

ECOTOXICOLOGICAL EFFECT OF GROUNDED *MV RIVER PRINCESS* ON THE INTERTIDAL BENTHIC ORGANISMS OFF GOA

*B. Ingole, S. Sivadas, R. Goltekar, S. Clemente, M. Nanajkar, R. Sawant,
C. D'Silva, A. Sarkar & Z. Ansari

National Institute of Oceanography, Dona Paula, Goa –403004; INDIA

Abstract:

The ecotoxicological effects of oil spill from the grounded vessel *MV River Princess* on the intertidal benthic organisms of Sinquerim – Candolim beach at Goa were investigated. An intertidal expanse of 1km on either side of the grounded vessel was selected to evaluate the concentration of Total Petroleum Hydrocarbon (TPH) in the sediment and its effects on the composition, abundance and diversity of micro-, meio- and macrobenthos. TPH in the intertidal sediment ranged from 7.8 to 89 $\mu\text{g g}^{-1}$ (mean 35.44 ± 26.35 SD). Microbenthos comprised of microalgae, protozoans and juvenile forms of meiobenthos. Apart from juvenile nematodes, which were abundant, *Coscinodiscus* spp, *Navicula* spp, and *Nitzschia* spp. representing microalgae were also observed in microbenthic samples. Meiobenthos was represented by 13 taxa and their total density ranged between 92-1057 no. 10cm^{-2} . Maximum meiobenthic abundance of 1057 no. 10cm^{-2} was observed at Sinquerim. Nematodes were the dominant meiobenthic taxa followed by turbellarians and harpacticoid copepods. The macrobenthoc was numerically dominated by polychaetes, followed by crustaceans whereas bivalve molluscs were less represented. There was substantial increase in the petroleum concentration in the beach sediment compared to the previously reported values and highest TPH ($89\mu\text{g.g}^{-1}$ sediment) values were in the vicinity of the grounded vessel. The polychaete/amphipod ratio and cumulative and partial dominance abundance- biomass curves showed significant negative impact of TPH on macrofauna. The benthic community structure also showed measurable changes, as there was significant decrease (60%) in the number of species. Given that the microalgal counts were low in sediment, it is assumed that the intertidal meiofauna was possibly using oil-degrading bacteria as alternate food source. In conclusion, the results reported here suggest that the grounded ore carrier is not only detrimental to the beach community, that may take longer time for recovery, but also affect the beach morphology which may have long-term impact on local fishery.

Keywords: Ecotoxicology, grounding, oil spills; *MV River Princess*; petroleum hydrocarbon; benthic fauna; Goa; India.

Corresponding author: baban@darya.nio.org

INTRODUCTION

It is well known that oil spills represent one of the major threats to the marine environment. Petroleum hydrocarbon from oil spills and various other sources constitutes a potential threat to the coastal environment and to growing economic activities, such as ecotourism and fisheries (Commendatore et al. 2000). Oil spill can cause increase in abundance of benthic fauna via organic enrichment or mass mortality, as a result of direct toxicity as well as asphyxiation. In addition, the incorporation of sub-lethal amounts of oil and oil products into organisms can result in reduced resistance to infection and other diseases thereby affecting the survivability of marine species, which stand higher in the marine food web. However, the degree of impacts of oil on marine organisms varies depending on the concentration of oil, oil type, duration of contact with oil, sensitivity of organisms and geographical location of spill (Gin et al. 2001). Out of the one billion gallons of oil that enter the world oceans each year, 36% is from runoff, 12% is accidentally released from tankers, 22% is intentionally released from oil tankers as normal operating functions, and 8% is from natural seeps (Suchanek 1993).

Benthic organisms are important component of the marine ecosystem and play a decisive role in maintaining ecological balance. They not only act as a major food source for many fish species but humans also consume some of the large sized bivalves and crustaceans. Polychaetes, bivalves and crustaceans are dominant among the macrobenthic forms and are considered as environmental indicators. In the benthic ecosystem, hydrocarbon pollution may cause irreversible changes such as elimination of organisms in the lower trophic level, which could be useful in the breakdown processes of carbon, nitrogen and sulphur cycles and also altering the species composition in the food web (Gray and Ventilla 1971). Cyanobacteria and microalgae (diatoms) are components of primary trophic level and contribute significantly to the primary productivity (MacIntyre and Cullen 1996) as well as sediment stabilization (Sutherland 1998) in the marine habitats. Meiobenthos, being an important link between macro-

and microbenthos, any adverse effects of petroleum on this integral component is enough to cause an imbalance in the food chain.

An ore-carrier “*MV River Princess*” ran aground hardly 500 meters off Goa’s internationally famous Sinkerim-Candolim-Calangute beach on 6th June 2000. This 240 meter-long ship (Fig.1) drifted away with rough heavy winds on 6th June 2000 after being anchored for one and a half year at Marmugao harbour. Almost 40 tonnes of oil was removed from the ship while the Coast Guard still suspects about 15 tonnes of leftover. Urgent removal of *MV River Princess* was anticipated as it was expected that, the ship over the time would affect the ecology of Sinkerim – a tourist spot in Goa. However, due to some unavoidable circumstances, removal of the ship was hindered and it remained grounded for a period of 3 years. It was assumed that grounding of the vessel for such a long period would affect the benthic biota. Thus, sampling in intertidal area was conducted with a view to study the impact of oil spill on the benthic organisms.

MATERIALS AND METHODS

Study Area

The study area is located between Lat. 15^o 30’-15^o 33’ N and Long.73^o 40’-73^o 46’ E along the Sinkerim – Calangute beach (Fig.2). The ship was grounded at Candolim, which is flanked by Sinkerim beach on one side, and Calangute on the other. Benthic samples were collected during low tide at mid tide level along the intertidal stretch of 2km starting from Sinkerim to Calangute, covering an area of 1km each on either side of the ship.

Field Sampling

Total 11 stations were fixed at \approx 200 m distance (Fig.2). The beach area from Sinkerim to Candolim (place where ship was grounded) was \approx 1km. Thus, for comparison purpose, sampling towards Calangute (north of the vessel) was also limited to 1km. Samples were collected at a regular interval of 200m from Sinkerim to Calangute. A total of 5 stations were sampled at Sinkerim (SQ1, SQ2, SQ3, SQ4, and SQ5); 1 at Candolim (CD) and remaining 5 stations (CL1,

CL2, CL3, CL4, and CL5) were sampled at Calangute. Sediment samples were collected separately for analysis of micro-, meio- and macrobenthos. Samples for macrobenthos were collected using quadrant (625cm²) and organisms retained on 0.5mm sieve were preserved in 5% formaldehyde with rose bengal stain for further identification. Duplicate quadrants were taken from each station. Acrylic core (Ø4.5cm) was used to collect the meiobenthos. Vertical distribution of meiobenthos in the sediment up to 10cm deep was studied by sectioning the core at an interval of 2cm each and the sections preserved in 5% formaldehyde with rose bengal stain. Microbenthic samples were collected using acrylic core (Ø2cm). Since benthic diatoms dominate these samples, only the top 2cm sediment was collected and preserved in Lugol's formaldehyde solution. .

