

# Seaweeds of the Southeast Coast of India



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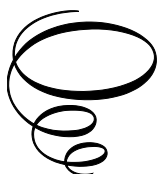
*Their Diversity and a Field  
Guide for Their Identification*

By

M. Ganesan, C.R.K. Reddy,

K. Eswaran and Bhavanath Jha

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Scholars  
Publishing**



Seaweeds of the Southeast Coast of India:  
Their Diversity and a Field Guide for Their Identification

By M. Ganesan, C.R.K. Reddy, K. Eswaran and Bhavanath Jha

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## FOREWORD



Currently, seaweeds are gaining significant attention worldwide due to their unparalleled nutritional, industrial as well as ecological values. Seaweed aquaculture is a fast emerging sector in the world and is widely touted as a sustainable source with immense potentials to meet the future needs and demands of humankind. The term seaweed represents an assemblage of a diverse group of photosynthetic aquatic plants that are exceptionally unique in their form, function, structure, and biochemical composition offering novel opportunities for their commercial exploitation. They largely remained as unexplored marine living resources in India in particular despite proven economic values. In Far East Asian countries, seaweeds are popularly utilized in human food preparations besides being used as a source of raw material for extraction of industrially important phycocolloids (agar, agarose, carrageenan, and alginates) and agro-based products. More recently, there has been a growing interest in the application of seaweed ingredients in beauty and novelty food products, nutraceuticals, bioplastics, beverages, etc. besides being a potential source for biofuels.

India has a coastline of more than 8000 km long and an exclusive economic zone (EEZ) of 2.17 million km<sup>2</sup> which equals 66% of that of the mainland area. This area provides substantial arable space for farming various economically important seaweeds and also hosts luxuriant seaweed biodiversity of immense value. Unlike other Asian countries, seaweeds in India are exclusively utilized for the production of typical phycocolloids such as agar, carrageenan and alginates from the raw material harvested from natural beds, particularly from southeast coast of Tamil Nadu. There are several households, particularly the womenfolk, traditionally engaged in seaweed collection from natural beds along the Gulf of Mannar coast, Tamil Nadu. Likewise, there are 32 MSMEs in the

country engaged in processing of seaweeds for production of phycocolloids. Therefore, seaweed collection from natural sources has not only become a source of raw material supply for local seaweed industry but also forms a new income stream for the rural coastal communities.

CSIR-Central Salt and Marine Chemicals Research Institute (CSIR-CSMCRI), a premier research laboratory under the aegis of Council of Scientific and Industrial Research (CSIR), New Delhi, India is pursuing seaweed research actively since 1960. The pioneering research efforts carried out over years helped to the development of sustainable farming as well as downstream technologies for various economically important seaweeds such as *Gracilaria dura*, *Gracilaria edulis*, *Gracilaria debilis*, *Gelidiella acerosa*, *Kappaphycus alvarezii*, *Hypnea musciformis*, *Sarconema filiforme* and *Ulva (Enteromorpha)* spp. and few of them successfully commercialised as well.

The southeast coast of India is endowed with rich seaweed diversity in the country. This coast also possesses UNESCO identified Gulf of Mannar Marine National Park. The present book on “Seaweed diversity of southeast coast of India- Field guide for identification” is an excellent source for students and researchers for easy identification of seaweeds species. The authors described 256 seaweed species in a simple language focussing morphological, anatomical and reproductive characters supported with high quality *in situ* seaweed photographs. Taxonomic key characters given for the genus add more value to the book as there was no such exercise made before. The unique features of southeast coast of India were elucidated nicely in the introductory chapter. The authors of the book have made a number of significant contributions advancing seaweed research in the country, and this book is yet another milestone in their achievements. I congratulate all the authors for accomplishing this stupendous task that will have a profound impact on the future research in the country. It gives me an immense pleasure and honour to have written foreword for this book and also assumes that scientific community, policy makers, students, resource manager and industry friends find this as most useful resource. Finally, I would also thank Cambridge Scholars Publishers for publishing this work.

Kannan Srinivasan  
Director, CSIR-CSMCRI 08.04.2020, Bhavnagar- 364 002  
India

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We express our profound gratitude to Prof. M. Umamaheswara Rao (deceased), Former Professor, Department of Botany, Andhra University, Visakhapatnam and Prof. V. Krishnamurthy (deceased), Krishnamurthy Institute of Algology, Chennai, the experts in seaweed taxonomy; who supported us in species level identification of seaweeds belonging to the genus *Sargassum*, *Dictyota*, *Padina*, *Gracilaria* and *Laurencia*.

