Review of literature
2. REVIEW OF LITRATURE

2.1 Distribution of seaweeds

Studies made on Indian seaweeds have been reviewed from time to time by many workers. (Agharkar, 1923; Biswas, 1932, 1934; Joshi, 1949; Iyengar, 1957; Randhawa, 1960; Srinivasan, 1965). Boergesen published a series of papers on the green, brown and red algae of the northern parts of the west coast (Boergesen, 1930, 1931, 1932a,b, 1933a,b, 1934a,b, 1935) and red algae of South India (Boergesen, 1937a,b, 1938). A general review of the marine algae of the western coast was published by Biswas (1945). Srinivasan (1946) studied the marine algal flora of Mahabalipuram. Varma (1960) studied the seaweeds growing on the pearl and chank beds off Tuticorin. Srinivasan (1960) gave a detailed account of marine algae of the east and west coasts of India and reported on the occurrence of 162 genera and 413 species of marine algae from the Indian seas. Misra (1966) prepared a monograph on brown algae occurring along the Indian seas. The algal flora of Tiruchendur was reported by Krishnamurthy (1980). Untawale et al. (1983) enumerated 624 species of marine algae and their distribution along the maritime states of India. Ecology and zonation of seaweeds in the Gulf of Mannar along the southeast coast of Bay of Bengal have been studied by Umamaheswara Rao (1972), Subbaramaiah et al. (1977), Krishnamurthy (1980), Krishnamurthy and Balasundaram (1990), Ganesan and Kannan (1995), Roslin et al. (1997), and Edwin James et al. (2004). Although all seaweeds are beneficial to man in one way or the other, only 49 species are presently
found to be useful either as directly edible materials or as industrial raw materials (Chennubhotla et al., 1987a).

2.2 Nutritive value of seaweed

Studies have been made on the chemical and proximate composition of seaweed mainly by Chidambaram and Unny (1947, 1953) and Joseph and Mahadevan (1948).

Chennubhotla et al. (1987b) reported that the food value of the seaweeds depend largely on their mineral, trace element, protein and vitamin content. Minerals, carbohydrate and other chemical constituents of seaweeds were estimated by Kaliaperumal et al. (1987).

Sitakara Rao and Tipnis (1967) have studied the chemical composition of some marine algae from Gujarat coast. Mehta and Baxi (1976) studied the mineral constituents and ion-exchange property of some brown seaweeds from the Indian coast. Like mineral constituents, lipid content of seaweed was also studied by Parekh and Chauhan (1987). Kesava Rao and Indusekhar (1987) described the carbon, nitrogen and phosphorus ratios in the seaweeds of Saurashtra coast. Lipid, sterol and chlorophyll contents of some of the Indian seaweeds were studied by Parekh et al. (1983). Ecobiochemical studies on some economically important intertidal algae from port Okha have been carried out by Murthy and Radia (1978).

Studies on the seasonal variations in biochemical composition of some seaweeds of Goa coast were mainly done by Sumitra Vijaraghavan et al. (1980a). Dhargalkar et al. (1980) estimated the protein, carbohydrate and organic carbon in 43 marine algal species from different areas along the Maharashtra coast.
Dave and Chauhan (1985) estimated the protein content of brown seaweeds from Gujarat coast. Protein content of red seaweeds of Gujarat coast was estimated by Dave et al. (1987). Parekh et al. (1977) estimated the chemical composition of green algae of Saurashtra coast.

Sobha et al. (1988, 1992) have studied the proximate composition and heavy metals of certain algae of Kovalam, southeast coast of India. Biochemical constituents and nutrient relationships in the seaweeds of Vishakhapatnam, in the east coast of India were established by Mrutyunjaya Rao et al. (1994), Sarojini and Subbarangaiah (1999) and Srinivasa Rao and Umamaheswara Rao (2004).

