The Economic Seaweeds of India

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THE ECONOMIC SEAWEEDS OF INDIA

By
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FOREWORD

Seaweeds are a rich resource for agar and algin which are used in confectioneries, pharmaceuticals, and other industries. Many marine algae are rich in proteins, vitamins, minerals and trace elements. Some of the species are directly utilized as human food or live-stock feed in different parts of the world. War-time shortages of agar for industrial purposes and bacteriological investigations etc., as also similar other products, compelled many countries to search for suitable substitutes or to make use of the indigenous seaweed resources. In this country systematic investigations on problems related to utilization of the seaweed resources have been commenced only in the post-war period. In the past two decades this Institute has been able to collect and collate all the available information on the subject and develop extraction techniques for agar and algin. Taxonomy, ecology and biology of a large number of Indian seaweeds of economic importance have been studied. The available information on varied aspects of seaweed resources and utilization has been compiled and presented in this bulletin. There is growing enthusiasm on the part of the private sector to develop the seaweed industry, although it is centred round at present in the production of agar and algin only. The utilization of edible seaweeds is practically nil. That there are extremely nutritious food algae like *Ulva, Porphyra* and *Centroceras* abounding in our waters is well-known. The fact that many of the industrial seaweeds lend themselves to culture in the shallow coastal lagoons etc. promises a bright future if farming techniques are adequately developed. There is, however, an urgent need for undertaking detailed surveys for estimation of the potential yields in respect of different species of economically important seaweeds. It is with great pleasure I wish to place on record my appreciation of the arduous task undertaken by Dr. M. Umamaheswara Rao in preparing this bulletin which, it is hoped, would serve as a useful guide to those interested in commercial utilization and biological researches carried out on the Indian seaweeds. I offer my sincere thanks to all concerned who helped in several ways in bringing out this publication.

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Mandapam Camp
Sept. 6, 1970.

I INTRODUCTION

The two chief types of plants occurring in the marine environment are the algae and sea grasses. These are capable of synthesizing the complex organic substances from the simple inorganic compounds present in sea water. Sea grasses are the seed producing plants which fall into the botanical division of Spermatophyta, whereas marine algae are the primitive group of plants with no true roots, stems and leaves as observed in higher plants and these come under the division Thallophyta. This division also includes certain fungi and bacteria, the latter especially forming an important group in the organic productivity of the sea. Among the algae in the marine habitats, the microscopic and free floating or swimming forms are known as Phytoplankton. The other macroscopic or attached ones, which often grow in the intertidal and subtidal environments, are commonly referred to as Seaweeds.

Most of these marine algae or seaweeds are beautifully coloured and attached to rocks or grow on other plants as epiphytes. A few of them are buried inside the sand and sometimes occur as loose lying communities. Depending upon the type of pigment present in them and other morphological and anatomical characters, macroscopic algae are subdivided into the following four classes:

1.Green Algae (Chlorophyceae)
2. Brown Algae (Phaeophyceae)
3. Red Algae (Rhodophyceae)
4. Blue-green Algae (Myxophyceae)

Algae belonging to the first three classes are treated here in detail since they constitute the vast majority of seaweeds of economic importance. Among the blue-green algae, some freshwater species of *Nostoc* are used as food gelly and many others are capable of fixing nitrogen and maintaining the fertility of the soil. Some information available on the marine flowering plants or sea grasses has also been included in this bulletin.

Large quantities of commercially valuable seaweeds are available in the seas around India. Prior to the initiation of work at the Central Marine Fisheries Research Institute on economically important seaweeds, very few attempts were made mainly to prepare agar from *Gracilaria* species at the time of Second World War. During the last twenty three years detailed studies have been made on the Indian seaweeds at this Institute and considerable amount of information has been gathered on different kinds of seaweeds available for agar and algin production and for food and manure. As a result of these intensive studies, seaweed industry has sprang up in the country and production of agar and algin has been commenced on a commercial scale. Since the seaweed industry is in the initial stages of development and the resources available along the Indian coast are not fully exploited, several enquiries are coming in recent years to know more about the Indian seaweeds and the products they give. An attempt has, therefore, been made here to bring together the valuable data collected by the Central Marine Fisheries Research Institute and other scientific organizations on Indian seaweeds and their utilisation.

Information available on various aspects concerning the taxonony, distribution, ecology, biology and chemistry of the seaweeds of economic importance is presented in different chapters of this bulletin. A key for the identification of important seaweed genera and species is given, together with illustration showing the morphological and anatomical details of the plants. Outlines of the processes for the manufacture of agar and algin on industrial basis developed by different workers are also given at the end of this publication as appendix.

II SEAWEEDS OF ECONOMIC IMPORTANCE

Various types of green, brown and red seaweeds occurring along the Indian coast and the possibilities of their utilization have been dealt with in the earlier papers published from the Central Marine Fisheries Research Institute (Thivy, 1958, 1960; Umamaheswara Rao, 1967, (1970 a). A systematic list of the important and common seaweed genera and species utilized for different purposes is given in the following pages:

Class : CHLOROPHYCEAE

Order: *Ulotrichales*

Family: Ulvaceae

Ulva fasciata Delile
U. lactuca Linnaeus
U. rigida Agardh
U. reticulata Forskal
Enteromorpha compressa (Linnaeus) Greville

Order: *Cladophorales*

Family Cladophoraceae

Chaetomorpha antennina Kuetzing

Order: *Siphonales*

Family: Caulerpaceae

Caulerpa racemosa (Forskal) J. Agardh
C. sertularioides (Gmelin) Howe
C. taxifolia (Vahl) C. Agardh
Caulerpa (Other species)

Family: Codiaceae

Codium adhaerens (Cabr.) C. Agardh
C. decorticatum (woodward) Howe
C. tomentosum (Hudson) Stackhouse

Class: PHAEOPHYCEAE

Order: *Dictyotales*

Family: Dictyotaceae

Dictyota dichotoma (Hudson) Lamouroux
Dictyota (other species)

Padina commersonii Bory
P. gymnospora (Kuetzing) Vickers
P. tetrastromatica Hauk

Order: *Punctariales*
Family: Punctariaceae
Colpomenia sinuosa (Roth) Derbis and Solier
Hydroclathrus clathratus (Bory) Howe
Rosenvingea intricata (J. Agardh) Boergesen
Rosenvingea (other species)
Chnoospora minima (Hering) Papenfuss

Order: *Fucales*
Family: Sargassaceae
Cystophyllum muricatum (Turner) J. Agardh
Hormophysa triquetra (Linnaeus) Kuetzing
Sargassum johnstonii Setchell and Gardner
S. myriocystum J. Agardh
S. tenerrimum J. Agardh
S. swartzii (Turner) C. Agardh
S. wightii (Greville) J. Agardh
Sargassum (other species)
Turbinaria conoides (J. Agardh) Kuetzing
T. ornata (Turner) J. Agardh

Class: RHODOPHYCEAE
Sub-Class: Bangioideae
Order: *Bangiales*
Family: Bangiaceae
Porphrya vietnamensis Tanaka and Ho

Order: *Gelidiales*
Family: Gelidaceae
**Gelidiella acerosa* (Forskal) Feldmann and Hamel

Order: *Cryptonemiales*
Family: Grateloupiaceae
Halymenia floresia (Clemente) C. Agardh
Grateloupia filicina (Wulfen) J. Agardh

* This alga has been identified as *Gelidium micropterum* Kuetzing by earlier workers and the same name was used by Thivy (1958, 1960) and in some other publications.

G. lithophia Boergesen

Order: *Gigartinales*
Family: Gracilariaceae
Gracilaria corticata J. Agardh
G. crassa (Harvey) J. Agardh
G. folifera (Forskal) Boergesen
G. lichenoides (Linnaeus) Harvey
G. verrucosa (Hudson) papenfuss

Family: Solieriaceae
Sarconema furcellatum Zanardini

Family: Hypneaceae
Hypnea musciformis (Wulfen) Lamouroux
Hypnea (Other species)

Family: Gigartinaceae
Gigartina acicularis (Wulfen) Lamouroux

Order: *Rhodymeniales*
Family: Rhodymeniaceae
Rhodymenia dissecta Boergesen
Rhodymenia (Other species)

Order: *Ceramiales*
Ceramiaceae
Centroceras clavulatum (C. Agardh) Montagne
Spryidia filamentosa (Wulfen) Harvey
S. fusiformis Boergesen
Family: Rhodomelaceae
Acanthophora spicifera (Vahl) Boergesen
Laurencia papillosa (Forskal) Greville
L. obtusa (Hudson) Lamouroux
Laurencia (Other species)

III SEAWEED PRODUCTS AND THEIR USES

Seaweeds are the only source for agar and algin and their use as food, fertilizer and fodder is well known in many parts of the world. Different products obtained from Indian seaweeds and their uses are given in this chapter.

Agar

This commercially important product is a colloidal carbohydrate present in the cell walls of certain red algae and it is a mixture of two polysaccharides, agarose and agaropectin. 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.

Important and commonly occurring agarophytes of India are *Gelidiella acerosa, Gracilaria lichenoides, Gracilaria crassa, Gracilaria verrucosa*, *Gracilaria corticata* and *Gracilaria folifera.* The yield and physical properties of the agar extracted from these red seaweeds vary particularly in *Gracilaria* species (see Table 7).

Agaroids

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

Carrageenan yielding plants seem to have not been reported from Indian waters, except for a rare and less abundant species of *Gigartina (G. acicularis)*occurring in the intertidal habits. But *Hypnea musciformis*, other spoecies of *Hypnea*, *Spyridia, Sarconema*, *Acanthophora, Laurencia* and *Chondria* growing along the Indian coast give gel-like extracts and some preliminary studies have been made at the Central

Marine Fisheries Research Institute on these plants (Pillai, 1957b; Thivy, 1951). From the information available it is evident that the yield of *Sarconema filiforme* extractive is 10% with a gel strength of 5gm/ cm^2 and a gelation temperature of 38^0C for 1.5% solution (Thivy, 1951). In the extractive of *Hypnea musciformis* (Rama Rao and Krishnamurthy, 1968) gel formation was not seen in 1.0% solution.

Algin

Algin or alginic acid is the main polysaccharide occurring in the cell walls of brown algae. It consists of D-manmuronic 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*, *Cystophyllum*, *Hormophysa*, *Dictyota* and *Padina* are some of the brown weeds reported from the Indian waters. Of these, *Sargassum* is the principal source for the production of algin in the country. In the laboratory tests conducted at the Central Marine Fisheries Research Institute *Turbinaria* was also found to be a good source for algin preparation, but its occurrence is restricted to certain areas of the coastline. The yield of alginic acid varied from species to species and *Sargassum tenerrimum*, *Sargassum wightii*, *Sargassum swartzii*, *Sargassum cinereum*, *Sargassum johnstonii*, *Turbinaria conoides* and *Turbinaria ornata* are some of the high yielding varieties occurring along the Indian coast.

Uses of Agar and Algin

In general both agar and algin serve as stabilizers, emulsifiers, thickeners, body-producers and gelling agents. Agar-agar is often used where firm gel is needed and algin for soft and viscous products. In ice cream industry both agar and algin are used as stabilizing agents to give smooth body and texture to the ice creams and also to prevent the formation of large ice crystals. Similarly these two seaweed colloids are employed in icings to prevent adhesion of the sugar coating to wrappers, in canning industry as coating materials for preserving fish, meat and other products, in the preparation of milk puddings, sherbats, dental impression materials and agricultural sprays. Some information on the food products requiring agar and their preparation, given by Thivy (1958), is presented 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 (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	$\frac{1}{2}$ teaspoonful (1g) per Ib. 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 Ib. 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)	1 level teaspoonful (3 g) per cup of milk with sugar	Dissolve agar in small amount of water in a double boiler and pour into warm milk, not voice versa.
Lime jelly	1 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.

There are certain specific uses for each of these two extractives. For instance agar is used in smoking tobacco and fruit cakes to serve as moisture retaining agent, in confectionary industry for making gelly candies, in drawing tungsten wires as a lubricant, in hectograph duplicators, in photofilms and plates. It is also widely used as microbiological culture medium, therapeutic agent in constipation and as coating material for capsules.

Algin is used for sizing textiles and paper, thickening textile paints and for boiler water treatment. This is the most useful colloidal carbohydrate in cosmetic industry for preparing creams, beauty milks, mouth washes, hair pomades, tooth pastes etc. it is also used in the preparation of tablets and pills as granulating and binding agents, in rubber industry as a creaming agent to separate the rubber, in the manufacture of lignite briquetts, in liquor clarification, in varnishes, paints, adhesives, leather polishing materials etc. Sodium alginate and other salts are employed in the manufacture of seaweed rayon. Studies were made on alginic acid sulphate and its salts to use them as blood anti-coagulants.

Algal proteins

Some green and red seaweeds such as *Ulva fasciata, Ulva rigida, Porphyra vietnamensis, Acanthophora muscoides* and *Centroceras clavulatum* are very rich in proteins. These algal proteins have many essential amino acids, including iodine containing amino acids. Studies have shown that the weeds mentioned above contain 16-30% of protein on dry weight basis and this amount is somewhat higher than in other food materials like cereals, eggs and fish (Visweswara Rao, 1964). Protein concentrates can be prepared by extracting protein from these green and red seaweeds, and dry powders of *Ulva, Porphyra, Acanthophora* etc. can be added to various foods of protein deficiency or consumed in small quantities along with the other food stuffs.

