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SEAWEED RESEARCH AND UTILIZATION IN INDIA

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
(Indian Council of Agricultural Research)
P. B. No. 2704, E. R. G. Road, Cochin 682 031, India

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Published by
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PREFACE

Seaweeds, constituting an important renewable marine resource, grow in the shallow waters of sea wherever suitable substrata are available. In India seaweeds are found more abundantly along the southeastern and northwestern parts of the coast, and they are very sparse or negligible along other parts. The seaweeds are traditionally harvested on a commercial scale by skin diving from the two important regions mentioned above.

There are 681 or so known species of seaweeds in India, of which 60 are commercially important. Seaweeds are used as food, fodder and fertilizer. Though the seaweeds can be of use in a wide variety of Industries, they are now used only for the production of agar-agar and algin. Seaweeds are also an important source of protein, vitamins and minerals.

In order to estimate the total resource of seaweeds in the country, the CMFRI, in collaboration with the CSMCRI and the Government of Tamil Nadu, conducted extensive surveys of the coast of Tamil Nadu. Similar surveys of the coasts of Kerala and other parts of the country are proposed for the future. At present, it is estimated that about 40,000 tonnes of seaweeds are annually harvested. However, it has been felt that the exploitation of the seaweeds which have been continuously exploited has in recent times exceeded their renewable capacity, especially along the Tamil Nadu coast. This reduction in the quantities of the seaweed now being exploited has also been partly attributed to the removal of coral stones from the shallow waters of the Gulf of Manner along the south-east coast of India. Fortunately, the Government of Tamil Nadu has already placed some restrictions on the exploitation of seaweed along the coast.

In view of the possible demand for seaweeds for conversion into industrial products, the CMFRI has initiated culture of seaweeds, especially species like *Gracilaria edulis*, in coastal areas and developed simple technology for the same. Other Institutes like the CSMCRI have also conducted research to develop culture technologies for certain species like *Gelidiella acerosa*. In addition to the surveys of coastal resources of seaweeds which are intensively exploited at the moment, it is also necessary to conduct surveys of deep water species along different parts of the coast. A beginning has already been made in this direction by this Institute in collaboration with the CSMCRI. Further, this Institute is now laying emphasis on accurate estimation of availability of seaweeds in different parts of the coast, and effect of harvesting on the biomass and capacity of different species to rejuvenate. Genetic studies on seaweeds have also been initiated to identify genetically superior strains and to propagate the same in suitable localities.

The present Bulletin, containing articles on different aspects of seaweeds like identification, distribution, resources, commercial exploitation, culture, post-harvest technology, transfer of technology, utilisation, present status of research and future prospects in research and development of the seaweed resources in this country, constitutes a major effort on the part of this Institute to bring together all information on seaweeds, particularly on the economically important species. It is hoped that this Bulletin would provide comprehensive information for identifying seaweeds and coordinating future efforts for research and development of this important marine resource. Dr. V. S. Krishnamoorthy Chennubhotla, and Dr. N. Kaliaperumal, Scientists of this Institute, and S/Shri S. Kalimuthu, J. R. Ramalingam, M. Najmuddin and M. Selva Raj, Technical Assistants, have been mainly responsible for consolidating the material presented in this Bulletin under the guidance of Dr. E. G. Silas, former Director of this Institute, and Dr. P. V. Ramachandran Nair, Senior Scientist. I deeply appreciate their efforts in planning to bring out this Bulletin.

P. S. B. R. James
Director
C. M. F. R. I, Cochin.

ONE

INTRODUCTION

E. G. SILAS, P. V. RAMACHANDRAN NAIR AND
V. S. K. CHENNUBHOTLA

Seaweeds are macroscopic algae, which form an important component of the marine living resource. They are available largely in shallow coastal waters wherever there is a substratum on which they can grow and flourish. Based on their pigmentation, the seaweeds are broadly grouped into green, brown, red and blue-green algae. They are harvested by man for centuries, particularly in Japan and China, where they form a part of the staple diet. The uses of seaweeds as food, fodder and manure are well known in many countries. Marine algae contain more than 60 trace elements in a concentration much higher than in terrestrial plants. They also contain protein, iodine, bromine, vitamins and substances of stimulatory and antibiotic nature. Seaweeds are the only source for the production of agar, alginate and carrageenan. These phytochemicals are extensively used in various industries such as of food, confectionary, textile, pharmaceutical, dairy and paper mostly as gelling, stabilising and thickening agents. Apart from these biochemicals, other products such as mannitol, laminarin and fucoidin are also obtained from marine algae. Now attempts are being made for screening pharmaceuticaly active compounds from seaweeds.

In earlier years marine algae were considered to be the major source for extraction of iodine and potash. Protein-rich seaweeds such as species of *Caulerpa*, *Porphyra*, *Gracilaria*, *Acanthophora* and *Laurencia* are used for human consumption in some of the South East Asian countries. However, in India, except for the use of *Gracilaria edulis* for making gruel in the coastal areas of Tamil Nadu, seaweeds are never used directly as a food item. There is a practice along some coastal areas in India of utilizing seaweeds washed ashore to manure coconut plantations, as seaweed manure has been found superior to the conventional organic (farm yard) manure. At the Central Marine Fisheries Research Institute a simple method has been formulated for preparing seaweed compost, which can be used as a cheap source of fertilizer. Seaweed extract can be used as a foliar spray for inducing faster growth in crops and fruiting plants. This has been practised recently on a large scale in countries such as U. S. A., U. K. and Norway.

It has been estimated that the seaweed resources of the world comprise about 1460 million tonnes wet weight brown algae and 261 million tonnes wet weight red algae. The total seaweed production may be about 1721 x 10^4 tonnes wet weight annually (Michanek 1975). The major sources of seaweeds are in the northeast, western central and southwest Atlantic and the eastern-central and northwest Pacific areas. There is not much information regarding the Antarctic and Arctic regions. India, with a long coastline (6100 km), has a vast resource of seaweeds along her many open coasts and estuarine areas. The Lakshadweep and Andaman-Nicobar Islands have rich seaweed vegetation. Resources surveys have been conducted by various organisations in India to assess the occurrence and distribution of seaweeds along our coasts, and it has been estimated that about 73,000 t of this resource is available along the areas explored so far.

The seaweeds mainly used by the seaweed industry in other countries for algin production are *Macrocystis*, *Nereocystis*, *Laminaria* and

Ascophyllum; for agar production *Gelidium, Gracilaria* and *Gelidiella;* and for carrageenan extraction *Eucheuma, Chondrus* and *Gigartina.* The seaweed utilization in India started during the Second World War, when soda ash, alginate and iodine were extracted from the seaweeds. Later, since the importance of seaweeds as a source of agar and alginates was realised, they began to be used for indigenous production of these materials. The seaweeds used for agar extraction in India are *Gelidiella acerosa, Gracilaria edulis* and *G. crassa* and for the production of alginates *Sargassum* and *Turbinaria* species are used.

Seaweeds such as *Gelidiella, Gracilaria* and *Sargassum* were being exported from India until 1975. But, the Government of India, considering the need of local agar and algin industries, later banned the export. However, the seaweed industries in India do not produce as yet the required quantities of sodium alginate and agar. As a result, India imports agar and algin every year, spending a considerable amount of foreign exchange. Commercial exploitation of seaweeds is neverthless going on in India since 1966. At present, seaweeds from Gujarat coast and many localities in Tamil Nadu are harvested by small- and large-scale industries. There are also many seaweed suppliers who harvest seaweeds *(Gelidiella acerosa, Gracilaria edulis, G. crassa* and species of *Sargassum* and *Turbinaria)* and sell them to industries. Sundried *Gelidiella acerosa, Gracilaria edulis* and *G. crassa* and formalin-treated and sundried *Sargassum* and *Turbinaria* are packed in gunnies, stored in sheds, and periodically transported to the processing plants.

Today there is a greater awareness in many countries of the need to cultivate seaweeds to meet the demand for food and of industry. In recent years many industries producing agar and algin have come up in our country too. Owing to the limited natural resources of desired seaweeds and to the industries' increasing demand for them, it has now become necessary for us to cultivate them on large scale. Some of the suitable sites for cultivation of seaweeds are found in Gulf of Mannar, Palk Bay, Gulf of Kutch, Malvan and the bays and lagoons of Lakshadweep and Andaman-Nicobar islands.

Species of *Monostroma, Caulerpa, Undaria, Laminaria, Macrocystis, Porphyra, Gracilaria, Eucheuma, Hypnea, Gloiopeltis* and *Chondrus,* belonging to Chlorophyta, Phaeophyta and Rhodophyta, are cultivated in different countries according to their needs, and different techniques are adopted for their cultivation. In Japan and China large industries are engaged in cultivation and processing of many of these seaweeds. In India, seaweeds are used mainly for the manufacture of agar and algin and hence attempts are being made to cultivate only the agar- and algin-yielding seaweeds. Rope net as base is being used for the species such as *Gracilaria edulis, Hypnea musciformis, Acanthophora spicifera,* species of *Sargassum* and *Turbinaria* and coralstone as base for *Gelidiella acerosa.* Since 1972, the Central Marine Fisheries Research Institute has been engaged in developing low-cost culture techniques for different species of seaweeds. These techniques now need to be taken up in large-scale application as full-time or part-time avocation in coastal villages where suitable sea conditions prevail. For this there should be planned programme which should not only augment production but also create large-scale job opportunities in the coastal rural sector.

At present, some of the national organisations such as Central Marine Fisheries Research Institute, Central Salt and Marine Chemical Research Institue and the National Institute of Oceanography and the Andhra University Botany Department are involved in major programmes of seaweed cultivation and utilization. The efforts of these institutions should be co-ordinated to identify need-based priority areas. Appropriate technologies for culture, harvesting and processing of seaweeds have to be developed. Extension programmes and transfer of proven technologies in seaweed culture should also receive immediate attention. Some centralised training for States' fisheries officials engaged in extension programmes may also be organized if necessary to accelerate developmental efforts.

TWO

ECONOMICALLY IMPORTANT SEAWEEDS

V. S. K. CHENNUBHOTLA, N. KALIAPERUMAL AND
S. KALIMUTHU

The plants in the sea other than seagrasses—what we call seaweeds—belong to the simplest group of plants : the marine algae. With few exceptions, these plants are so simple that they have no distinguishable roots, stems or leaves. The algae vary in size from microscopic single-celled forms (eg. diatoms) to the giant macrophytes of temperate waters *(Macrocystis, Nereocystis,* etc*)*.

Seaweeds are chlorophyll-bearing plants with a plant body showing no differentiation into true tissues. It never forms true roots, stems and leaves and so is called a thallus or frond. The thallus has no elements for the transport of fluids (nonvascular). Seaweeds exhibit a great diversity in organisation of their body. The filamentous forms are usually multicellular and the filament may be simple *(eg. Chaetomorpha)* or branched *(eg. Cladophora)*. There are coenocytic forms or siphonaceous forms in which the cells are multinucleate without cross walls so that the entire plant consists of a variously ramified hollow tube *(eg. Caulerpa* and *Codium)*. Other filamentous thalli, known as parenchymatous forms, are one or more layers of cells in thickness *(eg. Enteromorpha, Dictyota* and *Padina)*. Complex parenchymatous thalli of the Rhodophyta are formed by the aggregation of filaments *(eg. Centroceras* and *Spyridia)*. The most highly evolved marine algae exhibit external differentiation and considerable size. Some of them possess a plant body consisting of parts that bear superficial resemblance to the roots, leaves and stems of higher plants *(eg. Sargassum)*. Apart from the external structure, the vegetative thalli of Phaeophyta and Rhodophyta are internally differentiated into a few- layered photosynthetic cortex, below which occur hyaline storage cells called medulla.

The seaweed attaches itself to the sub, stratum by means of a holdfast. The manner of attachment differs widely from a holdfast consisting of a single modified basal cell *(eg. Chaetomorpha)* to various kinds of penetrating or entangling rhizoids *(eg. Turbinaria),* multicellular adherent discs, creeping stolons *(eg. Gelidium)* and massive clasping hapteras. In some multicellular forms the same cells perform both vegetative and reproductive functions, whereas in others special reproductive cells or organs such as tetrasporangia zoosporangia, male and female gametangia, antheridia, oogonia, receptacles, stichidia and cystocarps are developed. Illustrations of all the important algae are given in the chapter for easy identification of the different seaweeds (Figs. 1-14 and plates I to IV).

Taxonomical Work in India

Studies made on Indian algae have been reviewed from time to time by various authors, Agharkar (1923), Biswas (1932 and 1934), Joshi (1949), Iyengar (1957), Randhawa (1960) and Srinivasan (1965). Based on the collections of M. O. P. Iyengar and on his own collections, Boergesen has published a series of papers on the green, brown and red algae of the northern parts of the west coast (Boergesen, 1930, 1931, 1932 a, b, 1933 a, b, 1934 a, b and

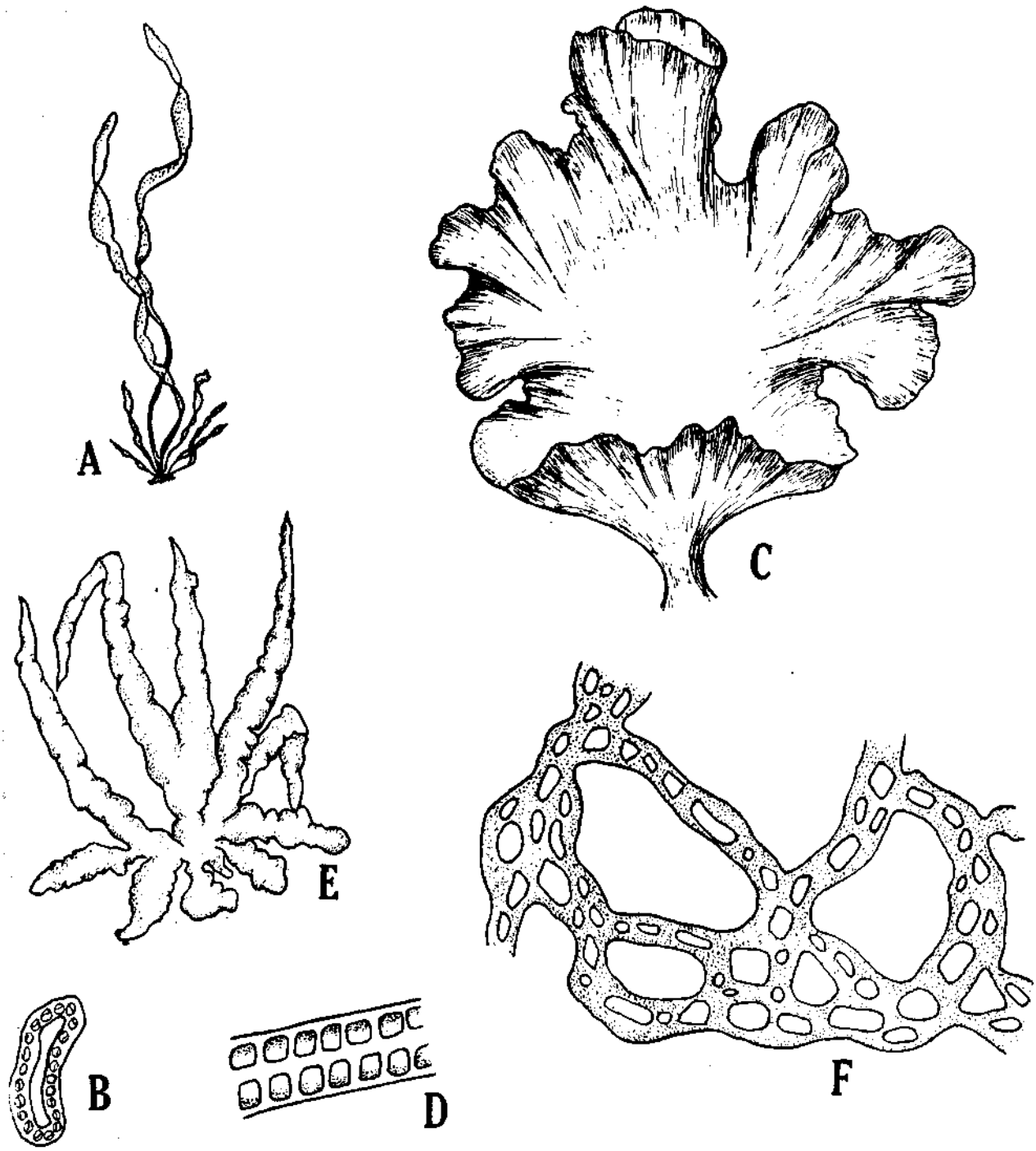


Fig. 1. Common green seaweeds of the Indian coast. A. *Enteromorpha compressa* (X 1) B. *Enteromorpha compressa* - transverse section of the thallus (X 100) C. *Ulva lactuca* (X 1) D. *Ulva lactuca* - transverse section of the thallus (X 260) E. *Ulva fasciate* (X 0.5) F. *Ulva reticulata* - part of a plant (X 2)

1935) and brown and red algae of south India (Boergesen, 1937 a, b and 1938).

After the valuable contribution of Boergesen, much work has been done on the morphology and taxonomy of Indian marine algae during the last four decades. A general review of the marine algae of the west coast was published by Biswas (1945). Srinivasan (1946) studied the marine algal flora of Mahabalipuram. Parija and Parija (1946) studied the vegetation of Chilka Lake. Chacko *et. al.* (1955) have listed the algal flora of the Krusadai Island and Varma (1960) studied

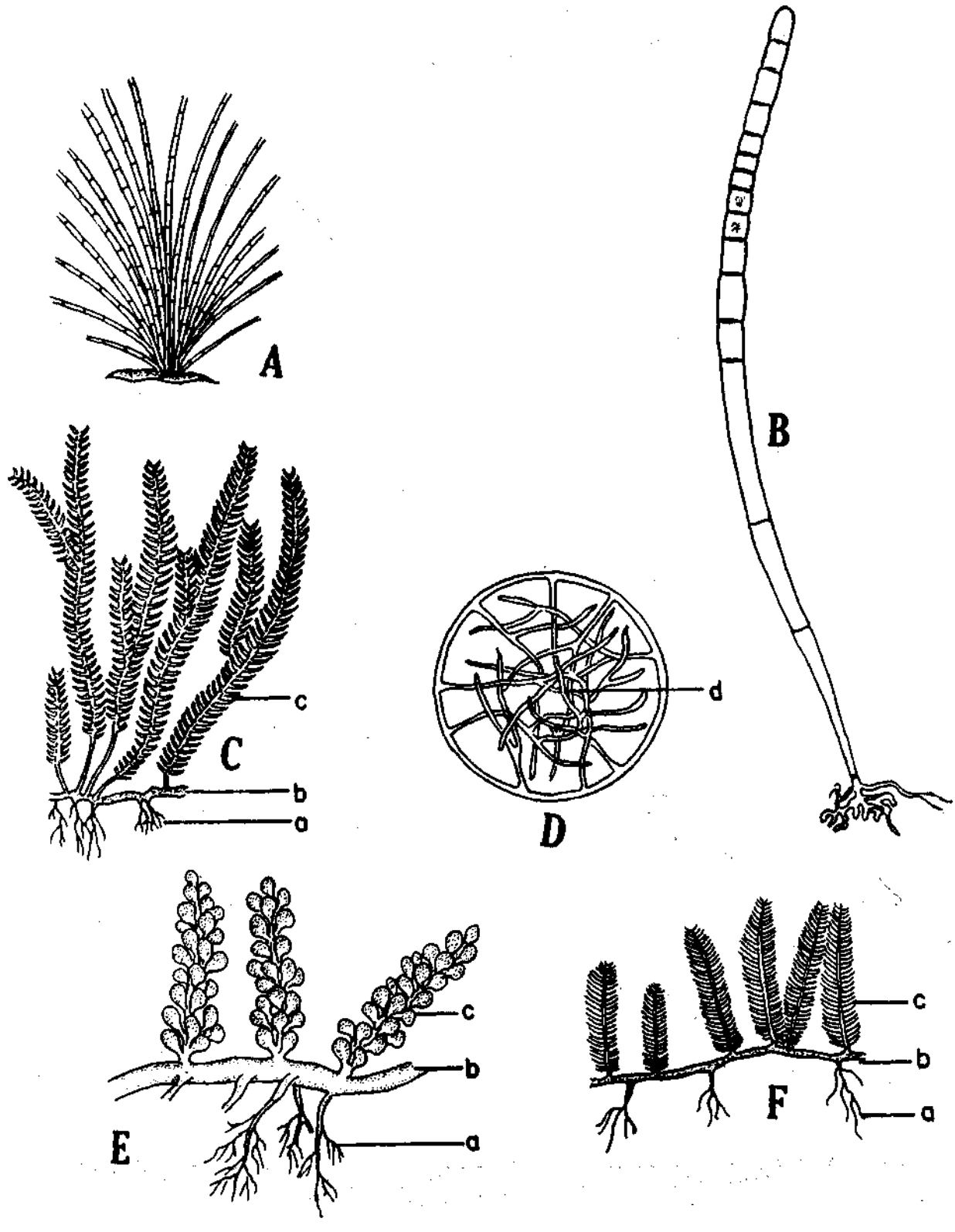


Fig. 2. Common green seaweeds of the Indian coast (contd.) A. *Chaetomorpha antennina* (X 1) B. *Chaetomorpha antennina* - a single filament enlarged (X 50) C. *Caulerpa taxifolia* (X 1) D. *Caulerpa* - transverse section (X 12.5) E. *Caulerpa racemosa* (X 1) F. *Caulerpa sertularioides* (X 1) a - rhizoid; b - rhizomce; - erect frond; d - trabeculae

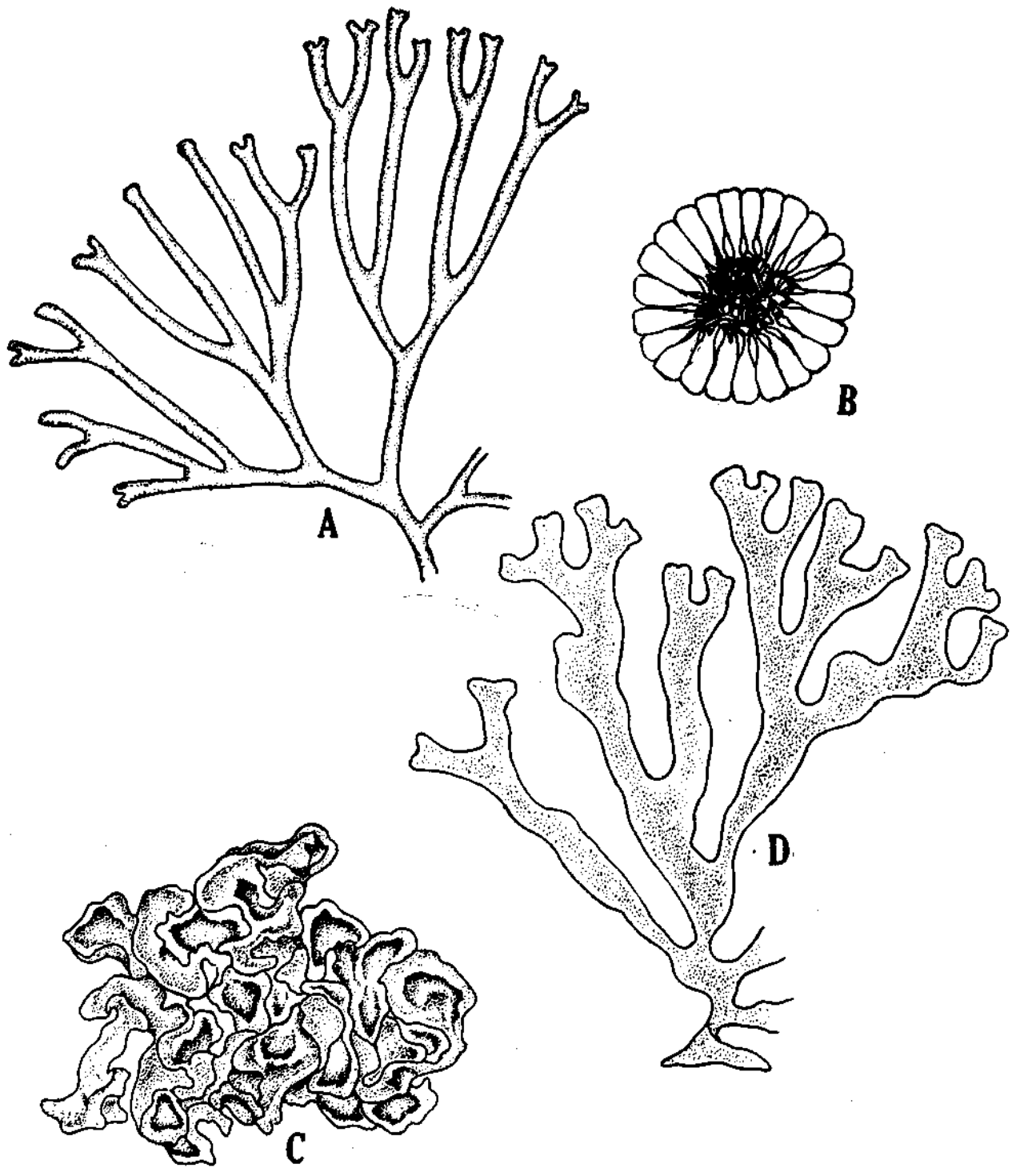


Fig. 3. Common green seaweeds of the Irdian coast (contd.) A. *Codium tomentosum* - part of a plant (X 1) B. *Codium* - transverse section of the thallus (X 20) C. *Codium adherens* (X 1) D. *Codium decorticatum* - part of a plant (X 1)

the seaweeds growing on the pearl and chank beds off Tuticorin. Srinivasan (1960) has given a detailed account of marine algae of the east and west coasts of India based on the then available reports. According to the estimates given by him, 162 genera and 413 species of marine algae were known from the Indian waters. Taylor (1964) has described the Indian species of *Turbinaria*. The checklists of Indian algae have been

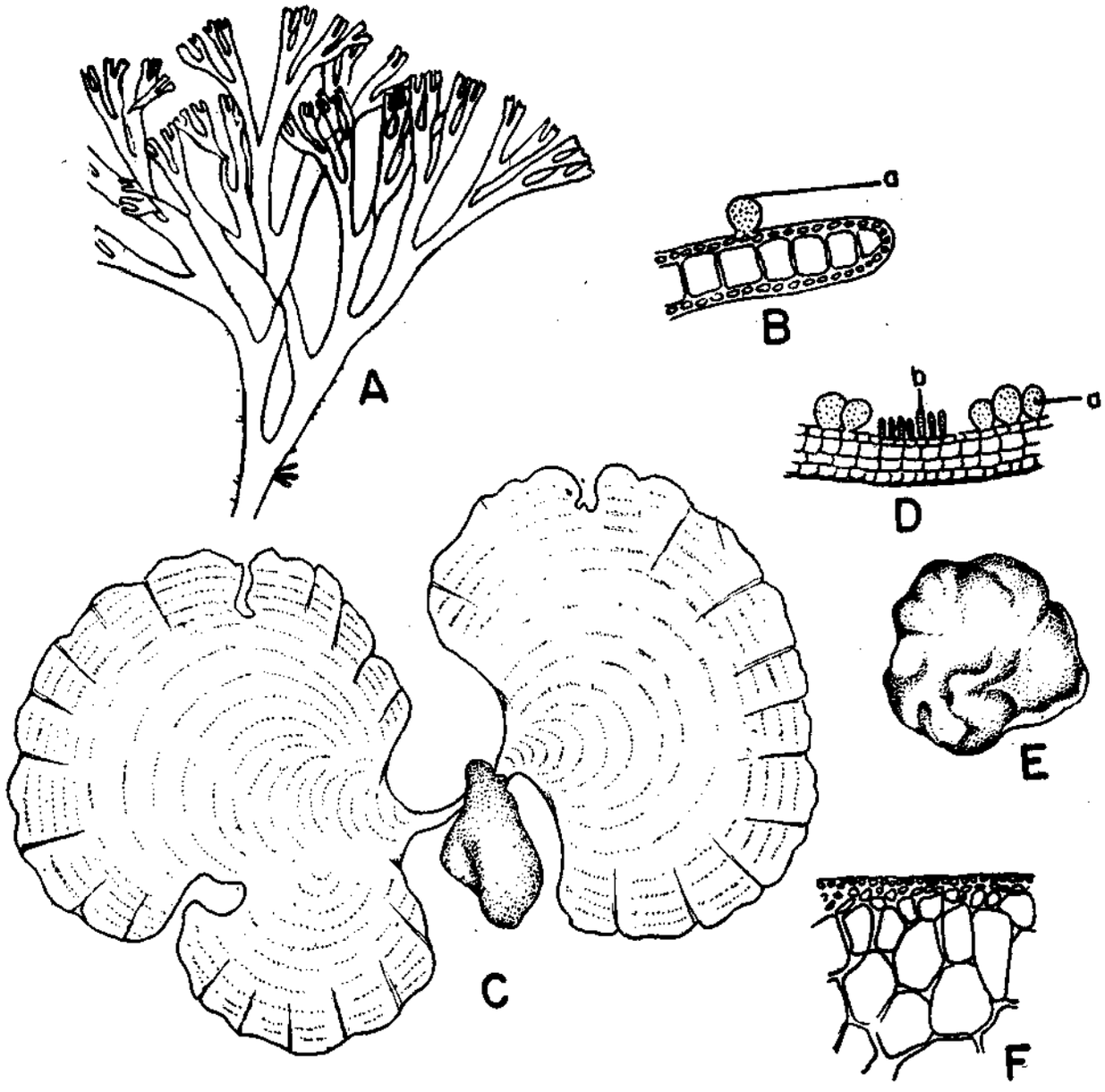


Fig. 4. Common brown seaweeds of Indian coast A. *Dictyota dichotoma* - part of a plant (X 1)
B. *Dictyota dichotoma* - transverse section of the thallus (X 95) C. *Padina gymnospora* (X 1)
D. *Padina tetrastromatica* - transverse section of the thallus (X 75) E. *Colpomenia sinuosa* (X 1)
F. *Colpomenia sinuosa* - sectional view of the thallus (X 70). a - tetrasporangium; b - hair

published by Dixit (1964 and 1968) and Srinivasan (1965). The list published by Dixit consists of 411 species, which also include records from Pakistan and Sri Lanka. Misra (1966) has prepared a monograph of the brown algae occurring along the Indian coast. Srinivasan (1966) has published an account of the Indian species of *Sargassum*. A list of 1980 algae collected from Mandapam area has been published by Umamaheswara Rao (1969 a). The composition of marine algae off Gopnath has been studied by Sreenivasa Rao and Kale (1969) and that of Gulf of Kutch by Gopalakrishnan (1969). The species of *Ulva* from Indian waters is published by Krishnamurthy and Joshi (1969). An annotated list of 80 algae growing along the Visakhapatnam coast has been given by Umamaheswara Rao and Sreeramulu (1970). Gopalakrishnan (1980) has reported 64 species of algae from the collection grounds of Dwarka, Okha, Adatra, Hanuma-ndandi and Balapur from Okha coast. A systematic account of 10 taxa of Indian Gelidiales has been given by Sreenivasa Rao (1970). A checklist of 520 species of Indian

marine algae has been published by Krishnamurthy and Joshi (1970).

Joshi and Krishnamurthy (1971) have listed 13 species of *Enteromorpha* from India. Umamaheswara Rao (1972 a) has published the coralreef flora of the Gulf of Mannar and Palk Bay. The description of 17 species and 2 varieties of *Gracilaria* and 2 species of *Gracilariopsis* and also their habitats and distribution in India are given in detail by Umamaheswara Rao (1972 b). Agadi and Untawale (1978)

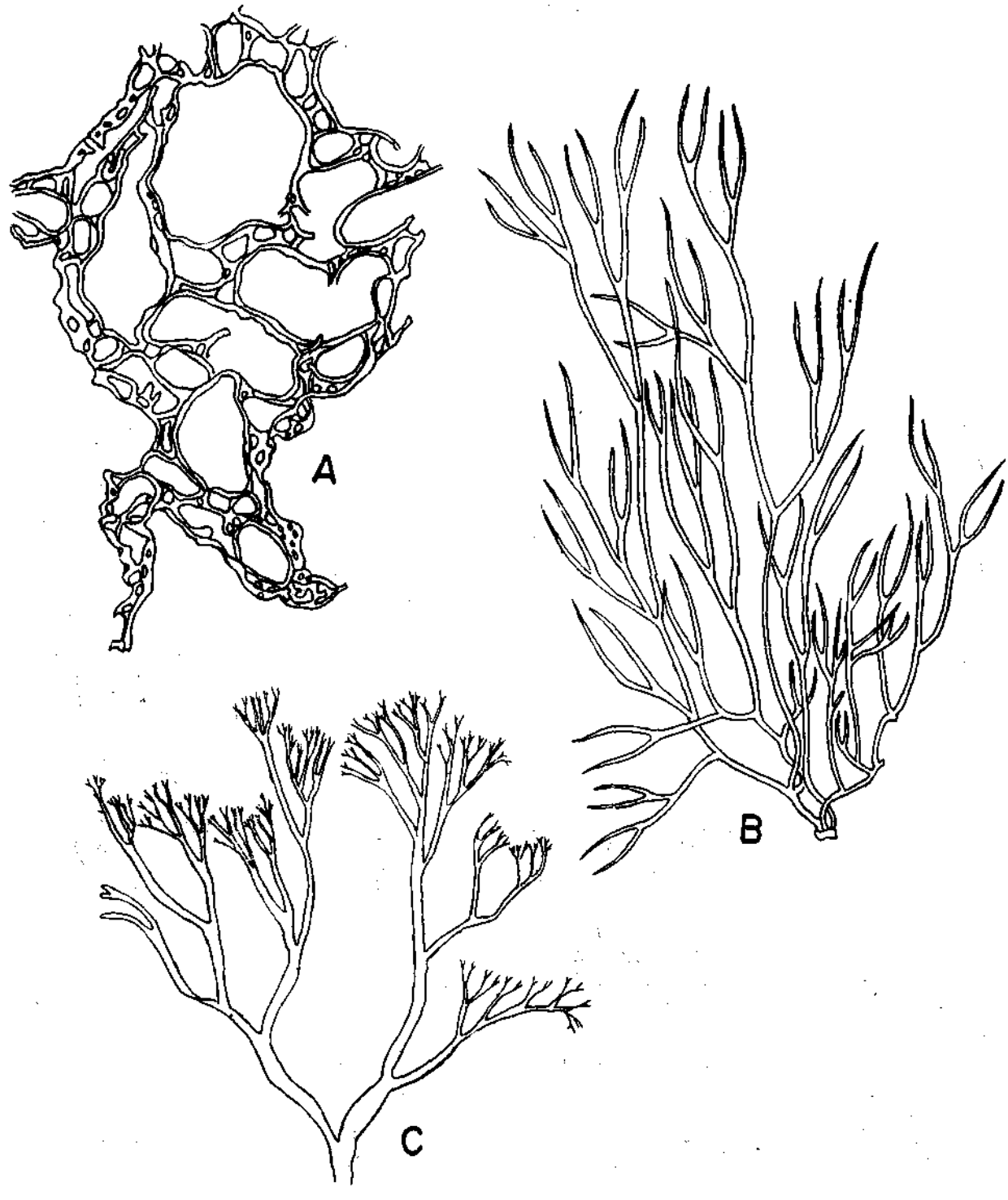


Fig. 5. common brown seaweeds of the Indian coast (contd.) A. *Hydroclathrus* - a portion of the plant (X 1) B. *Chnoospora minima* (X 1) C. *Rosenvingea intricata* - part of the plant (X 1)

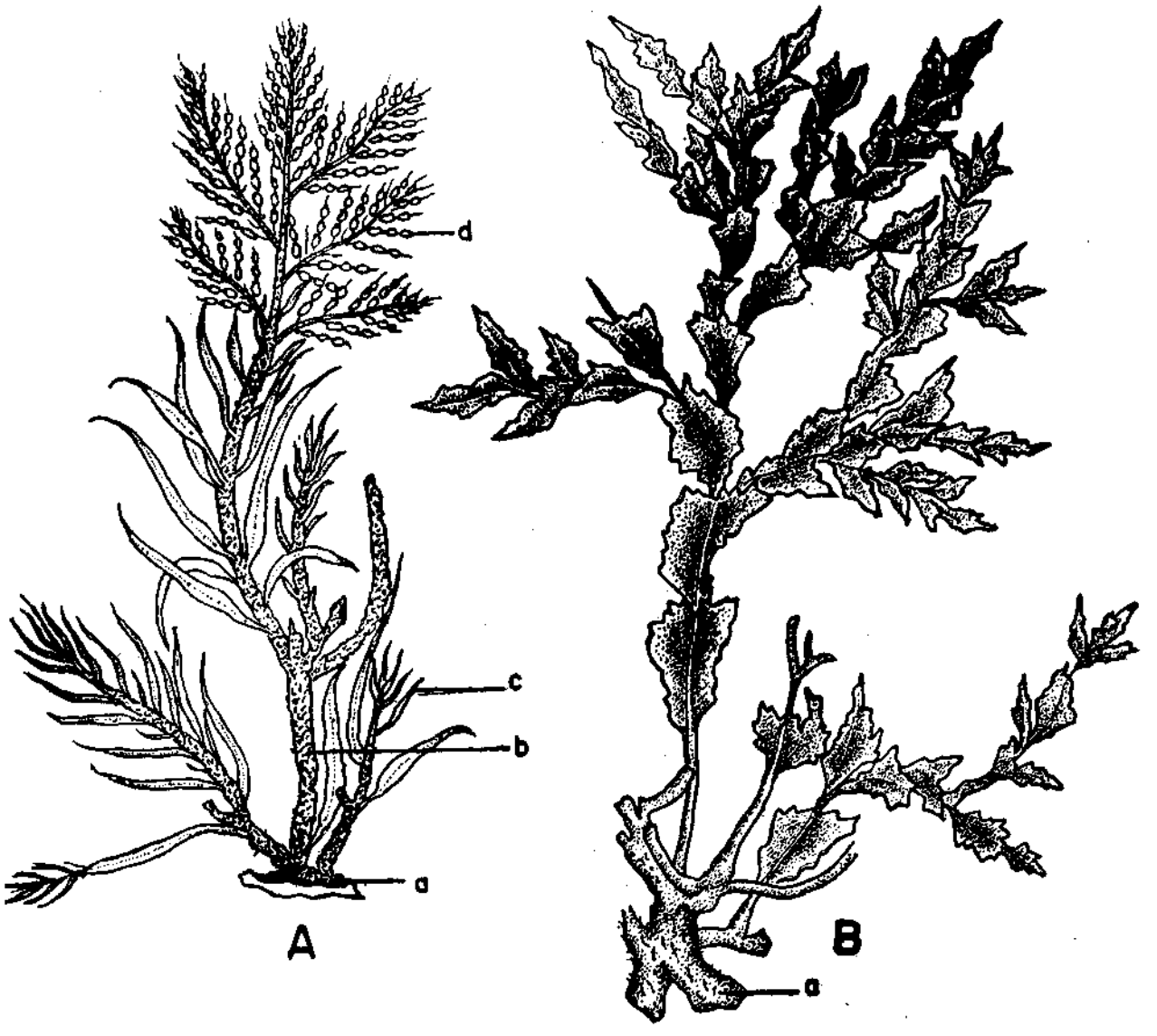


Fig. 6. common brown seaweeds of the Indian coast (contd.) A. *Cystoseira trinodis* B. *Hormophysa triquetra* (X 1) a - holdfast; b - stem; c - leaf; d - vesicles

have reported 50 algal species from the intertidal areas along the Goa coast. Qasim and Wafar (1979) have recorded in total 72 seaweeds from Ratnagiri, Malwan and Redi along the west coast. An account of 46 species of marine algae occurring at Tiruchendur on the Tamil Nadu coast has been given by Krishnamurthy (1980). Sarma and Khan (1980) have published a checklist of Indian fresh water and marine algae. A taxonomic account of Indian Ectocarpales and Ralfsiales has been given by Balakrishnan and Kinkar (1981). An annotated systematic list of 44 species of algae collected from 10 localities along the southern Kerala coast (including Asthamudi Lake and Kanyakumari) was published by Balakrishnan Nair *et. al.* (1982). Chennubhotla *et. al.* (1987) reported 35 species of seaweeds occurring along Kerala Coast. Stray marine algal collections have also been reported by various workers from different localities of Indian coast. Untawale *et. al.* (1983) enumerated 624 species of marine algae and their distribution along the maritime states of India. After 1983 some additions to the list are also made so as the number could be put around 680.

Although all the seaweeds are beneficial to man in one way or the other, only 49 species

which are presently found useful either as directly edible materials or as industrial raw materials are being dealt with in the classification given in this chapter following that of Fritsch (1935). The distribution of these economically important algae along the Indian coast are given along with a few other species commonly occurring in India in the Appendix III.

