II. Review of Literature

Coastal Environment

The coastal areas consist of 20% of the earth’s surface. Half of the world’s population live within a distance of less than 200km from the coast and 37% live no more than 60km away from the coast. Coastal areas have rich biological importance and support various life forms. They play an important role in nutrient cycling in the marine environment. The present scenario for many of the coastal ecosystem and resources are of great concern as their status is declining due to various human activities. Modern human civilization and coastal zones make poor companions. Most of the activities of people damaged coastal ecosystems either directly or indirectly (Knowlton, 2001).

In addition to direct human interference, global climate change and natural disasters such as storms, cyclones and tsunami pose serious threat. The impacts of disasters, whether natural or man-made, not only has human dimensions, but environmental as well. The coastal ecosystems were already experiencing multiple problems and many coastal resources are in highly stressed conditions due to threats mainly from human and nature. The sea contains all the elements necessary to maintain healthy life. Thus, seaweeds are considered the most nutritious plants on earth. Their nutritive values greatly exceed those found in other food sources and are in organic form that humans can readily utilize (Yaychuck, 2006). Seaweeds are marine macroalgae and primitive type of plants, growing abundantly in the intertidal and subtidal regions of the sea, estuaries and back waters. They flourish wherever rocky, coral or suitable substrata are available for their attachment.
Economic Importance of Seaweeds

About 6000 species of red seaweeds (Rhodophyceae), 2000 species of brown seaweeds (Phaeophyceae) and 1200 species of green seaweeds (Chlorophyceae) occurred globally and the world production of seaweeds was estimated as 21,65,675 million tons per year (Kaliaperumal, 2007). Seaweeds are one of the commercially important marine living and renewable resources of our country. They contain more than 60 trace elements, minerals, proteins, iodine, bromine, vitamins and several bioactive substances of economic value and they also serve as both feeding and breeding grounds for invertebrates and fishes (Patricia, 2003; Krishnamurthy, 2005). Of 9200 species in the world, 844 species are in India with total standing crop of 91,339 tons (FW) consisting of 6,000 tons of agar yielding seaweeds, 16,000 tons of algin yielding seaweeds and remaining edible seaweeds (Kaliaperumal, 2000).

Traditionally seaweeds have been used in treating arthritis, constipation, nervous disorders, rheumatism, colds and skin irritation (Yaychuck, 2006). It also improved lung function, prevents breast cancer (Ryan, 2005), boosts heart health (Fielder, 2005), weight loss, high cholesterol, heart disease, high blood pressure and thyroid disturbances. Seaweeds contain significant amounts of protein, sometimes as much as 48% and as a good source of enzymes it can be incorporated on vegan, vegetarian, macrobiotic and raw food diets (Risingtide, 2006). Seaweeds possess more bio-available minerals than any other class of food. It is an extraordinary source of colloidal minerals and trace elements. The large brown seaweeds known as kelp were also rich sources of alginic acids which remove heavy metals and radioactive isotopes from the body and the bones (Risingtide, 2006).
Seaweeds are especially rich in calcium and iodine. They also supply chromium (essential for glucose utilization), zinc (for collagen strength and healthy skin), iron, potassium, copper, sulphur, silver, tin, zirconium, phosphorus, silicon (crucial to skin elasticity), magnesium, manganese, boron, bromides, and other trace minerals necessary for health (Yaychuck, 2006). Seaweed solutions are also utilized as tonics for detoxification and nutritional supplementation resulting from diseases such as rickets, tuberculosis and various states of debility. Homeopathy also prescribed seaweed and its derivatives for various ailments including obesity (Mitton, 2006).

Modern agriculture has managed to increase the productivity of food grains with minimum use of plant nutrients. But the intensive application of chemical fertilizers deteriorated the soil fertility and disturbed the ecological equilibrium of biodiversity (Hansra, 1993). Hence the current effort is to explore the possibility of an alternative for chemical fertilizer. The merits of seaweed manure over farmyard manure are easy availability of macronutrients, easily compostable organic matter and the availability of trace elements. The seaweed fertilizers are found to be more successful in promoting productivity than chemical fertilizers (Bokil et al., 1972). The seaweed extracts contain macro nutrients, trace elements, organic substances like carbohydrates, amino acids and plant growth regulators such as auxin, cytokinins and gibberellins (Williams et al., 1981) and therefore seaweed extracts are used as Seaweed Liquid Fertilizer (SLF). The application of seaweed liquid fertilizer in agriculture has been attempted by many workers (Rama, 1990; Murugalakshmi et al., 2002).

Seaweeds are the important component of living resources of the sea and the world market of seaweeds or seaweed products is more than 10 billion dollars. Brown
seaweeds contain large amounts of polysaccharides and alginates while red seaweeds are rich source of carragenans and agar. Other minor polysaccharides include fucoidans (brown seaweeds), xylans (red and green seaweeds) and ulvans (green seaweeds). Seaweeds also contain the storage polysaccharides, notably laminarian in brown seaweeds and floriden starch in red seaweeds (Lahaye and Jailbault, 1991).

**World Scenario of Seaweed Resources**

It has been estimated that the seaweed resources of the world comprised about 1460 million tons wet weight brown algae and 261 million tons wet weight red algae. The total seaweed production may be about $1.721 \times 10^4$ tons wet weight annually (Michanek, 1975). The major sources of seaweeds are in the Northeast, Western Central and Southwest Atlantic and the Eastern Central and Northwest Pacific areas. There was not much information regarding the Antarctic and Arctic regions. Worldwide, there are nearly 42 countries with reports of commercial seaweed activity and about 221 species of seaweeds have been utilized commercially. Of these, about 145 species are used for food and 110 species for phycocolloid production (Sajid and Satam, 2003).

