All over the world, fishing is the livelihood of the society of coastal areas and has been continuing for millennia. The conventional system of fisheries management was intended to promote the landings of economically important species. With this motive, the fishing effort was increased in the last 100 years with the mechanization of commercial fishing boats, introduction of synthetic gear materials, improved harvest technology and advanced navigational know-how. But in the long run, the aim to optimize the catch resulted in the decrease of the targeted species. The Code of Conduct for Responsible Fisheries proposes in article 12, which deals with Fisheries Research, to carry out studies on the environmental impact of fishing gear to aid fisheries management studies and to safeguard the biodiversity of ecosystems (FAO, 1995). The fishing operations contributing to deterioration of marine ecosystem are towed fishing gears like trawling and dredging which over the years have emerged as the most important fishing methods in the world. The major gears causing impact vary from otter trawls, beam trawls, scallop dredge to even the *rapido* trawl which is a kind of beam trawl operated in the northern Adriatic Sea (Pranovi *et al.*, 2000).

Bottom trawling causes physical and biological damages that are irreversible, extensive and abiding. By catch and discards are ample evidences of impact of bottom trawling. Bottom trawling inflicts impact on environmental parameters, sediment geochemistry, epifauna, infaunal macrobenthos and
meiobenthos. An increase in turbidity, decrease in dissolved oxygen, reduction in sediment organic matter, and variations in sediment texture, disparity in sediment water column fluxes of nutrients, chlorophyll and pollutants are the different physicochemical impacts. The epifaunal seafloor habitats of seagrasses, seamounts and coral reefs that provide food, nurseries and shelter for a variety of marine organisms and sessile fauna of sponges, hydroids, anthozoans, bryozoans, gorgonians and polychaete worm tubes are destroyed by bottom trawling activities. An increase in abundance of opportunistic species and a reduction in faunal diversity are the impacts on infauna. Trawling contributes the major share in the global bycatch, which comes to around 35% of global bycatch. The benthic fishes, crustaceans and molluscs that form a major part of bycatch and discards are the impacts on non-target organisms. The dietary shifts in benthos are an indirect effect of trawling. Bottom trawling imparts both short term and long-term impacts.

1.1. Fishing operations in India

India, endowed with a long coastline of 8129 km, 2.02 million sq. km. of Exclusive Economic Zone (EEZ) and 0.5 million sq. km. of continental shelf and with an annual marine fishery potential of 3.93 million tonnes, occupies seventh position in the world marine capture fish production. The marine fish production in India during 2007-08 was estimated at 2.88 million tonnes, the mechanised sector accounted for 68%, motorized sector 28% and artisanal sector 4% of total production (CMFRI, 2008). The pelagic finfishes constituted 57%, demersal fishes 25%, crustaceans 14% and mollusks 4% of the total landings. In 2005
around 5 lakh tonnes of marine products were exported from India and the value reaching 1.63 billion US dollars (71 billion rupees) (MPEDA, 2007).

Trawling was introduced and established in India with an active initiative of the Central Institute of Fisheries Technology (CIFT) along with other Government Organisations like erstwhile Indo-Norwegian project. Many designs of two seam trawls, four seam trawls, six seam trawls, multiseam trawls, bulged belly trawls, high opening trawls and large mesh trawls etc. were designed, experimented and developed by the institute. Bottom trawling is in practice in India for nearly 50 years (Pravin and Vijayan, 2002). The fishing fleet of India consists of traditional (1,07,448), motorized (76,748) and mechanized (59,743) vessels (Anon, 2007). The mechanized vessels are excess in number against the recommended optimum mechanised fleet (1995-96) of 47,683. The coastal waters of India is prone to very high pressure from bottom trawlers as trawling became synonymous with shrimp trawling and there exists severe competition for harvesting of shrimps. The commercial trawling fleet of India consists of 29,241 small and medium-fishing boats (CMFRI, 2006). Trawling contributes about 11.7 lakh tonnes of the total marine fish landings in India. Though trawling is an efficient method of harvesting shrimp, it is also considered as one of the most destructive and non-selective method of fishing. The trawlers also land substantial quantities of the non-edible benthic biota consisting of juvenile fishes, bivalves, gastropods, crustaceans, and echinoderms.