Seaweeds as food

Fresh, dried and processed seaweeds are utilized as human food and for decorating the dishes. The algal carbohydrates are not easily digestable and the food value of the seaweeds depends on the minerals, trace elements, proteins and vitamins present in them. Majority of the seaweeds listed in chapter II are used as food in Japan, Indonesia, Ceylon, China, Philippines and other countries of the Indo-Pacific region. There are large industries in Japan on edible seaweeds like *Porphyra* (Laver or Nori). Thin algal sheets are prepared by washing and drying *Phorpyra* plants. The product thus obtained is an important food item and it costs 4.80 to 8.00 U.S. dollars per pound.

Species of *Ulva, Enteromorpha, Chaetomorpha, Caulerpa, Codium, Dictyota, Padina, Colpomenia, Hydroclathrus, Rosenvingea, Chnoospora, Sargassum, Turbinaria, Porphyra, Halymenia, Grateloupia, Gracilaria, Hypnea, Rhodymenia, Centroceras, Acanthophora, Laurencia* are some of the edible weeds found in different localities along the Indian coast. The important edible red seaweed *Porphyra* has so far been reported from Madras (Boergesen, 1937 b), Visakhapatnam and Cape Comorin (Umamaheswara Rao and Sreeramulu, 1963; Umamaheswara Rao, 1968). The same alga was collected recently from Colachel area on the west coast (Umamaheswara Rao, unpublished).

The only report available on the utilization of algae as food in the country is that of *Gracilaria lichenoides*. In the coastal districts of Tamil Nadu this weed is used for the preparation of porridge or “Kanji”.

Seaweed meal

As seaweeds are cheap sources for minerals and trace elements, meals prepared from seaweeds can be utilized as supplements to daily rations of the cattle, poultry and other farm animals. Seaweed meals can be prepared from *Ulva, Enteromorpha Gracilaria, Hypnea, Sargassum, Padina, Dictyota* etc. by pulverizing the cleaned and washed weeds. A simple method has been described by Thivy (1960) for the preparation of seaweed meal from *Gracilaria lichenoides.*

Seaweed manure

From time immemorial seaweeds have been used as manure in the coastal areas. Important feature of seaweed manure is that the minerals and trace elements occur in water soluble form and when the manure is applied these chemical constituents are readily absorbed by the plants. Carbohydrates and other organic matter occurring in seaweeds alter the nature of the soil and increase its moisture holding capacity. Deficiency diseases are also controlled by the minerals and trace elements present in the seaweed manure.

Large quantities of seaweeds and sea grasses like *Cymadocea, Diplanthera* and *Halophila* can be utilized as manure directly or in the form of compost. A method for composting the seaweeds with cow dung has been described by Thivy (1958; 1960). Field experiments have been conducted in the Central Marine Fisheries Research Institute applying seaweed compost to bhendi, sweet potato, tapioca, brinjal plants (Thivy, 1960) and high yields were obtained from these vegetables crops. In certain coastal areas of Tamil Nadu, cast ashore weeds are used as manure for coconut plantations.

Medicinal uses of seaweeds

There are some reports in the literature about the medicinal value of seaweeds. Species of *Sargassum* were used for cooling and blood cleansing effect. *Hypnea musciformis* was employed as vermifuge or worm expelling agent and *Centroceras clavulatum* as cathartic agent. Seaweeds rich in iodine such as *Asparagopsis taxiformis* and *Sarconema* can also be used for controlling goitre, diseases caused by the enlargement of thyroid gland.

IV TAXONOMY AND DISTRIBUTION OF SEAWEEDS

Although there are no detailed systematic accounts for the identification of commercially valuable seaweeds, certain amount of information has been gathered on the taxonomy of Indian marine algae in recent years. A brief account on the taxonomy and distribution of seaweeds is given in this chapter.

Taxonomy

Studies conducted on Indian algae have been reviewed from time to time by Agharkar (1923), Iyengar (1957), Biswas (1932; 1934), Joshi (1949), Randhawa (1960) and Srinivasan (1965). Our earliest knowledge on Indian marine algae is largely due to the explorative voyages conducted in the seas around India and from the collections made by the missionaries and other westerners who visited our country (Srinivasan, 1965). In 1930 Boergesen came to India and based on the extensive and valuable collections of Prof. M.O.P. Iyengar and his own collections from different localities of the east and west coasts of India, he published a series of papers on the green, brown and red algae of the northern parts of the sea coast (Boergesen, 1930, 1931, 1932a, b, 1933 a, b, 1934 a, b, 1935) and on brown and red algal flora of South India (Boergesen, 1937 a, b, 1938).

After the valuable contributions of Boergesen, some work has been done on the morphology and taxonomy of Indian marine algae during the last two decades. Many of these investigations have been published in various scientific journals and only relevant references on the systematic lists and other papers, which give the composition of the algal flora of different localities, are given here. Srinivasan (1946) studied the marine algal flora of Mahabalipuram near Madras and information on the algae of Chilka Lake is available in a paper published by Parija and Parija (1946). A general review of the marine algae of the west coast has been given by Biswas (1948). Srinivasan (1960) gave a detailed account on the marine algae of the east and west coasts of India based on the earlier reports available. According to the estimate given by him 162 genera and 413 species of marine algae are known from the Indian waters. Algal flora of the Krusadai Island has been listed (Chacko *et al*., 1955) and the seaweeds growing on the pearl and chank beds off Tuticorin have been studied (Varma, 1961). Descriptions of the Indian species of *Turbinaria* are given by Taylor (1964). Monographs on different groups of algae are now being published by the Indian Council of Agricultural Research, New Delhi and very recently a monograph on the brown algae occurring along the Indian coast has been prepared by Misra (1966). Srinivasan (1966) published a comprehensive account on the Indian *Sargassum* species. From the collections made in the vicinity of Mandapam and other materials available in the Central Marine Fisheries Research Institute, a list of 180 algae has been prepared by Umamaheswara Rao (1962a). Some recent contributions give information on the composition of marine algae of Gopnath (Sreenivasa Rao and Kale, 1969) and Gulf of Kutch (Gopalkrishnan, 1969). An annotated list of 80 algae growing along the Visakhapatnam coast has been published by Umamaheswara Rao and Sreeramulu (1970a).

Distribution of seaweeds

Seaweeds are confined to narrow littoral and sublitoral belts of the marine environment. As in land plants, they require certain environmental conditions for proper growth and establishment in different regions of the coast line. But the topography, physical nature of the substratum, salinity, currents, tidal action and other factors of the marine environment vary in different parts of the coast line and as a result of these fluctuations marked changes occur in the distribution and abundance of different kinds of seaweeds. Among the factors mentioned above the substratum that is used by majority of the plants as an anchoring surface, plays a key role and the luxuriance of seaweed growth largely depends on the availability of suitable substratum in the littoral and sublittoral areas of the coast line .

All along the 5,689 km long coastline of India, rocky or coral formations occur in Tamil Nadu and Gujarat States and in the vicinity of Bombay, Karwar, Ratnagiri, Goa, Vizhinjam, Varkala, Visakhapatnam and a few other places like Chilka and Pulicat Lakes. Indian seaweed resources are limited to these areas of the coastline and other places such as Laccadives, Andaman and Nicobar Islands occurring in the Indian waters. The coastal areas of Tamil Nadu and Gujarat States are the important seaweed growing regions in the country. Harvestable quantities of seaweeds grow in other areas of the east and west coasts and in the Laccadives, Andaman and Nicobar Islands.

General distribution of various kinds of marine algae on the east and west coasts has been reported by Srinivasan (1960). Distribution of the economically important seaweeds of India is given by Thivy (1959) and the agar and algin yielding seaweeds by Umamaheswara Rao (1969 b). From these studies it is clear that the horizontal distribution of different plants varied in relation to the natural habitats. For instance, *Gelidiella acerosa* has been found only on the coral formations of the Tamil Nadu coast and also at Gujarat. Many *Gracilaria* species have been reported from the localities between Mandapam and Cape Comorin. Some plants like *Sargassum, Gracilaria corticata, Ulva, Enteromorpha* and *Chaetomorpha* which thrive in the littoral habitats, have a continuous distribution all along the intertidal rocky surfaces of the coast line.

V KEY FOR IDENTIFICATION OF THE IMPORTANT SEAWEED GENERA AND SPECIES

A simple key for identification of the different genera and some species of green brown and red seaweeds listed in the earlier chapter is given here. As far as possible, external and internal characters of the vegetative plants are used in the preparation of this key. Illustrations are also given at the end for easy identification of the different genera and species (Text figs. 1-38 and Plate figs. 1-11).

GREEN ALGAE

Key to the 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 constriction	…	….	*Chaetomorpha antennina*
2.	Plants 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*
4.	Adult plants not tubular, flat, foliaceous and thallus two cells thick	…	…	*Ulva spp.* (III)

I. Key to the species of *Caulerpa*

1	Erect fronds with much crowded branchlets arising fom 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.	Branchlets cylindrical with pointed tips and closely arranged in the form of a feather		…	*C. sertularioides*

II. Key to the species of *Codium*

1.	Plants prostrate with irregularly lobed and spongy thallus, utricles 50-70/u and rarely 100/u in diameter	…	…	*C. adherens*
1.	Plants erect and repeatedly branched		…	2
2.	Plants cylindrical, dichotomously branched and utricles about 150-200 /u broad		…	*C. tomentosum*
2.	Plants compressed, flattening very conspicuous near the forks, utricles 300-500 /u broad	…	…	*C. decorticatum*

III. Key to the species of *Ulva*

1.	Plants with reticulate or net-like fronds or profusely perforated, often grow intermingled 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 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 15^0-45^0 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 intricate*

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. ornate*
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 (1-0-2.5mm, 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 flattered petioles or 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 different-tiated into a central medulla and outer cortex … 3

2. One cell thick and branched filaments or tricho-blasts present at the apical parts of the main axes and branches, thallus parenchymatous with uniform sized cells, tetrasporangia formed at the terminal portions of the branches or 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 …*Acnthophora spicifera*

4. Plants erect and bushy, more or less fleshy con-sistency, 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 the branchlets … … *Spyridia* (II)

3. Medulla or central part of the thallus filaments … 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 the thallus or cortex consisting of anticlinal branched rows of cells, tetrasporangia in sori or in groups … … *Gigartina acicularias*

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 … *Grateloupias* (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 the 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. 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/u in diameter, tetrasporangia in swollen branchlets … …. *Gelidiella acerosa*

10. Plants large, flat or cylindrical, with medulla of large colourless cells 100-500/u in diameter, tetrasporangia scattered in the cortex of the fonds … … … 11

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

11. Cystocarps with a mass of carpospores arising from thread-like structure, pericarp loose; plants upto 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 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 cylindrical … … 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 up to 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. lichenoides*	
4. Plants irregularly and multifariously branched, often grow upto 2.0 m in length, branches constricted below and tapering above, sometimes provided with short and spindle-shaped branch-lets, tetrasporangia in slightly modified cortex, antheridia in deep cavities	…	*G. verrucosa*	

VI CHEMICAL STUDIES ON SEAWEEDS

A great deal of chemical work has been done on Indian seaweeds during the last ten or fifteen years. Information so far gathered on the mineral constituents, carbohydrates and other algal chemicals is presented in the following pages.

Mineral constituents

As seaweeds are used as food and fertilizer, many studies were made on the chemical composition. Some earlier studies on the mineral constituents of algae have been made by Chidambaram and Unny (1947, 1953) and Joseph *et al*. (1948). *Sargassum, Turbinaria* and *Gracilaria* species collected at Madras and analysed by Chidambaram and Unny (1953) have the following composition.

	Sargassum	*Turbinaria*	*Gracilaria*
Moisture (air dried)	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 intensive studies have been made 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, nitrogen and amono acids (Pillai 1957 a,b) occurring in eleven green, brown and red seaweeds namely, *Chaetomorpha linum, Enteromorpha intestinalis, Gracilaria lichenoides, Chondria dasyphylla, Acanthophora spicifera, Laurencia papillosa, Hypnea musciformis, Sarconema furcellatum, Sarconema filiforme, Rosenvingea intricata* and *Padina tetrastromatica*. Recently Sitakara Rao and Tipnis (1967) analysed ten species of marine algae of the Gujarat coast. While working on the preparation of agar from red seaweeds, Kappanna and Visweswara Rao (1963) studies and chemical composition of *Gelidium micropterum* (*Gelidiella acerosa*) and *Gracilaria lichenoides*. To know the nutritive value of the Indian seaweeds, Neela (1956) estimated the protein, fat, calcium, phosphorus, iron, iodine and Vitamin-C contents in *Gracilaria* sp. *lichenoides, Hypnea* species and *Ulva lactuca*. The chemical composition of *Porphyra* growing on Visakhapatnam coast has been worked out by Tewari *et all*. (1968) and data obtained on this important edible weed have been compared with that of Japanese species. Results obtained on the major constituents and trace elements of algae studied by these authors are shown in Table 2 and 3. Pillai (1956) and Sitakara Rao and Tipnis (1967) estimated the water soluble constituents from dry weeds and Kappanna and Visweswara Rao (1963) from the ash of the weed.