Classification

Following the classification of Fritsch (1935), a systematic list of the important and common Indian seaweeds is given below:

I CLASS : CHLOROPHYCEAE

Order : Ulotrichales

a. Family : Ulvaceae

1. *Ulva fasciata*
2. *U. lactuca*
3. *U. rigida*
4. *U. reticulata*
5. *Enteromorpha compressa*

Order : Cladophorales

b. Family : Cladophoraceae

6. *Chaetomorpha antennina*

Order : Siphonales

c. Family : Caulerpaceae

7. *Caulerpa racemosa*
8. *C. sertularioides*
9. *C. taxifolia*

d. Family : Codiaceae

10. *Codium adharens*
11. *C. decorticatum*
12. *C. tomentosum*

II CLASS : PHAEOPHYCEAE

Order : Dictyotales

a. Family : Dictyotaceae

13. *Dictyota dichotoma*
14. *Padina commersoni*
15. *P. gymnospora*
16. *P. tetrastromatica*

Order : Punctariales

b. Family : Punctariaceae

17. *Colpomenia sinuosa*
18. *Hydroclathrus clathratus*
19. *Rosenvingea intricata*
20. *Chnoospora minima*

Order : Fucales

c. Family : Sargassaceae

21. *Cystoseira trinodis*
22. *Hormophysa triquetra*
23. *Sargassum johnstonii*
24. *S. myriocystum*
25. *S. swartzii*
26. *S. tenerrimum*
27. *S. wightii*
28. *Turbinaria conoides*
29. *T. ornata*

III CLASS : RHODOPHYCEAE

Sub-Class : Bangioideae

Order : Bangiales

a. Family : Bangiaceae

30. *Porphyra vietnamensis*

Order : Gelidiales

b. Family :Gelidiaceae

31. *Gelidiella acerosa*

Order : Cryptonemiales

c. Family : Grateloupiaceae

32. *Halymenia floresia*
33. *Grateloupia filicina*
34. *G. lithophila*

Order : Gigartinales

d. Family : Gracilariaceae

35. *Gracilaria corticata*
36. *G. crassa*
37. *G. foliifera*
38. *G. edulis*
39. *G. verrucosa*

e. Family : Solieriaceae

40. *Sarconema furcellatum*

f. Family : Hypneaceae

41. *Hypnea musciformis*

g. Family : Gigartinaceae

42. *Gigartina acicularis*

Order : Rhodymenials

h. Family : Rhodymeniaceae

43. *Rhodymenia dissecta*

Order : Ceramiales

I. Family : Ceramiaceae

44. *Centroceras clavulatum*
45. *Spyridia filamentosa*
46. *S. fusiformis*

j. Family : Rhodomelaceae

47. *Acanthophora spicifera*
48. *Laurencia papillosa*
49. *L. obtusa*

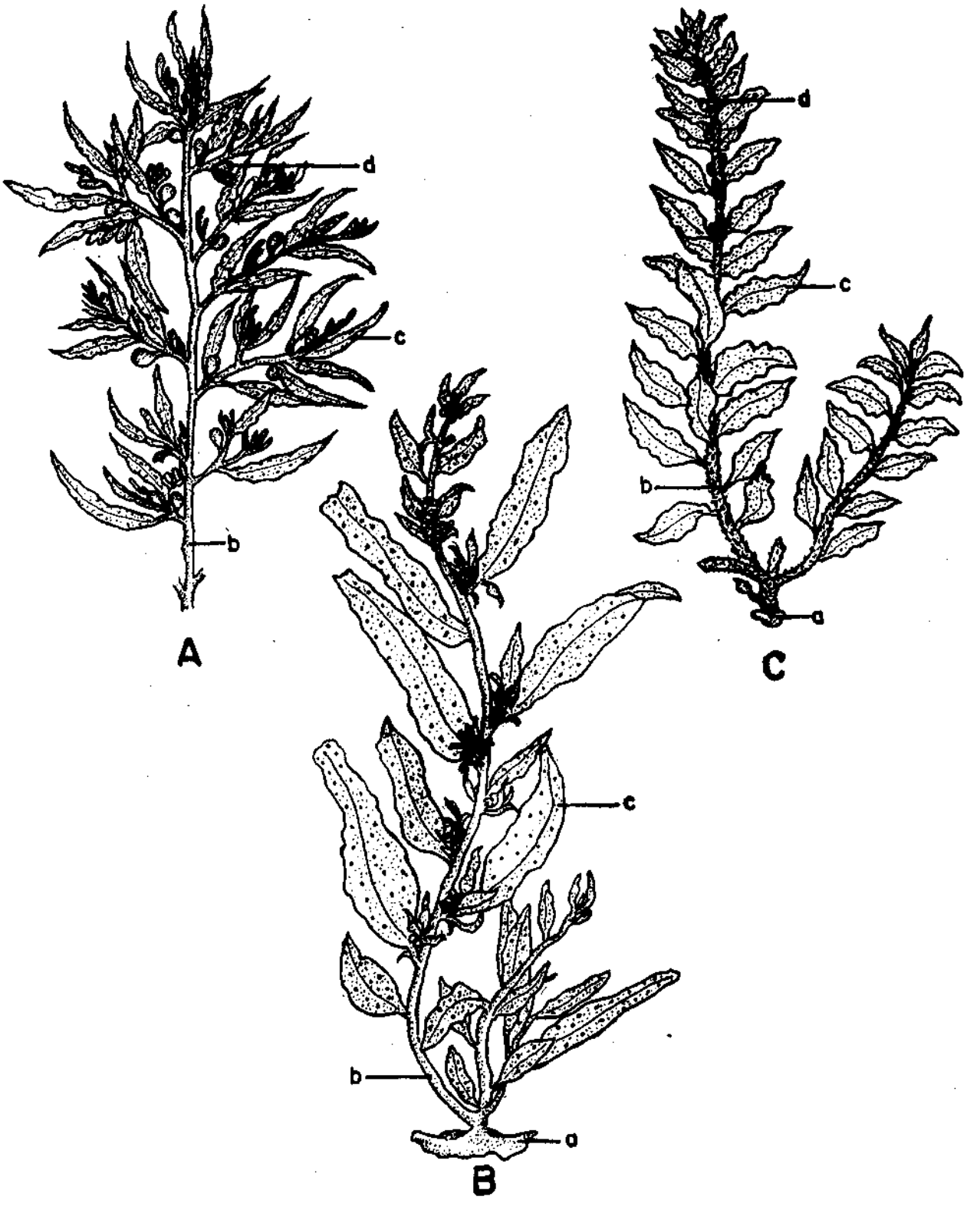


Fig. 7. common brown seaweeds of the Indian coast (contd.) A. *Sargassum tenerrimum* – part of the plant (X 1) B. *Sargassum wightii* (X 1) C. *Sargassum myriocystum* (X 1)
a - holdfast; b - stem; c - leaf; d - vesicle

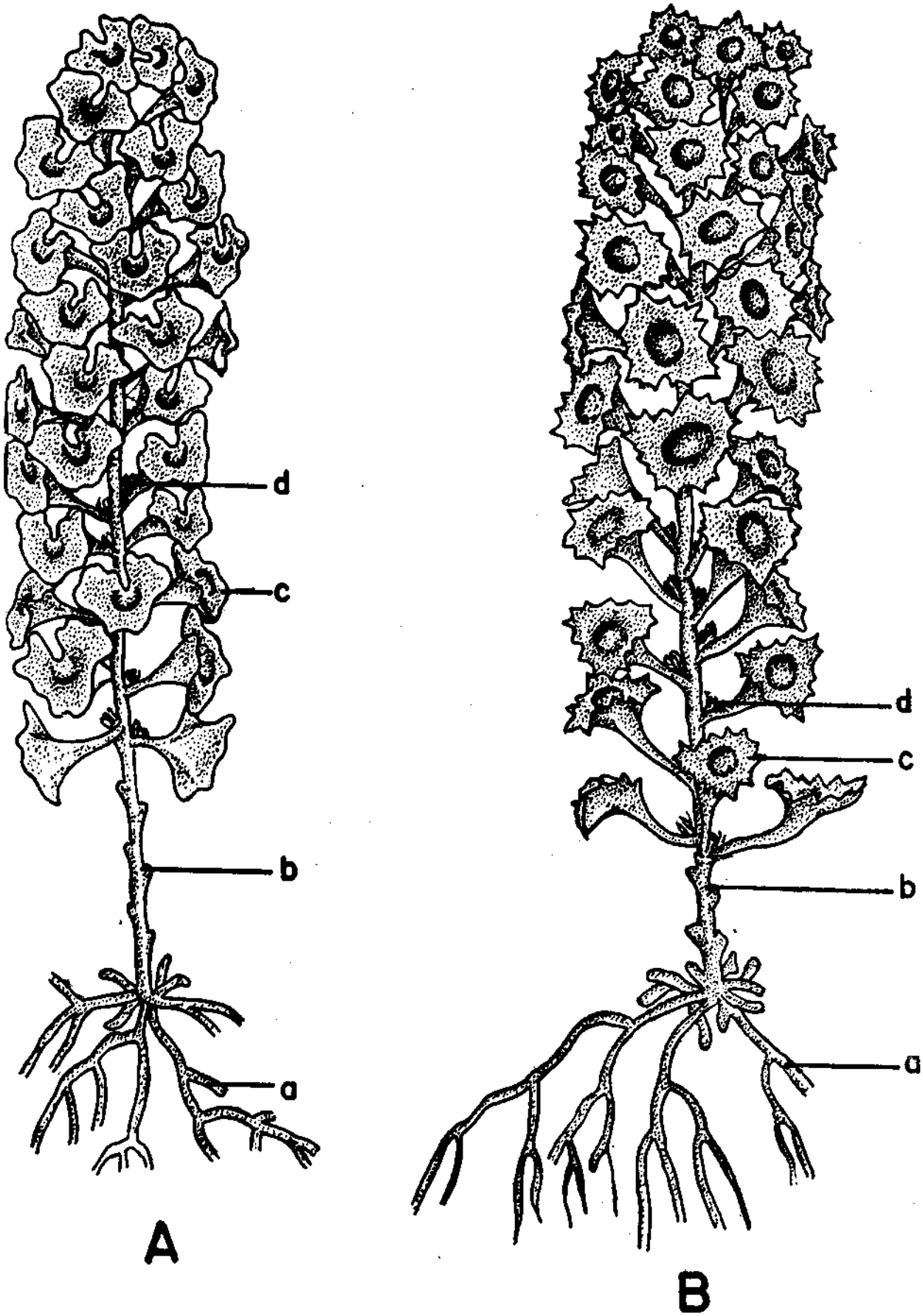


Fig. 8, common brown seaweeds of Indian coast (contd.) A. *Turbinaria conoides* (X 1)
B. *Turbinaria ornata* (X 1) a - heteron; b - stem; c - leaf; d - receptacle

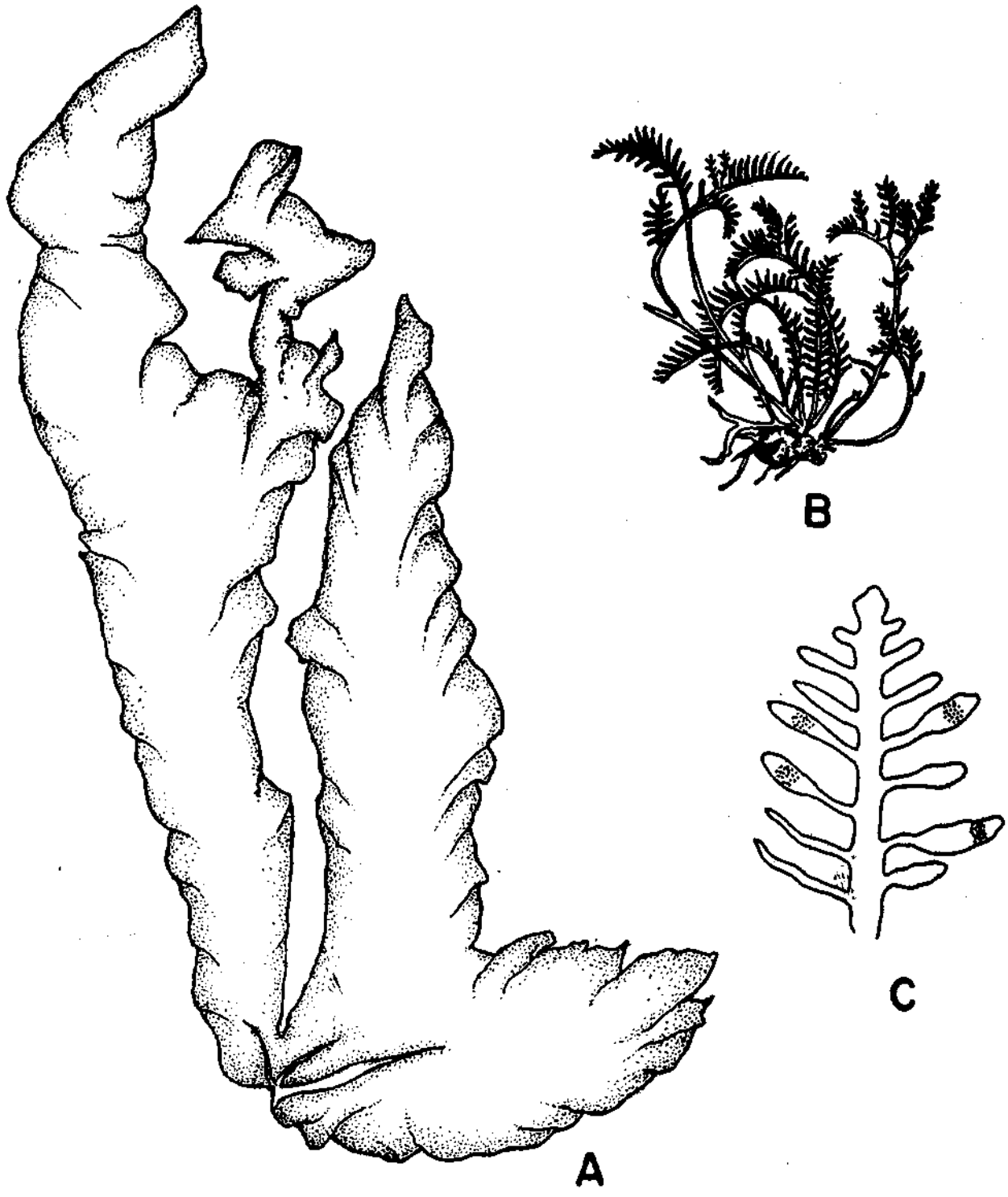


Fig. 9. Some common red seaweeds of Indian coast A. *Porphyra vietnamensis* (X 1)
B. *Gelidiella acerosa* (X 1) C. *Gelidiella acerosa* - axis showing swollen branchlets (X 50)

At present *Gelidiella acerosa* and *Gracilaria edulis* are used as raw material for the production of agar-agar in India. Species of *Hypnea, Gigartina, Spyridia, Sarconema Acanthophora* and *Laurencia* give gell-like extracts known as agaroids. Species of *Sargassum, Turbinaria, Cystoseira, Hormophysa, Dictyota* and *Padina* yield alginic acid and iodine. In India, sodium alginate is manufactured by the seaweed industries from

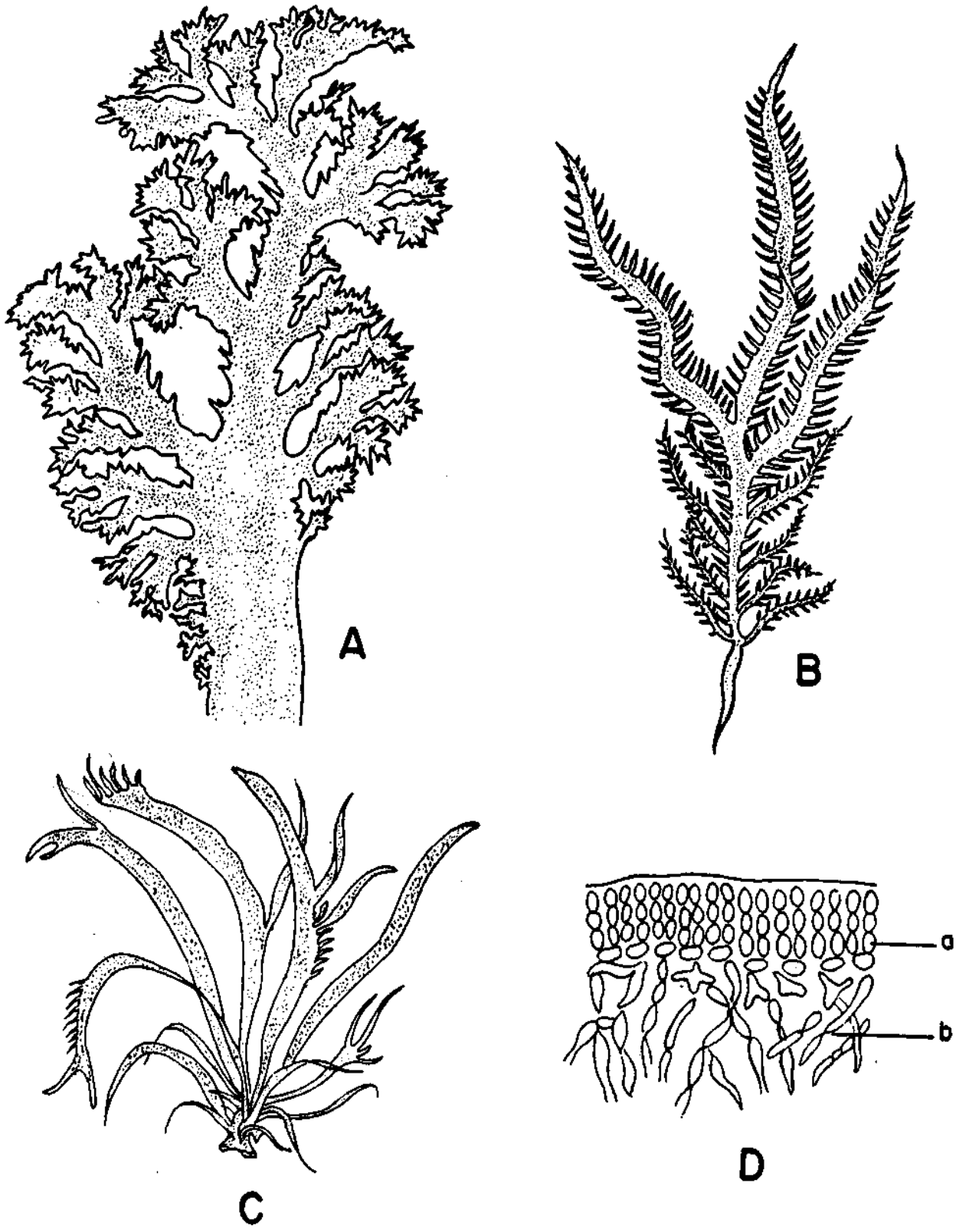


Fig. 10 Red seaweeds of Indian coast (contd.) A. *Halymenia floresia* - part of plant (X 2) B. *Grateloupia filicina* (X 2) C. *Grateloupia lithophila* (X 1) D. *Grateloupia lithophila* - transverse section of thallus (X 150) a - cortex; b - medulla

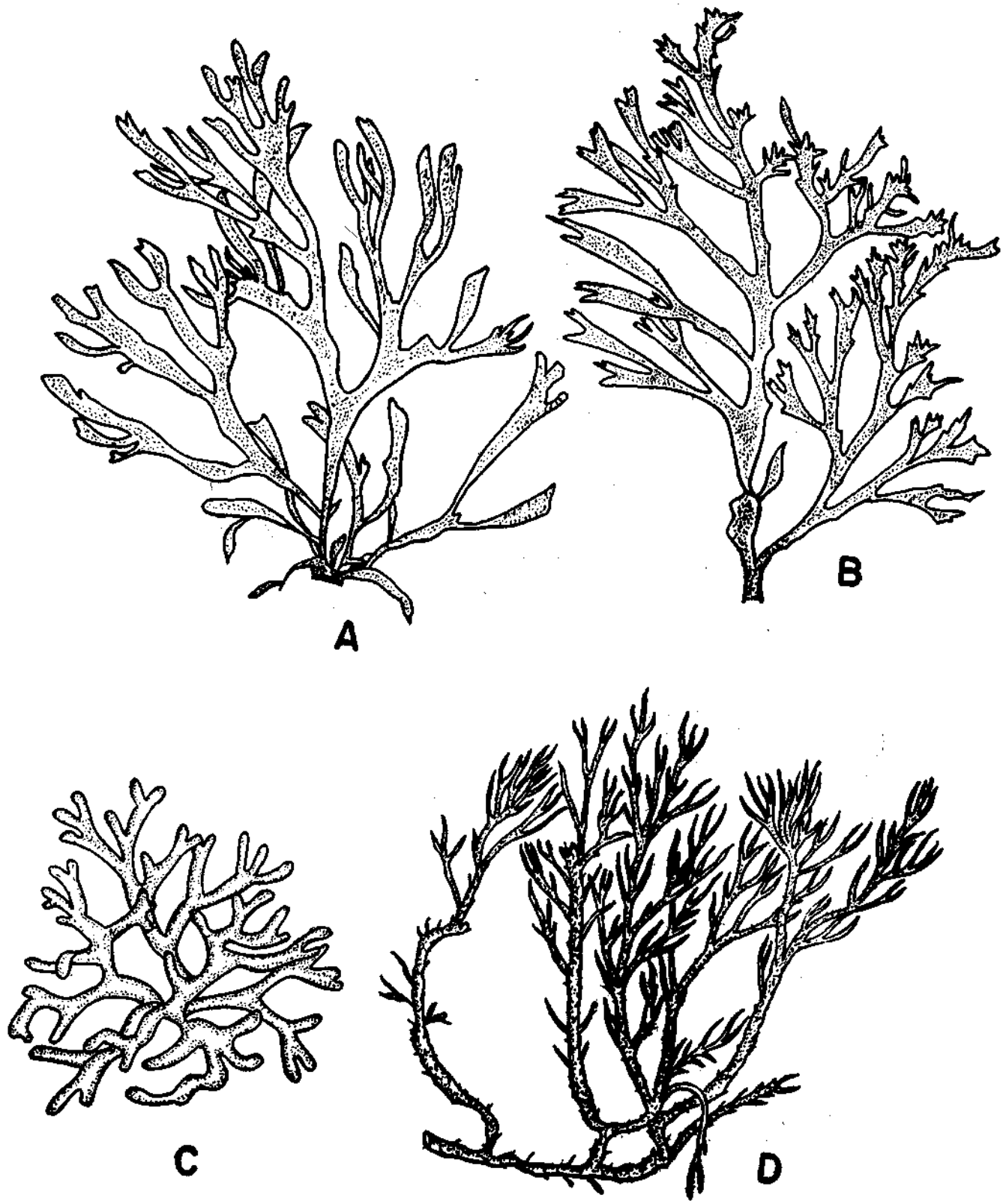


Fig. 11. Red seaweeds of Indian coast (contd.) A. *Gracilaria corticata* (X 1) B. *Gracilaria follifera* - part of a plant (X 1) C. *Gracilaria crassa* (X 1) D. *Gracilaria edulis* (X 1)

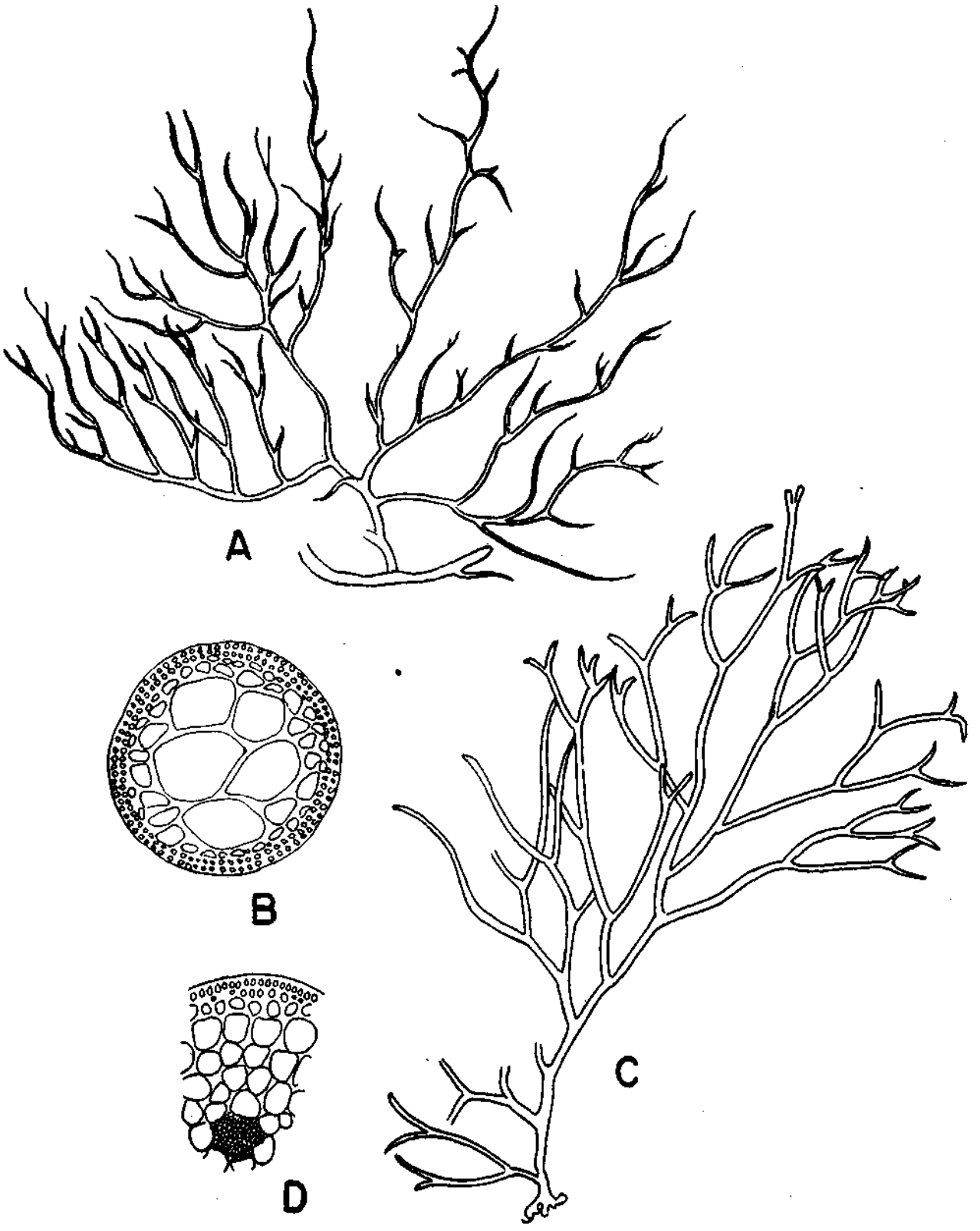


Fig. 12. Red seaweeds of Indian coast (contd.) A. *Gracilaria verrucosa* (X 1)
B. *Gracilaria verrucosa* - transverse section of the frond (X 60) C. *Sarconema furcellatum* (X 1)
D. *Sarconema furcellatum* - transverse section of the thallus (X 150)

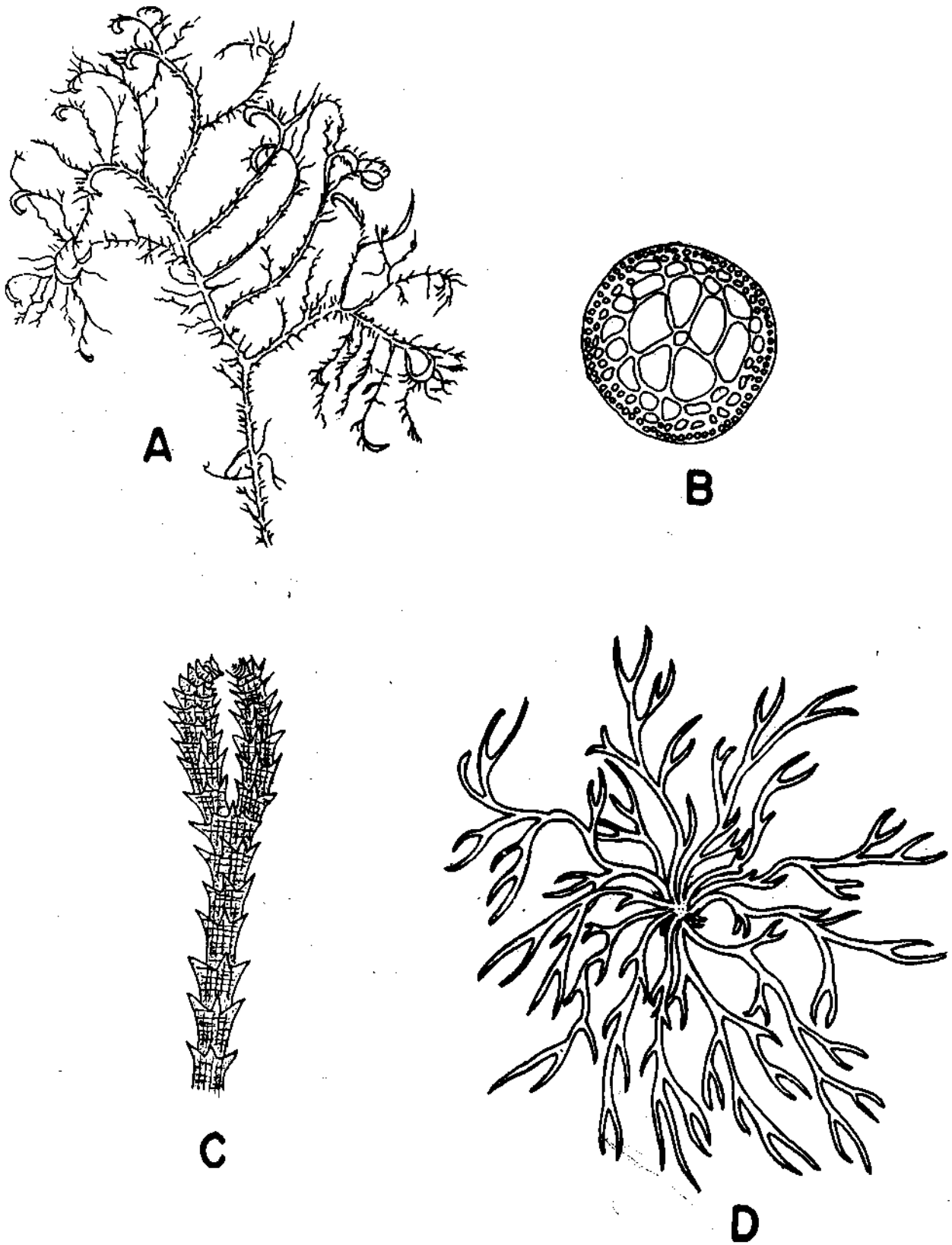


Fig. 13. Red seaweeds Indian coast (contd.) A. *Hypnea musciformis* (X 1) B. *Hypnea* - transverse section of thallus (X 75) C. *Centrocerks clavulatum* - part of a filament with whorls of spines at each node (X 50) D. *Gigartna acicularis* (X 3)

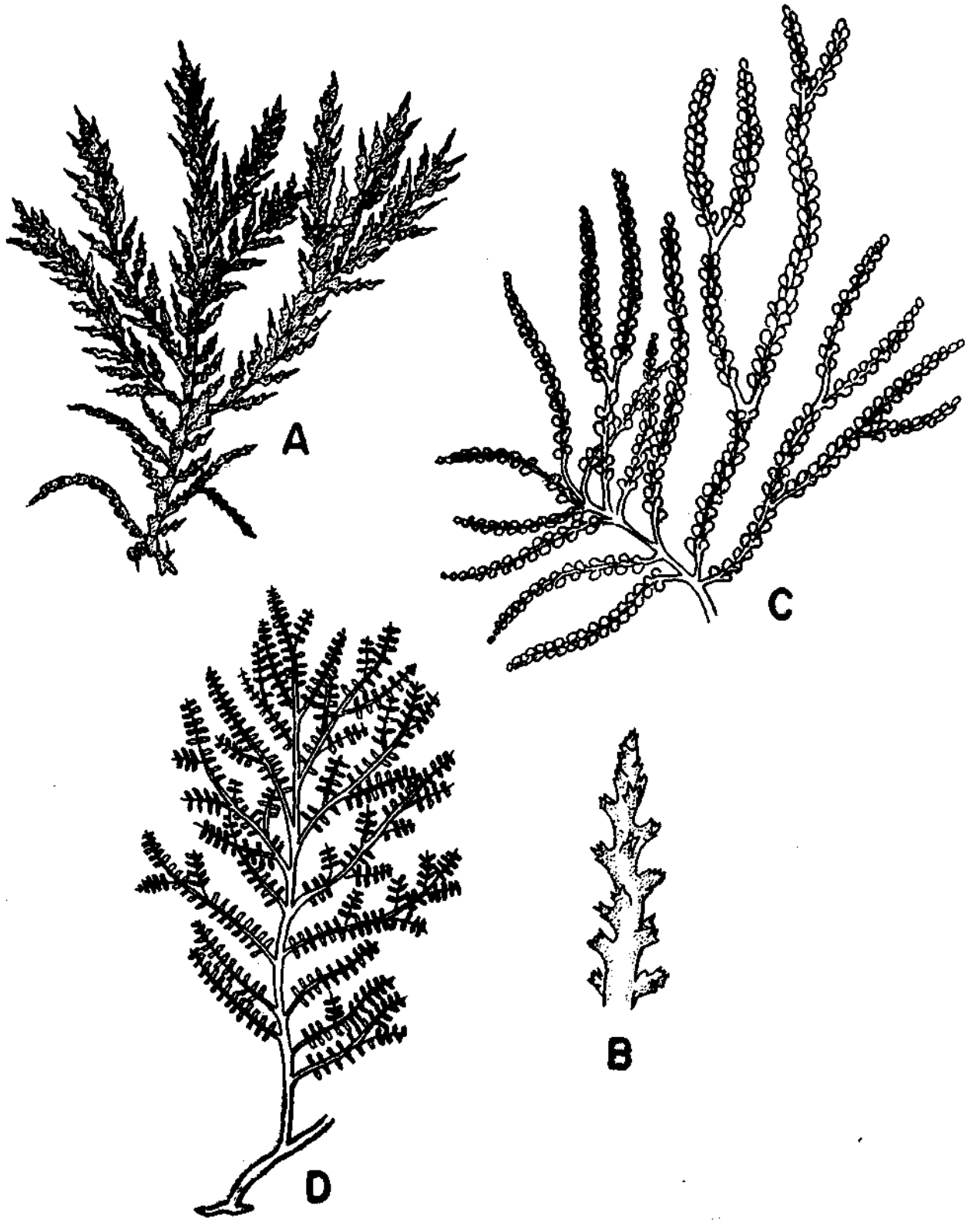
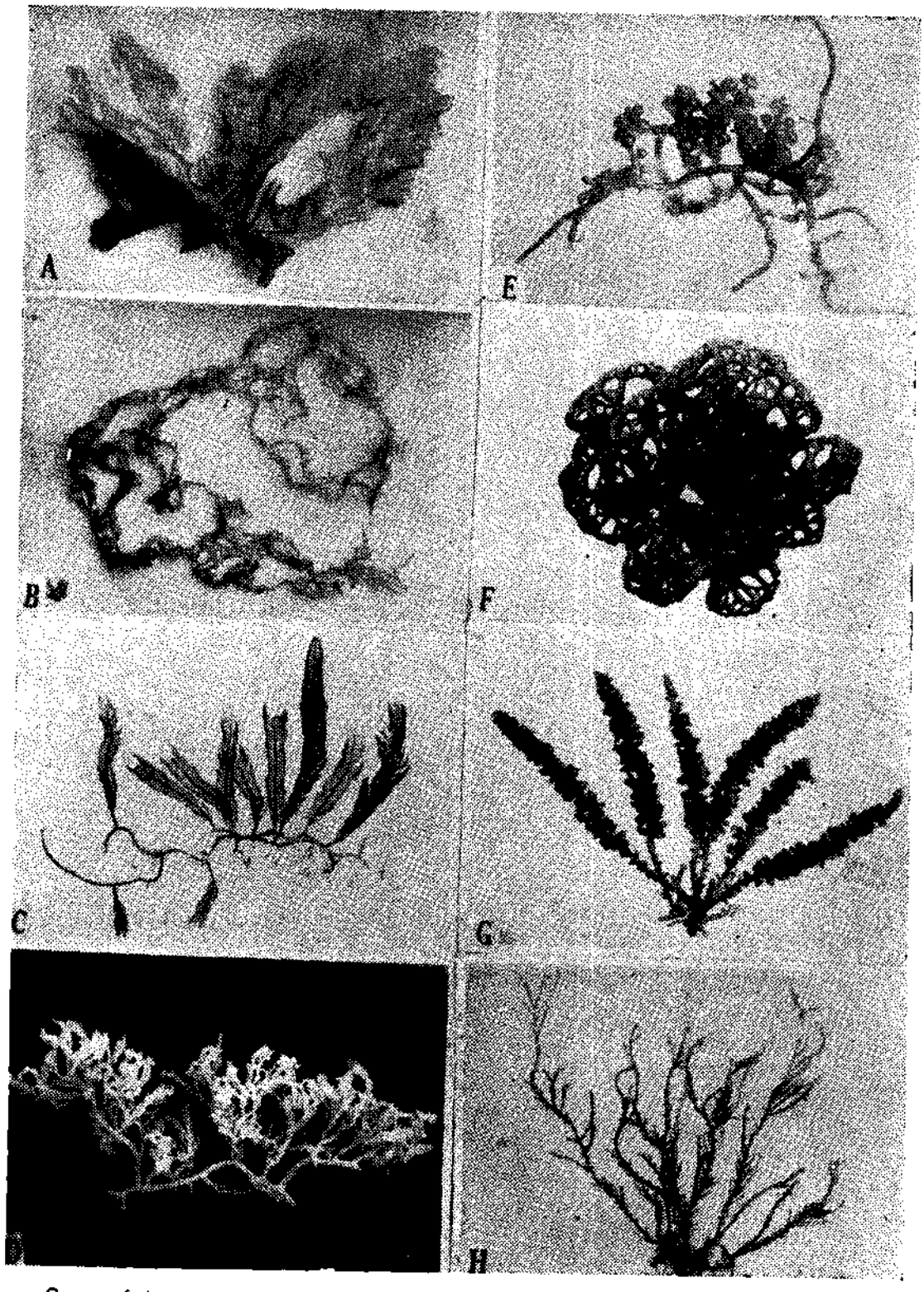
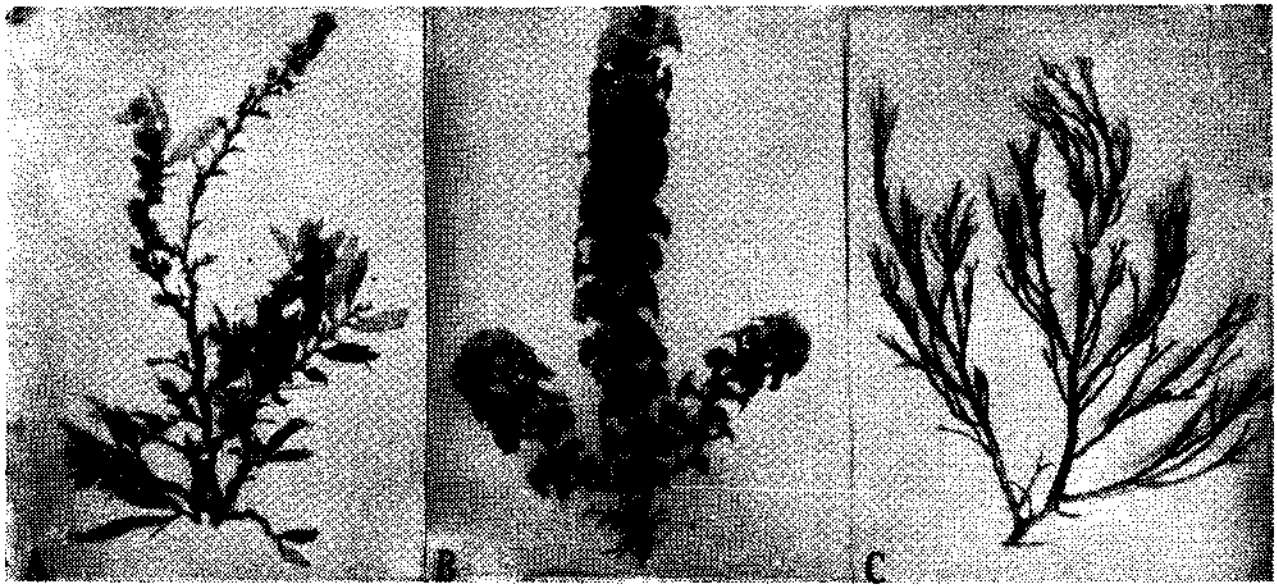


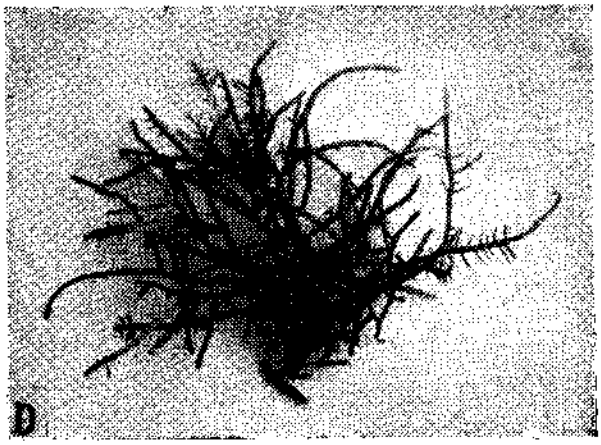
Fig. 14. Red seaweeds of Indian coast (contd.) A. *Acanthophora spicifera* (X 1) B. *Acanthophora spicifera* special part of the plant (X 5) C. *Laurencia papillosa* (X 1.5) D. *Laurencia* obtusa (X 3)

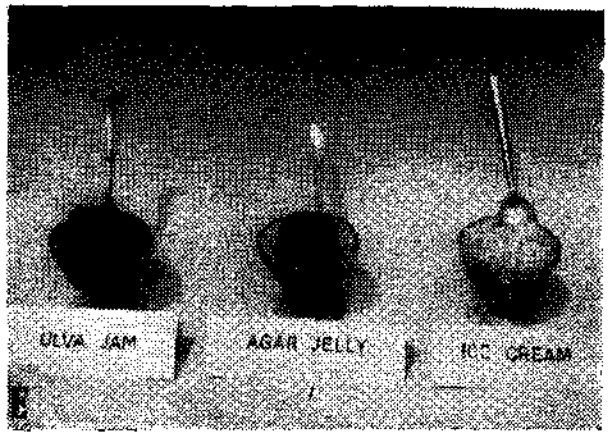
PLATE - I

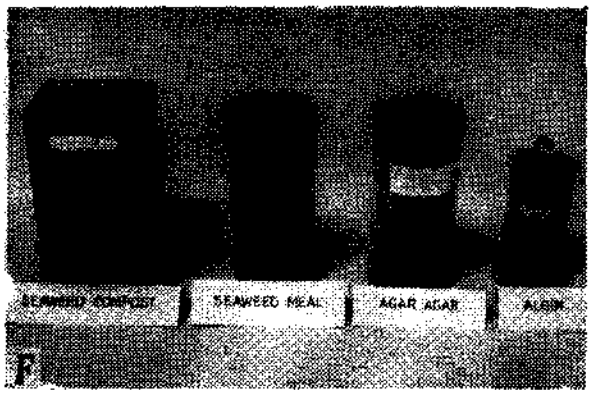


Some of the economically important seaweeds occurring along the Indian coast
A. *Ulva lactuca*, B. *U. reticulata*, C. *Caulerpa sertularioides*, D. *C. serrulata*, E. *C. racemosa*, F. *Hydroclathrus clathratus*, G. *Laurencia papillosa*, H. *Acanthophora spicifera*.