Sediment samples were also collected separately to analyze sediment chlorophyll, organic carbon and dissolved Total Petroleum Hydrocarbon (TPH). Analysis of physico-chemical parameters of the surf water like temperature, dissolved oxygen, nitrite, nitrate and phosphate were also carried out.

Laboratory analysis

In the laboratory, preserved macrobenthic samples were washed once again on 500µm sieve in running water, sorted and identified upto genus /species level. Meiobenthic samples were passed through 500µm and 63µm sieve and material retaining on 63µm sieve was considered as meiobenthos. Further, the meiobenthic organisms were counted and identified up to group level. Similarly, microbenthic samples were sieved through 500µm, 63µm and 25µm sieves and sample retained on 25µm sieve was collected and analyzed for microbenthos. Sediment chlorophyll was estimated with acetone extraction method (Holm-Hansen 1978), organic carbon was estimated with wet oxidation method (El Wakeel and Riley 1957). TPH content in sediment was analyzed by method given in Sleeter et al. (1980). All raw data was processed using standard excel statistical package. Correlation was sought between macrobenthic biomass and sediment TPH and Nematode Copepod ratio (N/C) ratio TPH. Species diversity,

cumulative (a) and partial dominance (b) abundance- biomass curves were calculated using PRIMER package (Clarke and Warwick 1991).

RESULTS AND DISCUSSION

Environmental parameters

The sampling stations did not show much variation in temperature (air, water and sediment; Table 1). Nitrite value of surf-water ranged from 0.28 – 0.30 $\mu\text{mol l}^{-1}$, whereas, nitrate varied from 0.6 - 0.9 $\mu\text{mol l}^{-1}$ at Candolim and Sinquerim, respectively. Phosphate ranged from 0.24 $\mu\text{mol l}^{-1}$ at Calangute and 0.34 $\mu\text{mol l}^{-1}$ at Sinquerim and Candolim. Dissolved nutrients and temperature showed higher values at Sinquerim as compared to other stations. The values obtained for dissolved oxygen were low (2.8-3.1 ml l^{-1}) compared to values reported for open water (Ansari et al. 2003) suggesting reduced oxygen conditions in surf-waters. Reduced oxygen levels could be due to the increased benthic biomass and respiratory activities of some aerobic bacteria, especially those that can mineralize hydrocarbon (which may have leaked from the grounded vessel) after an input of oil products (Bakke et al. 1982).

The TPH concentration in the sediment varied very drastically with values ranging from 7.77-89.01 $\mu\text{g.g}^{-1}$ at stn CL2 and CL1, respectively (Fig.3a). TPH value at station CD was 75.27 $\mu\text{g.g}^{-1}$ and decreased further north with lowest value recorded at station CL5 (11.59 $\mu\text{g.g}^{-1}$). Lower values of TPH at stn CL were mainly due to the dilution of TPH, which increases with distance from the grounded vessel. After an oil spill, the oil reacts with smaller particle in the sediment to form oil in water emulsion. These form clay flocs, which because of their buoyancy are dispersed and carried away by currents. Also chemical and biological degradation occurs during their transport. The combined effect of physical, chemical and biological processes explains why adjacent stations do not have high TPH (Bragg and Yang 1995). Since the grounding of the vessel, the intertidal expanse (width) at Candolim has increased along the vicinity of the ship as compared to the study area (Fig. 1). In the present study, the TPH values (7.77 to 89 $\mu\text{g.g}^{-1}$) showed 2-fold increase than those reported by Ansari and

Ingole (2002) from the same area. A comparative study showed almost negligible amount of TPH before 1994 spillage ($0.43 - 1.025 \mu\text{g.g}^{-1}$; Anon 1993). The major oil spill from *MV Sea Transporter* revealed an expected sharp increase in TPH concentration at Sinkerim ($216.84 \mu\text{g g}^{-1}$; Fig.4). During this period, there was no significant increase in TPH at adjacent Candolim and Calangute beaches. Very high TPH values at Sinkerim during the spill were reduced back to normal within a period of 5 weeks (Ansari and Ingole 2002). However, in the present study, TPH values recorded were one order higher in Candolim and Calangute, while a 2-fold increase was observed in Sinkerim. Hence, it can be assumed that accumulation of hydrocarbon in the sediment observed in the present study is due to continuous leakage of hydrocarbons over the years from the grounded vessel. Values for sediment organic carbon ranged from 2.66 - 3.65%, at Sinkerim and Calangute (Table 1). Higher values were recorded at stn. CL4 and lowest values were at stn. SQ3.

Biological parameters

Microbenthos

Microbenthos was comprised of microalgae, protozoans and juvenile forms of meiobenthos. The maximum counts of microbenthos ($65 \text{ nos } 3.3\text{cm}^{-2}$) were recorded at stn SQ1 (Fig.3b). As compared to the other stations, maximum counts of microalgae and nematodes were also observed at stn SQ1. This may be due higher nutrient recorded at this station. Intertidal area in the vicinity of this station was partly covered with rocks that served as a substratum for seaweeds like *Padina* sp, *Enteromorpha* sp and *Ulva reticulata*. Therefore, the higher counts of microalgae encountered at SQ1 could be the epiphytic population associated with the seaweeds washed in the sediment due to continuous splashing of the seawater on the rocks. *Coscinodiscus* spp, *Navicula* spp, and *Nitzschia* spp were the microalgae identified. Minimum density of microbenthos ($6 \text{ nos.} 3.3\text{cm}^{-2}$) was observed at stn SQ5 and was mostly comprised of juvenile nematodes.

The highest value for TPH ($89 \mu\text{g g}^{-1}$) was observed at stn CL1, where the density of microbenthos was very less and was dominated by nematodes (87%). Although there is no baseline microbenthic data for comparison purpose, in general, the contribution of microalgae to the microbenthos was negligible except at stn SQ1. Similarly, the concentration of chlorophyll in the sediment was also low (Table 1). Nematodes recorded in the microbenthic samples were the juvenile forms retained on $25\mu\text{m}$ sieve. The dominance of nematodes in meiobenthos and availability of juvenile forms in microbenthos clearly demonstrate their tolerance or insensitivity to increased TPH. While reporting the impact of oil spill on intertidal meiofauna, Danovaro et al. (1995) and Ansari and Ingole (2002) have also reported higher number of nematodes as compared to the other taxa.

Meiobenthos

Literature on the pre-pollution status of meiofauna from this area is scarce and limited only to Candolim (Ansari and Ingole 2002). In fact, since meiobenthic assemblages usually fluctuate on a seasonal and/or year-to-year basis, it is a difficult task to distinguish pollution-induced changes from natural changes. A number of workers reveal very contradictory results on the ill effects of oil spill on meiobenthos (Danovaro et al. 1995; Boucher 1980). The resilient nature of many meiobenthic species enables them to recover to normal abundances in a very short time (weeks to months). Generally, the effects of TPH on meiobenthos have been little studied compared to the number of investigations conducted on macrobenthos. However, meiobenthos are considered as better indicators of pollution due to their large numbers, small size, relatively short generation time, high fecundity and flexible feeding habits (Fleeger and Chandler 1983; Kim et al. 2000; Sanduli and Nicola 1990). A total of 13 meiobenthic taxa were recorded during the present study. Nematodes were most conspicuous contributing $\geq 60\%$ to the total meiobenthos.

