# Studies on the Effects of Bottom Trawling on the Benthic Fauna off Veraval Coast, Gujarat

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**DOCTOR OF PHILOSOPHY**

*In*

**MARINE BIOLOGY**



*By*

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**May 2009**

*To My Family with Lots of Love*

# Certificate

Certified that the thesis entitled '***Studies on the effects of bottom trawling on the benthic fauna off Veraval coast, Gujarat***' is an authentic record of the research work carried out by Ms. Usha Bhagirathan, M.Sc., under my guidance and supervision for the degree of Doctor of Philosophy and that no part thereof has previously formed the basis for the award of any degree, diploma, associateship, fellowship or any other similar titles of this or any other university or institution.

Cochin- 29
May, 2009

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# DECLARATION

I, Ms. Usha Bhagirathan, hereby declare that the thesis entitled **‘Studies on the effects of bottom trawling on the benthic fauna off Veraval coast, Gujarat’** is an authentic record of the research work carried out by me under the supervision and guidance of Dr. B. Meenakumari, Director, Central Institute of Fisheries Technology, Cochin, in partial fulfillment of the requirement for the Ph.D. degree in the Faculty of Marine Sciences and that no part thereof has previously formed the basis for the award of any degree, diploma, associateship, fellowship or any other similar title in any University or Institution.

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***Usha Bhagirathan***

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# ABBREVIATIONS

| | |
|---|---|
| ANOVA | Analysis of Variance |
| AOAC | Association of Official Analytical Chemists |
| CIDA | Canadian International Development Agency |
| $D_1$ | Station at 15-20 m water depth |
| $D_2$ | Station at 21-25 m water depth |
| $D_3$ | Station at 26-30 m water depth |
| $D_4$ | Station at 31-35 m water depth |
| $D_5$ | Station at 36-40 m water depth |
| FAO | Food and Agriculture Organization |
| GIS | Geographical Information System |
| GPS | Global Positioning System |
| ICP-AES | Inductively Coupled Plasma Emission Spectroscope |
| IUCN | International Union for Conservation of Nature |
| ND | Not detected |
| NIST | National Institute of Standards and Technology |
| OAL | Overall length |
| OM | Organic matter |
| ROV | Remotely Operated Vehicle |
| S.D. | Standard deviation |
| S.E. | Standard error |
| SONAR | Sound Navigation and Ranging |
| $T_1$/B.T. | Before trawling |
| $T_2$ /A.T. | After trawling |
| UNDP | United Nations Development Programme |
| UNEP | United Nations Environment Programme |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| UNU | United Nations University |
| PRIMER | Plymouth Routines In Multivariate Ecological Research |

| | |
|---|---|
| S | species |
| N | number |
| d | Margalef index |
| J' | Pielou's evenness index |
| H | Brillouin index |
| $\alpha$ | Fisher's Alpha |
| H' | Shannon index |
| $N_1$ and $N_2$ | Hill's no. |
| $1-\lambda'$ | Simpson's index |
| $\Delta$ or Tax_div | Taxonomic Diversity index |
| $\Delta^*$ or Tax_dist | Taxonomic Distinctness index |
| $\Delta+$ or AvTD | Average Taxonomic Diversity index |
| s $\Delta+$ or TTD | Total Taxonomic Distinctness |
| Lambda+ or VarTD | Variation in Taxonomic Distinctness |
| $\varphi+$ or AvPD | Average Phylogenetic Diversity |
| $s\varphi+$ or PD | Phylogenetic Diversity |
| ABC | Abundance-Biomass Comparison curves |
| SIMPER | Similarity of percentage |
| MDS | Multidimensional scaling |

# PREFACE

Bottom trawling is one among the most destructive human induced physical disturbances inflicted to seabed and its living communities. The bottom trawls are designed to tow along the sea floor, which on its operation indiscriminately smashes everything on their way crushing, killing, burying and exposing to predators the benthic fauna. Bottom trawling causes physical and biological damages that are irreversible, extensive and long lasting. The commercial trawling fleet of India consists of 29,241 small and medium-fishing boats. The northwest coast of India has the largest fishing fleet consisting of 23,618 mechanized vessels, especially the bottom trawlers. However, attempts were not made to study the impact of bottom trawling along Northwest coast of India. The estimated optimum fleet size of Gujarat is 1,473 mechanised trawlers while 7402 commercial trawlers are operated from the coast of Gujarat. Veraval 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. The aim of this study was to investigate the effects of bottom trawling on the substratum and the associated benthic communities of commercial trawling grounds of Veraval coast. The study compared the differences between the samples collected before and after experimental trawling to detect the impacts of bottom trawling. Attempts were made to assess the possible impact of bottom trawling on: (i) the sediment characteristics (ii) the sediment heavy metals (iii) epifauna (iv) macrobenthos and (v) meiobenthos. This study is expected to generate information on trawling impacts of the studied area that will help in better management of the biological diversity and integrity of the benthic fauna off Veraval coast. An exhaustive review on the studies conducted around the world and in India on impact of bottom trawling on the benthic fauna is also detailed.

In the present study, the bottom trawling induced variations on sediment organic matter, epifauna, macrobenthos and meiobenthos were evident. It was also observed that the seasonal/natural variations were more prominent masking the trawling effect on sediment texture and heavy metals.

Enforcement of control of excess bottom trawlers and popularization of semi pelagic trawls designed to operate a little distance above the sea bottom for off bottom resources will minimize disturbance on the sea bottom. Training and creating awareness in responsible fishing should be made mandatory requirements, to the coastal communities. They should be made wardens to protect the valuable resources for the benefit of sustainability. To protect the biodiversity and ecosystem health, the imminent need is to survey and make catalogue, identification of sensitive areas or hot spots and to adopt management strategies for the conservation and biodiversity protection of benthic fauna.

The present study is a pioneering work carried out along Veraval coast. This thesis will provide a major fillip to the studies on impact of bottom trawling on the benthic fauna along the coast of India.

# Chapter 1
# Introduction

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 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).

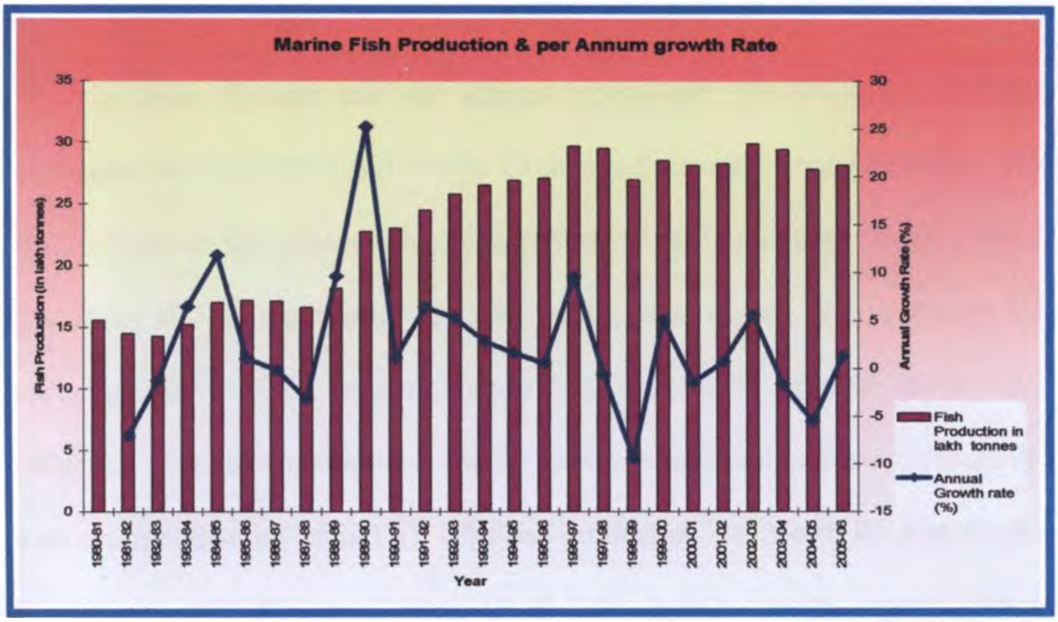



**Fig. 1.1.** Marine fish production (lakh tonnes) and per annum growth rate (%) of India (1980-2006) Source: Anon, 2007

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 a&b), Kerala (Kurup, 2004b) and Vishakapatanam (Raman, 2006) have brought to light the impact on hydrographical parameters and benthic fauna.

## 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.

**Tablel.1.** Finfish and shrimp landings of different states of India Source: Gujarat Fisheries Statistics. 2003-04

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

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.

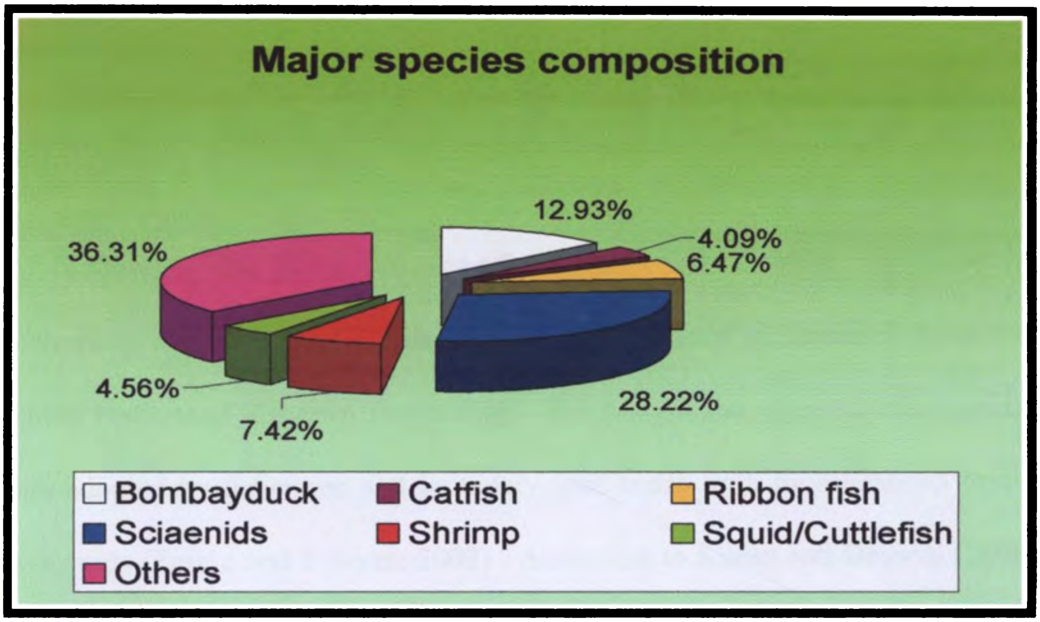



**Fig. 1.2.** Major species contributing to marine fish production of Gujarat
Source: Anon, 2005a

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 $km^2$ 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.

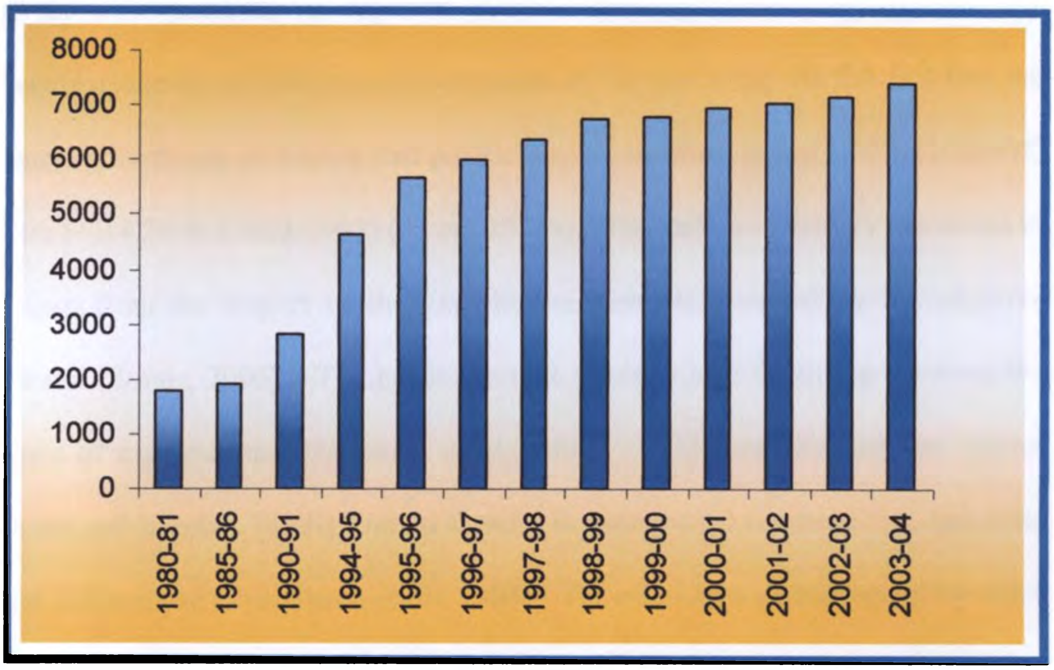



**Fig. 1.3.** The number of trawlers of Gujarat coast during the past 15 years Source: Anon, 2005a

The trawlers conduct single day fishing at 20-50 m depth and multiday fishing (5-7 days) at 20-100m 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 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 $km^2$) and a Marine Sanctuary (295.03 $km^2$) 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).

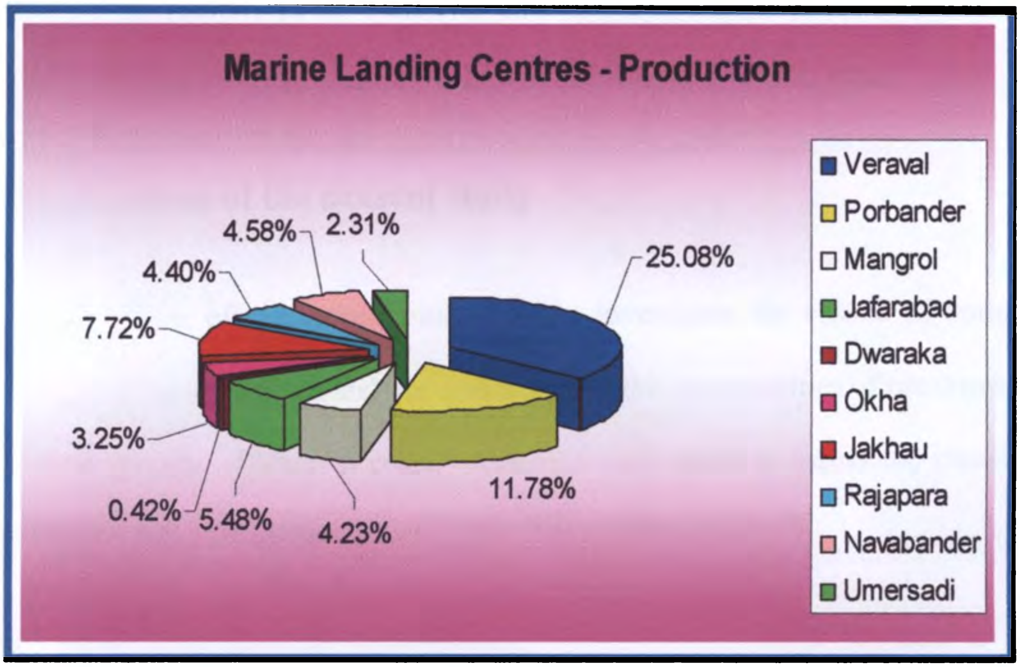



**Fig.1.4.** Production of top ten fish landing centres

Fisheries has always been the main industry in the town and is dominanted 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.

# Chapter 2

# Review of Literature

## 2.1. Introduction

Studies have shown that bottom trawling is among the most destructive human induced physical disturbances inflicted to seabed and its living communities (Jennings and Kaiser, 1998; Watling and Norse, 1998; Hall, 1999; Kaiser and de Groot, 2000; Kaiser *et al.*, 2000, 2001, 2002; Koslow, 2001; Bhat, 2003; Gowda, 2004; Zacharia *et al.*, 2005 and 2006a&b; Kurup, 2004b; Raman, 2006). The bottom trawls are designed to tow along the sea floor, which on its operation indiscriminately smashes everything on their way crushing, killing, burying and exposing to predators the benthic fauna. It also generates enormous bycatch and discards. The removal of organic matter by dispersion, alteration of sedimentation pattern, variations in sediment-water column fluxes, changes in predation rate, transformed population structure of predatory organisms are the other major consequences of incessant operation of bottom trawlers. Many organisms present at the seabed are unable to rebuild. A shift in benthic assemblage will have far-reaching consequences such as species replacement; threat to biodiversity and fishery potential and as a whole affecting the entire ecosystem. Once the ecosystem is affected there is less opportunity to recover to the pre-trawl conditions. Thus it causes physical and biological damages that are irreversible, extensive and long lasting (Hall, 1999; Kaiser and de Groot, 2000). Jones (1992) described the impacts inflicted to the benthic realm as direct and indirect effects. The discards, sediment scraping, resuspension of finer particles and damage of benthos by removal and destruction are the direct effects. The indirect effects comprise of stress suffered by benthos like post-fishing mortality of damaged fauna and the long lasting alterations attributed to the benthic community structure (Jones, 1992).

## 2.2. Benthic fauna and its significance

Benthos refers collectively to all aquatic organisms that live in, on or near the bottom of a body of water. The benthic community is made of a wide array of plants, animals and microbes, forming an important component of aquatic food web. Based on the functional status, benthos is classified as infauna, epibenthos and hyperbenthos, those organisms living within the substratum, on the surface of the substratum and just above it respectively (Pohle and Thomas, 2001). According to size, benthic animals are divided into three groups (i) macrobenthos (ii) meiobenthos and (iii) microbenthos (Mare, 1942). The macrobenthos are organisms that are retained in the sieve having mesh size between 0.5 mm and 1 mm. For meiobenthos, the size ranges between 0.5 mm and 63µ. The microbenthos are those organisms that are not retained in the finest sieve used for meiobenthos separation and include bacteria and most protozoans. The benthic fauna, most of them that may be of little edible value to humans, occupy key position in the marine food web. They provide food for benthic fishes (Damodaran, 1973), recycle the nutrients that reach the sea bottom, improve the oxygenation of sea bottom by burrowing, act as indicator organisms and continuously enrich the planktonic community that in turn forms food for pelagic fishes (Levington, 1982).

## 2.3. Methodologies used for studying impact of trawling

Jones (1992) on reviewing the studies on bottom fishing impacts interpreted that the results of different studies are allied to the weight of the gear on the seabed, the towing speed, the sediment texture and the influence of tides and currents. His view was supported by Lokkeborg (2005) on evaluating the studies on bottom fishing impacts conducted for a period of 15 years. He ascertained that the studies differ in methodology, scientific approach, gear type, gear design, disturbance regime, bottom texture, intensity of natural disturbance and benthic assemblage.

Studies on the impact of bottom trawling have quantified bycatch landed and discarded from bottom trawlers. Andrew and Pepperell (1992) estimated a global bycatch of 16.7 million tonnes in world shrimp fisheries. Alverson *et al.* (1994) approximated a world bycatch level of about 29 million tonnes out of which 27 million tonnes were discarded. According to the recent reports of FAO (2004), about 35% of global bycatch is a consequence of trawling and the average annual global discards are around 7.3 million tonnes during 1992-2002. A major portion of the bycatch and discards form epifaunal component of benthic ecosystem (De Groot, 1984; Menon, 1996; Watling and Norse, 1998; Kurup *et al.*, 2004). Bycatch and discards pose a threat to biodiversity and long-term sustainability of fishery resources.

Lokkeborg (2005) reviewed the literature of towed-gear fishing impact on benthic habitat and communities. He conferred a critical appraisal of the methodologies applied in different studies. He opined that most studies are far from fulfilling the criteria of an 'ideal study'. According to him an ideal study requires analysis over long time extent and comparisons between fished areas and identical untouched control sites.

### 2.3.1. Experimental trawling

According to Lokkeborg (2005) experimental trawling can be conducted on a site followed by a comparison of the physical and biological parameters at this site before and after the disturbance and / or with an undisturbed control site. Sparks and Watling (2001) investigated the effects of trawling disturbance on a soft-sediment system with experimental trawling in an area that had been closed to shrimp trawling activities for 20 years. In this study the bottom topography was altered and chlorophyll content of the trawled surface sediments was significantly elevated immediately after the trawling disturbance. Immediately after the trawling, the number of species, species abundance and diversity decreased. The sensitive species recorded were bivalves and polychaetes.

Lindegarth *et al.* (2000) tested the effects of trawling disturbances on temporal and spatial structure of benthic soft sediment assemblages in Gullmarsfjorden, Sweden which was previously protected. Three trawled sites and three untrawled (control) sites were sampled before and after experimental trawling. The spatial and temporal variability in the structure of assemblages after one year of trawling was comparatively larger at the trawled sites than at the untrawled sites.

A 3-year (1993-1995) otter trawling experiment was conducted on a deep-water sandy bottom ecosystem on the Grand Banks of Newfoundland that had not experienced trawling for 12 years (Kenchington *et al.*, 2001; Prena *et al.*, 1999). The study revealed that the width of the disturbance zones created was on the order of 120 to 250 m. Samples collected with an epibenthic sledge showed a significant reduction in the biomass of large epifauna. The benthic macrofauna were sampled before and after trawling (Prena *et al.*, 1999) and as an immediate effect of trawling, the abundance and biomass of polychaetes were found significantly lower. According to Kenchington *et al.* (2001) the trawling disturbance appeared to mimic natural disturbance; no distinctive trawling signature was observed.

Lindegarth *et al.* (2000) opined that having more than one control site in experimental trawling is preferable, as the temporal and spatial variations of different organisms will cause serious problems to the interpretation of experiments, which use only one control and one trawled area.

On reviewing the previous studies Lokkeborg (2005) suggested that experimental trawling ensures, sampling is done in a disturbed site and gives exact data of disturbance level, exact location, size of disturbed area and gear description. When only a narrow corridor is investigated, this method does not replicate the spatial and temporal scale of actual fishing grounds. The impacts interpreted may not be genuine as there is the possibility of migration (disturbed species) or immigration (scavengers) of mobile species into the studied corridor.

### 2.3.2. Historical data

Many authors mention that historical data is advantageous for the study and interpretation of impacts in a trawled ground. The impact studies based on historical data reflect disturbances in commercial fisheries and the actual intensity of disturbance is not evident as spatial distribution of trawling disturbance and gear configuration is usually unknown. The impact caused will be due to various aspects like dredging, beam trawling, otter trawling or a combination of these. A suitable control site rarely exists in historical data (Lokkeborg, 2005).

### 2.3.3. Control site

According to Lokkeborg (2005) a comparative study on commercial fishing grounds that are heavily and lightly fished will also bring out the impact of bottom trawling. Several studies on impact of trawling have been conducted by comparing the fauna of closed and open areas of fishing. Such studies were reported by Stone and Masuda (2003) in the Gulf of Alaska, Kaiser *et al.* (2000) off Devon in United Kingdom and Fisher (2004) in areas of Emerald and Western banks in Northwest Atlantic Ocean.

Open areas of the Central Gulf of Alaska was continuously monitored for 5 years and till 1998, the trawling intensity was estimated to be 11% - 29% per year. The closed areas were prohibited of bottom trawling for 11- 12 years. The utility of closed areas in the Gulf of Alaska was brought to light by Stone and Masuda (2003) by collecting samples from areas opened and closed to trawling in cruises of 1998 and 1999. Their study revealed that the sedimentary and biogeochemical characteristics of the seafloor are altered by bottom trawling.

On comparison of the fauna between the areas closed and open to towed fishing gears off Devon, United Kingdom, Kaiser *et al.* (2000) found significant dissimilarity apart from the fact that the areas were in close proximity. The closed areas were rich in species diversity and biomass. Areas fished by towed gear were dominated by smaller-bodied fauna and scavenging taxa.

Fisher (2004) studied areas of Emerald and Western banks in Northwest Atlantic Ocean. The area was closed to groundfish trawling in 1987 to conserve haddock (*Melanogrammus aeglefinus*). The changes in the fish community using multispecies abundance data collected since 1970 were examined and he found differences between the closed area and open reference area. An undisturbed control area is vital for trawling impact studies. Taking into account the natural variations in benthic communities it is necessary to compare the magnitude of temporal changes in fished areas with changes in control site (Lindegarth *et al.*, 2000). To avoid the risk of interpreting the spatial and temporal changes between trawled site and control site as an impact of trawling, replication of control sites is essential. The control site must resemble the disturbed site in depth, currents, sediment characteristics and benthic assemblage (Lokkeborg, 2005).

## 2.4. Physicochemical impacts

### 2.4.1.Turbidity

Palanques *et al.* (2001) conducted experimental trawling in the muddy unfished continental shelf of northwestern Mediterranean. During this study, an increase in turbidity of the water column was observed after trawling. According to Watling and Norse (2003) the frequent suspension of sediment will affect the suspension feeders. High levels of suspended sediment will increase the relative abundance of fish that locate food by touch or chemical sensors, and decrease those reliant on vision. Therefore, those species sensitive to high turbidity may move away from freshly trawled areas.

The sediment plumes are churned up as the weighted nets are ploughed along the ocean floor. The sediment trails caused by trawling could be seen from satellites along Gulf of Mexico (www.neatorama.com; www.foxnews.com), Yangtze River, China (www.treehugger.com) and off Louisiana coast (en.wikipedia.org).

**2.4.2. Dissolved Oxygen**

The decomposition of enormous amounts of discarded bycatch that settle down to the bottom leads to oxygen depletion, often termed as ground poisoning or spoiling (Alverson *et al.*, 1994). According to Warnken *et al.* (2003) even if moderate trawling activity does not have any adverse effects, repeated trawling will result in removal of the upper oxic sediment layers and would create anoxic surface sediments. The mixing of reduced products such as methane, hydrogen sulphide and resuspended particulate material like bacteria attached to sediments exert an increased oxygen demand in the water column (Riemann and Hoffmann, 1991).

Kaiser *et al.* (2002) suggested that the effects of low levels of trawling disturbance would be similar to those of natural bioturbators. But intensive trawling would cause sediment systems to become unstable due to large carbon fluxes between oxic and anoxic carbon compartments. In deeper areas with softer sediments where levels of natural disturbance due to wave and tide are low and at low levels of trawling disturbance, the macrofauna take the role of natural bioturbators, consume carbon and reduces the magnitude of available carbon fluxes. In contrast to this, chronic trawling intensity prevents the sediment system from reaching equilibrium due to large carbon fluxes between oxic and anoxic carbon compartments. This impact in Northern Sea is illustrated by a generalized soft sediment system by Duplisea *et al.* (2001).

### 2.4.3. Nutrients

According to Pilskaln *et al.* (1998) the extent of trawling-induced sediment resuspension determines the regional nutrient budgets. The resuspension imparts input of sedimentary nutrients into the water column. The nutrients released will cause abnormal algal blooms, causing further depletion of oxygen and liberation of lethal gases (Churchill *et al.*, 1988).

### 2.4.4. Chlorophyll content

Aspden *et al.* (2003) observed a significant difference in the chlorophyll *a* content of surface sediment before and after experimental trawling at Lagoon of Venice, Italy. On soft bottom habitat chlorophyll content of the trawled surface sediments significantly elevated immediately after the trawling disturbance (Sparks and Watling, 2001). Smith *et al.* (2000) observed significant differences in sedimentary chlorophyll and phaeopigments between stations during the trawling season along eastern Mediterranean commercial trawl fishing ground.

### 2.4.5. Pollutants

According to Kaiser *et al.* (2002) along with the resuspension of the upper layers of sedimentary seabed, bottom trawling remobilize the contaminants into the water column. He suggested that the possible ecological implications like eutrophication, altered biogeochemical cycling need further investigation. The shrimp trawling experiments conducted in Galveston Bay showed that the pre and post-trawl fluxes of oxygen, ammonium, silicate, manganese, nickel, copper and lead in sediments, did not differ significantly, while the flux of cadmium was affected (Warnken *et al.*, 2003).

### 2.4.6. Sediment texture

De Biasi (2004) conducted experimental trawling in fished and unfished area of Tuscany coast of Italy. He found that immediately after trawling an increase of the clay percentage occurred in the landward control. A simultaneous decrease in silt percentage was also observed. But, the variations recovered within twenty-four hours. According to Palanques *et al.* (2001) the sediment texture showed an increase in silt content of the surface sediment during first hour after experimental trawling in the muddy unfished continental shelf of northwestern Mediterranean. This variation was attributed to the settling of resuspended particles. The change was temporary as one day after trawling the surface sediment had a grain size pattern analogous to that of before trawling.

Schwinghammer *et al.* (1998) could not find any transformation in sediment grain size in sandy areas of Grand Banks of Newfoundland. According to him, the physical impacts of otter trawling are moderate and recovery occurs in about a year on a sandy substratum. On conducting experimental beam trawling in the sandy substratum of Belgian and Dutch coast, Fonteyne (2000) found that the resuspension of lighter sediment is pronounced in finer sand substratum. But he found that the suspended particles would settle down within a few hours. Ball *et al.* (2000) pointed out that undisturbed muddy sediments need longer recovery time than dynamic coarser sediments.

### 2.4.7. Organic Matter

The sedimentary organic matter forms the basis of energy supply for the marine food web, as it is the abode of nutrition for deposit feeders (Levington, 1982). The studies conducted by Schwinghammer *et al.* (1998) at sandy bottom of the Grand Banks of Newfoundland showed that trawling changed the individual sediment grains to smooth, clean and light in colour. This change was attributed to the reduction in biogenic sediment structure and flocculated organic matter. Smith *et al.* (2000) observed significant differences in sedimentary organic carbon between stations during the trawling season along eastern Mediterranean commercial trawl fishing ground. Contrary to the reduction of sedimentary organic carbon, the carcasses generated from discards and heavy mortality of benthos would in turn elevate the organic matter input into the benthic realm (Frid and Clark, 2000).

## 2.5. Biological impacts

### 2.5.1. Epifauna

Fishing activities causes direct mortality of benthos as bycatch and net damaged organisms (Frid and Clark, 2000). The complex seafloor habitats of seagrasses, seamounts and coral reefs that provide food, nurseries and shelter for a variety of marine organisms are destroyed by bottom trawling activities. These habitats have the longest recovery rate and take years to recolonise (Kaiser *et al.*, 2002; Gianni, 2004). In Mediterranean Sea bottom trawling caused elevated fine sediment composition leading to regression of the sea grass *Posidonia oceanica* (Ardizzone *et al.,* 2000). On conducting experimental trawling in the areas that were untrawled for 15-20 years in the Gulf of St. Vincent of South Australia Tanner (2003) noted that the probability of recolonisation of seagrasses were low in trawled sites than untrawled sites. The benthic fauna of seamounts of Newzealand waters is under the stress of bottom trawling for orange roughy (Koslow *et al.*, 2000; Clark and Driscoll, 2001; 2004). Strong decline of fishery is also recorded (Clark, 1999). The corals (*Solenosmilia variabilis*) that were dominant and diverse in the lightly trawled seamounts of south of Tasmania were absent in heavily fished areas (Koslow *et al.*, 2001). In the mid Norwegian continental shelf the trawlers damage the deep-water corals *Lophelia pertusa* significantly lowering the inhabitant fishery (Fossaa *et al.*, 2002). At the $7^{th}$ Conference of the UN Convention on Biological Diversity (2004) scientists of 69 countries signed a proclamation calling United Nations to ban bottom trawling in high seas, especially where coral reefs were known to occur within their Exclusive

Economic Zone (www.mcbi.org). Considering the destruction imposed by bottom trawling to coral reefs, the U.S Government called the North Pacific Fishery Management Council to ban commercial trawling near the Aleutian Islands which is an abode of food resources for the Alaskan fishery (Anon, 2005b).

Rosenberg *et al.* (2003) on carrying out experimental trawl study in the northwest Mediterranean found that the epifauna and polychaete tubes were either rare or not observed at all on trawled sediment surfaces.

Investigations on the short-term destructions imparted by trawlers in the Gulf of Alaska indicated that 14 - 67% of large sessile epifauna was damaged and densities of these epifauna were significantly higher in unfished reference sites. The motile invertebrates were not affected. There was a significant decrease in density of sponges and anthozoans in trawled hard-bottom seafloor versus reference transects (Freese *et al.*, 1999). Bergman and van Santbrink (2000b) reported the large-scale mortality of invertebrate species either as a result of direct mortality by the passage of the trawl or indirectly owing to disturbance, exposure and subsequent predation. Ball *et al.* (2000) cited that the destruction of epifauna depends on the sediment texture. In muddy habitat epifauna are generally scarce and the effect of trawling is limited when compared to harder sediment habitat. Gastropods suffered the greatest depletion as 95% were removed by the combined effect of 13 trawls on the same track in the Great Barrier Reef of Australia. Ascidians, sponges, echinoids, crustaceans and gorgonians were depleted by 74-86% (Burridge *et al.*, 2003). The experimental trawling conducted in areas untrawled for 15-20 years in Gulf St. Vincent, South Australia showed that most taxa of sessile benthic assemblages declined significantly in trawled areas compared with untrawled areas. In contrast to this, the recruitment rates of several taxa into the visible size classes increased after trawling, presumably because of a reduction in competition. The epifauna at trawled sites decreased in abundance by 28% within 2 weeks of trawling and by another 8% in the following 2-3 months. Bottom trawling removes predators such as algal-grazing urchins that play a vital role in the food web (Kaiser *et al.*, 2002).

The gravel sediment habitat of Georges Bank (East coast of North America) was an important nursery area for juvenile fish and the site of a productive scallop fishery. The colonial epifauna (bryozoans, hydroids and worm tubes) of this area provided a complex habitat for shrimp, polychaetes, brittle stars and small fish at undisturbed sites. Otter trawling and scallop dredging in this area removed this epifauna, thereby reducing the complexity and species diversity of the benthic community (Collie *et al.*, 2000). There is a direct relationship between the survival of newly settled juvenile fish and the complexity of the benthic habitat to which they settle. . According to Lindholm *et al.* (1997) the epifauna provides a shelter from predation for juvenile fishes and augment their survival, which points out the need to conserve the regions of high epifaunal growth.

Jennings *et al.* (2001) studied the effects of bottom trawling on the trophic structure of epifaunal benthic communities in two regions - Silver Pit and Hills of the central North Sea. The impacts of fishing were most pronounced in the Silver Pit region, where the range of trawling disturbance was greater. The epifaunal biomass decreased significantly with trawling disturbance.

### 2.5.2. Infauna

Other than direct mortality the impact of trawling on the infauna also depends on the alterations imparted to sediment texture. The recovery of infauna in muddy habitats following experimental trawling normally takes longer than other habitats. According to Ball *et al.* (2000) bottom trawling resulted in reduction of abundance of large-bodied fragile organisms, an increase in abundance of opportunistic species and a reduction in faunal diversity.

The biomass of infaunal bivalves and spatangoids (burrowing sea-urchins) declined considerably in the experimental trawling studies performed in the central North Sea (Jennings *et al.*, 2001) but could not observe change in the biomass of polychaetes. The invertebrate communities have high intrinsic rates of population increase to withstand the levels of mortality imposed by trawling. In another study (Jennings *et al.*, 2002) they found out that the small infaunal polychaetes that form major food of flat fishes in the North Sea have fast life histories and so they are less vulnerable to trawling disturbance.

#### 2.5.2.1.Macrobenthos

The direct mortality due to trawling occurs in the case of gastropods, starfishes, crustaceans, annelids and bivalves in the trawl track (Bergman and van Santbrink, 2000a). McConnaughey *et al.* (2000) examined the impacts of bottom trawling in a shallow, soft-bottom area of the Bering Sea and reported higher densities and diversity of macrofauna in historically unfished areas. They observed drastic variations (both positive and negative) in the abundance of several macrobenthic species between heavily fished and unfished areas. Small-bodied organisms such as polychaetes dominated heavily fished areas (Kaiser *et al.*, 2002). The increase in opportunistic species was detected in the trawled areas of Aegean Sea also (Simboura *et al.*, 1998).

The biomass and abundance of macrofauna decreased significantly after trawling in Gullmarsfjorden, Sweden. The mean abundance of echinoderms, in particular the brittle stars *Amphiura*, decreased significantly after trawling in Gullmarsfjorden, Sweden (Hansson *et al.*, 2000). Serpulids are macrofauna that provide shelter and food for juvenile commercial species and increase benthic biodiversity. They are opportunistic species that rapidly recolonize disturbed areas. According to Kaiser *et al.* (1999) no significant changes in composition, size or number were noted in Northeast Atlantic shelf seas that could be attributed to fishing disturbance.

The Silver Pit region of the central North Sea is regularly fished by beam trawlers targeting sole and plaice. Jennings *et al.* (2002) investigated the effects of trawling disturbance on the production of benthic infauna. The analyses showed that trawling frequencies of 0.35 to 6.14 times/year did not have significant effect on the production of small infaunal polychaetes. Since small infaunal polychaetes are a key source of food for flatfishes, the authors concluded that beam trawling does not have a positive or negative effect on their food supply. According to Rijnsdorp and Vingerhoed (2001) intensive beam trawling enhanced the abundance of small opportunistic benthic species such as polychaetes, improving the feeding conditions for flatfishes: plaice (*Pleuronectes platessa* L.) and sole (*Solea solea* L.). The study of Collie *et al.* (1997) revealed that many of the megafaunal species that were identified in the stomach content analysis of demersal fish on Georges Bank, were decreased in abundance at the disturbed sites.

Van Dolah *et al.* (1991) studied the effects of shrimp trawling on infaunal assemblages of two estuarine sounds in South Carolina. In this study it was concluded that 5 months of trawling did not have any obvious effect on the abundance, diversity or composition of the soft-bottom communities. Moreover, the natural seasonal variability was more prominent than trawling effects.

#### 2.5.2.2. Meiobenthos

Chronic trawling has a significant impact on the composition of meiofaunal assemblages. Schratzberger and Jennings (2002) analysed nematode communities in beam-trawled fishing areas in the central North Sea. The number of species, diversity and species richness of the community were significantly lower in the area, subjected to high levels of trawling disturbance than in the areas of low or medium levels of disturbance. The level of disturbance at the 'low' and 'medium' areas is insufficient to cause marked long term changes in community structure. The smaller meiofauna that are very productive and have fast generation times are relatively unaffected by trawling disturbance (Schratzberger *et al.*, 2002; Duplisea *et al.*, 2002).

### 2.5.3. Effects on non-target species

The benthic batoid elasmobranches that feed on benthic organisms like *Dasyatis brevicaudata* and *Himantura jenkinsii* are highly susceptible to capture in prawn trawls and is a bycatch of Australia's northern prawn fishery. Once depleted the recovery capacity of these species is very low (Stobutski *et al.*, 2002). The beam-trawl fishery for flatfish in the southern North Sea generated huge quantity of dying discards as well as damaged and disturbed benthos Groenewold and Fonds (2000). In the North Sea also, elasmobranchs showed a decline in their population. Even though not targeted, they are taken in the bycatch and were landed (Greenstreet and Rogers, 2000). One third of the total catch produced from bottom trawlers in the northwestern Mediterranean constituted discards, which consisted of 135 species of fishes, 60 crustaceans, 44 molluscs and 70 other invertebrates (Sanchez *et al.*, 2004). Rogers *et al.* (2001) found that the proportion of damaged starfish *Asterias rubens*, increased with intensity of bottom-trawl activity at the Irish Sea and Bristol Channel.

### 2.5.4. Dietary Shifts

Trawling will definitely result in increased food subsidies in the marine environment. Demestre *et al.* (2000) studied the behaviour of scavengers and predators in response to otter-trawling disturbance in muddy sediments in the North-West Mediterranean. The repeated trawling with a commercial fishing gear depleted the abundance of commercially important species. However, smaller scavenging and predatory species increased in abundance significantly with time. The aggregate response of scavengers was short-lived and lasted not more than several days, which indicated that additional food resources made available by the trawling activities were rapidly consumed.

The intensive beam trawl fishery for sole and plaice in the southern North Sea (off the coast of Netherlands) produced large amounts of discards and damage to benthic fauna. Seabirds scavenge on the discards but the major fraction sinks to the sea floor providing additional food source to the benthic scavengers and predators enhancing secondary production (Groenewold and Fonds, 2000). Fish consumes damaged and exposed benthos, while invertebrate scavengers such as crab and starfish mainly consume discarded fish. Trawling results in an increased rate of recycling of benthic fauna and fish through the food web due to food subsidies generated to opportunistic scavengers (Fonds and Groenewold, 2000). The responses of scavengers to towed beam trawl differed between different communities and between habitat types. In some areas as a result of the disturbance of beam trawling the abundance of starfishes increased, as there was an incursion of starfishes to nosh on damaged benthos. While at some other sites there was no obvious enhancement in scavenger numbers. Moreover, at the site near Walney Island, numbers of Hermit crabs, swimming crabs and starfish (*Asterias rubens)* decreased after trawling (Ramsay *et al.*, 1998).

The seasonal squid trawl fishery of squid in the Falkland Islands shelf altered the feeding spectra of rock cod (*Patagonotothen ramsayi*). The rock cod is a near bottom browser feeding mainly on crustacean plankton, comb jellies and salps. But during the seasonal squid fishery they also scavenge on the discards (Laptikhovsky and Arkhipkin, 2003).

Rodriguez *et al.* (2002) noted the dietary shift of *Diplodus annularis* of sea grass *Posidonia oceanica* in relation to trawling. The gut content analysis revealed that *Diplodus annularis* in trawled meadows consumed planktonic copepods whereas those in untrawled meadows preyed benthos. The studies conducted at Massachusettes Bay showed that flatfishes consumed spionid polychaetes more preferentially before trawling while it changed to amphipod after trawling (Anon, 2003). Engel and Kvitek (1998) suggested that trawling enhanced the abundance of polychaetes increasing the food resource for commercially important flatfishes off central California while in the North sea the small macrofauna that increased in abundance after trawling does not form food for fishes (Duplisea *et al.*, 2002).

Ramsay *et al.* (2000) suggested that as fishing effort increases, starfish numbers also increase until they reach a turning point, after which starfish numbers decline as fishing effort further increases. As fishing effort intensifies, the depletion of natural prey items and starfish mortality due to fishing cause a reduction in the size of starfish populations.

The response to beam trawl disturbance varied in the behaviour of two sympatric species of hermit crab, *Pagurus bernhardus* and *P. prideaux*. The proportion of crustaceans and polychaetes were enhanced in the stomachs of *P.bernhardus* collected from trawled grounds. This domino effect recommended that *P.bernhardus* migrated into recently trawled areas because they were capable to benefit from feeding on the damaged or disturbed fauna engendered by beam trawling. *P.prideaux* apparently neither moved into the trawled area nor responded to the additional food source if already present, even though they have akin dietary characteristics to *P.bernhardus* (Ramsay *et al.*, 1996).

Camphuysen and Garthe (2000) have pointed out that any shift in fishing effort or changes in the fishery policy could have unexpected side effects on seabirds. Most North Sea seabirds have increased in number over the last century. An additional source of food availability on account of discards from trawls attributes to this spectacular increase. But he also suggested that the gross overfishing of large predatory fish can lead to even decline in the seabird population. The feeding ecology, foraging strategies, functional responses of feeding seabirds and factors influencing prey availability has to be studied to bring out the population trends of piscivorous seabirds in relation to fishing effort.

A range of epibenthic species like crabs, echinoderms readily utilize invertebrates discarded from Clyde Sea Nephrops trawlers. In field and laboratory trials, heavy-shelled dead whelks (*Baccinum undatum* and *Neptunea antiqua*) sank very fast making most discards available to the benthos within minutes after discarding (Bergman *et al.*, 2002). Groenewold and Fonds (2000) pointed out that the beam-trawl fishery for flatfishes in North Sea created enormous mutilated benthos that increased the amount of food available to the benthic scavengers. This led to shortcut in trophic relationships. The disturbed sites of Georges Bank were dominated by scavenging crabs and echinoderms (Collie *et al.*, 1997).

In Ebrodelta of NW Mediterranean the consumption of discarded demersal fish increased the level of mercury in seabirds whose natural prey consisted of epipelagic fish (Arcos *et al.*, 2002). The short-lived species are favoured while long-lived species are more adversely affected, with the outcome that the disturbed communities will favour scavengers, predators other than fishery target species (Keegan *et al.*, 1998).

### 2.5.5. Biodiversity

Jennings and Reynolds (2000) enumerated the impacts of fishing on species diversity in the northeast Atlantic. A reduction in fish diversity resulted from the direct mortality of target species and a reduction in invertebrate diversity resulted from the effects of towed gears on the seabed. He has pointed out that diversity is not a particularly sensitive measure of fishing effects. So we have to identify indicator species that are vulnerable to fishing. Studies of the abundance and distribution of these species would aid in identifying areas impacted by fishing.

### 2.5.6. Long-term effects

Thayer (1999) suggested that bottom trawling turns out to cause colossal devastation affecting the long-term sustainability of coastal marine living resources. Most experimental studies have shown that it is possible to detect short-term changes in community structure in response to fishing disturbance. But studies on long-term effects are meager. The long-term impact of bottom trawling on a particular species is difficult to interpret as it will depend on a combination of factors like the direct mortality at each fishing event, the distribution of the fishing effort, the distribution of that species, its life history characteristics such as longevity and fecundity and above all the interference of natural perturbations.

Long-living fragile species with a low fecundity and not frequently disturbed by natural events will be affected more than short-living species with high fecundity. The opportunistic species, like members of the polychaete family Spionidae, are characterized by high growth rates, a short life span, a low reproductive age and a large reproductive output. These characteristics enabled them to adapt rapidly to environmental perturbation and quickly recolonise disturbed habitats. (Craeymeersch *et al.*, 2000; Kaiser, 1998). The long-term changes are ambiguous in habitats where seasonal changes in benthic community occur (Kaiser *et al.*, 1998).

Craeymeersch *et al.* (2000) enumerated the long-term changes of beam trawling on the Dutch Continental Shelf since 1993 to 1996. The total density of members of the polychaete family Spionidae increased with increasing fishing disturbances. This impact may not be solely due to trawling effort but also due to differences in environmental factors like eutrophication, pollution and fisheries.

The long-term effects of trawling was ascertained by the experimental trawling that was carried out in a fine muddy habitat of Scotland that has been closed to fishing for more than 25 years. The results of repeated experimental trawl disturbance over an 18-month period on benthic community structure and also the succeeding patterns of recovery over a further 18-month period were monitored. After 18 months of recovery the physical effects were not distinguishable but the changes in benthic community were still apparent signifying that even fishing during a restricted period of the year may be ample to maintain communities occupying fine muddy sediment habitats in an altered condition (Tuck *et al.*, 1998).

Fishes rapidly migrate into beam-trawled areas to feed on benthic fauna that are mutilated by trawling or on scavenging invertebrates. The food resource for opportunistic fish species will be increased. Kaiser and Spencer (1994) suggest that this can lead to alteration of long-term community structure.

Frid and Clark (2000) suggested reduced abundances of long-lived bivalves and increased abundances of scavenging crustaceans and sea stars in the German Bight. Kaiser (1998) found that a survey on organisms that record disturbances of the past in their shells or body structure (eg. bivalves, echinoderms) can give a picture of long-term effects.

According to Dinmore (2003), in the Central North Sea seasonal closures increased the homogeneity of overall disturbance and led to the redistribution of trawling activity to environmentally sensitive or previously unfished areas. Therefore effort reductions or permanent area closures should be considered as a management option. This would lead to a single but permanent redistribution of fishing disturbance, with lower cumulative impacts on benthic communities in the long run.

Gordon *et al.* (2002) conducted a three-year experiment to examine the effects of repetitive otter trawling on a sandy bottom ecosystem at a depth of 120-146 m on the Grand Banks of Newfoundland. The most pronounced impacts were the immediate effects on physical structures and direct removal of epifauna like snow crabs, basket stars, sand dollars, brittle stars, sea urchins and soft corals. The immediate and long-term effect on infauna was minor. The whole biological community recovered from the annual trawling disturbance in less than a year, and no significant effects could be seen on benthic community after 3 years of otter trawling.

The long-term changes in the benthos on a heavily fished ground off the NE coast of England provided some evidence for the role of direct effects of fishing in determining the abundance and composition of coastal macrofauna. Long-term monitoring of 2 benthic stations off the Northumberland coast was carried out since 1971. One station was located within a *Nephrops norvegicus* fishing ground, while the other station was located outside of the main fished area. At the heavily fished station the increase in fishing effort did not alter the abundance of the taxa predicted to decline, but the abundance of individuals in taxonomic groups predicted to increase did change (Frid *et al.*, 1999).

The long term changes in benthic community due to trawling was tested by Frid and Hall (1999) using a data set comprising stomach contents for fish (*Limanda limanda*) collected in early 1950s and a matched sample from 1996-97. The results of the test were consistent with the hypothesized effects of fishing, with an increased prevalence of scavengers and decreased occurrence of sedentary polychaetes in the diet.

Information on benthic communities within the North Sea was compiled by Frid *et al.* (2000) to assess the long term changes in the marine benthos on fishing grounds over 60 years. In two sites, Dogger Bank and Inner Shoal, he could not observe significant difference in community composition between the early 1920s and late 1980s. In the remaining three areas, Dowsing Shoal, Great Silver Pit and Fisher Bank, significant differences were observed.

In spite of clear short-term effects, the long-term effects of trawling and scallop dredging have not been adequately studied so far and little trawling impact is revealed in areas exposed to natural stress (Lokkeborg, 2005).

### 2.5.7. Fishery

Whether the impact on benthic ecosystem is reflected in the fishery is obscure. Martin *et al.* (1995) studied the abundance and distribution of small demersal fishes in the Gulf of Carpentaria, Australia. They recorded significant correlations between the presence of benthos and both the species diversity and abundance of fishes. They pointed out that the changes to benthic community resulting from trawling would affect fish community composition. Major alteration in benthic habitat can lead to changes in the composition of the resident fish fauna (Kaiser *et al.*, 2002). Fishes rapidly migrate into beam-trawled areas to feed on benthic fauna that are mutilated by trawling or on scavenging invertebrates. The food resource for opportunistic fish species will be increased which can lead to alteration of long-term community structure (Kaiser and Spencer, 1994).

The gut content analysis of commercially important species will bring forth the indirect effect imposed to fisheries. Several studies have accounted for the variations in food resources and dietary shifts of fishes in relation to trawling (Anon, 2003; Rodriguez *et al.*, 2002; Duplisea *et al.*, 2002; Engel and Kvitek, 1998). The bycatch and discards generated from bottom trawlers also adversely affect the fishery (Alverson *et al.*, 1994).

## 2.6. Studies conducted in India

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, 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). Even though several studies have been conducted in temperate waters on the impact of bottom trawling, such works in tropical waters remains poor (Kumar and Deepthi, 2006). The *Ocean and Atmospheric Sciences and Technology Cell* (OASTC) supported by Ministry of Earth Sciences initiated 5 projects in Indian waters. The coasts of Karnataka (Zacharia, 2004; Bhat, 2003; Gowda, 2004), Kerala (Kurup, 2004b) and Vishakapatanam (Raman, 2006) were studied. These studies give a picture of impact of bottom trawling. In all these studies the bycatch and discards generated from commercial trawlers were quantified and characterised. Experimental trawling was conducted at predetermined depths in the commercial fishing grounds to assess the impact after trawling. In Kakinada coast, an untrawled area was sited and unimpeded trawling was conducted for 72 hours. Apart from these studies, the dislocation of non-edible biota by the bottom trawlers was surveyed by Jagadis *et al.* (2003) in the Palk Bay and Gulf of Mannar, along the southeast coast of India while Menon *et al.* (2006) conducted a similar study along the southwest coast of India.

### 2.6.1. Physical impacts

#### 2.6.1.1. Hydrographical parameters

All the studies conducted in India revealed the impact on the environmental parameters immediately after trawling. Significant increase in turbidity is noticed after trawling (Bhat, 2003; Gowda, 2004; Zacharia, 2004; Thomas *et al.*, 2004; Bhat and Shetty, 2005). In bottom waters the dissolved oxygen decreased (Bhat, 2003; Gowda, 2004; Thomas *et al.*, 2004; Bhat and Shetty, 2005) while the concentrations of nitrite-nitrogen, inorganic phosphate and chlorophyll pigments increased (Kurup, 2004b; Thomas and Kurup, 2004). The variations in temperature, salinity and pH due to bottom trawling were found to be insignificant (Thomas *et al.*, 2004; Zacharia *et al.*, 2005 & 2006b; Thomas and Kurup, 2006a).

The increase in turbidity is due to the churning up of sediments and may leave the seabed with permanent sediment clouds in the water column. The reduction in dissolved oxygen after experimental trawling was attributed to the churning action of trawl nets on sea bottom (Thomas *et al.*, 2004; Thomas and Kurup, 2006a, 2005b). Two fold increase in chlorophyll pigments was ascribed to the release of sediment chlorophyll along with sediment particles dispersed during trawling, decreasing the chlorophyll pigmentation of the sediment (Thomas, 2003).

#### 2.6.1.2. Sediment characteristics

Owing to a reduction in clay fraction the sediment texture altered into more sandy and silty after trawling in the muddy bottom of 0-40 m depth (Thomas and Kurup, 2005a, b, c; 2006a). A reduction was also observed in clay proportion after trawling along Mangalore coast (Zacharia *et al.*, 2005) and Kakinada along Visakhapatnam coast (Raman, 2006). During trawling the lighter particles of clay will get suspended and as sand resettle faster, more sandy sediment is found immediately after trawling. A two-fold reduction in organic matter was also noticed due to the loss of sediment surface during the scraping of otter boards and nets (Thomas and Kurup, 2005a, b, c; 2006a). The reduction in organic matter is concurrent with the studies conducted at Kakinada along Visakhapatnam coast (Raman, 2006) and off Mangalore coast (Zacharia *et al.*, 2005).

### 2.6.2. Biological impacts

#### 2.6.2.1. Epifauna

According to Bhat (2003) and Raman (2006) the mostly affected epifaunal component is the invertebrates. The damage inflicted to epifauna was clearly evident from the enormous amount of dead shells obtained in trawled areas off Vishakapatanam comparing to untrawled areas (Raman, 2006). The most concerned issue in the trawl catches of Karwar coast was the invertebrate shell landed in substantial quantities and disposed (Bhat, 2003; Bhat and Shetty, 2005). In single day fleet off Karwar and Tadri (Karnataka) the major proportion of the total catch was non-targeted bycatch (45%) when compared to the targeted shellfishes (14%) and finfishes (45%) (Menon *et al.*, 2006). Apart from invertebrate shells many other epifaunal assemblage form a major component of discards. The squilla that forms the major discards off Karwar coast is being utilized in the manufacture of fertilizer and poultry feed (Bhat, 2003; Bhat and Shetty, 2005). 12% of total trawl landings along southwest coasts of India constituted of stomatopods and non-edible biota (Menon *et al.*, 2006). The quantity of epibenthos discarded from the bottom trawlers of Kerala was 1.68 and 1.31 lakh tonnes in the period 2000-01 and 2001-02 respectively. The species composition of the epibenthos discards revealed that crabs (*Charybdis smithii*) were dominant followed by stomatopods (*Oratosquilla nepa*), gastropods (*Turritella maculata*), juvenile shrimps & finfishes (20%), soles, echinoderms, jellyfishes, hermit crab, gorgonids and eggs of squid (Kurup *et al.*, 2004; Thomas and Kurup, 2005b; Menon *et al.*, 2006). Along Mangalore coast the dominant group discarded in single day fishing trawlers were stomatopods while finfishes formed the dominant group in multiday fishing trawlers (Zacharia, 2006a). The major proportion of bycatch landed in single day fishing trawlers along Mangalore also constituted of stomatopods (90%). The dislocated fauna mainly comprised of the benthic fauna with the non-edible crab forming the dominant group followed by echinoderms, stomatopods, molluscs, sponges and seapens at Rameswaram and Pamban (Jagadis *et al.*, 2003).

### 2.6.2.2. Infauna

The destruction caused to infauna by bottom trawling activities is clearly evident from the results of the studies of Gowda (2004), Zacharia (2004), Kurup (2004a,b), Krishnan *et al.* (2005), Thomas and Kurup (2005c, 2006b) and Thomas *et al.* (2006).

#### 2.6.2.2.1. Macrobenthos

Increase in the abundance and biomass and subsequent decrease in diversity indices of macrobenthos is noted as an immediate effect of trawling (Gowda, 2004; Zacharia, 2004; Kurup, 2004b; Krishnan *et al.*, 2005). The bivalves, gastropods, polychaetes, foraminiferans and scaphopods generally showed an increase after trawling while some of the gastropods like *Cerithium* spp., *Cavolina* spp., and *Strombus* spp. decreased after trawling (Zacharia, 2004). Polychaete, which is the most dominant macrofauna, increased in abundance and biomass during July when there is a ban on bottom trawlers in Kerala. This shows that the ban is useful for the regeneration and recoupement of polychaetes (Thomas and Kurup, 2005c; Thomas *et al.*, 2006). The increase in number of polychaetes has been attributed to the survival of opportunistic species in response to bottom trawling (Gowda, 2004; Kurup, 2004b). The experimental trawling operations conducted for a period of 2 years along Kerala coast showed that the abundance, biomass and diversity of the polychaetes increased immediately after trawling. This was attributed to their exposure due to the removal of top sediment. The polychaete abundance decreased in the second year compared to the first year. According to Thomas and Kurup (2006b) fast growing and continuous breeding species dominated the trawl ban period.

#### 2.6.2.2.2. Meiobenthos

Studies conducted at Kerala and Mangalore showed that after trawling there was a significant increase in the density of nematodes and foraminiferans while that of harpacticoids, polychaetes, kinorhynchs and molluscs decreased.

The diversity indices reduced after trawling (Zacharia, 2004; Kurup, 2004b). According to Zacharia (2004) the impact on meiobenthos varied with depth. The numerical density and biomass of meiofauna increased at 10 and 20 m depths after trawling while a decrease was noted at 30, 40 and 50 m depths. The increase in number of nematodes after trawling has been attributed to the dominance of opportunistic species in response to bottom trawling (Gowda, 2004). Post monsoon seasons of Kerala coast manifested a decline in abundance of nematodes. According to Kurup (2004a), the decline can be attributed to the lift of monsoon ban on trawling during this season.

**2.6.2.3. Biodiversity**

The discards of bottom trawling pose a threat to marine biodiversity. Kurup *et al.* (2003) quantified the discards generated from 375 bottom trawlers operated from six major fisheries harbours such as Sakthikulangara, Neendakara, Cochin, Munambam, Beypore and Puthiyappa. The annual discarded quantity during 2000-01 was 2.62 lakh tonnes and that of 2001-02 was 2.25 lakh tonnes. The major groups of discards were edible finfishes, non-edible finfishes, edible crabs, non-edible crabs, cephalopods, juvenile shrimps, gastropods, jellyfish, echinoderm, stomatopods and squid eggs. Temporal, seasonal and depthwise variations in discards were observed.

Zacharia *et al.* (2006a) assessed quantitatively and qualitatively the by-catch and discards of bottom trawlers along Karnataka during 2001-2002. The quantity of by-catch was estimated as 56,083 t in 2001 and 52,380 t in 2002 forming 54% and 48% of total trawl catch respectively. The quantity of discards was estimated as 34,958 t in 2001 (33.8% of total catch) and 38,318 t in 2002 (35.1% of the trawl catch). The dominant stomatopods group discarded in single day fishing trawlers and finfishes in multiday fishing trawlers also contribute to biodiversity loss. The amount of discarded catch generated is higher in shallower waters.

#### 2.6.2.4. Long-term impact

The government of Kerala has imposed a ban on trawling throughout Kerala during the monsoon months from 1988 onwards, with a duration varying from 22-61 days. Based on the data published by Central Marine Fisheries Research Institute (CMFRI), Kurup (2001) compared the average landings during the pre-ban (1978-87) and the ban periods (1988-97). An increase of 70.83% was indicated in the overall landings in the state during the ban period. This long-term comparative study revealed that the imposition of trawl ban was very effective in providing some respite for fish stocks in the coastal waters of Kerala.

## 2.7. Discussion

According to Lokkeborg (2005) the biological impact differs with the gear operated like otter trawl, beam trawl and dredge. The impact also varies with sediment texture and whether the study area is sheltered or protected. The otter trawling on hard bottom habitats with erect structures shows a significant decline in the abundance of large and erect sessile invertebrates like sponges and corals. The hard bottom habitats dominated by large sessile fauna may be severely affected by trawling. But the otter trawling studies conducted on soft bottom confer ambiguous results. This is due to lack of true or replicate control sites and prominence of spatial and temporal variations. The seafloor subjected to natural variations are resistant to trawling or the natural variations may mask the actual disturbance due to trawling as in clayey-silt bottoms. The studies on the intricacy and natural variations of benthic communities are still at the elementary level. This unawareness often puts the investigator in dilemma while interpreting the impact.

Intensive beam trawling causes reduction of infauna and epifauna as short-term changes. Long-term effects of beam trawling have not been studied. In prevalence of the temporal and spatial changes the short-term reduction in species density and abundance attributable to dredging impact was negligible. The dredging impacts were not evident in areas exposed to natural stress, e.g., wave action, eutrophication and salinity fluctuation (Lokkeborg, 2005).

The impact of bottom trawling depends on the sediment texture of the area, type of fauna of the area, natural physical disturbances of the area, fishing intensity of the area, fisheries of the area, behaviour of fishing, feeding behaviour of fishes of commercially important species etc. The time taken for recovery or recoupement of the fauna, long-term and short-term changes of trawling, sediment geochemical impact etc varies in different regions of the world. Briefly, the impact of trawling and the extent of impact are area specific and species specific. Therefore the period of closed season and the area to be closed varies with different regions around the globe.

Many authors (Engel and Kvitek, 1998; Kurup and Thomas, 2005) have stressed the need of sufficient time to be given for the revival of the benthic fauna. The implementation of closed areas or seasons without a thorough knowledge on the impact of trawling on benthic community taking into consideration the intensity of trawling and fisheries of the area will have adverse effects (Duplisea *et al.*, 2002). The inappropriate use of closed areas may displace fishing activities into habitats that are more vulnerable to disturbance (Kaiser *et al.*, 2002).

Intensive trawling is going on in shallow water depths targeting prawns all over the coast of India. 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 (Sathiadas, 1998). Many of the demersal marine finfishes of India are on the verge of extinction due to overfishing and irrational bottom trawling demolishing benthic ecosystems (Bensam and Menon, 1994). In the Indian background lack of control sites or sites protected from trawling is a methodological limitation (Kumar and Deepthi, 2006).

Kumar and Deepthi (2006) suggested that except scattered reports, detailed publishing on the quantity of trawl by-catch and its benthic faunal composition is lacking from the Indian waters. A major limitation for carrying out studies on the impact of trawling on benthic fauna in India is the inadequacy of taxonomic studies of benthic fauna of coastal and marine waters of the country. Knowledge of seasonal, annual and spatial variations in the benthic fauna is a prerequisite for interpreting the impacts of trawling (Lokkeborg, 2005). The studies conducted in

India on this aspect are generally confined to estuaries (Hussain and Mohan, 2001; Khan and Murugesan, 2005), intertidal beach (Rao and Srinath, 2002) and mangroves (Saravanakumar, 2002; Serebiah, 2002; Chinnadurai and Fernando, 2003). The published reports on the benthic studies of continental shelf, slope and deepsea are limited to the ecological aspects. The benthos of continental slope and deepsea has been explored only by Parulekar *et al.* (1982) during the cruises onboard *INS Darshak* (1973-74) and *RV Gaveshani* (1976-80). In this study, the benthic production has been assessed relating it to the demersal fishery resources of the Indian Seas (Arabian Sea, Bay of Bengal, Andaman Sea and Lakshadweep Sea). The depth zones of continental shelf, continental slope and deepsea were covered. In the $2^{nd}$, $12^{th}$ and $13^{th}$ cruises of *RV Gaveshani* during 1976-77, Harkantra *et al.* (1980) recorded the benthic biomass, sediment organic carbon, nature of substrata, demersal fish catch, distribution and abundance of faunal groups of west coast continental shelf at a depth of 10-70m. It has been established that the quantitative distribution of benthic fauna showed a direct relationship to the exploited demersal fisheries, in particular the shrimps. Sajan and Damodaran (2005) have reported the vertical distribution of nematodes on the continental shelf off Dabhol, Coondapore and Vadanappilly during the cruises onboard the FORV *Sagar Sampada* in 2001. The recent reports on the different species of polychaetes (Joydas, 2002; Jayaraj, 2006) and nematodes (Sajan, 2003) of shelf of west coast of India is giving some insight into the obscure benthic taxonomy of Indian marine waters. In view of the paucity of adequate information, more focused research on the taxonomy of benthic fauna of continental shelf, slope and deep sea is required for interpreting the impact of bottom trawling.

## 2.8. Conclusions

The bottom trawling should ensure bottom contact to achieve catch efficiency. So it is not possible to completely avoid the mortality of benthic organisms (Van Merlen, 2000). As bottom trawling should be continued as a livelihood for fishermen the impact caused by bottom trawling has to be assessed using different methodologies along east and west coast of India taking into account the variations in fishing gears used, fishing behaviour, substrate characteristics and taxonomy of resident benthic fauna. This field of research offers vast opportunities for the upcoming scientific activities. The results of these studies would generate information useful for the fisheries managers in the execution of measures to reduce the impact of trawling. The prospects for implementation of artificial reefs to prevent the illegal trawling of ships (Munoz-Perez *et al.*, 2000) have to be investigated. Based on impact studies issues like extent of usefulness of the closed season or reduction in fishing pressure, advantages of adoption of technical modifications like incorporation of release holes at the codends, water jet injection or electrical stimulation at the foot rope, provision for more floats and tickler chains (Keegan *et al.*, 1998; Van Merlen, 2000), incorporation of benthos release panels (Revill and Jennings, 2005) to reduce bycatch as to protect the biodiversity, provide scope for future studies.

## Chapter 3

# Fishing Craft, Gear, Experimental Site and Design

## 3.1. Experimental site

Veraval, situated at latitude 20°54′ 40″ N and longitude 70°22′ 12″ E is on the North West coast of India. Veraval town is in Junagadh District of Gujarat. Veraval ranks first in marine fish-landing, out of the 44 fishing harbours of Gujarat. Veraval port was established in 1986 and was designed initially for 1200 fishing trawlers but 2793 trawlers are being operated from this port now making it the largest concentration of trawlers in Gujarat (Anon, 2005a). Fishing season is very much related to the climatic conditions of the area. There is a traditional long standing practice of observing closed seasons during monsoon. During this period, the sea becomes very rough and also it is the breeding time for most of the commercial marine fishes. As the sea become rough from mid May onwards, the trawler fishermen reduce sea venture and prefer to take the craft out of sea for drying or repair work. The fishing activities are resumed during September. As per Gujarat Fishery Act 2003, from 10$^{th}$ June to 15$^{th}$ August is declared as closed fishing season. Traditional and medium class mechanized vessels are concentrated in the inshore area (< 50 m depth) of Indian coastal waters. Benthic studies carried out in the inshore area of Indian peninsula are scattered and a long term monitoring is never done. Hence data on the benthic ecosystem and impact of bottom trawling is lacking in many places. The present study is a pioneer work carried out in Veraval coast. A view of Veraval fisheries harbour is given in Figure 3.1, 3.2 & 3.3.

**Fig. 3.1**. A view of trawlers off Veraval fisheries harbour during closed season

**Fig. 3.2.** Dry docking

**Fig. 3.3.** Nets hauled up during closed season

Five transects representing five water depth zones ranging from 15 - 40m were selected for the study. This is the commercial fishing ground for traditional and mechanised fishing vessels conducting single day fishing. The five transects of study area included the five depth zones of 15-20 m, 21-25 m, 26-30 m, 31-35 m and 36-40 m in the commercial trawling grounds. The coordinates of each transect is as shown in Table 3.1 and Figure 3.4. Upto 15m water depth (5 nautical miles) the sea bottom is rocky and is not suitable for bottom trawling. The selection of site for the experimental field studies was based mainly on (i) port having the highest number of trawlers in India (ii) inshore waters where bottom trawling is prevalent (iii) sites where institute vessel can be engaged in experimental trawling.

**Table 3.1.** Showing the co-ordinates of study sites and distance from land

| Sl.No. | Water Depth zones | Transect | |
|---|---|---|---|
| | | GPS Position | Distance from land (km) |
| 1. | 15-20 m | Latitude 20°54′13″N<br>Longitude 70°20′18″ E | 5.55 |
| 2. | 21-25 m | Latitude 20°53′05″N<br>Longitude 70°21′04″ E | 5.55 |
| 3. | 26-30 m | Latitude 20°51′35″ N<br>Longitude 70°18′36″ E | 11.11 |
| 4. | 31-35 m | Latitude 20°50′56″ N<br>Longitude 70°18′32″ E | 22.22 |
| 5. | 36-40 m | Latitude 20°47′56″ N<br>Longitude 70°15′12″ E | 25.93 |

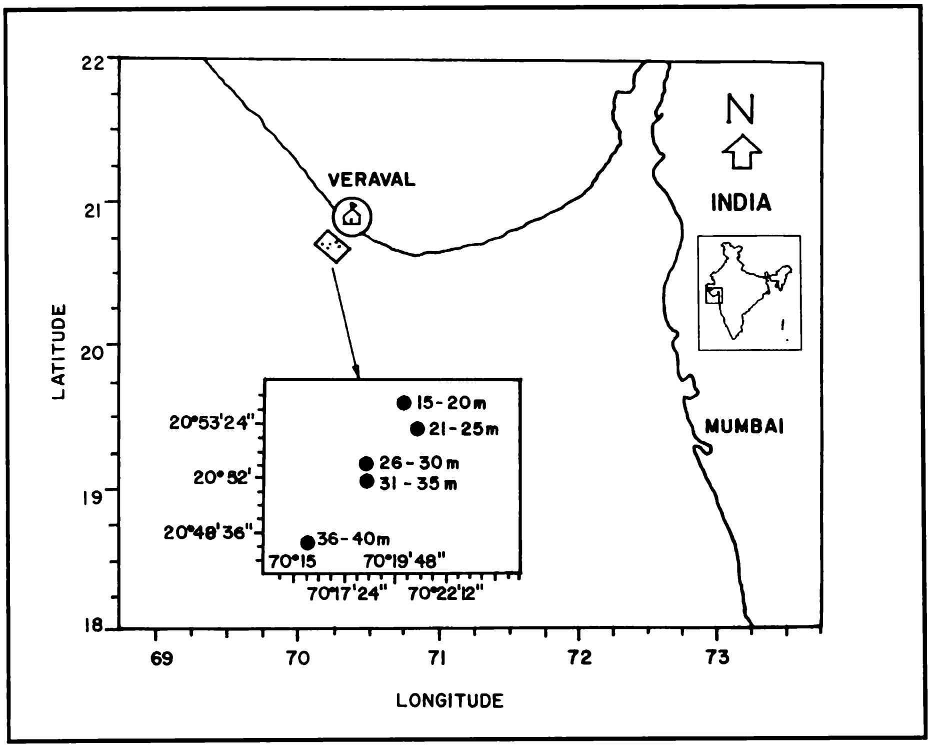



**Fig. 3.4.** Map showing study sites

## 3.2. Experimental protocol

### 3.2.1. Vessel description

The department research vessel of Veraval Research Centre of Central Institute of Fisheries Technology was used for conducting the field studies. Steel trawler MFV *Sagarkripa* (Table 3.2; Figure 3.5) (15.5 m OAL steel stem trawler equipped with 124 hp ALM 412, marine Engine). The trawler is equipped with split winch with 12mm wire rope 1200m capacity. The vessel has a free running speed of 9.5 knots (maximum) and a trawling speed of up to 3 knots. Transect, corresponding to a particular depth zone was fixed using a Garmin GPS (Figure 3.5) (with an accuracy of 4-6 m) installed onboard the vessel and coordinates were stored for navigation to the respective stations for sample collection. A 50/200 dual frequency Simrad fish finder (Figure 3.5) was also used to fix transects by avoiding areas with rocky bottom and other physical disturbances.


**Fig.3.5** MFV *Sagarkripa*,
Garmin GPS & Simrad fish finder (inset)

**Table 3.2.** Details of Research Vessel

| | | | | |
|---|---|---|---|---|
| 1. | Name | | : | *Sagarkripa* |
| 2 | Port of registry and number | | : | FKZK - 347 |
| 3. | Type | | : | Steel Trawler |
| 4. | OAL | | : | 15.5 m |
| 5. | Gross tonnage | | | 42 |
| 6. | Engine | BHP | | 122 BHP Diesel |
| | | Make | | Ashok Leyland |
| | | Model No | | ALM 412 |
| 7. | Type of gear | | | Trawl net |
| 8. | Number of gears onboard | | | 4 |
| 9. | Crew size | | | 7 |
| 10. | GPS | Model | | 128 GPS |
| | | Make | | GARMIN |
| 11. | Echosounder | Model | | 50/200 |
| | | Make | | SIMRAD |
| 12. | Type of otter board | | | "V" form, Suberkrub |
| 13. | Winch | Type | | SPLIT winch |
| | | Make | | Mechanical |
| | | Rope length | : | Wire rope , 1000 mt X 12 mm |
| 14. | Fish holding capacity | | : | 30 $m^3$ |

### 3.2.2. Gear operated

The Gear operated for the study was 34 m, four seam high opening bottom trawl net with 23 kg of sinkers, seven numbers of 150 mm Ø plastic floats and 80 kg V- form steel otterboards. The gear consisted of 34 m head rope, 38 m footrope, 400 mm wing section mesh size, 300 mm throat mesh size, four sections in the belly of 200, 140, 120 and 90 mm mesh size and codend of 40 mm mesh (Table 3.3; Figure 3.6). The weight of the gear imposed on the seabed is approximately 40 kg (including sinkers and floats). This is a local design used by fishermen of Veraval. This is used as the standard gear throughout the experiment. The speed of trawling (2.2-2.3 knots) and the scope ratio (1:4) was fixed by trials to ensure proper bottom contact and these standard gear settings were used throughout the experiment.

**Table 3.3.** Design details of gear operated

| | | | |
|---|---|---|---|
| 1. | Type of trawl gear | : | 4 seam high opening bottom trawl |
| 2. | Head rope length | : | 34 m |
| 3. | Foot rope length | : | 38 m |
| 4. | Codend mesh size | : | 40 mm |
| 5. | Material | : | 1.5 mm Ø HDPE |
| 6. | Type of float | : | plastic |
| 7. | No. of floats | : | 7 no |
| 8. | Weight of sinkers | : | 23 kg |
| 9. | Type of otter board | : | V- form steel Suberkrub |
| 10. | Bridle length | : | 20 m |
| 11. | Swept area (for each experimental trawling) | | 62, 968 $m^2$ |

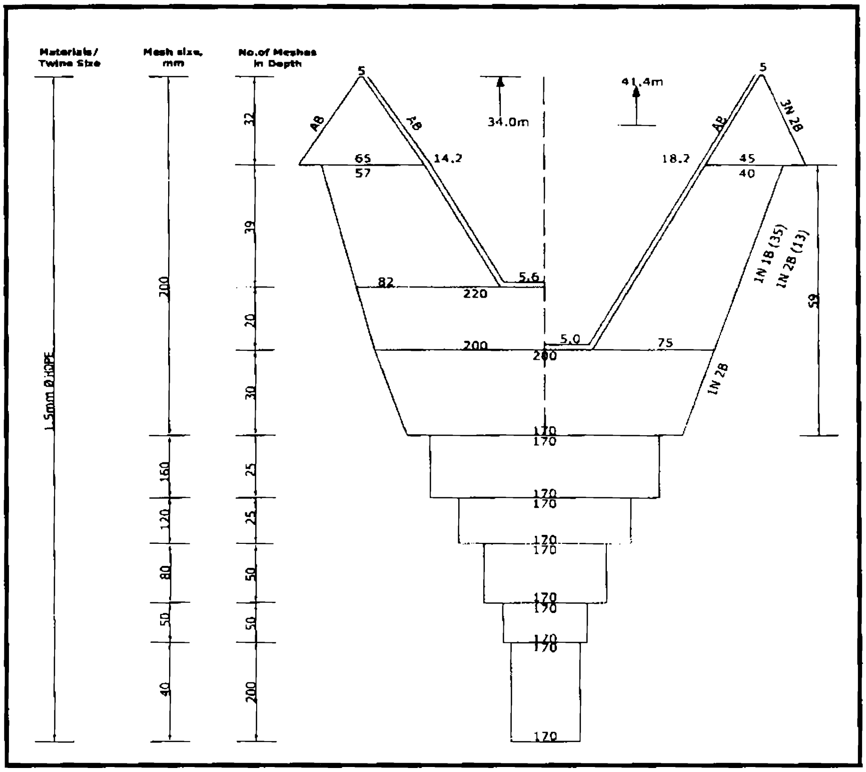



**Fig. 3.6.** Design of gear operated

### 3.2.3. Experimental design

Manipulative experiments are often used to investigate the effects of anthropogenic disturbance on natural populations. In the present study, experimental bottom trawling was carried out for 17 months, in a span of 20 months (September 2005 - April 2007) excluding the trawl ban period (June to August). The experimental design involved the collection of sediment samples before and after trawling with a standard trawl net along the pre-identified track. From the point fixed in the pre-identified depth zone samples of water, sediment and benthic fauna were collected, which is the sample for pre-trawled condition (control). The vessel then propelled away from this pre-fixed point at a speed of 5 knots for 10 minutes and turned back and navigated through this point with the help of GPS. During this sail, experimental trawling (2.2 knots speed) was carried out along the same corridor for one hour. Once the vessel crossed the pre-fixed point (as indicated by a beep in the GPS), the net was hauled in. The vessel was then propelled back to the pre-fixed point and samples were collected, which formed the after trawling condition of this identified point. The samples collected from this point were considered as indicative of the samples from an area where disturbance was caused by experimental trawling.

### 3.2. 4. Sampling equipments

The sediment samples were collected with a van Veen grab (of mouth area 0.1m$^2$) (Figure 3.7). The sediment characteristics, macrobenthos and meiobenthos were analysed with the sediment and infaunal samples collected in grab. The dredge (Figure 3.8) operated to collect epifauna was a rectangular dredge of SS sheets reinforced frame structure of dimensions 1x0.4x0.5 m with 100 cm long net; mesh size of 6 mm with attached sling for towing.

Fig. 3.7. van Veen grab

Fig. 3.8. Rectangular dredge

### 3.2.5. Strategies adopted for sampling

The trawling intensity was fixed as one tow for one hour and this was repeated at each depth zone for 20 months. The time taken to reach the point after the net crossing the fixed point varied from 15-20 minutes. The sampling was done from the same stations every month with the help of GPS.

## 3.3. Literature used for species identification

The organisms encountered in the study were identified using standard references and published literature. The octocorals, seaweeds, molluscs were identified following Allen and Steene, 1999; Carpenter and Niem, 1998; Dance, 1976 and www.gastropods.com. The crustaceans and fishes were identified as per www.fishbase.org. For identifying polychaetes, Day (1967 a & b) and Fauvel (1953) were made use of.

## 3.4. Data analysis

PRIMER software package (Version 5.2.9; Plymouth Marine Laboratory, Plymouth, UK) (Clarke and Warwick, 2001) and SPSS 12 version for Windows package were used for statistical analysis.

An array of diversity indices i.e. S (species), N (number), d (Margalef index), J' (Pielou's evenness index), H (Brillouin index), $\alpha$ (Fisher's Alpha), H'(Shannon index), Hill's no. ($N_1$ and $N_2$), 1-$\lambda$' (Simpson's index), $\Delta$ (Taxonomic Diversity index), $\Delta^*$ (Taxonomic Distinctness index), $\Delta^+$ or AvTD (Average Taxonomic Diversity index), s $\Delta^+$ or TTD (Total Taxonomic Distinctness), Lambda+ or VarTD (Variation in Taxonomic Distinctness), φ+ or AvPD (Average Phylogenetic Diversity) and sφ+ or PD (Phylogenetic Diversity) was calculated. The $\log_{10}$ (X+1) transformed indices were used for one way ANOVA of SPSS 12.0 to find out any significant difference in the mean value of the indices before and after trawling in each depth zone. Abundance-Biomass Comparison (ABC) curves were plotted in order to ascertain whether the benthic communities undergone any stress due to trawling pressure. SIMPER analysis revealed the most abundant species in each depth zone before and after trawling. Similarity matrix for each depth zone was constructed and MDS plots were made to visually determine disturbance on faunal assemblages before and after trawling.

The statistical analysis regarding seasonal, monthly, depthwise and trawling induced variations for sediment characteristics and heavy metals were carried out using SPSS 12 version for Windows package. The data was treated statistically using Multivariate Analysis. The statistical significance was measured at a $p \leq 0.05$.

Chapter 4

# Impact of Bottom Trawling on Sediment Organic Matter and Texture

## 4.1. Introduction

The sedimentary organic matter forms the basis of energy supply for the marine food web, as it is the abode of nutrition for deposit feeders (Levington, 1982). The role of sediment texture and organic matter in determining the distribution of benthos has been long recognised in several studies (Sanders, 1958; Harkantra *et al*., 1982; Rodrigues *et al.*, 1982; Ingole *et al.*, 2002; Kumar *et al.*, 2004; Jayaraj *et al.*, 2007). The bottom trawls are designed to tow along the sea floor, which on its operation causes, the removal of organic matter by scraping, alteration of sedimentation pattern and variations in sediment-water column fluxes. The impact of bottom trawling on sediment organic matter of coastal marine sediments has been documented by Schwinghamer *et al.* (1998) along Grand Banks of Newfoundland, Duplisea *et al.* (2001) in the North Sea and Pusceddu *et al.* (2005) in the Gulf of Thermaikos (Aegean Sea). A number of studies have been conducted on the impact of bottom trawling on the sediment texture (Schwinghamer *et al.*, 1996, 1998; Duplisea *et al.*, 2001; Palanques *et al.*, 2001). Jones (1992) on reviewing the studies on environmental impact of trawling on the seabed reported that bottom trawling causes the scraping and ploughing of the seabed and resuspension of sediment. In India, the coasts of Karnataka (Bhat, 2003; Zacharia, 2004; Gowda, 2004), Kerala (Kurup, 2004b) and Vishakapatanam

(Raman, 2006) were studied to bring out the impact of bottom trawling on the benthic communities. The aim of the present investigation is to bring out the possible impact of bottom trawling on the sediment characteristics off Veraval coast.