We are indebted to Dr. N. Kaliparumal, Former Principal Scientist, CMFRI, Bangalore, Prof. S. Nagaraj, CAS in Botany, University of Madras and Dr. V. Veeragurunathan, CSIR- CSMCRI, Mandapam for correcting few chapters of this book.

We are grateful to Mr. A. Sathakku and Mr. A.S.S. Ahamed skin divers (former employees of CSIR- CSMCRI), and scuba diving group from People Action Development Initiative (PADI), Vembar, India for collecting seaweeds up to 20 meter depth.

We gratefully acknowledge Mr. K. Selvaraj, Mrs. K. Chitra, Mrs. J. Malarvizhi, Mrs. A. Hanna Jeeja, Mr. B. Prince, and Miss, N. Nadukkattu Nayaki Research Scholars of our laboratory, for assisting in taxonomic key preparation and taking anatomical sections of seaweeds. We also thank Mr. N. Ramalingam, Mr. A. Nanthakumar, Mr. P. Ramachandran,

Mr. S. Uthayakumar, Mr. M. Muthu and Mr. G. Nesan, field staffs of our Institute for helping us in field activities like labelling and preservation of seaweeds and herbarium preparation. We would recognize the invaluable assistance they all provided for this present work.

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Finally we wish to thank all the people whose assistance was a milestone for successful completion of the project work.

The Authors

# INTRODUCTION

## The Southeast Indian Coast

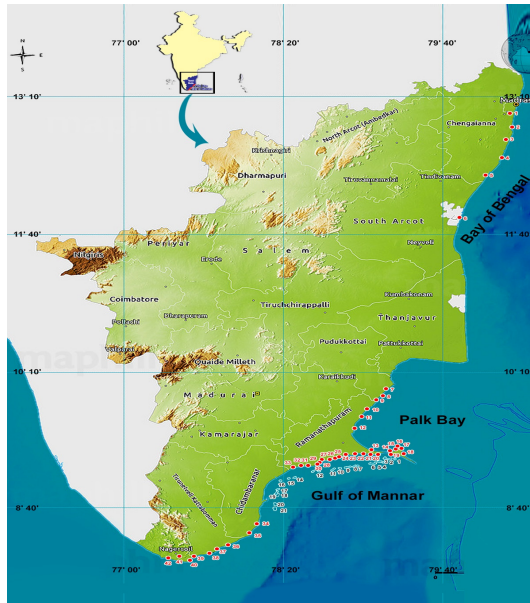


Fig. 1.1. Map showing sampling stations (*red dots*) on the Southeast Indian coast.

## Coastline

The southeast Indian coast (Fig. 1.1) is about 1000 km long with diverse and unique ecosystems like mangroves, coral and seagrass and seaweed ecosystems. The world's second longest sandy beach called "Marina beach" is located on the northern tip of this coast (Fig. 1.2A). Boulders and stones were placed parallel to the shore (Fig. 1.2B) to protect the harbours, temples and historic monuments. Pitchavaram mangrove forest spreads over a 1100-hectare area and is the second-largest mangrove cover in India. Muthupet mangrove swamp has thick mangrove vegetation in a 77.20-hectare area. The central part of this coastline is home to the

Cauvery Delta where several rivers and tributaries meet the sea. The Palk Bay shorelines are mostly muddy and extend up to 2-3 km inwards into the sea (Fig. 1.2C). The southern tip of the coastline has a rocky shore (Fig 1.2D), small bays (Fig. 1.2E) and intertidal rock pools (Fig. 1.2F). On the Kanyakumari coast, the sandy coast is replaced with rocks and cliffs of differing height (Fig 1.2G). The several coastal villages located close to the sea were heavily affected by the Tsunami in 2005 (Fig 1.2H). Sand dunes up to a height of 10-25 meters are common along the southern part of this coastline (Figs 1.3A, B). The Gulf of Mannar (GoM), and the UNESCO-identified Biosphere Reserve and Marine National Park are situated on the southern part of the coastline. The GoM has coral reefs (Fig.1.3 C), seagrass meadows, oyster beds, offshore islands (Fig. 1.3D) and lagoons (Figs. 1.3 E, F, and G, H) that form an ideal habitat for seaweeds.