During the major oil spill from “*MV Sea Transporter*”, meiofaunal density at Sinqerim ranged from 0 to 22 nos. 10cm^{-2} , which was mainly due to high TPH

content in the sediment ($216.84 \mu\text{g g}^{-1}$) and showed a slow recovery as the TPH concentration gradually decreased. It took almost 5 weeks for meiobenthic density to increase up to $64 \text{ nos. } 10\text{cm}^{-2}$ with the TPH content of $12 \mu\text{g g}^{-1}$. The immediate decline in meiobenthic counts was attributed to the synergistic effects of oil pollution and southwest monsoon (Ansari and Ingole 2002). In comparison, the present study showed one order increase in the meiobenthic count ($136 - 1057 \text{ nos. } 10\text{cm}^{-2}$, Fig.3c), despite of having mean TPH concentration of $31 \mu\text{g g}^{-1}$ in the sediment (Table 1). Average TPH concentration in the sediment at stn CD located in the vicinity of grounded vessel was $75.27 \mu\text{g g}^{-1}$. Meiobenthic density at this station was $264 \text{ nos. } 10\text{cm}^{-2}$ (Fig.3c) as against $111-202 \text{ nos. } 10\text{cm}^{-2}$ reported at same location by Ansari and Ingole (2002) with corresponding sediment TPH value of $0.121 \mu\text{g g}^{-1}$. Stn. CL, located further away from the grounded vessel, apparently was not affected by the spill as the TPH values ranged from $0.1-0.4 \mu\text{g g}^{-1}$ and the meiofauna count ranged from $102-186 \text{ nos. } 10\text{cm}^{-2}$ (Ansari and Ingole 2002). In present study, the average TPH concentration at CL was $33 \mu\text{g g}^{-1}$ with meiofaunal density ranging from $92-196 \text{ nos. } 10\text{cm}^{-2}$ (Fig.3c). Increased TPH could be due to the slow accumulation of hydrocarbon in the sediment that may have allowed the dominant metazoan (eg nematodes) to adapt to the prevailing TPH concentrations. Among the metazoan meiofauna, nematodes are the most resistant and remained unaffected to oil pollution but decrease in their density immediately after oil spill has been observed (Ansari and Ingole 2002). However, they are also known to recover after a month or year (Coull 1988). Lack of meiobenthic mortality was observed at TPH concentration of $13000 \mu\text{g g}^{-1}$ in a salt marsh where oil prevailed for long time, which indicated their strong tolerance to hydrocarbon stress (Boucher 1980).

Similarly, reduction in harpacticoid copepod density was reported after oil spills (Boucher 1980; Giere 1979) while they survived the toxic effects of oil during the *Azip Abrupp* oil spill (Danovaro, 1995) and the experimental spill (Fleeger and Chandler 1983). In the present study, an average copepod density of $62 \text{ nos. } 10\text{cm}^{-2}$ was recorded at stn. SQ and the values were much higher as

compared to 1994 data (Ansari and Ingole 2002). The N/C ratio proposed by Raffaelli and Mason (1981) strongly suggests the use of meiofauna in monitoring pollution studies (Ansari and Ingole 2002; Lamshead 1986; Shiells and Anderson 1985; Lamshead 1984). Also, following oil pollution from *Amoco Cadiz*, N/C ratio in sublittoral habitats increased to 83 and then decreased to the normal pre pollution values (Boucher 1980). As shown in figure 6, the N/C ratio did not exceed the values given by Raffaelli and Mason (1981). Generally, Crustaceans are considered as highly sensitive to oil spills (Dauvin 1998; Gomes Gesteria and Dauvin 2000). Higher percentage of copepods in the meiofaunal samples further suggests the adaptability of copepods to the TPH concentrations. Increase in copepod density after 30-60 days of experimental spill has been attributed to enhanced benthic bacterial production and subsequent copepod grazing (Naidu et al.1978).

Sedimentary bacteria and microalgae are major food source for meiobenthos (Miller et al. 1996; Mitbavker and Anil 2002). Although the bacterial counts in the sediment were not analysed in the present study, sediment chlorophyll was estimated. The values in the intertidal sediment ranged from 0.04 – 0.07 $\mu\text{g.g}^{-1}$. One of the well-documented effects on areas adjacent to heavily oiled shorelines are the increase in the number of TPH degrading microbes, which are fed upon by opportunistic species of meiobenthos (Lee and Page 1997). These oil-degrading bacteria are known to dominate the oil-contaminated sediment in the absence of benthic microalgal population (Lee and Page 1997). At the present study site, increased meiobenthic density compared to earlier values (Ansari and Ingole 2002) could be due to increased hydrocarbon degrading bacteria, which serve as a food source for opportunistic fauna (Lee and Page 1997). Moreover, opportunistic taxa such as nematodes may have been adapted themselves to the prevailing TPH concentrations. Hence, food availability may not be the only limiting factor for intertidal meiofauna and other abiotic factors such as wave action, current and predation could be equally important in regulating the intertidal meiobenthic population. It was apparent from this study that the meiobenthic diversity was reduced along the Sinqerim-

Calangute beach as compared to the earlier data and was dominated by nematodes *Rynchonema* spp. and *Viscocia* spp.. Thus, the meiobenthic community structure did indicate the occurrence of an overall acutely toxic event associated with the oil spill.

Vertical distribution of meiobenthos

Meiobenthic communities are known to concentrate in the top sedimentary layers (Coull 1988). The vertical distribution of meiobenthos studied upto a sediment depth of 10cm suggested that maximum organisms were concentrated in the upper 2cm sediment section. Nematodes were dominant in all the depths, followed by turbellarians and harpacticoids. Both these groups also showed a vertical reduction in density. Other groups that included Polychaeta, Oligochaeta, Gastrotricha, Sarcostomatophora, Nemertina and Amphipoda, which were randomly distributed in all the depths (Fig. 5).

Macrobenthos

A total of 21 macrobenthic taxa were identified during the present study. Polychaetes and crustaceans were the dominant groups representing 38% (8 species) and 33% (7 species), respectively of the observed taxa. Molluscs were represented by a single class, Bivalvia (19%) and were comprised of 4 species recorded at stn CD (Table 2). Highest numbers of species were recorded at Calangute (15 species) and lowest in Candolim (11 species) near the grounded vessel. Mysid *Gastrosaccus* spp. was the most dominant species with a mean density of $640 \pm 913 \text{ nos.m}^{-2}$ and was recorded at all the stations except at SQ2 and SQ3. Mean abundance of polychaetes was 115 nos.m^{-2} followed by Bivalvia (62 no.m^{-2}). Abundance of macrobenthos varied from 32 (Stn SQ3) to 4080 nos.m^{-2} (Stn CL2) with a mean value of 862 ± 1157 (Fig. 3d) and biomass varied from 0.017 (Stn SQ3) to 43 gm.m^{-2} (Stn CL2) with a mean value of 7 gm.m^{-2} . Mysidacea contributed to 74 % of the total density followed by polychaeta (13%), Bivalvia (7%) and Amphipoda (3%). Other groups contributed to remaining 3% of the total density. Overall, the mysid shrimp *Gastrosaccus* spp. (74%) and pisionid polychaete, *Pisionidens indica* (9%), dominated the benthic

communities. Grall and Glemarec (1997) have suggested five groups of pollution resistant polychaetes. Accordingly, 13% of the polychaetes were represented by group-IV that are second order opportunistic and 75% belonged to the group-II, which do not show any change with enrichment, suggesting the possible adaptation of polychaete communities to the altered condition. Remaining 12% polychaetes could not be identified as a separate group.