## 4.2. Materials and Methods

A portion of the meticulously blended sediment samples was dried (60°C) and the sediment texture was analysed by pipette analysis (Carver, 1971) (Figure 4.1). The dried and powdered samples were analysed for organic carbon by wet oxidation method (Walkley and Black, 1934) Figure 4.2). Organic carbon was then converted to organic matter following (Trask, 1939). The equation used was as given below,

Organic matter (%) = Organic carbon (%) x 1.72

The percentage composition of sand, silt and clay was calculated and plotted as triangular diagram based on the nomenclature suggested by Shepard (1954) using software ORIGIN version 6.

For statistical interpretations the stations were designated as $D_j$; $j$ = 1,2,3,4 and 5 for stations at the five discrete water depths from 15 to 40 m at 5 m interval. The trawling mode was indicated as $T_i$; $i$ = 1 for before and 2 for after trawling. The statistical analysis regarding seasonal, monthly, variations with water depth and trawling induced variations was carried out using the three-way ANOVA, Student's t test and Trellis diagram (Snedecor and Cochran 1967; Jayalakshmy 1998). Cluster analysis was carried out on the similarity matrix formed from

Bray-Curtis similarity index on non-standardized non-transformed data using PRIMER v5. The statistical significance was measured at 5% level.

**Fig. 4.1.** Pipette analysis (Carver, 1971)

**Fig. 4.2.** Wet oxidation method (Walkley and Black, 1934)

## 4.3. Results and Discussion

### 4.3.1. Organic matter

The organic matter (OM) was found to vary between a mean value of 1.07 % ($D_5$) and 1.78 % ($D_1$) before trawling (Table 4.1). Highly significant monthly variation was observed in OM content ($F_{(11,44)}$ =15.21, P<0.05) (Table 4.2) leading to depth-month specificity for OM distribution ($F_{(44,44)}$ =6.38, P<0.05).

**Table 4.1.** Average and standard deviation (S.D.) of organic matter and sediment fractions

| Trawling | Depth | Notation | Organic matter (%) (mean±S.D.) | Silt (%) (mean± S.D.) | Clay (%) (mean±S.D.) | Sand (%) (mean±S.D.) |
|---|---|---|---|---|---|---|
| Before | 15-20m | $T_1D_1$ | 1.78 ±0.32 | 80.26 ±11.46 | 19.44 ±11.55 | 0.30 ±0.21 |
| Before | 21-25m | $T_1D_2$ | 1.70 ±0.24 | 80.35 ±7.20 | 19.01 ±7.36 | 0.65 ±0.47 |
| Before | 26-30m | $T_1D_3$ | 1.47 ±0.28 | 73.05 ±14.17 | 26.25 ±14.23 | 0.70 ±0.38 |
| Before | 31-35m | $T_1D_4$ | 1.12 ±0.37 | 76.81 ±7.67 | 20.53 ±8.65 | 2.65 ±2.36 |
| Before | 36-40m | $T_1D_5$ | 1.07 ±0.27 | 72.94 ±9.78 | 17.38 ±11.04 | 9.68 ±4.05 |
| After | 15-20m | $T_2D_1$ | 1.69 ±0.25 | 77.64 ±15.37 | 22.06 ±15.46 | 0.30 ±0.20 |
| After | 21-25m | $T_2D_2$ | 1.65 ±0.39 | 78.64 ±12.65 | 20.95 ±12.65 | 0.40 ±0.20 |
| After | 26-30m | $T_2D_3$ | 1.43 ±0.28 | 76.91 ±12.96 | 22.53 ±13.14 | 0.56 ±0.39 |
| After | 31-35m | $T_2D_4$ | 1.07 ±0.34 | 79.05 ±10.28 | 16.64 ±9.59 | 4.30 ±6.18 |
| After | 36-40m | $T_2D_5$ | 0.92±0.23 | 72.43 ±6.94 | 16.15 ±6.45 | 11.41±4.17 |

$T_iD_j$ indicate trawling mode and water depth value. $i$ = 1 for before and 2 for after trawling. $j$ = 1,2,3,4 and 5 for stations at the five discrete water depths from 15 to 40 m at 5 m interval

Before trawling at $D_1$, the peak OM value was observed in the month of March 2006 while the smallest amount was recorded in November 2005. At $D_2$, the highest value was noted in February 2006 and lowest value in October 2005.

At $D_3$, the maximum OM was recorded in January 2006 and minimum in September 2005. At $D_4$, the upper limit value was noticed in September 2006 and lowest in January 2006. At $D_5$, the highest value was detected in September 2006 and least value in December 2006. The seasonal variations were comparatively higher before trawling. Before trawling at $D_1$, $D_2$ and $D_3$ the highest values of OM were recorded in premonsoon while lowest values were noted in post monsoon. At $D_4$ and $D_5$ the highest values were observed in post monsoon, just after the trawl ban. These depths were heavily trawled, and trawl ban may be giving some respite to the bottom profile so that higher values were observed immediately after trawl ban. This may also be due to the input of organic matter into the coastal areas during monsoon. According to Jayaraj (2006), the seasonal variation in organic matter could not be shown due to one time sampling from 30-200m.

**Table 4.2.** Three way ANOVA table to compare before and after trawling, between depths, between months and their first order interactions based on sand (%), silt (%), clay (%) and organic matter (%)

| Source | dof | F ratio | | | | 5% level F value |
|---|---|---|---|---|---|---|
| | | organic matter | sand | silt | clay | |
| Before and after trawling (A) | 1 | 6.38[a] | 2.50 | 0.02 | 0.25 | 4.06 |
| Between depths (B) | 4 | 90.74[a] | 105.73[a] | 2.34 | 2.17 | 2.58 |
| Between months (C) | 11 | 15.22[a] | 1.95 | 3.73[a] | 4.08[a] | 2.01 |
| AB interaction | 4 | 0.41 | 1.39 | 0.52 | 0.63 | 2.58 |
| BC interaction | 44 | 3.39[a] | 3.20[a] | 1.76[a] | 1.66[a] | 1.65 |
| AC interaction | 11 | 1.35 | 0.98 | 1.22 | 1.10 | 2.01 |
| Error | 44 | | | | | |
| Total | 119 | | | | | |

[a] Calculated F statistic is significant at 5% level

**Table 4.3.** Significance of Student's t statistic for comparing stations at various depths to study the effect of trawling on organic matter (OM) (%), sand concentration (%), silt concentration (%) and clay concentration (%)

| Trawling | Depth | $T_1D_1$ | $T_1D_2$ | $T_1D_3$ | $T_1D_4$ | $T_1D_5$ | $T_2D_1$ | $T_2D_2$ | $T_2D_3$ | $T_2D_4$ | $T_2D_5$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **(a) Organic matter (OM) (%) and Sand concentration (%)** | | | | | | | | | | | |
| Before | $T_1D_1$ | 0 | 0.62 | 2.44[a] | 4.40[d] | 5.60[d] | 0.76 | 0.87 | 2.69[b] | 5.07[d] | 7.23[d] |
| Before | $T_1D_2$ | *2.21*[a] | 0 | 2.13[a] | 4.32[d] | 5.80[d] | 0.17 | 0.41 | 2.43[a] | 5.08[d] | 7.82[d] |
| Before | $T_1D_3$ | *3.00*[c] | *0.29* | 0 | 2.43[a] | 3.38[c] | 1.93 | 1.23 | 0.30 | 3.02[c] | 5.01[d] |
| Before | $T_1D_4$ | *3.30*[c] | *2.77*[b] | *2.71*[b] | 0 | 0.38 | 4.12[d] | 3.19[c] | 2.16[a] | 0.38 | 1.53 |
| Before | $T_1D_5$ | *7.67*[c] | *7.35*[d] | *7.32*[d] | *4.97*[c] | 0 | 5.51[d] | 4.00[d] | 3.04[c] | 0.04 | 1.40 |
| After | $T_2D_1$ | *0.02* | *2.24*[a] | *3.05*[c] | *3.30*[c] | *7.67*[d] | 0 | 0.28 | 2.22[a] | 4.85[c] | 7.44[d] |
| After | $T_2D_2$ | *1.10* | *1.59* | *2.28* | *3.16*[c] | *7.59*[d] | *1.15* | 0 | 1.47 | 3.71[c] | 5.29[d] |
| After | $T_2D_3$ | *1.96* | *0.47* | *0.85* | *2.91*[c] | *7.44*[d] | *1.99* | *1.25* | 0 | 2.73[b] | 4.62[d] |
| After | $T_2D_4$ | *2.14*[a] | *1.96* | *1.92* | *0.83* | *2.41*[b] | *2.15* | *2.09*[a] | *2.00*[c] | 0 | 1.17 |
| After | $T_2D_5$ | *8.82*[d] | *8.50*[d] | *8.48*[d] | *6.06*[d] | *0.99* | *8.82* | *8.74*[d] | *8.59*[d] | *3.16*[c] | 0 |
| **(b) Silt concentration (%) and Clay concentration (%)** | | | | | | | | | | | |
| Before | $T_1D_1$ | 0 | 0.02 | 1.31 | 0.83 | 1.61 | 0.45 | 0.31 | 0.64 | 0.26 | 1.94 |
| Before | $T_1D_2$ | *0.10* | 0 | 1.52 | 1.12 | 2.02 | 0.53 | 0.39 | 0.77 | 0.34 | 2.63[b] |
| Before | $T_1D_3$ | *1.23* | *1.50* | 0 | 0.77 | 0.02 | 0.73 | 0.98 | 0.67 | 1.14 | 0.13 |
| Before | $T_1D_4$ | *0.25* | *0.45* | *1.14* | 0 | 1.03 | 0.16 | 0.41 | 0.02 | 0.58 | 1.4 |
| Before | $T_1D_5$ | *0.43* | *0.40* | *1.63* | *0.74* | 0 | 0.85 | 1.18 | 0.81 | 1.43 | 0.14 |
| After | $T_2D_1$ | *0.45* | *0.59* | *0.66* | *0.29* | *0.82* | 0 | 0.17 | 0.12 | 0.25 | 1.02 |
| After | $T_2D_2$ | *0.29* | *0.44* | *0.92* | *0.09* | *0.70* | *0.18* | 0 | 0.32 | 0.08 | 1.43 |
| After | $T_2D_3$ | *0.59* | *0.78* | *0.64* | *0.42* | *0.99* | *0.08* | *0.29* | 0 | 0.43 | 1.01 |
| After | $T_2D_4$ | *0.62* | *0.65* | *1.86* | *1.00* | *0.17* | *0.99* | *0.90* | *1.20* | 0 | 1.77 |
| After | $T_2D_5$ | *0.82* | *0.97* | *2.14*[a] | *1.35* | *0.32* | *1.17* | *1.12* | *1.45* | *0.14* | 0 |

$T_iD_j$ indicate trawling mode and water depth value. $i$ = 1 for before and 2 for after trawling. $j$ = 1,2,3,4 and 5 for stations at the five discrete water depths from 15 to 40 m at 5 m interval. Data in normal font are organic matter; data in italics font are sand concentrations; data in bold font are silt concentrations; data in bold italics font are clay concentrations

[a] Calculated $t$ statistic is significant at 5% level,

[b] Calculated $t$ statistic is significant at 0.5% level,

[c] Calculated $t$ statistic is significant at 1% level,

[d] Calculated $t$ statistic is significant at 0.1% level,

[e] Calculated $t$ statistic is significant at 10% level

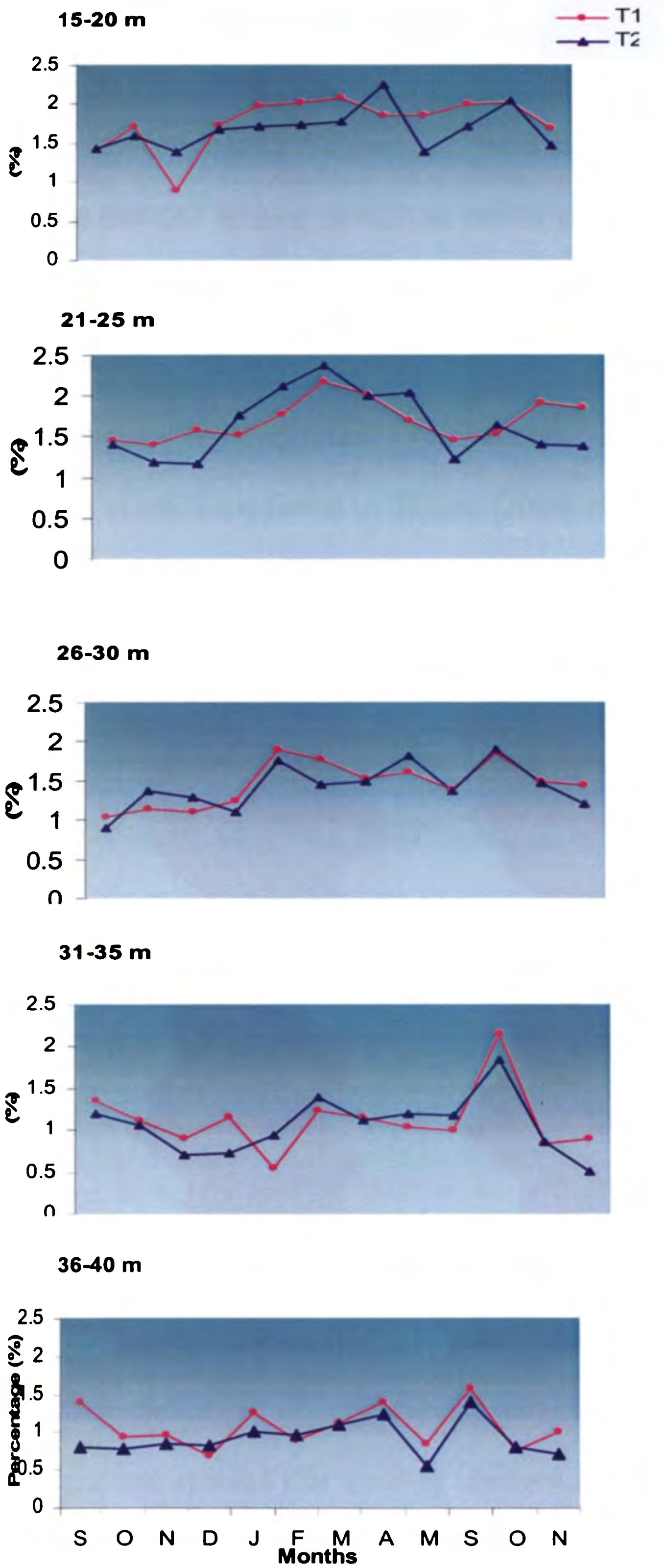



**Fig. 4.3.** Pattern of variations in sediment organic matter before and after trawling during September 2005 to November 2006. $T_i$ indicate trawling mode, $i = 1$ for before and 2 for after trawling

The variation of OM content at different water depths is highly significant ($F_{(4,44)}$ =90.74, P<0.001) (Table 4.2). On comparing the depths in pairs, it was observed that OM content in shallow depths were significantly higher ($t_{(22,5\%)}$ > 2.13, P<0.05, Table 4.3a, Figure 4.3) both before and after trawling. The organic matter variation with water depth can be indicative of organic wastes from sewage entering the marine environment. This variation with water depth is agreeing with the result of study conducted by Jayaraj (2006) along northwest Indian shelf. In this study, the organic matter content increased towards shallower depth from deeper regions.

Trawling can reduce the organic matter (OM) content at all depths (Table 4.1) as shown by three-way ANOVA ($F_{(1,44)}$ = 6.38, P<0.05) (Table 4.2). An average of 0.08% reduction in OM was observed. The maximum reduction was observed at 36-40 m (0.15% reduction). The rate of decrease was 5.06%, 2.94%, 2.72%, 4.46% and 14.02% at $D_1$, $D_2$, $D_3$, $D_4$ and $D_5$ respectively. The relative decrease enhanced towards deeper depths as these areas are heavily trawled compared to lightly trawled shallow water depths. The reduction in organic matter is on par with the results of studies conducted by Schwinghamer *et al.* 1998; Thomas and Kurup, 2005a, b, c and Raman, 2006. The studies conducted by Schwinghamer *et al.* (1998) at sandy bottom of the Grand Banks of Newfoundland showed that trawling changed the individual sediment grains to smooth, clean and light in colour. This change was attributed to the reduction in surficial biogenic sediment structure and flocculated organic matter. A two-fold reduction in organic matter was also noticed due to the loss of sediment surface during the scrapings of otter boards and nets (Thomas and Kurup, 2005a, b, c; 2006). The reduction in organic matter is concurrent with the studies conducted at Kakinada along Visakhapatnam coast (Raman, 2006). According to Duplisea *et al.* (2001) intense trawling will affect the carbon flow throughout a marine ecosystem. In soft sediment where natural disturbance due to waves and tides is low, intense trawling could cause large carbon fluxes between oxic and anoxic carbon compartments never reaching an equilibrium state. Smith *et al.* (2000) observed significant differences in sedimentary organic carbon between stations during the trawling season along eastern Mediterranean commercial trawl fishing ground. Mayer *et al.* (1991) described that heavy scallop dredge would cause surficial organic matter removal from the drag site and also mixing of surface organic material into subsurface layers. This organic material burial would result in removal from the surface aerobic system to an anaerobic system. Pusceddu *et al.* (2005) recorded significant increase in OM immediately after the initiation of trawling activities in coastal area of the Gulf of Thermaikos (Aegean Sea). The increase in sediment organic content was related with the release of organic matter from deeper sediment layers in their study. The suspended OM scraped off from sediment will have far-reaching consequences. According to Anderson and Meyer (1986) the suspended organic material by clam dredges will improve the food value of the suspended material available to filter feeders. It would also decrease the food value since filter feeders had to filter more material to obtain nutrients.

**4.3.2. Sediment texture**

The average values of sand, silt and clay proportions at different water depths studied, both before and after trawling are given in Table 4.1.

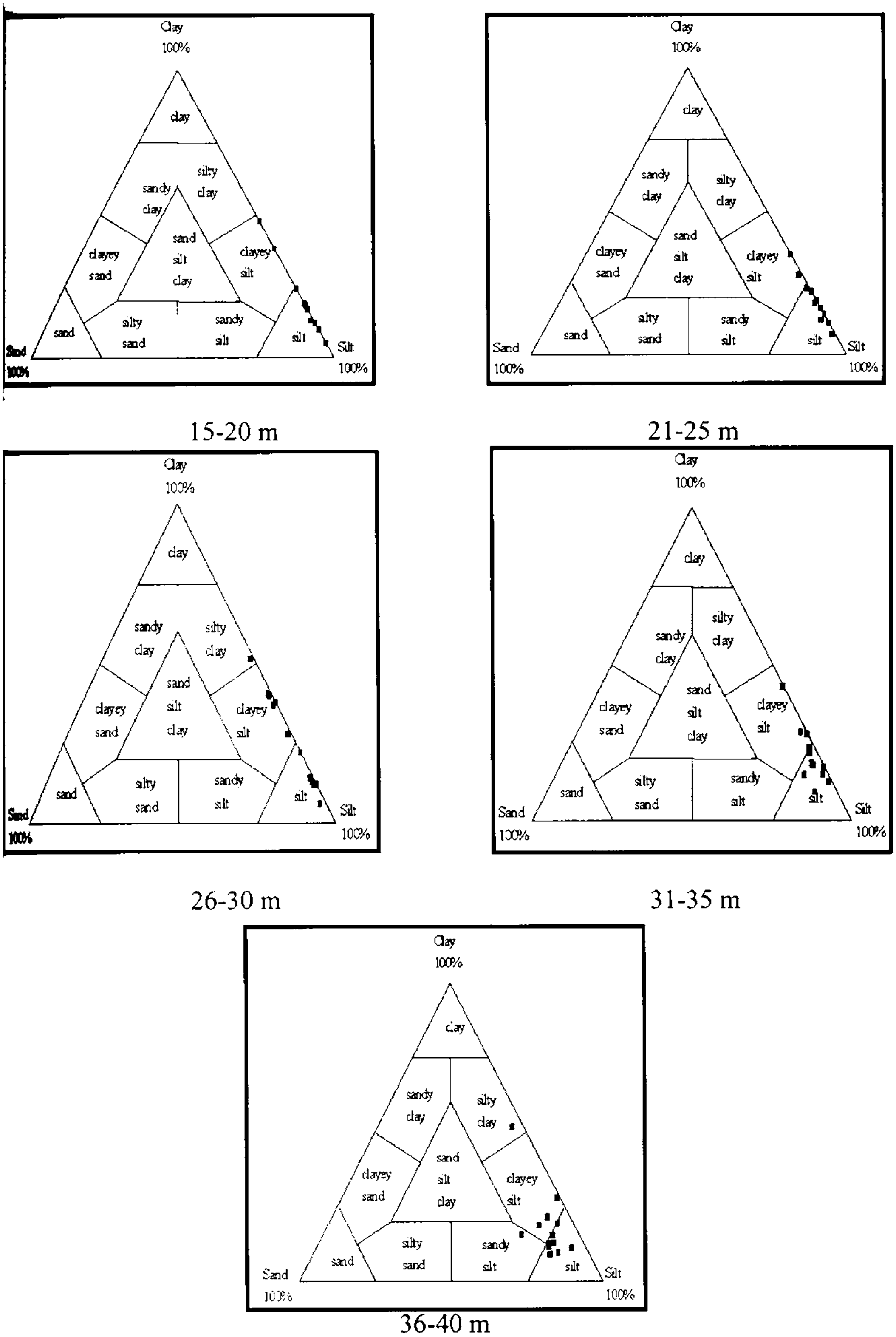



**Fig. 4.4a.** Ternary diagram of before trawling samples of stations at different water depths (after Shepard *et al.*, 1954)

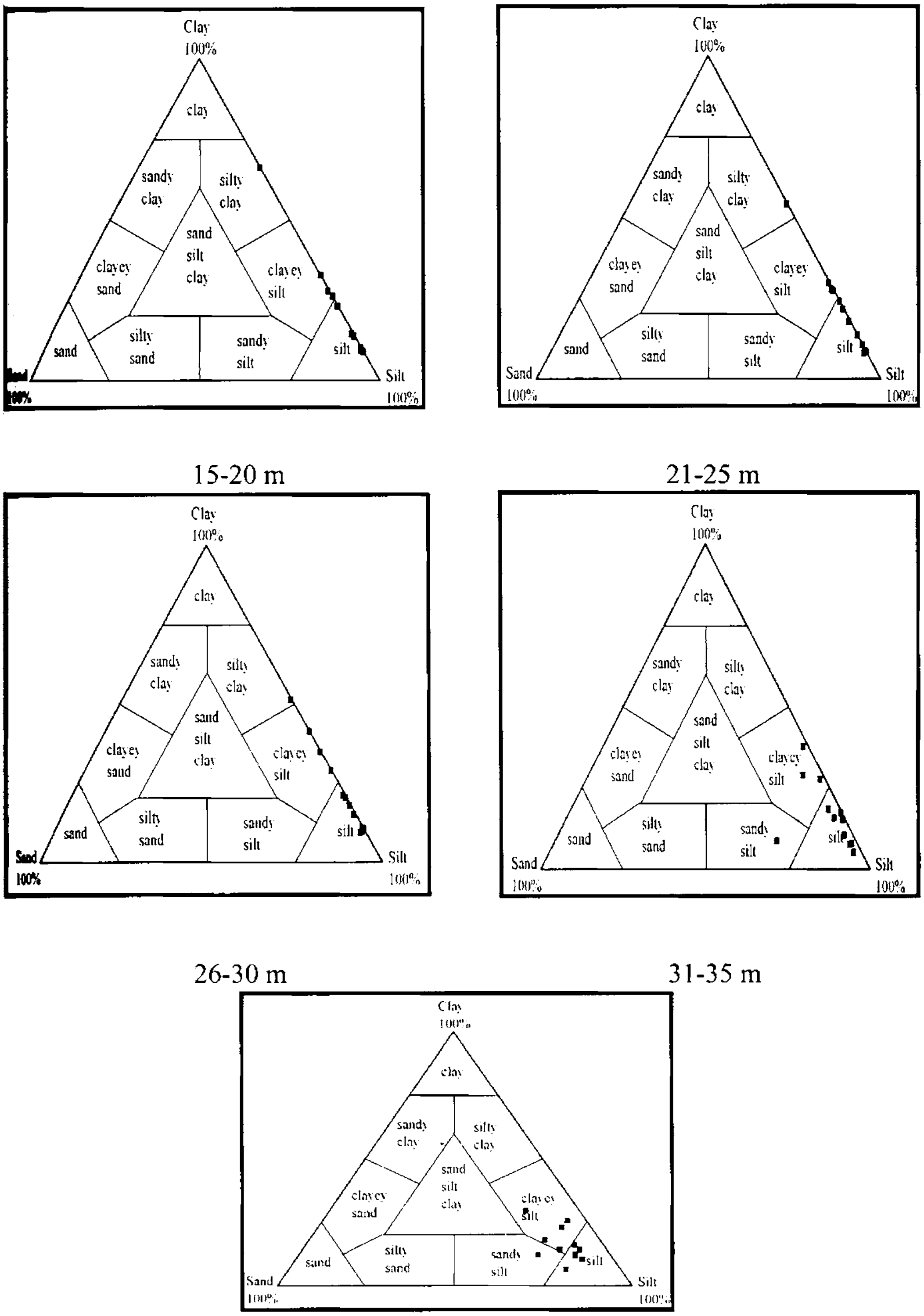



**Fig. 4.4b**. Ternary diagram of after trawling samples of stations at different water depths (after Shepard *et al.*, 1954)

Before trawling, four types of sediment textures were observed in the study area namely silt, clayey silt, silty clay and sandy silt (Figure 4.4a). The sediment texture was generally silty (15-40 m) with an average high value of silt (76.68±10.97 %) followed by clay (20.52±11.36 %) and sand (2.79±4.16 %) before trawling. The same sequence was observed in the study area after trawling namely, (silty, clayey silt, silty clay and sandy silt) (Figure 4.4b). Generally after trawling also the sediment texture was silty with an average high value of silt (76.94±11.66%) followed by clay (19.67±11.46%) and sand (2.60±2.43%) in the study area. The pattern of variation of sediment texture owing to experimental trawling during the study period is depicted in Figure 4.5. There were also occasional instances of coralline rocks.

**4.3.2.1. Variations in sand**

The seasonal variation in the sand concentration was only due to random fluctuations ($P>0.05$). The sand concentration showed depth-month specificity ($F_{(44,44)}=3.20$, $P<0.05$) (Table 4.2). At $D_1$ the peak sand proportion was recorded in the month of October 2006 and the least value in the month of October 2005. At $D_2$ the highest sand proportion was noted in September 2006 and lowest in September 2005. At $D_3$ the maximum sand proportion corresponded to September 2006 and minimum to October 2005. At $D_4$ the highest sand proportion was observed in May 2006 and the smallest amount in October 2005. At $D_5$ the sand proportion peaked in November 2006 and showed lowest value in April 2006. The seasonal distribution of sand showed that seasonal average was a steadily increasing value with depth. This trend remained the same both before and after trawling. The coefficient of variation over seasons was least at $D_5$ and maximum at $D_4$ irrespective of trawling effect.

The three-way ANOVA indicated that the variation with water depth observed in the sand fraction was significantly high ($F_{(4,44)}$ = 105.73, P<0.05) (Table 4.2). The variation in sediment texture at different water depths was prominent as the sand proportion increased with water depth with highest values at $D_5$ and minimum at $D_1$ (Table 4.1). At shallow depth the proportion of sand was negligible and increased with water depth. The variation with water depth is concurrent with the result of study conducted by Jayaraj *et al.* (2007) along 30-200 m depth of northwest Indian shelf. In their study, the sand proportion increased towards deeper regions.

The sand concentration in deeper depths i.e., at $D_4$ and $D_5$, showed slight increase after trawling (not statistically significant). According to Thomas and Kurup (2005a, b,c) the sediment texture altered into more sandy and silty after experimental trawling. During trawling the lighter particles (e.g. clay) would be suspended and as sand tends to resettle faster, more sandy sediment could be expected immediately after trawling. The sand content in the present study was not highly affected by trawling (P>0.05). In a similar study, Schwinghamer *et al.* (1998) could not find any transformation in sediment grain size where 3 year experimental trawling was conducted on sandy bottom of Grand Banks of Newfoundland. According to them, the physical impacts of otter trawling are moderate and recovery occurs in about a year on a sandy substratum. On conducting experimental beam trawling in the sandy substratum of Belgian and

Dutch coast, Fonteyne (2000), found that the resuspension of lighter sediment was pronounced in finer sand substratum. But he found that the suspended particles would settle down within a few hours.

**4.3.2.2. Variations in silt**

The month-wise variation in silt distribution at different depths was significant ($F_{(11,44)}$ =3.73, P<0.05) (Table 4.2). The silt values ranged from 44.55% (April 2006 at $D_5$) to 94.57% (May 2006 at $D_1$). Since month-wise variation was high, depth-month interaction on silt content was also significant ($F_{(44,44)}$=1.76, P<0.05) (Table 4.2). At $D_1$, the maximum and minimum silt proportions were recorded in the month of May 2006 and September 2005 respectively. At $D_2$, the upper limit and lower limit fractions were found to be in May 2006 and in September 2005 respectively. At $D_3$, the highest silt proportion was recorded in September 2006 and lowest in January 2006. At $D_4$, the silt proportion peaked in September 2006 and showed extreme dip in April 2006. At $D_5$ the highest silt proportion was observed in March 2006 and lowest in April 2006. The distribution of silt at different water depths was homogeneous (P>0.05).

Silt content was not affected by trawling (P>0.05). Since trawling has no significant impact on silt content, depth-trawling interaction was also not high (P>0.05). According to Palanques *et al.* (2001) the sediment texture showed an increase in silt content of the surface sediment during first hour after experimental trawling in the muddy unfished continental shelf of northwestern Mediterranean. This variation was attributed to the settling of resuspended particles. The change was temporary as one day after trawling; the surface sediment had a grain size pattern analogous to that of before trawling.

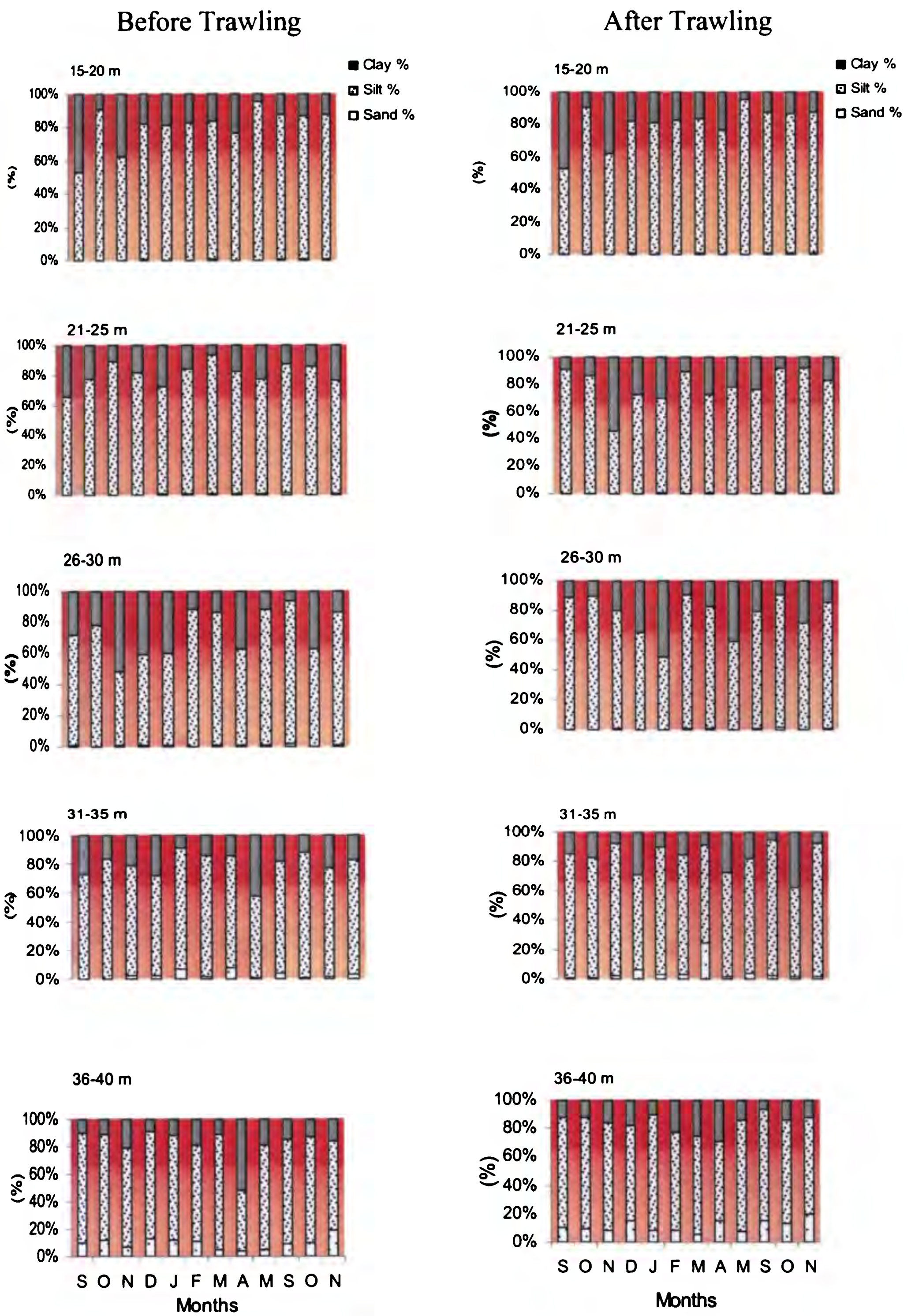



**Fig. 4.5.** Pattern of variations in sediment texture before and after trawling during September 2005 to November 2006

#### 4.3.2.3. Variations in clay

The clay values varied between 5.05% (May 2006 at $D_1$) and 51.76% (November 2005 at $D_2$). The seasonal variation had great influence on the clay distribution ($F_{(11,44)}$=4.08, P<0.05, (Table 4.2). The highest values of clay fraction was observed in post monsoon (i.e. immediately after trawl ban) at $D_1$, $D_2$ and $D_3$. This is relatively lightly trawled area and clay fractions are more settled after trawl ban. It was further observed that depth-month interaction was significantly high ($F_{(44,44)}$ =1.66, P<0.05) (Table 4.2). The monthly variations in the average clay content were higher in the samples taken after trawling at all depths. The highest clay proportion recorded at $D_1$ and $D_2$ were in the months of September 2005; $D_3$ was November 2005; $D_4$ and $D_5$ were in April 2006. The lowest values noted at $D_1$ and $D_2$ were in the months of May 2006; $D_3$ and $D_5$ in September 2006; $D_4$ in January 2006. The distribution of clay at different water depths showed a normal pattern with peak value at $D_3$ in both, before and after trawling.

The analysis of variance (ANOVA) by three-way classification showed that trawling had no significant effect on clay content (P>0.05). Trawling resulted in a more homogeneous pattern in the first two depths whereas it was steeply high at $D_3$ compared to first two depths before trawling (Table 4.1). The samples collected from $D_4$ and $D_5$ had the least clay content after trawling. While comparing the data in pairs, the various depths before and after trawling, it was observed that only samples taken from $D_3$ before and $D_5$ after trawling showed significant differences in clay content ($t_{(22,5\%)}$ =2.14, P<0.05) (Table 4.3b). De Biasi (2004) conducted experimental trawling in fished and unfished area of

Tuscany coast of Italy. He found that immediately after trawling, an increase of the clay percentage occurred in the control experiment. A simultaneous decrease in silt percentage was also observed. However, the variations were recovered within twenty-four hours. Zacharia *et al.* (2005) observed a reduction in clay proportion after trawling along Mangalore coast. In another study along Kakinada coast the mean particle diameter increased after trawling (Raman, 2006).

The impact on sediment texture was not evident in this study, as soft sediment subjected to heavy trawling disturbance remains suspended for longer period or it can be due to masking of impact by natural variations. Ball *et al.* (2000) has pointed out that undisturbed muddy sediments need longer recovery time than dynamic coarser sediments. The results of meager studies on soft substrata are still obscure (Lokkeborg, 2005; Kumar and Deepthi, 2006). According to Lokkeborg (2005), the studies on clayey-soft bottoms do not give a clear and consistent outcome as it is masked by the more pronounced temporal variability.

### 4.3.3. Bray-Curtis similarity index

The Bray-Curtis similarity index was applied on the non-standardized non-transformed original data to extract the ecologically significant groups of months/depths based on the sediment texture as well as organic matter. The significant difference between months obtained for sand (Figure 4.6a), silt (Figure 4.6b), clay (Figure 4.6c) and OM (Figure 4.6d) was clearly indicated by the distinct clusters of months obtained. On grouping the water depths (Figure 4.7a, b, c, d), the clusters obtained could be designated as shallow (coastal; 15-30 m) and deeper waters (oceanic; 31-40 m) regardless of the trawling effect. This classification was more prominent in the case of sand (Figure 4.7a) and organic matter (Figure 4.7d). The following groups of months could be designated as before trawl ban (BTB), immediately before trawl ban (IBTB), after trawl ban (ATB) and immediately after trawl ban (IATB).

Based on proportion of sand present at the site, the clusters of months obtained at 80% level were

1) Oct 06, Sep 05 and Oct 05 (IATB),
2) Jan 06, May 06, Nov 05, Feb 06 (BTB) and
3) Apr 06, Nov 06, Dec 05, Sep 06 (ATB) (Figure 4.6a).

Based on the proportion of silt present, the clusters of months obtained at 87% level were

1) Feb 06, Oct 05, May 06, Sep 06, Nov 06,
2) Mar 06, Dec 05, Oct 06 (Figure 4.6b).

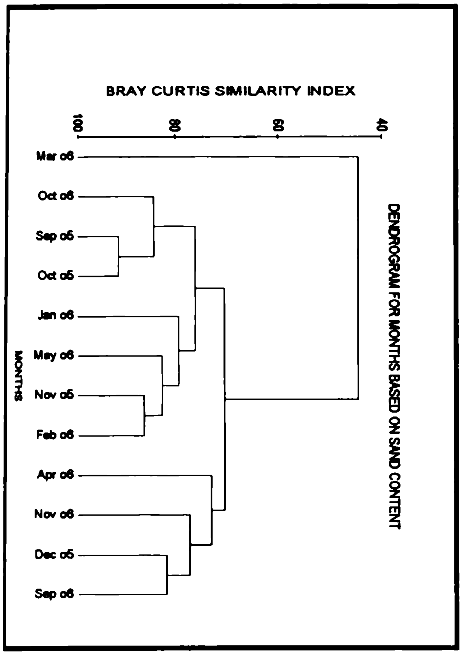
Based on the proportion of clay content, the clusters linked at 70% similarities were

1) Sep 06, Feb 06, Nov 06, Oct 05, May 06,
2) Apr 06, Jan 06, Dec 05, Oct 06 and
3) Sep 05, Nov 05 (ATB) (Figure 4.6c).

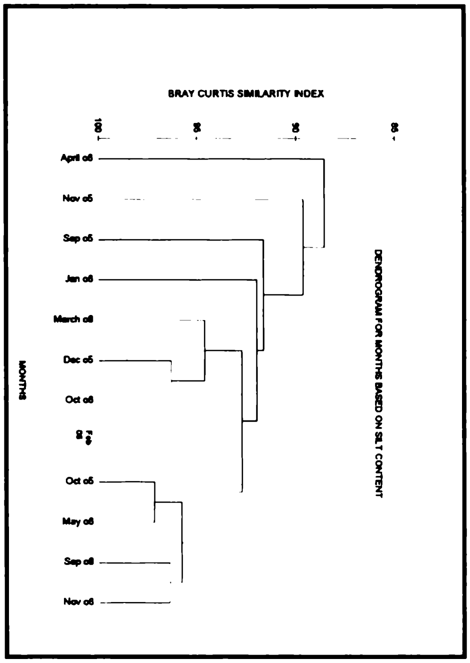
Based on organic matter content two distinct clusters of months linked at 85% similarities were

1) Sep 05, Nov 05, Oct 06, Nov 06, Dec 05, Oct 05, May 06 (ATB)
2) Sep 06, Feb 06, Mar 06, Jan 06, Apr 06 (BTB) (Figure 4.6d).

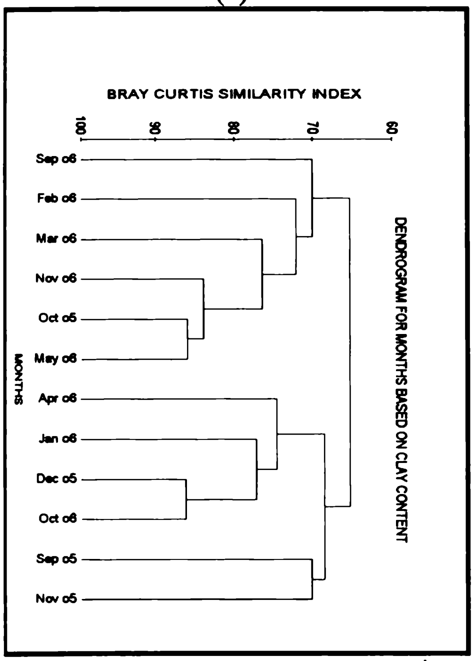
The clusters showing similarity based on trawl ban revealed that trawl ban has an indispensable role in determining the sediment characteristics of the area studied.



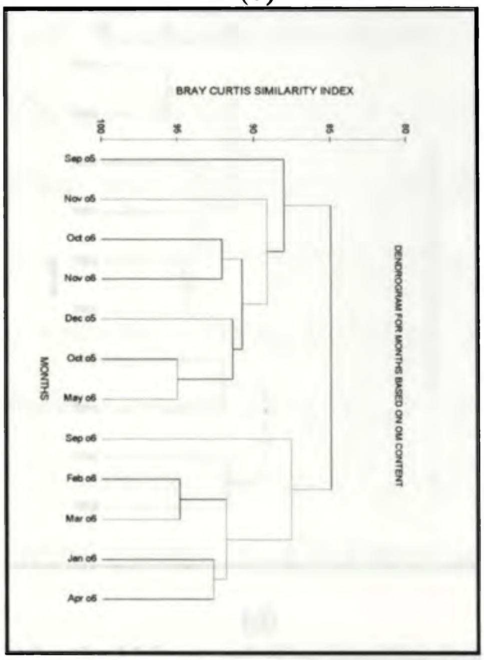

(a)




(b)

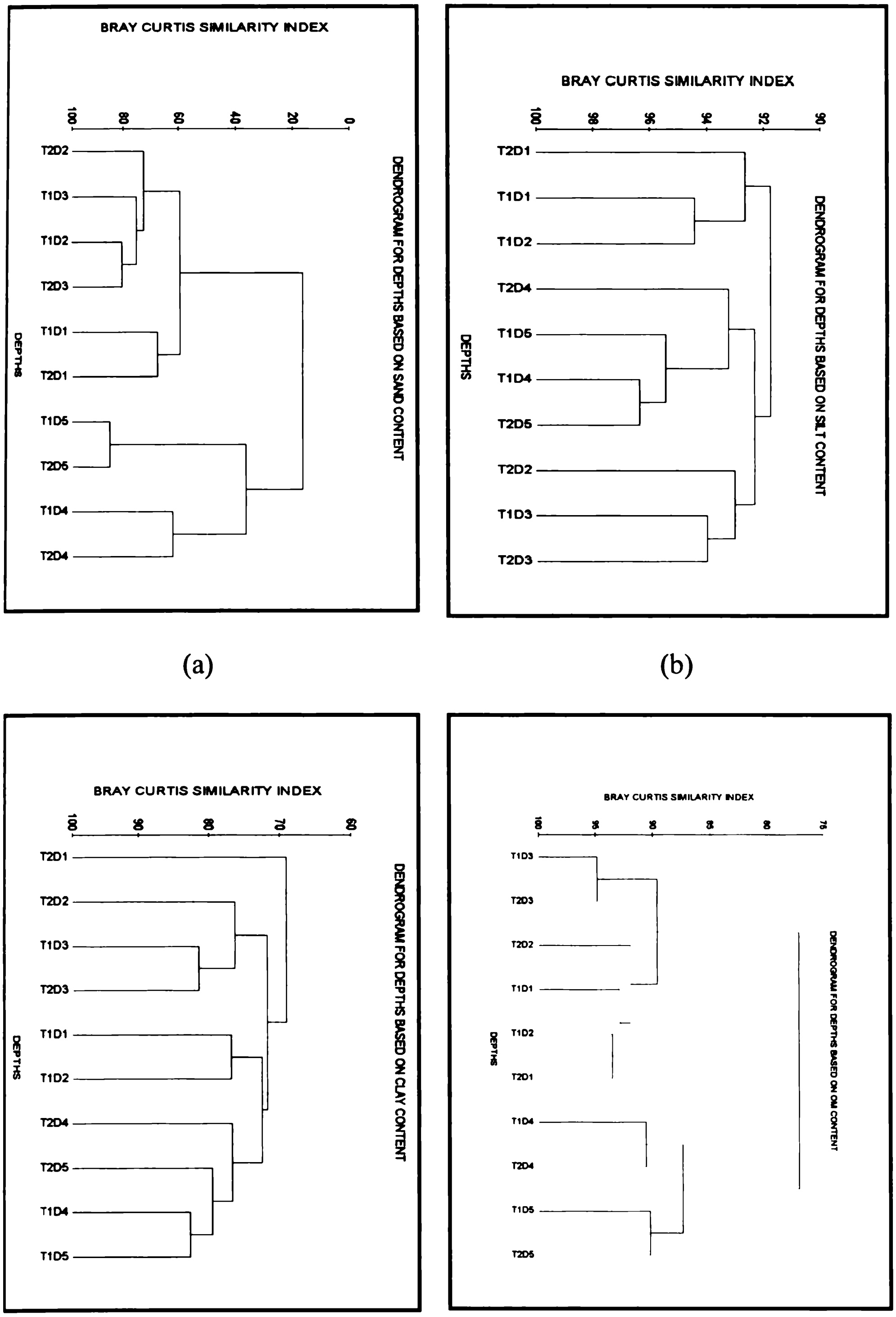



(c)




(d)

Fig. 4.6. Dendrograms for grouping of the months based on (a) sand, (b) silt, (c) clay, and (d) organic matter content in the 5 depths (before and after trawling pooled together)




(c) (d)

**Fig. 4.7.** Dendrograms for grouping of the depths before and after trawling based on (a) sand, (b) silt, (c) clay, and (d) organic matter content in the 12 months. $T_iD_j$ indicate trawling mode and water depth value. $i$ = 1 for before and 2 for after trawling. $j$ = 1,2,3,4 and 5 for stations at the five discrete water depths from 15 to 40 m at 5 m interval

## 4.4. Conclusions

The sediment organic matter exhibited seasonal variation. The dissimilarity with water depth was evident for OM and sand fractions. A single experimental trawling itself considerably reduced the organic matter content at all depths. Continued and incessant trawling operation can cause even more drastic reductions, where already OM content is very less. The relative decrease of OM enhanced towards deeper depths as these areas are heavily trawled compared to lightly trawled shallow water depths. The variations of sand, silt and clay proportions with trawling effect were not significant. The sediment of the study area was predominant in silt proportion and the effect on it was of prime importance. It was observed that the seasonal/natural variations were more prominent masking the trawling effect on silt. The present study conducted for a span of 15 months did not show any conspicuous changes on the soft bottom of the study area. Suitable untrawled control sites were not available at this area for comparative assessment. The control site selected for the study was before the experimental trawling and here regularly operating commercial trawlers might have trawled previously. To conduct studies on trawling impacts, appropriate control sites are very much necessary. Continuous monitoring of sediment characteristics for a long period will also reveal changes, which may occur in the area.

# Chapter 5

# Effect of Bottom Trawling on Sediment Heavy Metals

## 5.1. Introduction

With the rapid industrialization along coastal regions, heavy metals are being introduced to estuarine and coastal environment around the world (Feng *et al.*, 2004; Romano *et al.*, 2004; Santos *et al.*, 2005). Sediment plays an important role in environmental assessment as they form a main repository of infauna and at the same time toxicants. It provides a long-term record of the dispersion of contaminants. Sediment is considered as ultimate sink of most heavy metals in the water bodies, because when compared to the heavy metal concentration in water, sediment and organism the sediment will be having the highest concentration (Adebayo *et al.*, 2007). Sediments are used to estimate the level of pollution in a region (Butron and Scott, 1992; Caccia *et al.*, 2003). These heavy metals participate in various biogeochemical mechanisms that have significant mobility, which affects the ecosystems through bioaccumulation and bio-magnification processes and are potentially toxic for environment and human life (Gonzalez-Marcias 2006; Ip *et al.*, 2007). Various studies have demonstrated that the sediments from coastal areas are contaminated by heavy metals (Pekey 2006; Buccolieri *et al.*, 2006; Bellucci *et al.*, 2002). According to Kaiser *et al.* (2002) along with the resuspension of the upper layers of sedimentary seabed, bottom trawling remobilizes the contaminants if any, into the water column. The effects of shrimp trawling on the sediment- water fluxes of trace metals have been studied by Warnken *et al.* (2003) in Galveston Bay.

The sediment quality of the coastal ecosystems of India is affected by industrial and agricultural activities in the urban and rural areas, respectively. Several studies have documented the distribution of heavy metals in sediment of Indian coast (Nalla *et al.*, 2008; Raj and Jayaprakash, 2007; Karbassi and Shankar, 2005). Veraval coast is being polluted by the industrialization and fishing activities. Heavy metals have been reported from the sediments off Veraval coast (CMFRI, 2006). The primary objective of the present investigation is to evaluate the consequence of bottom trawling on eight sedimentary heavy metals (cadmium, chromium, copper, manganese, nickel, lead, zinc and magnesium) of commercial trawling grounds of Veraval coast. This is also the first attempt to study the regional distribution of heavy metals in sediments off Veraval. The spatial and temporal distributions give background and baseline levels for the study area. The data generated provides basic information, which will be advantageous for the forthcoming studies in the same field and can be used in the formulation of management strategies.

## 5.2. Materials and Methods

A portion of the meticulously blended sediment samples collected in van Veen grab was dried (60°C) and powdered. The heavy metal extraction was done according to Association of Official Analytical Chemists (AOAC, 2000). Inside a microwave digestion system (Ethos Plus High Performance Microwave Lab station) the samples were digested (0.2 g dry weight) in conc. $HNO_3$ - $HClO_4$

mixture (9:4) at 170° C and 12-bar pressure. After digestion it was filtered through acid washed Whatman 40 filter paper and made upto 100 ml. The heavy metal concentration of eight heavy metals (Mg, Mn, Ni, Cr, Cu, Zn, Pb, Cd) were analysed in Inductively Coupled Plasma Emission Spectroscope (ICP-AES - Perkin Elmer-Optima 2000 DV) using NIST standards.

The statistical analysis regarding seasonal, depthwise and trawling induced variations was carried out using SPSS 12 version for Windows package. A single factor analysis of variance (one-way ANOVA) was used to determine whether the data (before and after trawling) from two stations at two different depths (B.T. 15-20 m, A.T. 15-20m, B.T. 35-40, A.T. 35-40m) were significantly different. On performing the test of homogeneity of variances, the metals that were found to be of equal variances were subjected to Duncan's test (Cr, Cu, Mn, Zn). Those of unequal variances were subjected to Dunnett T3 test (Ni, Mg, Pb). The data for analysing trawl ban effect and season were treated statistically using Multivariate Analysis. The closed fishing season for trawlers (June, July and August) is hereafter referred to as trawl ban. For analysing the trawl ban effect the months were treated together as immediately before trawl ban (April-May), immediately after trawl ban (September-October) and post trawl ban (November-March). A p value of $<0.05$ was taken to be significant in all statistical tests.

## 5.3. Results and Discussion

Studies on the effect of trawling on heavy metals in the sediment are very meager. In India the studies conducted on the impact of bottom trawling have not studied this aspect (Zacharia 2004; Bhat, 2003; Gowda, 2004, Kurup, 2004b, Raman, 2006). Hence, this is the first study to explore the effect of bottom trawling on sediment heavy metals along Indian coast. Of the analysed heavy metals, all metals except cadmium were detected in measurable but varied concentrations in sediment collected from both depth zones, before and after trawling. The heavy metal mean concentrations exhibited a pattern of distribution at 15-20 m before trawling as Mg (11974.75 ppm)> Mn (514.31ppm)> Cr (68.96ppm)> Zn (58.27ppm)> Ni (57.99ppm)> Cu (55.97ppm)> Pb (3.39ppm). After trawling this pattern was changed as Mg (11922.76ppm)> Mn (533.93ppm)> Ni (123.01ppm)> Cr (81.82ppm)> Cu (57.64ppm)> Zn (51.20ppm)> Pb (7.20ppm). The pattern of distribution before trawling at 36-40 m was Mg (10192.33ppm)> Mn (415.69ppm)> Ni (102.69ppm)> Cr (58.14ppm)> Cu (46.73ppm)> Zn (35.80ppm)> Pb (2.26ppm). Similar pattern of distribution was observed at 15-20 m after trawling and at 36-40 m before trawling. At 36-40 m after trawling, the pattern was changed to Mg (10100.83ppm)> Mn (420.46ppm)> Ni (57.46ppm)> Cu (49.14ppm)> Cr (47.73ppm)> Zn (38.70ppm)> Pb (2.90ppm). The changes in pattern of distribution at two depths before and after trawling were found to be different. Mg and Mn exhibited very high values both before and after trawling.

Chromium, manganese and zinc showed similar pattern of distribution with changes in water depth. These metals increased comparatively at 15-20 m depth. The depth wise variation in metal concentration coincides with the distance from land. The station at 15-20 m depth was 5.55 km away from land while that at 36-40 m depth was 25.93 km away from land. This indicates that there is a detectable anthropogenic input into the marine environment from land. According to Warnken *et al.* (2003), the heavy metals of surface sediment (where trawl disturbance is relevant) would be resuspended several times during one trawling season. At the same time the historical contaminants that have been buried by several centimeters of sediment would remain buried and could become exposed only after more aggressive activities such as dredging.

**Table 5.1.** Average concentrations (ppm) of heavy metals in before experimental trawling sediments treated as immediately before trawl ban, immediately after trawl ban and post trawl ban. ND- Not detected

| | 15-20 m | | | 36-40 m | | |
|---|---|---|---|---|---|---|
| Heavy metals | Immediately before trawl ban (Apr-May) | Immediately after trawl ban (Sep-Oct) | Post trawl ban (Nov-Mar) | Immediately before trawl ban (Apr-May) | Immediately after trawl ban (Sep-Oct) | Post trawl ban (Nov-Mar) |
| Mg | 13437.93 | 12124.33 | 11283.58 | 10885.89 | 11390.16 | 9591.30 |
| Mn | 532.45 | 507.41 | 509.49 | 454.81 | 461.58 | 391.54 |
| Ni | 59.91 | 60.16 | 56.23 | 52.50 | 285.60 | 77.67 |
| Cr | 73.68 | 64.06 | 69.03 | 53.55 | 106.12 | 49.38 |
| Cu | 47.01 | 64.82 | 56.02 | 49.76 | 64.16 | 41.08 |
| Zn | 58.31 | 54.11 | 60.04 | 51.11 | 45.03 | 30.51 |
| Pb | 2.14 | 2.77 | 4.21 | ND | ND | 3.48 |
| Cd | ND | ND | ND | ND | ND | ND |

### 5.3.1. Cadmium

Cd was below detectable levels in all the sediment samples collected before and after trawling during the period of the present study. This is in disparity with earlier reports. 2.02 ppm concentration of Cd has been reported from the sediment samples from Veraval (CMFRI, 2006). In India, Cd is one of the primary heavy metal contaminants of various natural water bodies. Prafulla *et* al. (2001) recorded the incidence of Cd in squids collected from south west coast of India. Zynudheen *et al.* (2003) has reported the incidence of cadmium in processed products of cephalopods from Gujarat. The study done by Warnken *et al.* (2003) in Galveston Bay showed that the pre and post-trawl sediment –water fluxes of cadmium (Cd) was affected by shrimp trawling. It was suggested in this study that the decreased fluxes of Cd after trawling might be due to decreased interface concentration gradients or due to removal of Cd onto solid surfaces such as co-precipitation with Mn and Fe oxyhydroxides.

**5.3.2. Magnesium**

The concentration of Mg was found to be higher than other metals studied. As shown in box-and-whisker plots in Figure 5.1, at 15-20 m water depth before trawling the concentration (ppm) varied from 4860.64 to 16034.90 while after trawling it was found to be between 4870.99 and 15386.03. The concentration of this metal at 36-40 m depth before trawling varied from 6526.82 -11924.90 and after trawling from 7710.58 - 13664.58. The Post Hoc tests of multiple comparisons (Dunnett T3 test) showed that the variations in concentrations of this metal before and after experimental trawling were found to be insignificant ($p > 0.05$). The test of multivariate analysis showed that seasonal and trawl ban effect differences were found to be insignificant ($p > 0.05$). The average Mg concentration immediately before trawl ban, immediately after trawl ban and post trawl ban is as shown in table 5.1. Before trawling, at 15-20 m water depth the maximum concentration was recorded in the month of January 2005 (16034.90 ppm) and minimum in December 2005 (4860.64 ppm). At 36-40 m depth the maximum recorded was in May 2006 (11924.90 ppm) and minimum in December 2005 (6526.82 ppm). Analysing the data collected immediately before (May 2006) and after trawl ban (September 2006), an increase in concentration was noted at 15-20 m depth after trawl ban. The concentration noted before trawl ban is 12326.28 ppm, and after trawl ban is 13229.90 ppm. But this result was not consistent at 36-40 m depth as a decrease was noted after trawl ban (May: 11924.90 ppm; September 11390.98 ppm). Therefore it is assumed that the monthly natural variations and variations with the depth are more prominent than the immediate effect of experimental bottom trawling.

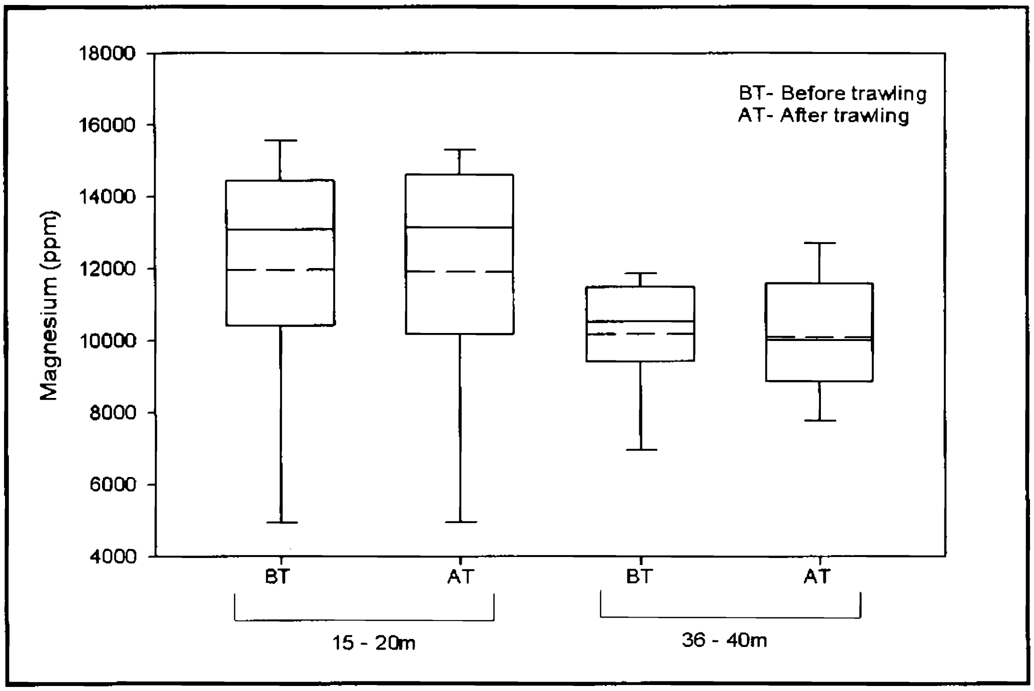



**Fig. 5.1.** Box-and-whisker plots obtained for Mg in sediment samples collected during the period September 2005 – April 2007. BT - before trawling; AT - after trawling. The heavy horizontal bar in the boxes is the median value; the dotted line indicates mean; top and bottom of the boxes are the $5^{th}$ and $95^{th}$ percentiles respectively. The whiskers denote standard error and whisker caps encompass the extreme values.

### 5.3.3. Manganese

One-way ANOVA showed that manganese (p=0.000) exhibited significant variation with different water depths. This metal exhibits spatial variance, as the concentration at 15-20 m depth is clearly elevated than 36-40 m depth. This is similar to Cr and Zn. The box-and-whisker plot of Mn is given in Figure 5.2. The concentration was higher at 15-20 m depth than at 36-40 m depth. The mean concentration before trawling at 15-20 m was 514.31ppm while that at 36-40 m water depth was 415.69 ppm. This variation was found to be consistent after trawling also with mean concentration as 533.93 ppm at 15-20 m and 420.46ppm at 36-40 m. At shallow depth before trawling manganese concentration varied from 363.64 to 687.03 ppm while after trawling it was found to be between 410.98 to 615.99 ppm. The concentration at 36-40 m depth before trawling was 280.53 - 511.15 and after trawling was 341.27 - 554.05. The Post Hoc tests of multiple comparisons (Duncan's test) showed that the variations in concentrations of this metal before and after experimental trawling were found to be insignificant (p > 0.05). The tests of multivariate analysis with data pertaining to immediately before trawl ban, immediately after trawl ban, post trawl ban and monsoon did not exhibit significant variation (p>0.05). The average Mn concentration with respect to trawl ban is as shown in table 5.1. Before trawling, at 15-20m depth the metal concentration peaked in March 2006 (687.03 ppm) and recorded lowest values in December 2005 (363.64 ppm). At 36-40 m depth the highest values were recorded in the month of May 2006 (511.15 ppm) and lowest in March 2007 (280.53 ppm). Examining the values obtained immediately before (May 2006) and after trawl ban (September 2006), a decrease in concentration was noted at both the depths after trawl ban. At 15-20 m the concentration noted before trawl ban was 567.61 ppm while after trawl ban was 541.15 ppm. At 36-40 m depth the decrease was noted from 511.15 ppm (May 2006) to 488.76 ppm (September 2006). The decrease in concentration can also be attributed to the effect of monsoon. The monthly variations and spatial variations may be masking the experimental bottom trawling impact.

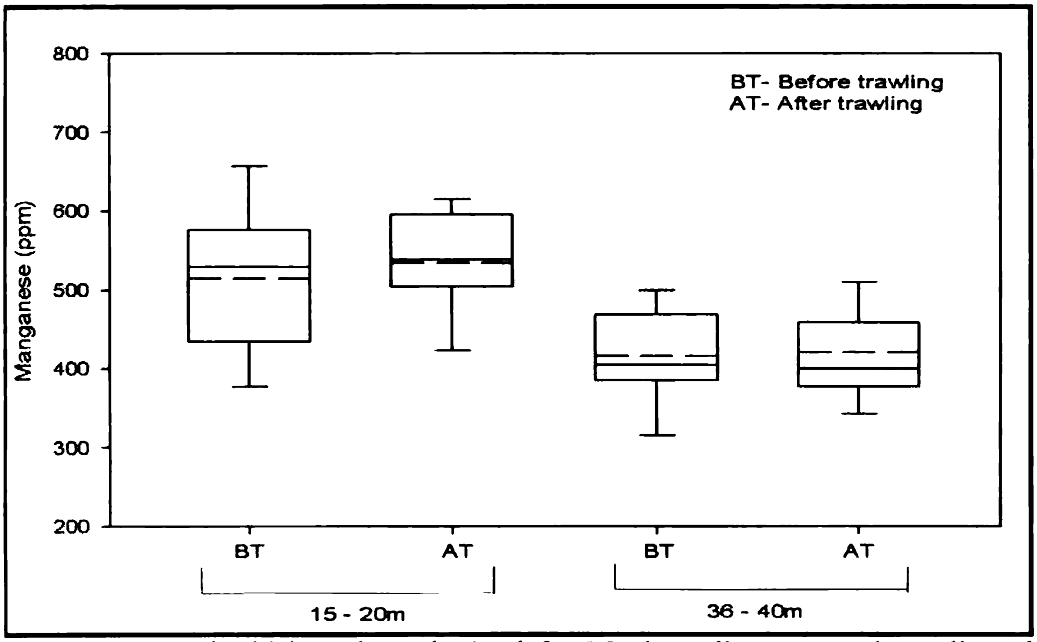



**Fig. 5.2.** Box-and-whisker plots obtained for Mn in sediment samples collected during the period September 2005 – April 2007. BT - before trawling; AT - after trawling. The heavy horizontal bar in the boxes is the median value; the dotted line indicates mean; top and bottom of the boxes are the 5th and 95th percentiles respectively. The whiskers denote standard error and whisker caps encompass the extreme values.

According to Warnken *et al.* (2003), the experiments conducted in 1998 showed that shrimp trawling resulted in increase of sediment- water exchange flux of manganese by a factor of 2–3. He had attributed this to resuspension of the upper 1 cm of sediment that removes pore waters with elevated Mn concentrations nearer to the sediment- water interface thereby increasing the overlying water concentration gradient. He could not repeatedly observe this, due to the fact that the variations in Mn fluxes were concurrent with variations of ammonium. Therefore the increase in Mn fluxes was not likely due to trawling, but can be owing to the linear relationship with the presence of ammonium.

### 5.3.4. Nickel

The box-and-whisker plot of Ni is given in Figure 5.3. The concentrations (ppm) of this metal at 15-20 m water depth before trawling varied from 26.68 to 83.50 and after trawling it was found to be between 42.72 and 568.51. At 36-40 m depth, before trawling values ranged from 24.96 to 402.88 and after trawling was 22.50 to 150.92. According to CMFRI (2006), the sediment samples from Veraval recorded 16.16 ppm concentration of Ni. The Post Hoc tests of multiple comparisons (Dunnett T3 test) showed that the variations in concentrations of this metal before and after experimental trawling were found to be insignificant ($p > 0.05$). The tests of multivariate analysis illustrated that the variations due to trawl ban and monsoon were not significant ($p>0.05$). The average Ni concentration with respect to trawl ban is shown in table 5.1. The concentrations (ppm) of this metal at 15-20 m water depth before trawling peaked at January 2006 (83.50 ppm) and showed lowest value in September 2005 (26.68ppm). At 36-40 m depth before trawling values ranged from 24.96 (December 2005) to 402.88 (October 2005). Analysing the values obtained immediately before (May 2006) and after trawl ban (September 2006), an increase in concentration was noted at both water depths after trawl ban. The concentration noted before trawl ban was 45.13 ppm and after trawl ban was 74.00 ppm. This result is consistent at 36-40 m depth with an increase in concentration noted after trawl ban period (May: 68.00 ppm; September 168.31 ppm). The increase in concentration can be attributed to trawl ban period, as there is reduction in scraping off of surface sediment. The variation can also be due to monsoon. The monthly variations and spatial variations are more prominent hiding the experimental bottom trawling impact. In the shrimp trawling experiments conducted by Warnken *et al.* (2003) in Galveston Bay during 1998 and 1999 showed that the sediment- water exchange fluxes of Ni were not significantly different in the pre- trawl and post -trawl conditions.

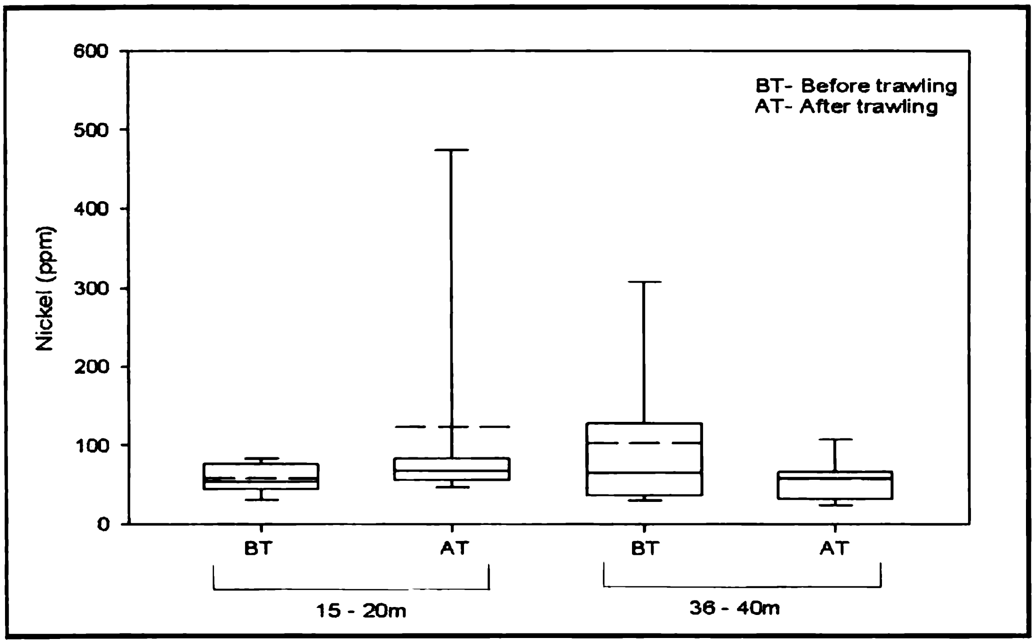



**Fig. 5.3.** Box-and-whisker plots obtained for Ni in sediment samples collected during the period September 2005 – April 2007. BT - before trawling; AT - after trawling. The heavy horizontal bar in the boxes is the median value; the dotted line indicates mean; top and bottom of the boxes are the 5th and 95th percentiles respectively. The whiskers denote standard error and whisker caps encompass the extreme values.

### 5.3.5. Chromium

One-way ANOVA showed that chromium (p=0.003) exhibited significant variation with varying water depth. Analogous to Mn and Zn, Cr showed spatial variation as the concentration at 15-20 m depth is obviously higher than 36-40 m depth. The box-and-whisker plot of Cr is given in Figure 5.4. The concentration was higher at 15-20 m depth than at 36-40 m depth. The mean concentration (ppm) before trawling at 15-20 m was 68.96 while that at 36-40 m water depth was 58.14. This variation was found to be consistent after trawling also, with mean concentration as 81.82 at 15-20 m and 47.73 at 36-40 m. At shallow depth before trawling, Cr concentration varied from 51.85 to 95.55 ppm while after trawling it was found to be between 35.81 to 187.39 ppm. The concentration of this metal at 36-40 m depth before trawling ranged from 36.84 to 127.54 and after trawling 30.94 - 30.94. The Post Hoc tests of multiple comparisons (Duncan's test) proved that the variations in concentrations of this metal before and after experimental trawling were found to be insignificant ($p > 0.05$). The tests of multivariate analysis showed the seasonal and trawl ban effect differences were insignificant ($p > 0.05$). The average Cr concentration with respect to trawl ban is as shown in table 5.1. Considering the before trawling values alone, at 15-20 m depth Cr concentration showed highest values at January 2006 (95.55 ppm) and lowest at February 2007 (51.85 ppm). At 36-40 m the peak values were noted in the month of October 2005 (127.54 ppm) and lowest in January 2007 (36.84 ppm). Immediately before (May 2006) and after trawl ban (September 2006) values showed a slight increase in concentration, at 15-20 m after trawl ban. The concentration noted before trawl ban was 62.05 ppm while after trawl ban was 64.05 ppm. But this result was not consistent at 36-40 m depth as an increase was noted after trawl ban (May: 69.05 ppm; September 84.70 ppm). So it can be assumed that the monthly natural variations and variations with waterdepth are more prominent than bottom trawling variation.

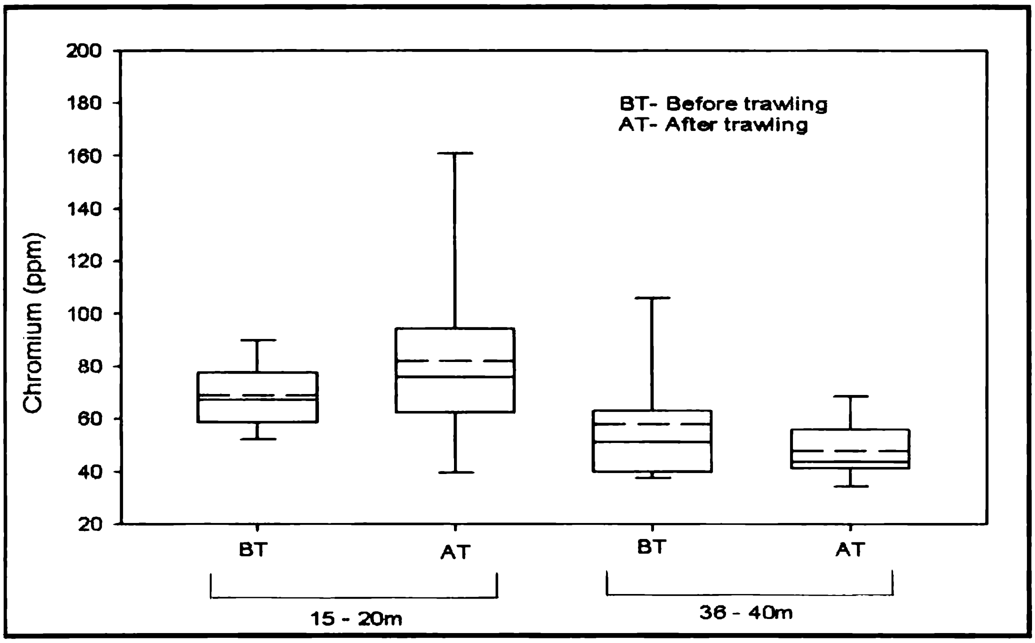



**Fig.5.4.** Box-and-whisker plots obtained for Cr in sediment samples collected during the period September 2005 – April 2007. BT - before trawling; AT - after trawling. The heavy horizontal bar in the boxes is the median value; the dotted line indicates mean; top and bottom of the boxes are the 5$^{th}$ and 95$^{th}$ percentiles respectively. The whiskers denote standard error and whisker caps encompass the extreme values.

### 5.3.6. Copper

Even lower concentration of copper may pose a threat to ecological life in a marine environment in comparison to other heavy metals. The box-and-whisker plot of Cu is given in Figure 5.5.

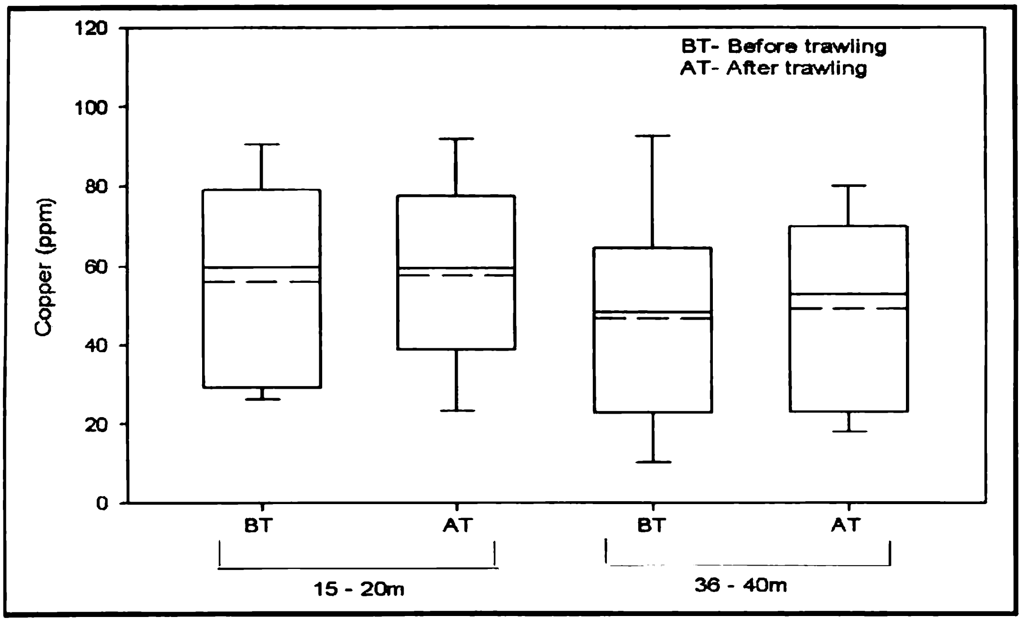



**Fig 5.5.** Box-and-whisker plots obtained for Cu in sediment samples collected during the period September 2005 – April 2007. BT - before trawling; AT stands for after trawling. The heavy horizontal bar in the boxes is the median value; the dotted line indicates mean; top and bottom of the boxes are the $5^{th}$ and $95^{th}$ percentiles respectively. The whiskers denote standard error and whisker caps encompass the extreme values.

At 15-20 m water depth before trawling the concentration (ppm) of Cu varied from 25.80 to 95.15 while after trawling it was found to be between 21.01 and 94.32. The concentration of this metal at 36-40 m depth before trawling was from undetectable level -106.51 and after trawling was 17.98 - 85.20. The Post Hoc tests of multiple comparisons (Duncan's test) showed that the variations in concentrations of this metal before and after experimental trawling were found to be insignificant ($p > 0.05$). The multivariate analysis showed that trawl ban and monsoon did not exhibit significant variation ($p>0.05$). The average Cu concentration with respect to trawl ban is as shown in table 5.1. At 15-20 m water depth before trawling the maximum value was recorded in the month of January 2006 (95.15 ppm) and lowest in February 2007 (25.80 ppm). At 36-40 m depth also the highest value was recorded in January 2006 (106.51 ppm) but the lowest was recorded in March 2007 (below detectable level). On verifying the immediately before (May 2006) and after trawl ban (September 2006) values, an increase in concentration was noted at 15-20 m after trawl ban. The concentration noted before trawl ban is 26.93 ppm while after trawl ban is 67.15 ppm. But this result was not consistent at 36-40 m depth as a slight decrease was noted after trawl ban (May: 78.65 ppm; September 75.89 ppm). Therefore it can be assumed that the monthly natural variations and variations with waterdepth are more prominent than bottom trawling variation. During both pre-trawl and post-trawl experiments in Galveston Bay, shrimp trawling did not change the sediment-water exchange fluxes of Cu (Warnken *et al.*, 2003).

### 5.3.7. Zinc

One-way ANOVA showed that zinc exhibit significant variation (p=0.007) with varying water depth. The box-and-whisker plot of Zn is given in Figure 5.6. The concentration was higher at 15-20 m depth than at 36-40 m depth. The mean concentration before trawling at 15-20 m was 58.27 while that at 36-40 m water depth was 35.81. This variation was found to be consistent after trawling also with mean concentration as 51.20 at 15-20 m and 38.70 at 36-40 m. This is analogous to the pattern of distribution of Mn and Cr. At shallow depth before trawling Zn concentration varied from 32.27 to 106.40 ppm while after trawling is found to be between 20.25 to 83.10 ppm. The concentration of this metal at 36-40 m depth before trawling was from undetectable level -72.40; after trawling was 17.79 - 68.20.

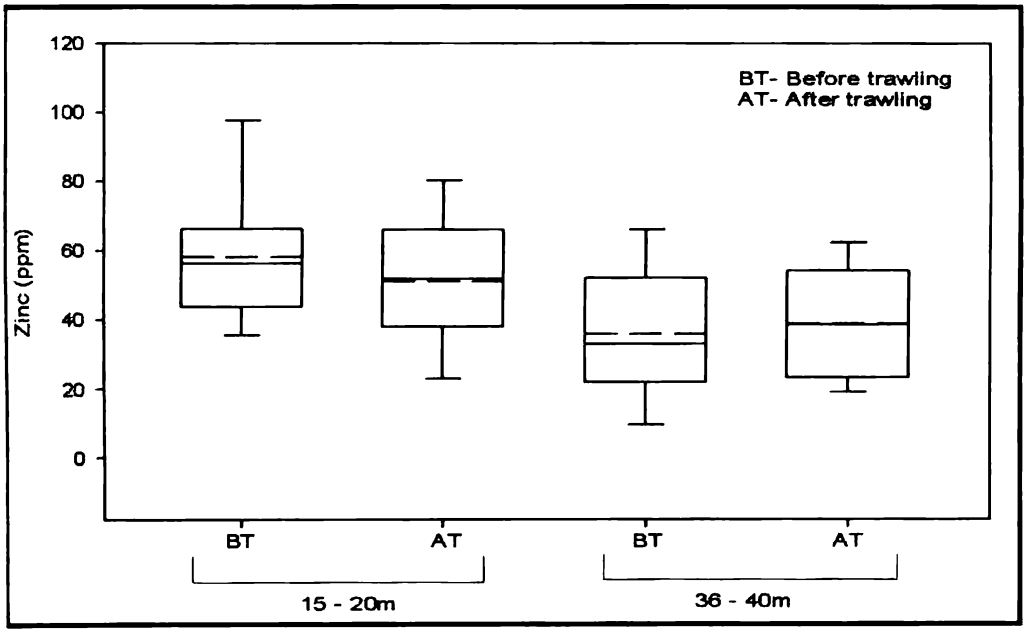



Fig.5.6. Box-and-whisker plots obtained for Zn in sediment samples collected during the period September 2005 – April 2007. BT - before trawling; AT - after trawling. The heavy horizontal bar in the boxes is the median value; the dotted line indicates mean; top and bottom of the boxes are the 5th and 95th percentiles respectively. The whiskers denote standard error and whisker caps encompass the extreme values.

The Post Hoc tests of multiple comparisons (Duncan's test) showed that the variations in concentrations of this metal before and after experimental trawling were found to be insignificant ($p > 0.05$). The multivariate analysis showed that trawl ban and monsoon did not exhibit significant variation ($p>0.05$). The average Zn concentration with respect to trawl ban is as shown in table 5.1. In view of before trawling values alone, at shallow depth the metal exhibited peak values in January 2006 (106.40 ppm) and lowest in February 2007 (32.27 ppm). At 36-40 m also the highest values were recorded in January 2006 (72.40 ppm) but the lowest values were recorded in March 2007 (below detectable level). Analysing immediately before (May 2006) and after trawl ban (September 2006) a decrease in concentration was noted at both water depths after trawl ban. The concentration noted at 15 -20 m water depth, before trawl ban was 60.40 ppm and after trawl ban was 56.40 ppm. At 36-40 m depth this result was consistent as a decrease was noted after trawl ban (May: 59.90 ppm; September 58.29 ppm). The variation noted can be attributed to seasonal variation. Therefore monthly natural variations and spatial variations may be more pronounced hiding the bottom trawling effect.



