interference, we use only the second row of S and keep all other samples of D together. To preserve the signal content, an edge effect-free prediction filter is designed, which is able to preserve the primary signal as the filter never exceeds the edge of the 3D data slice.

The most common SI originates from other seismic sources working in the same area at the same time. This has been studied by the application of *f–x–y* prediction filters in the *f–x* domain and tested on a new dataset from the Gulf of Mexico with a long streamer configuration of 9000 m. The input RMS noise plot from a line that was contaminated with seismic interference is plotted for the first 350 traces (for better resolution) as shown in Figure 3 *a*. The amplitude of the SI varies from 15 to 30 μbar. The output of the process is given in Figure 3 *b*. In the dataset, where signal and high-amplitude SI are present together, the process preserves the signal while attenuating SI.

Interference noise and random noise have also been studied on the stack sections which are also contaminated. An example of the seismic stack section from a different line in the Gulf of Mexico is presented in Figure 4 *a*. High-amplitude SI and random noise are clearly visible on the stack section. The *f–x–y* prediction filter technique identifies and removes SI from stacks belonging to a single subsurface line of a 3D marine recording. Hence it is applied to the original data (NMO corrected) to eliminate SI (Figure 4 *b*). The difference between the raw and denoised stack is calculated as shown in Figure 4 *c*. Another example from a different area is shown in Figure 5.

Depending on the type of survey, significant level of seismic interference can drastically reduce the true prospects of an area. Standard 3D processing can provide some attenuation of seismic interference but cannot eliminate it completely. The method described here combines inline and crossline *f–x* prediction filters in detecting and attenuating ST on 3D marine seismic data from the Gulf of Mexico. This approach maximizes signal fidelity while avoiding the transform artifacts found in other methods. In this method the direction as well as amplitude of seismic interference do not matter. Thus the asynchronous character of the interference is the only condition for the success of this technique. In this way, a frequency that does not contain interference noise can be treated differently from frequencies that do.

The present study suggests that application of inline and crossline *f–x* prediction filters efficiently eliminates noises generated by neighbouring ships as well as the random noise. We observe that the process preserves reflection energy while suppressing SI and enhances spatial continuity. This will reduce the financial risk associated with advanced seismic processing for fluid/lithology discrimination and the imaging of saturation and pressure changes using time-lapse seismic data.

Quality control during seismic data acquisition is governed by predefined specifications or ‘specs’. A spec defines the extent to which a given component of the acquisition system is allowed to degrade before it must be repaired or acquisition must be delayed. All specs should be reconsidered periodically to ensure that they take into account advances in acquisition and processing technology, as well as new demands in interpretation. Only through adherence to properly chosen specs can one obtain data that, after processing, will yield results not unacceptably compromised by choices made in the acquisition.

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How vulnerable is Indian coast to oil spills? Impact of MV *Ocean Seraya* oil spill

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On 30 May 2006, a bulk carrier, MV *Ocean Seraya* ran aground along the Karwar coast spilling 650 tonnes of oil. Due to the rough SW monsoon, the spill spread to some beaches in south Goa. The aim of this communication is to study the immediate impact of oil spill on benthic ecology. We have also reviewed the impact of frequent spills on the benthic community in

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particular, and marine fishery in general. Intertidal sampling was carried out on 10 June 2006. Organic carbon (1%) and petroleum hydrocarbon (13 μg g^{-1}) were highest at Polem, as it was closest to the spill site. Twenty macrobenthic taxa which included crustaceans and bivalves were identified. Although the study is based on short-term sampling, it showed an increase in petroleum hydrocarbon in the sediment. A review of the oil spill data indicates that accidental spills have shown a decline globally, in contrast to increase in maritime transport. However, a reverse trend was observed along the Indian coast for the Arabian Sea. Further, majority of the spills occurred during the SW monsoon period, which coincided with the recruitment period of most commercial and non-commercial species. Therefore, although the spills occurring along the west coast are of small volume, frequent occurrence, particularly during the critical stages of the life cycle of organism, may have a long-term impact on the marine biota.

Keywords: Benthos, fishery, MV *Ocean Seraya* spill, organic carbon, petroleum hydrocarbon.