In spite of the increased marine fish production with the mechanization and advanced navigational knowledge, the annual growth rate of marine fishery is
Chapter I

decreasing (Anon, 2007) (Figure 1.1). The decline in landings per trip of different kinds of fishing units, alteration in species, decrease in the fish size etc have been attributed to the rise in the number of trawlers and increased fishing effort (Sathiadas, 1998).

Fig. 1.1. Marine fish production (lakh tonnes) and per annum growth rate (%) of India (1980-2006) Source: Anon, 2007

While in western countries all the by-catch is discarded, in India by-catch is brought back to the landing centres because of its economic utilities. In tropical countries like India bycatch issue is more complex due to the multi-species nature of the fisheries. Bycatch and discards still remain a potent threat to the biodiversity and long-term sustainability of fishery resources of India. 40% of the by-catch is discarded by the trawlers on the east coast, amounting to 26-50,000 tonnes (Salagrama, 1999). Discards on the west coast are considered negligible. Studies on impact of bottom trawling conducted along the coasts of Karnataka (Bhat and Shetty, 2005; Bhat, 2003; Gowda, 2004; Zacharia et al., 2005 and 2006
1.2. Fishery scenario of Gujarat

1.2.1. Fishery resources of Gujarat

In India Gujarat has the longest coast line (19.71%), the broadest continental shelf (30.94%) and a wide Exclusive Economic Zone (10.59%). The estimated marine fish potential of the state was 0.7 million tonnes, which is about 18% of the all-India potential. In 2003-04, the state ranked first in marine fish production (0.6 million tonnes) contributing to 26.31% of total marine fish production of India. Gujarat occupied first position in finfish production and third in shrimp production (Table 1.1). The fish production was worth Rs. 614.41 (Rs. in crores) in 2003-04, contributing 10.09% to India's foreign export. But in 2007-08, the landings decreased by 6.5% compared to 2006. Kerala topped in marine fish production (2007-08) making Gujarat second in position. There are 217 marine fish landing centres in the state. There are 44 fishing harbours extending between the minor landing centres of Koteswar in Kutch and Ummergaon in the south. The total fishermen population of the state exceeds 4.93 lakh, out of which around 1.72 lakh people are actively engaged in fishing. 2.91 lakh people constitute marine fishermen population.
Table 1.1. Finfish and shrimp landings of different states of India Source: Gujarat Fisheries Statistics. 2003-04

<table>
<thead>
<tr>
<th>States</th>
<th>Finfish Landings (Tonnes)</th>
<th>States</th>
<th>Shrimp Landings (Tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gujarat</td>
<td>641138</td>
<td>Maharashtra</td>
<td>107337</td>
</tr>
<tr>
<td>Kerala</td>
<td>619428</td>
<td>Kerala</td>
<td>56801</td>
</tr>
<tr>
<td>Maharashtra</td>
<td>414103</td>
<td>Gujarat</td>
<td>55483</td>
</tr>
<tr>
<td>Tamilnadu</td>
<td>381148</td>
<td>Andra Pradesh</td>
<td>33963</td>
</tr>
<tr>
<td>Andra Pradesh</td>
<td>263926</td>
<td>Tamilnadu</td>
<td>28603</td>
</tr>
<tr>
<td>Karnataka</td>
<td>195156</td>
<td>West Bengal</td>
<td>21000</td>
</tr>
<tr>
<td>West Bengal</td>
<td>182100</td>
<td>Karnataka</td>
<td>13728</td>
</tr>
<tr>
<td>Orissa</td>
<td>102169</td>
<td>Orissa</td>
<td>10658</td>
</tr>
<tr>
<td>Goa</td>
<td>83756</td>
<td>Goa</td>
<td>6656</td>
</tr>
<tr>
<td>Pondicherry</td>
<td>42096</td>
<td>Pondicherry</td>
<td>3470</td>
</tr>
<tr>
<td>Andaman &amp; Nicobar Island</td>
<td>30639</td>
<td>Andaman &amp; Nicobar Island</td>
<td>705</td>
</tr>
<tr>
<td>Daman &amp; Diu</td>
<td>12278</td>
<td>Daman &amp; Diu</td>
<td>192</td>
</tr>
<tr>
<td>Lakshadweep</td>
<td>10030</td>
<td>Lakshadweep</td>
<td>0</td>
</tr>
</tbody>
</table>

