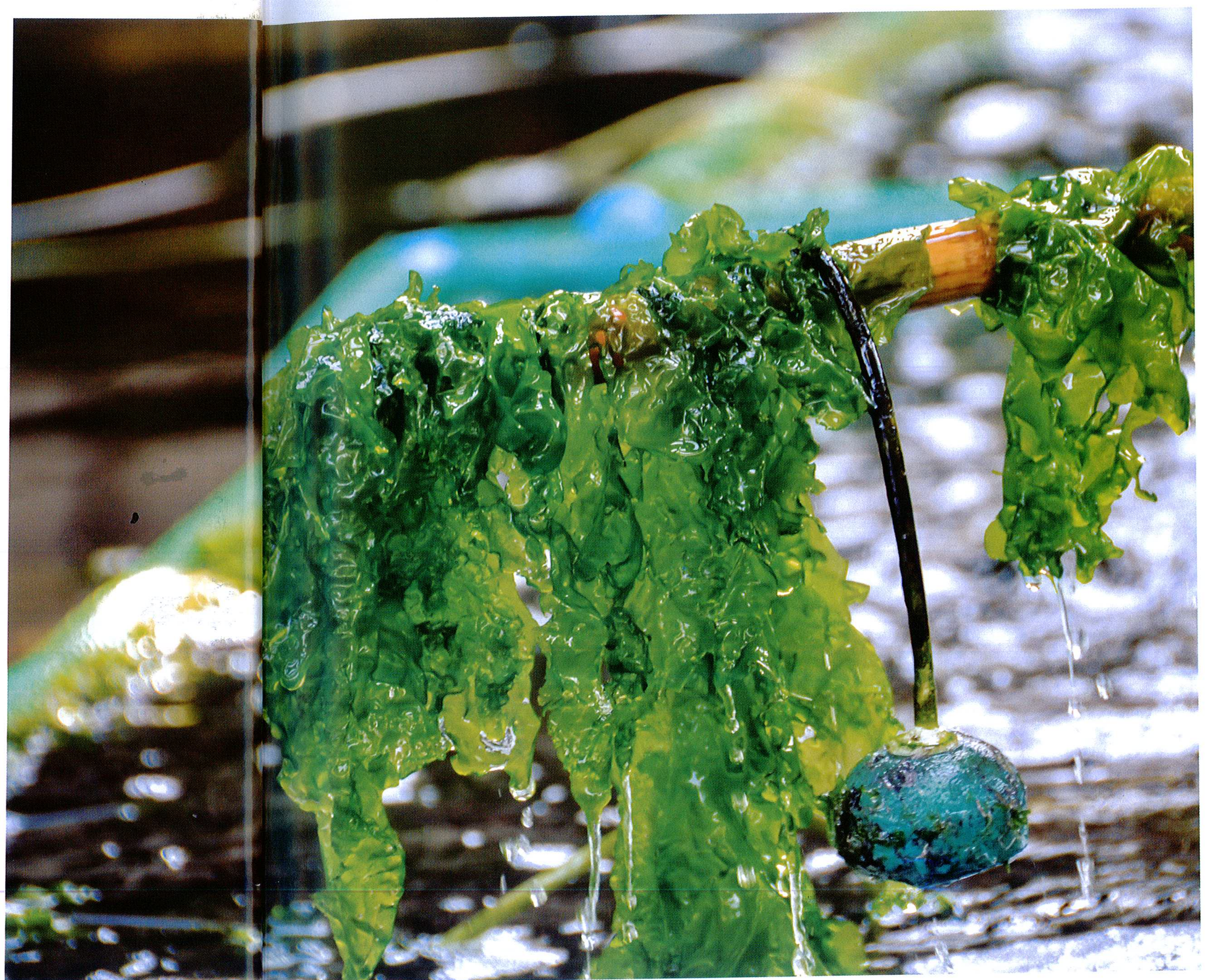
SEAWEED FARMING

Seaweed *Kappaphycus alwarizii*



Sea Lettuce - *Ulva lactuca*

Marine macro-algae or the seaweeds are high fetching commodity for the coastal community. It is a livelihood for the fishers who reside at the sea-shore besides being an integral biological component for carbon sequestration. The coastal belt and the shallow seas of our country is blessed with diverse species of this valuable resource, the seaweeds. The ecosystem in coastal regions is not suitable for agriculture due to the high saline nature. Farmers and fishers, inhabiting in such areas can cultivate these plants-"Coastal Agriculture' and utilize them to sustain their livelihood.