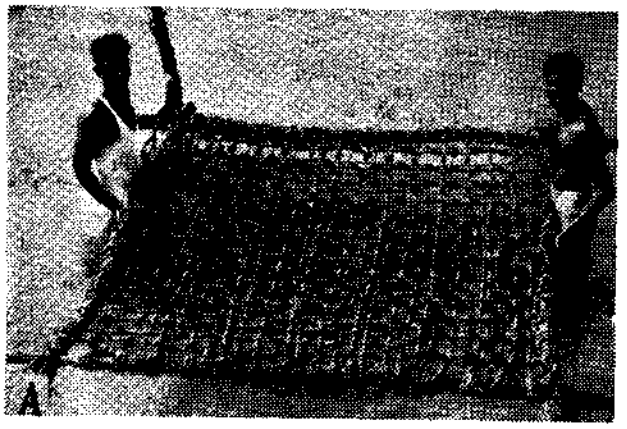


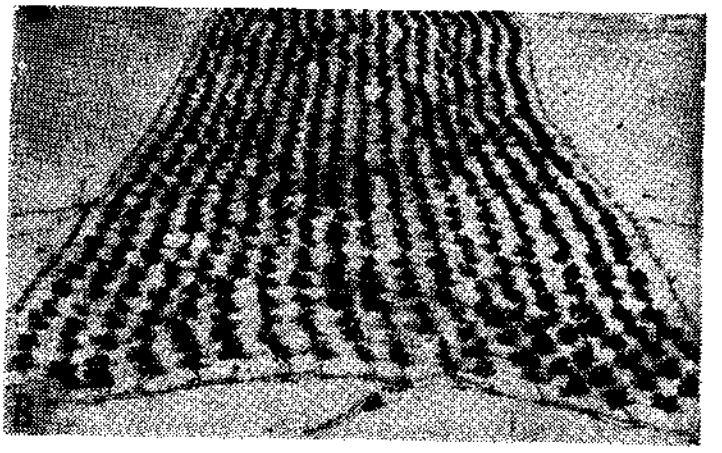


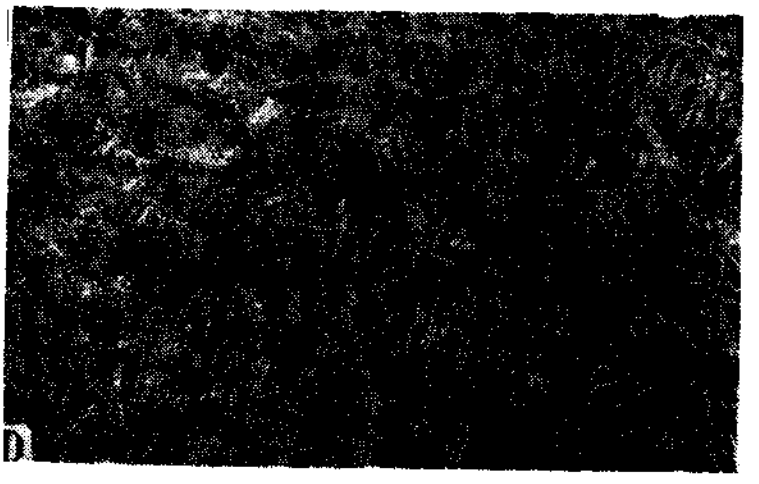


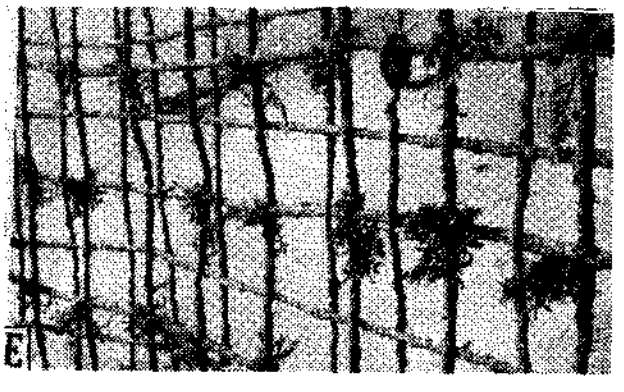
Some of the economically important seaweeds, seaweed products and a stage in processing of seaweeds.

A. *Sargassum wightii*, B. *Turbinaria ornata*, C. *Gracilaria edulis*, D. *Gelidiella acerossa*, E. Food products made out of seaweeds, F. Seaweed products of economic importance, G. *Gelidiella acerosa* plants spread on the beach sand for drying.



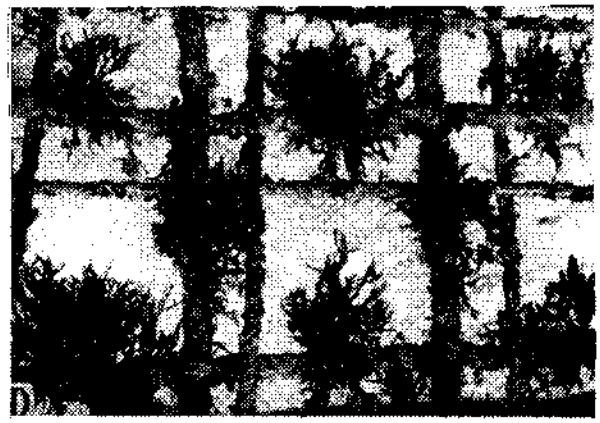






Different stages of seaweed culture:

A. Fragments of *G. edulis* introduced in the twists of the coir rope of 2 x 2m size net.
B. HDP rope net (5 x 2m size) with seed material *(Gracilaria edulis).*
C. 60 days growth of *G. edulis* in coir net of 5 x 2m size
D. A portion of the coir net showing 60 days growth of *G. edulis.*
E. Sprouting *Sargassum weightii* plants from fragments in the coir net.
F. Harvestable size of (5 months growth) plants of *Gelidiella acerosa* on the coral stone



Different stages of seawed culture and a stage in processing the seaweed and storage of them.
A. Seeding of HDP rope net with fragments of *Giacilaria edulis*, keeping the net inside water.
B. HDP rope net showing *Gracilaria edulis* after 70 days growth.
C. Formalin-treated *Sargassum* plants being removed from the tank.
D. 15 days growth of *G. edulis* after introduction in the coir net.
E. Storing of dried *Sargasssum* plants in the shed before marketing.
F. HDP rope culture net showing *Gelidiella acerosa* just before harvest — 60 days growth.

Sargassum and *Turbinaria* spp as raw meterial. Species of *Ulva, Chaetomorpha, Enteromorpha, Caulerpa, Codium, Colpomenia, Hydroclathrus, Rosenvingea, Chnoospora, Porphyra, Halymenia, Grateloupia Gracilaria, Hypnea, Rhodymenia, Centroceras, Acanthophora* and *Laurencia* are being utilized as human food in Japan, China, Korea, Indonesia, Philippines, USA and many other countries, but in India the seaweed as food is yet to be popularised.

Distribution of Seaweeds in India

Along the coastline of India, the littoral and sublittoral rocky areas support a good growth of different seaweeds (agarophytes, alginophytes and other edible seaweeds). There is luxuriant growth of seaweeds along the southeast coast of Tamil Nadu, from Mandapam to Kanyakumari; Gujarat coast; Lakshadweep Island and the Andaman and Nicobar Islands. Fairly rich seaweed beds are present in the vicinity of Bombay, Ratnagiri, Goa, Karwar, Varkala, Kovalam, Vizhinjam, Visakhapatnam and few other places such as Chilka and Pulicat lakes.

The distribution of economically important seaweed resources of India has been mapped by Thivy (1958). Umamaheswara Rao (1969 b and 1972 c) gave accounts on the four most important agar- and algin-yielding seaweeds, *Gracilaria, Gelidiella, Sargassum* and *Turbinaria. Gracilaria edulis* grows in lagoons and protected areas, attached to pebbles and shells in muddy substratum. *G. crassa* grows in shallow nearshore areas and *G. verrucosa* on sandy bottoms of saltwater lakes and other protected areas with its basal part buried in sand or attached to small stones. Many *Gracilaria* species have been reported from localities between Mandapam and Kanyakumari. *Gelidiella acerosa (=Gelidium micropterum)* is found on surf-exposed areas of the coral reef and is therefore restricted to the Mandapam area and northwest part of Kathiawar peninsula, Gujarat (Thivy, 1958). *Turbinaria conoides, T. decurrens* and *T. ornata* need hard substratum and are found mainly on sheltered parts in the two coral reef areas mentioned above. *Gracilaria corticata* and species of *Sargassum, Ulva, Enteromorpha* and *Chaetomorpha.* which thrive in littoral habitats, have a more continuous distribution all along the intertidal rocky areas of the Indian coastline

THREE

KEY FOR IDENTIFICATION OF ECONOMICALLY IMPORTANT SEAWEEDS

M. UMAMAHESWARA RAO

The design of keys for identification of algae is based on the external form with addition of obvious cytological details Form alone can be used for large thalloid algae. Form combined with pigmentation and chromatophore shape can lead to the identification of many algae. It is often necessary to examine the apex of branches to determine the manner of growth. It will be worthwhile to take particular notice of the apices of branches in the red algae since the characteristics of the apex will provide important clues for

identification in that group. I nmany instances, the kind of attachment of seaweed to the substratum is an important generic or specific character and identification may be impossible without a knowledge of it. Unlike the several seed-bearing marine flowering plants, the algae reproduce, with few exceptions, by means of microscopic spores. Although these spores are very small, the reproductive structures which produce them are often large enough to be visible to the naked eye and are useful in providing distinctive characters for identification purposes The habitat of the alga, ie. marine or freshwater, may be of value in identification, but is not a reliable taxonomic character. A key for identification of the economically important genera and species of green, brown and red seaweeds listed in the previous chapter is given below. The external and internal characters of the plants are used in the preparation of this key.

GREEN ALGAE

Key to Genera and Species

1.	Plants multicellular, main fronds and branches consisting of small cells	 2
1.	Plants non-cellular, coenocytic	 3
2.	Plants unbranched with one-cell thick cell rows, filamentous, brush like, attached by long basal cells with constrictions	.. *Chetomorpha antennina* (1)
2.	Plant branched, not filamentous	4
3.	Plants differentiated into roots, horizontal stems and erect foliar elements, branched filaments or trabeculae arising from the inner wall of the fronds	... *Caulerpa* (I)
3.	Plants erect or prostrate with interwoven filaments and enlarged sac-like structures or utricles	... *Codium* (II)
4.	Adult plants usually tubular with one-cell-thick membrane, more or less compressed, profusely branched at the basal parts	... *Enteromorpha compressa* (2)
4.	Adult plants not tubular, flat, foliaceous and thallus two-cell thick	... *Ulva* spp. (III)

I. Key to Species of *Caulerpa*

1.	Erect fronds with much crowded branchlets arising from all sides, branchlets swollen sub-spherical, with or without a stalk	... *C. racemosa*
1.	Erect fronds with branchlets in two rows	 2
2.	Branchlets flat, constricted at the base and sickle-shaped	... *C. taxifolia*
2.	Branchles cylindrical with pointed tips and closely arranged in the form of a feather	... *C. sertularioides*

II. Keys to the species of *Codium*

1.	Plants prostrate with irregularly lobed and spongy thallus, utricles 50-70 μ and rerely 100 μ in diameter	... *C. adharens*
1.	Plants erect and repeatedly branched	2
2.	Plants cylindrical, dichotomously branched and utricles 150-200μ broad	... *C. tomentosum*
2.	Plants compressed, flattening very conspicuous near the forks, utricles 300-500 μ broad	... *C, docorticatum*

III. Key to the Species of *Ulva*

1.	Plants with reticulate or net-like fronds or profusely perforated, often grow inter-mingled with other algae	*U. reticulata*
1.	Plants variously shaped and attached to rocks with definite holdfasts	 2
2.	Fronds delicate, grow as large sheets, cells square or slightly elongated in sectional view of the thallus	. *U. lactuca*
2.	Cells distinctly elongated in sectional view of the thallus	3
3.	Fronds firm and stiff with a distinct holdfast and short cylindrical stipe, usually divided into broad lobes	... *U. rigida*
3.	Thallus divided into narrow ribbon-like lobes (0.5 – 2.5 cm broad) with pale green central portion	... *U. fasciata*

BROWN ALGAE

Key to the Genera and Species

1.	Plants large with leaf-like, stem-like and organs and vesicles or air bladders	 2
1.	Plants small with different shapes of thalli	 3
2.	Vesicles or air bladders immersed in the leaves or branches	4
2.	Vesicles or air bladders not immersed in the leaves	 5
4.	Fronds angular, winged, compressed, often spinulose and irregularly branched	... *Hormophysa triquetra*
4.	Plants attached by branching haptera with turbinate or obconical leaves	.... *Turbinaria* (I)
5.	Vesicles or air bladders single	... *Sargassum* (II)
5.	Vesicles seriate with beaded appearance, stems covered with short processes giving muricated appearance	... *Cystophyllum muricatum*
3.	Plants flat with terminal growth, often 2-4 cells thick, cells regularly arranged in sectional view	 6
3.	Plants not flat with intercalary growth, many cells thick, parenchymatous and cells irregularly arranged	7
6.	Plants ribbon-like, regularly dichotomous with narrow angles of 15°-45° near the forks and long internodes, thallus 3-5 mm broad with entire and somewhat proliferous margins, three cells thick in sectional view, groups of hairs and reproductive structures scattered over the surface of the frond	... *Dictyota dichotoma*
6.	Plants fan-shaped, apical margin of the thallus rolled inward, hairs and reproductive structures arranged in concentric rings	... *Padina* (III)
7.	Plants clathrate, spongy and net-like	... *Hydroclathrus clathratus*
7	Plants not net-like or reticulate	 8

8. Plants somewhat dichotomously branched with slightly compressed and solid axes, axes 2-3 mm broad ... *Chnoospora minima*

8. Plants tubular or hollow 9

9. Plants sac-like, spherical or irregularly lobed with crisp texture, plurilocular sporangia associated with paraphyses ... *Colpomenia sinuosa*

9. Plants profusely and irregularly branched at the upper parts, branches compressed, 2-5 mm broad, sporangia not associated with paraphyses ... *Rosenvingea intricata*

I. Key to the Species of *Turbinaria*

1. Plants simple or moderately branched, leaves densely packed, arising all round the stem, rounded or somewhat triangular in surface view with marginal teeth ... *T. ornata*

1. Plants generously branched, leaves not closely arranged, triangular or heart-shaped with a cylindrical stalk ... *T.conoides*

II. Key to the Species of *Sargassum*

1. Inflorescence mixed with receptacles, leaves and vesicles 2

1. Inflorescence not mixed with receptacles, air bladders and leaves 3

2. Plants with fluted conical holdfast, leaves narrow (1.0-2.5 mm), linear, thick or fleshy with entire margin and blunt tips, vesicles oval or elliptic, receptacles simple or unbranched and somewhat spindle-shaped ... *S. johnstonii*

2. Plants delicate with a disc-shaped holdfast, leaves broad (3-5 mm), thin, translucent with somewhat dentate margins, vesicles spherical, receptacles single or branched and spinose ... *S. tenerrimum*

3. Stems and branches somewhat flattened with smooth surface, vesicles or bladders large, ellipsoidal or oval on flattened petioles of stalks 4

3. Stems and branches densely covered with short processes or muricate, vesicles small, 1-2 mm broad and densely crowded, leaves 2 cm long and 0.5 cm broad below, smaller above with dentate margin, receptacles somewhat spinulose and very much ramified ... *S. myriocystum*

4. Receptacles in clusters, repeatedly branched with corymbose or tassel-shaped appearance ... *S. wightii*

4. Receptacles not repeatedly branched and not having tassel-like appearance ... *S. swartzii*

III. Key to the Species of *Padina*

1. Fructiferous organs found on both sides of a row of hairs, thallus usually four cells thick ... *P. tetrastromatica*

1. Fructiferous organs not found on both sides of the rows of hairs, thallus two to three cells thick 2

2. Sporangia found just above the rows of hairs ... *P. commersonii*

2. Sporangia present at the central part of the thallus occurring in between the rows of hairs ... *P. gymnospora*

RED ALGAE

Key to the Genera and Species

1. Plants multicellular with one-cell thick and flat thallus, dark violet to mahogany-red in colour, cells with stellate contents, fronds with spinous margin ... *Porphyra vietnamensis*

1. Plants multicellular, the whole plant or parts of the plant consisting of a single row of cells 2

1. Plants multicellular, the whole plant or parts of the plant many cells thick, often differentiated into a central medulla and outer cortex 3

2. One-cell thick and branched filaments or trichoblasts present at the apical parts of the main axes and branches, thallus parenchymatous with uniform sized cells, tetrasporangia at the terminal portions of the branches or formed branchlets, immersed in the thallus 4

2. Thallus with one cell thick main axis which is clearly visible in sectional view, covered with cortical cells, tetrasporangia formed at the nodes often in whorls, not immersed in the thallus 5

4. Plants coarse with small and spinous branchlets alternately and spirally arranged, growing apex protruded, spermatangial clusters plate-like ... *Acanthophora spicifera*

4. Plants erect and bushy, more or less fleshy consistency, cylindrical or compressed, growing apex in sunken pits, antheridial clusters present in the enlarged apical pits of the fertile branchlets ... *Laurencia* (I)

5. Plants small 3-8 cm in height, filamentous, dichotomously branched, rhizoids one-cell thick, main axes completely covered by vertical rows of cortical cells, spines arranged in whorls at each segment .. *Centroceras clavulatum*

5. Plants 10-20 cm or more in height, irregularly and alternately branched, main axis and branches corticated, thickly covered by rhizoidal filaments, ultimate branchlets uniseriate or one-cell thick with small cortical bands at the nodes, internodes colourless, spines often present at the tips of branchlets ... *Spyridia* (II)

3. Medulla or central part of thallus filamentous 6

3. Medulla cellular, not filamentous 7

6. Plants small, entangled, dark or blackish red in colour, irregularly branched, with cylindrical axes, outer portion of thallus or cortex consisting of anticlinal branched rows of cells, tetrasporangia in sori or in groups ... *Gigartina acicularis*

6. Plants large, stellate or star-shaped cells present between the cortex and filamentous medulla, tetrasporangia not in sori but scattered in the cortex of the thallus 8

8. Plants firmly gelatinous, flat or cylindrical, pinnately or radially branched, cortex in sectional view consisting of small anticlinal rows of cells ... *Grateloupia* (III)

8. Plants large, flat, soft and gelatinous, rose-red in colour and pinnately branched, cortex parenchymatous, not arranged in regular rows ... *Halymenia floresia*

7. Central axis clearly visible in the sectional view of mature thallus, plants irregularly branched in all directions, and abundantly covered with short branchlets or ramuli, terminal portions of the branches twisted as tendrils, tetrasporangia zonate ... *Hypnea musciformis*

7. Central axis not clearly visible in the sectional view of mature or fully grown fronds 9

9. Thallus with a medulla of very small cells, cortical cells larger than the medullary cells, plants dichotomously branched, brick-red or yellowish-red in colour, tetrasporangia zonate ... *Sarconema furcellatum*

9. Medullary cells larger than the peripheral or cortical cells, ... 10

10. Plants tufted, wiry, erect axes sparsely branched, provided with short determinate branchlets, 2-6 mm long, spirally or pinnately arranged, medulla with thick walled cells, 18-30 mm in diameter, tetrasporangia in swollen branchlets ... *Gelidiella acerosa*

10. Plants large, flat or cylindrical, with a medulla of large colourless cells 100-500 mm in diameter, tetrasporangia scattered in the cortex of the fronds 11

11. Cystocarps with a parenchymatous gonimoblast arrounded by carpospores, nutritive filaments present connecting the genimoblast tissue and the pericarp ... *Gracilaria* (IV)

11. Cystocarps with a mass of carpospores arising from thread-like structures, pericarp loose; plants up to 20 cm tall, di- or subdichotomously branched, 3-7 mm broad, proliferations arising from the basal parts of the thallus ... *Rhodymenia dissecta*

I. Key to the Species of *Laurencia*

1. Plants cartilaginous, firmly attached to rocks by a broad disc, main axes and branches densely covered by short wart-like branchlets, 2-4 mm broad, peripheral cells of the thallus radially elongated ... *L. papillosa*

1. Plants soft, attached by small discs or rhizoids, cylindrical and filiform, pinnately and multifariously branched, ultimate branchlets clavate, thallus 1-2 mm broad, peripheral cells not radially elongated ... *L. obtusa*

II. Key to the Species of *Spyridia*

1. Plants bushy, ramified on all sides with long and cylindrical branches, branches not constricted near the base ... *S. filamentosa*

1. Plants closely branched at the upper parts, articulate, main axes moniliform, lateral branches short, fusiform and very much constricted near the base ... *S. fusiformis*

III. Key to the Species of *Grateloupia*

1. Plants 10–25 cm tall, bushy with cylindrical and rarely compressed axes, pinnately, alternately and irregularly branched, fronds 2-3 mm compressed in diameter, filiform ... *G. filicina*

1. Plants 10-12 cm tall, firmly attached to rocks, thallus compressed, 0.25 to 1.0 cm broad, sinuate, simple and pinnately branched ... *G. lithophila*

IV. Key to the Species of *Gracilaria*

1. Plants compressed or flat 2

1. Plants cylindircal 3

2. Plants regularly dichotomous with thick and cartilaginous fronds, margins entire, rarely proliferous .. *G. corticata*

2. Plants polychotomously, irregularly and sometimes pinnately branched with thin and brittle fronds, margins proliferous ... *G. foliifera*

3. Plants small, succulent, sometimes constricted, branches upto 4.0 mm in diameter, arched and decumbent, developing haptera on reaching the substratum ... *G. crassa*

3. Plants not succulent, 30 cm or more in height, fronds thin, 2-3 mm in diameter 4

4. Plants alternately, irregularly branched, branches hardly constricted, tetrasporangia surrounded by unmodified cortical cells ... *G. edulis*

4. Plants irregularly and multifariously branched, often grow up to 2.0 m in length, branches contricted below and tapering above, sometimes provided with short and spindle-shaped branchlets, tetrasporangia in slightly modified cortex, antheridia in deep cavities ... *G. verrucosa*

COMMON SEAWEED PRODUCTS

V. S. K. CHENNUBHOTLA, N. KALIAPERUMAL AND
S. KALIMUTHU

The seaweeds are the only source for agar and algin. They are also used as food material, livestock feed and fertilizer in many parts of the world. The various products obtained from Indian seaweeds and their uses are dealt with here.

Agar-Agar

Agar-agar is a gelatinous substance obtained from the red algae like *Gelidium, Gelidiella* and *Gracilaria* . and has a great commercial value. Agar is a colloidal carbohydrate present in the cell walls of some red algae and is a mixture of two polysaccharides, agarose and agaropection. Humm (1951) and Yaphe (1959) have defined agar as a gel-forming substance soluble in hot water and requiring one percent solution to set as a gel on cooling.

The important and commonly occurring agarophytes of India are *Gelidiella acerosa, Gracilaria edulis, G. crassa, G. verrucosa, G. corticata* and *G. foliifera.* The yield and physical properties of agar extracted from these red seaweeds are given in the Appendix. Among these seaweeds only *Gelidiella acerosa, Gracilaria, edulis* and *G, crassa* are used at present as raw material for the production of agar-agar in India, since the yield and quality of agar are good and the plants are also available in harvestable quantities.

Agaroids

The gel-like extracts produced from certain types of red seaweeds are commonly known as agaroids. Carrageenan obtained from *Chondrus, Gigartina* and *Eucheuma* species come under this group. The organic sulphate content is very much higher in these compounds and the chemical nature and properties of agaroids vary from that of agar. Pure solutions of agaroids are viscous and do not form gel when cooled. However, various inorganic and organic solutes alter the properties and increase the gelling bower of agaroids.

Carrageenan-yielding plants have not been reported from Indian waters except tor a rare and less abundant species, *Gigartina acicularis,* occurring in the intertidal region. But *Hypnea musciformis,* other species of *Hypnea, Spyridia. Sarconema, Acanthophora, Laurencia* and *Chondria* growing along the Indian coast give gel-like extracts.

Algin or Alginic Acid

Algin is the main polysaccharide occurring in the cell walls of brown algae. It consists of D-mannuronic acid and 2-guluronic acid in various proportions. The sodium, potassium and magnesium salts of alginic acid are soluble in water and they give viscous solutions without gel formation. Calcium alginate and other salts of copper, cobalt, mercury, etc are insoluble in water.

Species of *Sargassum, Turbinaria, Dictyota, Padina, Cystoseira, Hormophysa, Colpomenia, Spatoglossum* and *Stoechospermum* are some of the algin-yielding seaweeds occurring in Indian waters. The alginic acid content of these seaweeds is given in Table 10. Of these, *Sargassum* and *Turbinaria* are utilised as raw material for the manufacture of algin in India, since they are high-yielding varieties and also available in large quantities.

Uses of Agar and Algin

Agar and algin are used in food, confectionary and dairy industries as gelling, stabilising and thickening agents, mainly in the manufacture of sweets, jellies, ice-creams, sherbats etc. They are also useful in a number of other industries.

Agar : Agar is extensively used in the making of food and medicines. The best known use of agar is as a solidifying agent in media used in bacteriological culture. It is also used as a stiffening agent in a number of food products, as a sizing material, and mucilage and in clarifying liquors. With its quality of keeping substances in suspension it goes in the manufacture of various pharmaceutical preparations, photographic film coatings and paints. It is employed in canning meat and in poultry, in laxative preparations, as a constituent of medical pills and capsules, in numerous pharmaceutical and cosmetic creams and jellies, as a dental-impression mould and as a lubricant for drawing tungsten in electrical bulbs.

Aalgin : Algin is also equally and extensively used in the preparation of various pharmaceutical, food and rubber products (natural and synthetic latex creaming and thickening, finished articles, automobile carpetting, electrical insulations, foam cushions, and rubber coating on tyres), textile products (size compound for cotton and rayon, textile print pastes and plastic laundry starch), adhesives (for all boards, paper bags, shipping containers, gummed tapes), paper products, food packages, pharmaceutical and detergent, packages, milk containers, butter cartons, frozen food packages, insulation boards, food wrappers, greaseproof paper and acoustical tiles) and miscellaneous products (paints, ceramic glazes, porcelain wares, leather finishers, autopolishes, welding-rod coatings, boiler compounds, batteryplate separators, wall-board-joint cement, beet-sugar processing and wax emulsions).

Some of the food products requiring agar and their method of preparation (Thivy, 1958) are given in Table 1.

Table 1

Food products requiring agar
(From Thivy, 1958)

Food stuff	Quantity of agar used	Method of addition
Ice-cream	1/8 teaspoonful (½ g) per cup of ice-cream mix.	Dissolved in boiling water and added to warm ice-cream mix (Prevent it from melting soon)
Tomato sauce	½ teaspoonful (1 g) per 1b. of tomato sauce	Dissolved in boiling water and added to the sauce towards the end. boiling after adding agar should be avoided.
Jams, jelly, Marmalade	One level teaspoonful (2 g) per 1b. of these	Dissolved in boiling water and added to the sauce towards the end. Boiling after adding agar should be avoided.
Blancmange (without corn flour)	1½ level teaspoonful (3 g) per cup of milk with sugar	Dissolve agar in a small amount of water in a double boiler and pour in to warm milk, not vise versa.
Lime jelly	1½ level teaspoonful (3 g) per cup of water with sugar and lime juice	Dissolve agar in the water in a double boiler, add sugar and strain; keep aside and then, when somewhat cool, add lime-juice and pour into mould.

Algal Proteins

Some green and red seaweeds such as *Ulva fasciata, U. rigida, Porphyra vietnamensis* and *Centrocer asclavulatum* contain very rich proteins. These algal proteins have many essential amino acids including iodine-containing amino acids. Studies revealed that these seaweeds contain 16-30% of protein on dry weight basis and this amount is somewhat higher than that in other food materials such as cereals, eggs and fish (Visweswara Rao, 1964). Protein can be extracted from these seaweeds and as such dry powders of *Ulva, Porphyra, Acanthophora* etc. can be added to various foods deficient in protein or taken along with other food stuffs in small quantities.

Seweed as Food

Fresh, dried and processed seaweeds are utilised for human consumption. The algal carbohydrates are not easily digestible and the food value of the seaweeds depends on the minerals, trace elements, proteins and vitamins present in them. Many seeweeds such as species of *Caulerpa, Codium, Hydroclathrus, Sargassum, Porphyra, Gracilaria, Acanthophora* and *Laurencia* are used as food in Japan, Indonesia, China, Philippines and other countries of Indo-Pacific regions (Subba Rao, 1965; Levring *et. al,* 1969; Michanek, 1975 and Chapman and Chapman, 1980). They are eaten as salad, curry, soup or vegetables. There are large industries in Japan using edible seaweeds like *Porphyra. Thin* algal sheets are prepared by washing and drying *Porphyra* plants and this forms an important food item in Japan.

Some of the edible seaweeds occurring in different localities along the Indian coast are species of *Ulva, Enteromorpha, Chaetomorpha, Caulerpa, Codium, Dictyota, Padina, Colpomenia, Hydroclathrus, Rosenvingea, Chnoospora, Sargassum, Turbinaria, Porphyra, Halymenia, Grateloupia, Gracilaria, Hypnea, Rhodymeina, Centroceras, Acanthophora,* and *Laurencia.* The important edible red seaweed *Porphyra* has been reported from Madras (Boergesen, 1937 b), Visakhapatnam and Cape Comorin (Umamaheswara Rao and Sreeramulu, 1963 and Umamaheswara Rao, 1973) and Goa Coast (Dhargaikar *et. al.,* (1981). The methods of preparing different recipes from seaweeds are given in detail by Chennubhotla *et. al.* (1981). The seaweed *Gracilaria edulis* is being used since decades for making gruel in the coastal areas of Tamil Nadu.

Seaweed Meal

Seaweeds are cheap sources of minerals and trace elements. Hence the meals prepared from seaweeds can be given as supplements to the daily rations of the cattle, poultry and other farm animals, Seaweed meal can be obtained by grinding cleaned and washed seaweeds such as *Ulva, Enteromorpha, Sargassum, Padina, Dictyota, Gracilaria* and *Hypnea.* Thivy (1960) has described a simple method for the preparation of seaweed meal from *Gracilaria edulis (—G. lichenoides).* Seaweed meal can also be mixed with fish meal and used as a poultry feed. Seaweeds have been utilised as animal feed in some countries. Dave *et. al.* (1977) assessed the possibility of seaweeds being used as supplementary animal feed and they reviewed the feeding trials of animals with seaweeds conducted in Japan, Germany, U. K.. Norway and other countries. The seaweed meal prepared from *Sargassm* and the results of its feeding trials on chicks, sleep and cattle are given by Dave *et. al.* (1979). Studies on feeding *Gracilaria* meal to white leghorn egg laying birds were made by Chaturvedi *et. al.* (1979), to find out the effect of algal-feed on the contents of egg. The results of this feeding experiment indicated that there was no significant difference in the number of eggs produced, total egg mass, internal quality of eggs and the body weight of the birds in the conventional ration group and those kept on ration with 5 and 10% *Gracilaria* meal. The *Gracilaria* meal at the level of 10% can be included in the ration of egg-laying birds, replacing yellow maize Feeding trials replacing ragi (*Eleusine* coracana) with 0, 5, 10 and 15% of seaweed were conducted in unsexed day-old white leghorn chicks (Jagannathan and Venkatakrishnan. 1979) using six species of seaweeds commonly available in Tamil Nadu coast. 120 to 240

numbers of chicks were randomly allotted to the four diets with three to six replicates in each treatment. The trails were run for ten weeks. It is found that all these six seaweeds, particularly *Hypnea musciformis* and *Gracilaria edulis*, can be beneficially used to replace ragi at 5% level.

Seaweed Manure

Use of seaweeds as manure is a common practice in coastal areas throuhout the world. In India it is used for coconut plantations especially in coastal Tamil Nadu and Kerala. The high amount of water soluble potash, other mineral and trace elements present in seaweeds are readily absorbed by plants and they control deficiency diseases. The carbohydrates and other organic matter present in seaweeds alter the nature of the soil and improve its moisture retaining capacity. Hence, large quantities of seaweeds including seagrasses such as *Cymodocea*, *Diplanthera*, *Enhalus* and *Halophila* can be used as manure in all parts of the country either directly or in rhe form of compost. A method for composting the seaweeds with cowdung has been described by Thivy (1958 and 1960). In the field trials conducted at the Central Marine Fisheries Research Institute, *Hypnea* compost when applied to bhendi, induced 73% increase in yield compared to cowdung and wood ash. Good results were also achieved with brinjal, tapioca, clustered beans, beans gouards, Amaranthus, Virdis lime, papaya and drumstick when manured with seaweed compost. Crotons and zinnias also grew well with seaweed treatment (Thivy, 1960). The nitrifiability of organic nitrogen from *Ulva lactuca* and drift seaweeds from Veraval was studied and found to be high compared to farmyard manure or a few other organic manures (Mehta *et. al.*, 1967). Application of seaweed manure can maintain a high level of available nitrogen in soil. The easy decomposability of seaweed organic matter is beneficial for the growth of soil micro organisms. According to these authors, seaweeds, especially the drift seaweed, which is a mixture of a variety of species cast ashore, can be a promising supplementary organic manure. The results of seaweed manurial trials on *Pennisetum typhoides* (pearl millet) and *Arachis hypogea* (ground nut) are reported by Bokil *et. al.* (1972). The application of seaweed manure along with inorganic fertilizers have improved the quality of the produce. The use of seaweed manure had no significant influence over the yield of *Pennisetum typhoides* But the quality of its grains and fodder was favourably influenced. In the experiments on *Arachis hypogea* seaweed manure was comparable to that of farm yard manure and in general the performence of treatments in which seaweed manure was included was better than other treatments. With a view to find out the effect of seaweed manure on the uptake of inorganic nutrients by the wheat plant, a pot culture experiment was conducted (Bokil *et. al.*, 1974). The performance of the seaweed manure was found to be superior to the conventional manures, the performance of the seaweed manure is significantly better than that of farm yard manure due to the easy decomposibility of its carbonaceous matter and presence of micro-nutrients. The performance of brown seaweed manure, which contains higher proportion of alginic acid and analogous compounds, is relatively superior to that of drift seaweed manure with respect to both the yield and quality attributed. Regarding the quality of grains, the use of brown seaweed manure in conjunction with the inorganic fertilizers is significantly better than the others. Bhosle *et. al.* (1975) studied the seaweed extract on the growth of *Phaseolus vulgaris*. Marine algal extracts obtained from *Spatoglossum asperum*, *Ulva fasciata* and *Enteromorpha intesstinalis* were found to promote germination in seeds and growth of seedlings of gram, ground nut and maize (Bukhari and Untawale, 1978). Dilute extracts were found to be more effective than the concentrated extracts. Foliar spray of *Spatoglossum* extract caused in an increase in the leaf size and better growth in *Hydrangia* sp. The method of preparation and properties of liquid seaweed fertrilizer from *Sargassum* was given by Sreenivasa Rao *et. al.* (1979 a).

Seaweed as a Source of Energy

Sreenivasa Rao *et. al.* (1979 b) have conducted experiments on production of fuel gas for domestic use, utilizing *Sargassum* as raw

material. Digester design and operating parameters are given. According to them a mixutre of about six micro-organisms mostly derived from marine environments were used in digesters. Addition of indole acetic acid stimulated anaerobic digesters. Salinity of the liquid above 20% was stated to be detrimental to production of fuel gas.

Medicinal Uses of Seaweeds

Seaweeds were considered to be of medicinal value in the Orient as early as 3000 B. C. The Chinese and Japanese used them in the treatment of goitre and other glandular diseases. Although the Romans believed seaweeds to be useless, they also used them to heal wounds, burns, scurvy and rashes. The British used *Porphyra* to prevent scurvy during long voyages.

Various red algae (particularly *Corallina officinalis, C. rubens and Alsidium helimintho-corton*) were employed as vermifuges in ancient times. Dulse is reported to be a laxative and also used to reduce fever. Several red algae (including *Chondrus crispus, Gracilaria, Gelidium* and *Pterocladia*) have been used to treat various stomach and intestinal disorders. The algae apparently absorb enough water and its water content helps relieving constipation and other associated discomforts. The stipes of *Laminaria cloustoni* have been used to aid in child birth by distending the uterus during labour. A number of species of marine algae have been found to have anticoagulant and antibiotic properties. Carrageenan may be useful in ulcer therapy and the alginates are found to prolong the "rate of activity" of certain drugs (Mathieson, 1969). Species of *Sargassum* were used for cooling and blood cleaning effect. *Hypnea musciformis* was employed as vermifuge or worm expelling agent and *Centroceras clavulatum* as cathartic agent. The iodine rich seaweeds such as *Asparagopsis taxiformis* and *Sarconema* can be used for controlling goitre disease caused by the enlargement of thyroid gland (Umamaheswara Rao, 1970).

Though the importance of different seaweed products in pharmacology is known, the development of antimicrobial, antifungal and antiviral substances from seaweeds is still in an initial stage of research and development. Extracts from *Chondrus crispus* and *Gelidium cartilagineum* have been found to be active against influenza B and mumps virus, (Garber *et, al.*, 1958). Henriquez *et al* (1979) assayed 33 species of Chilean marine algae for their antibacterial activity against *Sarcina lutea* ATCC 001, *Staphylococcus aureus* ATCC 65388 and *Bacillus subtilis* ATCC 6633. Some degree of antibacterial activity was found to be present in 17 of these 33 extracts. Caccamese *et. al.* (1980) tested the lipid extracts of more than 20 algae from eastern Sicily for antimicrobial activity against tobacco mosaic virus Some of them mainly belonging to Dictyotales were found to be active. Caccamese *et. al.* (1981) tested lipid extracts of 13 algae from Eastern Sicily for antimicrobial activity against *Bacillus subtilis* and *Phoma tracheiphila* and for antiviral activity against tobacco mosaic virus. *Zanardine prototypus* and *Cystoseira balearica* exhibited the best antimicrobial and antiviral activity among the species tested. Blunden *et. al.* (1981) examined the extracts of British marine algae for anti-influenza virus activity based on nhibition of influenza neuraminidese. The antibacterial and antifungal activity of Indian seaweed extracts (Sreenivasa Rao *et. al.*, 1979 c; Sresnivasa Rao and Shelat, 1979 and Sreenivasa Rao and Parekh, 1981) and also the effect of seaweed extracts on *Mycrobacterium tuberculosis* (Sreenivasa Rao *et. al.*, 1979 d) have been studied. Antibiotic substance isolated from *Enteromorpha* effected complete inhibition of growth of the tubercle bacilli in the cultures. Naqvi *et. al.*, (1981) examined the extracts of 25 seaweeds from Indian coast for antiviral, antibacterial, antifungal, antiprotozoal, antifertility activities and a wide range of pharmacological activities. Significant biological activity was obtained in 13 species of seaweeds, the most promising activity being 100% antifertility (anti-implantation) activity observed in 3 species namely *Padina tetrastromatica, Gelidiella acerosa* and *Acanthophora spicifera*.