The pelagic resources formed 36% of the total production. The demersal resources contributed 35% followed by crustaceans (22%) and cephalopods 7% (CMFRI, 2008). The major resources exploited along Gujarat coast include ribbonfishes, croakers, Bombay duck, shrimps, cephalopods, perches, seerfishes, threadfin breams, lizardfishes, flatfishes, catfishes, elasmobranchs, crabs, lobsters, clupeids, carangids, threadfins, pomfrets, mudskippers, oysters, chanks and seaweeds. The major species contributing to the marine fish production (Anon, 2005a) is as shown in Figure 1.2. In 2007-08, ribbonfishes (31%) and Bombayduck (24%) were the major contributors to the pelagic fishery. The major demersal resource was sciaenids (37% of demersal landings). Nonpenaeid shrimps formed 70% of the crustacean landings and penaeid shrimp formed 17%. In 2007, there was the revival of the ghol and koth fishery and the emergence of a
new fishery for the deep sea squid (*Sthenoteuthis oualaniensis*). The marine fisheries of the state is supported by ice and cold storage plants, freezing plants and frozen storages, boat building yards, fish meal/ pulverizing plants and net/gear fabrication units.

![Major species composition](image)

**Fig. 1.2. Major species contributing to marine fish production of Gujarat**  
*Source: Anon, 2005a*

The northwest coast of India has the highest number (23,618) of mechanized vessels operated in Arabian Sea (*Vivekanandan et al., 2005*). Commercial fishing is concentrated on 90,000 km² area that contribute to the largest inshore area (< 50 m depth) of India. The fishing industry of Gujarat has a fishing fleet of over 31,000 mechanised (60.11%) and non-mechanised (39.89%) crafts. The mechanized fishing vessels (18,635 numbers) operated consist of trawlers (7402), gill netters (3082), Dolnetters (1498), FRP (6390), wooden (263) etc (Anon, 2005a). The gears operated include trawl net, dol nets, gill nets, hooks and lines, cast nets, stake nets, bag nets, drag nets, fence nets and trap nets.
According to Vivekanandan et al. (2005), the landings of northwest coast increased substantially during 1990-2000. This increase was ascribed to the increase of the top predators like sharks, lizardfishes, rockcods, ribbonfishes, horse mackerel, seer fishes, tunas, and barracudas. The fishing is targeted for top predators and the increase in landings is also due to enhanced fishing capacity and knowledge.

1.2.2. Trawling in Gujarat

Trawling was introduced along Saurashtra coast in 1960s with the advent of trawling experiments at Veraval under the guidance of Research Centre of Central Institute of Fisheries Technology. The designs introduced by the Institute were adopted by fishermen and is widely used today with modifications to suit their needs (Pravin and Vijayan, 2002). According to Kurup and Devaraj (2000), the estimated optimum fleet size of Gujarat is 1,473 mechanised trawlers. The number of trawlers has increased (Figure 1.3) during the past few years and according to the latest reports (Anon, 2005a). From the coast of Gujarat 7402 commercial trawlers are operated. They contribute to 47% of the total marine fish landings of the state. In India Gujarat ranks first in marine fish production with 7402 commercial trawlers contributing to 47% of the total marine fish landings of the state. The commercial trawling fleet in Gujarat state consists of small and medium-fishing boats of size ranging from 9-17m OAL fitted with diesel engines of 88-165 hp.
Fig. 1.3. The number of trawlers of Gujarat coast during the past 15 years
Source: Anon, 2005a

The trawlers conduct single day fishing at 20-50 m depth and multiday
fishing (5-7 days) at 20-100 m depths and sometime venture even 200 m. Long
trip boats generally go to deeper waters mainly off Kutch, Dwaraka, Jakhau,
Jagadiya and Bombay High. A large range of bottom trawl nets for shrimp and
fish in terms of size and designs are being operated along Gujarat coast, suitable
for vessels in the range of 12 m – 17 m OAL. Two seam shrimp and fish trawls
are operated with a head rope length ranging from 20-60 m. All the nets are
fabricated with polyethylene. Each vessel on an average carries six trawl nets for
exploitation of different target species. Most of the fish trawls are using 600 mm
mesh size in the fore parts but the mesh sizes used in the cod ends are very small
(10 mm).

