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Economically Important Seaweeds of Kerala coast, India – A Review

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ABSTRACT

Seaweeds are the potential marine living resources in the world. More than 20,000 seaweeds are distributed throughout the world, of which only 221 (1.1%) are commercially utilized, which includes 145 species for food and 110 species for phycocolloid production (Sahoo, 2000). During September 2011 to March 2013, extensive field surveys were conducted to Kerala coast and a total of 137 species of seaweed were recorded. Based on the review of available literature, totally 42 species were found economically important. Of these, 29 species are edible for humans, 24 species are suitable for industrial sector to extract the phycocolloides (agar-agar, agaroids, algin, carageenans etc.), 14 species used as fodder for domestic animals, 11 species for the production of manures in the form of Seaweeds Liquid Fertilizers (SLF) and 7 species suitable for various medicinal purposes. The red seaweeds are dominant with 19 species, followed by green seaweeds with 14 species and brown seaweeds with 9 species. The rich diversity and luxuriant growth of seaweeds were recorded at Mullur Kadalapuram, Vizhinjam, Kovalam, Varkala, Edava, Thangassery, Thirumullavaram, Baypore, Thikkodi, Mahe, Ezhimala Manjeshwar and Hosabettu coasts. The presence of natural rocks, bedrocks, the artificially made cement boulders and laid stones along the coast support the growth of a large number of seaweeds.

Introduction

India has a coastline of about 7500 km including those of islands of Andaman & Nicobar and Lakshadweep. It harbours unique marine habitats which display a wide variety of marine biological diversity. The variety of coastal ecosystems along the Indian coastline includes estuaries, lagoons, mangroves, backwaters, salt marshes, rocky coasts, sandy stretches and coral reefs. These marine habitats play very significant role in ecological and economical stability of the country. It has an Exclusive Economic Zone (EEZ) of around 2.5 million sq km and accounts for about 8% of the global biodiversity (Oza, 2005). The Indian mainland coast is divided into the east coast and the west coast. The west coast is usually exposed with heavy surf, rocky shores and headlands while the east coast is generally shelving with beaches, lagoons, delta and marshes.

Kerala has a coastline of about 580 km, which is extended in 9 districts of the state from Poovar, Thiruvananthapuram district in south to Thalapady, Kasaragod district in north. It is the third largest coast in the west coast of India after Gujarat with 1600 km (Jha *et al.*, 2009) and Maharashtra with 720 km (Sakhalkar & Mishra, 2014). The coast of Kerala supports a large number of marine flora and fauna, owing to its variety of habitats such as beaches, back waters, estuaries, cliffs, lagoons, mangroves and coral reefs. Thus it forms an integral part of the marine biodiversity of India.

Since ancient times, seaweeds are used as a direct food source to humans, especially in East Asia (Japan), the Indo-Pacific (China, Indonesia) and Pacific (Hawaii). Presently, there are 42 countries in the world with reports of commercial exploitation of seaweeds. Among them, China holds first rank, followed by North Korea, South Korea, Japan, Philippines, Chile, Norway, Indonesia, USA and India. These top ten countries contribute up to 95% of the world's commercial seaweed utilization (Khan & Satam, 2003). In the recent years, varieties of health care products like lotions, bath gels, shampoos, soaps, creams and pharmaceutical components are being produced from the seaweeds. China and Japan are the two major seaweed harvesting countries, where more than 70 species of seaweeds are consumed as salads directly or after cooked. Braune & Guiry (2011) reported that a total of about 400,000 tonnes of seaweeds such as *Porphyra* (for Nori), *Laminaria* (for Kombu), *Undaria* (for Wakame) are harvested annually throughout the world.

