

# MANAGEMENT OF COASTAL ZONE VEGETATION

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## I DUNE VEGETATION ALONG THE INDIAN COAST

1. Introduction :The coastal vegetation is of a specialised nature which grows under different conditions. It consists mainly of 4 different groups (1) marine algae or seaweeds (2) sea grasses (3) mangroves and (4) sand dune vegetation or strand flora. Marine algae and sea grasses are purely aquatic communities while the mangroves are partially aquatic plants which prefer intertidal areas having tidal influence. The sand dune vegetation or strand flora on the other hand, is a totally different plant community which grows on a sandy shore beyond the highest high tide level.

The ability of dune vegetation for binding the sand is well known. Cleghorn and Iyer have described the sand binding plants of the south-east coast of India. The rapid increase in the dessert area of the world has prompted intensive efforts to determine new and effective measures to stop or at least to control the movement of the sand dunes. Flora of the littoral states of India written by Hooker, Gamble, Haines, Blotter and Cooke include the classical works in which different species of the dune vegetation have been described.

Phytogeographical distribution of dune vegetation along the Indian coastline has received much attention from the beginning of this century. Champion and Seth have classified the littoral and tidal swamp forests of India. This was subsequently followed by the important work of Rao and Sastry on the classification of coastal vegetation.

Dune formation along the coast takes place as a result of movement of sand particles from the intertidal to the backshore region with the help of wind. These sandy beaches or dunes constantly change their profile or structure because of their dynamic nature. Sometimes, the moving sand dunes pose much danger to the shoreline. Here, the dune vegetation plays a major role in minimising the wind speed and also the movement of sand from the dunes. Along the east and west coasts of India, vast areas have been covered by sandy beaches or dunes.

## 2. Climatological factors

Climate of different maritime states shows a distinct variation. Four typical examples on the west coast (Jamnagar and Mormugao) and on the east coast (Pamban and Vishakhapatnam) will give a fair idea of the fluctuations in climatological conditions.

## 3. Classification of a sandy shore

Krumbein and Slack have suggested 4 zones of sandy shores, namely (1) nearshore bottom (2) foreshores, (3) backshore and (4) dunes. Champion and Seth have classified the dunes under 'littoral forests' (type 4A/11). Rao and Sastry have classified the strand vegetation into (1) Strand sand (Type 4A/SS1). (2) Strand rock (Type 4A/SR2). (3) Strand coal (Type 4A/SC3). The 'strand sand' has further been subdivided into (i) open pioneer zone or outer zone (ii) closed herbaceous zone (iii) middle mixed or bushy zone and (iv) inner woodland zone.

Generally, the pioneer zone of the sand dune area is covered by coarse sand as the finer sand particles are blown by the wind towards woodland zone. The soil in pioneer zone has low water holding capacity and it is slightly alkaline to acidic.

Different aspects of the sand dune like granulometry, pH, percentage of organic matter, etc. varies in open pioneer zone, closed herbaceous zone, middle mixed zone and woodland zone. Accordingly, soil changes from fine sand to coarse and with clay or silt. pH varies from 6.5 to neutrality. Percentage of calcium carbonate decreases, while organic matter increases from pioneer zone towards woodland zone. Increase in organic matter enhances the water holding capacity of the soil.

Chapman has divided the dunes into (i) embryo dune (ii) yellow dune and (iii) grey dune according to the growth of the dune with its vegetation.

**3.1 Species distribution** : There are several types of dune vegetation distributed along the east and west coasts of India. The composition of the vegetation changes with the climatological and edaphic factors. As mentioned earlier, the climate along the east and west coast shows considerable variation. As a result of this the species also show different patterns in distribution, zonation, etc.

Rao has further subdivided the west and east coasts into Kutch, Saurashtra, south Gujarat, Maharashtra, Mysore, Kerala, Tamilnadu, Andhra Pradesh, Orissa and West Bengal. So far, about 148 species, representing 115 genera of 49 different families which can be considered as dune vegetation have been reported from the Indian coasts.