Seaweed Mariculture, the fastest-growing component of global food production, can also offer a number of opportunities to mitigate, and adapt to climate change. A lot of research has been done and is still progressing on culture activities of seaweeds, its value addition and industrial applications. The ensuing article is one such, from one among the research organizations involved in seaweed mariculture and research.

Seaweed farming is encouraged in developing countries as it provides employment for poor fishermen in growing the seaweed as well as in processing industries. One of the biggest exporters of cultured seaweed is China where the industry employs between 100,000-120,000 people. Presently seaweed cultivation has been expanding rapidly. Thanks to the growing demand as novel and sustainable sources of compounds for use in pharmaceuticals, nutraceuticals and antimicrobial products, as well as biotechnological applications. Based upon the pigments present in them, nutrients, and chemical composition seaweeds are classified as Rhodophyta (red algae), Phaeophyta (brown algae) and Chlorophyta (green algae).

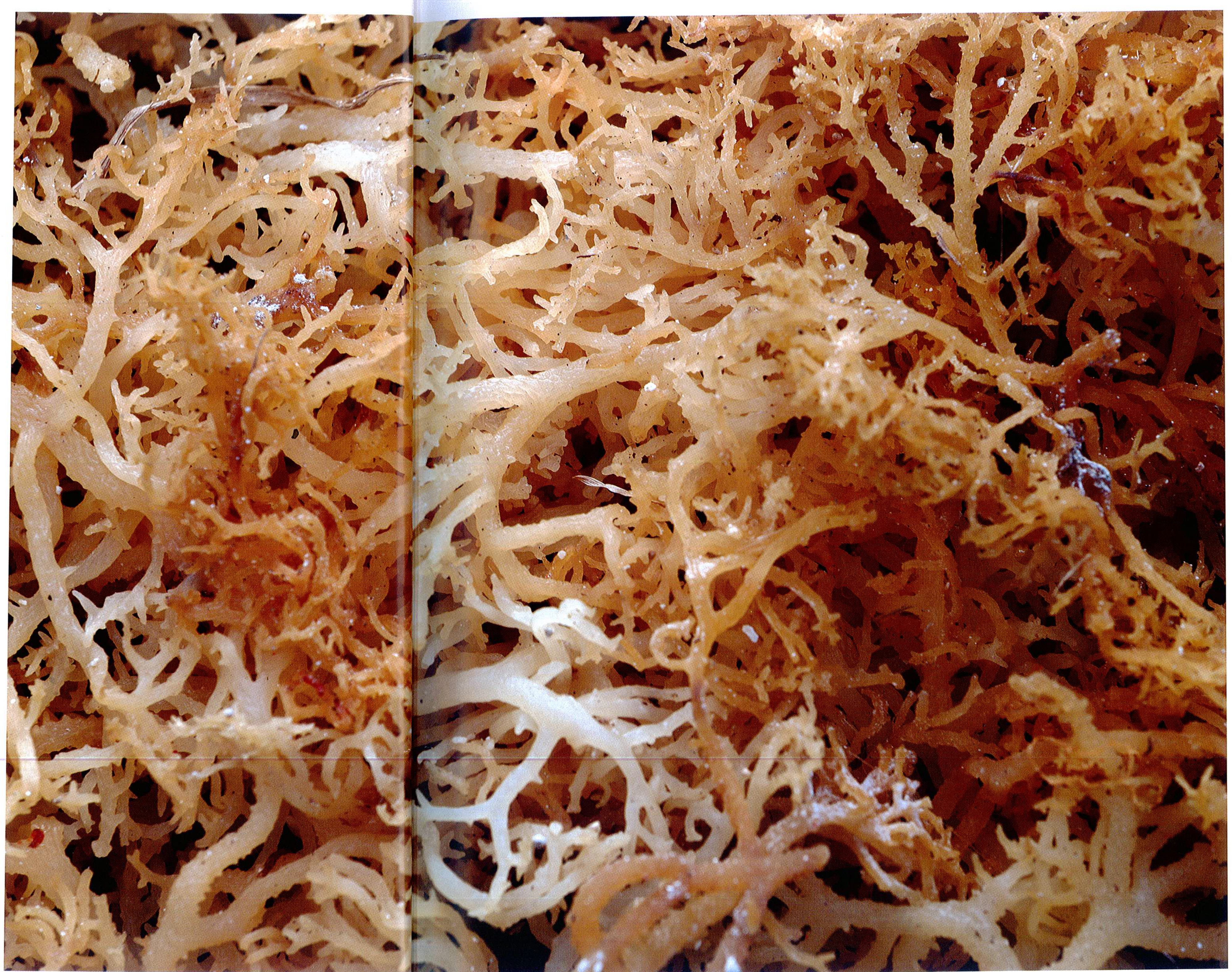
Seaweed cultivation – the Indian Scenario

