grev. var. *ligulata* (J. Ag.) Hauck *Ann. Bot.*, **3** : 375-398
- Rama Rao, K. 1970 Studies on growth cycle and phycocolloid content in *Hypnea musciformis* (Wulf.) Lamour. *Bot. mar.*, **13** : 163-165
- Rama Rao, K. 1972 Role of critical tide factor in the vertical distribution of *Hypnea musciformis* (Wulf.) Lamour. *Proc. Indian natl. Sci. Acad.*, **38** : (3 & 4) : 267-272
- Rama Rao, K. 1977 Studies on Indian Hypneaceae II. Reproductive capacity in the two species of *Hypnea* over the different seasons *Bot. mar.* **20** (1) : 33-39
- Rama Rao, K. 1979 Studies on Indian Hypneaceae V. Spores and natural propagules in the selected species of *Hypnea*, the potential Indian carrageenophyte, for its field cultivation *Proc. Internatl Symp. Marine Alg. Indian Ocean Reg.*, Bhavnagar, India, pp. 31-32 (Abstract)

- Rama Rao, K. and P.C. Thomas 1974 Shedding of carpospores in *Gracilaria edulis* (Gmel.) Silva *Phykos*, **13** : 54-59
- Rama Rao, K., P.C. Thomas and K. Subbaramaiah 1976 Fruiting behaviour of *Gelidiella acerosa* (Forsskal) Feldmann et Hamel, the perennial agarophyte *Phykos*, **15** (1 & 2) : 35-37
- Sreenivasa Rao, P. 1969 Systematics, ecology and life history of Indian Gelidiales with special reference to agarophyte, *Gelidiella acerosa* (Forsskal) Feldmann et Hamel *Salt Res. Ind.*, **6** : 46-47
- Sreenivasa Rao, P. 1970 Systematics of Indian Gelidiales *Phykos*, **9** (2) : 63-78
- Sreenivasa Rao, P. 1971 Studies on *Gelidiella acerosa* (Forsskal) Feldmann et Hamel IV. Spores studies *Bull. Jap. Soc. Phycol.*, **19** : 9-14
- Sreenivasa Rao, P. 1974 Studies on *Gelidiella acerosa* (Forsskal) Feldmann et Hamel II. Growth and phenological events in the annual life of the alga *Phykos*, **13** : 7-15
- Sreenivasa Rao, P. and S.R. Kale 1969 Marine algae from little known places of Gujarat coast I. Algae from Gopinath *Phykos*, **8** : 71-82
- Srinivasan, K.S. 1946 Ecology and seasonal succession of marine algae at Mahabalipuram (Seven Pagodas) near Madras *J. Indian bot. Soc.* (M.O.P. Iyengar Comm. Vol.) pp. 267-278
- Srinivasan, K.S. 1960 Distribution patterns of marine algae in Indian seas *Proc. Symp. Algology*, New Delhi, pp. 219-242
- Srinivasan, K.S. 1966 Conspectus of *Sargassum* species from Indian territorial waters *Phykos*, **5** : 127-129
- Subbaramaiah, K. 1970 Growth and reproduction of *Ulva fasciata* Delile in nature and in culture *Bot. mar.*, **13** : 25-27
- Subbaramaiah, K., S. R. Kale and V. Krishnamurthy 1967 Gametes and germlings of *Ulva fasciata* Delile *Curr. Sci.*, **36** : 128-129
- Subbaramaiah, K., M.R.P. Nair and V. Krishnamurthy 1977 Distribution pattern of marine algae on the shore of Pamban *Seaweed Res. Utiln.*, **2** (2) : 74-77
- Taylor, W.R. 1964 The genus *Turbinaria* in eastern seas *J. Linn. Soc. London (Botany)*, **58** : 475-490
- Thomas, P.C., K. Rama Rao, and K. Subbaramaiah 1975 a Periodicity in growth and production of agar of *Gelidiella acerosa* (Forssk.) Feldmann et Hamel *Indian J. mar. Sci.*, **4** : 210-212
- Thomas, P.C., K. Rama Rao and K. Subbaramaiah 1975 b Changes in the natural growth of *Gelidiella acerosa* (Forsskal) Feldmann et Hamel in an exploited population *Bot. mar.*, **18** : 241-243