With a view to understanding the manurial value of seaweeds, certain chemical studies were made. Seaweeds like *Sargassum* and *Turbinaria* have been composted with fish – offal and shark liver oil sediments in the ratio of 15:3:4 by weight for a period of three months (Chidambaram and Unny, 1947). Chemical analysis of this compost indicated that it contains 2.4% of nitrogen, 3.5 % potash and 0.7% of phosphate. Observations have been made on the nitrifiability of the organic nitrogen from *Ulva lactuca* and drift weeds collected from Veraval (Mehta *et al*, 1967). Pillai (1955b) has 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* are added to the blue-green algal cultures.

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

Table 2

Water soluble minerals in Indian seaweeds (Results are expressed in gm/100 gm of dry weed)

Plants	Sodium	Potassium	Calcium	Magnesium	Chloride	Nitrogen	Sulphate	Author
GREEN ALGAE								
1. *Enteromorphoa 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 ALGAE								
7. *Padina australis*	1.28	0.93	0.50	0.50	2.40	0.60	1.8	Pillai, 1956
8. *P. gymnospora*	1.40	1.06	0.16	0.02	0.87	-	1.39	Sitakara Rao and Tipnis, 1967.
9. *Calpomenia sinuosa*	0.56	0.85	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 accrosa*)	0.08	0.02	0.28	0.07	0.09	1.34	0.73	Kappanna and Visweswara Rao, 1963
15. *Gracilaria lichencides*	0.23	2.01	0.40	0.16	3.84	0.70	4.50	Pillai, 1956
16. *G. licbenoides*	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	0.75	2.00	Do.
19. *Laurencia papillosa*	1.16	0.82	0.61	0.31	2.40	1.00	3.8	Do.

Table 3

Minor constituents in Indian seaweeds (Results are expressed in mg/100 gm 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 intricate*	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. *Sargassum cinereum*	224.05	1.45	4.19	0.24	1.08	3.02	Do.
v. berberifolia		203					
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 filiformo*	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	550	-	Do.

Iodine content

Though the mineral deposits of Chile are the important sources for the production of iodine, it is still extracted in small amounts from brown weeds in Japan, Norway and France and from red seaweeds like *Phyllophora nervosa* in Russia. Seaweeds are good sources to meet dietary requirements of iodine and goitre disease caused by iodine deficiency is less prevalent in countries where marine algae form part of the diet. Some amount of iodine occurs in seaweeds in the readily available form of the precursor of thyroxine and hence this source of iodine is far better than mineral iodine (Thivy 1960).

Joseph *et al*. (1948) collected some information on the iodine content of *Sargassum* and a seagrass, *Enhalus koenigii*. Later Pillai (1956) estimated the iodine content in eleven species of marine algae growing around Mandapam. Recently Kappanna and Sitakara Rao (1962), Sitakara Rao and Tipnis (1967) and Dave *et al*. (1969) have determined the quantity of iodine present in many green, brown and red algae of the Gujarat coast. Values obtained by these authors together with the localities from which the algae collected are shown in Table 4. Maximum values obtained in a year are given for the algae studied by Pillai (1956). In general the iodine content was high in green and red algae analysed (Table 4) than in brown weeds. However, among the brown algae studied 104.50 mg of iodine was reported in *Myrioloea Sciurus* and 500 mg. in *Padina australis* (Table 4). Maximum amount of 566.70 mg/100 gm was observed in a small red alga *Asparagopsis.* Other weeds in which high quantity of ioidine (above 200 mg/100 gm) observed are *Udotea indica, Gracilaria lichenoides* and *Sarconema furcellatum.*

Proteins, peptides and free amino acids

Protein content in the marine algae has been estimated by Chidambaram and Unny (1953), Neela (1956), Pillai (1957a) and Sitakara Rao and Tipnis (1964, 1967). In *Sargassum, Turbinaria* and *Gracilaria* species analysed by Chidambaram and Unny (1953), the protein content was found to be less than 10%. Data collected during recent years on protein content of different green, brown and red algae are summarized in Table 5. It may be seen from Table 5 that the protein is high in green and red seaweeds investigated than in the brown weeds. In *Ulva fasciata, Ulva*

Table4

Iodine content of Indian seaweeds

Name		Locality	mg of Iodine/ 100 gm dryweed	Author
GREEN ALGAE				
1.	*Enteromorpha intestinalis*	Mandapam	58.00	Pillai, 1956
2.	*Enteromorpha* spp	Porbander	4.16	Dave *et al*, 1969
3.	*Ulva fasciata*	Veraval	7.40	Do.
4.	*U. lactuca*	Okha	3.31	Do.
5.	*U. lactuca*	Porbander	6.27	Do.
6.	*U. rigida*	Gopnath	4.83	Sitakara Rao & Tipnis, 1967
7.	*Chaetomorpha linum*	Mandapam	72.00	Pillai, 1956
8.	*Cladophora expansa*	Porbander	18.00	Dave *et al*, 1969
9.	*C. monumentalis*	Okha	64.64	Sitakara Rao & Tipnis, 1967
10.	*Cladophora* spp.	Porbander	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 & Tipnis, 1967
15.	*Chamaedoris auriculata*	Veraval	10.43	Dave *et al*, 1969
BROWN ALGAE				
16.	*Myriogloea sciurus*	Okha	104.50	Kappanna &Sita kara Rao, 1962
17.	*Stoechospermum marginatum*	Okha	5.44	Dave *et al*, 1969
18.	*Spathoglossum variabile*	Do.	16.44	Kappanna &Sita kara 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 & Tipnis, 1967
24.	*Cystophyllum* spp.	Porbander	34.19	Dave *et al*, 1969
25.	*Cystophyllum* spp.	Veraval	16.53	Do.

Table 4 (Contd.)

Name	Locality	mg of Iodine/ 100 g dryweed	Author
26. *Sargassum cinereum* v. *berberifolia*	Sikka	33.20	Sitakara Rao & Tipnis, 1967
27. *S. johnstonii*	Okha	39.80	Do.
28. *S. swartzii*	Do.	28.18	Dave *et al*, 1969
29. *S. tenerrimum*	Do.	37.21	Do.
30. *S. vulgare*	Porbander	29.29	Do.
RED ALGAE			
31. *Scinaia indica*	okha	5.62	Kappanna &Sita kara Rao, 1962
32 *Asparagopsis taxiformis*	Do.	499.30	Dave *et al*, 1969
33 *Asparagopsis* spp.	Do.	556.70	Do.
34. *Gelidiella acerosa*	Porbander	54.00	Do.
35. *Amphiroa anceps*	Okha	5.15	Do.
36. *Halymenia venusta*	Do.	25.00	Do.
37. *Gracilaria corticata*	Porbander	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 &Sita kara Rao, 1962
42. *S. furcellatum*	Mandapam	357.00	Pillai, 1956
43. *Solieria robusta*	Okha	15.54	Kappanna &Sita kara 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 &Sita kara Rao, 1962
49. *Polysiphonia ferulacea*	Do.	39.06	Do.
50. *Polysiphonia* spp	Do.	4.78	Do.
51. *Acanthophora* spp.	Do.	5.78	Do.
52. *A. spicifera*	Mandapam	90.00	Pillai, 1956
53. *Laurencia papillosa*	Do.	137.00	Do.

rigida, Acanthophora muscoides and *Centroceras clavulatum* 22-26% of protein was estimated. Lewis and Gonzalves (1960) reported protein content higher than 28% in the algae collected from Bombay coast.

Table 5

Protein content of Indian seaweeds

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

Extensive work has been carried out by Lewis and Gonzalves (1959 a-c, 1960, 1962 a-c) and Lewis (1962 a,b, 1963 a-d, 1964 and 1967) on the aminoacids present in free state and in the protein and peptide hydrolysates. The following are some of the green brown and red seaweeds studied by these authors: *Caulerpa racemosa, C. peltata, C. sertularioides*

Enteromorpha prolifera, Ulva lactuca V. rigida, Valoniopsis pachynema, Padina tetrastomatica, P. distromatica, P. gymnospora, Spathoglossum asperum, Dictyota maxima, Sargassum cinereum, Chondrococcus hornemanni, Centroceras clavulatum, Spyridia fusciformis, Laurencia papillosa, Chondria dasyphylla, Calliblepharis jubata, Hypnea musciformis, Gracilaria compressa, G. confervoides, G. lichenoides, G. corticata, Grateloupia lithophila, G.filicina and *Agardhiella robusta*. While reviewing the work done on proteins, peptides and free aminoacids, Lewis (1967) has pointed out that the Indian marine algae have all the essential aminoacids needed in the human diet and the importance of seaweeds is mainly due to the occurrence of aminoacids like methionine and triptophane which are not available in other vegetable food materials.

Extraction of protein from marine algae

Parekh and Visweswara Rao (1964) reported a method to extract proteins from the green seaweed, *Ulva rigida*. In this process the powdered weed is first treated with either-water mixture (1:4 ratio) for about 3 hours and extracted with one normal sodium hydroxide solution. The protein present in the alkali extract was then precipitated with 10% solution of trichloro acetic acid at pH 4-5. The precipitated protein was washed, dried and powdered. Among the precipitating agents tried by these authors, trichloro acetic acid gave best results and it has been found that a concentrate containing 60% of protein can be obtained by this method.

Vitamins

Different Vitamins such as Vitamin – A, Vitamin – B_{12}, Vitamin – C Vitamin – D and Vitamin-E have been reported from marine algae growing in the other parts of the world. In India, a few studies were made on the ascorbic acid content (Vitamin-C) of marine algae and the results obtained on the algae of Mandapam area (Thivy, 1960) are shown in the Table 6. The amount of ascorbic acid present in *Sargassum myriocystum* (Table 6) is very high and it is slightly more than the amount present in citrus fruit (Thivy, 1960). Variations in the ascorbic acid content in relation to growth and reproduction of *Ulva fasciata* have been studied by Subbaramaiah (1967). Highest concentration of 2.4 mg/gm was observed in very young plants of about 5 mm in length. With increase in length of the frond the ascorbic acid content decreased and only 0.73 mg/gm was observed in plants more than 7.0 cm in length. The concentration of Vitamin-C was found to be higher in reproductive parts of the thallus than in the vegetative parts.

Carbohydrates

Laminarin, mannitol, fucoidan, alginic acid, agar, carrageenan and many other varieties of carbohydrates have been isolated from green, brown and red algae (Black, 1954; Percival, 1968). In india much attention has been paid so far on the economically important algal carbohydrates such as agar and algin. Investigations carried out on these and other carbohydrates are detailed below:

Agar:- During and after the Second World War some studies were made to produce agar from the Indian seaweeds (Bose *et al.*, 1943; Chakraborthy, 1945; Joseph and Mahadevan, 1948 and Karunakar *et al*., 1948). These authors used different techniques for the purification of agar gel. In the method developed by Bose *et al.* (1943) the whole weed is leached for 18 hours before extraction and the gel obtained was maintained at 60^0C to remove the suspended impurities. Starch present in the gel was removed by treating with 0.2% acetic acid for one hour and then by washing the gel in water. Bacterial method has been employed by Karunakar *et al*. (1948) for the purification of agar gel. Chakraborthy (1945) used the freezing technique to remove the suspended material in the gel of *Gracilaria verrucosa* and working on the same species Mahonty (1956) later reported that heating under pressure at 230^0 F was necessary for the removal of impurities in the gel.

At the Central Marine Fisheries Research Institute, more detailed investigations were made since its inception on Indian agarophytes to utilize the indigenous seaweed resources for the production of agar in the country. Agar-agar was extracted from different species of *Gracilaria* and the seaweeds like *Gelidiella acerosa* occurring along the Indian coast and the physical properties of agar samples obtained from these plants were studied (Thivy, 1951, 1960; Sarangan, unpublished). In these investigations *Gelidiella acerosa*, commonly growing on the coral substrata in the Gulf of Mannar area was found to be an important source for the manufacture of high quality agar. The yield, gel strength and data on some other physical properties of *Gelidiella acerosa* and *Gracilaria* species obtained are given in Table 7

Table 6

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

Alga		mg/100 g 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
Laurencia papillosa	…	5.92

Table 7

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

Agarophyte	Yield (%)	Gel strength (1.5% solution)	Setting temp. (1.5% solution)	Melting temp. (1.5% solution)
Gelidiella acerosa	45	300 gm/cm^2	40^{0}C	92^{0}C
Gracilaria lichenoides	43	120 gm/cm^2	45^{0}C	84^{0}C
G. crassa	23	140 gm/cm^2	48^{0}C	84^{0}C
G. corticata	38	20 gm/cm^2	44^{0}C	68^{0}C
G. foliifera	12	15 gm/cm^2	40^{0}C	-

During the course of chemical studies carried out in this Institute on marine algae (Pillai, 1955 c) it was observed that in *Gracilaria lichenoides* 60-90% of minerals and a good amount of sulphur, nitrogenous matter and carbohydrates occur in water soluble form and these compounds, which come as impurities while extracting agar, can be removed by pulverizing, soaking and washing the weed. Based on this important observation, a cottage industry method has been developed in the Central Marine Fisheries Research Institute for the manufacture of pure agar from *Gracilaria lichenoides* (Pillai, 1955c; Thivy 1960). Details of the method developed are given in the appendix. In this method the impurities are removed from the seaweed before extraction and not from the gel. The leaching process will minimize the cost of production since large scale equipments are not used for freezing gel etc. and the yield from the pulverized weed is higher than in the earlier methods reported.

