5. DISCUSSION

Seaweed is a sustainable natural resource with industrial potential that is not fully utilized. About eight million tonnes of wet seaweeds are harvested annually worldwide (McHugh 2003). Currently, human consumption of green algae (5%), brown algae (66.5%) and red algae (33%) is high in Asia, mainly Japan, China and Korea (Dawes 1998).Utilization of seaweeds for food have been extended to North America, South America and Europe (McHugh 2003). The different species consumed have a great nutritional value as source of proteins, carbohydrates, minerals and vitamins. These seaweeds are harvested and utilized for a variety of purposes such as feed, fertilizer, bioactive compounds and as a source of raw material for industrial production of phycocolloids of commercial importance (Kirkman and Kendrick,1997; Robledo and Freile-Pelegrin, 1997;Arunkumar and Rengasamy,2005).

Biological diversity has been declined during the past few decades due to habitat destruction and global climate change (Tilman et al., 1994, Vitousek et al., 1997). Growth, distribution and abundance of seaweeds depend on many factors such as nature of substratum, climate, nutritional availability etc. About 9200 species of seaweeds have been recorded so far in the World Ocean and seas of which 6000 species are red, 1500 brown and 900 green. India has a coastline of more than 8,000 kms that harbours about 844 species of seaweeds. Distribution of seaweed species in India as, Gujarat 202; Maharashtra 152; Goa 75; Karnataka 39; Kerala 20; Lakshadweep 89; Tamil Nadu 302; Andhra Pradesh 78; Orissa 1; West Bengal 6 and Andaman & Nicobar Islands 34 (NAAS, 2003). Floristic studies on the marine algae occurring along the coast of Madapam(Umamaheswara Rao, 1969, 1972, 1973), Krusadai island(Chacko et al., 1955),Pamban(Subbaramaih et al., 1977), Rameswaram to Kilakarai(Kalimuthu et al., 1992; Kaliaperumal et al., 1996), Porto Novo (Kannan and Krishnomurthy,1978), Arockiapuram(Stella Roslin et al., 1997), Kanyakumari to Idinthakarai (Sreekala Devi et al., 2004), Madras (Srinivasan, 1960; Rengasamy and Ilanchelian, 1988) and estuaries and backwaters of Tamil Nadu and Pondicherry coastal regions have been made. However, floristic information is not available on seaweeds occurring at Thondi and its adjourning regions of Palk Bay, Southeast coast of Tamil Nadu where tsunami left untouched.

Floristic studies made on the occurrence of seaweeds at various places along the Indian coast showed that species composition and abundance may differ from each locality. Number of species recorded from Idinthakarai coast was 41(Kaliaperumal and Pandian, 1984), 22(Sasidharan and Krishnamurthy, 1998), 46(Selvaraj and Selvaraj, 1997) and 38(Sreekala Devi et al., 2004). Even in the same locality occurrence of seaweeds varied and this may be due to dynamics of nutritional status and physico-chemical parameters over the period of time(Sreekala Devi et al., 2004). In the present investigation, floristic survey of seaweeds along the Thondi coastal regions (Bay of Bengal) recorded 25 species. Of these, 9 genera with 16 species are red algae (*Rhodophyta)*, 2 genera with each one species are brown algae (*Phaeophyta*) and 5 genera with 7 species are green algae (*Chlorophyta*). Sand and muddy substratum and ropes continuously immersed in the seawater for anchoring the boats in the Thondi coasts and its adjourning areas of Palk Bay supported the growth and distribution of red and green seaweeds than brown algae. The present finding is similar with the works made in other Palk Bay regions of

