Review of Literature
Artificial reefs are eco-friendly technologies. Ecologically, a succession of marine life, not only as encrusting biofoulers on the hard substratum takes place, but also succession of fish fry, fingerlings and adult fish colonise this reef for shelter, feeding and breeding. Seaman and Sparague (1991) indicated that in last few decades, the applications of artificial habitat technologies have increased. This artificial reef technology is now employed in over forty countries (Sanjeeva Raj, 1996). The artificial reef creates a new fishing ground and improves the production potential of the existing grounds (Rajamani, 1996).

The majority of the scientific community considers all bodies, objects or modules which serve to increase the fishable biomass in the protected areas, whether they are located on the bottom or float on the surface, as artificial structures or artificial reefs (Bombace, 1996). Kurien (1996) described the efforts being made by communities of coastal fisher folk in South India to build artificial reefs as a means of rejuvenating the ecosystem of their coastal waters damaged by indiscriminate trawling. Baine (2001) explained that the artificial reefs as a submerged structure placed on the substratum deliberately, which mimic some characteristics of a natural reef.

Hillmer (2002) stated that the artificial reefs are considered to be a tool to improve living aquatic resources in coastal areas where coral reefs are unsuitable for attracting fish or other commercially marine organisms. He also
stated that globally organizations and individuals have deployed a rather
diverse array of structures to influence the behavior and ecology of aquatic
organisms.

The water quality parameters observed in artificial reef studies are water
temperature, irradiance radiation, visibility and current speed (Sanders et al.,
1985). These parameters are important to water column productivity and the
biotic success of artificial reefs (Bortone and Kimmel, 1991) and also forms a
part of an ecological survey of the colonization of the reef (Lam, 1999).
Bradford et al. (1991) studied the biomass of phytoplankton in relation to the
surface hydrography and their possible effects on the food chain for southern
New Zealand coast.

The parameters such as wave direction and force, tidal and oceanic
currents have been shown to play an important role in the success of artificial
reefs (McAllister, 1981). Sakuda et al. (1981) conducted an experiment on
hydrodynamic characteristics of large-scale artificial reefs and explained the
hydrodynamic characteristics of artificial reef models in Okinawa, Japan.

Murugan and Ayyakkannu (1993) studied the phytoplankton species
changes over time in their dominance and diversity with reference to the
differential effects of changing physical, chemical and biological factors on
individual species for Uppanar backwater, Southeast coast of India. Polat
(2002) recorded monthly changes in chlorophyll a, phytoplankton abundance
and nutrient concentrations in the inshore and the deep waters of the northern
part of Iskenderum Bay.
The coastal and marine biodiversity of the Indian ecosystems, from the past literature, museum records and other lesser-known sources of information shows that the number of species known could be of the order 13,000 or higher (Venkataraman and Wafar, 2005). Selvaraj et al. (2003) described the seasonal abundance of phytoplankton and its productivity in the surf zone of the sea and backwaters at Cochin with reference to cell counts, chlorophyll $a$ and photosynthesis in relation to hydrographic parameters. The abundance of zooplankton diversity and richness depends on the seasonal variation of the hydrographical parameters (Prasad, 2003; Santhanam and Perumal, 2003; Eswari and Ramanibai, 2004).

The studies carried out on the infaunal community surrounding artificial reefs provide different results for earlier workers. No measurable variation in the infauna or sediment size was recorded near an artificial reef in shallow water of San Diego, Southern California (Davis et al., 1982). Fricke et al. (1986) observed alteration on both sediment size and meiofauna biomass when comparing to the control in South Africa. Ambrose and Anderson (1990) recorded modification in both the sediment size and the infaunal community in a limited area close to the Pendleton Artificial Reef, California. But in most studies, the infaunal communities adjacent to an artificial reef is less complex than that of the natural reef and do not find measurable variation in either the infauna or sediment structure near an artificial reef (Lindquist et al., 1994; Fabi et al., 2002; Steimle et al., 2002).

Bohnsack (1989) described that the role of artificial reef is important to understand the role played by an artificial reef system, including the interaction
with the surrounding soft bottom communities. Badalamenti and D'Anna (1990) developed the monitoring techniques for zoo benthic communities in the artificial reef. Kazanci et al. (2003) conducted study in in Koycegiz – Dalyan estuarine, Mediterranean sea, Turkey and explained that the distribution of benthic macro invertebrates depends upon the salinity, temperature and phosphate of the water.

Most of the studies revealed that the high benthic faunal distribution and abundance are associated with moderate salinity, high primary production, silty clay bottom and high organic carbon content of the sediments (Harkantra and Parulekar, 1987; Edward and Ayyakannu, 1992) and the other important factor regulating the distribution of benthos is the availability of food (Humprey, 1972).