FIVE

CHEMICAL COMPOSITION OF SEAWEEDS

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Considerable work has been done on the chemical aspects of Indian seaweeds during the last three decades, of which those up to 1970 have been reviewed by Umamaheswara Rao (1970). In this chapter the information so far collected on the mineral constituents, carbohydrates and other chemicals is presented.

Mineral Constituents

As seaweeds are utilized as food and fertilizer, many studies have been made on their chemical composition, such as by Chidambaram and Unny (1947 and 1953) and Joseph et al (1948). Chidambaram and Unny (1953) have analysed *Sargassum, Turbinaria* and *Gracilaria* collected from Madras for estimating the gross contents such as moisture, soluble and insoluble materials and protein. The compositions as given by them are as follows:

	Sargassum	*Turbinaria*	*Gracilaria*
Moisture (in air-dried material)	11.7%	6.13%	10.71%
Loss on ignition	61.63%	63.07%	71.59%
Insolubles	0.17%	0.50%	2.41%
Solubles	26.4%	30.30%	15.29%
Nitrogen	1.02%	0.96%	1.48%

In the Central Marine Fisheries Research Institute, studies were carried out on the chemical composition of the marine algae growing in the vicinity of Mandapam (Pillai 1955 a, 1956 and 1957 a, b). Detailed information was gathered on the water-soluble minerals, trace elements (Pillai 1956), different forms of sulphur and nitrogen and aminoacids (Pillai 1957 a, 1957 b) occurring in elevan green, brown and red seaweeds, namely *Chaetomorpha linum, Enteromorpha intestinalis, Gracilaria lichenoides* (= *G. edulis*), *Chondria dasyphylla, Acanthophora spicifera, Laurencia papillosa, Hypnea musciformis, Sarconema furcellatum, S. filiforme, Rosenvingea intricata* and *Padina tetrastromatica*. Sitakara Rao and Tipnis (1967) analysed ten species of marine algae of the Gujarat coast Recently Zingde et al (1976) studied the distribution of a few trace elements such as arsenic, copper, zinc and manganese in marine flora and fauna of Goa. Parekh et al (1977) studied the chemical composition of 27 species of green seaweeds of Saurashtra coast. Significant variations in chemical composition were observed among the different genera of seaweeds. The same species collected from different localities at different periods also showed considerable variations. The biochemical contents of *Ulva lactuca, Sargassum swartzii* and *Gelidiella acerosa* from Port Okha were studied in relation to eclogical factors by Murthy and Radia (1978), and presented the month-wise protein, fat carbohydrate, crude-fibre, sodium, potassium, calcium and phosphorus contents of these species. Dhargalkaar (1979), estimating the major metabolites such as proteins, carbohydrates and lipids, found carbohydrate decreasing in *Ulva reticulata* in December, probably due to the spore formation and extensive growth of thallus. Protein values also followed the same trend while lipid did not show any significant seasonal variation. But C:N ratio and protein values showed inverse relationship. Seventeen species of marine algae collected from five localities

of Goa were analysed by Agadi et al (1978) for Co, Cu, Fe, Mn, Ni, Pb and Zn. All the seven metals showed considerable variations in their concentration. Seasonal variations in biochemical composition of some seaweeds from Goa coast was followed by Sumitra Vijayaraghavan et al (1980). She found that the carbohydrate contents in *Chaetomorpha media, Dictyota dichotoma, Ulva fasciata, Padina tetrastromatica, Hypnea musciformis* and *Gracilaria corticota* were almost similar, whereas caloric content, organic carbon and lipids were high in *Hypnea musciformis* and protein was rich in *Padina tetrastromatica Chaetomnrpha media* and *Ulva fasciata*. The biochemical constituents in these species in general did not show marked seasonal variations owing to the like reproductive pattern of the algae. Dhargalkar et al (1980) estimated protein. carbohydrate and organic carbon in 43 marine algal species from different stations along the Maharashtra coast. These species showed variation in their biochemical contents. Protein varied from 10% to 33%. Compared to brown algae, the green and red algae were rich in protein and carbohydrate. Chlorophyceae had the maximum organic carbon, average value being 33% . C:N ratio varied from 5.2 to 29.8 and showed inverse relationship with protein.

Solimabi et al (1980) studied the seasonal changes in biochemical constituents namely carbohydrate, protein ond sulphate of *Hypnea musciformis* from Goa coast. Carbohydrate varied from 31% to 50% with maximum values in October, November and May and minimum in January and February. Protein ranged from 9.92% to 17% and showed a gradual increase from October to May. The sulphate content varied from 12.48% to 20.8% with the peak value in January.

Neela (1956) estimated the protein, fat calcium, phosphorus, iron, iodine and vitamin-C contents in *Gracilaria* sp., *G. lichenoides, Hypnea* sp. and *Ulva lactuca*. The chemical composistion of *Porphyra* growing on Visakhapatnam coast has been worked out by Tewari et. al (1968), comparing with that of Japanese species. Results obtained on the major constituents and trace elements of algae studied by these workers are shown in Tables 2 and 3. Pillai (1956) and Sitakara Rao and Tipnis (1967) estimated the water-soluble constituents from dry algae and Kappanna and Visweswara Rao (1963) from the ash of the algae.

Seaweeds like *Sargassum* and *Turbinaria* composted with fishoffal and shark-liver oil sediments in the ratio 15: 3: 4 by weight for a period of three months (Chidambaram and Unny 1947) showed that they contained 2.4% nitrogen, 3.5% potash and 0.7% phosphate. The nitrifiability of the organic nitrogen from *Ulva lactuca* and drift weeds collected from Veraval were studied by Mehta et al, (1967). Pillai (1955 b) carried out some interesting experiments to study the influence of water soluble extracts of seaweeds on the growth of blue-green algae. In these investigations considerable increase in growth was noticed when extracts of *Gracilaria lichenoides, Chondria dasyphylla* and *Hypnea musciformis* were added to the blue-green algal cultures.

Other chemical studies on Indian seaweeds are those of Langalia et al (1967) on the alkali contents of marine algae and Sitakara Rao and Tipnis (1967) and Dhandhukia and Seshadri (1969) on the arsenic content of seeweeds. Higher concentrations of arsenic, ranging from 14-68 ppm, were reported from brown algae whereas less than 1-2 ppm were observed in green and red algae (Dhandhuria and Seshadri 1969). Information regarding the naturally occurring radioactive substances in species of *Enteromorpha, Caculerpa* and *Gracilaria* was given by Unni (1967).

Quantitative Changes in Mineral Constituents

Marked changes in the chemical constituents were found to occur with change of seasons, environmental conditions as well as in the various phases of the plant's growth and fruiting cycle. Pillai (1956; 1957 a, b) studied the seasonal variations in the major and minor constituents of 11 green, brown and red algae. The maximum values obtained in different months as well as the seasonal range in the quantities of some of the major constituents are given in Table 4. Quantitative changes in the inorganic constituents were noticed in different growth stages of plant by Pillai (1956; 1957 a,

Table 2

Water soluble minerals in Indian seaweeds (g / 100 g of dry weed)

Plant	Sodium	Potassium	Calcium	Magnesium	Chloride	Nitrogen	Sulphate	Author
GREEN ALGAE								
1. *Enteromorpha intestinalis*	1.16	0.71	0.51	0.41	2.40	0.38	4.00	Pillai, 1956
2. *Ulva lactuca*	1.71	1.58	0.63	1.64	0.79	—	12.10	Sitakara Rao and Tipnis, 1967
3. *U. rigida*	1.11	0.68	0.34	0.98	0.27	—	7.74	-do-
4. *Cladophora monumentalis*	0.57	3.59	0.52	0.07	2.90	—	2.41	-do-
5. *Boodlea composita*	4.82	4.09	0.41	0.12	5.19	—	4.43	-do-
6. *Codium dwarkense*	10.74	2.35	1.19	0.18	15.63	—	5.99	-do-
BROWN ALAGE								
7. *Padina australis*	1.28	0.93	0.50	0.50	2.40	0.60	1.80	Pillai, 1956
8. *P. gymnospora*	1.40	1.06	0.16	0.02	0.87	—	1.39	Sitakara Rao and Tipnis, 1967
9. *Colpomenia sinuosa*	0.56	8.85	0.12	0.04	0.53	—	1.33	-do-
10. *Cystophyllum spp*	1.20	1.25	0.02	0.02	0.84	—	2.54	-do-
11. *Sargassum cinereum v. berberifolia*	1.67	7.35	0 02	0.08	7.20	—	1.50	-do-
12. *S. johnstonii*	1.47	1.67	0.02	0.01	1.39	—	1.82	-do-
RED ALGAE								
13. *Porphyra (P vietnamensis)*	5.66	1.11	0.30	0.45	3.58	—	0.11	Tewari *et. al.* 1968
14. *Gelidium micropterum (= Gelidiella acerosa)*	0.08	0.02	0.28	0.07	0.09	1.34	0.73	Kappanna and Visweswara Rao, 1963
15. *Gracilaria lichenoides*	0.23	2.01	0.40	0.16	3.84	0.70	4.50	Pillai, 1956
16. *G. lichenoides*	1.23	0,93	0.57	0.02	1.26	2.14	3.65	Kappanna and Visweswara Rao, 1963
17. Sarconema furcellatum	0.56	0.40	0.51	0.41	2.40	0.93	2.90	Pillai, 1956
18. *Acanthophora spicifera*	0.32	0.18	0.42	0.38	3.06	0.74	2.00	-do-
19. *Laurencia papillosa*	1.16	0.82	0.61	0.31	2.40	1.00	3.80	-do-

Table 3

Minor constituents in Indian seaweeds (mg/100g of dry weed)

Plant	Iron	Copper	Manganese	Boron	Zinc	Phosphorus	Author
GREEN ALGAE							
1. *Enteromorpha intestinalis*	14.00	0.25	13.00	0.60	4.40	—	Pillai, 1956
2. *Ulva lactuca*	0.37	0.89	8.23	15.60	0.74	277.60	Sitakara Rao and Tipnis. 1967
3. *U rigida*	257.20	4.66	38.40	10.00	1.62	286.30	do
4. *Chaetomorpha linum*	21.70	0.50	38.50	0.44	3.00	—	Pillai, 1956
5. *Cladophora monumentalis*	144.45	0.54	6.15	23.54	2.27	116.20	Sitakara Rao and Tipnis, 1967
6. *Boodlea composita*	468.55	1.05	17.62	4.50	1.86	258.35	do
7. *Codium dwarkense*	60.60	0.73	2.31	1.10	1.97	205.70	do
BROWN ALGAE							
8. *Padina australis*	50.40	1.12	45.00	1.10	4.40	—	Pillai, 1956
9. *P gymnospora*	456.10	1.96	24.75	3.21	3.46	28.63	Sitakara Rao and Tipnis, 1967
10. *Colpomenia sinuosa*	249.70	1.47	0.04	4.02	0.13	98.36	do
11. *Rosenvingea intricata*	22.40	0.50	57.50	0.74	3.20	—	Pillai, 1956
12. *Cystophyllum spp*	30.07	0.02	13.80	2.58	0.70	197.95	Sitakara Rao and Tipnis, 1967
13. *Sangassum cinereum v. berberifolia*	224.05	1.45	4.19	0.24	1.08	3.02	do
14. *S. Johnstonii*	107.40	0.61	9.07	1.64	2.14	203.60	do
RED ALGAE							
15. *Gracilaria lichenoides*	28.00	1.00	55.00	1.43	8.30	—	Pillai, 1956
16. *Sarconema filiforme*	19.60	0.65	18.70	0.73	6.40	—	do
17. *S. furcellatum*	14.00	3.00	39.00	0.94	5.80	—	do
18. *Hypnea musciformis*	28.00	0.90	19.50	0.80	8.00	—	do
19. *Chondria dasyphylla*	30.80	0.90	17.50	0.85	6.80	—	do
20. *Acanthophora spicifera*	28.00	1.20	8.50	0·43	7.00	—	do
21. *Laurencia papillosa*	37.80	0.50	24.00	0.46	5.50	—	do

Table 4

Seasonal maxima and minima in the mineral contents of eleven Indian marine algae

(From Pilllai, 1956, 1957 a, b)

Mineral	Month		g/100g	
	Maximum	Minimum	Maximum	Minimum
	I. *Enteromorpha intestinalis*			
Potassium	June	December	1.35	0.65
Sodium	October	April	0.75	0.35
Magnesium	December	April	0.70	0.15
Calcium	March	October	0.85	0 25
Chloride	February	September	1.40	0.75
Nitrogen	December	August	0.38	0.10
Sulphate	April	October	4.00	1.30
	II. *Chaetomorpha linum*			
Potassium	June	December	1.55	0.60
Sodium	November	-do-	0.75	0.25
Magnesium	May	-do-	0.30	0.20
Calcium	June	October	0.35	0.20
Chloride	May	November	1.85	0.50
Nitrogen	-	-	-	-
Sulphate	June	December	4.30	1.30
	III. *Padina australis*			
Potassium	January	August	2.00	0.80
Sodium	December	July	1.45	0.65
Magnesium	March	December	0.65	0.40
Calcium	February	July	0.65	0.30
Chloride	December	August	2.25	0.95
Nitrogen	October	May	0.60	0.15
Sulphate	November	April	1.70	1.00
	IV. *Rosenvingea intricata*			
Potassium	December	April	4.40	1.75
Sodium	October	-do-	1.85	0.55
Magnesium	January	July	0.90	0.30
Calcium	February	September	0.85	0.25
Chloride	February	May	2.75	0.75
Nitrogen	-	-	-	-
Sulphate	May	October	1.10	0.40
	V. *Gracilaria lichenoides*			
Potassium	June	August	3.25	0.80
Sodium	November	-do-	0.40	0.15
Magnesium	January	April	0.70	0.25
Calcium	December	-do-	0.50	0.10
Chloride	February	August	2.55	0.75
Nitrogen	December	April	0.73	0.18
Sulphate	April	May	4.40	1.20

Mineral	Month		g/100g	
	Maximum	Minimum	Maximum	Minimum
		VI. *Sarconema filiforme*		
Potassium	June	September	2.45	0.80
Sodium	December	August	0.50	0.20
Magnesium	September	December	0.45	0.20
Calcium	May	November	1.10	0.30
Chloride	March	April	2.00	0.25
Nitrogen	-	-	-	-
Sulphate	October	December	3.40	1.30
		VII. *Sarconema furcellatum*		
Potassium	May	August	3.20	0.85
Sodium	November	January	1.40	0.25
Magnesium	April	August	0.70	0.20
Calcium	October	-do-	0.60	0.35
Chloride	November	May	2.05	0.30
Nitrogen	-do-	July	0.93	0.10
Sulphate	May	January	3.00	1.80
		VIII. H*ypnea musciformis*		
Potassium	May	December	2.65	0.80
Sodium	January	April	0.25	0.05
Magnesium	August	-do-	0.55	0.20
Calcium	February	-do-	1.00	0.35
Chloride	January	September	2.50	0.50
Nitrogen	November	March	0.93	0.13
Sulphate	September	June	3.20	2.50
		IX. *Chondria dasyphylla*		
Potassium	June	September	3.05	0.07
Sodium	November	January	0.75	0.20
Magnesium	November	April	0.55	0.30
Calcium	June	-do-	0.95	0.10
Chloride	August	-do-	2.10	0.85
Nitrogen	November	-do-	1.00	0.18
Sulphate	May	September	4.40	1.20
		X. *Acanthophora spicifera*		
Potassium	May	September	2.60	0.65
Sodium	December	April	1.35	0.20
Magnesium	-do-	-do-	0.70	0.25
Calcium	August	December	0.95	0.25
Chloride	May	October	2.05	0.85
Nitrogen	-do-	February	0.73	0.25
Sulphate	July	January	2.10	1.50
		XI. *Laurencia papillosa*		
Potassium	February	September	2.55	0.35
Sodium	December	April	1.35	8.28
Magnesium	September	October	0.70	0.35
Calcium	August	April	0.90	0.35
Chloride	Februay	-do-	0.95	0.25
Nitrogen	November	May	1.00	0.18
Sulphate	June	September	3.90	2.00

b) and in plants collected from different localities (Tables 2 and 3). Patel and Joshi (1967) determined seasonal fluctuations of carbohydrates, nitrogen and other major chemical consitutents of *Ulva lactuca* and discussed the relationship between the chemical changes in the plant and in the metabolic environment and atmospheric temperature.

Iodine

Iodine is still extracted in small quantities from brown seaweeds in Japan, Norway and France, and from red seaweeds like *Phyllophora nervosa* in Russia. As seaweeds are good source to meet dietary requirements of iodine, goitre caused by iodine deficiency is less prevalent in countries where marine algae form part of the diet. The iodine that occurs in seaweeds is in the readily available from and, as such, is superior to the mineral iodine (Thivy 1960).

Some species of seaweeds, especially red and brown varieties, have the ability to accumulate iodine and thus are a more concentrated source of it.

Laminaria, *Phyllophora* and *Ecklonia* are the seaweeds from which iodine is extracted in Japan, Britain and other countries.

The iodine content of the Indian *Sargassum* was studied by Joseph et al. (1948). Pillai (1956) estimated in a more elaborate way the iodine contents of eleven species of algae growing around Mandapam. The iodine contents of five genera which are relatively richer in iodine, viz *Gelidium*, *Myriogloea*, *Sargassum*, *Asparagopsis*, and *Udotea*, are as follows:

Gelidium	38—54 ppm
Myriogloea	100—140 ppm
Sargassum	40—160 ppm
Asparagopsis	440—550 ppm
Udotea	215 ppm

The quantity of iodine present in many green, brown and red algae of the Gujarat coast was determined by Pillai (1956), Kappanna and Sitakara Rao (1962), Sitakara Rao and Tipnis (1967) and Dave et. al (1969). Values obtained by these authors along with the localities from where the seaweeds were collected are shown in Table 5. The iodine content was observed to to be generally lower in the brown algae than in the red and green (Solimabi and Das 1977) (Table 5). But the brown algae *Myriogloea sciurus* and *Padina australis* are exceptions in that 104.5 mg and 500 mg of iodine were respectively, reported, from these, (Table 5). Maximum quantity of 566.70 mg/100 g was observed in a small red alga, *Asparagopsis*. Other algae in which high amounts of iodine (above 200 mg/100 g) were observed are *Udotea indica*, *Gracilaria lichenoides* and*Sarconema furcellatum*. Solimabi et al (1981) found that the iodine content in 16 species of algae (red, brown and green) of the Andaman Sea varied from 0.003% to 0.0119%.

Proteins, Peptides an Free Amino Acids

The protein contents in the marine algae were estimated by Chidambaram and Unny (1953), Neela (1956), Pillai (1957 a) and Sitakara Rao and Tipnis (1964, 1967). In the species of *Sargassum*, *Turbinaria* and *Gracilaria* analysed by Chidambaram and Unny (1953) the protein content was found to be less than 10%. Data collected on the protein contents of different green, brown and red algae are summarised in Table 6. It may be seen from this that protein is high in the green and red algae than in the brown algae. In *Ulva fasciata*, *Acanthophora muscoides* and *Centroceras clavulatum* protein was estimated to be 22-26%. Lewis and Gonzalves (1960) reported more than 28% protein in the algae collected from Bombay coast. Dave and Parekh (1975), studying 8 genera of green algae of Saurashtra coast, found significant variation in protein in same species of algae grown in different localities and at different periods. The algae which form rich sources of protein are *Ulva rigida*, *U. fasciata*, *U. stenophylla*, *Caulerpa scalpelliformis*, *Cladophora monumentalis* and species of *Bryopsis*.

Table 5

Iodine contents of Indian seaweeds

Species	Locality	mg of iodine/ 100 g dry weed	Author
GREEN ALGAE			
1. *Enteromorpha intestinalis*	Mandapam	58.00	Pillai, 1956
2. *Entermorpha spp*	Porbandar	4.16	Dave *et. al.* 1969
3. *Ulva fasciata*	Veraval	7.40	-do-
4. *U. lactuca*	Okha	3.31	-do-
5. *U. lactuca*	Porbandar	6.27	-do-
6. *U. rigida*	Gopnath	4.83	Sitakara Rao and Tipnis, 1967
7. *Chaetomorpha linum*	Mandapam	72.00	Pillai, 1956
8. *Cladophora expansa*	Porbandar	18.06	Dave *et. al.*, 1969
9. *C. monumentalis*	Okha	64.64	Sitakara Rao and Tipnis, 1967
10. *Cladophora spp*	Porbandar	18.83	Dave *et. al.*, 1969
11. *Boodlea composita*	Okha	29.77	-do-
12. *Udotea indica*	-do-	215.30	-do-
13. *Halimeda tuna*	-do-	31.30	-do-
14. *Codium dwarkense*	-do-	5.31	Sitakara Rao and Tipnis, 1967
15. *Chamaedoris auriculata*	Veraval	10.43	Dave *et. al.*, 1969
BROWN ALGAE			
16. *Myriogloea sciurus*	Okha	104.50	Kappanna and Sitakara Rao, 1962
17. *Stoechospermum marginatum*	Okha	5.44	Dave *et. al.*, 1969
18. *Spatoglossum variabile*	-do-	16.44	Kappanna and Sitakara Rao, 1962
19. *Dictyopteris australis*	-do-	23.48	Dave *et. al.*, 1969
20. *Dictyopteris* spp	-do-	25.81	-do-
21. *Padina australis*	Mandapam	500.00	Pillai, 1956
22. *P. gymnospora*	Okha	7.95	Dave *et. al.*, 1969
23. *Colpomenia sinuosa*	-do-	8.99	Sitakara Rao and Tipnis, 1967
24. *Cystophyllum* spp	Porbandar	34.19	Dave *et. al.*, 1969
25. *Cystophyllum* spp	Veraval	16.53	-do-
26. *Sargassum cinereum* v. *berberifolia*	Sikka	33.20	Sitakara Rao and Tipnis, 1967
27. *S. johnstonii*	Okha	39.80	Sitakara Rao and Tipnis, 1967

	Species	Locality	mg of Iodine/ 100 g dry weed	Author
28.	*S. swartzii*	Okha	28.18	Dave *et. al.*, 1969
29.	*S. tenerrimum*	-do-	37.21	-do-
30.	*S. vulgare*	Porbandar	29.29	-do-
RED ALGAE				
31.	*Scinaia indica*	Okha	5.62	Kappanna and Sitakara Rao 1962
32.	*Asparagopsis taxiformis*	-do-	499.30	Dave *et. al.*, 1969
33.	*Asparagopsis* spp	-do-	556.70	-do-
34.	*Gelidiella acerosa*	Porbandar	54.00	-do-
35.	*Amphiroa anceps*	Okha	5.15	-do-
36.	*Halymenia venusta*	-do-	25.00	-do-
37.	*Gracilaria corticata*	Porbandar	18.41	-do-
38.	*G. foliifera*	Okha	8.07	-do-
39.	*G. lichenoides*	Mandapam	208.00	Pillai, 1956
40.	*Sarconema filiforme*	-do-	107.00	-do-
41.	*S. furcellatum*	Okha	8.63	Kappanna and Sitakara Rao, 1992
42.	*S. furcellatum*	Mandapam	357.00	Pillai, 1956
43.	*Solieria robusta*	Okha	15.54	Kappanna and Sitakara Rao, 1962
44.	*Agardhiella tenera*	-do-	12.65	-do-
45.	*Hypnea musciformis*	Mandapam	100.00	Pillai, 1956
46.	*H. musciformis*	Okha	12.74	Dave *et. al.*, 1969
47.	*Centroceras clavulatum*	-do-	20.79	-do-
48.	*Heterosiphonia muelleri*	-do-	10.01	Kappanna and Sitakara Rao, 1962
49.	*Polysiphonia ferulacea*	-do-	39.06	-do-
50.	*Polysiphonia* spp	-do-	4.78	-do-
51.	*Acanthophora delilei*	-do-	5.78	-do-
52.	*A. spicifera*	Mandapam	90.00	Pillai, 1956
53.	*Laurencia papillosa*	-do-	137.00	-do-

Table 6

Protein contents of Indian seaweeds

Seaweed	Protein/ 100 g of seaweed	Author
GREEN ALGAE		
1. *Ulva fasciata*	25.48	Sitakara Rao and Tipnis 1964
2. *U. lactuca*	7.69	—
3. *U. rigida*	22.42	—
4. *Cladophora monumentalis*	16.28	—
5. *Boodlea composita*	10.32	—
6. *Udotea indica*	13.00	—
7. *Codium dwarkense*	7.22	—
8. *Chamaedoris auriculata*	13.67	—
BROWN ALGAE		
9. *Dictyopteris australis*	8.14	—
10. *Spatoglossum variabile*	15.66	—
11. *Padina gymnospora*	12.27	—
12. *Colpomenia sinuosa*	6.62	—
13. *Cystophyllum* spp	11.21	—
14. *Sargassum cinereum* v. *berberifolia*	9.61	—
15. *S. johnstonii*	10.90	—
16. *S. tenerrimum*	12.14	—
RED ALGAE		
17. *Porphyra* sp.	16.01	Tewari *et. al* 1968
18. *Scinaia indica*	12.51	Sitakara Rao and Tipnis, 1964
19. *Asparagopsis taxiformis*	16.19	—
20. *Gracilaria lichenoides*	7.62	Neela, 1956
21. *Hypnea* spp.	7.50	—
22. *Centroceras clavulatum*	20.12	Sitakara Rao and Tipnis, 1964
23. *Acanthophora muscoides*	21.83	—

Extensive works were carried out by Lewis and Gonazalves (1959 a-c, 1960, 1962 a-c) and Lewis (1962 a, b, 1963 a-d and 1967) on aminoacids present in free state and on portein and peptide hydrolysates in many green, brown and red seaweeds. Lewis (1967) pointed out that Indian marine algae have all the essential aminoacids needed in human diet, including methionine and triptophane, which are not available in vegetable food materials.

Extraction of protein : Parekh and Visweswara Rao (1964) devised a method to extract proteins from the green alga *Ulva rigida*. The powdered seaweed is first treated with either-water mixture (1:4 ratio) for about 3 hours and then with 1 N sodium hydroxide solution. The protein is then precipitated with 10% solution by trichloro acetic acid at pH 4–5. The precipitated protein is washed, dried and powdered. Among the different precipitating agents tried by these authors, trichloro acetic acid gave best results, giving a concentrate containing 60% of protein.

Vitamins

Different vitamins, such as Vitamin-B 12, Vitamin-C, Vitamin-D and Vitamin-E, have been reported from marine algae growing in other parts of the world. In India, a few studies were made on the ascorbic acid content (Vitamin-C). The results obtained by Thivy (1960) on the algae of Mandapam are presented in Table 7. As revealed by this study, the amount of ascorbic acid present in *Sargassum myriocystum* is high and is, infact, more than that present in citrus fruit. Variation in ascorbic acid content in relation to growth and reproduction of *Ulva fasciata* was studied by Subbaramaiah (1967). Highest concentration, 2.4 mg/g, was in very young plants of about 5mm in length. With increase in length of the frond, the ascorbic acid content was found to decrease, diminishing to 0.73mg/g in plants more than 7.0 cm in length. The concentration of Vitamin-C was higher in the reproductive parts of thallus than in the vegetative parts.

Table 7

Ascorbic acid content in Indian marine algae (From Thivy, 1960)

Alga	mg/100g of fresh weed
Chaetomorpha brachygonia	5.92
Cladophora fritschii	6.04
Ulva reticulata	5.69
Ulva lactuca	6.10
Enteromorpha prolifera	0.22
Padina australis	7.86
Sargassum myriocystum	66.60
Hypnea musciformis	8.58
Gracilaria lichenoides	7.25
Acanthophora spicifera	4.00
Laurenica papillosa	5.92

Bromine

Nineteen species of seaweeds consisting of green, red and brown algae, from Goa coast were examined by Naqvi et.al (1979) for bromine content. The bromine content, on a dry-weight basis, varied between 0.024% and 0.247% in the green algae, 0.020% and 0.4% in the red algae and 0.015%- 0.055% in the brown algae (Table 8) Only two species namely *Chondria armata* and *Codium elongatum, had* relatively high bromine content, 0.4% and 0 247%, respectively. The bromine content of 16 species of algae (red, brown and green) of the Andaman Sea varied between 0.008% and 0.128%) (Solimabi et. al. 1981).

Carbohydrates

Laminarin, mannitol, fucoidin, alginic acid, agar, carrageen an and many other varieties of carbohydrates were isolated from green, brown and red algae elsewhere (Black 1954, Percival 1968). In India, on the other hand, much attention was paid only on the economically important carbohydrates, namely agar and algin. Investigations carried out on these and a few other carbohydrates are given below.

Agar and agaroid: During and after the Second World War, some a attempts were made to extract agar from Indian seaweeds (Bose et al 1943; Chakraborty 1947; Joseph and Mahadevan 1948; Karunakar et al 1948). These authors used different techniques for purification of agar gel. In the method developed by Bose et al (1943), the whole weed was leached for 18 hours before extraction and the gel was maintained at 60°C to remove the suspended impurities, Starch present in the gel was removed by treating with 0.2% acetic acid for 1 hour and then washing the gel in water. Karunakar et al (1948) employed bacterial method for purification of gel and Chakraborty (1945) used freezing technique to remove the suspended material. Mahonty (1956) found that heating under pressure at 230°F was necessary for the removal of impurities in the gel of *Gracilaria verrucosa*.

At Central Marine Fisheries Research Institute, more detailed investigations were made to extract agar-agar from different species of *Gracilaria* and from *Gelidiella acerosa* and to know physical properties of the agar obtained from them (Thivy1951, 1960). As a result, *Gelidiella acerosa* was found to be an excellent source for manufacture of high quality agar The yield, gel strength and other physical properties of agar-agar obtained from these species are summraised in Table 9.

Table 8

Bromine content of marine algae from the coast of Goa (From Naqvi et. al. 1979)

Species	Bromine % (on dry weight basis)
CHLOROPHYTA	
Cladophora sp	0.024
Chaetomorpha media	0.105
Enteromorpha sp	0.032
Caulerpa racemosa	0.130
Caulerpa sertularioides	0.027
Codium elongatum	0.247
RHODOPHYTA	
Gracilaria corticata	0.078
Hypnea musciformis	0.027
Acanthophora spicifera	0.095
Chondria armata	0.400
Chondrococcus sp	0.054
Corallina sp	0.020
Centroceras clavulatum	0.063
PHAEOPHYTA	
Sargassum tenerrimum	0.040
Dictyota dumosa	0.022
Padina tetrastromatica	0.022
Spatoglossum asperum	0.055
Dictyota bartayresii	0.015
Dictyopteris ausrtalis	0.039

Table 9

Yield and physical properties of agar obtained from Gelidiella *and* Gracilaria *species*

Agarophyte	Yield (%)	Gel strength (1.5% solution)	temp. (1.5% solution)	Melting temp. (1.5% solution)
Gelidiella acerosa	45	300 g/cm²	40°C	92°C
Gracilaria lichenoides	43	120 g/cm²	45°C	84°C
G. crassa	23	140 g/cm²	48°C	84°C
G. corticata	38	20 g/cm²	44°C	68°C
G. foliifera	12	15 g/cm²	40°C	—

Pillai (1955 C), during the course of chemical studies on marine algae carried out in Central Marine Fisheries Research Institute, observed that in *Gracilaria lichenoides* there were 60–90% of minerals and a good amount of sulphur, nitrogenous matter and carbohydrates occurring in water-soluble form and these compounds, which come as impurities while extracting agar, could be removed by pulverising, soaking and washing the weed. Based on this important observation, a cottage industry method was developed in the Institute for manufacture of pure agar from *Gracilaria lichenoides* (Pillai 1955 c and Thivy 1960), of which the details are given in the Appendix II. In this method, the impurities are removed from the seaweed before extraction and not from the gel. The leaching process will minimise the cost of production since large-scale equipments are not used for freezing the gel. The yield from the pulverised weed is also higher than that obtained by the earlier methods reported.

Another method was also described by Thivy (1960) for the extraction of agar-agar from *Gelidiella acerosa* (=*Gelidium mycropterum*), in which freezing technique is employed to retain the coldwater-soluble fraction of agar, but, without being able to remove the impurities from the weed effectively as in the case of *Gracilaria lichenoides* (=*G. edulis*).

Several methods were described subsequently for large-scale extraction of agar, with minor modifications in the process given by Thivy. Kappanna and Visweswara Rao (1963) suggested that the quality of agar could be improved by freezing and thawing. In the pilot-plant trials condcuted later, Visweswara Rao, et. al. (1965) soaked the pulverised weed overnight in fresh water before wet-grinding and extracting the agar. Details of this method is given in Appendix III. The method suggested by Srinivasan and Santhanaraja (1967) is more or less similar to the one described by Kappanna and Visweswara Rao (1963) but for the seaweed having been pulverised into fine powder before extraction. To eliminate the cost of freezing, Desai (1967) suggested 90% industrial alcohol for the flocculation of agar from filtrate.

Monthly variations in agar content in *Gracilaria lichenoides* were reported by Pillai (1955 c). Changes were noticed in the gel-like extractives (Pillai, 1957 b) obtained from the red algae *Chondria dasyphylla, Acanthophora spicifera, Laurencia papillosa, Hypnea musciformis* and *Sarconema filiforme* in close relationship with the changes in the hot-water fraction of sulphur and organic extractives of these.

Some preliminary studies were also made by Thivy (1951) and Pillai (1957) on the agaroid content of species of *Hypnea, Spyridia, Sarconema, Acanthophora, Leurenica* and *Chondria*. The available information indicates that the yield of *Sarconeme filiforme* extractive was 10% with a gel strength of 5g/cm² and a gelling temperature of 38°C for 1.5% solution.

Rama Rao (1970), studying the seasonal changes in yield and gel strength of the agar from *Hypnea musciformis* in relation to the growth cycle of the alga, found the phycocolloid content to be increasing gradually from less than 35 g/100 g dry alga to about 48 g/100 g from October to March. The gel strength of 1.5%, 2% and 2.5% solutions increased from October with maximum values in March. The maximum yield of agar and gel strength were observed during October-March, when peak vegetative activity was prevalent as was indicated by fresh and dry weights of the plant. In *Gelidiella acerosa* periodicity in the production of agar was observed by Thomas et. al. (1975). Yield and gel strength of agar showed two peak values of 50% and 367 g/cm² in May-June and 53% and 286 g/cm² in September-October. The yield and gel strength of agar attained highest levels about a month prior to the peak periods of growth. Gelling and melting temperatures of agar varied from 44.5° to 52.5° C and 81° to 84° C, respectively. Seasonal variations in gelling and melting temperatures were irregular and peak values occurred at the same time as that of yield and gel strength. As for *Gracilaria edulis*, the yield and quality of agar were determined by Thomas and Krishnamurthy (1976) in cultivated plants (from 4 harvests). Extraction was carried out for periods ranging from one to six hours. The maximum yield was obtained in four-hour extraction. Though the percentage yield of agar in all the harvests was more or less uniform, it was found that gel strength and gelling and melting temperatures were greater in the agar obtained from the second and third harvests. The extractions over 2 to 4 hours gave a product with increased gel strength and gelling and melting points. In order to determine the most suitable time for harvesting the plants, the agar was extracted from monthly samples. It is evident from the results that the best yield of agar was from plants harvested 3 months after planting. The data ragarding the details of agar obtained from plants of different age are as follows:

Age of plant	Percentage yield	Gel strength (g/cm²) of 1.5% agar	Gelling temp (°C)	Melting temp (°C)
One month	40	31	42	73
Two months	38	36	42	75
Three months	33	119	45	82
Four months	32	85	43	80
Five months	31	85	43	78

* Duration of extraction was 2h in all the cases.

Thomas (1977) reported seasonal variation in yield and physical properties of agar-agar from *Gracilaria verrucosa*. A maximum yield of 43% with highest gel strength of 173 g/cm² was seen in July. The yield was lowest (26%) in March and gel strength lowest (95 g/cm²) in September. Gelling temperature of agar varied between 40° and 44° C and melting temperature between 80° and 83°C.

Listing the phyco-colloid contents and their properties in 6 species of red algae, viz. *Gelidiella indica, Gracilaria corticata, G. fergusonii, G. foliifera, Acanthophora spiciiera and Laurencia papillosa, Subba Rao et. al* (1977) gave the methods of phycocolloid extraction from these species. According to them, the yield and physical properties of agar-agar from *Gelidiella indica* and 3 species of *Gracilaria* are as follows:

Seaweed	Percentage yield	Physical properties of 1.5% phyco colloid		
		Gel strength (g/cm²)	Gelling temp. (°C)	Melting temp. (°C)
Gelidiella indica	44	30	52	76
Gracilaria corticata	44	19	33	51
G. fergusonii	35	19	22	38
G. foliifera	25	31	41	68

The maximum yield obtained from *Acanthophora spicifera* was 12% and from *Laurencia papillosa* 19%.

A comparative study was made (Chennubhotla *et al* 1977 a) on the yield and physical properties of agar-agar from three different agarophytes, namely *Gelidiella acerosa*, *Gracilaria edulis*, *G. verrucosa*. The results were as follows:

	Percentage yield	Physical properties of 1.5% agar		
		Gel strength (g cm²)	Setting temp (°C)	Melting tem (°C)
Gelidiella acerosa	40	125	46	73
Gracilaria edulis	55	63	48	65
G. verrucosa	23	41	40	55

Similar studies were conducted also on three blends, B I, B II, B III, made by compounding the aforesaid three species in the following proportions;

	B I	B II	B II
Gelidiella acerosa	45%	25%	25%
Gracilaria edulis	15%	50%	25%
G. verrucosa	40%	25%	50%

The yield was found to be highest in Blend III, but gel strength and setting and melting temperatures were low. In Blend II, the gel strength and setting and melting temperatures were maximum, and were nearer to those of the agar from *Gelidiella acerosa*, and *G. pusillum* from Saurashtra coast yielded 24% agar with a gel strength of 169 g/cm², and the same species grown in culture yielded 22% agar having a gel strength of 210 g/cm² (Mairh and Sreenivasa Rao 1978). The yield and gel strength of agar extracted from *Gracilaria corticata* and *Pterocladia heteroplatos (=Gelidium beteroplatos)* collected from Visakhapatnam area (Umamaheswara Rao 1978) are given below:

Seaweed	Yield (%)	Gel strength 1.0%	(g/cm2) 1.5% sol
Gracilaria corticata	44.64	64	134
Pterocladia heteroplatos (=Gelidium heteroplatos)	15.57	297	602

Oza (1978) studied the seasonal variations in the gel strength and gelling and melting temperatures of agar from *Gracilaria corticata* occurring in Veraval coast. The yield of agar varied between 14.5% and 22.5% in different months. The lowest yield was in August, September, October and May whereas the highest yield was in June-July and November-April. The low yield coincided with shedding of branches after liberation of tetraspores in August-September. The gel strength showed a minimum value of 17 g/cm² in July and maximum value of 27 g/cm² in November. During August, September and November, the gel strength remained more or less the same, varying only between 20 and 25 g/cm². The melting temperature of phycocolloid showed a narrow range of monthly variation, from 60° to 62°C, and gelling temperature from 40° to 42°C.

Rama Rao and Krishnamurthy (1978) reported seasonal variation in yield and gel strength of phycocolloid from *Hypnea musciformis* and *Hypnea valentiae*. The yield of phycocolloid in *Hypnea musciformis* varied between 49.9% in March and 27.2% in May. The gel strength was better (37.4 g/cm² to 75.0 g/cm²) when the yield was high (48.4%) and poor (30.05-52.3 g/cm²) when the yield was low (27.2%). The yield of phycocolloid in *Hypnea valentiae* varied between 38.95% in April and 27.2% in August in a year. A correlation between the yield and the gel strength was also noticed, the latter being high in April (86.27-151.25 g/cm²) when the yield was high (38.95%) and low in October (30.11 to 50.19 g/cm²) when the yield was lowest (30.10%). Thus, the maximum values of yield and gel strength of agar approximately coincided with the luxuriant growth of alga.