Ports, fishing harbours, nuclear and thermal power plants and a number of refineries, fertilizers and marine chemicals plants are situated on the coastline. A nuclear power plant with 2000 MW ( $2 \times 1000$  MW) capacity power generation is present at Kudankulam coast in the southern part of the coastline (Fig. 1.4A). Another nuclear power plant with  $2 \times 1000$  MW capacity power generation is located at Kalpakkam coast, in the northern part of the coastline. A thermal power plant with 1050 MW ( $5 \times 210$  MW) capacity power generation is functioning at Tuticorin coast, (Fig. 1.4B) in the southern part of the coastline. A road and railway bridge across the sea with 2.3 km length, connecting Rameswaram Island to the mainland is one of the unique structures of this coastline (Fig. 1.4C). A memorial for Swami Vivekananda and a statue of Tamil poet Thiruvalluvar, constructed on giant offshore rocks in the mid-sea off the Kanyakumari coast attract millions of tourists from all over the world (Fig. 1.4D). The Hindu God Vinayaka's temple in the sea at Kodyakarai (Fig 4E) and the Swami Vivekananda memorial on the Pamban coastline (Fig. 1.4F) are other tourist attractions on this coast. In addition, a palace constructed by the Pallava King at Tranquebar (Fig. 1.4G), and a tower donated to the British Empire by the Chola King at Manora (Fig 1.4H) are symbols of Indian architecture on the shoreline.





Fig. 1.2. Coast types: A. Long sandy beach (Chennai). B. Big boulders and stones along the shore (Pondicherry) C. Muddy coast with cast-ashore seagrass (Kottaiappattinam) D. A long rocky platform edges out the sand (Nochiurani). E. An enclosed bay at Seeniappa Dharga F. Intertidal rock pools at Manapad. G. Massive rocks in the sandy beach at Kanyakumari. H. A coastal village close to the sea.

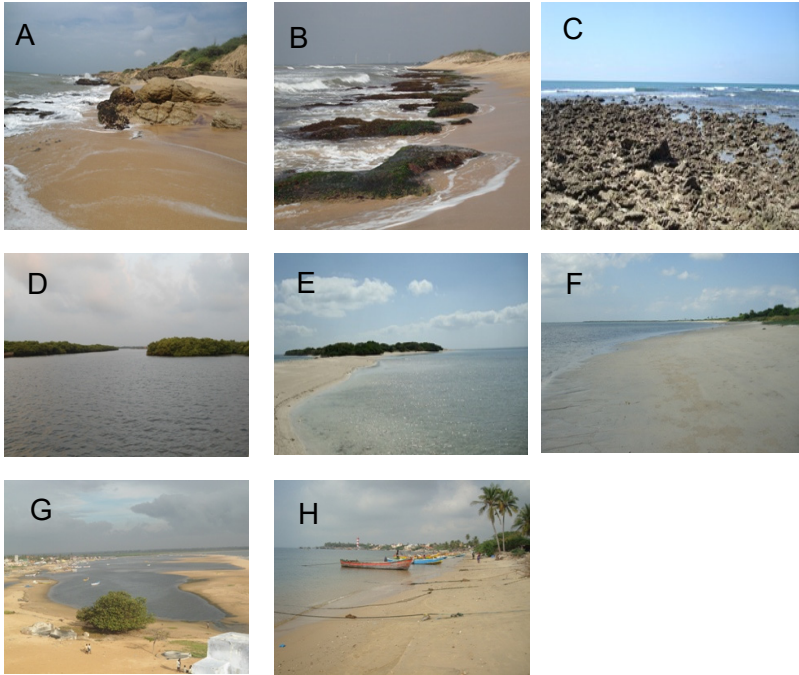


Fig. 1.3. Coast types: A & B. Beach rocks and intertidal rocks alternating with sand dunes (Manapad). C. A long *Galaxaura* reef (Krusadai Island). D. Two islands (Manoli and Manoli Putti Islands) closely located. E. Lagoon on Valai Island F. Lagoon during lowest low tide on Krusadai Island. G. Huge coastal lagoon at Manapad. H. Sandy beach with country boats for fishing (Keelakarai).