Studies on the benthic faunal succession with biogeochemical process in marine sediments were carried out by Sanders (1968), Aller (1988) and Rosenberg (2001) in Mediterranean Sea. Harkantra and Rodrigues (2003) in Goa, west coast of India. The benthic fauna of the Kayamkulam backwater and adjacent sea composed mainly of foraminifera’s, polychaetes nematodes, amphipods, isopods and bivalves (Devi et al., 1996).

Prabhu and Reddy (1987) revealed that the organic carbon content of sediment is an important parameter for benthic populations. The environmental impact assessment study was carried out to evaluate the macrobenthic community and the relevant sediment parameters in an area along the Dabhol
Coast by Ingole et al. (2002) who observed that the clayey silt fraction increase the abundance of macrobenthic community.

Various studies on the epibenthic communities formed on the reef modules have been conducted by Bohnsack and Sutherland (1985), Bohnsack et al. (1991), Ardizzone et al. (1989) and Bailey-Brock (1989). Bech (1995) estimated the distribution of epibenthic organisms on the artificial reef at Kohlanta, Thailand to estimate the amount of food on the reef modules available to sea-farming of carnivorous. The colonization process of benthos on two different types of materials revealed no significant difference both qualitative and quantitative in Eastern Ligurian Riviera, Mediterranean Sea (Relini et al., 1995).

Epibenthic communities at three different temperate reef sites was studied by Chang and Pearce (1995) and he observed that different reef construction materials functioned to attract and establish fouling communities which were important to sustain reef dwelling finfish in temperate mid-Atlantic coastal waters. Tumbilo et al. (1995) studied the biomass of benthic invertebrates living on the exposed surfaces of a concrete artificial structure in the Gulf of Castellammare (North – West Sicilian coast) and he found that horizontal surfaces have higher biomass when compared to vertical surface. Hatcher (1995) conducted experiments to quantify the sessile epibiotic community in the Poole Bay artificial reef (PBAR) of coal-waste and concrete blocks and he observed a stabilized biomass production in both the reefs.
Steimle and Figley (1996) described the effective use of artificial reefs to enhance populations of black sea bass *Centropristis striata* along the Atlantic coast of North America. Nelson *et al.* (1994) observed that the fouling communities play an important role in decreasing the potential of leaching of elements from the block surface as the surface are covered by organisms. A stabilized coal combustion solid residue artificial reef was deployed at Hoi Ha Wan, Hong Kong and the colonization experiment of the artificial reef revealed that the reef favours 27 taxa of algae and sessile invertebrates (Lam, 2000; Lam, 2001). Recruitment of the epibenthic organisms such as mollusks, barnacles, sponges, and ascidians on the surface of the artificial reef modules forms the food source for fishes (Ramkumar and Edward, 2004).

Robertson *et al.* (1981) and Hixon and Beets (1993) concluded that the shelter is one of the major limiting factors for settlement of fishes on coral reefs. Stone *et al.* (1991) stated that the fishermen have discovered floating object or an underwater structure enhanced their catches. Bohnsack *et al.* (1991) indicated that the artificial reefs and other aquatic habitats created from natural materials and man-made structures offer a potential opportunity for improving habitat, increasing resources and manipulating assemblages of organisms in ways that benefit human kind.

Leung *et al.* (1995) had deployed artificial reef in Hong Kong and observed that the abundance of fish species had increased at the artificial reef. Raja (1996) observed that the principle of fish aggregation is based on the tendency of fish to concentrate around floatsam and sunken structures for food, shade and shelter. Thus the unproductive areas can be changed into potential
fisheries sites through the artificial reef (Philipose, 1996). Similarly study carried out by James and Lazarus (1996) in Trivandrum coast, South west coast of India, Pickering and Whitmarsh (1996), Whitmarsh and Pickering (1997) and Pickering et al. (1998) in Portsmouth, United Kingdom revealed that the artificial reefs are important tool for rehabilitation of coastal ecosystems and increase of commercial reef based fishery.

The biotic colonization and fishing yield of artificial reefs are a straightforward response to local environmental conditions (D'Anna et al., 2000; Bombace et al. 2000). Jensen (2002) indicated that the artificial reefs have been placed in European waters for around 30 years and the majority now play a role in protecting valuable Mediterranean seagrass beds from trawl damage, and most aspire to a fisheries function. Similarly, Lok et al (2002) noted that the artificial reef deployed at Uzmir Inner Bay, Turkey have protected fish spawning and nursery areas from illegal trawling and created new sites for recreational fishing and diving. Sherman et al. (2002) observed enhancement in fish abundance, richness and biomass on artificial reefs in Fort Lauderdale, Florida, where floating attractants and manipulating structural complexity was seen. Similar studies were carried out by Kawasaki (2003) at Ryukyu Islands in Japan on the relationship between habitat physical complexity of artificial reef and recruitment of the coral reef damselfish, Pomacentrus amboinensis and he observed that the complex structure was responsible for more number of fishes.

