1.0. GENERAL INTRODUCTION

1.1. What are seagrass?

Seagrass are marine flowering plants that are capable of completing their life cycles even when covered by saline water. Although they superficially resemble true grasses, they are not members of the family poaceae, but belong to related families of monocots such as hydrocharitaceae and potamogetonaceae. Seagrass often grow in meadows that resemble grasslands and undergo pollination when they are submerged in water. Like terrestrial plants, they undergo photosynthesis and as a result they bound in the inter-tidal zone, the near-shore areas and shallow waters where penetration by sunlight is high.

About 60 species of seagrass have been described and they are distributed across 13 genera. Among them, six of which are found in temperate seas (Amphibolis, Heterozostera, Phyllospadix, Posidonia, Pseudalthenia and Zostera) and the rest are tropical in nature (Cymodocea, Enhalus, Halodule, Halophila, Syringodium, Thalassia and Thalassodentron). The maximum diversity of seagrass species is in tropical and sub tropical seas.
1.2. Functions of seagrass ecosystem

Seagrass ecosystem is one of the most common and productive marine habitats which play an important role in the overall health of coastal ecosystems (Ferguson et al., 1993). High standing crop produces large amounts of dissolved and particulate detritus which form the basis of important food chains both within the seagrass ecosystem and shore ward and offshore as the materials are washed away from the seagrass. The leaves and erect shoot surfaces are home for epibiotic organisms. This increases both primary and secondary productivity, as well as providing a large amount of food sources for fish and invertebrates. Because, the seagrass are rooted in their substrate and produce shoots with leaf bundles, they stabilize their habitat. The leaves form a baffle, which slows and retards current and wave activity, which promotes sedimentation of particles as well as inhibiting re-suspension of organic and inorganic materials. Seagrass creates an active environment for nutrient cycle (Wood et al., 1969). Overall, seagrass ecosystems enhance the ecological function of coastal zones by increasing the productivity and biomass of the region (Heck et al., 2003).
1.3. Distribution of seagrass—Global scenario

Seagrass are found along most of the coastlines of all countries except in the waters of North Arctic circle and South Antarctic circle (Green and Short, 2003; Phillips and Durako, 2000) (Fig. 1.1). The distribution patterns of seagrass may change quickly due to local environmental changes. Moreover, the shifts in species composition will likely occur rapidly in response to global climate change. However, it is difficult to detect whether species composition shifts are caused by climate change impacts or by other human impacts. It has been reported that, the global seagrass coverage can presently be estimated to exceed 177,000 km² (Green and Short, 2003). A more exact determination of the global extent of seagrass is difficult because most seagrass meadows have not been mapped due to the cost of comprehensive mapping is high.

Fig. 1.1. Map showing the global distribution of seagrass
The distribution of seagrass has been defined into six global bioregions (Short et al., 2007). The tropical Indo-Pacific is the region of the highest seagrass biodiversity in the world, with many species often found in mixed meadows that have no clear dominant species. High species diversity is also found in the tropical Atlantic bioregion, with *Thalassia testudinum* often dominating in clear waters. The three distinct temperate bioregions are: the temperate North Atlantic, the temperate North Pacific and the temperate Southern oceans, with the Mediterranean bioregion having both tropical and temperate species. The North Atlantic Ocean has low seagrass diversity, with eelgrass, *Zostera marina*, being the dominant species. The temperate North Pacific is also dominated by several *Zostera* species as well as *Phyllospadix* species in the surf zone. The Southern oceans bioregion is a circum global area including the temperate coastlines of Australia, Africa and South America, where extensive meadows of low to high diversity temperate seagrass species are found. The clear waters of the Mediterranean Sea are dominated by *Posidonia oceanica* growing in vast meadows, but this bioregion also supports other temperate and several tropical seagrass.

In both the Northern and Southern hemisphere, the global distribution of seagrass is remarkably consistent, with both hemispheres containing 10 genera and only one unique genus in each hemisphere.
However, some genera have more species than others, as evident in the multispecies genus *Halophila*. There are about the same number of species in tropical and temperate bioregions. The most widely distributed seagrass is *Ruppia maritima*, which occurs in both tropical and temperate bioregions and in waters from fresh to hypersaline. Seagrass bioregions at the scale of ocean basins are identified based on species distributions which are supported by genetic patterns of diversity. Seagrass bioregions provide a useful framework for interpreting ecological, physiological and genetic results collected in specific locations or from particular species.