OIL pollution of the marine environment has been an issue of considerable national and international concern. India relies heavily on the marine environment for trade and commercial operations. Further, two major oil choke points of the world – Strait of Hormuz and Strait of Malacca lie on the west and east coasts of India. Due to the narrowness of these lanes, the routes are accident-prone. Moreover, import of oil and gas is growing faster than the demand, particularly in the developing countries led by China and India. The world's demand for petroleum products has been estimated[1] to go up from 84 mb/day in 2005 to 116 mb/day in 2030. The risk of major oil spill occurring along the west coast of India is considerably higher now, as there has been a significant increase in all types of maritime trade. A major oil spill could cause widespread ecological damage, and cripple or destroy marine commercial operations. Therefore, continued discharge of oil into the sea can pose a potential risk of severe pollution to the sensitive coastal ecosystem.

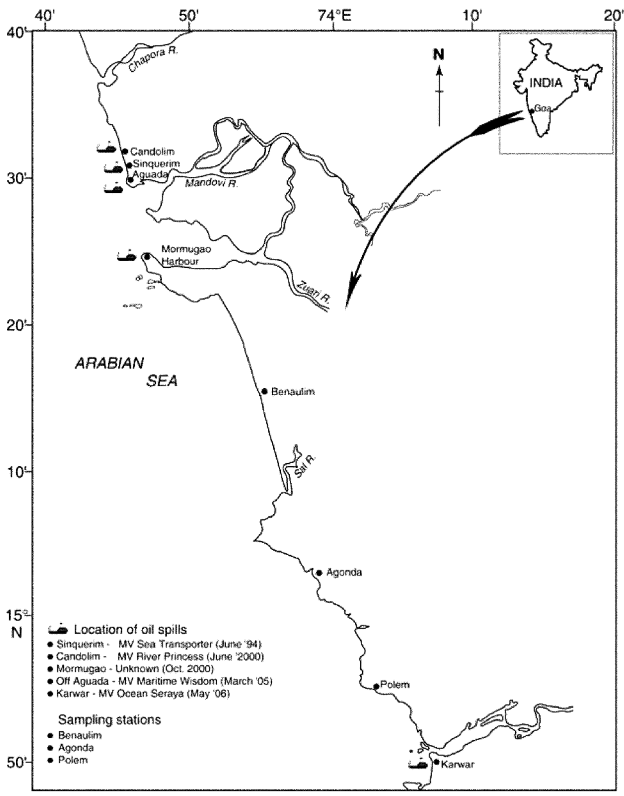
Goa, located along the mid west coast of India, also lies along the oil tanker route. Since 1994, four spills have been reported (Figure 1) along the small coastal strip of Goa. Grounding of MV *Ocean Seraya* on the Karwar coast was reported to have affected the beaches in south Goa from Polem to Benaulim. Earlier, in August 2005, large deposits of tarballs were reported from the beaches in south Goa (www.nio.org). In view of the increased incidents of oil spills, it was felt necessary to analyse and discuss the impact of oil spills on the benthic community and coastal fishery. Therefore, the present study was carried out to assess the immediate response and damage, if any, to the intertidal benthic community at Polem, Agonda and Benaulim. We also discuss the potential impact of frequent oil spills on the macrobenthic community and marine fishery.

MV *Ocean Seraya*, a Panamanian bearing flag bulk carrier carrying 650 tonnes of fuel oil and 40 tonnes of diesel, drifted and ran over submerged rocks off Karwar on 30 May 2006 (Figure 2). On 2 June 2006, the oil spill touched Polem beach on the Goa–Karnataka border. Due to the monsoon winds, the impact of the slick was also visible more than 20 km away in south Goa at Palolem and Canacona.

Polem (74°4′E, 14°54′N) and Agonda (73°59′E, 15°2′N) are situated in the southern most part of Goa (Figure 1). Benaulim (73°50′E and 15°15′N) forms a part of the long stretch of shallow, sandy beaches, interrupted by Zuari river in the north and Sal river in the south.

Field sampling was carried out on 10 June 2006 during low tide at Polem, Agonda and Benaulim. Samples for macrobenthos were collected using an acrylic core (∅ 12 cm). Sediment from the surface down to a depth of 10 cm was collected, sieved and preserved in neutralized 5% formaldehyde–Rose Bengal solution. Sediment was collected separately for organic carbon (OC) and petroleum hydrocarbon (PHC) using an acrylic core (∅ 4.5 cm). Temperature (sediment, air and water) and salinity were recorded using a field thermometer and refractometer respectively.