It is observed that the dune species on the west coast of India are almost double than those of the east coast. The maximum dune species have been recorded from Tamilnadu followed by Kerala, Karnataka, Maharashtra, Andhra Pradesh and Saurashtra.

Rao has grouped the dune vegetation according to its specialised characters.

- (1) Mat forming and stranded creepers
- (2) Diffusely branching, prostrate or erect strand herbs and hedges
- (3) Strand climbers
- (4) Strand plants with perrenating organs
- (5) Strand shrubs and trees
- (6) Strand stunted trees

On the basis of these observations, he is of the opinion that the dune vegetation of India is a mixture of Polynesian and Malaysian, Persio-Arabian/Western and a few indigenous species.

3.2 Dominant dune vegetation : The major components of the dune vegetation from Saurashtra coast are Hydrophyllax maritima, Ipomea pes-caprae, Asparagus dumosus, Halopyrum mucronatum, Cyperus conglomeratus, C. aristatus and Sporobolus trimulus.

The sand dune flora of the Goa coast is represented by Ipomea pes-caprae, Spinifex littoreus and Cyperus arenarius.

Rao et al have described the dune flora of coastal Tamilnadu. The principal floral elements are Ipomea pes-caprae, Cyperus arenarius, Spinifex littoreus and these are found in the open pioneer zone.

Large scale plantations of coconut, cashew-nut, Casurina equisetifolia on the sand dunes can be included as the recently introduced species. However, there are some interesting species like Hyphnae indica along the Saurashtra and Goa coasts, which have come from other countries. It has generally been accepted that the dune flora includes a large element derived from the weed flora of the adjoining agricultural fields.

#### 4. Environmental factors

Climatological factors such as rainfall, air temperature, humidity and wind speed as well as the edaphic factors like sand texture, pH, humus content, soil temperature and the ground moisture play an important role in the distribution and growth of dune vegetation. Because of the extreme conditions the dune plants have developed certain characteristic features in their internal and external morphology.

Atmospheric temperature in the dune regions directly affects the dune temperature. The barren dune temperature is usually more than that in the vegetation area. The humus content and moisture minimise the temperature in the vegetation zone.

The rate of precipitation and the duration of rainfall are important factors for the dune community. These help in the germination of seeds, decomposition of organic matter, rapid growth of the dune plants and create favorable condition in the dune region. The rainfall by itself binds the sand temporarily. Generally the dune plants complete their life cycles during the monsoon and postmonsoon seasons.

Wind is one of the most important factors in the dune ecosystem. It helps in the formation, movement and also destruction of the dunes. It also decreases the surface moisture and the surface temperature. Increase in the wind speed enhances the transpiration rate in dune plants. Cyclonic or stormy conditions usually result in the destruction of dunes by dispersing dune vegetation and by changing the configuration of dunes.

Dune vegetations have a tendency to develop extensive rhizoidal root system which also helps in binding the sand. The shoot portion of the plants prevent or minimises the movement of sand while the fibrous or rhizoidal roots of these plants perform important physiological and mechanical functions. To face extreme conditions of high temperature, wind velocity and low water availability, these plants have developed thick cuticle, sunken stomata, specialised inflorescence and seeds, as well as fleshy leaves.

##### 5. Formation, growth pattern and propagation of dunes

The main species generally start their growth at the strandline and backshore region. This is a very sensitive area where there is every chance of dune erosion, either by the incoming waves during the highest tide or by strong winds.

The seeds, propugules and fragments of the dune vegetation start their germination from the strandline in favorable season (monsoon). At the strandline, the dune generally has litter or debris, which after undergoing decomposition, adds to the humus content. Once the seed germinates and the plant establishes the rate of their further growth, if conditions are favorable, becomes very fast. They try to develop horizontal and vertical root systems as early as possible. By the time favorable season is over, the plants are well rooted. This is the first stage in the formation of dune vegetation.