About 20,000 species of seaweeds are distributed throughout the world, of which 221 are commercially utilized, which includes 145 species for food and 110 species for phycocolloid production (Sahoo, 2000, Chennubhotla *et al.*, 2013). In India, the marine floral diversity includes a total of 844 species of seaweeds (in 217 genera), 14 species of seagrasses and 69 species of mangroves (Saxena, 2012). Scrutiny of literature on the studies of the economic utility of seaweeds reveals that there are only very meager and sporadic works have been carried out in various maritime states of India: Andhra Pradesh (Umamaheswara Rao, 1970, 2011; Anon, 1995); Andaman & Nicobar Islands (Jagtap, 1983, 1992; Gopinathan & Panigrahi, 1983; Rao, & Rao, 1999; Palanisamy, 2012; Karthick *et al.*, 2013); Gujarat (Thivy, 1958, 1982; Jha *et al.*, 2009); Goa (Agadi & Untawale, 1978; Dhargalkar, 1981) Lakshadweep (Kaliaperumal *et al.*, 1989; Koya *et al.*, 1999; Koya, 2000; Kaladharan, 2001; Kumar & Kaladharan, 2007); Maharashtra (Dhargalkar *et al.*, 1980); Odisha (Sahoo *et al.*, 2001, 2003) and Tamil Nadu (Chennubhotla, 1977, 1996; Chennubhotla *et al.*, 1981, 1987, 1988; Kaliaperumal *et al.*, 1990, 1992, 1995, 2004). Subba Rao & Mantri (2006) published a review on the Indian seaweed resources and its sustainable utilization.

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Similarly, several studies on the economical importance of the seaweeds of Kerala have been done by Kaliaperumal & Chennubhotla (1997), Sulekha & Panikkar (2006), Sobha & Nair (1985), Sobha *et al.* (2001, 2008), Pramitha & Lipton (2013) and Shynu *et al*. (2013). The estimated standing stock of seaweeds in Kerala is 1000 tonnes (wet wt.), of which about 150 tonnes are economically important seaweeds (Chennubhotla *et al*., 2000). The economic values of some of the species of the genera namely *Asparagopsis* (Manilal *et al*., 2010); *Ulva*, *Caulerpa*, *Padina*, *Sargassum*, *Gracilaria* (Sobha *et al*., 2008; Kaliaperumal *et al.*, 1992); *Kappaphycus* (Khambaty *et al*., 2012) have been documented in the recent decades. The bioactive compounds and the extracts obtained from the seaweeds are highly important in food, pharmaceuticals, cosmetics and chemical industries. In the fact of the above view, the present paper has highlighted the economically important seaweed resources of the Kerala coast.