In the laboratory, macrofauna were sorted, identified, counted and biomass was estimated by the wet weight



Location of sampling stations

Figure 1. Map showing the location of the study area.

Figure 2. Grounded vessel MV *Ocean Seraya* off Karwar coast (source: Indian Coast Guard).

Table 1. Environmental parameters in the study area

	Temperature (°C)			Salinity (psu)	Surface water (μg l^{-1})	
	Sediment	Water	Air	Water	Chlorophyll	Phaeophytin
Polem	26	28	28	15	0.11	0.31
Agonda	27	29	26	29	0.42	1.28
Benaulim	–	–	–	30	0.57	1.93

–, not available.

method. Mole crab, *Emerita holthuisi* and the wedge clam, *Donax incarnatus* were dominant in terms of faunal abundance. Therefore, the populations of both species were counted as adult and juvenile. The females of *E. holthuisi* carrying eggs were again separated for further analysis. All the eggs were separated, enumerated and studied for any abnormalities. Sediment OC was estimated using the wet oxidation method[2] and PHC by hexane extraction[3]. Chlorophyll and phaeophytin were estimated by acetone extraction method[4].

The structure of the benthic community at each site was calculated in terms of number of species (*S*), total abundance, total biomass, Shannon–Weiner species diversity index (H'), evenness (*J*) and species richness (SR) using PRIMER[5]. The faunal density data were subjected to multidimensional scaling (MDS) ordination and Bray–Curtis cluster analysis. Correlation was sought between the biological factors (macrofaunal abundance, biomass and diversity) and sedimentary (OC, chlorophyll *a* (chl *a*) and PHC) parameters.

MV *Ocean Seraya* ran aground off the Oyster Rocks in Karwar, spilling 650 tonnes of fuel oil. The spill started spreading towards the Goa coast due to the rough SW monsoon winds. Frequent occurrence of tarballs and oil pollution along the beaches of Goa is a major threat to the tourism, which is one of the main employment-generating industries in the state. About two million tourists (both domestic and foreign) visit the Goan beaches every year, which accounts for 12% of all the tourist arrivals in India. There are around 439 medium and 11 five-star hotels in Goa. Oil spills not only affect ambience of the beaches, but are also known to affect the coastal ecology and fishery on a long-term basis[6].

Environmental parameters (temperature: air, sediment, surface water; salinity) observed were in accordance with those recorded normally during the monsoon season (Table 1). Salinity ranged between 15 and 30 psu. Low salinity recorded (15 psu) at Polem was mainly due to heavy rains on the sampling day. The values for surface water chlorophyll were highest (0.57 μg l^{-1}) at Benaulim.

Sediment chl *a* ranged from 0.01 to 0.03 μg g^{-1}, with the highest value at Benaulim. OC values ranged from 0.2 to 1%, Polem showing the higher value (Figure 3 *a*). PHC level in the sediment varied from 1.97 to 13 μg g^{-1} (Figure 3 *b*). Higher PHC was recorded at Polem and the lower at Agonda. The higher PHC observed at Polem was due to its close proximity to the oil spill site. Lower values of PHC at other stations could have been due to its dilution, which increases with distance from the spill site. The average sediment hydrocarbon level along the Goa coast was observed[7] to be 7.1 μg g^{-1}, indicating that PHC was higher at Polem compared to the other beaches. Experimental evidence suggests that about 56% of the spilled oil is adsorbed onto the bottom sediment[8], where oxidation may take place over several years[9]. Oil stranded from *Exxon Valdez* persisted for >10 years on some boulder-