Second phase starts after the monsoon is over, that is, during the post-monsoon period. Surface moisture reduces during these months because of increase in the wind speed and air temperature. This results in the loosening of the sand grains

which are blown by wind. The dune flora obstructs the flow of sand and ultimately a mound is formed near the plant. If the rate of sand movement or accretion is more, the dune plants get completely buried under the sand. If the layer of sand is very thick and the dune plants are not able to grow, they ultimately die off. Otherwise, generally offshoots from the lateral sides or axils of the plants grow rapidly to come out of the sand dune for further growth. Occasionally due to high wind velocity, the dune vegetation gets uprooted and breaks into fragments, while the dune itself migrates. In favorable conditions, these scattered fragments get established and form their own small or big dunes. Once the plant is well settled and forms a dune, the offshoots of the same plants creep above or below the surface and forms another smaller dune (primary and secondary dunes). The secondary dunes, eventhough small in size, give some protection to the primary dune by regulating the wind speed.

Untawale and Nair have reported the growth pattern in some pioneer dune species from the Goa coast. These are as follows :

1. Ipomea pes-caprae (I. biloba) : This species belonging to the family Convolvulaceae has very long branches. It creeps all over the dune surface. The average length of the tap root varies from 5 to 8 m. The length of the creeping branches is from 5 to 7 m. The shoot system spreads covering a large area. At regular intervals, two rootlets develop in the nodal region to give mechanical strength to the creeper and also help in binding the dune sand. The average internode was found to be 10.3 cm, while the rootlets were 35.95 cm in length.
2. Spinifex littoreus (S. squarossus) : This plant belongs to the family Poacea (grass family). It is a very sturdy plant and shows all the characters of a typical dune vegetation. This plant also has similar tendency of growth like I. Pes-caprae. The average length of the main rhizoidal root is above 15-20 cm while the length of the rootlets at nodes is about 28.5 cm. Its shoot attains the average height of 72.1 cm. The length of the internode is about 6.7 cm.
3. Launea pinnatifida : This species belongs to the family Asteraceae (Compositae). Its tap root goes up to a depth of 50 cm depending upon the moisture content of the dune. The shoot portion develops into many offshoots which creep over the dune surface. At every node, there is a rhizoidal growth. The average length of these rootlets is about 8.25 cm, while the shoot is very dwarf, approximately 1.90 cm in height. The average length of the internode is 9.5 cm.
4. Cyperus arenarius : This is a Cyperaceous plant, which forms a dense mat on the dune surface, particularly in areas which are moist. Its rhizome is of a shallow type. The stolons of this plant creep below the surface about 3.5 cm deep. The shoot, however, attains an average height of 32.1 cm. The distance between the nodes is 4.55 cm.

The success of the dune plants lies in their ability to perennate and to develop extensive horizontal and vertical root and shoot systems in unfavorable conditions.

Propagation in dune plants is both by vegetative means and by seeds. Sprouting from the disintegrated shoots is common and important. The fruits and seeds of dune plants can remain viable in the d as well when occasionally exposed to sea water. The entire inflorescence or the arrangement of fruits in Spinifix littoreus has been specially developed to favour their dispersal in a wide area.

During the dry season most of the herbaceous species on the dunes, excepting a few sturdy plants, die off and remain dormant for a long time. However, again during the monsoon, they sprout and start their normal growth.

#### 6. Management of dune vegetation

From time immemorial the coastal regions along with sandy dunes, have been used by man for different activities. As a result of population pressure, the coastal dunes have been utilized without understanding the dangerous effects, their disappearance can cause to the surrounding environment. Indiscriminate cutting of coastal vegetation and over-exploitation of beach can for developmental works have resulted in erosion of vast coastal areas. Sand dunes are very important systems which need careful planning and management.

In India sandy shores and nearby areas are being extensively used for agriculture, housing, high ways, recreation and tourist resorts. Therefore, it is necessary to have effective management policies for the conservation and protection of sand dunes. Chapman and Ranwell have some important suggestions on the development of sand dunes with the help of plants. The most important factor in the dune management is the vegetation cover of the dunes. A few suggestions given below in developing or increasing the vegetation cover may be useful.

Movement of the sand or dune can be checked by growing appropriate plant species which should be planted in the backshore from where the sand movement begins. Thus a good carpet vegetation will effectively minimise the sand movement.