### 5.3.8. Lead

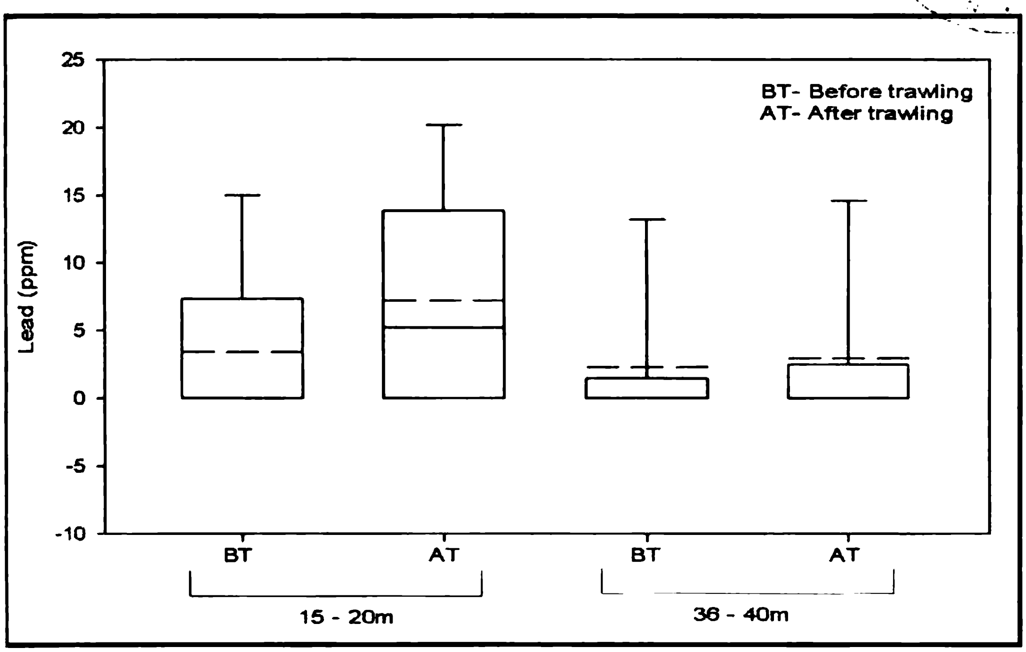



**Fig.5.7.** Box-and-whisker plots obtained for Pb in sediment samples collected during the period September 2005 – April 2007. BT - before trawling; AT - after trawling. The heavy horizontal bar in the boxes is the median value; the dotted line indicates mean; top and bottom of the boxes are the $5^{th}$ and $95^{th}$ percentiles respectively. The whiskers denote standard error and whisker caps encompass the extreme values.

The box-and-whisker plot of Pb is given in Figure 5.7. At 15-20 m water depth before trawling, the lead concentration (ppm) was found to vary from undetectable level to 15.95 and after trawling it was found to be between undetectable level and 22.37. The concentration of this metal at 36-40 m depth before trawling was undetectable level -19.54 and after trawling was undetectable level - 18.16. The Post Hoc tests of multiple comparisons (Dunnett T3 test) showed that the variations in concentrations of this metal before and after experimental trawling were found to be insignificant ($p > 0.05$). The multivariate analysis showed that variations owing to trawl ban and monsoon did not exhibit significant variation ($p>0.05$). The average Pb concentration with respect to trawl ban is as shown in table 5.1. Before trawling, at both water depths studied most of the samples showed values below detectable level and the metal concentration peaked at January 2006 (15-20 m – 15.95 ppm and 36-40 m –19.54 ppm). Immediately before (May 2006) and after trawl ban (September 2006) at both water depths the concentration was below detectable level. The monthly variations and spatial variations are more pronounced than the bottom trawling variation. During both pre-trawl and post-trawl experiments in Galveston Bay, shrimp trawling did not alter the sediment- water exchange fluxes of Pb (Warnken *et al.,* 2003).

## 5.4. Conclusions

The concentrations of the eight heavy metals (Mg, Mn, Ni, Cr, Cu, Zn, Pb, Cd) off Veraval coast were studied to test the hypothesis that the pattern of concentration of heavy metals before and after experimental bottom trawling provides insight into the impact of bottom trawling. The data generated provide new information on the distribution of these heavy metals in surficial sediments in the study area. The general pattern of distribution was found to be Mg>Mn>Ni>Cr>Cu>Zn>Pb>Cd. The sediment contains very high levels of Mg and Mn with maximum values of 16034.90 ppm and 687.03 ppm respectively.

These maximum values were recorded for both metals before trawling at 15-20 m depth. There is a clear spatial distribution of the heavy metals (Cr, Mn and Zn) along the coast with maximum levels at 15-20 m depth and minimum at 36-40 m depth. The effects of monsoon and trawl ban were found to be insignificant. All the metals analysed did not give any consistent changes in concentration, that can be attributed to the effect of bottom trawling. This can be due to the fact that the spatial (with water depth) and temporal (monthly) variations are more prominent than bottom trawling changes. According to Lokkeborg (2005) the otter trawling studies conducted on soft bottom confer ambiguous results owing to lack of true or replicate control sites and prominence of spatial and temporal variations. He opined that the seafloor subjected to natural variations are resistant to trawling or the natural variations may mask the actual disturbance due to trawling as in clayey-silt bottoms. In the present study the sediment is predominantly clayey-silt and trawling is carried out from 1960's onwards. The present study conducted for 20 months could not detect conspicuous change as an effect of bottom trawling on sediment heavy metals. There is a need for alternative sampling method to establish the impact of bottom trawling. A suitable control site to compare the data is lacking, which can mask the impact of bottom trawling. This will enable to effectively compare and interpret data generated from experimental studies.

# Chapter 6

# Impact of Bottom Trawling on Epifauna

## 6.1. Introduction

Epifauna are defined as those animals living on, protruding from, anchored in, or attached to, the substratum. The sedentary forms include hydroids, bryozoans, corals, seagrasses, sponges etc. Apart from sessile forms, epifauna include polychaetes, shrimp, brittle stars, mussels and small fishes. Most of these species form food for commercially important fish species. Epifauna are more vulnerable to fishing disturbance and changes in the occurrence or abundance of epifaunal species were among the first indications of fishing disturbance on benthic communities. Regression of complex habitats as seagrass meadows, sponges, soft corals, sea fans and decrease in catch rate of fishery sheltered by these complex habitat are major impacts. Gradual replacement of tube-dwelling forms by small opportunistic species is another sign of stress. Low species diversity, dominated by species resistant to trawling disturbance is another marker of stressed areas (Jennings *et al.*, 2001).

Fishing activities causes direct mortality of epibenthos as bycatch and net damaged organisms (Frid and Clark, 2000). The complex seafloor habitats of seagrasses, seamounts and coral reefs that provide food, nurseries and shelter for a variety of marine organisms are destroyed by bottom trawling activities (Kaiser *et al.*, 2002; Gianni, 2004). According to Ardizzone *et al.* (2000), in Mediterranean

Sea bottom trawling caused elevated fine sediment composition leading to regression of the sea grass *Posidonia oceanica*. On conducting experimental trawling in the areas that were untrawled for 15-20 years in the Gulf of St. Vincent of South Australia, Tanner (2003) noted that the probability of recolonisation of seagrasses was low in trawled sites than untrawled sites. The benthic fauna of seamounts of Newzealand waters is under the stress of bottom trawling for orange roughy (Koslow *et al.*, 2000; Clark and Driscoll, 2001; Clark *et al.*, 2004). Strong decline of fishery is also recorded (Clark, 1999). Bergman and van Santbrink (2000b) have reported the large-scale mortality of invertebrate species either as a result of direct mortality by the passage of the trawl or indirectly owing to disturbance, exposure and subsequent predation. Ball *et al.* (2000) cited that the destruction of epifauna depends on the sediment texture. In muddy habitat epifauna are generally scarce and the effect of trawling is limited when compared to harder sediment habitat. Bottom trawling removes predators such as algal-grazing urchins that play a vital role in the food web (Kaiser *et al.*, 2002).

In India, studies (Bhat 2003; Bhat and Shetty, 2005; Raman, 2006; Menon *et al.*, 2006; Kurup *et al.*, 2004; Zacharia, 2006a; Jagadis *et al.*, 2003) that have been conducted to study the impact of trawling on epifauna have mostly enumerated the impact by quantifying and characterising the proportion of epifauna in bycatch and discards. According to Bhat (2003) and Raman (2006), the mostly affected epifaunal component is the invertebrates. In the trawl catches of Karwar coast invertebrate shells were landed in substantial quantities and disposed (Bhat, 2003; Bhat and Shetty, 2005). 12% of total trawl landings along southwest coats of India constituted of stomatopods and non-edible biota (Menon *et al.*, 2006). The quantity of epibenthos discarded from the bottom trawlers of Kerala was 1.68 and 1.31 lakh tonnes in the period 2000-01 and 2001-02 respectively. The species composition of the epibenthos discards revealed that crabs were dominant followed by stomatopods, gastropods, juvenile shrimps & finfishes (20%), soles, echinoderms, jellyfishes, hermit crab, gorgonids and eggs of squid (Kurup *et al.*, 2004; Menon *et al.*, 2006). Along Mangalore coast the dominant group discarded in single day fishing trawlers were stomatopods while finfishes formed the dominant group in multiday fishing trawlers (Zacharia, 2006a). The major proportion of bycatch landed in single day fishing trawlers along Mangalore also constituted of stomatopods (90%). The dislocated fauna mainly comprised of the benthic fauna with the non-edible crab forming the dominant group followed by echinoderms, stomatopods, molluscs, sponges and seapens at Rameswaram and Pamban (Jagadis *et al.*, 2003).

The present chapter intends to bring out the impact of trawling on epifauna in the commercial trawling grounds off Veraval coast. This is the first attempt to document the epifaunal species of the study area. The possible impact of bottom trawling on the sustainability of epifauna is also depicted here.

## 6.2. Materials and Methods

The epifauna collected monthly in dredge (Figure 6.1) before and after experimental trawling for a period of two years (September 2005 – April 2007) excluding the ban period (June to August) were sorted and identified to generic/ species level as far as possible. The spicules of epifaunal alcyonarians and gorgonians were extracted using potassium hydroxide. The spicules were examined under compound microscope to identify the specimens. The octocorals, seaweeds and molluscs were identified using standard references and published literature (Allen and Steene, 1999; Carpenter and Niem, 1998; Dance, 1976; www.gastropods.com). The crustaceans and fishes were identified as per www.fishbase.org. The numerical abundance and wet weight were noted. The numerical abundance is noted as number/haul and biomass in gram/haul. The statistical analysis was performed by PRIMER v5 (Clarke and Warwick, 2001) and SPSS version 12 for Windows.

**Fig.6.1.** Operation of rectangular dredge for collecting epifauna

An array of diversity indices i.e. S (species), N (number), d (Margalef index), J' (Pielou's evenness index), H (Brillouin index), α (Fisher's Alpha), H'(Shannon index), Hill's no. ($N_1$ and $N_2$), 1-λ' (Simpson's index), Δ (Taxonomic diversity index), Δ* (Taxonomic distinctness index), Δ+ or AvTD (Average Taxonomic Diversity index), s Δ+ or TTD (Total Taxonomic Distinctness), Lambda+ or VarTD (Variation in Taxonomic Distinctness), φ+ or AvPD (Average Phylogenetic Diversity) and sφ+ or PD (Phylogenetic Diversity) was calculated.

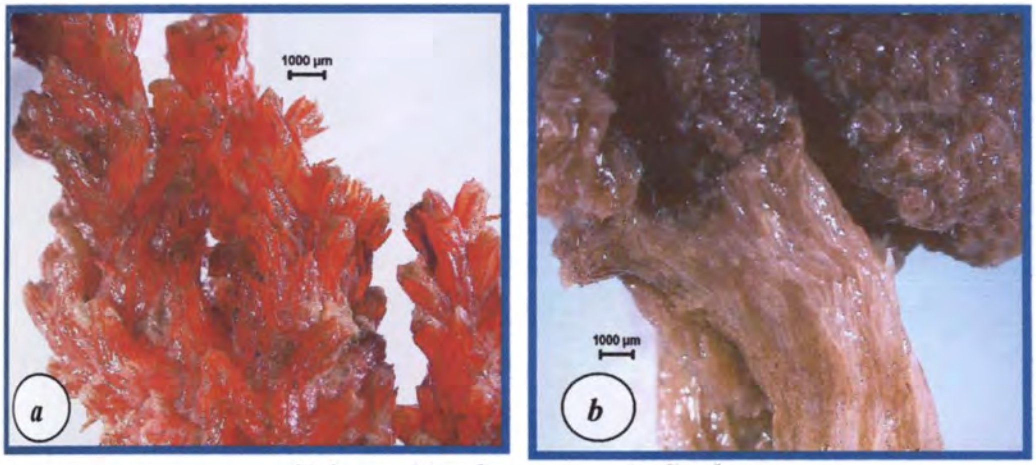
The $\log_{10}$ (X+1) transformed indices were used for one way ANOVA of SPSS to find out any significant difference in the mean value of the indices before and after trawling in each depth zone. Abundance-Biomass Comparison (ABC) curves were plotted in order to ascertain whether the benthic communities undergone any stress due to trawling pressure. SIMPER analysis revealed the most abundant species in each depth zone before and after trawling. Similarity matrix for each depth zone was constructed and MDS plots were made to visually determine disturbance of epifaunal assemblages before and after trawling.

## 6.3. Results and Discussion

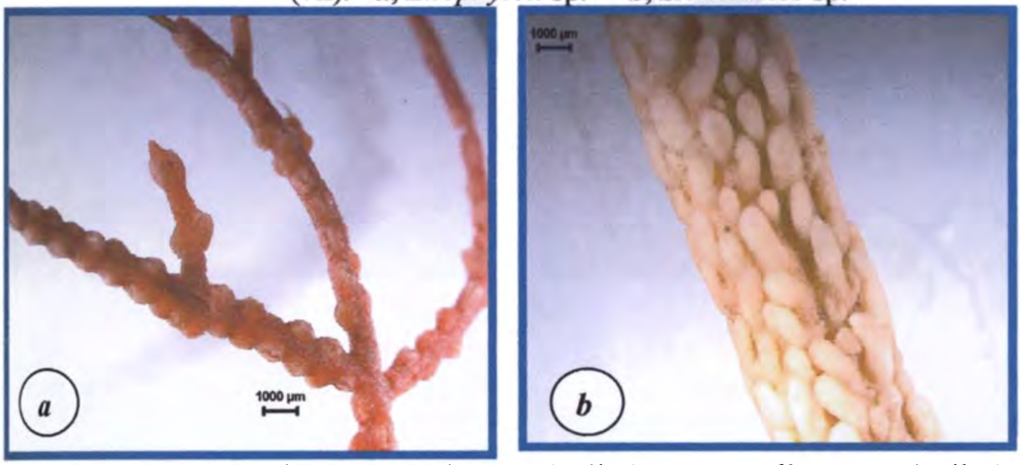
### 6.3.1. Abundance and biomass

Altogether 41 species of gastropods (molluscs), 1 species of scaphopod (mollusc), 19 species of bivalves (molluscs), 3 species of crab (crustacean), 3 species of shrimps (crustacean), 2 species of balanus (crustacean), 1 species of stomatopod (crustacean), 4 species of finfishes, 2 species of brown algae and 4 genera of octocorals were identified. The gastropods belonged to 20 families, bivalvia to 9 families, crustaceans to 5 families, octocorals to 4 families, finfishes to 4 families and brown algae to 2 families. The abundance and biomass lists of epifauna (80 species) identified in the dredge samples from study area are given in Appendix I (Figure 6.2, 6.3 & 6.4).

The occurrence of sessile fauna was found to be very less in the study area. *Balanus* spp., hydroids, bryozoans, molluscan eggs, seaweeds, octocorals etc were the sessile fauna encountered during the study. Of these, except *Balanus* spp. and sedentary polychaetes all of them were observed only at 15-20 m depth before experimental trawling. The sessile fauna were destroyed after experimental trawling. The polychaete tubes abundant before trawling showed reduction (Figure 6.5). The hydroids and eggs of molluscs abundant before trawling at 15-20m water depth (just after trawl ban) were destroyed during trawling. The polychaete tubes, hydroids, bryozoans, molluscan eggs collected in dredge are shown in Figure 6.2. Hydroids, octocorals and bryozoans abundant in September (just after trawl ban) were found destroyed after trawling. According to Jennings *et al.* (2001) infrequently fished areas were characterized by abundant growth of bryozoans, hydroids and tube worms. Rosenberg *et al.* (2003) on carrying out experimental trawl study in the northwest Mediterranean found that the epifauna and polychaete tubes were either rare or not observed at all on trawled sediment surfaces. Investigations on the short-term destructions imparted by trawlers in the Gulf of Alaska indicated that 14 - 67% of large sessile epifauna was damaged and densities of these epifauna were significantly higher in unfished reference sites. The motile invertebrates were not affected (Freese *et al.*, 1999). The experimental trawling conducted in areas untrawled for 15-20 years in Gulf St. Vincent, South Australia showed that most taxa of sessile benthic assemblages declined significantly in trawled areas compared with untrawled areas. In contrast to this, the recruitment rates of several taxa into the visible size classes increased after trawling, presumably because of a reduction in competition. The epifauna at trawled sites decreased in abundance by 28% within 2 weeks of trawling and by another 8% in the following 2-3 months (Kaiser *et al.*, 2002). The gravel sediment habitat of Georges Bank (East coast of North America) is an important nursery area for juvenile fish and the site of a productive scallop fishery. The colonial epifauna (bryozoans, hydroids and worm tubes) of this area provide a complex habitat for shrimp, polychaetes, brittle stars and small fish at undisturbed sites. Otter trawling and scallop dredging in this area removed this epifauna, thereby reducing the complexity and species diversity of the benthic community (Collie *et al.*, 2000). Jennings *et al.* (2001) studied the effects of bottom trawling on the trophic structure of epifaunal benthic communities in two regions - Silver Pit and Hills of the central North Sea. The impacts of fishing were most pronounced in the Silver Pit region, where the range of trawling disturbance was greater. The epifaunal biomass decreased significantly with trawling disturbance. The sessile animals were relatively more abundant in lightly trawled areas of North Sea, while areas with higher levels of trawling were characterized by a higher relative biomass of mobile animals (Tillin *et al.*, 2006).




Soft corals (7x). **a**, *Litophyton* sp. **b**, *Studeriotes* sp.



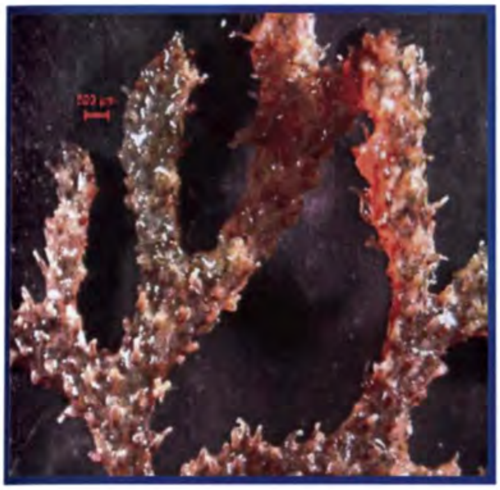

Gorgonians (7x). **a**, *Subergorgia suberosa* (Pallas) **b**, *Juncella juncea* (Pallas)

Seaweed- *Cystoseira trinodis*

Seaweed- *Sargassum wightii*

Hydrozoan- *Plumularia* sp.

Hydrozoan



Bryozoans

Molluscan eggs

Polychaete tubes

**Fig. 6.2.** Stereomicroscopic view of sedentary epifauna (7x) observed during the study

Gastropoda: *Tibia curta*

Gastropoda. *Xenophora solaris*

Gastropoda: *Turricula javana*

Gastropoda: *Surcula amicta*

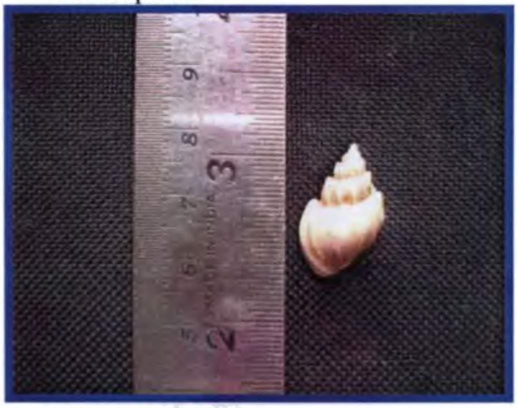
Gastropoda: *Surcula* sp

Gastropoda: *Xenoturris cingulifera*

Gastropoda: *Mitra eremiatrum*

Gastropoda: *Nassarius thersites*

Gastropoda: *Nassarius arcularis*

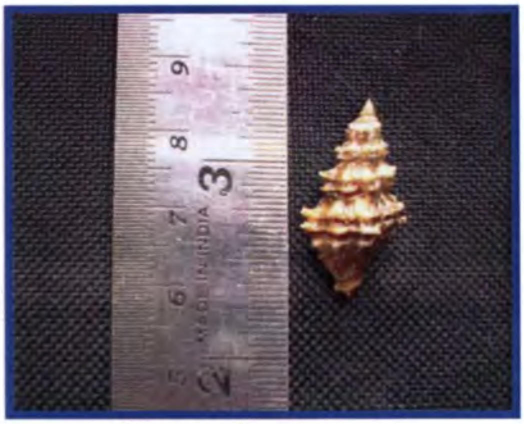


Gastropoda: *Nassarius suturalis*

Gastropoda: *Bursa echinata*

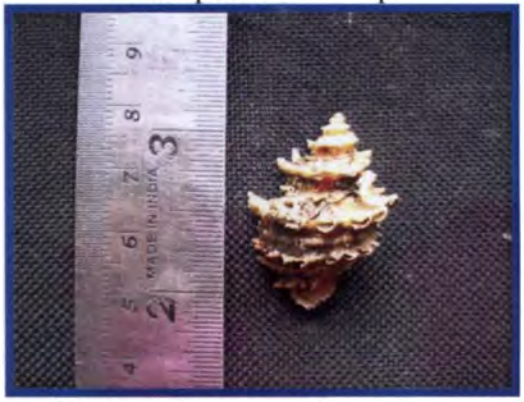
Gastropoda: *Bursa spinosa*

Gastropoda: *Murex acanthostephes*



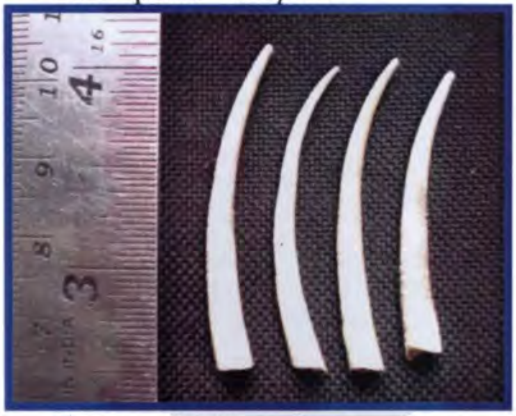
Gastropoda: *Murex* sp

Gastropoda: *Chicoreus brunneus*

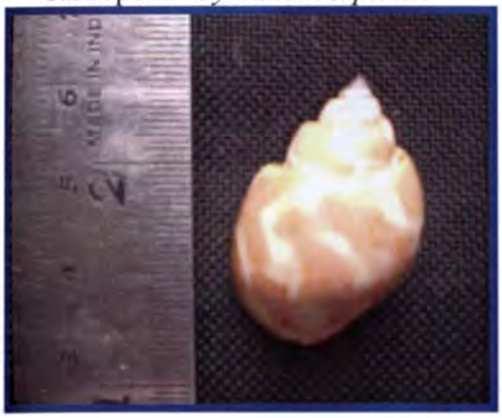


Gastropoda: *Hexaplex trunculus*

Gastropoda *Cymatium aquatile*



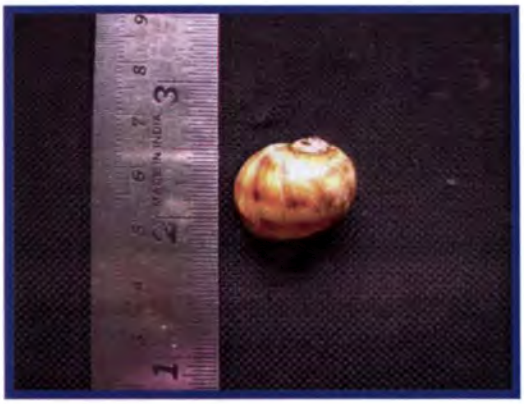
Gastropoda: *Dentalium aprinum*



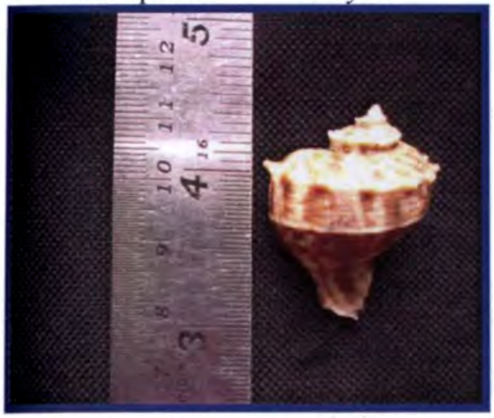
Gastropoda: *Babylonia spirata*

Gastropoda: *Natica lineata*

Gastropoda: *Natica didyma*

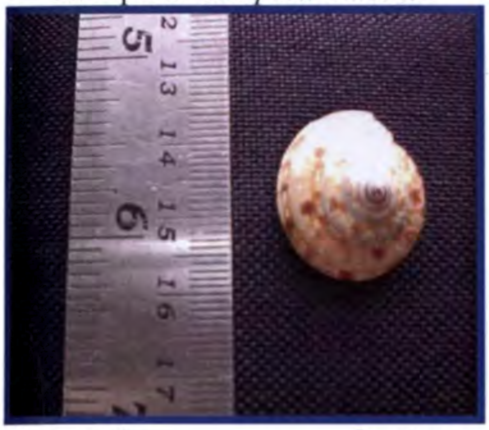


Gastropoda: *Natica vitellus*

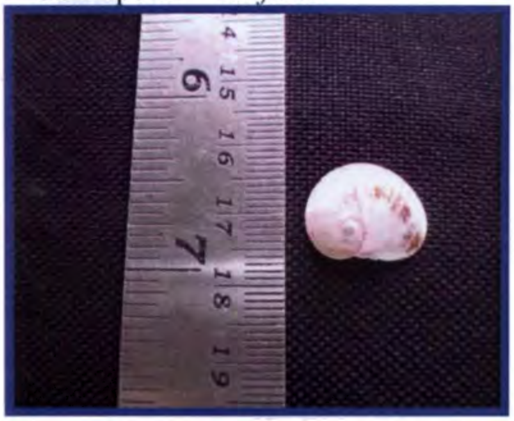


Gastropoda. *Rampana bulbosa*

Gastropoda: *Hemifusus cochlidium*



Gastropoda: *Architectonica laevigata*



Gastropoda: *Sinum* sp.

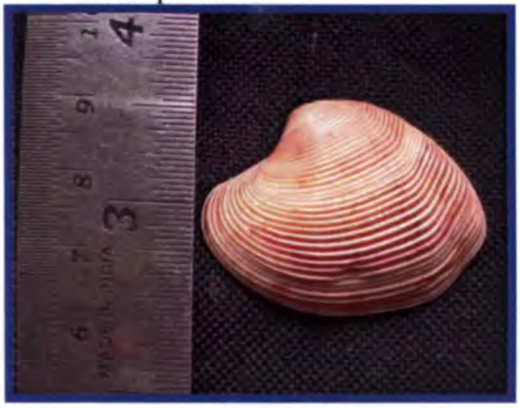
Gastropoda: *Umbonium* sp.

Gastropoda: *Trochus raditus*

Gastropoda: *Conus eldredi*

Gastropoda: *Conus betulinus*

Bivalvia: *Paphia textile*



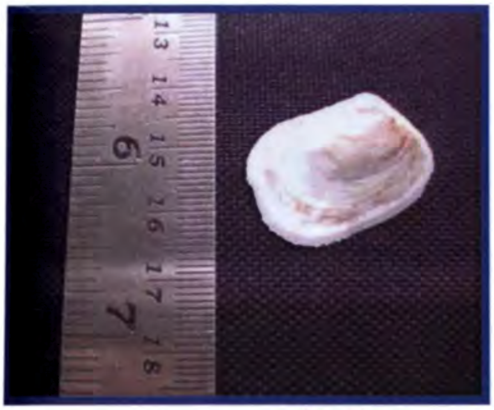
Bivalvia: *Paphia papilionis*

Bivalvia: *Dosinia cretacea*

Gastropoda: *Dosinia gibba*

Bivalvia: *Anadara* sp.

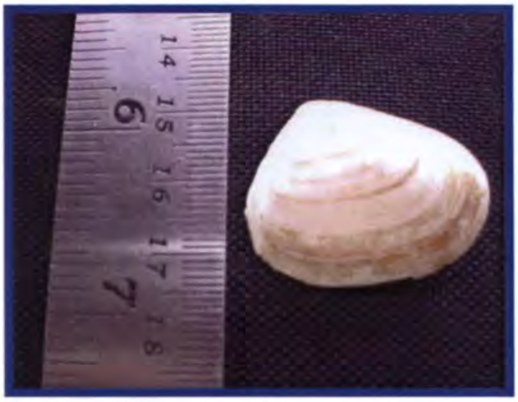
Bivalvia: *Scarpha* sp.



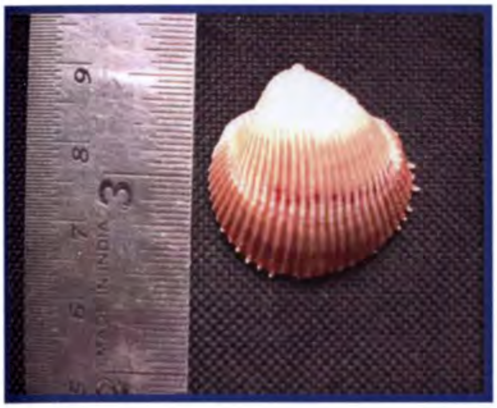
Bivavia: *Anomia ephippium*

Bivavia: *Arca navicularis*

Bivalvia: *Donax scortum*



Bivalvia: *Donax* sp

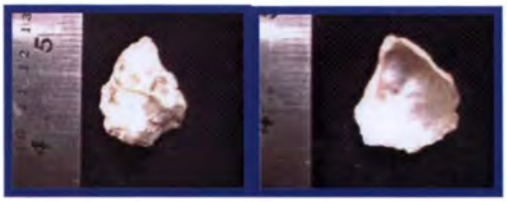


Bivalvia: *Cardium asiaticum*

Bivalvia: *Meropesta pellucida*

Bivalvia: *Pholas* sp.

Bivalvia: *Trisodos tortuosa*



Bivalvia: *Chlamys* spp. Bivalvia: *Cassostrea madrasensis*

**Fig. 6.3.** Epifaunal molluscs encountered in dredge

Crab- *Charybdis lucifeara* Polychaete tubes (calcareous and soft tubes)

**Fig. 6.4.** Other constituents of epifauna

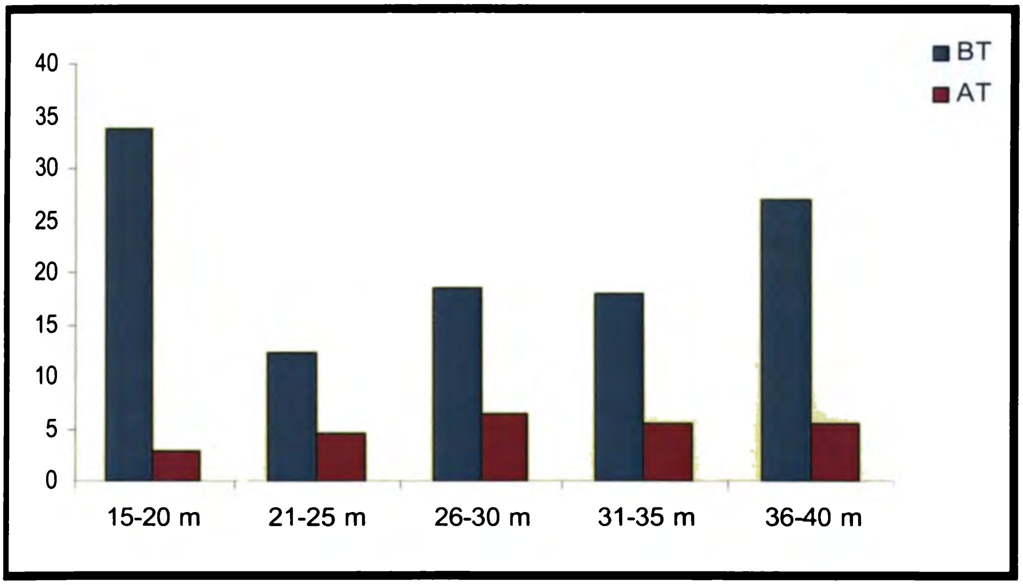



**Fig. 6.5.** Average biomass of polychaete tubes at different water depths before and after trawling

The epifauna collected in dredge mainly composed of dead and damaged molluscan shells that can be attributed to as an impact of trawling. The proportion of damaged shells showed increase in %weight after trawling (Figure 6.6). This is in conformity with the reports of Raman (2006). The damage inflicted to epifauna was clearly evident from the enormous amount of dead shells obtained in trawled areas off Vishakapatanam comparing to untrawled areas (Raman, 2006). In the present study, at 15-20 m water depth *Tibia curta* and *Anadara* spp. were found to be the most dominant species before and after trawling. At 26-30 m *Anadara* spp. was the most dominant and at 31-35 m and 36-40 m *Paphia textile* was the most dominant species observed. The species dominant in trawling grounds can be opportunistic species resistant to trawling disturbance. *Paphia textile* dominant in heavily trawled area is small in size compared to large sized *Tibia curta* dominant at 15-20 m (lightly trawled). The gastropods suffered the greatest depletion as 95% were removed by the combined effect of 13 trawls on the same track in the Great Barrier Reef of Australia (Burridge *et al.*, 2003). In megafaunal species of North Sea, trawling induced direct mortalities were found to be up to 68% for bivalves (Bergman and van Santbrink, 2000a).

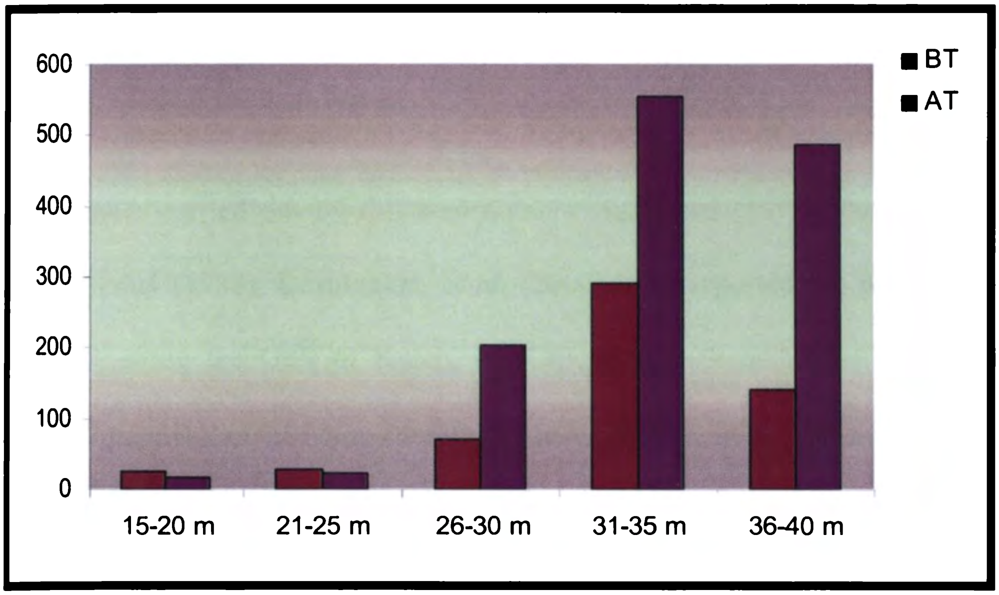



**Fig. 6.6.** Average biomass of damaged molluscan shells at different water depths

The epifaunal octocorals were encountered in the dredge operated at a depth of 15-20 m (latitude 20°54′ 13″ N and longitude 70°22′ 18″ E) in October 2005 and October 2006 before experimental trawling. Four genera of octocorals were recorded at 15-20 m depth which is not reported from Veraval waters previously. The soft corals found were *Litophyton* sp. (Figure 6.2 a) and *Studeriotes* sp. (Christmas tree soft coral) (Figure 6.2 b). The gorgonians collected were young stage of *Subergorgia suberosa* (Pallas) (Figure 6.3 a) and *Juncella juncea* (Pallas) (Whip coral) (Figure 6.3 b). The adult forms of these corals were not recorded during the study period which made species level identification difficult. During monthly trawling experiments the epifaunal corals were not observed in other transects. At 15-20 m depth there was no incidence of corals in the pre-trawl ban period. The biomass of octocorals is given in Table 6.1.

**Table 6.1.** The biomass of epifaunal octocorals obtained in dredge

| Sl.No. | Octocoral | October 2005 (Before trawling) g/ haul | October 2006 (Before trawling) g/ haul |
|---|---|---|---|
| 1. | *Litophyton* sp. | 20 | 35 |
| 2. | *Studeriotes* sp. | 15 | 20 |
| 3. | *Subergorgia suberosa* | 5 | 5 |
| 4. | *Juncella juncea* | 10 | 10 |

Studies carried out by different authors viz., Patel (1978), Patel (1988), Pillai and Patel (1988), Deshmukhe *et al.* (2000) have reported the presence of corals only along the Gulf of Kutch, off Gujarat. Raghunathan *et al.* (2004) recorded the patchy distribution of stony corals (*Porites lutea*, *Tubastrea aurea*, *Turbinaria crater*, *Polycyathus verrilli*) and *Gorgonium* sp. at a depth of 2-5 m in the intertidal regions of Veraval. This was the first record of corals from Veraval waters. This study conducted by Raghunathan *et al.* (2004) suggested the chances of the presence of coral reefs along the sub-tidal region of Veraval. The present study confirms this possibility by recording soft corals and gorgonians from the sub-tidal waters of Veraval.

The presence of epifaunal octocorals recorded in the sub-tidal region of Veraval in the month of October, immediately after the closed season (June to August) when the sea bottom is not heavily trawled suggests that this area is an abode of corals and a favourable site for coral reef formation. But intense trawling in the succeeding months destroys these valuable entities of ecosystem and the samples were not encountered in the subsequent months. Thus encrusting forms and alcyonarian were destroyed. Massive forms were not observed as they might have been destroyed.

The impact of bottom trawling on coral reefs has been studied in different parts of the world where it is mentioned that bottom trawling crushed or buried corals leading to increased mortality of coral populations (Koslow *et al.*, 2001; Fossa *et al.*, 2002). They have cautioned that the destruction of the corals will also affect the associated fauna of fishes and invertebrates, which was evident from the complete loss of associated community from the shallow heavily fished seamounts of Tasmania (Koslow *et al.*, 2001). Lokkeborg (2005) on reviewing the studies conducted for the past 15 years reported that the sessile organisms like sponges and corals decreased considerably at the passage of otter trawl. At seamounts of Tasmania the dominant colonial coral, *Solenosmilia variabilis* and its associated fauna were eliminated from the shallow, heavily fished seamounts (Koslow, *et al.*, 2001). Kaiser *et al.* (2000) reported off Start Bay, Devon, United

Kingdom that the biomass of soft corals was higher in the areas closed to fishing gear than those areas under bottom-fishing pressures even at a small scale. In the mid Norwegian continental shelf the trawlers damage the deep-water corals *Lophelia pertusa* significantly lowering the inhabitant fishery (Fossa *et al.*, 2002). There was a significant decrease in density of sponges and anthozoans in trawled hard-bottom seafloor versus reference transects in the Gulf of Alaska (Freese *et al.*, 1999). In the Great Barrier Reef of Australia, ascidians, sponges, echinoids, crustaceans and gorgonians were depleted by 74-86% (Burridge *et al.*, 2003). The complex habitats like coral reefs have the longest recovery rate and take years to recolonise (Kaiser *et al.*, 2002; Gianni, 2004).

**6.3.2. Change in total epifaunal diversity indices**

The diversity indices before and after trawling are given in Tables 6.2, 6.3, 6.4, 6.5 and 6.6. Analysing the species/group identified, the changes before and after trawling in diversity indices viz., S (species) & N (number) were significant at 15-20 m. This result can be attributed to the damage inflicted to sedentary fauna like octocorals, hydroids, bryozoans etc. Most of the diversity indices were not significantly different before and after trawling. As the large bodied epifauna have been affected by intense trawling prevalent in the area, the impact is not evident in heavily trawled areas. Since 15-20 is lightly trawled, the impact is more evident. Jennings and Reynolds (2000) enumerated the impacts of fishing on species diversity in the northeast Atlantic. A reduction in diversity resulted from the direct mortality of target species and a reduction in invertebrate diversity resulted from the effects of towed gears on the seabed. In unfished sheltered

Scottish sea loch, the epifaunal diversity indices Shannon's H', Simpson's reciprocal D and evenness decreased in the trawled area relative to the reference site (Tuck *et al.*, 1998).

**Table 6.2.** Diversity indices of total epifauna at 15-20 m. *Significant difference of the index before and after trawling (P<0.05)

| Diversity Index | Before Trawling | | | | After Trawling | | | |
|---|---|---|---|---|---|---|---|---|
| | Minimum | Maximum | Mean | S.E. | Minimum | Maximum | Mean | S.E. |
| S* | 2.00 | 33.00 | 11.13 | 3.45 | 1.00 | 8.00 | 3.67 | 0.76 |
| N* | 7.00 | 281.00 | 92.50 | 33.80 | 2.00 | 47.00 | 14.78 | 4.77 |
| Margalef | 0.51 | 6.16 | 2.28 | 0.64 | 0.00 | 1.82 | 1.06 | 0.21 |
| Pielou | 0.59 | 0.95 | 0.77 | 0.05 | 0.69 | 1.00 | 0.90 | 0.03 |
| Brillouin | 0.28 | 2.44 | 1.42 | 0.24 | 0.00 | 1.69 | 0.77 | 0.18 |
| Fisher | 0.93 | 11.85 | 3.94 | 1.27 | 0.38 | 3.98 | 1.83 | 0.41 |
| Shannon | 0.41 | 2.69 | 1.62 | 0.26 | 0.00 | 1.93 | 1.00 | 0.20 |
| Simpson | 0.29 | 0.92 | 0.70 | 0.07 | 0.00 | 1.00 | 0.65 | 0.10 |
| Hill's N1 | 1.51 | 14.80 | 6.31 | 1.59 | 1.00 | 6.88 | 3.19 | 0.63 |
| Hill's N2 | 1.32 | 9.84 | 4.58 | 1.06 | 1.00 | 5.83 | 2.88 | 0.53 |
| Tax_div | 15.25 | 58.40 | 35.65 | 5.71 | 0.00 | 83.33 | 39.52 | 7.84 |
| Tax_dist | 24.56 | 66.67 | 50.72 | 5.30 | 0.00 | 83.33 | 53.52 | 8.61 |
| AvTD | 27.78 | 75.25 | 56.44 | 5.22 | 0.00 | 83.33 | 54.36 | 8.63 |
| TTD | 83.33 | 2111.46 | 676.18 | 231.45 | 0.00 | 442.86 | 212.17 | 47.37 |
| VarTD | 0.00 | 640.42 | 266.03 | 69.45 | 0.00 | 555.56 | 173.51 | 70.35 |
| AvPD | 38.89 | 83.33 | 50.76 | 5.11 | 47.92 | 100.00 | 71.59 | 6.18 |
| PD | 150.00 | 1300.00 | 497.92 | 131.36 | 100.00 | 383.33 | 231.48 | 33.04 |

**Table 6.3.** Diversity indices of total epifauna at 21-25 m

| Diversity Index | Before Trawling | | | | After Trawling | | | |
|---|---|---|---|---|---|---|---|---|
| | Minimum | Maximum | Mean | S.E. | Minimum | Maximum | Mean | S.E. |
| S | 2.00 | 13.00 | 6.18 | 0.95 | 1.00 | 17.00 | 8.00 | 1.62 |
| N | 4.00 | 136.00 | 30.91 | 10.97 | 7.00 | 169.00 | 42.33 | 16.61 |
| Margalef | 0.69 | 2.44 | 1.63 | 0.20 | 0.00 | 3.20 | 1.99 | 0.37 |
| Pielou | 0.72 | 1.00 | 0.91 | 0.03 | 0.75 | 0.98 | 0.88 | 0.03 |
| Brillouin | 0.45 | 2.08 | 1.23 | 0.13 | 0.00 | 2.52 | 1.33 | 0.23 |
| Fisher | 1.03 | 14.12 | 3.72 | 1.10 | 0.29 | 19.95 | 5.41 | 1.96 |
| Shannon | 0.69 | 2.23 | 1.52 | 0.13 | 0.00 | 2.70 | 1.61 | 0.25 |
| Simpson | 0.67 | 0.93 | 0.79 | 0.03 | 0.00 | 0.95 | 0.72 | 0.10 |
| Hill's N1 | 2.00 | 9.31 | 4.94 | 0.62 | 1.00 | 14.83 | 6.19 | 1.31 |
| Hill's N2 | 2.00 | 7.99 | 4.36 | 0.53 | 1.00 | 13.56 | 5.18 | 1.24 |
| Tax_div | 31.62 | 63.33 | 45.77 | 2.88 | 0.00 | 79.37 | 44.32 | 7.18 |
| Tax_dist | 44.05 | 67.86 | 57.72 | 2.41 | 0.00 | 83.33 | 53.85 | 7.57 |
| AvTD | 44.44 | 66.67 | 57.04 | 2.37 | 0.00 | 83.33 | 54.95 | 7.51 |
| TTD | 133.33 | 708.33 | 352.11 | 54.35 | 0.00 | 1100.00 | 483.55 | 105.23 |
| VarTD | 0.00 | 555.56 | 298.94 | 54.28 | 0.00 | 424.38 | 227.80 | 43.32 |
| AvPD | 38.46 | 83.33 | 56.10 | 3.79 | 40.91 | 100.00 | 59.09 | 6.63 |
| PD | 166.67 | 500.00 | 316.67 | 32.64 | 100.00 | 733.33 | 403.70 | 62.53 |

**Table 6.4.** Diversity indices of total epifauna at 26-30 m.*Significant difference of the index before and after trawling (P<0.05)

| Diversity Index | Before Trawling | | | | After Trawling | | | |
|---|---|---|---|---|---|---|---|---|
| | Minimum | Maximum | Mean | S.E. | Minimum | Maximum | Mean | S.E. |
| S | 1.00 | 23.00 | 10.70 | 2.20 | 6.00 | 24.00 | 14.33 | 1.86 |
| N | 5.00 | 248.00 | 70.80 | 23.33 | 26.00 | 2135.00 | 319.33 | 228.28 |
| Margalef | 0.00 | 5.44 | 2.39 | 0.49 | 1.54 | 3.84 | 2.85 | 0.28 |
| Pielou | 0.87 | 1.00 | 0.93 | 0.02 | 0.36 | 0.97 | 0.81 | 0.06 |
| Brillouin | 0.00 | 2.42 | 1.69 | 0.22 | 1.12 | 2.64 | 1.84 | 0.16 |
| Fisher | 0.38 | 14.33 | 4.78 | 1.29 | 2.09 | 6.99 | 4.78 | 0.59 |
| Shannon | 0.00 | 2.89 | 1.95 | 0.25 | 1.15 | 2.84 | 2.07 | 0.17 |
| Simpson | 0.00 | 0.95 | 0.79 | 0.09 | 0.39 | 0.93 | 0.80 | 0.06 |
| Hill's N1 | 1.00 | 18.04 | 8.63 | 1.55 | 3.14 | 17.13 | 8.87 | 1.41 |
| Hill's N2 | 1.00 | 14.07 | 7.18 | 1.11 | 1.64 | 13.77 | 6.97 | 1.27 |
| Tax_div | 0.00 | 54.89 | 43.88 | 5.02 | 22.06 | 61.54 | 48.71 | 4.12 |
| Tax_dist* | 0.00 | 62.14 | 49.72 | 5.62 | 51.76 | 68.09 | 60.40 | 1.92 |
| AvTD | 0.00 | 64.35 | 50.73 | 5.74 | 55.19 | 64.14 | 58.30 | 0.97 |
| TTD | 0.00 | 1259.09 | 596.97 | 126.25 | 333.33 | 1420.29 | 841.54 | 113.87 |
| VarTD | 0.00 | 427.66 | 266.24 | 37.47 | 202.53 | 461.40 | 308.98 | 27.42 |
| AvPD | 34.06 | 100.00 | 50.11 | 5.94 | 36.46 | 50.00 | 42.72 | 1.63 |
| PD | 100.00 | 783.33 | 448.33 | 66.60 | 300.00 | 883.33 | 590.74 | 58.08 |

**Table 6.5.** Diversity indices of total epifauna at 31-35 m

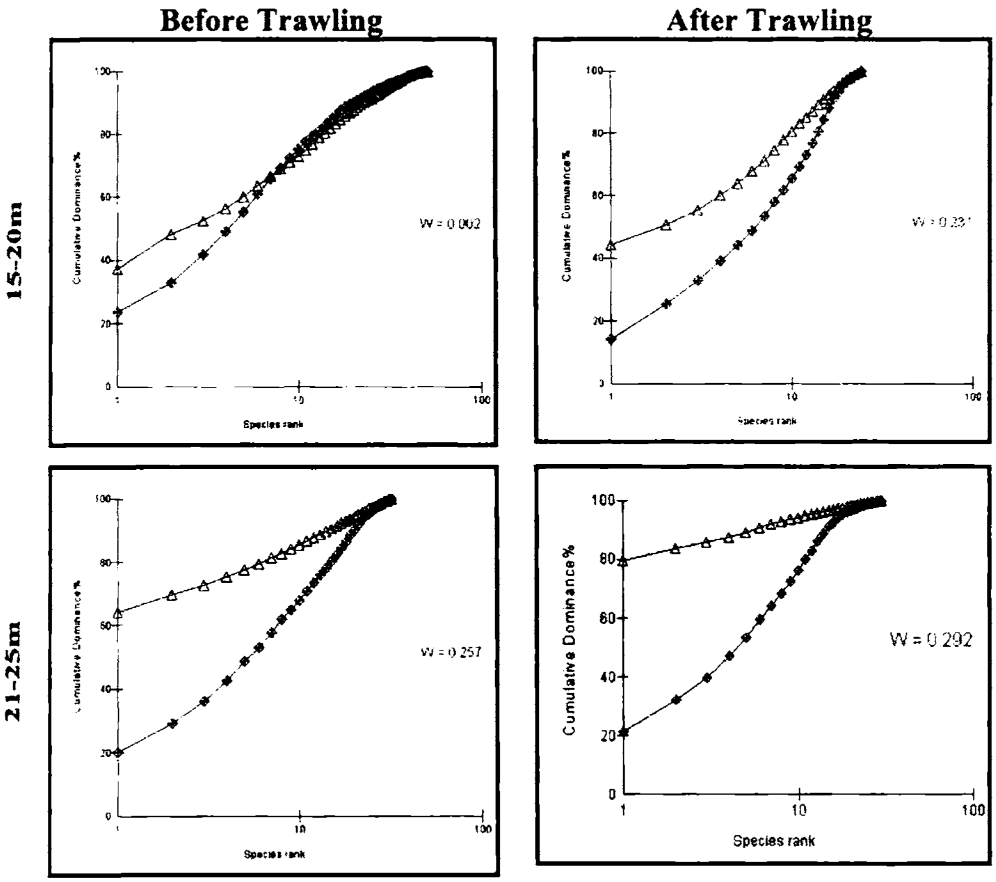
| Diversity Index | Before Trawling | | | | After Trawling | | | |
|---|---|---|---|---|---|---|---|---|
| | Minimum | Maximum | Mean | S.E. | Minimum | Maximum | Mean | S.E. |
| S | 1.00 | 19.00 | 11.71 | 2.60 | 5.00 | 27.00 | 14.56 | 2.46 |
| N | 4.00 | 454.00 | 230.57 | 59.32 | 12.00 | 2503.00 | 741.22 | 328.38 |
| Margalef | 0.00 | 3.51 | 1.97 | 0.49 | 0.97 | 3.75 | 2.47 | 0.34 |
| Pielou | 0.51 | 0.97 | 0.80 | 0.08 | 0.52 | 0.94 | 0.77 | 0.05 |
| Brillouin | 0.00 | 2.57 | 1.62 | 0.34 | 1.05 | 2.34 | 1.78 | 0.17 |
| Fisher | 0.43 | 6.03 | 2.90 | 0.76 | 1.19 | 5.97 | 3.80 | 0.57 |
| Shannon | 0.00 | 2.76 | 1.71 | 0.36 | 1.14 | 2.52 | 1.93 | 0.17 |
| Simpson | 0.00 | 0.94 | 0.68 | 0.12 | 0.65 | 0.92 | 0.80 | 0.03 |
| Hill's N1 | 1.00 | 15.76 | 7.61 | 2.16 | 3.14 | 12.47 | 7.67 | 1.16 |
| Hill's N2 | 1.00 | 14.77 | 6.20 | 1.92 | 2.74 | 10.61 | 5.61 | 0.86 |
| Tax_div | 0.00 | 55.69 | 34.14 | 7.19 | 22.75 | 56.69 | 42.87 | 4.30 |
| Tax_dist | 0.00 | 59.10 | 42.17 | 7.57 | 35.23 | 64.58 | 52.57 | 3.82 |
| AvTD | 0.00 | 60.29 | 48.76 | 8.16 | 52.78 | 61.48 | 56.71 | 1.03 |
| TTD | 0.00 | 1059.26 | 657.55 | 153.71 | 266.67 | 1553.85 | 832.35 | 143.81 |
| VarTD | 0.00 | 347.46 | 210.90 | 39.18 | 209.88 | 424.82 | 299.16 | 24.64 |
| AvPD | 37.72 | 100.00 | 51.55 | 8.57 | 34.57 | 52.78 | 41.95 | 2.33 |
| PD | 100.00 | 716.67 | 488.10 | 87.04 | 250.00 | 933.33 | 570.37 | 75.65 |

Table 6.6. Diversity indices of total epifauna at 36-40 m

| Diversity Index | Before Trawling | | | | After Trawling | | | |
|---|---|---|---|---|---|---|---|---|
| | Minimum | Maximum | Mean | S.E. | Minimum | Maximum | Mean | S.E. |
| S | 9.00 | 25.00 | 16.10 | 1.74 | 7.00 | 29.00 | 16.00 | 2.09 |
| N | 35.00 | 708.00 | 254.80 | 62.52 | 34.00 | 3261.00 | 790.73 | 348.51 |
| Margalef | 1.62 | 4.70 | 2.91 | 0.32 | 1.24 | 3.72 | 2.49 | 0.24 |
| Pielou | 0.60 | 0.94 | 0.79 | 0.03 | 0.28 | 1.00 | 0.68 | 0.07 |
| Brillouin | 1.68 | 2.46 | 1.98 | 0.07 | 0.54 | 2.40 | 1.68 | 0.16 |
| Fisher | 2.14 | 8.17 | 4.60 | 0.68 | 1.52 | 5.57 | 3.41 | 0.35 |
| Shannon | 1.72 | 2.68 | 2.14 | 0.09 | 0.58 | 2.48 | 1.78 | 0.17 |
| Simpson | 0.71 | 0.90 | 0.83 | 0.02 | 0.25 | 0.90 | 0.74 | 0.06 |
| N1 | 5.59 | 14.57 | 8.78 | 0.80 | 1.78 | 11.99 | 6.70 | 0.95 |
| N2 | 3.46 | 9.54 | 6.36 | 0.60 | 1.33 | 8.61 | 5.06 | 0.71 |
| Tax_div | 29.35 | 60.03 | 43.00 | 2.60 | 14.10 | 49.38 | 36.28 | 3.48 |
| Tax_dist | 40.19 | 66.51 | 51.35 | 2.29 | 34.71 | 57.26 | 48.77 | 2.08 |
| AvTD | 50.46 | 63.68 | 56.96 | 1.25 | 52.35 | 61.31 | 55.76 | 0.91 |
| TTD | 454.17 | 1473.61 | 925.11 | 107.32 | 366.67 | 1619.05 | 904.18 | 125.32 |
| VarTD | 190.13 | 406.89 | 306.73 | 19.42 | 222.75 | 430.84 | 295.63 | 18.95 |
| AvPD | 34.03 | 46.15 | 39.30 | 1.12 | 34.48 | 45.83 | 40.34 | 1.05 |
| PD | 383.33 | 900.00 | 620.00 | 53.62 | 316.67 | 1000.00 | 624.24 | 67.66 |

### 6.3.3. Abundance Biomass Comparison (ABC) curves for total epifauna

The abundance biomass comparison (ABC) curve for total epifauna is given in Figure 6.7. ABC plots were built and difference between biomass and abundance curves was quantified by the measure of w. According to the theory, the fauna is unstressed, when the abundance curve lies below biomass curve (w>0). The fauna is moderately stressed when the abundance curve and biomass curve lie close together (w=0). The fauna is grossly stressed when biomass curve lie below abundance curve (w<0). At 15-20 m, the k-dominance curve was more or less unstressed or moderately stressed. At 26-30 m before trawling the curve showed unstressed fauna. But after trawling, the curve indicated grossly stressed fauna. Similarly at 31-35 m and 36-40 m, the k-dominance curve was observed to be moderately stressed before trawling and grossly stressed after trawling. The rate of stress increased with water depth as shallow depths are lightly trawled and as water depth increases the trawling intensity increases. The short term changes due to trawling are evident from damage to molluscan shells and polychaete tubes after experimental trawling. The long term impact is less explained by experimental trawling. But ABC curve reveal long-term impact by showing unstressed fauna in lightly trawled areas and grossly stressed fauna in heavily trawled area. In unfished sheltered Scottish sea loch, the ABC plots confirmed that epifaunal community changes occurred following trawling disturbance, with impact visible after 18 months of recovery (Tuck *et al.*, 1998).



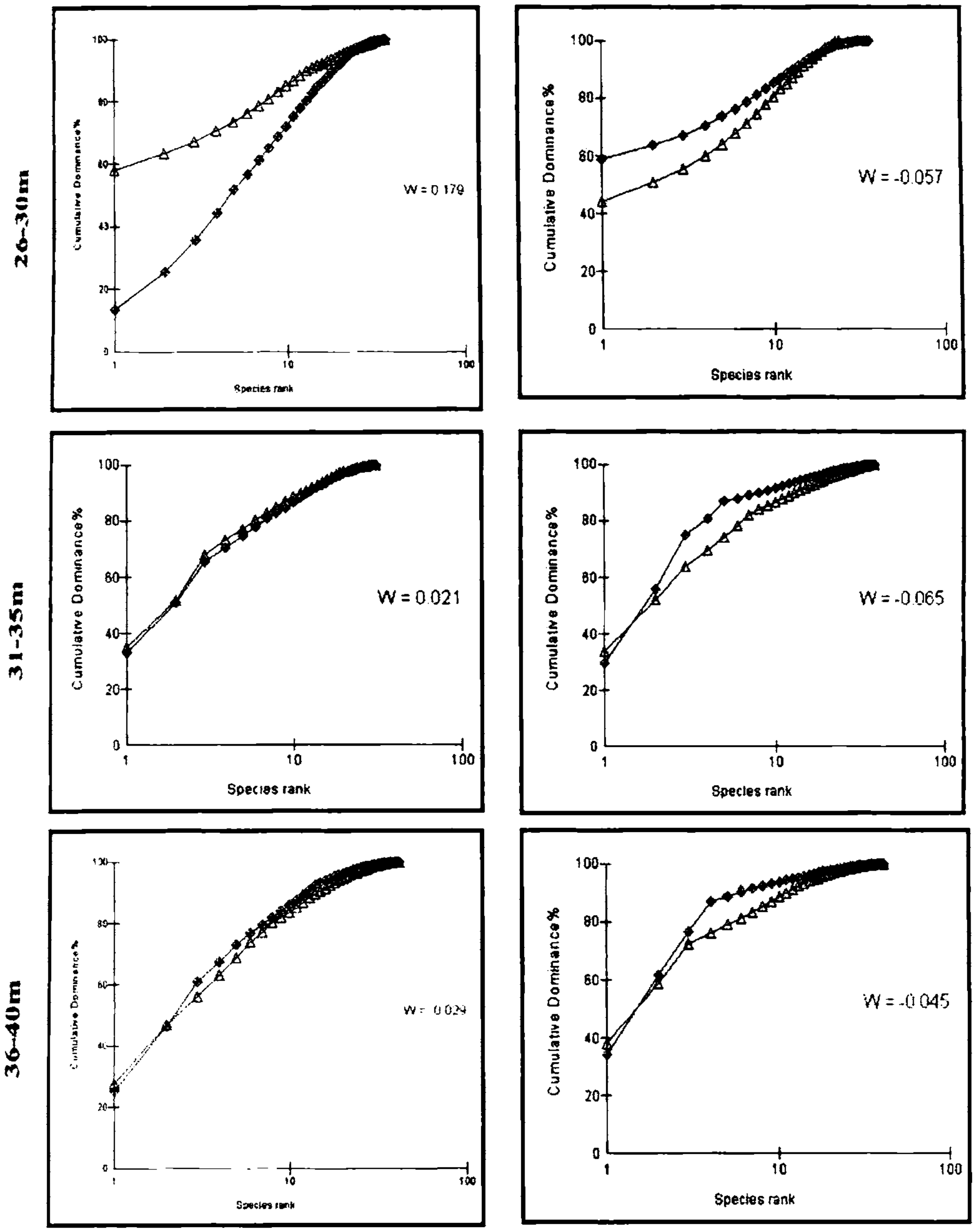



**Fig. 6.7** Abundance Biomass Comparison curves for total epifauna.
◆ Abundance Δ Biomass

The Wilcoxon Signed rank test revealed no significant difference in before trawling-after trawling W-statistic value for each depth zone (asymp. Sig. 2 tailed: 0.686) analyzing for all the species identified. On including polychaete tubes and damaged molluscan shells also, Wilcoxon Signed rank test was found to be significant (p= 0.043). This can be attributed to the increase in the proportion of damaged shells and decrease in proportion of polychaete tubes after trawling. In Figure 6.7 & Figure 6.8, the W-statistic values were found to be negative in heavily trawled areas (26-30 m, 31-35 m and 36-40 m) and positive in lightly trawled areas (15-20 m and 21-25 m). In the present investigation it is difficult to conclude whether negative values of the W-statistic relates to an acceptable trawling impact or to an unacceptable chronic trawling. This situation may be partly due to limited number of comparable studies in a small area, but also due to the complexity of the problem. Analysis of time-series data that encompasses the whole range of ecological states (i.e. virgin state to heavily trawled) and comparisons among similar assemblages from different areas subject to different levels of stress have to be performed.

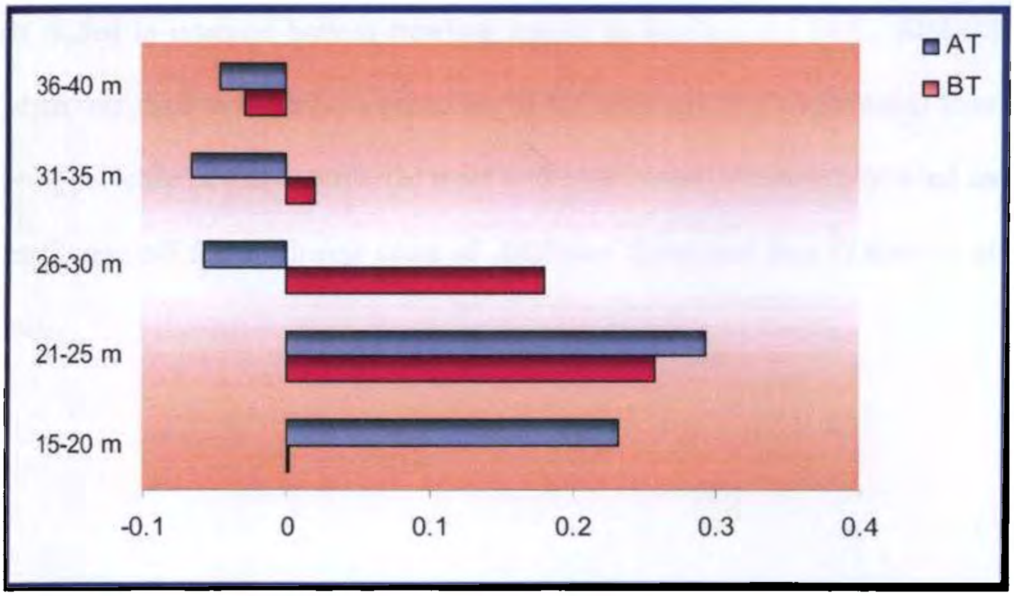



**Fig. 6.8.** The W-statistic value of before and after trawling at different water depths

### 6.3.4. Similarity of percentage (SIMPER) analysis for total epifauna

The results of SIMPER analysis considering different species of epifauna identified are given in Tables 6.7, 6.8, 6.9, 6.10 and 6.11. The average dissimilarity between before and after trawling is highest at 15-20 m water depth (lightly trawled area). This dissimilarity decreased with increasing water depths and was observed to be lowest at 36-40 m (heavily trawled area). The order of average dissimilarity is 15-20 m (91.16) > 21-25 m (70.19) > 26-30 m (62.03) > 31-35 m (57.41) > 36-40 m (52.28). The dissimilarity of fauna before and after experimental trawling is more evident in lightly trawled area and remains masked in heavily trawled area. Tuck *et al.* (1998) used SIMPER test to identify the epifaunal species that contributed to the similarity or dissimilarity between two sites studied to interpret bottom trawling impact in Scottish sea loch. SIMPER analysis was used to describe a reduction in the abundance of megafaunal slow-moving polychaetes that contributed most to the dissimilarity between trawled and control areas off the northwest coast of Anglesey, Liverpool Bay (Kaiser *et al.*, 1998).

**Table 6.7.** SIMPER analysis of epifaunal abundance data for 15-20 m depth. The average dissimilarity between before and after trawling was 91.16

| Species | Average Abundance BT | Average Abundance AT | Average Dissimilarity | Dissimilarity / s.d. | Contribution (%) | Cumulative (%) |
|---|---|---|---|---|---|---|
| *Anadara* spp. | 3.38 | 2.11 | 6.49 | 0.77 | 7.11 | 7.11 |
| *Nassarius arcularis* | 8.63 | 0.56 | 4.61 | 0.85 | 5.05 | 12.17 |
| *Tibia curta* | 2.88 | 0.78 | 4.46 | 1.07 | 4.89 | 17.06 |
| *Metapenaeus monoceros* | 0.25 | 0.89 | 4.42 | 0.53 | 4.84 | 21.90 |
| *Chicoreus* sp. | 1.50 | 0.00 | 3.65 | 0.67 | 4.00 | 25.90 |
| *Paphia textile* | 5.75 | 0.11 | 3.45 | 0.82 | 3.79 | 29.69 |
| *Balanus amphitrite* | 6.88 | 1.11 | 3.18 | 0.61 | 3.48 | 33.17 |
| *Murex* sp | 0.75 | 0.00 | 3.10 | 0.57 | 3.40 | 36.58 |
| *Metapenaeus dobsoni* | 0.25 | 0.67 | 3.09 | 0.54 | 3.39 | 39.96 |
| *Chlamys tranquebaricus* | 21.88 | 0.00 | 3.07 | 0.56 | 3.36 | 43.33 |
| *Babylonia spirata* | 2.63 | 0.11 | 2.85 | 0.50 | 3.13 | 46.46 |
| *Arca navicularis* | 0.00 | 0.67 | 2.79 | 0.46 | 3.07 | 49.52 |
| *Trisodos tortuosa* | 4.50 | 0.56 | 2.70 | 0.73 | 2.96 | 52.49 |
| *Balanus reticulatus* | 5.00 | 0.56 | 2.70 | 0.63 | 2.96 | 55.45 |
| *Conus eldredi* | 1.50 | 0.00 | 2.67 | 0.40 | 2.93 | 58.38 |
| *Chlamys singaporina* | 8.13 | 0.00 | 2.40 | 0.56 | 2.64 | 61.02 |
| *Calappa lophos* | 0.00 | 0.44 | 2.40 | 0.46 | 2.64 | 63.66 |
| *Donax* sp. | 1.75 | 0.22 | 2.26 | 0.80 | 2.47 | 66.13 |
| *Bursa echinata* | 0.63 | 0.33 | 2.14 | 0.61 | 2.34 | 68.47 |
| *Dosinia cretacea* | 0.63 | 0.67 | 2.07 | 0.62 | 2.28 | 70.75 |
| *Conus betulinus* | 0.63 | 0.00 | 2.05 | 0.37 | 2.25 | 73.00 |
| *Portunus sanguinolentus* | 0.00 | 0.33 | 1.88 | 0.33 | 2.06 | 75.06 |
| *Mitra eremiatrum* | 1.63 | 0.00 | 1.78 | 0.51 | 1.95 | 77.01 |
| *Oratosquilla nepa* | 0.38 | 0.11 | 1.42 | 0.50 | 1.56 | 78.57 |
| *Bursa spinosa* | 2.13 | 0.00 | 1.32 | 0.55 | 1.45 | 80.02 |
| *Litophyton* sp. | 1.50 | 0.00 | 1.30 | 0.54 | 1.43 | 81.45 |
| *Scarpha inaequivalvis* | 1.25 | 0.00 | 1.24 | 0.54 | 1.36 | 82.81 |
| *Studeriotes* sp. | 1.00 | 0.00 | 1.10 | 0.53 | 1.20 | 84.01 |
| *Charybdis lucifeara* | 0.13 | 0.56 | 1.09 | 0.38 | 1.19 | 85.20 |
| *Paphia papilionis* | 0.00 | 1.67 | 1.05 | 0.34 | 1.15 | 86.35 |
| *Nassarius* spp. | 0.63 | 0.56 | 1.04 | 0.47 | 1.14 | 87.49 |
| *Architectonica laevigata* | 0.38 | 0.00 | 1.01 | 0.47 | 1.10 | 88.59 |
| *Thais bufo* | 0.13 | 0.56 | 0.84 | 0.40 | 0.92 | 89.51 |
| *Donax scortum* | 0.63 | 0.00 | 0.80 | 0.37 | 0.88 | 90.39 |

**Table 6.8.** SIMPER analysis of epifaunal abundance data for 21-25 m depth. The average dissimilarity between before and after trawling was 70.19

| Species | Average Abundance BT | Average Abundance AT | Average Dissimilarity | Dissimilarity/ s.d. | Contribution (%) | Cumulative (%) |
|---|---|---|---|---|---|---|
| *Tibia curta* | 2.00 | 4.44 | 5.88 | 1.07 | 8.37 | 8.37 |
| *Anadara* spp. | 6.18 | 9.11 | 5.12 | 0.82 | 7.29 | 15.66 |
| *Bursa spinosa* | 0.82 | 2.56 | 3.96 | 0.82 | 5.65 | 21.31 |
| *Scarpha inaequivalvis* | 0.27 | 3.11 | 3.91 | 0.82 | 5.57 | 26.88 |
| *Turricula javana* | 0.64 | 3.22 | 3.86 | 1.19 | 5.50 | 32.38 |
| *Paphia textile* | 2.82 | 1.33 | 3.35 | 0.95 | 4.77 | 37.15 |
| *Nassarius suturalis* | 1.36 | 0.22 | 3.22 | 0.71 | 4.59 | 41.74 |
| *Donax scortum* | 0.27 | 1.33 | 3.02 | 0.80 | 4.31 | 46.05 |
| *Bursa echinata* | 0.64 | 1.78 | 2.86 | 0.88 | 4.08 | 50.13 |
| *Murex acanthostephes* | 0.91 | 0.56 | 2.59 | 0.56 | 3.70 | 53.83 |
| *Nassarius thersites* | 1.91 | 1.67 | 2.02 | 0.67 | 2.87 | 56.70 |
| *Arca navicularis* | 0.64 | 0.11 | 1.86 | 0.60 | 2.65 | 59.35 |
| *Balanus reticulates* | 0.73 | 1.11 | 1.75 | 0.55 | 2.49 | 61.84 |
| *Natica didyma* | 0.45 | 0.11 | 1.74 | 0.67 | 2.47 | 64.31 |
| *Chlamys tranquebaricus* | 1.36 | 2.78 | 1.73 | 0.60 | 2.46 | 66.77 |
| *Balanus amphitrite* | 0.64 | 1.44 | 1.71 | 0.58 | 2.43 | 69.21 |
| *Oratosquilla nepa* | 0.09 | 0.11 | 1.61 | 0.46 | 2.29 | 71.50 |
| *Rampana bulbosa* | 0.64 | 0.11 | 1.60 | 0.53 | 2.28 | 73.78 |
| *Donax* sp | 0.00 | 0.56 | 1.50 | 0.65 | 2.14 | 75.92 |
| *Chlamys singaporina* | 0.91 | 2.00 | 1.48 | 0.60 | 2.11 | 78.02 |
| *Nassarius* spp. | 0.73 | 0.00 | 1.31 | 0.30 | 1.87 | 79.89 |
| *Dosinia cretacea* | 0.00 | 1.67 | 1.23 | 0.51 | 1.75 | 81.64 |
| *Dosinia gibba* | 1.36 | 0.56 | 1.20 | 0.46 | 1.72 | 83.36 |
| *Pholas* sp. | 0.55 | 0.33 | 1.01 | 0.39 | 1.44 | 84.80 |
| *Natica lineata* | 0.36 | 0.00 | 0.96 | 0.44 | 1.36 | 86.17 |
| *Trypauchen vagina* | 0.00 | 0.11 | 0.95 | 0.35 | 1.35 | 87.52 |
| *Sargassum wightii* | 0.00 | 0.11 | 0.95 | 0.35 | 1.35 | 88.86 |
| *Cystoseira trinodis* | 0.00 | 0.11 | 0.95 | 0.35 | 1.35 | 90.21 |

**Table 6.9.** SIMPER analysis of epifaunal abundance data for 26–30 m depth. The average dissimilarity between before and after trawling was 62.03

| Species | Average Abundance BT | Average Abundance AT | Average Dissimilarity | Dissimilarity/ s.d. | Contribution (%) | Cumulative (%) |
|---|---|---|---|---|---|---|
| *Paphia textile* | 5.30 | 188.22 | 3.58 | 1.10 | 5.77 | 5.77 |
| *Tibia curta* | 3.30 | 4.11 | 3.36 | 0.87 | 5.42 | 11.19 |
| *Scarpha inaequivalvis* | 6.00 | 7.78 | 3.14 | 1.07 | 5.05 | 16.25 |
| *Anadara* spp. | 8.60 | 15.89 | 3.05 | 0.86 | 4.92 | 21.17 |
| *Donax scortum* | 2.70 | 2.78 | 3.04 | 1.19 | 4.90 | 26.07 |
| *Bursa echinata* | 2.30 | 10.44 | 2.90 | 1.19 | 4.67 | 30.74 |
| *Bursa spinosa* | 2.60 | 5.56 | 2.74 | 1.07 | 4.41 | 35.15 |
| *Balanus reticulates* | 0.90 | 6.22 | 2.70 | 1.00 | 4.35 | 39.50 |
| *Chlamys tranquebaricus* | 9.40 | 10.56 | 2.57 | 0.87 | 4.14 | 43.63 |
| *Dentalium aprinum* | 1.70 | 6.78 | 2.51 | 1.15 | 4.05 | 47.68 |
| *Turricula javana* | 0.60 | 4.78 | 2.46 | 1.14 | 3.96 | 51.65 |
| *Dosinia cretacea* | 2.20 | 10.22 | 2.34 | 1.11 | 3.78 | 55.42 |
| *Nassarius thersites* | 3.50 | 8.56 | 2.28 | 1.08 | 3.67 | 59.09 |
| *Donax* sp. | 1.50 | 1.89 | 2.27 | 0.96 | 3.66 | 62.76 |
| *Balanus amphitrite* | 0.90 | 4.11 | 2.25 | 1.01 | 3.62 | 66.38 |
| *Chlamys singaporina* | 7.30 | 7.67 | 2.25 | 0.79 | 3.62 | 70.00 |
| *Nassarius suturalis* | 2.00 | 1.67 | 2.09 | 0.96 | 3.37 | 73.36 |
| *Natica didyma* | 1.10 | 4.56 | 1.68 | 1.08 | 2.70 | 76.07 |
| *Arca navicularis* | 1.10 | 1.56 | 1.63 | 0.79 | 2.62 | 78.69 |
| *Murex carbonnieri* | 0.30 | 1.22 | 1.51 | 0.68 | 2.43 | 81.12 |
| *Surcula amicta* | 1.60 | 3.00 | 1.32 | 0.71 | 2.12 | 83.24 |
| *Murex acanthostephes* | 0.80 | 1.11 | 1.30 | 0.89 | 2.10 | 85.34 |
| *Rampana bulbosa* | 1.10 | 3.78 | 1.11 | 0.67 | 1.78 | 87.12 |
| *Natica lineate* | 0.20 | 0.67 | 1.08 | 0.69 | 1.74 | 88.86 |
| *Umbonium vestiarium* | 0.80 | 0.00 | 0.99 | 0.43 | 1.59 | 90.45 |

**Table 6.10.** SIMPER analysis of epifaunal abundance data for 31-35 m depth. The average dissimilarity between before and after trawling was 57.41

| Species | Average Abundance BT | Average Abundance AT | Average Dissimilarity | Dissimilarity/ s.d. | Contribution (%) | Cumulative (%) |
|---|---|---|---|---|---|---|
| *Chlamys tranquebaricus* | 76.43 | 194.22 | 4.46 | 0.94 | 7.77 | 7.77 |
| *Tibia curta* | 4.43 | 5.33 | 4.09 | 0.76 | 7.13 | 14.90 |
| *Chlamys singaporina* | 33.57 | 139.44 | 4.05 | 0.96 | 7.05 | 21.95 |
| *Anadara* spp. | 11.57 | 45.11 | 3.56 | 1.01 | 6.20 | 28.15 |
| *Paphia textile* | 40.57 | 220.89 | 3.12 | 0.74 | 5.43 | 33.59 |
| *Dosinia cretacea* | 7.71 | 44.44 | 2.87 | 1.12 | 4.99 | 38.58 |
| *Nassarius thersites* | 9.86 | 8.33 | 2.86 | 1.07 | 4.98 | 43.56 |
| *Bursa spinosa* | 4.14 | 6.00 | 2.50 | 1.04 | 4.35 | 47.90 |
| *Bursa echinata* | 1.57 | 5.78 | 2.35 | 1.19 | 4.09 | 51.99 |
| *Dentalium aprinum* | 6.43 | 5.89 | 2.13 | 1.03 | 3.71 | 55.70 |
| *Turricula javana* | 4.57 | 7.44 | 2.09 | 1.09 | 3.64 | 59.34 |
| *Balanus reticulatus* | 0.71 | 7.78 | 1.84 | 0.74 | 3.21 | 62.55 |
| *Scarpha inaequivalvis* | 4.29 | 1.44 | 1.82 | 0.90 | 3.17 | 65.72 |
| *Nassarius suturalis* | 2.86 | 1.78 | 1.71 | 0.76 | 2.98 | 68.70 |
| *Donax* sp. | 2.43 | 2.78 | 1.65 | 0.88 | 2.87 | 71.57 |
| *Balanus amphitrite* | 0.43 | 5.00 | 1.54 | 0.70 | 2.69 | 74.26 |
| *Natica didyma* | 3.71 | 4.89 | 1.48 | 1.05 | 2.58 | 76.84 |
| *Donax scortum* | 1.86 | 1.11 | 1.21 | 0.67 | 2.11 | 78.95 |
| *Surcula amicta* | 0.71 | 2.78 | 1.19 | 0.69 | 2.07 | 81.02 |
| *Murex acanthostephes* | 2.57 | 1.33 | 1.18 | 0.84 | 2.06 | 83.08 |
| *Dosinia gibba* | 1.43 | 4.00 | 1.12 | 0.81 | 1.95 | 85.03 |
| *Trisodos tortuosa* | 2.00 | 2.78 | 0.96 | 0.89 | 1.67 | 86.70 |
| *Xenophora solaris* | 1.57 | 3.33 | 0.90 | 0.67 | 1.56 | 88.26 |
| *Natica vitellus* | 0.71 | 0.44 | 0.77 | 0.64 | 1.34 | 89.60 |
| *Natica lineata* | 1.43 | 0.56 | 0.75 | 0.67 | 1.31 | 90.91 |

**Table 6.11.** SIMPER analysis of epifaunal abundance data for 36–40 m depth. The average dissimilarity between before and after trawling was 52.28

| Species | Average Abundance BT | Average Abundance AT | Average Dissimilarity | Dissimilarity/ s.d. | Contribution (%) | Cumulative (%) |
|---|---|---|---|---|---|---|
| *Chlamys singaporina* | 37.00 | 118.18 | 3.51 | 1.34 | 6.72 | 6.72 |
| *Chlamys tranquebaricus* | 64.00 | 79.91 | 3.06 | 1.04 | 5.85 | 12.57 |
| *Dosinia cretacea* | 16.30 | 217.82 | 2.87 | 1.17 | 5.50 | 18.06 |
| *Anadara* spp. | 14.50 | 15.45 | 2.83 | 1.20 | 5.41 | 23.48 |
| *Tibia curta* | 4.40 | 6.00 | 2.40 | 1.28 | 4.60 | 28.08 |
| *Paphia textile* | 54.50 | 270.91 | 2.38 | 0.97 | 4.55 | 32.63 |
| *Nassarius thersites* | 9.10 | 13.82 | 2.31 | 1.35 | 4.42 | 37.05 |
| *Umbonium vestiarium* | 4.40 | 3.64 | 2.03 | 1.13 | 3.88 | 40.93 |
| *Dosinia gibba* | 7.40 | 8.27 | 2.01 | 1.12 | 3.85 | 44.78 |
| *Donax* sp | 6.00 | 0.91 | 1.95 | 0.92 | 3.74 | 48.52 |
| *Bursa spinosa* | 2.70 | 4.55 | 1.93 | 1.12 | 3.69 | 52.20 |
| *Dentalium aprinum* | 4.70 | 5.73 | 1.87 | 1.27 | 3.57 | 55.77 |
| *Scarpha inaequivalvis* | 3.60 | 1.55 | 1.83 | 1.00 | 3.50 | 59.27 |
| *Natica didyma* | 0.70 | 2.73 | 1.73 | 0.82 | 3.31 | 62.58 |
| *Trisodos tortuosa* | 5.20 | 3.36 | 1.64 | 0.80 | 3.13 | 65.71 |
| *Turricula javana* | 1.70 | 3.00 | 1.49 | 0.93 | 2.84 | 68.55 |
| *Bursa echinata* | 1.10 | 4.64 | 1.43 | 1.00 | 2.73 | 71.29 |
| *Balanus amphitrite* | 1.60 | 1.45 | 1.34 | 0.77 | 2.57 | 73.85 |
| *Murex acanthostephes* | 4.00 | 1.09 | 1.27 | 0.97 | 2.44 | 76.29 |
| *Natica vitellus* | 1.30 | 1.73 | 1.15 | 1.01 | 2.20 | 78.48 |
| *Xenophora solaris* | 0.40 | 5.27 | 1.09 | 0.99 | 2.09 | 80.58 |
| *Balanus reticulatus* | 1.10 | 2.00 | 1.09 | 0.84 | 2.09 | 82.67 |
| *Nassarius suturalis* | 0.80 | 0.45 | 1.08 | 0.66 | 2.06 | 84.73 |
| *Paphia papilionis* | 1.70 | 1.00 | 0.93 | 0.57 | 1.77 | 86.51 |
| *Rampana bulbosa* | 0.90 | 3.09 | 0.92 | 0.83 | 1.75 | 88.26 |
| *Babylonia spirata* | 0.30 | 3.18 | 0.87 | 0.86 | 1.67 | 89.93 |
| *Natica lineata* | 0.70 | 1.09 | 0.76 | 0.69 | 1.46 | 91.38 |

### 6.3.5. Multidimensional scaling (MDS) plots for total epifauna

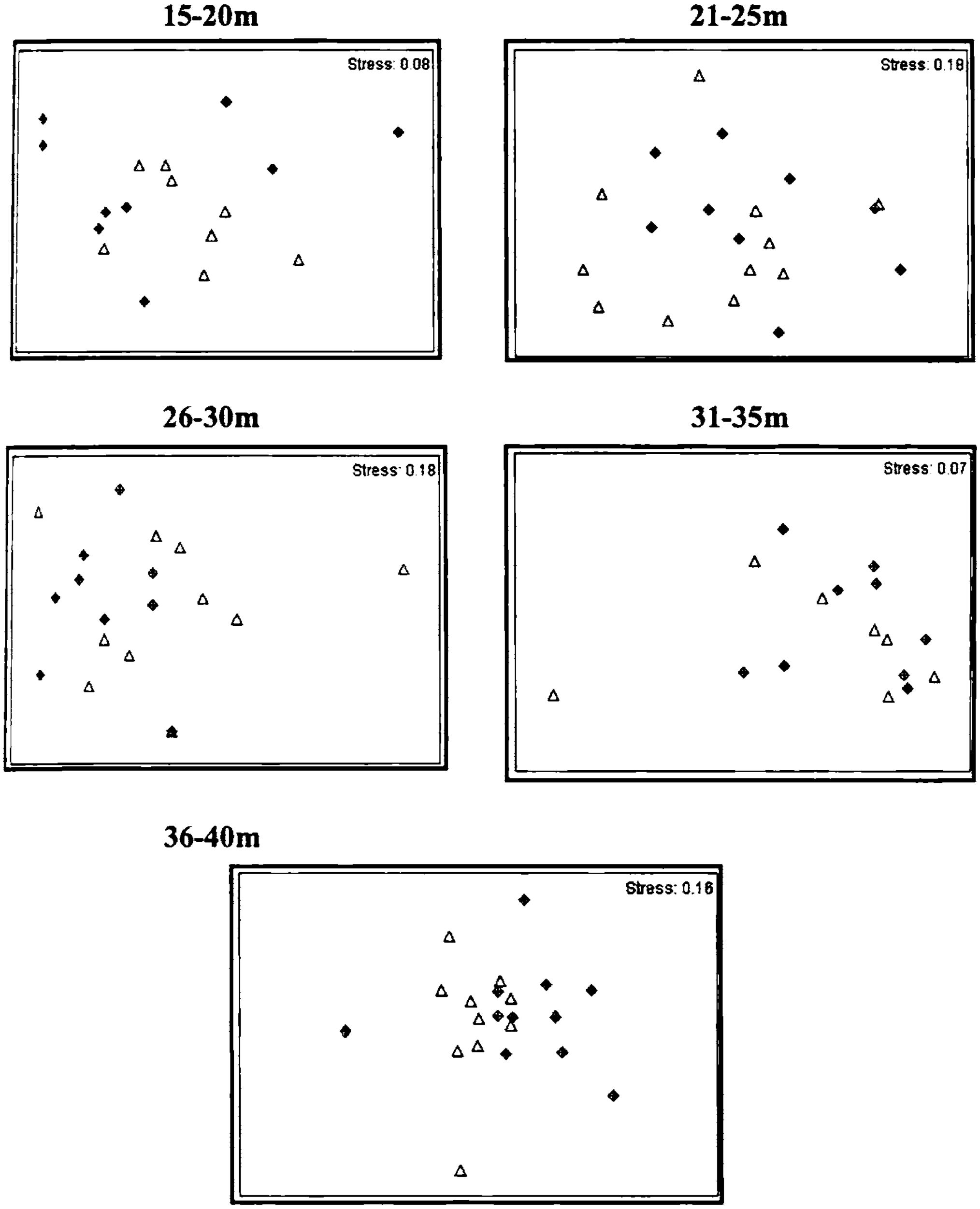



Fig. 6.9. Multidimensonal scaling (MDS) plots for total epifauna

△ Before Trawling ◆ After Trawling

In multidimensional scaling (MDS) plots (Figure 6.9), at 15-20 m water depth, the after trawling markers are more scattered than before trawling. Before trawling markers form a cluster at 15-20 m depth. At all other depths, before and after trawling markers are randomly scattered, showing no trawling impact. Tuck *et al.* (1998) used MDS plots to show that the treatment and reference areas were partly separated before trawling experiment; they became more distinct once the experimental trawling commenced and the communities changed over time.