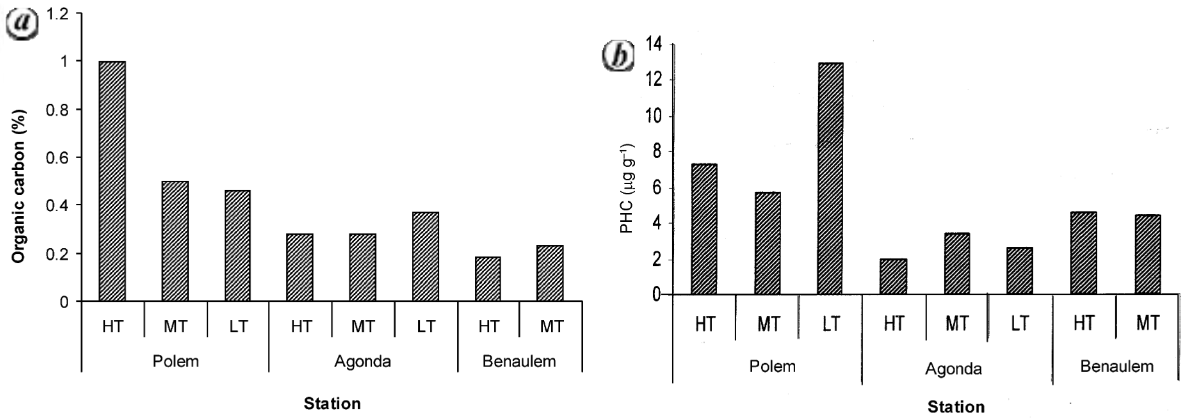


Figure 3. Organic carbon (***a***) and petroleum hydrocarbon (PHC) (***b***) concentration in the study area (June 2006).

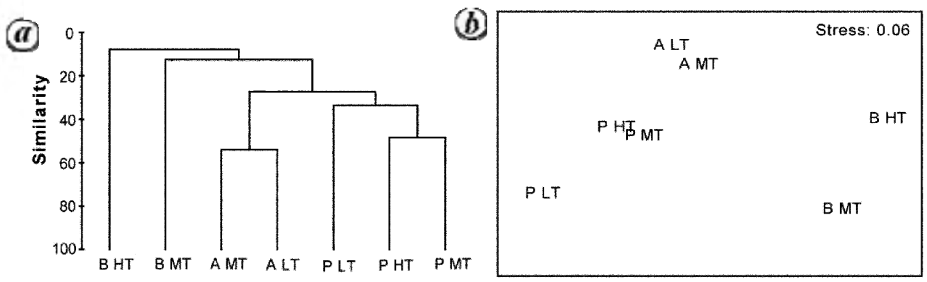


Figure 4. Cluster (***a***) and MDS (***b***) based on macrofaunal abundance. B, Benaulim; A, Agonda; P, Polem; HT, High tide; MT, Mid tide; LT, Low tide.

armoured beaches bordering the Gulf of Alaska. These sites are 300–700 km away from the spill and the oil was chemically similar to the 11-day oil of *Exxon Valdez*[10]. Thus, the degree of oil pollution in the marine environment may be more accurately assessed by measuring oil in the sediment[11] and the impact of oil spill can be well evaluated through benthic fauna[6].

A total of 20 macrobenthic taxa were identified from the intertidal area during the present study. The macroinvertebrates at Polem were dominated by Nemertean, followed by Polychaeta. *Macropthalamus* sp. (45%) and *Pisione oerstedii* (37.5%) were the most dominant polychaetes. In Agonda, crustaceans dominated the intertidal community. *E. holthuisi* was the most abundant in terms of population counts and biomass. Juveniles of *E. holthuisi* dominated the population and contributed to >80% of the total abundance. The mature *E. holthuisi* measured 13–18 mm and fecundity ranged from 500 to 2880. Most of the eggs were in early development (stages I and II)[12] and did not show any abnormality. The major spawning of *E. holthuisi* extends from December to June, with a peak in March and supplementary minor peak in October[13]. As a result, individuals are being recruited almost throughout the year. However, the main recruitment period along the Goan beaches appears to be during June–July[13]. Corroborating with earlier findings[14], abundance of *D. incarnatus* and *Gastrosaccus* sp. was higher at Benaulim beach. Clustering and MDS plot showed that all the three study areas differ in macrofaunal community (Figure 4). In Benaulim, mid tide was dominated by *D. incarnatus* (2872 ind m^{-2}) and high tide was represented by a low abundance of the polychaete, *Saccocirrus* sp. (22 ind m^{-2}) and the isopod, *Eurydice* sp. (22 ind m^{-2}). In Polem, Nemertean dominated in the high tide (265 ind m^{-2}) and mid tide (155 ind m^{-2}) whereas low tide was dominated by polychaetes (884 ind m^{-2}). Similarly, Agonda (mid tide and low tide) clustered at 54% due to the presence of the bivalves, *D. spiculum* in similar density (552 ind m^{-2}).