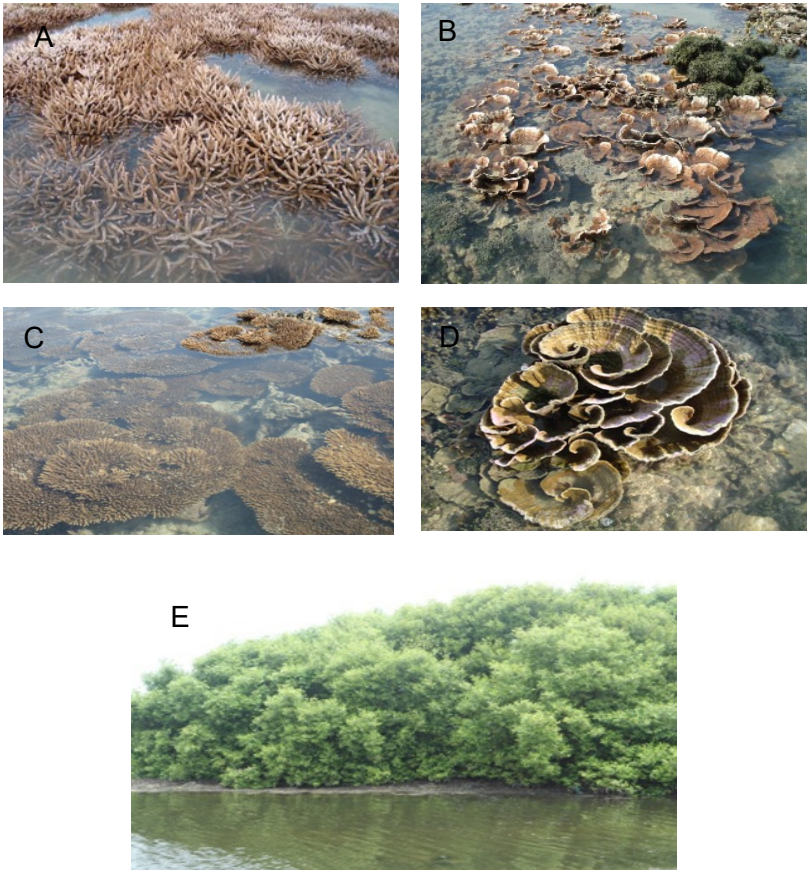
Fig. 1.4. A nuclear power plant (Kudankulam). B. Thermal power station (Tuticorin). C. Pamban bridge connecting Rameswaram Island to the mainland. D. Swami Vivekananda memorial and a giant statue of Tamil poet Thiruvalluvar (Kanyakumari). E. A temple to the God Vinayaka in the sea (Kodiyakarai). F. Swami Vivekananda temple (Pamban). G. Palace of the Pallava king (Tranquebar). H. Monument built by a Chola King at Manora on the seashore of the Adhirampattinam coast.

## **Diverse Ecosystems along the Southeast Coast of India**

### **Gulf of Mannar Marine Biosphere Reserve**

The Gulf of Mannar, the first Marine Biosphere Reserve in India, extends to 140 km in a north-south direction and spreads across an area of 10, 500 km<sup>2</sup>. Twenty-one islands parallel to the coastline are located at an average distance of 8 km from the mainland coast. The Gulf is bestowed with a mangrove forest, seaweed beds, seagrass meadows and a coral reef. About

117 species of corals belonging to 37 genera (Figs. 1.5A, B, C, D), 24 mangrove species, (Figs. 1. 5E, F) and 13 seagrass species are reported in the Gulf of Mannar Biosphere Reserve (Figs. 1.5G, H). All three highly productive ecosystems harbour a rich diversity of flora and fauna. The Gulf has 3,600 species of floral and faunal diversity, making it one of the biologically wealthiest coastal ecosystems in India (Global Environment Facility, 1999). Considering its biological wealth, UNESCO declared the Gulf of Mannar as a Biosphere Reserve in 1983. Subsequently, the Union Government of India declared the Gulf of Mannar as a Marine National Park in 1989.