Fig. 1. Map showing the seaweed collection localities

Materials and Methods

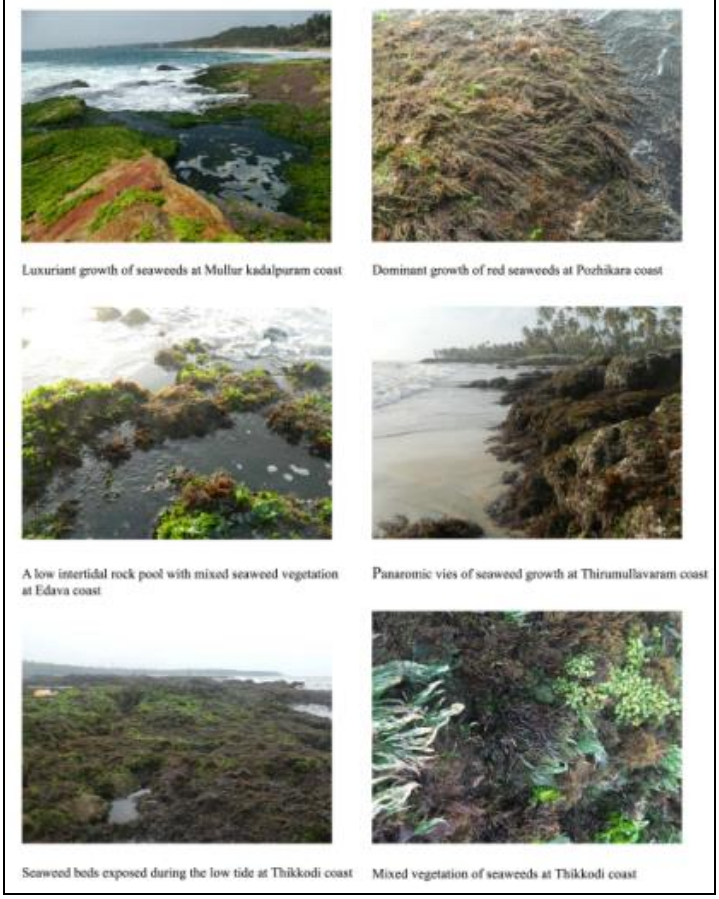
Study Area

In the present study, the entire Kerala coast (8° 18' - 12° 48' N & 74° 52' - 72° 22' E) has been surveyed during the years 2011–2013 (**Fig. 1**). The long coastline of Kerala is extended in nine districts [i.e. Thiruvananthapuram, Kollam, Alappuzha, Ernakulam, Thrissur, Malappuram, Kozhikode (including Mahe), Kannur and Kasaragod] from Poovar, Thiruvananthapuram in southernmost to Thalapady, Kasaragod in extreme north. The narrow coastal belt of Kerala is interrupted with sandy stretches, beaches, rivers, and natural rocks and artificial sea wall facing the Arabian Sea.

Collection of samples and its preservation

Total of seven field tours were conducted to collect seaweeds in various seasons during the low tides as per Meteorological data. More than 1200 field numbers of seaweeds were collected from a total of 125 localities in Kerala coast. The GPS reading of each collection locality was recorded using portable GPS (Garmin 12 channels).

Plate 1 - Important seaweed natural habitats at Kerala coast



Luxuriant growth of seaweeds at Mullur kadalpuram coast

Dominant growth of red seaweeds at Pozhikara coast

A low intertidal rock pool with mixed seaweed vegetation at Edava coast

Panaromic vies of seaweed growth at Thirumullavaram coast

Seaweed beds exposed during the low tide at Thikkodi coast

Mixed vegetation of seaweeds at Thikkodi coast

The original field photographs showing the nature of seaweed habitats at the coast (**Plate 1**) were taken with NIKON (Coolpix) camera and the important information regarding the habit (**Plate 2**), locality, population status, nature of the coast etc. were noted in the field. The important physico-chemical parameters of the sea water such as Salinity, pH value, Total Dissolved Solvents (TDS), Dissolved Oxygen (DO) and Atmospheric and Water Temperature were measured using the portable Water Analysis Kit (LABTRONICS).

The seaweed samples were collected randomly from the intertidal regions. Collected samples were thoroughly washed in sea water and subsequently in fresh water without damaging the specimens. A set of herbarium specimens were prepared for each field number and the live samples were preserved in 4% formalin. All the collected specimens are deposited at Botanical Survey of India, Madras Herbarium (MH), Coimbatore. All the wet and dry specimens were examined carefully under the light microscope (NIKON SMZ 1500 and NIKON ECLIPSE 50*i*) coupled with digital camera. The taxonomic descriptions were made based on the morphological and anatomical characters of the specimens for each species. Identity of the collected samples was confirmed following the standard available literatures (Srinivasan, 1969, 1973; Desikachary *et al*., 1990, 1998; Silva *et al*., 1996; Krishnamurthy, 2000; Jha *et al*., 2009; Krishnamurthy & Baluswamy, 2010; Braune & Guiry 2011). The standard abbreviations of author names are followed strictly as per Brummitt & Powel (1992).