The indiscriminate exploitation of certain seaweed species from specific localities, especially Gelidiella and Gracilaria from the Tamil Nadu coast, resulted in depletion and consequent shortage in the supply of raw material. This situation has encouraged production of seaweed resources through cultivation. In India, Mariculture of seaweed was attempted by the Central Salt and Marine Chemicals Research Institute (CSMRI), Central Marine Fisheries Research Institute (CMFRI) and the National Institute of Oceanography (NIO).

The CMFRI at its Regional Centre at Mandapam Camp since 1970's ventured to contribute its might towards cultivation technology of seaweeds like *Gracilaria edulis* and *Acanthophora spicifera*. The cultivation of agar yielding seaweeds *Gelidiella acerosa, Gracilaria edulis*, carrageenophyte *Hypnea spp*., alginophyte *Sargassum spp*., and edible seaweeds *Ulva fasciata* and *Enteromorpha compressa* at different locations on Northwest and Southeast coast of India by the CSMCRI using various culture techniques were of noteworthy. In 1964, seaweed culture experiments were conducted for the first time in ponds at Porbander by attaching small plants of brown alga Sargassum to coir nets The plants of Sargassum grew to a height of 15-52 cm in 40 days from the initial height of 5-10 cm. This experiment revealed good possibilities for cultivation of Sargassum and other seaweeds in India. Agar yielding seaweed *Gracilaria edulis* was first cultured by long line rope method in a sandy lagoon on the eastern side of the Kurusadi Island (Rameswaram).

Methods of cultivation

There are two methods for cultivation of seaweeds; one by means of vegetative propagation using fragments from mother plants and the other



Seaweed drying

Caulerpa peltata

by different kinds of spores such as zoospores, monospores, tetraspores and carpospores. In the vegetative propagation method, the fragments are inserted in the twists of ropes, tied to nylon twine or polypropylene straw and cultured in the inshore areas of the sea. The fragments are also cultured by broadcasting them in outdoor ponds and tanks.

Vegetative propagation

In the vegetative propagation method, seaweed thallus (fronds) is used as the seed material. These can be collected from the intertidal areas during low tide. Seaweeds are cultivated on substrata such as 2 x 2 m nets (20 cm mesh) made of either nylon or coir (obtained from coconut husks) and on 10 m long ropes. Approximately 5 g each of fronds is inserted or sandwiched between the twists of the rope at a distance of 10 cm in the long line or at each mesh in the 2 m^2 nets. These "seeded" ropes or nets attached to floating rafts or bottom set fixed structures in the sea, especially protected bays, lagoons or shallow coast. The seeded ropes/nets are kept afloat in water either at surface or at the subsurface, by series of floats and sinkers.

There are many techniques for vegetative propagation of seaweeds based upon the nature of the site, season of farming and the species to be cultivated.

Net tube method is the very recent method in which long sleeves (10 m long and 6 cm diameter) made of nylon nets (1 cm mesh) are seeded with vegetative bits that appear like "net tubes". Both the ends are then tied and allowed to float in seawater. Anchors are fastened to bamboo poles. Harvest is done after 60 days.

Reproductive method

The propagation of seaweed through reproductive method can be carried out by using the reproductive units like zoospores, carpospore, tetraspore, conchospore etc. In India, reproductive propagation

Hypnea valentiae

of seaweed was successfully done in *Gracilaria edulis* liberating the carpospores on different substrata like nylon twine, cement blocks, HDP rope and old fishing net. The spores liberated on the substrata were allowed to grow to germling stage in a nursery and then transplanted to natural environment during favourable period of growth. The spores attain the germling stage within 13-17 days of liberation and attach to the substrata. Three successive harvests can be made from the same seed after 105 days till 135 days of culture period.

The favourable period of growth for cultivation of Gracilaria in southeast and south west coast was found to be from November to March.