The visual technique to assess the fish population was developed by Harmelin-Vivien and Harmelin (1975). Likewise Bohnsack and Bannerot
(1986) developed another visual census technique for quantitatively assessing community structure of reef fishes. The appearance of juveniles is mainly in the latter half of the summer and autumn in the Loano artificial reef at Ligurian sea north western-Mediterranean, which was studied by Relini et al. (1994). Potts and Hulbert (1994) indicated that the structural complexity of artificial and natural habitats might be responsible for aggregating and maintaining fish populations.

Bombace et al. (1994) carried out visual census by SCUBA divers and bottom trammel nets, fished from dusk to dawn and from dawn to dusk in concrete artificial reef and control sites in the Central Adritic Sea, where they observed high fish assemblages in artificial reef area. Rooker et al. (1997) observed increase in fish assemblage coincided with increasing habitat rugosity and degree of fouling during visual survey in the artificial reef at Flower Garden Banks National Marine Sanctuary, U.S.A. Ohman et al. (1997) studied the distribution and abundance of reef fishes in relation to habitat structure in Bar Reef Marine Sanctuary (BRMS) in north western Sri Lanka and on an adjacent reef, which was disturbed by destructive fishing techniques.

Rilov and Benayahu (1998) described the relationship between pillar size, structural complexity with fish abundance, species richness and diversity and also studied the effect of bottom proximity on the fish assemblage. Santos et al. (2002) carried out visual census during daytime and nighttime at artificial reef site in the coastal waters of the Algarve, Southern Portugal and they concluded that most species present have a diurnal activity pattern.
The framework and composition of the reef structure being of great importance for attracting fishes, higher the structure more hiding places it provides and great number of fishes that will live on and in it (Randall, 1963). Risk (1972) often considered the structural complexity to be the positive influence in fish species diversity at Virgin island, United Kingdom, while Luckhurst and Luckhurst (1978) and Carpenter et al. (1981) noted the same in Philippines. Chandler et al. (1985) and Ohman and Rajasuriya (1998) evaluated the effects of substrate complexity on the structure of fish communities at two artificial reefs in Bar Reef Marine Sanctuary, Sri Lanka and their results revealed that the reefs with a greater availability of space resources considerably supported a more abundant and diverse resident fish community than less complex reefs.

Spanier et al. (1985) studied the colonization of fishes in a reef constructed with old car tires, which showed initially a large presence of fish density and then leveled off slowly. Modular artificial reefs had been demonstrated by Brock and Norris (1989) to support more diverse fish assemblages than reefs constructed of scrap materials. Fitzhardinge and Bailey-Brock (1989) reported that the concrete-gravel aggregate was considered to represent the most suitable cost-effective man-made material for reef construction.

Grove et al. (1991) described that the engineering of artificial aquatic habitats has its origins in a diverse history of observations of fishes interacting with submerged objects. Collins et al. (1990) explained the constructive use of coal-fired power station waste products for building of artificial reefs in United
Kingdom, and their study in 1994 also showed the uses of stabilized wastes for habitat restoration, coastal defense and fishery enhancement. Williams (1991) and Rilov and Benayahu (2000) indicated that some species are closely associated with certain habitats, and their study also revealed that these patterns might be determined by varied needs such as food and shelter requirements which characterize different assemblages.

One of the effective way of monitoring the fishing status of a reef is to record the catch data in terms of the effort employed, as catch per unit effort (CPUE). Turner et al. (1969); Buchanan (1973) and Wickham et al. (1973) explained that catch rate was higher at the artificial reef when compared with the control site. Gannon et al. (1985) and Relini and Relini (1989) described that gill and trammel nets were used to assess the standing stock of fishes associated with artificial reefs. Moring et al. (1989) stated those standard gill nets were used usually in a commercial fishery while for scientific sampling, often an “experimental” net is used to capture fish of different sizes.

Bombace et al. (1989) reported that preliminary analysis of catch data from artificial reefs in central Adriatic was conducted to study the effect of artificial interference on the evolution of fish assemblages and on the catch over the years. Arculeo et al. (1990) studied the evaluation of fishing yield in protected and unprotected coastal areas of northwest Sicily and they observed higher fishing yields inside the sheltered zone. Similarly Fabi and Fiorentini (1994) carried out comparative study on fish assemblage living inside and around the reef with that of the control site and evaluated the effectiveness of the man-mad substrates in terms of fishing yields.
Cruz et al. (1994) conducted studies in the natural and artificial reefs in Kerala, India and suggested that the modular artificial reefs were an economically variable option for artisanal communities. Lucy and Barr (1994) used random telephone survey technique as monitoring tool for evaluating relative fishing performance of reefs and other structure sites in Virginia’s Chesapeake Bay. The studies on the effectiveness of the artificial reef in attracting fish assemblages and in enhancing fishing yield than the control site was conducted at Gulf St. Vincent, South Australia by McGlennon and Branden (1994) and at Faro, Algarve, South Portugal by Polovina and Sakai (1989) and Santos and Monteiro (1998).