## 6.4. Conclusions

The impact on bottom trawling on octocorals was evident in lightly trawled areas of 15-20 m water depth where bottom trawling is not prevalent due to rocky nature of seabed. Management strategies have to be adopted for the conservation and biodiversity protection of octocorals. A comprehensive underwater study needs to be undertaken to bring to light the precise impact. This will lead to management issues of mapping the areas where corals thrive and limiting or closing bottom trawling in these regions. In the present study, the abundance biomass comparison curves, multidimensional scaling plots and similarity of percentage analysis have proved to be a powerful indicator of impact of trawling disturbance on epifaunal communities of the area studied. The epifaunal abundance-biomass curve showed that the rate of stress increased with water depth. The shallow depths are lightly trawled due to intermittent rocky nature of bottom and as water depth increases, the trawling intensity increases. The W-statistic which is a synoptic descriptor of abundance-biomass curve were found to be negative in heavily trawled areas (26-30 m, 31-35 m and 36-40 m) and positive in lightly trawled areas (15-20 m and 21-25 m). By using the similarity of percentages in the SIMPER routine, the average epifaunal dissimilarity between before and after trawling was highest at 15-20 m water depth. This dissimilarity decreased with increasing water depths and was observed to be lowest at 36-40 m. The dissimilarity of fauna before and after experimental trawling was more evident in lightly trawled area and remained masked in heavily trawled area. The short-term effects were damage to molluscan shells and polychate tubes. The long term effects were evident on comparing lightly and heavily trawled areas.

# Chapter 7

# Impact of Bottom Trawling on Infaunal Macrobenthos

## 7.1. Introduction

Macrofauna constitute of small-bodied invertebrate organisms living in or on the sediments (Mare, 1942). They are an important component of the marine ecosystem and are indicators of the health of an ecosystem. They play an important role in an ecosystem through trophic dynamics as both prey and predator. The other errands of macrofauna include feeding and burrowing (bioturbation) activities, stabilizing sediments through tube-building and contributing larvae into pelagic and soft-bottom ecosystems. The macrofauna, being less mobile than the larger invertebrates and fishes, more accurately reflect the changes in the physical and chemical conditions of the soft-bottom ecosystem than the more mobile organisms. Monitoring the macrofaunal community is important because these organisms live in direct contact with the sediments and often ingest sediments and suspended particulates, which may contain organic food and/or contaminants (Gray *et al.*, 1992; Diener *et al.*, 1995). Soft-bottom sediments provide a long-term record of changing environmental conditions reflecting the effects created by natural or man-made disturbances. Impacts of anthropogenic inputs will be manifested in the sediments by changes in macrofaunal community structure (e.g., abundance, diversity, and biomass). The macrofaunal assemblage can reflect a gradient of tolerances (enhancement to degradation) in relation to environmental (man-made or natural) stresses (Warwick and Clark 1993, 1994; Diener *et al.*, 1995; Sheppard 1995).

McConnaughey *et al.* (2000) examined the impacts of bottom trawling in a shallow, soft-bottom area of the Bering Sea and reported higher densities and diversity of macrofauna in historically unfished areas. They observed drastic variations (both positive and negative) in the abundance of several macrobenthic species between heavily fished and unfished areas. Small- bodied opportunistic organisms such as polychaetes dominated heavily fished areas (Simboura *et al.*, 1998; Kaiser *et al.*, 2002). The biomass and abundance of macrofauna decreased significantly after trawling in Gullmarsfjorden, Sweden. The mean abundance of echinoderms, in particular the brittle stars *Amphiura*, decreased significantly after trawling in Gullmarsfjorden, Sweden (Hansson *et al.*, 2000). According to Kaiser *et al.* (1999) no significant changes in composition, size or number were noted in Northeast Atlantic shelf seas that could be attributed to fishing disturbance. Van Dolah *et al.* (1991) studied the effects of shrimp trawling on infaunal assemblages of two estuarine sounds in South Carolina. They concluded that five months of trawling did not have any obvious effect on the abundance, diversity or composition of the soft-bottom communities. Moreover, the natural seasonal variability was more prominent than trawling effects.

The present chapter intends to bring out the impact of trawling on macrobenthos in the commercial trawling grounds off Veraval coast. This is the first attempt to document the macrofaunal species of the study area.

## 7.2. Materials and Methods

After hauling the van Veen grab, the sediment samples for macrobenthos were sieved through 500µm sieve; sediment retained on sieve were transferred to one litre plastic bottles and preserved in 7% buffered formalin. In the laboratory, the sediment samples were again sieved through 500µm sieve for further identification. The organisms retained in the sieve were sorted out and preserved in 5% formalin. All organisms were identified to group level (Figure 7.1). Polychaetes (Fauvel, 1953, Day 1967a&b) and molluscs (Dance, 1976; Carpenter and Niem, 1998; www.gastropods.com) were identified to the species/ genus level as far as possible using stereomicroscope (Leica). The numerical abundance and wet weight were taken. The molluscs were weighed along with shell (wet weight). The numerical abundance was expressed as number $metre^{-2}$ and biomass expressed in gram $metre^{-2}$.

The statistical analysis was performed by SPSS version 12.0.1. An array of diversity indices was calculated using PRIMER v5 software package (Version 5.2.9; Plymouth Marine Laboratory, Plymouth, UK) (Clarke and Warwick, 2001). The diversity indices analysed were species (S), number (N), Margalef index (d), Pielou's evenness index (J'), Brillouin index (H), Fisher's Alpha (α), Shannon index (H'), Simpson index (1-λ') and Hill's no. (N1 and N2). The $\log_{10}$ (X+1) transformed indices were used for paired t test to find out any probable significant difference in the mean value of the indices before and after trawling in each depth zone. The statistical significance was measured at a $p < 0.05$. Abundance-Biomass Comparison (ABC) curves were plotted in order to ascertain whether the benthic communities had undergone any stress due to trawling pressure. The multidimensional-scaling (MDS) plots were constructed to visually determine the disturbance on macrofaunal assemblages before and after trawling.

**Fig. 7.1**. Sorting and identification

## 7.3. Results and Discussion

The groups of fauna represented were polychaetes, molluscs (gastropods, bivalves and scaphopods) crustaceans (crab, shrimp, cumaceans, amphipods, ostracods, isopods, copepods, squilla, balanids), foraminferans, nemerteans, cnidaria (octocorals), sipunculids, teleost fishes (mainly *Trypauchen vagina*, followed by *Filimanus similis*, leptocephalus and *Cynoglossus* sp.), pogonophores, pterobranchia, and brittle stars. A total of 81 species of polychaetes belonging to Errantia (36) and Sedentaria (45) were identified. 15 species of gastropods, 13 species of bivalves and 1 species of scaphopod constituted the molluscs. One macrobenthic octocoral was also identified (Figure 7.2). The major constituents of macrofauna are given in figures 7.3, 7.4, 7.5, 7.6 and 7.7. The abundance and biomass lists of macrofauna are given in Appendix II.

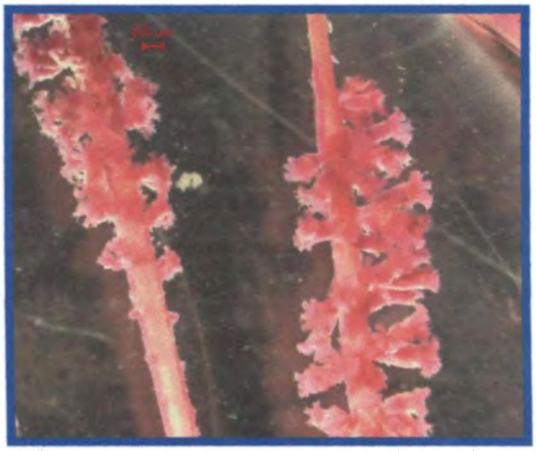


**Fig. 7.2.** Stereomicroscopic view of octocoral (7x).
*Lituaria* sp.

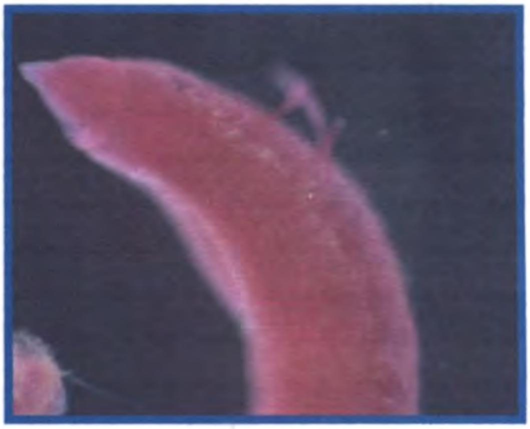

*Prionospio pinnata*

*Sternaspis scutata*

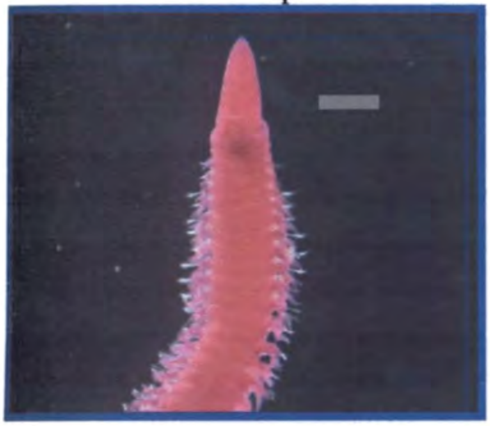
*Nereis* sp.

*Cossura coasta*

*Pherusa* sp.



*Cirratulus* sp.



*Lumbrinereis aberrans*

*Magelona cincta*

**Fig. 7.3.** Stereomicroscopic view of polychaetes (115x).

*Nassarius thersites*


*Meropesta pellucida*

*Olivia* $sp_1$

*Olivia* $sp_2$.

*Umbonium* sp.

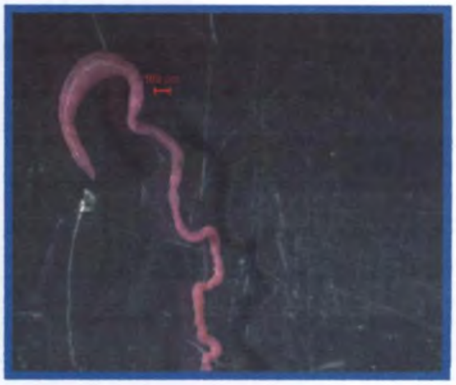
*Chlamys* sp.

**Fig. 7.4.** Stereomicroscopic view of molluscs (7x).

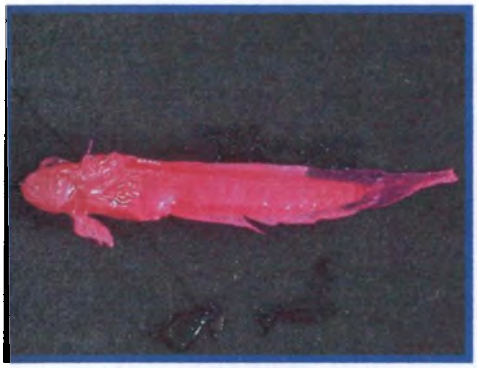
**Fig. 7.5.** Stereomicroscopic view of amphipods (7x).

Fig. 7.6. Stereomicroscopic view of cumaceans (7x).

Nemertine (7x)



Sipunculid (7x)

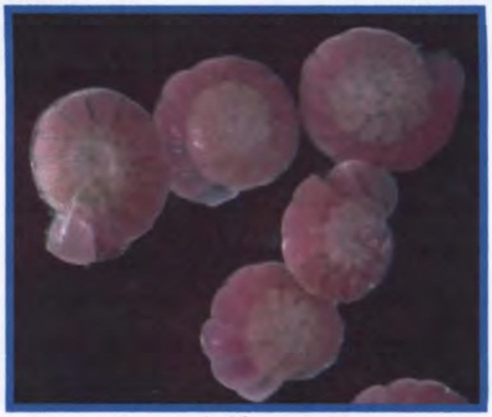


*Trypauchen vagina*

*Filimanus similis* (7x)

Leptocephalus

*Oratosquilla nepa*



Foraminiferans (7x)

**Fig. 7.7.** Other constituents of macrofauna

**7.3.1. Abundance and biomass**

The total numerical density of macrofauna increased after trawling exposing them from their natural habitat due to trawling (Figure 7.8). This is in par with the studies of Tuck *et al.* (1998), Ball *et al.* (2000), Pranovi *et al.* (2000), Sanchez *et al.* (2000), Gowda (2004), Zacharia (2004), Kurup (2004b) and Krishnan *et al.* (2005). They have also recorded an increase in the abundance of macrobenthos as an immediate effect of trawling. In the present study, the numerical density of macrofauna increased after trawl ban showing that trawl ban is giving some respite to the fauna for rejuvenation (Figure 7.8). According to Thomas and Kurup (2005c) and Thomas *et al.* (2006) the polychaetes increased in abundance and biomass during July when there was a ban on bottom trawlers in Kerala. They opined that the ban is useful for the regeneration and recoupement of polychaetes. The increase in number of polychaetes has been attributed to the survival of opportunistic species in response to bottom trawling (Gowda, 2004; Kurup, 2004b).

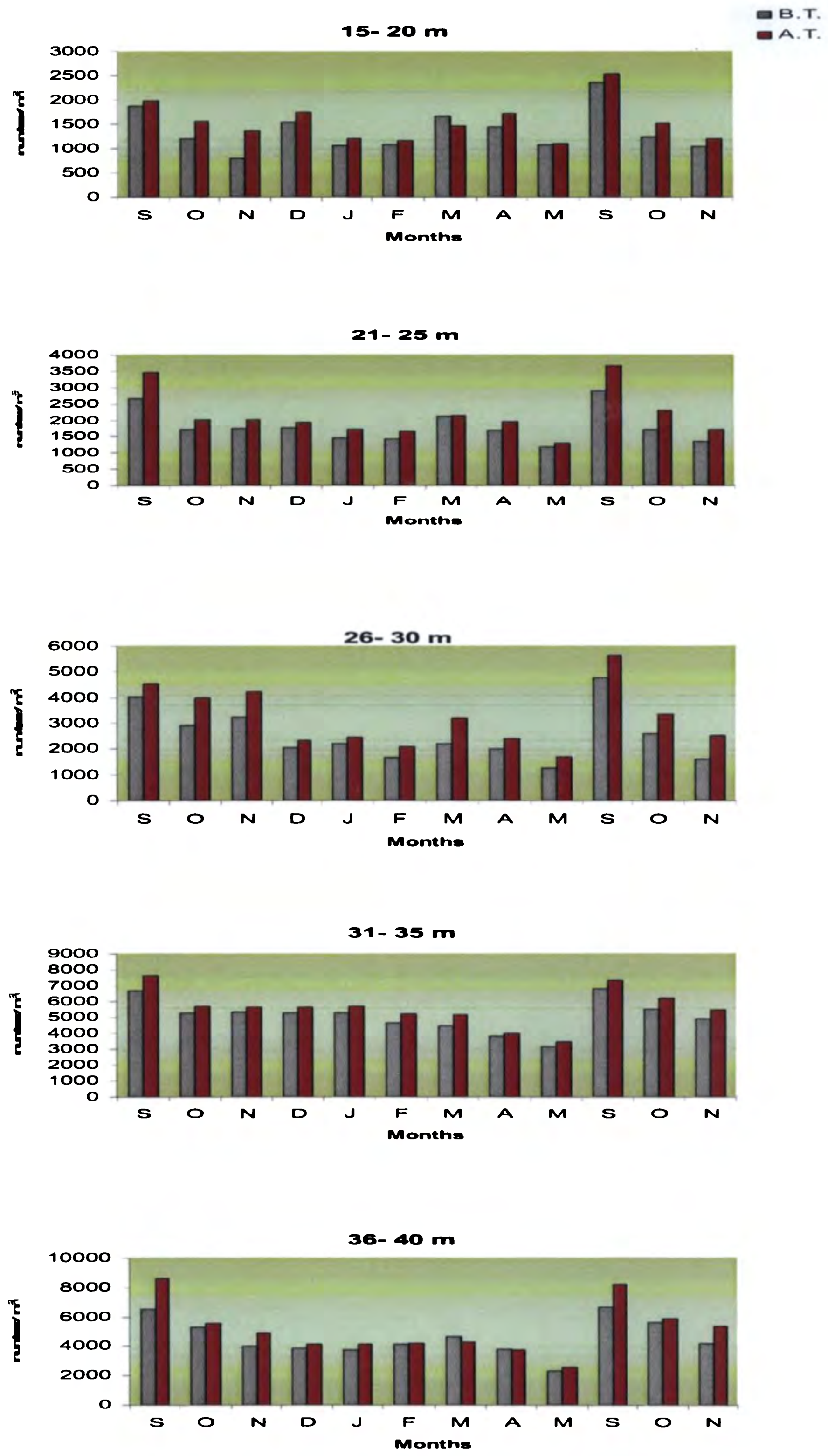
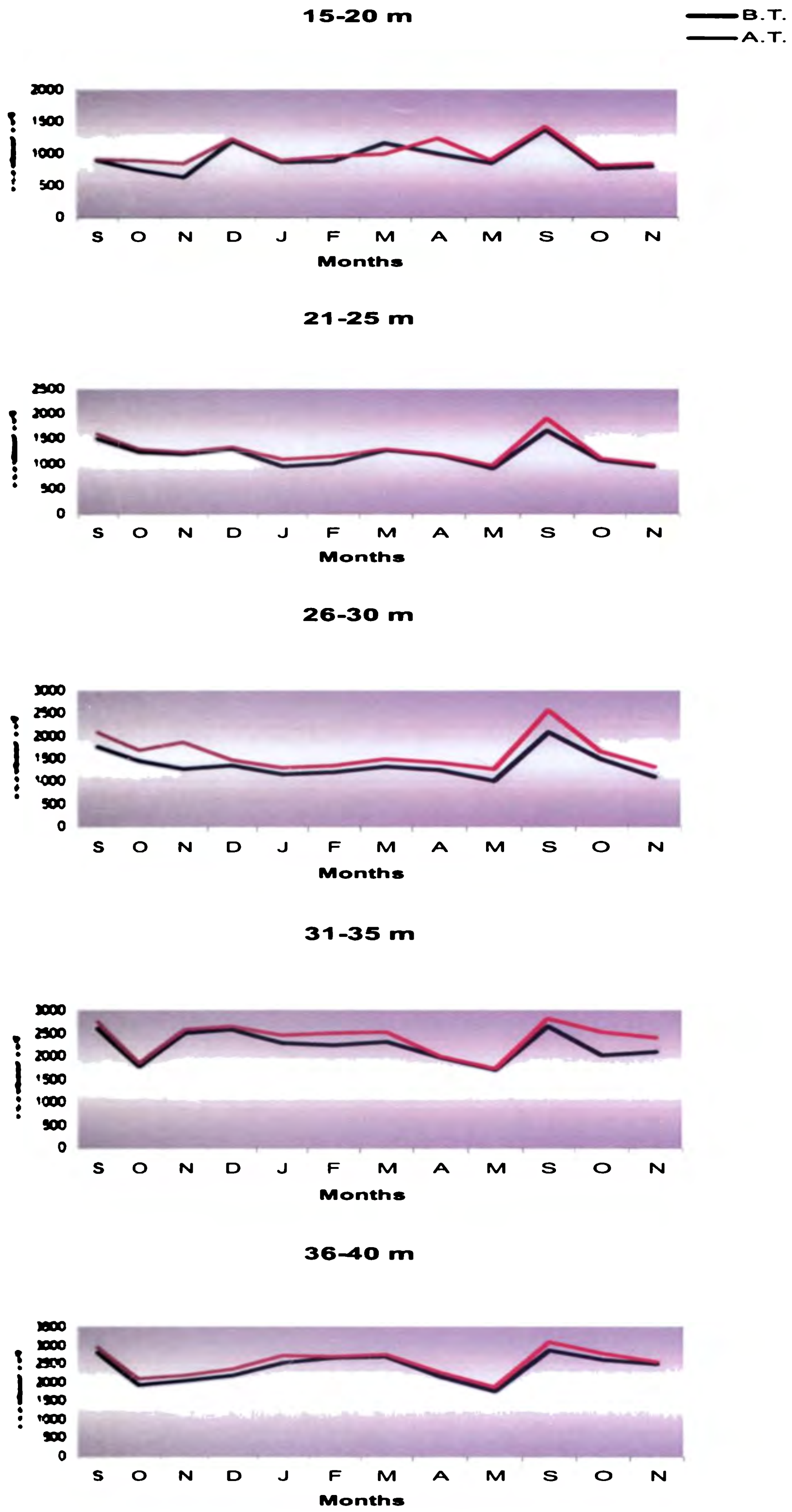



**Fig. 7. 8.** Variations in total numerical density (no.m$^{-2}$) of macrofauna before and after trawling during September 2005 to November 2006. BT - before trawling; AT - after trawling.

The polychaetes form the dominant macrobenthic community in the present study which is on par with the other studies conducted along northwest coast of India (Ingole *et.al.*, 2002; Joydas, 2002; Jayaraj, 2006). Immediately after experimental trawling, there was an increase in numerical density of polychaetes (Figure 7.9). Sedentarians were dominant both before and after trawling. The species dominant both before and after trawling in the study area are *Sternaspis scutata, Prionospio pinnata, Cossura coasta* and *Magelona cincta.* Polychaetes are small-sized, short-lived and exhibit a high secondary production. Hence they are an important link in marine food webs and contribute significantly in the diets of many bottom- feeding fishes. Being small-sized organisms, they play a crucial role in ecology and environmental impact assessment. As many of the polychaetes are sedentary in nature, changes in their abundance and diversity have been used in environmental monitoring (Khan and Murugesan, 2005). The experimental trawling operations conducted along Kerala coast showed that the abundance, biomass and diversity of the polychaetes increased immediately after trawling. This was attributed to their exposure due to the removal of top sediment. According to Thomas and Kurup (2006b) the fast growing and continuous breeding species dominated the trawl ban period. The Silver Pit region of the central North Sea is regularly fished by beam trawlers targeting sloe and plaice. Jennings *et al.* (2002) investigated the effects of trawling disturbance on the production of benthic infauna. The analyses showed that trawling did not have significant effect on the production of small infaunal polychaetes. Since small infaunal polychaetes are a key source of food for flatfishes, they concluded that beam trawling does not have a positive or negative effect on their food supply.

But contrasting reports by Rijnsdorp and Vingerhoed (2001) indicated that intensive beam trawling enhanced the abundance of small opportunistic benthic species for example polychaetes, thereby improving the feeding conditions for flatfishes such as plaice (*Pleuronectes platessa*) and sole (*Solea solea*). The study of Collie *et al.* (1997) revealed that many of the megafaunal species that were identified in the stomach content analysis of demersal fish on Georges Bank were decreased in abundance at the disturbed sites.




[illegible] Variations in total numerical density (no.$m^{-2}$) of polychaetes before and after trawling during September 2005 to November 2006 BT - before trawling; AT - after trawling.

The characteristic features of trawling impact i.e., the occurrence of broken polychaete tubes, molluscs shells and of brittle stars were observed in the study area. The molluscs were dominant at 40 m depth. The numerical abundance and biomass of molluscs increased with depth. This can be due to the marginal increase of sand proportion with depth (Bhagirathan *et al.*, 2008). According to Jayaraj *et al.* (2007), the molluscs were abundant in deeper areas having sandy sediment. On visual observation, bivalves were found mostly in damaged condition where as gastropods were found with intact shells. The intact shells of gastropods exhibited more diversity than bivalves. The damaged shells were mostly of bivalves like *Paphia textile, Dosinia cretacea* and *Arca navicularis.* The total numerical density of gastropods increased after experimental trawling at all depths (Figure 7.10). The numerical density of bivalves decreased after experimental trawling at all depths (Figure 7.11). This can be due to the exposure of gastropods while churning up of sediment and direct damage to bivalves. The direct mortality due to trawling occurs in the case of gastropods and bivalves in the trawl track (Bergman and van Santbrink, 2000a).

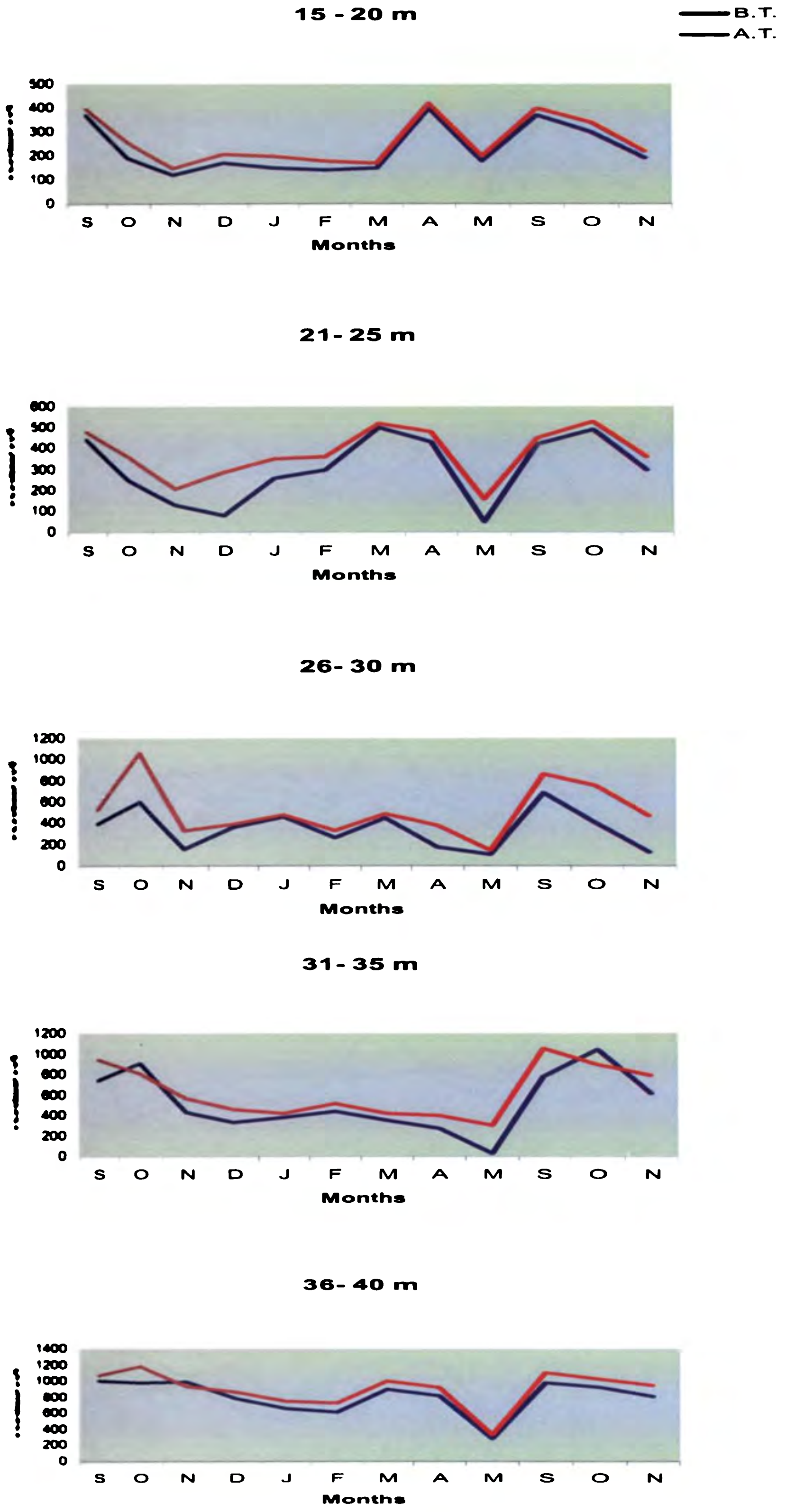



Fig. 7.10. Variations in total numerical density (no.$m^{-2}$) of gastropods before and after trawling during September 2005 to November 2006 BT - before trawling; AT - after trawling.

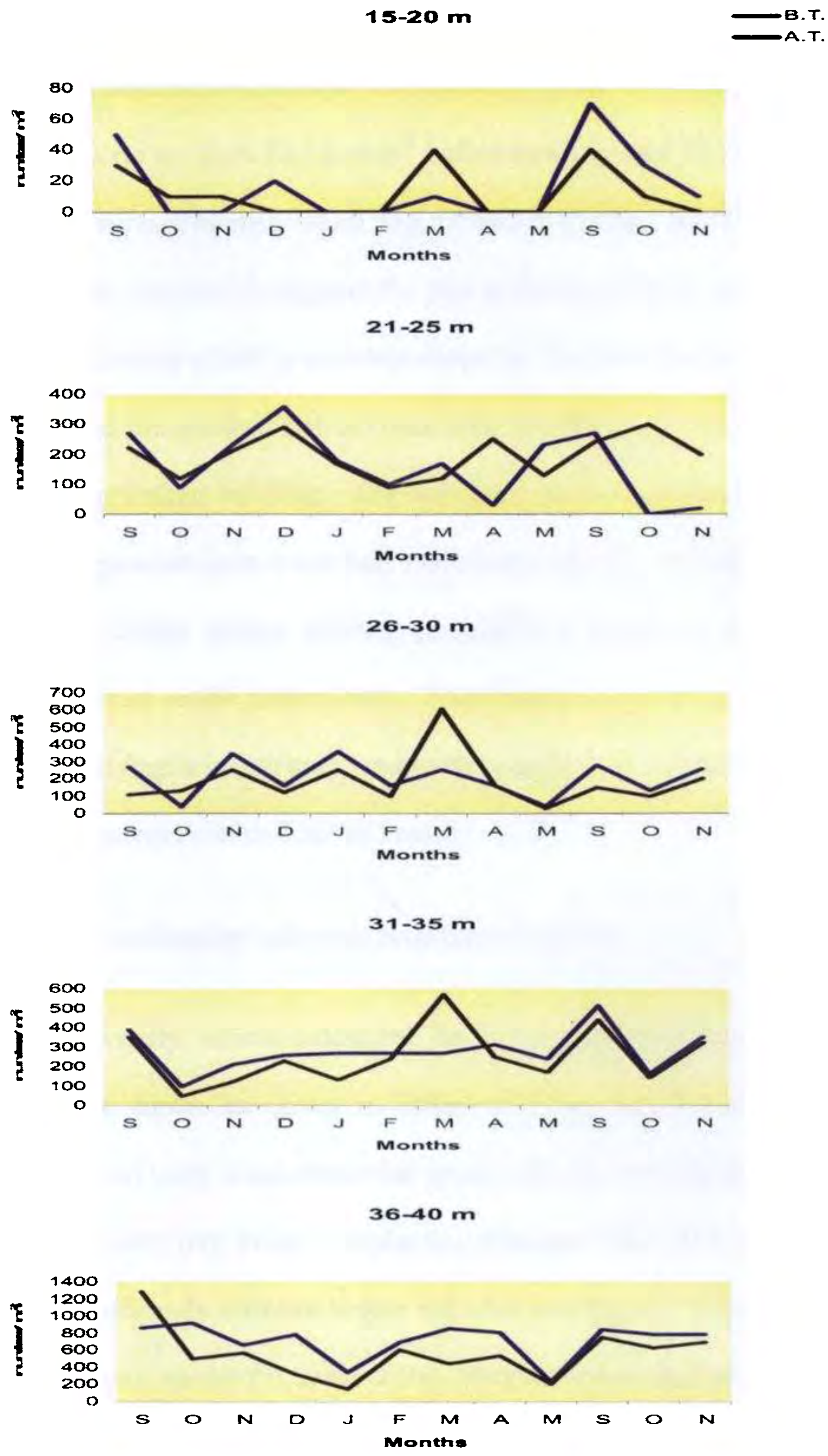



**Fig. 7.11.** Variations in total numerical density (no.$m^{-2}$) of bivalves before and after trawling during September 2005 to November 2006. BT - before trawling; AT - after trawling.

The macrobenthic octocoral observed in the current study was *Lituaria* sp. It was found at depths 21-40 m depth throughout the year. The average numerical density of *Lituaria* sp. were 13-14 no.$m^{-2}$ before trawling and 19-20 no.$m^{-2}$ after trawling. The average biomass was 0.06 g.$m^{-2}$ before trawling and 0.09 g.$m^{-2}$ after trawling. It was observed throughout the year at depths of 21-40 m because they escape from trawling effect to a certain extent as they live buried in sediment. The increase in the number and biomass after trawling signifies that they are exposed during bottom trawling. The sessile or erect structures like hydroids abundant in September (after trawl ban) were destroyed after trawling. According to Lokkeborg (2005), bottom trawling resulted in a significant decline in the abundance of erect sessile invertebrates. Blanchard *et al.* (2004) has opined that both sessile and fragile invertebrate species were lower in the most strongly fished areas off the western Atlantic coast of France.

### 7.3.2. Change in diversity indices of total macrobenthos

The diversity indices calculated for before and after trawling at five different water depths are given in Tables 7.1, 7.2, 7.3, 7.4 and 7.5. On performing paired t test, it was found that species (S), number (N), Margalef index (d), Brillouin index (H), Fisher's Alpha (α), Shannon index (H') and Hill's no. (N1) were significantly different before and after trawling ($P< 0.05$) at 15-20 m. At 21-25 m depth, species (S), number (N), Margalef index (d), Pielou's evenness index (J'), Brillouin index (H), Shannon index (H'), Simpson index (1-λ') and Hill's no. (N1 and N2) were significantly different before and after trawling ($P<0.05$). At 26-30 m, 31-35 m and 36-40 m, only number (N) was significantly different ($P<0.05$). All other indices were not significantly different before and after trawling at these depths ($P>0.05$). Hence it can be concluded that the diversity indices were significantly different before and after trawling at 15-20 m and 21-25 m. This variation was not observed at other water depths studied. This can be due to the fact that the stress on diversity was evident in lightly trawled areas, whereas it is masked in heavily trawled areas. The stations plotted at 15-20 m and 26-30 m can be considered as lightly trawled due to the intermittent rocky nature of sea bottom and prevalence of traditional fishing practices like gill netting. Due to chronic trawling by commercial vessels the exact impact may have been masked at stations 26-30 m, 31-35 m and 36-40 m. But a definite pattern of variation for before and after trawling diversity indices was not observed in the present study. Contrary to this, the Shannon's diversity index (H') increased in most of the stations immediately after trawling along Kerala coast (Thomas and Kurup, 2006b). Immediately after the trawling disturbance, the number of species, species abundance and diversity decreased in the trawled area in comparison to the reference area in Gulf of Maine (Sparks-McConkey and Watling, 2001). Van Dolah *et al.* (1991) on studying trawling impacts along South Carolina opined that there were no significant differences between trawled and non-trawled sites with regard to diversity indices. The diversity indices H', N1 and N2 were significantly greater in the moderately exploited area than in the strongly exploited area off the western Atlantic coast of France. In the same study, no significant variations were found for species richness, evenness, taxonomic diversity and distinctness (Blanchard *et al.*, 2004). The study conducted along Bay of Biscay, France showed that species richness was lower in heavily trawled areas (Vergnon and Blanchard, 2006). In a study conducted in a previously unfished sheltered Scottish Sea loch, H' and evenness decreased in the trawled area relative to the reference site (Tuck *et al.*, 1998).

**Table 7.1.** Diversity indices of before and after trawling at 15-20 m water depth

| Diversity Index | Before Trawling (Mean ± S.E.) | After Trawling (Mean ± S.E.) | Paired t test | Remarks |
|---|---|---|---|---|
| S | 31.08 ±3.47 | 21.92±2.16 | P = <0.001 | Significant |
| N | 1369.17±125.61 | 1546.67 ±119.23 | P = 0.007 | Significant |
| Margalef | 4.14±0.42 | 2.84±0.27 | P = <0.001 | Significant |
| Pieolu | 0.82±0.02 | 0.81±0.01 | P = 0.879 | Not Significant |
| Brillouin | 2.71±0.09 | 2.44±0.09 | P = 0.005 | Significant |
| Fisher | 5.68±0.67 | 3.63±0.38 | P = <0.001 | Significant |
| Shannon | 2.76±0.09 | 2.47±0.09 | P = 0.004 | Significant |
| Simpson | 0.89±0.01 | 0.87±0.01 | P = 0.245 | Not Significant |
| Hill's no. (N1) | 16.60±1.65 | 12.46±1.26 | P = 0.002 | Significant |
| Hill's no. (N2) | 10.42±0.99 | 8.66±0.85 | P = 0.090 | Not Significant |

**Table 7.2.** Diversity indices of before and after trawling at 21-25 m water depth

| Diversity Index | Before Trawling (Mean ± S.E.) | After Trawling (Mean ± S.E.) | Paired t test | Remarks |
|---|---|---|---|---|
| S | 25.33±2.67 | 29.33±2.34 | P = 0.020 | Significant |
| N | 1817.50 ±148.97 | 2157.50 ±204.11 | P = <0.001 | Significant |
| Margalef | 3.22 ± 0.32 | 3.68 ± 0.27 | P = 0.041 | Significant |
| Pieolu | 0.82 ± 0.01 | 0.88 ± 0.01 | P = <0.001 | Significant |
| Brillouin | 2.58± 0.09 | 2.92 ± 0.09 | P = <0.001 | Significant |
| Fisher | 4.17 ± 0.46 | 4.81 ± 0.38 | P = 0.053 | Not Significant |
| Shannon | 2.62 ± 0.09 | 2.95± 0.09 | P = <0.001 | Significant |
| Simpson | 0.90± 0.01 | 0.93± 0.01 | P = <0.001 | Significant |
| Hill's no. (N1) | 14.37± 1.42 | 20.01 ± 1.70 | P = <0.001 | Significant |
| Hill's no. (N2) | 10.40 ± 0.93 | 14.89± 1.23 | P = <0.001 | Significant |

**Table 7.3.** Diversity indices of before and after trawling at 26-30 m water depth

| Diversity Index | Before Trawling (Mean ± S.E.) | After Trawling (Mean ± S.E.) | Paired t test | Remarks |
|---|---|---|---|---|
| S | 26.25±2.31 | 30.33±4.55 | P = 0.150 | Not Significant |
| N | 2553.33±299.54 | 3200.83±340.74 | P = <0.001 | Significant |
| Margalef | 3.21 ± 0.25 | 3.60 ± 0.51 | P = 0.249 | Not Significant |
| Pieolu | 0.79 ± 0.01 | 0.80 ± 0.01 | P = 0.913 | Not Significant |
| Brillouin | 2.53 ± 0.07 | 2.59 ± 0.09 | P = 0.344 | Not Significant |
| Fisher | 4.09 ± 0.34 | 4.66 ± 0.75 | P = 0.253 | Not Significant |
| Shannon | 2.56 ± 0.07 | 2.62 ± 0.09 | P = 0.381 | Not Significant |
| Simpson | 0.89 ± 0.01 | 0.89 ± 0.01 | P = 0.950 | Not Significant |
| Hill's no.(N1) | 13.32 ± 0.94 | 14.28 ± 1.27 | P = 0.309 | Not Significant |
| Hill's no.(N2) | 9.53 ± 0.70 | 9.46 ± 0.65 | P = 0.908 | Not Significant |

Table 7.4. Diversity indices of before and after trawling at 31-35 m water depth

| Diversity Index | Before Trawling (Mean ± S.E.) | After Trawling (Mean ± S.E.) | Paired t test | Remarks |
|---|---|---|---|---|
| S | 36.00±3.12 | 37.25 ±4.10 | P = 0.536 | Not Significant |
| N | 5115.00±301.26 | 5615.00±336.95 | P = <0.001 | Significant |
| Margalef | 4.09 ± 0.34 | 4.18± 0.44 | P = 0.692 | Not Significant |
| Pieolu | 0.69 ± 0.01 | 0.67±0.01 | P = 0.148 | Not Significant |
| Brillouin | 2.41 ± 0.04 | 2.37 ± 0.05 | P = 0.442 | Not Significant |
| Fisher | 5.25 ± 0.49 | 5.38 ± 0.65 | P = 0.694 | Not Significant |
| Shannon | 2.43 ± 0.04 | 2.39 0.05 | P = 0.430 | Not Significant |
| Simpson | 0.82 ± 0.01 | 0.82 ± 0.01 | P = 0.502 | Not Significant |
| Hill's no.(N1) | 11.40 ± 0.43 | 11.08 ± 0.61 | P = 0.538 | Not Significant |
| Hill's no.(N2) | 5.65 ±0.20 | 5.55 ± 0.19 | P = 0.552 | Not Significant |

Table 7.5. Diversity indices of before and after trawling at 36-40 m water depth

| Diversity Index | Before Trawling (Mean ± S.E.) | After Trawling (Mean ± S.E.) | Paired t test | Remarks |
|---|---|---|---|---|
| S | 46.42±5.57 | 46.92±4.33 | P = 0.780 | Not Significant |
| N | 4595.83 ± 363.82 | 5134.17 ±512.24 | P = 0.025 | Significant |
| Margalef | 5.36 ± 0.61 | 5.36 ± 0.45 | P = 0.994 | Not Significant |
| Pieolu | 0.82 ± 0.01 | 0.83 ± 0.02 | P = 0.363 | Not Significant |
| Brillouin | 3.06 ± 0.08 | 3.14 ± 0.03 | P = 0.350 | Not Significant |
| Fisher | 7.23 ± 0.94 | 7.15 ± 0.66 | P = 0.840 | Not Significant |
| Shannon | 3.09 ± 0.08 | 3.16 ± 0.03 | P = 0.364 | Not Significant |
| Simpson | 0.92 ± 0.01 | 0.93 ± 0.01 | P = 0.484 | Not Significant |
| Hill's no.(N1) | 22.89 ± 2.12 | 23.84 ± 0.85 | P = 0.661 | Not Significant |
| Hill's no.(N2) | 13.87 ± 0.99 | 15.29 ± 1.14 | P = 0.427 | Not Significant |

### 7.3.3. Abundance Biomass Comparison curves for total macrobenthos

The Abundance Biomass Curve and W-statistic of the total macrofauna showed that the fauna of the area studied were moderately or grossly stressed (Figure 7.12). A paired t test revealed no significant difference in before trawling-after trawling w- statistic value for each water depth (P>0.05). It can be assumed that as bottom trawling is prevalent in the area since 1960's, the fauna is already stressed. So no changes could be observed before and after trawling in abundance biomass curve as the fauna is already stressed. Moderately or grossly stressed fauna may be indicative of long-term stress. The ABC curve of macrofaunal communities off the western Atlantic coast of France showed an undisturbed pattern with the biomass curve above the abundance curve. While the communities in the most strongly trawled areas showed a disturbed pattern (abundance curve above the biomass curve) and a moderately disturbed pattern with intersecting curves as described by Blanchard *et al.*, 2004. The ABC method is based on the assumption that increasing disturbance shifts communities from dominance by large-bodied species with low turn over rates toward dominance by small-bodied species with high turn over rates. In contrast with the theory that underlies the ABC method, along Bay of Biscay, France; higher trawl efforts do not shift benthic macrofaunal communities toward increasing domination by small-bodied opportunistic species. The dominant species in disturbed conditions were large-bodied organisms (Vergnon and Blanchard, 2006). In the current study, the short-term effects were revealed by damage to molluscan shells, polychaete tubes, presence of broken arms of brittle stars, damage to sessile structures and by stress to diversity indices. Simpson and Watling (2006), on studying the impacts of shrimp trawling in the Gulf of Maine, found that short term changes in macrofaunal community were evident, but did not result in long-term changes. Eventhough the impact on the tube dwelling polychaete, *Lanice conchilega* reefs of France was evident; it was followed by a relatively quick recovery (Rabaut *et al.*, 2008).

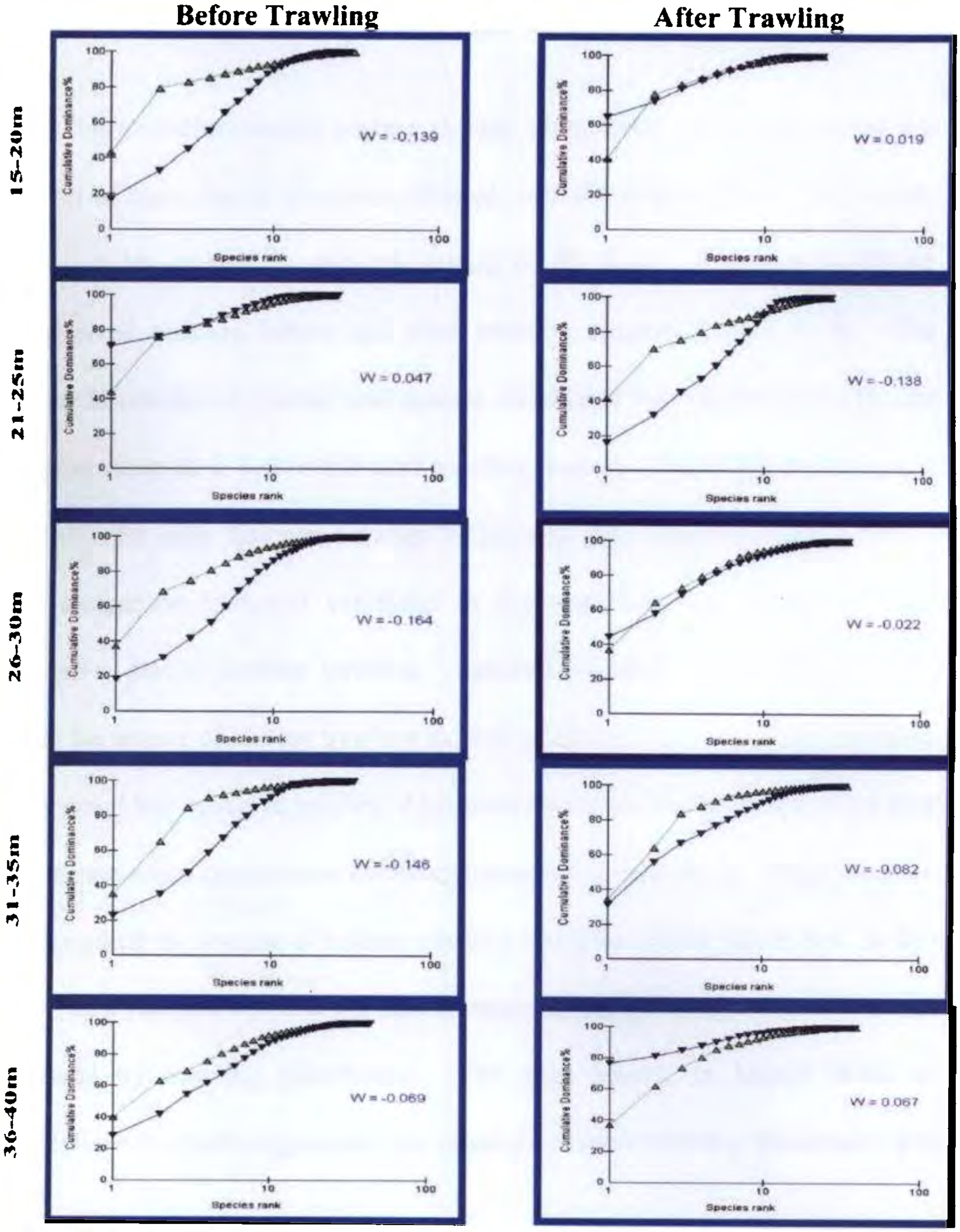



**Fig. 7.12.** Abundance Biomass Comparison curves for total macrobenthos at different water depths showing variations between before and after trawling

▲ Abundance ▼ Biomass

### 7.3.4. Multidimensional scaling (MDS) Plots for total macrobenthos

The multidimensional scaling (MDS) plots were constructed using the entire set of macrofaunal samples collected over the course of the experiment. MDS plots also enabled to prove the impact on the fauna. A definite stretching was observed between before and after trawling clusters (Figure 7.13). The variation in number of species and species abundance may be the cause for the stretching observed in before and after trawling clusters. According to Thomas *et al.* (2006), the wide distance between before and after trawling clusters, in the MDS comparison indicated variations in the abundance and biomass of the polychaetes due to bottom trawling. Sparks-McConkey and Watling (2001) studied the impact of bottom trawling in Gulf of Maine. In their study, the MDS plot revealed that sensitive species of bivalves decreased in abundance at the post trawl station while carnivorous nemertea increased in abundance. Duplisea *et al.* (2002) studied the impacts of bottom trawling along the central North Sea. In this study, MDS plot showed that the size structure of the infaunal communities was influenced by trawling disturbance. The sites subject to higher levels of disturbance was clearly separated from those sites where trawling disturbance was low.

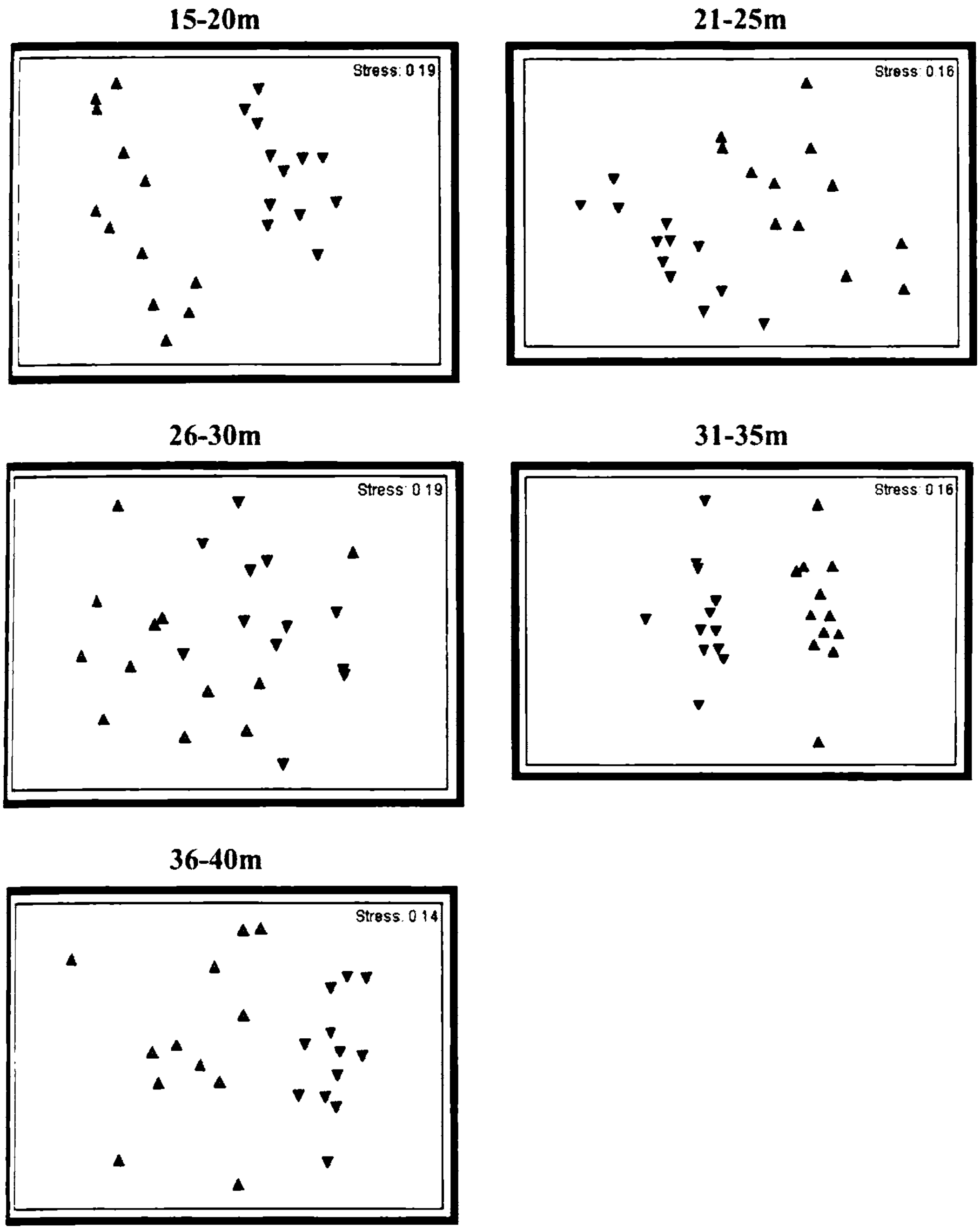



**Fig. 7.13.** Multidimensional scaling (MDS) plots for total macrobenthos
▲ **Before trawling** ▼ **After trawling**

### 7.3.5. Similarity of percentage (SIMPER) analysis for total macrobenthos

The results of SIMPER analysis considering different groups of fauna is given in Tables 7.6, 7.7, 7.8, 7.9 and 7.10. The average dissimilarity between before and after trawling was highest (average dissimilarity 26.87) at 15-20 m water depth (lightly trawled area). This dissimilarity decreased with other water depths. The average dissimilarity is in the order of 15-20 m (26.87) > 21-25 m (25.52)> 26-30 m (21.07)> 31-35 m (13.94). At 36-40 m the average dissimilarity was 22.46. The dissimilarity between before and after trawling is more evident in lightly trawled area of 15-20 m. With increasing water depths, the dissimilarity is decreasing as heavy trawling may be masking the impact after trawling. The dissimilarity between before and after trawling was contributed mostly by foraminiferans at 15-20 m and 21-25 m water depths. The sipunculids contributed maximum to the dissimilarity at 26-30 m, 31-35 m and 36-40 m water depths. The foraminiferans and sipunculids were found to increase in abundance after trawling.

**Table 7.6.** SIMPER analysis of macrofaunal abundance data for 15-20 m depth. The average dissimilarity between before and after trawling was26.87

| Species | Average Abundance BT | Average Abundance AT | Average Dissimilarity | Dissimilarity/ s.d. | Contribution (%) | Cumulative (%) |
|---|---|---|---|---|---|---|
| Foraminiferan | 43.33 | 134.17 | 5.28 | 1.43 | 19.65 | 19.65 |
| Nemertean | 36.67 | 46.67 | 3.40 | 1.44 | 12.65 | 32.30 |
| Teleost | 45.83 | 23.33 | 3.04 | 1.37 | 11.30 | 43.60 |
| Copepod | 15.83 | 20.00 | 2.37 | 1.28 | 8.83 | 52.42 |
| Sipunculid | 15.83 | 20.83 | 2.30 | 1.24 | 8.56 | 60.98 |
| Bivalve | 15.83 | 11.67 | 1.99 | 1.16 | 7.40 | 68.38 |
| Amphipod | 8.33 | 9.17 | 1.34 | 1.15 | 5.00 | 73.38 |
| Cumacean | 5.83 | 5.83 | 1.29 | 1.15 | 4.79 | 78.17 |
| Gastropod | 227.50 | 262.50 | 1.13 | 1.31 | 4.22 | 82.39 |
| Shrimp juvenile | 4.17 | 5.00 | 1.10 | 0.98 | 4.11 | 86.49 |
| Brittle Star | 2.50 | 2.50 | 0.72 | 0.73 | 2.68 | 89.18 |
| Polychaete | 934.17 | 1002.50 | 0.69 | 1.39 | 2.56 | 91.74 |

BT - before trawling; AT - after trawling

**Table 7.7.** SIMPER analysis of macrofaunal abundance data for 21-25 m depth. The average dissimilarity between before and after trawling was25.52

| Species | Average Abundance BT | Average Abundance AT | Average Dissimilarity | Dissimilarity/s.d. | Contribution (%) | Cumulative (%) |
|---|---|---|---|---|---|---|
| Foraminiferan | 16.67 | 135.00 | 4.29 | 1.26 | 16.80 | 16.80 |
| Cumacean | 40.00 | 33.33 | 2.87 | 1.32 | 11.25 | 28.05 |
| Bivalve | 162.50 | 195.00 | 2.85 | 1.07 | 11.18 | 39.23 |
| Sipunculid | 23.33 | 37.50 | 2.75 | 1.51 | 10.78 | 50.01 |
| Nemertean | 41.67 | 40.00 | 2.63 | 1.40 | 10.30 | 60.30 |
| Gastropod | 304.17 | 379.17 | 1.93 | 1.07 | 7.56 | 67.86 |
| Copepod | 5.83 | 20.00 | 1.73 | 0.90 | 6.79 | 74.65 |
| Amphipod | 6.67 | 13.33 | 1.34 | 1.03 | 5.26 | 79.91 |
| Shrimp juvenile | 5.83 | 10.83 | 1.09 | 1.25 | 4.25 | 84.16 |
| Teleost | 8.33 | 5.00 | 1.06 | 1.13 | 4.17 | 88.33 |
| Ostracod | 3.33 | 9.17 | 0.96 | 0.98 | 3.77 | 92.10 |
| Brittle star | 5.83 | 1.67 | 0.70 | 0.70 | 2.74 | 94.84 |
| Octocoral | 3.33 | 1.67 | 0.59 | 0.40 | 2.33 | 97.17 |
| Polychaete | 1190.00 | 1274.17 | 0.54 | 1.37 | 2.12 | 99.29 |
| Crab juvenile | 0.00 | 1.67 | 0.18 | 0.42 | 0.71 | 100.00 |

BT - before trawling; AT - after trawling

**Table 7.8.** SIMPER analysis of macrofaunal abundance data for 26-30 m depth. The average dissimilarity between before and after trawling was21.07

| Species | Average Abundance BT | Average Abundance AT | Average. Dissimilarity | Dissimilarity/ s.d. | Contribution (%) | Cumulative . (%) |
|---|---|---|---|---|---|---|
| Sipunculid | 245.83 | 301.67 | 4.35 | 1.32 | 20.63 | 20.63 |
| Foraminiferan | 212.50 | 361.67 | 2.31 | 0.96 | 10.98 | 31.61 |
| Bivalve | 205.00 | 184.17 | 2.23 | 1.44 | 10.56 | 42.17 |
| Shrimp juvenile | 43.33 | 32.50 | 1.83 | 1.36 | 8.70 | 50.88 |
| Copepod | 28.33 | 33.33 | 1.59 | 1.21 | 7.54 | 58.42 |
| Pogonophore | 18.33 | 34.17 | 1.58 | 1.18 | 7.51 | 65.93 |
| Gastropod | 350.00 | 520.00 | 1.34 | 1.27 | 6.36 | 72.29 |
| Cumacean | 16.67 | 25.83 | 0.98 | 1.10 | 4.63 | 76.92 |
| Amphipod | 26.67 | 34.17 | 0.94 | 1.18 | 4.47 | 81.39 |
| Teleost | 12.50 | 12.50 | 0.91 | 1.21 | 4.30 | 85.69 |
| Octocoral | 4.17 | 13.33 | 0.87 | 0.67 | 4.15 | 89.84 |
| Polychaete | 1378.33 | 1630.00 | 0.72 | 1.40 | 3.40 | 93.24 |
| Isopod | 5.00 | 10.00 | 0.59 | 0.79 | 2.82 | 96.06 |
| Ostracod | 4.17 | 6.67 | 0.55 | 0.77 | 2.63 | 98.69 |
| Crab juvenile | 0.83 | 0.00 | 0.11 | 0.30 | 0.52 | 99.21 |
| Nemertean | 1.67 | 0.00 | 0.10 | 0.44 | 0.45 | 99.66 |
| *Balanus* sp. | 0.00 | 0.83 | 0.07 | 0.30 | 0.34 | 100.00 |

BT - before trawling; AT - after trawling

Table 7.9. SIMPER analysis of macrofaunal abundance data for 31-35 m depth. The average dissimilarity between before and after trawling was 13.94

| Species | Average .Abundance BT | Average. Abundance AT | Average Dissimilarity | Dissimilarity/s.d. | Contribution (%) | Cumulative (%) |
|---|---|---|---|---|---|---|
| Sipunculid | 65.00 | 87.50 | 2.21 | 1.20 | 15.87 | 15.87 |
| Bivalve | 278.33 | 250.83 | 1.76 | 1.31 | 12.59 | 28.46 |
| Gastropod | 525.83 | 630.00 | 1.66 | 0.92 | 11.88 | 40.34 |
| Octocoral | 16.67 | 30.00 | 1.28 | 0.78 | 9.18 | 49.52 |
| Nemertean | 20.00 | 33.33 | 1.23 | 1.32 | 8.81 | 58.33 |
| Copepod | 7.50 | 23.33 | 0.95 | 1.25 | 6.83 | 65.16 |
| Cumacean | 15.83 | 20.83 | 0.86 | 1.34 | 6.20 | 71.36 |
| Amphipod | 13.33 | 22.50 | 0.81 | 1.68 | 5.80 | 77.16 |
| Teleost | 10.00 | 10.00 | 0.67 | 0.91 | 4.78 | 81.94 |
| Ostracod | 6.67 | 14.17 | 0.64 | 1.16 | 4.60 | 86.54 |
| Polychaete | 2235.83 | 2405.00 | 0.56 | 1.36 | 3.99 | 90.53 |
| Shrimp juvenile | 5.00 | 5.83 | 0.43 | 0.90 | 3.11 | 93.64 |
| Scaphopod | 6.67 | 2.50 | 0.40 | 0.86 | 2.86 | 96.51 |
| Foraminiferan | 1908.33 | 2076.67 | 0.35 | 1.29 | 2.53 | 99.04 |
| Isopod | 0.00 | 1.67 | 0.09 | 0.30 | 0.63 | 99.67 |
| *Oratosquilla nepa* | 0.00 | 0.83 | 0.05 | 0.30 | 0.33 | 100.00 |

BT - before trawling; AT - after trawling

Table 7.10. SIMPER analysis of macrofaunal abundance data for 36-40 m depth. The average dissimilarity between before and after trawling was 22.46

| Species | Average .Abundance BT | Average .Abundance AT | Average Dissimilarity | Dissimilarity/ s.d. | Contribution (%) | Cumulative (%) |
|---|---|---|---|---|---|---|
| Foraminiferan | 369.17 | 820.00 | 5.94 | 1.19 | 26.43 | 26.43 |
| Sipunculid | 82.50 | 105.00 | 2.76 | 1.24 | 12.30 | 38.72 |
| Nemertean | 58.33 | 91.67 | 2.39 | 1.20 | 10.63 | 49.35 |
| Amphipod | 53.33 | 66.67 | 1.60 | 1.31 | 7.13 | 56.48 |
| Bivalve | 715.00 | 556.67 | 1.60 | 1.28 | 7.13 | 63.61 |
| Octocoral | 17.50 | 22.50 | 1.47 | 0.91 | 6.52 | 70.13 |
| Scaphopod | 34.17 | 16.67 | 1.42 | 1.44 | 6.33 | 76.46 |
| Copepod | 11.67 | 19.17 | 1.19 | 0.96 | 5.28 | 81.74 |
| Polychaete | 2400.83 | 2520.83 | 0.89 | 1.44 | 3.94 | 85.68 |
| Gastropod | 810.83 | 883.33 | 0.80 | 1.35 | 3.55 | 89.23 |
| Shrimp juvenile | 10.83 | 5.83 | 0.60 | 1.03 | 2.69 | 91.92 |
| *Balanus* sp. | 7.50 | 10.00 | 0.56 | 0.88 | 2.51 | 94.43 |
| Crab juvenile | 8.33 | 2.50 | 0.47 | 0.82 | 2.08 | 96.51 |
| Cumacean | 7.50 | 9.17 | 0.43 | 1.21 | 1.93 | 98.44 |
| *Oratosquilla nepa* | 2.50 | 0.00 | 0.16 | 0.55 | 0.71 | 99.14 |
| *Pterobranchia* spp. | 0.83 | 0.00 | 0.07 | 0.30 | 0.32 | 99.47 |
| Pogonophore | 0.83 | 0.00 | 0.07 | 0.30 | 0.29 | 99.76 |
| Isopod | 0.00 | 0.83 | 0.05 | 0.30 | 0.24 | 100.00 |

BT - before trawling; AT - after trawling

Simpson and Watling (2006) used SIMPER analysis to show that macrofaunal communities in trawled and untrawled areas at Pumpkin were more dissimilar than at Monhegan, in the Gulf of Maine. The quick recovery of macrofaunal community after experimental trawling in *Lanice conchilega* (tube dwelling polychaete) reefs of France were explained by SIMPER analysis with decreasing dissimilarities over time (Rabaut *et al.*, 2008).

## 7.4. Conclusions

The total numerical density of macrofauna increased after trawling exposing them from their natural habitat due to trawling. The numerical density of macrofauna increased after trawl ban showing that trawl ban is giving some respite to the fauna for rejuvenation. The diversity indices were found to be significantly different before and after trawling at 15-20 m water depth and 21-25 m water depth. The stress on diversity was evident in lightly trawled areas while masked in heavily trawled areas. The short-term effects were revealed by damage to molluscan shells, polychaete tubes, presence of broken arms of brittle stars, damage to sessile structures and by stress to diversity indices. The Abundance Biomass Curve and w-statistic of the total macrofauna showed that the fauna of the area studied were moderately or grossly stressed. This may be indicative of long-term stress. MDS plots also enabled to prove the impact on the fauna. In SIMPER analysis, the dissimilarity between before and after trawling was more evident in lightly trawled area of 15-20 m. The dissimilarity decreased with increasing water depth. The present study ascertains the need for controlling the excess number of bottom trawlers. Continuous monitoring of macrofauna for a long period will also enable to build a database on changes in macrofaunal assemblage. The taxonomic studies on macrobenthos of fishing grounds have to be promoted. An updated electronic configuration key for polychaetes, gastropods, bivalves, amphipods, copepods, cumaceans etc will enable in making a permanent database for the macrobenthos. Cataloging the biodiversity, identification of indicator species and updating the new data generated will aid in taking up steps towards conservation of macrobenthos. Appropriate untrawled control sites and historical data on species composition for comparative studies are very much necessary for these kinds of studies. Whether the increase in numerical density of macrofauna has far reaching effects on commercial fishery has to be studied. Gut content analysis of commercially important fishes will reveal whether the impact on benthic fauna is reflected in the fishery.

# Chapter 8

# Impact of Bottom Trawling on Infaunal Meiobenthos

## 8.1. Introduction

Infauna are those animals that live entirely within the sediment. Meiofauna are infaunal organisms that pass through a 500µm sieve, but are retained in a 63µm sieve (Mare, 1942). They contribute significantly to the processing of carbon by benthic communities because they are abundant and have higher rates of reproduction and growth. The meiofauna have high diversity and lack pelagic larvae. For these reasons, meiofauna are widely regarded as the ideal organisms to study the potential ecological effects of anthropogenic impacts (Coull and Chandler, 1922). The impact of chronic trawling disturbance on meiofauna has been investigated in North Sea by Schratzberger and Jennings (2002), Schratzberger *et al.* (2002) and Duplisea *et al.* (2002). In India, this topic of research has been dealt along Kerala (Kurup, 2004a; Sreedevi, 2008) and Mangalore coast (Zacharia, 2004; Gowda, 2004). According to Zacharia (2004) the impact on meiobenthos varied with depth. The numerical density and biomass of meiofauna increased at 10 and 20 m depths after trawling while a decrease was noted at 30, 40 and 50 m depths. The increase in number of nematodes after trawling has been attributed to the dominance of opportunistic species in response to bottom trawling (Gowda, 2004). Post monsoon seasons of Kerala coast manifested a decline in abundance of nematodes. According to Kurup (2004a), the decline can be attributed to the lift of monsoon ban on trawling during this season. The aim of the present study is to assess the probable response of meiofaunal communities to experimental bottom trawling on real fishing grounds off Veraval coast.

## 8.2. Materials and Methods

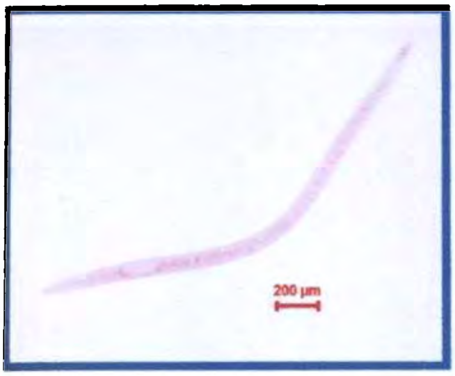
Immediately after hauling the van Veen grab, the undisturbed nature of the sediment was ascertained and sub samples were taken for meiobenthos by using a glass corer with an internal diameter of 3.81 cm and a length of 20 cm. The core samples were sliced onboard into 3 equal parts of upper, lower and middle portion. Each portion was then transferred to 150 ml plastic bottles and fixed in 7% buffered formalin. In the laboratory, the core samples were washed through a set of 500µm and 63µm sieves. The sediment retained in the 63µm was used for meiofauna extraction by the classic method of decantation. All meiofaunal organisms were sorted from sediment and enumerated under stereomicroscope (Leica). The organisms were preserved in 5% buffered formalin and identified to the group level. The number and wet weights of the organism were taken. The organisms that were intact were counted. Incomplete organisms were tallied as fragments. The numerical density was expressed in number/10 $cm^2$ and biomass in mg/10 $cm^2$. Primer v5 was the statistical package used for calculating the diversity indices of meiofaunal organisms before and after trawling (Clarke and Warwick, 2001). The sediment core samples collected before and after experimental trawling during the period September 2005 to November 2006 were made use for this study.

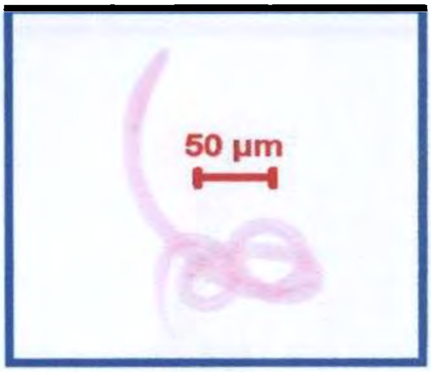
The total number of individuals (N), total number of species (S), Shannon-Wiener-Index (H'), species richness (Margalef's d), eveness (Pielou's J'), Brillouin index (H), Fisher's Alpha (α), Hill's no. ($N_1$ and $N_2$), Simpson's index (1-λ'), Taxonomic diversity index (Δ), Taxonomic distinctness index (Δ*), Average Taxonomic Diversity index (Δ+ or AvTD), Total Taxonomic Distinctness (s Δ+ or TTD), Variation in Taxonomic Distinctness (Var TD or Lambda+), Average Phylogenetic Diversity (φ+ or AvPD) and Phylogenetic Diversity (s φ+ or PD) were calculated to describe meiofaunal community structure. The $\log_{10}$ (X+1) transformed indices were used for one way ANOVA of SPSS 12.0.1. to find out any significant difference in the mean value of the indices before and after trawling in each depth zone. Abundance-Biomass Comparison (ABC) curves were plotted in order to ascertain whether the benthic communities undergone any stress due to trawling pressure. The similarity percentages programme (SIMPER) analysis revealed the most abundant species in each depth zone before and after trawling. Similarity matrix for each depth zone was constructed and multidimensional scaling (MDS) plots were made to visually determine disturbance on faunal assemblages before and after trawling.

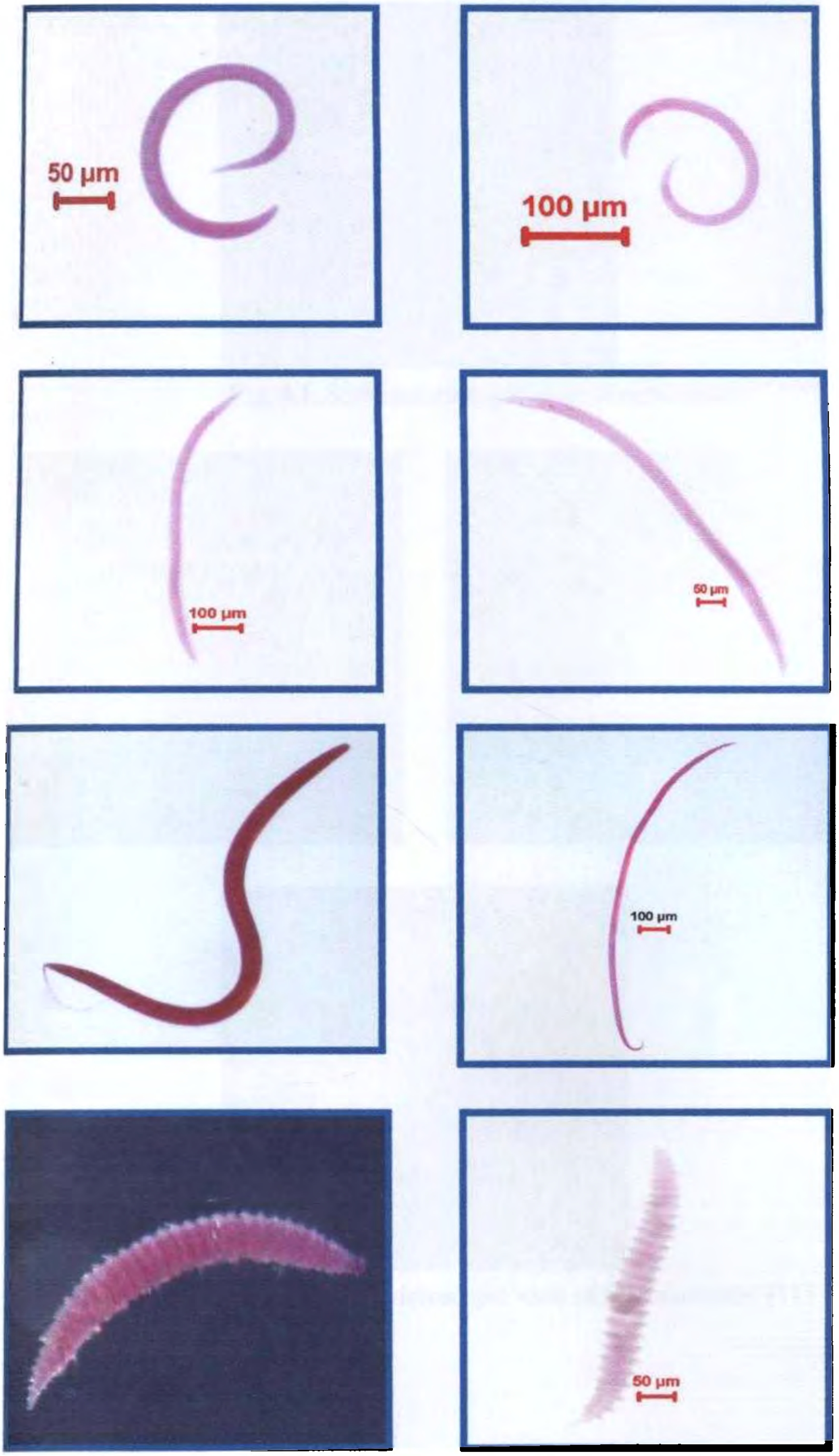
## 8.3. Results and Discussion

### 8.3.1. Infaunal meiofaunal abundance

The meiobenthos were represented by eight groups, of which the nematodes (48%) (Figure 8.1) constituted the bulk of the population followed by foraminiferans (47%) (Figure 8.2). Polychaetes (Figure 8.3), kinorhynchs (Figure 8.4), harpacticoid copepods (Figure 8.5), ostracods (Figure 8.6), acari (Figure 8.7), and bivalves were present in low densities and were of irregular occurrence. The abundance and biomass lists of meiofauna are given in Appendix III. The total meiofauna ranged from 134 to 710, 180 to 737, 385 to 1247, 509 to 1581, and 668 to 1851 No./10cm$^2$ before trawling at stations at depth 15-20 m, 21-25 m, 26-30 m, 31-35 m and 36-40 m respectively. After trawling the abundance ranged in between 153 - 762, 258 - 835, 472 - 1405, 557 - 1656, 668 - 1851 and 788 - 2273 No./10cm$^2$ at depths 15-20 m, 21-25 m, 26-30 m, 31-35 m and 36-40 m respectively. Meiobenthos densities were appreciably high along 36-40 m depth (mean 1177 nos./10 cm$^2$) and lowest at depth 15-20 m (mean 391 nos./10 m$^2$). More than 90% of the fauna resided in the upper core (Figure 8.8 and Figure 8.9). The total numerical abundance increased after trawling at all depths (Figure 8.10). An average 13 % increase in abundance was noted after experimental trawling. This increase in abundance after trawling is mainly contributed by nematodes and foraminiferans that form the major proportion of fauna at all depths (Figure 8.11). Similar results were observed in the studies conducted at Kerala and Mangalore showing significant increase in the density of nematodes and foraminiferans after trawling (Zacharia, 2004; Kurup, 2004b).