Suggested species of plants for the dunes are :

- (a) Ipomea pes-caprae
- (b) Spinifix littoreus
- (c) Cyperus arenarius
- (d) Periploca sp.
- (e) Urochondria sp.

At the land ward end of the backshore region, cover can be given by growing trees as wind breaker. The species suggested for this zone is Casurina equisetifolia which grows extremely well in Indian conditions. The litter fall of this species forms a dense mat on the surface, which not only checks the sand movement but also creates a favorable condition for the ground flora. The same trees after a few years can be effectively used for the fabrication of dune fence systems and mattresses to prevent the dune movement further.

Afforestation of dune areas can be done either by directly using suckers, stolons, fragments or by broadcasting of the seeds of dune plants. In the monsoon months, transplanting the seedlings from nurseries to dune areas will also be very helpful. These nurseries can be planned in coastal sandy areas. Seedlings can be grown in small polythene bags which could be transferred as such to the desired areas.

#### 7. Harvesting and processing

The plants should be dug out with care that most roots remain attached to the plants. The clumps should be separated into suckers with the desired number of stems. Plants should be cleaned of dead vegetation and should be trimmed to a length of 45 to 50 cm to facilitate mechanical transplanting.

Transplanting techniques for most species of beach grass are well known. Transplantation is highly recommended for the areas adjacent to the beach berm and for vulnerable areas which are subjected to erosion. Most critical areas require densely spaced transplants to ensure successful stabilisation. Transplanted seedlings of dune species can be protected by checker board methods using dead branches of any tree. The size of these checkers can be decided according to wind velocity and sand movement.

Seeding is practical only when protection from erosion and from dry winds has already been provided by mulching or frequent irrigation and is therefore not applicable to most beach areas. Beach grass seeds are not available from commercial sources and must be harvested from wild plants. The exploitation or cutting of dune vegetation by man or by cattle grazing should be strictly prohibited. Similarly, disturbing the seedlings of dune vegetation should also be avoided.

Sand dune areas could possibly be used for the cultivation of suitable crop plants which tolerate maximum salinity. Such species can even be grown under irrigation using brackish water or sea water. Efforts are being made by the Central Salt and Marine Chemicals Research Institute, Bhavnagar (Gujarat) to grow certain species of wheat, bajra, barley, cotton, jawar, kodo millet, onion, etc. on the coastal dunes of the Orissa. Also, large scale plantation of jojoba (oil plant) and guayule (rubber plant) in arid regions may prove to be economical.

Movement of the dune sand in the barren area could be controlled by using dune fences. These fences could be fabricated by using dry wood or dead branches of the most abundant trees of various coastal states, like Casurina, coconut, cashew and various mangrove trees. However utmost care is essential to avoid large scale cutting of well grown trees which may cause secondary problems.

#### 8. Fertilizers and manures for dune vegetation

In India, not much work have been done on the effects of fertilizers and manures for the sanddune vegetation. According to Adriani and Terwindt the use of nitrogen has a better effect than phosphates for the growth of dune vegetation. They have also investigated the possibility of using sand binders such as COLAS. Shell Sandfix and UNISOL. These sand binders are useful in the coastal areas with a moderate wind speed and thus lead to less sand movement. However, the regions which are frequently experiencing stormy weathers, the sand binders may not be of much importance.

Marine algae along the Indian coast get accumulated on the shores every year in a large quantity. Mixed seaweed meal or liquid extract from the seaweeds can be used either as a manure or liquid fertilizers particularly in the nurseries established for dune vegetations. These algae have agar, alginate, carrageenan, mucilage as well as several growth promoting hormones. Some of the algal extracts also can be used as sand binders. However, some of these aspects require further studies.

## II - RESEARCH AND MANAGEMENT OF MANGROVE ECOSYSTEM IN INDIA

1. Introduction : Mangroves along the Indian coast are one of the most neglected living resources which have been over exploited for various purposes. They have received inadequate and insufficient attention over the past several decades. The studies are few and scattered. No sustained effort has seriously been made to study them in a comprehensive manner. Even now the surveys on mangroves are far from adequate.

