1.0. GENERAL INTRODUCTION

1.1. Fisheries sector – An overview

Fishes are the first vertebrates with jaws, which are cold-blooded animals and can breathe through gills, there are about 36,000 species, which represent the 40% of the total vertebrate present. Fishes have evolved during Ordovician period and widely distributed during Devonian period, which is known as ‘Golden age of fishes’. The study of fishes is known as Ichthyology. They live in all the seas, rivers, brackish waters, lakes, reservoirs, canals, tanks etc. Fishes have great significance in the life of mankind, being an important natural source of protein and omega 3 fatty acids and providing certain other useful products as well as economic sustenance to many nations (Piska and Naik, 1999).

The process of fishing is otherwise known as capturing of fishes and other aquatic species from marine and other aquatic regions are called as fisheries. Recently FAO (2010a) reported that, total global fishery production from capture fisheries and aquaculture combined reached 142 million tonnes in 2008, of that 37% coming from aquaculture. World capture fisheries production alone was 90 million tonnes during the year of 2008 (FAO, 2010b). Mainly fish production is divided in to two sub sectors viz.,
capture fisheries which overly depend on naturally recruited wild population and formed food fish sub sector known as “Aquaculture” (De Silva, 2001). Fishing activities are mainly based on small scale and large scale fisheries. Small scale fishing products contribute 94% of the global fishing fleets and small scale fisheries provide an important source for many coastal communities (FAO, 2002).

Small scale fishing boats are individually able to catch fewer fish than their large scale counterparts, small scale marine fisheries reportedly account for 40% of the marine fishes taken for human food (FAO, 1998). Unlike the large scale industry, aimed at providing high valued species (eg. tuna) to the international market, artisanal fishers tend to supply local markets with lowered value fish and invertebrates catches (King, 1991). Such small scale fisheries products provide an important source of protein to people throughout the developing world (Saila, 1988; King, 1991; Nickerson Tietze, 2000).

World fisheries and aquaculture production increased as 142 and 53 million in 2008 respectively and valued at around US$99 billion in 2008 (FAO, 2010b). In Asian countries such as China (15 million tonnes), Indonesia (5 million tonnes) and Japan (4 million tonnes) are mainly involving in the production of world capture fisheries (FAO, 2010a). Further fisheries
activities in India can be classified in a number of ways that depends upon the sources of the harvesting based on sea under marine fisheries or fresh/brackish water fisheries under inland fisheries. A total of about 74% Indian fishers population are engaged with inland fisheries, and the 26% fishers involved in marine fishing (Datta et al., 2010).

Inland fisheries and aquaculture also contribute about 25% to the world production. In addition, many important estuarine and coastal fisheries are strongly linked to the ecological processes that occur in fresh water systems. The value of fresh water production to human nutrition and income is much greater than gross national production. The bulk of production is generate by small-scale activities, with exceedingly high levels of participation not only in catching and farming, but also in processing and marketing, inland fisheries are often critical to local food security. Inland fisheries related export and regional trade plays important role in the economy of many regions and countries. Recently, African country provides an annual fish captures of about 570,000 tonnes with a value of US$ 295 million income per year. Further, Indian inland aquaculture system provides 1.7 million tonnes of fish production per year (FAO, 2004).
Inland aquaculture has emerged as a major source in fish producing system in India. Fishes such as roho (*Labeo rohita*), catla (*Catla catla*), mrigal carp (*Cirrhinus mrigala*), grass carp (*Ctenopharyngodon idellus*), common carp (*Cyprinus carpio*), silver carp (*Hypothalmichthys molitrix*), catfish (*Clarius batrachus*), rainbow trout (*Oncorhynchus mykiss*) and giant river prawn (*Macrobrachium rosenbergii*) are the major fish products are being under cultivation.