Considerable work on seaweed distribution has already been carried out in various parts of the ocean and coasts around the world. A review of seaweed resources of the world has been made by Michanek (1970 and 1975). Information is available on the seaweed resources of North American coasts (Taylor, 1957 and 1960; Matheison and Benniman, 1986; Abbott, 1983 and 1989), Brazil (Soriano, 1999), Western Atlantic (Wyne, 1998) and Uruguayan coasts (Coll and Oliveira, 1999). Seaweed resources and their utilization were reported from Mediterranean coast (Michanek, 1986; Rao and Bekheet, 1977) and Red sea (Aleem, 1978). The richest seaweed vegetation occurred
along the coast of South Africa (Gillespie et al., 1995), Mauritius (Dulyamode, 1995) and Naissar Island (Kukk et al., 1997).

Basic research on taxonomy and ecology of macroalgae provides important information for further uses of seaweeds; for example in taxonomy and uses of economically important species in south east Asia (Prudhomme and Trono, 2001) and a series of taxonomy of economic seaweeds with reference to some Pacific species (Abbott, 1994, 1995). However, there are only a few scientific publications on macroalgae from Southeast Asian waters (Ogawa et al., 2003), although they are known to be highly valuable both ecologically and economically.

Today there is the greatest awareness in many Asian countries also for the need of seaweeds to meet the demand for their economic importance especially in Japan (Suto, 1949), China (Johnston, 1966), Philippines and Indonesia (Taylor, 1966), Pakistan (Shameel et al., 1989), Thailand (Egerod, 1974), Sri Lanka (Boergesen, 1937) and Oman (Wyne and Jupp, 1988). Various countries concentrated their researches on seaweed resources. But in India the seaweed research was in the experimental stage only.

**Seaweed Resources in India**

A series of systematic and scientific surveys along the Indian coast for seaweed resources have been initiated by various agencies including CSMCRI in collaboration with different research and government organizations (Subba Rao and Vaibhav, 2006). Most of these surveys were carried out to assess the economically important seaweeds only. The survey was carried out along Gujarat coast (Chauhan and Mairh, 1978) and Maharashtra coast (Chauhan, 1978). About 1250 tons and 780 tons (FW) of seaweeds per year were reported from the respective coastal regions. Goa coast was surveyed by
Untawale et al. (1983) from Donapaula to Chapora regions whereas Dhargalkar (1981) reported 2000 tons (FW) of seaweeds for the entire coast of Goa. The Karnataka coast was showed poor seaweed growth and data for qualitative survey only were able (Agadi, 1985).

The seaweed resources in Kerala coast were given by Chennubhotla et al. (1988). The total standing crop of 1000 tons fresh weight was estimated. Survey was conducted during May to June 1988 to study the seaweed distribution and resources along the Kerala coast. Seaweeds collection was made at 15 localities from intertidal and subtidal regions and totally 35 species belonging to 28 genera and 18 families were recorded of which 8 genera and 13 species belong to Chlorophyceae, 3 genera and 3 species to Phaeophyceae, 15 genera and 17 species to Rhodophyceae and 2 genera and 2 species to Cyanophyceae (Kaliaperumal and Chennubhotla, 1997).

The Andhra Pradesh coast was surveyed by CSMCRI in collaboration with Department of Fisheries and Government of Andhra Pradesh during 1979-1982 in three sectors. The average standing crops were found to be about 7500 tons in FW (Anon, 1984). As such, data for seaweed resources of Orissa coast were not available, but a few surveys were made for Chilka Lake, which were summarized here. First estimates for seaweed resources of this lake came from Mitra (1946) who reported 4-5 tons (FW) of Gracilaria per year. However more recently, Rath and Adhikari (2004) gave potential estimates of 26,970 tons (DW) of macroalgae for the lake for the year 1999-2000.

The West Bengal coastline has been surveyed for its seaweed resources availability by Mukhopadhyay and Pal (2002). This survey was provided only an idea of the biodiversity of seaweeds along the coastal region of West Bengal. A systematic
survey was conducted only for the islands of Lakshadweep during 1977-1979 by CSMCRI and the estimated values ranged from 4955 to 10,077 tons (FW) for all the ten islands surveyed, with an average value of 7519 tons in FW (Anon, 1979). The Andaman and Nicobar Islands have been partly surveyed by CMFRI. The standing crop of 19,111 tons (FW) was estimated for an area of 40km$^2$ out of 212km shoreline of South Andaman Island (Muthuvelan et al., 2001). An estimate of 120 tons (FW) of seaweeds was recorded for Little Andaman islands by Gopinathan and Panigrahy (1983). Unfortunately, remoteness and lack of logistic support hampered the detailed and complete survey of seaweed wealth for many of the islands. No systematic survey was undertaken for the union territories of Pondicherry, Daman and Diu and very less scattered information available was for species diversity and distribution pattern.