A separate method has also been described (Thivy, 1960) for the extraction of agar-agar from *Gelidiella acerosa (Gelidium micropterum).* Freezing technique is employed in this method to retain the cold water soluble fraction of agar and since it is not possible to remove the impurities from the weed effectively as in the case of *Gracilaria lichenoides.*

Several methods have been described recently for large scale extraction of agar with some minor changes in the process worked out by Thivy (1960). In the studies made by Kappanna and Visweswara Rao (1963) on the preparation of agar from *Gelidium micropterum (Gelidiella acerosa)* and *Gracilaria lichenoides*, it was pointed out that the quality of agar can be improved by freezing and thawing; and that soaking the material for 24 hours has no effect on the quality of agar. In the pilot plant trials conducted later (Visweswara Rao *et al*., 1965) pulverized weed was soaked overnight in fresh water before wet grinding and extracting the agar. The method suggested by Srinivasan and Santhanaraja (1967) is more or less similar to the one described by Kappana and Visweswara Rao (1963), but the seaweed is pulverised into fine powder before extraction. To eliminate the cost of freezing Desai (1967) used 90% industrial alcohol for flocculating the agar from the filtrate.

The sulphate content of the agar-yielding seaweeds plays an important role in determining the gel strength of agar. Marked increase in the stability and gel strength of agar was observed in the experiments conducted (Doshi and Sreenivasa Rao, 1967 a,b) by exposing the seaweed samples to Cobalt-60 gamma radiations. Small doses varying from $0.5 \times 10^{18} eV./g.to 3.0 \times 10^{18} eV./g.$ increased the gel strength (1-2.5 times) in *Gelidiella acerosa* ,*Gelidium micropterum* and *Gracilaria millardetiii* (Doshi and Sreenivasa Rao, 1967 b). These changes caused by the radiations have been ascribed to the breaking up of the organic sulphate fraction in the agar molecule. Later, the sulphate content present in the extractives of *Gelidium* spp., *Gelidiella acerosa Gracilaria folifera, G. millardetii, G. corticata, Hypnea musciformis* and *Furcellaria* sp has been precipitated with barium chloride and gel strength of these agar samples was determined (Doshi, Raju and Sreenivasa Rao, 1968). As expected, increase in gel strength was found in these experiments with corresponding decrease in the sulphate content.

As mentioned earlier, the physical properties of the colloids obtained from *Hypnea* and *Chondrus* are altered by the addtion of certain solutes like potassium chloride. However, the properties of *Gelidium* and *Gracilaria* agars are not effected by the solutes (Humm, 1957). In a recent study on *Hypnea musciformis* occurring on the Gujarat coast (Rama Rao and Krishnamurthy, 1968), rapid increase in gel strength , setting and melting temperautures was reported with the addtion of 0.5% potassium chloride to different concentrations of *Hypnea* extractive. For the preparation of *Hypnea* agar it has been suggested by these authors that the potassium chloride must be added filtering the hot extract and freezing and thawing should not be done to retain the solutes in the *Hypnea* gel.

Alginic acid:- Very few studies were made on Indian alginophytes when compared with the work done on agar-yielding plants. Alginic acid content present in the brown algae of Mandapam area (Valson, 1955) and Gujarat coast (Kappana *et al.*,1962) has been determined. Data gathered on the alginic acid content of Indian brown seaweeds are shown in Table 8, along with the localities from which the weeds have been gathered. Values of

Table 8

Alginic acid content in Indian brown seaweeds

Seaweed	Locality	Yield of Alginic Acid (%)	Author
1. *Dictyota* spp.	Sikka	5.50	Kappanna *et al*, 1962
2. *Padina* spp.	Mandapam	10.35	Valson 1955
3. *Cystophyllum muricatum*	Mandapam	15.63	Do.
4. *Cystophyllum muricatum*	Sikka	19.74	Kappanna *et al*, 1962
5. *Hormophysa triquetra*	Mandapam	18.22	Valson, 1955
6. *Sargassum cinereum v. berberifolia*	Dwarka	29.17	Kappanna *et al*,1962
7. S. *johnstonii*	Okha	22.34	Do.
8. *S. myriocystum*	Mandapam	24.70	Umamaheswara Rao, (Un published)
9. *S. tenerrimum*	Dwarka	4.85	Kappana *et al*,1962
10. *S. tenerrimum*	Okha	10.08	Do.
11. *S. tenerrimum*	Sikka	14.77	Do.
12. *S. wightii*	Mandapam	31.70	Umamaheswara Rao, 1969c.
13. *Sargassum* spp.	Do.	19.22	Valson, 1955.
14. *Turbinaria conoides*	Do.	18.08	Do.
15. *T. conoides*	Do.	35.60	Umamaheswara Rao, 1969c
16. *T. ornate*	Do.	32.18	Umamaheswara Rao, (Un published)

Valson (1955) and Kappanna *et al*. (1962) presented in Table 8 are based on the titration method of Cameron *et al*. (1948) and those of Umamaheswara Rao (1969 c) on the maximum yield obtained from the fully grown plants.

Studies on the structure, properties and optimum conditions for the preparation of alginic acid were carried out with *Sargassum tenerrimum* and *S. wightii* (Sadasivan Pillai and Varier, 1952). At the Central Marine Fisheries Research Institute investigations were undertaken (Pillai, 1959 c) using three species of *Sargassum (S. tenerrimum, S. myriocystum* and *S. cinereum)* growing around Mandapam and a simple method has been described for the extraction of alginic acid from *Sargassum* species. Sodium hypochlorite was used in many processes for bleaching crude alginic acid. Trials were made in this study with different decolorising agents and potassium permanganate was found to be suitable for bleaching alginic acid. Bleaching was effected in this process by treating the precipitate of alginic acid with potassium permanganate solution in the presence of hydrochloric acid. A cottage industry method has also been reported for the extraction of calcium alginate and alginic acid by Sadasivan pillai (1961). In the recent study conducted on brown weeds of Sourashtra coast (Visweswara Rao and Mody, 1964), it was observed that the alginic acid obtained from calcium alginate is superior to the alginic acid precipitated directly from the extract of sodium alginate. A method for the production of commercial grades of sodium alginate has been give by Desai (1967) using 90% industrial alcohol to coagulate sodium alginate. Other workers (Shah *et al.,* 1967) also pointed out that alcohol coagulation gives alginates of high viscosity, but this method may not be economical because of the large quantities of alcohol required for the separation of sodium alginate.

Some preliminary experiments have been conducted by Pillai (1964) using sodium alginate as coating material, to control the flavour changes, oxidation of fat, dehydration etc. in frozen seafoods during storage. 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 they were quick frozen and stored at low temperatures.

Methods for the extraction of agar and algin:- The processes developed at the Central Marine Fisheries Research institute and by other investigators for the manufacture of agar (Thivy, 1960 and Visweswara Rao *et al*, 1965) and algin (Pillai, 1957 c; Sadasivan Pillai, 1961 and Visweswara Rao and Mody, 1964) are given at the end of this Bulletin as Appendix to show the different stages in the extraction of these colloids and modifications suggested by different workers.

Mannitol:- Mannitol is a sugar alcohol present in the cell sap of brown algae and it has also been reported from other types of weeds. From the fragmentary information available it is clear that the mannitol content of Indian brown weeds is very low with a seasonal variation ranging from 1-8% (Umamaheswara Rao, 1969c). Highest values obtained on the mannitol content of *Sargassum myriocystum, Turbinaria ornate* (Umamaheswara Rao, unpublished), *Sargassum wightii* and *Turbinaria conoides* (Umamaheswara Rao, 1969c) by the titration method of Cameron *et al*.(1948) are given below: An attempt has also been made earlier by Varier and Sadasivan Pillai (1952) to extract mannitol with 80% ethyl alcohol and the data obtained by these authors on two species of *Sargassum* growing at Cape comorin are also included here.

Seaweed	**Mannitol** (gm/100 gm dry weed)
Sargassum tenerrimum (Cape comorin)	9.4
S. wightii (Cape of comorin)	7.3
S. wightii (Mandapam)	6.2
S. myriocystum (Mandapam)	5.0
Turbinaria conoides (Mandapam)	7.4
T. ornate (Mandapam)	7.1

Among the four algae studies at Mandapam, maximum content was observed in young and vegetative plants (Umamaheswara Rao, 1969c).

Quantitative changes in the mineral constituents and organic extractives

Marked changes in the chemical constituents occur in different seasons, environmental conditions and the growth and fruiting cycles of the plant. Detailed studies were made on this aspect at the Central Marine Fisheries Research Institute. Seasonal variations in the major and minor constituents of eleven green brown and red algae have been studied (Pillai, 1956; 1957 a,b). To show the seasonal range in the quantities of some of the major constituents, maximum and minimum values obtained in different months of the year are shown in Table 9. Quantitative changes in the inorganic constituents were noticed also in different growth stages of the plant (Pillai, 1956; 1957 a,b) and plants collected in different localities (see Tables 4 and 8). Recently seasonal fluctuations in titratable acidity, carbohydrates, nitrogen and other major chemical constituents of *Ulva lactuca* have been determined (Patel and Joshi, 1967) and the relationship between the chemical changes in the plant and the changes in the metabolic environment and atmospheric temperature are discussed.

Table 9

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

(From Pillai, 1956, 1957 a,b)

Mineral	Month		gm/100 gm	
	Maximum	Minimum	Maximum	Minimum
		I. ***Enteromorpha intestinalis***		
Potassium	June	December	1.33	0.65
Sodium	October	April	0.75	0.3
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	September	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	September	1.85	0.50
Nitrogen	-	-	-	-
Sulphate	June	December	4.30	1.30
		III. ***Padina australis***		
Pottasium	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 intricate***		
Pottassium	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

Table 9 (Contd.)

Mineral	Month		gm/100gm	
	Maximum	Minimum	Maximum	Minimum
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
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	1.40
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. ***Hypnea 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

Table 9 (Contd.)

Mineral	Month Maximum	Month Minimum	gm/100gm Maximum	gm/100gm Minimum
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	0.70
Sodium	November	January	0.75	0.20
Magnesium	Do.	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	0.20
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	0.20
Magnesium	September	October	0.70	0.35
Calcium	August	April	0.90	0.35
Chloride	February	Do.	1.95	0.25
Nitrogen	November	May	1.00	0.18
Sulphate	June	September	3.90	2.00

Investigations have also been carried out on the seasonal fluctuations in agar, algin and other organic extractives of seaweeds. Monthly variations in the agar content of *Gracilaria lichenoides* have been reported by Pillai (1955 c). Detailed studies were mady by Sarangan (unpublished) on *Gracilaria crassa, G. corticata* and *G. lichenoides* for about two years to understand the changes in the yield of agar, gel strength, setting and melting temperature of the agar samples extracted. Ten to fifteen percent seasonal range in the yield was observed in the three species of *Gracilaria* studied and maximum yield was obtained during the period from April to August. Marked seasonal changes were not seen in the gel strength setting and melting temperatures of the agar extracted in different months of the year. In another investigation with *Chondria dasyphylla, Acanthophora specifera, Laurencia papillosa, Hypnea musciformis* and *Sarconema filiforme* (Pillai, 1957 d), seasonal changes were noticed in the gel-like extractives obtained from these algae and a close relationship was reported between the changes in the hot water fraction of the sulphur and the organic extractives of these red seaweeds.

In the brown weeds occurring along the Indian coast, seasonal changes in the alginic acid content and viscosity of sodium alginate have been reported in four species of *Sargassum* collected from Gujarat coast during the period from November 1964 to February 1965 (Shaw *et al*., 1967). Increase in the degree of polymerization was observed with increase in the growth of the plants. Variations in growth, alginic acid and mannitol contents of *Sargassum wightii* and *Turbinaria conoides* growing in the Gulf of Mannar, have been followed for two and a half years from August 1965 to January 1968 (Umamaheswara Rao, 1969 c). In *Sargassum wightii*, the alginic acid component varied from 21.3% to 31.7% and in *Turbinaria conoides* from 23.2 to 35.6%. Peak quantities were found in these two brown weeds during their maximum growth periods from October to December or January. The amount of mannitol varied from 1.2 to 6.2% in *Sargassum wightii* and from 1.78 to 7.4% in *TurbinariaConoides.* Unlike the alginic acid, mannitol accumulated in the plants during the vegetative phase of growth cycle and decreased to minimum during the maximum growth and fruiting periods of the algae. From the above studies on seasonal fluctuations it is clear that the time of collection, growth stage and sometimes the locality differences determine the yield and quality of the end product.

VII ECOLOGICAL AND BIOLOGICAL STUDIES ON SEAWEEDS

Though detailed studies are yet to be made with special reference to seaweeds of economic importance, some amount of information has been collected on the ecology and biology of marine algae growing along the Indian coast. Information available on these aspects has been summarized in this chapter.