Gesteira and Dauvin (2000) suggested the use of polychaetes/amphipod ratio for detecting the impact of pollution. In the present study, the polychaetes/amphipod ratio was equal to 1 indicating that macrobenthic community was undeniably affected due to the TPH concentration. The ABC dominance curve (Fig.7a) exhibits a moderately disturbed state as there is perhaps a suggestion from the partial dominance curve a loss of biomass dominance resulting in a slight merging of the curves (Fig.7b). Thus, the intertidal macrobenthic community along Siquerim-Calangute beach was moderately affected by hydrocarbon concentration in the beach sediment. Ansari and Ingole (2002) and Dauvin (1998) suggested that intertidal benthic communities are generally sensitive to oil spills, but the effects of oil pollution strongly depend on the proportion of hydrocarbon-sensitive species, especially crustaceans. Benthic amphipods are exceedingly sensitive to oil pollution (Sanders et al.1980; Elmgren and Firthsen 1982). This group was represented by 4 species belonging to a single-family Gammaridae (*Phoxocephalus* sp., *Urothoe* sp., *Ampithoe* sp. and *Synchelidium* sp.). Further, mysids shrimps are considered as highly sensitive to environmental pollution and commonly used in the biological monitoring studies. The genus *Gastrosaccus* was very abundant and constituted more than 80% of the faunal density at Calangute where TPH concentration was comparatively low ($33 \mu\text{g g}^{-1}$).

The present study revealed 11 macrobenthic species at Candolim as against 27 species reported earlier by Harkantra and Parulekar (1984) out of which only three were common (Table 2). Since the TPH content in the surface sediment was very high compared to previous studies (Fig.4) and has not only

affected the macrofaunal diversity but also changed the faunal composition as many of the dominant species (viz., *Pisionidens indica*, *Eurydice peraticis*, *Pontharoinia unirostrata*, *Gastrosaccus simulans*) recorded during the earlier study (Harkantra and Parulekar 1984) were absent or observed in very low density during the present study. Although, through a detailed one-year study on intertidal meiofauna of this area, rapid recovery of meiofauna following a major oil spill was observed by Ansari and Ingole (2002) recovery times following spills can vary and there is no clear-cut correlation between size and extent of damage. According to them, the aromatics present in the fuel oil get quickly evaporated, leaving only residual component in the sediment. Therefore, it is worth mentioning that the values of TPH observed during the present study were high as compared to the previous data (Ansari and Ingole 2002) and affected the benthic fauna to a very large extent. When physical and biological parameters vary slightly and predictably from year to year, fauna is diverse and relatively stable in numbers and composition. Whenever some environmental parameters or some exotic influence exceeds normal range of variation, the fauna suffers dislocation or stress or severe mortality. The high values of TPH observed during the present study could be due to the possible oil leakage from the grounded vessel and their accumulation in the sediments. Natural oil seeps have shown high abundance of bacteria near oil seeps, which results in high densities of meio- and macrofauna (Montagna et al. 1987). Increased densities of such communities associated with seep is a function of bacteria adapting to utilize petroleum as a source of carbon and energy and this in turn is consumed by benthic invertebrates specially nematodes (Montagna et al. 1987). Lee and Page (1997) have reported that at lower but significant concentrations of TPH, the effect of oil is to produce an environment suitable for opportunistic species, which can take advantage of increase in microflora thriving on hydrocarbons.

Accurate evaluation of the impacts of an oil spill on coastal ecosystem is difficult. Because it is virtually impossible to predict the time and space of an accident, data on pre-disturbances conditions are generally unavailable (Peterson and Eates 2001). Therefore, one of the greatest challenges when determining the

impact on benthic communities is the lack of baseline data and overall context in which benthic communities can be compared.

TPH showed a negative correlation with meio- and macrofaunal abundance and positive correlation with microbenthic abundance. However, the variation was not significant (Table 3). Moreover a change in beach morphology has been observed in the area where the ship is grounded. It was seen that the intertidal expansion has been increased in the area, where the ship was grounded (Candolim, Fig. 1, per. Obs.). Since the biological parameters are considered as useful tool to evaluate the ecological quality of marine ecosystem, our study certainly provides essential data on status of sediment TPH and benthic community of the three intertidal beaches of Goa. Given the importance of these beaches, which are famous tourist spots, any damage to them will directly affect the state's economy because tourism is a major industry in Goa. Nevertheless, the data presented here is based on a single sampling and hence has its limitations on the inferences. Also, it is very much essential to understand the natural population changes in oil spill area before attributing all changes after an oil spill to oil effects. Further investigations therefore, are necessary to provide evidence to extent of potential danger of grounded "*MV River Princess*" to the ecology of the study area.

Acknowledgement- The author thanks the Director, NIO, Goa for facilities. We also would like to thanks Mr. Kishan Kunkolikar for field and laboratory assistance and two anonymous reviewers for their constructive criticisms. Comments of Dr. Melanie Austin, of Plymouth Marine Laboratory Plymouth, UK helped in improving the manuscript. This is a contribution No..... of NIO Goa.

REFERENCES

- Anon. Coastal Ocean Monitoring and prediction system (COMAPS), Annual Report 1992-93, NIO/SP-24/94; 1993.
- Ansari, Z. A. Ingole, B.S. Effect of an oil spill from *M.V. Sea Transporter* on intertidal meiofauna at Goa, India. *Mar. Pollut. Bull.* 44: 396-402; 2002.
- Ansari, Z.A.; Sreepada, R.A.; Dalal, S.G.; Ingole, B.S.; Chatterji, A. Environmental influences on the trawl catches in a bay-estuarine system of Goa, west coast of India. *Estuar. Coastal Shelf Sci.* 26: 503-515; 2003.
- Bakke, T.; Dale, T.; Thingstad, T.F.; Structural and metabolic responses of a suntuinal sediment community to water extracts of oil. *Neth. J. Sea Res.* 16: 524-537; 1982.
- Boucher, G. Impact of Amocco Cadiz oil spill on intertidal and subtidal meiofauna. *Mar. Pollut. Bull.* 11: 95-101; 1980.
- Bragg, J.R.; Yang, S.H. Clay – oil flocculation and its role in natural cleansing in Prince William Sound following the Exxon Valdez Oil Spill, in: *Exxon Valdez Oil Spill Fate and Effects in Alaskan Waters*, edited by Wells P G, Butler J N & Hughes J S, (American Society for Testing and Materials (1219) Philadelphia, PA) 1995 pp. 178 – 214.
- Clarke, K.R.; Warwick, R.M. Changes in marine communities: an approach to statistical analysis and interpretation. *Plymouth, Plymouth Marine Laboratory, Pub. UK*, 1994 pp. 144.
- Commendatore, M.G.; Esteves, J.L.; Colombo, J.C. Hydrocarbons in coastal sediments of Patagonia, Argentina: Levels and Probabale Sources. *Mar. Pollut. Bull.* 40(11): 989-998; 2000.
- Coull B C, Ecology of marine meiofauna, In: *Introduction to the Study of Meiofauna* edited by Higgins R P & Thiel H, (Smithsonian Institution Press, Washington, D.C), 18-38; 1988.
- Danovaro, R.; Fabiano, M.; Vincx, M. Meiofauna response to the Agip Abruzzo oil spill in subtidal sediments of the Ligurian Sea. *Mar. Pollut. Bull.* 30(2): 133-145; 1995.
- Dauvin, J. C. The fine sand *Abra alba* community of the Bay of Morlaix twenty years after the *Amoco Cadiz* oil spill. *Mar. Pollut. Bull.* 36: 669-676; 1998.
- El Wakell, S.K. Riley, J.P. The organic carbon of marine mud. *J. Cons. Perm. Ins. Explor. Mar.* 22: 180; 1957.