1.2. Marine fisheries- In particular

1.2.1. Global scenario

Marine fisheries are conducted in all the oceans and seas of the world, including bays and estuaries. The capturing and culturing of the aquatic organisms in salt water accounts for bulk of the fishery products that reaches world markets. World capture fisheries production and aquaculture peaked about 140 metric tonnes in 2002 (FAO, 2002). In most countries, marine fisheries employ many of the fishers (Abu Talib *et al.*, 2003a; Boonchuwongse and Dechboon, 2003; Cruz Trinidad, 2003; Long, 2003). The marine sector dominates capture fisheries production in all countries, 60-85% and these tend to be dominated by demersal species (Janetkitkosol *et al.*, 2003; Abu Talib *et al.*, 2003b). Srilanka and the Philippines are exception where pelagic species dominated the landings from coastal fisheries (Barut *et al.*, 2003).
The coastal fisheries can be divided into two broad sectors, small scale fisheries and large scale or industrial fisheries. The small scale fisheries are mainly characterized by small boats (Charles, 2001). Small scale fisheries involve both non-motorized and motorized vessels and covers with many types of gears such as gillnet, trammel hook and line trap, small push net and seine nets (Abu Talib et al., 2003a; Barut et al., 2003; Rahman et al., 2003). The industrial sector is characterized by larger motorized vessels that tend to have greater fishing and high storage capacity. Countries such as Malaysia and Thailand large scale fishing is dominated by trawlers (Abu Talib et al., 2003a; Janetkitkosol et al., 2003) but countries such as India and the Philippines large scale fishing dominated by vessels that destroy the pelagic resources (Barut et al., 2003; Vivekanandan et al., 2003). Moreover, in Bangladesh, Indonesia, Philippines and Vietnam over 80% of the fishing fleet are small scale vessels. Further, small scale sector contributes 95% in Bangladesh and 30% in the Philippines, Sri Lanka and Vietnam. The landings of small scale fisheries and their contribution to food security are underestimated in most countries because of the difficulties associated with accurate monitoring (Ninnes, 2003).
Nowadays, the global production statistics for capture fisheries sector to increase global economic and provide food security to 1 billion people. In 2006, 47.5 million people were employed as fishers in fisheries sector (FAO, 2009). Currently, the world’s fisheries deliver annual profits to fishing enterprises worldwide of about US$8 billion and support directly and indirectly 170 million jobs, providing some US$35 billion in household income a year. When the total direct, indirect and induced economic effects arising from marine fish populations in the world economy are accounted for the contribution of the sector to global economic output is found to amount to some US$235 billion per year. This is based on evidence from a recent report showing that potential total rent in world fisheries is about US$50 billion per year at Maximum Economic Yield (MEY) (World Bank and FAO, 2009).

In 2008, nearly 81% (115 million tonnes) of world fish production was destined for human consumption, while the rest (27 million tonnes) was used for non-food purposes. Seventy six percent of world fish production destined for non-food purposes (20.8 million tonnes) was reduced to fishmeal and fish oil; the remaining 6.4 million tonnes was largely utilized as fish for ornamental purposes, for culture (fingerlings, fry, etc.), for bait, for pharmaceutical uses as well as raw material for direct feeding in
aquaculture, for livestock and for animals (FAO, 2010a) and at the same year 39.7% (56.5 million tonnes) of world fish production was marketed as fresh, while 41.2% (58.6 million tonnes) of fish was frozen, cured or otherwise prepared for direct human consumption. Globally, fishers caught the most economical important fish species in World Ocean such as tuna, anchovy, salmon, ground fish, shrimp and cephalopods. Among the fish species share in world trade as salmon 12%, ground fish 10% and cephalopods 4 % (cuttlefish, squid and octopus etc) (FAO, 2010a).

1.2.2. Indian scenario

India is endowed with 2.02 million sq.km of Exclusive Economic Zone (EEZ) along with a coastline of 8129 km and 0.5 million sq. km continental shelf with a catchable annual fishery potential of 3.93 million tonnes occupying a very important strategic position in the Indian Ocean. The aquaculture resources in the country comprise 2.25 million hectares of ponds and tanks. Among the Asian countries, India ranks second in aquaculture production and third in capture fish production and one of the top leading exporters of sea foods (Kumar et al., 2003).

Indian coast comprised the four sub division viz., South west coast, South East coast and North West and East coast. The South West coastal region comprising the state of Kerala, Karnataka and Goa with a coastal line
of 994 km and 7.83 lakh fisherman population depend on marine fisheries, these had been the most productive and the largest contributor to the country total marine fish landings. Marine fish production in this region during the year 2008 has been estimated as 1.11 lakh tonnes, contributing about 34.5% to the all India landings (MFIS, 2010). Among the different states, the maximum contribution was obtained from Kerala 6, 70,100 tonnes (60%), followed by Karnataka 3,30,060 tonnes (30%) and the rest 1,10,508 tonnes from Goa. During the year 2008 marine fish landings was 1, 02,438 tonnes in the south west coast of India. Of these, pelagic fish population contributed 67%, demersal fishes 19%, crustaceans 8% and mollusk 6.5%. Pelagic fish increased from about 7.26 lakh tonnes in 2007 to 7.44 lakh tonnes in 2008. Among these population, oilsardine (49%), mackerel (15%), stolephorus sp. (96%), carangids (7.3%), tunnies (3.4%) and ribbon fishes (4.3%) were the major components of pelagic fin fish production. The landings of demersal resources have increased from 1.6 lakh tonnes in 2007 to 2.07 in 2008. A total 270 species were landed in Kerala, 138 in Karnataka and 66 in Goa during 2008 (MFIS, 2010).