Ecological studies have been carried out on the marine algal vegetation of the Mahabalipuram coast (Srinivasan, 1946), salt marshes at Madras (Krishnamurthy, 1954), Chilka Lake (Parija and Parija, 1946), Okha, Porbandar, Veraval and Bombay areas (Misra, 1960). Visakhapatnam coast (Umamaheswara Rao and Sreeramaulu,1964) and Mandapam area (Varma, 1959; Umamaheswara Rao, 1970 b). Many of these investigations provided data on the seasonal changes and zonation of the algae and on the environmental conditions of the areas studied. The probable factors effecting the changed in growth and zonation of the intertidal algae were studied by Umamaheswara Rao and Sreeramulu (1964) and Umamaheswara Rao (1970 b). In these ecological studies, seasonal fluctuations in growth and abundance of economically important seaweeds such as *Enteromorpha compressa, Chaetomorpha antennina, Chnoospora fastigata (c. minima), Grateloupia lithophila* and *Gracilaria corticata* growing on the Mahabalipuram coast were given in some detail by Srinivasan (1946). Similarly the annual changes observed in the growth and abundance of *Enteromorpha compressa, Ulva fasciata*, *Chaetomorpha antennina, Chnoospora minima*, *Grateloupia lithophila*, *Grateloupia filicina*, *Padina tetrastromatica*, *Sargassum* spp., *Porphyra vietnamensis* and *Gracilaria (G.corticata)* growing on the Visakhapatnam coast have been described by Umamaheswara Rao and Sreeramulu (1964) from the data collected for a period of three years. At the Central Marine Fisheries Research Institute ecological and biological studies have been taken up on the important agarophytes, alginophytes and some edible algae of Mandapam area. Results obtained on the growth cycles of *Sargassum wightii, Turbinaria conoides Gracilaria corticata* and *Enteromorpha compressa* were published recently (Umamaheswara Rao, 1969c; 1970b). Data on the annual growth variations have also been collected (Umamaheswara Rao, unpublished) on *Turbinaria ornate , Sargassum myriocystum, Ulva lactuca, Chaetomorpha antennina,* *Gracilaria lichenoides*, *G. foliifera*, *Gelidiella acerosa* growing at Pudumadam, Mandapam and Rameswaram areas. From the information obtained on the growth behaviour of the algae of Mandapam, Visakhapatnam and Mahabalipuram coasts, it is evident that many of the seaweeds grow either throughout the year or for certain months of the year and the periods of regeneration, maximum growth, and decline of the different algal forms vary from species to species and also from one locality to the other. In general, in many seaweeds studied maximum growth was observed in two seasons of the year, one from June to August and the other from November to December or January. However, for certain forms like *Porphyra vietnamensis* peak growth was found during the period from February to April (Umamaheswara Rao and Sreeramaulu,1963,1964).

Local enviormental conditions also influence the growth cycles of algae to a large extent. In the investigations carried out on *Enteromorpha* and *Sargassum* growing on the Gulf of Mannar and Palk Bay sides of Mandapam, certain variations were noticed in the Maximum growth periods (Umamaheswara Rao, 1969c; 1970 b). For *Enteromorpha compressa* growing on the Gulf of Mannar side maximum growth was observed between June and August and on the Palk Bay side during Novmber or December. Similarly, highest development was observed in some *Sargassum* species growing on the Gulf of Mannar side during the period from October to December and on the Palk Bay side between December and March. Studies made so far on the environmental conditions have shown that the changes in the tidal emergence and submergence, topography of the coast, surf action, levels at which the plants grow contribute much to the fluctuations in the growth behaviour of the algae (Umamaheswara Rao and Sreeramaulu,1964 and (Umamaheswara Rao, 1970 b). As a result of these changes in the peak growth periods the economically useful weeds must be collected only in certain seasons of the year to get maximum yield of raw material. From these studies it may also be mentioned that the life span of many algal forms is limited to one year or for a short period of the year. Every year fresh plants develop from the reproductive bodies liberated by the plants of the previous generation or from the perennial basal portions of the old plants.

Since the settlement of reproductive structure of different algae and their growth is confined to certain levels in the intertidal and subtidal environments, studies on the zonal distributions and recolonization of the algae would be useful for propogating the seaweeds in the inshore areas. With a view to studying the possibilities of propogating the algae on fresh substrata, experiments have been carried out (Varma, 1959) by suspending concrete boulders in the Palk Bay and data were collected on the settlement of spores, and further development of different algae colonized on the concrete blocks. Recolonization studies have also been made on Visakhapatnam coast clearing areas of $0.5m^2$ in the *Gracilaria corticata* belt (Umamaheswara Rao and Sreeramaulu,1968). The sequence of the colonization was followed for a period of five months. *Ulva* and *Enteromorpha* were seen as first colonizers and fresh germlings of *Gracilaria corticata* reappeared in the denuded areas after four months.

Variations in the zonal distribution of algae may be seen in the papers published by Umamaheswara Rao and Sreeramaulu,(1964) on the intertidal species of Visakhapatnam coast and on the agar and algin-yeilding plants of Mandapam (Umamaheswara Rao,. 1969 b). Distribution of *Gelidiella acerosa*, *Gracilaria lichenoides, Sargassum, Turbinaria* and many other important species growing in the lagoons and coral reefs of the Gulf of Mannar and Palk Bay has been studied (Umamaheswara Rao, 1969 d).

Very few attempts have been made to study the life-histories of seaweeds, spore output, the periods at which the spores are liberated and other biological aspects essential for maintaining the seaweed beds in the natural habitats and for cultivating the weeds on artificial substrata. Some aspects of the life history of *Enteromorpha compressa* have been studied by Ramanathan (1939). Prakasa Rao (1946) reported the morphology and life history of *Sargassum tenerrimum.* The morphology and cytology of *Grateloupia lithophila* has been worked out by Balakrishnan (1946). Observations were made recently on the shell boring conchocelis phase of *Porphyra vietnamensis* growing on the Visakhapatnam coast (Prakasa Rao, 1964). Ahmed (1966) reported some observations on the growth and reproduction of *Gracilaria confervoides* occurring in Chilka Lake. Cystocarpic plants were seen in this alga between December and June with maximum number in January. In the studies carried out on the life cycles of *Cystoseria indica* growing at Port Okha (Mairh, 1967), two fruiting periods were observed, one from May to June and other from November to December. However, the spore shedding was very low in the first fruiting period and maximum number of spores were liberated mainly in the month of May (Krishnamurthy and Mairh, 1967). Sreenivasa Rao (1969) carried out investigations on the ecology and life-history of *Gelidiella acerosa.* As reported in *Cystoseia indica,* two fruiting periods were obserbed in the life cycle of this agarophyte, one period between April and May and other in October and November. The water temperature of 28-29^0 C occurring in these periods was found to be responsible for the two spore producing seasons of the year. Information on the fruiting periods and relative preponderance of vegetative and reproductive plants of *Dictyota dichotoma, Padina tetrastromatica, Centroceras clavulatum* and other algae has been collected by Umamaheswara Rao and Sreeramulu (1970b). In the studies undertaken at the Central Marine Fisheries Research Institute, fruiting periods were determined for *Sargassum wightii* and *Turbinaria conoides* (Umamaheswara Rao, 1969c). In these two algin-yeilding plants, receptacles were seen between October and December or January. Data on the periods at which fruiting bodies are formed and liberated were collected for other red and brown seaweeds such as *Turbinaria ornate, Sargassum myriocystum, Gracilaria lichenoides, G. foliifera, G. corticata* and *Gelidiella acerosa* (Umamaheswara Rao, unpublished). All these studies conducted so far on the periods of reproduction indicate that the fruiting behaviour varies in different plants growing along the Indian coast. Though reproduction was observed throughout the year in many cases, two fruiting seasons were seen for plants like *Cystoseria indica* and *Gelidiella acerosa* and one fruiting season for *Turbinaria conoides, Sargassum wightii, Gracilaria verrucosa* and some other algae studies by various workers.

In recent years some information has been collected on the spore out put and development of germlings in *Cystoseria indica* (Krishnamurthy and Mairh, 1967 and Mairh and Krishnamurthy, 1968), *Sargassum swartzii* (Chauhan and Krishnamurthy, 1967), *Ulva fasciata* (Subbaramaiah *et al.,* (1967), *Gracilaria verrucosa* (Oza and Krishnamurthy, 1967, 1968) and in *Gelidiella acerosa* (Sreenivasa Rao, 1969). The spore production per plant estimated by these authors is 1,15,34,400 spores for *Ulva fasciata*, 5,53,331 spores for *Sargassum swartzii* and 20,000 spores in *Gelidiella acerosa*. In *Cystoseria indica* the spore production per plant ranged from 5423 to 511252 spores during the fruiting periods of this alga

(Mairh and Krihnamurthy, 1968) and in *Gracilaria verrucosa* definite rhythm of spore liberation was reported during the six months period of this study (Oza and Krishnamurthy, 1968), with maximum liberation of carpospores in December and minimum in the month of May. The viability, settlement and development of these spores produced in large quantities in the natural habitats are controlled by many hydrobiological factors such as water movements, tidal exposure, water temperature, competition for space, predators or grazing organisms and only a small quantity of spores grow to the maximum size.

In order to investigate the possibilities of cultivating the seaweeds some preliminary work has also been done. At Porbandar culture experiments were conducted tying small plants of *Sargassum cinctum, S. vulgare, S. swartzii* and *Gelidiella acerosa* to coir nets (Thivy, 1964). In these experiments plants *Sargassum cinctum* with an initial height of 10.0 am had grown to a height of 37 to 52 cm within forty days. Excised pieces of *Ulva lactuca v. rigida* taken from the basal, middle, apical and marginal regions of the thallus were cultured in the laboratory for a period of one month with a view to utilizing the vegetative parts on the plants for propagation (Kale and Krishnamurthy, 1967). In these studies, maximum increase in the linear growth and breadth was observed in plant bits taken from the apical and marginal regions. Some preliminary culture experiments were conducted by Uma maheswara Rao (1968) with the fragments of *Gracilaria corticata* and *Gracilaria lichenoides*. Slow growth was observed for the first 45 days in the fragments of *G. corticata* maintained in seawater aquaria and rapid increase in length of the fronds from 1.8 to 5.5 cm was recorded during the next 45 days. Experiments with *G. lichenoides* were carried out near Mandapam Jetty suspending two coir net frames of about 0.5 m^2 with small pieces of *G. lichenoides*. Many new shoots developed from the cut ends of the plant bits and after two months the frames were covered with profusely branched plants of *G. lichenoides*. The height of these plants varied from 14-16 cm and the two frames suspended in the sea gained a weight of 213 gm and 257 gm respectively at the end of two months. From these experiments it may be mentioned that the regenerating power is high in *G. corticata* and *G. lichenoides* and they grow rapidly by vegetative means to harvestable size within three of four months.

VIII SEAWEED RESOURCES AND THEIR EXPLOITATION ON A COMMERCIAL SCALE

Seaweed growing regions in India are given in the third chapter of this bulletin while discussing the distribution of seaweeds. Our present knowledge on the quantities of seaweeds available in these areas for commercial exploitation is very limited. Some surveys have been made to estimate the resources of the Chilka Lake (Mitra, 1946), certain areas of the Tamil Nadu (Koshy and John, 1948; Chacko and Malupillai, 1958; Thivy, 1960; Varma and Krishna Rao, 1964; Desai, 1967 and Uma maheswara Rao, 1968) and Gujarat coasts (Sreenivasa Rao *et al.*, 1964; Desai, 1967 and Chauhan and Krishnamurthy, 1968). Of these, studies of Mitra (1946), Koshy and John (1948), Chacko and Malupillai (1958) and Thivy (1960) may be treated as general or preliminary resources surveys and the methods adopted for estimation were not given by these authors. The total quantities of agarophytes and alginophytes estimated by these workers are shown below:

Locality	Agarophytes (Dry weight)	Alginophytes (Dry weight)
Chilka Lake (Mitra, 1946)	4-5 tons	-
Cape Comorin-Colachel (Koshy and John, 1948)	10,00 lbs	-
Point Calimere – Cape Comorin	6,00 tons	60,000 tons
Tamil Nadu coast (Thivy, 1960)	7.1 tons	-

Studies were initiated in the Central Marine Fisheries Research Institute during1958 to survey the resources available in the vicinity of Mandapam. Two surveys were made (a preliminary one in 1958 and a detailed one in 1962-63) in 234.25 sq. km area between Dhanushkodi and Hare Island in the Gulf of Mannar (Varma and Krishna Rao, 1964). The whole area was divided into three sections namely, Hare Island section, Krusadai section and outside section covering the channel between the islands and mainland. The algal growth is very poor in the outer section and the results obtained from the Krusadai Island and Hare Island sections on harvestable wet and dry agar and algin-yielding plants are given below:

Details	**Weight in metric tons** (1958)	(1962-63)
Gracilarias		
Harvestable wet algae	188.85	334.90
Harvestable dry algae	18.89	34.49
Yeild of agar-agar	2.83	5.02
Gelidiella acerosa (*Gelidium micropterum*)		
Harveatable wet algae	6.45	18.89
Harvestable dry algae	0.65	1.89
Yield of agar-agar	0.19	0.57
Browns		
Harvestable wet algae	419.18	657.94
Harvestable dry algae	62.88	98.69
Yield of alginic acid	7.55	11.84