Table 1. List of the economically important seaweeds of Kerala coast, India

Sl. No.	Name of the taxa	Uses	References
1.	**CLASS: CHLOROPHYCEAE** FAMILY: ULVACEAE *Enteromorpha compressa* (L.) Nees	Edible, Fodder, Medicinal	Kaliaperumal *et al*., 1995; Shynu *et al*., 2013
2.	*Ulva fasciata* Delile	Edible, Fodder, Medicinal	Sobha *et al*., 2008; Shynu *et al*., 2013
3.	*Ulva lactuca* L.	Edible, Fodder, Medicinal, Manure	Shynu *et al*., 2013
4.	*Ulva reticulata* Forssk.	Edible	Sobha *et al*., 2008; Kaliaperumal *et al*., 1995
5.	*Ulva rigida* C.Agardh	Edible	Kaliaperumal *et al*., 1995; Shynu *et al*., 2013
6.	*Ulva quilonensis* Sindhu & Panikkar	Edible, Fodder, Medicinal	Kaliaperumal *et al*., 1995; Shynu *et al*., 2013
7.	FAMILY: ACROSIPHONIACEAE *Acrosiphonia orientalis* (J. Agardh) P.C. Silva	Medicinal	Manilal *et al*., 2012.
8.	FAMILY: CLADOPHORACEAE *Cladophora prolifera* (Roth) Kutz.	Edible, Fodder	Shynu *et al*., 2013
9.	*Cladophora fascicularis* (G. Mertens ex C.Agardh) Kutz.	Edible, Fodder	Kaliaperumal *et al*., 1995; Shynu *et al*., 2013
10.	FAMILY: BRYOPSIDACEAE *Bryopsis plumosa* (Huds.) C. Agardh	Edible, Fodder, Manure	Shynu *et al*., 2013
11.	FAMILY: CAULERPACEAE *Caulerpa peltata* J.V. Lamour.	Edible, Fodder, Manure	Shynu *et al*., 2013
12.	*Caulerpa racemosa* (Forssk.) J. Agardh	Edible	Kaliaperumal *et al*., 1995; Sobha *et al*., 2008
13.	*Caulerpa sertularioides* (S.G. Gmel.) M. Howe	Edible, Fodder, Manure	Kaliaperumal *et al*., 1995; Shynu *et al*., 2013
14.	*Caulerpa taxifolia* (Vahl) C. Agardh	Edible, Fodder, Manure	Shynu *et al*., 2013
15.	**CLASS: PHAEOPHYCEAE** FAMILY: DICTYOTACEAE *Dictyopteris bartayresiana* J.V. Lamour.	Edible, Fodder, Medicinal, Manure	Shynu *et al*., 2013
16.	*Lobophora variegata* (J.V. Lamour.) Womersley ex E.C. Oliveira	Industrial	Shynu *et al*., 2013
17.	*Padina gymnospora* (Kutz.) Sond.	Edible, Fodder, Industrial, Manure	Shynu *et al*., 2013
18.	*Padina tetrastromatica* Hauck	Edible, Fodder, Industrial, Manure	Sobha *et al*., 2008; Shynu *et al*., 2013
19.	FAMILY: SARGASSACEAE *Sargassum myriocystum* J. Agardh	Edible, Manure, Industrial (Algin)	Kaliaperumal *et al*., 1995; Shynu *et al*., 2013
20.	*Sargassum tenerrimum* J. Agardh	Edible, Manure, Industrial (Agaroid)	Kaliaperumal *et al*., 1995; Shynu *et al*., 2013
21.	*Sargassum wightii* Grev.	Edible, Fodder, Industrial (Algin)	Kaliaperumal *et al*., 1995; Sobha *et al*., 2008; Shynu *et al*., 2013
22.	*Turbinaria conoides* (J. Agardh) Kutz.	Industrial (Algin)	Kaliaperumal *et al*., 1995
23.	*Turbinaria ornata* (Turner) J. Agardh	Edible, Industrial (Agaroid)	Kaliaperumal *et al*., 1995; Shynu *et al*., 2013
24.	**CLASS: RHODOPHYCEAE** FAMILY: BANGIACEAE *Porphyra indica* V. Krishnam. & Baluswami	Edible	Kaliaperumal *et al*., 1995
25.	*Porphyra kanyakumariensis* V. Krishnam. & Baluswami	Edible	Shynu *et al*., 2013
26.	GELIDIACEAE *Gelidium micropterum* Kutz.	Edible, Industrial (Agar)	Kaliaperumal *et al*., 1995; Shynu *et al*., 2013
27.	*Gelidium pusillum* (Stackhouse) Le Jolis	Industrial (Agar)	Kaliaperumal *et al*., 1995
28.	*Gelidiella acerosa* (Forssk.) J. Feldmann & G. Hamel	Industrial (Agar)	Kaliaperumal *et al*., 1995
29.	FAMILY: GRACILARIACEAE *Gracilaria corticata* (J. Agardh) J. Agardh	Industrial (Agar)	Kaliaperumal *et al*., 1995; Sobha *et al*., 2008; Shynu *et al*., 2013
30.	*Gracilaria corticata* (J. Agardh) J. Agardh var. *cylindrica* M.U. Rao	Industrial (Agar)	Kaliaperumal *et al*., 1995
31.	*Gracilaria edulis* (S.G.Gmel.) P.C. Silva	Edible, Industrial (Agar)	Kaliaperumal *et al*., 1995; Shynu *et al*., 2013
32.	*Gracilaria foliifera* (Forssk.) Borgesen	Industrial	Shynu *et al*., 2013
33.	*Gracilaria verrucosa* (Hudson) Papenf.	Manure, Industrial (Agar)	Kaliaperumal *et al*., 1995; Shynu *et al*., 2013
34.	FAMILY: BONNEMAISONIACEAE *Asparagopsis taxiformis* (Delile) Trevis.	Edible, Industrial (Antifouling agent)	Kaliaperumal *et al*., 1995; Manilal *et al*., 2010
35.	FAMILY: HALYMENIACEAE *Grateloupia filicina* (J.V. Lamour.) C.Agardh	Edible, Industrial (Carageenan)	Shynu *et al*., 2013; Sahu & Kumar, 2014
36.	FAMILY: CORALLINACEAE *Corallina elongate* J. Ellis & Sol.	Medicinal	Shynu *et al*., 2013
37.	*Jania adherens* J.V. Lamour.	Industrial	Shynu *et al*., 2013
38.	FAMILY: HYPNEACEAE *Hypnea musciformis* (Wulfen) J.V. Lamour.	Edible, Medicinal, Industrial (Carageenan)	Kaliaperumal *et al*., 1995; Pramitha & Lipton, 2013; Shynu *et al*., 2013
39.	*Hypnea valentiae* (Turner) Mont.	Edible, Medicinal, Industrial	Kaliaperumal *et al*., 1995; Pramitha & Lipton,