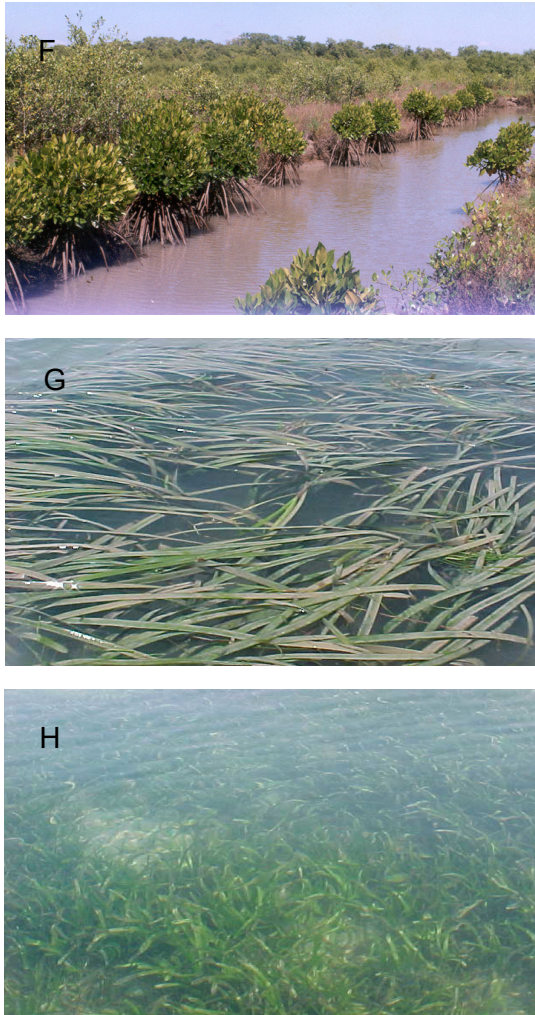


Fig. 1.5. Coral, mangrove and seagrass ecosystem of the Gulf of Mannar, SE Indian coast. A, B, C, D corals; E Mangrove forest on Krusadai Island F. Mangrove on Manoli Island. G. Seagrass *Enhalus acoroides* meadow in Pamban passes. H. Seagrass *Cymodocea rotundata* meadow on Krusadai Island

**Pulicat Lake**

Fig. 1.6. A. View of Pulicat Lake on the SE Indian coast. B. Birds searching food in Pulicat Lake

Pulicat Lake, the second largest brackish water lake in India is located on the northern tip of this coastline. (Fig. 1.6A). The lake has a 350 sq. km water spread area with an average depth of about 1 m. The lagoon has rich floral and faunal diversity, and supports active commercial fishing. *Chaetomorpha* sp., *Enteromorpha* sp., *Cladophora* sp., *Rhizoclonium* sp., *Rosenvingea* sp., *Padina* sp., *Polysiphonia* sp., *Gracilaria* sp. and *Hypnea*

*sp.* are the important algal species recorded in Pulicat Lake. Migratory birds, mainly from Central Asia and Eastern Europe, visit this sanctuary (Fig. 1.6B). The lagoon has gained importance through its recognition by the International Union of Conservation of Nature (IUCN).

### Pitchavarm Mangrove Forest

Pitchavaram mangrove is the second largest mangrove forest in India. The forest cover is about 1100 hectares and it is separated from the sea by a huge sand bar (Figs. 1. 7A, B). The Pitchavaram mangrove ecosystem has a great wealth of biological diversity. It serves as the best nursery ground for shrimp, lobster, crab and turtle. The seaweeds *Enteromorpha*, *Cladophora*, *Chaetomorpha*, *Padina*, *Gracilaria* and *Hypnea* and seagrass *Halophila* are reported in this ecosystem. *Avicennia* is the most common mangrove genus, followed by *Rhizophora*, *Bruguiera* and *Aegiceras*.



Fig. 1.7. A & B. Views of Pitchavaram mangrove forest on the SE Indian coast.

### Muthupet Mangrove Swamp

The Muthupet mangrove swamp spreads across an area of 12,500, out of which 77.20 ha. has thickly covered mangrove trees while the remaining area is sparsely covered by the mangrove trees (Figs. 8A, B). *Avicennia marina* is the most abundant species followed by *Excoecaeria agallocha*, *Aegiceras corniculatum*, *Acanthus ilicifolius* *Suaeda maritima* and *Suaeda monoica*. Cutting of the wood for fuel and grazing by cattle have caused great

damage to the mangrove forest. Seaweeds like *Chaetomorpha*, *Enteromorpha*, *Gracilaria* and *Hypnea* are found growing in Muthupet swamp.