Later, sample surveys were made during 1965 and 1966 selecting transects from shore to coral reef in a 3.58 sq. km area on the Palk Bay side of the coast line near Mandapam (Umamaheswara Rao, 1968). In this survey data on the standing crops of edible seaweeds and sea grasses have been collected for the first time, together with the information on the agar and algin-yielding seaweeds. Standing crops of different seaweeds estimated in 3.58 sq. km area between Pamban bridge and Theedai are presented below:

Seaweed	**Fresh weight 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
Total	1041.69	864.77

Except in agarophytes, significant change was not observed in standing crops of seaweeds estimated in the two years of this survey. *Agarophytes* like *G.lichenoides* have been harvested from Pamban bridge area since 1966 and the fall in the standing crop of agarophytes in 1966 may probably be due to collection of *G. lichenoides* from this area, before carrying out the survey work. About one-fourth of the total area surveyed was covered by sea grass beds and the total standing crop in this area was higher than the total standing crop of seaweeds. Quantitative data obtained on sea grasses in the two sample survey are presented below:

Year	Areas covered by Segrass (sq.km)	Fresh weight (Metric tons)
1965	0.75	1916.19
1966	0.88	2170.81

In the surveys carried out on Gujarat coast, 60 metric tons of fresh Sargassums have been estimated in 0.015 sq. km area of the Adatra reef, near Okha (Sreenivasa Rao *et al.*, 1964). Desai (1967) gave high estmimates ranging from 300 to 5000 tons of dry agarophytes and algin-yeilding weeds for the Gulf of Kutch and Gulf of Mannar areas. Recently Chauhan and Krishnamurthy (1968) surveyed Dera, Goos, Nardra, Sikka, Karumbar and Baida areas of the Gulf of Kutch; estimated 18765.5 metric tons of fresh seaweeds in 10.65 sq. km area and out of which *Sargassum* alone accounts for 12,010.5 tons. From the results obtained these authors suggested that annually about 4000 metric tons of fresh Sargassums can be harvested from the Gulf of Kutch area.

Some efforts have been made to estimate the drift weeds. As early as 1918, Hornell estimated about 100 tons of fresh *Sargassum* cast ashore annually along the Gujarat coast. Krishnamurthy *et al.* (1967) reported the data obtained on different drift weeds collected at Pamban and Idindakarai for a period of three months. An account on the different methods used in assessing the seaweed resources was given by Subrahmanyan (1967).

The above surveys conducted recently in limited areas of the east and west coasts of India clearly indicate the abundance of seaweed resources in the country. Detailed surveys in the other areas of the coastline would throw much light on the resources occurring in the natural habitats and on the raw material available for commercial utilization.

At present the areas exploited for this marine resources are also confined to certain localities on the Tamil Nadu and Gujarat coasts. Commercial harvesting of seaweeds has been started since 1966 near Pamban, Kilakarai and other places along the Tamil Nadu coast and *Gracilaria lichenoides, Gelidiella acerosa and Sargassum* species are harvested from these areas. Some data collected (Umamaheswara Rao, 1968) on the quantities of seaweeds harvested from Pamban, Periyapatnam and Kilakarai are shown in Table 10.

Table 10

Seaweeds harvested from three localities around
Mandapam (Metric tons)
(From Umamaheswara Rao,1968)

Year	Pamban	Periyapatnam	Kilakarai	Total Dry weight	Total fresh weight**
1966	15.19	-	-	15.19	75.95
1967	18.33	65.55	58.07	141.97	709.85
1968*	16.59	8.00	304.65	329.24	1646.20

* Till October 1968.
** Fresh weight was estimated based on 80% moisture.

The agar and algin seaweed industry is established in the country in recent years and some private firms in Gujarat and Tamil Nadu states have started production of agar and algin utilizing the raw materials collected along the Indian coast. However, for some time export trade is also developed and data given below show the quantities of agarophytes (mostly *Gelidiella acerosa)* exported from India during the three years period from 1966 to 1968 (From Seafood Exports Journal).

Year	**Quantity** (metric tons)	**Value** (Rs.)
1966	162.61	4,17,677
1967	198.04	7,40,542
1968	92.23	2,13,732

Export of this commodity is very low in 1968 and no data is available for 1969. These changes may be due to recent restrictions on the export of seaweeds. From the above information on seaweed resources it may be mentioned that there is vast scope for expanding the seaweed industry in the country. Intensive surveys for a long period in all seaweed growing areas of the east and west coasts of India are very essential to achieve this goal.

IX CONCLUSION

From the forgoing account it may be mentioned that considerable amount of data on different aspects, particularly on the chemistry of Indian seaweeds, have been collected during the last ten or fifteen years. Sufficient information is now available on the utilization of seaweeds for various purposes. However, our knowledge on the seaweed populations occurring along the Indian coast is very limited and the quantities of seaweeds available in certain restricted areas of the Tamil Nadu and Gujarat coasts have been surveyed so far. Special efforts should be made to explore the different parts of the Indian coast, including Laccadives, Andaman and Nicobar Islands and to estimate the harvestable quantities of agarophytes, alginophytes and other important seaweeds growing in these areas.

Our knowledge on the taxonomy of seaweeds is still incomplete and detailed studies have not been made on the algal flora of sublitoral regions, particularly in Laccadives, Andaman and Nicobar Islands. Much work is needed in this direction and acoounts on local floras have to be prepared for proper identification of the various seaweeds of commercial importance.

Collection of seaweeds on a large scale has been started during the last four or five years and agar and algin are being manufactured from the processes developed in the country. More detailed chemical studies are necessary in the near future to improve the quality of agar and algin, to manufacture different grades of agar and align needed by the consumer industry and also to know more about the other carbohydrates present in the red, brown and green algae and the seasonal changes in the extractive contents.

Results obtained on the chemical analysis of Indian seaweeds have shown that some common red and green algae are good sources for proteins, Vitamin-C, iodine etc. and that large quantities of minerals and trace elements needed for growth occur in water soluble form. Attempts must, therefore, be made in future to process the seaweeds rich in protein and other chemicals for preparing different types of seaweed foods for human consumption. Experimental studies are also necessary for utilizing these seaweeds as live-stock and poultry feed.

Studies on the ecology, spore prduction and other biological aspects have brought to light some interesting facts about the growth cycles, fruiting reasons and spore liberating mechanisms. The growth cycles of the plants varied from one locality to the other and definite fruiting seasons were observed for certain brown and red algae investigated. Thorough investigations on the autecology and biology of the commercially important seaweed genera such as *Gracilaria*, *Gelidiella*, *Sargassum*, *Turbinaria*, *Ulva* and *Porphyra* growing in different localitites, laboratory and field experiments on the growth and reproductive behaviour of the algae must be carried out for proper utilization of the available resources and for large-scale cultivation of the economically important seaweeds in the country.

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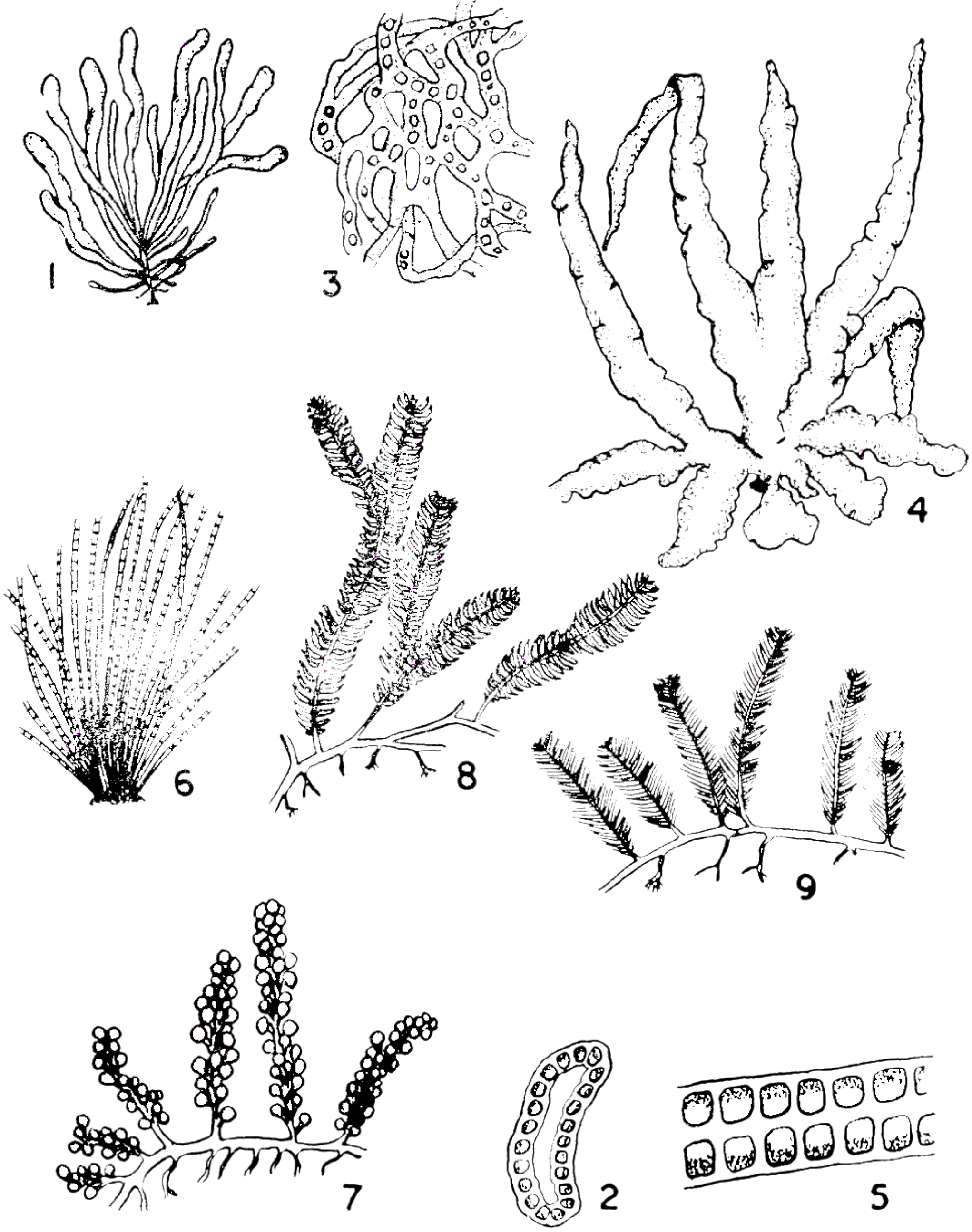
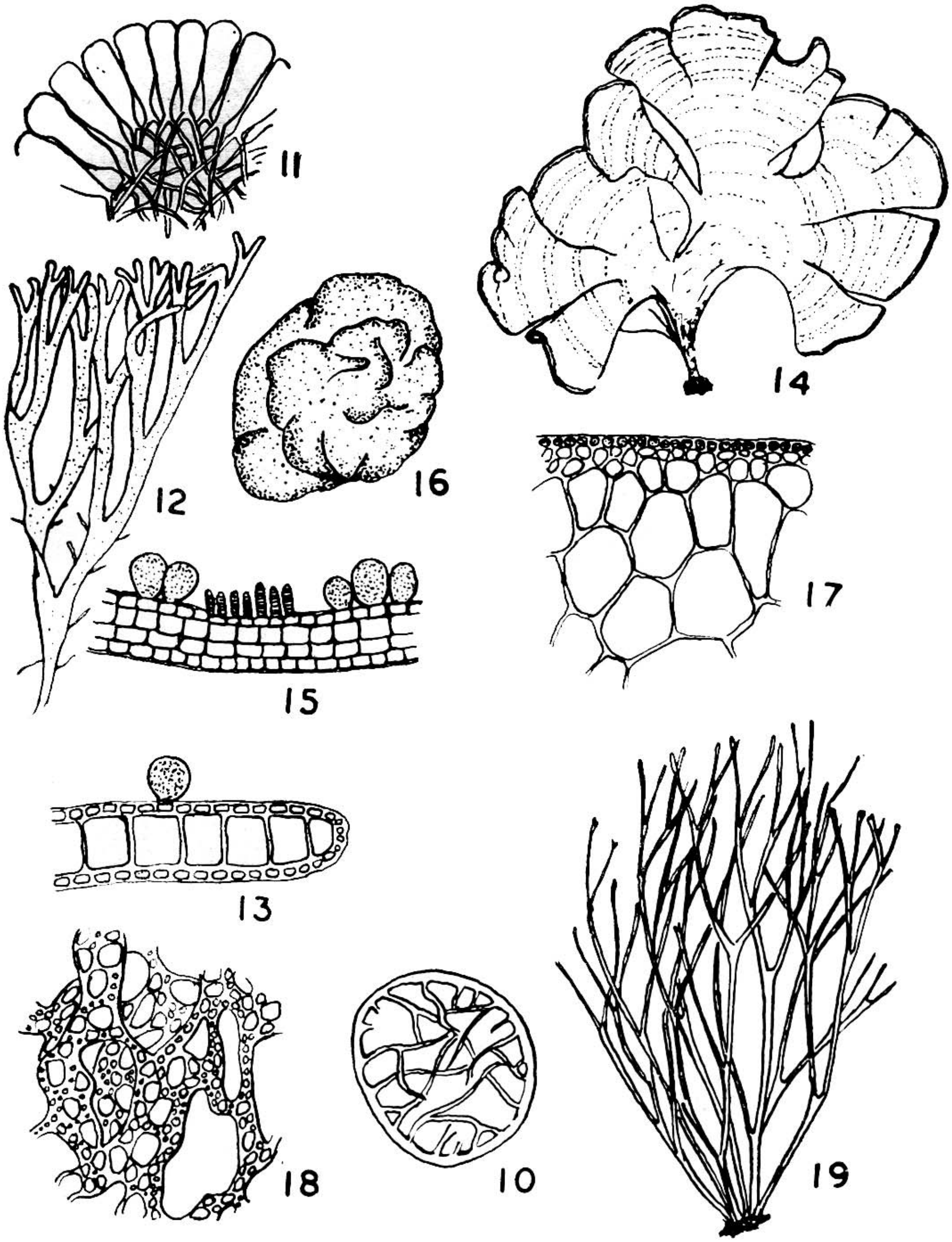
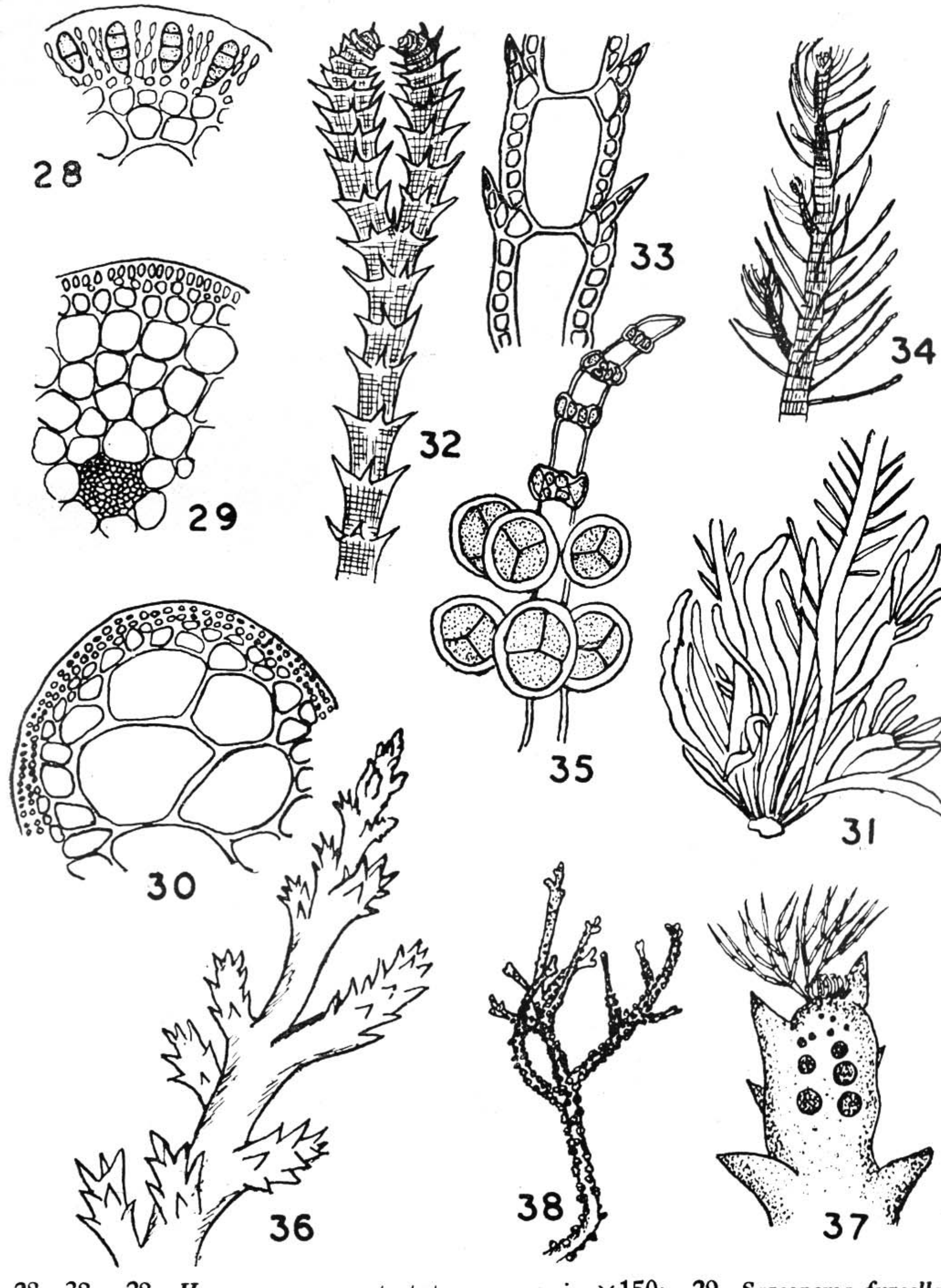