**Seaweed Wealth of Tamil Nadu**

The Tamil Nadu coast was surveyed during 1971-1976, covering a distance of 320km from Rameswaram and adjoining islands to Melmidalam (Colachal) by CSMCRI, in collaboration with Central Marine Fisheries Research Institute (CMFRI), Cochin and Department of Fisheries, Government of Tamil Nadu. The survey was conducted in five sectors. The total standing crop of seaweeds in the intertidal region of Tamil Nadu was estimated at 22,044 tons (FW) in a potential area of 9891.35ha of the 20,000ha total area surveyed (Anon, 1978). In India, about 850 species of seaweeds were reported (Oza and Zaidi, 2001) and their commercial exploitation has been commenced from 1966 onwards. At present industries were annually utilizing 1518 tons (DW) of red seaweed and 2285 tons (DW) of brown seaweed for the manufacture of agar, algin and liquid fertilizer (Kaliaperumal et al., 2004).
Seaweeds were cultivated for supply of raw material to the seaweed industries and for their use as human food. In India, seaweeds collected from wild were used as raw material for the production of agar, alginate and liquid seaweed fertilizer. About 20 agar and algin industries were functioning at different places in the maritime states of India such as Tamil Nadu, Karnataka and Kerala. Annually about 2000 tons (DW) of alginophytes (*Sargassum* spp, *Turbinaria* spp and *Cystoseira trinodis*) and 1000 tons (DW) of agarophytes (*Gelidiella acerosa, Gracilaria edulis, Gracilaria crassa, Gracilaria foliifera, Gracilaria verrucosa and Gracilaria salicornia*) exploited from the natural seaweed beds of south Tamil Nadu coast were used as raw materials by these industries. These quantities, particularly agar yielding seaweeds were inadequate to meet the raw material requirements of Indian seaweed industries. As numbers of seaweed industries were coming up every year, there was an increasing demand for the raw materials, which the existing resource cannot meet (Krishnamurthy, 1967 and 2005; Kaliaperumal and Kalimuthu, 1994).

In India, rich seaweed beds occurred only in certain areas. Several species of green, brown and red algae with luxuriant growth observed along the southern coastal region of Tamil Nadu from Rameswaram to Kanyakumari covering 21 islands in Gulf of Mannar (Kaliaperumal, 2007). Studies were made by Chacko and Malupillai (1958), Thivu (1960), Varma and Krishna (1962) and Desai (1967) on seaweed resources of Gulf of Mannar area. Tamil Nadu possessed the third largest coastline in India extending over about 907km. The coast line had variety of coastal and marine ecosystems harboring rich marine resources. The Gulf of Mannar region was an area of special concern for its priority and diversity and multiple use management status. Out of 142 species of seaweed
(marine algae) comprising 42 species of green algae, 31 species of brown algae and 69 species of red algae occurred in Gulf of Mannar area. About 17 economically important species of agarophytes, carrageonophytes, alginophytes and edible seaweeds were recorded from the area.

Gulf of Mannar Biosphere Reserve has a very good diversity of seaweeds. The marine environment water current, less pollution and shallow water surroundings are favorable for good diversity of seaweeds in the area. The coral reef areas found around 21 islands in the Gulf of Mannar also provided better space for growth of seaweeds. The agarophytes and alginophytes resource from point Calimere to Cape Comorin was estimated at 6,000 tons and 60,000 tons (DW) respectively (Chacko and Malupillai, 1958). The agarophyte resources in Pamban area was estimated at 7.1tons/annum (Thivu, 1960).

The first detailed seaweed survey in the Gulf of Mannar was conducted by Desai (1967) in a 10 mile area at Rameswaram and 20 mile area at Kilakkarai for red algal resources. The estimates for Gelidium and Gracilaria were 300 and 3000 tons (DW) per annum respectively.

Seaweed resources survey was conducted by Varma and Krishna (1962) in Mandapam area. Two surveys, a preliminary one in 1958 and the other detailed one during 1962-1963 covering a total area of 234.25sq.km between Dhanushkodi and Hare Island were made. The estimated standing crop (FW) in the survey made during 1958 was 33,769tones for Gracilaria spp. 1,290 tones for Gelidiella acerosa and 83, 835tones for brown algae. In the survey conducted during 1962-1963, the estimated standing crop was 66,989, 3375 and 1,31,588tones (FW) for Gracilaria spp., Gelidiella acerosa and brown algae respectively.
The seaweed flora of Gulf of Mannar was studied by different persons since 1955 to 2006. Chacko et al. (1955) have reported 134 algae and Krishnamurthy and Joshi (1970) listed 103 species from Krusadai Island. 180 seaweeds collected from Mandapam area has been published by Umamaheswara Rao (1969). The coral reef flora of Gulf of Mannar and Palk Bay areas around Mandapam was studied by Umamaheswara Rao (1972) and reported a total number of 61 seaweed species. Subbaramaiah (1974) reported 41 species of seaweed from Mandapam Camp. Subbaramaiah et al., (1977) studied the distribution pattern of seaweed at Pamban

An account of 46 species of seaweed occurring at Trichendur was given by Krishnamurthy (1980). Seaweeds were collected from six localities in Gulf of Mannar namely Tuticorin, Manapad, Trichendur, Idinthakarai, Kovalam and Muttam (Kaliaperumal and Pandian, 1984). The number of seaweed species recorded from these places was 56, 43, 34, 41, 38 and 25 respectively. A total number of 155 species have been reported in the seaweed resources survey conducted from Rameswaram to Athankarai and from Thonithurai to Melamidalam covering 21 islands in Gulf of Mannar at 0 to 4m depth during 1971-1976. In this survey, 102 species of seaweeds were recorded (Anon, 1978). Varma (1960) reported 51 seaweed species from pearl beds from Tuticorin. Mahadevan and Nagappan (1967) recorded 12 numbers of in deep waters of Tuticorin. A total number of 99 seaweed species (20 species of green algae, 18 species of brown algae and 61 species of red algae were encountered in the seaweed resources survey conducted at deep waters from Dhanushkodi to Kanyakumari (Kaliaperumal et al., 1998).