- Elmgren, R.; Frithsen, J.B. The use of experimental ecosystems for evaluating the experimental impact of pollution: a comparison of an oil spill in the Baltic Sea and two long term, low level oil addition experiments in mesocosms, In: *Marine mesocosms. Biological and chemical research in experimental ecosystems*, edited by G. D. Grice & M. R. Reeve, (Springer, Verlag, Berlin. 153-169; 1982.
- Firhtsen, J.B.; Elmgren, R.; Rudnick, D. T. Responses of benthic meiofauna to long-term, low level additions of No. 2 fuel oil. *Mar. Ecol. Prog. Ser.* 23 :1-14; 1985.
- Fleeger, J.W.; Chandler, G.T. Meiofauna response to an experimental oil spill in a Louisiana salt marsh. *Mar. Ecol. Prog. Ser.* 11: 257-264; 1983.
- Gestiera, G.; Dauvin, J.C. Amphipods are good indicators of the impact of oil spills on soft-bottom macrobenthic communities. *Mar. Pollut. Bull.* 40(11): 1017-1027; 2000.
- Giere, O. The impact of oil pollution on intertidal meiofauna. Field studies after the La Coruna spill, May 1976. *Cahiers de Biologie Mar.* 20: 231-251; 1979.
- Gin, K.Y.H.; Huda, M.D.K.; Lim, W.K.; Tklich, P. An oil spill – Food chain interaction model for coastal waters. *Mar. Pollut. Bull.* 40(7): 590-597; 2001.
- Gomez Gesteria, J. L.; Dauvin, J. C. Amphipods are good indicators of the impact of oil spills on the soft-bottom macrobenthic communities. *Mar. Pollut. Bull.* 40(11): 1017-1027; 1998.
- Grall, J.; Glémarec, M. Using biotic indices to estimate macrobenthic community perturbation in the Bay of Brest, Estuar. *Coastal Shelf Sci.* 44 (suppl. A): 43-53; 1997.
- Gray, J.S.; Ventilla, R.J. Pollution effects on Micro- and meiofauna of sand. *Mar. Pollut. Bull.* 2: 39-43; 1971.
- Harkantra, S. N.; Parulekar, A. H. Intertidal benthic community ecology of sand-dwelling macroinvertebrates of Goa beaches, *Biology of benthic marine organisms: Techniques and methods as applied to the Indian Ocean.* Thompson, M. ed. Oxford IBH; 73-81:1984.
- Holm-Hansen, O. Chlorophyll a determination: Improvements in methodology. *Oikos.* 30: 438- 447; 1978.
- Kim, D.S.; Jee, J.G.; Lee, J.H. The community structure and spatial distribution of Meiobenthos in the Kanghwa Tidal flat, west coast of Korea. *Ocean. Res.* 22(1): 15-23; 2000.

- Lamshead, P.J.D. Sub-catastrophic sewage and industrial waste contamination as revealed by marine nematode faunal analysis. *Mar. Ecol. Prog. Ser.* 29: 247-260; 1986.
- Lamshead, P.J.D. The nematode/copepod ratio, some anomalous results from the Firth of Clyde. *Mar. Pollut. Bull.* 15: 256-259; 1984.
- Lee, R. F.; Page, D. S. Petroleum hydrocarbons and their effects in subtidal region after Major Oil Spills. *Mar. Pollut. Bull.* 34(11): 20928-211;1997.
- MacIntyre, H. L.; Cullen, J. J. Primary production by suspended and benthic microalgae in a turbid estuary: time-scales of variability in San Antonio Bay, Texas. *Mar. Ecol. Prog. Ser.* 145: 245-268; 1996.
- Miller, C. D.; Gieder, J. R.; MacIntyre, H. L. Microphytobenthos: the ecological role of the " Secret Garden" of Unvegetated, shallow water marine habitats. II Role in sediment stability and shallow water food webs, *Estuaries.* 19 (2A): 202-212; 1996.
- Mitbavkar, S.; Anil, A. C. Diatoms of microphytobenthic community: population structure in a tropical intertidal sand flat. *Mar. Biol.* 140 :41-57; 2002.
- Montagna, P.A.; Bauer, J.E.; Toal, J.; Hardin, D.; Spies, R.B. Temporal variability and the relationship between benthic meiofaunal and microbial populations of a natural coastal petroleum seep. *J. Mar. Res.* 45: 761-789; 1987.
- Naidu, A. F.; Feder, H. M.; Norrel, S. The effect of Prudhoe Bay crude oil on a tidal flat ecosystem in Port Valdez, Alaska. *Offshore Technology Conference.*97-103; 1978.
- Peterson, C.H.; Eates, J.H. Conservation and management of marine communities, In: Bertness, M.D., Gaines, S.D., Hay, M.E., *Marine Community Ecology.* Sinauer Associates, Sunderland. 469-507; 2001.
- Raffaelli, D.; Mason, C. F. Pollution monitoring with meiofauna, using the ratio of nematodes to copepods. *Mar. Pollut. Bull.* 12: 158-163; 1981.
- Sanders, H.L; Gassle, J.F.; Hampson, G.R.; Morse, L.S. Garner-Price, S.; Jones, C.C. Anatomy of an oil spill: long term effects from the grounding of barge Florida Off West Falmouth, Massachusetts. *J. Mar. Res.* 38:265-380; 1980.
- Sandulli, R.; De Nicola, M. Pollution effects on the structure of meiofaunal communities in the bay of Naples. *Mar. Pollut. Bull.* 21: 144-153; 1990.
- Shiells, G.M.; Anderson, K.J. Pollution monitoring using the nematode/copepod ratio. A practical application. *Mar. Pollut. Bull.* 16:62-68; 1985.

- Sleeter, T.D.; Butler, J.N.; Barbash, J.E. Hydrocarbons in the sediments of the Bermuda region: Lagoonal to abyssal depths. In: Petrakis, L., Weiss, F.T. (Eds.), Petroleum in the Marine Environment. Advances in Chemistry Series, vol. 185. American Chemical Society, Washington, DC, pp. 268 – 288.
- Suchanek, T.H. Oil impacts on marine invertebrate populations and communities. Ame. Zool.. 33(6): 510-523; 1993.
- Sutherland, T.F. The effects of carbohydrate production by the diatom *Nitzschia curvilincata* on the erodibility of sediment. Limnol. Oceanogr. 43: 65-72; 1998.
- Warwick, R.M. Environmental impact studies on marine communities: pragmatical considerations. Australian J. Eco. 18: 63-80; 1993.