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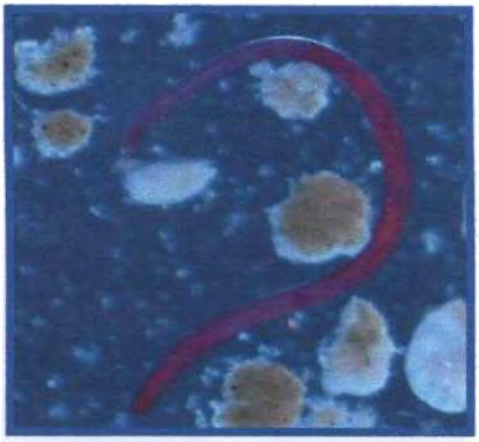


Fig. 8.1. Stereomicroscopic view of nematodes (115 x)

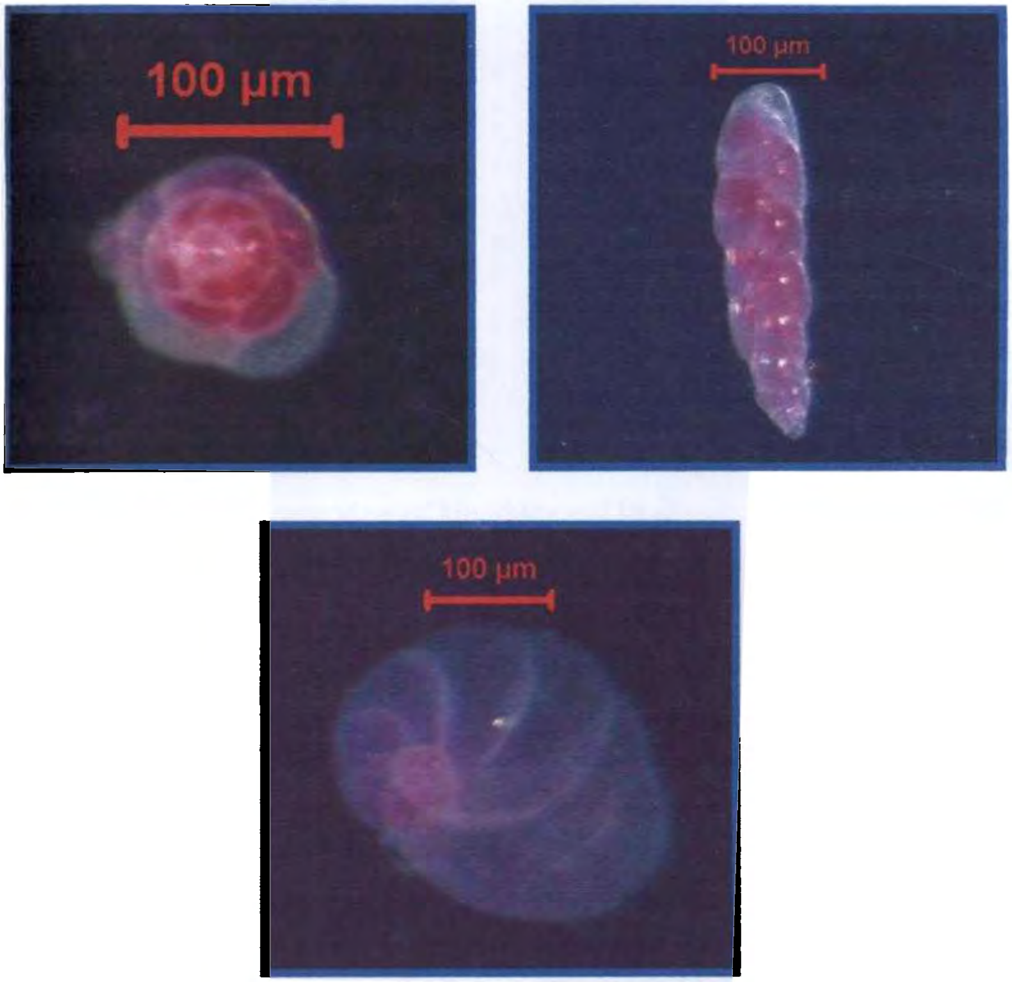



Fig. 8.2. Stereomicroscopic view of foraminiferans (115 x)


Fig. 8.3. Stereomicroscopic view of polychaetes (115 x)

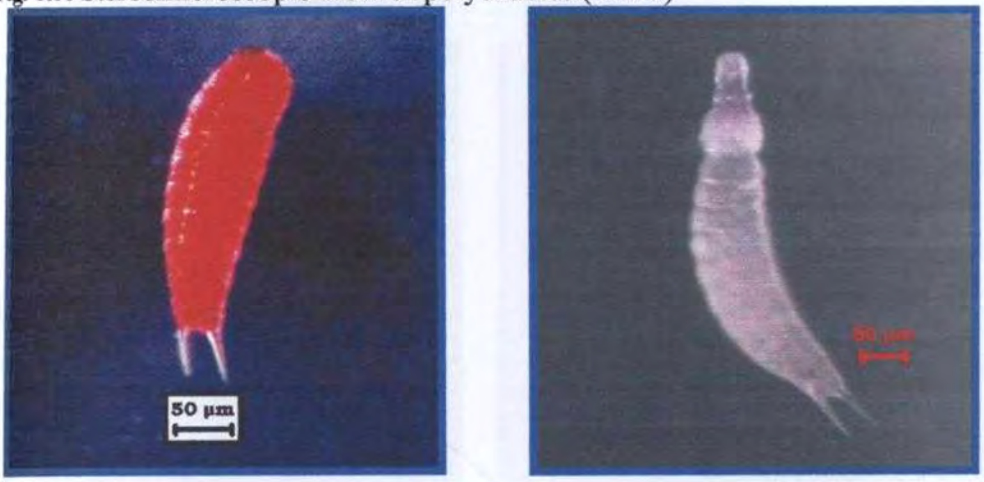



Fig. 8.4. Stereomicroscopic view of kinorhyncs (115 x)

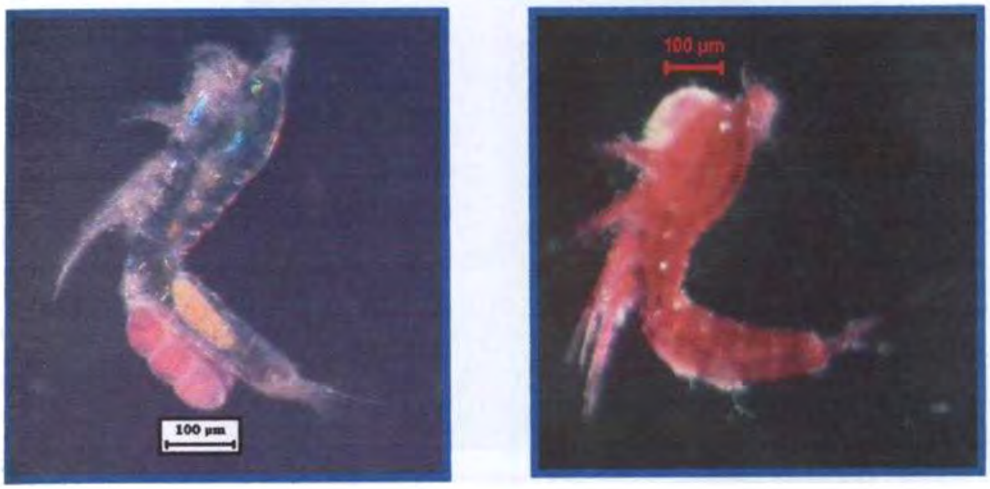



Fig. 8.5. Stereomicroscopic view of harpacticoid copepods (115 x)

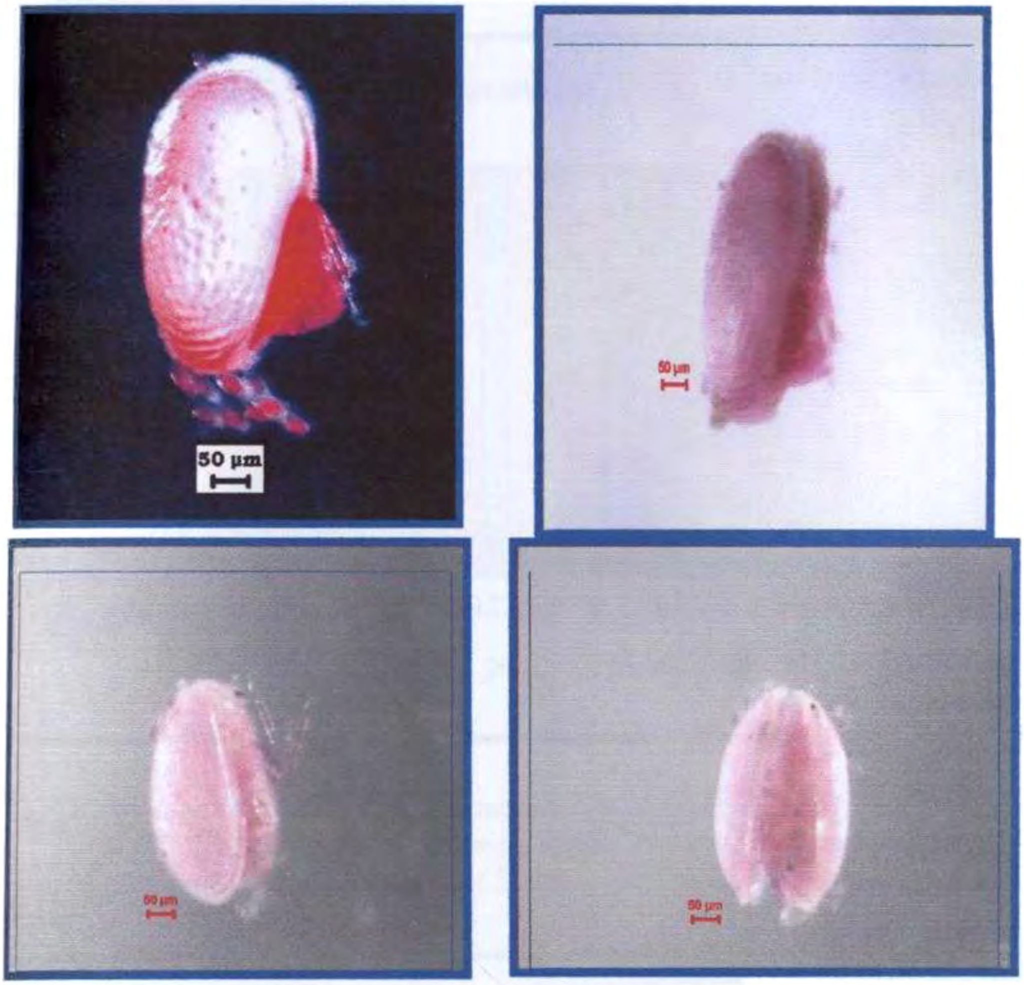



Fig. 8.6. Stereomicroscopic view of ostracods (115 x)

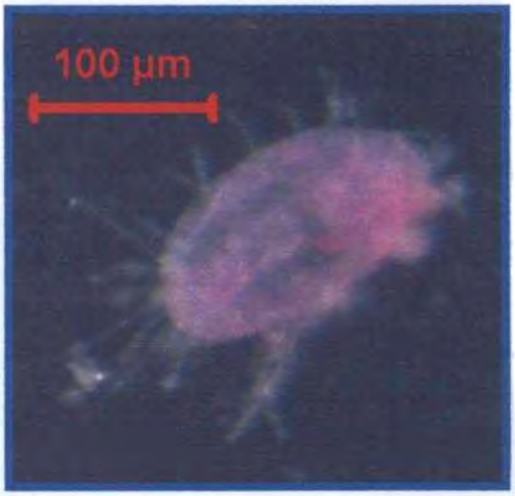



Fig. 8.7. Stereomicroscopic view of acari (115 x)

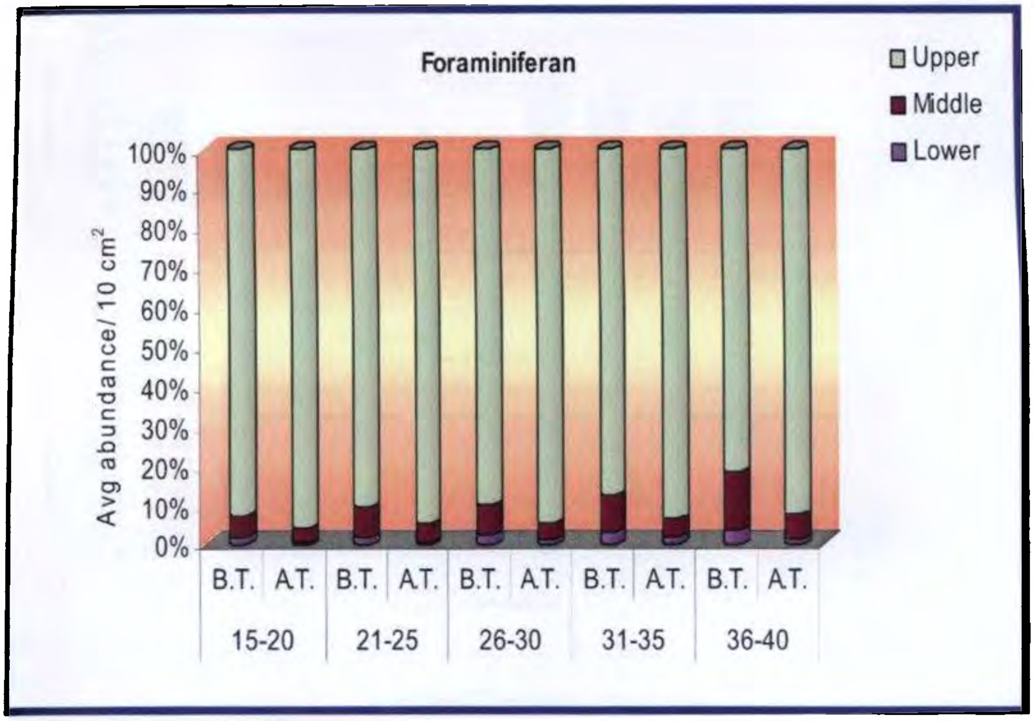



**Fig. 8.8.** Average numerical density (number/ 10 $cm^2$) of meiofaunal foraminiferan at different water depths showing upper, middle and lower core abundance (September 2005 – November 2006)

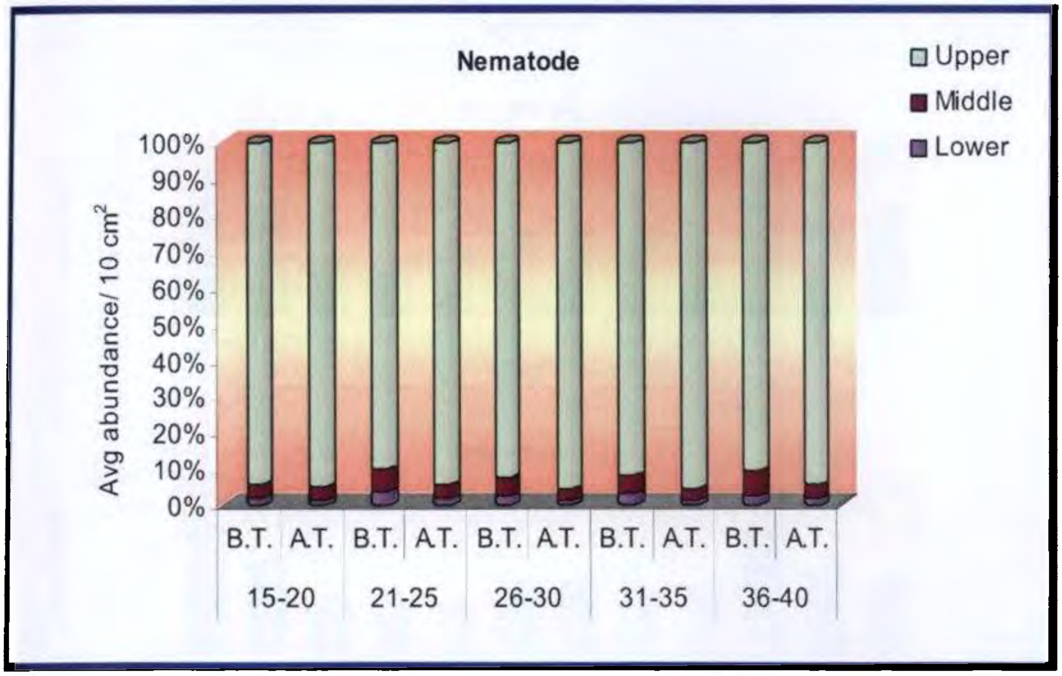



**Fig. 8.9.** Average numerical density (number/ 10 $cm^2$) of meiofaunal nematodes at different water depths showing upper, middle and lower core abundance (September 2005 – November 2006)

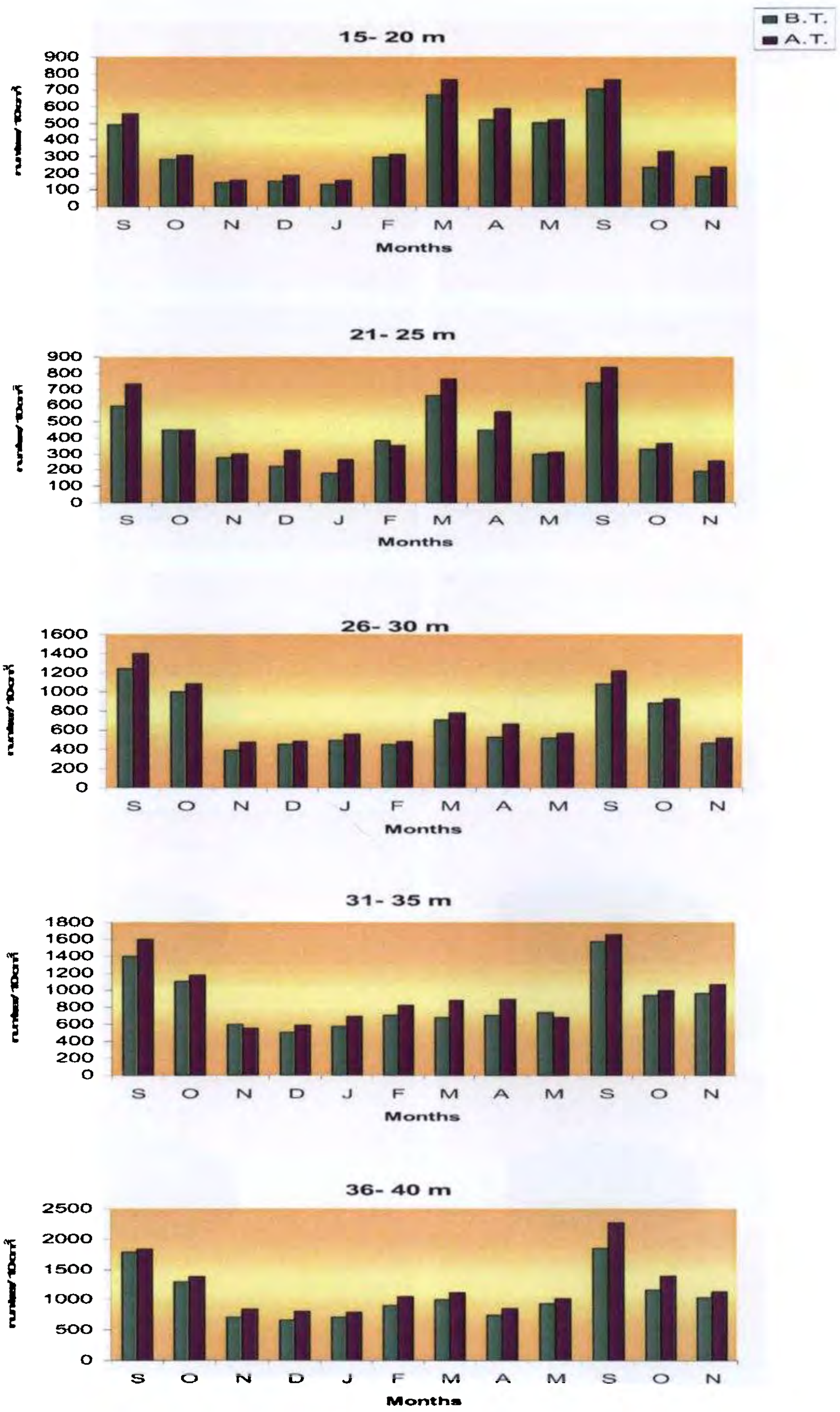



**Fig. 8.10.** Variations in total numerical density (number/ 10 $cm^2$) of meiofauna before and after trawling during September 2005 to November 2006

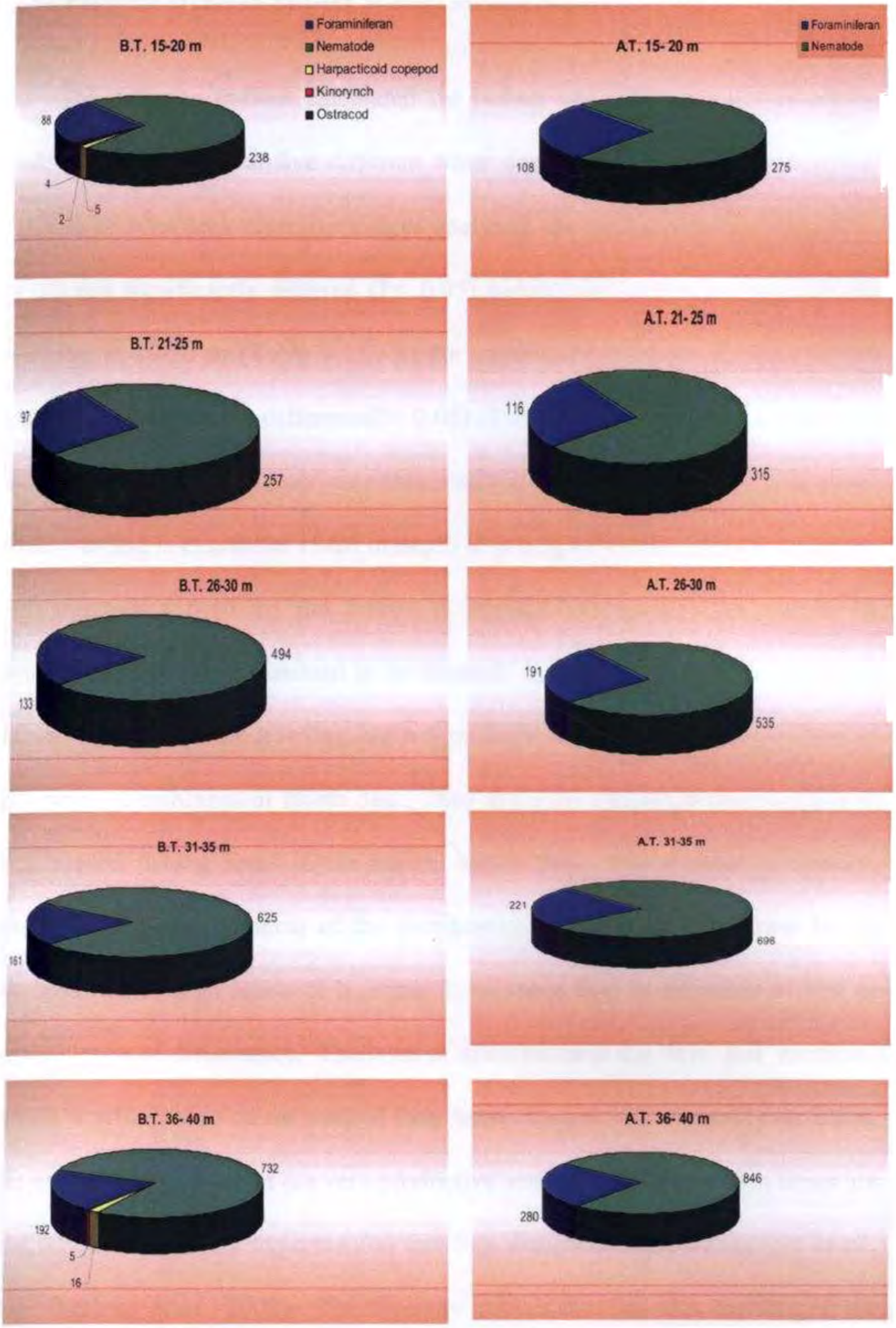



**Fig.8.11.** Average numerical density (number/ 10 $cm^2$) of dominant meiofaunal taxa at different water depths showing before and after trawling values (September 2005 – November 2006)

**8.3.2. Change in diversity indices of total meiobenthos**

The diversity indices calculated for before and after trawling in upper, middle and lower cores at five different water depths are given in Tables 8.1 to 8.15. Out of seventeen diversity indices analysed, the highest number of indices (ie, ten) that significantly differed (P< 0.05) before and after trawling is in the upper core at 15-20 m (Table 8.1). In the upper core at 36-40 m, none of the indices were significantly different (P> 0.05) (Table 8.13). As more than 90% of the fauna, resides in the upper core this result is very important. The impact of bottom trawling is evident at 15-20 m depth as it is lightly trawled area. As water depth increases (36-40 m) the station is heavily trawled and the impact on diversity indices may be assumed to be masked. According to Schratzberger and Jennings (2002), chronic trawling has a significant impact on the composition of meiofaunal assemblages of North Sea. They analysed nematode communities in beam-trawled fishing areas in the central North Sea. The number of species, diversity and species richness of the community were significantly lower in the area subjected to high levels of trawling disturbance than in the areas of low or medium levels of disturbance. The level of disturbance at the 'low' and 'medium' areas is insufficient to cause marked long term changes in community structure. The smaller meiofauna that are very productive and have fast generation times are relatively unaffected by experimental trawling disturbance (Schratzberger *et al.*, 2002; Duplisea *et al.*, 2002). The diversity indices reduced after trawling in the studies conducted by Zacharia (2004) and Kurup (2004b) along Kerala coast.

Table 8.1. Diversity indices of total meiobenthos in upper core at 15-20 m.
* Significant difference of the index before and after trawling (P<0.05)

| Diversity Index | Trawling Mode | Mean | S.E. | Minimum | Maximum |
|---|---|---|---|---|---|
| S* | BT | 5.00 | 0.54 | 2.00 | 7.00 |
| | AT | 3.00 | 0.19 | 2.00 | 4.00 |
| N | BT | 417.00 | 71.62 | 147.00 | 825.00 |
| | AT | 473.00 | 76.49 | 173.00 | 930.00 |
| Margalef * | BT | 0.59 | 0.08 | 0.19 | 0.95 |
| | AT | 0.26 | 0.03 | 0.15 | 0.47 |
| Pieolu* | BT | 0.52 | 0.05 | 0.36 | 0.97 |
| | AT | 0.68 | 0.06 | 0.40 | 0.99 |
| Brillouin | BT | 0.68 | 0.05 | 0.31 | 0.97 |
| | AT | 0.58 | 0.03 | 0.34 | 0.68 |
| Fisher* | BT | 0.74 | 0.09 | 0.31 | 1.12 |
| | AT | 0.37 | 0.03 | 0.24 | 0.58 |
| Shannon | BT | 0.70 | 0.05 | 0.33 | 0.99 |
| | AT | 0.59 | 0.03 | 0.36 | 0.69 |
| Simpson | BT | 0.42 | 0.03 | 0.18 | 0.53 |
| | AT | 0.39 | 0.02 | 0.20 | 0.50 |
| Hill's N1* | BT | 2.03 | 0.09 | 1.39 | 2.68 |
| | AT | 1.81 | 0.05 | 1.43 | 1.99 |
| Hill's N2 | BT | 1.74 | 0.07 | 1.22 | 2.14 |
| | AT | 1.67 | 0.06 | 1.26 | 1.98 |
| Tax_ div | BT | 40.86 | 2.56 | 18.45 | 50.50 |
| | AT | 39.03 | 2.44 | 20.46 | 49.75 |
| Tax_ dist* | BT | 98.15 | 0.53 | 94.67 | 100.00 |
| | AT | 99.65 | 0.22 | 97.32 | 100.00 |
| AvTD* | BT | 87.92 | 2.08 | 80.00 | 100.00 |
| | AT | 95.83 | 1.49 | 83.33 | 100.00 |
| TTD* | BT | 392.11 | 40.56 | 200.00 | 573.33 |
| | AT | 244.44 | 14.05 | 200.00 | 333.33 |
| VarTD | BT | 186.98 | 42.22 | 0.00 | 455.56 |
| | AT | 75.00 | 36.88 | 0.00 | 455.56 |
| AvPD* | BT | 85.62 | 2.65 | 76.00 | 100.00 |
| | AT | 95.56 | 1.71 | 80.00 | 100.00 |
| PD* | BT | 378.33 | 36.97 | 200.00 | 540.00 |
| | AT | 243.33 | 13.45 | 200.00 | 320.00 |

**Table 8.2.** Diversity indices of total meiobenthos in middle core at 15-20 m. No significant difference of the index before and after trawling (P>0.05)

| Diversity index | Trawling Mode | Mean | S.E. | Minimum | Maximum |
|---|---|---|---|---|---|
| S | BT | 2.25 | 0.18 | 2.00 | 4.00 |
| | AT | 1.83 | 0.11 | 1.00 | 2.00 |
| N | BT | 17.58 | 2.88 | 5.00 | 32.00 |
| | AT | 18.33 | 6.77 | 3.00 | 88.00 |
| Margalef | BT | 0.48 | 0.06 | 0.29 | 1.04 |
| | AT | 0.36 | 0.07 | 0.00 | 0.91 |
| Pieolu | BT | 0.75 | 0.06 | 0.34 | 0.99 |
| | AT | 0.81 | 0.06 | 0.27 | 0.99 |
| Brillouin | BT | 0.47 | 0.05 | 0.19 | 0.82 |
| | AT | 0.37 | 0.06 | 0.00 | 0.58 |
| Fisher | BT | 0.81 | 0.10 | 0.47 | 1.59 |
| | AT | 0.80 | 0.18 | 0.36 | 2.62 |
| Shannon | BT | 0.58 | 0.06 | 0.23 | 1.01 |
| | AT | 0.47 | 0.07 | 0.00 | 0.69 |
| Simpson | BT | 0.42 | 0.05 | 0.12 | 0.61 |
| | AT | 0.36 | 0.06 | 0.00 | 0.67 |
| Hill's N1 | BT | 1.83 | 0.12 | 1.26 | 2.76 |
| | AT | 1.64 | 0.10 | 1.00 | 1.99 |
| Hill's N2 | BT | 1.69 | 0.11 | 1.13 | 2.35 |
| | AT | 1.54 | 0.10 | 1.00 | 1.98 |
| Tax_div | BT | 41.54 | 4.76 | 12.10 | 60.00 |
| | AT | 36.08 | 6.19 | 0.00 | 66.67 |
| Tax_dist | BT | 99.62 | 0.26 | 97.20 | 100.00 |
| | AT | 83.33 | 11.24 | 0.00 | 100.00 |
| AvTD | BT | 98.61 | 0.96 | 90.00 | 100.00 |
| | AT | 83.33 | 11.24 | 0.00 | 100.00 |
| TTD | BT | 220.00 | 14.35 | 200.00 | 360.00 |
| | AT | 166.67 | 22.47 | 0.00 | 200.00 |
| VarTD | BT | 15.74 | 10.63 | 0.00 | 100.00 |
| | AT | 0.00 | 0.00 | 0.00 | 0.00 |
| AvPD | BT | 98.61 | 0.96 | 90.00 | 100.00 |
| | AT | 100.00 | 0.00 | 100.00 | 100.00 |
| PD | BT | 220.00 | 14.35 | 200.00 | 360.00 |
| | AT | 183.33 | 11.24 | 100.00 | 200.00 |

Table 8.3. Diversity indices of total meiobenthos in lower core at 15-20 m. No significant difference of the index before and after trawling (P>0.05)

| Diversity Index | Trawling Mode | Mean | S.E. | Minimum | Maximum |
|---|---|---|---|---|---|
| S | BT | 1.00 | 0.28 | 0.00 | 2.00 |
| | AT | 1.00 | 0.27 | 0.00 | 2.00 |
| N | BT | 8.00 | 3.46 | 0.00 | 33.00 |
| | AT | 7.00 | 2.26 | 0.00 | 22.00 |
| Margalef | BT | 0.36 | 0.04 | 0.29 | 0.48 |
| | AT | 0.36 | 0.09 | 0.00 | 0.72 |
| Pieolu | BT | 0.71 | 0.13 | 0.33 | 1.00 |
| | AT | 0.81 | 0.09 | 0.44 | 1.00 |
| Brillouin | BT | 0.29 | 0.09 | 0.00 | 0.59 |
| | AT | 0.32 | 0.08 | 0.00 | 0.55 |
| Fisher | BT | 0.62 | 0.07 | 0.47 | 0.86 |
| | AT | 0.84 | 0.14 | 0.53 | 1.59 |
| Shannon | BT | 0.20 | 0.08 | 0.00 | 0.69 |
| | AT | 0.28 | 0.09 | 0.00 | 0.69 |
| Simpson | BT | 0.35 | 0.08 | 0.12 | 0.53 |
| | AT | 0.33 | 0.09 | 0.00 | 0.60 |
| Hill's N1 | BT | 1.27 | 0.11 | 1.00 | 2.00 |
| | AT | 1.38 | 0.12 | 1.00 | 2.00 |
| Hill's N2 | BT | 1.39 | 0.15 | 1.00 | 1.99 |
| | AT | 1.50 | 0.14 | 1.00 | 2.00 |
| Tax_div | BT | 14.60 | 6.12 | 0.00 | 52.94 |
| | AT | 21.99 | 7.37 | 0.00 | 60.00 |
| Tax_dist | BT | 41.67 | 14.86 | 0.00 | 100.00 |
| | AT | 50.00 | 15.08 | 0.00 | 100.00 |
| AvTD | BT | 41.67 | 14.86 | 0.00 | 100.00 |
| | AT | 50.00 | 15.08 | 0.00 | 100.00 |
| TTD | BT | 83.33 | 29.73 | 0.00 | 200.00 |
| | AT | 100.00 | 30.15 | 0.00 | 200.00 |
| VarTD | BT | 0.00 | 0.00 | 0.00 | 0.00 |
| | AT | 0.00 | 0.00 | 0.00 | 0.00 |
| AvPD | BT | 58.33 | 14.86 | 0.00 | 100.00 |
| | AT | 66.67 | 14.21 | 0.00 | 100.00 |
| PD | BT | 100.00 | 27.52 | 0.00 | 200.00 |
| | AT | 116.67 | 27.06 | 0.00 | 200.00 |

**Table 8.4.** Diversity indices of total meiobenthos in upper core at 21-25 m. No significant difference of the index before and after trawling (P>0.05)

| Diversity Index | Trawling Mode | Mean | S.E. | Minimum | Maximum |
|---|---|---|---|---|---|
| S | BT | 2.67 | 0.51 | 0.00 | 6.00 |
| | AT | 3.33 | 0.41 | 2.00 | 6.00 |
| N | BT | 320.42 | 74.62 | 0.00 | 800.00 |
| | AT | 509.83 | 70.29 | 220.00 | 934.00 |
| Margalef | BT | 0.37 | 0.08 | 0.15 | 0.89 |
| | AT | 0.38 | 0.06 | 0.16 | 0.74 |
| Pieolu | BT | 0.72 | 0.08 | 0.27 | 1.00 |
| | AT | 0.61 | 0.07 | 0.27 | 0.98 |
| Brillouin | BT | 0.55 | 0.03 | 0.42 | 0.68 |
| | AT | 0.58 | 0.03 | 0.42 | 0.75 |
| Fisher | BT | 0.53 | 0.09 | 0.25 | 1.08 |
| | AT | 0.49 | 0.07 | 0.26 | 0.88 |
| Shannon | BT | 0.54 | 0.05 | 0.00 | 0.69 |
| | AT | 0.59 | 0.03 | 0.43 | 0.78 |
| Simpson | BT | 0.38 | 0.03 | 0.24 | 0.50 |
| | AT | 0.38 | 0.03 | 0.20 | 0.50 |
| Hill's N1 | BT | 1.73 | 0.08 | 1.00 | 2.00 |
| | AT | 1.82 | 0.06 | 1.54 | 2.18 |
| Hill's N2 | BT | 1.62 | 0.07 | 1.32 | 2.00 |
| | AT | 1.64 | 0.07 | 1.25 | 1.98 |
| Tax_div | BT | 34.46 | 4.12 | 0.00 | 50.22 |
| | AT | 37.56 | 2.87 | 19.00 | 49.41 |
| Tax_dist | BT | 90.17 | 8.27 | 0.00 | 100.00 |
| | AT | 98.95 | 0.53 | 94.80 | 100.00 |
| AvTD | BT | 88.17 | 8.23 | 0.00 | 100.00 |
| | AT | 93.72 | 1.77 | 84.00 | 100.00 |
| TTD | BT | 247.33 | 41.15 | 0.00 | 504.00 |
| | AT | 304.50 | 32.08 | 200.00 | 504.00 |
| VarTD | BT | 45.67 | 25.42 | 0.00 | 224.00 |
| | AT | 71.81 | 21.36 | 0.00 | 224.00 |
| AvPD | BT | 87.50 | 8.27 | 0.00 | 100.00 |
| | AT | 93.22 | 2.02 | 80.00 | 100.00 |
| PD | BT | 100.00 | 27.52 | 0.00 | 200.00 |
| | AT | 116.67 | 27.06 | 0.00 | 200.00 |

Table 8.5. Diversity indices of total meiobenthos in middle core at 21-25 m. No significant difference of the index before and after trawling (P>0.05)

| Diversity Index | Trawling Mode | Mean | S.E. | Minimum | Maximum |
|---|---|---|---|---|---|
| S | BT | 2.00 | 0.23 | 0.00 | 3.00 |
| | AT | 2.00 | 0.08 | 1.00 | 2.00 |
| N | BT | 29.00 | 5.58 | 0.00 | 56.00 |
| | AT | 23.00 | 4.46 | 3.00 | 52.00 |
| Margalef | BT | 0.40 | 0.04 | 0.26 | 0.64 |
| | AT | 0.36 | 0.06 | 0.00 | 0.91 |
| Pieolu | BT | 0.70 | 0.06 | 0.44 | 1.00 |
| | AT | 0.79 | 0.05 | 0.50 | 1.00 |
| Brillouin | BT | 0.47 | 0.04 | 0.26 | 0.65 |
| | AT | 0.41 | 0.05 | 0.00 | 0.64 |
| Fisher | BT | 0.64 | 0.06 | 0.42 | 0.94 |
| | AT | 0.72 | 0.18 | 0.25 | 2.62 |
| Shannon | BT | 0.50 | 0.06 | 0.00 | 0.74 |
| | AT | 0.50 | 0.06 | 0.00 | 0.69 |
| Simpson | BT | 0.37 | 0.04 | 0.17 | 0.57 |
| | AT | 0.38 | 0.05 | 0.00 | 0.67 |
| Hill's N1 | BT | 1.69 | 0.09 | 1.00 | 2.09 |
| | AT | 1.68 | 0.09 | 1.00 | 2.00 |
| Hill's N2 | BT | 1.58 | 0.09 | 1.20 | 1.99 |
| | AT | 1.58 | 0.10 | 1.00 | 2.00 |
| Tax_div | BT | 32.77 | 4.89 | 0.00 | 57.14 |
| | AT | 37.70 | 5.36 | 0.00 | 66.67 |
| Tax_dist | BT | 88.35 | 8.26 | 0.00 | 100.00 |
| | AT | 91.67 | 8.33 | 0.00 | 100.00 |
| AvTD | BT | 88.76 | 8.21 | 0.00 | 100.00 |
| | AT | 91.67 | 8.33 | 0.00 | 100.00 |
| TTD | BT | 199.62 | 19.99 | 0.00 | 265.15 |
| | AT | 183.33 | 16.67 | 0.00 | 200.00 |
| VarTD | BT | 67.49 | 35.25 | 0.00 | 269.97 |
| | AT | 0.00 | 0.00 | 0.00 | 0.00 |
| AvPD | BT | 88.76 | 8.21 | 0.00 | 100.00 |
| | AT | 100.00 | 0.00 | 100.00 | 100.00 |
| PD | BT | 199.62 | 19.99 | 0.00 | 265.15 |
| | AT | 191.67 | 8.33 | 100.00 | 200.00 |

**Table 8.6.** Diversity indices of total meiobenthos in lower core at 21-25 m. No significant difference of the index before and after trawling (P>0.05)

| Diversity Index | Trawling Mode | Mean | S.E. | Minimum | Maximum |
|---|---|---|---|---|---|
| S | BT | 1.42 | 0.23 | 0.00 | 2.00 |
| | AT | 1.25 | 0.25 | 0.00 | 2.00 |
| N | BT | 13.67 | 4.51 | 0.00 | 46.00 |
| | AT | 9.58 | 3.44 | 0.00 | 37.00 |
| Margalef | BT | 0.27 | 0.07 | 0.00 | 0.56 |
| | AT | 0.35 | 0.09 | 0.00 | 0.72 |
| Pieolu | BT | 0.80 | 0.07 | 0.56 | 1.00 |
| | AT | 0.76 | 0.08 | 0.52 | 1.00 |
| Brillouin | BT | 0.31 | 0.07 | 0.00 | 0.54 |
| | AT | 0.26 | 0.07 | 0.00 | 0.54 |
| Fisher | BT | 0.59 | 0.08 | 0.30 | 1.05 |
| | AT | 0.78 | 0.16 | 0.23 | 1.59 |
| Shannon | BT | 0.32 | 0.09 | 0.00 | 0.69 |
| | AT | 0.26 | 0.08 | 0.00 | 0.69 |
| Simpson | BT | 0.29 | 0.07 | 0.00 | 0.60 |
| | AT | 0.30 | 0.08 | 0.00 | 0.67 |
| Hill's N1 | BT | 1.44 | 0.12 | 1.00 | 2.00 |
| | AT | 1.35 | 0.12 | 1.00 | 2.00 |
| Hill's N2 | BT | 1.45 | 0.12 | 1.00 | 2.00 |
| | AT | 1.39 | 0.13 | 1.00 | 2.00 |
| Tax_div | BT | 24.14 | 6.85 | 0.00 | 60.00 |
| | AT | 20.27 | 6.99 | 0.00 | 66.67 |
| Tax_dist | BT | 58.33 | 14.86 | 0.00 | 100.00 |
| | AT | 50.00 | 15.08 | 0.00 | 100.00 |
| AvTD | BT | 58.33 | 14.86 | 0.00 | 100.00 |
| | AT | 50.00 | 15.08 | 0.00 | 100.00 |
| TTD | BT | 116.67 | 29.73 | 0.00 | 200.00 |
| | AT | 100.00 | 30.15 | 0.00 | 200.00 |
| VarTD | BT | 0.00 | 0.00 | 0.00 | 0.00 |
| | AT | 0.00 | 0.00 | 0.00 | 0.00 |
| AvPD | BT | 83.33 | 11.24 | 0.00 | 100.00 |
| | AT | 75.00 | 13.06 | 0.00 | 100.00 |
| PD | BT | 141.67 | 22.89 | 0.00 | 200.00 |
| | AT | 125.00 | 25.00 | 0.00 | 200.00 |

Table 8.7. Diversity indices of total meiobenthos in upper core at 26-30 m. *Significant difference of the index before and after trawling (P<0.05)

| Diversity Index | Trawling Mode | Mean | S.E. | Minimum | Maximum |
|---|---|---|---|---|---|
| S* | BT | 4.00 | 0.40 | 2.00 | 6.00 |
| | AT | 3.00 | 0.23 | 2.00 | 4.00 |
| N | BT | 773.00 | 99.87 | 405.00 | 1451.00 |
| | AT | 895.00 | 112.26 | 533.00 | 1670.00 |
| Margalef * | BT | 0.37 | 0.05 | 0.16 | 0.70 |
| | AT | 0.22 | 0.03 | 0.13 | 0.46 |
| Pieolu | BT | 0.53 | 0.08 | 0.11 | 0.97 |
| | AT | 0.70 | 0.07 | 0.19 | 0.99 |
| Brillouin | BT | 0.53 | 0.05 | 0.15 | 0.70 |
| | AT | 0.58 | 0.05 | 0.13 | 0.83 |
| Fisher* | BT | 0.48 | 0.05 | 0.26 | 0.82 |
| | AT | 0.32 | 0.03 | 0.22 | 0.56 |
| Shannon | BT | 0.54 | 0.05 | 0.16 | 0.71 |
| | AT | 0.58 | 0.05 | 0.13 | 0.85 |
| Simpson | BT | 0.35 | 0.04 | 0.06 | 0.48 |
| | AT | 0.39 | 0.04 | 0.06 | 0.52 |
| Hill's N1 | BT | 1.74 | 0.07 | 1.17 | 2.03 |
| | AT | 1.82 | 0.08 | 1.14 | 2.33 |
| Hill's N2 | BT | 1.59 | 0.08 | 1.07 | 1.93 |
| | AT | 1.70 | 0.09 | 1.06 | 2.08 |
| Tax_div | BT | 34.94 | 3.92 | 6.14 | 48.19 |
| | AT | 38.75 | 3.85 | 5.67 | 50.82 |
| Tax_dist | BT | 99.38 | 0.25 | 97.31 | 100.00 |
| | AT | 99.66 | 0.21 | 97.77 | 100.00 |
| AvTD | BT | 92.72 | 1.54 | 84.00 | 100.00 |
| | AT | 96.94 | 1.39 | 86.67 | 100.00 |
| TTD* | BT | 318.00 | 30.78 | 200.00 | 512.00 |
| | AT | 238.89 | 17.79 | 200.00 | 360.00 |
| VarTD | BT | 84.26 | 18.24 | 0.00 | 224.00 |
| | AT | 41.67 | 20.29 | 0.00 | 222.22 |
| AvPD | BT | 92.22 | 1.80 | 80.00 | 100.00 |
| | AT | 96.81 | 1.49 | 85.00 | 100.00 |
| PD* | BT | 315.00 | 29.14 | 200.00 | 500.00 |
| | AT | 238.33 | 17.49 | 200.00 | 360.00 |

Table 8.8. Diversity indices of total meiobenthos in middle core at 26-30 m. *Significant difference of the index before and after trawling (P<0.05)

| Diversity Index | Trawling Mode | Mean | S.E. | Minimum | Maximum |
|---|---|---|---|---|---|
| S | BT | 2.00 | 0.17 | 1.00 | 3.00 |
| | AT | 2.00 | 0.22 | 0.00 | 3.00 |
| N* | BT | 49.00 | 4.42 | 15.00 | 65.00 |
| | AT | 31.00 | 5.16 | 0.00 | 60.00 |
| Margalef | BT | 0.30 | 0.05 | 0.00 | 0.63 |
| | AT | 0.25 | 0.04 | 0.00 | 0.52 |
| Pieolu | BT | 0.71 | 0.06 | 0.37 | 0.97 |
| | AT | 0.78 | 0.05 | 0.52 | 0.99 |
| Brillouin | BT | 0.46 | 0.05 | 0.00 | 0.64 |
| | AT | 0.42 | 0.07 | 0.00 | 0.72 |
| Fisher | BT | 0.48 | 0.05 | 0.24 | 0.91 |
| | AT | 0.45 | 0.03 | 0.28 | 0.72 |
| Shannon | BT | 0.50 | 0.06 | 0.00 | 0.67 |
| | AT | 0.43 | 0.08 | 0.00 | 0.79 |
| Simpson | BT | 0.33 | 0.04 | 0.00 | 0.49 |
| | AT | 0.31 | 0.05 | 0.00 | 0.51 |
| Hill's N1 | BT | 1.68 | 0.08 | 1.00 | 1.96 |
| | AT | 1.59 | 0.12 | 1.00 | 2.21 |
| Hill's N2 | BT | 1.53 | 0.08 | 1.00 | 1.92 |
| | AT | 1.52 | 0.10 | 1.00 | 1.98 |
| Tax_div | BT | 32.90 | 4.08 | 0.00 | 48.81 |
| | AT | 28.62 | 5.59 | 0.00 | 51.23 |
| Tax_dist | BT | 91.35 | 8.31 | 0.00 | 100.00 |
| | AT | 74.69 | 13.01 | 0.00 | 100.00 |
| AvTD | BT | 90.00 | 8.23 | 0.00 | 100.00 |
| | AT | 74.44 | 12.97 | 0.00 | 100.00 |
| TTD | BT | 203.33 | 21.15 | 0.00 | 280.00 |
| | AT | 156.67 | 28.05 | 0.00 | 280.00 |
| VarTD | BT | 22.22 | 11.61 | 0.00 | 88.89 |
| | AT | 7.41 | 7.41 | 0.00 | 88.89 |
| AvPD | BT | 98.33 | 0.87 | 93.33 | 100.00 |
| | AT | 91.11 | 8.30 | 0.00 | 100.00 |
| PD | BT | 211.67 | 14.45 | 100.00 | 280.00 |
| | AT | 173.33 | 20.94 | 0.00 | 280.00 |

Table 8.9. Diversity indices of total meiobenthos in lower core at 26-30 m. No significant difference of the index before and after trawling (P>0.05)

| Diversity Index | Trawling Mode | Mean | S.E. | Minimum | Maximum |
|---|---|---|---|---|---|
| S | BT | 2.00 | 0.13 | 1.00 | 2.00 |
| | AT | 1.00 | 0.22 | 0.00 | 2.00 |
| N | BT | 19.00 | 3.69 | 0.00 | 42.00 |
| | AT | 11.00 | 3.37 | 0.00 | 42.00 |
| Margalef | BT | 0.25 | 0.04 | 0.00 | 0.42 |
| | AT | 0.26 | 0.07 | 0.00 | 0.51 |
| Pieolu | BT | 0.58 | 0.09 | 0.18 | 0.97 |
| | AT | 0.65 | 0.11 | 0.30 | 0.97 |
| Brillouin | BT | 0.25 | 0.06 | 0.00 | 0.59 |
| | AT | 0.22 | 0.07 | 0.00 | 0.53 |
| Fisher | BT | 0.55 | 0.03 | 0.38 | 0.80 |
| | AT | 0.57 | 0.07 | 0.26 | 0.94 |
| Shannon | BT | 0.30 | 0.07 | 0.00 | 0.67 |
| | AT | 0.22 | 0.08 | 0.00 | 0.67 |
| Simpson | BT | 0.20 | 0.05 | 0.00 | 0.51 |
| | AT | 0.21 | 0.07 | 0.00 | 0.53 |
| Hill's N1 | BT | 1.39 | 0.10 | 1.00 | 1.96 |
| | AT | 1.30 | 0.11 | 1.00 | 1.96 |
| Hill's N2 | BT | 1.29 | 0.09 | 1.00 | 1.92 |
| | AT | 1.28 | 0.11 | 1.00 | 1.92 |
| Tax_div | BT | 19.86 | 5.34 | 0.00 | 50.53 |
| | AT | 15.65 | 5.74 | 0.00 | 53.33 |
| Tax_dist | BT | 75.00 | 13.06 | 0.00 | 100.00 |
| | AT | 50.00 | 15.08 | 0.00 | 100.00 |
| AvTD | BT | 75.00 | 13.06 | 0.00 | 100.00 |
| | AT | 50.00 | 15.08 | 0.00 | 100.00 |
| TTD | BT | 150.00 | 26.11 | 0.00 | 200.00 |
| | AT | 100.00 | 30.15 | 0.00 | 200.00 |
| VarTD | BT | 0.00 | 0.00 | 0.00 | 0.00 |
| | AT | 0.00 | 0.00 | 0.00 | 0.00 |
| AvPD | BT | 100.00 | 0.00 | 100.00 | 100.00 |
| | AT | 83.33 | 11.24 | 0.00 | 100.00 |
| PD | BT | 175.00 | 13.06 | 100.00 | 200.00 |
| | AT | 133.33 | 22.47 | 0.00 | 200.00 |

Table 8.10. Diversity indices of total meiobenthos in upper core at 31-35 m. *Significant difference of the index before and after trawling (P<0.05)

| Diversity Index | Trawling Mode | Mean | S.E. | Minimum | Maximum |
|---|---|---|---|---|---|
| S | BT | 4.00 | 0.58 | 2.00 | 8.00 |
| | AT | 3.00 | 0.39 | 2.00 | 5.00 |
| N | BT | 981.00 | 117.84 | 540.00 | 1822.00 |
| | AT | 1132.00 | 123.85 | 652.00 | 1911.00 |
| Margalef | BT | 0.48 | 0.08 | 0.14 | 0.95 |
| | AT | 0.29 | 0.06 | 0.13 | 0.60 |
| Pieolu | BT | 0.45 | 0.05 | 0.13 | 0.77 |
| | AT | 0.56 | 0.07 | 0.21 | 0.91 |
| Brillouin | BT | 0.57 | 0.05 | 0.18 | 0.84 |
| | AT | 0.51 | 0.05 | 0.14 | 0.73 |
| Fisher | BT | 0.59 | 0.09 | 0.24 | 1.10 |
| | AT | 0.39 | 0.06 | 0.22 | 0.71 |
| Shannon | BT | 0.57 | 0.05 | 0.18 | 0.87 |
| | AT | 0.52 | 0.05 | 0.14 | 0.74 |
| Simpson | BT | 0.34 | 0.03 | 0.08 | 0.48 |
| | AT | 0.32 | 0.03 | 0.06 | 0.48 |
| Hill's N1 | BT | 1.80 | 0.09 | 1.20 | 2.38 |
| | AT | 1.69 | 0.07 | 1.16 | 2.09 |
| Hill's N2 | BT | 1.56 | 0.07 | 1.08 | 1.91 |
| | AT | 1.51 | 0.07 | 1.07 | 1.91 |
| Tax_div | BT | 33.09 | 3.50 | 7.40 | 47.36 |
| | AT | 31.70 | 3.45 | 6.36 | 47.46 |
| Tax_dist | BT | 98.20 | 1.12 | 86.00 | 100.00 |
| | AT | 99.20 | 0.46 | 95.47 | 100.00 |
| AvTD | BT | 90.87 | 1.72 | 81.90 | 100.00 |
| | AT | 95.61 | 1.62 | 88.00 | 100.00 |
| TTD | BT | 361.56 | 38.66 | 200.00 | 573.33 |
| | AT | 280.00 | 31.14 | 200.00 | 440.00 |
| VarTD* | BT | 102.75 | 19.97 | 0.00 | 224.94 |
| | AT | 39.74 | 14.19 | 0.00 | 100.00 |
| AvPD* | BT | 89.91 | 2.17 | 77.14 | 100.00 |
| | AT | 95.61 | 1.62 | 88.00 | 100.00 |
| PD | BT | 355.00 | 35.60 | 200.00 | 540.00 |
| | AT | 280.00 | 31.14 | 200.00 | 440.00 |

Table 8.11. Diversity indices of total meiobenthos in middle core at 31-35 m. No Significant difference of the index before and after trawling (P>0.05)

| Diversity Index | Trawling Mode | Mean | S.E. | Minimum | Maximum |
|---|---|---|---|---|---|
| S | BT | 2.00 | 0.22 | 2.00 | 4.00 |
| | AT | 2.00 | 0.17 | 1.00 | 3.00 |
| N | BT | 65.00 | 8.66 | 35.00 | 151.00 |
| | AT | 43.00 | 6.42 | 14.00 | 90.00 |
| Margalef | BT | 0.32 | 0.05 | 0.23 | 0.73 |
| | AT | 0.22 | 0.04 | 0.00 | 0.44 |
| Pieolu | BT | 0.74 | 0.04 | 0.63 | 1.00 |
| | AT | 0.79 | 0.06 | 0.53 | 1.00 |
| Brillouin | BT | 0.55 | 0.05 | 0.39 | 0.84 |
| | AT | 0.40 | 0.08 | 0.00 | 0.77 |
| Fisher | BT | 0.48 | 0.05 | 0.37 | 0.96 |
| | AT | 0.41 | 0.04 | 0.20 | 0.64 |
| Shannon | BT | 0.59 | 0.05 | 0.44 | 0.90 |
| | AT | 0.44 | 0.08 | 0.00 | 0.82 |
| Simpson | BT | 0.38 | 0.03 | 0.27 | 0.55 |
| | AT | 0.30 | 0.06 | 0.00 | 0.54 |
| Hill's N1 | BT | 1.83 | 0.09 | 1.55 | 2.47 |
| | AT | 1.60 | 0.12 | 1.00 | 2.26 |
| Hill's N2 | BT | 1.66 | 0.09 | 1.36 | 2.19 |
| | AT | 1.52 | 0.12 | 1.00 | 2.13 |
| Tax_div | BT | 38.15 | 3.06 | 27.07 | 53.86 |
| | AT | 29.85 | 5.96 | 0.00 | 53.11 |
| Tax_dist | BT | 99.42 | 0.45 | 94.70 | 100.00 |
| | AT | 74.90 | 13.04 | 0.00 | 100.00 |
| AvTD | BT | 98.33 | 1.12 | 90.00 | 100.00 |
| | AT | 74.44 | 12.97 | 0.00 | 100.00 |
| TTD* | BT | 226.67 | 17.98 | 200.00 | 360.00 |
| | AT | 156.67 | 28.05 | 0.00 | 280.00 |
| VarTD | BT | 16.67 | 11.24 | 0.00 | 100.00 |
| | AT | 7.41 | 7.41 | 0.00 | 88.89 |
| AvPD | BT | 98.33 | 1.12 | 90.00 | 100.00 |
| | AT | 99.44 | 0.56 | 93.33 | 100.00 |
| PD | BT | 226.67 | 17.98 | 200.00 | 360.00 |
| | AT | 181.67 | 15.66 | 100.00 | 280.00 |

**Table 8.12.** Diversity indices of total meiobenthos in lower core at 31-35 m. *Significant difference of the index before and after trawling (P<0.05)

| Diversity Index | Trawling Mode | Mean | S.E. | Minimum | Maximum |
|---|---|---|---|---|---|
| S* | BT | 1.92 | 0.08 | 1.00 | 2.00 |
| | AT | 1.42 | 0.15 | 1.00 | 2.00 |
| N | BT | 29.75 | 6.23 | 5.00 | 80.00 |
| | AT | 15.92 | 4.41 | 2.00 | 50.00 |
| Margalef * | BT | 0.30 | 0.04 | 0.00 | 0.62 |
| | AT | 0.15 | 0.06 | 0.00 | 0.56 |
| Pieolu | BT | 0.64 | 0.07 | 0.35 | 0.92 |
| | AT | 0.81 | 0.11 | 0.39 | 0.96 |
| Brillouin | BT | 0.34 | 0.05 | 0.00 | 0.56 |
| | AT | 0.20 | 0.07 | 0.00 | 0.62 |
| Fisher | BT | 0.55 | 0.07 | 0.34 | 1.24 |
| | AT | 0.51 | 0.07 | 0.20 | 1.05 |
| Shannon | BT | 0.41 | 0.06 | 0.00 | 0.64 |
| | AT | 0.23 | 0.09 | 0.00 | 0.66 |
| Simpson | BT | 0.27 | 0.04 | 0.00 | 0.46 |
| | AT | 0.17 | 0.07 | 0.00 | 0.53 |
| Hill's N1 | BT | 1.53 | 0.08 | 1.00 | 1.89 |
| | AT | 1.32 | 0.12 | 1.00 | 1.94 |
| Hill's N2 | BT | 1.39 | 0.08 | 1.00 | 1.80 |
| | AT | 1.28 | 0.11 | 1.00 | 1.89 |
| Tax_div | BT | 27.32 | 4.45 | 0.00 | 46.38 |
| | AT | 17.33 | 6.73 | 0.00 | 53.33 |
| Tax_dist* | BT | 91.67 | 8.33 | 0.00 | 100.00 |
| | AT | 41.67 | 14.86 | 0.00 | 100.00 |
| AvTD* | BT | 91.67 | 8.33 | 0.00 | 100.00 |
| | AT | 41.67 | 14.86 | 0.00 | 100.00 |
| TTD | BT | 183.33 | 16.67 | 0.00 | 200.00 |
| | AT | 83.33 | 29.73 | 0.00 | 200.00 |
| VarTD | BT | 0.00 | 0.00 | 0.00 | 0.00 |
| | AT | 0.00 | 0.00 | 0.00 | 0.00 |
| AvPD | BT | 100.00 | 0.00 | 100.00 | 100.00 |
| | AT | 100.00 | 0.00 | 100.00 | 100.00 |
| PD* | BT | 191.67 | 8.33 | 100.00 | 200.00 |
| | AT | 141.67 | 14.86 | 100.00 | 200.00 |

Table 8.13. Diversity indices of total meiobenthos in upper core at 36-40 m. No Significant difference of the index before and after trawling (P>0.05)

| Diversity Index | Trawling Mode | Mean | S.E. | Minimum | Maximum |
|---|---|---|---|---|---|
| S | BT | 4.00 | 0.43 | 2.00 | 6.00 |
| | AT | 4.00 | 0.54 | 2.00 | 8.00 |
| N | BT | 1165.00 | 123.49 | 719.00 | 1940.00 |
| | AT | 1392.00 | 151.78 | 847.00 | 2488.00 |
| Margalef | BT | 0.44 | 0.06 | 0.14 | 0.76 |
| | AT | 0.35 | 0.08 | 0.13 | 1.04 |
| Pieolu | BT | 0.47 | 0.05 | 0.14 | 0.81 |
| | AT | 0.59 | 0.07 | 0.26 | 0.94 |
| Brillouin | BT | 0.59 | 0.05 | 0.19 | 0.81 |
| | AT | 0.58 | 0.04 | 0.35 | 0.77 |
| Fisher | BT | 0.54 | 0.06 | 0.24 | 0.89 |
| | AT | 0.45 | 0.09 | 0.22 | 1.22 |
| Shannon | BT | 0.60 | 0.05 | 0.20 | 0.82 |
| | AT | 0.59 | 0.04 | 0.36 | 0.79 |
| Simpson | BT | 0.35 | 0.04 | 0.08 | 0.51 |
| | AT | 0.37 | 0.03 | 0.19 | 0.46 |
| Hill's N1 | BT | 1.85 | 0.09 | 1.22 | 2.26 |
| | AT | 1.81 | 0.06 | 1.43 | 2.20 |
| Hill's N2 | BT | 1.58 | 0.08 | 1.09 | 2.02 |
| | AT | 1.62 | 0.06 | 1.24 | 1.86 |
| Tax_div | BT | 34.26 | 3.53 | 8.29 | 49.67 |
| | AT | 36.82 | 2.79 | 18.91 | 46.19 |
| Tax_dist | BT | 97.44 | 0.95 | 88.20 | 100.00 |
| | AT | 99.16 | 0.40 | 96.19 | 100.00 |
| AvTD | BT | 90.78 | 1.58 | 84.00 | 100.00 |
| | AT | 93.68 | 1.83 | 82.14 | 100.00 |
| TTD | BT | 363.33 | 33.44 | 200.00 | 512.00 |
| | AT | 317.43 | 41.78 | 200.00 | 657.14 |
| VarTD | BT | 103.19 | 19.85 | 0.00 | 224.00 |
| | AT | 65.87 | 18.23 | 0.00 | 181.12 |
| AvPD | BT | 89.94 | 1.92 | 80.00 | 100.00 |
| | AT | 93.13 | 2.14 | 77.50 | 100.00 |
| PD | BT | 358.33 | 31.57 | 200.00 | 500.00 |
| | AT | 313.33 | 39.11 | 200.00 | 620.00 |

**Table 8.14.** Diversity indices of total meiobenthos in middle core at 36-40 m. *Significant difference of the index before and after trawling (P<0.05)

| Diversity index | Trawling Mode | Mean | S.E. | Minimum | Maximum |
|---|---|---|---|---|---|
| S | BT | 2.00 | 0.18 | 2.00 | 4.00 |
| | AT | 2.00 | 0.31 | 1.00 | 5.00 |
| N | BT | 118.00 | 21.30 | 67.00 | 308.00 |
| | AT | 68.00 | 16.41 | 3.00 | 204.00 |
| Margalef | BT | 0.26 | 0.03 | 0.18 | 0.52 |
| | AT | 0.34 | 0.06 | 0.00 | 0.75 |
| Pieolu | BT | 0.80 | 0.06 | 0.33 | 1.00 |
| | AT | 0.80 | 0.07 | 0.47 | 1.00 |
| Brillouin | BT | 0.57 | 0.04 | 0.24 | 0.73 |
| | AT | 0.55 | 0.06 | 0.00 | 0.72 |
| Fisher* | BT | 0.40 | 0.03 | 0.30 | 0.65 |
| | AT | 0.54 | 0.06 | 0.36 | 0.93 |
| Shannon | BT | 0.60 | 0.04 | 0.27 | 0.76 |
| | AT | 0.59 | 0.06 | 0.00 | 0.80 |
| Simpson | BT | 0.41 | 0.03 | 0.14 | 0.52 |
| | AT | 0.40 | 0.04 | 0.00 | 0.53 |
| Hill's N1 | BT | 1.83 | 0.06 | 1.30 | 2.14 |
| | AT | 1.84 | 0.10 | 1.00 | 2.23 |
| Hill's N2 | BT | 1.72 | 0.07 | 1.16 | 2.05 |
| | AT | 1.71 | 0.09 | 1.00 | 2.00 |
| Tax_div | BT | 40.80 | 3.11 | 14.02 | 51.41 |
| | AT | 39.46 | 4.45 | 0.00 | 53.33 |
| Tax_dist | BT | 99.88 | 0.08 | 99.17 | 100.00 |
| | AT | 90.57 | 8.26 | 0.00 | 100.00 |
| AvTD | BT | 98.61 | 0.96 | 90.00 | 100.00 |
| | AT | 89.11 | 8.22 | 0.00 | 100.00 |
| TTD | BT | 220.00 | 14.35 | 200.00 | 360.00 |
| | AT | 222.50 | 30.00 | 0.00 | 430.00 |
| VarTD | BT | 15.74 | 10.63 | 0.00 | 100.00 |
| | AT | 29.41 | 16.15 | 0.00 | 164.00 |
| AvPD | BT | 98.61 | 0.96 | 90.00 | 100.00 |
| | AT | 97.28 | 1.54 | 84.00 | 100.00 |
| PD | BT | 220.00 | 14.35 | 200.00 | 360.00 |
| | AT | 230.00 | 24.56 | 100.00 | 420.00 |

**Table 8.15.** Diversity indices of total meiobenthos in lower core at 36-40 m. No significant difference of the index before and after trawling (P>0.05)

| Diversity Index | Trawling Mode | Mean | S.E. | Minimum | Maximum |
|---|---|---|---|---|---|
| S | BT | 2.00 | 0.11 | 1.00 | 2.00 |
| | AT | 2.00 | 0.29 | 0.00 | 4.00 |
| N | BT | 31.00 | 5.14 | 4.00 | 59.00 |
| | AT | 26.00 | 8.90 | 0.00 | 97.00 |
| Margalef | BT | 0.25 | 0.04 | 0.00 | 0.40 |
| | AT | 0.21 | 0.07 | 0.00 | 0.66 |
| Pieolu | BT | 0.70 | 0.08 | 0.31 | 1.00 |
| | AT | 0.71 | 0.09 | 0.50 | 1.00 |
| Brillouin | BT | 0.36 | 0.07 | 0.00 | 0.60 |
| | AT | 0.26 | 0.08 | 0.00 | 0.66 |
| Fisher | BT | 0.47 | 0.04 | 0.19 | 0.69 |
| | AT | 0.53 | 0.07 | 0.20 | 0.84 |
| Shannon | BT | 0.40 | 0.07 | 0.00 | 0.69 |
| | AT | 0.28 | 0.09 | 0.00 | 0.71 |
| Simpson | BT | 0.28 | 0.05 | 0.00 | 0.53 |
| | AT | 0.21 | 0.07 | 0.00 | 0.56 |
| Hill's N1 | BT | 1.54 | 0.10 | 1.00 | 2.00 |
| | AT | 1.38 | 0.13 | 1.00 | 2.03 |
| Hill's N2 | BT | 1.44 | 0.10 | 1.00 | 1.99 |
| | AT | 1.33 | 0.12 | 1.00 | 2.00 |
| Tax_div | BT | 27.55 | 5.43 | 0.00 | 52.94 |
| | AT | 18.78 | 6.31 | 0.00 | 55.56 |
| Tax_dist | BT | 83.33 | 11.24 | 0.00 | 100.00 |
| | AT | 49.82 | 15.02 | 0.00 | 100.00 |
| AvTD | BT | 83.33 | 11.24 | 0.00 | 100.00 |
| | AT | 49.17 | 14.85 | 0.00 | 100.00 |
| TTD | BT | 166.67 | 22.47 | 0.00 | 200.00 |
| | AT | 113.33 | 36.46 | 0.00 | 360.00 |
| VarTD | BT | 0.00 | 0.00 | 0.00 | 0.00 |
| | AT | 8.33 | 8.33 | 0.00 | 100.00 |
| AvPD | BT | 100.00 | 0.00 | 100.00 | 100.00 |
| | AT | 90.83 | 8.30 | 0.00 | 100.00 |
| PD | BT | 183.33 | 11.24 | 100.00 | 200.00 |
| | AT | 155.00 | 26.30 | 0.00 | 360.00 |

### 8.3.3. Abundance Biomass Comparison curves for total meiobenthos

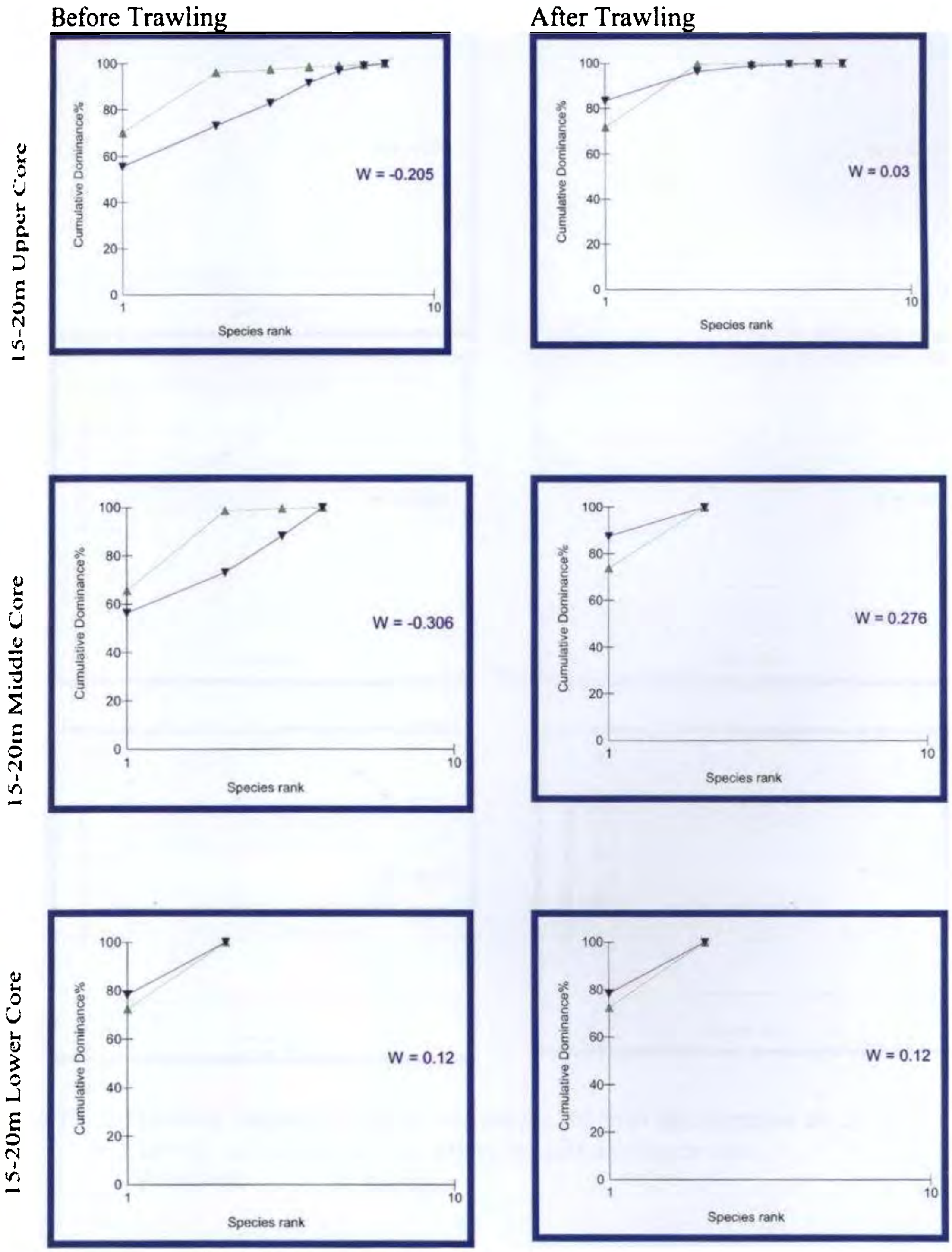



Fig. 8.12. Abundance Biomass Comparison curves for total meiobenthos at 15-20 m showing variations between upper, middle and lower core

▲ Abundance ▼ Biomass

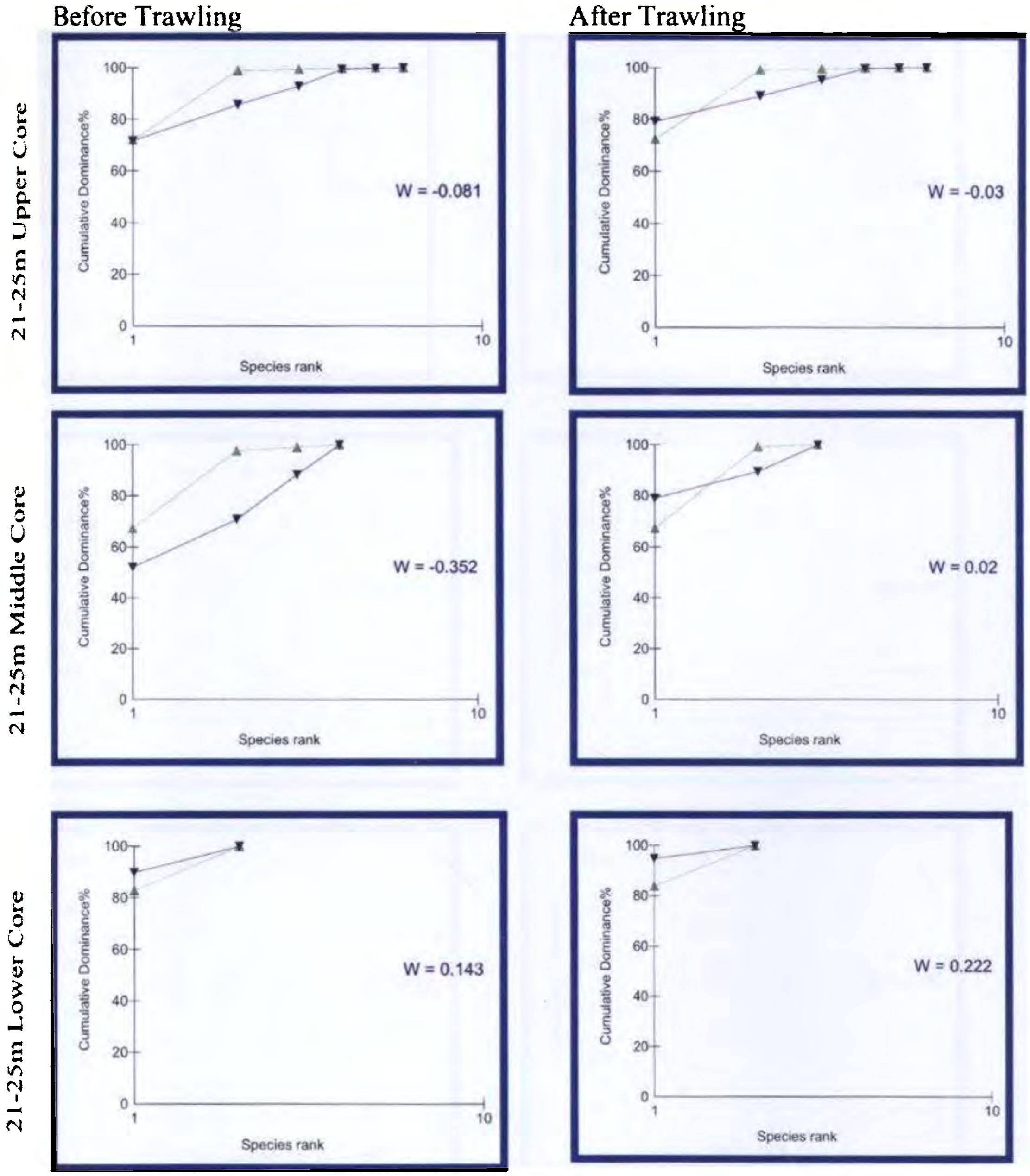



**Fig.8.13.** Abundance Biomass Comparison curves for total meiobenthos at 21-25 m showing variations between upper, middle and lower core

▲ Abundance ▼ Biomass

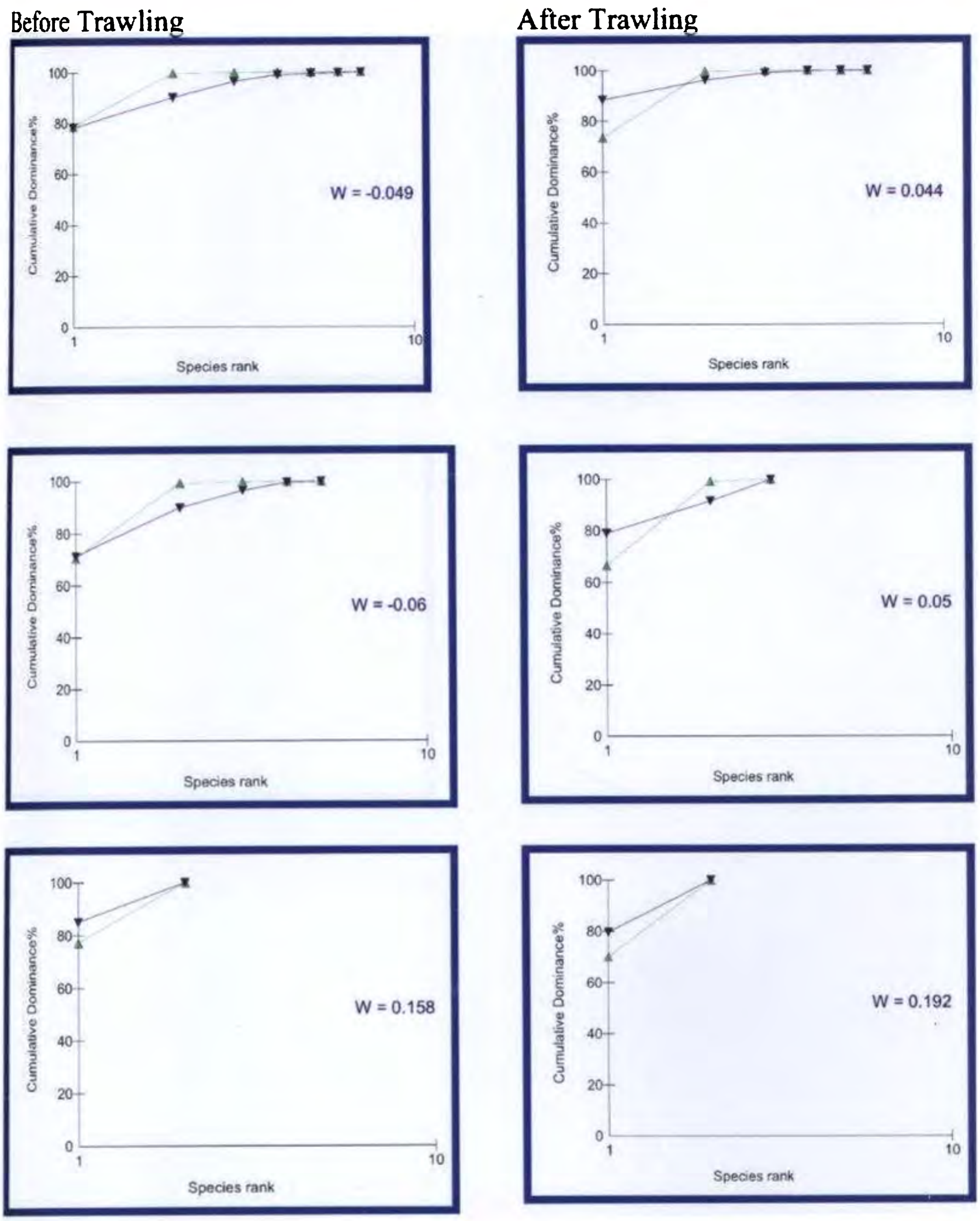



**Fig. 8.14.** Abundance Biomass Comparison curves for total meiobenthos at 26-30 m showing variations between upper, middle and lower core
▲ Abundance ▼ Biomass

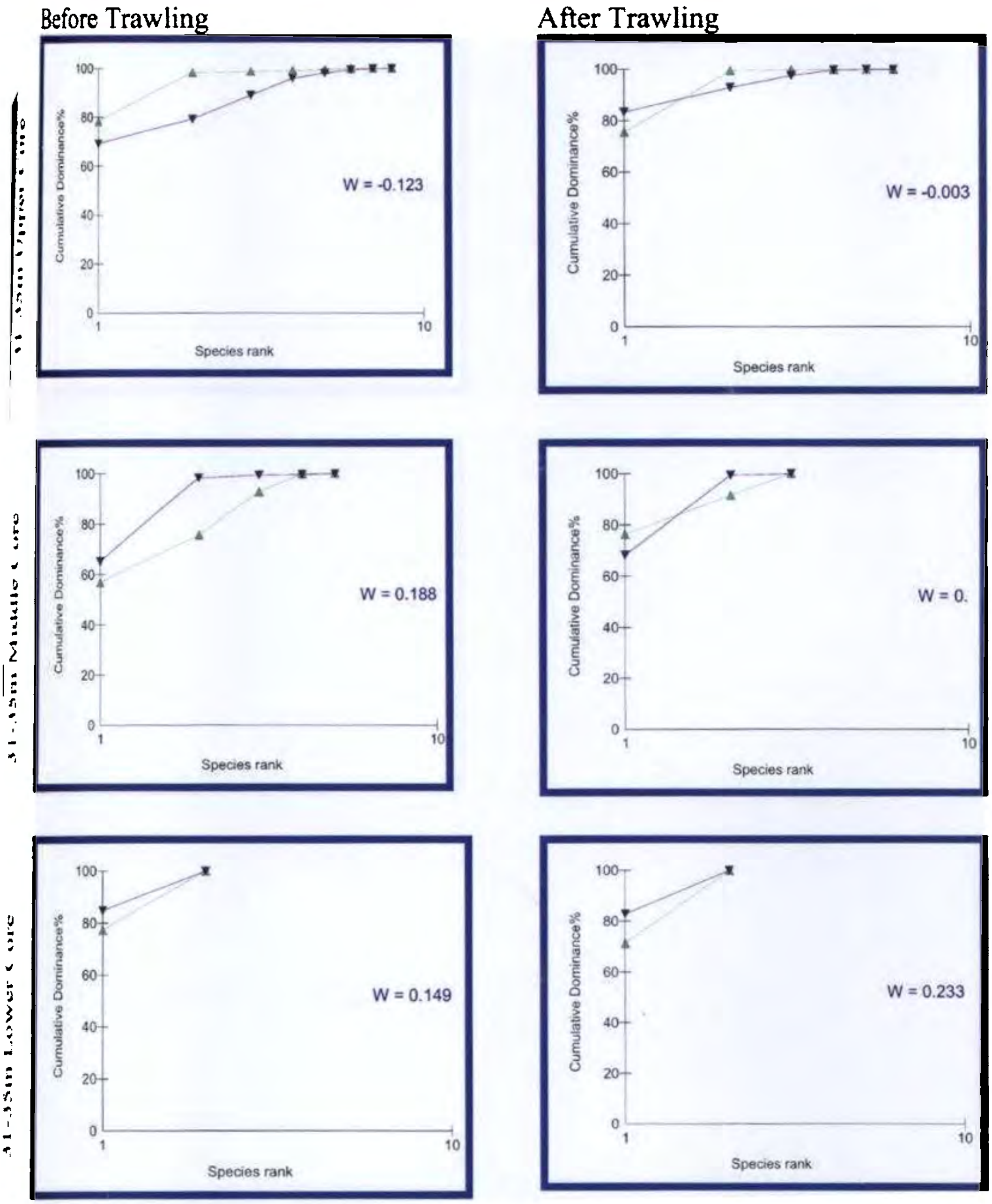



**Fig. 8.15.** Abundance Biomass Comparison curves for total meiobenthos at 31-35 m showing variations between upper, middle and lower core

▲ Abundance ▼ Biomass

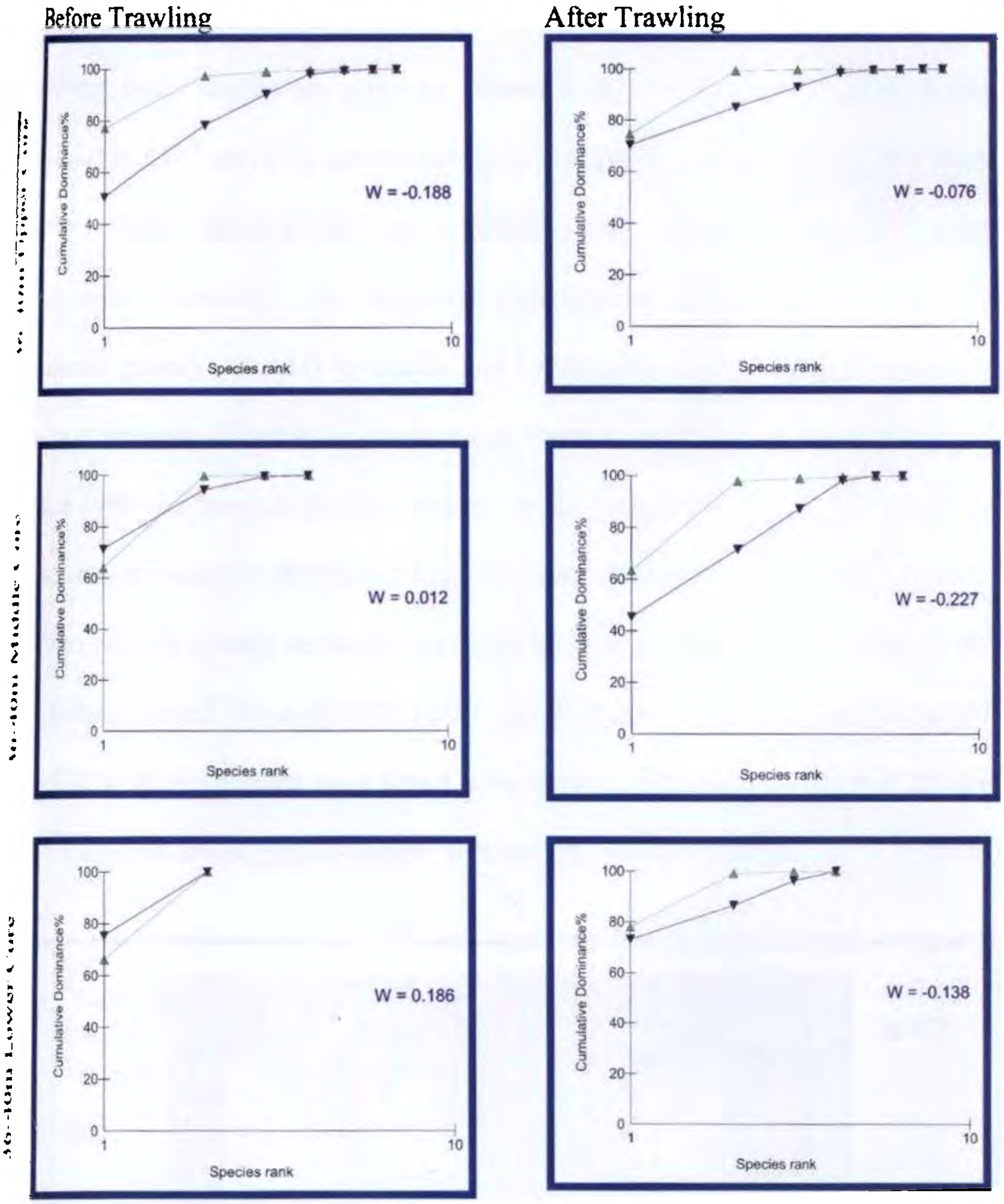



**Fig. 8.16.** Abundance Biomass Comparison curves for total meiobenthos at 36-40 m showing variations between upper, middle and lower core

▲ Abundance ▼ Biomass

The Abundance Biomass Curves for total meiobenthos studied at five different water depths are given in Figures 8.12 to 8.16. At all water depths studied, in ABC curve the abundance curve lied above biomass curve in the upper core. This indicated that the organisms were stressed before and after experimental trawling. The organisms were relatively less stressed (moderately stressed/ grossly stressed) in middle and lower core. In most cases, lower core were unstressed. It can be assumed that as bottom trawling is prevalent in the area since 1960, the fauna is already stressed. So no changes could be observed before and after trawling in abundance biomass curve as the fauna is already stressed. Moderately or grossly stressed fauna may be indicative of long-term stress. By following Paired T test of SPSS 12.0.1, the W-statistic values for upper core (BT vs AT) at all depth zones were found to be significant ($P < 0.05$) (Figure 8.17) and at middle and lower core W-statistic was insignificant ($P > 0.05$).