South East coast of India comprising the states of Andhra Pradesh, Tamil Nadu and Pondicherry have a total coastal line of 2050 km, which occupy 34% coastal line of the India. The estimation of marine fish landings
for the South East coast region for 2008 was 6,63,790 tonnes which accounted for 21% of the total landings in the country. The percentage contribution from Andhra Pradesh, Tamil Nadu and Pondicherry were 64%, 34% and 2% respectively. Important groups according to their landings in the region were oil sardine 74, 118 tonnes (11%), lesser sardine 72, 710 tonnes (11%), silver bellies 53, 734 tonnes (8%), penaeid prawns 43,982 tonnes (7%), Indian mackerel 31,067 tonnes (5%) and carangids 26, 244 tonnes (4%), ribbon fishes 23, 005 tonnes (3%), other perches 18, 910 tonnes (3%), other clupeids 18,738 tonnes (3%), croakers 18,312 tonnes (3%), crabs 17,945 tonnes (3%), stolephorus 13, 358 tonnes (2%) and goat fishes 13, 300 tonnes (2%) (MFIS, 2010).

North West coast of India comprise two major coastal states viz., Gujarat, Maharashtra and the union territory Doman and Diu, the estimated marine fish landings of the coast was 9.5 lakh tonnes in 2008 as against 8.4 lakh tonnes in the previous year. Major fish groups were contributed to their respective group of important in Maharashtra perches (51.01%), pomfrets (49.66%), seerfish (69.38%), penaeid prawns (32.38%) and non penaeid prawns (79.64%) and the Gujarat coast contribute the major species such as perches (47.05%), carangids (27.64%), pomfrets (83.57%), seerfish (53.60%), penaeid (32.8%) and non peneaid prawns (83.42%) (MFIS, 2010).
North East coast comprises the state of West Bengal and Orissa coast. There are 100 landings centre distributed in the two coastal regions, the estimated marine fish landings in this region was 4.833 lakh tonnes in 2008, which is formed about 15% of the total all India landings. The state of West Bengal accounts for the largest share in the landings (62%) and the remainder (38%) was from Orissa. In this region, total marine fish landings accounted by pelagic fish has risen from about 53% in 2007 to over 56% in 2008. Demersal fish production also showed an increase from 30% in 2007 to 32% in 2008 and other animals accounted such as crustacean (14%) mollusk (1%) of the total fish production during the year 2008. Indian coast receives maximum fish production during the monsoon season between the months of October to December than other seasonal period (MFIS, 2010).

In recent years, the Indian ocean has produced approximately 10% of the almost 93 million tons of annual global fish production, with the Western Indian ocean producing about 50% of the Indian ocean landings (FAO, 2009). Offshore fisheries operating in the Western Indian ocean are large-scale industrial fisheries with a high level of technology and investment. Industrial fishers tend to be distant water fishing fleets from Asia and Europe that target a wide range of migratory fish, such as tuna, kingfish, bonito, and mackerel, most of which are sold in the export market (FAO, 2009).
1.3. Types of marine fisheries

Capture fisheries are extremely diversified, comprising a large number of types of fisheries that are categorized by different level of classification. Capture fishery is classified as industrial, small scale, artisanal, recreational and commercial fisheries.