The above studies showed that a total number of 142 species of seaweed comprising 42 species of green algae, 31 species of brown algae and 69 species of red
algae occurred in the Gulf of Mannar region. The number of algae of different groups recorded in the Gulf of Mannar Mainland, Gulf of Mannar Islands and Palk Bay are given below.

<table>
<thead>
<tr>
<th>Group of Algae</th>
<th>Gulf of Mannar Main land</th>
<th>Gulf of Mannar Island</th>
<th>Palk Bay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green algae</td>
<td>17</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Brown algae</td>
<td>13</td>
<td>24</td>
<td>8</td>
</tr>
<tr>
<td>Red algae</td>
<td>26</td>
<td>57</td>
<td>22</td>
</tr>
</tbody>
</table>

This reveals the richness and varied species composition in Gulf of Mannar region. The following economically important species were recorded apart from other species, *Gelidiella acerosa*, *Gracilaria edulis*, *Gracilaria foliifera*, *Gracilaria canaliculata*, *Gracilaria spp.* (agarophytes); species of *Hypnea* and *Acanthophora* (Carrageenophytes); *Sargassum spp.*, *Turbinaria spp.*, *Cystoseira trinodis* and *Hormophysa Cuneiformis* (alginophytes); species of *Ulva, Enteromorpha, Caulerpa, Codium, Hydroclathrus* and *Laurencia* (edible seaweeds). Kannan and Thangaradjou (2006) reported 117 of seaweeds (31 species of green algae, 32 species of brown algae and 54 species of red algae) from Gulf of Mannar region. From the previous reports, the number of species available from Idinthakarai coast were 41 (Kaliaperumal and Pandian, 1984), 22 (Sasidharan and Krishnamurthy, 1998) and 46 (Selvaraj and Selvaraj, 1997), from Kanyakumari coast was 33 (Nair et al., 1993) and from Arockiapuram coast was 86 (Stella et al., 1997).

The total number of genera and species of seaweed belonging to three divisions, occurring at Kanyakumari, Vattakottai, Kootapuzhi, Kudankulam and Idinthakarai were
listed. Maximum number of 98 seaweed species from Kudankulam and minimum number of 62 species from Kootapuzhi were recorded. A total number of 96 species from Idinthakarai, 94 from Kanyakumari and 67 species from Vattakottai were collected. The red algae dominated in all these places than the green and brown algae. Totally 121 species were recorded in all the five places of which 31 species belong to Chlorophyta, 25 species to Phaeophyta and 65 species to Rhodophyta (Edwin, 2004).

**Seaweed Ecology and Distribution Pattern**

The distribution pattern of seaweeds on the shores of Pamban was given by Subbaramaiah *et al.* (1977). Studies on the distribution and seasonal changes in the seaweed flora were made at seven localities along Rameswaram, Pamban, Mandapam, Pudumadam and Kilakkarai (Kalimuthu *et al.*, 1992). Totally 102 species of seaweeds were recorded from all stations of which 37 species belonged to Chlorophyta, 21 species to Phaeophyta and 44 species to Rhodophyta. Out of 102 species 44 species were seasonal and occurred during some part of the year, while 60 species occurred throughout the year. Among these localities, more number of 77 species at Mandapam and less number of 35 species at Rameswaram were recorded. A total number of 67 species from Pudumadam, 49 species from Kilakkarai and 45 species from Pamban were recorded.

Survey of the deep water area from Kilakkarai (Appa Tivu) to Rameswaram Island (Dhanushkodi) was undertaken from December 1990 to January 1991 in the fourth sector survey of deep water seaweed resources off Tamil Nadu coast, which formed the last phase of the survey from Rameswaram to Kanyakumari carried out during 1986-91. The area of 417.5 sq.km was surveyed yielding a total biomass of 18,162.5 tons (wet) seaweeds. Out of 167 stations surveyed in 13 transects, vegetation occurred only in 12
stations. Of the 29 species of seaweeds recorded 8 belonged to Chlorophyceae, 8 to Phaeophyceae, 12 to Rhodophyceae, and 1 to Cyanophyta, One species of sea grass *Cymodocea serrulata* was also recorded. Twenty species were found in estimable quantities, of which the following 8 species were abundant: *Halimeda macroloba*, *Spatoglossum asperum*, *Zonaria cre- nata*, *Sargassum ilicifolium*, *Amphiroa fragilissima*, *Hypnea musciformis*, *Botrycladia leptopoda* and *Lyngbya majuscula* with a biomass of 1325, 9775, 650, 1550, 1925, 300, 862.5 and 1012.5 tons (wet) respectively. The species of *Hypnea* and *Sargassum* could be exploited for the manufacture of phytochemicals (Rama et al., 1993).

The distribution of seaweeds and seagrasses during the deep sea survey conducted in the first sector from Kattapadu to Trichendur in Tamil Nadu coast between December 1986 and March 1987 covering an area of 650 sq. km. In this survey, 58 species of marine algae were recorded of which 7 belong to Chlorophyceae, 12 to Phaeophyceae and 39 to Rhodophyceae. Three species of seagrasses viz. *Cymodocea serrulata*, *Halophila ovalis* and *Halophila ovala* were also recorded at the depths ranging from 5.5 to 21.5 m. *Halimeda macroloba*, *Dictyota bartayresiana*, *Dictyota maxima*, *Gracilaria corticata* var. *corticata*, *Gracilaria edulis*, *Sarcodia indica*, *Sarconema filiforme*, *Solieria robusta*, *Hypnea esperi* and *Hypnea valentiae* were found to be dominant and widely distributed (Kaliaperumal et al., 1995).