Figs. 1—9. 1—2. ***Enteromorpha compressa***. 1. habit of a plant × 0.5; 2. transverse section of the thallus showing one cell thick membrane × 100; 3. ***Ulva reticulata***. habit of part of a plant × 0.75; 4. ***Ulva fasciata***. habit of a plant × 0.5; 5. ***Ulva lactuca*** transverse section showing two cells thick thallus × 260; 6. ***Chaetomorpha antennina***. plant habit × 1; 7. ***Caulerpa racemosa***. plant showing the erect fronds with subspherical branchlets × 0.5; 8. ***Caulerpa taxifolia***. plant habit ×0.5; 9. ***Caulerpa sertularioides***. habit of a plant ×0.5.



Figs. 10—19. 10. ***Caulerpa***. transverse section of rhizome showing the trabeculae ×15; 11. ***Codium***. sectional view of the thallus with filamentous central part and marginal vesicles ×20; 12—13. ***Dictyota dichotoma***. 12. habit of part of a plant ×0.6; 13. sectional view of the thallus ×95; 14. ***Padina gymnospora***. plant habit × 0.6; 15. ***Padina tetrastromatica***. transverse section of thallus showing regular arrangement of cells and the sporangia on either side of the hairs ×75; 16—17. ***Colpomenia sinuosa***. 16. habit of a plant ×0.5; 17. sectional view of the thallus showing the parenchymatous nature or irregular arrangement of cells × 70; 18. ***Hydroclathrus calthratus***. habit of part of the thallus × 0.75; 19. ***Chnoospora minima***. plant habit ×0.75.

Figs. 20—27. 20. ***Hormophysa triquetra***. part of a plant showing angular and winged nature of the thallus ×0.6; 21—22. ***Cystophyllum muricatum***. 21. basal portion of the plant with muricated stems ×0.6; 22. seriate bladders or vesicles ×0.5; 23. ***Turbinaria***. leaves with receptacles and immersed vesicle ×1.3; 24. ***Sargassum tenerrimum***. inflorescence with vesicles, receptacles and leaves ×1.5; 25. ***Gelidiella acerosa***. axis showing swollen branchlets with tetrasporangia ×3; 26. ***Grateloupia lithophila***. transverse section of thallus showing filamentous medulla and vertical rows of cortical cells ×75; 27. ***Hypnea*** sp. transverse section of thallus showing the central axial cell ×75.



Figs. 28—38. 28. *Hypnea* sp. zonate tetrasporangia ×150; 29. ***Sarconema furcellatum.*** transverse section of thallus showing medulla of small cells at the centre ×150; 30. ***Gracilaria verrucosa*** sectional view of the frond showing large medullary cells at the centre ×60; 31 ***Grateloupia lithophila.*** habit of a plant ×0.5; 32—33. ***Centroceras clavulatum.*** 32. part of a filament with whorls of spines at each node ×50; 33. longitudinal section of the filament showing the central axial cell and outer cortical cells ×125; 34. ***Spyridia filamentosa.*** terminal part of the plant with lateral branches and one cell thick branchlets ×8; 35 ***Spyridia fusiformis.*** one cell thick branchlet showing cortical bands and tetrasporangia ×220; 36-37. ***Acanthophora spicifera.*** 36. Apical part of the plant showing spinous branchlets × 8; 37. branchlet with tetrasporangia and trichoblasts × 25; 38. ***Laurencia papillosa.*** habit of part of a plant ×1. 2.

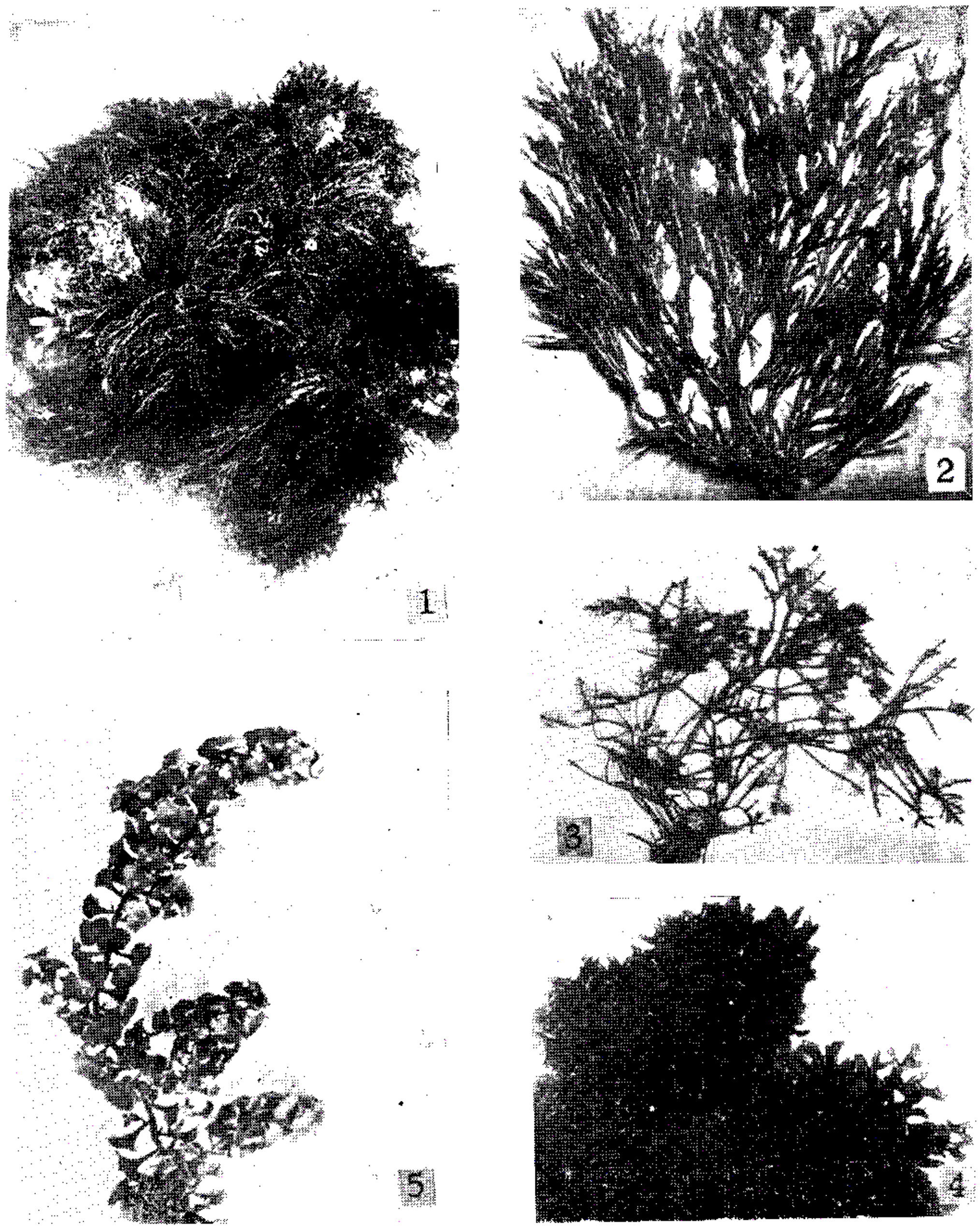


Plate I. 1—2. ***Gracilaria lichenoides.*** 1. plants growing on a dead coral stone ×0.1.
2. habit of a plant ×0.25.
3. ***Gelidiella acerosa.*** habit of a plant ×0.5.
4. ***Gracilaria crassa.*** plant habit ×0.3.
5. ***Turbinaria conoides.*** habit of part of a plant ×0.3.