Chennubhotla et al (1979) studied the seasonal variations in the yield and physical properties of agar-agar from some of the commonly occurring agarophytes around Mandapam, the result obtained of which are presented below:

The monthly variations in carrageen content of *Hypnea musciformis* from Goa coast were studied by Solimabi et al (1980). The maximum yield of 51.6% was obtained in

Seaweed and Location	Max. yield of agar (%)	Month of yield	Gel strength (g/cm²)	Gelling temp. (°C)	Melting temp. (°C)
Gelidiella acerosa					
Pudumadam	48.0	Jan.	316	36-44	62-86
Kilakarai	46.8	Nov.	320	42-49	61-83
Krusadai	50.8	Jan.	325	43-52	67-84
Gracilaria edulis					
Rameswaram	49.2	Sept.	111	41-57	46-69
Krusadai	45.0	Nov.	139	44-50	61-78
G. corticata					
Pudumadam	42.8	June.	22	40-49	49-60
G. foliifera					
Rameswaram	50.4	Sept.	55	38-51	48-70

December and minimum of 29.23% in May. The carrageen content increased from October to December and then declined. The low values of phycocolloid from February to May coincided with the decline in vegetative growth of the alga.

Kaliaperumal and Umamaheswara Rao (1981) studied the phycocolloid of *Gelidium pusillum* and *Pterocladia heteroplatos* growing in the intertidal habitats of Visakhapatnam coast. The yield and properties of agar extracted from these two gelidioid algae are given below.

Species	Yield	Gel strength (g/cm²) 1.0% conc.	Gel strength (g/cm²) 1.5% conc.	Gelling temp (°C) 1.5% conc.	Melting tem(°C) 1.5% conc.
Gelidium pusillum	50.0	175	276	38	86
Pterocladia heteroplatos	35.1	167	288	38	83

The yield of agar from *Pterocladia heteroplatos* varied from 32.2% to 37.9% without any marked seasonal pattern, except that high values were obtained between November and March. The gel strength of 1.0% and 1.5% agar solutions also varied slightly in different months with high values in the period from November to February and in August. Though there was no seasonal change in the gelling temperature, the melting temperature varied in different months between a minimum of 76°C and a maximum of 88°C, the high values being between March and June.

The sulphate content of seaweed plays a major role in determining the gel strength of agar. Marked increases in the stability and gel strength of agar were observed in the experiments conducted by Doshi and Sreenivasa Rao (1967 a, b) by exposing the seaweed samples to cobalt-60 gamma radiations. Small doses varying between 0.5×10^{18} eV./g and 3.0×10^{18} eV /g increased the gel strength (1-2.5 times) in *Gelidiella acerosa, Gelidium micropterum* and *Gracilaria millardetii* (Doshi and Sreenivasa Rao 1967 b). These changes caused by radiations have been described to be due to breaking up of the organic sulphate fraction in the agar molecule. As such, the sulphate content present in the extractives of *Gelidium* spp. *Gelidiella acerosa, Gracilaria foliifera, G. millardetii, G. corticata, Hypnea musciformis* and *Furcellaria sp.* was precipitated with barium chloride and gel strength of agar was determined (Doshi et al 1968). The increase in gel strength was found corresponding with the decrease in the sulphate content.

Rama Rao and Krishnamurthy (1968) found that the physical properties of phycocolloids were alterable by the addition of pottassium chloride. They found that there was no gel formation in 1.0% solution of extractive from *Hypnea musciformis*. But addition of 0.5% potassium chloride to the extractive resulted in a remarkable increase in gel strength. These authors therefore suggested that, for the preparation of *Hypnea* agar, potassium chloride should be added before filtering the hot extract and the gel obtained be subjected to repeated freezing and thawing. Nevertheless, Thomas and Krishnamurthy (1976) did not find such increase in gel strength on addition of 0.5% potassium chloride in the agar from *Gracilaria edulis*. Subba Rao et al (1977) obtained two fractions. the upper soluble and lower insoluble, when the extractives of *Acanthophora spicifera* and *Laurencia papillose* were treated with 0.5% potassium chloride. The effect of pH on the yield and properties of agar extracted from *Gelidium pusillum* and *Pterocladia heteroplatos* was determined, by Kaliaperumal and Umamaheswara Rao (1981). In general, there was no marked difference in yield, gel strength and gelling and melting temperatures of the phycocolloid extracted in acidic and alkaline pH ranging from 5 to 10. However, the melting-temperature values were not uniform in these algae and the gel strength was slightly more in the alkaline pH.

Alginic acid: Some studies were made on Indian alginophytes. Alginic acid content present in the brown algae of Mandapam (Valson 1955), Gujarat (Kappanna et al 1962), Goa (Solimabi and Naqvi 1975) and Andhra (Umamamaheswara Rao, 1978) coasts was determined. Data gathered on the alginic acid content of Indian brown seaweeds along with the localities from where the weeds have been collected are shown in the Table 10. Values of Valson (1955) and Kappanna et al (1962) presented in Table 10 are based on the titration method of Cameron et al (1948) and those of others, except Solimabi and Naqvi (1975), Durairaj et al (1978) and Umamaheswara Rao (1978), are on the maximum yield obtained from fully grown plants.

Table 10

Alginic acid content in Indian brown seaweeds

Seaweed	Locality	Yield of alginic acid (%)	Author
Dictyota spp	Sikka	5.50	Kappanna *et. al*, 1962
D. bartayresiana	Goa	22.94	Solimabi and Naqvi, 1975
D. dumosa	,,	13.34	,,
D. dichotoma	Andhra Pradesh	21.79	Umamaheswara Rao, 1978
Padina spp	Mandapam	10.35	Valson, 1955
P. tetrastromatica	Goa	8.48	Solimabi and Naqvi, 1975
,,	Andhra Pradesh	23.34	Umamaheswara Rao, 1978
P. gymnospora	Pudumadam (Mandapam)	24.80	Chennubhotla *et. al.*, 1977 b
Cystophyllum muricatum	Mandapam	15.63	Valson, 1955
,,	Sikka	19.74	Kappanna *et. al*, 1962
Cystoseira indica	Port Okha	15.60	Mairh, 1982
Hormophysa triquetra	Mandapam	18.22	Valson, 1955
Colpomenia sinuosa	Goa	16.65	Solimabi and Naqvi, 1975
Spatoglossum asperum	,,	17.14	,,

Table 10 contd.

Seaweed	Locality	Yield of alginic acid (%)	Author
Stoechosperum marginatum	Pudumadam	23.80	Kalimuthu *et. al.*, 1980
Sargassum cinereum v. *berberifolia*	Dwarka	29.17	Kappanna *et. al.*, 1962
S. ilicifolium	Andhra Pradesh	34.93	Umamaheswara Rao, 1978
,,	Mandapam	30.80	Chennubhotla *et. al.*, 1982
S. johnstonii	Okha	22.34	Kappanna *et. al.*, 1962
S. myriocystum	Pamban	34.50	Chennubhotla *et. al.*, 1982
,,	Pudumadam	26.07	Kalimuthu, 1980
,,	Andhra Pradesh	32.34	Umamaheswara Rao, 1978
S. tenerrimum	Dwarka	4.85	Kappanna *et. al.*, 1962
,,	Okha	10.08	,,
,,	Sikka	14.77	,,
,,	Saurashtra coast	10.39	Chauhan, 1970
,,	Goa	15.16	Solimabi and Naqvi, 1975
S. vulgare	Andhra Pradesh	25.46	Umamaheswara Rao, 1978
S. wightii	Mandapam	31.70	Umamaheswara Rao, 1969 c
Sargassum spp	Mandapam	19.22	Valson, 1955
Sargassum spp	Hare Island (Off Tuticorin)	25.00	Durairaj *et. al.*, 1978
Turbinaria conoides	Mandapam	18.08	Valson, 1955
,,	,,	35.60	Umamaheswara Rao, 1969 c
T. decurrens	,,	26.30	Kaliaperumal and Kalimuthu, 1976
T. ornata	,,	32.18	Umamaheswara Rao and Kalimuthu, 1972

Sadasivan Pillai and Varier 1952 studied the structure and properties and the optimum conditions for preparation of the alginic acid from *Sargassum tenerrimum* and *S. wightii*. Later, Pillai (1957 c) at the Central Marine Fisheries Research Institute described a simple method for the extraction of alginic acid from *Sargassum* species. Of the different bleaching agents tried in this study, potassium permanganate was found most suitable for alginic acid. Bleaching was effected by treating the precipitate of alginic acid with potassium permanganate solution in the presence of hydrochloric acid. This method is given in Appendix IV. A cottage-industry method was also reported for the extraction of calcium alginate and alginic acid by Sadasivan Pillai (1961), which is given in Appendix V. In a study conducted on brown seaweeds of Saurashtra coast, Visweswara Rao and Mody (1964) observed that the alginic acid obtained from calcium alginate was superior to the alginic acid precipitated directly from the extract of sodium alginate. Details of this method is given in Appendix VI. A method for the production of commercial grades of sodium alginate using 90% industrial alcohol to coagulate sodium alginate was reported by Desai (1967). Other workers (Shah et al 1967) also pointed out that alcohol coagulation gave alginates high viscosity. However, this method may not be economical because of the large quantities of alcohol required for separation of sodium alginate. Preparation of

sodium alginate with improved viscosity from *Sargassum* spp has been reported by Durairaj et al (1978).

Some preliminary experiments, that has yielded some favourable results, were conducted by Pillai (1964) to control flavour changes, oxidation of fat, dehydration, etc, in frozen seafoods during storage, using sodium alginate as coating material. In these experiments fishes like *Sardinella gibbosa*, *Elops* sp. *Sillago* sp. and two species of prawns were coated with an alginate gelly prepared by mixing 2.5%solution of sodium alginate, sodium and phosphate salts and citric acid and were quick frozen and stored at low temperature.

Seasonal changes in the alginic acid contents and viscosity of sodium alginates of four species of *Sargassum* collected from Gujarat coast was studied by Shah et al (1967). They observed increase in degree of polymerisation with increase in growth of plants. Variations in the alginic acid contents of *Sargassum wightii* and *Turbinaria conoides* growing in Gulf of Mannar were followed by Umamaheswara Rao (1969 c) for two and a half years. In *Sargassum wightii* the alginic acid content varied from 21.3% to 31.7% and in *Turbinaria conoides* from 23.2% to 35.6%. Peak quantitites were found in these two brown algae during their maximum growth periods, from October to December or to January. Chauhan (1970) studied the variations in alginic acid content in relation to growth in two species of *Sargassum*. In *Sargassum tenerrimum* the alginic acid was found to vary from 7.1% to 10.39%, maximum in mature plants and minimum in young plants But, Umamaheswara Rao and Kalimuthu (1972) found marked changes in the yield of alginic acid during the growth and development phases of *Turbinaria ornata*. They obtained high yield of alginic acid from both young and fully grown plants with minor variations from month to month Kaliaperumal and Kalimuthu (1976), however, observed more marked monthly changes in the alginic acid content of *Turbinaria decurrens*, in which the yield during one year from March to February varied from 16.3% to 26.3%, with low values in April and May. Chennubhotla et al (1977 b) studied the seasonal variation of alginic acid in *Padina gymnospora* for two years. The yield varied from 9.4% in September to 24.8% in following March. The alginic acid in *Stoechospermum marginatum* collected from Pudumadam varied from 14.5% to 23.8%, with maximum yield from September to December (Kalimuthu et al 1980). In *Sargassum myriocystum*, also collected from Pudumadam, the alginic acid content varied from 14.26% to 26.07%, with irregular yield during the entire period of study (Kalimuthu 1980), The alginic acid content in *Sargassum ilicifolium* collected from Mandapam ranged from 22.3% to 30.8% and that in *S. myriocystum* collected from Pamban ranged from 15.9% to 34.5%. In these two algae the yield of alginic acid was generally high during July to September, which almost coincided with the peak growth of the algae (Chennubhotla et al 1982). The alginic acid content in *Cystoseria indica* varied from 7.3% to 15.3% of dry weight (Mairh 1982), yielding highest value in September, when the aerial branches were mostly defoliated and the rhizomatous branches predominated. The next best values were found in June-July and November-December (about 10%), when the alga reached harvestable size and attained fruiting stage.

Mannitol

Mannitol, a sugar alcohol present in the cell sap of brown algae, has been reported from many brown seaweeds. Mannitol was extracted with 80% ethyl alcohol from two spicies of *Sargassum* growing at Cape Comorin by Varier and Sadasivan Pillai (1952), the details of which are given in Table 11. Highest values obtained of the mannitol contents of *Padina gymnospora* (Cheneudbhotla et. al. 1977 b), *Stoechospermum marginatum* (Kalimuthu et al 1980), *Sargassum myriocystum* (Kalimuthu 1980; Chennubhotla et al 1982), *S. ilicifolium* (Chennubhotla et al 1982), S. *wightii* and *Turbinaria conoides* (Umamaheswara Rao 1969 c), *T. ornata* (Umamaheswara Rao and Kalimuthu 1972) and *T. decurrens* (Kaliaperumal and Kalimuthu 1976) by the titration method of Cameron et al (1948) are also given in in this table. Shah and Rao (1969) determined the mannitol contents of several species of

Table 11

Mannitol content in Indian brown seaweeds

Seaweed	Locality	Mannitol (%)	Authors
Padina gymnospora	Pudumadam (Mandapam)	2.1	Chennubhotla *et. al.*, 1977 b Kalimuthu *et. al.*, 1980
Stoechospermum marginatum	,,	2.8	Kalimuthu, 1980
Sargassum myriocystum	Pudumadam	5.0	Chennubhotla *et. al.*, 1982
,,	Pamban	5.0	,,
S. ilicifolium	Mandapam	5.0	Varier and Sadasivan Pillai, 1952
S. tenerrimum	Cape Comorin	9.4	,,
S. wightii	,,	7.3	Umamaheswara Rao, 1969 c
,,	Mandapam	6.2	,,
Turbinaria conoides	,,	7.4	Umamaheswara Rao & Kalimuthu, 1972
T. ornata	,,	7.1	,,
T. decurrens	,,	8.7	Kaliaperumal and Kalimuthu, 1976

Table 12

Values of Mannitol contents in different species and date of collection (Shah and Rao 1969)

Species	Habitat	Date of collection	Mannitol(%)
Sargassum swartzii	Okha Port reef	July. 1967	4.3
S. tenerrimum	,,	Dec. 1967	4.6
,,	Mandapam Camp	Nov. 1968	2.7
Sargassum (drift)	Idinthakarai	Sept. 1965	4.1
,,	,,	Oct. 1965	3.7
,,	,,	Nov. 1955	4.0
,,	,,	Dec. 1965	4.4
,,	Pamban	Aug. 1965	2.5
,,	,,	Nov. 1965	3.4
S. wightii	Mandapam Camp	Nov. 1968	6.2
S. johnstonii	Okha Port reef	Dec. 1967	Traces
S. cinereum	Sikka	-	12.9
Turbinaria sp,	Pamban	Oct. 1965	2.6
Cystoseiraceae	Okha	Aug. 1967	Traces

brown seaweeds obtained from different localities, of which the data are given below.

The mannitol contents of 15 species of brown algae collected from various localities of Saurashtra coast such as Okha, Porbandar, Chorwad and Veraval from August 1964 to March 1966 were determined by Mehta and Parekh (1978). Variations in mannitol content were observed among different genera of the seaweeds. The same species collected from different locations and at different periods also showed considerable variation. The maximum values of mannitol content in different species with the place and month of collection for each seaweed is given in Table 13.

Table 13

Maximum values of mannitol contents in different species of algae.

Alga	Place of collection	Month of collection	Mannitol content
Dictyota bartayresiana	Okha Port	March	7.10
Dictyopteris australis	Porbandar	December	7.37
Iyengaria stellata	Okha Port	January	7.32
Levringia boergesenii	Okha Port	March	10.80
Padina tetrastromatica	Porbandar	December	5.63
Sargassum cinctum	Porbandar	December	11.53
S. swartzii	Porbandar	December	11.11
S tenerrimum	Okha Port	November	3.56
S. vulgare	Porbandar	December	11.59
Spatoglossum asperum	Okha Port	August	7.63
S. variabile	Okha Port	January	9.70
Stoechospermum marginatum	Okha Port	March	16.00
Cystophyllum sp.	Okha Port	November	5.63
Cystoseira indica	Porbandar	December	15.16
Hydroclathrus clathratus	Porbandar	December	6.50

Seasonal variation in the mannitol content was also recorded in different brown seaweeds by various workers. The amount of mannitol varied from 1.2 to 6.2% in *Sargassum wightii* and from 1·78 to 7.4% in *Turbinaria conoides* (Umamaheswara Rao 1969 c). Unlike the alginic acid, mannitol accumulated in the plants during the vegetative phase of the growth cycle and decreased to minimum during the maximum growth and fruiting periods of the algae. Monthly changes of mannitol in *Turbinaria ornata* was reported by Umamaheswara Rao and Kalimuthu (1972). From the seasonal trends followed for four years, they found high mannitol content occurring during the early stages of growth, roughly from February to May. The amount of mannitol decreased with the development of receptacles. The estimated mannitol content in *T. decurrens* varied from 1.5% to 8.7% and the monthly changes were somewhat irregular (Kaliaperumal and Kalimuthu 1976). But, in general, the mannitol content of this alga appeared to be high during peak growth cycle. The mannitol content showed a variation from 0.5% in July to 2.1% in December in *Padina*

gymnospora, (Chennubhotla et. al 1977 b). In *Stoechospermum marginatum* the amount of mannitol varied from 1.2% to 2 7%. The mannitol content was found to be highest in October and during the months of May and June secondary peaks were noted (Kalimuthu et. al 1980). In *Sargassum myriocystum* collected from Pudumadam, the mannitol content ranged from 1.8% to 5.0% and the yield was irregular throughout the period of investigation (Kalimuthu 1980). Mannitol content ranged from 2% to 5% in *S ilicifolium* collected from Pamban. There was no relationship between the seasonal changes of the mannitol and growth in these two species studied by Chennubhotla et. al (1982).

From the studies conducted by various workers on the variations in growth, yield of agar, algin and mannitol in many agarophytes and alginophytes of different localities, it is clear that the stature of plants at the time of collection in each locality determines the yield of agar or algin and monnitol.

SIX

SEAWEED RESOURCES OF INDIA

N. KALIAPERUMAL V. S. K. CHENNUBHOTLA AND S. KALIMUTHU

A review of the seaweed resources of the world has been made by Michanek (1975). Further, some information is available on the seeweed resources of Indian waters, such as of Chilka Lake (Mitra, 1946), certain areas of Tamil Nadu (Chacko and Malupillai, 1958; Thivy' 1960; Varma and Krishna Rao, 1964; Desai, 1967; Umamaheswara Rao, 1972 a, 1973; Kannan and Krishnamurthy, 1978 and Subbaramaiah *et. al.*, 1979 a), Kerala coast (Koshy and John, 1948), Gujarat coast (Sreenivasa Rao, *et. al.*, 1964; Desai, 1967, Chauhan and Krishnamurthy, 1968; Bhanderi, 1974 a; Bhanderi and Raval, 1975; Bhanderi and Trivedi, 1975, Chauhan and Mairh, 1978 and Ragothaman, 1979), Maharashtra coast (Chauhan, 1978 and Untawale *et. al.* 1979), Goa coast (Untawale and Dhargalkar, 1975), Andhra Pradesh coast (Umamaheswara Rao, 1978) and Lakshadweep (Subbaramaiah *et. al.* 1979 b). Of these, the observations of Mitra (1946), Koshy and John (1948), Chacko and Mulupillai (1958) and Thivy (1960) are of preliminary nature, and the methods adopted for estimation are not given by them. The total quantities of agarophytes and alginophytes as estimated by these workers are given on page 52.

A detailed survey of red algae was conducted by Desai (1967) in the Gulf of Mannar, in a 10 - mile area at Rameswaram (north east of the temple) and 20-mile area north and south off Kilakarai. The estimates of dry *Gelidium* and *Gracilaria* were 300 and 3000 tons respectively per annum.

Locality	Agarophytes (Dry weight)	Alginophytes (Dry weight)	Authors
Chilka Lake	4-5 tons/annnm	-	Mitra, 1946,
Kerala coast (Travancore coast)	10,000 lbs during 1942-46	-	Koshy and John, 1948,
Point calimere-Cape Comorin	6,000 tons	60,000 tons	Chacko and Malupillai, 1958
Pamban area (Tamil Nadu coast)	7.1 tons/annum	-	Thivy, 1960

Surveys were started by Central Marine Fisheries Research Institute during 1958 to estimate the available seaweed resources in the Mandapam area. Varma and Krishna Rao (1964) made two surveys (a preliminary one in 1958 and the other detailed one during 1962-63), covering a total area of 234.25 sq km between Dhanushkodi and Hare Island. The entire area surveyed was divided into 3 sections, namely Krusadai section, Hare Island section and Outside section. Since very little algae of economic value were present, the Outside section, was not taken into consideration. The detailed estimates for species of *Gracilaria*; *Gelidiella acerosa* (= *Gelidium micropterum*) and brown algae for the other sections are given below:

Details	Fresh weight in metric tons	
	1958	1962-63
Gracilaria spp		
Estimated algae (wet wt)	33769	66979
Harvestable algae (wet wt)	188.85	334.90
(dry wt)	18.89	34.49
Yield of agar-agar	2.83	5.02
Gelidiella acerosa (= *Gelidium micropterum*)		
Estimated algae (wet wt)	1290	3775
Harvestable wet algae (wet wt)	6.45	18.88
(dry wt)	0.65	1.89
Yield of agar-agar	0.19	0.57
Brown algae		
Estimated algae (wet wt)	83835	131588
Harvestable algae (wet wt)	419.18	657.94
dry weight	62.88	98.69
Yield of alginic acid	7.55	11.84

The total Indian algin potential is 500 metric tonnes (refined) annually and the agar potential is 13 metric tonnes (bacteriological grade) annually, as estimated based on the possible yield of 19% (range 7-30%) of algin by dry weight and 28% (range 12-43%) of agar by dry weight (Thivy, 1964).

Sample surveys were conducted by Umamaheswara Rao (1973) in a 3.58 sq. km area between Pamban bridge and Theedai during the calm seasons of 1965 and 1966. The quantitative data obtained on the standing crop of different seaweeds are shown below.

Seaweed	Fresh wt. in metric tons	
	1965	1966
Agarophytes	233.15	47.92
Alginophytes	161.83	173.43
Edible algae	188.84	245.91
Other algae	457.87	398.51

Except in agarophytes, there was no significant variation in the standing crop of different types of seaweeds. About one fourth of the total area surveyed was covered with seagrass, standing crop of which was higher than that of marine algae. The data obtained on the area occupied by the seagrass beds and the standing crop in the two surveys are given below:

Year	Area covered by seagrass (sq. km)	Fresh weight of sea grass metric tonnes)
1965	0.75	1916.19
1966	0.88	2170.81

Thus considerable quantities of seagrass occur around Mandapam, which can be utilized for manure or as packing and insulating material.

A preliminary survey was conducted by Kannan and Krishnamurthy (1978) on the marine algae in and around Porto Novo and in the Porto Novo-Pondicherry region. *Ulva*, *Chaetomorpha* and *Enteromorpha* were more commonly found in the Pondicherry region. *Padina* was more common at Cuddalore, where *Hypnea* sp and *Enteromorpha* sp were also present. *Gracilaria* was rare, found drifting. At Porto-Novo the survey included four main biotypes, viz. neritic, estuarine, backwater and mangrove. *Ceramium*, among other algae, occurred in the neritic inlet of Vellar estuary-backwater complex, at Chinnavaikkal. The blue-green alga *Lyngbya* sp. was usually common in Porto-Novo waters.

CMFRI carried out for 5 years survey of marine algal resources along Tamil Nadu coast (1971–76) in collaboration with Central Salt and Marine Chemical Research Institute and Department of Fisheries, Government of Tamil Nadu (Subbaramaiah *et. al.*, 1979 a). The area covered was from Athankarai to Rameswaram in the Palk Bay (45 km distance) and from Mandapam to Colachel, Kanyakumari Dt. (413 km distance) and the adjoining islands in Gulf of Mannar from HWM to a depth of 4 m. The standing crop in the coastal area of 17125 ha was estimated at 22044 tons, consisting of 1709 tonne agarophytes, 10266 tonne alginophytes and 10069 tonne other seaweeds. The resources of the commercially important species are as follows:

Seaweed	wet weight
Gelidiella acerosa	74 tons
Gracilaria spp	974 ,,
Hypnea spp	798 ,,
Sargassum spp	9381 ,,
Turbinaria spp	714 ,,

By surveys conducted along Gujarat coast, Sreenivasa Rao *et. al.* (1964) estimated fresh *Sargassum* at 60 metric tons in 0.015 sq m area of the Adatra reef near Okha. According to the estimation of Central Salt and Marine Chemicals Research Institute, the resources of the agarophytes along Gujarat coast is 12 tons (fresh wt.). In the Gulf of Kutch 10,000 tonnes of brown algae by dry weight, 5 tons of wet *Gelidiella* and 20 tons of *Gracilaria* bydry weight can be harvested (Desai, 1967). Chauhan and Krishnamurthy (1968) have surveyed Dera, Goos, Narara, Sika, Karumbhar and Baide areas of Gulf of Kutch, and estimated the fresh seaweeds at 18765.5 metric tons in 10.65 sq. km of coastal waters. In this, *Sargassum* spp form 12010 5 tons, of which about 4000 metric tons are harvestable each year. The resource of iodine-yielding seaweed *Asparagopsis taxiformis* in some subtidal reefs of Saurashtra coast was estimated by Bhanderi (1974 a). The surveys were conducted in places near Okha, viz. Okha, Adatra, Dwarka, Hanumandandi, Dona and Boria reefs in 1972-73, showing that only in two places, namely Okha and Boria, there was luxuriant growth of *A. taxiformis* while in other places, such as Dona, Hanumandandi and Adatra, there were hardly 1 or 2 plants and in Dwarka reef the plant was totally absent. The maximum harvestable quantity from Okha and Boria reef was found to be 12.15 m. tons(fresh). Out of this, 12.0 tons were in Boria reef, in 0.060 sq. km area in March 1973. and 0.15 tons in Okha reef, in 0.007 sq. km area in December 1972. In 1973-74, Bhanderi and Raval (1975) conducted surveys on the tidal region of Okha-Dwarka coastline and estimated fresh *Sargassum* at 1000 metric tons. Other alginophytes such as *Cystophyllum muricatum*, *Hormophysa triquetra* and *Turbinaria* spp were also found in some quantity. *Sargassum tenerrimum* was the chief species of harvestable alginophytes. According fo the assessment of the authors, about 1 ton of fresh *Gelidiella* and 10 tons of fresh *Gracilaria* could be harvested from the coastline; These findings coincided with that of Centra. Salt and Marine Chemicals Research Institute Bhanderi and Trivedi (1975) also reported the seaweed resources of Hanumandandi reef and Vumani reef near Okha Port.

The survey of seaweed resources from Okha to Mahuva in Saurashtra coast was carried out jointly by the Central Salt and Marine Chemicals Research Institute and the Department of Fisheries, Government of Gujarat (Chauhan and Marih, 1978). The brown seaweed *Sargassum* constituted three-fourth of the algal biomass. The green alga *Ulva* was next to *Sargassum* and *Gracilaria* and *Gelidiella* were forming minor quantities. The estimated standing crops of the species are as follows

	Wet weight in tons
Sargassum tenerrimum	238.383-541.984
Gracilaria corticata	15.039- 23.086
Gelidiella acerosa	3.047- 5.695
Ulva	26.099- 39.073

Ragothaman (1979) conducted surveys at Devka, Golvad and Daman to study the distribution pattern of marine algae. The algae growing in this area were *Ulva Entermorpha, Polysiphonia, Platysiphonia, Laurencia, Gelidiella, Acanthophora* and *Corallina*.

The marine algal resource of Maharashtra coast was reported on by Chauhan (1978). The total harvestable standing crops according to them are as follows:

	Weight of the fresh seaweed in metric tons	
	Lower limit	Upper limit
Sargassum	238.417	310.097
Ulva	3.483	4.516

The seaweed resources survey of the Goa coast was conducted by Untawale and Dhargalkar (1975). The total standing crop of the coast from Dona Paula to Chapora (0.150 sq. km area) was about 256.6 metric tons fresh weight per year.

The seaweed resources of Andhra Pradesh are dealt with in detail by Umamaheswara Rao (1978). In general agarophytic resources are less while *Sargassum* species are more abundant in different localities of the coastline *Gracilaria corticata, Sargassum* spp, *Ulva fasciata Enteromorpha compressa* etc grow in harvestable quantities. Recently, Central Salt and Marine Chemicals Research Institute has surveyed the Andhra Pradesh coastline to assess the total standing crop.

The marine algal resources of Lakshadweep was published recently (Subbaramaiah *et.al.*, 1979 b). Among the 9 islands surveyed, Kavaratti, Agatti, Kadamet, Chetlat, Kiltan, Androth and Kalpeni supported marine algal growth while Bangarem was barren. Out of the total area of 2555 ha surveyed, 785 ha was found to be productive. The total standing crop of the marine algae estimated was 3645-7598 tons (wet weight). The groupwise biomass and their percentage of standing crop of the population are:

Agarophytes	961-2074 tons	27.0%
Alginophytes	9-15 tons	0.2%
Other seaweeds	2675-5509 tons	72.8%

Some attempts have been made to estimate the drift seaweeds. According to the estimate of Hornell (1918) 100 tons of fresh *Sargassum* were cast ashore per year along the 40 km Okhamendal coast of Gujarat, ie. from Juranga to Okha, including Adatra. Krishnamurthy *et. al.* (1967) estimated the different drift seaweeds at Idinthakarai and Pamban for a period of three months. The total drift weed around Idinthakarai was 61450 kg and at Pamban area was 16750 kg fresh weight. An account of the various methods used in assessing the seaweed resources has been given by Subrahmanyan (1967).

The above surveys carried out in certain areas of the east and west coasts of India clearly show the diversity and abundance of seaweed resources in our country. Intensive surveys for a long period in other areas along the Indian coast would throw much light on the resources occurring in the natural habitat and on the raw material available for expanding the seaweed industry in our country.

SEVEN

COMMERCIAL EXPLOITATION OF SEAWEEDS IN INDIA

E. G. SILAS AND S. KALIMUTHU

The commercial exploitation of seaweeds in India has started in 1966. At present the seaweeds are exploited in Gujarat coast and many localities in Tamil Nadu. The following are the seaweed centres along the southeast coast of Tamil Nadu:

1. Rameswaram
2. Pamban
3. Vedalai
4. Seeniappa Darga
5. Pudumadam
6. Periapattanam
7. Kalimankundu
8. Kilakarai
9. Ervadi
10. Valinokkam
11. Mundal
12. Kanyakumari area

The seaweeds harvested from these areas are *Gelidiella acerosa, Gracilaria edulis, G. crassa* and species of *Sargassum* and *Turbinaria*. The places and season of harvest of each species and the drying techniques for them are given below.

Gelidiella *Acerosa*

G. acerosa is being harvested from 1966 onwards It can be collected throughout the year since it is a perennial plant attached to rocks and coral stones. It is collected at six centres namely Rameswaram, Pamban, Vedalai, Seeniappa Darga, Kilakarai and Ervadi. The collection is mainly done around the islands in Gulf of Mannar, using country boats. Shore collection is done at Kilakarai and Ervadi throughout the year, whenever the tide conditions are favourable. Shore collection is done mainly by women and children. The seaweed is sold fresh to the dealers on the seashore itself, and they dry it on the beach before transporting to godown. The ratio between fresh wt and dry wt of G. *acerosa* is 3:1. But, invariably, *G. acerosa* is found mixed up with *Ulva reticulata*. Also, other coral associated plants are plucked out, too, along with *G. acerosa*. Hence the dried material may only be 50% pure, which has again 25% moisture. The rate for this material is Rs. 5000 per ton. As the availability of *acerosa* is inadequate, *Gracilaria edulis* is generally added with it for agar extraction. The dried plants are to be cleared of all epiphytes and materials got collected along with the plants, and this is done by engaging labourers. Then the plants are washed thoroughly, dried and bleached.

Gracilaria edulis

Gracilaria edulis is being collected since 1966 from five centres, namely Rameswaram, Pamban, Vedalai, Seeniappa Darga and Kilakarai. The collection of *G. edulis* is possible throughout the year around the islands in Gulf of Mannar. Generally, many other algae get mixed up with the harvested *G. edulis* plants, viz. *Gracilaria foliifera, Hypnea valentiae, Sarconema furcellatum' Acanthophora spicifera, Laurencia papillosa* etc., growing in the same area. The shore collection is very meagre in the case of *G. edulis* and the major part of the collection is made around the islands using country craft. Fresh *G. edulis* plants are sold at the rate of 50 paise per kg. The ratio of fresh and dry weight is 7:1. The cost of 1 tonne of dried *G. edulis* is Rs. 11600/- when it is 60%

pure with a moisture content of 22%. Fresh plants are dried on the beach for one day before stocking in sheds. Unwanted plants are removed before weighing and loading.

Gracilaria crassa

Gracilaria crassa is being collected since 1983 from three centres: Pamban, Vedalai and Kilakarai. As *G. crassa* grows attached to pebbles and stones in shallow areas, collection is by handpicking. The plant is prostrate and entangling, and so lots of sediments settle over the plants. And added to this, the standing crop is very little. Therefore, only negligible quantity is harvested, and that too when there is no collection of *G. edulis*. The cost of *G. crassa* is Rs. 1000/-per t (dry wt).

Sargassum

Species of *Sargassum* are the major constituent of the seaweeds that have been harvested for commercial use since 1966. Of these, *S. wightii* is the most important. The rest are *S. myriocystum, S. ilicifolium, S. plagiophyllum* and *S. tenerrimum*. The major portion harvested is from the Gulf of Mannar islands. Shore collection is done only at Pudumadam and Kanyakumari areas (Kooduthalai to Leepuram). Generally *Sargassum* is brought in boatloads. They are not weighed in fresh condition. Instead, the weight is decided by eye estimation, which is agreeable to both seaweed collectors and seaweed dealers. The rate is fixed at Rs. 70/-per t (wet weight) of seaweed. Algin industries like M/s Cellulose Products of India Ltd, Ahemadabad, requires formalin-treated material, because, procured during the peak harvesting season, i. e., August/September-December/January, it has to be stocked for as long as a year. Other algin industries procure beach-dried *Sargassum*. In formalin treatment, the fresh plants are soaked in 2% formalin for a 2-hour period and then dried in sun. The formalin is supplied by the algin industries free of cost. Formalin treatment is generally done in large wooden or cement tanks constructed on the beach, often changing the formalin after a few soakings. The ratio between fresh weight and dry weight is 5:1. However, during recent years, the treatment is being done by spraying formalin. A layer of fresh weed is spread and formalin is sprayed over it and then another layer of weed is spread above and sprayed, this process continuing according to the bulk to be treated. After 2 hours of treatment the plants are spread in sun and dried. This method is more economical than the soaking method.

Dried *Sargassum* is baled after weighing, since the dried weed is voluminous and yet one gunnybag full weighs only 30 kg or so. The cost of ordinary dried *Sargassum* is Rs. 650 per t and that of formalin-treated *Sargassum* is Rs. 700 per t with 80% purity and 20% moisture content. *Sargassum* form about 70% of the total seaweed harvested.

Turbinaria

Turbinaria conoides, T. decurrens and *T. ornata* are the three species growing in Mandapam area. Since 1975, *Turbinaria* is being collected from six centres, namely Rameswaram, Pamban, Vedalai, Seeniappa Darga, Periapattanam and Kilakarai. The collected material is eye-estimated and is sold at the rate of Rs. 40 per ton. The weed is dried on the beach. The ratio between fresh weight and dry weight is 7:11 The cost is Rs. 650 per t of dry seaweed with 75% purity and 25% moisture content.

The season for the collection of *Turbinaria* varies from one area to another. At Kilakarai January to March is the peak season, whereas at Periapattanam it is between August and December and at Seeniappa Darga, Vedalai Pamban and Rameswaram April-July is the season.

Transport and Other Expenditures

Generally the transportation is by road for most of the nearby industries producing agar and algin. But, for the industries situated at distant places such as Ahamedabad and Bombay the seaweed is transported up to

Madurai by road and from there by rail. In addition to the cost of transport, the seaweed industry has to incur expenditure towards the cost of formalin, transport of formalin carbuoys to the main supplier, cost of gunny bags, etc. Including all these expenses, the cost of 1 ton (dry weight) of formalin-treated *Sargassum* on arrival at Ahamedabad from Kanyakumari may cost approximately Rs. 1,600.

The seaweed dealer has to incur the following expenditure:

1. Erection of stocking sheds.
2. Transport of formalin carbuoys to the collection spot.
3. Return of carbuoys from collection spot.
4. Labour cost for soaking/spraying the seaweed in formalin, drying and storing.
5. Transport up to the storage shed.
6. Transport of gunny bags to the collection spot.
7. Packing charges.
8. Loading charges.
9. Salary to employees.
10. Commission to subdealers.

Employment Opportunities

The fishermen of the coast from Rameswaram to Mundal and of Kanyakumari area get employment in seaweed collection in addition to their normal fishery activities, During the peak *Sargassum and Turbinaria* collecting season, many fishermen leave fishing activity and go for seaweed collection. Later, whenever the conditions are unfavourable for fishing, they go for collection of seaweeds such as *Gelidiella acerosa* and *Gracilaria edulis*. Each fisherman gets an income of Rs. 30 to 50 per day during the peak season. For the formalin treatment, drying, packing, etc, many persons are engaged as daily wage labourers. The wage per day varies from Rs. 10 to 12 for men and Rs. 5 to 8 for women. Approximately 2000 persons get employment during the peak *Sargassum* collecting season August-January. Even thought the employment opportunity is seasonal, an assured income of Rs. 30 to 50 per day attracts them towards seaweed collection. Some data collected by Umamaheswara Rao (1970 and 1973) on the quantities of seaweeds harvested from Pamban, Periapattanam and Kilakarai are shown below The fresh weight was estimated based on 80% moisture.

Data on harvested seaweed (tonnes)

	Locality			Total	Total
	Pamban	Peria-patnam	Kila-karai	diy weight	fresh weight
1966	15.19	—	—	15.19	75 95
1967	18.35	65.55	58.07	141.97	709.85
1968	16.59	8.00	304 65	329.24	1646.20

The data on harvested seaweeds collected by Central Marine Fisheries Research Institute for a period of eight years from 1978 to 1985 from different centres are given in Table 12. The figures were arrived at by enquiry from the fishermen and from records maintained by the dealers, sub dealers and industrial personnel.

Agar Industries

The list of the agar-and algin-producing industries in India is given below.

1. Ice and Agar Industry, Pamban, Ramnad District, Tamil Nadu.
2. Crystals, Kilakarai, Ramnad District. Tamil Nadu.
3. Sayee Industries, Manaloor, Pasumpon Muthuramalingam Dist., Tamil Nadu.
4. Cellulose Products of India Ltd., Kappaloor, Madurai Dist., Tamil Nadu.
5. Indian Polysaccharides, Tiruparankundran, Madurai Dist., Tamil Nadu
6. Indian Phycocolloids, Tennagar, Madurai Dist., Tamil Nadu.
7. Maya Marine Enterprises, Tiruvedagam Post, Sholavandan, Madurai Dist., Tamil Nadu.