In spite of the fact that the number of trawlers operated from Gujarat coast
is ever increasing and the practice of multiday fishing is well accepted, the fishery
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of the state presently is reported to be dwindling. The data recorded by Commissionerate of Fisheries, Government of Gujarat bring out the fact that the annual growth rate of marine fish production has declined to (-)18.09% (2003-04) from (+)14.26 % (2002-2003) (Anon, 2005a). The failure of fishery resources to recoup from the impact of the exploitation stress is revealed by the negative growth (Zofair, 2005). The catch per unit effort is also declining showing the stress of exploitation (Narayanan et al., 2003). In Gujarat, discards are almost absent and bycatch, locally known as kutta is mainly used for dried fish, fish meal and fish manure (Zynudheen et al., 2004). The maximum percentage of by-catch in India is from Gujarat (92.58%) (George et al., 1981). The quality of catch has been altered significantly in that the large sized and high value fish is declining and the small-sized and low value fish is dominating the catch. The landings of high value species like lobsters, whitefish, pomfrets, threadfins, eels, penaeid shrimps etc are declining while low valued croakers, non-penaeids, crabs etc are supporting the catch (Nair et al., 2003; Zofair et al., 2003). In export market of Gujarat, fresh frozen fish dominated in terms of volume (59.36 %) and value (43.69 %), followed by squid, cuttle fish, shrimp and dried items. High value seafood items like shrimp, lobster and surimi are absent from the export list.

1.2.3. Maritime rules and regulations

The state of Gujarat is blessed with the fact that both the government and the fishermen are aware of the importance of conservation issues, which is evident from the observation of fishing holidays from 1st June to 15th August (65 days). This is observed under the guidelines of the Government of India with the
participation of the state government, industrialists, fishermen and traders. During the monsoon the sea here is very rough that fishermen do not venture for fishing. Gujarat Fisheries Act (2003) banned bottom-trawling upto 5 nautical miles (9 km) along coast. This is due to the rocky nature of bottom and to protect traditional fishing activities in this region. In the Gulf of Kutch the Government has declared a Marine Park (162.89 km²) and a Marine Sanctuary (295.03 km²) under the Wild Life (Protection) Act (1972), and Forests Act (1976). The Marine National Park is having 37 varieties of hard and soft corals, 70 species of sponges, 150-200 species of fishes, 27 species of prawns, 30 species of crabs, 94 species of water birds, 3 species of sea mammals, 78 species of terrestrial birds, 108 species of brown, green & red algae and more than 200 species of molluscs.

1.3. Veraval

Junagadh district of Gujarat contributes highest to the total fishing fleet to the tune of 30.86 %. 4084 trawlers are being operated from this district. Veraval Fishing harbour was established in 1986, in Junagadh district. This port was designed initially for 1,200 fishing trawlers but 2793 trawlers are being operated from this port making it the largest trawler port of Gujarat. Veraval fishing harbour ranks first in marine fish landing out of the 44 fishing harbours of the state (Figure 1.4).
Fisheries has always been the main industry in the town and is dominated by the Kharwas (fisherfolk). Veraval also has a large boat making industry. On an average there are 25 fishing days per month. Veraval is home to a large number of fish processing factories which export prime quality seafood to USA, Japan, SE Asian, Gulf and EU countries. The seafood-industry which was started through government initiative is now in its prime and many importers are attracted towards Veraval from around the globe.

1.4. Scope of the present study

There are no studies conducted hitherto along Northwest coast of India to bring out the impact of bottom trawling on the benthic fauna. Taking into account the enormous trawler fleet and the present crisis of Gujarat fishery, studies on the impact of bottom trawling on benthic fauna along Gujarat coast is vital. This study is expected to generate information that will help to manage the biological
integrity and diversity of the benthic fauna. It will also enable the conservation and better management of coastal marine resources of the Veraval coast.

1.5. Objectives of the present study

The aim of the present study was to investigate the effects of bottom trawling on the substratum and the associated benthic communities of commercial trawling grounds of Veraval coast. Attempts were made to assess the possible impact of bottom trawling on:

(i) the sediment characteristics
(ii) the sediment heavy metals
(iii) the epifauna
(iv) the macrobenthos and
(v) the meiobenthos.

The present study has been pursued giving due emphasis to the benthic habitat and communities off Veraval coast; cataloging different species, and sediment characteristics. Experimental bottom trawling off Veraval coast has been done to bring to light the impact of bottom trawling. The study compared the differences between the samples collected before and after experimental trawling to detect the impacts of bottom trawling. This study assessed the impact of bottom trawling on the epifauna, macrobenthic and meiobenthic communities along the Veraval coast.