Seagrass globally have five centers of high diversity all of which occur in the Eastern hemisphere and four of which occur in the Tropical Indo Pacific bioregion; the fifth, South-Western Australia, occurs in the adjacent Temperate Southern Oceans bioregion. The first and largest of these, with by far the greatest number of seagrass species lies over insular South-East Asia and extends across North tropical Australia, including the Great Barrier Reef; all but two of the species, *Z. muelleri* and *Z. japonica*, contributing to this regions have high diversity are tropical seagrass. A second, much smaller center of diversity is found in South-Eastern India, represented by 13 all tropical species. The third center having high diversity globally, located in Eastern Africa, Southern Japan and South-Western Australia, obtains this designation by being located at or near a bioregional
interface, encompassing both tropical and temperate seagrass species. East Africa, with 12 species, has only one temperate species, *Z. capensis*, contributing to its mix of mostly tropical species. Southern Japan also has 12 species, with *Z. japonica* the one temperate species that contributes to the diversity of this tropical region. In the temperate Southern Oceans bioregion, South-Western Australia with 13 species has 4 tropical species contributing to its high diversity. Looking at diversity patterns in more detail and also at the individual species ranges that underpin them (Green and Short, 2003), seagrass bioregions are discussed from greatest to least seagrass diversity.

Seagrass continue to be the dominant biological community in Florida Bay approximately 97% (Durako *et al.*, 2001). In North-Eastern Florida Bay, *Thalassia* was present at 75.9% and *Halodule* was present at 69%. The entire South Florida coastal zone, including the areas of West Florida Bay and within the Florida Keys National Marine Sanctuary, is dominated by seagrass habitats. Fourquarean *et al.* (2001) assessed seagrass species composition and density at 1207 sites distributed across 19,402 km² of near shore marine and estuarine environments in South Florida. *Thalassia testudinum* (Turtle Grass) was the most commonly encountered species, being found at 898 sites. *Halodule wrightii* (Shoal Grass) was the second most commonly encountered species, occurring at 459 sites; followed by
Syringodium filiforme (Manatee Grass, 239 sites), Halophila decipiens (Paddle Grass, 96 sites), Ruppia maritime (Widgeon Grass, 41 sites) and Halophila engelmannii (Star Grass, 28 sites) were recorded around the Florida bay.

1.4. Distribution of seagrass—Indian scenario

India has several seagrass floral diversity which consists of 15 species belonging to 7 genera and accounts for 30.61% of the total seagrass reported in the world (Fig.1.2). In India, seagrass habitats are mainly limited to mudflats and sandy regions in the lower intertidal zone at a depth between 10–15 m along the open shores and in the lagoons around islands (Jagtap, 1991; Ramamurthy et al., 1992). The major seagrass meadows in India occur along the SouthEast coast particularly Gulf of Mannar, Palk Bay and Andaman and Nicobar (Bay of Bengal) and the islands of Lakshadweep (Arabian Sea). It has been reported that, the Gulf of Mannar and Palk Bay, the maximum extent of around 3000 ha of seagrass (Jagtap and Inamdar, 1991). In Lakshadweep islands, there are 112 ha of seagrass has been recorded. However, a total of 830 ha of seagrass have been covered in Andaman and Nicobar islands (Jagtap, 1992; Das, 1996). The seagrass formations have been reported to be either in long or broken stretches or small to large patches (Jagtap and Inamdar, 1991; Das, 1996; Jagtap, 1996).
The seagrass cover varies from different regions which can be generally identified by using aerial photographs, ground survey and naval hydrographic charts. However, standing crop was calculated by using biomass data with the help of either line transect or quadrat methods. The maximum seagrass cover, abundance and species richness are generally found in the sandy regions along the seashores and in the lagoons of islands, where salinity of overlying water remains 33 PSU throughout the year.
1.5. Economic importance of seagrass

Seagrass meadows are the nursery grounds for many commercial fishes and crustacean species. The juveniles come into the seagrass meadows for protection against predators, to feed on the epiphytes growing on seagrass plants and to feed on the organic detrital rain that falls into the meadow from the water above. The juvenile tiger prawns (*Penaeus esculentus* and *P. semiscatus*) and endeavour prawns (*Metapenaeus ensis* and *M. endeavouri*) have seagrass meadows as their nursery grounds in Gulf of Carpentaria, the East coast of Queensland (Staples *et al.*, 1985; Poiner *et al.*, 1987; Coles *et al.*, 1993). Post-larvae of both tiger and endeavour prawns settle from the water column into the shallow inshore seagrass meadows and they move into the deeper meadows after getting the matured growth. The juveniles of the Western rock lobster forage in seagrass meadows close to the reefs in which they shelter (Joll and Phillips, 1984). This meadow is helpful to improve the diversity of most of the organisms which are economically important. Seagrass meadows reduce the speed and change the pattern of currents. This process results in depositional environments (Fonseca, 1986).
Few larger animals possess the ability to actually digest seagrass leaves (dugong, turtle, geese, brants and some herbivorous fish). Seagrass leaves often harbour a multitude of organisms such as algae and invertebrates, which serve as food for transient fish, as well as the permanent fauna within the seagrass meadow. Moreover, adult fish migrate from adjacent habitats, like coral reefs and mangrove areas, to the seagrass meadows at night to feed on the rich food sources within the seagrass meadows. Many small subsistence fishing practices, such as those practiced in Zanzibar (Tanzania), are totally depend on seagrass meadows for their fishing grounds. The coastal populations in such areas receive most of their protein from fishing within seagrass meadows (Torre-Castro and Ronnback, 2004).