Table 12

(Total Seaweed Landings dry weight in tonnes)

Landing Centre	*Sargassum* spp								*Turbinaria* spp							
	1978	1979	1980	1981	1982	1983	1984	1985	1978	1979	1980	1981	1982	1983	1984	1985
Rameswaram	—	—	50	—	—	—	—	—	22	40	150	30	126	50	10	15
Pamban	635	700	300	85	150	185	100	70								
Vedalai & Seeniappa Darga	675	600	608	400	1025	605	160	582	250	300	180	20	63	25	—	—
									550	345	95	62	305	100	45	80
Pudumadam	40	5	5	10	10	20	20	5	—	—	—	—	—	—	—	—
Periapattanam	850	1170	708	550	655	350	30	315	44	50	—	—	10	—	—	—
Kalimankundu	5	—	—	25	—	—	—	—	—	—	—	10	—	—	—	—
Kilakari	841	1060	857	700	546	250	150	630	155	546	13	100	150	200	160	270
Ervadi	350	275	190	350	105	300	10	226	—	—	—	—	50	—	20	20
Valinokkam	160	100	120	120	75	—	—	123	—	—	—	—	—	—	—	—
Mundal	60	230	115	145	140	35	—	50	—	—	—	—	—	—	—	—
Kanyakumari area	20	116	137	137	470	325	310	95	—	—	—	—	—	—	—	—
Total	3636	4256	3090	2522	3176	2070	780	2096	1021	1281	438	222	704	375	235	385

Landing Centre	*Gelidiella acerosa*								*Gracilaria edulis*								*Gracilaria crassa*		
	1978	1979	1980	1981	1982	1983	1984	1985	1978	1979	1980	1981	1982	1983	1984	1985	1983	1984	1985
Rameswaram	7	10	70	16	25	50	15	20	—	4	40	—	—	1	—	—	—	4	—
Pamban	112	100	40	40	5	30	60	27	175	200	60	24	40	4	15	30	—	2	—
Vedalai & Seeniappa Darga	15	86	—	—	—	—	—	—	187	120	112	68	180	285	300	225	85	80	21
Pudumadam	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Periapattanam	2	—	5	—	7	3	—	5	—	—	—	—	—	—	—	—	—	—	—
Kalimankundu	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Kilakarai	142	345	77	50	50	145	70	110	33	18	1	25	5	1	5	14	—	10	24
Ervadi	10	—	55	25	15	65	65	27	—	—	—	—	—	—	—	—	—	—	—
Valinokkam	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mundal	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Kanyakumari area	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	288	541	247	131	102	293	210	189	395	342	213	117	225	291	320	269	85	96	45

8. Sri Industries, Silaiman, Madurai Dist., Tamil Nadu.
9. Marine Byproducts, Kappaloar, Madura Dist., Tamil Nadu.
10. Nellai Agar-Agar Industries, Vannarpet Tirunelveli Dist. Tamil Nadu.
11. Bharath Agar Industries, Industrial Estate, Kovilpatti, Tirunelveli, Dist. Tamil Nadu
12. Indo-Nippon Seafoods, Thuvakudi Industrial Estate, Tiruchirapallai, Tamil Nadu.
13. Gurukripa Chemicals, Ahamedabad, Gujarat State.
14. Gel Products (P) Ltd., Prantij; Gujarat State.
15. Gel Enterprises, Vallabh Vidyanagar, Gujarat State.
16. Oceanic Products (P) Ltd., Latti Bazaar, Kakthapith, Ahamedabad, Gujarat State.
17. Sea Products of India Ltd., Chembur Industrial Estate. Bombay, Maharashtra State.
18. Cochin agar and Chemicals, Chulickal, Cochin-5, Kerala State.
19. South Sea Chemicals, Judimetla, Hyderabad, Andhra Pradesh.
20. Algae Chemicals, Muralinagar, Visakhapatnam, Andhra Pradesh.
21. Inagar Chemicals Ltd., Mahatab Road, Cuttack-3, Orissa.

Algin Industries

1. Altex, Pamban, Ramnad Dist, Tamil Nadu.
2. Meenakshi Chemicals, Kappallor, Madurai Dist.. Tamil Nadu.
3. Madurai Marine Chemicals, Kappaloor, Madurai Dist., Tamil Nadu.
4. Kothari Phytochemicals, Nagari, Madurai Dist., Tamil Nadu.
5. Marine Byproducts, Kappaloor, Madurai Dist., Tamil Nadu.
6. Omege Industries, Kappaloor, Madurai Dist., Tamil Nadu.
7. Lakshminarayana Chemicals, Madurai, Tamil Nadu.
8. Seachem Industries, Amaravathipudur, Karaikudi, Tamil Nadu.
9. Snap Natural & Alginate Products, Ltd., Plot No. 1, Sipcot Industrial complex, Ranipet. North Arcot, Tamil Nadu.
10. Sri Balaji Chemicals, T. J. Road, Coimbatore, Tamil Nadu.
11. Excel Industries, Madras, Tamil Nadu.
12. Pondicherry Alginate & Allied Products Kirumanbakkam, Pondicherry.
13. Pat Brothers, Ahamedabad, Gujarat.
14. Cellulose Products of India (P) Ltd., Ahamedabad, Gujarat State.
15. Algitex and Allied Chemicals, Ahamedabad, Gujarat.
16. Ramkarsh Industries, Kapasic Bazaar, Ahamedabad, Gujarat.
17. Ashahi Chemical Industries (P) Ltd., Firobos R. A. Mehta Road, Shaibuf, Ahamedabad, Gujarat.
18. Algae Chem Industries, Odhar, Odhar Road, Ahemadabad, Gujarat.
19. S. Kumar & Sons, 7th Floor, Kamalde Flats, Ellus Bridge, Ahamedabad, Gujarat.
20. Western Chemicals, Ahamedabad, Gujarat.
21. Excel Industries, Hadapson Industrial Estate, Poona, Maharashtra.
22. Harivardhana Chemicals, Ernakulam, Kerala State.
23. Belur Chemicals, Mysore, Karnataka, state.
24. Brahmaweer Chemicals, Brahmawara, South Kanara, Karnataka State.
25. Indian Ocean Alginates. Pattancheru Industries Estate, Hyderabad, Andhra Pradesh.

EIGHT

SEAWEED CULTURE

V. S. K. CHENNUBHOTLA, N. KALIAPERUMAL, S. KALIMUTHU
J. R. RAMALINGAM, M. SELVARAJ AND M. NAJMUDDIN

Seaweed culture has perforce to be adopted should the supply of raw material to Industries be uninterrupted ,like in the case of the Japanese and Korean *Porphyra* industries, the Chinese *Laminaria* industry and the Philippines *Eucheuma* Industry, which are now in the main based on cultured raw material. The culture is at present almost entirely confined to the Orient, reaching its peak of sophistication in Japan and China. The necessity of marine algal cultivation in India and the principles and problems involved therein are discussed by Thivy (1964), Krishnamurthy (1967) and Chennubhotla (1976).

There are several advantages in the cultivation of seaweeds. In addition to making possible a continuous supply of alga, crops of single species can be maintained continuosly; by taking proper care a harvest consisting of a desired seaweed unmixed with other algae can be obtained and this alga would be uniform in quality. By adopting scientific breeding and other modern techniques of crop improvement, the yield and quality of the seeweed could also be improved. Further, if seaweed cultivation is carried out on large scale, natural beds could be preserved purely for obtaining seed material.

Basically there are two methods for cultivation of seaweeds; one by means of vegetative propagation, using fragments, and the other by means of spores such as swarmers (gametes), oospores, tetraspores and carpospores. The vegetative propagation method, using fragments from mother plants, is a simple method and gives quick results, though a large number of mother plants have to be sacrificed for seed material. In the culture of seaweed from spores, the latter are first collected on suitable substrat such as bamboo splints and nets and these substrata are transplanted to the desired sites, where the seaweed can grow into harvestable size. The only disadvantage in this method is that it takes a long period for the development of spores to plants of harvestable size.

For cultivation of seaweed, suitable sites have to be selected and prepared for long-term usage. When seaweeds are brought under intensive cultivation, predators and diseases naturally increase and damage the crop. The culture sites can be protected from these with latticed fence, which would reduce surf action and at the same time allow free flow of water in and out of the enclosures. It also would prevent the entry of fish which may feed on the crop. Harvesting of the algae has to be done at the proper developmental stage, depending on the utility of the alga.

SEAWEED CULTURE IN INDIA

In India, seaweeds which are used as raw material in the seaweed industry are harvested from natural beds along Tamil Nadu and Gujarat coasts since 1966. There are about 21 agar industries and more than 25 algin factories in India (Silas and Kalimuthu, 1986). As many seaweed Industries are still coming up, there is an increasing demand for this raw material, particularly agarophytes, which the existing resources cannot meet.

Hence, the culture of seaweed is attempted at by Central Marine Fisheries Research Institute, Central Salt and Marine Chemical

Research Institute and National Institute of Oceanography.

CULTURE EXPERIMENTS IN CENTRAL MARINE FISHERIES RESEARCH INSTITUTE

Since 1972, Central Marine Fisheries Research Institute is involved in the experimental culture of agarophytes *Gracilaria edulis* and *Gelidiella acerosa*; alginophytes *Sargassum wightii* and edible seaweeds *Acanthophora spicifera* and *Ulva lactuca* (Plates 3 & 4). It has developed a suitable technique for the large-scale culture of *G. edulis*. The rate of production of these seaweeds and also the economics of farming *G. edulis* are as follows.

Culture of Agar Yielding Seaweeds

Gracilaria: Culture experiments were conducted on *Gracilaria edulis* and *G. corticata* (Umamaheswara Rao, 1973). Fragments of *G. corticata* were kept in the twists of a small coir rope at regular intervals and the rope was suspended in seawater aquarium. Slow growth was observed for a period of 45 days and, thereafter, rapid increase in length from 1.8 cm to 5.5 cm was recorded during the next 45 days. Experiments on *G. edulis* were conducted in the sea near Mandapam, using coir-net frames of about 0.5 cm^2. Small fragments of *G. edulis* were introduced on each frame and were suspended horizontally in the sea. Many new shoots developed from the cut ends of the plant bits and, after 2 months, the entire frames were covered with plants of profuse branches. The average height of the plants varied from 14 cm to 16 cm and, at the end of 2 months, the plant bits that had been kept in the two frames gained weights, respestively, of 213 g and 257 g. From these experiments, the regeneration in *G. corticata* and *G. edulis* was found to be high, the plants growing to harvestable size with in 3 to 4 months.

To know if *Gracilaria edulis* can be cultivated in open-shore enviroment, field experiments were conducted in the Gulf of Mannar (Umamaheswara Rao, 1974 a). Two coir nets of 4 x 2 m size were used for seeding. Fragments of *G. edulis* of about 4.0 cm length taken from the apical parts of plants were inserted in the twists of the coir rope. Nearly 2.5 kg. of seed material was introduced for each frame and the frames, tied honizontally to poles with coir ropes, were kept at subtidal level so as to keep them permanently submerged. Harvesting was done after 80 days, leaving the basal parts of plants for further growth. The density of the crop varied on the two frames, and an average yield of 4.4 kg fresh seaweed was obtained from the seed material of 313 g per square metre area of the coir net.

Experiments were also carried out for cultivating *G. edulis* in the inshore waters of Gulf of Mannar, in submerged free-floating condition (Chennubhotla *et, al.*, 1978 a). Culture frame of 2 x 2 m size fabricated with teak wood and coir nettings of 7 cm mesh size made out of ropes of 2.5 cm and 1.3 cm thick were used. A total weight of 1.42 kg *G. edulis* fragments of 4.5 cm length were used for seeding, inserting them in the twists of the coir ropes. The frame was tied loosely to the poles fixed in the nearshore waters at 1 m depth in a submerged floating condition so as to facilitate its going up and down vertically according to the tide. Harvesting was made after 45 days. The fresh weight of the harvested meterial was 1.985 kg per square metre against the seed meterial of 355 g. The harvested meterial was pure, without contamination of other seaweeds and sediments. Thus, the submerged free-floating condition at 1 m depth is suitable not only for culturing the alga but also for obtaining pure cultures, without any contamination. The experiments conducted simultaneously at sub-tidal level were, however, hampered by much sedimentation, which adversely affected the growth of seaweeds.

Thus, the seaweed cultivation in the inshore waters is shown to be beset with problems such as sedimentation, as well as grazing of seed meterial and grown up plants by fishes. To overcome these constraints, cultivation of *G. edulis* was attempted at slightly deeper water, of 3-4 m depth, where sedimentation is less. The coir nets were replaced by nets made of hardened plastic (HDP) rope. The nets were of 5 x 2 m size, and were fabricated with ropes of 3 mm thickness, using 4 mm thick rope for their margins. The mesh size of the nets was 10 cm, and each net had altogether 1000 mesh intersections. The seed materials were tied at

the mesh intersections with the help of nylon twine, and the nets were suspended at different levels with the help of plastic buoys and granite stone sinkers. Three such nets were introduced, with seed material of 665g m^2, at midwater level in a 4-m depth zone, and the yield after 90 days was 1617 g/m^2. Another net, containing 700 g seed material, was introduced just below the surface, and this yielded 2570 g/m^2 after 70 days.

Economics of Gracilaria edulis *Farming*

Based on the results obtained on the field culture of *G edulis* in the Gulf of Mannar and Palk Bay near Mandapam, Central Marine Fisheries Research Institute has evolved a technique for culturing *G. edulis* using coir rope nets (Anon, 1983). According to this method, one kg of seed material of *G. edulis* would yield on an average 3 kg per sq. m of net after 60 days. In one ha area of nets (i. e. 1000 nets) 30 tonnes fresh *G. edulis* could be obtained in one harvest. Six harvests could be made in a year if the condition of the sea was favourable. The nets could be used for several crops.

For the cultivation of *G. edulis* in one ha 1000 coir nets of 5 x 2 m size, 2000 casuarina poles of 1.5 m height and 10.000 kg of fresh seed material (for initial introduction) are required. The cost of 2000 casuarina poles is Rs. 6,000 and cost of 1000 coir rope net is Rs. 33,000, including charges for fabrication. The seed material can be collected for the initial introduction from the natural beds, and from the cultured crop for subsequent seeding. Wages for seeding, harvesting and maintenance of the seaweed farm for 4 persons at the rate of Rs. 10 per day for 360 days work out to Rs. 14,400. The total expenditure for one year would be Rs. 54,000, including miscellaneous expenditure of Rs. 600.

The estimated cost is arrived at on the assumption that a minimum of four harvests could be made in a year. A total of 120 tonnes (fresh weight) of crop could be obtained from the four harvests in a year when the yield is 3 kg/m^2. If the seaweed is dried (75% moisture) and marketed at a rate of Rs. 2000 per tonne, the net profit would be Rs. 6,000 for one year.

Gelidiella acerosa : Chennubhotla *et. al.* (1977 c) cultured *G. acerosa* by tying small fragments along with the substratum (coral piece) to the coir ropes interwoven in 4 sq m size G. I. pipe frames. The frames were tied in submerged condition to poles fixed in the inshore waters. One frame was introduced with 0.9 kg and the other with 1 kg seed material. The crop was harvested after 76 days and an increase of 1.6 kg and 2.0 kg was obtained, respectively. Recently field cultivation of *G. acerosa* was attempted in two methods. In one method, the fragments of the seaweed were tied to nylon twines at regular intervals and the seeded twines were then wound round the nails hammered into coral stones. The coral stones were kept in cages which were suspended at 2 m depth. In the other method the fragments of the seaweed were tied in the mesh intersections of the HDP rope nets and introduced at a 4 m deep station in floating condition with the help of plastic buoys and anchors. In one net of 5x2 m size introduced at mid water level with *G. acerosa* seed material of 650 g/m^2, the yield was 1300 g/m^2 after 55 days growth. Another net of 5x2 m size introduced just below the surface level yielded 1060 g/m^2 for the seed material of 650 g/m^2 after 60 days growth. The fragments of *G. acerosa* fastened to coral stones with the help of iron nails reached harvestable size after 5 months and 1.0 kg of seed material yielded 3.1 kg.

Culture of Edible Seaweeds

Acanthophora spicifera : Cultivation of *Acanthophora spicifera* was carried out in a pond (60 m X 30 m size) at the fish farm of Regional Centre of Central Marine Fisheries Research Institute, Mandapam Camp, which is situated on the Palk Bay side. The pond was connected to the sea through a feeder canal and so there was regular inflow and out-flow of seawater, depending upon the high and low tide, respectively. The depth of water ranged from 40 to 60 cm and the bottom was muddy with loose sand. The seeding on the nets was done in 2 HDP rope nets of 5X2 m size in the pond itself by keeping the nets in the water in order to avoid drying of seed material in the open air. The seaweed was cut into small fragments

of 6 to 8 cm length and tied at the mesh intersections of the nets with the help of nylon threads. The culture nets thus seeded were tied in the centre of the pond to the palmyra poles already erected, at a level of 24 cm from the bottom of the pond so that they were always submerged even during the low tide conditions of the sea. The plastic floats were tied to the nets so that the nets may not sink to the bottom due to the weight of the plants when they grew. Seed material introduced was 620 g m^2 in both nets. Two harvests were made from the nets. The first harvest was made after 45 days growth. A yield of 2262 g/m^2 was obtained from the two nets and it was 3.6 fold increase over the initial seed material. The remnants were allowed to grow for the second harvest which was made after another 35 days. An yield of 1440 g/m^2 was obtained in the second harvest. There was no epiphytic growth of other algae on the nets Silt deposition was found on the plants but it had not hampered the growth of the seaweeds. These observations revealed that pond system is suitable for the cultivation of *A. spicifera* as similar culture experiments conducted simultaneously with *Gracilaria edulis Gelidiella acerosa, Hypnea valentiae, Sargassum wight*[ii]*, Turbinaria conoides* and *Ulva lactuca* in the same pond did not give encouraging results due to too much sedimentation on the plants and also other factors like high salinity.

Ulva lactuca : Culture of *Ulva lactuca* was attempted in the laboratory in two plastic troughs (58 cm dia X 23 cm ht) with 20 cm water level. 50 g of excised pieces of *U. lactuca* were uniformly broadcasted in each trough. Aeration was provided for both troughs and the water was changed once in a week. The experiment was conducted in the varandah of the laboratory where the plants received direct sunlight for 4 hours during the after-noon hours and diffused sunlight during the rest of the day. Growth rate was determined by weighing the seaweed in each trough at every fortnight. The data were collected for a period of 75 days. The weight of the plants increased two fold after 15 days growth . Maximum weight of 120 g was obtained in each trough after 30 days and thereafter gradual decrease was observed. The weight of plant was 106 g, 85 g and 67 g after 45, 60 and 75 days growth respectively. Experiments on *Ulva lactuca* pretreated with Ascorbic acid and in different salinities have indicated that 18‰ boosts up the production to 8 times in 92 days.

SEAWEED CULTURE BY OTHER RESEARCH ORGANISATIONS IN INDIA

Some preliminary field and laboratory culture experiments were also conducted by other research organisations on the economically important seaweeds namely *Gelidiella acerosa, Gracilaria edulis, G corticata, Gelidiopsis variabilis, Gelidium pusillum, Hypnea musciformis, Hormophysa triquetra* and *sargassum* spp and the results obtained are given below.

Gelidiella acerosa: Bhanderi (1974 b) cultured *Gelidiella acerosa* for 105 days by vegetative propagation in aquarium. Vegetative fragments of 2.5 cm were obtained from the apical region of the plant, weighed and inserted in the twists of string of known weight and then suspended in an aquarium full of seawater. He observed a linear growth of 0.01 cm/day and an increase of 0.01 g/day in weight. Krishnamurthy *et. al.* (1975) conducted some experiments on *G. acerosa* in a lagoon on the southern side of Krusadai Island in November-December, ,1969 by inserting 2 cm fragments in the twists of ropes. In April, 1970, the fragments were grown into full sized plants, about 10 cm in length with 7 to 8 main branches.

Subbaramaiah *et. al.* (1975) conducted cultivation of *G. acerosa* in a shallow lagoon at Krusadai island. Planting was done using 2 cm apical fragments which were fastened to a nylon string at fixed intervals and the seeded string was wound round the rope. The rope was tied in the cultivation ground between poles and it was always submerged under seawater at a depth of 0.5 to 1.0 m. Three harvests were made during one year and the growth and harvest values were maximum in the third harvest during February and July. The maximum growth attained was 6.6 cm and the rate of production was 3.13 g/m/month(wet). The total production of seaweed was 421g/m (wet.)

Experimental field cultivation of *G. acerosa* using coral stones as the substratum was done at Ervadi (Patel *et. al.*, 1979). An annual yield of 115.83 g/m² (dry) on overall basis was obtained which was 33 fold increase over the seed material. Patel *et al.* (1980) reported a maximum yield of 122 g/m² (dry) in one of their six monthly harvests made in January 1979 from the field cultivation of *G acerosa* at Ervadi.

Gracilaria edulis: Raju and Thomas (1971) cultured *G. edulis* by long line rope method in a sandy lagoon on the estern side of the Krusadi Island where the water is calm for most part of the year. Fragments of 1 cm and 2.5-3.0 cm length were used for planting and they grew to a length of 35-40 cm in about 5 months period. Three harvests were made at the end of 5, 8 and 10½ months after planting and the total harvest during the year was about 3.5 kg from 1 m length of rope.

Krishnamurthy *et. al.* (1975) carried out cultivation of *G. edulis* in a lagoon on the southern side of Krusadai Island in June and July, 1967. Fragments of 2.5 cm length removed from the apices of the healthy plants were inserted between the twists of ropes, one each at intervals of four inches along the length of the ropes. These ropes were tied to bamboo poles planted to the sea bottom and adjusted at a level of roughly one foot above the bottom. In about 5 months, the plants attained a length of about 30 cm and the average weight of plant was about 300 g. In the fifth month, a harvest was made by clipping the plants close to the rope and the remnants were left on the rope for further growth Two more harvests were made at intervals of 10 weeks, thus giving 3 h.rvests in a period of 10 months.

Other red algae: Bhanderi (1974 b) recorded a linear increase of 0.02 cm/day and an increase of 0.07 g/day in the weight in his culture experiment on *G. corticata* in seawater aquarium. Bhanderi (1974 b) cultured *Gelidiopsis variabilis* for 105 days by vegetative propagation in an aquarium. The linear increase obtained was 0.12 cm/day and the increase in weight was 0.04 g/day.

Mairh and Sreenivasa Rao (1978) cultured *Gelidium pusillum* in the laboratory under free floating conditions using different enrichments and under controlled conditions of light and temperature. The plants grown under different photoperiods as well as under continuous illumination reached maximum fresh weight and full size within 3 to 4 months. This experiment showed that fragments of *G. pusillum* as small as 2 mm in length can regenerate without any loss in their capacity to produce proliferations.

Rama Rao and Subbaramaiah (1980) culture *Hypnea musciformis* in the lagoon of Krusadai Island. Vegetative fragments of *H. musciformis* were used as seed material and cultured in long line rope. Fourfold increase in biomass in 25 days growth was achieved.

Sargassum *spp:* Thivy (1964) conducted culture experiments in ponds at Porbander by attaching small plants of *S. cinctum, S. vulgare* and *S. wightii* to coir nets with the help of tape. The seed materials were collected from their natural beds of reef at Porbandar and their size ranged from 5-10 cm length. The plants of *Sargassum* grew to a height of 15 to 52 cm within forty days and most of them were in fruiting condition. The experiment revealed that there are good possibilities for cultivation of *Sargassum* and other seaweeds in India.

Hormophysa triquetra: Bhanderi and Trivedi (1977) made an attempt to study the possibility of culturing *Hormophysa triquetra* by vegetative propagation in an aquarium. Stipes of about 3 cm size without fronds and fragments of 3 cm size distal end of fronds were obtained, weighed and then inserted at the intervals into the separate nylon strings. The rate of linear growth of stipes was found to be 0.083 cm/day while that of the fronds was slightly more i. e. 0.085 cm/day. At the end of the cultivation period the stipes had increased the fresh weight equal to that of its inserted weight at a rate of 0.089 g/day. The fragments gained 7 times fresh weight than that of their initial weight at a rate of 0.333 g/day.

SEAWEED CULTIVATION IN FOREIGN COUNTRIES

The important seaweeds for which commercial cultivation is practised or is being developed are *Enteromorpha, Monostroma* and *Ulva* (green algae); *Alaria, Ascophyllum, Ecklonia Hijikia, Sargassum* and *Undaria* (brown algae) and the red algae *Agardhiella, Chondrus, Eucheuma, Furcellaria, Gelidium, Gigartina, Gloiopeltis, Gracilaria, Hypnea, Porphyra* and *Rhodymenia* (Neish, 1979 and Saito, 1979). The seaweeds cultivated in different countries in the Indo-Pacific region and the extent of development are given by Ling (1973). At present edible seaweeds are intensively cultivated in Japan, Korea and China. The genera cultivated in North-West Pacific are *Porphyra. Monostroma, Enteromorpha, Undaria, Laminaria* and *Nemacystus.* The red alga *Eucheuma* is cultivated in the Philippines (Satio, 1979).

Culture of Red Algae

Porphyra: The genus *Porphyra* is known as 'Laver' in European and American countries and as 'Nori' in Japan. The methods of its cultivation are reviewed by various authors (Tamiya, 1960; Kurogi, 1963; Thivy, 1964; Krishnamurthy, 1967; Sreenivasa Rao, 1967; Ryther 1968 a; Bardach *et. al.* 1972; Furukawa, 1973; Ling 1973; Miura' 1975; Background, 1976 and Saito, 1979). *Porphyra* culture has a history of over 200 years in Japan. It began in Tokyo Bay in the 17 th century. The original culture method involves placing bundles of leafless branches of bamboo, oak or other trees at or just above the mean water level in areas located well away from brackish water during winter (September to October). Within 2 to 4 weeks the non-motile monospores settle on the branches and develop into leafy thalli. The branches along with the leafy thalli are moved inshore preferably to an area such as around a river mouth where high concentrations of dissolved nutrients occur. The thalli grow there and are harvested periodically. Though the method has now become obsolete in Japan, it is still practised in Korea.

Efficient culture methods were developed only after the second world war and the industry expanded rapidly and extensively in Japan and Korea after the discovery that the Conchocelis stage of the alga is passed in a shell during summer and produces monospores, which grow in to the leafy thallus. This discovery provided the basic knowledge for the development of technique for mass production of seedlings under controlled conditions.

The most successful and common practice of *Porphyra* culture is known as 'floating rack method'. The racks are made of bamboo and are set in shallow coastal areas where the water is clean and comparatively well protected from storms and heavy wave action. A net with seedlings attached is hung horizontally on each rack. The net is made of plant or synthetic fibre about 18 to 45 m long and 1.3 to 1.5 m wide with a mesh size of about 33cm.

The preparation of seedlings (production of monospores from Conchocelis) under controlled conditions is done during winter (December to March). Conchocelis are induced to produce monospores by various temperature and chemical treatments. The monospores attach readily to the net when it is passed through the tank which contains the spores. The nets with monospres attached may be made into single unit sheet or into a roll that can be cut into 10 to 25 sheets and stored under a temperature of 20°C to 24°C for several months with the spores remaining viable. Within 15 to 20 days after the setting of nets the alga grow to 10 to 15 cm length, when the first harvest is done. The remaining plants continue to grow and harvest is repeated 3 to 4 times before the net is replaced.

Gracilaria : Culture of *Gracilaria* is being practised fairly successfully since 15 years in Taiwan in shallow coastal flats and ponds and is expanding steadily. The method of *Gracilaria* culture at Taiwan is described by Chen (1976). Of the 4 species of *Gracilaria*

of economic importance viz. *G. gigas (= G. chorda)*, *G. confervoides*, *G. lichenoides* and *G. compressa*, *G. confervoides* is the species most commonly cultured in ponds. *G. gigas* is also cultured in some areas. Culture of *Gracilaria* started in 1962 and the cuttings of *Gracilaria* are used as planting stock. Each plant is cut into pieces, which are planted uniformly usually in April on the bottom of the pond. 3000 to 5000 kg of the fragmented plants are planted in a pond of one hectare size. The planting stocks are placed uniformly on the bottom. They are usually fixed on bamboo sticks planted on the bottom or covered with old fish nets to prevent them from drifting to one side or one corner of the pond. Either organic or inorganic fertilizer is used to accelerate the growth of *Gracilaria*. Harvest by hand or by use of scoop nets is done once in 10 days from June to December. *Gracilaria* is cultivated as side crop in some places in Philippines (Blanco, 1973). Substrate additions to increase stocks of *Gracilaria* has also been practised in tropical areas by spreading dead coral over predominantly sandy areas where these seaweeds can not attach (Neish, 1979). Culture experiments in the laboratory with plant segments of *Gracilaria debilis* were conducted by Goldstein (1973). The segments regenerated branches from the cut surfaces and they showed rapid vegetative propagation when coral stones and lime stone blocks were used as substrate.

Eucheuma : The culture of the red algal genus *Eucheuma* is described by Blanco (1973), Kow *et. al.* (1973), Parkar (1974) and Deveau and Castle (1979). Two methods of culture have been developed for *E. cottonii* namely the net method and line method. The method using net consists of fabricating 2.5X5 m size nets with monofilament nylon and with a mesh size of approximately 0.3 m (1 foot). Each net has 127 mesh intersections where vegetative fragments are tied. The nets are installed horizontally 0.6-1.5 m above the bottom and below lowest tide depth by attaching net corners to mangrove wood poles, driven in the reef bottom, an area previously tested for growing ablilty. The nets are seeded with 100 g pieces of seaweed by tying them to the net with a thin plastic strip which does not cut the fronds and allows them to move in the current. Once the plants have reached a weight of 1200-1500 g they are pruned to 500 g and the process continues. Attempts are being made to grow *E. spinosum* commercially. A brief account of the experimental cultivation of *E. spinosum* in Singapore water and culture conditions are given by Kow *et. al.* (1973).

Tank culture method of *Eucheuma* was given by Deveau and Castle (1979). *E. isoforme* was cultured in tank and the basic cuitivation system used was a square tank with a slanted bottom and its water was agitated by bubbling air into the deepest part of the tank. This established a circulation pattern strong enough to keep the dense *E. isoforme* in constant suspension and this assured that all plants would receive their share of sunlight and be uniformly exposed to the dissolved nutrients in the seawater. The tank culture method was sought for developing a controlled combined supply of the raw materiai of *Eucheuma* to that cultured in the sea.

Culture of other red algae: A number of other algae are cultured in Japan. The most important edible alga cultured is *Gloiopeltis* (Funori) which is used in the manufacture of glue. Production of *Gloiopeltis* has been increased by simply placing boulders or chunks of concrete at suitable locations in the sea to provide substrate for settlement. Advanced experimental culture of *Hypnea* sp. in the Philippines are based on suspending thalli, under protected and other optimal growing conditions (Bardach *et. al.*, 1972). Some measures of success had been achieved in the culture of *Chondrus crispus* (Saito, 1979). The method consists of propagating *Chondrus* in detached from in agitated ponds or tanks. Although this technique is still in the initial stage, it is under active commercial development and is expected to

produce significant quantities of Chondrus within the next 5 years. This system is also being considered for culture of *Gigartina* and *Hypnea* (Neish, 1979). *Hypnea musciformis* was cultured (Guist *et. al.*, (1982) in outdoor plywood tanks (2.4 m x 1.2 m; maximum depth 1.1 m; minimum dapth 0:5 m; 2.9 m^2 surface area and 2400 1 capacity) at Summerland Key, Florida for 15 months. A continuous flow of untreated seawater (790 1/h) was supplied to each tank, Each culture tank was agitated with a continuous flow of compressed air pumped through a sparger located along the deep end of the culture tanks. Sodium nitrate, ammonium nitrate or ammonium sulphate was used as the source of nitrogen, while trisodium phosphate served as phosphate source. Enriched tanks received 208-400 µM of nitrogen and 1.6 - 3.2 µM. of phosphate each day. The highest growth rates were observed when the water temperature was between 18° and 24°C and with continuous water flow, supplemental nitrogen and phosphate and an initial biomass of 1.86 kg weed per square metre of surface area in the culture. tanks.

Culture of Brown Algae

A few brown algae, mostly the large species known as kelp are cultured. In Japan the most important brown algae cultured are *Undaria pinnatifida* (Wakame) and *Laminaria* spp (Konbu). Among these two, *Undaria pinnatifida* is more intensively cultivated.

Undaria: The culture method of *Undaria is* given in detail by Ryther (1968 b), Bardach *et. al.* (1972) and Saito (1975). Until the late fifties. methods of culture of *Undaria* were extremely primitive and consisted of only anchoring plastic floats at suitable depths for attachment of young plants. By about 1956, a technique of artificial spore production was worked out at Onagawa, in the Sendai region of northern Honshu. Most of the increase in the production of *Undaria* can be attributed to the introduction of artificial spore collection technique developed in 1960. The preparation of seedling culture begins at the end of the season when *Undaria* plants mature and develop zoospores. Seedling twines are used for spore collection and the culture of germlings, The meterial used for seedling twine is mostly synthetic fibre yarn of 2 3 mm diameter. The 100 m long twine is wound around at intervals of about 1 cm in a square plastic frame of 50 x 50 cm size.

Mature sporophytes of *Undaria* which have been partially dried are placed in concrete or plastic tanks filled with fresh seawater. The sporophylls are removed after a large number of spores have been released in the seawater. The string or twine frames are arranged in layers inside the tank to collect the zoospores. The frames are removed after 1 or 2 hours and hung vertically in culture tanks of about 1 m depth. The seedlings which develop are cultured throughout the summer. Within the tanks, according to changes of water temperature, light intensity is regulated so as to keep the growth of the gametophytes in good condition and their survival rate at high level. If necessary the tank water is changed, circulated or supplied with nutrients. The frames with their seedling twines are later taken from the tanks and suspended in the sea from a raft in order to raise the germlings into healthy young thalli until they grow to 2.3 cm in length. Operations for growing *Undaria* thalli start in autumn (September - November) when the water temperature falls below 20°C and danger of attachment of epiphytic organisms diminishes. Seedling twines are attached to a 10-20 mm diameter synthetic fibre rope at suitable intervals. Sometimes the twine is cut into short pieces of 5-6 cm length and inserted in twists of the rope. The cultivation ropes are set in the sea by hanging from bamboo rafts or buoyed long lines. In rough waters, 100 m long cultivation rope is held in the sea with buoys and anchors and many ropes are aften hung from the main rope. In calm waters like bay, the ropes are stretched out horizontally in the sea by rafts. When the thalli have grown to more than 50-60 cm in length, harvest is made by hauling the rope to a boat and cutting the thalli with the sickle. The use of seedling

twines for the cultivation of *Undaria* was started in Korea in about 1960. In China after the second world war both *Undaria* and *Laminaria* cultivations were industrialised.

Laminaria : Methods of *Laminaria* cultivation are elaborately given by Bardach *et. al.* In Japan until 1943 cultivation of *L. Japonica* was confined to the practice of throwing stones bearing spores or young sporophytes into the sea. Attempts at more intensive culture both on rafts and on bottom were made by the Japanese. The basic technique involved in artificial propagation of *L. japonica* consists of collecting zoospores from sporophytes in late autumn and lodging them on short ladders made of bamboo splint and hung from floating rafts. Young sporophytes appear on the ladders by January and are removed for use in one of the methods of *Laminaria* cultivation.

The earliest attempts at culture of *Laminaria* sporophytes involved growing the plants on the sea floor. Bottom culture is still employed in China as well as in Japan and Korea, but most of the tremendous increase in the Chinese production of *L. japonica* has come as the result of various forms of raft culture. Rafts which are generally anchored to stakes driven into the bottom in water at about 10m depth are of 3 types namely basket raft, single line tube raft and double line tube raft. The details of these 3 types of rafts are given by Bardach *et. al.* (1972).

Productivity is generally calculated in terms of amount of algae produced per kg of fertilizer. Though the basket raft required somewhat less labour to operate and produce higher quality of Laminaria, it yields about 1 kg of algae per kg of fertilizer, while the single line and double line tube rafts are capable of producing 3.75 kg and 3.0 kg of algae respecti vely per kg of fertilizer. So the single line tube raft is most popular.

Bottom culture of *L. japonica* persists in China largely because of the low cost in terms of labour, material and capital investment. Bottom culture is also carried out along with raft culture to take advantage of excess fertilizer. In addition, growth of *Laminaria* on the sea floor is encouraged because the plants provide shelter for various edible fishes and invertebrates which in turn help to fertilize the algae.

The classical method of bottom culture is called 'stone casting'. Originally stone casting consisted of not more than placing large stones, averaging 16 kg in weight in the shallow water to provide an attachment surface for naturally produced zoospores Now zoospores are collected and allowed to attach to the stones before deposition. The Chinese have brought exposed rocky areas into production by construction of 'tiered farms'. These culture areas consist of pools of varying depth from 40 to 150 cm bounded by rock and cement dams of graduated height. Stones are placed in the pools for attachment of zoospores. A cheap and simple method of culturing *L. japonica* is to attach young sporophytes directly to ropes anchored on the sea floor. This technique is being tested in China but is still in the experimental stages.

Cultured *L. japonica* sporophytes reach a length of more than 3 m in 4 to 5 months and they are large enough for harvest. The maximum length attained in raft culture is above 6 m. Raft cultured *Laminaria* is harvested from boats, but harvest of bottom grown plants is made with the help of trained divers.

Macrocystis : The culture of the giant kelp *Macrocystis* is described by Saito (1979). In the United States, seedlings of *Macrocystis* have been cultured on plastic rings and the rings set on rocky substrates using an under-water epoxy cement. Recently in the U. S. methods for mass culture of *Macrocystics* embryos and their dispersal into the sea have been developed. Seedlings attached to polye-thylene film substrates or glass fibre cloth substrates are cultured in a refrigerated room in a long tray through which chilled filtered and sterilized seawater flows. The embryos growing

on the substrates are scraped out, suspended in seawater and dispersed on a rocky bottom by pouring them down through a hose. Sometimes dispersal is done by a diver. These methods seem to be effective in the restoration of kelps resources. In North America preliminary investigations are underway by carrageenan producing companies to determine whether the hatchery produced macrophytes can be grown economically in a detached form in agitated culture tanks (Neish, 1979).

Culture of Green Algae

The green algae commonly used as food by man are *Enteromorpha* and *Monostroma*. Bardach *et. al.* (1972) have given an account of the culture of green algae in Japan and Taiwan. In Japan these algae are cultured along with *Porphyra*. *Monostroma* is cultured separately. Similar to *Porphyra* culture, the crop of *Monostroma* is grown on nets suspended horizontally at intertidal levels near river mouths. From a net of 36 x 1.5 m size usually 3 crops of 10 kg. 10 kg. and 6 kg (wet weight) are harvested after 100, 45 and 30 days respectively. The methods used in the highly successful culture of *Gracilaria coronopifolia* in Taiwan have been adapted to farming of *Caulerpa* sp for the fresh vegetable market in the Philippines. *Caulerpa* is grown in brackish water ponds seeded with chopped fresh pieces of the mature plant.

Selection of Strains of Seed Stock

Vegetative propagation of selected clones is a commercial reality in the Philippines, where various strains of *Eucheuma* are cultured. Selection of fast growing clones with desirable characteristics contributed to the high productivity of *Eucheuma* in Philippines. Selected strains of seed stock of *Chondrus* grow 2 to 3 times as fast as mixtures of wild stock (Neish, 1979). In China fast growing *Laminaria* strain such as Hai-Ching No. 1 have increased yields.

Use of Fertilizer in the Culture of Seaweeds

For intensive cultivation natural nitrogen levels are inadequate in most of the areas. Hence nitrogen fertlizers are used in *Porphyra* and *Laminaria* cultivation. In *Porphyra* culture, whenever the nutrients are poor culture sites are fertilized to get a better quality of harvest. In Japan the aim of fertilization is to obtain a high survival rate of young nori and to prevent the discolouration of older plants. The fertilizer is used at the rate of 600 mg/m² of water area and continuously for 2 to 3 days. The composition applied at the rate of 150 mg/m² of water area are given by Furukawa (1973). The fertilizing methods in the culture of *Laminaria* by basket raft and tube raft system are given in detail by Bardach *et. al.* (1972). Some culturists give a head start to young sporophytes of *Laminaria* by immersing them in a solution of fertilizer, usually ammonium nitrate. Absorption of nitrogen by plants so treated has been found to increase with concentrations up to 1 g/m² when the time of immersion does not exceed 6 hours. Stronger solutions may be used if the immersion time is reduced accordingly. 15 minutes is sufficient in a solution containing 400 g/m³ of fertilizer. Immersion accompanied by aeration and constant stirring may be carried out weekly. The fertilizer solution may be reused several times. Culture of *Laminaria* in sterile waters such as the Yellow Sea greatly increased the demand for chemical fertilizer, which are already in high demand and low supply for the use on terrestrial crops. Chinese researchers are currently considering another substitute source of fertilizer for *Laminaria*, and it is the large scale introduction of nitrogen fixing algae and bacteria in the Yellow Sea.

Experiments conducted by Parkar in Zamboanga, Mindanao (Philippines) in 1972 revealed that in *Eucheuma spinosum* test plant growth rates increased by 40-50% when 4.8 kg ammonium sulphate (21% Nitrogen and 24% sulphur) was applied to the test area over a 10 day period. Control plants showed no increase in growth rates during the same period. In Taiwan the growth of *Gracilaria* is accelerated by using either organic or inorganic fertilizers. In some areas 3 kg of urea are supplied weekly

to one hectare pond and in some other farms 120to 180 kg of fermented manure from pigsties are supplied to each hectare of the pond every 2 or 3 days at the time when water is being introduced (Chen, 1976).

Fertilizer pellets were applied in the field cultivation experiments of *Gelidiella acerosa* at Mandapam (Mairh *et. al.* 1979) with a view to get higher yield of the alga. These pellets were tried in the field rope cultivation of *Gelidiella acerosa* in a slotted polythene bag tied per metre rope. During nine months period, the pellets gave 20 to 30% increase in yield per metre rope over the control experiment,. There was no much change in the quantity and quality of agar obtained from the fertilizer supplied material and control.

Fertilizers are not used for culture of seaweeds in Korea. In general, fertilizing is not economical primarily because a system of slow and uniform release of fertilizer in sufficient quantities has yet to be perfected. One could consider fertilizing the culture area with inorganic fertilizer but tide would wash too much fertilizer away into non-exploited areas.