		(Carageenan)	2013; Shynu *et al*., 2013
40.	FAMILY: LOMANTARIACEAE *Gelidiopsis intricata* (C. Agardh) Vickers	Industrial	Shynu *et al*., 2013
41.	FAMILY: CERAMIACEAE *Spyridia hypnoides* (Bory) Papenf.	Industrial (Agaroid)	Chennubhotla *et al*., 1987; Kumar & Bai, 2008.
42.	FAMILY: RHODOMELACEAE *Acanthophora spicifera* (Vahl) Borgesen	Edible, Industrial (Agaroid)	Chennubhotla *et al*.,1987; Shynu *et al*., 2013

Plate 2 - Economically important seaweeds

Enteromorpha compressa (L.) Nees

Ulva fasciata Delile

Padina tetrastromatica Hauck

Sargassum tenerrimum J. Agardh

Gracilaria corticata (J. Agardh) J. Agardh

Asparagopsis taxiformis (Delile) Trevis.

Results

The results of present study and scrutiny of earlier reports reveal that a total of 42 economically important seaweeds species found in Kerala coast (**Table 1**). Among these, 29 species are edible for humans, 24 species are suitable for industries to extract the phycocolloides (agar-agar, agaroids, algin, carageenans etc.), 14 species as fodder for domestic animals, 11 species for the production of manures and 7 species are medicinal. The number of species cited above for each usage explicitly indicates that many of them have multipurpose significance. Total of 14 species are used as both food and fodder while 3 species of green seaweeds such as *Enteromorpha compressa* (L.) Nees, *Ulva fasciata* Delile and *U. quilonensis* Sindhu & Panikkar are used as food, fodder and medicinal. The class wise representation of enumerated seaweed species shown in pie chart (**Fig. 2**), indicates the dominance of red (Rhodophyceae) with 19 species (45%), followed by green (Chlorophyceae) with 14 species (33%) and brown (Phaeophyceae) with 9 species (22%).

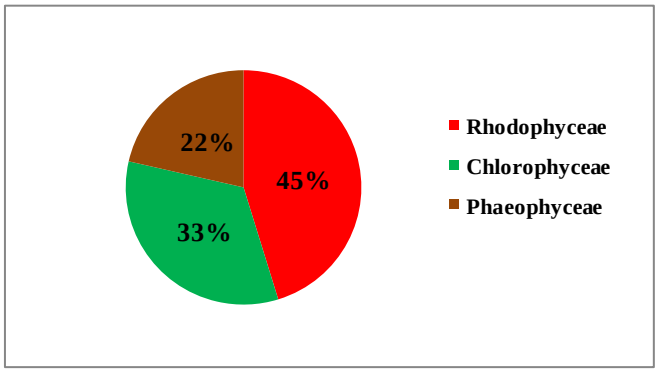


Fig. 2. Pie chart showing percentage share of economically important seaweeds.