Tamil Nadu(Kannan and Krishnamurthy, 1978; Kalimuthu et al., 1992; Palanisamy and Selvaraj, 1998). However, drift of some brown seaweed found along the coast was not taken for record in the present investigation. On the contrary, distribution and abundance of brown seaweeds are fairly high along the coast of Rameswaram to Kanyakumari in the regions of Gulf of Mannar, Tamil Nadu. Unlike in the present localities of Thondi, regions of Gulf of Mannar are known for rocky substratum with coral reefs and pebbles (Kalimuthu et al., 1992; Selvaraj and Selvaraj, 1997; Stella Roslin et al., 1997; Sreekala Devi et al., 2004; Edwin James et al., 2004). In the present study, seasonal changes in the occurrence and abundance of seaweeds were observed and maximum diversity of seaweeds was found during the post-monsoon and monsoon seasons whereas during summer the occurrence was less as reported by Kalimuthu et al.(1992). However, the agarophytes *Gracilaria corticata* var. *corticata, G. corticata* var. *cylindrica, G. edulis* and *G. verrucossa* ; green algae *Enteromorpha flexuosa* ,*E.intestinalis* and *Chaetomorph linum* occurred in fairly high density in all the four localities during all seasons. These seaweeds showed good adoptability to the environmental conditions prevailing at Thondi regions and these may be ideal candidate species for economical exploitation. The present study showed that Thondi coastal regions in Palk Bay side of Tamil Nadu is one potential seaweed growing areas. Occurrence and diversity of seaweeds were not only influenced by nature of substratum but also by seasonal and environmental conditions. Among the four localities, all 25 species were recorded at Theerthandathanam(Station- IV) as maximum diversity followed by 24 species at Thondi(Station-II), 21 species at M R Pattnam(Station-III) and 17 species at Nambutalai(Station-I). High species diversity was recorded at Theerthandathanam(Station- IV) and Thondi(Station-II) and optimum species diversity was observed at M R Pattanam(Station-III), and less number of species was observed at Nambutalai(Station-I).

Biochemical composition of seaweeds varied according to species, seasons and habitats. Green algae contain more proteins than brown and red algae (Parekh et al., 1977). It has been reported that green algae contains 68-88% water, 3-18% protein (Burkholder et al., 1971; Levring et al., 1969), 0.6-4.3% fat (Munda, 1972), 1- 47% carbohydrate (Burkholder et al., 1971; Imbamba, 1972), 2.5-41.6% Calcium and 0.51-4.9% Magnesium (Imbamba, 1972). In the present investigation, biochemical characteristics such as dry weight, ash content, total chlorophyll, phycocyanin, allophycocyanin, phycoerythrin and total lipids from fresh samples of seaweeds; and total carbohydrate, total protein, total amino acids, total phenol, water retention capacity (WRC), agar, carrageenan, alginate and sulphate from crude carbohydrate extracted from 16 red, 2 brown and 7 green seaweeds collected from the Thondi were varied depending on species. High biochemical characteristics were recorded in red algae followed by brown and green algae except total chlorophyll which found high in green seaweeds. Sánchez-Machado et al.(2004) reported ash content ranged from 19.07±0.61 to 34.00±0.11 g/100 g dry weight from *Himanthalia elongata, Laminaria ochroleuca, Undaria pinnatifida, Palmaria* sp. and *Porphyra* sp. In the present study, maximum of 39.6±4.6 mg g^{-1} dry wt. and minimum of 09.4±2.1 mg g^{-1} dry wt. of ash content was recorded from the all seaweeds. Dawczynski et al.(2007) demonstrated low lipid contents and proved to be a rich source of dietary fibre. The pure protein content of seaweed products varied widely. All essential amino acids were detected in the seaweed species tested. Burtin(2003) recorded less protein content in brown seaweeds whereas high protein contents were recorded in green and red seaweeds. In the present study, highest total protein content was recorded in red *Gracilaria verrucosa* among all three groups of seaweeds investigated. Burtin(2003) reported 1-5 % of lipids in seaweeds in algal dry matter. In the present study, maximum total lipids of 67.23±3.6 mg g^{-1} fresh wt. was recorded in red alga *G. verrucosa* and minimum lipids of 27.42±4.1 mg g^{-1} fresh wt. was recorded in red alga *Jania rubens* among the seaweeds investigated whereas Chackrobarthy and Santra(2003) found high lipid content in green seaweed *Enteromorpha intestinalis.* In the present study, very low lipid content was observed in algae especially those algae having high phycocolloids. This is in conformity with earlier reports (Heiba et al., 1997; Kamenarska et al., 2002) pertaining to other seaweeds.