1.3.1. Industrial fisheries or large scale fisheries

Industrial fisheries used the large vessels with a high degree of mechanization and they provide the advanced fishing technology and navigational equipment. Such fisheries have a high production capacity and the catch per unit effort is relatively high. The term industrial fishery is often used as offshore fishing in large vessels. In general, industrial fisheries involved capture fishing area greater than 15 m in length for fishing activity that is usually carried out in offshore areas. The present industrial fishing activity consists mainly of two types of tuna fishing and shrimp trawling by using gears such as purse seine, trawl net, long line gears (Roberts, 2002). Further, Industrial trawlers are used destructive fishing gear that destroys the bottom habitat on which exploited species depend (Chuenpagdee et al., 2006; Zeller and Pauly, 2007), industrial sector reduces 20–30 millions of fish annually into fishmeal to feed pigs, chickens and farmed fish (Alder and Pauly, 2006).
1.3.2. Small-scale fisheries

Small-scale fisheries are characterized as fishers operating in boats or without boats in 15 m depth or less (Chuenpagdee et al., 2006). The small-scale fisheries discard little number of fish and also do not destroy benthic communities. Small-scale fishers are capable of targeting different fish species on the basis of their availability (Munro, 1979). Furthermore, small-scale fisheries produce little fishmeal, whereas the small-scale fisheries employ 25 times more people and use one quarter the fuel to catch roughly the same amount of edible fish (roughly 30 million tonnes) as the large-scale industrial fishing sector (Chuenpagdee et al., 2006). According to FAO, there are about 25 million small-scale fishers on the planet (FAO, 2009).

1.3.3. Artisanal fisheries

Artisanal fisheries capture fish by small fishing vessels, making short fishing trips, close to shore, mainly for local consumption. Artisanal fisheries can be varied as hand collection on the beach or a one-person canoe in poor developing countries to more than 20 m. In developed countries, trawlers, seiners or long liners are used over 20 m depth for fishing. Artisanal fisheries can be subsistence or commercial fisheries, providing for local consumption or export.
1.3.4. Recreational fisheries

Recreational fishing, also called sport fishing. It can be contrasted with commercial fishing, which is fishing for profit, or subsistence fishing, which is fishing for survival. The most common form of recreational fishing is done with a rod, reel, line, hooks and any one of a wide range of baits. Other devices, commonly referred to as terminal tackle used to capture the target fish. Recreational fishing is fishing activities from boats to catch large open-water species such as tuna, sharks, marlin and trout tickling (Cowx, 2002).

1.3.5. Commercial fisheries

The large quantity of fishes are captured from marine environment to market level, through auction halls, direct contracts, or other forms of trade. Commercial fishermen harvest almost all aquatic species such as tuna, cod, salmon, shrimp, krill, lobster, clams, squid and crab, in various fisheries for these species. Commercial fishing methods have become very efficient using large nets and sea-going processing factories.

In India, many fishers mainly involved in the important marine fisheries are, mackerel fishery, Bombay duck fishery, sardine fishery, sciaenid fishery, ribbon fishery, silver fish fishery, carangid fishery, pomfret fishery, flat fishery, prawn fishery, lobster fishery, molluscan fishery such as squid, mussels, scallops, clams, bivalve and snails etc.
1.4. Export value of marine fisheries

In 2008, an estimated 45 million people were directly engaged in the primary fisheries sector and aquaculture. An additional 6.5 million are engaged in the sector occasional basis (FAO, 2010c). Fishing is an important source of livelihood in developing countries, particularly in low-income coastal communities, where job options are limited. Fisheries contribute to the Gross Domestic Products (GDP) of many countries including, Namibia 6% and Iceland 11%, India 1.2 % (Ninan and Sharma, 2006; Agnarson and Arnason, 2007). International trade in fisheries products continues to increase from US$17 billion in 1985 to over US$55.2 billion in 1996 (Deere, 2000) and to US$71.5 billion in 2004 and to US$85.9 billion in 2006 (SOFIA, 2006). Developing countries net export in fisheries products rose from US$4.9 billion in 1984 to US$16.0 billion in 1994 and to US$20.4 in 2004 (SOFIA, 2006). Fish products are now one of the most valuable commodity exports for some coastal developing countries. Meanwhile, developed countries dominate the import market, with the European Union (EU), Japan and the United States (US) accounting for 80% of world imports by value in 1994 (Bruinsma, 2003). These apart, fish also have socio-cultural and recreational importance.
In 2008, the world major top exporter countries such as China (US$10.3 billion), Norway (US$ 7.0 billion), Thailand (US$ 6.5 billion), USA (US$ 4.5 billion), Vietnam (US$ 4.6 billion), Denmark (US$ 4 billion), Canada (US$ 3.7 billion), Chile (US$ 4.0 billion), Spain (US$ 2.8 billion), Netherlands (US$ 2.8 billion) (FAO, 2010c). Shrimp continues to be the most important commodity traded in value terms, accounting for 15% of the total value of internationally traded fish products in 2008. The other main groups exported species were ground fish (11% eg. hake fish, haddock fish, cod, and Alaska pallock), salmon (12%) and tuna (8%). In 2008, fish meal represented around 3% of the value of exports and fish oil less than 1% (FAO, 2010c).