The biodiversity and density of seaweeds of Gulf of Mannar have come down gradually over a period of years (Krishnamurthy, 2006; Kannan and Thangaradjou, 2006). The rich seaweed flora was seen in early seventies. Many of the genera and species have become scarce and several are altogether absent after 1980. The region was
having more than 200 species of seaweeds. Now 78 species of seaweeds (27 green algae, 19 brown algae and 32 red algae) were commonly found growing in the Gulf of Mannar region. The decrease in the species composition is mainly due to indiscriminate collection of seaweeds for commercial exploitation. During commercial exploitation of *Gelidiella acerosa*, the seaweed canopy was removed and the shade loving seaweed were exposed to air and such exposes and desiccation cause degeneration of seaweed in their natural habitats. This probably was the main reason for the loss of biodiversity in Gulf of Mannar region. It also caused serious problems to the coral reef ecosystem. They were now either scarce or extinct from the natural seaweed beds of Gulf of Mannar.

The decrease in seaweed resources was also due to sand cover on the reef, making the habitats unsuitable to many benthic algae which were abundant in earlier years on the coral stones. This may be also due to bottom trawling and shore to seine fishing on seaweed beds and changes in other ecological and environmental conditions. So it is necessary to conserve and increase the seaweed biodiversity in Gulf of Mannar.

The survey of seaweed resources in Gulf of Mannar was conducted 33 years back also (Anon, 1978). It was very essential to conduct periodical resources survey of seaweeds in the Gulf of Mannar to monitor the marine algal biodiversity and to know the changes taking place in the distribution, seasonal variation, frequency, density, abundance and standing crops of seaweeds. It was also very necessary to conserve the wild species of seaweeds occurring in the Gulf of Mannar by adopting rational commercial exploitation during the peak growth period of the seaweeds from July to January every year without causing any damages to the seaweed ecosystem. A ban on harvest of seaweeds from February to June may be implemented strictly in order to allow
the young plants to grow. During the period February to June, the fisher folk involved in seaweed collection may be engaged in seaweed cultivation and other mariculture activities (Kaliaperumal, 2006 and 2007).

Seaweeds play a pivotal role as one of the main groups of primary producers in marine ecosystems. Diversity, distribution and abundance of seaweeds are known to be influenced by both physical and biological factors (Lobban and Harrison, 1994; Nybakken, 2001). Grazing pressure, a biological factor, has been regarded as the major factor controlling the structure of macro algal communities (Anderson and Underwood, 1997; Underwood, 1998). There have been various studies on inter and intra specific competition for nutrients and space of macroalgae during the last fifteen years (McCook, 1997, 1999, 2001; Miller and Hay, 1998; McCook et al., 2001; Lirman, 2001) and they are known to determine patterns of macro algal dominance or exclusion in coral reef ecosystems.

Water motion, a physical factor, has been proven to be a key determinant of macro algal production (Lobban and Harrison, 1994), influencing a number of abiotic and biotic factors that control macro algal zonation and community structure, including nutrient availability, temperature (Costa et al., 2002) and rates of herbivory (Lubchenco, 1978; Kim, 1997; Lotze et al., 2000; Belliveau and Paul, 2002). Water motion can also influence the community structure via wave action (Lobban and Harrison, 1994), which influences propagule dispersal, fertilization, settlement and recruitment (Vadas et al., 1990; Serrao et al., 1996; Costa et al., 2001).
The role of marine macro algae in the economic life of humans and ecosystems is relatively well known. In recent years, seaweeds have also been considered as potential solar energy converters to provide biomass as a source of nutrients and energy for methane producing bacteria (Lobban and Harrison, 1994). Some 400-500 species of seaweeds are collected for food, fodder, or chemicals, but fewer than 20 species in 11 genera are commercially cultivated (Lobban and Harrison, 1994). These values of seaweeds are known and have been supported for a series of cultivation studies for example FAO reports (Leipzig, 1996).

Seaweeds typically showed high species diversity and cover on coral reefs. The seaweed distribution of coral reefs of Lakshadweep have been reported (Anon, 1979; George et al., 1986; Jagtap, 1987; Kaliaperumal et al., 1989; Chennubhotla, 1992). Untawale and Jagtap (1984) studied the seaweeds of minicoy. Kaladharan and Kandan (1997), Gulshad et al. (1999) studied the productivity of seaweeds in Minicoy. Coral reef seaweeds exhibited definite seasonal variation that was linked to changes in environmental factors (Hillis, 1980; Martin, 1993; Santelices, 1997).

Seaweed distribution and abundance in three regions of coral reef was studied at Minicoy Island in Lakshadweep. Significant seasonal differences were noticed in the three regions with maximum biomass during monsoon and minimum biomass in the post-monsoon season. Laurencia ceylanica formed a continuous mat coral reef and Halimeda gracilis (56.0%) and Turbinaria ornata (32.0%) were the major seaweeds of the coral reef. Minor seaweeds on the reef were Gelidiella acerosa, Boergesenia forbessi, Sargassum duplicatum and Cladophoropsis zollingeri (Gulshad et al., 2000).
Studies on seasonal distribution of seaweeds were carried out by Varma (1959), Rajendran et al. (1991), Anon (1991) and Kalimuthu et al. (1992). Studies on seaweed distribution in the deeper waters have been made by Varma (1960), Mahadevan and Nagappan (1967) and Kim et al. (1998).