Biochemical composition of the marine algae from Mandapam coast and Tuticorin coast, Gulf of Mannar region have been studied by many workers (Chennubhotla et al., 1990; Reeta Jayasankar et al., 1990; Venkataraman Kumar, 1993a, 1993b; Ganesan and Kannan, 1994; Kaliaperumal et al., 2002; Vimalabai et al., 2003).

Ganga Devi et al. (1996) studied the biochemical constituents of the marine algae of Cape Comorin. Selvi et al. (1999) have studied the biochemical content of the macroalgae from Cuddalore and Thirumullaivasal estuaries of Tamilnadu.

Roslin (2001a, 2001b, 2003) and Muthuraman and Ranganathan (2004) have carried out biochemical studies on some marine algae of Arockiapuram coast and Kanyakumari coast respectively. The biochemical composition of some common seaweeds from Lakshadweep has been studied by Kaliaperumal et al. (1994).

Chapman and Chapman (1980), Arasaki and Arasaki (1983), Abbott (1988) and Abbott and Cheney (1982) have reviewed the uses of seaweed for food. There are
a few references to edible seaweeds in Fuji (Adams and Foscarini, 1990; Prakash, 1990; South, 1993). Abbott (1984) has provided a detailed account of edible seaweeds from Hawaii.

Percival (1968) has worked on the carbohydrate of seaweeds. Chemical composition of the littoral seaweeds common to North Adriatic sea has been studied by Zavodnik (1973, 1987). Honya et al. (1992) have studied the various lipid classes in *Laminaria japonica*. The seasonal influence on the lipid composition of some marine macrophytes including seaweeds from the sea of Japan has been studied by Kostetsky et al. (2004). Elemental composition of some marine algae from the Bahrain coastline (Arabian Gulf) has been investigated by Basson and Abbas (1992). From the same coastline, Abbas et al. (1992) have determined the protein content of benthic marine algae. Durairatnam et al. (1988) have studied the chemical composition of some species of marine brown algae collected in the sublittoral areas of the state of Rio Grande Do Norte, Brazil. McDermid and Stuercke (2003) have analyzed twenty-two species of edible Hawaiian macroalgae (6 Chlorophyta, 4 Phaeophyta, 12 Rhodophyta) for protein, lipid, carbohydrate, ash, caloric, mineral and vitamin content. The chemical composition of the brackish water green alga *Cladophora rivularis* from near southern Black sea shore was investigated by Kamenarska et al. (2004).

Fatty acid profile of seaweeds has been studied by workers in India and other countries (Johns et al., 1979; Marolia et al., 1982; Parekh et al., 1984; Takagi et al., 1985; Quasim, 1986; Khotimchenko and Vaskovsky, 1990; Khotimchenko, 1991, 1993, 2003; Khotimchenko et al., 2002; Dembitsky et al., 1991; Floreto et al., 1993;
Amino acid profile in seaweeds has been investigated by Allsopp, 1948; Dokhan, 1953; Lewis and Gonzalves, 1959; Lewis, 1967; Dave and Chauhan, 1993 and Dave and Parekh, 1997.

In general, many workers confirmed that marked changes in the chemical composition of marine algae were not only due to seasons and environmental conditions but are also caused by the phases of growth and fruiting cycles of these plants.

2.3 Decomposition of seaweeds, their nutritive values and microbial status

The importance of plant detritus originated through the decomposition of vascular macrophytes such as seagrasses, marsh grasses and mangroves in aquatic ecosystems was emphasized (Odum et al., 1972; Mann, 1973; De La Cruz and Gabriel, 1974; De La Cruz, 1975; De La Cruz and Poe, 1975; Harrison and Mann, 1975; Fenchel, 1977; Knauer and Ayers, 1977; Thayer et al., 1977; Godshalk and Wetzel, 1978). As macroalgae are directly consumed more frequently than vascular plants by herbivores than detrivores less attention has been devoted to macroalgal decomposition (Paine and Vadas, 1969; Mann, 1973; Tenore, 1975, 1977; Hunter, 1976; Hanson, 1982; Rice, 1982; Albright et al., 1982; Bouvy et al., 1986).