Quantity of macroalgal pigment is mostly used to define algal biomass influenced by environmental factors. Many studies indicated that environmental factors such as salinity, temperature, nutrients, and intense irradiance influenced on pigment production (Marin et al., 1998; Boussiba et al., 1999; Zucchi and Necchi, 2001). In the present study, total chlorophyll and accessory pigments in seaweeds varied depending on the species and there were insignificant inter specific differences recorded. Total chlorophyll was more in green algae than red and brown algae whereas accessory pigments were higher in latter than former. Many researchers made similar findings that the nutritional contents of macroalgae depend not only on season and geography (Fleurence, 1999, Fleurence et al., 1999, Haroon et al., 2000) but also on the nutrient content of the environment (Marin et al.,1998). Moreover, Zucchi and Necchi (2001) determined that physical factors such as light density and quality, photoperiod and temperature, can alter pigment contents. In addition, Muthuvelan et al. (1997) stated that Chl *a*, Chl *b* and total protein contents indicated an increase in white light in an *Ulva* species.

Nutritive value of seaweeds is mainly due to their protein, polysaccharide, mineral and vitamin contents. The high levels of non-digestible polysaccharide in their cell wall make seaweeds a rich source of dietary fibre (Rupérez and Saura-Calixto, 2001). Together with their low lipid content, seaweeds only provide a very low amount of energy. Consumption of seaweeds can increase the intake of dietary fibre and lower the occurrence of some chronic diseases (Southgate, 1990). Water retention capacity (WRC) indirectly indicates the dietary fibre in the crude carbohydrate extracts of seaweeds. Thus, red and brown seaweeds contain phycocolloids such as agar, carrageenan, alginates, fucans and laminarians as soluble dietary fibre that hold WRC(Carvalho et al.,2009).In the present investigation, crude carbohydrate of those red and brown seaweeds recorded high agar, carrageenan and alginate showed more WRC than seaweeds of not economically used for phycocolloids extraction especially green seaweeds. Femenia et al. (1997) and Rupérez and Saura-Calixto (2001) reported that WRC is attributed to insoluble fibre, high content of uronic acids and components of soluble fraction of dietary fibre. As a corroboration to the earlier studies, seaweeds such as red *Grateloupia filicina, Gracilaria corticata* var. *corticata, G. corticata* var. *cylindrical, G. edulis* , *G. canaliculata* , *G.*

verrucosa, G. foliifera, Grateloupia filicina, Hypnea flgelliformis, H.musciformis and *H. valentiae;*and brown *Dictyota dichotoma* contained substantiate amount of commercially important cell wall polysaccharides showed high WRC, observed in the present investigation.

Seaweeds are exposed to seasonal variations that influenced on their metabolic responses (photosynthesis and growth rates) and levels of proximate constituents (Ordu˜na-Rojas et al., 2002). For subtropical species seawater temperature, light and nutrients have been shown to be the primary factors that modify the seasonal photosynthesis of red seaweeds (Lapointe and Ryther 1978;Durako and Dawes 1980; Penniman and Mathieson 1985; Lapointe 1987). Seasonal variations in the chemical composition and nutritive value have been reported in common marine seaweeds from different parts of the world such as Hong Kong (Kaehler and Kennish,1996), India(Kumar,1993) and Ireland(Mercer et al.,1993). In the present study, significant variation in dry wt., total carbohydrate and total chlorophyll content of two red algae *Gracilaria edulis* and *G. verrucosa* and two green algae *Ulva lactuca* and *Chaetomorpha linum* recorded among four different seasons at four localities along the Thondi coastal region. In the present study, significant seasonal variations in dry wt. of seaweeds have been observed in all the four sampling stations. The dry wt. showed a declining trend from post-monsoon season to summer season. The biomass of seaweeds largely depends upon season, population structure and several other ecological factors (Krishnamurthy,1967). Further, the physico-chemical variable especially nutrients and salinity also contribute to the growth of seaweeds(Thakur et al.,2008). The biomass of seaweed can be correlated with the abiotic factors that prevailed before or during the collection period (McQuaid, 1985). In the present work, maximum dry wt. of seaweeds was observed during post-monsoon and monsoon seasons than the pre-monsoon and summer seasons and increasing growth as more dry wt. accompanied with high total carbohydrate content in seaweeds collected during post-monsoon and monsoon seasons as reported by Marinho-Soriano et al.(2006) that biomass maximum coincides with carbohydrate maximum suggesting a link between seaweed growth and carbohydrate content.