PHC content in the sediment was negatively correlated with macrofaunal density. Though the present study did not show direct impact of oil spill from MV *Ocean Seraya* on the intertidal macrobenthic community, PHC values were high (13 $\mu g\ g^{-1}$) at the site closest to the spill (Polem). Sediment-associated oil from major spills has been shown to persist in the marine environment for years, and can be re-released in potentially toxic concentrations[15]. Dauvin[16] 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. While discussing the short- and long-term impact of oil

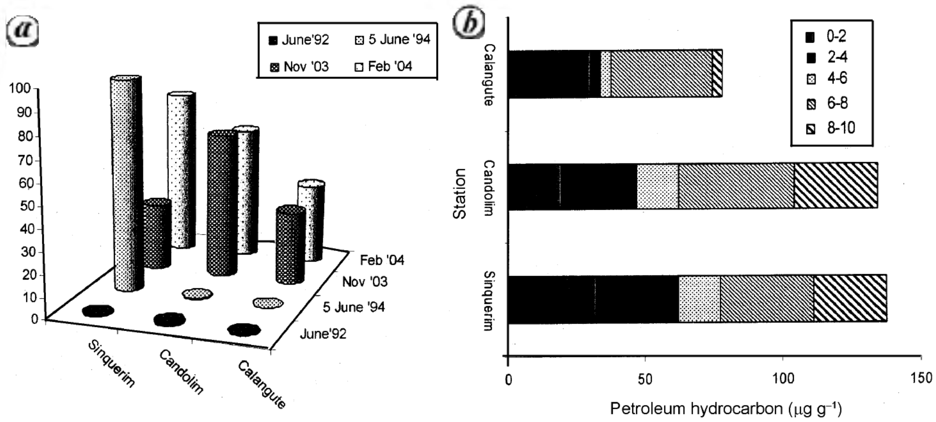


Figure 5. Variation in PHC concentration (*a*) and vertical distribution of PHC (*b*) at Sinquerim–Calangute–Candolim.

Table 2. Macrofaunal abundance in the study area

	Abundance (ind m^{-2})	Biomass (g m^{-2})	No. of species	Dominant group
Polem	1635	0.99	9	Polychaeta
Agonda	7499	9.6	11	Nemertenia
Benaulim	6419	448	7	Bivalvia

spill from grounded MV *Sea Transporter* on the intertidal meiobenthic communities, Ansari and Ingole[17] indicated that the short-term effect of oil spill was severe as most of the microscopic organisms were eliminated from the intertidal habitat. Strong wave action on the open beach and manual beach cleaning by the local administration assisted in reducing PHC content in the sediment. This resulted in faster recovery of meiobenthic communities. On the other hand, while studying the impact of oil spill from another grounded vessel, MV *River Princess*, Ingole *et al.*[6] demonstrated that relatively small-scale but persistent oil spill not only reduced benthic standing stock (abundance and biomass), but also some of the oil-sensitive species were eliminated. PHC concentration was high at the grounded site (Candolim) and the concentration in the area showed further increase from 43 to 58 μg g^{-1} (Figure 5 *a*). Increased PHCs in sediment was due to possible leakage from the grounded MV *River Princess* vessel[6]. Further, hydrocarbon values were highest in the sediment depth of 6–8 cm (Figure 5 *b*). The macrobenthic community of Candolim showed a decrease from 27 (ref. 18) to 11 (ref. 6).

The vulnerability of organisms to oil is related to seasonal changes in their distribution and abundance. Accordingly, for a particular species, spilled oil may have less impact during one part of the year than the another. Monsoon is the recruitment period for most of tropical benthic organisms and commercial fish. As is evident from the present study, major recruitment of *E. holthuisi* occurs during monsoon, as the *Emerita* population was dominated by juveniles (>80%). More than 90% of the benthic organisms have planktonic larvae[19]. Generally, the effect of oil spills is first observed in the pelagic organism. An oil spill is not stationary in the water column. It spreads over a larger surface area under the influence of winds (monsoonal or otherwise), during which it affects the pelagic organisms.