The FAO estimates that, about 45% of the world fish catch enters international trade. In 2006, the total world exports of fish and fish products reached US$ 85.9 billion, which represents an increase of 55% from 2000. Similarly, the value of imports in the same period reached US$89.6 billion or an increase of 49% (SOFIA, 2006). Developed States absorb more than 80% of total world fisheries imports in value terms. The European commission are the largest global market for fish, accounting for approximately 40% of global imports. Japan and the US account approximately for an additional 35% of total world imports of fisheries products. The significant contribution of developing states in the international trade of fish is undeniable. The net
exports of fish by developing states have shown a continuous increasing trend over the decades, which is estimated at 49% in value and 59% in quantity of the total fishery exports in 2006. This overall trend is primarily driven by China, which has now become the world’s largest exporter of fish.

The rising trade values and volumes for all fish commodities reflect the increasing globalisation of fisheries value chains, in which processing is being outsourced to Asia, as well as Central and Eastern Europe and North Africa (FAO, 2007). Outsourcing of processing takes place both at the regional and global levels, depending on the product form, labour costs and transportation time. Many species, such as salmon, tuna, catfish and tilapia, are increasingly traded in their processed form. In addition, there has been a growth in the internationalisation or globalisation of distribution channels through the demands of large retailers (FAO, 2007).

1.5. Factor affecting the marine fisheries

Marine fisheries affected by natural and human factors, before the industrial revolution variation in climate occurred naturally. Increase in sea temperature as a result of natural atmospheric circulations, such as the El Nino - Southern Oscillation (ENSO), the North Atlantic Oscillation (NAO) and the Pacific Decadal Oscillation (PDO) had short and long-term impacts on a variety of fish populations. Other natural factors such as salinity, wind
speed and direction, ocean currents, nutrient availability, carbon dioxide concentration in the ocean, strength of upwelling, rain and snow, as well as the interaction among these factors, have tremendous effects on fishery resources (Krovnin and Rodionov, 1992; Stenseth, 2002).

1.5.1. Climate change

The most basic way that climate change affects fish is through increase in global temperature. The 2007 Report of the Intergovernmental Panel on Climate Change (IPCC) reveals that, global average surface temperatures over the last 100 years have increased by 0.74°C ± 0.18°C (Trenberth et al., 2007).

Ocean warming globally affects marine fishery resources in many ways. In the first place, although El Nino events are naturally induced and inevitable, simulations of the El Nino cycle indicate they are becoming stronger and with wider swings as the global climate warms. Increased sea temperature is one of the major causes of destruction of coral reef ecosystems. Coral reefs are highly sensitive and can only survive between 18°C and 30°C. Most coral bleaching is mainly affected the marine fisheries. Coral reefs serve as habitat to at least 25% of all marine species and thirty-two of the 33 animal phyla. Presently, 30% of coral reefs have been damaged because of increasing sea temperatures and coral mining. Another impact of
climate change that threatens fishes is sea level rise (Timmermann, 1999; Reynaud et al., 2003; UNEP-WCMC, 2006).

Fish species are ectothermic (cold blooded), thus, sea temperature affects all facets of their lives including, spawning, growth, distribution, migration patterns and incidence of disease. Schrank (2007) and Pierce (1995) provide the first empirical evidence on the correlation between fish stocks level and temperature, subsequent studies have continued to reveal the negative and positive impacts of increases in sea temperature on fish stocks. Until, recently one could assume that because global warming mostly affects the surface layer of the sea, demersal fish stocks were affected by climate change than pelagic fish.

1.5.2. Overfishing

Globally, overfishing is the primary human activity constituting a threat to fishery resources. Overfishing defined as when so many fish are taken from a population. Overfishing is caused by several interrelated factors such as over exploitation, using the trawl net and using the cyanide, dynamite bomb for over fishing from marine environment.
1.5.2.1. Over exploitation

Commercial fishermen introduced long line nets and deep-sea bottom trawling. Long line net fishing and deep-sea bottom trawling for shrimps constitute major unselective and non-environmentally safe ways of fishing and are causing serious concern and also fishers bring so much non-target fish and other non-fish species by trawling. This has led to an enormous volume of other species being caught incidentally as bycatch. Bache (2002) argued that bycatch is one of the highest causes of human induced marine resource mortality.