Table 1: Physico-Chemical parameters of the study area investigated on 22nd November, 2003

Stations	DO (ml/l)	Air (^o C)	Water (^o C)	Sed (^o C)	NO ₂ (μ mole/l)	NO ₃ (μ mole/l)	PO ₄ (μ mole/l)	OC (%)	TPH (μg/g)	Chlorophyll a (μg/g)
Sinquerim	3.135	25	29	30	0.30	0.9	0.34	2.66	31	0.0452
Candolim	2.798	25	28	29	0.30	0.6	0.34	3.05	75	0.005
Calangute	2.97	25	28	29	0.28	0.7	0.24	3.65	33	0.073

Table 2. Macrobenthic species recorded from the Candolim beach, Goa

Species	1984*	Present study
<i>Lineus sp.</i>	+ (CM)	-
<i>Cerebratulus</i>	+ (VR)	-
<i>Pisionidens indica</i>	+(VC)	-
<i>Pisione sp.</i>	+(VR)	-
<i>Syllis sp.</i>	+(VR)	-
<i>Nereis sp.</i>	+ (CM)	-
<i>Glycer alba</i>	+ (VC)	+(VR)
<i>Prionospio polybranchiata</i>	-	+(VR)
<i>Polydora sp.</i>	+ (RR)	-
<i>Sphaeroma walkeri</i>	+(VR)	-
<i>Eurydice peraticis</i>	+(VC)	-
<i>Cyathura sp.</i>	+(VR)	-
<i>Pontharoinia unirostrata</i>	+(VC)	-
<i>Parhyalella natalensis</i>	+(RR)	-
<i>Perioculodes sp.</i>	+(CM)	-
<i>Talorchestia spinipalm</i>	+(VR)	-
<i>Phoxocephalus sp.</i>	-	+(RR)
<i>Urothoe sp.</i>	-	+(VR)
<i>Ampithoe sp.</i>	-	+(VR)
Cumacea	-	+(VR)
<i>Gastrosaccus simulans</i>	+(VC)	+(VC)
<i>Alpheus malabarica</i>	+(VR)	-
<i>Diogene affinis</i>	+(VR)	-
<i>Emerita holthuisi</i>	+(RR)	-
<i>Matuta lunaris</i>	+(VR)	-
<i>Philyra globosa</i>	+(VR)	-
<i>Ocypode ceratophthalma</i>	+(RR)	-
<i>Paphia textile</i>	+(VR)	-
<i>Gafrarium pectinatum</i>	+(VR)	-
<i>Mactra cuneatus</i>	+(VR)	-
<i>Donax incarnatus</i>	+(VR)	+(VR)
<i>Sunetta scripta</i>	-	+(VR)
<i>Sunetta solandri</i>	-	+(VR)
<i>Sunetta sp.</i>	-	+(VR)
<i>Oliva gibbosa</i>	+(VR)	-

* Harkantra and Parulekar (1984)

VC- very common (40-60%)

CM- Common (20-40%)

RR- rare (10-20%)

VR- very rare (<10%)

Table 3: Correlation matrix of environmental parameters and benthic abundance (n=11).

	TPH	OC	Chlorophyll	Micro	Meio	Macro
TPH	1					
OC	-0.28	1				
Chlorophyll	-0.33	0.45	1			
Micro	0.15	0.16	0.47	1		
Meio	-0.03	-0.19	0.38	0.61	1	
Macro	-0.27	0.48	0.08	0.02	-0.28	1

Legends to the figures:

Fig. 1. The ore- vessel "*River Princess*" grounded at Candolim.

Fig. 2. Location of sampling stations.

Fig. 3. Variation in the abundance of benthic fauna and TPH in the beach sediment.

Fig. 4. Variation in hydrocarbon for period of ten years.

Fig. 5. Vertical distribution of meiobenthos at all stations.

Fig. 6. Correlation between N/C ratio and TPH.

Fig. 7. Cumulative (a) and partial dominance (b) curves of abundance and biomass curve.

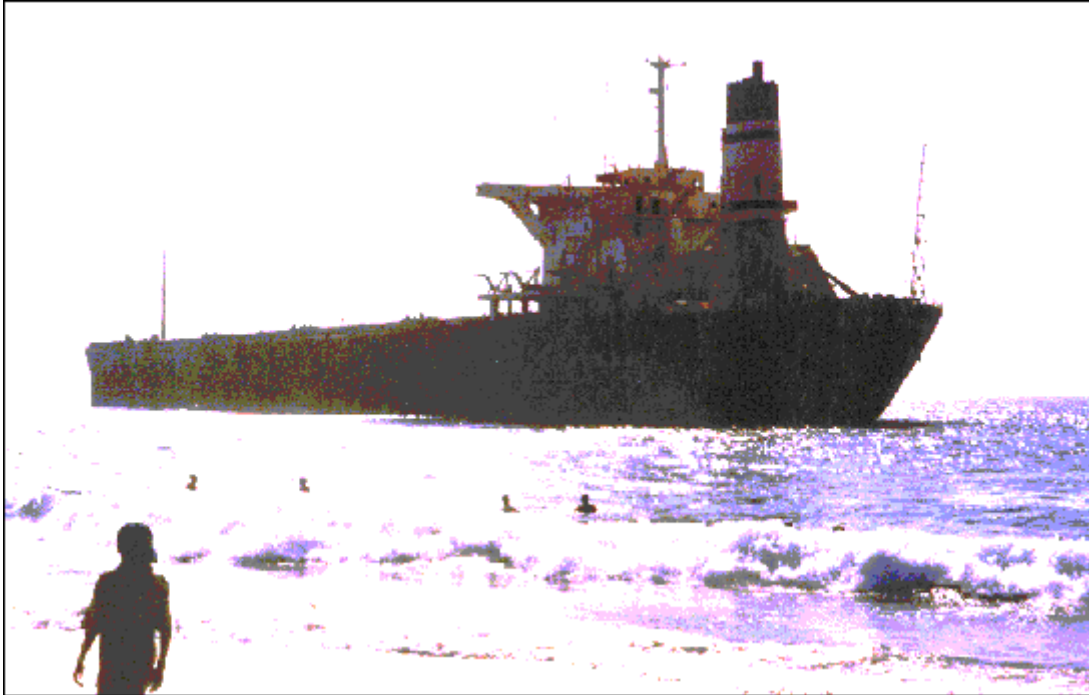


Fig. 1. The ore- vessel "*River Princess*" grounded at Candolim.