The decomposition of marine tropical green macroalgae Caulerpa cupressoide was studied by Williams (1984) in order to assess its importance as a means of supplying nutrients to the sediments of seagrass beds. He observed that C. cupressoide lost 50% of its original biomass in seven days in litter bags positioned in the water.
column and the C/N ratio in the particulate matter of decomposed *C. cupressoide* significantly decreased over time in the flasks and increased in the sediments.

Changes in the carbon and nitrogen content during decomposition of three species of macrophytes in fresh water and marine environments were studied by Hunter (1976), who suggested that initial differences in the nutritional value of aquatic macrophytes diminish during decomposition and the C/N ratio depends more on the type of the decomposing organisms than on the organic matter. The importance of detritus in aquatic ecosystems was reviewed by Odum and De La Cruz (1967) and Kaushik and Hynes (1971).

Thallus parts of *Macrocystis integrifolia* and *Nereocystis luetkeana* from the North American Pacific coast, enclosed in litter bags exposed in the sub littoral zone, became fragmented to detritus particle sizes of less than 1.5mm in diameter within five to eight weeks, and 60% of the algal biomass reappeared in the form of bacterial biomass (Albright *et al.*, 1980). Of the South African sub littoral *Ecklonia maxima* vegetation, probably 5% becomes intertidally stranded (Koop *et al.*, 1982); a quarter of the organic carbon is transformed into bacterial biomass within the accumulated kelp masses, while the remaining organic carbon seeps into the sand as an organic solution where it is mineralized by bacteria within eight days.

Studies are scanty on bacteria associated with decomposing algal biomass. Viable counts of bacteria in the study on *in situ* decomposition of *Ulva lactuca* (Vasantha *et al.*, 1997) varied between $10^1$ and $10^{11}$ g$^{-1}$ during decomposition. The same study investigated the changes in mass and biochemical constituents during microbial decomposition of *Ulva lactuca* in a tropical mangrove environment.
Seaweeds are not eaten as such by sessile animals, but detritus derived largely from decaying algae is an important food source for suspension feeding animals (Harris, 1990). Seaweed detritus starts with a lower fibre content and a higher nitrogen content. Many animals can use it directly, and even a short period of microbial colonization renders it highly nutritious (Mann, 1988).

2.4 Fish feed preparation

The major factors governing a sustainable aquaculture are those relating to the use of balanced high quality feed and other inputs, apart from proper water quality management (Jayakumar, 1997). As far as feed is concerned, use of environment friendly and economically viable artificial feeds of good growth promoting quality should be given top priority (Paulraj, 1993; Ganesh and Joseph, 1997). Commercial farming of fresh water carps involves supplementary feeding for better growth and survival (New and Singholka, 1982; Nandheesa, 1993).

Supplementary feeds in aquaculture range from kitchen wastes or mixture of rice bran and oil cake to almost nutritionally complete compounded feeds (Devaraj and Keshavappa, 1986). In aquaculture, feed cost accounts to 60-80% of the total operational cost (Nandheesa, 1993; Cagauan and Pullin, 1994; Mohanty and Das, 1995). Traditionally fish meal is used as a protein source in aqua feeds.

In the wake of decreasing quality, inconsistent supply and soaring price of fish meal, substitution of this expensive animal protein with the non-conventional plant feed stuffs like soya, aquatic fern (Azolla), duck weed, water hyacinth, subabul etc., are incorporated into the feeds of fishes and prawns (Duthu and Kilgen, 1975;

Azolla has attracted attention as a nitrogen fertilizer (Kannaiyan, 1992) and as a source of dietary nitrogen for herbivorous fishes and livestock (Almazan et al., 1986) moreover, Azolla contains a high protein content (24-30%) in addition to good amino acid profiles (El-Sayed, 1992; Sherief and Theresiamma James, 1994).

Feeding fresh Azolla as such to carps, incorporating Azolla meal in fish feeds and integrating Azolla in rice-fish farming is found to be highly profitable in aquaculture (Antoine et al., 1986; Gavina, 1994). Further, Azolla grows very fast and doubles its weight in 2-3 days (Cagauan and Pullin, 1994).