1.5.2.2. Trawler fishing

The use of small-mesh nets mainly seine nets despite their official ban, and gillnets (smaller than the recommended minimum mesh size of 5 cm) in shallow water areas by large number of fishermen has caused considerable damage by the indiscriminate catching of all fishes, large and small, in the area irrespective of their value. This might have led to local overfishing of specific stocks. These nets further destroy coral reefs and sea grasses when they are dragged on the bottom and when they get entangled.

By using the trawl nets cause to discards the unwanted fishery population and reduce the fish biodiversity in the ocean. Davies et al. (2009) estimates that, trawl catch would be just over half of the nominal total
marine catch. However, Bhathal (2005) reported that 1,800,000 non-shrimp catch was discarded through by catch, the total discards would be about 600,000 tonnes. The total estimated trawl catch of 2,250,000 tonnes, all of which is considered bycatch.

1.5.3. Habitat destruction

Habitat loss and environmental degradation of coastal zones, wetlands, deltas, coral and mangrove areas due to developmental activities and growth in aquaculture constitute the main reasons for the collapse of marine fish species that spawn in freshwaters. In the case of the Pacific salmon, building of hydropower dams and modification of natural river flows are some of the factors contributing to salmon decline. The fact that 90% of the world’s coasts will become developed by 2050 will definitely exacerbate the already lamentable state of marine fishery resources. Habitat loss also occurs in the high seas through deep sea fishing activities (Williams, 2007; Roberts, 2002).

There is an increasing mangrove cutting for timber, poles, fuel wood, charcoal and local medicine uses (Moochii et al., 1998). Uncontrolled cutting of mangroves that serve as nursery grounds for variety of fish, shellfish and prawns leads to reduction of the stock. Indeed, dynamite fishing has destroyed many coral reefs that are important breeding grounds. It has been
observed that, coral reefs and mangrove forests increase the carrying capacity of the marine environment. Hence, their destruction reduces the capacity of the environment to accommodate larger stocks, and less stock implies less catch.

1.5.4. Advanced technology

Technology has revolutionised fishing operations to such an extent that the actual fishing capacity is estimated to have increased fourfold since 1965. Many fishing vessels are factory trawlers with sophisticated methods of catching fish and able to carry on board thousands of tonnes of fish. These trawlers now use radar to navigate in dense fog, sonar to detect schools of fish in deep ocean waters and electronic navigation and image aids such as Global Positioning System, which helps vessels to return to site where fish gather and breed. They also use satellite weather maps to track water temperature fronts that indicate the likely location of fish and tracker planes to spot fish. This has led to overfishing of many fish stocks in developing coastal states waters (Mullen, 2007).

1.5.5. Aquatic pollution

Pollution of the aquatic environments constitutes another major threat to marine fish populations all over the world. Marine accidents, such as the one involving Prestige off the Galician coast in 2002, have disastrous
consequences on fish stocks. Dumping of toxic waste in the sea and emptying of ballast water from ships into the sea are other human activities polluting the aquatic environment. The problem of invasion of exotic fish species is linked to ballast water from ships.

The sources of pollution of the aquatic environment are industrial waste, raw/untreated domestic sewage, run-off of fertilisers and pesticides, sand mining, construction of canals and oil spills. The millions of tonnes of polythene bags and other types of non-biodegradable debris that have been washed by rain water into the aquatic environment constitute new threats to marine fisheries.

Generally, in addition to the fish diseases, the mortality rates of the fish are affected during the stage of fish rearing, early larval stage, by the Vibrio sp. (Thompson et al., 2004; Austin and Austin, 1989; Diggles et al., 2000).

1.6. Biological activities of marine sponges

Marine sponges are an important component of benthic communities throughout the world, regarding its biomass as well as their potential to influence benthic or pelagic processes (Dayton et al., 1974; Dayton, 1989; Gili and Coma, 1998; Maldonado et al., 2005). Sponges (phylum Porifera) are
among the oldest multicellular animals (Metazoa) and show relatively little
differentiation and tissue coordination (Bergquist and Bedford, 1978;
Simpson, 1984; Leys and Meech, 2006). They are grouped into three classes,
the Hexactinellida (glass sponges), the Calcarea (calcareous sponges) and the
Demospongiae. The latter class contains the vast majority of extent sponges
living today. Sponges inhabit every type of marine environment. More than
8,000 species of sponges were described all over the world; they inhabit a
wide variety of marine and freshwater ecosystems and are found throughout
tropical, temperate and polar regions (Hooper and Van Soest, 2002).