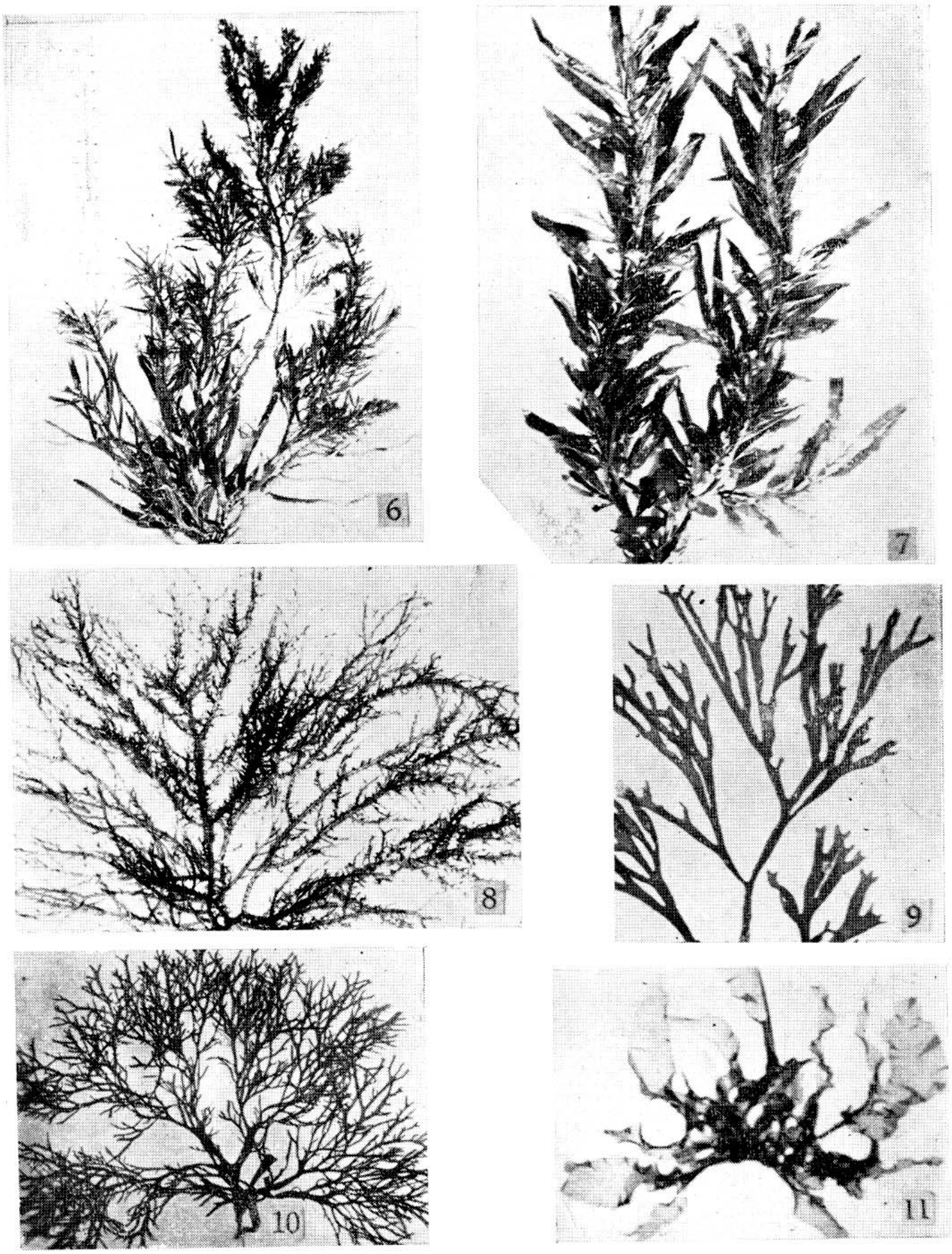
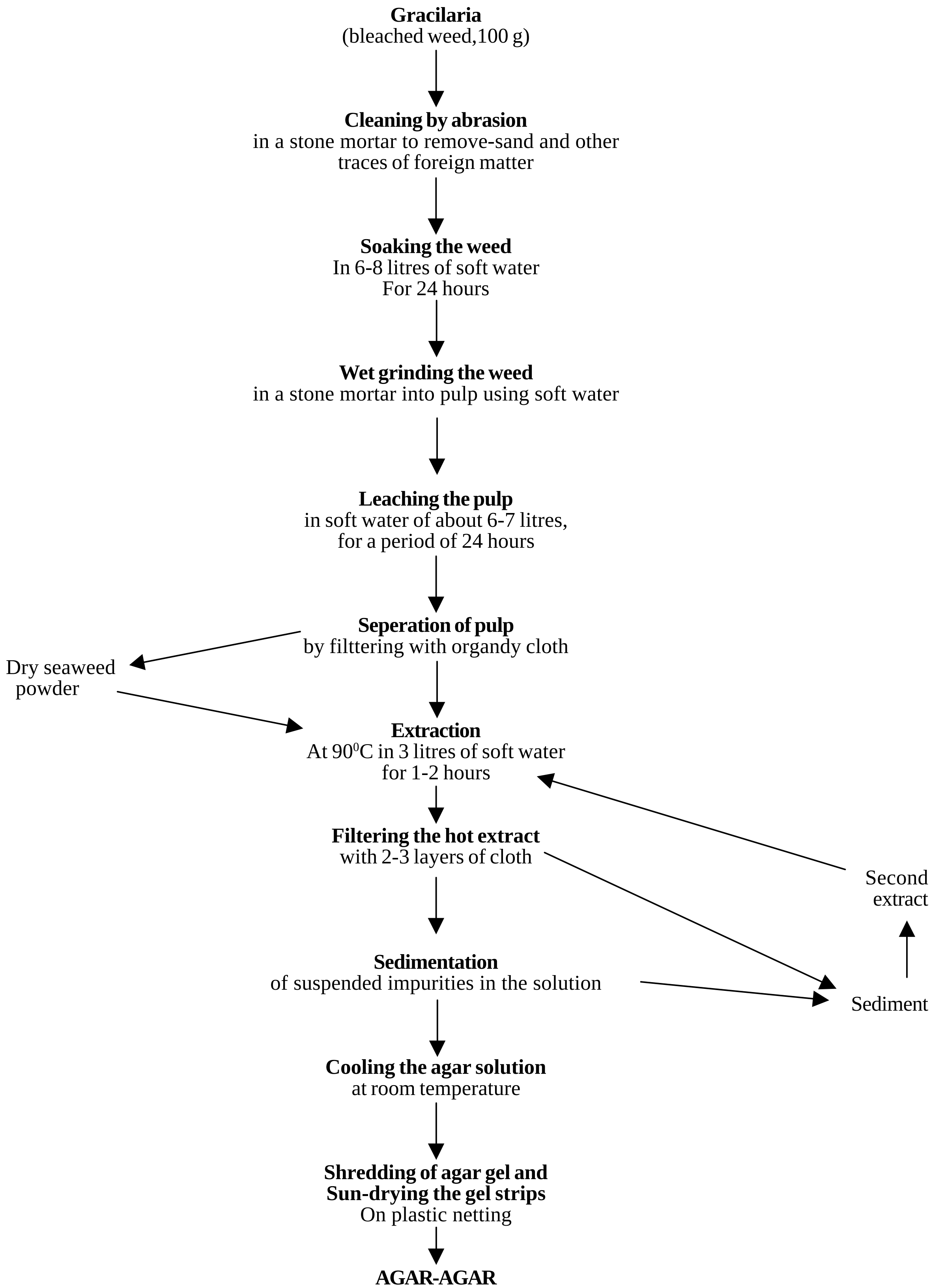


Plate II.
6. ***Cystophyllum muricatum.*** habit of a plant ×0.2
7. ***Sargassum wightii.*** small vegetative plant with air bladders ×0.3
8. ***Hypnea*** sp. general view of the plant ×0.5
9. ***Gracilaria corticata.*** habit of part of a plant ×0.5
10. ***Gracilaria foliifera.*** plant habit ×0.3
11. ***Porphyra vietnamensis*** plant habit ×0.25

APPENDIX

C.M.F.R.I. – Cottage industry method for the Extraction of agar from *Gracilaria* species

(From Thivy, 1960)



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

Raw material
(7.5 kg pulverised seaweeds)

↓

Washing in freshwater

↓

Soaking overnight in freshwater

↓

Wet grinding for 30 minutes
in edge runner or pestle-mortar type grinder

↓ ← Washing with soft water

Seaweed pulp

↓

Extraction with 100 litres of water for 2 hours
in a double jacketed open-pan evaporator
circulated with steam;
adjusting the pH to 6 with
400-500 ml of N Sulphuric acid

↓

Filtering
(in a double jacketed vacuum filter)

↓

Cooling the filterate at room temperature

↓

Shredding the agar gel in gel chopper

↓

Freezing the agar for 24 hours
(in ice plant)

↓

Thawing
(at room temperature)

↓

Drying
(in air or in an oven with hot air circulation)

↓

AGAR-AGAR
(1.0 kg yield)

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

Dry seaweed

↓ ← Washing with water

Boiling with water
for 30 minutes

↓

Boiling with 0.3% Hydrochloric acid
at 100^0C for 30 minutes

↓ ← Washing with water

Digestion at room temperature
with 2% soda ash solution
for 1-2 hours

↓

Filtration

↓ ← Dilution with water

Crude sodium alginate

↓

Precipitation of alginic acid
(with 5% Hydrochloric acid at PH of 2.5

↓

Filtration

↓

Bleaching
with 2% Potassium permanganate
and 5% Hydrochloric acid

↓

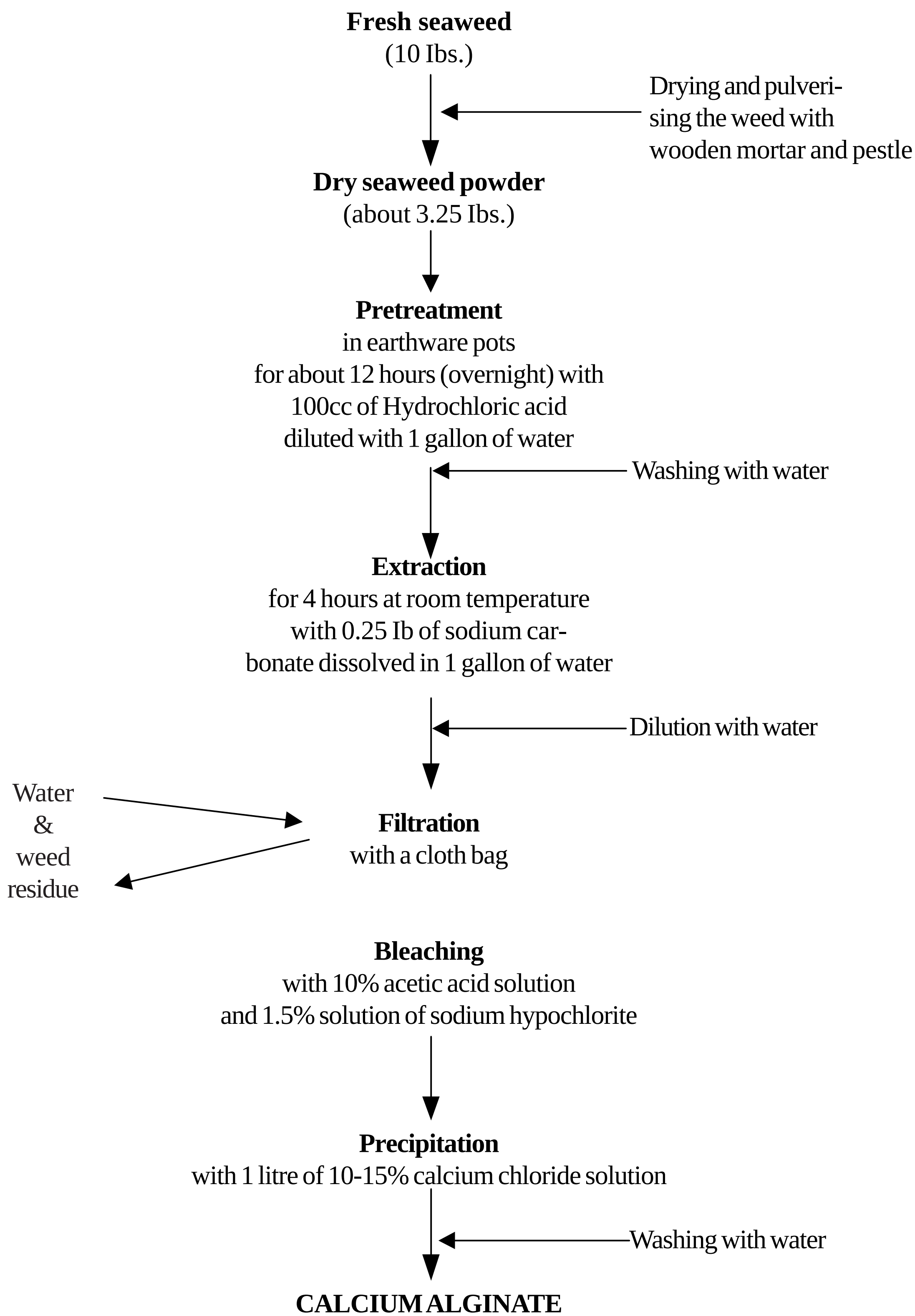
Filtration

↓ ← Washing with water

ALGINIC ACID

Flow sheet for the preparation of Calcium alginate on a Cottage-industry basis

(From Sadasivan Pillai, 1961)



Methods for extraction of Sodium alginate, Calcium alginate and Alginic acid

(From Visweswara Rao & Mody, 1964)