Though organic wastes and decomposed weeds are known to possess high nutritive values, they are not utilized properly for fish culture (Devaraj and Keshavappa, 1986). During decomposition of aquatic weeds, there is a commendable increment in the protein content with time (De La Cruz, 1975; Sumitra Vijayaraghavan et al., 1980b; Sharma and Goel, 1986). The composted aquatic weeds are well suitable as a complete feed or as an ingredient in supplementary feed for fishes, prawns, shrimps and cray fishes (Ramadhas and Sumitra Vijayaraghavan, 1979; Edwards and Wee, 1985; Olha et al., 1990).

Fishery workers have been paying attention to assess the nutritive value of algae as fish food. Meske and Pfeffer (1978) conducted experiments on common carp Cyprinus carpio with certain dried algal meals such as Cladophora glomerata, Scenedesmus obliquus, Chlorella spp. and Euglena spp. Krishnamurthy et al. (1982)
prepared formulated feeds for *Penaeus indicus*, utilising an alga, *Enteromorpha elatiorata* and leaves of *Rhizophora mucronata* and *Prosopis spicigera*.

Large macroalgae / seaweeds, which might continue to grow after detachment, combine a relatively high food value with high flotation potential (Thiel, 2003). The kelp *Laminaria hyperborea* acts as a food potential for fishes (Jorgensen and Christie, 2003). Amphipods were found to be associated with red algae for their food requirements (Norderhaug, 2004). Both temporary and permanent meiofauna were found to be associated with the sublittoral population of the kelp *Laminaria ochroleuca* (Arroyo et al., 2004). Macroalgal canopies are a source of food for herbivores feeding on them, or filter feeders benefiting from the release of organic matter (Begin et al., 2004). Distribution and abundance of fishes associated with *Sargassum* mats in the north – western Gulf of Mexico were examined (Wells and Rooker, 2004). The aforesaid literature clearly reflects the possibility of incorporating seaweeds in fish feeds.

The nutritive value of the marine alga *Ulva fasciata* as a fish feed for two economically important fishes *Labeo rohita* and *Oreochromis mossambicus* was assessed (Sobha et al., 1999).

The nutritive efficacy and the suitability of three different species of marine algae, *Ulva fasciata*, *Spyridia insignis* and *Sargassum wightii* in the formulated diets on the digestive enzymes of *Ctenopharyngodon idella* were assessed (Bindu et al., 2003).

In a study involving comparison of estimates of feeding rates, alimentary tract structure and temporal patterns of food processing obtained from twelve species of
herbivorous fishes, diets of macroscopic brown algae, red and green algae were employed (Choat et al., 2004).

Russel and Balazs (1994) reported that green turtles feed mostly on marine algae in selected grazing areas. From the stomach samples taken from Hawaiian green turtles there were 275 species of green algae, brown algae, blue green algae and seagrasses (Russel and Balazs, 2000). Kannan and Rajagopalan (2004) confirmed that seaweeds and seagrasses were the major food for the endangered green turtle, Chelonia mydas.

Kaushik (1995) reported a considerable variation in the optimal protein levels (25 - 50%) in the diets of common carp. Nutritional requirements of fresh water cultivable fish, energy metabolism, formulation and preparation of fish feeds were reported by Santhanam et al. (1990).

Even though several studies have been made on the formulated feeds and their role in the growth of shrimps and fresh water fish, reports on the use of decomposed seaweeds in aqua feeds are hitherto wanting. The present study emphasizes on the nutritional values of seven species of decomposed seaweeds viz., Ulva lactuca, U. reticulata, Caulerpa scalpelliformis, C. racemosa, Sargassum ilicifolium, Padina tetrastromatica and Gracilaria corticata. Four of these species were used as one of the ingredients for the preparation of fish feeds and studied their impact on food utilization in chosen cultivable fish species.