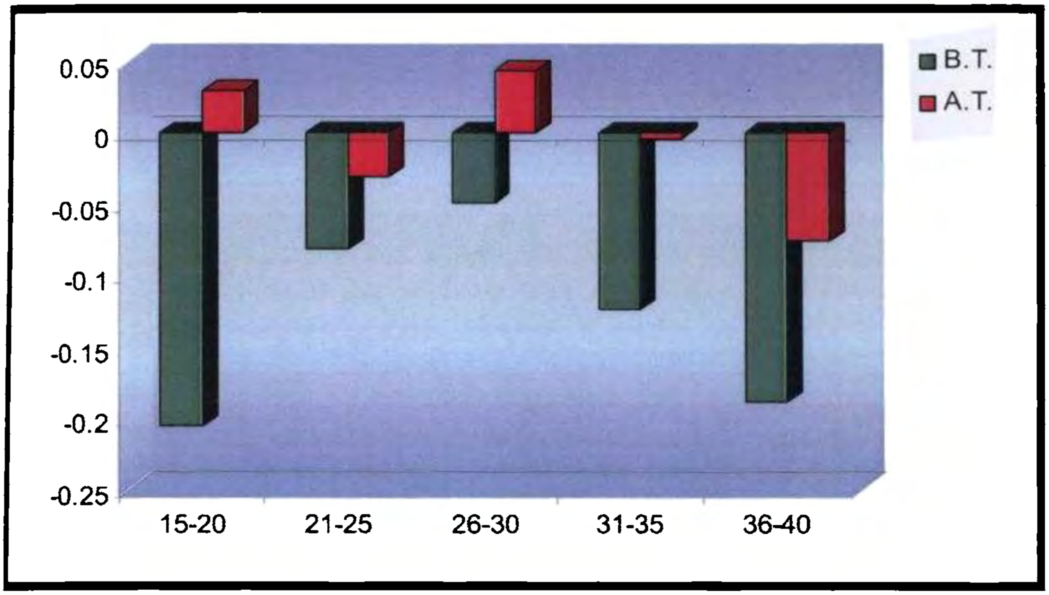



Fig. 8.17. The W-statistic values for upper core (BT vs AT) at all water depth zones were found to be significant ($P < 0.05$) following Paired T test of SPSS

### 8.3.4. Similarity of percentage (SIMPER) analysis for total meiobenthos

The results of SIMPER analysis considering different groups of fauna are given in Tables 8.16 to 8.30. The SIMPER analysis showed that in the upper core, the average dissimilarity was highest at 15-20 m (16.87) in comparison with other depths. The highest dissimilarity at 15-20 m water depth is contributed by the fragments of organisms. The increase in the density of fragments of organisms after experimental trawling showed that the organisms are not only exposed but also crushed into pieces. In lower core, eventhough the density of meiobenthos was lowest the dissimilarity between before and after trawling was evident. Schratzberger and Jennings (2002) made use of SIMPER analysis to find out the species that were responsible for the main differences between nematode assemblages in the areas subject to different levels of disturbance in North Sea.

**Table 8.16.** SIMPER analysis of meiofaunal abundance data for 15-20 m depth upper core. The average dissimilarity between before and after trawling was 16.87

| Species | Average Abundance BT | Average Abundance AT | Average Dissimilarity | Dissimilarity/s.d. | Contribution (%) | Cumulative (%) |
|---|---|---|---|---|---|---|
| Fragments | 11.00 | 18.92 | 5.76 | 1.46 | 34.14 | 34.14 |
| Harpacticoid copepod | 6.25 | 0.67 | 2.92 | 1.23 | 17.33 | 51.46 |
| Ostracod | 4.58 | 1.17 | 2.11 | 1.05 | 12.52 | 63.99 |
| Foraminiferan | 108.50 | 132.58 | 2.07 | 1.13 | 12.29 | 76.27 |
| Polychaete | 1.92 | 0.08 | 1.15 | 0.81 | 6.84 | 83.12 |
| Acari | 1.75 | 0.00 | 1.14 | 0.83 | 6.73 | 89.85 |
| Kinorynch | 2.33 | 0.17 | 1.12 | 0.73 | 6.61 | 96.46 |

**Table 8.17.** SIMPER analysis of meiofaunal abundance data for 15-20 m depth middle core. The average dissimilarity between before and after trawling was 17.94

| Species | Average Abundance BT | Average Abundance AT | Average Dissimilarity | Dissimilarity/s.d. | Contribution (%) | Cumulative (%) |
|---|---|---|---|---|---|---|
| Nematode | 11.50 | 13.50 | 7.64 | 0.76 | 42.59 | 42.59 |
| Foraminiferan | 5.83 | 4.83 | 5.70 | 1.15 | 31.76 | 74.35 |
| Fragments | 0.00 | 0.33 | 2.16 | 0.30 | 12.05 | 86.40 |
| Harpacticoid copepod | 0.17 | 0.00 | 1.60 | 0.44 | 8.91 | 95.30 |

**Table 8.18.** SIMPER analysis of meiofaunal abundance data for 15-20 m depth lower core. The average dissimilarity between before and after trawling was 22.35

| Species | Average Abundance BT | Average Abundance AT | Average Dissimilarity | Dissimilarity/s.d. | Contribution (%) | Cumulative (%) |
|---|---|---|---|---|---|---|
| Foraminiferan | 4.00 | 2.50 | 14.58 | 1.14 | 65.24 | 65.24 |
| Nematode | 10.43 | 7.25 | 7.77 | 0.64 | 34.76 | 100.00 |

**Table 8.19.** SIMPER analysis of meiofaunal abundance data for 21-25 m depth upper core. The average dissimilarity between before and after trawling was 14.70

| Species | Average Abundance BT | Average Abundance AT | Average Dissimilarity | Dissimilarity/s.d. | Contribution (%) | Cumulative (%) |
|---|---|---|---|---|---|---|
| Fragments | 14.92 | 28.33 | 4.77 | 1.36 | 32.42 | 32.42 |
| Foraminiferan | 118.83 | 142.42 | 3.60 | 1.37 | 24.51 | 56.93 |
| Harpacticoid copepod | 1.83 | 2.00 | 1.74 | 0.84 | 11.80 | 68.73 |
| Nematode | 314.92 | 386.00 | 1.56 | 1.10 | 10.61 | 79.34 |
| Polychaete | 1.17 | 1.92 | 1.49 | 0.62 | 10.15 | 89.49 |
| Kinorynch | 1.42 | 0.58 | 1.24 | 0.71 | 8.41 | 97.90 |

**Table 8.20.** SIMPER analysis of meiofaunal abundance data for 21-25 m depth middle core. The average dissimilarity between before and after trawling was 21.02

| Species | Average Abundance BT | Average Abundance AT | Average Dissimilarity | Dissimilarity/s.d. | Contribution (%) | Cumulative (%) |
|---|---|---|---|---|---|---|
| Fragments | 0.17 | 1.67 | 6.13 | 0.81 | 29.18 | 68.10 |
| Foraminiferan | 10.25 | 6.92 | 8.18 | 1.04 | 38.92 | 38.92 |
| Harpacticoid copepod | 0.50 | 0.17 | 2.44 | 0.52 | 11.60 | 94.81 |
| Nematode | 22.75 | 14.58 | 3.18 | 0.97 | 15.12 | 83.21 |

**Table 8.21.** SIMPER analysis of meiofaunal abundance data for 21-25 m depth lower core. The average dissimilarity between before and after trawling was 15.83

| Species | Average Abundance BT | Average Abundance AT | Average Dissimilarity | Dissimilarity/s.d. | Contribution (%) | Cumulative (%) |
|---|---|---|---|---|---|---|
| Foraminiferan | 3.00 | 2.00 | 13.78 | 1.17 | 87.07 | 87.07 |
| Nematode | 14.40 | 10.38 | 2.05 | 1.07 | 12.93 | 100.00 |

**Table 8.22.** SIMPER analysis of meiofaunal abundance data for 26-30 m depth upper core. The average dissimilarity between before and after trawling was 12.29

| Species | Average Abundance BT | Average Abundance AT | Average Dissimilarity | Dissimilarity/s.d. | Contribution (%) | Cumulative (%) |
|---|---|---|---|---|---|---|
| Fragments | 64.67 | 73.58 | 4.75 | 1.32 | 38.68 | 38.68 |
| Foraminiferan | 162.75 | 234.50 | 3.88 | 1.01 | 31.56 | 70.24 |
| Harpacticoid copepod | 1.00 | 2.92 | 1.28 | 0.62 | 10.41 | 80.65 |
| Nematode | 606.42 | 656.33 | 0.94 | 1.33 | 7.66 | 88.31 |
| Polychaete | 1.50 | 0.50 | 0.84 | 0.92 | 6.82 | 95.13 |

**Table 8.23.** SIMPER analysis of meiofaunal abundance data for 26-30 m depth middle core. The average dissimilarity between before and after trawling was 24.12

| Species | Average Abundance BT | Average Abundance AT | Average Dissimilarity | Dissimilarity/s.d. | Contribution (%) | Cumulative (%) |
|---|---|---|---|---|---|---|
| Fragments | 3.25 | 4.09 | 9.05 | 1.19 | 37.51 | 37.51 |
| Foraminiferan | 14.00 | 11.09 | 4.53 | 1.27 | 18.80 | 88.99 |
| Harpacticoid copepod | 0.08 | 0.27 | 1.25 | 0.43 | 5.19 | 94.18 |
| Nematode | 34.25 | 22.73 | 7.88 | 0.76 | 32.68 | 70.19 |

**Table 8.24.** SIMPER analysis of meiofaunal abundance data for 26-30 m depth lower core. The average dissimilarity between before and after trawling was 38.91

| Species | Average Abundance BT | Average Abundance AT | Average Dissimilarity | Dissimilarity/s.d. | Contribution (%) | Cumulative (%) |
|---|---|---|---|---|---|---|
| Fragments | 0.42 | 0.27 | 9.75 | 0.73 | 25.06 | 100.00 |
| Foraminiferan | 4.33 | 3.45 | 14.05 | 1.16 | 36.11 | 74.94 |
| Nematode | 14.58 | 8.09 | 15.11 | 0.95 | 38.83 | 38.83 |

**Table 8.25.** SIMPER analysis of meiofaunal abundance data for 31-35 m depth upper core. The average dissimilarity between before and after trawling was 15.11

| Species | Average Abundance BT | Average Abundance AT | Average Dissimilarity | Dissimilarity/s.d. | Contribution (%) | Cumulative (%) |
|---|---|---|---|---|---|---|
| Fragments | 63.67 | 76.00 | 3.84 | 1.38 | 25.38 | 52.69 |
| Foraminiferan | 197.17 | 270.58 | 4.13 | 1.23 | 27.31 | 27.31 |
| Harpacticoid copepod | 4.25 | 4.67 | 2.01 | 0.96 | 13.30 | 65.99 |
| Nematode | 766.67 | 853.92 | 1.07 | 0.73 | 7.11 | 90.86 |
| Polychaete | 3.67 | 1.08 | 1.35 | 1.07 | 8.96 | 74.95 |
| Kinorynch | 4.00 | 0.92 | 1.33 | 0.65 | 8.81 | 83.76 |

**Table 8.26.** SIMPER analysis of meiofaunal abundance data for 31-35 m depth middle core. The average dissimilarity between before and after trawling was 20.91

| Species | Average Abundance BT | Average Abundance AT | Average Dissimilarity | Dissimilarity/s.d. | Contribution (%) | Cumulative (%) |
|---|---|---|---|---|---|---|
| Fragments | 1.83 | 0.33 | 5.55 | 0.83 | 26.56 | 69.96 |
| Foraminiferan | 21.42 | 13.33 | 9.08 | 0.92 | 43.40 | 43.40 |
| Harpacticoid copepod | 0.75 | 0.25 | 2.12 | 0.53 | 10.16 | 94.82 |
| Nematode | 42.08 | 29.33 | 3.08 | 0.96 | 14.71 | 84.66 |

**Table 8.27.** SIMPER analysis of meiofaunal abundance data for 31-35 m depth lower core. The average dissimilarity between before and after trawling was 26.87

| Species | Average Abundance BT | Average Abundance AT | Average Dissimilarity | Dissimilarity/s.d. | Contribution (%) | Cumulative (%) |
|---|---|---|---|---|---|---|
| Foraminiferan | 6.75 | 4.58 | 17.04 | 1.44 | 63.43 | 63.43 |
| Nematode | 23.00 | 11.33 | 8.38 | 0.61 | 31.18 | 94.62 |

**Table 8.28.** SIMPER analysis of meiofaunal abundance data for 36-40 m depth upper core. The average dissimilarity between before and after trawling was 14.55

| Species | Average Abundance BT | Average Abundance AT | Average Dissimilarity | Dissimilarity/s.d. | Contribution (%) | Cumulative (%) |
|---|---|---|---|---|---|---|
| Fragments | 67.42 | 78.67 | 3.68 | 1.44 | 25.32 | 25.32 |
| Foraminiferan | 235.67 | 343.67 | 3.17 | 1.13 | 21.79 | 71.06 |
| Harpacticoid copepod | 19.50 | 5.17 | 3.49 | 1.27 | 23.95 | 49.27 |
| Kinorynch | 6.17 | 1.67 | 1.55 | 0.84 | 10.68 | 81.74 |
| Polychaete | 5.58 | 2.33 | 1.55 | 1.16 | 10.64 | 92.38 |

**Table 8.29.** SIMPER analysis of meiofaunal abundance data for 36-40 m depth middle core. The average dissimilarity between before and after trawling was 24.24

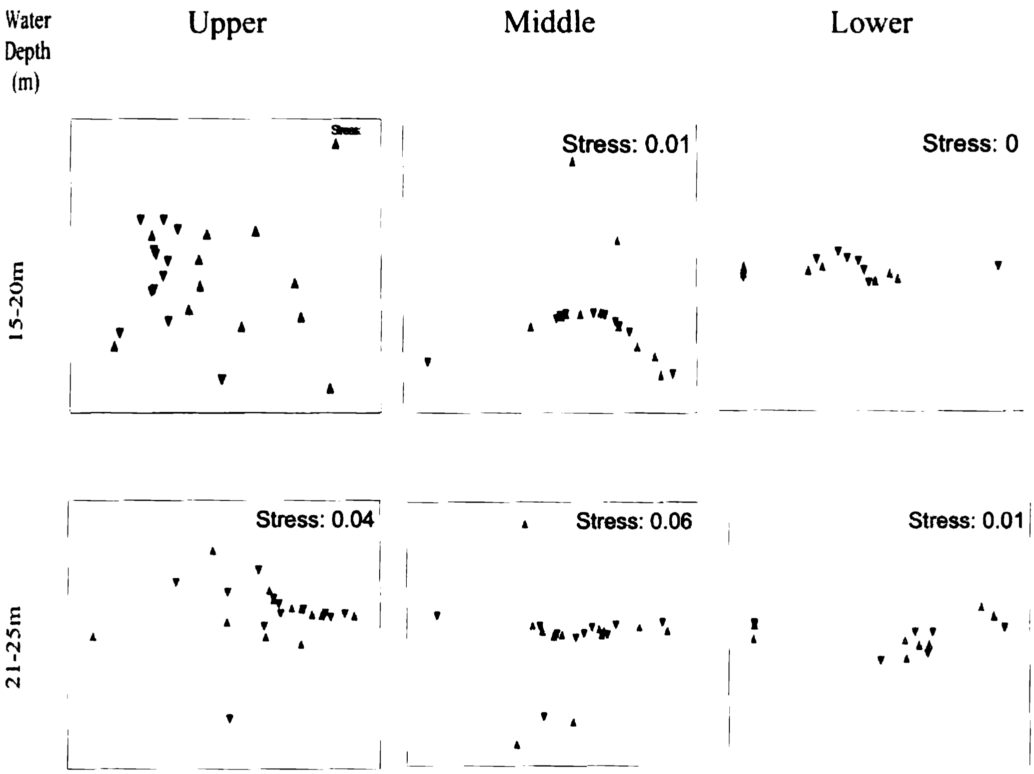
| Species | Average Abundance BT | Average Abundance AT | Average Dissimilarity | Dissimilarity/s.d. | Contribution (%) | Cumulative (%) |
|---|---|---|---|---|---|---|
| Fragments | 7.08 | 4.17 | 7.16 | 1.13 | 29.55 | 29.55 |
| Foraminiferan | 42.25 | 23.50 | 5.57 | 0.78 | 22.99 | 52.54 |
| Nematode | 75.00 | 43.08 | 5.12 | 0.63 | 21.10 | 73.64 |
| Polychaete | 0.00 | 0.67 | 4.24 | 0.42 | 17.47 | 91.11 |

**Table 8.30.** SIMPER analysis of meiofaunal abundance data for 36-40 m depth lower core. The average dissimilarity between before and after trawling was 29.30

| Species | Average Abundance BT | Average Abundance AT | Average Dissimilarity | Dissimilarity/s.d. | Contribution (%) | Cumulative (%) |
|---|---|---|---|---|---|---|
| Foraminiferan | 10.50 | 5.91 | 13.94 | 1.10 | 47.57 | 47.57 |
| Nematode | 20.50 | 21.73 | 10.95 | 0.76 | 37.38 | 84.95 |
| Fragments | 0.50 | 0.00 | 3.41 | 0.54 | 11.63 | 96.58 |

## 8.3.5. Multidimensional Scaling (MDS) Plots for total meiofauna

The multidimensional scaling analyses (MDS) showed that before and after trawling values are clearly segregated in the upper core. This is concurrent with the results of diversity indices analysis, SIMPER and ABC curve outcome. Schratzberger and Jennings (2002) used MDS ordinations to show that differences in nematode assemblage structure due to trawling intensity were greater than the seasonal differences. Schratzberger *et al.* (2002) applied MDS plots to show that meiofauna samples collected within the first 181 days of the experiment formed clusters at the left-hand side of the plot, whereas samples collected 1 year after the beginning of the experiment form a cluster at the right-hand side.



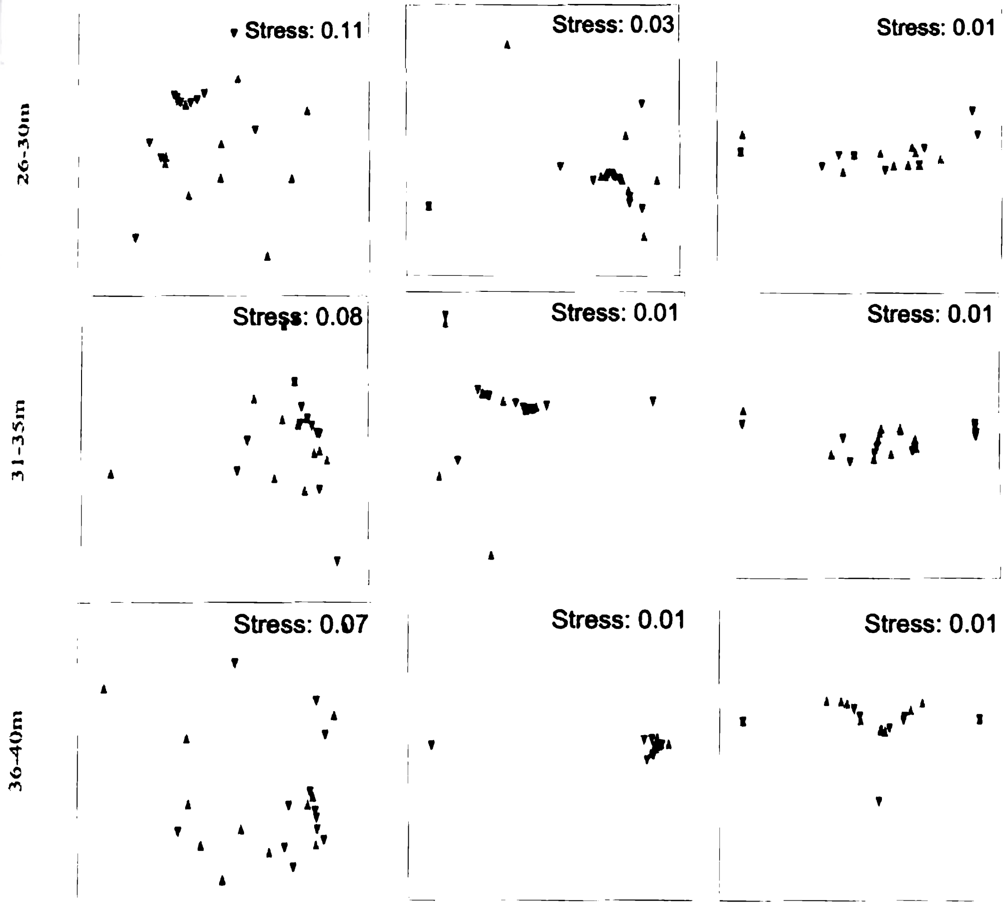



**Fig. 8.18.** Multidimensional scaling (MDS) plots for effect of trawling on meiobenthic fauna at different water depths

▲ Before Trawling ▼ After Trawling

## 8.4. Conclusions

The disturbance to the meiobenthic fauna due to bottom trawling is evident at all water depths investigated in the present study. The total numerical density increased after trawling due to exposure of organism during churning up of sediment. Regarding diversity indices, the impact was obvious in lightly trawled station at 15-20 m water depth. The Abundance Biomass Curve and W-statistic of the total meiofauna showed that the fauna of the upper core were moderately or grossly stressed. MDS plots also enabled to prove the impact on the fauna. SIMPER analysis revealed that the exposed fauna are crushed into pieces which were also striking at 15-20 m. In heavily trawled areas these impacts may have been masked. The trawling impact was evident in the upper core where bulk of the fauna is present. The highest numerical densities in the month of September show that trawl ban period is giving some respite to the fauna for recoupement.

Studies on impact of trawling should be taken up focused on each group of meiofauna. Studies for identifying nematodes and foraminiferans to the species level are recommended. Impact studies on minor groups such as polychaetes, kinorhyncs, ostracods, acari, harpacticoid copepods etc also may give more insight to the problem of impact of trawling. These studies will be useful in identifying indicators of bottom trawling impact.

# Chapter 9

# Summary, Conclusions and Recommendations

## 9.1. Summary

Bottom trawling causes physical and biological damages that are irreversible, extensive and long lasting. The impacts inflicted can be direct or indirect and can be short term or long-term. 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 selected sedimentary heavy metals (iii) epifauna (iv) macrobenthos and (v) meiobenthos.

The experimental design involved the collection of benthic samples before and after experimental trawling along the pre-identified track. The samples collected before and after experimental trawling were compared to detect the impacts of bottom trawling. The five stations studied were at five discrete water depth zones of 15-20 m, 21-25 m, 26-30 m, 31-35 m and 36-40 m. The sediment organic matter, sediment texture, sediment heavy metals, macrobenthos and meiobenthos were analysed with the sediment and infaunal samples collected in van Veen grab. The epifauna collected in rectangular dredge was also analysed.

## 9.2. Conclusions

The major findings of the present study are as follows:

- A single experimental trawling itself considerably reduced the organic matter content at all depths. Continued and incessant trawling operation can cause even more drastic reductions, where already OM content is very less.
- The relative decrease of OM enhanced towards deeper depths as these areas are heavily trawled compared to lightly trawled shallow water depths.
- The variations of sand, silt and clay proportions with trawling effect were not significant. It was observed that the seasonal/natural variations were more prominent masking the trawling effect on silt.
- The general pattern of distribution of heavy metals studied were found to be Mg>Mn>Ni>Cr>Cu>Zn>Pb>Cd.
- All the heavy metals analysed did not give any consistent changes in concentration, that can be attributed to the effect of bottom trawling. This can be due to the fact that the natural variations like spatial (with water depth) and temporal (monthly) variations are more prominent than bottom trawling changes.
- The epifauna identified were 41 species of gastropods (molluscs), 1 species of scaphopod (mollusc), 19 species of bivalves (molluscs), 3 species of crab (crustacean), 3 species of shrimps (crustacean), 2 species of *Balanus* (crustacean), 1 species of stomatopod (crustacean), 4 species of finfishes, 2 species of brown algae and 4 species of octocorals.

- The epifaunal soft corals found were *Litophyton* sp. and *Studeriotes* sp. (Christmas tree soft coral). The gorgonians collected were young stages of *Subergorgia suberosa* (Pallas) and *Juncella juncea* (Pallas) (Whip coral). The specimens are recorded for the first time from the sub-tidal region of Veraval coast. The presence of epifaunal octocorals recorded in the month of October, immediately after the closed season (June to August) when the sea bottom is not heavily trawled suggests that this area is an abode of corals and a favourable site for coral reef formation. But intense trawling in the succeeding months destroys these valuable entities of ecosystem and the samples were not encountered in the subsequent months.
- The changes before and after trawling in epifaunal biodiversity indices were significant at 15-20 m. This result can be attributed to the damage inflicted to sedentary fauna like octocorals, hydroids, bryozoans etc.
- The epifaunal abundance-biomass curve showed that the rate of stress increased with water depth. The shallow depths are lightly trawled due to intermittent rocky nature of bottom and as water depth increases, the trawling intensity increases. The $W$ statistic which is a synoptic descriptor of abundance-biomass curve were found to be negative in heavily trawled areas (26-30 m, 31-35 m and 36-40 m) and positive in lightly trawled areas (15-20 m and 21-25 m).
- By using the similarity of percentages in the SIMPER routine, the average epifaunal dissimilarity between before and after trawling was highest at 15-20 m water depth. This dissimilarity decreased with increasing water depths and was observed to be lowest at 36-40 m. The dissimilarity of fauna before and

after experimental trawling was more evident in lightly trawled area and remained masked in heavily trawled area.

- The groups of macrofauna represented were polychaetes, molluscs (gastropods, bivalves and scaphopods) crustaceans (crab, shrimp, cumaceans, amphipods, ostracods, isopods, copepods, squilla, balanids), foraminferans, nemerteans, cnidaria (octocorals), sipunculids, teleost fishes (mainly *Trypauchen vagina*, followed by *Filimanus similis*, leptocephalus and *Cynoglossus* sp.), pogonophores, pterobranchia, brittle stars and teleost fishes. A total of 81 species of polychaetes belonging to Errantia (36) and Sedentaria (45) were identified. 15 species of gastropods, 13 species of bivalves and 1 species of scaphopod constituted the molluscs. One macrobenthic octocoral was also identified.

The macrobenthic octocoral observed was *Lituaria* sp. It was observed throughout the year at depths of 21-40 m because they escape from trawling effect to a certain extent as they live buried in sediment. The increase in the number and biomass after trawling signifies that they are exposed during bottom trawling.

The biodiversity indices of macrofauna were found to be significantly different before and after trawling at 15-20 m water depth and 21-25 m water depth. The stress on biodiversity was more evident in lightly trawled areas than in heavily trawled areas.

The Abundance Biomass Curve and *W*-statistic of the total macrofauna showed that the fauna of the area studied were moderately or grossly stressed.

- In multidimensional scaling (MDS) plots of macrofauna, wide distance was observed between before and after trawling clusters. The variation in species and abundance may be the cause for the stretching observed.
- The meiobenthos were represented by eight groups, of which the nematodes constituted the bulk of the population followed by foraminiferans. Polychaetes, kinorhynchs, harpacticoid copepods, ostracods, acari, and bivalves were present in low densities and were of irregular occurrence.
- The disturbance to the meiobenthic fauna due to bottom trawling was evident at all water depths. The total numerical density increased after trawling due to exposure of organism during churning up of sediment. An average 13 % increase in abundance was noted after experimental trawling. This increase in abundance after trawling is mainly contributed by nematodes and foraminiferans that form the major proportion of fauna at all depths.
- The biodiversity indices of meiofauna showed that the impact was obvious in lightly trawled station at 15-20 m water depth.
- The analysis of similarity of percentages in Simper also revealed striking impact at 15-20 m for meiofauna. In heavily trawled areas these impacts may have been masked.
- The trawling impact was evident in the upper core where bulk of the meiofauna was present.
- The numerical density of macrofauna and meiofauna increased after trawl ban showing that trawl ban was giving some respite to the fauna for rejuvenation.

## 9.3. Recommendations

- **Control of excess bottom trawlers**

The estimated optimum fleet size of Gujarat is 1,473 mechanised trawlers (Kurup and Devaraj, 2000) while 7402 commercial trawlers are operated from here (Anon, 2005a). 2793 trawlers are being operated from Veraval port, which was designed initially for 1,200 fishing trawlers. Their number has to be regulated in a responsible fishing regime. There is a need for revalidating the potential resource estimates for more reliable determination of fleet size and their composition for sustainable harvesting of resources of the state. Effective use of Geographical Information System (GIS) has to be made for resource mapping, exploitation and control of bottom trawlers.

**ROV and SONAR could assess the impact on epifauna and substratum**

The occurrence of octocorals in the sub-tidal trawling ground warrants the need for conducting further studies on the impact of bottom trawling on the reef ecosystem. A comprehensive underwater study using remotely operated vehicle (ROV) and SONAR needs to be undertaken to bring to light the precise impact. This will aid in tackling management issues of mapping the areas where corals thrive and limiting or closing bottom trawling in these regions. The impact on other epifauna and substratum will also be more evident from these studies.

- **Database on resources**

Gujarat coast lacks adequate database on resources and environment, which is a prerequisite for decision making support for any thriving industry. Strong information system on marine fisheries, marine ecology, biodiversity and environment has to be developed and made available to the decision makers and fishery managers. Continuous monitoring of benthic fauna will enable to build a database on changes in benthic assemblages. Time-series data are needed to describe the long-term effects of fishing.

**Taxonomic studies should be promoted**

The taxonomy of benthic fauna of fishing grounds has to be documented. The investigators often neglect this field of research as taking up studies in benthic taxonomy is time consuming and obscure. In vogue of the fact that benthic taxonomists are few in India, studies on benthic taxonomy of fishing grounds have to be promoted and catalogued. The benthic habitat and communities have to be periodically checked. The species composition of benthic fauna can indicate the 'health' of a community. Indicator species are essential to assess the impact of bottom trawling. Cataloging the biodiversity, identification of indicator species and updating the new data generated will aid in taking up steps towards conservation of epifauna, macrobenthos and meiobenthos.

- **Trophic relationships of benthic fauna with fishery have to be checked**

Gut content analysis of commercially important fishes will reveal whether the impact on benthic fauna is reflected in the fishery. Whether bottom trawling is increasing or decreasing the food resource of commercially important fish species has to be investigated. Whether the increase in numercal density of meiofauna and macrofauna has far reaching effects on commercial fishery has to be studied.

- **Studies on dispersion of contaminants**

The importance of bottom trawling resuspension of contaminants must be evaluated. The concentration of contaminants in water samples (bottom and surface) and sediment should be monitored simultaneously before/after experimental trawling to understand the changes in their sediment –water interface fluxes induced by bottom trawling. Studies have to be taken up on whether bottom trawling can remobilize substantial amounts of sediment associated contaminants (e.g. heavy metals) and add to the pollution load.

- **Comparative studies using different gear type and design**

The impact can vary with operational design of gears. Comparative studies operating gears with different rigging, swept area, mesh size etc can be done. The tow duration and number of tows along the same path can be varied. The impact generated by bottom trawl can be compared with trawl nets with modifications.

- **Recoupement of fauna after specific period of time after trawling**

The recoupement of fauna after specific period of time subsequent to experimental trawling have to be assessed. After trawling, the bottom fauna has to be sampled at regular intervals as immediately after trawling, different hours after trawling, 15 days after trawling and 30 days after trawling. Also long-term studies for three to five years are necessary.

**Closed areas/ seasons**

Closure of certain areas in the sea for fishing and banning of fishing in certain seasons are some of the well-known methods in vogue in the management of the exploited fishery resources. There is a traditional long standing practice, in Gujarat, of observing closed seasons during monsoon. Most species in Indian waters with the exception of a few in which seasonal breeding has been clearly established, are continuous breeders (James, 1992). So the implementation of a closed season along Gujarat coast mostly serves the purpose of a reduction in fishing effort rather than protecting the spawning stocks (Devaraj *et al.*, 1998). It is an effective method to reduce excess fishing pressure and to give respite to the benthic fauna enabling recoupement. Further research on the breeding biology of all the major commercially valuable species is necessary to know whether trawl ban is during the peak breeding season of commercially exploited valuable species. Closed areas for trawling should be advocated as this study has recorded the presence of octocorals in sub-tidal areas.

- **Appropriate control sites necessary**

Suitable untrawled control sites were not available in the present study, for comparative assessment. The control site selected for the study was before the experimental trawling and here commercial trawlers might have trawled previously. To conduct studies on trawling impacts, appropriate control sites are very much necessary. The control site must resemble the disturbed site in depth, currents, sediment characteristics and benthic assemblage.

- **Eco-friendly gears**

Ecofriendly trawls with light rigging have to be promoted to minimize physical disturbance to the benthic fauna. The impact of bottom trawl on the substratum can be lessened, by rigging them to operate a small distance above the sea bottom as in semi-pelagic trawl. Semi- pelagic trawl systems have been developed for medium size trawlers by CIFT and hold potential for introduction to Veraval for efficient harvesting of off-bottom resources.

- **Studies on technical modifications of trawl nets to be promoted**

Studies on gear modifications like water jet injection or electrical stimulation at the foot rope instead of tickler chains, provision of more floats, incorporation of release holes at codends, benthos release panels etc can be promoted.

- **Diversification of fishing methods**

Trawlers can be modified adopting less damaging fishing gears such as optimized gill nets, long lines and hand lines.

- **Deep sea fishing**

Deep sea fishing can be promoted to reduce the severe fishing pressure in coastal areas. Aimed midwater trawling for horse mackerel and pelagic drift long lines for oceanic tunas, pelagic sharks and sailfish can be encouraged.

- **Training and education of fishermen / Awareness programme**

Training and creating awareness in responsible fishing should be made mandatory requirements, to the coastal communities. They should be made wardens to protect the valuable resources for the benefit of sustainability.

- **Biodiversity conservation**

Many organisations such as UNESCO, UNU, CIDA, FAO, IUCN, UNDP, UNEP etc have shown great deal of interest in the biodiversity investigations ever since the 'Biodiversity Convention' was signed in 1992 in Rio de Janeiro. India is a signatory to this convention. To protect the biodiversity and ecosystem health, the imminent need is to survey and make inventory, data base development, identification of sensitive areas or hot spots and to adopt management strategies for the conservation and biodiversity protection of benthic fauna.

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# APPENDIX I

## Appendix I: Epifaunal Species Lists

**Table I:** Abundance list of the species found in the epibenthic samples around Veraval coast. The average numerical abundance (number) is expressed as % composition/haul. BT – Before Trawling; AT – After Trawling

| | | 15-20 m | | 21-25 m | | 26-30 m | | 31-35 m | | 36-40 m | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Species** | **BT** | **AT** | **BT** | **AT** | **BT** | **AT** | **BT** | **AT** | **BT** | **AT** |
| **Gastropoda** | | | | | | | | | | | |
| Architectonicidae | *Architectonica laevigata* | 0.4 | 0 | 0 | 0 | 0 | 0 | 0.06 | 0 | 0.12 | 0.08 |
| Buccinidae | *Babylonia spirata* | 2.83 | 0.75 | 0.29 | 0 | 0.28 | 0 | 0.06 | 0.45 | 0.12 | 0.4 |
| Cancellaridae | *Cancellaria costifera* | 0.27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Conidae | *Conus betulinus* | 0.67 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Conus eldredi* | 1.62 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.08 | 0.23 |
| Ficidae | *Ficus gracilis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.04 | 0 |
| Melongenidae | *Hemifusus cochlidium* | 0.13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mitridae | *Mitra eremiatrum* | 1.75 | 0 | 0 | 0 | 0.14 | 0 | 0 | 0 | 0 | 0.06 |
| Muricidae | *Chicoreus brunneus* | 0.13 | 0 | 0 | 0 | 0.14 | 0.03 | 0 | 0 | 0.08 | 0 |
| | *Chicoreus sp.* | 1.62 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Hexaplex trunculus* | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Murex acanthostephes* | 0.13 | 0 | 2.94 | 1.44 | 1.13 | 0.35 | 1.12 | 0.18 | 1.57 | 0.14 |
| | *Murex carbonnieri* | 0 | 0 | 0 | 0 | 0.42 | 0.38 | 0.19 | 0.15 | 0.39 | 0.23 |
| | *Murex maurus* | 0.27 | 0 | 0 | 0 | 0.28 | 0.21 | 0 | 0.13 | 0.2 | 0 |
| | *Murex* sp. | 0.81 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0.12 | 0 |
| | *Rampana bulbosa* | 0.4 | 0.75 | 2.06 | 0.29 | 1.55 | 1.18 | 0 | 0.31 | 0.35 | 0.39 |
| | *Thais bufo* | 0.13 | 3.76 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nassariidae | *Nassarius arcularis* | 9.31 | 3.76 | 0 | 0.58 | 0.14 | 0 | 0 | 0.21 | 0 | 0.15 |
| | *Nassarius* spp. | 0.67 | 3.76 | 2.35 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 |
| | *Nassarius suturalis* | 0.13 | 0 | 4.41 | 0.58 | 2.82 | 0.52 | 1.24 | 0.24 | 0.31 | 0.06 |
| | *Nassarius thersites* | 0 | 0 | 6.18 | 4.32 | 4.94 | 2.68 | 4.28 | 1.12 | 3.57 | 1.75 |
| Naticidae | *Natica didyma* | 0 | 0 | 1.47 | 0.29 | 1.55 | 1.43 | 1.61 | 0.66 | 0.27 | 0.34 |
| | *Natica lineata* | 0 | 0 | 1.18 | 0 | 0.28 | 0.21 | 0.62 | 0.07 | 0.27 | 0.14 |
| | *Natica vitellus* | 0.27 | 0 | 0.59 | 0 | 0.99 | 0.1 | 0.31 | 0.06 | 0.51 | 0.22 |
| | *Sinum* sp. | 0 | 0 | 0 | 0 | 0 | 0.03 | 0 | 0.01 | 0 | 0 |
| Potamididae | *Potamides cingulatus* | 0 | 3.76 | 0 | 0 | 0 | 0 | 0 | 0 | 0.04 | 0.06 |
| Pyrenidae | *Pyrene* sp. | 0.27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ranellidae | *Cymatium aquatile* | 0.54 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Strombidae | *Strombus mutabulis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.03 | 0 | 0 |

| | Species | 15-20 m BT | 15-20 m AT | 21-25 m BT | 21-25 m AT | 26-30 m BT | 26-30 m AT | 31-35 m BT | 31-35 m AT | 36-40 m BT | 36-40 m AT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Tibia curta* | 3.1 | 5.26 | 6.47 | 10.62 | 4.66 | 1.29 | 1.92 | 0.72 | 1.73 | 0.76 |
| Trochidae | *Umbonium vestiarium* | 0 | 0 | 0 | 0 | 1.13 | 0 | 0 | 0.3 | 1.73 | 0.46 |
| Turridae | *Surcula amicta* | 0 | 0 | 0.29 | 0 | 2.26 | 0.94 | 0.31 | 0.37 | 0.24 | 0.09 |
| | *Surcula* sp. | 0.13 | 0 | 0.59 | 0 | 0.14 | 0 | 0.19 | 0.15 | 0.08 | 0 |
| | *Turricula javana* | 0 | 0 | 2.06 | 8.35 | 0.85 | 1.5 | 1.98 | 1 | 0.67 | 0.38 |
| | *Xenoturris cingulifera* | 0.27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Xenophoridae | *Xenophora solaris* | 0 | 0 | 0 | 0 | 0.14 | 0.7 | 0.68 | 0.45 | 0.16 | 0.67 |
| Bursidae | *Bursa echinata* | 0.67 | 2.26 | 2.06 | 4.61 | 3.25 | 3.27 | 0.68 | 0.78 | 0.43 | 0.59 |
| | *Bursa spinosa* | 2.29 | 0 | 2.65 | 6.62 | 3.67 | 1.74 | 1.8 | 0.81 | 1.06 | 0.57 |
| Calliostomatidae | *Calliostoma sp.* | 0 | 3.76 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fissurellidae | *Diodora lima* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.16 | 0.05 |
| Trochidae | *Trochus raditus* | 0.13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Scaphopoda** | | | | | | | | | | | |
| Dentallidae | *Dentalium aprinum* | 0 | 0 | 2.94 | 2.88 | 2.4 | 2.12 | 2.79 | 0.79 | 1.84 | 0.72 |
| **Bivalvia** | | | | | | | | | | | |
| Cardiidae | *Cardium asiaticum* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.15 | 0 | 0 |
| Donacidae | *Donax scortum* | 0.67 | 0 | 0.88 | 3.45 | 3.81 | 0.87 | 0.81 | 0.15 | 0.04 | 0 |
| | *Donax* sp. | 1.89 | 1.5 | 0 | 1.44 | 2.12 | 0.59 | 1.05 | 0.37 | 2.35 | 0.11 |
| Mactridae | *Mactra cornea* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0.07 |
| | *Meropesta pellucida* | 0 | 0 | 1.47 | 0 | 0.71 | 0.03 | 0 | 0.3 | 0 | 0.06 |
| Pholadidae | *Pholas* sp. | 0 | 0 | 1.76 | 0.86 | 0 | 0.14 | 0.62 | 0 | 0 | 0.01 |
| Veneridae | *Dosinia cretacea* | 0.67 | 4.51 | 0 | 4.32 | 3.11 | 3.2 | 3.35 | 6 | 6.4 | 27.55 |
| | *Dosinia gibba* | 0.27 | 0 | 4.41 | 1.44 | 0.71 | 0.35 | 0.62 | 0.54 | 2.9 | 1.05 |
| | *Paphia papilionis* | 0 | 11.28 | 0 | 0 | 0 | 0 | 0 | 0 | 0.67 | 0.13 |
| | *Paphia textile* | 6.21 | 0.75 | 9.12 | 3.45 | 7.49 | 58.94 | 17.6 | 29.8 | 21.39 | 34.26 |
| Anomiidae | *Anomia ephippium* | 0.13 | 0 | 0 | 0 | 0 | 0.03 | 0 | 0 | 0 | 0 |
| Arcidae | *Anadara* spp | 3.64 | 14.28 | 20 | 21.5 | 12.15 | 4.98 | 5.02 | 6.09 | 5.69 | 1.95 |
| | *Arca navicularis* | 0 | 4.51 | 2.06 | 0.29 | 1.55 | 0.49 | 0.19 | 0.22 | 0.04 | 0.14 |
| | *Scarpha inaequivalvis* | 1.35 | 0 | 0.88 | 8.06 | 8.47 | 2.44 | 1.86 | 0.19 | 1.41 | 0.2 |
| | *Trisodos tortuosa* | 4.86 | 3.76 | 7.06 | 0 | 0 | 0.17 | 0.87 | 0.37 | 2.04 | 0.43 |
| Ostreidae | *Crassostrea madrasensis* | 0 | 0 | 0 | 0 | 0.56 | 0.03 | 0 | 0 | 0.04 | 0.02 |
| Pectnidae | *Chlamys singaporina* | 8.77 | 0 | 2.94 | 5.18 | 10.31 | 2.4 | 14.56 | 18.81 | 14.52 | 14.95 |
| | *Chlamys tranquebaricus* | 23.62 | 0 | 4.41 | 7.2 | 13.28 | 3.31 | 33.15 | 26.2 | 25.12 | 10.11 |

| | Species | 15-20 m | | 21-25 m | | 26-30 m | | 31-35 m | | 36-40 m | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| **Crustacea** | | | | | | | | | | | |
| Calappidae | *Calappa lophos* | 0 | 3.01 | 0 | 0.58 | 0 | 0 | 0 | 0.04 | 0 | 0 |
| Penaeidae | *Metapenaeus dobsoni* | 0.27 | 4.51 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Metapenaeus monoceros* | 0.27 | 6.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Portunidae | *Charybdis cruciata* | 0.54 | 0 | 0.88 | 0.78 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Charybdis lucifeara* | 0.13 | 3.76 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Portunus sanguinolentus* | 0 | 2.26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Squillidae | *Oratosquilla nepa* | 0.4 | 0.75 | 0.29 | 0.29 | 0 | 0 | 0 | 0 | 0 | 0 |
| Balanidae | *Balanus amphitrite* | 7.42 | 7.52 | 2.06 | 3.74 | 1.27 | 1.29 | 0.19 | 0.67 | 0.63 | 0.18 |
| | *Balanus reticulatus* | 5.4 | 3.76 | 2.35 | 2.88 | 1.27 | 1.95 | 0.31 | 1.05 | 0.43 | 0.25 |
| **Osteichthyes** | | | | | | | | | | | |
| Apogonidae | *Apogon* sp. | 0.13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gobiidae | *Trypauchen vagina* | 0 | 0 | 0 | 0.29 | 0 | 0 | 0 | 0 | 0 | 0 |
| Polynemidae | *Filimanus similis* | 0 | 0 | 0.88 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cynoglossidae | *Cynoglossus macrostomus* | 0 | 0 | 0 | 0.52 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Phaeophyceae** | | | | | | | | | | | |
| Cystoseiraceae | *Cystoseira trinodis* | 0.27 | 0 | 0 | 0.29 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sargassaceae | *Sargassum wightii* | 0.4 | 0 | 0 | 0.29 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Anthozoa** | | | | | | | | | | | |
| Nephtheidae | *Litophyton* sp. | 1.62 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Subergorgiidae | *Studeriotes* sp. | 1.08 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ellisellidae | *Juncella juncea* | 0.27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Paralcyoniidae | *Subergorgia suberosa* | 0.27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 2**: Biomass list of the species found in the epibenthic samples around Veraval coast. The average biomass (grams) is expressed as % composition/haul. BT – Before Trawling; AT – After Trawling

| | | 15-20 m | | 21-25 m | | 26-30 m | | 31-35 m | | 36-40 m | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Species** | **BT** | **AT** | **BT** | **AT** | **BT** | **AT** | **BT** | **AT** | **BT** | **AT** |
| **Gastropoda** | | | | | | | | | | | |
| Architectonicidae | *Architectonica laevigata* | 0.49 | 0 | 0 | 0 | 0 | 0 | 0.08 | 0 | 0.13 | 0.1 |
| Buccinidae | *Babylonia spirata* | 0.49 | 0.53 | 0.35 | 0 | 0.28 | 0 | 0.15 | 0.35 | 0.13 | 0.75 |
| Bursidae | *Bursa echinata* | 0.92 | 1.07 | 1.22 | 1.23 | 3.26 | 4.43 | 1.16 | 2.21 | 1.33 | 1.79 |
| | *Bursa spinosa* | 1.96 | 0 | 1.64 | 1.84 | 2.65 | 2.98 | 2.39 | 2.52 | 2.4 | 1.18 |
| Cancellaridae | *Cancellaria costifera* | 0.07 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Conidae | *Conus betulinus* | 0.49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Conus eldredi* | 1.64 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.03 | 0.06 |
| Ficidae | *Ficus gracilis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.33 | 0 |
| Melongenidae | *Hemifusus cochlidium* | 0.49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mitridae | *Mitra eremiatrum* | 0.49 | 0 | 0 | 0 | 0.28 | 0 | 0 | 0 | 0 | 0.03 |
| Muricidae | *Chicoreus brunneus* | 0.03 | 0 | 0 | 0 | 0.14 | 0.11 | 0 | 0 | 0.07 | 0 |
| | *Chicoreus* sp. | 1.08 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Hexaplex trunculus* | 0.33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Murex acanthostephes* | 0.16 | 0 | 0.87 | 0.7 | 2.07 | 0.83 | 2.31 | 0.48 | 4.4 | 0.21 |
| | *Murex crabonnieri* | 0 | 0 | 0 | 0 | 0 | 0.76 | 0.23 | 0.18 | 1.31 | 0.26 |
| | *Murex maurus* | 0.33 | 0 | 0 | 0 | 0.28 | 0.21 | 0 | 0.18 | 0.33 | 0 |
| | *Murex* sp | 0.82 | 0 | 0 | 0 | 3.26 | 0.21 | 0 | 0 | 0.2 | 0 |
| | *Rampana bulbosa* | 0.49 | 2.13 | 2.27 | 0.28 | 2.65 | 0.83 | 0 | 0.53 | 0.72 | 0.67 |
| | *Thais bufo* | 0.16 | 1.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nassariidae | *Nassarius arcularis* | 3.27 | 0.53 | 0 | 0.28 | 0 | 0 | 0 | 0.22 | 0 | 0.1 |
| | *Nassarius* spp. | 0.33 | 1.6 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 |
| | *Nassarius suturalis* | 0.1 | 0 | 1.75 | 0.31 | 0 | 0.39 | 0.54 | 0.18 | 0.24 | 0.06 |
| | *Nassarius thersites* | 0 | 0 | 1.22 | 0.56 | 0 | 1.27 | 1.36 | 0.62 | 1.26 | 1.12 |
| Naticidae | *Natica didyma* | 0 | 0 | 1.5 | 0.14 | 0.28 | 0.73 | 0.62 | 0.71 | 0.22 | 0.64 |
| | *Natica lineata* | 0 | 0 | 0.87 | 0 | 0.14 | 0.3 | 0.23 | 0.18 | 0.22 | 0.3 |
| | *Natica vitellus* | 0.33 | 0 | 0.52 | 0 | 0 | 0.21 | 0.77 | 0.13 | 0.62 | 0.27 |
| | *Sinum* sp. | 0 | 0 | 0 | 0 | 0 | 0.04 | 0 | 0.04 | 0 | 0 |
| Potamididae | *Potamides cingulatus* | 0 | 1.6 | 0 | 0 | 2.07 | 0 | 0 | 0 | 0.04 | 0.03 |
| Pyrenidae | *Pyrene* sp. | 0.07 | 0 | 0 | 0 | 0.41 | 0 | 0 | 0 | 0 | 0 |
| Ranellidae | *Cymatium aquatile* | 0.33 | 0 | 0 | 0 | 0.28 | 0 | 0 | 0 | 0 | 0 |

| | Species | 15-20 m BT | 15-20 m AT | 21-25 m BT | 21-25 m AT | 26-30 m BT | 26-30 m AT | 31-35 m BT | 31-35 m AT | 36-40 m BT | 36-40 m AT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Strombidae | *Strombus mutabulis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.09 | 0 | 0 |
| | *Tibia curta* | 31.56 | 35.72 | 54 | 72.92 | 0.83 | 28.04 | 23.35 | 18.84 | 21.42 | 8.98 |
| Trochidae | *Umbonium vestiarium* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.09 | 0.38 | 0.22 |
| Turridae | *Surcula amicta* | 0 | 0 | 0.35 | 0 | 0.14 | 0.69 | 0.15 | 0.35 | 0.16 | 0.18 |
| | *Surcula* sp. | 0.16 | 0 | 0.17 | 0 | 0 | 0 | 0.08 | 0.09 | 0.13 | 0 |
| | *Turricula javana* | 0 | 0 | 1.05 | 1.68 | 1.44 | 1.27 | 0.68 | 0.65 | 0.66 | 0.46 |
| | *Xenoturris cingulifera* | 0.16 | 0 | 0 | 0 | 1.38 | 0 | 0 | 0 | 0 | 0 |
| Xenophoridae | *Xenophora solaris* | 0 | 0 | 0 | 0 | 0.41 | 0.14 | 0.62 | 0.57 | 0.29 | 1.05 |
| Calliostomatidae | *Calliostoma* sp. | 0 | 1.07 | 0 | 0 | 0.28 | 0 | 0 | 0 | 0 | 0 |
| Fissurellidae | *Diodora lima* | 0 | 0 | 0 | 0 | 0.69 | 0 | 0 | 0 | 0.08 | 0.1 |
| Trochidae | *Trochus raditus* | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Scaphopoda** | | | | | | | | | | | |
| Dentallidae | *Dentalium aprinum* | 0 | 0 | 0.35 | 0.28 | 0 | 0.86 | 0.72 | 0.38 | 0.75 | 0.38 |
| **Bivalvia** | | | | | | | | | | | |
| Cardiidae | *Cardium asiaticum* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.13 | 0 | 0 |
| Donacidae | *Donax scortum* | 0.49 | 0 | 0.56 | 0.7 | 0 | 0.89 | 0.25 | 0.18 | 0.07 | 0 |
| | *Donax* sp. | 1.31 | 0.53 | 0 | 0.36 | 0 | 0.47 | 0.6 | 0.27 | 0.72 | 0.06 |
| Mactridae | *Mactra cornea* | 0 | 0 | 0 | 0 | 53.47 | 0 | 0 | 0 | 0.53 | 0.1 |
| | *Meropesta pellucida* | 0 | 0 | 0.35 | 0 | 0.53 | 0.07 | 0 | 0.13 | 0 | 0.03 |
| Pholadidae | *Pholas* sp. | 0 | 0 | 0.52 | 0.08 | 0.64 | 0.11 | 0.23 | 0 | 0 | 0.06 |
| Veneridae | *Dosinia cretacea* | 0.49 | 2.67 | 0 | 0.56 | 0.14 | 4.67 | 1.57 | 3.36 | 5.45 | 13.48 |
| | *Dosinia gibba* | 0.07 | 0 | 0.52 | 0.14 | 0.44 | 0.28 | 0.15 | 0.36 | 1.12 | 1.53 |
| | *Paphia papilionis* | 0 | 3.73 | 0 | 0 | 0 | 0 | 0 | 0 | 0.39 | 0.1 |
| | *Paphia textile* | 2.62 | 1.07 | 2.45 | 1.62 | 0.28 | 15.2 | 10.63 | 9.95 | 15.18 | 25.02 |
| Anomiidae | *Anomia ephippium* | 0.16 | 0 | 0 | 0 | 0 | 0.07 | 0 | 0 | 0 | 0 |
| Arcidae | *Anadara* spp. | 2.78 | 3.73 | 4.89 | 3.65 | 0 | 3.16 | 1.29 | 1.25 | 2.56 | 0.99 |
| | *Arca navicularis* | 0 | 1.6 | 0.7 | 0.14 | 0 | 0.42 | 0.03 | 0.13 | 0.07 | 0.38 |
| | *Scarpha inaequivalvis* | 0.49 | 0 | 0.35 | 1.93 | 0.58 | 1.32 | 0.71 | 0.22 | 0.92 | 0.19 |
| | *Trisodos tortuosa* | 0.85 | 2.67 | 1.05 | 0 | 0 | 0.07 | 0.54 | 0.27 | 1.24 | 0.38 |
| Ostreidae | *Crassostrea madrasensis* | 0 | 0 | 0 | 0 | 1.58 | 0.07 | 0 | 0 | 0.13 | 0.01 |
| Pectnidae | *Chlamys singaporina* | 3.6 | 0 | 0.52 | 0.36 | 0.55 | 0.68 | 3.78 | 2.03 | 3.94 | 1.41 |
| | *Chlamys tranquebaricus* | 9.16 | 0 | 0.7 | 0.7 | 0 | 1.11 | 11.25 | 6.41 | 7.03 | 2.43 |

| | Species | 15-20 m | | 21-25 m | | 26-30 m | | 31-35 m | | 36-40 m | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| **Crustacea** | | | | | | | | | | | |
| Calappidae | *Calappa lophos* | 0 | 3.2 | 0 | 0.28 | 0.28 | 0 | 0 | 0.13 | 0 | 0 |
| Penaeidae | *Metapenaeus dobsoni* | 0.33 | 2.13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Metapenaeus monoceros* | 1.64 | 5.33 | 0 | 0 | 2.18 | 0 | 0 | 0 | 0 | 0 |
| Portunidae | *Charybdis cruciata* | 0.65 | 0 | 0.7 | 0.38 | 0.28 | 0 | 0 | 0 | 0 | 0 |
| | *Charybdis lucifeara* | 0.16 | 2.67 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Portunus sanguinolentus* | 0 | 3.2 | 0 | 0 | 3.4 | 0 | 0 | 0 | 0 | 0 |
| Squillidae | *Oratosquilla nepa* | 0.82 | 0.85 | 0.35 | 0.14 | 0 | 0 | 0 | 0 | 0 | 0 |
| Balanidae | *Balanus amphitrite* | 1.64 | 1.07 | 0.35 | 0.36 | 5 | 0.37 | 0.08 | 0.35 | 0.34 | 0.16 |
| | *Balanus reticulatus* | 1.31 | 0.53 | 0.52 | 0.28 | 0.69 | 0.64 | 0.15 | 0.57 | 0.26 | 0.16 |
| **Osteichthyes** | | | | | | | | | | | |
| Apogonidae | *Apogon* sp. | 0.33 | 0 | 0 | 0 | 2.07 | 0 | 0 | 0 | 0 | 0 |
| Gobiidae | *Trypauchen vagina* | 0 | 0 | 0 | 0.22 | 0 | 0 | 0 | 0 | 0 | 0 |
| Polynemidae | *Filimanus similis* | 0 | 0 | 0.87 | 0 | 0.28 | 0 | 0 | 0 | 0 | 0 |
| Cynoglossidae | *Cynoglossus macrostomus* | 0 | 0 | 0 | 0.2 | 1.8 | 0 | 0 | 0 | 0 | 0 |
| **Phaeophyceae** | | | | | | | | | | | |
| Cystoseiraceae | *Cystoseira trinodis* | 1.64 | 0 | 0 | 0.14 | 2.63 | 0 | 0 | 0 | 0 | 0 |
| Sargassaceae | *Sargassum wightii* | 3.27 | 0 | 0 | 0.42 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Anthozoa** | | | | | | | | | | | |
| Nephtheidae | *Litophyton* sp. | 1.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Subergorgiidae | *Studeriotes* sp. | 1.14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ellisellidae | *Juncella juncea* | 0.65 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Paralcyoniidae | *Subergorgia suberosa* | 0.33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Polychaeta** | Polychaete tubes | 8.83 | 2.67 | 4.72 | 1.12 | 0 | 0.79 | 1.93 | 0.44 | 3.55 | 0.38 |
| **Mollusca** | Damaged shells | 6.54 | 16.52 | 11.01 | 6.01 | 0 | 25.34 | 31.37 | 44.22 | 18.66 | 34.16 |

# APPENDIX II

## Appendix II: Macrofaunal Species Lists

**Table 1:** Abundance list of the species found in the macrobenthic samples around Veraval coast.

The numerical abundance is expressed as number /m2. BT – Before Trawling; AT – After Trawling

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15-20 | B.T | **Foraminifera** | Foraminiferan | 170 | 110 | 30 | 20 | 10 | 0 | 0 | 0 | 0 | 120 | 50 | 10 |
| | | **Polychaeta** | | | | | | | | | | | | | |
| | | **Errantia** | | | | | | | | | | | | | |
| | | Amphinomidae | *Amphinome rostrata* | 30 | 20 | 0 | 0 | 10 | 0 | 70 | 0 | 0 | 50 | 20 | 0 |
| | | | *Euphrosine capensis* | 10 | 0 | 0 | 0 | 0 | 10 | 10 | 0 | 0 | 10 | 0 | 0 |
| | | | *Pherecardia striata* | 20 | 10 | 0 | 50 | 10 | 0 | 10 | 30 | 0 | 40 | 10 | 0 |
| | | Aphroditidae | *Lepidasthenia mossambica* | 10 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | Eunicidae | *Diopatra* sp. | 10 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 10 | 0 | 0 |
| | | | *Lumbrineris aberrans* | 30 | 30 | 50 | 0 | 40 | 60 | 60 | 100 | 50 | 50 | 30 | 90 |
| | | | *Lumbrineris hartmani* | 10 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | *Lumbrineris latreilli* | 10 | 0 | 0 | 0 | 10 | 10 | 20 | 20 | 40 | 10 | 0 | 20 |
| | | Glyceridae | *Glycera longipinnis* | 10 | 0 | 10 | 0 | 10 | 0 | 10 | 20 | 0 | 10 | 0 | 0 |
| | | | *Glycinde oligodon* | 10 | 0 | 0 | 0 | 0 | 20 | 10 | 10 | 0 | 10 | 0 | 0 |
| | | | *Goniada emerita* | 10 | 0 | 0 | 0 | 0 | 30 | 10 | 10 | 0 | 10 | 0 | 0 |
| | | | *Goniadella gracilis* | 20 | 10 | 0 | 0 | 10 | 0 | 60 | 40 | 40 | 40 | 0 | 20 |
| | | Nephtyidae | *Nephtys dibranchis* | 20 | 10 | 10 | 30 | 10 | 0 | 0 | 20 | 0 | 40 | 10 | 0 |
| | | Nereidae | *Platynereis* spp. | 10 | 20 | 0 | 0 | 10 | 0 | 30 | 0 | 0 | 20 | 20 | 0 |
| | | Pilargidae | *Ancistrosyllis robusta* | 10 | 0 | 10 | 0 | 30 | 0 | 10 | 0 | 10 | 10 | 0 | 0 |
| | | Syllidae | *Syllis* spp. | 20 | 10 | 10 | 0 | 30 | 0 | 0 | 20 | 30 | 20 | 10 | 30 |
| | | **Sedentaria** | | | | | | | | | | | | | |
| | | Capitellidae | *Pulliella armata* | 10 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 20 | 10 | 0 | 0 |
| | | Cirratulidae | *Cirratulus concinnus* | 10 | 0 | 0 | 0 | 30 | 0 | 10 | 0 | 30 | 10 | 20 | 30 |
| | | | *Tharyx filibranchia* | 10 | 0 | 10 | 0 | 0 | 20 | 30 | 0 | 0 | 20 | 0 | 0 |
| | | Cossuridae | *Cossura coasta* | 100 | 90 | 60 | 50 | 90 | 110 | 120 | 50 | 90 | 150 | 110 | 80 |
| | | | *Cossura* $sp_2$ ? | 20 | 10 | 10 | 30 | 30 | 40 | 0 | 20 | 30 | 30 | 0 | 20 |

| Water Depth (m) | BT/ AT | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Paraonidae | *Aricidea longobranchiata* | 10 | 0 | 50 | 10 | 0 | 0 | 10 | 0 | 0 | 10 | 0 | 0 |
| **15-20 B.T.** | | *Paraonides lyra lyra* | 20 | 10 | 80 | 0 | 0 | 10 | 0 | 0 | 0 | 30 | 10 | 0 |
| | Serpulidae | *Spirorbis laevis* | 10 | 0 | 0 | 0 | 20 | 20 | 0 | 0 | 0 | 10 | 0 | 0 |
| | Spionidae | *Boccardia* spp. | 30 | 10 | 50 | 0 | 60 | 20 | 0 | 0 | 60 | 30 | 0 | 40 |
| | | *Prionospio pinnata* | 100 | 90 | 40 | 220 | 150 | 170 | 110 | 100 | 170 | 150 | 120 | 90 |
| | | *Prionospio* spp. | 40 | 120 | 60 | 170 | 160 | 180 | 60 | 50 | 180 | 100 | 110 | 80 |
| | | *Rhynchospio glutaea* | 10 | 30 | 20 | 10 | 10 | 40 | 0 | 10 | 0 | 10 | 0 | 20 |
| | Sternaspidae | *Sternaspis scutata* | 290 | 280 | 160 | 620 | 120 | 150 | 520 | 500 | 100 | 480 | 300 | 280 |
| | | Polychaete fragments | 750 | 770 | 800 | 840 | 660 | 760 | 780 | 850 | 910 | 700 | 750 | 770 |
| | | Polychaete tubes | 60 | 20 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 10 | 0 |
| | **Crustacea** | | | | | | | | | | | | | |
| | Amphipoda | Amphipod | 10 | 10 | 10 | 10 | 0 | 10 | 10 | 10 | 10 | 10 | 10 | 0 |
| | Cumacea | Cumacean | 10 | 10 | 0 | 10 | 0 | 0 | 10 | 0 | 0 | 10 | 10 | 10 |
| | Decapoda | | | | | | | | | | | | | |
| | | *Oratosquilla nepa* | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | Crab juvenile | 10 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 0 |
| | | Shrimp juvenile | 10 | 10 | 0 | 0 | 0 | 0 | 10 | 10 | 0 | 10 | 0 | 0 |
| | Harpacticoida | Copepod | 40 | 0 | 0 | 30 | 30 | 20 | 40 | 10 | 0 | 20 | 0 | 0 |
| | Ostracoda | Ostracod | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Balanidae | *Balanus sp.* | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 10 | 0 |
| | **Sipuncula** | Sipunculid | 50 | 10 | 10 | 10 | 0 | 0 | 50 | 0 | 0 | 60 | 0 | 0 |
| | **Nemertea** | Nemertean | 110 | 50 | 10 | 10 | 0 | 0 | 110 | 0 | 0 | 130 | 20 | 0 |
| | **Pogonophora** | Pogonophore | 20 | 10 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 10 | 0 | 0 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Gastropoda** | | | | | | | | | | | | | |
| 15-20 | B.T. | Trochidae | *Olivia* $sp_1$ | 20 | 50 | 30 | 30 | 40 | 30 | 40 | 20 | 30 | 10 | 0 | 10 |
| | | | *Olivia* $sp_2$ | 20 | 20 | 0 | 20 | 10 | 30 | 0 | 20 | 20 | 10 | 0 | 0 |
| | | | *Umbonium vestiarium* | 70 | 70 | 60 | 20 | 60 | 50 | 50 | 80 | 70 | 80 | 70 | 10 |
| | | Nassariidae | *Nassarius thersites* | 30 | 0 | 0 | 50 | 0 | 0 | 20 | 50 | 30 | 40 | 40 | 50 |
| | | Naticidae | *Natica vitellus* | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 10 | 0 | 0 |
| | | Turridae | Turridae spp. | 10 | 50 | 30 | 20 | 40 | 30 | 30 | 10 | 30 | 10 | 0 | 10 |
| | | Cassidae | *Phalium* sp. | 190 | 0 | 0 | 20 | 0 | 0 | 10 | 210 | 0 | 200 | 190 | 110 |
| | | Terebridae | *Terebra* sp. | 10 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | **Bivalvia** | | | | | | | | | | | | | |
| | | Anomiidae | *Anomia ephippium* | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | Arcidae | *Anadara* spp. | 30 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 40 | 30 | 10 |
| | | | *Arca navicularis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | *Scarpha inaequivalvis* | 10 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 10 | 0 | 0 |
| | | **Ophiuroidea** | *Brittle star* | 10 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | **Osteichthyes** | | | | | | | | | | | | | |
| | | Muraenesocidae | *Muraenesox* sp. | 10 | 10 | 0 | 10 | 0 | 10 | 10 | 0 | 10 | 10 | 0 | 10 |
| | | Gobiidae | *Trypauchen vagina* | 50 | 10 | 0 | 40 | 10 | 10 | 30 | 10 | 10 | 40 | 20 | 10 |
| | | Polynemidae | *Filimanus similis* | 50 | 20 | 0 | 0 | 0 | 10 | 50 | 0 | 20 | 60 | 10 | 10 |
| 15-20 | A.T | **Foraminifera** | Foraminiferan | 300 | 240 | 250 | 200 | 0 | 0 | 0 | 0 | 0 | 270 | 250 | 100 |
| | | **Polychaeta** | | | | | | | | | | | | | |
| | | **Errantia** | | | | | | | | | | | | | |
| | | Amphinomidae | *Amphinome rostrata* | 20 | 10 | 0 | 0 | 20 | 0 | 0 | 0 | 20 | 20 | 0 | 0 |
| | | | *Hipponoa gaudichaudi agulhana subsp. nov* | 20 | 0 | 40 | 0 | 0 | 20 | 0 | 0 | 0 | 30 | 30 | 40 |
| | | Eunicidae | *Lumbrineris aberrans* | 20 | 20 | 10 | 20 | 0 | 20 | 20 | 20 | 0 | 60 | 0 | 0 |
| | | | *Lumbrineris latreilli* | 10 | 0 | 0 | 10 | 0 | 10 | 10 | 0 | 0 | 20 | 0 | 0 |
| | | Glyceridae | *Goniada emerita* | 60 | 60 | 0 | 90 | 0 | 70 | 80 | 100 | 0 | 100 | 0 | 0 |

| Water Depth (m) | BT/ AT | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **15-20** | **A.T.** | *Goniadella gracilis* | 40 | 30 | 0 | 50 | 0 | 30 | 40 | 50 | 0 | 60 | 0 | 0 |
| | Nephtyidae | *Nephtys* spp. | 20 | 0 | 0 | 20 | 0 | 10 | 20 | 0 | 0 | 20 | 0 | 0 |
| | Nereidae | *Nereidae* spp. | 10 | 0 | 10 | 0 | 0 | 10 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | *Platynereis* spp. | 20 | 0 | 0 | 0 | 20 | 10 | 0 | 0 | 20 | 10 | 0 | 0 |
| | **Sedentaria** | | | | | | | | | | | | | |
| | Cirratulidae | *Cirratulus filiformis* | 30 | 30 | 0 | 30 | 0 | 30 | 30 | 30 | 0 | 40 | 0 | 0 |
| | Cossuridae | *Cossura coasta* | 70 | 50 | 60 | 80 | 70 | 60 | 70 | 80 | 70 | 80 | 50 | 60 |
| | | *Cossura* $sp_2$ ? | 40 | 30 | 0 | 50 | 40 | 40 | 10 | 50 | 50 | 60 | 0 | 0 |
| | Orbinidae | *Scolaricia dubia* | 10 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 20 |
| | Paraonidae | *Aricidea capensis* | 10 | 0 | 0 | 10 | 0 | 0 | 10 | 0 | 0 | 10 | 0 | 0 |
| | Spionidae | *Boccardia* spp. | 30 | 80 | 130 | 150 | 60 | 70 | 0 | 150 | 100 | 200 | 100 | 130 |
| | | *Prionospio pinnata* | 40 | 30 | 30 | 40 | 30 | 30 | 40 | 70 | 30 | 40 | 30 | 20 |
| | | *Prionospio* spp. | 250 | 340 | 300 | 340 | 360 | 300 | 320 | 340 | 300 | 360 | 330 | 300 |
| | Sternaspidae | *Sternaspis scutata* | 220 | 220 | 250 | 350 | 300 | 250 | 350 | 360 | 310 | 300 | 280 | 280 |
| | | Polychaete fragments | 800 | 900 | 1000 | 1050 | 820 | 850 | 860 | 920 | 1100 | 830 | 920 | 990 |
| | | Polychaete tubes | 20 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | **Crustacea** | | | | | | | | | | | | | |
| | Amphipoda | Amphipod | 20 | 20 | 10 | 0 | 10 | 0 | 10 | 0 | 0 | 30 | 10 | 0 |
| | Cumacea | Cumacean | 20 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 0 | 0 |
| | Decapoda | Shrimp juvenile | 0 | 0 | 10 | 0 | 10 | 0 | 0 | 20 | 0 | 10 | 0 | 10 |
| | Harpacticoida | Copepod | 50 | 0 | 20 | 40 | 40 | 10 | 40 | 10 | 0 | 10 | 20 | 0 |
| | Ostracoda | Ostracod | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 |
| | Balanidae | *Balanus sp.* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | **Sipuncula** | Sipunculid | 60 | 20 | 0 | 10 | 10 | 0 | 60 | 0 | 0 | 70 | 10 | 10 |
| | **Nemertea** | Nemertean | 130 | 60 | 10 | 20 | 20 | 10 | 120 | 10 | 0 | 140 | 30 | 10 |