In contrast to the increase in oil consumption, resulting in increase in maritime transportation, incidents of accidental oil spill have shown a decrease globally since the 1970s. Tanker spills annually account for 12% of the oil entering the sea and a total of 531 spills have been reported[20] internationally from 1979 to 2004. Among the accidental tanker spills, 34.4% occurred due to grounding of vessel and 28.3% due to collisions[20]. According to Clarke[21], most of the oil affecting the marine ecosystem is derived from tanker operations and accidents. However, compared to the decrease in oil spills incidents globally, the number of tanker spills/accidents has increased along the Indian coast. Of the total observed spills, 70% were reported from the west coast of India (Table 3; Figure 6 and 7). Moreover, the data also revealed that majority of the spills occurred during the SW monsoon period. Model studies, based on historical data of winds and surface currents indicate that during the SW monsoon, the along shore surface currents developed an easterly shoreward component[22,23] resulting in rough weather conditions. This makes the west coast vulnerable to any oil spills in the Arabian Sea during the SW monsoon. The spawning periodicity of majority of marine organisms and commercial fishes coincides with the monsoon season so that their larvae could utilize the abundant plank-

Table 3. Major oil spills on the Indian coast since 1970

Date	Quantity spilled (t)	Position	Vessel/other incidents
Aug '70	15,622/FO	NW coast of India (off Kutch)	Greek oil tanker *Ampuria*
Jun '73	18,000/LDO	NW coast of India of the Arabian Sea	MT *Cosmos Pioneer*
Sep '74	3325/FO	Kiltan, Lakshadweep	American oil tanker *Transhuron*
Jul '76	29,000	Off Mumbai	*Crestan Star*
Jun '79	11,000	Cochin	*Aviles*
1982	NK	West coast	*Sagar Vikas*
Oct '88	1000	Bombay Harbour, Maharashtra	*Lajpat Rai*
1989	NK	West coast	*SEDCO 252*
Jun '89	5500	795 n mile SW of Mumbai	MT *Puppy*
Aug '89	NK	Bombay Harbour	ONGC tanker
Aug '89	NK	Saurashtra coast, Gujarat	Merchant ship
Aug '89	NK	Bombay Harbour	NK
Mar '90	NK	NW of Kochi, Kerala	Merchant ship
Sep '91	692/FO	Gulf of Mannar, Tamil Nadu	MT *Jayabola*
Nov '91	40,000/crude	Bombay High, Maharashtra	MT *Zakir Hussain*
Feb '92	Tanker wash	40 n mile south of New Moore Island, Bay of Bengal	Unknown
Apr '92	1000/crude	54 n mile west of Kochi, Kerala	MT *Homi Bhabha*
Aug '92	1060/SKO	Madras Harbour, Tamil Nadu	MT *Albert Ekka*
Nov '92	300/FO	Bombay Harbour, Maharashtra	MV *Moon River*
Jan '93	40000	Off Nicobar	Maersk navigator
Mar '93	NK/crude	Off Narsapur, Andhra Pradesh	ONGC rig, Kumarada
Apr '93	110/crude	Bombay Harbour, Maharashtra	MT *Nand Shivchand*
May '93	90/FO	Bhavnagar, Gujarat	MV *Celelia*
May '93	6000/crude	Bombay High, Maharashtra	Riser pipe rupture
Aug '93	260/FO	Off New/Mangalore	MV *Challenge*
Oct '93	90/crude	Cochin Harbour, Kerala	MT *Nand Shivchand*
May '94	1600/crude	Off Sac Romanto	*Innovative-1*
May '94	-/FO	360 NM SW of Porbandar	MV *Stolidi*
Jun '94	1025/crude	Off Aguada Lighthouse, Goa	MV *Sea Transporter*
Jul '94	100/FO	Bombay Harbour, Maharashtra	MV *Maharshi Dayananad*
Nov '94	288/HO	Off Madras, Tamil Nadu	MV *Sagar*
Mar '95	200/diesel	Off Vizag, Andhra Pradesh	Dredger *Mandovi-2*
Sep '95	-/FO	Off Dwarka, Gujarat	MC *Pearl*
Nov '95	Tanker wash	Eliot beach, Chennai	Unknown
May '96	370 FO	Off Hooghly River	MV *Prem Tista*
Jun '96	120/FO	Off Prongs Lighthouse. Maharashtra	MV *Tupi Buzios*
Jun '96	132/FO	Off Bandra, Maharashtra	MV *Zhen Don*
Jun '96	128/FO	Off Karanja, Maharashtra	MV *Indian Prosperity*
Jun '96	110/FO	Off Worli, Maharashtra	MV *Romanska*
Aug '96	124/FO	Malabar coast, Kerala	MV *Al-Hadi*
Jan '97	Tank wash	Kakinada coast, Andhra Pradesh	Unknown
Jun '97	210/FO	Off Prongs Lighthouse, Maharashtra	MV *Arcadia Pride*
Jun '97	NK	Hooghly River, West Bengal	MV *Green Opal*
Sep '97	Naptha, diesel petrol	Vizag, Andhra Pradesh	HPC refinery
Aug '97	70/FO	Off Mumbai, Maharashtra	MV *Sea Empress*
Jun '98	20/crude	Off Vadinar, Gujarat	Vadinar, SBM
Jun '98		Off Porbandar, Gujarat	Ocean barge
Jun '98		Off Veraval, Gujarat	Ocean Pacific
Jul '98	15/FO	Mul Dwarka, Gujarat	*Pacific Acadian*
Jul '00	–	Off Sagar Island, West Bengal	MV *Prime Value*
Sep '00	–	Off Fort Aguada, Goa	MV *River Princess*
Dec '00	1/FO	Bombay Harbour, Maharashtra	MV *Stonewall Jackson*
Jun '01	–	Vadinar, Gulf of Kachchh	Not known
Jul '01		Hooghly River, West Bengal	MV *Lucnam*
Aug '01		SBM Vadinar, Gujarat	
Sep '02		220 n mile off Pt Calimare	MV *Hiderbahy*
Apr '03	1.8/light crude oil	5 miles off Kochi, Kerala	MT *BR Ambedkar*
May '03	145 FO	Off Haldia, West Bengal	MV *Segitega Biru*
Aug '03	300/crude oil	ONGC rig (BHN), Maharashtra	URAN pipeline
Feb '04	01/crude oil	ONGC pipeline at MPT oil jetty	Crude oil transfer
Oct '04	0.56	Berthed-MPT–8, Goa	
Mar '05	110	Off Aguada Lighthouse, Goa	MV *Maritime Wisdom*