Seasonal studies on marine macro algae of Indian waters from East and West coast of India and other islands were studied by various authors (Srinivasan, 1946, Gopalakrishnan, 1970; Umamaheswara Rao, 1972; Untawale et al., 1989; Kalimuthu et al., 1995; Jayachandran and Ramaswamy, 1997; Selvaraj and Selvaraj, 1997; Mohammed et al., 1999; Venkataraman, 2005; Rath and Adhikary, 2005; Sulekha and Panikkar 2007). Seasonal studies on marine algae of the Visakhapatnam coast was studied by Umamaheswara Rao and Sreeramulu, (1964 and 1970). Numerical studies on marine algae of Visakhapatnam coast was carried out by Narasimha Rao (1984) and Prasanna (2009).

**Physico-chemical Characteristic of Marine Water**

Oceans constitute the most important part of physical and chemical environment. About 71% of the global surface is covered by the oceans and seas. More than two thirds of the earth’s surface lies beneath the sea. It is heterogeneous in the distribution and of biological and physico-chemical factors. Different parts of the sea have different types of organisms based on geographical, topographical and environmental parameters. The quality as well as quantity of these variations changes with respect to place and time. Depending on the interaction of these factors, vegetation may vary in various parts of the sea (Seshappa, 1991).
Physico-chemical factors play an important role in the growth and distribution of seaweeds. Smith (1950) reported that elements which are essential for the growth of algae are also necessary for the growth of higher plants. Turcotte (1953) described that the algae obtain their food material from soluble nitrogen, phosphorous, potassium and other compounds present in surface waters. The amount of nutrient materials controls the growth of algal population. Palmer (1964) pointed out that the amount of algal flora may be small or very extensive depending upon the concentration of nutrients, temperature and length of light exposure. Enormous quantities of water in the ocean basins have capacity for storing the solar energy. The ocean water contains all the elements that are found in the rocks of the continental land masses. Economically, therefore, the oceans are called “the treasure house” of all the precious minerals (Lal, 2005). Of the several physico-chemical parameters of the sea, a few parameters have immediate toxic effect on seaweeds.

Marine water and its surroundings were analyzed for the last seven decades by several researchers around the world (Issac, 1938; Holm, 1969; Taylor, 1973; Cadee and Hegeman, 1977; Munda, 1978; Park, 1979; Walker and Donnel, 1981; Yamamoto, 1984; Ignatiades et al., 1985; Anderson and Gardner, 1986; Silva et al., 1987; Viaroli et al., 1996). A study was conducted on physico-chemical parameters of water from the mangrove swamps of Lagos lagoon, Nigeria. The study was aimed to estimate eleven physical and chemical parameters in the lagoon between January and December 2001. Air temperature varied between 26-31.75°C, water temperature 20.0-30.50°C, pH 1.89-8.50, salinity 0.2-16.75 %), dissolved oxygen 0.58-10mg/l, dissolved carbon dioxide 9-29-25.97mg/l, total alkalinity 20.5-90.0mg/l, total acidity 11.0-22.5mg/l and rainfall 2.4-
Similar works has been carried out on the physico-chemical properties of the sea water around India. The pattern of fluctuations of hydrobiological factors in the west coast of India has been studied by many researchers (Bal et al., 1946; Subramanyan, 1959; Annigeri, 1968 and 1980; Noble, 1968; Dehadrai, 1970 and 1979; Untawale et al., 1989; Ramesh and Fernandes, 1994).

Variation in living organisms were reported depending upon the environmental factors in the hydrobiology of the east coast of India (Ramamurthy, 1953; Chacko et al., 1954; Jeyaraman, 1954; Chacko and Malupillai, 1957; Ganapathy and Rao, 1958; Chacko and Rajendran, 1959; Malupillai, 1962; Freda and Sudhakar, 1968; Muthusamy, 1974; Marichamy and Pon, 1979; Thangaraj et al., 1979; De Sousa et al., 1981; Panakala and Sastry, 1981; Marichamy et al., 1985; Prabhakarar and Ramesh, 1986; Anon, 1987; Sasamal, 1989; Vasantha, 1989; Mitra et al., 1990; Choudhury and Panigrahy, 1991; Selvaraj, 1995; Govindasamy and Jayapaul, 1997; Subramanian and Kannan, 1998; Roslin, 2001).

Temperature is considered as one of the most important environmental factors which control all the atmospheric conditions and the biochemical reactions of aquatic system. Almost all the physical and chemical properties of marine water are determined by its temperature conditions. There are often variations in water temperature mainly due to seasonal changes and rainfall (Santhosh et al., 2006). Both the atmospheric and water temperatures often get fluctuated with reference to the topography of the location and from season to season (Lal, 2005). Temperature has also a significant influence on the growth and biochemical composition of marine communities (Takahiro and Yoshiko, 1981).
Due to the solar radiation and clean sky prevalent during the summer season, therefore water temperature was high in this season. This was reported by Thangaraj et al. (1979), Anbazhagan (1988) from Kodikkarai, Rajapandian et al. (1990) from Tuticorin, Anon (1989) from Trichendur, Selvaraj and Selvaraj (1997) from Trichendur and Idinthakarai coasts. Lower temperature during the post-monsoon season in the months of January and February was due to cloudy sky and rainfall brought down the temperature to the minimum (Kannan and Kannan, 1996). Similar observations have been reported by Thangaraj (1985), Gothandaraman (1993) and Seenivasan (1998) from Vellar estuary, Mani (1989), Vasantha (1989), Kaliaperumal (1992) and Karuppasamy (1997) from Pichavaram mangroves water, Saraswathi (1993) from Arasalar and Kaveri estuarine complex and Kannan and Kannan (1996) from Palk Bay.