| Water Depth (m) | BT/AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15-20 | A.T | **Gastropoda** | | | | | | | | | | | | | |
| | | Trochidae | *Olivia* sp. | 20 | 0 | 0 | 0 | 30 | 20 | 30 | 30 | 0 | 30 | 0 | 0 |
| | | | *Umbonium vestiarium* | 110 | 90 | 40 | 110 | 90 | 80 | 40 | 120 | 110 | 130 | 130 | 100 |
| | | Nassariidae | *Nassarius thersites* | 120 | 90 | 70 | 70 | 60 | 80 | 60 | 130 | 90 | 90 | 80 | 80 |
| | | Turridae | Turridae spp. | 60 | 40 | 0 | 0 | 20 | 0 | 0 | 60 | 0 | 80 | 70 | 20 |
| | | Cassidae | *Phalium* sp. | 90 | 40 | 40 | 30 | 0 | 0 | 40 | 80 | 0 | 70 | 60 | 20 |
| | | **Bivalvia** | | | | | | | | | | | | | |
| | | Veneridae | *Paphia textile* | 20 | 10 | 10 | 0 | 0 | 0 | 20 | 0 | 0 | 20 | 10 | 0 |
| | | Arcidae | *Scarpha inaequivalvis* | 10 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 20 | 0 | 0 |
| | | **Ophiuroidea** | *Brittle star* | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 10 |
| | | **Osteichthyes** | | | | | | | | | | | | | |
| | | Muraenesocidae | *Muraenesox* sp. | 10 | 10 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 10 | 0 | 0 |
| | | Gobiidae | *Trypauchen vagina* | 10 | 40 | 10 | 20 | 10 | 0 | 0 | 10 | 0 | 50 | 10 | 0 |
| | | Polynemidae | *Filimanus similis* | 30 | 0 | 10 | 0 | 0 | 0 | 10 | 0 | 0 | 20 | 10 | 0 |
| 21-25 | B.T | **Foraminifera** | Foraminiferan | 50 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 20 | 0 |
| | | **Anthozoa** | | | | | | | | | | | | | |
| | | Veretillidae | *Lituaria* sp. | 0 | 0 | 0 | 0 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | **Polychaeta** | | | | | | | | | | | | | |
| | | **Errantia** | | | | | | | | | | | | | |
| | | Amphinomidae | *Amphinome rostrata* | 80 | 90 | 100 | 70 | 0 | 0 | 40 | 30 | 0 | 60 | 20 | 80 |
| | | | *Euphrosine capensis* | 20 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | Aproditidae | *Sigalion squamatum* | 10 | 10 | 0 | 0 | 10 | 0 | 0 | 0 | 10 | 10 | 0 | 0 |
| | | Eunicidae | *Lumbrineris aberrans* | 30 | 20 | 0 | 10 | 30 | 40 | 0 | 40 | 30 | 40 | 40 | 10 |
| | | | *Lumbrineris hartmani* | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 10 | 0 | 0 |
| | | | *Lumbrineris latreilli* | 20 | 10 | 0 | 10 | 0 | 0 | 30 | 10 | 0 | 10 | 0 | 0 |
| | | Glyceridae | *Goniadella gracilis* | 10 | 0 | 0 | 0 | 20 | 20 | 0 | 0 | 10 | 20 | 0 | 0 |
| | | Nephtyidae | *Nephtys dibranchis* | 20 | 0 | 20 | 10 | 0 | 0 | 30 | 10 | 0 | 20 | 0 | 0 |
| | | Nereidae | *Ceratonereis mirabilis* | 10 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 10 | 0 | 0 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *Nereidae* spp. | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 20 | 0 | 20 | 0 | 0 |
| 21-25 | B.T. | | *Platynereis* spp. | 20 | 0 | 0 | 0 | 0 | 0 | 30 | 10 | 0 | 10 | 0 | 0 |
| | | Phyllodocidae | *Lopadorhyncus uncinatus* | 30 | 20 | 0 | 40 | 0 | 0 | 0 | 0 | 0 | 40 | 0 | 0 |
| | | Pilargidae | *Ancistrosyllis parva* | 10 | 0 | 0 | 10 | 0 | 0 | 20 | 0 | 0 | 10 | 0 | 0 |
| | | | *Ancistrosyllis robusta* | 10 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | **Sedentaria** | | | | | | | | | | | | | |
| | | Ampharetidae | *Ampharete acutifrons* | 20 | 10 | 30 | 20 | 0 | 0 | 0 | 10 | 0 | 30 | 0 | 30 |
| | | Cirratulidae | *Cirratulus filiformis* | 10 | 0 | 0 | 0 | 40 | 50 | 30 | 0 | 30 | 20 | 50 | 10 |
| | | Cossuridae | *Cossura coasta* | 150 | 130 | 150 | 90 | 140 | 150 | 190 | 130 | 130 | 130 | 120 | 110 |
| | | Magelonidae | *Magelona cincta* | 80 | 100 | 50 | 20 | 100 | 100 | 50 | 60 | 100 | 50 | 100 | 40 |
| | | Maldanidae | *Maldanidae* spp. | 10 | 20 | 0 | 20 | 0 | 0 | 0 | 10 | 0 | 20 | 0 | 0 |
| | | Serpulidae | *Spirorbis laevis* | 50 | 40 | 30 | 60 | 20 | 20 | 20 | 10 | 20 | 60 | 30 | 10 |
| | | Spionidae | *Boccardia* spp. | 80 | 90 | 0 | 70 | 90 | 80 | 40 | 30 | 70 | 70 | 20 | 10 |
| | | | *Prionospio pinnata* | 320 | 300 | 300 | 520 | 0 | 10 | 270 | 300 | 0 | 490 | 300 | 260 |
| | | | *Prionospio* spp. | 190 | 150 | 200 | 230 | 250 | 270 | 160 | 200 | 240 | 230 | 200 | 200 |
| | | Sternaspidae | *Sternaspis scutata* | 300 | 260 | 300 | 90 | 260 | 270 | 320 | 290 | 260 | 260 | 200 | 190 |
| | | Terebellidae | *Terebellidae* spp. | 10 | 0 | 20 | 0 | 0 | 0 | 0 | 10 | 0 | 20 | 0 | 0 |
| | | | Polychaete fragments | 800 | 840 | 860 | 890 | 700 | 850 | 870 | 900 | 1100 | 750 | 870 | 900 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Polychaete tubes | 120 | 100 | 40 | 20 | 10 | 0 | 0 | 0 | 0 | 100 | 60 | 0 |
| | | **Crustacea** | | | | | | | | | | | | | |
| | | Amphipoda | Amphipod | 30 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 0 | 0 |
| | | Cumacea | Cumacean | 120 | 0 | 120 | 0 | 0 | 0 | 0 | 10 | 10 | 130 | 60 | 30 |
| | | Decapoda | Shrimp juvenile | 10 | 0 | 10 | 0 | 0 | 10 | 10 | 0 | 0 | 10 | 10 | 10 |
| | | Harpacticoida | Copepod | 10 | 10 | 0 | 0 | 0 | 10 | 20 | 0 | 0 | 20 | 0 | 0 |
| | | Ostracoda | Ostracod | 10 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 0 |
| | | **Sipuncula** | Sipunculid | 60 | 20 | 10 | 10 | 0 | 0 | 30 | 10 | 0 | 70 | 50 | 20 |
| **21-25** | **B.T** | **Nemertea** | Nemertean | 140 | 60 | 30 | 20 | 10 | 0 | 90 | 0 | 10 | 120 | 10 | 10 |
| | | **Gastropoda** | | | | | | | | | | | | | |
| | | Trochidae | *Olivia* $sp_1$ | 30 | 0 | 0 | 0 | 60 | 30 | 0 | 20 | 0 | 30 | 0 | 0 |
| | | | *Olivia* $sp_2$ | 10 | 0 | 10 | 50 | 40 | 20 | 70 | 70 | 0 | 10 | 10 | 10 |
| | | | *Umbonium vestiarium* | 60 | 70 | 50 | 0 | 40 | 100 | 200 | 0 | 50 | 60 | 110 | 10 |
| | | Nassariidae | *Nassarius thersites* | 90 | 100 | 20 | 30 | 120 | 130 | 150 | 40 | 0 | 80 | 80 | 30 |
| | | Cassidae | *Phalium* sp. | 230 | 60 | 50 | 0 | 0 | 20 | 50 | 290 | 0 | 220 | 290 | 250 |
| | | Terebridae | *Terebra* sp. | 20 | 20 | 0 | 0 | 0 | 0 | 30 | 10 | 0 | 20 | 0 | 0 |
| | | **Bivalvia** | | | | | | | | | | | | | |
| | | Veneridae | *Paphia textile* | 170 | 90 | 30 | 350 | 180 | 60 | 100 | 20 | 30 | 170 | 0 | 0 |
| | | Arcidae | *Anadara* spp. | 90 | 0 | 200 | 0 | 0 | 40 | 70 | 10 | 200 | 90 | 0 | 20 |
| | | | *Scarpha inaequivalvis* | 10 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | **Ophiuroidea** | *Brittle star* | 10 | 0 | 0 | 0 | 0 | 0 | 10 | 20 | 0 | 30 | 0 | 0 |
| | | **Osteichthyes** | | | | | | | | | | | | | |
| | | Muraenesocidae | *Muraenesox* sp. | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Gobiidae | *Trypauchen vagina* | 20 | 20 | 0 | 0 | 10 | 0 | 0 | 10 | 0 | 30 | 0 | 0 |
| **21-25** | **A.T** | **Foraminifera** | Foraminiferan | 500 | 150 | 110 | 0 | 50 | 0 | 0 | 0 | 0 | 450 | 260 | 100 |
| | | **Anthozoa** | | | | | | | | | | | | | |
| | | Veretillidae | *Lituaria* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 0 |
| | | **Polychaeta** | | | | | | | | | | | | | |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **21-25** | **A.T** | **Errantia** | | | | | | | | | | | | | |
| | | Amphinomidae | *Amphinome rostrata* | 80 | 70 | 40 | 60 | 50 | 50 | 110 | 40 | 20 | 90 | 30 | 40 |
| | | Eunicidae | *Lumbrineris hartmani* | 80 | 80 | 0 | 80 | 20 | 0 | 100 | 0 | 0 | 90 | 50 | 0 |
| | | | *Lumbrineris latreilli* | 40 | 20 | 0 | 20 | 60 | 70 | 40 | 0 | 0 | 50 | 40 | 50 |
| | | Glyceridae | *Goniada emerita* | 40 | 0 | 0 | 0 | 0 | 0 | 30 | 0 | 0 | 50 | 0 | 0 |
| | | | *Goniadella gracilis* | 40 | 20 | 0 | 0 | 20 | 0 | 20 | 0 | 0 | 50 | 0 | 0 |
| | | Nephtyidae | *Nephtys dibranchis* | 100 | 90 | 20 | 100 | 90 | 0 | 130 | 0 | 0 | 140 | 20 | 0 |
| | | Nereidae | *Ceratonereis mirabilis* | 40 | 20 | 0 | 30 | 10 | 40 | 40 | 0 | 0 | 50 | 0 | 0 |
| | | | *Platynereis* spp. | 20 | 0 | 0 | 0 | 0 | 20 | 30 | 0 | 0 | 50 | 0 | 0 |
| | | **Sedentaria** | | | | | | | | | | | | | |
| | | Ampharetidae | *Ampharete acutifrons* | 70 | 70 | 100 | 20 | 40 | 30 | 30 | 100 | 20 | 80 | 0 | 20 |
| | | Capitellidae | *Capitella capitata* | 80 | 90 | 0 | 90 | 70 | 80 | 110 | 0 | 0 | 90 | 40 | 30 |
| | | Cirratulidae | *Cirratulus filiformis* | 30 | 40 | 20 | 40 | 30 | 30 | 0 | 20 | 0 | 40 | 30 | 20 |
| | | Cossuridae | *Cossura coasta* | 210 | 190 | 140 | 190 | 130 | 200 | 300 | 150 | 180 | 260 | 250 | 140 |
| | | | *Cossura* $sp_2$ ? | 50 | 50 | 0 | 50 | 50 | 30 | 40 | 0 | 0 | 60 | 50 | 30 |
| | | Magelonidae | *Magelona cincta* | 40 | 20 | 0 | 20 | 50 | 60 | 60 | 0 | 40 | 50 | 60 | 40 |
| | | Maldanidae | *Maldanidae* spp. | 40 | 20 | 0 | 20 | 30 | 50 | 0 | 0 | 0 | 50 | 20 | 0 |
| | | Serpulidae | *Spirorbis laevis* | 40 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 50 | 30 | 10 |
| | | Spionidae | *Prionospio pinnata* | 90 | 90 | 80 | 90 | 60 | 100 | 0 | 80 | 100 | 70 | 100 | 80 |
| | | | *Prionospio* spp. | 200 | 190 | 310 | 300 | 170 | 290 | 160 | 290 | 320 | 190 | 160 | 280 |
| | | | *Rhynchospio glutaea* | 30 | 20 | 40 | 20 | 10 | 0 | 0 | 40 | 40 | 50 | 20 | 30 |
| | | Sternaspidae | *Sternaspis scutata* | 250 | 200 | 420 | 200 | 200 | 90 | 80 | 400 | 220 | 260 | 200 | 180 |
| | | Terebellidae | *Terebellidae* spp. | 30 | 20 | 60 | 20 | 10 | 0 | 0 | 60 | 30 | 60 | 20 | 50 |
| | | Trochochaetidae | *Poecilochaetus serpens* | 20 | 0 | 20 | 0 | 0 | 10 | 0 | 20 | 0 | 50 | 0 | 0 |
| | | | Polychaete fragments | 860 | 760 | 840 | 1100 | 860 | 740 | 1100 | 1200 | 1250 | 150 | 920 | 850 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Crustacea** | | | | | | | | | | | | | |
| 21-25 | A.T | Amphipoda | Amphipod | 40 | 0 | 0 | 0 | 20 | 0 | 10 | 0 | 10 | 50 | 30 | 0 |
| | | Cumacea | Cumacean | 150 | 40 | 0 | 10 | 0 | 0 | 0 | 0 | 30 | 100 | 50 | 20 |
| | | Decapoda | Crab juvenile | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 10 | 0 | 0 |
| | | Decapoda | Shrimp juvenile | 30 | 0 | 20 | 0 | 0 | 10 | 20 | 10 | 0 | 30 | 10 | 0 |
| | | Harpacticoida | Copepod | 60 | 0 | 10 | 0 | 0 | 50 | 100 | 10 | 0 | 10 | 0 | 0 |
| | | Ostracoda | Ostracod | 30 | 10 | 30 | 0 | 10 | 0 | 0 | 0 | 0 | 30 | 0 | 0 |
| | | **Sipuncula** | Sipunculid | 150 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 200 | 0 | 0 |
| | | **Nemertea** | Nemertean | 160 | 30 | 70 | 0 | 20 | 10 | 30 | 0 | 0 | 140 | 0 | 20 |
| | | **Gastropoda** | | | | | | | | | | | | | |
| | | Trochidae | *Olivia* $sp_1$ | 80 | 50 | 40 | 10 | 80 | 80 | 30 | 40 | 0 | 30 | 40 | 20 |
| | | | *Olivia* $sp_2$ | 60 | 70 | 80 | 50 | 40 | 60 | 80 | 80 | 0 | 10 | 80 | 60 |
| | | | *Umbonium vestiarium* | 50 | 50 | 0 | 80 | 40 | 30 | 90 | 90 | 0 | 100 | 90 | 60 |
| | | Nassariidae | *Nassarius thersites* | 50 | 30 | 40 | 20 | 40 | 50 | 70 | 50 | 20 | 50 | 70 | 30 |
| | | Turridae | Turridae spp. | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 0 | 0 |
| | | Cassidae | *Phalium* sp. | 190 | 160 | 50 | 130 | 150 | 140 | 200 | 180 | 140 | 180 | 200 | 170 |
| | | Terebridae | *Terebra* sp. | 20 | 0 | 0 | 0 | 0 | 0 | 50 | 40 | 0 | 50 | 50 | 20 |
| | | **Bivalvia** | | | | | | | | | | | | | |
| | | Donacidae | *Donax scortum* | 30 | 0 | 0 | 20 | 0 | 0 | 30 | 0 | 0 | 20 | 40 | 20 |
| | | Veneridae | *Paphia textile* | 120 | 70 | 180 | 180 | 140 | 40 | 30 | 180 | 100 | 150 | 180 | 140 |
| | | Arcidae | *Anadara* spp. | 30 | 40 | 20 | 50 | 10 | 30 | 40 | 50 | 30 | 40 | 40 | 20 |
| | | | *Scarpha inaequivalvis* | 40 | 10 | 10 | 40 | 20 | 20 | 20 | 20 | 0 | 30 | 40 | 20 |
| | | **Ophiuroidea** | *Brittle star* | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | **Osteichthyes** | | | | | | | | | | | | | |
| | | Gobiidae | *Trypauchen vagina* | 10 | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 0 | 20 | 0 | 10 |
| 26-30 | B.T | **Foraminifera** | Foraminiferan | 500 | 200 | 500 | 50 | 100 | 0 | 100 | 150 | 100 | 600 | 200 | 50 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Anthozoa** | | | | | | | | | | | | | |
| 26-30 | B.T. | Veretillidae | *Lituaria* sp. | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 40 | 0 | 0 | 0 | 0 |
| | | **Polychaeta** | | | | | | | | | | | | | |
| | | **Errantia** | | | | | | | | | | | | | |
| | | Eunicidae | *Lumbrineris aberrans* | 20 | 20 | 0 | 40 | 0 | 0 | 10 | 0 | 0 | 10 | 20 | 0 |
| | | Glyceridae | *Goniada emerita* | 20 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 20 | 0 |
| | | | *Goniadella gracilis* | 40 | 40 | 0 | 0 | 0 | 0 | 30 | 10 | 0 | 30 | 40 | 0 |
| | | Syllidae | *Exogone normalis* | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 10 |
| | | **Sedentaria** | | | | | | | | | | | | | |
| | | Ampharetidae | *Ampharete acutifrons* | 20 | 20 | 70 | 30 | 0 | 70 | 0 | 0 | 0 | 0 | 20 | 0 |
| | | Capitellidae | *Capitellidae* spp. | 20 | 20 | 0 | 10 | 0 | 0 | 10 | 0 | 30 | 10 | 20 | 0 |
| | | Cirratulidae | *Cirratulus concinnus* | 20 | 0 | 30 | 0 | 0 | 30 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | *Cirratulus filiformis* | 20 | 20 | 30 | 20 | 0 | 30 | 20 | 0 | 0 | 10 | 20 | 10 |
| | | Cossuridae | *Cossura coasta* | 440 | 340 | 30 | 290 | 390 | 30 | 210 | 400 | 310 | 380 | 350 | 370 |
| | | | *Cossura* $sp_2$ ? | 80 | 40 | 0 | 30 | 0 | 0 | 30 | 10 | 0 | 70 | 40 | 10 |
| | | Magelonidae | *Magelona cincta* | 60 | 0 | 70 | 50 | 0 | 80 | 100 | 0 | 10 | 50 | 30 | 10 |
| | | Serpulidae | *Spirorbis laevis* | 20 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 20 | 0 |
| | | Spionidae | *Boccardia* spp. | 160 | 0 | 170 | 110 | 0 | 170 | 150 | 0 | 0 | 150 | 100 | 50 |
| | | | *Prionospio pinnata* | 260 | 220 | 0 | 230 | 180 | 220 | 260 | 200 | 160 | 250 | 200 | 170 |
| | | | *Prionospio* spp. | 20 | 120 | 770 | 180 | 110 | 200 | 190 | 120 | 80 | 590 | 130 | 100 |
| | | | *Rhynchospio glutaea* | 40 | 40 | 50 | 10 | 10 | 50 | 10 | 20 | 0 | 40 | 40 | 0 |
| | | Sternaspidae | *Sternaspis scutata* | 480 | 480 | 70 | 360 | 450 | 330 | 300 | 480 | 410 | 430 | 390 | 370 |
| | | Terebellidae | *Terebellidae* spp. | 20 | 40 | 0 | 0 | 10 | 0 | 10 | 20 | 0 | 30 | 40 | 0 |
| | | Trochochaetidae | *Poecilochaetus serpens* | 20 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 20 | 0 |
| | | | Polychaete fragments | 970 | 1100 | 1150 | 1200 | 1160 | 1210 | 1270 | 1300 | 1230 | 950 | 1050 | 1120 |
| | | | Polychaete tubes | 20 | 10 | 0 | 10 | 20 | 0 | 0 | 0 | 0 | 30 | 10 | 0 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Crustacea** | | | | | | | | | | | | | |
| 26-30 | B.T | Amphipoda | Amphipod | 30 | 30 | 30 | 10 | 20 | 10 | 30 | 50 | 10 | 30 | 40 | 30 |
| | | Cumacea | Cumacean | 30 | 20 | 20 | 10 | 10 | 0 | 20 | 40 | 10 | 30 | 10 | 0 |
| | | Decapoda | Crab juvenile | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Shrimp juvenile | 100 | 0 | 150 | 10 | 10 | 0 | 20 | 40 | 0 | 130 | 40 | 20 |
| | | Harpacticoida | Copepod | 20 | 50 | 20 | 0 | 20 | 0 | 30 | 80 | 0 | 70 | 40 | 10 |
| | | Isopoda | Isopod | 20 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | Ostracoda | Ostracod | 30 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | **Sipuncula** | Sipunculid | 710 | 510 | 670 | 100 | 50 | 0 | 0 | 0 | 0 | 680 | 230 | 0 |
| | | **Nemertea** | Nemertean | 90 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 100 | 0 | 0 |
| | | **Pogonophora** | Pogonophore | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | **Gastropoda** | | | | | | | | | | | | | |
| | | Trochidae | *Olivia* $sp_1$ | 10 | 0 | 0 | 20 | 40 | 20 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | | *Olivia* $sp_2$ | 10 | 80 | 0 | 100 | 200 | 150 | 60 | 30 | 10 | 30 | 50 | 0 |
| | | | *Umbonium vestiarium* | 160 | 410 | 120 | 110 | 130 | 60 | 90 | 50 | 40 | 260 | 270 | 90 |
| | | Muricidae | *Murex* sp. | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Nassariidae | *Nassarius thersites* | 200 | 80 | 10 | 50 | 90 | 40 | 50 | 70 | 50 | 200 | 80 | 10 |
| | | Naticidae | *Natica lineata* | 0 | 0 | 10 | 10 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 10 |
| | | | *Natica* sp. | 0 | 0 | 10 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 |
| | | Turridae | *Turricula javana* | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 0 | 10 |
| | | | Turridae spp. | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 60 | 0 | 0 |
| | | Bursidae | *Bursa* sp. | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Cassidae | *Phalium* sp. | 0 | 20 | 0 | 50 | 0 | 0 | 240 | 30 | 10 | 80 | 0 | 0 |
| | | **Bivalvia** | | | | | | | | | | | | | |
| | | Veneridae | *Paphia textile* | 250 | 0 | 200 | 110 | 350 | 150 | 250 | 0 | 0 | 250 | 110 | 150 |
| | | Arcidae | *Anadara* spp. | 10 | 40 | 60 | 30 | 10 | 10 | 0 | 30 | 20 | 10 | 20 | 50 |
| | | | *Arca navicularis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 130 | 20 | 0 | 0 | 0 |
| | | | *Scarpha inaequivalvis* | 10 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 10 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pectnidae | *Chlamys* sp. | 0 | 0 | 70 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 50 |
| 26-30 | A.T | **Osteichthyes** | | | | | | | | | | | | | |
| | | Muraenesocidae | *Congresox talabanoides* | 20 | 10 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 10 | 0 | 0 |
| | | | *Muraenesox* sp. | 10 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | Polynemidae | *Filimanus similis* | 30 | 0 | 10 | 0 | 10 | 0 | 0 | 0 | 0 | 10 | 10 | 0 |
| | | **Foraminifera** | Foraminiferan | 650 | 350 | 640 | 150 | 250 | 300 | 350 | 200 | 150 | 750 | 350 | 200 |
| | | **Anthozoa** | | | | | | | | | | | | | |
| | | Veretillidae | *Lituaria* sp. | 0 | 0 | 110 | 0 | 0 | 0 | 20 | 30 | 0 | 0 | 0 | 0 |
| | | **Polychaeta** | | | | | | | | | | | | | |
| | | **Errantia** | | | | | | | | | | | | | |
| | | Amphinomidae | *Amphinome rostrata* | 10 | 0 | 10 | 0 | 0 | 0 | 40 | 20 | 0 | 20 | 0 | 0 |
| | | | *Chloeia inermis* | 30 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | *Eurythoe complanata* | 20 | 0 | 0 | 0 | 0 | 0 | 60 | 0 | 0 | 30 | 0 | 0 |
| | | Eunicidae | *Lumbrineris aberrans* | 10 | 20 | 10 | 0 | 0 | 0 | 40 | 0 | 0 | 20 | 0 | 0 |
| | | | *Lumbrineris latreilli* | 10 | 0 | 0 | 0 | 0 | 0 | 40 | 20 | 0 | 20 | 0 | 0 |
| | | Glyceridae | *Glycera* sp. | 10 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | *Goniada emerita* | 10 | 0 | 0 | 0 | 0 | 0 | 40 | 0 | 0 | 20 | 0 | 0 |
| | | | *Goniadella gracilis* | 10 | 0 | 20 | 20 | 0 | 0 | 60 | 10 | 0 | 30 | 0 | 0 |
| | | Nephtyidae | *Nephtys dibranchis* | 20 | 0 | 0 | 0 | 0 | 0 | 40 | 0 | 0 | 20 | 0 | 0 |
| | | Nereidae | *Ceratonereis mirabilis* | 10 | 0 | 0 | 0 | 0 | 0 | 40 | 0 | 0 | 20 | 0 | 0 |
| | | | *Leonnates persica* | 10 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | *Nereidae* spp. | 10 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | *Platynereis caladonta* | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 20 | 0 | 0 |
| | | | *Platynereis* spp. | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 0 | 30 | 0 | 0 |
| | | | *Unanereis macgregori* | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 10 | 0 | 0 |
| | | Pilargidae | *Ancistrosyllis parva* | 10 | 0 | 0 | 0 | 0 | 0 | 20 | 10 | 0 | 10 | 0 | 0 |
| | | | *Ancistrosyllis robusta* | 10 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 10 | 0 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Sedentaria** | | | | | | | | | | | | | |
| 26-30 | A.T | Ampharetidae | *Amphurete acutifrons* | 100 | 50 | 140 | 100 | 90 | 110 | 20 | 100 | 10 | 130 | 100 | 20 |
| | | Capitellidae | *Notomastus latericeus* | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 10 | 0 | 0 |
| | | Cirratulidae | *Cirratulus concinnus* | 20 | 0 | 30 | 20 | 0 | 0 | 0 | 0 | 0 | 30 | 0 | 0 |
| | | | *Cirratulus filiformis* | 10 | 0 | 10 | 0 | 0 | 0 | 20 | 0 | 0 | 10 | 0 | 0 |
| | | | *Cirriformia afer* | 50 | 0 | 70 | 80 | 60 | 0 | 80 | 0 | 0 | 70 | 0 | 0 |
| | | Cossuridae | *Cossura coasta* | 270 | 230 | 150 | 170 | 150 | 130 | 400 | 370 | 280 | 310 | 290 | 310 |
| | | | *Cossura* $sp_2$ ? | 10 | 10 | 0 | 0 | 0 | 0 | 0 | 40 | 0 | 40 | 0 | 0 |
| | | Flabelligeridae | *Pherusa monroi?* | 10 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | Magelonidae | *Magelona cincta* | 100 | 90 | 120 | 130 | 100 | 80 | 20 | 50 | 120 | 80 | 110 | 100 |
| | | Maldanidae | *Maldanidae* spp. | 50 | 30 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 50 | 30 | 0 |
| | | Paraonidae | *Aricidea longobranchiata* | 10 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | Spionidae | *Boccardia* spp. | 30 | 0 | 40 | 50 | 50 | 60 | 0 | 0 | 50 | 40 | 0 | 0 |
| | | | *Prionospio pinnata* | 30 | 70 | 80 | 80 | 60 | 50 | 20 | 100 | 50 | 80 | 70 | 0 |
| | | | *Prionospio* spp. | 740 | 670 | 920 | 700 | 650 | 650 | 340 | 300 | 550 | 870 | 700 | 600 |
| | | | *Rhynchospio glutaea* | 40 | 0 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 |
| | | | *Spio filicornis* | 10 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | Sternaspidae | *Sternaspis scutata* | 320 | 410 | 100 | 100 | 140 | 280 | 220 | 290 | 210 | 370 | 300 | 310 |
| | | Terebellidae | *Terebellidae* spp. | 60 | 40 | 70 | 20 | 0 | 0 | 0 | 0 | 0 | 70 | 60 | 0 |
| | | Trochochaetidae | *Poecilochaetus serpens* | 10 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | Polychaete fragments | 1000 | 1150 | 1300 | 1350 | 1250 | 1300 | 1320 | 1350 | 1400 | 970 | 1100 | 1200 |
| | | | Polychaete tube | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 10 | 0 | 0 |
| | | **Crustacea** | | | | | | | | | | | | | |
| | | Amphipoda | Amphipod | 60 | 50 | 40 | 20 | 30 | 0 | 20 | 50 | 30 | 50 | 30 | 30 |
| | | Cumacea | Cumacean | 40 | 30 | 30 | 20 | 20 | 0 | 30 | 50 | 20 | 40 | 20 | 10 |
| | | Decapoda | Shrimp juvenile | 50 | 0 | 100 | 0 | 0 | 10 | 70 | 20 | 0 | 100 | 30 | 10 |
| | | Harpacticoida | Copepod | 30 | 60 | 30 | 0 | 30 | 0 | 20 | 80 | 0 | 80 | 50 | 20 |
| | | Isopoda | Isopod | 30 | 0 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 |

| Water Depth (m) | BT/AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ostracoda | Ostracod | 40 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 30 | 0 | 0 |
| **26-30** | **A.T** | Balanidae | *Balanus* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 |
| | | **Sipuncula** | Sipunculid | 750 | 560 | 730 | 150 | 80 | 0 | 50 | 0 | 10 | 760 | 300 | 230 |
| | | **Nemertea** | Nemertean | 110 | 30 | 40 | 0 | 0 | 0 | 10 | 0 | 30 | 160 | 20 | 10 |
| | | **Gastropoda** | | | | | | | | | | | | | |
| | | Trochidae | *Olivia* $sp_1$ | 0 | 0 | 0 | 120 | 210 | 140 | 0 | 0 | 0 | 100 | 0 | 0 |
| | | | *Olivia* $sp_2$ | 60 | 10 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 10 | 0 | 0 |
| | | | *Umbonium vestiarium* | 120 | 660 | 80 | 50 | 190 | 0 | 160 | 120 | 50 | 250 | 290 | 170 |
| | | Nassariidae | *Nassarius thersites* | 180 | 340 | 210 | 140 | 80 | 190 | 110 | 60 | 0 | 340 | 300 | 190 |
| | | Naticidae | *Natica lineata* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | | *Natica* sp. | 20 | 20 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Strombidae | *Tibia curta* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 10 | 0 | 0 |
| | | Turridae | *Turricula javana* | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 30 | 0 |
| | | | Turridae spp. | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 40 | 20 | 0 |
| | | Cassidae | *Phalium* sp. | 110 | 30 | 0 | 80 | 0 | 0 | 220 | 160 | 100 | 70 | 120 | 110 |
| | | Neritidae | *Nerita* sp. | 10 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | Terebridae | *Terebra* sp. | 20 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | **Bivalvia** | | | | | | | | | | | | | |
| | | Mactridae | *Meropesta pellucida* | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 80 | 0 |
| | | Veneridae | *Paphia textile* | 60 | 100 | 230 | 110 | 230 | 50 | 590 | 130 | 20 | 80 | 20 | 180 |
| | | Arcidae | *Anadara* spp. | 20 | 30 | 20 | 10 | 10 | 30 | 0 | 30 | 0 | 50 | 0 | 10 |
| | | | *Scarpha inaequivalvis* | 20 | 0 | 0 | 0 | 10 | 20 | 20 | 0 | 10 | 10 | 0 | 10 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Osteichthyes** | | | | | | | | | | | | | |
| | | Muraenesocidae | *Congresox talabanoides* | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Muraenesocidae | *Muraenesox* sp. | 10 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | Gobiidae | *Trypauchen vagina* | 10 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| **26-30** | **A.T** | Polynemidae | *Filimanus similis* | 20 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 10 | 10 |
| **31-35** | **B.T** | **Foraminifera** | Foraminiferan | 2600 | 2300 | 1960 | 2000 | 2160 | 1650 | 1420 | 1250 | 1150 | 2450 | 2100 | 1860 |
| | | **Anthozoa** | | | | | | | | | | | | | |
| | | Veretillidae | *Lituaria* sp. | 0 | 0 | 0 | 10 | 140 | 0 | 0 | 0 | 20 | 0 | 10 | 20 |
| | | **Polychaeta** | | | | | | | | | | | | | |
| | | **Errantia** | | | | | | | | | | | | | |
| | | Amphinomidae | *Amphinome rostrata* | 40 | 0 | 50 | 20 | 30 | 40 | 30 | 0 | 0 | 30 | 20 | 0 |
| | | | *Pherecardia striata* | 10 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | Eunicidae | *Lumbrineris aberrans* | 10 | 40 | 0 | 30 | 20 | 30 | 30 | 0 | 50 | 10 | 0 | 0 |
| | | | *Lumbrineris hartmani* | 10 | 40 | 0 | 0 | 30 | 0 | 0 | 0 | 20 | 10 | 0 | 0 |
| | | Glyceridae | *Glycera longipinnis* | 30 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | | *Goniada emerita* | 10 | 110 | 0 | 60 | 30 | 0 | 0 | 0 | 50 | 20 | 0 | 0 |
| | | | *Goniadella gracilis* | 20 | 50 | 40 | 50 | 30 | 10 | 40 | 30 | 50 | 30 | 30 | 30 |
| | | Nephtyidae | *Nephtys dibranchis* | 10 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | Nereidae | *Nereidae* spp. | 50 | 0 | 50 | 30 | 40 | 40 | 40 | 40 | 50 | 30 | 20 | 10 |
| | | | *Unanereis macgregori* | 10 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Pilargidae | *Ancistrosyllis parva* | 10 | 30 | 0 | 0 | 0 | 10 | 10 | 0 | 20 | 20 | 0 | 0 |
| | | **Sedentaria** | | | | | | | | | | | | | |
| | | Ampharetidae | *Ampharete acutifrons* | 90 | 30 | 160 | 120 | 70 | 30 | 100 | 70 | 20 | 140 | 120 | 130 |
| | | Capitellidae | *Capitellidae* spp. | 30 | 120 | 0 | 0 | 60 | 80 | 80 | 70 | 120 | 30 | 70 | 100 |
| | | Cirratulidae | *Cirratulus africanus* | 0 | 0 | 20 | 10 | 0 | 20 | 20 | 0 | 0 | 20 | 0 | 0 |
| | | | *Cirratulus concinnus* | 150 | 0 | 140 | 100 | 90 | 110 | 110 | 110 | 0 | 100 | 90 | 80 |
| | | | *Cirratulus filiformis* | 30 | 70 | 40 | 100 | 50 | 40 | 40 | 20 | 70 | 30 | 20 | 10 |
| | | | *Cirriformia afer* | 40 | 50 | 50 | 10 | 0 | 50 | 50 | 0 | 50 | 60 | 0 | 0 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cossuridae | *Cossura coasta* | 460 | 240 | 100 | 450 | 320 | 400 | 360 | 320 | 150 | 530 | 390 | 410 |
| | | | *Cossura* $sp_2$ ? | 20 | 50 | 0 | 20 | 0 | 10 | 0 | 0 | 0 | 20 | 0 | 0 |
| **31-35** | **B.T.** | Magelonidae | *Magelona cincta* | 30 | 80 | 30 | 10 | 60 | 60 | 60 | 100 | 100 | 20 | 50 | 70 |
| | | Maldanidae | *Maldanidae* spp. | 20 | 60 | 0 | 50 | 60 | 50 | 50 | 50 | 60 | 10 | 50 | 50 |
| | | Paraonidae | *Aricidea longobranchiata* | 20 | 0 | 20 | 0 | 0 | 10 | 10 | 0 | 0 | 20 | 0 | 0 |
| | | Sabellidae | *Sabellidae* spp. | 10 | 0 | 20 | 10 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | Serpulidae | *Protula tubularia* | 10 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | *Spirorbis laevis* | 10 | 30 | 0 | 20 | 0 | 0 | 0 | 0 | 30 | 10 | 0 | 0 |
| | | | *Serpulidae* spp. | 10 | 0 | 20 | 10 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | Spionidae | *Boccardia* spp. | 20 | 50 | 30 | 10 | 0 | 10 | 10 | 0 | 50 | 20 | 0 | 0 |
| | | | *Prionospio pinnata* | 260 | 170 | 220 | 160 | 210 | 200 | 190 | 180 | 160 | 190 | 150 | 140 |
| | | | *Prionospio* spp. | 880 | 240 | 1030 | 900 | 800 | 790 | 680 | 600 | 430 | 960 | 810 | 830 |
| | | | *Rhynchospio glutaea* | 50 | 30 | 110 | 90 | 80 | 60 | 80 | 80 | 20 | 100 | 80 | 80 |
| | | Sternaspidae | *Sternaspis scutata* | 190 | 220 | 180 | 190 | 140 | 150 | 180 | 130 | 150 | 150 | 130 | 160 |
| | | Terebellidae | *Terebellidae* spp. | 50 | 0 | 180 | 90 | 180 | 50 | 150 | 170 | 0 | 10 | 0 | 0 |
| | | | *Terebellides stroemi* | 10 | 50 | 0 | 20 | 0 | 0 | 0 | 0 | 50 | 20 | 0 | 0 |
| | | | Polychaete fragments | 1100 | 1180 | 1340 | 1380 | 1330 | 1350 | 1360 | 1320 | 1390 | 1010 | 1150 | 1220 |
| | | | Polychaete tube | 10 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 |
| | | **Crustacea** | | | | | | | | | | | | | |
| | | Amphipoda | Amphipod | 20 | 0 | 30 | 10 | 10 | 10 | 10 | 10 | 10 | 30 | 20 | 0 |
| | | Cumacea | Cumacean | 30 | 10 | 10 | 0 | 10 | 10 | 30 | 10 | 0 | 60 | 20 | 0 |
| | | Decapoda | Shrimp juvenile | 20 | 20 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | Harpacticoida | Copepod | 0 | 0 | 30 | 10 | 10 | 0 | 0 | 0 | 0 | 30 | 10 | 0 |
| | | Ostracoda | Ostracod | 30 | 0 | 0 | 10 | 10 | 0 | 0 | 0 | 0 | 30 | 0 | 0 |
| | | **Sipuncula** | Sipunculid | 160 | 110 | 150 | 40 | 0 | 0 | 80 | 0 | 0 | 140 | 100 | 0 |
| | | **Nemertea** | Nemertean | 60 | 50 | 10 | 0 | 0 | 0 | 20 | 0 | 0 | 60 | 40 | 0 |
| | | **Gastropoda** | | | | | | | | | | | | | |
| | | Trochidae | *Olivia* $sp_2$ | 100 | 130 | 0 | 80 | 120 | 0 | 100 | 60 | 0 | 130 | 150 | 60 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *Umbonium vestiarium* | 460 | 650 | 420 | 200 | 240 | 380 | 230 | 200 | 10 | 500 | 710 | 450 |
| 31-35 | B.T | Nassariidae | *Nassarius thersites* | 80 | 90 | 10 | 20 | 20 | 60 | 20 | 10 | 20 | 40 | 110 | 60 |
| | | Naticidae | *Natica vitellus* | 20 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 20 | 0 |
| | | Turridae | Turridae spp. | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 0 | 0 |
| | | Cassidae | *Phalium* sp. | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | Terebridae | *Terebra* sp. | 20 | 30 | 0 | 30 | 0 | 0 | 0 | 0 | 0 | 50 | 50 | 40 |
| | | **Scaphopoda** | | | | | | | | | | | | | |
| | | Dentallidae | *Dentalium* sp. | 20 | 0 | 20 | 10 | 0 | 20 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | **Bivalvia** | | | | | | | | | | | | | |
| | | Donacidae | *Donax scortum* | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 0 | 0 |
| | | | *Donax sp.* | 40 | 30 | 40 | 20 | 0 | 40 | 0 | 0 | 0 | 50 | 50 | 30 |
| | | Veneridae | *Paphia textile* | 70 | 0 | 60 | 100 | 160 | 120 | 160 | 100 | 30 | 80 | 0 | 100 |
| | | Arcidae | *Anadara* spp. | 40 | 30 | 0 | 20 | 40 | 0 | 30 | 40 | 10 | 50 | 50 | 0 |
| | | | *Scarpha inaequivalvis* | 50 | 40 | 50 | 50 | 30 | 50 | 30 | 30 | 0 | 60 | 60 | 50 |
| | | | *Trisodos tortuosa* | 20 | 0 | 0 | 20 | 0 | 0 | 20 | 20 | 10 | 20 | 0 | 10 |
| | | Pectnidae | *Chlamys* sp. | 160 | 0 | 60 | 50 | 40 | 60 | 30 | 120 | 180 | 240 | 0 | 160 |
| | | **Osteichthyes** | | | | | | | | | | | | | |
| | | Gobiidae | *Trypauchen vagina* | 30 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | Polynemidae | *Filimanus similis* | 20 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| 31-35 | A.T | **Foraminifera** | Foraminiferan | 3100 | 2550 | 2000 | 2150 | 2200 | 1970 | 1560 | 1340 | 1230 | 2570 | 2350 | 1900 |
| | | **Anthozoa** | | | | | | | | | | | | | |
| | | Veretillidae | *Lituaria* sp. | 0 | 20 | 10 | 20 | 260 | 0 | 0 | 0 | 20 | 0 | 20 | 10 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Polychaeta** | | | | | | | | | | | | | |
| | | **Errantia** | | | | | | | | | | | | | |
| | | Amphinomidae | *Amphinome rostrata* | 20 | 0 | 0 | 0 | 20 | 0 | 10 | 0 | 0 | 20 | 0 | 0 |
| | | | *Pherecardia striata* | 50 | 0 | 0 | 0 | 50 | 40 | 40 | 30 | 0 | 40 | 40 | 50 |
| | | Aphroditidae | *Sthenelais boa* | 30 | 0 | 0 | 0 | 30 | 0 | 0 | 0 | 0 | 10 | 0 | 30 |
| 31-35 | A.T | Eunicidae | *Lumbrineris aberrans* | 10 | 20 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 10 | 20 | 0 |
| | | | *Lumbrineris latreilli* | 30 | 0 | 0 | 0 | 0 | 0 | 30 | 20 | 0 | 30 | 20 | 0 |
| | | Glyceridae | *Glycera longipinnis* | 30 | 40 | 0 | 20 | 0 | 0 | 0 | 0 | 30 | 20 | 20 | 0 |
| | | | *Goniada emerita* | 10 | 20 | 10 | 0 | 10 | 0 | 10 | 0 | 0 | 20 | 0 | 0 |
| | | | *Goniadella gracilis* | 50 | 0 | 0 | 0 | 30 | 0 | 50 | 40 | 0 | 30 | 0 | 10 |
| | | Nephtyidae | *Nephtys dibranchis* | 10 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | Nereidae | *Nereidae* spp. | 10 | 20 | 10 | 0 | 0 | 0 | 10 | 0 | 0 | 10 | 0 | 0 |
| | | | *Platynereis* spp. | 30 | 0 | 0 | 0 | 30 | 0 | 20 | 0 | 0 | 20 | 0 | 30 |
| | | Pilargidae | *Ancistrosyllis parva* | 10 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 20 | 0 |
| | | **Sedentaria** | | | | | | | | | | | | | |
| | | Ampharetidae | *Ampharete acutifrons* | 60 | 140 | 150 | 120 | 0 | 130 | 110 | 50 | 140 | 140 | 90 | 0 |
| | | | *Sabellides octocirrata* | 20 | 40 | 0 | 20 | 0 | 0 | 0 | 0 | 40 | 30 | 0 | 0 |
| | | Chaetopteridae | *Spiochaetopterus* sp. | 10 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 10 | 0 | 0 |
| | | Cirratulidae | *Cirratulus concinnus* | 40 | 0 | 40 | 40 | 40 | 20 | 10 | 0 | 0 | 30 | 20 | 40 |
| | | | *Cirratulus filiformis* | 90 | 0 | 110 | 110 | 130 | 120 | 100 | 70 | 0 | 120 | 120 | 130 |
| | | | *Cirriformia afer* | 20 | 0 | 20 | 20 | 20 | 0 | 10 | 0 | 0 | 10 | 0 | 20 |
| | | | *Cirriformia filigera* | 10 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | | *Tharyx filibranchia* | 40 | 0 | 10 | 10 | 60 | 40 | 50 | 50 | 0 | 50 | 50 | 50 |
| | | Cossuridae | *Cossura coasta* | 230 | 200 | 300 | 270 | 300 | 260 | 250 | 210 | 180 | 250 | 310 | 300 |
| | | | *Cossura* $sp_2$? | 40 | 50 | 0 | 50 | 0 | 40 | 0 | 0 | 40 | 30 | 40 | 10 |
| | | Flabelligeridae | *Pherusa* sp. | 10 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | Magelonidae | *Magelona cincta* | 50 | 40 | 80 | 60 | 50 | 80 | 70 | 60 | 30 | 50 | 80 | 70 |
| | | Maldanidae | *Asychis capensis* | 20 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 40 | 40 | 0 | 30 |

| Water Depth (m) | BT/ AT | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Axiothella jarli* | 10 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | Paraonidae | *Aricidea longobranchiata* | 10 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 10 | 0 | 0 |
| 31-35 A.T. | | *Paraonides lyra lyra* | 10 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | Sabellidae | *Sabellidae* spp. | 40 | 0 | 50 | 50 | 0 | 40 | 30 | 20 | 0 | 20 | 40 | 0 |
| | Serpulidae | *Spirorbis laevis* | 10 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | *Serpulidae* spp. | 20 | 0 | 20 | 0 | 0 | 10 | 0 | 0 | 0 | 20 | 0 | 0 |
| | Spionidae | *Boccardia* spp. | 80 | 20 | 110 | 90 | 100 | 110 | 120 | 70 | 30 | 120 | 60 | 150 |
| | | *Polydora caeca* | 10 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | *Prionospio pinnata* | 180 | 110 | 210 | 210 | 10 | 210 | 190 | 160 | 90 | 180 | 170 | 240 |
| | | *Prionospio* spp. | 990 | 610 | 940 | 1110 | 1200 | 970 | 1010 | 880 | 720 | 950 | 970 | 850 |
| | | *Rhynchospio glutaea* | 30 | 30 | 40 | 40 | 10 | 40 | 30 | 20 | 30 | 40 | 40 | 0 |
| | | *Spiophanes bombyx* | 30 | 0 | 40 | 0 | 0 | 30 | 20 | 20 | 0 | 10 | 30 | 0 |
| | Sternaspidae | *Sternaspis scutata* | 320 | 300 | 350 | 350 | 360 | 330 | 280 | 250 | 300 | 310 | 330 | 360 |
| | Terebellidae | *Amaeana trilobata* | 10 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 10 | 0 | 0 |
| | | *Terebellidae* spp. | 60 | 0 | 80 | 80 | 0 | 50 | 70 | 50 | 0 | 40 | 70 | 50 |
| | | *Terebellides stroemi* | 10 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | Polychaete fragments | 1220 | 1300 | 1400 | 1450 | 1420 | 1460 | 1450 | 1470 | 1500 | 1070 | 1350 | 1480 |
| | | Polychaete tube | 0 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Crustacea** | | | | | | | | | | | | | |
| | Amphipoda | Amphipod | 50 | 40 | 40 | 30 | 20 | 10 | 0 | 0 | 0 | 50 | 30 | 0 |
| | Cumacea | Cumacean | 40 | 30 | 50 | 0 | 10 | 0 | 0 | 10 | 0 | 70 | 30 | 10 |
| | Decapoda | *Oratosquilla nepa* | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Shrimp juvenile | 10 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 20 | 20 | 10 | 0 |
| | Harpacticoida | Copepod | 50 | 60 | 40 | 20 | 40 | 0 | 0 | 0 | 0 | 40 | 30 | 0 |
| | Isopoda | Isopod | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Ostracoda | Ostracod | 40 | 10 | 0 | 20 | 20 | 0 | 0 | 0 | 0 | 50 | 20 | 10 |
| | **Sipuncula** | Sipunculid | 180 | 170 | 170 | 60 | 100 | 0 | 90 | 0 | 0 | 160 | 120 | 0 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31-35 | A.T | **Nemertea** | Nemertean | 80 | 60 | 20 | 0 | 40 | 0 | 30 | 0 | 30 | 80 | 50 | 10 |
| | | **Gastropoda** | | | | | | | | | | | | | |
| | | Trochidae | *Olivia* sp1 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | | *Olivia* sp2 | 100 | 30 | 10 | 0 | 0 | 0 | 0 | 0 | 60 | 100 | 100 | 70 |
| | | Nassariidae | *Nassarius suturalis* | 0 | 0 | 0 | 0 | 30 | 0 | 10 | 30 | 10 | 20 | 0 | 0 |
| | | | *Nassarius thersites* | 300 | 260 | 240 | 200 | 180 | 200 | 210 | 150 | 150 | 280 | 250 | 240 |
| | | Naticidae | *Natica* sp. | 0 | 10 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | Trochidae | *Umbonium vestiarium* | 400 | 500 | 210 | 180 | 170 | 260 | 200 | 220 | 30 | 420 | 400 | 430 |
| | | Turridae | Turridae spp. | 130 | 0 | 80 | 10 | 0 | 60 | 0 | 0 | 50 | 90 | 100 | 50 |
| | | Cassidae | *Phalium* sp. | 0 | 10 | 10 | 40 | 20 | 0 | 0 | 0 | 0 | 60 | 50 | 0 |
| | | Terebridae | *Terebra* sp. | 0 | 0 | 0 | 30 | 20 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | **Scaphopoda** | | | | | | | | | | | | | |
| | | Dentallidae | *Dentalium* sp. | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | **Bivalvia** | | | | | | | | | | | | | |
| | | Donacidae | *Donax scortum* | 10 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | | *Donax* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 10 | 0 | 0 |
| | | Mactridae | *Meropesta pellucida* | 20 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | Veneridae | *Paphia textile* | 10 | 10 | 50 | 20 | 120 | 80 | 0 | 90 | 60 | 50 | 90 | 100 |
| | | Arcidae | *Anadara* spp. | 10 | 20 | 0 | 0 | 10 | 10 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | *Trisodos tortuosa* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 20 | 0 | 0 |
| | | Pectnidae | *Chlamys* sp. | 300 | 0 | 60 | 210 | 0 | 150 | 560 | 160 | 100 | 310 | 50 | 220 |
| | | **Osteichthyes** | | | | | | | | | | | | | |
| | | Gobiidae | *Trypauchen vagina* | 10 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 10 |
| | | Polynemidae | *Filimanus similis* | 10 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | Cynoglossidae | *Cynoglossus macrostomus* | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| 36-40 | B.T | **Foraminifera** | Foraminiferan | 1150 | 1100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1200 | 980 | 0 |
| | | **Anthozoa** | | | | | | | | | | | | | |
| | | Veretillidae | *Lituaria* sp. | 0 | 0 | 0 | 0 | 20 | 60 | 100 | 0 | 10 | 10 | 10 | 0 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Polychaeta** | | | | | | | | | | | | | |
| | | **Errantia** | | | | | | | | | | | | | |
| | | Alciopidae | *Vanadis* spp. | 20 | 20 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| **36-40** | **B.T** | Amphinomidae | *Amphinome rostrata* | 10 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | *Pherecardia striata* | 0 | 0 | 0 | 0 | 20 | 10 | 0 | 0 | 0 | 20 | 10 | 0 |
| | | Aphroditidae | *Sthenelais* sp. | 20 | 0 | 0 | 0 | 0 | 0 | 80 | 0 | 0 | 10 | 0 | 0 |
| | | Eunicidae | *Lumbrineris aberrans* | 200 | 160 | 0 | 180 | 10 | 220 | 40 | 190 | 180 | 250 | 200 | 150 |
| | | | *Lumbrineris latreilli* | 10 | 0 | 80 | 0 | 10 | 0 | 0 | 0 | 0 | 50 | 0 | 0 |
| | | | *Onuphis geophiliformis* | 10 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | Glyceridae | *Glycinde oligodon* | 20 | 0 | 20 | 0 | 10 | 0 | 80 | 0 | 0 | 10 | 0 | 0 |
| | | | *Goniada emerita* | 20 | 0 | 0 | 0 | 0 | 0 | 80 | 0 | 0 | 10 | 0 | 0 |
| | | | *Goniadella gracilis* | 70 | 50 | 0 | 50 | 50 | 50 | 280 | 60 | 40 | 60 | 50 | 50 |
| | | Nephtyidae | *Nephtys dibranchis* | 10 | 10 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | *Nephtys sphaerocirrata* | 80 | 0 | 0 | 0 | 0 | 0 | 30 | 0 | 0 | 70 | 0 | 0 |
| | | | *Nephtys* spp. | 100 | 60 | 100 | 60 | 10 | 0 | 80 | 60 | 50 | 90 | 0 | 0 |
| | | Nereidae | *Ceratonereis mirabilis* | 10 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | *Nereidae* spp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 80 | 0 | 0 |
| | | | *Platynereis caladonta* | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | | *Platynereis* spp. | 40 | 10 | 20 | 0 | 40 | 30 | 0 | 0 | 0 | 30 | 30 | 0 |
| | | Syllidae | *Exogone normalis* | 60 | 30 | 0 | 30 | 0 | 10 | 0 | 0 | 10 | 50 | 0 | 0 |
| | | | *Syllis* spp. | 50 | 50 | 60 | 50 | 0 | 0 | 0 | 40 | 20 | 40 | 0 | 0 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Sedentaria** | | | | | | | | | | | | | |
| | | Ampharetidae | *Ampharete acutifrons* | 80 | 30 | 0 | 120 | 210 | 100 | 150 | 100 | 10 | 110 | 180 | 130 |
| | | Capitellidae | *Capitella capitata* | 20 | 30 | 100 | 80 | 10 | 30 | 40 | 70 | 20 | 90 | 0 | 0 |
| 36-40 | B.T. | Chaetopteridae | *Spiochaetopterus* sp. | 20 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | Cirratulidae | *Caulleriella acicula* | 140 | 50 | 160 | 110 | 0 | 40 | 0 | 100 | 80 | 130 | 0 | 110 |
| | | | *Cirratulus africanus* | 0 | 0 | 0 | 0 | 10 | 10 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | *Cirratulus cirratus* | 60 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 60 | 0 | 0 |
| | | | *Cirratulus concinnus* | 60 | 30 | 0 | 30 | 140 | 120 | 40 | 0 | 20 | 70 | 130 | 100 |
| | | | *Cirratulus filiformis* | 40 | 50 | 0 | 50 | 190 | 160 | 40 | 60 | 40 | 100 | 180 | 140 |
| | | | *Cirriformia afer* | 100 | 20 | 40 | 130 | 200 | 150 | 160 | 140 | 20 | 120 | 190 | 150 |
| | | | *Tharyx dorsobranchialis* | 10 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | *Tharyx filibranchia* | 80 | 0 | 0 | 0 | 100 | 80 | 80 | 0 | 0 | 90 | 80 | 0 |
| | | Cossuridae | *Cossura coasta* | 120 | 100 | 180 | 100 | 70 | 170 | 80 | 110 | 130 | 250 | 190 | 150 |
| | | | *Cossura* $sp_2$ ? | 20 | 0 | 0 | 0 | 30 | 0 | 0 | 0 | 0 | 20 | 30 | 20 |
| | | Magelonidae | *Magelona cincta* | 600 | 550 | 800 | 710 | 40 | 350 | 320 | 850 | 570 | 200 | 160 | 330 |
| | | Maldanidae | *Maldanidae* spp. | 100 | 20 | 180 | 20 | 10 | 130 | 50 | 20 | 0 | 130 | 100 | 80 |
| | | Paraonidae | *Aricidea capensis* | 20 | 20 | 0 | 10 | 10 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | *Aricidea longobranchiata* | 10 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | *Paraonides lyra lyra* | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | Sabellidae | *Sabellidae* spp. | 30 | 10 | 0 | 0 | 30 | 20 | 0 | 0 | 0 | 20 | 20 | 0 |
| | | Serpulidae | *Spirorbis laevis* | 40 | 0 | 0 | 0 | 50 | 40 | 40 | 0 | 0 | 40 | 40 | 0 |
| | | | *Serpulidae* spp. | 20 | 20 | 0 | 20 | 0 | 0 | 80 | 0 | 0 | 10 | 0 | 0 |
| | | Spionidae | *Boccardia* spp. | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 0 | 0 |
| | | | *Polydora capensis* | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | | *Prionospio pinnata* | 100 | 70 | 260 | 110 | 60 | 230 | 200 | 100 | 120 | 150 | 200 | 250 |
| | | | *Prionospio* spp. | 80 | 450 | 0 | 270 | 1010 | 590 | 700 | 250 | 430 | 100 | 710 | 790 |
| | | | *Rhynchospio glutaea* | 20 | 30 | 0 | 30 | 40 | 30 | 0 | 0 | 20 | 30 | 30 | 10 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *Spio filicornis* | 10 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | *Spiophanes bombyx* | 50 | 20 | 0 | 20 | 60 | 50 | 50 | 0 | 0 | 40 | 50 | 0 |
| | | Sternaspidae | *Sternaspis scutata* | 60 | 10 | 20 | 0 | 20 | 20 | 0 | 0 | 0 | 50 | 20 | 40 |
| **36-40** | **B.T** | Terebellidae | *Terebellidae* spp. | 10 | 10 | 20 | 0 | 30 | 20 | 0 | 0 | 0 | 30 | 20 | 0 |
| | | | *Terebellides stroemi* | 80 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 50 | 0 | 0 |
| | | | Polychaete fragments | 1250 | 1420 | 1460 | 1480 | 1500 | 1520 | 1150 | 1390 | 1560 | 1100 | 1400 | 1540 |
| | | | Polychaete tubes | 120 | 100 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 60 | 10 |
| | | **Crustacea** | | | | | | | | | | | | | |
| | | Amphipoda | Amphipod | 50 | 30 | 0 | 40 | 30 | 50 | 10 | 10 | 10 | 290 | 100 | 20 |
| | | Cumacea | Cumacean | 20 | 0 | 0 | 10 | 0 | 10 | 10 | 10 | 0 | 10 | 10 | 10 |
| | | Decapoda | | | | | | | | | | | | | |
| | | | *Oratosquilla nepa* | 0 | 0 | 10 | 0 | 0 | 0 | 10 | 0 | 0 | 10 | 0 | 0 |
| | | | Crab juvenile | 30 | 0 | 30 | 10 | 0 | 0 | 0 | 0 | 0 | 20 | 10 | 0 |
| | | | Shrimp juvenile | 40 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 | 50 | 10 | 10 |
| | | Harpacticoida | Copepod | 10 | 0 | 0 | 20 | 10 | 10 | 20 | 0 | 50 | 10 | 10 | 0 |
| | | Balanidae | *Balanus* sp. | 30 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 20 | 0 |
| | | **Sipuncula** | Sipunculid | 240 | 220 | 210 | 0 | 120 | 0 | 30 | 0 | 0 | 150 | 20 | 0 |
| | | **Nemertea** | Nemertean | 230 | 140 | 0 | 0 | 10 | 0 | 10 | 0 | 0 | 200 | 110 | 0 |
| | | **Pogonophora** | Pogonophore | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | **Hemichordata** | Pterobranchia spp. | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | **Gastropoda** | | | | | | | | | | | | | |
| | | Trochidae | *Olivia* $sp_1$ | 60 | 20 | 10 | 0 | 40 | 0 | 0 | 0 | 40 | 50 | 50 | 50 |
| | | | *Olivia* $sp_2$ | 20 | 10 | 20 | 10 | 20 | 0 | 0 | 10 | 20 | 20 | 20 | 20 |
| | | | *Umbonium vestiarium* | 420 | 400 | 650 | 410 | 320 | 300 | 400 | 430 | 60 | 450 | 400 | 370 |
| | | Muricidae | *Murex* sp. | 20 | 20 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | *Rapana bulbosa* | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | Nassariidae | *Nassarius thersites* | 190 | 200 | 90 | 180 | 140 | 170 | 200 | 190 | 120 | 170 | 180 | 170 |
| | | Naticidae | *Natica* sp. | 20 | 50 | 30 | 30 | 0 | 20 | 50 | 40 | 20 | 10 | 40 | 30 |

| Water Depth (m) | BT/AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Strombidae | *Tibia curta* | 30 | 50 | 10 | 0 | 0 | 0 | 50 | 0 | 0 | 40 | 50 | 20 |
| 36-40 | B.T | Turridae | *Turricula javana* | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | Turridae spp. | 30 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 0 | 0 |
| | | Bursidae | *Bursa* sp. | 10 | 30 | 0 | 0 | 0 | 0 | 20 | 0 | 30 | 20 | 0 | 0 |
| | | Cassidae | *Phalium* sp. | 140 | 130 | 140 | 110 | 120 | 100 | 130 | 110 | 0 | 100 | 140 | 130 |
| | | Conidae | *Conus betulinus* | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | Terebridae | *Terebra* sp. | 30 | 70 | 20 | 40 | 20 | 30 | 50 | 40 | 0 | 50 | 40 | 20 |
| | | **Scaphopoda** | | | | | | | | | | | | | |
| | | Dentallidae | *Dentalium* sp. | 50 | 0 | 50 | 40 | 10 | 30 | 50 | 40 | 0 | 40 | 50 | 50 |
| | | **Bivalvia** | | | | | | | | | | | | | |
| | | Donacidae | *Donax* sp. | 40 | 60 | 0 | 0 | 20 | 0 | 60 | 0 | 0 | 50 | 0 | 50 |
| | | Mactridae | *Meropesta pellucida* | 180 | 190 | 90 | 160 | 0 | 150 | 190 | 180 | 0 | 150 | 190 | 180 |
| | | Veneridae | *Dosinia cretacea* | 10 | 10 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | *Dosinia gibba* | 10 | 0 | 0 | 0 | 30 | 0 | 0 | 0 | 20 | 10 | 0 | 0 |
| | | | *Paphia textile* | 250 | 260 | 230 | 240 | 150 | 220 | 260 | 240 | 30 | 220 | 230 | 230 |
| | | Arcidae | *Anadara* spp. | 10 | 10 | 50 | 50 | 0 | 40 | 40 | 50 | 0 | 50 | 50 | 50 |
| | | | *Scarpha inaequivalvis* | 20 | 10 | 0 | 0 | 30 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | | *Trisodos tortuosa* | 10 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 20 | 20 | 0 | 0 |
| | | Pectnidae | *Chlamys* sp. | 320 | 370 | 280 | 330 | 100 | 290 | 300 | 340 | 160 | 300 | 320 | 280 |
| | | Ostreidae | *Crassostrea madrasensis* | 20 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| 36-40 | A.T | **Foraminifera** | Foraminiferan | 2300 | 1250 | 1100 | 500 | 200 | 0 | 0 | 0 | 0 | 2450 | 1120 | 920 |
| | | **Anthozoa** | | | | | | | | | | | | | |
| | | Veretillidae | *Lituaria* sp. | 0 | 0 | 0 | 0 | 0 | 120 | 0 | 0 | 30 | 0 | 20 | 100 |
| | | **Polychaeta** | | | | | | | | | | | | | |
| | | **Errantia** | | | | | | | | | | | | | |
| | | Alciopidae | *Vanadis* spp. | 80 | 20 | 70 | 70 | 80 | 50 | 70 | 30 | 0 | 70 | 80 | 80 |
| | | Amphinomidae | *Amphinome rostrata* | 20 | 10 | 20 | 0 | 10 | 20 | 0 | 0 | 0 | 20 | 10 | 0 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **36-40** | **A.T.** | | *Pherecardia striata* | 20 | 10 | 0 | 0 | 30 | 20 | 0 | 0 | 0 | 30 | 20 | 0 |
| | | Aphroditidae | *Sthenelais* sp. | 60 | 20 | 0 | 40 | 30 | 60 | 60 | 0 | 10 | 60 | 60 | 60 |
| | | Eunicidae | *Lumbrineris aberrans* | 150 | 100 | 100 | 160 | 130 | 160 | 150 | 140 | 90 | 170 | 150 | 160 |
| | | | *Lumbrineris hartmani* | 10 | 10 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | | *Lumbrineris latreilli* | 50 | 10 | 30 | 30 | 50 | 50 | 50 | 30 | 0 | 20 | 50 | 50 |
| | | | *Onuphis geophiliformis* | 10 | 0 | 0 | 10 | 10 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | Glyceridae | *Glycera convoluta* | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | | *Goniada emerita* | 60 | 30 | 50 | 50 | 30 | 60 | 60 | 50 | 20 | 60 | 60 | 60 |
| | | | *Goniadella gracilis* | 100 | 80 | 0 | 40 | 70 | 100 | 90 | 80 | 110 | 100 | 90 | 90 |
| | | Iospilidae | *Phalacrophorus uniformis* | 10 | 0 | 0 | 10 | 10 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | Nephtyidae | *Nephtys dibranchis* | 40 | 30 | 0 | 0 | 20 | 30 | 30 | 0 | 20 | 40 | 40 | 30 |
| | | Nereidae | *Nereidae* spp. | 10 | 20 | 0 | 0 | 20 | 10 | 0 | 0 | 10 | 10 | 0 | 0 |
| | | | *Platynereis* spp. | 20 | 10 | 0 | 0 | 30 | 20 | 0 | 0 | 0 | 30 | 20 | 0 |
| | | Phyllodocidae | *Phyllodoce longipes* | 20 | 10 | 0 | 0 | 30 | 20 | 0 | 0 | 0 | 30 | 20 | 0 |
| | | Pilargidae | *Ancistrosyllis parva* | 10 | 20 | 0 | 0 | 10 | 20 | 0 | 0 | 10 | 10 | 0 | 0 |
| | | Syllidae | *Exogone normalis* | 120 | 100 | 0 | 60 | 90 | 120 | 110 | 100 | 90 | 120 | 110 | 110 |
| | | | *Syllis* spp. | 20 | 20 | 0 | 10 | 0 | 20 | 0 | 0 | 10 | 20 | 0 | 0 |
| | | **Sedentaria** | | | | | | | | | | | | | |
| | | Ampharetidae | *Ampharete acutifrons* | 130 | 100 | 120 | 90 | 110 | 80 | 90 | 100 | 70 | 120 | 90 | 10 |
| | | Cirratulidae | *Caulleriella acicula* | 10 | 0 | 20 | 10 | 0 | 20 | 0 | 0 | 0 | 20 | 0 | 0 |
| | | | *Cirratulus africanus* | 80 | 50 | 0 | 0 | 40 | 70 | 70 | 0 | 40 | 80 | 60 | 60 |
| | | | *Cirratulus concinnus* | 210 | 180 | 190 | 210 | 220 | 180 | 200 | 190 | 170 | 220 | 200 | 150 |
| | | | *Cirratulus filiformis* | 160 | 150 | 160 | 130 | 140 | 120 | 160 | 160 | 140 | 160 | 160 | 100 |
| | | | *Cirriformia afer* | 130 | 90 | 80 | 30 | 120 | 70 | 130 | 80 | 80 | 140 | 130 | 130 |
| | | | *Tharyx dorsobranchialis* | 10 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | *Tharyx filibranchia* | 60 | 10 | 120 | 100 | 110 | 90 | 100 | 120 | 0 | 60 | 60 | 90 |
| | | Cossuridae | *Cossura coasta* | 380 | 350 | 270 | 300 | 350 | 360 | 380 | 310 | 370 | 400 | 380 | 380 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *Cossura* sp$_2$ ? | 10 | 10 | 0 | 0 | 20 | 10 | 0 | 0 | 0 | 10 | 0 | 0 |
| **36-40** | **A.T** | Magelonidae | *Magelona cincta* | 290 | 270 | 330 | 340 | 300 | 330 | 300 | 290 | 260 | 330 | 270 | 260 |
| | | Maldanidae | *Maldanidae* spp. | 80 | 60 | 80 | 80 | 150 | 160 | 200 | 70 | 50 | 80 | 200 | 210 |
| | | Paraonidae | *Aricidea longobranchiata* | 10 | 10 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | Sabellidae | *Sabellidae* spp. | 10 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | Serpulidae | *Protula tubularia* | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | 0 |
| | | | *Serpulidae* spp. | 20 | 0 | 40 | 40 | 20 | 30 | 40 | 30 | 0 | 20 | 30 | 30 |
| | | Spionidae | *Prionospio pinnata* | 40 | 50 | 40 | 40 | 30 | 20 | 30 | 40 | 30 | 40 | 40 | 30 |
| | | | *Prionospio* spp. | 280 | 200 | 250 | 280 | 270 | 230 | 260 | 280 | 260 | 270 | 270 | 280 |
| | | | *Rhynchospio glutaea* | 20 | 10 | 60 | 50 | 60 | 40 | 50 | 60 | 30 | 30 | 30 | 40 |
| | | | *Spio filicornis* | 10 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | *Spiophanes bombyx* | 10 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | Sternaspidae | *Sternaspis scutata* | 70 | 10 | 50 | 60 | 40 | 70 | 70 | 50 | 0 | 20 | 70 | 70 |
| | | Terebellidae | *Terebellidae* spp. | 80 | 10 | 80 | 80 | 70 | 50 | 70 | 30 | 10 | 70 | 80 | 80 |
| | | | *Terebellides stroemi* | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | Polychaete fragments | 1390 | 1570 | 1630 | 1700 | 1800 | 1870 | 1940 | 1990 | 2020 | 1420 | 1570 | 1670 |
| | | | Polychaete tubes | 70 | 50 | 0 | 10 | 10 | 0 | 0 | 0 | 0 | 80 | 20 | 0 |
| | | **Crustacea** | | | | | | | | | | | | | |
| | | Amphipoda | Amphipod | 60 | 40 | 10 | 60 | 40 | 60 | 0 | 20 | 30 | 320 | 120 | 40 |
| | | Cumacea | Cumacean | 30 | 10 | 0 | 0 | 10 | 0 | 0 | 10 | 0 | 20 | 20 | 10 |
| | | Decapoda | Crab juvenile | 10 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | | Shrimp juvenile | 20 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 20 | 0 | 10 |
| | | Harpacticoida | Copepod | 40 | 0 | 10 | 30 | 20 | 0 | 30 | 0 | 60 | 20 | 20 | 0 |
| | | Isopoda | Isopod | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Balanidae | *Balanus sp.* | 20 | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 10 | 10 |
| | | **Sipuncula** | Sipunculid | 530 | 190 | 90 | 0 | 170 | 0 | 0 | 0 | 50 | 180 | 40 | 10 |
| | | **Nemertea** | Nemertean | 310 | 230 | 0 | 0 | 100 | 0 | 30 | 0 | 0 | 230 | 150 | 50 |
| | | **Gastropoda** | | | | | | | | | | | | | |

| Water Depth (m) BT/AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Trochidae | *Olivia* sp$_1$ | 60 | 20 | 20 | 0 | 20 | 0 | 0 | 0 | 90 | 20 | 0 | 0 |
| **36-40 A.T.** | | *Olivia* sp$_2$ | 100 | 10 | 0 | 0 | 20 | 0 | 60 | 0 | 0 | 60 | 60 | 0 |
| | | *Umbonium vestiarium* | 580 | 530 | 440 | 450 | 370 | 430 | 600 | 540 | 120 | 400 | 550 | 540 |
| | Muricidae | *Murex* sp. | 20 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 20 | 0 | 0 |
| | | *Rapana bulbosa* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 40 | 0 | 0 |
| | Nassariidae | *Nassarius suturalis* | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | *Nassarius thersites* | 90 | 190 | 160 | 160 | 210 | 230 | 200 | 180 | 90 | 160 | 190 | 180 |
| | Naticidae | *Natica* sp. | 20 | 100 | 20 | 0 | 20 | 0 | 60 | 0 | 10 | 20 | 60 | 0 |
| | Strombidae | *Tibia curta* | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | Turridae | *Turricula javana* | 20 | 60 | 60 | 60 | 20 | 0 | 20 | 60 | 0 | 70 | 20 | 70 |
| | | Turridae spp. | 0 | 0 | 30 | 30 | 0 | 0 | 0 | 0 | 0 | 80 | 0 | 0 |
| | Bursidae | *Bursa* sp. | 20 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | Cassidae | *Phalium* sp. | 60 | 150 | 140 | 160 | 50 | 70 | 20 | 140 | 0 | 80 | 100 | 160 |
| | Conidae | *Conus betulinus* | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 |
| | Terebridae | *Terebra* sp. | 40 | 50 | 40 | 0 | 40 | 0 | 0 | 0 | 0 | 50 | 0 | 0 |
| | **Scaphopoda** | | | | | | | | | | | | | |
| | Dentallidae | *Dentalium* sp. | 40 | 20 | 20 | 0 | 0 | 0 | 40 | 0 | 0 | 40 | 40 | 0 |
| | **Bivalvia** | | | | | | | | | | | | | |
| | Donacidae | *Donax scortum* | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | | *Donax* sp. | 30 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 10 |
| | Mactridae | *Meropesta pellucida* | 60 | 0 | 140 | 70 | 0 | 150 | 0 | 110 | 0 | 40 | 160 | 150 |
| | Veneridae | *Dosinia cretacea* | 20 | 60 | 0 | 0 | 10 | 0 | 20 | 50 | 0 | 10 | 0 | 40 |
| | | *Paphia textile* | 450 | 140 | 60 | 10 | 0 | 70 | 100 | 60 | 40 | 50 | 80 | 100 |
| | Arcidae | *Anadara* spp. | 30 | 0 | 20 | 0 | 0 | 20 | 0 | 20 | 10 | 20 | 0 | 0 |
| | | *Scarpha inaequivalvis* | 20 | 0 | 0 | 0 | 10 | 0 | 20 | 0 | 0 | 10 | 0 | 0 |
| | Pectnidae | *Chlamys* sp. | 660 | 270 | 350 | 240 | 120 | 360 | 300 | 290 | 150 | 590 | 390 | 400 |
| | Ostreidae | *Crassostrea madrasensis* | 0 | 10 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |

Table 2: Biomass list of the species found in the macrobenthic samples around Veraval coast.
The biomass is expressed as grams /m2. BT – Before Trawling; AT – After Trawling