The leaf canopy and the network of rhizome and root fix and stabilize the sediment over which seagrass grow, and reduce the re-suspension of the sediment by currents and waves. This role is driven by reduced water motion due to canopy friction and by the structural frame that rhizomes and roots provide to the sediments. Sediments vegetated by seagrass are less likely to be mobilized by waves and currents, so that seagrass can reduce the erosion of the coastline. Detached seagrass leaves, which are lost either at the end of their life or earlier due to waves and storms, and their accumulation in the beaches, represent another way by
which seagrass has a role in the protection of the shoreline. Large accumulation of leaves, such as those of *Posidonia oceanica* in the Mediterranean and Eelgrass in Northern Europe, dissipate wave energy and directly protect beach sediments from the impact of waves. Seagrass are important elements of coastal protection through the sediments being eroded. In the Mediterranean, the particles that constitute the sediment have in many cases a biological origin being fragments of the skeletons, shells or spines of marine animals or being the calcareous remains of benthic algae. As seagrass harbor a large diversity of marine organisms, the meadows can be considered a net source of new sediment. Biogenic particles can be the main component of sediment in coastlines with no rivers or with low fluxes of particulate matter from land to the sea. In such areas sediment produced by seagrass meadows may contribute significantly to feed the beaches, further contributing to curb coastal erosion (Koch et al., 2001).

Seagrass play a very important role as basic land builders and shore stabilizers, similar to that of sand dune and mangrove vegetation. Seagrass, although of limited direct economic profit, have been used for various purposes in different parts of the world (Fortes, 1990). Coastal people use rhizomes of *Cymodocea* sp. (nicknamed as sea sugarcane) as food, for the preparation of salad. Seagrass are also used as raw materials in paper
industry and in the production of fertilizer, fodder and feed. Most of the seagrass are used extensively as soil fertilizer for coconut and other plantations. A variety of medicines and chemicals are also prepared from them. Agar like substance and zosterin is extracted from Zostera sp.

1.6. Traditional uses of seagrass

Traditionally, seagrass have many uses (Terrados et al., 2004). Seagrass are used to prepare the baskets, extracted for soda salt and used as minor fuel, stuffing, insulating and packing material, fertilizers, etc. In addition to that, they have been used as a sewage filters, coastal stabilizers, paper manufacture, fodder and compost. Further, it can be utilized for roof covering and after removing the excess salts in the leaf, it can be used as house insulation. Moreover, in the Mediterranean and in Africa, it is also used as a traditional medicine against skin diseases (Torre-Castro and Ronnback, 2004). Seagrass seeds of several species are used as a food source. Seagrass leaves from several species viz., Z. marina, T. ciliatum, E. acoroides, P. oceanica, P. iwatensis and P. torreyi are gathered from the wrack line or cut above the surface of the sediment, dried and used for thatch, animal bedding, mattress and pillow stuffing and cordage (Felger and Moser, 1985; Wyllie-Echeverria and Cox, 1999; Aoi and Nakaoka, 2003; Bandeira and Gell, 2003; Ochieng and Erftemeijer, 2003; Procaccini et al.,
2003; Coles et al., 2003). The seeds (raw) and rhizomes (ground into flour) of *E. acoroides* are also consumed (Bandeira and Gell, 2003; Ochieng and Erftemeijer, 2003) as food. *H. ovata* leaves are principal ingredient in a paste used to treat various skin ailments.

Evidence suggests that, the particular seagrass species had value even before the development of market based economies. In the Channel Islands of the coast of California in the United States (34° N; 120° W), the coastal chumash began to fashion cordage, thatch and footwear from the leaves of *Phyllospadix torreyi* (Salls, 1988; Connolly et al., 1995). Coastal people used the thin and silicate strengthened leaves of this plant as raw material to weave fishing line and thatch shelters for thousands of years. While it is more difficult to demonstrate the intrinsic value of these wild plants in agricultural and industrial societies. There is tangible evidence that the splendour and function of seagrass species enhances both poetry and art within these cultures (Standing et al., 1975; Whitt, 1988).