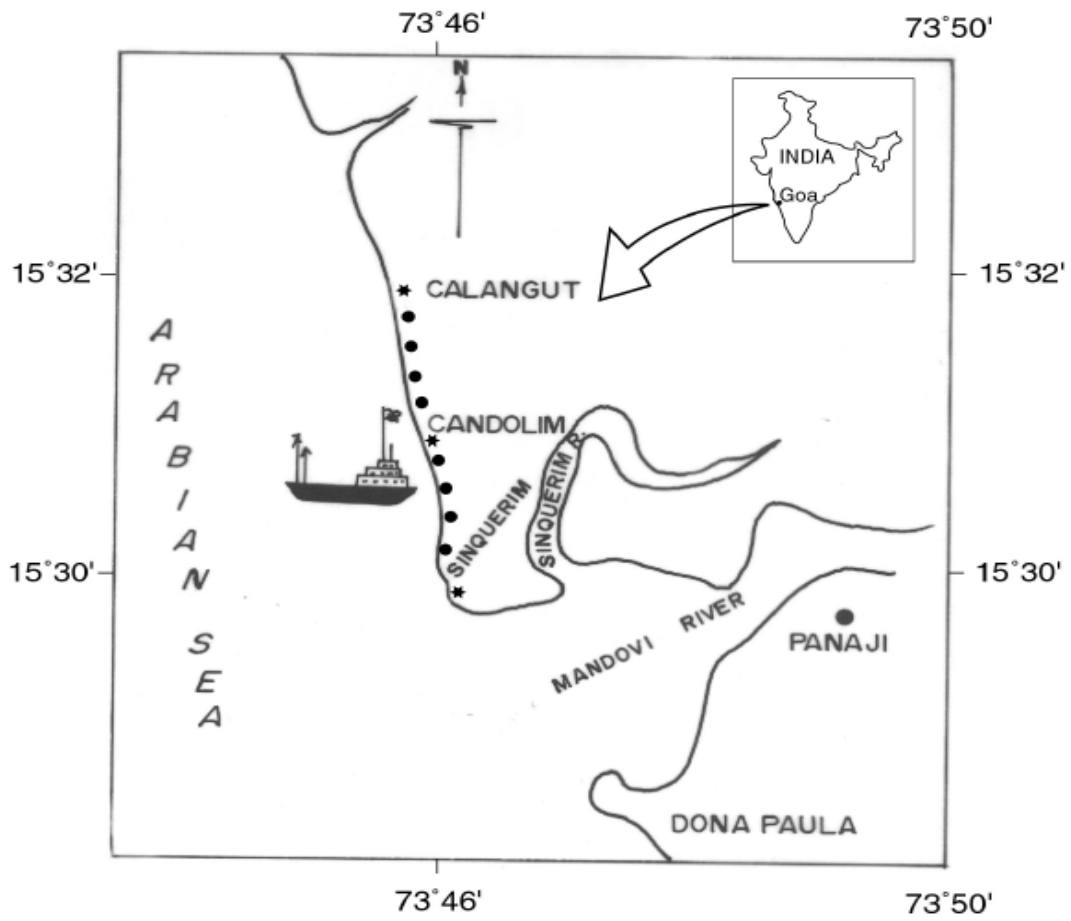


Fig. 2. Location of sampling stations

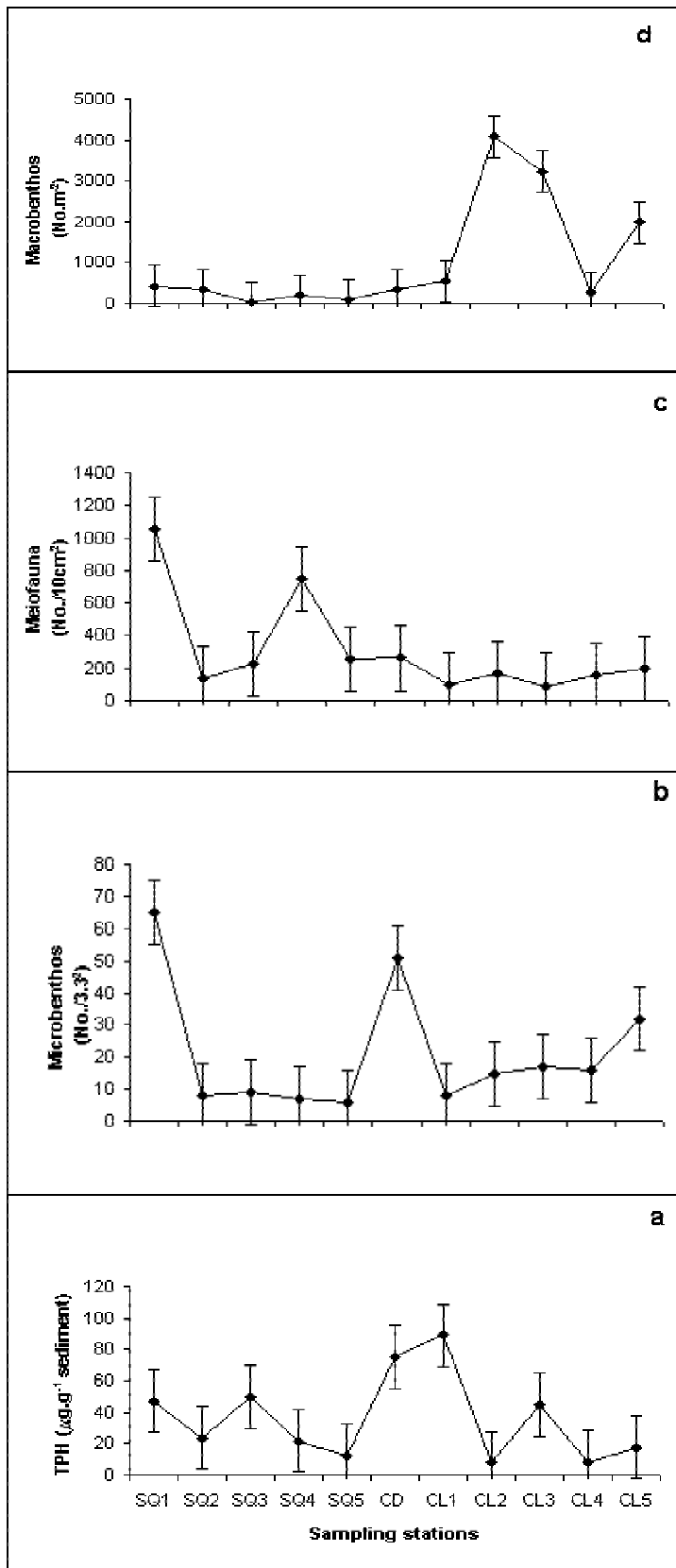


Fig. 3. Variation in abundance of benthic fauna and hydrocarbon in the beach sediment