Use of Growth Promoting Substances or Hormones in the Culture

Studies on this aspect were carried out by Davidson (1950) on the growth of vegetative thalli of *Fucus evanescens* and *Ascophyllum nodosum* and by Oza (1971) on *Gracilaria corticata*. In all these cases low concentrations of IAA progressively stimulated the growth of the algae while higher concentrations were found to be lethal. Provasoli (1957) demonstrated the positive response to the exogenous application of gibberellins in *Ulva*. Raju (1971) conducted experiments on the effect of growth hormones and fertilizers on the phostosynthetic carbon assimilation in *Ulva fasciata*, *Sargassum* sp. and *Gracilaria corticata*. The photosynthetic uptake of C^{14} was maximum in *Gracilaria corticata* followed by *Ulva fasciata* treated with gibberellic acid. In *Sargassum* maximum effect on photosynthetic C^{14} assimilation was observed in plants supplied with ammonium sulphate. The effect of a morphaction on the vegetative growth of *Gelidiella acerosa* was studied by Tewari (1975). Chlorflurenol in hormonal range increased the fresh weight and the number of proliferations. But the elongation growth of the alga was inhibited. The possible applications of chlorflurenol for marine algae was also discussed (Tewari, 1975). Chauhan and Joshi (1979) reported that indole-3 acetic acid at the concentration of 10^{-6} M proved stimulant on the growth of *Sargassum swartzii* germlings than the other concentrations tried. The 10^{-3} to 10^{-6}M concentration of gibberellic acid helped in increasing the length of pseudophylls of the sporelings.

Diseases

Diseases are a matter of extreme concern in most intensive algal monoculture enterprises. Fungal, viral and external diseases have been described in *Laminaria* and *Porphyra* culture. At times diseases occur in *Porphyra* culture in association with unsuitable weather, environmental conditions in the sea and with overpopulation of the plants in the cultivating ground (Saito, 1979). The nori plants are susceptible to disease and most of the diseases are bacterial in nature. A fungus disease caused particularly by *Pythium* sp is lethal to *Porphyra* thalli, particularly at temperature above 10°C. When prevalent, this may wipe out 50% or more of the nori crop. Fungus may be at least partially prevented by exposing the seaweed to air during part of the tidal cycle. On the other hand, too much exposure may reduce growth and toughen the thallus, making it unsuitable for food. The most satisfactory compromise is to expose the algae for approximately 4 hrs/day (Bardach *et. al.*, 1972). The knowledge acquired on the disease resistance of various species of *Porphyra* is duly applied in selecting the variety to be grown. If disease has been observed in a crop, extra care has to be taken in washing and drying the nets before reusing them. Disinfectants have not been used so far (Background, 1976).

There is a disease problem also in the culture of *Undaria* and it causes detachment of young fronds and can result in a serious reduction of the crop. The origin and nature of the disease is not known. A number of diseases including various rot diseases are reported in *Laminaria japonica* but no effective means of control has been found (Bardach *et. al.*, 1972).

Predators, Fouling Organisms and Epiphytes

Predatory organisms attack the nori crop only when other seaweeds settle on the nets. These include green algae such as *Enteromorpha* and *Ulva* and also some diatoms. Careful manipulation of the level of the nets can overcome this problem. Most of the competing algae can not withstand exposure to air as much as the nori but one should be careful to avoid drying out of the nori plants as this is fatal to them (Background, 1976). Fouling organisms mainly barnacles settle on *Undaria* and cause some dificulties. But they do not result any heavy losses. Similarly predators and fouling organisms including bryozoans ascidians, amphipods and unwanted algae are found on *Laminaria japonica*. But no effective measures of control have been found for any of these constraints (Bardach *et. al.*, 1972).

Transplanted buds of *Macrocystis* are often eaten by gastropods and other grazers, resulting in failure in their propagation. Two methods have been tried to prevent this damage to the buds. One method is to try to supply these grazers with additional food by cultivating a large amount of seaweeds at or near the surface of the sea as a substitute for the food otherwise provided by young plant buds. These trials have been carried out on a large scale in northern districts of the Pacific coast of Japan. In the other method, after the concrete blocks wound with seedling twines bearing young buds are set out, they are covered by cages of synthetic fibre twines and the harmful grazers in the cages are removed. The cage is in the shape of a box (1.5 X 3 X 3m) or a cylinder (3 to 10m in diameter and 3 m height). The cage remains as protection from grazers until the plants become adult. This meihod has been tried in the southern districts of Japan and similar trials have been made in California (Saito, 1979).

The major predators in the culture of *Eucheuma* at Philippines are sea urchins. However, as the plants are elevated and as long as eel grass is kept short, sea urchins are not a serious problem. The farmers secure and remove them with a sharp stick. The epiphytes if unchecked will cover nets and plants of *Eucheuma* and reduce the growth. To accomplish this, the farmers brush nets with a plastic scouring pad and clean the plants with their fingers (Parker, 1974).

In India, the fishes *Signaus javus* and *S. canaliculatus* were found to feed voraciously on the cultured seaweed *Gracilaria edulis*. The crabs *Thalamita crenata* and *T. integra* cause extensive damage to growing parts of the seaweed by merely clipping them with their chelipeds as they crawl about amongst the seaweed (James *et. al.*, 1980). The 'problem of predators can be solved to a great extent by enclosing the cultivation area with a latticed fence or a net of a suitable mesh size.

Culture of Spores

The number of spores produced by an alga is enormous. In nature only a small number of spores grow to mature plants since viability, settlement and development of these spores are controlled by many hydrobiological factors such as water movement, tidal exposure, water temperature, competition for space and predators or grazing organisms. But when these spores are raised into germlings on suitable substrata in the laboratory or nursery and then transplanted to the field, a high rate of germlings grow to harvestable size plants. Some work in the direction of culturing the spores of economically important seaweeds was carried out in recent years. The estimate of spore output was made in a number of algae by different workers and the data are

presented in Table 13. Periodicity in the liberation of spores was observed in *Ulva fasciata*, *Cystoseira*, *Sargasaum swartzii* and *Gracilaria verrucosa*, but there is no such periodicity in *Sargassum wightii* and species of *Turbinaria*. Some information has been collected by Subbaramaiah *et. al.* (1967). Chauhan and Krishnamurthy (1967), Mairh and Krishnamurthy (1968), Krishnamurthy *et. al.* (1969), Subbaramaiah (1970), Raju and Venugopal (1971), Chauhan (1972) and Umamaheswara Rao and Kaliaperumal (1976) on settlement and development of germlings of different species of seaweeds in the laboratory and transplantation in the sea. Subbaramaiah and Krishnamurthy (1967) described the condition and media developed in recent years for the culture of seaweeds in the loboratory.

Subbaramaiah *et. al.* (1967) cultured germlings of *Ulva fasciata*. The germlings were kept growing in attached or in a free floating condition in petridishes containing sterile seawater which was changed once a week. In 2 months the germlings differentiated into cylindrical plants with 2-3 branches arising from the basal cells. The floating plants were longer (1.25-1.7 m) and produced branches while the attached ones were shorter (0.75-0.83mm) and unbranched. The growth of germlings did not advance beyond the cylindrical from during these 2 months. Subbaramaiah (1970) observed the settlement and growth of germlings 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 germlings attained a size of 5 mm in 100 days when they were raised on nylon string. The swarmer formation, liberation, settlement and growth of germlings on nets were also obtained in an experimental pond. The germlings attained on the average a length of 24.3 mm and breadth of 5.7 mm in 60 days. The effect of different culture media on growth and sporulation of laboratory raised germlings of *Ulva fasciata* has been given (Oza and Sreenivasa Rao, 1977). Kale and Krishnamurthy (1967) studied the effect of different media like plain seawater, Erdschreiber seawater and artificial seawater medium (modified ASP-6) on the growth of germlings of *Ulva lactuca* var. *rigida*.

Mairh and Krishnamurthy (1968) observed 100% germination of oospores of *Cystoseira* and subsequently 94% of their survival. The germlings survived and grew into young healthy plants under experimental conditions. Chauhan and Krishnamurthy (1967) cultured the oospores of *Sargassum swartzii* in petridishes lined with filter paper. They developed into germlings and some of them grew for a period of 5 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 germlings while a large number did not survive. Continuous illumination of the culture experiments with a light intensity of 600-800 lux, 23°-26°C temperature and circulation of a thin stream of filtered seawater were found favourable for healthy growth of germlings. Chauhan (1972) observed the survival of germlings in *Sargaasum swartzii* for about 6 months under the 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 germlings respectively. The filtered seawater and seawater with enrichment were found to be the most suitable culture media for the growth of germlings. The use of media like ASP-6 and ASP-12 did not give good growth of germlings. Continuous illumination was more beneficial than 18 hours photoperiod.

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 and growth, The

Table 13

Spore output in Indian marine algae

Algae (1)	Type of spore (2)	Number of spores liberated (Maximum spore output) (3)	Authors (4)
Ulva fasciata	Swarmers (Gametes)	1,15,34,400 spores/plant	Subbaramaiah *et. al.*, 1967
Cystoseira indica	oospores	5,11,251 ,,	Mairh and Krishnamurthy, 1968
Sargassum swartzii	,,	5,53,331 ,,	Chauhan and Krishnamurthy, 1967
S. wightii	,,	3,70,272 ,,	Umamaheswara Rao and Kaliaperumal, 1976
Turbinaria conoides	,,	11,312 ,,	Chennubhotla *et. al.*, 1978 b
T. decurrens	,,	28,196 ,,	Kaliaperumal and Umamaheswara Rao, 1975
T. ornata	,,	33,810 ,,	Kaliaperumal *et. al.*, 1977
Gelidiella acerosa	Tetraspores	20,000 ,,	Sreenivasa Rao, 1969
do	,,	10,000 Spores/g fr. wt./day	Umamaheswara Rao, 1974 b
Gelidiopsis variabilis	,,	2,60,940 ,,	Kaliaperumal and Umamaheswara Rao, 1982
Gracilaria corticata	,,	3,98,000 ,,	Umamaheswara Rao, 1976
do	Carpospores	2,374 Spores/Cystocarp/Day	,,
do	,,	8,66,700 Spores/plant	Mohan Joseph and Krishnamurthy, 1977
G. edulis	,,	6,49,873 ,,	Rama Rao and Thomas, 1974
G. millardettii	,,	42,782 ,,	Krishnamurthy, 1967
do	Tetraspores	68,520 ,,	,,
Gracilaria verrucosa	Carpospores	70,000 ,,	Oza and Krishnamurthy, 1968
Hypnea valentiae	,,	7,01,607 ,,	Rama Rao, 1979
do	Tetraspores	3,14,914 ,,	,,

concrete cylinders were lowered in *Sargassum* beds. Observation revealed that the appearance of *Sargassum* germlings on the cylinder 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 the spores within the year and some had regenerated from persisting holdfasts. There appear to be a potentiality for regeneration for a third year in a few plants. Umamaheswara Rao and Kaliaperumal (1976) maintained the oospores of *Sargassum wightii* in a medium of seawater enriched with agar and found that 47.6% of germlings were in healthy condition at the end of 60 days.

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.

From all these studies it is clear that with proper care and under controlled conditions of the laboratory a high rate of survival of germlings can be achieved and transplantation of germlings to the sea could be done successfully if any large scale culture of seaweed has to be undertaken. The rhythmic liberation of spores also indicates the possibility of successfully raising the germlings in a nursery and further culture.

NINE

POST HARVEST TECHNOLOGY

V. S. K. CHENNUBHOTLA, K. KALIAPERUMAL AND S. KALIMUTHU

In India, the seaweeds are harvested by handpicking. In the United States rapid industrialisation has been brought in during 1917-1918 in harvesting the *Macrocystis* beds by mechanical harvestors (Dawson, 1966). Mathieson (1969) described the harvest of *Macrocystis* using motor-driven barges with mowers. The mechanical harvestors cut the kelp canopy just under one metre below the water surface and transport the material to the barge. This way, several hundred tons of seaweed can be cut in a day. After being harvested, the material is washed and chopped, and the algin extracted. Irish moss *(Chondrus)* is gathered by raking from a small boat or from the shore. Long handled rakes (3 to 5m long) are used to scrape it from the rocks where it grows A good raker will remove only the large blades and leave the others to be harvested at a later date. More than one crop can be harvested per season if a bed is properly raked. Large mechanical dryers have been used for drying the wet weed (Mathieson, 1969).

Gelidiella acerosa and *Gracilaria edulis* are the red algae used in India for commercial agar extraction. These plants are handpicked, dumped in boats, brought to the shore and dried on the beach sand. The impurities are

cleared before weighing and packing the seaweed. Species of *Sargassum* and *Turbinaria*, which are used for algin extraction, are either dried on the beach sand or treated with formalin in wet condition and then dried on the beach sand. The percentage of moisture and purity decide the cost of seaweed at the time of sale. Cleared dry seaweeds are weighed, packed in gunny bags and despatched to industries. The process of manufacture of agar-agar and algin are detailed below.

Agar-Agar

The extraction of agar-agar in the case of species of *Gracilaria* is done by soaking the dried seaweeds, grinding into pulp, leaching in soft water and introducing as dried pulp into boiling water for extraction. The supernatant clear sol is romoved after it gels. Drying of the gel is done on plastic netting. The resulting agar, which analysis compares favourably with any imported product, is 45% to 50% in weight of the clean dry seaweed. The residue (which is high in mineral and trace element contents) obtained after the removal of agar. when dried and pulverised, is a useful supplementary stock feed. The water used in leaching the seaweed pulp is a rich source of trace elements potassium, calcium, magnesium, sulphur etc. and organic compounds and could be used in fish ponds, gardens, orchards or for yeast culture.

In the method of Bose *et. al.* (1943) for preparation of *Gracilaria* agar, the whole seaweed is leached for 18 hours and then extracted. The sol is allowed to gel, and the gel is heated to 60°C and maintained at it for sometime, this last step resulting in sedimentation of the suspended impurities. The starch is removed by treating the gel with 0.2% acetic acid for one hour; this is followed by washing the gel with water. Karunakar *et. al.* (1948) employed bacterial growth for breaking down and absorbing algal metabolites. They suspended the chopped up gel in soft water containing inoculum, keeping the culture for two 24-hour periods, with one change of water. Chakraborty (1945) applied the Japanese freezing method to *Gracilaria verrucosa* of Chilka Lake. With same species from Chilka Lake, Mahonty (1956) found autoclaving at 230°F necessary, as a previous step to freezing for removal of suspended impurities. A cottage industry method for *Gracilaria edulis* agar in which freezing is not obligatory was worked out by Thivy (1958). The method is based on the finding of Pillai (1955 b) that a third of the carbohydrate, 60 to 90% of the inorganic compounds and some of the organic nitrogen are withdrawn from the seaweed when it is finely ground in distilled water. Early workers had found that most of the ash of seaweeds is water soluble. The speed of the dissolving out of ions depends on nature of the epidermal layer and this is in turn on the depth at which the algae are growing (Vinogradov, 1953). Thus, by comminuting the seaweed, the barrier formed by the epidermal layer is broken up and the water soluble compound is more complete in this method than in the other methods studied in India with reference to *Gracilaria*. The advantage of this method is that the comminuted seaweed is purified whereas in the other methods the gel also has to undergo purification, and it is easier to manipulate the seaweed pulp than the sol or gel for removal of impurities. Furthermore, the yield in the cottage industry method is higher because extraction from the seaweed pulp is efficient.

Freezing Method

In the case of *Gelidiella acerosa*, the weed which was soaked in acidulated water for 24 hours is introduced into soft water at 100°C, the proportion being one part by weight of dry weed to forty of water preferably rain water or distilled water. The pH at the beginning of the extraction is adjusted to 6.0 after introducing the seaweed, but slightly acidic conditions will enhance extraction of the product. Extraction is carried out for one hour at this temperature, then the liquid is allowed to simmer for another hour. Finally, the enamel vessel in which the extraction is carried out together with the liquid is

left in a warm chamber to cool gradually, permitting sedimentation of the suspended particles. When cold, the gel is removed, melted in a water bath and poured into enamel trays to gel again. After three hours the gel is cut into strips and these are placed in wooden trays and frozen at temperatures between 0° and -5°C. They are frozen for 24 hours and then allowed to thaw at room temperature. As soon as the thaw water has drained off, the strips of gel are placed on plastic screen placed on galvanised wirenetting and dehydration is completed either in the sun or in hot air at 65°C. This agar is of superior quality and is 40% of the dry seaweed.

In Japan and United States the freezing is done by simple exposure and no costly equipment is involved. For eliminating this cost, the filtrate is treated with 90% industrial alcohol, so that agar is flocculated.

Method of Extraction for Commercial Grades of Sodium Alginate

Stanford (1883) discovered the presence of alginic acid in the cell walls of brown algae. Several methods were then devised for the extraction of alginate. Two industrial processes are those of Kelco Co. and Algin Corporation.

Stanford's method consists of macerating the algae with ten times the weight of sodium carbonate, and acidifying the extract to obtain alginic acid. It is mixed with either sodium or calcium salts to make sodium or calcium alginate. In the Kelco Co. and Algin Corporation processes, they are first treated with acid or calcium chloride to reduce the salt content. Sodium alginate in crude form extracted by digestion with sodium carbonate is treated with calcium chloride solution to form calcium alginate and then acidified before converting to sodium alginate.

Viscosity of the alginate solution is a very important property for its use in textile and pharmaceutical industries. Viscosities as high as 4000-5000 centipoise are required by the industry, whereas the sodium alginate obtained from the above methods have very low viscosity. Therefore, it is desirable to modify the process so that different grades of alginate can be prepared (Desai, 1967). The details of the process are as follows.

The dry algae are thoroughly cleaned in running water and washed for 2 hours in hot water at 52°C, the water drained out and immersed in 0 3 to 0.5 N sulphuric acid in the ratio 1:3 and kept at 42°C. The acid is washed out and the pH is brought to neutral. The algae are then digested in 4% solution of sodium carbonate overnight. The solution is centrifuged and filtered through a filter press to obtain a clear fluid of crude sodium alginate. It is then bleached with sodium hypochlorite and with sodium bisulphite. The resultant solution is mixed with half the volume of 90% industrial alcohol. The used alcohol could be redistilled for further use. Sodium alginate is collected and dried at 70° in oven.

This method has been found to give most suitable quality of sodium alginate. Different grades of viscosities can be easily produced by varying the time and temperature of acid wash. If both the temperature and time increased, the viscosity is lowered and if the temperature is reduced with a slight increase in time, higher viscosity is obtained.

Some studies on alginic acid were also made in India. Valson (1955) determined the alginic acid content of several species of brown algae occurring in the Gulf of Mannar. Varier and Pillai (1952) studied the extraction of alginic acid and determined the optimum condition. Pillai (1957) employed acidified potassium permanganate as the bleaching agent in his process. Kappanna *et. al.* (1962) have determined the alginic acid content in several species of brown algae occurring on the Saurashtra

coast. Visweswara Rao and Mody (1964) gave a slightly more simplified process than the one described earlier. Shah *et. al.* (1967) reviewed the work done on alginates till 1965.

The cultivation of seaweeds for industrial purposes may be practised anywhere, but the greater demand for edible seaweeds will probably continue in Asia, at least in the future. The red alga known as dulse (*Rhodymenia palmata*) is widely eaten in Canada and Europe. Certain large kelps are made into pickles in Alaska. Other uses of seaweeds and their products are narrated by Chennubhotla (1977) and Chennubhotla *et. al.* (1981).

The laver (nori) harvested in Japan is first washed in seawater and then chopped up finely and again washed in fresh water. The chopped laver is spread out by hand or machine within a frame or on a mat of bamboo splints with a measure of 600 sq cm. By this procedure the chopped lavers only remain on the mat as a sheet. The water is removed by passing through the mat. Chopped lavers of 4 kg produce 100 or more sheets. The mats with the wet laver sheets are dried in the sun. During cloudy days the sheets are dried in a drying room maintained at a temperature of 35°C. Here the sheets dry in about 3 h. The dried sheet of laver is generally 20 X 19 cm in size and weighs 2.5 g. The sheets are used for domestic consumption (Sreenivasa Rao, 1967).

I. S. I. Specification for Agar-Agar and Algin

Agar-agar : The agar should be white or pale yellow in colour. It should be either odourless or having a slight characteristic odour, and a muscilaginous taste. It should be insoluble in boiling water. The other requirements are as given in the following table.

S. No.	Characteristics	Requirements
1.	Moisture, percent by weight, on drying at 105°C for five hours maximum	20
2.	Total ash, percent by weight, maximum	6.5
3.	Acid insoluble ash, percent by weight maximum	1.0
4.	Insoluble matter, percent by weight maximum	1
5.	Arsenic (as As), mg/kg, maximum	3
6.	Lead (as Pb), mg/kg, maximum	10
	Water absorption Gelatin Starch and dextrines	As given in Indian Standard specification for agar; food grade, 1970

Alginic Acid: It occurs as a white to yellowish-white fibrous powder. It should be odourless and tasteless. It should be insoluble in water, readily soluble in alkaline solution and insoluble in organic solvents. The material should conform to the I. S. I. requirements given below.

(Indian Standard Specification for alginic acid, food grade, 1976)

S. No.	Characteristics	Requirement
1.	Purity $(C_6 H_8 O_6)n$ percent by mass, minimum	91
2.	Moisture, percent by mass, on drying at 105°C for 4 hr, maximum	15
3.	Insoluble matter, percent by mass, maximum	0.2
4.	Ash percent by mass, maximum	4
5.	Lead (as pb) mg/kg, maximum	10
6.	Arsenic (as As), mg/kg, maximum	3

TRANSFER OF TECHNOLOGY ON SEAWEED CULTURE

V. S. K. CHENNUBHOTLA, S. KALIMUTHU, J. R. RAMALINGAM, M. NAJMUDDIN AND N. KALIAPERUMAL

Experiments on cultivation of economically important seaweeds such as *Gracilaria edulis, Gelidiella acerosa, Sargassum* spp and *Turbinaria* spp have been carried out during the past few years at the Central Marine Fisheries Research Institute. A suitable technique of culture of the agarophyte *Gracilaria edulis* has been developed. Technique for culturing the other seaweeds have not yet been streamlined. The culture technology developed for *G. edulis* comprises of introduction of small fragments of the seaweed into the twists of the coir rope fabricated in the form of nets and tied to the fixed poles in the inshore waters and monitoring their growth. A yield of 3 kg/m^2 was obtained in 60 days from an initial seed material of 1 kg. In the preliminary experiments conducted by using the same technique a yield of 3 kg/m^2 was obtained in 80 days in the case of *G. acerosa*. The regenerative capacity of vegetative fragments in species of *Sargassum* and *Turbinaria* also has been observed in the experimental trials. To transfer the technology of seaweed culture to farmers and entrepreneurs, need-based training programmes have been instituted. The details of the training courses, their content and utility are given below.

Training Programme

The first one is for the farmers, in which the entire farming community of the area where seaweed cultivation is feasible is educated about the significance and the benefits of the seaweed culture programmes in their villages. The families which come forward to take up the seaweed culture should be made to understand the benefits that the technology would bring them and what assistance they can expect from the financing agencies connected with rural development programmes. When technology and financial assistance are made available to them, their contribution should be work and money. The programme of release of seaweed culture technology and demonstrations will be closely linked up with organising appropriate training programmes for the fishermen, marginal agricultural farmers, landless labour and women folk. The training programmes which will be organized in local languages will be of short term duration and will be phased in a manner that they do not interrupt the normal activities of the trainees. The progress of work must be closely monitored in the culture site periodically.

The training part includes an initial orientation training, subsequent training at the appropriate time for the different phases of culture operations, post harvest technology and a final refresher training.

The second programme is for the interested parties and entrepreneurs who can afford to invest money for purchasing the inputs required and for engaging the people to carry out culture operations. For them, the training will be given at the institute itself, so that they can put to practise the technology learnt by them in a

place of their choice that is suitable for seaweed culture.

The transfer of technology programme also includes printing of handouts and pamphlets in regional languages and distribution among the public. The message and methods of science and technology could be spread by conducting farm fairs (Krishi-Melas) inviting fishermen, landless labour and other interested public to witness the various aspects of technology being demonstrated. Mobile exhibition to reach the coastal sector and participation of the concerned scientists in the rural programmes of All India Radio and organizing public lectures in the coastal areas will be helpful for popularising seaweed cultivation in the coastal areas.

Implementation

The Indian Council of Agricultural Research during its Golden Jubiles Year 1979 has started a programme "Lab-to-Land", under which the technologies developed in different Institutes are transferred to the marginal and small farmers and the landless labour. The Central Marine Fisheries Research Institute is involved in transfer of technologies developed on marine prawn and fish culture, open-sea mussel farming, oyster culture and seaweed culture.

The Lab-to-Land programme in seaweed culture was implemented at Mandapam (Tamil Nadu) because the inshore areas of the Gulf of Mannar and Palk Bay are rich in agarophytes. Because of continuous harvest for industrial exploitation the standing crop of agarophytes has depleted. In order to enhance the production to augment the supply, culture of these seaweeds by appropriate technique has to be undertaken. Under the above programme two families from Marakayarpatnam, five form Vedalai and one from Seeniappa Darga were selected after collecting the data of the households on the economic status, occupation, land holding, back ground literacy and leadership qualities for spreading the new technologies to other families. The technology developed for culture of the agarophyte *Gracilaria edulis* was transferred to these fishermen. This includes fabrication of coir nets (5X2 m size), collection of seed material, introduction of the same into the twists of the coir rope and fixing the nets in the coastal waters with the help of palmyra rafters. The seaweed fragments introduced reach harvestable size after 60 days growth. Utilizing 10 kg of seed material for each net, an average yield of 30 kg of seaweed per net can be obtained.

Collection of Feedback Data

Collection of feedback data is considered as the most important aspect of transfer of technology programme. This requires the co-operation of the farmers also for knowing the constraints faced by them. Because of this arrangement, new problems and lacunae in the technology are identified, which enable the scientists to improve the culture technology further.

The seaweed culture has immense potentialities for augmenting the raw material for agar-agar and algin industries, but its significance is greatest as a technology for the economic upliftment of coastal villages. Through this, the fishermen have come in direct contact with the seaweed culture technology for the first time which in course of time may help to supplement the natural seaweed resources available in India.

ELEVEN

PROSPECTS OF SEAWEED RESEARCH AND UTILIZATION

E. G. SILAS

Considerable work has been carried out on various aspects of Indian seaweeds. Owing to the utilisation of seaweeds in India for commercial production of agar and algin, the research on seaweeds has attained a new impetus. The assessment of available seaweed resource in India has been necessitated by more and more algin and agar industries coming up in the recent years. Survey of the seaweed resources on the coasts of Tamil Nadu, Goa, Maharashtra, Gujarat and Lakshadweep has been completed and the estimates of standing crop of these areas are available. The seaweed survey of Andhra Pradesh coast has been done recently. The resources survey on the rest of the Indian coastline and of Andaman-Nicobar Islands has to be undertaken to estimate the total standing crop and, in particular, the harvestable quantities of agarophytes and alginophytes.

Our knowledge on the taxonomy of seaweeds especially those of Andaman and Nicobar Islands is still incomplete. Much work in this direction has to be undertaken. Data on the local flora of each region will help the seaweed industry fo utilise the various commercially important seaweeds.

In order to meet the increasing demand of seaweeds for the agar and algin industries, large-scale cultivation of economically important algal species in coastal waters have to be undertaken. The suitable sites along the east and west coast have to be explored. Investigations on the growth and fruiting behaviour of economically important seaweeds growing in different areas must be made for proper utilization of the available resources and for cultivation of these seaweeds. Seaweed culture technology for the Indian agarophytes and alginophytes has not attained perfection in spite of continued effort by various research organisations. An economically viable and easy technology has to be evolved. Seaweed cultivation on commercial scale could augment the supply of seaweed and provide employment to the coastal population, which may help in improving their economic condition and thus help in rural upliftment.

Recently, agar industries use *Gelidiella acerosa* and *Gracilaria edulis* and algin industries use species of *Sargassum* and *Turbinaria* as raw materials, since the yield and quality of the product is good in these species. Other plants which are being wasted could be utilised properly. Species like *Hypnea,* which is available in large quantities in different parts of Indian coast, can be used for production of good quality carrageenan. Species of brown algae other than *Sargassum* and *Turbinaria* can be tried for alginate extraction after some chemical process. Economically important high-yielding seaweeds from other countries could be introduced in our coastal waters. *Eucheuma*, which is being cultivated on a large scale in South East Asian countries such as Philippines, Indonesia and U. S A. as a source of kappa carrageenan, is an ideal seaweed for introduction in our country. The growth of seaweeds in cultivation could be improved by using various growth

promoting harmones, fertilizers and genetical techniques.

In some developed countries, efforts are being made for using the seaweeds such as *Laminaria* and *Macrocystis* for production of methanol. In our country, species of *Sargassum* could be used for this purpose. Proper technology has to be evolved to utilise the hydrogen released by some seaweeds during photosynthesis. Seaweeds could be utilised for the production of biogas by fermantation technique. Efforts have to be taken to develop suitable techniques to utilise the cast-ashore seaweed in our coastline as a source of energy for producing methanol, hydrogen and biogas and for using as fodder, manure and liquid fertiliser.

Data collected by chemical analysis of some Indian seaweeds indicate that they are good sources of proteins, vitamins, iodine, minerals and trace elements. Much information remains to be collected on the chemical contents of yet other seaweeds.

Edible seaweeds such as *Gracilaria edulis*, *Caulerpa* spp., *Acanthophora spicifera*, *Codium* sp., *Porphyra* etc. can be cultivated for human consumption. These protein-rich seaweeds could provide supplementary diet and so should be made palatable and popularised. It is also possible to carry out seasonal cultivation of *Porphyra* sp. in Gujarat and other places as is being done in Japan, during winter months. *Porphyra* and *Monostroma* are popular food items in Japan, Korea and other South East Asian countries and they are cultivated there in a large scale. The occurrence of thes species have been reported along the east and west coasts of India.

Pond culture of seaweeds should also be taken up. There are immense possibilities for seaweed culture in brackishwater areas, too, where they form major component among aquatic macrophytes as well as in some estuarine areas and coastal inundated wates in our country.

The extraction of bio-active agents from seaweed is a new line of work which has opened up further possibility of utilising this resource. Connected with this would be the better utilisation of seaweeds for production of many important pharmacological products.

It is imperative that we develop on a large scale the simple techniques for culture of seaweeds at low cost in our inshore, estuarine and backwater areas. Recently, Malaysia has achieved a commendable lead in the culture of *Gracilaria*, and the techniqes should be appropriately and widely adopted in our coastal waters.

I also feel that if seaweed cultivation is to be taken as a coastal rural programme, it should also be combined with post-harvest processing units for extraction of some of the products, so as to bring better economic returns to the seaweed cultivators. The package of practices involving low-cost technology of product development has to be evolved so the research and development in this direction becomes very relevant.

Besides the selected areas along the coast including estuaries and lagoons, Andaman & Nicobar and Lakshadweed islands too have immense possibilities for culture of seaweeds. Hence technology-transfer programme should be planned to cover also these areas, where very productive results could be achieved. I am very optimistic that seaweed culture through proper techniques would yield far better results as its production potential is immense compared to exploiation from natural resources.

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Classification and name of the algae	Gopnath	Gulf of Kutch	Okha	Dwarka	Porbander	Veraval	Diu	Bombay	Malwan
	1	2	3	4	5	6	7	8	9
A. Division : Chlorophyta									
i. Class : Chlorophyceae									
i Order : Ulvales									
a. Family : Ulvaceae									
1. *Enteromorpha clathrata* (Roth) J. Agardh					—			—	
2. *E. compressa* (Linnaeus) Grev.								—	
3. *E. Flexosa* (Wulf.) J. Ag.				—				—	—
4. *E. intestinalis* (Linn.) Link	—								
5. *Ulva fasciata* Delile						—		—	
6. *U. Lactuca* Linn		—	—	—	—		—	—	
7. *U. reticulata* Forsskal			—				—	—	
8. *U. regida* C. Ag.	—								
ii Order : Cladophorales									
b. Family : Cladophoraceae									
9. *Chaetomorpha antennina* (Bory) Kuetz			—	—				—	
10. *Cladophora fascicularis* (Martens) Kuetz	—	—	—					—	
11. *Spongomorpha indica* Thivy and Visalakshi	—	—	—					—	
Order : Siphonales									
c. Family : Bryopsidaceae									
12. *Bryopsis hypnoides* Lamour			—					—	
13. *B. plumosa* (Huds.) Ag.	—		—	—				—	
14. *Pseudobryopsis mucronata* Boergs.			—	—				—	
d. Family : Caulerpaceae									
15. *Caulerpa cupressoides* (Vahl.) Ag.								—	
16. *C. fastigiata* Montagne	—		—					—	
17. *C. peltata* Lamour				—				—	
18. *C. racemosa* (Forssk.) Weber v. Bosse			—	—				—	
19. *C. scalpelliformis* (R. Br.) Web. v. Bosse		—	—	—		—		—	
20. *C. sertularioides* (Gmelin) Howe				—					
21. *C. taxifolia* (Vahl.) C. Ag.		—	—	—				—	
22. *C. verticillata* J. Ag.			—					—	
e. Family : Dasycladaceae									
23. *Acetabularia calyculus* Quoit et Guimard			—					—	
f. Family : Codiaceae									
24. *Avrainvillea erecta* (Berk.) Gepp									

the area of occurrence)

Goa	@ Karwar	Cannanore	Alleppey	Quilon	Varkala	Vizhinjam	Kanyakumari	Tiruchendur	Tuticorin	Mandapam	Porto-Novo	Mahabalipuram	Madras	Visakhapatnam	Chilka	Calcutta	Lakshadweep	Andaman & Nicobar Islands
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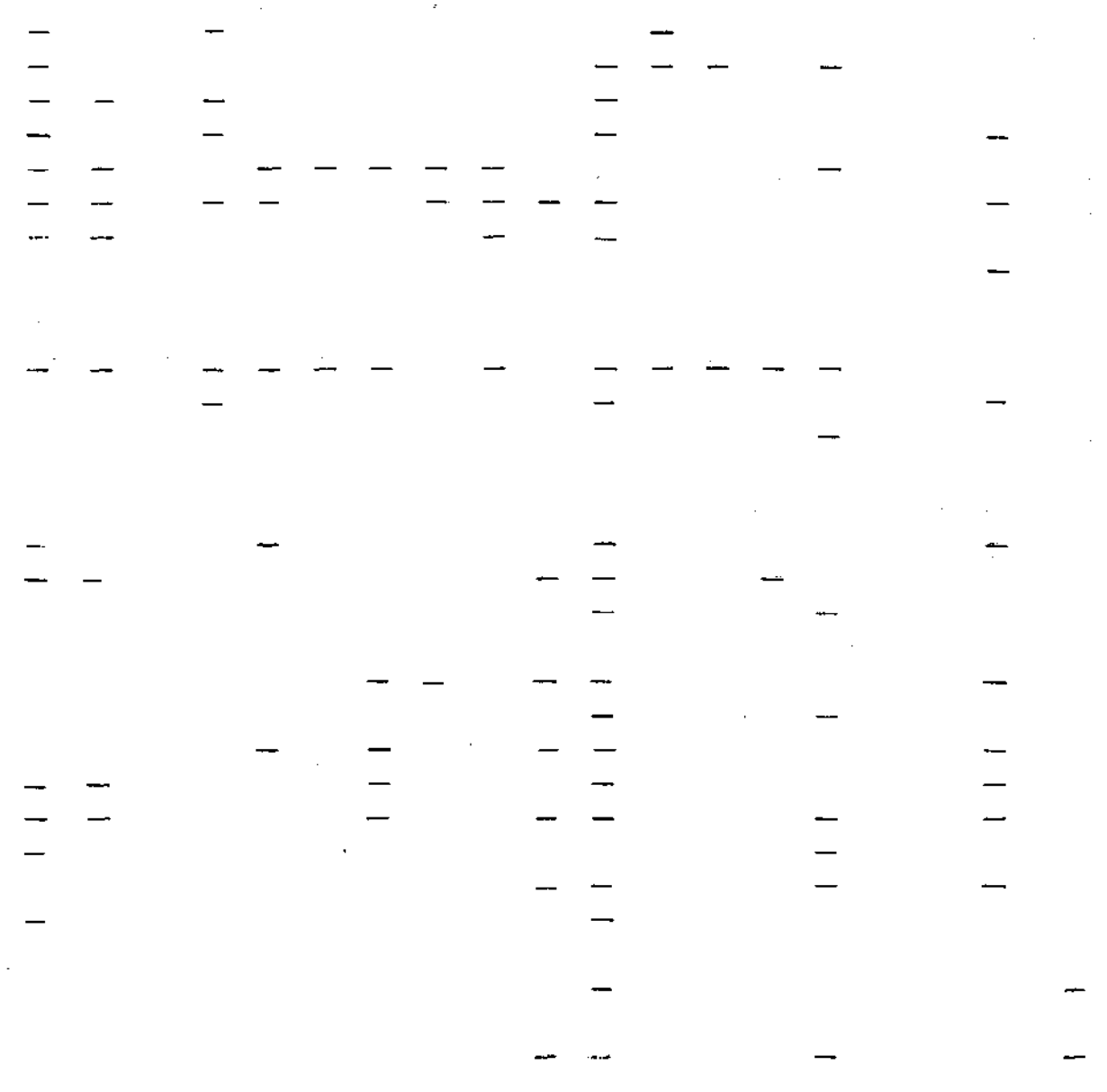
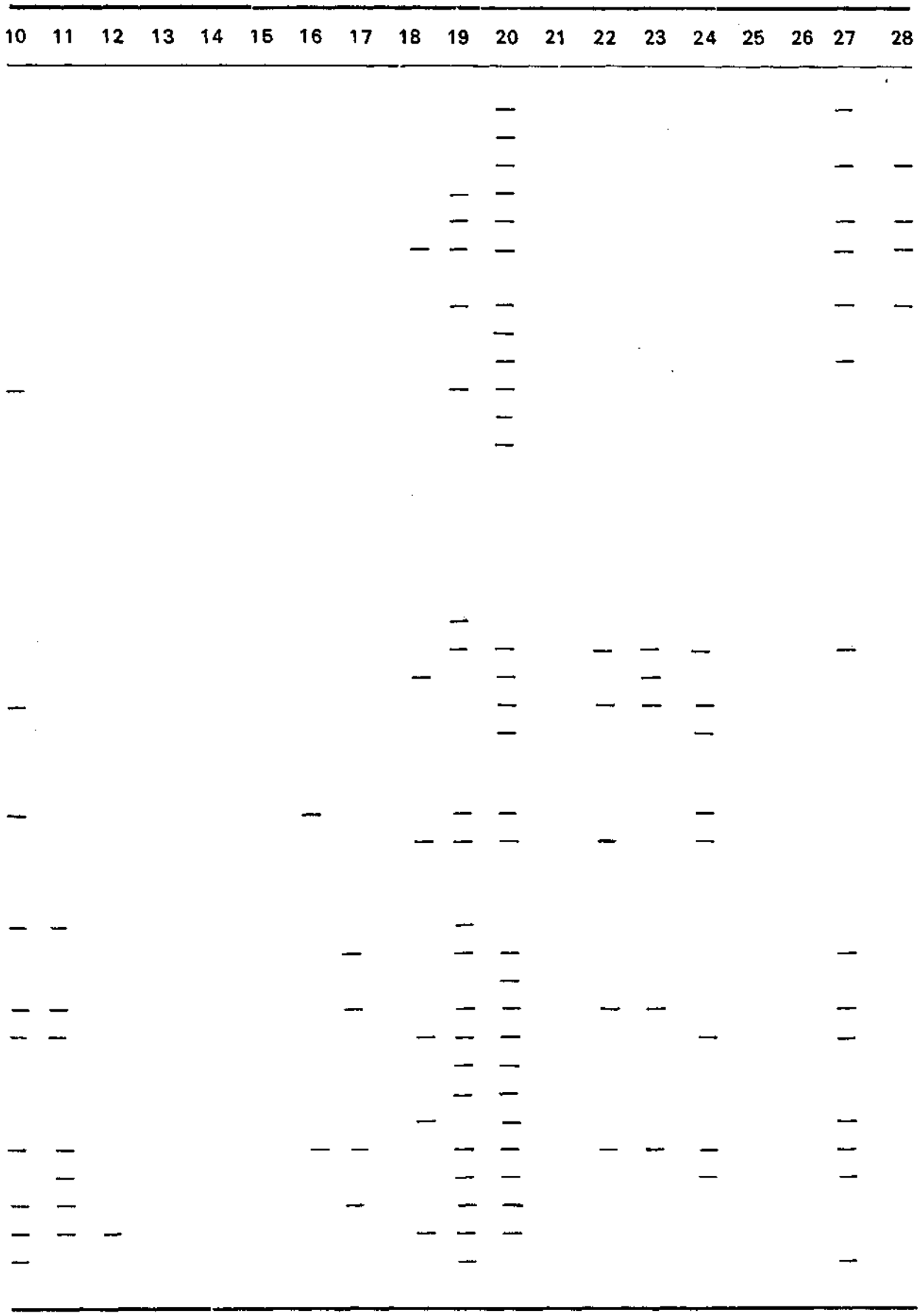