The kappaphycus wave in India

The Central Salt and Marine Chemical Research Institute introduced this fast growing species of red seaweed (Rhodophyta) in the Diu coast (Gujarat) in 1995 for experiments in confined waters from the Philippines. The species is a source of k-carrageenan, a gel-forming polysaccharide widely used in the pharmaceutical and food industries. After successful introduction and acclimatization, this Institute has commercialized the culture technology and transferred the material and the technology to Pepsi Co India holdings Ltd., only after convincing itself that its cultivation would be ecologically safe. Later it was transferred to Ms. Aquagri (P) Ltd, New Delhi and to Indian Seaweed Industries, Vijayawada.

In India seaweed farming, stands out as the best example of Community Based Coastal Resources Management (CBCRM) approaches that have enhanced the levels of employment and income among coastal communities). Aquagri Ltd is currently engaged in promoting Kappaphycus cultivation through self-help groups in India which provide livelihood opportunity to coastal communities. The Aquagri model using self-help groups mainly comprising of women is an innovative model not practiced anywhere globally. Offering a fixed pre-determined price to provide a predictable income is also been put into practice for the first time, which eliminates the cultivators' risk in India as the market risk is the biggest impediment faced by the cultivators in other countries.

Seaweed *Kappaphycus alvarezii* being cultivated on bamboo rafts

Contract farming of *Kappaphycus alvarezii*, by the fisher folks of East Coast of India has touched 2000 tones (dry weight)/year. Cultivation of this seaweed generated employment for hundreds of thousands of fisher folk in some coastal districts of Tamil Nadu viz., Ramanathapuram, Pudukkottai, Tanjavur, Tuticorin and Kanyakumari districts who earn Rs. 15000/- to Rs. 16000/- per person per month Currently some companies like M/s. Linn Plantae Private Limited, Madurai and M/s. SNAP Natural and Alginate Products Pvt Ltd, Ranipet, are involved in Kappaphycus cultivation. Feasibility of Kappaphycus cultivation in Gujarat coast was successfully done on Okha Mandal region at Mithapur, Okha and Beyt Dwaraka which indicated that out of nine stations Okha Mandal and Diu coastal area most suitable for Kappaphycus alvarezii culture in summer, winter and monsoon seasons. Gujarat Livelihood Promotion Company (GLPC) under the Sagarlaxmi project in association with the technical assistance from the Bhavnagar unit of CSMCRI initiated large scale Mariculture of Kappaphycus along select centers of Gujarat coast aimed at self- employment generation and livelihood improvement of more than 10000 fisher families.

Subsequently, cultivation of this seaweed was carried out at different locations on Indian coast such as Kerala - Vizhinjam and Thangaserry, Narakkal and Padanna Tamil Nadu - Mandapam, Kilakarai, Tutocorin and Kanyakumari coast; Andhra Pradesh - Chepala Timmapuram and Mukkam and Gujarat - Okha; Porbandar and Diu coast . It is estimated that the entire global harvest of *Kappaphycus* production is 1, 83, 000 tons (dry) and it comes from cultivation alone.

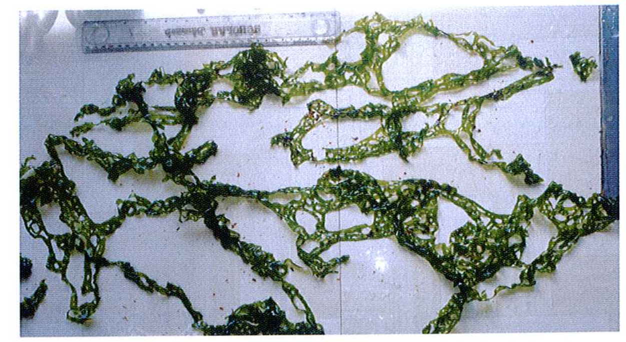
The Philippines and Indonesia contribute to 92% of the entire global production. According to an FAO report published in 2013, rapid expansion of *Kappaphycus* and *Eucheuma* cultivation has resulted in production increase from 9,44,000 tons (wet weight) in 2000 (48% of total red seaweed production) to 5.6 million wet tons in 2010 (63%) with corresponding value from USD 72 million to USD 1.4 billion. The production from other countries viz. Malaysia, China and Solomon Island is considerable, while Indian contribution is so meagre. In India, *Kappaphycus* farming suffered a major setback in 2014 registering very low levels of production and now restoration efforts are being made to revive the production.