The total mangrove area along the Indian coast has been estimated tentatively to be 700,000 ha and 355,500 ha. The East coast, including Andaman-Nicobar Islands, contributes about 82% while West coast has only 18% of mangroves. There are about 45 species of mangrove flora and numerous other groups of floral and faunal components. The major factors responsible for the distribution and destruction of mangroves are the geomorphological and environmental characters as well as deforestation, reclamation and pollution. In the absence of any national plan, land use plan, as well as, conservation and utilisation strategy, mangroves along the Indian coast have reached an alarming stage, particularly along the west coast



A brief review of the status of various aspects of mangrove research suggests certain areas for future investigations. A tentative National Mangrove Plan is proposed for implementation of the Research and Development programmes in this field.

## 2. Research programmes

Recently, there have been a sudden change in the general outlook towards mangroves. Mangroves were abused for a long time, however from 1970 upto the present an awareness has been created as a result of which several research programmes on different aspects of mangroves have been undertaken.

The National Mangrove Committee under the Department of Environment is now the major funding agency for mangrove research programmes. There are others, particularly state forest departments, social organizations. State Pollution Boards, Wildlife Advisory Boards, World Wildlife Fund-India and Marine Park Authorities, which undertake various Research and Development activities in mangrove areas.

The major scientific work on mangroves presently going on along the Indian coast are indicated. There are about 14 major centres or institutions in India which are engaged in mangrove research. The important Research and Development programmes are on survey and distribution, remote sensing, eco-biology, fisheries, aquaculture, physiology, soil, pollution, productivity, afforestation, management and wildlife.

## 3. National Mangrove Management

In India, only a limited area of mangrove forests, like the Sundarbans, Andaman-Nicobar Islands, Mahanadi and Godavari delta, are managed. Forest products are mainly timber of selected species, poles, wood for charcoal and raw materials for the match industry and paper and pulp industries. However, no recent data on revenues earned from these used are available.

At its meeting in 1979, the National Mangrove Committee of India created by the Department of Environment, government of India recommended the following objectives for research and development as well as management of the mangrove environment.

## 4. Objectives

- a) Nationwide mapping of the mangrove areas, preferably by remote sensing techniques coupled with land surveys. Time series should be obtained to make an assessment of the rate of degradation of the ecosystem.

- b) Survey of mangrove forests quantitatively for area, climatic regime, rate of growth of forest trees, seasonal variations of environmental parameters.
- c) i) Assessment of suitable sites for 'Reserve Forests'  
ii) Conservation programme
- d) Afforestation of degraded mangroves
- e) Research and development activities to be increased in mangrove ecosystem
- f) Management of mangrove forests
- g) Ecology of mangroves
- h) Floral and faunal components
- i) Microbiological role
- j) Qualitative and quantitative studies for organic production and
- k) Biochemistry of organic matter and sediments

#### 5. Suitability Assessment

No effort was made earlier for any type of mangrove land use assessment. As a result, several thousand hectares of mangrove forests have been reclaimed or deforested. Recently, the benefit of such land use assessment has been recognized by the Government and its people. The government of India formed a National Mangrove Committee which is now preparing a National Mangrove Plan. Pending completion of such plan, existing mangroves along the Indian coasts are being protected from further destruction.

#### 6. Research for Planning

Most of the research projects undertaken by various organisations in India are application-oriented. These projects cover various aspects, i.e. remote sensing surveys, species distribution, ecology, utilization and conservation. Once these data are processed, a mangrove plan can then be prepared.

Apart from these activities, efforts are being made to protect the pristine mangrove areas and their wildlife.

#### 7. Development Alternative/Decision Tools

The Indian mangrove forests along the east and west coasts were totally neglected till recently. Logging and reclamation were undertaken without proper land use planning. Vast areas in the Gangetic Sundarban, Cochin backwaters, Bombay and Gulf of Kutch have lost their mangroves. However, the government of India has realized the importance of mangroves in the coastal environment and various aspects of planning are being carefully studied from the implementation point of view.

## 8. Allocation of Denuded/degraded Areas

Economic use : At present there is no definite allocation of denuded or degraded areas for specific purposes. However, a probable "Land Use Plan" shows the possibility of using these areas for various activities.