pH is a variable in water quality assessment as it influences many chemical and biological processes within the aquatic ecosystem. Variations in pH of the marine water may occur due to rains, rate of evaporation, salinity changes, biological systems etc. However, it is being steadily maintained to some extent by nature. Organisms living in aquatic systems are adapted to an average pH and do not withstand abrupt changes. It is understood that during rainy season pH decreases and as a result the biological system gets interrupted (George, 1997; Mini et al., 2003). The low pH observed during the months of January to February may be due to the influence of fresh water influx, dilution of sea water, low temperature and organic matter decomposition as suggested by Ganesan (1992). This trend in pH was supported by Thangaraj (1985), Hemalatha (1996) and Seenivasan (1998) from the Veller estuarine system, Mathevan (1994) from Cuddalore coastal waters and Ananthan (1994) from Pondicherry coastal water.
The lower dissolved oxygen could be due to the decrease in oxygen solubility because of increase in temperature and salinity of the water column during the summer season. This was reported by Padmavathi and Satyanarayana (1999) from the estuary waters of the Godavari which had the significant negative correlation obtained between dissolved oxygen and water temperatures. The total hardness of marine water was represented the total concentration of calcium and magnesium ions expressed as calcium carbonate (Aarti et al., 2008). Bahura (1990), Sharma (1992) and Jain (1996) have been reported that during the summer season total hardness was very high and during the monsoon season total hardness was very low. Pearsall (1932) found that the alkalinity was contributed by the bicarbonates and the range was 72.50-95.00mg/l in English lake. The waters can be called hard because Zafar (1964) characterized hard waters having carbonate contents to be over 35 or 40mg/l.

The lower salinity was recorded during the months of January and February from Vellar estuary (Hemalatha, 1996; Seenivasan, 1998), Pichavaram mangrove water (Mani, 1989; Kaliaperumal, 1992), Cuddalore Uppanar water (Mathevan, 1994), Pondicherry coast (Ananthan, 1994), Palk Bay (Kannan and Kannan, 1996) and coastal waters of Kalpakkam (Satpathy, 1996).

**Nutrients availability in Marine Water**

According to Rilley and Skirrow (1965, 1968), over 60 elements were found in marine water. Marine water contains all these elements in dissolved form. The amount of these elements varied in different marine water with reference to changes in the intrinsic and extrinsic factors. Practically marine water contains all the elements which made up of sodium, magnesium, calcium and strontium, together with sulphates, chlorides, fluorides,
carbonic and boric acids (John, 1964; Taher et al., 1995; Lal, 2005). The marine water also contains the plant nutrients, phosphorous and nitrogen, trace elements like bromine, iodine, vanadium and gold (Lal, 2005).

A large number of elements such as chlorides, sulphates, calcium, magnesium, sodium, potassium, iron, manganese etc. were present in the marine water and they elevated the density of water and the solubility of gases (Ashish et al., 2004). Varma et al. (1978) have observed that it was due to the industrial waste, animal waste, agricultural waste etc., and also caused by evaporation and less rainfall. The high amount of solids recorded could be attributed due to the effluent discharge as evidenced by Ushamary et al. (1998).

Total phosphate may show the fluctuations throughout the year. It could be due to the land runoff from the irrigation channels and released of phosphate from the sediments due to high wind action during this season (Chapman and Craigie, 1972; Hanisak, 1979; Germann et al., 1987). The lower phosphate concentration during the summer season could be the utilization of the nutrient by the flora and fauna in the marine water, which occurred in higher densities during the post-monsoon seasons (Foster et al., 1978). The same trends were also observed by Sundararaj and Krishnamurthy (1975) from Pitchavaram waters and Rajasegar (1998) from Vellar estuary.

Qasim and Reddy (1967) also observed that the amount of nitrate was high during the month of January and February. Murugesan and Sivasubramanian (2008) stressed that the increase in concentration of nitrate in the natural water was usually accompanied by development and dominance of flora. The higher concentration of nitrite and seasonal variation could be due to the excretion and oxidation of ammonia and reduction of nitrite
(Kannan and Kannan, 1996). The low contents of nitrates during the months of March to July were due to less fresh water input and also uptake by flora and fauna. The same observation were recorded by Chandran (1982), Sivakumar (1992) and Shekar (1987) from Vellar estuary, Patterson and Ayyakannu (1991) from Kolhdarn estuary, Mathevan (1994) from Cuddalore Uppanar estuary, Kannan and Kannan (1996) from Palk Bay from Uppanar estuary and Satpthy (1996) from coastal water of Kalpakkam.

Blum (1956) discussed the interaction of potassium in various species of fresh water algae. According to Round (1973), potassium is a requirement for all algal groups. Under low concentrations growth and photosynthesis become low and respiration becomes high. Boney (1975) reported that in natural habitat potassium is found low concentrations so it inhibit the growth of algae. During the survey of lakes Chopra (1978) observed that the range of potassium was more than 5.0mg/l. Latha and Ramachandra (2010) reported that potassium is an important cation, it was high in monsoon and post-monsoon seasons (11.5mg/l) and decreased in pre-monsoon season (8.67mg/l).

**Variation in Physico-chemical parameters in Marine water**

Hydrological data were also collected from area surveyed. The atmospheric and bottom water temperature varied from 25.0 to 36.8°C and 26.0 to 31.8°C respectively. The pH ranged from 8.3 to 8.6 and the salinity from 26.39 to 33.43%. The dissolved oxygen ranged from 342 to 647ml/l. The phosphate content varied from 0.05 to 0.15µg/l, silicate from 4.00 to 12.00µg/l, nitrate from 0.25 to 1.00µg/l and nitrite from 1.05 to 3.99µg/l (Kaliaperumal et al., 1995).