| Water Depth (m) | BT/AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15-20 | B.T. | **Foraminifera** | Foraminiferan | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 |
| | | | Total Polychaetes | 4.20 | 3.50 | 2.94 | 5.60 | 4.01 | 4.15 | 7.05 | 1.88 | 3.96 | 2.42 | 3.59 | 3.73 |
| | | | Fragments | 2.40 | 2.46 | 2.56 | 2.69 | 2.11 | 2.43 | 2.50 | 2.72 | 2.91 | 2.24 | 2.40 | 2.46 |
| | | | Polychaete tubes | 30.72 | 10.24 | 5.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 25.60 | 5.12 | 0.00 |
| | | **Crustacea** | | | | | | | | | | | | | |
| | | Amphipoda | Amphipod | 0.05 | 0.02 | 0.01 | 0.01 | 0.00 | 0.02 | 0.01 | 0.01 | 0.01 | 0.03 | 0.02 | 0.00 |
| | | Cumacea | Cumacean | 0.01 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 |
| | | Decapoda | Shrimp juvenile | 0.15 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.13 | 0.00 | 0.00 |
| | | Harpacticoida | Copepod | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| | | Ostracoda | Ostracod | 0.00 | 0.00 | 0.00 | 0.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Balanidae | *Balanus sp.* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.50 | 0.00 | 0.00 |
| | | **Sipuncula** | Sipunculid | 0.71 | 0.14 | 0.15 | 0.13 | 0.00 | 0.00 | 0.71 | 0.00 | 0.00 | 0.86 | 0.00 | 0.00 |
| | | **Nemertea** | Nemertean | 0.31 | 0.15 | 0.03 | 0.02 | 0.00 | 0.00 | 0.31 | 0.00 | 0.00 | 0.37 | 0.06 | 0.00 |
| | | **Gastropoda** | | | | | | | | | | | | | |
| | | Trochidae | *Olivia* $sp_1$ | 0.00 | 0.20 | 0.12 | 0.12 | 0.16 | 0.12 | 0.16 | 0.08 | 0.12 | 0.04 | 0.00 | 0.04 |
| | | | *Olivia* $sp_2$ | 1.08 | 1.08 | 0.00 | 1.08 | 0.54 | 1.62 | 0.00 | 1.08 | 1.08 | 0.54 | 0.00 | 0.00 |
| | | Nassariidae | *Nassarius thersites* | 3.38 | 0.00 | 0.00 | 1.56 | 0.00 | 0.00 | 0.58 | 5.63 | 3.38 | 0.00 | 4.51 | 5.63 |
| | | Naticidae | *Natica vitellus* | 0.39 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 | 0.00 | 0.20 | 0.00 | 0.00 |
| | | Trochidae | *Umbonium vestiarium* | 0.15 | 0.16 | 0.13 | 0.04 | 5.98 | 0.11 | 0.12 | 0.17 | 0.15 | 0.17 | 0.15 | 0.02 |
| | | Turridae | Turridae spp. | 0.08 | 0.41 | 0.25 | 0.17 | 0.33 | 0.25 | 0.25 | 0.08 | 0.25 | 0.08 | 0.00 | 0.08 |
| | | Cassidae | *Phalium* sp. | 1.51 | 0.00 | 0.00 | 0.33 | 0.00 | 0.00 | 0.14 | 1.66 | 0.00 | 1.58 | 1.51 | 0.87 |
| | | Conidae | *Conus betulinus* | 4.83 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Terebridae | *Terebra* sp. | 0.10 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 |
| | | **Bivalvia** | | | | | | | | | | | | | |
| | | Anomiidae | *Anomia ephippium* | 2.35 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.35 | 0.00 | 0.00 |
| | | Arcidae | *Anadara* spp. | 10.19 | 0.00 | 0.00 | 6.80 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 13.59 | 10.19 | 3.40 |
| | | | *Scarpha inaequivalvis* | 7.96 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.96 | 0.00 | 0.00 | 7.96 | 0.00 | 0.00 |
| | | **Ophiuroidea** | Brittle star | 0.80 | 0.00 | 0.00 | 0.00 | 0.80 | 0.00 | 0.00 | 0.00 | 0.00 | 0.80 | 0.00 | 0.00 |
| | | **Osteichthyes** | | | | | | | | | | | | | |
| | | Muraenesocidae | *Muraenesox* sp. | 7.11 | 7.11 | 0.00 | 7.11 | 0.00 | 7.11 | 5.72 | 0.00 | 7.11 | 7.11 | 0.00 | 7.11 |
| | | Gobiidae | *Trypauchen vagina* | 3.34 | 0.67 | 0.00 | 1.81 | 0.67 | 0.67 | 4.19 | 53.96 | 0.67 | 2.67 | 1.34 | 0.67 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Polynemidae | *Filimanus similis* | 4.81 | 1.92 | 0.00 | 0.00 | 0.00 | 0.96 | 4.81 | 0.00 | 1.92 | 5.77 | 0.96 | 0.96 |
| 15-20 | A.T. | **Foraminifera** | Foraminiferan | 0.04 | 0.03 | 0.01 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.02 | 0.01 |
| | | **Polychaeta** | Total Polychaetes | 1.61 | 1.58 | 1.49 | 2.17 | 1.58 | 1.68 | 1.75 | 2.19 | 1.58 | 2.53 | 1.44 | 1.49 |
| | | | Polychaete Fragments | 1.97 | 2.22 | 2.46 | 2.58 | 2.02 | 2.09 | 2.12 | 2.26 | 2.71 | 2.04 | 2.26 | 2.44 |
| | | | Polychaete tubes | 300.00 | 100.00 | 50.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 250.00 | 50.00 | 0.00 |
| | | **Crustacea** | | | | | | | | | | | | | |
| | | Amphipoda | Amphipod | 0.06 | 0.06 | 0.03 | 0.00 | 0.02 | 0.00 | 0.01 | 0.00 | 0.00 | 0.09 | 0.03 | 0.00 |
| | | Cumacea | Cumacean | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Decapoda | Shrimp juvenile | 0.00 | 0.00 | 0.06 | 0.00 | 0.05 | 0.00 | 0.00 | 0.09 | 0.00 | 0.05 | 0.00 | 0.04 |
| | | Harpacticoida | Copepod | 0.07 | 0.00 | 0.03 | 0.06 | 0.06 | 0.01 | 0.06 | 0.01 | 0.00 | 0.01 | 0.03 | 0.00 |
| | | Ostracoda | Ostracod | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 |
| | | Balanidae | *Balanus sp.* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.18 | 0.00 | 0.00 |
| | | **Sipuncula** | Sipunculid | 0.13 | 0.04 | 0.00 | 0.03 | 0.02 | 0.00 | 0.13 | 0.00 | 0.00 | 0.15 | 0.02 | 0.01 |
| | | **Nemertea** | Nemertean | 12.01 | 5.54 | 0.92 | 1.85 | 1.85 | 0.92 | 11.08 | 0.92 | 0.00 | 12.93 | 2.77 | 0.92 |
| | | **Gastropoda** | | | | | | | | | | | | | |
| | | Trochidae | *Olivia* sp$_2$ | 2.46 | 0.00 | 0.00 | 0.00 | 3.69 | 2.46 | 1.45 | 1.61 | 0.00 | 3.69 | 0.00 | 0.00 |
| | | | *Umbonium vestiarium* | 11.53 | 9.43 | 4.19 | 10.62 | 9.43 | 8.38 | 0.09 | 12.58 | 11.53 | 0.26 | 13.62 | 10.48 |
| | | Nassariidae | *Nassarius thersites* | 2.86 | 2.14 | 1.67 | 1.67 | 1.43 | 1.90 | 1.43 | 3.10 | 2.14 | 13.55 | 1.90 | 1.90 |
| | | Turridae | Turridae spp. | 0.06 | 0.04 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.06 | 0.00 | 0.08 | 0.07 | 0.02 |
| | | Cassidae | *Phalium* sp. | 0.79 | 0.35 | 0.35 | 0.26 | 0.00 | 0.00 | 0.20 | 0.70 | 0.00 | 0.05 | 0.53 | 0.18 |
| | | **Bivalvia** | | | | | | | | | | | | | |
| | | Veneridae | *Paphia textile* | 20.00 | 9.98 | 9.10 | 0.00 | 0.00 | 0.00 | 19.52 | 0.00 | 0.00 | 19.95 | 9.98 | 0.00 |
| | | Arcidae | *Scarpha inaequivalvis* | 1.74 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.48 | 0.00 | 0.00 | 3.48 | 0.00 | 0.00 |
| | | **Ophiuroidea** | Brittle star | 0.00 | 0.00 | 0.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.50 | 0.00 | 0.50 |
| | | **Osteichthyes** | | | | | | | | | | | | | |
| | | Muraenesocidae | *Muraenesox* sp. | 3.75 | 3.75 | 0.00 | 0.00 | 0.00 | 0.00 | 3.75 | 0.00 | 0.00 | 3.75 | 0.00 | 0.00 |
| | | Gobiidae | *Trypauchen vagina* | 5.21 | 0.58 | 0.15 | 0.29 | 0.58 | 0.00 | 0.00 | 0.15 | 0.00 | 0.73 | 0.15 | 0.00 |
| | | Polynemidae | *Filimanus similis* | 8.96 | 0.00 | 2.99 | 0.00 | 0.00 | 0.00 | 2.99 | 0.00 | 0.00 | 5.97 | 2.99 | 0.00 |
| 21-25 | B.T. | **Foraminifera** | Foraminiferan | 0.20 | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.40 | 0.08 | 0.00 |
| | | **Anthozoa** | | | | | | | | | | | | | |
| | | Veretillidae | *Lituaria* sp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | **Polychaeta** | Total Polychaetes | 3.75 | 3.12 | 3.00 | 8.70 | 0.00 | 2.52 | 3.20 | 3.95 | 2.25 | 9.78 | 2.70 | 2.37 |
| | | | Polychaete Fragments | 2.56 | 2.69 | 2.75 | 2.85 | 2.24 | 2.72 | 2.78 | 2.88 | 3.52 | 3.45 | 2.78 | 2.88 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Polychaete tubes | 240.00 | 200.00 | 80.00 | 40.00 | 20.00 | 0.00 | 0.00 | 0.00 | 0.00 | 200.00 | 120.00 | 0.00 |
| | | **Crustacea** | | | | | | | | | | | | | |
| 21-25 | B.T. | Amphipoda | Amphipod | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 |
| | | Cumacea | Cumacean | 0.00 | 0.00 | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.13 | 0.06 | 0.03 |
| | | Decapoda | Shrimp juvenile | 0.14 | 0.00 | 0.13 | 0.00 | 0.00 | 0.12 | 0.10 | 0.00 | 0.00 | 0.15 | 0.13 | 0.12 |
| | | Harpacticoida | Copepod | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Ostracoda | Ostracod | 0.09 | 0.03 | 0.09 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.09 | 0.00 | 0.00 |
| | | **Sipuncula** | Sipunculid | 0.00 | 0.04 | 0.02 | 0.02 | 0.00 | 0.00 | 0.06 | 0.02 | 0.00 | 0.15 | 0.11 | 0.04 |
| | | **Nemertea** | Nemertean | 0.40 | 0.17 | 0.09 | 0.06 | 0.03 | 0.00 | 0.26 | 0.00 | 0.03 | 0.34 | 0.03 | 0.03 |
| | | **Gastropoda** | | | | | | | | | | | | | |
| | | Trochidae | *Olivia* $sp_1$ | 0.27 | 0.00 | 0.00 | 0.00 | 0.55 | 0.27 | 0.00 | 0.18 | 0.00 | 0.27 | 0.00 | 0.00 |
| | | | *Olivia* $sp_2$ | 0.22 | 0.00 | 0.21 | 1.55 | 0.88 | 0.44 | 2.02 | 7.56 | 0.00 | 0.63 | 0.22 | 0.21 |
| | | | *Umbonium vestiarium* | 0.20 | 5.96 | 2.01 | 0.00 | 1.61 | 4.01 | 3.68 | 0.00 | 2.01 | 1.79 | 4.41 | 0.40 |
| | | Nassariidae | *Nassarius thersites* | 3.64 | 7.69 | 0.81 | 5.09 | 4.86 | 5.26 | 11.20 | 6.35 | 0.00 | 4.15 | 3.24 | 1.21 |
| | | Naticidae | *Natica vitellus* | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Cassidae | *Phalium* sp. | 2.30 | 0.72 | 0.69 | 0.00 | 0.00 | 0.27 | 0.69 | 3.25 | 0.00 | 2.55 | 3.98 | 3.43 |
| | | Conidae | *Conus betulinus* | 4.83 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Terebridae | *Terebra* sp. | 0.27 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.41 | 0.14 | 0.00 | 0.27 | 0.00 | 0.00 |
| | | **Bivalvia** | | | | | | | | | | | | | |
| | | Veneridae | *Paphia textile* | 12.91 | 9.52 | 2.28 | 10.30 | 6.45 | 4.56 | 7.60 | 1.52 | 2.28 | 12.91 | 0.00 | 0.00 |
| | | Anomiidae | *Anomia ephippium* | 0.24 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Arcidae | *Anadara* spp. | 0.45 | 0.00 | 0.00 | 0.00 | 0.00 | 5.14 | 8.99 | 0.19 | 25.70 | 11.56 | 0.00 | 2.57 |
| | | | *Scarpha inaequivalvis* | 8.40 | 0.00 | 0.00 | 7.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.62 | 0.00 | 0.00 |
| | | **Ophiuroidea** | Brittle star | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 1.59 | 0.00 | 0.10 | 0.00 | 0.00 |
| | | **Osteichthyes** | | | | | | | | | | | | | |
| | | Muraenesocidae | *Muraenesox* sp. | 0.57 | 0.00 | 0.00 | 5.72 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Gobiidae | *Trypauchen vagina* | 0.00 | 9.10 | 0.00 | 0.00 | 1.83 | 0.00 | 0.00 | 0.65 | 0.00 | 1.95 | 0.00 | 0.00 |
| 21-25 | A.T. | **Foraminifera** | Foraminiferan | 0.06 | 0.02 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.03 | 0.01 |
| | | **Anthozoa** | | | | | | | | | | | | | |
| | | Veretillidae | *Lituaria* sp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | **Polychaeta** | Total Polychaetes | 3.82 | 3.06 | 2.95 | 3.18 | 2.59 | 2.71 | 3.25 | 2.83 | 2.29 | 4.55 | 2.64 | 2.36 |
| | | | Fragments | 2.75 | 2.43 | 2.69 | 3.52 | 2.75 | 2.37 | 3.52 | 3.84 | 4.00 | 0.48 | 2.94 | 2.72 |
| | | | Polychaete tubes | 30.00 | 25.00 | 10.00 | 5.00 | 2.50 | 0.00 | 0.00 | 0.00 | 0.00 | 25.00 | 15.00 | 0.00 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Crustacea** | | | | | | | | | | | | | |
| 21-25 | A.T. | Amphipoda | Amphipod | 0.09 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.09 | 0.00 | 0.00 |
| | | Cumacea | Cumacean | 0.76 | 0.20 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 | 0.51 | 0.25 | 0.10 |
| | | Decapoda | Crab juvenile | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.33 | 0.00 | 0.00 | 0.33 | 0.00 | 0.00 |
| | | | Shrimp juvenile | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.05 | 0.02 | 0.00 | 0.07 | 0.02 | 0.00 |
| | | Harpacticoida | Copepod | 0.06 | 0.00 | 0.01 | 0.00 | 0.00 | 0.05 | 0.06 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 |
| | | Ostracoda | Ostracod | 0.09 | 0.03 | 0.09 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.09 | 0.00 | 0.00 |
| | | **Sipuncula** | Sipunculid | 0.32 | 0.00 | 0.21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.42 | 0.00 | 0.00 |
| | | **Nemertea** | Nemertean | 14.78 | 2.77 | 6.47 | 0.00 | 1.85 | 0.92 | 2.77 | 0.00 | 0.00 | 12.93 | 0.00 | 1.85 |
| | | **Gastropoda** | | | | | | | | | | | | | |
| | | Trochidae | *Olivia* $sp_1$ | 0.09 | 0.67 | 0.54 | 0.13 | 1.07 | 1.07 | 0.40 | 0.54 | 0.00 | 0.40 | 0.54 | 0.27 |
| | | | *Olivia* $sp_2$ | 5.10 | 5.95 | 6.80 | 4.25 | 3.40 | 5.10 | 1.76 | 6.80 | 0.00 | 0.46 | 6.80 | 5.10 |
| | | | *Umbonium vestiarium* | 4.96 | 4.82 | 0.00 | 7.94 | 0.43 | 2.98 | 8.94 | 8.94 | 0.00 | 0.38 | 8.94 | 5.96 |
| | | Nassariidae | *Nassarius thersites* | 0.15 | 4.14 | 5.52 | 2.76 | 5.52 | 6.89 | 4.46 | 5.04 | 2.76 | 2.51 | 9.65 | 4.14 |
| | | Turridae | Turridae spp. | 0.57 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.58 | 0.00 | 0.00 |
| | | Cassidae | *Phalium* sp. | 2.97 | 2.50 | 0.78 | 2.03 | 2.34 | 2.19 | 3.12 | 2.60 | 2.19 | 1.77 | 3.12 | 2.65 |
| | | Terebridae | *Terebra* sp. | 0.44 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.10 | 0.88 | 0.00 | 0.43 | 1.11 | 0.44 |
| | | **Bivalvia** | | | | | | | | | | | | | |
| | | Donacidae | *Donax scortum* | 0.54 | 0.00 | 0.00 | 0.36 | 0.00 | 0.00 | 0.54 | 0.00 | 0.00 | 0.36 | 0.72 | 0.36 |
| | | Veneridae | *Paphia textile* | 8.64 | 5.04 | 12.96 | 12.96 | 10.08 | 2.88 | 4.14 | 12.96 | 7.20 | 10.80 | 12.96 | 10.08 |
| | | Arcidae | *Anadara* spp. | 0.72 | 4.87 | 2.44 | 6.09 | 1.22 | 3.65 | 4.87 | 1.78 | 3.65 | 4.87 | 4.87 | 2.44 |
| | | | *Scarpha inaequivalvis* | 0.94 | 4.08 | 4.08 | 16.32 | 8.16 | 8.16 | 5.15 | 8.16 | 0.00 | 12.24 | 16.32 | 8.16 |
| | | **Ophiuroidea** | Brittle star | 0.60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.60 | 0.00 | 0.00 |
| | | **Osteichthyes** | | | | | | | | | | | | | |
| | | Gobiidae | *Trypauchen vagina* | 3.87 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.77 | 0.41 | 0.00 | 7.68 | 0.00 | 4.20 |
| 26-30 | B.T. | **Foraminifera** | Foraminiferan | 0.00 | 0.02 | 0.06 | 0.01 | 0.04 | 0.00 | 0.01 | 0.02 | 0.01 | 0.07 | 0.02 | 0.01 |
| | | **Anthozoa** | | | | | | | | | | | | | |
| | | Veretillidae | *Lituaria* sp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.19 | 0.00 | 0.00 | 0.49 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | **Polychaeta** | Total Polychaetes | 9.41 | 7.72 | 6.82 | 7.19 | 6.08 | 6.39 | 7.03 | 6.66 | 5.28 | 3.43 | 7.93 | 5.81 |
| | | | Fragments | 3.23 | 3.67 | 3.83 | 4.00 | 3.87 | 4.03 | 4.23 | 4.33 | 4.10 | 3.17 | 3.50 | 3.73 |
| | | | Polychaete tubes | 2.00 | 20.00 | 0.00 | 20.00 | 40.00 | 0.00 | 0.00 | 0.00 | 0.00 | 60.00 | 20.00 | 0.00 |
| | | **Crustacea** | | | | | | | | | | | | | |
| | | Amphipoda | Amphipod | 0.00 | 0.03 | 0.03 | 0.01 | 0.02 | 0.01 | 0.03 | 0.05 | 0.01 | 0.03 | 0.04 | 0.03 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cumacea | Cumacean | 0.00 | 0.02 | 0.02 | 0.01 | 0.01 | 0.00 | 0.02 | 0.04 | 0.01 | 0.03 | 0.01 | 0.00 |
| 26-30 | B.T. | Decapoda | Shrimp juvenile | 1.29 | 0.00 | 1.94 | 0.13 | 0.13 | 0.00 | 0.26 | 0.52 | 0.00 | 1.68 | 0.52 | 0.26 |
| | | Harpacticoida | Copepod | 0.01 | 0.02 | 0.01 | 0.00 | 0.01 | 0.00 | 0.01 | 0.03 | 0.00 | 0.03 | 0.02 | 0.00 |
| | | Isopoda | Isopod | 0.06 | 0.00 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 |
| | | Ostracoda | Ostracod | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.12 | 0.00 | 0.00 |
| | | **Sipuncula** | Sipunculid | 2.28 | 1.63 | 2.15 | 0.32 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 2.18 | 0.74 | 0.00 |
| | | **Nemertea** | Nemertean | 0.26 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.29 | 0.00 | 0.00 |
| | | **Gastropoda** | | | | | | | | | | | | | |
| | | Trochidae | *Olivia* $sp_1$ | 0.53 | 0.00 | 0.00 | 1.05 | 0.50 | 1.05 | 0.00 | 0.00 | 0.00 | 1.05 | 0.00 | 0.00 |
| | | | *Olivia* $sp_2$ | 0.00 | 2.26 | 0.00 | 2.83 | 6.86 | 4.24 | 4.02 | 0.70 | 0.28 | 0.70 | 1.41 | 0.00 |
| | | | *Umbonium vestiarium* | 0.60 | 3.43 | 2.59 | 2.38 | 12.57 | 1.30 | 1.95 | 1.40 | 0.86 | 14.90 | 5.84 | 1.95 |
| | | Muricidae | *Murex* sp. | 11.89 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Nassariidae | *Nassarius thersites* | 2.11 | 6.94 | 0.87 | 4.34 | 9.95 | 3.47 | 6.31 | 10.48 | 4.34 | 23.01 | 6.94 | 0.87 |
| | | Naticidae | *Natica lineata* | 0.00 | 0.00 | 27.00 | 27.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 27.00 | 0.00 | 27.00 |
| | | | *Natica* sp. | 0.00 | 0.00 | 5.02 | 0.00 | 0.00 | 0.00 | 5.02 | 0.00 | 0.00 | 0.00 | 0.00 | 5.02 |
| | | | *Natica vitellus* | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Turridae | *Turricula javana* | 0.00 | 0.00 | 1.53 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.58 | 0.00 | 1.53 |
| | | | Turridae spp. | 0.00 | 0.00 | 0.00 | 0.23 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.70 | 0.00 | 0.00 |
| | | Bursidae | *Bursa* sp. | 0.00 | 1.69 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Cassidae | *Phalium* sp. | 0.00 | 0.25 | 0.00 | 0.62 | 0.00 | 0.00 | 4.51 | 0.41 | 0.12 | 1.35 | 0.00 | 0.00 |
| | | Neritidae | *Nerita* sp. | 0.30 | 0.00 | 0.30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.30 | 0.00 | 0.00 |
| | | Conidae | *Conus betulinus* | 4.83 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Terebridae | *Terebra* sp. | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | **Bivalvia** | | | | | | | | | | | | | |
| | | Veneridae | *Paphia textile* | 14.25 | 0.00 | 11.40 | 6.27 | 15.60 | 8.55 | 14.25 | 0.00 | 0.00 | 14.25 | 6.27 | 8.55 |
| | | Anomiidae | *Anomia ephippium* | 0.24 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Arcidae | *Anadara* spp. | 0.65 | 4.00 | 3.92 | 1.96 | 1.34 | 0.65 | 0.00 | 1.96 | 1.31 | 8.48 | 1.31 | 3.27 |
| | | | *Arca navicularis* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 24.26 | 3.73 | 0.00 | 0.00 | 0.00 |
| | | | *Scarpha inaequivalvis* | 0.17 | 0.00 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.33 | 0.00 | 0.17 |
| | | **Ophiuroidea** | Brittle star | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | **Osteichthyes** | | | | | | | | | | | | | |
| | | Muraenesocidae | *Congresox talabanoides* | 31.70 | 15.85 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 15.85 | 0.00 | 15.85 | 0.00 | 0.00 |
| | | | *Muraenesox* sp. | 0.57 | 0.00 | 0.00 | 0.00 | 5.72 | 0.00 | 0.00 | 0.00 | 0.00 | 5.72 | 0.00 | 0.00 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Gobiidae | *Trypauchen vagina* | 0.42 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Polynemidae | *Filimanus similis* | 5.48 | 0.00 | 1.83 | 0.00 | 1.83 | 0.00 | 0.00 | 0.00 | 0.00 | 0.89 | 1.83 | 0.00 |
| 26-30 | A.T. | **Foraminifera** | Foraminiferan | 0.09 | 0.04 | 0.07 | 0.02 | 0.03 | 0.03 | 0.04 | 0.02 | 0.02 | 0.08 | 0.04 | 0.02 |
| | | **Anthozoa** | | | | | | | | | | | | | |
| | | Veretillidae | *Lituaria* sp. | 0.00 | 0.00 | 1.83 | 0.00 | 0.00 | 0.00 | 0.09 | 0.19 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | **Polychaeta** | Total Polychaetes | 10.85 | 8.73 | 9.61 | 7.60 | 6.72 | 7.03 | 6.61 | 7.48 | 6.56 | 13.28 | 8.63 | 6.92 |
| | | | Fragments | 1.10 | 1.27 | 1.43 | 1.49 | 1.38 | 1.43 | 1.46 | 1.49 | 1.54 | 1.07 | 1.21 | 1.32 |
| | | | Polychaete tubes | 6.53 | 3.27 | 0.00 | 3.27 | 6.53 | 0.00 | 0.00 | 0.00 | 0.00 | 9.80 | 3.27 | 0.00 |
| | | **Crustacea** | | | | | | | | | | | | | |
| | | Amphipoda | Amphipod | 0.18 | 0.15 | 0.12 | 0.06 | 0.09 | 0.00 | 0.06 | 0.15 | 0.09 | 0.15 | 0.09 | 0.09 |
| | | Cumacea | Cumacean | 0.20 | 0.15 | 0.15 | 0.10 | 0.10 | 0.00 | 0.15 | 0.25 | 0.10 | 0.20 | 0.10 | 0.05 |
| | | Decapoda | Shrimp juvenile | 1.84 | 0.00 | 3.67 | 0.00 | 0.00 | 0.37 | 2.57 | 0.73 | 0.00 | 3.67 | 1.10 | 0.37 |
| | | Harpacticoida | Copepod | 0.03 | 0.06 | 0.03 | 0.00 | 0.03 | 0.00 | 0.02 | 0.08 | 0.00 | 0.08 | 0.05 | 0.02 |
| | | Isopoda | Isopod | 0.33 | 0.00 | 0.44 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.55 | 0.00 | 0.00 |
| | | Ostracoda | Ostracod | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.09 | 0.00 | 0.00 |
| | | Balanidae | *Balanus* sp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.56 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | **Sipuncula** | Sipunculid | 1.58 | 1.18 | 1.53 | 0.32 | 0.17 | 0.00 | 0.11 | 0.00 | 0.02 | 1.60 | 0.63 | 0.48 |
| | | **Nemertea** | Nemertean | 10.45 | 2.85 | 3.80 | 0.00 | 0.00 | 0.00 | 0.95 | 0.00 | 2.85 | 15.20 | 1.90 | 0.95 |
| | | **Gastropoda** | | | | | | | | | | | | | |
| | | Trochidae | *Olivia* $sp_1$ | 0.00 | 0.00 | 0.00 | 1.78 | 3.11 | 2.07 | 0.00 | 0.00 | 0.00 | 1.48 | 0.00 | 0.00 |
| | | | *Olivia* $sp_2$ | 1.53 | 0.59 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.65 | 0.00 | 0.49 | 0.00 | 0.00 |
| | | | *Umbonium vestiarium* | 19.29 | 5.74 | 6.06 | 3.79 | 7.50 | 0.00 | 20.78 | 11.01 | 3.79 | 18.95 | 21.98 | 12.89 |
| | | Nassariidae | *Nassarius thersites* | 16.13 | 14.50 | 18.82 | 12.54 | 8.70 | 17.02 | 19.48 | 5.42 | 0.00 | 43.98 | 26.88 | 17.02 |
| | | Naticidae | *Natica lineata* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.26 | 0.00 | 0.00 |
| | | | *Natica* sp. | 3.17 | 3.17 | 1.59 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Strombidae | *Tibia curta* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 22.34 | 0.00 | 0.00 |
| | | Turridae | *Turricula javana* | 1.99 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.58 | 9.87 | 0.00 |
| | | | Turridae spp. | 0.00 | 0.00 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.34 | 0.17 | 0.00 |
| | | Cassidae | *Phalium* sp. | 3.58 | 0.27 | 0.00 | 2.60 | 0.00 | 0.00 | 4.00 | 2.57 | 3.26 | 1.35 | 3.91 | 3.58 |
| | | Neritidae | *Nerita* sp. | 0.26 | 0.00 | 0.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.26 | 0.00 | 0.00 |
| | | Terebridae | *Terebra* sp. | 0.26 | 0.00 | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | **Bivalvia** | | | | | | | | | | | | | |
| | | Mactridae | *Meropesta pellucida* | 6.97 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.97 | 55.76 | 0.00 |

| Water Depth (m) | BT/ AT | Species | | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Veneridae | *Paphia textile* | 9.46 | 12.36 | 28.43 | 13.60 | 42.36 | 6.18 | 72.94 | 26.02 | 2.47 | 9.89 | 2.47 | 22.25 |
| 26-30 | A.T. | Arcidae | *Anadara* spp. | 107.52 | 9.74 | 107.52 | 53.76 | 53.76 | 161.27 | 0.00 | 2.64 | 0.00 | 268.79 | 0.00 | 53.76 |
| | | | *Scarpha inaequivalvis* | 1.83 | 0.00 | 0.00 | 0.00 | 1.14 | 2.17 | 2.17 | 0.00 | 1.09 | 0.21 | 0.00 | 1.09 |
| | | **Osteichthyes** | | | | | | | | | | | | | |
| | | Muraenesocidae | *Congresox talabanoides* | 0.00 | 0.00 | 2.30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | | *Muraenesox* sp. | 3.86 | 0.00 | 3.86 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.86 | 0.00 | 0.00 |
| | | Gobiidae | *Trypauchen vagina* | 7.21 | 0.00 | 0.00 | 14.42 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.52 | 0.00 | 0.00 |
| | | Polynemidae | *Filimanus similis* | 1.40 | 0.70 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.40 | 0.70 | 0.70 |
| 31-35 | B.T. | **Foraminifera** | Foraminiferan | 0.29 | 0.26 | 0.22 | 0.23 | 0.24 | 0.19 | 0.16 | 0.14 | 0.13 | 0.28 | 0.24 | 0.21 |
| | | **Anthozoa** | | | | | | | | | | | | | |
| | | Veretillidae | *Lituaria* sp. | 0.00 | 0.00 | 0.00 | 1.00 | 1.84 | 0.00 | 0.00 | 0.00 | 0.08 | 0.00 | 0.08 | 0.26 |
| | | **Polychaeta** | Total Polychaetes | 24.12 | 16.61 | 23.38 | 23.93 | 21.34 | 20.87 | 21.52 | 18.28 | 15.77 | 24.77 | 18.83 | 19.48 |
| | | | Fragments | 3.67 | 3.93 | 4.47 | 4.60 | 4.43 | 4.50 | 4.53 | 4.40 | 4.63 | 3.37 | 3.83 | 4.07 |
| | | | Polychaete tube | 20.00 | 20.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 20.00 | 0.00 |
| | | **Crustacea** | | | | | | | | | | | | | |
| | | Amphipoda | Amphipod | 0.00 | 0.00 | 0.03 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.03 | 0.02 | 0.00 |
| | | Cumacea | Cumacean | 0.03 | 0.01 | 0.01 | 0.00 | 0.01 | 0.01 | 0.03 | 0.01 | 0.00 | 0.06 | 0.02 | 0.00 |
| | | Decapoda | Shrimp juvenile | 0.25 | 0.25 | 0.00 | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.12 | 0.00 | 0.00 |
| | | Harpacticoida | Copepod | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| | | Ostracoda | Ostracod | 2.00 | 0.50 | 0.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.50 | 1.00 | 0.50 |
| | | **Sipuncula** | Sipunculid | 0.51 | 0.35 | 0.48 | 0.13 | 0.00 | 0.00 | 0.26 | 0.00 | 0.00 | 0.45 | 0.32 | 0.00 |
| | | **Nemertea** | Nemertean | 0.17 | 0.14 | 0.03 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.17 | 0.11 | 0.00 |
| | | **Gastropoda** | | | | | | | | | | | | | |
| | | Trochidae | *Olivia* $sp_2$ | 5.27 | 3.76 | 0.00 | 4.22 | 6.33 | 0.00 | 5.27 | 3.16 | 0.00 | 6.86 | 7.91 | 3.16 |
| | | | *Umbonium vestiarium* | 25.24 | 35.66 | 23.04 | 10.97 | 18.21 | 20.85 | 12.62 | 10.97 | 1.56 | 6.01 | 38.95 | 24.69 |
| | | Nassariidae | *Nassarius thersites* | 16.50 | 18.56 | 2.06 | 4.12 | 4.12 | 12.37 | 4.12 | 2.06 | 2.58 | 3.38 | 22.68 | 12.37 |
| | | Naticidae | *Natica vitellus* | 1.66 | 0.83 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.66 | 1.66 | 0.00 |
| | | Turridae | Turridae spp. | 1.79 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.34 | 0.00 | 0.00 |
| | | Cassidae | *Phalium* sp. | 2.32 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.16 | 0.00 | 0.00 |
| | | Conidae | *Conus betulinus* | 4.83 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Terebridae | *Terebra* sp. | 0.01 | 0.29 | 0.00 | 0.29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.49 | 0.49 | 0.39 |
| | | **Scaphopoda** | | | | | | | | | | | | | |
| | | Dentallidae | *Dentalium* sp. | 0.00 | 0.00 | 7.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 14.11 | 0.00 | 0.00 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Bivalvia** | | | | | | | | | | | | | |
| 31-35 | **B.T.** | Donacidae | *Donax scortum* | 0.46 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.46 | 0.46 | 0.00 | 0.00 |
| | | | *Donax sp.* | 6.71 | 5.04 | 6.71 | 3.36 | 0.00 | 6.71 | 0.00 | 0.00 | 0.00 | 8.39 | 8.39 | 5.04 |
| | | Veneridae | *Paphia textile* | 32.31 | 0.00 | 27.69 | 46.16 | 73.85 | 55.39 | 73.85 | 46.16 | 14.72 | 36.92 | 0.00 | 46.16 |
| | | Anomiidae | *Anomia ephippium* | 0.24 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Arcidae | *Anadara* spp. | 13.59 | 10.19 | 0.00 | 6.80 | 7.44 | 0.00 | 10.19 | 13.59 | 1.43 | 16.99 | 16.99 | 0.00 |
| | | | *Scarpha inaequivalvis* | 14.80 | 11.84 | 14.80 | 14.80 | 8.88 | 14.80 | 8.88 | 8.88 | 0.00 | 17.76 | 17.76 | 14.80 |
| | | | *Trisodos tortuosa* | 33.53 | 0.00 | 0.00 | 33.53 | 0.00 | 0.00 | 7.15 | 33.53 | 16.77 | 33.53 | 0.00 | 16.77 |
| | | Pectnidae | *Chlamys* sp. | 35.66 | 0.00 | 13.37 | 11.15 | 1.61 | 13.37 | 10.19 | 26.75 | 40.12 | 53.50 | 0.00 | 35.66 |
| | | **Ophiuroidea** | *Brittle star* | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | **Osteichthyes** | | | | | | | | | | | | | |
| | | Muraenesocidae | *Muraenesox* sp. | 0.57 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Gobiidae | *Trypauchen vagina* | 15.84 | 10.56 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.45 | 0.00 | 0.00 |
| | | Polynemidae | *Filimanus similis* | 0.70 | 0.70 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.70 | 0.00 | 0.00 |
| 31-35 | **A.T.** | **Foraminifera** | Foraminiferan | 0.34 | 0.28 | 0.22 | 0.24 | 0.24 | 0.22 | 0.17 | 0.15 | 0.14 | 0.28 | 0.26 | 0.21 |
| | | **Anthozoa** | | | | | | | | | | | | | |
| | | Veretillidae | *Lituaria* sp. | 0.00 | 0.10 | 0.35 | 0.20 | 0.93 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.29 | 0.25 |
| | | **Polychaeta** | Total Polychaetes | 5.22 | 3.35 | 4.90 | 5.07 | 4.83 | 4.78 | 4.67 | 3.80 | 3.27 | 2.63 | 4.82 | 4.59 |
| | | | Fragments | 1.83 | 1.11 | 2.10 | 2.18 | 2.13 | 2.19 | 2.18 | 2.21 | 2.25 | 1.61 | 2.03 | 2.22 |
| | | | Polychaete tube | 0.00 | 15.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | **Crustacea** | | | | | | | | | | | | | |
| | | Amphipoda | Amphipod | 0.05 | 0.04 | 0.04 | 0.03 | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 | 0.05 | 0.03 | 0.00 |
| | | Cumacea | Cumacean | 0.17 | 0.13 | 0.21 | 0.00 | 0.04 | 0.00 | 0.00 | 0.04 | 0.00 | 0.29 | 0.13 | 0.04 |
| | | Decapoda | *Oratosquilla nepa* | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | | Shrimp juvenile | 0.26 | 0.00 | 0.00 | 0.00 | 0.26 | 0.00 | 0.00 | 0.00 | 0.52 | 0.52 | 0.26 | 0.00 |
| | | Harpacticoida | Copepod | 0.06 | 0.08 | 0.05 | 0.03 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.04 | 0.00 |
| | | Isopoda | Isopod | 0.00 | 0.00 | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Ostracoda | Ostracod | 0.08 | 0.02 | 0.00 | 0.04 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.04 | 0.02 |
| | | **Sipuncula** | Sipunculid | 2.57 | 0.70 | 2.43 | 0.86 | 0.21 | 0.00 | 1.29 | 0.00 | 0.00 | 2.29 | 1.71 | 0.00 |
| | | **Nemertea** | Nemertean | 7.39 | 5.54 | 1.85 | 0.00 | 3.69 | 0.00 | 2.77 | 0.00 | 2.77 | 7.39 | 4.62 | 0.92 |
| | | **Gastropoda** | | | | | | | | | | | | | |
| | | Trochidae | *Olivia* $sp_1$ | 0.70 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.70 | 0.00 | 0.00 |
| | | | *Olivia* $sp_2$ | 4.06 | 0.27 | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.44 | 4.06 | 4.06 | 2.84 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *Umbonium vestiarium* | 8.25 | 1.13 | 15.65 | 3.71 | 40.36 | 5.36 | 13.58 | 4.54 | 3.88 | 8.66 | 8.25 | 8.86 |
| 31-35 | A.T. | Nassariidae | *Nassarius suturalis* | 0.00 | 0.00 | 0.00 | 0.00 | 11.57 | 0.00 | 3.86 | 11.57 | 2.84 | 7.71 | 0.00 | 0.00 |
| | | | *Nassarius thersites* | 13.23 | 18.51 | 17.34 | 25.66 | 23.09 | 25.66 | 8.12 | 19.24 | 21.07 | 35.92 | 32.07 | 30.79 |
| | | Naticidae | *Natica* sp. | 0.00 | 2.87 | 0.28 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.75 | 0.00 | 0.00 |
| | | Turridae | Turridae spp. | 2.75 | 0.00 | 1.69 | 0.21 | 0.00 | 1.27 | 0.00 | 0.00 | 1.06 | 1.92 | 2.11 | 1.06 |
| | | Cassidae | *Phalium* sp. | 0.00 | 0.20 | 0.17 | 0.79 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 1.19 | 0.99 | 0.00 |
| | | Terebridae | *Terebra* sp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | **Scaphopoda** | | | | | | | | | | | | | |
| | | Dentallidae | *Dentalium* sp. | 0.00 | 0.00 | 0.57 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.14 | 0.00 | 0.00 |
| | | **Bivalvia** | | | | | | | | | | | | | |
| | | Donacidae | *Donax scortum* | 1.42 | 2.84 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.84 | 0.00 | 0.00 |
| | | | *Donax sp.* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.42 | 0.00 | 0.00 | 2.42 | 0.00 | 0.00 |
| | | Mactridae | *Meropesta pellucida* | 1.10 | 0.00 | 0.55 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.10 | 0.00 | 0.00 |
| | | Veneridae | *Paphia textile* | 2.80 | 1.08 | 4.80 | 1.92 | 4.89 | 7.68 | 0.00 | 8.64 | 5.76 | 4.80 | 8.64 | 9.60 |
| | | Arcidae | *Anadara* spp. | 2.84 | 2.20 | 0.00 | 0.00 | 0.47 | 2.84 | 0.00 | 0.00 | 0.00 | 15.61 | 0.00 | 0.00 |
| | | | *Trisodos tortuosa* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.84 | 1.67 | 0.00 | 0.00 |
| | | Pectnidae | *Chlamys* sp. | 49.68 | 0.00 | 2.73 | 34.78 | 0.00 | 24.84 | 92.74 | 26.50 | 16.78 | 51.34 | 8.28 | 36.43 |
| | | **Osteichthyes** | | | | | | | | | | | | | |
| | | Gobiidae | *Trypauchen vagina* | 3.30 | 13.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.30 | 0.00 | 3.30 |
| | | Polynemidae | *Filimanus similis* | 0.68 | 0.68 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.68 | 0.00 | 0.00 |
| | | Cynoglossidae | *Cynoglossus macroston* | 0.00 | 0.00 | 0.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.50 | 0.00 | 0.00 |
| 36-40 | B.T. | **Foraminifera** | Foraminiferan | 0.26 | 0.14 | 0.12 | 0.06 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.27 | 0.13 | 0.10 |
| | | **Anthozoa** | | | | | | | | | | | | | |
| | | Veretillidae | *Lituaria* sp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.08 | 0.12 | 0.20 | 0.00 | 0.07 | 0.26 | 0.26 | 0.00 |
| | | **Polychaeta** | Total Polychaetes | 19.30 | 13.16 | 14.05 | 15.01 | 17.26 | 18.28 | 14.00 | 14.66 | 12.00 | 19.64 | 17.87 | 17.05 |
| | | | Fragments | 0.69 | 0.79 | 0.81 | 0.82 | 0.83 | 0.84 | 0.64 | 0.77 | 0.87 | 0.61 | 0.78 | 0.86 |
| | | | Polychaete tubes | 240.00 | 51.21 | 40.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 240.00 | 144.00 | 24.00 |
| | | **Crustacea** | | | | | | | | | | | | | |
| | | Amphipoda | Amphipod | 3.15 | 1.89 | 0.00 | 2.52 | 1.89 | 3.15 | 0.63 | 0.63 | 0.63 | 18.27 | 6.30 | 1.26 |
| | | Cumacea | Cumacean | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 |
| | | Decapoda | *Oratosquilla nepa* | 0.00 | 0.00 | 9.48 | 0.00 | 0.00 | 0.00 | 19.00 | 0.00 | 0.00 | 19.00 | 0.00 | 0.00 |
| | | | Crab juvenile | 2.03 | 0.00 | 2.03 | 0.68 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.36 | 0.68 | 0.00 |
| | | | Shrimp juvenile | 0.52 | 0.00 | 0.00 | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.13 | 0.65 | 0.13 | 0.13 |
| | | Harpacticoida | Copepod | 0.25 | 0.00 | 0.00 | 0.49 | 0.25 | 0.25 | 0.49 | 0.00 | 1.23 | 0.25 | 0.25 | 0.00 |

| Water Depth (m) | BT/AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Balanidae | *Balanus* sp. | 9.21 | 0.00 | 2.18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 20.91 | 13.94 | 0.00 |
| 36-40 | B.T. | **Sipuncula** | Sipunculid | 1.52 | 1.40 | 0.67 | 0.00 | 0.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.95 | 0.13 | 0.00 |
| | | **Nemertea** | Nemertean | 0.66 | 0.40 | 0.00 | 0.00 | 0.03 | 0.00 | 0.03 | 0.00 | 0.00 | 0.57 | 0.31 | 0.00 |
| | | **Gastropoda** | | | | | | | | | | | | | |
| | | Trochidae | *Olivia* sp$_1$ | 1.54 | 0.43 | 0.40 | 0.00 | 1.40 | 0.00 | 0.00 | 0.00 | 6.64 | 3.55 | 8.30 | 8.30 |
| | | | *Olivia* sp$_2$ | 2.77 | 0.45 | 1.22 | 1.39 | 2.77 | 0.00 | 0.00 | 1.39 | 1.44 | 2.77 | 2.77 | 2.77 |
| | | | *Umbonium vestiarium* | 14.40 | 33.70 | 27.80 | 34.54 | 24.27 | 25.27 | 25.85 | 36.22 | 5.98 | 33.96 | 33.70 | 31.17 |
| | | Muricidae | *Murex* sp. | 2.16 | 0.94 | 0.38 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.08 | 0.00 | 0.00 |
| | | | *Rapana bulbosa* | 0.94 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.94 | 0.00 | 0.00 |
| | | Nassariidae | *Nassarius thersites* | 37.94 | 23.08 | 8.71 | 22.24 | 24.16 | 21.01 | 33.76 | 23.48 | 13.78 | 21.01 | 22.24 | 21.01 |
| | | Naticidae | *Natica* sp. | 1.92 | 2.55 | 1.65 | 4.29 | 0.00 | 2.86 | 7.15 | 5.72 | 5.58 | 1.43 | 5.72 | 4.29 |
| | | | *Natica vitellus* | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Strombidae | *Tibia curta* | 111.42 | 141.60 | 0.40 | 0.00 | 0.00 | 0.00 | 141.60 | 0.00 | 0.00 | 113.28 | 141.60 | 56.64 |
| | | Turridae | *Turricula javana* | 9.67 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.39 | 0.00 | 0.00 |
| | | | Turridae spp. | 0.53 | 0.00 | 0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.30 | 0.00 | 0.00 |
| | | Bursidae | *Bursa* sp. | 5.50 | 11.30 | 0.00 | 0.00 | 0.00 | 0.00 | 122.18 | 0.00 | 4.29 | 122.18 | 0.00 | 0.00 |
| | | Cassidae | *Phalium* sp. | 10.92 | 1.94 | 1.57 | 2.83 | 3.09 | 2.58 | 3.35 | 2.83 | 0.00 | 1.62 | 3.61 | 3.35 |
| | | Conidae | *Conus betulinus* | 48.30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 48.30 | 0.00 | 0.00 |
| | | Terebridae | *Terebra* sp. | 0.68 | 1.25 | 0.20 | 0.90 | 0.79 | 0.68 | 1.13 | 0.90 | 0.00 | 1.13 | 0.90 | 0.45 |
| | | **Scaphopoda** | | | | | | | | | | | | | |
| | | Dentallidae | *Dentalium* sp. | 8.85 | 0.00 | 4.58 | 7.08 | 3.47 | 5.31 | 8.85 | 7.08 | 0.00 | 7.08 | 8.85 | 8.85 |
| | | **Bivalvia** | | | | | | | | | | | | | |
| | | Donacidae | *Donax sp.* | 4.15 | 14.50 | 0.00 | 0.00 | 2.07 | 0.00 | 6.22 | 0.00 | 0.00 | 5.19 | 0.00 | 5.19 |
| | | Mactridae | *Meropesta pellucida* | 101.41 | 2.65 | 7.52 | 13.37 | 0.00 | 12.53 | 15.88 | 15.04 | 0.00 | 12.53 | 15.88 | 15.04 |
| | | Veneridae | *Dosinia cretacea* | 57.16 | 26.70 | 0.00 | 0.00 | 4.74 | 0.00 | 0.00 | 0.00 | 0.00 | 57.16 | 0.00 | 0.00 |
| | | | *Dosinia gibba* | 8.12 | 0.00 | 0.00 | 0.00 | 6.48 | 0.00 | 0.00 | 0.00 | 4.12 | 8.12 | 0.00 | 0.00 |
| | | | *Paphia textile* | 72.56 | 157.21 | 22.08 | 189.49 | 71.09 | 173.70 | 150.45 | 189.49 | 9.23 | 173.70 | 181.60 | 181.60 |
| | | Anomiidae | *Anomia ephippium* | 0.24 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Arcidae | *Anadara* spp. | 0.00 | 5.97 | 8.88 | 8.88 | 0.00 | 7.10 | 7.10 | 8.88 | 0.00 | 8.88 | 8.88 | 8.88 |
| | | | *Scarpha inaequivalvis* | 4.56 | 5.85 | 0.00 | 0.00 | 6.83 | 0.00 | 0.00 | 0.00 | 0.00 | 4.56 | 0.00 | 0.00 |
| | | | *Trisodos tortuosa* | 9.79 | 0.00 | 3.86 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.50 | 19.59 | 0.00 | 0.00 |
| | | Pectnidae | *Chlamys* sp. | 41.64 | 26.40 | 20.75 | 42.95 | 13.82 | 37.74 | 25.47 | 44.25 | 26.83 | 47.94 | 41.64 | 36.44 |
| | | Ostreidae | *Crassostrea madrasensi* | 10.86 | 5.43 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.70 | 0.00 | 0.00 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Ophiuroidea** | Brittle star | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 36-40 | B.T. | **Osteichthyes** | | | | | | | | | | | | | |
| | | Muraenesocidae | *Muraenesox* sp. | 0.57 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Gobiidae | *Trypauchen vagina* | 0.42 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 36-40 | A.T. | | | 0.0011 | 0.0011 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0011 | 0 | 0 |
| | | **Anthozoa** | | | | | | | | | | | | | |
| | | Veretillidae | *Lituaria* sp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.58 | 0.00 | 0.00 | 0.08 | 0.00 | 0.30 | 1.73 |
| | | **Polychaeta** | Total Polychaetes | 0.00 | 12.14 | 12.72 | 13.65 | 15.84 | 15.61 | 16.02 | 13.18 | 10.93 | 17.92 | 16.07 | 14.80 |
| | | | Fragments | 2.09 | 2.36 | 2.45 | 2.55 | 2.70 | 2.81 | 2.91 | 2.99 | 3.03 | 2.13 | 2.36 | 2.51 |
| | | | Polychaete tubes | 711.68 | 803.84 | 834.56 | 870.40 | 921.60 | 957.44 | 993.28 | 1018.88 | 1034.24 | 727.04 | 803.84 | 855.04 |
| | | **Crustacea** | | | | | | | | | | | | | |
| | | Amphipoda | Amphipod | 4.41 | 3.15 | 0.00 | 0.63 | 0.63 | 0.00 | 0.00 | 0.00 | 0.00 | 5.04 | 1.26 | 0.00 |
| | | Cumacea | Cumacean | 0.14 | 0.05 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.05 | 0.00 | 0.09 | 0.09 | 0.05 |
| | | Decapoda | Crab juvenile | 0.04 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 |
| | | | Shrimp juvenile | 0.09 | 0.00 | 0.00 | 0.00 | 0.00 | 0.09 | 0.00 | 0.00 | 0.00 | 0.09 | 0.00 | 0.05 |
| | | Harpacticoida | Copepod | 0.10 | 0.00 | 0.03 | 0.08 | 0.05 | 0.00 | 0.08 | 0.00 | 0.15 | 0.05 | 0.05 | 0.00 |
| | | Isopoda | Isopod | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Balanidae | *Balanus sp.* | 10.60 | 32.75 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.92 | 5.46 | 5.46 |
| | | **Sipuncula** | Sipunculid | 1.43 | 0.51 | 0.23 | 0.00 | 0.46 | 0.00 | 0.00 | 0.00 | 0.13 | 0.22 | 0.11 | 0.03 |
| | | **Nemertea** | Nemertean | 29.30 | 21.74 | 0.00 | 0.00 | 9.45 | 0.00 | 2.84 | 0.00 | 0.00 | 21.74 | 14.18 | 4.73 |
| | | **Gastropoda** | | | | | | | | | | | | | |
| | | Trochidae | *Olivia* $sp_1$ | 7.88 | 0.78 | 6.63 | 0.00 | 0.70 | 0.00 | 0.00 | 0.00 | 1.96 | 0.97 | 0.00 | 0.00 |
| | | | *Olivia* $sp_2$ | 9.34 | 0.42 | 0.00 | 0.00 | 2.88 | 0.00 | 2.38 | 0.00 | 0.00 | 3.17 | 5.60 | 0.00 |
| | | | *Umbonium vestiarium* | 51.47 | 39.30 | 36.33 | 39.93 | 36.16 | 38.16 | 54.96 | 47.92 | 11.97 | 39.86 | 48.80 | 47.92 |
| | | Muricidae | *Murex* sp. | 2.97 | 0.74 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.89 | 2.97 | 0.00 | 0.00 |
| | | | *Rapana bulbosa* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.75 | 0.00 | 0.00 |
| | | Nassariidae | *Nassarius suturalis* | 0.00 | 0.60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.60 | 0.00 | 0.00 |
| | | | *Nassarius thersites* | 10.44 | 18.33 | 18.84 | 18.84 | 37.77 | 27.08 | 38.46 | 21.19 | 13.54 | 18.07 | 22.37 | 21.19 |
| | | Naticidae | *Natica* sp. | 4.52 | 4.50 | 0.79 | 0.00 | 4.30 | 0.00 | 6.52 | 0.00 | 5.13 | 3.03 | 13.57 | 0.00 |
| | | Strombidae | *Tibia curta* | 0.00 | 1.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.03 | 0.00 | 0.00 |
| | | Turridae | *Turricula javana* | 35.53 | 4.03 | 50.55 | 50.55 | 16.85 | 0.00 | 16.85 | 50.55 | 0.00 | 58.98 | 16.85 | 58.98 |
| | | | *Turridae* spp. | 0.00 | 0.00 | 0.84 | 0.84 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.10 | 0.00 | 0.00 |
| | | Bursidae | *Bursa* sp. | 8.81 | 0.81 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8.81 | 0.00 | 0.00 |

| Water Depth (m) | BT/ AT | | Species | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cassidae | *Phalium* sp. | 4.68 | 2.13 | 2.85 | 12.48 | 1.12 | 5.46 | 0.28 | 10.92 | 0.00 | 1.63 | 7.80 | 12.48 |
| 36-40 | A.T. | Conidae | *Conus betulinus* | 7.41 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.41 | 0.00 | 0.00 |
| | | Terebridae | *Terebra* sp. | 1.04 | 0.38 | 0.49 | 0.00 | 0.79 | 0.00 | 0.00 | 0.00 | 0.00 | 1.30 | 0.00 | 0.00 |
| | | **Bivalvia** | | | | | | | | | | | | | |
| | | Donacidae | *Donax scortum* | 2.84 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.42 | 0.00 | 0.00 |
| | | | *Donax* sp. | 8.08 | 5.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.69 | 0.00 | 2.69 |
| | | Mactridae | *Meropesta pellucida* | 1.82 | 0.00 | 4.24 | 2.12 | 0.00 | 4.54 | 0.00 | 3.33 | 0.00 | 1.21 | 4.84 | 4.54 |
| | | Veneridae | *Dosinia cretacea* | 18.72 | 8.50 | 0.00 | 0.00 | 1.57 | 0.00 | 18.25 | 93.58 | 0.00 | 18.72 | 0.00 | 74.87 |
| | | | *Paphia textile* | 276.44 | 33.74 | 31.29 | 6.14 | 0.00 | 43.00 | 54.14 | 36.86 | 39.92 | 13.22 | 49.14 | 61.43 |
| | | Arcidae | *Anadara* spp. | 19.78 | 0.00 | 13.19 | 0.00 | 0.00 | 13.19 | 0.00 | 13.19 | 3.42 | 13.19 | 0.00 | 0.00 |
| | | | *Scarpha inaequivalvis* | 8.94 | 0.00 | 0.00 | 0.00 | 4.47 | 0.00 | 4.36 | 0.00 | 0.00 | 4.47 | 0.00 | 0.00 |
| | | Pectnidae | *Chlamys* sp. | 66.38 | 15.73 | 12.94 | 24.14 | 18.00 | 36.21 | 27.69 | 29.17 | 42.43 | 49.17 | 39.22 | 40.23 |
| | | Ostreidae | *Crassostrea madrasens* | 0.00 | 1.27 | 0.00 | 0.00 | 1.27 | 0.00 | 0.00 | 0.00 | 0.00 | 1.27 | 0.00 | 0.00 |
| | | Trochidae | *Olivia* $sp_1$ | 7.88 | 0.78 | 6.63 | 0.00 | 0.70 | 0.00 | 0.00 | 0.00 | 1.96 | 0.97 | 0.00 | 0.00 |
| | | | *Olivia* $sp_2$ | 9.34 | 0.42 | 0.00 | 0.00 | 2.88 | 0.00 | 2.38 | 0.00 | 0.00 | 3.17 | 5.60 | 0.00 |
| | | | *Umbonium vestiarium* | 51.47 | 39.30 | 36.33 | 39.93 | 36.16 | 38.16 | 54.96 | 47.92 | 11.97 | 39.86 | 48.80 | 47.92 |
| | | Muricidae | *Murex* sp. | 2.97 | 0.74 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.89 | 2.97 | 0.00 | 0.00 |
| | | | *Rapana bulbosa* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.75 | 0.00 | 0.00 |
| | | Nassariidae | *Nassarius suturalis* | 0.00 | 0.60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.60 | 0.00 | 0.00 |
| | | | *Nassarius thersites* | 10.44 | 18.33 | 18.84 | 18.84 | 37.77 | 27.08 | 38.46 | 21.19 | 13.54 | 18.07 | 22.37 | 21.19 |
| | | Naticidae | *Natica* sp. | 4.52 | 4.50 | 0.79 | 0.00 | 4.30 | 0.00 | 6.52 | 0.00 | 5.13 | 3.03 | 13.57 | 0.00 |
| | | Strombidae | *Tibia curta* | 0.00 | 1.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.03 | 0.00 | 0.00 |
| | | Turridae | *Turricula javana* | 35.53 | 4.03 | 50.55 | 50.55 | 16.85 | 0.00 | 16.85 | 50.55 | 0.00 | 58.98 | 16.85 | 58.98 |
| | | | Turridae spp. | 0.00 | 0.00 | 0.84 | 0.84 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.10 | 0.00 | 0.00 |
| | | Bursidae | *Bursa* sp. | 8.81 | 0.81 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8.81 | 0.00 | 0.00 |
| | | Cassidae | *Phalium* sp. | 4.68 | 2.13 | 2.85 | 12.48 | 1.12 | 5.46 | 0.28 | 10.92 | 0.00 | 1.63 | 7.80 | 12.48 |
| | | Conidae | *Conus betulinus* | 7.41 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.41 | 0.00 | 0.00 |
| | | Terebridae | *Terebra* sp. | 1.04 | 0.38 | 0.49 | 0.00 | 0.79 | 0.00 | 0.00 | 0.00 | 0.00 | 1.30 | 0.00 | 0.00 |
| | | **Scaphopoda** | | | | | | | | | | | | | |
| | | Dentallidae | *Dentalium* sp. | 28.21 | 2.72 | 4.80 | 0.00 | 0.00 | 0.00 | 9.84 | 0.00 | 0.00 | 2.28 | 28.21 | 0.00 |

## Appendix III: Meiofaunal Lists

**Table 1:** Abundance list of meiofauna samples around Veraval coast.

The abundance is expressed as number / 10 $cm^2$. BT – Before Trawling; AT – After Trawling

| Water Depth (m) | B.T./ A.T. | Organisms | Core | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15-20 | B.T. | Foraminiferan | Upper | 68 | 59 | 12 | 34 | 42 | 104 | 183 | 114 | 122 | 187 | 69 | 67 |
| | | | Middle | 8 | 7 | 2 | 2 | 2 | 3 | 4 | 7 | 8 | 8 | 5 | 2 |
| | | | Lower | 7 | 5 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 7 | 0 | 0 |
| | | Nematode | Upper | 377 | 204 | 108 | 98 | 84 | 182 | 414 | 346 | 319 | 458 | 158 | 103 |
| | | | Middle | 5 | 3 | 24 | 16 | 2 | 2 | 3 | 18 | 13 | 15 | 1 | 10 |
| | | | Lower | 3 | 2 | 0 | 0 | 0 | 1 | 0 | 25 | 21 | 7 | 1 | 0 |
| | | Harpacticoid copepod | Upper | 4 | 2 | 0 | 2 | 2 | 2 | 36 | 0 | 3 | 8 | 2 | 0 |
| | | | Middle | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Polychaete | Upper | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 4 | 6 | 1 | 0 |
| | | | Middle | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Kinorynch | Upper | 7 | 0 | 0 | 0 | 0 | 0 | 10 | 1 | 2 | 4 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Ostracod | Upper | 5 | 0 | 0 | 0 | 1 | 2 | 23 | 5 | 7 | 3 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Acari | Upper | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 5 | 6 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | **Total** | | **495** | **282** | **146** | **152** | **134** | **294** | **672** | **522** | **507** | **710** | **236** | **181** |
| | A.T. | Foraminiferan | Upper | 73 | 70 | 16 | 37 | 47 | 108 | 231 | 116 | 134 | 249 | 109 | 104 |
| | | | Middle | 3 | 4 | 7 | 3 | 6 | 2 | 2 | 6 | 7 | 5 | 2 | 1 |
| | | | Lower | 2 | 1 | 3 | 2 | 2 | 0 | 0 | 0 | 2 | 5 | 0 | 0 |
| | | Nematode | Upper | 387 | 225 | 126 | 133 | 93 | 200 | 525 | 445 | 348 | 480 | 218 | 126 |
| | | | Middle | 68 | 5 | 2 | 8 | 2 | 1 | 0 | 16 | 11 | 14 | 0 | 3 |
| | | | Lower | 11 | 2 | 3 | 0 | 2 | 0 | 0 | 2 | 16 | 9 | 0 | 0 |
| | | Harpacticoid copepod | Upper | 5 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# APPENDIX III

| Water Depth (m) | B.T./ A.T. | Organisms | Core | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Polychaete | Upper | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Kinorhynch | Upper | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Ostracod | Upper | 7 | 0 | 0 | 0 | 0 | 2 | 0 | 3 | 0 | 0 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | **Total** | | **557** | **307** | **157** | **183** | **153** | **312** | **760** | **588** | **519** | **762** | **329** | **234** |
| 21-25 | B.T. | Foraminifera | Upper | 78 | 69 | 10 | 86 | 100 | 128 | 192 | 63 | 53 | 171 | 134 | 77 |
| | | | Middle | 5 | 4 | 3 | 19 | 32 | 16 | 2 | 3 | 2 | 8 | 3 | 2 |
| | | | Lower | 7 | 3 | 0 | 0 | 0 | 2 | 0 | 5 | 3 | 2 | 2 | 0 |
| | | Nematode | Upper | 460 | 323 | 199 | 89 | 43 | 227 | 460 | 290 | 209 | 497 | 182 | 103 |
| | | | Middle | 13 | 30 | 34 | 21 | 5 | 6 | 3 | 38 | 24 | 34 | 4 | 9 |
| | | | Lower | 28 | 17 | 7 | 3 | 0 | 2 | 3 | 33 | 4 | 19 | 2 | 0 |
| | | Harpacticoid copepod | Upper | 2 | 0 | 7 | 0 | 0 | 0 | 0 | 7 | 0 | 2 | 1 | 0 |
| | | | Middle | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Polychaete | Upper | 2 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 |
| | | | Middle | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Kinorynch | Upper | 2 | 0 | 7 | 0 | 0 | 0 | 0 | 5 | 0 | 1 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Ostracod | Upper | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | **Total** | | **597** | **447** | **276** | **218** | **180** | **381** | **661** | **448** | **296** | **737** | **328** | **190** |
| | A.T. | Foraminiferan | Upper | 89 | 84 | 46 | 182 | 55 | 122 | 200 | 41 | 68 | 176 | 189 | 141 |
| | | | Middle | 0 | 3 | 10 | 21 | 3 | 14 | 1 | 7 | 2 | 6 | 2 | 0 |
| | | | Lower | 0 | 2 | 4 | 0 | 0 | 0 | 0 | 6 | 1 | 1 | 0 | 0 |
| | | Nematode | Upper | 610 | 336 | 212 | 101 | 186 | 210 | 560 | 451 | 222 | 605 | 173 | 109 |

| Water Depth (m) | B.T./ A.T. | Organisms | Core | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Middle | 11 | 16 | 20 | 16 | 3 | 2 | 2 | 18 | 13 | 31 | 2 | 7 |
| | | | Lower | 15 | 9 | 3 | 0 | 0 | 2 | 1 | 24 | 3 | 11 | 0 | 0 |
| | | Harpacticoid copepod | Upper | 5 | 0 | 0 | 0 | 2 | 0 | 1 | 11 | 0 | 2 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Polychaete | Upper | 0 | 0 | 0 | 0 | 15 | 0 | 0 | 2 | 0 | 2 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Kinorhynch | Upper | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Ostracod | Upper | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Acari | Upper | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | **Total** | | **732** | **450** | **296** | **320** | **264** | **350** | **764** | **561** | **310** | **835** | **366** | **258** |
| 26-30 | B.T. | Foraminifera | Upper | 165 | 26 | 51 | 163 | 173 | 170 | 209 | 130 | 134 | 90 | 157 | 125 |
| | | | Middle | 14 | 20 | 3 | 13 | 16 | 12 | 8 | 14 | 12 | 8 | 8 | 8 |
| | | | Lower | 10 | 11 | 2 | 4 | 2 | 2 | 3 | 2 | 2 | 1 | 2 | 2 |
| | | Nematode | Upper | 1012 | 900 | 279 | 242 | 300 | 272 | 438 | 320 | 333 | 905 | 648 | 282 |
| | | | Middle | 34 | 29 | 42 | 32 | 2 | 0 | 38 | 38 | 21 | 37 | 35 | 26 |
| | | | Lower | 7 | 5 | 7 | 0 | 0 | 0 | 8 | 20 | 15 | 29 | 32 | 20 |
| | | Harpacticoid copepod | Upper | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 3 | 2 | 2 | 1 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Polychaete | Upper | 2 | 3 | 0 | 0 | 2 | 0 | 3 | 0 | 0 | 2 | 2 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Kinorynch | Upper | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Ostracod | Upper | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |

| Water Depth (m) | B.T./ A.T. | Organisms | Core | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Acari | Upper | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | **Total** | | **1247** | **995** | **385** | **454** | **498** | **456** | **708** | **527** | **518** | **1081** | **885** | **463** |
| | A.T. | Foraminiferan | Upper | 240 | 31 | 60 | 192 | 198 | 192 | 271 | 212 | 139 | 365 | 191 | 203 |
| | | | Middle | 11 | 3 | 20 | 11 | 7 | 8 | 0 | 10 | 11 | 6 | 7 | 7 |
| | | | Lower | 5 | 0 | 8 | 2 | 5 | 1 | 0 | 8 | 0 | 0 | 1 | 1 |
| | | Nematode | Upper | 1121 | 1030 | 369 | 256 | 351 | 283 | 509 | 347 | 401 | 793 | 689 | 271 |
| | | | Middle | 24 | 18 | 7 | 20 | 0 | 0 | 0 | 25 | 13 | 43 | 32 | 21 |
| | | | Lower | 3 | 0 | 3 | 0 | 1 | 0 | 0 | 26 | 4 | 10 | 11 | 15 |
| | | Harpacticoid copepod | Upper | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 24 | 0 | 1 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Polychaete | Upper | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Kinorhynch | Upper | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Ostracod | Upper | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Acari | Upper | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | **Total** | | **1405** | **1082** | **472** | **481** | **562** | **483** | **782** | **659** | **568** | **1218** | **929** | **518** |
| 31-35 | B.T. | Foraminifera | Upper | 200 | 37 | 26 | 43 | 191 | 209 | 227 | 110 | 140 | 263 | 281 | 201 |
| | | | Middle | 7 | 27 | 12 | 21 | 26 | 8 | 7 | 59 | 14 | 9 | 11 | 8 |
| | | | Lower | 3 | 17 | 7 | 5 | 1 | 3 | 2 | 17 | 2 | 5 | 2 | 2 |
| | | Nematode | Upper | 1096 | 984 | 412 | 397 | 350 | 438 | 403 | 394 | 553 | 1209 | 568 | 694 |
| | | | Middle | 39 | 29 | 33 | 43 | 5 | 38 | 29 | 59 | 15 | 44 | 41 | 36 |
| | | | Lower | 26 | 5 | 13 | 0 | 3 | 8 | 7 | 48 | 21 | 38 | 34 | 20 |

| Water Depth (m) | B.T./ A.T. | Organisms | Core | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Harpacticoid copepod | Upper | 3 | 0 | 26 | 0 | 0 | 0 | 3 | 5 | 2 | 1 | 2 | 0 |
| | | | Middle | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Polychaete | Upper | 2 | 3 | 13 | 0 | 5 | 3 | 3 | 0 | 0 | 3 | 2 | 0 |
| | | | Middle | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Kinorynch | Upper | 2 | 0 | 26 | 0 | 0 | 0 | 3 | 6 | 0 | 2 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Ostracod | Upper | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Others | Upper | 16 | 1 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Acari | Upper | 4 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | **Total** | | **1400** | **1103** | **594** | **509** | **580** | **708** | **686** | **703** | **746** | **1581** | **941** | **962** |
| | A.T. | Foraminiferan | Upper | 266 | 38 | 55 | 54 | 241 | 249 | 639 | 99 | 170 | 314 | 283 | 238 |
| | | | Middle | 4 | 0 | 10 | 11 | 10 | 7 | 0 | 36 | 12 | 30 | 10 | 0 |
| | | | Lower | 2 | 0 | 0 | 4 | 3 | 2 | 0 | 8 | 0 | 25 | 0 | 0 |
| | | Nematode | Upper | 1284 | 1127 | 463 | 486 | 424 | 524 | 205 | 666 | 484 | 1240 | 650 | 797 |
| | | | Middle | 29 | 14 | 13 | 34 | 2 | 31 | 24 | 35 | 15 | 28 | 35 | 26 |
| | | | Lower | 20 | 2 | 3 | 0 | 2 | 6 | 5 | 17 | 2 | 15 | 25 | 14 |
| | | Harpacticoid copepod | Upper | 0 | 0 | 10 | 0 | 3 | 0 | 9 | 20 | 0 | 3 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Polychaete | Upper | 0 | 0 | 3 | 0 | 3 | 0 | 3 | 1 | 0 | 0 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Kinorhynch | Upper | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Water Depth (m) | B.T./ A.T. | Organisms | Core | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ostracod | Upper | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Bivalve | Upper | 0 | 0 | 0 | 0 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | **Total** | | **1605** | **1181** | **557** | **589** | **691** | **820** | **887** | **894** | **684** | **1656** | **1003** | **1075** |
| 36-40 | B.T. | Foraminifera | Upper | 242 | 46 | 39 | 53 | 192 | 282 | 324 | 144 | 192 | 282 | 274 | 234 |
| | | | Middle | 47 | 32 | 19 | 26 | 51 | 57 | 24 | 52 | 30 | 37 | 20 | 18 |
| | | | Lower | 1 | 29 | 5 | 3 | 8 | 7 | 24 | 13 | 10 | 2 | 0 | 2 |
| | | Nematode | Upper | 1271 | 1130 | 544 | 533 | 447 | 524 | 544 | 434 | 626 | 1215 | 797 | 716 |
| | | | Middle | 139 | 39 | 42 | 53 | 4 | 28 | 47 | 44 | 28 | 212 | 52 | 46 |
| | | | Lower | 14 | 15 | 12 | 0 | 2 | 7 | 10 | 35 | 31 | 17 | 29 | 28 |
| | | Harpacticoid copepod | Upper | 29 | 0 | 23 | 0 | 7 | 0 | 26 | 17 | 24 | 64 | 1 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Polychaete | Upper | 16 | 5 | 15 | 0 | 4 | 2 | 3 | 2 | 0 | 7 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Kinorynch | Upper | 19 | 0 | 23 | 0 | 0 | 0 | 3 | 5 | 0 | 11 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Ostracod | Upper | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Acari | Upper | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | **Total** | | **1782** | **1298** | **721** | **668** | **714** | **907** | **1005** | **749** | **940** | **1851** | **1174** | **1042** |
| | A.T. | Foraminiferan | Upper | 430 | 137 | 102 | 86 | 258 | 352 | 329 | 155 | 279 | 494 | 451 | 289 |
| | | | Middle | 7 | 3 | 5 | 21 | 0 | 53 | 18 | 17 | 24 | 57 | 10 | 15 |
| | | | Lower | 3 | 2 | 2 | 2 | 0 | 4 | 11 | 8 | 0 | 20 | 0 | 0 |
| | | Nematode | Upper | 1389 | 1202 | 681 | 656 | 518 | 623 | 704 | 497 | 669 | 1522 | 916 | 775 |
| | | | Middle | 7 | 26 | 20 | 46 | 0 | 21 | 34 | 91 | 24 | 106 | 11 | 35 |

| Water Depth (m) | B.T./ A.T. | Organisms | Core | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Lower | 0 | 10 | 13 | 0 | 0 | 4 | 8 | 55 | 23 | 57 | 2 | 23 |
| | | Harpacticoid copepod | Upper | 0 | 0 | 3 | 0 | 3 | 0 | 11 | 25 | 0 | 8 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | Polychaete | Upper | 0 | 5 | 10 | 0 | 7 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| | | | Middle | 0 | 0 | 3 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Kinorhynch | Upper | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 9 | 0 | 3 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| | | Ostracod | Upper | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Bivalve | Upper | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Acari | Upper | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | | | Middle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | | Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | **Total** | | **1836** | **1386** | **848** | **813** | **788** | **1057** | **1116** | **868** | **1019** | **2273** | **1389** | **1137** |

**Table 2:** Biomass list of meiofauna samples around Veraval coast.

The biomass is expressed as milligrams / 10 cm$^2$. BT – Before Trawling; AT – After Trawling

| Water Depth (m) | B.T./ A.T. | Organisms | Core | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15-20 | B.T. | Foraminiferan | Upper | 0.681 | 0.577 | 0.118 | 0.292 | 0.302 | 0.664 | 1.154 | 0.709 | 0.727 | 1.844 | 0.644 | 0.551 |
| | | | Middle | 0.081 | 0.072 | 0.016 | 0.014 | 0.012 | 0.021 | 0.026 | 0.040 | 0.048 | 0.080 | 0.045 | 0.013 |
| | | | Lower | 0.065 | 0.048 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.010 | 0.015 | 0.072 | 0.000 | 0.000 |
| | | Nematode | Upper | 7.275 | 2.384 | 1.244 | 1.487 | 0.883 | 1.859 | 4.107 | 3.128 | 2.562 | 18.138 | 2.059 | 1.602 |
| | | | Middle | 0.094 | 0.038 | 0.283 | 0.248 | 0.026 | 0.017 | 0.032 | 0.162 | 0.105 | 0.581 | 0.011 | 0.153 |
| | | | Lower | 0.063 | 0.019 | 0.000 | 0.000 | 0.000 | 0.008 | 0.000 | 0.228 | 0.170 | 0.258 | 0.011 | 0.000 |
| | | Harpacticoid c | Upper | 1.310 | 0.543 | 0.000 | 0.362 | 0.543 | 0.362 | 7.957 | 0.000 | 0.688 | 2.620 | 0.362 | 0.000 |
| | | | Middle | 0.262 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.262 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Polychaete | Upper | 2.934 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.456 | 1.141 | 2.567 | 0.302 | 0.000 |
| | | | Middle | 0.367 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Kinorhynch | Upper | 0.404 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.118 | 0.002 | 0.020 | 0.252 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Ostracod | Upper | 0.293 | 0.000 | 0.000 | 0.000 | 0.033 | 0.065 | 0.913 | 0.147 | 0.196 | 0.196 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Acari | Upper | 0.981 | 0.000 | 0.000 | 0.000 | 0.196 | 0.000 | 0.000 | 0.496 | 0.993 | 1.717 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Total | | **14.809** | **3.681** | **1.660** | **2.402** | **1.994** | **2.997** | **14.307** | **5.378** | **6.664** | **28.588** | **3.433** | **2.319** |
| | A.T. | Foraminiferan | Upper | 0.729 | 0.689 | 0.157 | 0.320 | 0.343 | 0.696 | 1.463 | 0.719 | 0.795 | 2.454 | 1.016 | 0.861 |
| | | | Middle | 0.032 | 0.040 | 0.063 | 0.028 | 0.041 | 0.010 | 0.015 | 0.035 | 0.039 | 0.048 | 0.023 | 0.007 |
| | | | Lower | 0.024 | 0.008 | 0.031 | 0.014 | 0.012 | 0.000 | 0.000 | 0.000 | 0.010 | 0.048 | 0.000 | 0.000 |
| | | Nematode | Upper | 7.479 | 2.632 | 14.509 | 2.019 | 0.977 | 2.043 | 5.207 | 4.018 | 2.791 | 19.009 | 2.833 | 1.958 |
| | | | Middle | 1.323 | 0.057 | 0.283 | 0.124 | 0.026 | 0.008 | 0.000 | 0.147 | 0.092 | 0.549 | 0.000 | 0.051 |
| | | | Lower | 0.220 | 0.029 | 0.377 | 0.000 | 0.026 | 0.000 | 0.000 | 0.022 | 0.131 | 0.355 | 0.000 | 0.000 |
| | | Harpacticoid c | Upper | 1.572 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.362 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Polychaete | Upper | 0.000 | 0.000 | 0.000 | 0.000 | 0.302 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

| Water Depth (m) | B.T./ A.T. | Organisms | Core | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Kinorhynch | Upper | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Ostracod | Upper | 0.391 | 0.000 | 0.000 | 0.000 | 0.000 | 0.065 | 0.000 | 0.098 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | **Total** | | **11.771** | **3.455** | **15.419** | **2.505** | **1.727** | **2.823** | **7.047** | **5.039** | **3.860** | **22.463** | **3.872** | **2.876** |
| 21-25 | B.T. | Foraminiferan | Upper | 0.769 | 0.680 | 0.091 | 0.708 | 0.696 | 0.769 | 1.146 | 0.378 | 0.298 | 1.648 | 1.170 | 0.609 |
| | | | Middle | 0.048 | 0.040 | 0.030 | 0.154 | 0.221 | 0.098 | 0.015 | 0.020 | 0.014 | 0.078 | 0.028 | 0.013 |
| | | | Lower | 0.064 | 0.032 | 0.000 | 0.000 | 0.000 | 0.015 | 0.000 | 0.029 | 0.018 | 0.024 | 0.014 | 0.000 |
| | | Nematode | Upper | 6.178 | 3.773 | 2.291 | 1.706 | 0.424 | 2.186 | 4.206 | 2.597 | 1.661 | 16.953 | 2.352 | 1.489 |
| | | | Middle | 0.175 | 0.353 | 0.394 | 0.407 | 0.048 | 0.055 | 0.030 | 0.343 | 0.195 | 1.167 | 0.053 | 0.130 |
| | | | Lower | 0.372 | 0.200 | 0.075 | 0.063 | 0.000 | 0.024 | 0.030 | 0.292 | 0.032 | 0.639 | 0.021 | 0.000 |
| | | Harpacticoid c | Upper | 0.524 | 0.000 | 1.447 | 0.000 | 0.000 | 0.000 | 0.000 | 1.547 | 0.000 | 0.524 | 0.181 | 0.000 |
| | | | Middle | 0.262 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.860 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Polychaete | Upper | 1.100 | 0.000 | 2.412 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.733 | 0.302 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 1.206 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Kinorhynch | Upper | 0.101 | 0.000 | 0.079 | 0.000 | 0.000 | 0.000 | 0.000 | 0.009 | 0.000 | 0.050 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Ostracod | Upper | 0.049 | 0.000 | 0.033 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.049 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | **Total** | | **9.643** | **5.078** | **8.059** | **3.037** | **1.389** | **3.147** | **5.426** | **6.074** | **2.218** | **21.866** | **4.120** | **2.241** |
| | A.T. | Foraminiferan | Upper | 0.873 | 0.823 | 0.424 | 1.490 | 0.397 | 0.735 | 1.195 | 0.245 | 0.385 | 1.695 | 1.645 | 1.121 |
| | | | Middle | 0.000 | 0.032 | 0.091 | 0.174 | 0.024 | 0.083 | 0.005 | 0.039 | 0.009 | 0.055 | 0.014 | 0.000 |
| | | | Lower | 0.000 | 0.016 | 0.038 | 0.000 | 0.000 | 0.000 | 0.000 | 0.034 | 0.005 | 0.008 | 0.000 | 0.000 |
| | | Nematode | Upper | 8.205 | 39.259 | 2.442 | 1.012 | 0.485 | 2.029 | 5.123 | 4.034 | 1.771 | 20.621 | 2.236 | 1.584 |
| | | | Middle | 0.153 | 1.906 | 0.225 | 0.163 | 0.009 | 0.024 | 0.015 | 0.160 | 0.104 | 1.056 | 0.032 | 0.106 |
| | | | Lower | 0.197 | 1.048 | 0.038 | 0.000 | 0.000 | 0.016 | 0.007 | 0.219 | 0.026 | 0.361 | 0.000 | 0.000 |
| | | Harpacticoid c | Upper | 1.572 | 0.000 | 0.000 | 0.000 | 0.362 | 0.000 | 0.181 | 2.235 | 0.000 | 0.524 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.524 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Polychaete | Upper | 0.000 | 0.000 | 0.000 | 0.000 | 5.428 | 0.000 | 0.000 | 0.456 | 0.000 | 1.100 | 0.000 | 0.000 |

| Water Depth (m) | B.T./ A.T. | Organisms | Core | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Kinorhynch | Upper | 0.101 | 0.000 | 0.020 | 0.000 | 0.000 | 0.000 | 0.000 | 0.005 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Ostracod | Upper | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Acari | Upper | 0.000 | 0.000 | 0.000 | 0.000 | 0.196 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | **Total** | | **11.102** | **43.085** | **3.278** | **2.839** | **6.900** | **2.886** | **6.526** | **7.428** | **2.300** | **25.945** | **3.927** | **2.811** |
| 26-30 | B.T. | Foraminifera | Upper | 1.592 | 0.255 | 0.446 | 1.293 | 1.012 | 1.000 | 1.043 | 0.768 | 0.724 | 0.847 | 1.309 | 0.951 |
| | | | Middle | 0.133 | 0.191 | 0.029 | 0.103 | 0.095 | 0.072 | 0.041 | 0.082 | 0.066 | 0.077 | 0.068 | 0.062 |
| | | | Lower | 0.094 | 0.111 | 0.014 | 0.032 | 0.010 | 0.014 | 0.016 | 0.010 | 0.009 | 0.008 | 0.020 | 0.012 |
| | | Nematode | Upper | 13.463 | 1.152 | 3.203 | 2.408 | 2.918 | 2.504 | 3.948 | 2.767 | 2.593 | 26.778 | 7.794 | 2.876 |
| | | | Middle | 0.455 | 0.038 | 0.487 | 0.316 | 0.016 | 0.000 | 0.346 | 0.331 | 0.165 | 1.086 | 0.422 | 0.266 |
| | | | Lower | 0.087 | 0.006 | 0.084 | 0.000 | 0.000 | 0.000 | 0.074 | 0.169 | 0.114 | 0.868 | 0.382 | 0.208 |
| | | Harpacticoid c | Upper | 0.000 | 0.000 | 0.000 | 0.000 | 0.543 | 0.000 | 0.000 | 0.688 | 0.344 | 0.524 | 0.262 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.172 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Polychaete | Upper | 1.100 | 1.206 | 0.000 | 0.000 | 0.603 | 0.000 | 1.206 | 0.000 | 0.000 | 1.100 | 0.603 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.367 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Kinorhynch | Upper | 0.050 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.252 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.020 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Ostracod | Upper | 0.049 | 0.000 | 0.033 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.147 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Acari | Upper | 0.245 | 0.196 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | **Total** | | **17.268** | **3.155** | **4.295** | **4.153** | **5.216** | **3.591** | **6.673** | **4.987** | **4.016** | **32.053** | **10.860** | **4.376** |
| | A.T. | Foraminiferan | Upper | 2.313 | 0.302 | 0.532 | 1.519 | 1.160 | 1.130 | 1.347 | 1.257 | 0.755 | 3.450 | 1.587 | 1.548 |
| | | | Middle | 0.110 | 0.032 | 0.173 | 0.084 | 0.038 | 0.048 | 0.000 | 0.058 | 0.057 | 0.054 | 0.054 | 0.056 |

| Water Depth (m) | B.T./ A.T. | Organisms | Core | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Lower | 0.047 | 0.000 | 0.072 | 0.019 | 0.029 | 0.005 | 0.000 | 0.048 | 0.000 | 0.000 | 0.007 | 0.006 |
| | | Nematode | Upper | 15.646 | 119.117 | 4.242 | 2.546 | 3.418 | 2.602 | 4.587 | 3.000 | 3.120 | 23.473 | 8.285 | 2.760 |
| | | | Middle | 0.341 | 2.073 | 0.075 | 0.203 | 0.000 | 0.000 | 0.000 | 0.218 | 0.101 | 1.279 | 0.382 | 0.216 |
| | | | Lower | 0.046 | 0.000 | 0.037 | 0.000 | 0.008 | 0.000 | 0.000 | 0.225 | 0.032 | 0.289 | 0.127 | 0.150 |
| | | Harpacticoid c | Upper | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.723 | 5.157 | 0.000 | 0.262 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.516 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Polychaete | Upper | 0.000 | 0.000 | 1.809 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Kinorhynch | Upper | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.008 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Ostracod | Upper | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Acari | Upper | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.245 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | **Total** | | **18.503** | **121.524** | **6.940** | **4.372** | **4.652** | **3.785** | **6.658** | **10.487** | **4.066** | **29.052** | **10.442** | **4.736** |
| 31-35 | B.T. | Foraminifera | Upper | 1.857 | 0.354 | 0.223 | 0.334 | 1.015 | 1.095 | 1.074 | 0.616 | 0.695 | 2.422 | 2.221 | 1.453 |
| | | | Middle | 0.068 | 0.259 | 0.104 | 0.164 | 0.139 | 0.043 | 0.035 | 0.329 | 0.069 | 0.082 | 0.084 | 0.059 |
| | | | Lower | 0.030 | 0.165 | 0.056 | 0.038 | 0.004 | 0.017 | 0.012 | 0.096 | 0.008 | 0.045 | 0.019 | 0.012 |
| | | Nematode | Upper | 13.477 | 11.333 | 4.714 | 3.854 | 3.329 | 3.943 | 3.623 | 3.175 | 4.177 | 29.612 | 6.771 | 6.527 |
| | | | Middle | 0.481 | 0.338 | 0.382 | 0.419 | 0.047 | 0.345 | 0.263 | 0.472 | 0.111 | 1.078 | 0.486 | 0.337 |
| | | | Lower | 0.321 | 0.056 | 0.149 | 0.000 | 0.031 | 0.073 | 0.066 | 0.387 | 0.160 | 0.938 | 0.408 | 0.192 |
| | | Harpacticoid c | Upper | 1.048 | 0.000 | 5.787 | 0.000 | 0.000 | 0.000 | 0.723 | 1.031 | 0.362 | 0.262 | 0.362 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.723 | 0.000 | 0.000 | 0.000 | 0.000 | 0.860 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Polychaete | Upper | 1.100 | 1.206 | 4.825 | 0.000 | 1.809 | 1.206 | 1.206 | 0.000 | 0.000 | 1.467 | 0.905 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.603 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Kinorhynch | Upper | 0.101 | 0.000 | 0.316 | 0.000 | 0.000 | 0.000 | 0.039 | 0.011 | 0.000 | 0.151 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Ostracod | Upper | 0.049 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.147 | 0.000 | 0.000 |

| Water Depth (m) | B.T./ A.T. | Organisms | Core | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Others | Upper | 0.852 | 0.040 | 0.924 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Acari | Upper | 1.227 | 0.000 | 0.393 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.227 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | **Total** | | **20.612** | **13.752** | **19.199** | **4.810** | **6.373** | **6.723** | **7.041** | **6.980** | **5.582** | **37.431** | **11.256** | **8.580** |
| | A.T. | Foraminiferan | Upper | 2.471 | 0.369 | 0.473 | 0.416 | 1.283 | 1.304 | 3.029 | 0.557 | 0.841 | 2.887 | 2.234 | 1.718 |
| | | | Middle | 0.038 | 0.000 | 0.084 | 0.088 | 0.052 | 0.038 | 0.000 | 0.201 | 0.061 | 0.277 | 0.077 | 0.000 |
| | | | Lower | 0.015 | 0.000 | 0.000 | 0.032 | 0.017 | 0.013 | 0.000 | 0.046 | 0.000 | 0.232 | 0.000 | 0.000 |
| | | Nematode | Upper | 15.792 | 12.986 | 52.921 | 4.717 | 4.035 | 4.722 | 1.844 | 5.360 | 3.660 | 30.390 | 7.752 | 7.811 |
| | | | Middle | 0.361 | 0.160 | 1.491 | 0.332 | 0.016 | 0.279 | 0.220 | 0.282 | 0.117 | 0.679 | 0.418 | 0.256 |
| | | | Lower | 0.240 | 0.019 | 0.373 | 0.000 | 0.016 | 0.051 | 0.044 | 0.138 | 0.018 | 0.379 | 0.301 | 0.136 |
| | | Harpacticoid c | Upper | 0.000 | 0.000 | 0.391 | 0.000 | 0.723 | 0.000 | 1.989 | 4.298 | 0.000 | 1.048 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.516 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Polychaete | Upper | 0.000 | 0.000 | 1.206 | 0.000 | 1.206 | 0.000 | 1.206 | 0.228 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Kinorhynch | Upper | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.017 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Ostracod | Upper | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Bivalve | Upper | 0.000 | 0.000 | 0.000 | 0.000 | 0.391 | 0.000 | 0.098 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | **Total** | | **18.917** | **13.533** | **56.939** | **5.585** | **7.739** | **6.408** | **8.430** | **11.642** | **4.697** | **35.893** | **10.783** | **9.921** |
| 36-40 | B.T. | Foraminifera | Upper | 2.091 | 0.417 | 0.312 | 0.336 | 0.952 | 1.396 | 1.255 | 0.754 | 0.887 | 2.490 | 2.059 | 1.623 |
| | | | Middle | 0.408 | 0.285 | 0.150 | 0.166 | 0.250 | 0.282 | 0.091 | 0.273 | 0.140 | 0.331 | 0.153 | 0.124 |
| | | | Lower | 0.007 | 0.263 | 0.039 | 0.021 | 0.040 | 0.032 | 0.091 | 0.068 | 0.045 | 0.014 | 0.000 | 0.011 |
| | | Nematode | Upper | 15.505 | 12.887 | 6.143 | 5.144 | 4.212 | 4.543 | 4.702 | 3.447 | 4.025 | 16.575 | 8.927 | 6.726 |
| | | | Middle | 1.690 | 0.446 | 0.479 | 0.511 | 0.038 | 0.240 | 0.409 | 0.350 | 0.178 | 2.890 | 0.584 | 0.429 |

| Water Depth (m) | B.T./ A.T. | Organisms | Core | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Lower | 0.169 | 0.177 | 0.138 | 0.000 | 0.015 | 0.064 | 0.085 | 0.279 | 0.199 | 0.233 | 0.329 | 0.260 |
| | | Harpacticoid c | Upper | 9.431 | 0.000 | 5.064 | 0.000 | 1.447 | 0.000 | 5.787 | 3.610 | 4.985 | 20.697 | 0.181 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.344 | 0.000 | 0.262 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Polychaete | Upper | 7.335 | 1.809 | 5.428 | 0.000 | 1.508 | 0.905 | 1.206 | 0.456 | 0.000 | 3.301 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Kinorhynch | Upper | 1.160 | 0.000 | 0.276 | 0.000 | 0.000 | 0.000 | 0.039 | 0.009 | 0.000 | 0.656 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.050 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Ostracod | Upper | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.049 | 0.000 | 0.098 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Acari | Upper | 0.981 | 0.196 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | **Total** | | **38.778** | **16.481** | **18.029** | **6.177** | **8.463** | **7.462** | **13.667** | **9.639** | **10.459** | **47.598** | **12.233** | **9.175** |
| | A.T. | Foraminiferan | Upper | 3.718 | 1.230 | 0.814 | 0.549 | 1.275 | 1.743 | 1.274 | 0.810 | 1.291 | 4.361 | 3.389 | 2.002 |
| | | | Middle | 0.056 | 0.029 | 0.039 | 0.135 | 0.000 | 0.262 | 0.069 | 0.090 | 0.109 | 0.504 | 0.074 | 0.107 |
| | | | Lower | 0.028 | 0.022 | 0.013 | 0.016 | 0.000 | 0.020 | 0.044 | 0.043 | 0.000 | 0.173 | 0.000 | 0.000 |
| | | Nematode | Upper | 16.936 | 13.704 | 7.699 | 6.331 | 4.888 | 5.398 | 6.091 | 3.952 | 4.302 | 20.766 | 10.260 | 7.286 |
| | | | Middle | 0.080 | 0.297 | 0.221 | 0.448 | 0.000 | 0.184 | 0.296 | 0.726 | 0.157 | 1.445 | 0.119 | 0.329 |
| | | | Lower | 0.000 | 0.111 | 0.147 | 0.000 | 0.000 | 0.035 | 0.070 | 0.441 | 0.147 | 0.778 | 0.018 | 0.215 |
| | | Harpacticoid c | Upper | 0.000 | 0.000 | 1.048 | 0.000 | 0.723 | 0.000 | 2.351 | 5.329 | 0.000 | 2.620 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.516 | 0.000 | 0.524 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.262 | 0.000 | 0.000 |
| | | Polychaete | Upper | 0.000 | 1.809 | 3.619 | 0.000 | 2.412 | 0.000 | 0.000 | 0.456 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 1.206 | 0.000 | 0.905 | 0.000 | 0.000 | 0.000 | 0.000 | 0.367 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Kinorhynch | Upper | 0.050 | 0.000 | 0.039 | 0.000 | 0.000 | 0.000 | 0.000 | 0.017 | 0.000 | 0.202 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.006 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.101 | 0.000 | 0.000 |
| | | Ostracod | Upper | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.024 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Bivalve | Upper | 0.000 | 0.098 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.098 | 0.000 | 0.000 | 0.000 | 0.000 |

| Water Depth (m) | B.T./ A.T. | Organisms | Core | Sep-05 | Oct-05 | Nov-05 | Dec-05 | Jan-06 | Feb-06 | Mar-06 | Apr-06 | May-06 | Sep-06 | Oct-06 | Nov-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | Acari | Upper | 0.000 | 0.000 | 1.571 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.245 | 0.000 | 0.000 |
| | | | Middle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.165 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | Lower | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | **Total** | | **20.868** | **17.301** | **16.417** | **7.478** | **10.204** | **7.643** | **10.196** | **12.673** | **6.006** | **32.347** | **13.859** | **9.939** |

# APPENDIX IV

## List of Publications

- **Bhagirathan, U**., Meenakumari, B., Jayalakshmy, K.V., Panda, S.K., Madhu, V.R. and Vaghela, D.K. 2008. Impact of bottom trawling on sediment characteristics – A study along inshore waters off Veraval coast, India. *Environmental Monitoring and Assessment.* Doi: 10.1007/s10661-008-0700-0.

- **Bhagirathan, U**., Panda, S.K., Madhu, V.R. and Meenakumari, B. 2008. Occurrence of live Octocorals in the trawling grounds off Veraval coast, Gujarat, Arabian Sea. *Turkish Journal of Fisheries and Aquatic Sciences.* 8 (2): 369-372.

- **Bhagirathan, U**., Panda, S.K., Madhu, V.R. and Meenakumari, B. 2008. Bottom trawling – threat to sustainability of Octocorals off Veraval coast. In: *Glimpses of Aquatic Biodiversity*, Natarajan *et al.* (eds.). Glimpses of Aquatic Biodiversity – Rajiv Gandhi Chair Spl. Pub., 7 : 270-275.

- Meenakumari, B., **Bhagirathan, U**., and Pravin, P. 2008. Impact of bottom trawling on benthic communities: A review. *Fishery Technology.* 45 (1), 1-22.