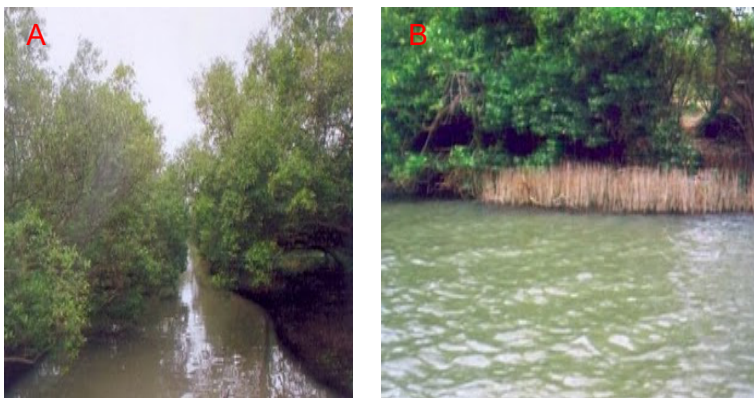


Fig. 1.8. A & B Views of Muthupet mangrove swamp on the SE Indian coast.

### Seasons and Climate

The southeast Indian coast has a typical tropical climate. The climate ranges from dry sub-humid to semi-arid. The maximum temperature occasionally rises to 40° C during the hottest months of April, May and June. The coast is heavily dependent on the monsoonal rains, influenced by the southwest monsoon rain from June to September and the northeast monsoon rain between October and December. The normal annual rainfall is about 945 mm (37.2 in) of which 68% is coming from the northeast monsoon, and 32% from the southwest monsoon.

### Currents, Tides, Wave Action, Seawater Temperature and Salinity

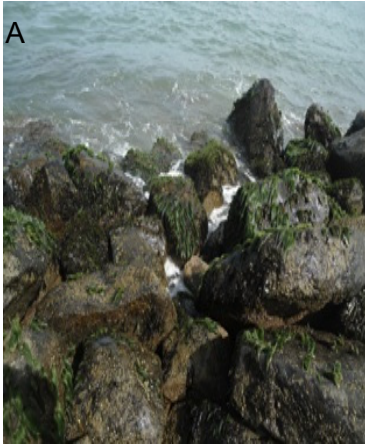
The oceanic current changes its direction twice in a year. The “East Indian currents” pass in a northward direction from January to October and, during the remaining period of the year, the “East Indian winter jet current” passes in a southerly direction. The current is very active during September to December, producing severe cyclones that affect the SE Indian coast (Potemra et al. 1991). The tidal amplitude is lowest among the other coastlines of India. The maximum tidal range is about 70 cm. The coast has a semi-diurnal tidal pattern with two high and two low tides in a day. The monsoonal winds influence the wave direction. During the



southwest monsoon months, the wave direction is from the southwest to the south and during the northeast monsoon months it is from the northeast to the north. The height of the waves increases from September to January with a peak in November, and then decreases up to August. The seawater temperature ranges between 24 and 32°C. The salinity of the seawater ranges from 26-36 ppt with peak values in May during the summer.

## Seaweed Vegetation

The southeast Indian coastline exhibits greater variations in the nature of the substratum in intertidal and subtidal regions. The northern part of the coastline has artificial boulders and stones in the upper intertidal region. It is prone to severe wave surf action and very few algal species which are surf resistant are dominant in this region. The species belonging to the genus *Ulva*, *Chaetomorpha*, *Enteromorpha*, *Bryopsis* and *Grateloupia* are common (Figs. 1.9A, B). The Palk Bay coast has muddy intertidal and subtidal regions due to the confluence of many rivers into the sea. Several species of *Gracilaria* like *G. edulis*, *G. foliifera*, *G. verrucosa* and *G. salicornia* are dominant in this region. The seaweed-based industries in Tamil Nadu collect *Gracilaria* spp. from this region for agar extraction. The Gulf of Mannar has a rich diversity of all 3 groups of seaweeds. Intertidal and subtidal rocks extending up to 1 meter depth are rich sources of *Sargassum*, *Acanthophora* and *Hypnea* (Figs 1. 9 C, D, and E). The flat coral reef in the subtidal region is bestowed with *Gelidiella acerosa*, *Turbinaria Saragassum* and *Ulva* vegetation. (Figs. 1.9 F, G). All 20 Gulf of Mannar islands are surrounded by the coral reef. *Asparagopsis taxiformis* is the dominant alga in the deep water around the islands of Gulf of Mannar (Fig. 1.9H).