Sridhar et al. (2006) determined the water quality in terms of physicochemical characteristics in the coastal waters of Kattumavadi, Palk Bay for a period of one year
from April 2002 to March 2003. Air and surface water temperatures varied from 28°C to 32.50°C and from 27.5 to 32.0°C while Light Extinction Coefficient (LEC) varied between 0.95 and 1.85. Salinity ranged from 26.0 to 34.5% and the pH ranged between 7.95 and 8.35. Variation in dissolved oxygen content was from 4.15 to 7.18 ml/l and the Particulate Organic Carbon (POC) content varied between 0.49 and 2.28 mg/l. Concentrations of nutrients viz. nitrate (2.15 to 8.28 µM), nitrite (0.12 to 0.62 µM), inorganic phosphate (1.28 to 2.15 µM) and reactive silicate (5.15 to 12.52 µM) also varied independently.

The monthly variation in the hydrographical parameters at three stations on the Veli-Akkulam lake along Thiruvananthapuram coast were investigated during the period from February 2005 to January 2006. The results of the study revealed that hydrographical conditions and nutrient content fluctuated widely throughout the year. The seasonal variation in water temperature, pH, salinity and dissolved oxygen invariably showed high values in pre-monsoon and low in monsoon months. The seasonal variability of nutrients such as nitrate, nitrite, ammonia and silicate in the Veli-Akkulam lake was a reflection of the variation in nature of the water in the estuary depending on the influence of the fresh water influence during monsoon period (Jisha et al., 2008).

Soundarapandian et al. (2009) carried out to find out the changes of physico-chemical parameters in two stations in Uppanar estuary. Among the various parameters, temperature was high in station II and it was low in station I. This may be due to the effluents discharged from station II. The pH showed greater variation from 6.2 to 7.9 in both the stations due to irregular treatment of the effluents reloaded into the estuary. The dissolved oxygen concentrations found to be lower and salinity was higher in the area.
The total dissolved solids, calcium, total phosphorus content, nitrite and ammonia was found to be higher in the station II than in station I.

Manakkudy estuary located on the south west coast of India has production of seaweeds to an amount of 15.59kg/m²/year. Four different types of seaweeds viz., Chaetomorpha aerea, Enteromorpha compressa, Gracilaria verrucosa and Hypnea musciformis were observed in this estuary. Highest production of biomass of seaweeds was recorded in May. Seaweeds were observed in the atmospheric temperature ranging between 22.20°C to 30.43°C, water temperature from 23.57°C to 31.70°C, pH 7.87-8.42, salinity range of 11.15-27.18%, dissolved oxygen from 4.36-7.73ml/l, carbon-dioxide from 1.24-8.71mg/l and alkalinity from 15.34-52.43mg/l (Jansi and Ramadhas, 2009).

Studies were made on the seasonal variation of physico-chemical parameters in the Perumal lake for a period of one year from March 2007 to February 2008. The physico-chemical factors such as water temperature, pH, salinity, dissolved oxygen, and total dissolved solids were at the ranges of 29.0-34.4°C, 7.9-8.4mg/l, 1.2-2.5mg/l, 2.62-4.34mg/l and 2.5-5.2mg/l respectively. Water temperature, pH and salinity were high during summer season and low during monsoon season. Whereas dissolved oxygen and total dissolved solids were maximum during monsoon season and minimum during summer season (Ramadosu and Sivakumar, 2010).

Mary et al. (2011) focused upon the seasonal variation of physicochemical parameters in water samples from coconut husk retting area near Thengapattanam. The purpose was to assess the quality of water from the sources in three different seasons. Water samples were analyzed for physicochemical parameters including pH, electrical conductivity, turbidity, total dissolved solids, alkalinity, total hardness, dissolved oxygen,
BOD, COD and anions analyzed were Ca, Mg, Fe, Mn, NO₃, NO₂, SO₄ and PO₄. The data showed variation of the investigated parameters in samples as followed: pH 6.72-7.71, electrical conductivity 852-578micS/cm, PO₄, 1.77-2.8mg/l, NO₃ 3-12mg/l, NO₂ 0.05-1.51mg/l, SO₄ 21-120mg/l, Fe 1.53-3.76mg/l, Mn 0.33-0.67mg/l. The concentrations of most of the investigated parameters in the water sample from coconut husk retting area were exceeded the permissible limit of WHO water quality guidelines.

Mitra et al. (2011) studied the changes of hydrological parameters in Hooghly estuary in response to a severe tropical cyclone. Due to the severe cyclonic storm, there were changes in surface water salinity, pH and dissolved oxygen. The average salinity of surface marine water increased from 17.08ppt to 25.2ppt, pH changed from 7.99 to 9.99 and dissolved oxygen decreased from 5.24ppm to 4.95ppm. Such drastic changes of hydrological parameters due to natural calamities may pose an adverse impact on the ecology of the deltaic complex and requires a systematic planning to combat the ecological effect of the disaster.

Seasonal data on environmental and hydrographical parameters of surface waters at three different study sites of Bhimili Coast was studied along with occurrence and distribution of marine macro algae for a period of one year from March 2009 to February 2010. Minimum values of salinity, pH and temperature were recorded during winter months and maximum values were observed in the summer months. Seasonal growth of marine macro algae at Bhimili coast was studied by using 0.5x0.5m quadrat. A total of 39 marine algal species were recorded in 75 quadrat samples. Maximum number of species was collected during November to February months and minimum number of species (26) was reported during July to October months (Satya et al., 2011).