Particulars	2011	2012	2013
Annual dried seaweed production (20 kg/raft)	5400 kg	5400 kg	3600 kg
Price of dried seaweed (Rs.per kg)	20	22	25
Annual Revenue (Rs.)	1,08,000	1,18,800	90,000
Annual Costs (Rs.)	47,400	38,650	31,350
Annual Net Profit (Rs.)	60,600	80,150	58,650
Profit Margin (%)	56	67	65
Break Even Price	9	7	9

Economics of Kappahycus farming (sourced from Dr. B. Johnson, CMFRI., Mandapam Centre)

Carbon sequestration potential of seaweeds

Carbon sequestration can be defined as process of capture, utilization and long term storage of Carbon dii oxide from atmosphere, reservoirs or ocean. Due to indiscriminate discharge of pollutants, industrial effluents and toxic metals,



Ulva reticulata

Sargassum wightii

Ulva lactuca

hydrocarbons and pesticides from agricultural land runoff through rivers the carbon di oxide levels have increased considerably over the years. The carbon captured by living organisms in oceans widely known as **blue carbon** is stored in the form of biomass and sediments from primary producers such as phytoplankton, seaweeds, seagrasses (marine flowering plants), mangroves and salt marshes. Excess carbon di oxide dissolved in seawater reduces the availability of carbonate ions in sea which can impair exoskeleton formation in corals, shells, prawns and crab. High levels of carbon dioxide turns seawater to hypoxic and accelerates the formation of dead zones in the ocean. Seaweeds has immense potential to utilize the carbon and thus effectively diminish the release of Carbon di oxide.

Three species of seaweed *Gracilaria corticata*, *Sargassum polycystum* and *Ulva lactuca* were found to be efficient in carbon sequestration.
As the green seaweeds are dominant and coupled with their higher carbon assimilation efficiency, their carbon sequestration potential is always higher.

Benefits of seaweed farming

- Seaweed cultivation being integrated with intensive fish farming, provide nursery grounds for juvenile commercial fish and crustaceans.
- Seaweed farms filter undesired nutrients and improve the marine environment thereby reducing eutrophication.
- Seaweed Mariculture sites enhance marine fish habitats.
- Support seaweed industries by constant supply of raw materials of same quality and maturity stage unadulterated with noncommercial species.
- Reduce exploitation pressure and conserve the natural beds.
- Easy harvest and hence supply of raw material is assured.
- Seaweed Mariculture, is a green aquaculture practice -Coastal Agriculture and hence does not require application of either fertilizers or pesticides
- Mitigate ocean acidification.
- Reduce over-fishing in many regions, and provide coastal communities with an alternative livelihood

In India, the seaweed farming particularly, the farming of *Kappaphycus* species has played a vital role in economic upliftment of many women self-help groups.

Conclusion

It is estimated that the seaweed biomass alone, along the Indian coast is capable of utilizing 9052 t CO_2/d against emission of 365 t CO_2/d indicating a net carbon credit of 8687 t/d. In addition to this, if large scale Mariculture of seaweeds is undertaken in favourable locations all along the coastline in full potential, the carbon sequestration efficiency by seaweeds will greatly increase and we can contain ocean acidification to a great extent. The promising resources for seaweed Mariculture in India are *Gelidiella acerosa* in intertidal regions, *Kappaphycus* alvarezii in deep waters and *Gracilariopsis lemaneiformis* in brackishwater regions. Hence large scale Mariculture of seaweeds which is a green technology employing *Gracilaria*, *Gelidiella* for agar, *Kappaphycus alvarezii* for k-carrageenan and *Ulva* and *Caulerpa* for their nutraceuticals and other secondary metabolites can help mitigate major greenhouse gas and can check ocean acidification, while the seaweed farmers can make a living out of the harvest.

Dr. P. Kaladharan is one of the most noted scientists working on Seaweeds in India. He has made significant studies and contributions on Primary productivity, Seaweed Mariculture, Seagrass ecosystems, Mangrove ecosystems & Coastal pollution along the Indian peninsular coast as well as Laccadive and Andaman archipelagoes. He has authored over 150 publications in journals of national and international repute. Dr. Kaladharan is currently working as a Principal Scientist at the Central Marine Fisheries Research Institute, Cochin under the Indian Council of Agricultural Research, Govt. of India.