Discussion

Seaweeds constitute an important part of the global marine biodiversity. The coastline of Kerala shows a rich diversity of seaweeds. However, the distribution pattern of these seaweeds exhibits a wide range of variation in different areas. The southern parts of Kerala coast (Thiruvanthapuram and Kollam districts) are extended with rocks, bedrocks and cliffs which are suitable for luxuriant growth of seaweeds. The central parts of the Kerala coast (Alappuzha, Ernakulam, Thrissur and Malappuram) are low laying area and fully protected with artificially laid stones and shows less occurrence of seaweeds. The northern parts of Kerala coast are mainly sandy with scattered rocks and bedrocks which support the maximum numbers of seaweed. The rich diversity and luxuriant growth of seaweeds were recorded at Somatheeram, Mullur Kadalapuram, Vizhinjam, Kovalam, Valliathura, Varkala, Edava, Thangassery, Thirumullavaram, Neendakara, Azheekkal, Kochi fort (Muttenchery), Vypeen island, Munambam, Pudu Ponnani, Baypore, Kappad, Thikkodi, Mahe, Thalassery, Ezhimala, Kappil beach, Hosabettu and Manjeshwar coasts.

The importance and uses of seaweeds as food in the form of recipes, salads, soups, jellies and vinegar dishes is well known in many Indo-Pacific countries since long ago (Chennubhotla *et al*., 2013). However, in Indian context, the uses of seaweeds in the form of food are still very limited. Sobha *et al*., (2008) studied six species of seaweeds (*Ulva fasciata*, *U. reticulata*, *Caulerpa racemosa*, *Padina tetrastromatica*, *Sargassum wightii* and *Gracilaria corticata*) collected from the southern Kerala coast, as food products in the form of ulva toffy, ulva squash, mixed algae pickle, algae cutlet, algae biriyani, algae thoran etc. These seaweeds are very much popular in South Asian countries like China, Japan, Korea and even in USA (Chapman & Chapman, 1980; Chennubhotla *et al.*, 2013). Among all the edible seaweeds, Nori (*Porphyra*) has got maximum popularity in Japanese cuisine (Sahoo, 2000).

As far as the industrial value of seaweeds is concerned, the annual production of the marine algae along the Indian coast has been estimated to 2,60,876 tonnes (Chennubhotla, 1992, 1999) and now it has been revised to 3,01,646 tonnes (Chennubhotla *et al.*, 2011). Among the various maritime Indian states, the bulk production comes from Tamil Nadu and Andaman & Nicobar Islands amounting to nearly 60% while the rest from the coast of Maharashtra, Goa and Kerala. Nearly 5% of the raw material is contributed by just single species *Kappaphycus alvarezii*, which is cultivated artificially at larger scale especially in the Gulf of Mannar region of Tamil Nadu (Chennubhotla *et al.*, 2013). Recently it was reported in a national daily newspaper (Times of India, 25th December 2014) that a group of people can harvest up to 400 kg (150-200 kg in dry wt.) of fresh seaweeds after 8 hours of diving. The dried seaweeds are sold in market at the rate of Rs. 8 to 25/kg. The species of *Gelidium*, *Gelidiella*, *Gracilaria*, *Gelidiopsis* etc. are used as raw materials for the production of agar-agar whereas species of *Hypnea*, *Spyridia*, *Acanthophora*, *Sargassum* and *Turbinaria* are used for the production of agaroid. In the recent years, species such as *Kappaphycus alvarezii* has been used for the production of biofuels as an alternative source for fossil fuels (Chennubhotla *et al.*, 2011; Khambaty *et al*., 2012).

The observation of the present study shows that the quantitative value of the economically important seaweeds in Kerala coast is comparatively lesser than other maritime states of India (Chennubhotla *et al.*, 2013) to support or establish the seaweed based industries. Therefore it is suggested here that this can be overcome by encouraging the coastal communities to cultivate the economically valuable seaweeds such as *Ulva fasciata, U. Reticulata, Caulerpa peltata, C. racemosa, C. taxifolia, Padina gymnospora, P. tetrastromatica, Sargassum tenerrimum, S. wightii, Turbinaria conoides, T. ornata, Kappaphycus alvarezii, Gelidium micropterum, G. pusillum, Gelidiella acerosa, Gracilaria corticata, G.edulis, foliifera, Hypnea musciformis, H. valentiae, Acanthophora spicifera* etc. In addition, this practice would support the livelihood activities of the coastal communities.

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