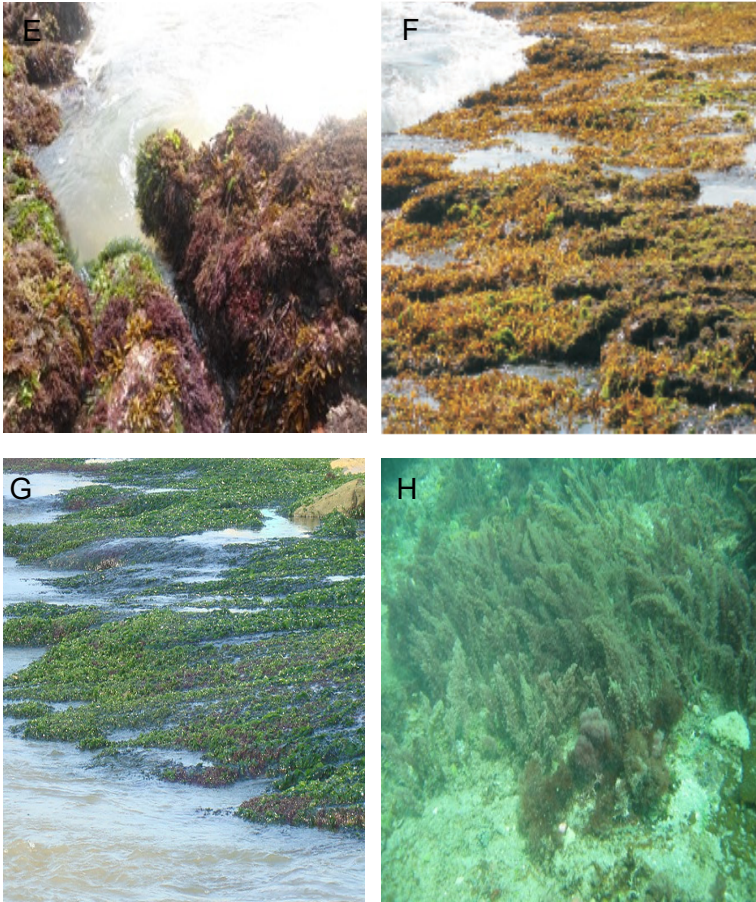


Fig. 1.9. Seaweed vegetation: A. Big boulders with *Grateloupia* population. B. Rock covered with *Bryopsis* population alternates with the sandy coast (Velankanni nagar). C. Intertidal rocks with seaweed vegetation (Seeniappa Dharga). D Lower intertidal rocks with seaweed population (Arockiapuram). E. Rocks in surf zone with rich seaweed diversity (Manapad). F. Intertidal rock pools with dense *Sargassum* population (Manapad). G. Long flat rocks in the intertidal region with *Ulva fasciata* (Idinthakarai). H. Dense *Asparagopsis taxiformis* population at 10-meter depth (Valimunai Island).

## Seaweed Diversity

### Sampling of seaweeds

Seaweed sampling was done at 56 sampling stations along the entire southeast coast, of which 42 sampling stations were located on the mainland coast and 14 stations on the Gulf of Mannar islands. The southeast coast has a semi-diurnal tide with two low tides and two high tides in a day. The intertidal region is exposed for four hours per day. The tide starts to recede two hours before the low tide period and floods after two hours. Therefore, the biodiversity assessment and the seaweed sampling were carried out during these 4 hours during which most of the seaweed species were exposed in the intertidal and subtidal regions.