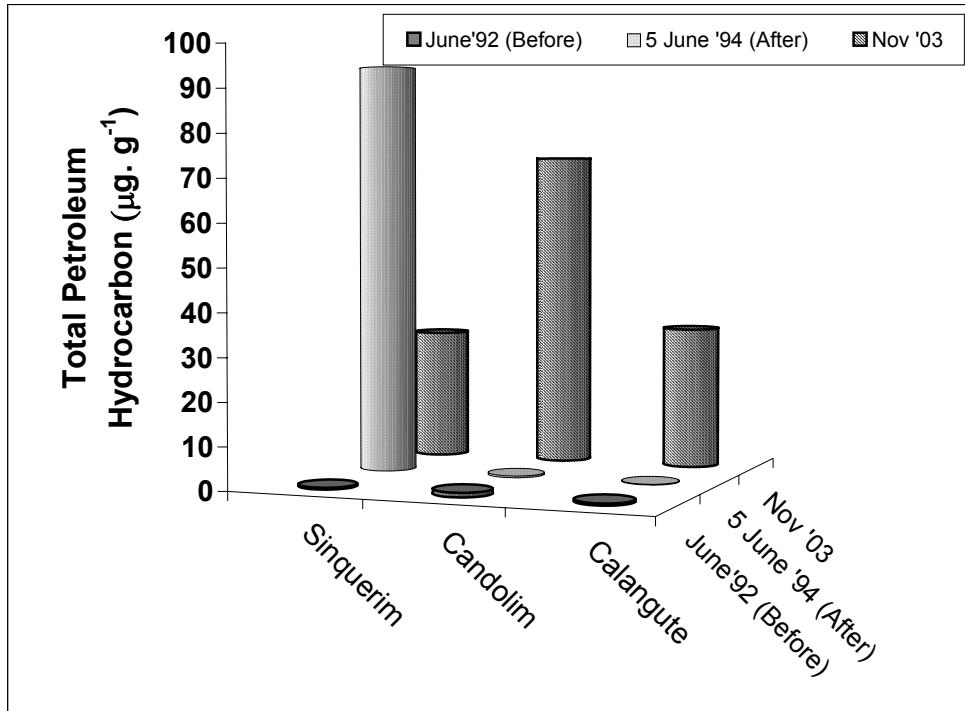


Fig. 4. Variation in hydrocarbon for period of ten years.

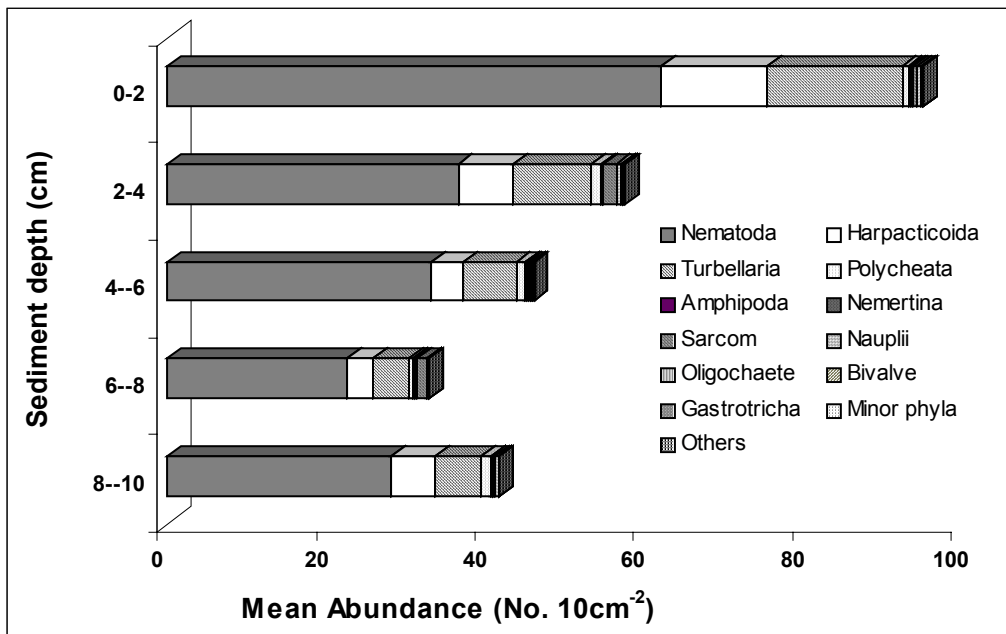


Fig.5: Vertical distribution of meiobenthos at all stations

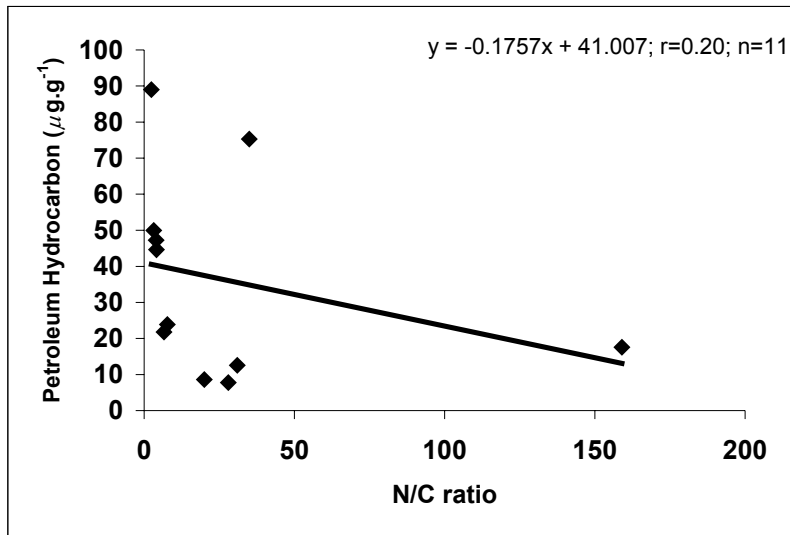


Fig. 6. Correlation between N/C ratio and TPH

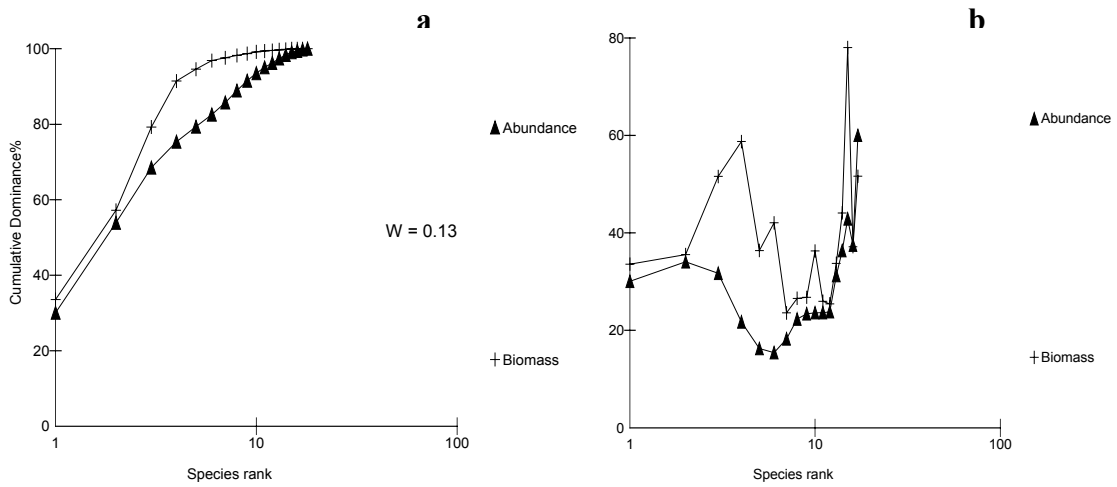


Fig. 7. Cumulative (a) and partial dominance (b) curves of abundance and biomass curve.