1.7. **Threats to Seagrass**

The abundance of seagrass is being destroyed due to the several activities particularly anthropogenic activity. Direct human impacts to seagrass which includes; fishing and aquaculture, introduced exotic species, boating and anchoring, and habitat alteration *viz.*, dredging, reclamation
and coastal construction, etc. Fishing methods such as dredging and trawling may significantly affect seagrass by direct removal. Damage to *Zostera marina* by scallop dredging reduces shoot density and plant biomass and digging for clams can also exert extensive damage. Many of these impacts remain un-quantified as yet and their long term effects are poorly known. Most of the coastal waters are now being used in economic activities such as eco-tourism, fish caging and docking area and recreation areas. The multiple uses of these water bodies greatly receive the high pressure from the human population. Resulting impact ranges from siltation, oil spills and pollution causing fish killing and other environmental damage.

The exploitation of marine resources and the use of certain types of fishing gear like bottom trawls have detrimental effects on seagrass beds. Mussel harvest in the Dutch Wadden sea is believed to be a major factor in the loss of *Z. marina* and *Z. noltii*. Moreover, the use of dynamite poison (Cyanide) which contribute to the rapid destruction of the seagrass habitat. The impact of dynamite on the reproductive capacity of fish will surely lead to a decline in fish population in a certain habitat. Likewise, the residual effects of cyanide are irreversible or it may take several years to recover the seagrass ecosystem. In addition to that, the large scale loss of seagrass that occurred on both sides of the North Atlantic Ocean in the early 1930s, a
result of “eelgrass wasting disease” had many effects on the ecosystem (Rasmussen, 1977). Associated with this loss were a collapse of scallop fisheries and dramatic reductions in waterfowl populations. In addition, it resulted in the extinction of a marine gastropod (Carlton et al., 1991).

Direct boat propeller damage to seagrass communities has been recorded, particularly in the Florida Keys. Boat anchoring is one of the major problems which thrives the scars in the seagrass beds especially, *Posidonia oceanica* landscapes. Return of large temperate meadow forming seagrass to mooring scars may take decades. Boating may also be associated with organic inputs in areas where boats do not have holding tanks. Dredging and reclamation of marine environments, either for extraction of sediments or as part of coastal engineering or construction, can remove seagrass. Filling of shallow coastal areas, known as reclamation, can directly eliminate seagrass habitat and results in hardening of the shoreline, which further eliminates productive seagrass habitat, as seen throughout Tokyo Bay. Groynes alter sediment transport in the nearshore zone.

Dredging removes seagrass habitat as well as the underlying sediment, leaving bare sand at greater depth, resulting in changes to the biological, chemical and physical habitat values that seagrass support. Beach replenishment may have impact on adjacent seagrass by delivering
sediment that may shade or bury the seagrass. Beach nourishment can also impact seagrass growing in areas where sediments are collected, often at depths < 30m (Duarte and Rui Santos, 2004).

Increased nutrient inputs, causing eutrophication is a major component to seagrass loss. Increased siltation of coastal waters is also a major human impact on seagrass ecosystems, which derives from changes in land use leading to increased erosion rates and silt export from watersheds. Siltation is particularly an acute problem in other regions of the world, such as South East Asian coastal waters, which receive the highest sediment delivery in the world as a result of high soil erosion rates derived from extensive deforestation and other changes in land use, and may be important in European waters adjacent to deforested watersheds.

Siltation severely have impact on seagrass meadows through increased light attenuation and burial which leads to seagrass loss and, where less intense siltation occurs, a decline in seagrass diversity, biomass and production. Large scale coastal engineering often alters circulation and salinity distributions, leading to seagrass loss. Hence, seagrass meadows, previously abundant in Dutch coastal areas, are now much reduced in surface, partially related to shifts of coastal waters from marine to brackish or freshwater regimes. Pollution, other than that of nutrients and organic
inputs, may be an additional source of human impacts on seagrass ecosystems. Although, seagrass appears to be rather resistant to pollution by organic and heavy metal contaminants. These substances may possibly harm some components of the seagrass ecosystem, although such responses have not been examined to a significant extent.

Biodiversity of seagrass meadows is greater than in adjacent un-vegetated areas and higher faunal densities are present inside the meadows. It can be used as a shelter for most of the valuable marine resources (Hemminga and Duarte, 2000). Keeping this view in mind, the present study made an attempt to explore the possible utilization of the seagrass bio-wastes deposited along Palk Strait coast for the bioethanol production without affecting the biodiversity.