- Umamaheswara Rao, M. 1969 a Catalogue of marine algae in the reference collection of the Central Marine Fisheries Research Institute *Bull. cent. mar. Fish. Res. Inst.*, **9** : 37-48
- Umamaheswara Rao, M. 1969 b Seasonal variations in growth, alginic acid and mannitol contents of *Sargassum wightii* and *Turbinaria conoides* from the Gulf of Mannar, India *Proc. 6th Internat. Seaweed Symp.*, pp. 579-584
- Umamaheswara Rao, M. 1972 a Coral reef flora of the Gulf of Mannar and Palk Bay *Proc. Symp. Corals and Coral reefs Mar. Biol. Assn. India*, Cochin pp. 217-230
- Umamaheswara Rao, M. 1972 b On the Gracilariaceae of the seas around India *J. mar. biol. Assn. India*, **14** (2) : 671-696
- Umamaheswara Rao, M. 1972 c Ecological, observations on some intertidal algae of Mandapam coast *Proc. Indian natl. Sci. Acad.* **38** Part B. (3 & 4) : 298-307
- Umamaheswara Rao, M. 1973 a Growth and reproduction of *Gelidiella acerosa* in the Palk Bay and Gulf of Mannar near Mandapam *Indian J. Fish.*, **20** : 411-416
- Umamaheswara Rao, M. 1973 b Growth and reproduction in some species of *Gracilaria* and *Gracilariopsis* in the Palk Bay *Indian J. Fish.*, **21** : 182-192
- Umamaheswara Rao, M. 1974 Observations on fruiting cycle, spore output and germination of tetraspores of *Gelidiella acerosa* in the Gulf of Mannar *Bot. mar.*, **17** (4) : 204-207
- Umamaheswara Rao, M. 1976 Spore liberation in *Gracilaria corticata* J. Agardh growing at Mandapam *J. exp. mar., Biol. Ecol.*, **21** : 91-98

- Umamaheswara Rao, M. and T. Sreeramulu 1963 Vertical zonation and seasonal variation in the growth of *Porphyra* on Visakhapatnam coast *Curr. Sci.*, **32** : 173-174
- Umamaheswara Rao, M. and T. Sreeramulu 1964 An ecological study of some marine algae of the Visakhapatnam coast *J. Ecol.*, **52** : 595-616
- Umamaheswara Rao, M. and T. Sreeramulu 1968 Recolonization of algae on denuded rocky surfaces of the Visakhapatnam coast *Bot. mar.*, **11** : 122-126
- Umamaheswara Rao, M. and T. Sreeramulu 1970 a An annotated list of the marine algae of Visakhapatnam (India) *Bot. J. Linn. Soc.*, **63** : 23-45
- Umamaheswara Rao, M. and T. Sreeramulu 1970 b The fruiting behaviour of some marine algae at Visakhapatnam coast *Bot. mar.*, **13** (1) : 47-49
- Umamaheswara Rao, M. and S. Kalimuthu 1972 Changes in mannitol and alginic acid contents of *Turbinaria ornata* (Turner) J. Agardh in relation to growth and fruiting *Bot. mar.*, **15** : 57-59
- Umamaheswara Rao, M. and T. Sreeramulu 1974 Observations on changes in the growth of four intertidal algae at Visakhapatnam *Bot. mar.*, **17** : 52-54
- Umamaheswara Rao, M. and N. Kaliaperumal 1976 Some observations on the liberation and viability of oospores in *Sargassum wightii* (Greville) J. Ag. *Indian J. Fish.*, **23** : 232-235
- Untawale, A.G., V.K. Dhargalkar and V.V. Agadi 1983 List of marine algae from India N.I.O., Dona Paula, Goa pp. 1-42
- Varma, R.P. 1959 Studies on the succession of marine algae on a fresh substratum in Palk Bay *Proc. Indian Acad. Sci.*, **B.49** : 245-263
- Varma, R. P. 1960 Flora of the pearl beds off Tuticorin *J. mar. biol. Assn. India*, **2** : 221-225