Classification and name of the algae	1	2	3	4	5	6	7	8	9
25. *Codium adhaerens* Anderson									
26. *C. decorticatum* (Woodward) Harvey									
27. *C. tomentosum* (Hudson) Stackhouse									
28. *Halimeda macroloba* Decaisne									
29. *H. opuntia* f. typica Barton									
30. *H. tuna* (Ell. et. Sol.) Lamour			—	—					
g Family : Valoniaceae									
31. *Boergesenia forbesii* (Harv.) Feldm.									
32. *Boodlea composita* (Harv. et Hook. f.) Brand			—	—				—	
33. *Cladophoropsis zollingeri* (Kuetz.) Boergs.	—							—	
34. *Microdictyon tenuis* (Ag) Decsne.	—							—	
35. *Valonia aegagrophila* C. Ag.	—	—		—					
36. *Valoniopsis pachynema* (Martens) Boerga.	—			—	—				
B. Division : Phaeophyta									
II Class : Phaeophyceae									
i Order : Ectocarpales									
a Family : Ectocarpaceae									
1. *Ectocarpus arabicus* Fig. et De Not				—	—				
2. *E. breviarticulatus* J. Ag.									
3. *Feldmannia irregularis* (Kuetz.) Hamel								—	
4. *Giffordia mitchellae* (Harv). Hamel			—	—	—	—		—	
5. *G. regularis*			—					—	
Order : Sphacelariales									
b Family : Sphacelariaceae									
6. *Sphacelaria furcigera* Kuetz.				—				—	
7. *S. tribuloides* Meneghin				—					
¡i Order : Dictyotales									
c Family : Dictyotaceae									
8. *Dictyopteris australis* Sonder		—	—	—	—			—	
9. *D. delicatula* Lamour			—						
10. *D. woodwardii* (Brown) J. Ag.		—	—	—					—
11. *Dictyota bartayresiana* Lamour.			—	—				—	
12. *D. dichotoma* (Huds.) Lamour.			—	—				—	
13. *Padina boryana* (Bory) Thivy ex Taylor				—					
14. *P. gymnospora* (Kuetz.) Vickers				—				—	
15. *P. pavonica* (L.) Thivy ex Taylor				—					
16. *P. tetrastromatica* Hauck		—	—	—				—	
17. *Pocockiella variegata* (Lamour.) Papenfuss		—	—	—				—	
18. *Spatoglossum asperum J. Ag.*		—	—	—				—	—
19. *Stoechospermum marginatum* (Ag.) Kuetz.			—	—				—	—
20. *Zonaria variegata* (Lamour.) Ag.				—					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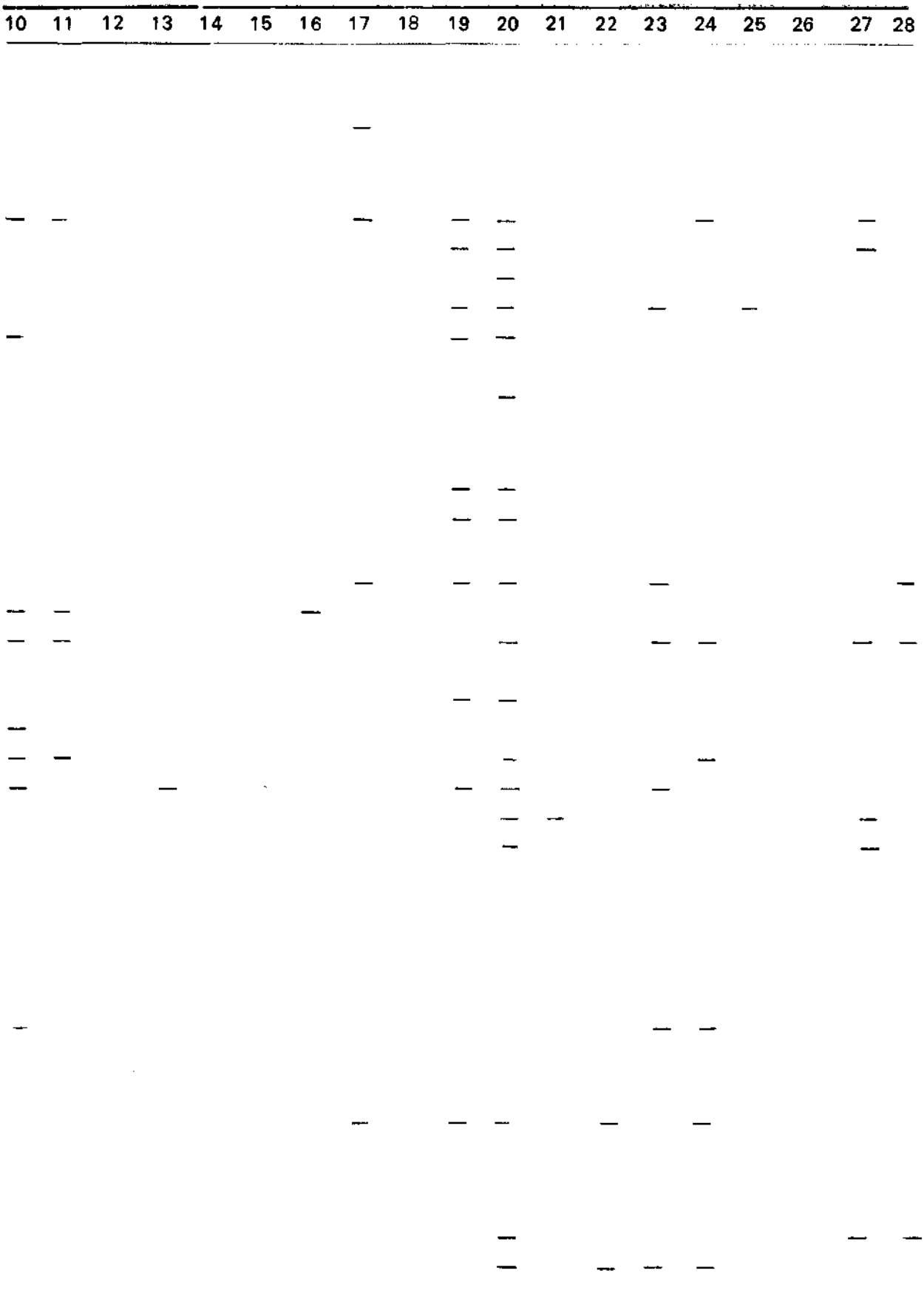
Classification and name of the algae	1	2	3	4	5	6	7	8	9
iii Order : Chordariales									
d Family : Chordariaceae									
21. *Levringia borgensenii* Kylin			—	—		—			
iv Order : Dictyosiphonales									
e Family : Punctariaceae									
22. *Colpomenia sinuosa* Derb. et Sol.		—	—	—	—	—		—	
23. *Hydroclathrus clathratus* C. Ag.				—					
24. *Iyengaria stellata* (Boergs.) Boergs.		—	—	—					
25. *Rosenvingea intricata* (J. Ag.) Boergs.			—	—					
26. *R. orientalis* J. Ag.								—	
f Family : Chnoosporaceae									
27. *Chnoospora minima* (Hering) Papenfuss									
v Order : Fucales									
g Family : Cystoseiraceae									
28. *Cystoseira trinodis* (Forsskal) C. Ag.			—	—				—	
29. *Hormophysa triquetra* (L) Kuetz.			—						
h Family : Sargassaceae									
30. *Sargassum aquifolium* (Turn.) C. Ag.									
31. *S. cinereum* var *barberfolia* Gruenow		—						—	
32. *S. ilicifolium* (Turner) J. Ag.								—	
33. *S. johnstonii* Setchell and Garnner			—						
34. *S. myriocystum* J Ag.									
35. *S. swartzii* (Turn.) C. Ag.			—					—	
36. *S. tenerrimum* J. Ag.		—	—	—				—	
37. *S. wightii* Greville								—	
38. *Turbinaria conoides* Kuetz									
39. *T. ornata* J. Ag.									
C. Division : Rhodophyta									
III Class : Rhodophyceae									
Sub-class : Bangioideae									
i Order : Bangiales									
a Family : Bangiaceae									
1. *Porphyra vietnamensis* Tanaka et Ho.									
ii Order : Erythropeltidales									
b Family : Erythropeltidaceae									
2. *Erythrocladia subintegra* Rosenvinge									
Sub-class : Florideae									
iii Order : Nemalionales									
c Family : Helminthocladiaceae									
3. *Liagora albicans* Lamouroux			—						
4. *L. erecta* Zeh.									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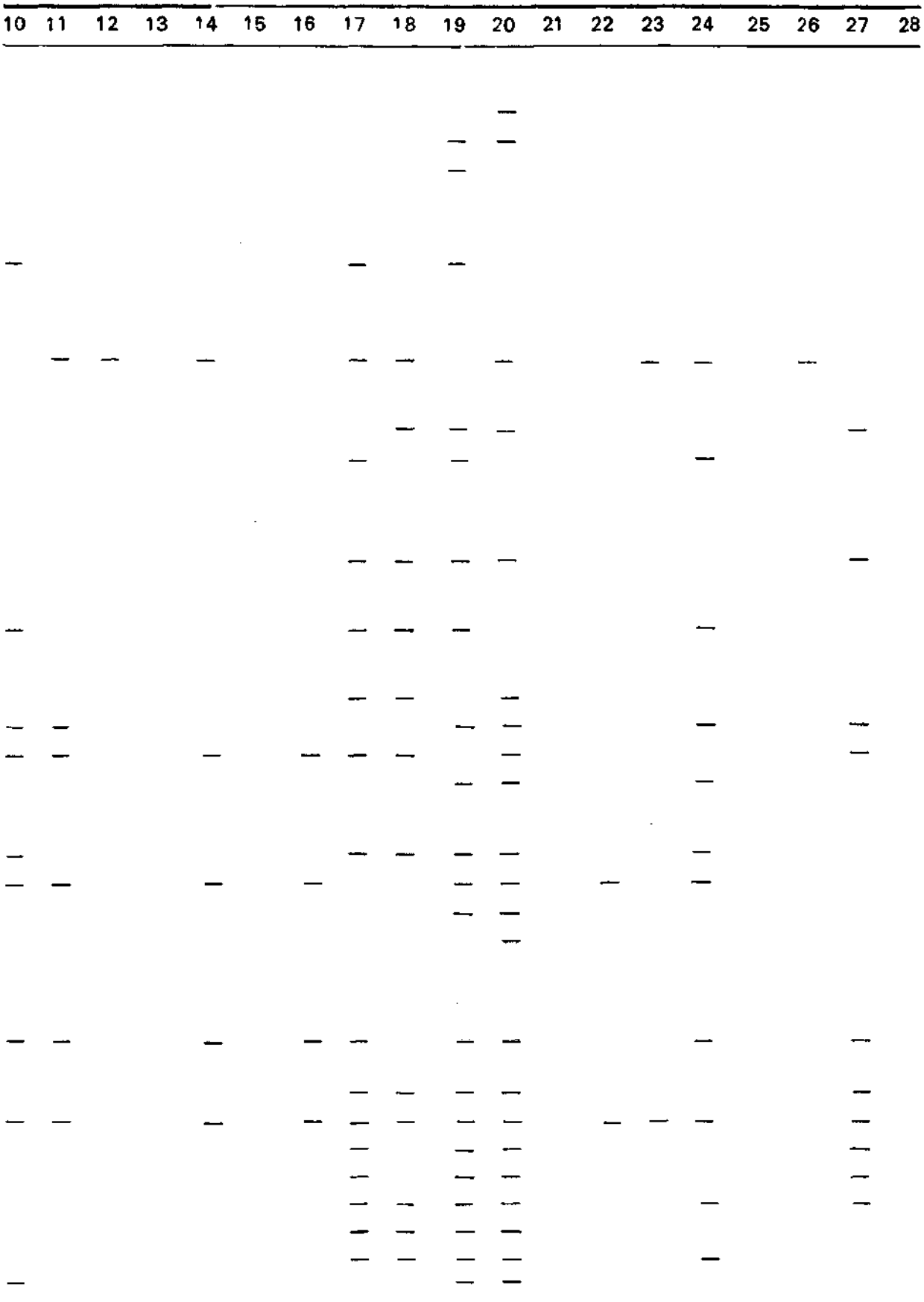
	Classification and name of the algae	1	2	3	4	5	6	7	8	9
d	Family : Chaetangiaceae									
	5. *Actinotrichia fragilis* (Forssk.) Boergesen			—	—				—	
	6. *Galaxaura oblongata* Lamour			—	—					
	7. *Scinaia hatei* Boergesen			—	—				—	
e.	Family : Bonnemaisoniaceae									
	8. *Asparagopsis taxiformis* (Delile) Collins et Harvey			—	—					
iv	Order : Gelidiales									
f.	Family : Gelidiaceae									
	9. *Gelidium pusillum* (Stack-house) Le Jolis				—				—	
g.	Family : Gelidiellaceae									
	10. *Gelidiella acerosa* (Forssk.) Feldman et Hamel			—	—	—	—			
	11. *Myrioclada* (Boergesen) Feldman et Hamel	—							—	
v.	Order : Cryptonemiales									
g.	Family : Rhizophyllidaceae									
	12. *Chondrococcus hornemanii* (Mert.) Schmitz									
h.	Family : Hildenbrandtiaceae									
	13. *Hildenbrandtia prototypus* Nard °								—	
i.	Family : Corallinaceae									
	14. *Amphiroa anceps* (Lamk.) Decsne.				—	—				
	15. *A. fragilissima* (L.) Lamour.	—							—	
	16. *Cheilosporum spectabile* Harvey								—	
	17. *Jania rubens* (L.) Lamour.					—			—	
j	Family : Grateloupiaceae									
	18. *Grateloupia filicina* (Wulf.) J. Ag.								—	
	19. *G. lithophila* Boergesen								—	
	20. *Halymenia floresia* (Clem.) Ag.									
	21. *H. porphyroides* Boergesen			—	—				—	
V.	Order : Gigartinales									
k.	Family : Gracilariaceae									
	22. *Gelidiopsis variabilis* (Greville) Schmitz			—					—	
	23. *Gracilaria arcuata* var *arcuata* (Zan.) Umamaheswara Rao									
	24. *G. corticata* var. *corticata* J. Ag.				—				—	
	25. *G. crassa* (Harvey)									
	26. *G. edulis* (Gmelin) Silva									
	27. *G. foliifera* (Forssk.) Boergesen	—		—					—	
	28. *G. obtusa* Grev.									
	29. *G. textorii* (Suringar) J. Ag.									
	30. *G. verrucosa* (Huds.) Papenfuss			—					—	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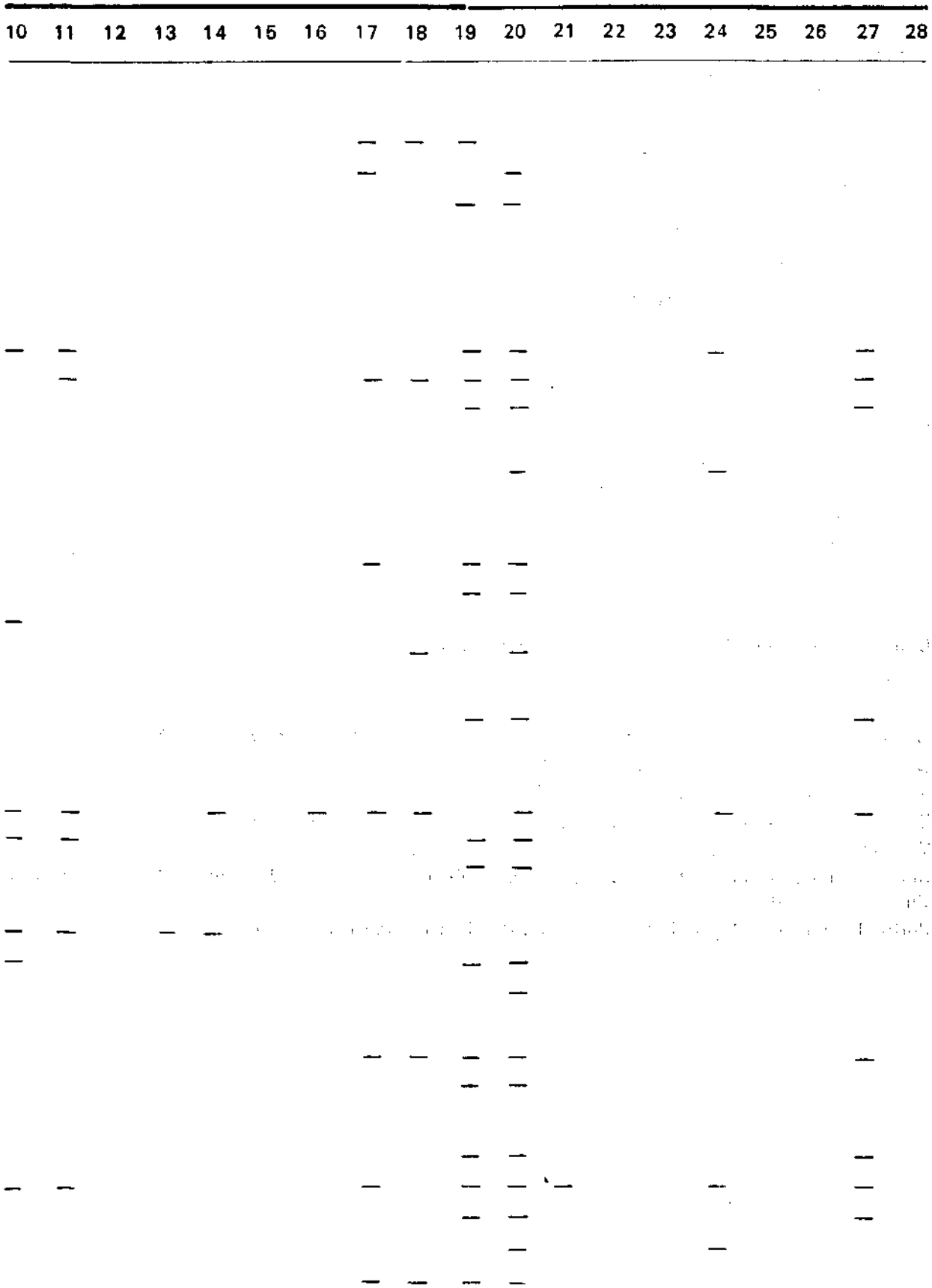
Classification and name of the algae	1	2	3	4	5	6	7	8	9
l. Family : Solieriaceae									
31. *Sarconema filiforme* (Sond.) Kylin								—	
32. *S. furcellatum* Zan.									
33. *Solieria robusta* (Grev.) Kylin			—	—				—	
m. Family : Rhabdoniaceae									
34. *Catenella repens* (Lightf.) Batt.	—	—	—	—	—			—	
n. Family : Hypneaceae									
35. *Hypnea musciformis* (Wulf.) Lamour.	—		—	—				—	
36. *H. pannosa* J. Ag.								—	
37. *H. valentiae* (Turn.) Mont.								—	
o Family : Gigartinaceae									
38. *Gigartina acicularis* (Wulf.) Lamour.	—							—	
VI. Order : Rhodymeniales									
p. Family : Rhodymeniaceae									
39. *Botryocladia leptopoda* (J. Ag.) Kylin			—	—					
40. *Coelarthrum opuntia* (J. Ag.) Boergs			—	—					
41. *Rhodymenia australis* Sonder			—	—				—	
42. *R. dissecta* Boergesen				—				—	
q. Family : Lomentariaceae									
43. *Champia parvula (C. Ag.)* Harvey			—						
VII Order : Ceramiales									
r. Family : Ceramiaceae									
44. *Centroceras clavulatum* (C. Ag.) Mont.	—			—				—	
45. *Spyridia filamentosa* (Wulf.) Harvey								—	
46. *S. fusiformis* Boergesen									
s. Family : Delesseriaceae									
47. *Caloglossa leprieurii* (Mont.) J. Ag.			—					—	
48. *Martensia fragilis* Harvey								—	
49. *Taenioma purpusillum* J. Ag.				—				—	
t. Family : Dasyaceae									
50. *Dictyurus purpurescens* Bory									
51. *Heterosiphonia muelleri* (Sonder) Detoni			—	—					
u. Family : Rhodomelaceae									
52. *Acanthophora mucoides* (L.) Boergs.			—						
53. *A. spicifera* (Vahl.) Boergs.			—					—	
54 *Chondria armata* var. *plumaris* Boergesen			—	—					
55. *C. cornuta* Boergesen	—							—	
56. *Enantiocladia prolifera* (Grev.) Falkenberg	—								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Classification and name of the algae	1	2	3	4	5	6	7	8	9
57. *Herposiphonia insidiosa* (Grev.) Falkenberg									
58. *Laurencia obtusa* (Huds.) Lamour.				—					
59. *L. papillosa* (Forssk.) Grev.			—					—	
60. *Leveillea jungermannioides* (Mart.) et Hering) Harvey				—					
61. *Neurymenia fraxinifolia* (Mert.) J. Ag.									
62. *Polysiphonia platycarpa* Boergesen								—	
63. *Roschera glomerulata* (C. Ag.) Web. v. Bosse			—	—					
D. Division : Cyanophyta									
IV. Class : Cyanophyceae									
i Order : Nostacales									
a. Family : Oscillatoriaceae									
1. *Lyngbya semiplena* (C. Ag.) J. Ag. ex Gomont									
2. *Microcoleus chthonoplastes* Thuret ex Gomont								—	
3. *Oscillatoria nigroviridis* Thwaites ex Gomont			—						
4. *Phormidium fragile* (Meneghini) Gomont			—					—	

Okha area — Okha, Adatra, Hanumandandi and Balapur

* Includes Bombay and other places of Maharashtra

@ Includes Karwar and other places of Karnataka

Alleppey area — Alleppey, Ashtamudi, Kanjirakode, Murukkampuzha and Perumathura

Quilon area — Thangasseri, Thirumullavaram, Quilon and Neendakara

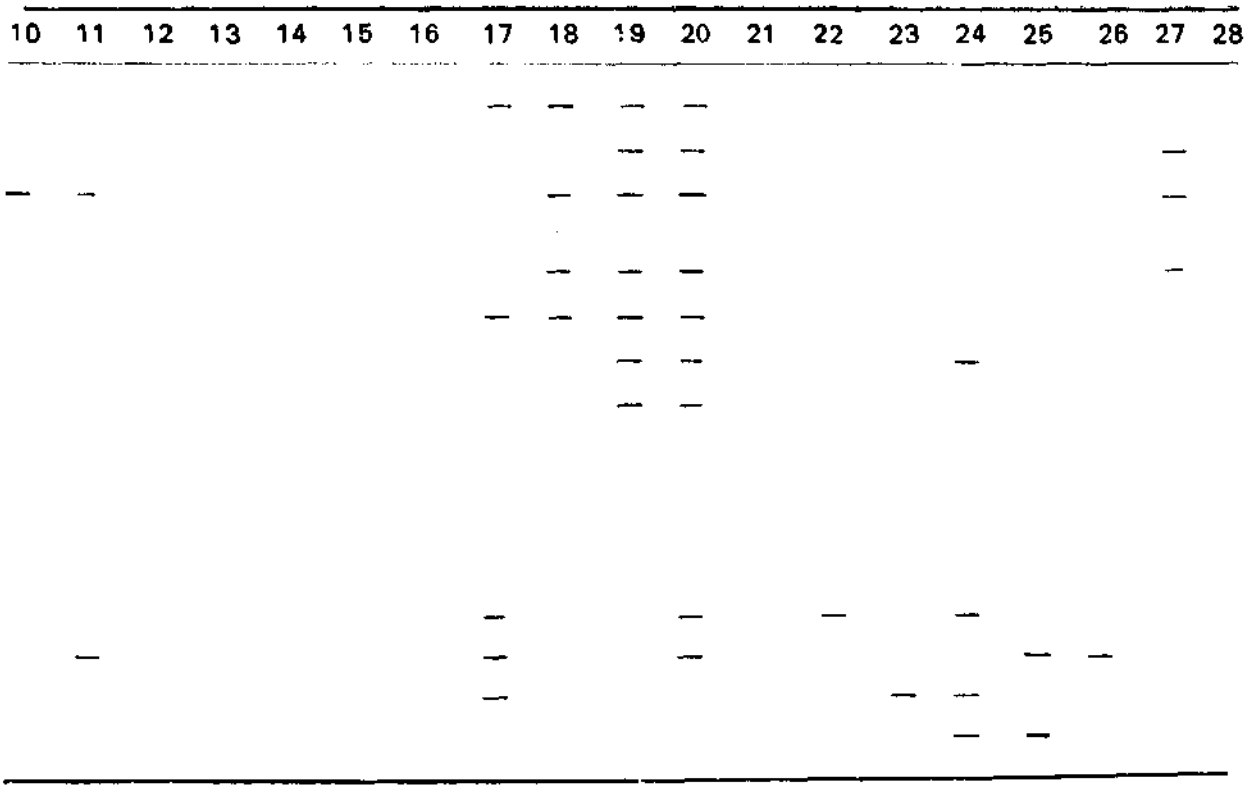
Vizhinjam area — Poovar, Vizhinjam and Kovalam

Kanyakumari area — Kanyakumari, Muttam Chinnamuttam, Kaniapatnam and Colachel

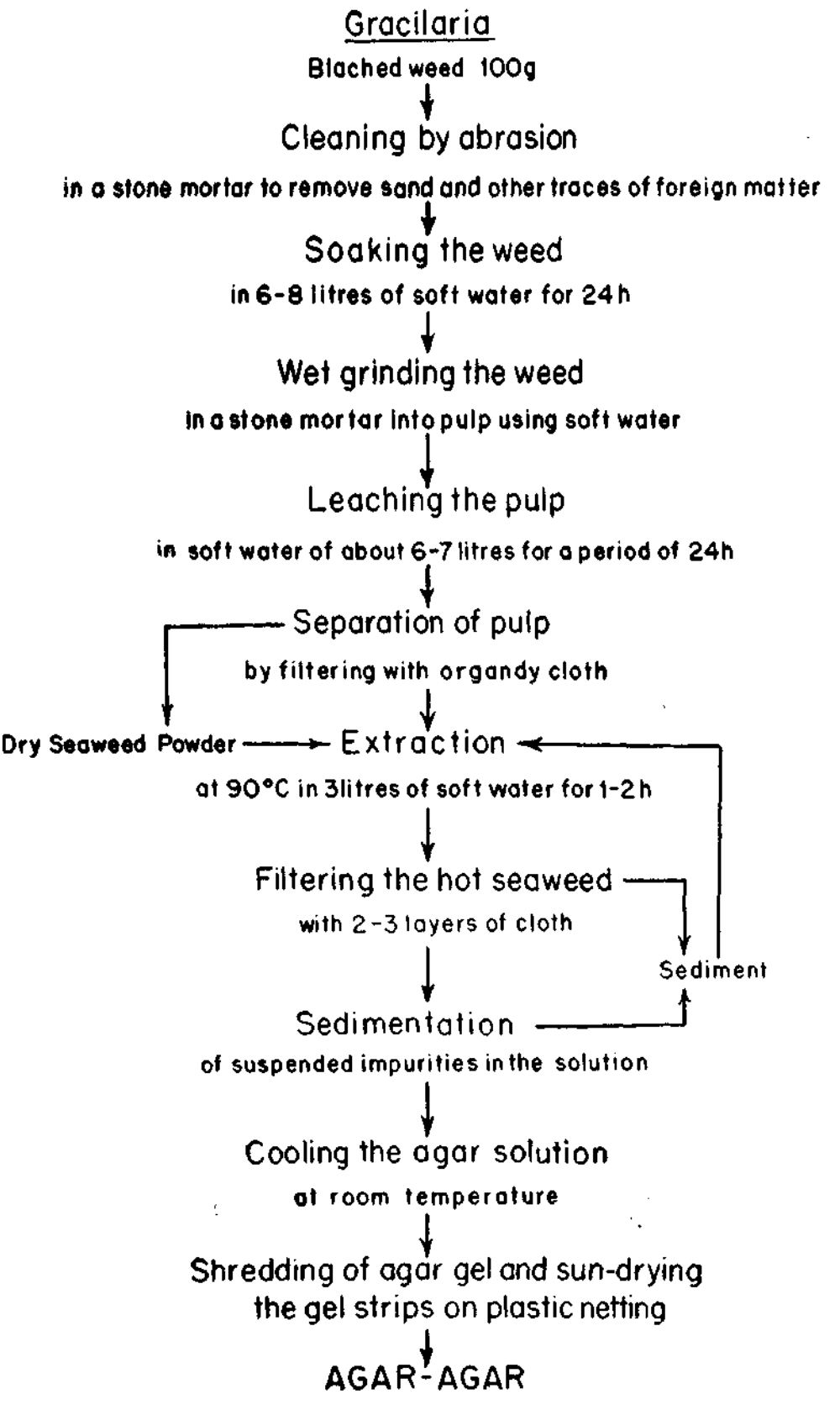
Tiruchendur area — Tiruchendur, Manapad and Idinthakarai

Mandapam area— Rameswaram, Dhanuskodi, Pamban, Krusadai Island, Shingle Island, Mandapam Pudumadam, and Kilakkarai

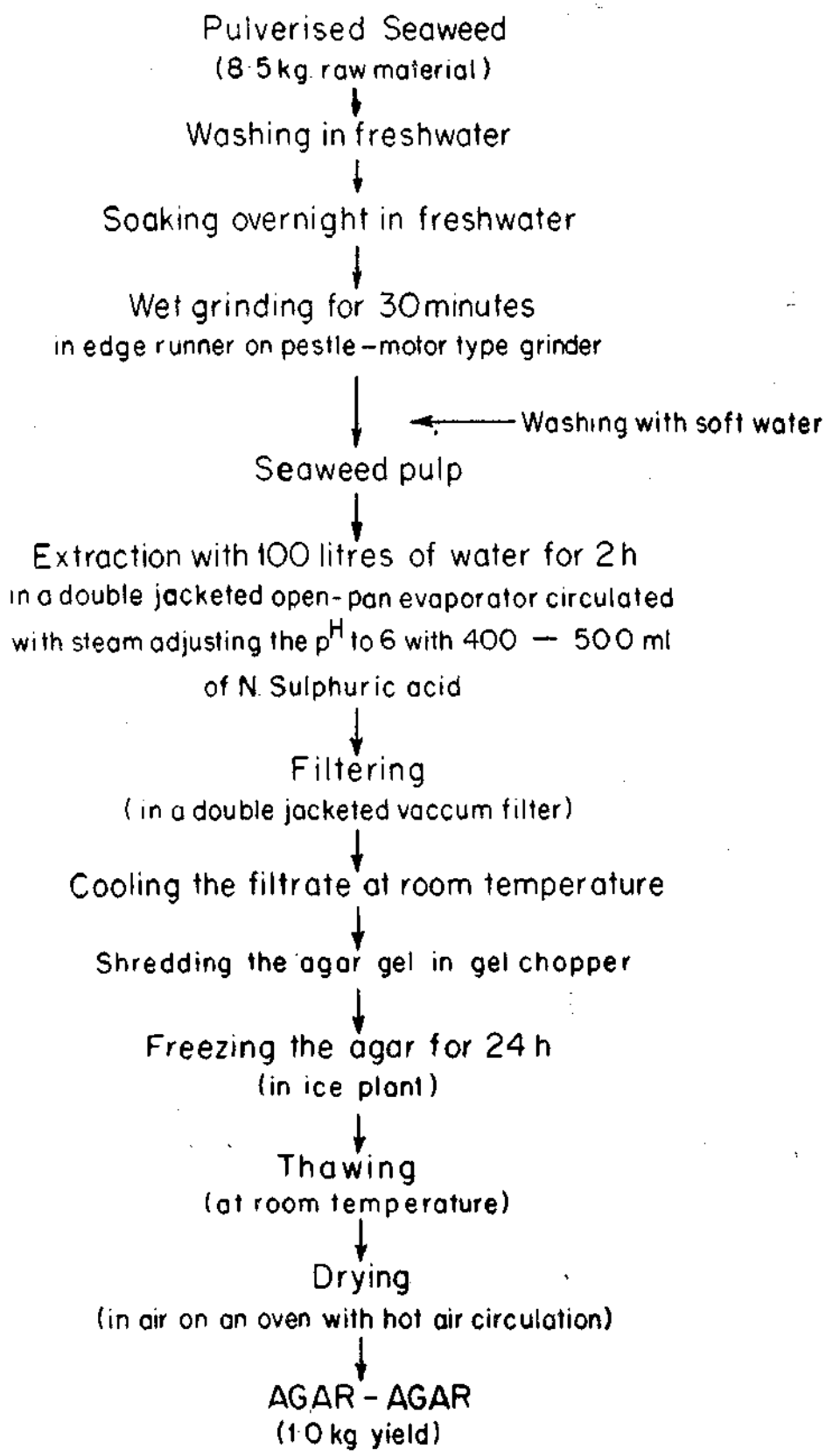
Porto-Novo area — Porto-Novo, Cuddalore, Pondicherry and Tranquebar.


10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28

APPENDIX-I *C. M. F. R. I. — Cottage industry method for the extraction of agar from* Gracilaria *species (From Thivy, 1960)*

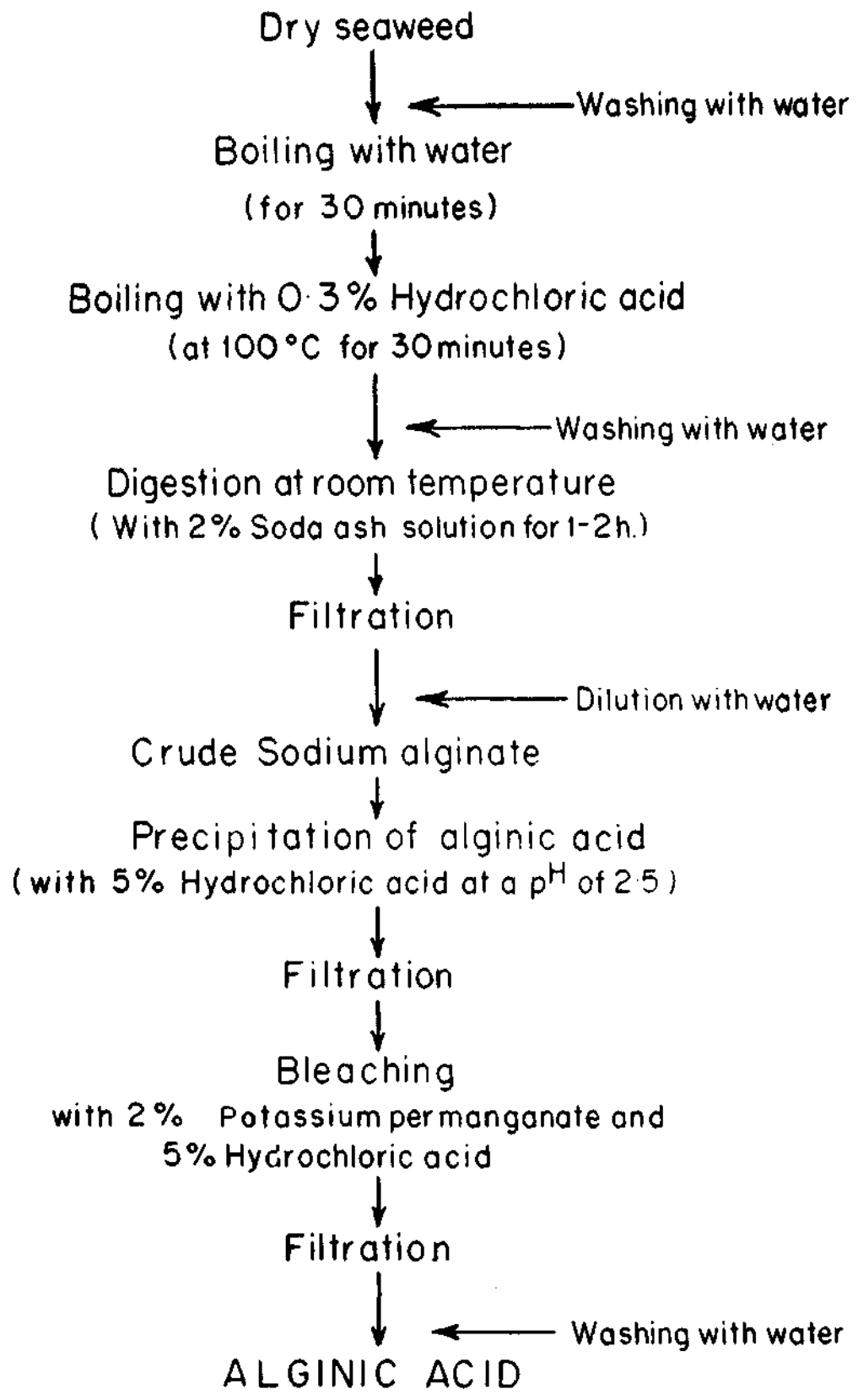


APPENDIX-II *Method for agar manufacture on a commercial scale (Visweswara Rao et al., 1965)*

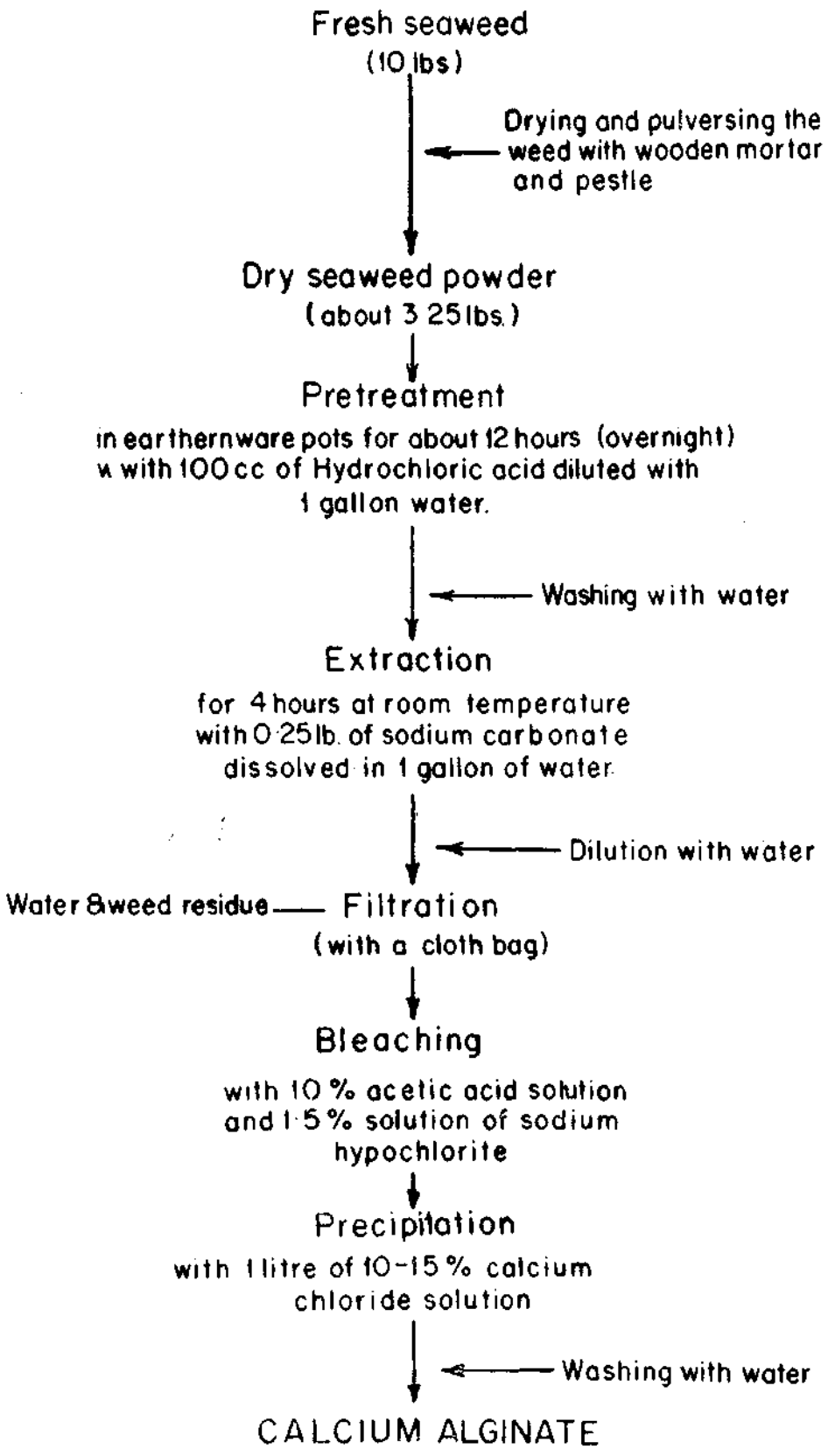


APPENDIX-III

Process for extraction of alginic acid
(From Pillai, 1957 c)



APPENDIX-IV *Flow sheet for the preparation of* Calcium alginate *on a Cottage industry basis (From Sadasivan Pillai, 1961)*



APPENDIX-V *Method for extraction of Sodium Alginate, Calcium Alginate and Alginic acid (From Visweswara Rao and Mody, 1964)*