Even though there is no plan for the allocation, the coastal marshy areas are increasingly being used for industrial, housing, roads and many other purposes.

## 9. National Management Plan

Indian mangroves may be considered unique in the sense that they are inhabited by human populations for a considerable length of time. There has been great utilization of this resource as a source of livelihood. However, land use of mangrove areas has rapidly changed resulting in several ecological and economic losses.

It is therefore, necessary to prepare land use plans for the mangrove areas along the Indian coast for the purpose of management, preservation and utilization, keeping in view the socio-economic implications. It has been roughly estimated, on the basis of available information, that the original mangrove area in the past might have been approximately 14,00,000 ha. Out of this, at present only 700,000 ha area is covered by mangroves, while remaining areas has either been reclaimed or converted for different purposes as discussed.

Taking into consideration the conflicting interests and the multiple use practices of mangrove areas a tentative 'National Mangrove Plan' is proposed here, which indicates different guidelines for conservation and exploitation of various mangrove areas on the basis of the national priority. The coordination of the regional and state level committees, however, should be the responsibility of a National Mangrove Committee. The implementation of this set up would positively restore the coastal ecological balance, improve the environment and also the economy of the coastal population.

## III SEAWEED UTILIZATION AND ITS PRESENT STATUS IN INDIA

1. Introduction : Marinealgae as manure have been used since ancient time for paddy and fruit bearing plants. Recently, it was confirmed that seaweed manure is superior to the conventional organic manure. Seaweed as a liquid fertilizer has been successfully tried in the laboratory and in the field.

The present paper briefly discusses the status of Indian seaweed, its exploitation for industrial purpose, management and effective measures to conserve this valuable marine living resource. It also describes application of recently developed

techniques such as tissue culture, genetic engineering, molecular biology for improving yield and quality. Use of marine living resource on sustainable yield basis has also been discussed.

## 2. Status of Marine Algae in India

- a) Species diversity - Indian phycologists have conducted extensive research on morphology, taxonomy and distribution of Indian marine algae. According to Untawale et al. there are about 624 marine algal species of various groups. From station-wise distribution of seaweeds for different algal groups it seems that Tamil Nadu coast dominates in number of algal species (302) followed by Gujarat (202), Maharashtra (159) Lakshadweep group of islands (89), Goa (82), etc. The recorded algal species belong to 204 genera, 61 families and 15 orders.
- b) Resource survey - It has been estimated that about 100,000 tonnes (wet wt.) of seaweeds can be harvested annually from the Indian coast. Global seaweed potential is estimated to be about  $1821 \times 10^4$  tonnes wet wt. of which about 4.83% is being harvested from east and west Indian ocean. Along the Indian coastline, Gulf of Kutch and Palk Bay are proven areas for luxuriant seaweed biomass and are being exploited for quite some time. At these localities some seaweed species such as Sargassum, Gelidiella and Gracilaria have been overexploited.

The methodology used for survey purpose differs widely and the estimates are incomparable. A standard methodology for the proper and reliable estimation of the biomass is required to be followed.

The algal surveys conducted so far are mostly from the intertidal areas and for commonly and abundantly growing species. The subtidal areas have been neglected due to non-availability of equipments and trained manpower. Recently introduced new and effective techniques such as underwater diving, remote sensing such as satellite imageries and infra red as well as coloured aerial photography, if employed, could increase the present estimates.

- c) Seaweed Utilization - Utilization of seaweeds for industrial purposes in India dates back to the 2nd World War when soda ash, alginates and iodine were extracted from seaweeds. Increasing demand of agar and alginates lead to over exploitation of the phycocolloid yielding seaweeds. The major seaweeds that are used for the purpose are Gelidium spp., Gelidiella spp., Gracilaria spp for agar and Sargassum and Turbinaria spp for alginates. Agar and alginate contents in the seaweeds are given. The estimated harvestable qualities of these economically important seaweeds found along the Indian coast is given. Our seaweed industries produce about 60 tons of agar and 600 tons of

alginates annually. Of this quantity, 50% of agar is in the form of bacteriological grade.