(*Contd*)

Table 3. (*Contd*)

Date	Quantity spilled (t)	Position	Vessel/other incidents
Jun '05	49,537/cargo and 640/FO	Vishakhapatnam Port	MV *Jinan VRWD-5*
Jul '05	350 m^3 base lube oil	Mumbai Harbour	Dumb barge *Rajgiri*
Jul '05	33/FO	NE of Paget Island (N. Andaman)	MV *Edna Maria*
Jul '05	80	Off Prongs Lighthouse, Off Mumbai	OSV *Samudra Suraksha*
Aug '05	–	9 n mile off Tuticorin	MV *IIDA*
Sep '05	100	Off Visakhapatnam	MV *Royal Ocean 2*
May '06	650/FO	Oyster rocks, Karwar	MV *Ocean Seraya*
Aug '06	4500	Grear Nicobar Island	*Bright Artemis*

FO, Fuel oil; HO, Heavy oil; NK, Not known.

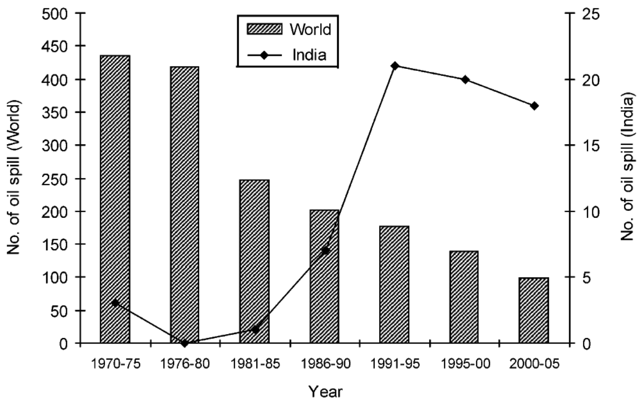


Figure 6. Comparison of oil spill incidents in the world and Indian waters.

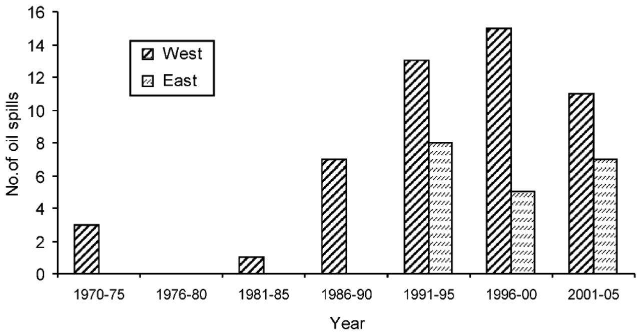


Figure 7. Comparison of oil spill incidents along the west and east coasts of India.

tonic food resulting from the seasonal upwelling[24]. Therefore, oil spills occurring during the critical stage of the marine organisms may have a long-term impact on the recruitment and population of the organisms.