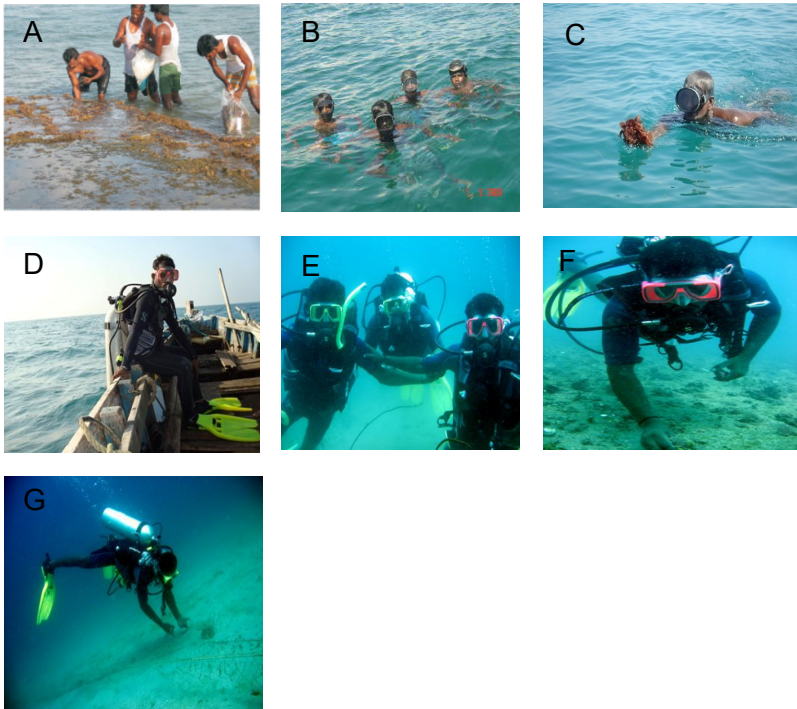


Fig. 1.10. Seaweed Collection: A. Sampling in the intertidal region (0.5 m deep). B, C. Seaweed sampling by snorkelling up to 2-meter depth. D, E, F, G. Fully equipped Scuba diving for sampling beyond 3-meter depth.

All the seaweed collection persons wear rubber safety boots to walk on the uneven rocks, coral surfaces and on muddy areas for the seaweed sampling (Fig. 1.10A). Snorkelling was done to collect the seaweed samples up to 3-meter depth (Figs 1.10B, C). The scuba diving experts were hired for the algal sampling above 3 meters and up to 20 meter-depth (Figs 1.10 D, E, F, G).

## **Qualitative Assessment**

All the seaweeds growing in a particular site, irrespective of quantity, size, as epiphytes or firmly attached on the substratum, either free floating or submerged, are collected. This will ensure having the complete list of the seaweed diversity in that particular coastal locality.

Individual seaweed species were collected in full form, kept in the individual polythene bag with ample seawater, and labelled. The occurrence of the alga either as exposed or submerged in the supra-littoral, intertidal or subtidal region was noted. Global location of the sampling station was recorded with the Global Positioning System (GPS).

The bags with algal specimens were kept in an ice box and brought to the laboratory for further processing.

## **Preparation of Herbarium**

- a) The individual alga was transferred to a tray and filled with clean sea water.
- b) A thin tin sheet was put in the water and a cardboard sheet corresponding to the size of the specimen was placed over the tin sheet
- c) The serial number of the alga given in the field note book, preceded by collection site in three letters (e.g. PUD for Pudumadam), was written in the right down corner of the sheet.
- d) The specimen was placed on the sheet, spread in an optimal way by a small brush (Fig.1.11A).
- e) A tin sheet along with a cardboard sheet with the specimen were gently lifted out of the water and surplus water was drained off.

- f) The specimen was covered with adsorbent cloth (preferably mull cloth) and kept in an air-dryer for some time (Fig.1.11B).
- g) The air-dried specimens were kept between the newspapers and arranged evenly in a plant press.
- h) The plant press was tightly tied with nylon thread and a weight was placed over it.
- i) The plant press was kept under direct sunlight to avoid fungal attack.
- j) Newspaper was changed daily until the specimens were completely dried.
- k) The specimen was mounted on a standard herbarium sheet with a label in the bottom right corner.
- l) Details of the plant name, place of collection, date of collection and the ecology of the collection site have been labelled.
- m) Herbarium sheets were stored in a cabinet specially made for this purpose (Fig. 1.11C).

## **Preservation of Algal Sample**

### **I. *Formalin preservation***

Algal specimens were preserved in the glass bottles with 4% formaldehyde (pure formalin is = 40%, so 1 part of formalin was diluted with 9 part of seawater). The glass bottles were labelled as per the number given on the herbarium sheets (Fig. 1.11D).

### **II. *Silica- gel preservation***

Algal specimens needing to be subjected to molecular analysis for identification were stored in the silica gel. A small fragment (a few millimetres in length) with an apical part has been cut and cleaned off well with the help of a brush to remove epiphytes and diatoms, before being dried with tissue paper. The fragment was put in the zip lock bag and fine grains of silica gel were added to surround the entire fragment. The zip lock polythene bag was closed tightly, otherwise the silica gel would attract air humidity.