The quantity of alginates and agar produced cannot meet the present industrial demands. Hence fair amounts of these products are being purchased from other countries. The demand for phycocolloid and their raw materials is estimated to increase by 10% annually and with available resources it will not be possible to cope up with the increasing trend, hence large scale cultivation of the economically important seaweeds is the only alternative we can think of at present.

- d) Other uses of seaweeds - Use of seaweeds as fodder is known from ancient times. The coastal inhabitants used seaweeds to feed cattle, poultry, piggery, etc. Some of the green algae are used as fish food in aquaculture. Various minerals and vitamins are also extracted from the marine algae. Uses of seaweeds as manure is increasing day by day. Organic fertilizers have been prepared from the seaweeds and effectively used (Bhosle et al., 1975; Dhargalkar and Untawale, 1980). Large quantities of drifted seaweeds on beaches could be used for this purpose.

Use of seaweeds as human food is being practiced in South East Asian countries for a long time. However, it is not being used in India till now. Efforts have to be initiated to develop taste for seaweeds as part of the Indian diet to overcome protein, iodine and trace metal deficiency. Some of the seaweed species have shown biological activities. About 50 marine algae have been screened for bioactive compounds. Results achieved so far are very encouraging.

### 3. Seaweed Cultivation

Although some indigenous technical know-how for the cultivation of different economically important seaweeds have been developed, it has not gained much attention for large scale cultivation. Technical know-how in this field has been demonstrated at Malwan, Okha, Mandapam to cultivate Gelidium spp., Gracilaria edulis, Hypnea musciformis, Monostroma sp. and Enteromorpha sp. Most of the industries depend entirely on the natural resources of the Indian coast. It is high time to take up cultivation of these plants on larger scale in order to increase raw materials and production of these vital phycocolloids to meet growing demands.

To augment these resources further, techniques, such as tissue culture, genetic engineering, molecular biology could be taken up to have desired strains and high quality yield of respective products. A few institutes and universities have initiated this programme in India. These techniques may be applied to obtain high yielding species for agar, alginates, carrageenan, proteins of any desired-quality and may also be useful in producing a few kelp species like Macrocystis and Laminaria which can be grown in Indian waters. Intensive

inbreeding and selection, X-ray induced mutants to produce new and improved strains are possible. Successful application of these techniques will open new vistas in seaweed research in the next country.

The ability of some algal species to tolerate sewage pollution has been recognized. Industrial complexes along the coast discharge effluents in the surrounding waters, and these have shown diverse effects on marine algae. Efforts are required to cultivate some of the seaweeds that can grow in these effluents to reclaim the area to some extent.

In view of future large scale seaweed farming, it would be necessary to know about the diseases caused by various marine organisms and also suitable remedies to control these diseases.

#### 4. Introduction of new algal species

One of the major aspects for the future development of seaweed industrial potential will be introduction of some economically important and high yielding marine algal species in suitable coastal waters. Algal species like *Eucheuma*, which is being cultivated in Philippines, Indonesia and USA on large scale is a good source of Kappa-Carrageenan, may be ideal seaweed for Indian conditions. Some more high yielding algal species may be taken up. Although this aspect will increase the production, lot of research and development work is needed in this field so that species introduced will not outrage existing species, upsetting the ecological balance.

#### 5. Energy from biomass

Investigations have been carried out on the potential of seaweed as fuel through anaerobic digestion on methane. It has been technically feasible to develop and cultivate a particular clone with specific characteristic through tissue culture. For instance, a particular clone of *Gracilaria tikvahiae* has a capacity to propagate vegetatively for long periods without genetic change. Such seaweeds can be used as "energy crops" to meet present energy crises.

#### 6. Marine taxonomy

Although vast literature is available on taxonomy of Indian seaweeds, it has been neglected for some or the other reasons. With a view of seaweed utilization occupying forefront in the next century, it is necessary to have well organized marine algal taxonomical centres in India. Coastal Universities can take up this programme and develop a chain of herbarium centres in India. Existing centres in the Universities and institutions are required to be strengthened and improved with adequate manpower and financial assistance.