Marine sponges are sessile invertebrates with a wide variety of
colours, shapes and consistencies. The presence and abundance of spicules is
variable among some sponge species (e.g. from the orders Lithistida and
Astrophorida) have dense or fused siliceous skeletons and therefore a hard
consistency, whereas other species have few or no spicules, thus lacking
physical defenses. Instead, they have evolved to develop chemical defences
against predators and larval settlement of other sessile organisms
(Kobayashi, 2000). In addition, sponges have strategies to defend themselves
against foreign prokaryotic and eukaryotic organisms, by the production of
secondary metabolites that repel them (Sarma et al., 1993 and Proksch, 1994).
In fact, marine sponges are among the richest sources of interesting chemicals produced by marine organisms.

Chemical classes from sponge and associated microbes such as bioactive terpenes, sterols, cyclic peptides, alkaloids, fatty acids, peroxides and amino acid derivatives etc., are widely distributed (Ichiba et al., 1994; Yousaf et al., 2002; Blunt, et al., 2004, 2005; Sipkema et al., 2005; Keyzers and Davies, 2005; Moore, 2006; Piel, 2004; Jacob Inbaneson, 2010).

Sponge chemical constituents namely hydroxymanazamine, amphilactams A and D, sigmosceptrellin-B, peroxylactone, plakortide, cribrostatins are previously proved to have potential biological activity viz., antibacterial, antifungal, antiviral, anticancer, antifouling, antimalarial, nematociadal, antiplasmodial, antihelminthics, anti- \( M \) \( \text{tuberculosis} \), antineoplastic and antimicrobial, antiprotozoal, anti-inflammatory and cytotoxic activities etc (Ang et al., 2000; Rashid et al., 2001; Faulkner, 2002; Torres et al., 2002; Orabi et al., 2002; Mayer and Gustafson, 2003; Harwood et al., 2003; Liu et al., 2004; Blunt et al., 2004; Thakur and Muller, 2004; Marinho et al., 2006; Galeano and Martinez, 2007; Touati et al., 2007; Laport et al., 2009; Carlton and Newman, 2009; Blunt et al., 2009; Ortlepp et al., 2008; Limna Mol et al., 2010; Luter et al., 2007 and Qian et al., 2010).
1.7. Biological activities of Sponge associated microorganisms

Marine invertebrates have developed highly specific relationships with numerous associated microorganisms and these associations are of recognized ecological and biological importance (Sponga et al., 1999; Armstrong, 2001; Strahl et al., 2002). It has been reported that, the ratio of microorganisms with antimicrobial activity from invertebrates was higher than from other sources (Ivanova et al., 1998; Burgess et al., 1999), which suggested that, invertebrate associated microorganisms might play a chemical defence role for their hosts. This kind of microorganism as a sustainable resource has a high potential to biosynthesize novel biologically active secondary metabolites. Marine sponges harbour large amounts of bacteria in their tissues that can amount to 40% of their biomass (Vacelet, 1975; Vacelet and Donadey, 1977) exceeding that of seawater by two to three orders of magnitude (Friedrich et al., 2001). In addition, sponges have symbiotic relationship with variety of microorganisms such as heterotrophic bacteria and cyanobacteria, actinomycetes, fungi (Sara et al., 1998; Kohlmeyer and Volkmann Kohlmeyer, 1991; Thakur and Muller, 2004), aerobic chemoheterotrophic bacteria (Wilkinson, 1987), nitrogen - fixing bacteria (Wilkinson, 1987), methane-oxidizing bacteria (Vacelet et al., 1996),

Bacterial counts in the oceans average one million cells per milliliter (Rheinheimer, 1992). In the past ten years, 659 marine bacterial compounds have been described. Except for four compounds from sources with no taxonomic identification, all the compounds isolated between 1997 and 2008 originated from five bacterial phyla: bacteroidetes (34 compounds), firmicutes (35), proteobacteria (78), cyanobacteria (220) and actinobacteria (256). Cyanobacterial compounds were primarily from the genera *Lyngbya* or *Symploca* and 85% of the metabolites from the phyla actinobacteria were from the genera *Streptomyces* (57%) or *Salinispora* (28%) (Williams *et al.*, 2007).