Temperature, salinity, dissolved oxygen, pH and nutrients affect the growth of seaweeds(Nedumaran and Perumal,2009). Riosmena-Rodriguez (2000) reported phenological and morphological differences between *Porphyra* populations related to temperature and day length. Varela-A´lvarez et al.(2007) explained the growth of *P. linearis* populations with seasons and a clear distinct change in the frequency distribution observed from September to May. There was a strong seasonal dependency of growth and phenology on environmental factors recorded at two different sites. Significant correlations between relative growth rates and climatic data (light, temperature, and rainfall) were determined for different periods and seasons at both sites. Generally, relative growth rates correlated most significantly with temperature. In the present study, significant positive correlation observed between total rain fall and relative humidity with dry wt., total chlorophyll and total carbohydrate of seaweeds as like the findings of Varela-A´lvarez et al.(2007).

The amino acid composition in free or bound form observed significant difference between protein and amino acid contents of red, brown and green algae (Mateus et al., 1976; Dave and Parekh, 1978; Margaret and Geyler, 1979). In the present study, 9 essential amino acids and 8 non-essential amino acids were recorded from the crude amino acids of 4 seaweeds. Among the 4 seaweeds, a maximum of total and essential amino acids were recorded in *Gracilaria verrucosa* followed by *Ulva lactuca*, *Gracilaria edulis* and *Chaetomorpha linum*. The distribution pattern of these amino acids reveals some significant differences among the species investigated.

Seaweeds have been used as supplementary feeds to cattle, poultry, shrimps and fin fishes to boost immune system (Dave et al., 1977). In the present study, immunosuppressive rats and immunosuppressive rats fed with crude amino acid extracts and powdered samples of *Gracilaria edulis, G. verrucosa, Ulva lactuca* and *Chaetomorpha linum* showed significant variation in RBC,WBC, neutrophils, neutrophil adhesive and total protein level. Protein content showed higher value in the immunosuppressive rats fed with crude amino acids extracts and powdered samples of seaweeds than immunosuppressive rats. Large amount of nutritional properties such as protein, amino acids, carbohydrate, and dietary fibre in seaweeds powder and high amino acids in the crude extracts used as feed to rats would be the reasons for the enhancement of immune system of rats, observed in the present investigation. Low WBC, RBC and protein content were recorded in the blood of immunosuppressive rats. It inferred that seaweeds could be a good source of nutritional supplement (Urbano et al., 2002).

A complete blood cell count is used to assess the overall health of an individual. The differential count of the WBC allows an assessment of cellular immune function. WBC count is the measurement of the number of leukocytes within the blood. Neutrophils are the most abundant WBC. They are recruited to inflammatory sites and are capable of phagocytising and digesting microbes (Aiello, 1998). Antibodies block toxins from affecting cells through steric hindrance. Microbes can be neutralized by any isotype as it only involves the antigen binding region of the antibody. The most abundant type of neutralizing antibody is IgG. Many vaccines work by this process of stimulating the production of neutralizing antibodies (Abbas et al., 2000). Cellular immunity in cattle was increased as a result of feed of *Ascophyllum nodusum* (Allen et al., 2001; Saker et al., 2001).In the present study, immunosuppressive rats fed with crudes amino acids and powdered sample of seaweeds as supplementary food. It was observed that significant increase in RBC, WBC, neutrophils and total protein were recorded in the blood samples of immunosuppressive rats fed with powdered samples and crude amino acids extracts of seaweeds than immunosuppressive control whereas increase in neutrophils adhesive did not show significant. In the present investigation, increase in RBC and WBC were higher in rats fed with crude amino acids extracts than powder samples of seaweeds whereas increase in neutrophils, neutrophils adhesive, total protein and IgG were more in the blood of rats fed with powder samples than crude amino acids of seaweeds.