Marine sponge associated bacteria, actinomycete and fungal isolates have been proved to significant bioactivity including antifouling, antibacterial, antifungal, antiplasmodial and cytotoxic activities and their numerous studies medical exploration and ecology investigation (Holler *et al.*, 2000; Burja and Hill, 2001; Osinga *et al.*, 2001, Jacob Inbanesan, 2010). The occurrence of potential resources in the invertebrate associated microorganisms might be due to the competition for nutrition, space and light (Ivanova *et al.*, 1998; Burgess *et al.*, 1999; Armstrong *et al.*, 2001). In accordance with the associated microbial populations, *Actinomycetes* sp.
plays important roles in the production of biological activities (Bull et al., 2005). A variety of new chemical entities and bioactive metabolites are widely identified by several authors (Blunt et al., 2004; Salomon et al., 2004; Fiedler et al., 2005; Jensen et al., 2005; Bull, 2004; Bull et al., 2005).

Among the actinomycetes, the genus Streptomyces sp. were majorly presented. Although the “Micromonospora-Rhodococcus- Streptomyces” group seems ubiquitous incultured actinobacteria from marine environments (Maldonado et al., 2005), only Micromonospora sp. and Streptomyces sp. were isolated from the sponge Haliclona sp. (Zhang et al., 2006). Over half of the bioactive compounds in the antibiotic are mainly produced by the actinomycetes (Lazzarini et al., 2000). The increasing numbers of rare actinobacteria found from marine sponges indicate that sponges are potentially unique sources of novel actinobacteria (Zhang et al., 2006). Vibrio sp. associated with the sponge Dysidea sp. were shown to synthesize cytotoxic and antibacterial tetrabromodiphenyl ethers (Elyakov et al., 1991). The diketopiperazines associated with the sponge Tedania ignis were found to be produced by a Micrococcus sp. (Stierle et al., 1988). Recently, the antifungal peptide theopalauamide, isolated from the marine sponge Theonella swinhoei was shown to be contained in novel d-proteobacterial symbionts of the sponge (Schmidt et al., 2000).
Hentschel et al. (2001) isolated the 238 bacterial isolates from the sponge *A. aerophoba* were tested for their antimicrobial activity. Of that, 27 isolates showed a positive response in an inhibition zone assay against bacteria. *Bacillus* sp. isolated from marine sponges as a source of antimicrobial agents and it can produce many antibiotics including cyclic peptides, cyclic lipopeptides and novel thiopeptides (Nagai et al., 2003). Until 2002, 12 bioactive compounds were reported from marine *bacillus* sp. (Dobler et al., 2002). Burja et al. (1999) have reported that gram-positive bacteria make approximately 10% of the total isolates from sponges. Marine *Bacillus* sp. is often isolated from sediments and invertebrates (Pabel et al., 2003). The species of this genus are known to generate spores under adverse conditions, such as those encountered in marine ecosystems (Hentschel et al., 2001). In the marine environment, members of the genus Bacillus, known for the production of metabolites with antimicrobial, antifungal or generally cytotoxic properties were regularly isolated from invertebrates and thus display a high potential in the search for new antimicrobial substances (Muscholl-Silberhorn et al., 2007).

Previously, many researchers reported the sponge associated biological activities with different microbial isolates such as *Bacillus* sp., *Myrothecium* sp., *Pseudomonas putitda*, *Pseudoalteromonas piscicida*, *Alcaligenes*
faecalis, Saccharopolyspora sp. Bacillus vallismortis, Penicillium auratiogriseum, Letendraea helminthicola from different sponges viz., Axinella sp., Mycale microsigmatosa, Mycale plumose, Acanthella cavernosa, Dysidea avara (Zheng et al., 2005; Xin et al., 2005; Blunt et al., 2007; Yang et al., 2007; Xie et al., 2008; Li et al., 2008; Yu et al., 2009). So far, many of the drugs discovered from marine sponges for the treatment of human as well as animal diseases. However, work related with the crude extracts from sponge associated microbes for the fish diseases management is too limited. Hence, the present study has been made an attempt to find out the antibacterial drugs from marine sponge associated microbes.