Increasing data are available regarding the susceptibility of early developmental stages to oil, especially at the cellular and sub-cellular level, sometimes at substantially lower concentrations[25]. The cumulative impact of *North Cape* oil on winter flounder embryos was a reduction of 51% in the number of embryos surviving to the larval stage[26]. Naphthalene and phenanthrene, both light-weight PAHs, are among the most toxic fractions of oil[27]. When raw oil is exposed to sunlight, more persistent and toxic compounds are produced[28] and the peroxides induce mutation. Many of the commercial fishes exploit the near-shore area for spawning and development of sensitive embryonic and larval stages. This could work against these species when the area becomes contaminated with toxic material such as oil. Survival through planktonic development stages is believed to be the most important event controlling the abundance of marine organisms. Also the early stages of these species are vulnerable to significant losses due to natural events and will be further affected by anthropogenic disturbances like oil spills[26].

Benthos are the major food source for demersal fisheries and benthic production shows strong seasonality. Consequently, any impact on benthos will affect the demersal fishery production of the area. Analysis of benthic biomass distribution and demersal fish showed a positive correlation and high biomass area was found supporting greater density of bottom fishes[29].

The marine fish landing for the year 2004 was 635,094 tonnes along the west coast contributing to about 73% of the total marine fish catch of the country[30]. Fish catches have increased considerably in the last few decades. However, this has been attributed to mechanization and increase in the number of fishing trawlers as well as advancement in gear technology[31]. Landings of major fishery resources in the Indian Ocean region have declined significantly. Over-exploitation is attributed to be the main cause of decline in fish catches worldwide, which may be further affected by increase in oil spill occurrence.

Significant changes in commercial fish stocks take place in the inshore areas, although attempts are not usually made to link them with any single pollutant[32]. However, oil spills could be one of the reasons for fluctuation in total fish catch, as hydrocarbons can greatly reduce the individual organism's chances of survival[33] and accordingly, population changes are of potential concern. According to McIntyre[32], fisheries on the continental shelves are at a greater risk than those offshore, and this affects the shallow coastal intertidal areas.

Apart from accidental spills, oil pollution occurs during routine operations such as loading, discharging and bunkering, which are normally carried out in ports or at oil terminals. Concerns have arisen recently about the number of illegal discharges from the large volume of shipping within the region. After evaporation of the lighter fractions of oil and photooxidation, the heavier fraction gradually forms into tarballs. Driven by wind and current, these tarballs are deposited on the beaches. Periodic tar ball and raw oil pollution is observed at all the major beaches, mainly during the onset of monsoon and sometimes throughout the year. The life of tarballs in the sea varies from 33 to 58 days, while the same is not yet known for the beaches. However, due to the half yearly changes in surface circulation, these tarballs are deposited along the beaches of India, including Goa. Estimates from data for two years give 40 tonnes as the yearly deposit of tarballs along the beaches of Goa[34]. In August 2005, oil spill from an unknown source caused the deposition of tar along the major tourist beaches and heavy mortality of beach organisms[35]. Threats of oil contamination in the sea and the coastal area as a result of petrol-related activities and usage of petroleum and petroleum products are serious, since they could cause irreparable damage to the marine ecosystem, thereby affecting the socio-economic status of the population which depends on the coastal resources for its livelihood.

Further, residual oil from the oil spill carpets the seabed and remains in contact with the seabed for longer time, thus having a long-term effect on the benthic environment. The increasing trend of oil spills around the coast could certainly have a negative impact on the marine community, as observed earlier, as well as the economy in terms of fisheries and tourism. A comprehensive long-term investigation is therefore required to study the impact of oil pollution on coastal ecology that will help in conserving the coastal biodiversity.

The present study did not show any major impact of MV *Ocean Seraya* on the intertidal macrobenthic community of beaches in south Goa. However, PHC content was high at the site closer to the spill. India has had only relatively minor oil spills its coastal waters, primarily from tanker accidents. The possibility however of a major oil spill occurring along the Indian coast is considerably higher today, as there has been a significant increase in all types of oil tankers/bulk carriers/container ships passing through the Indian Ocean. Further, India also depends on sea transport for majority of its trade. Coastal areas all over the world have been reported to be damaged from pollution, thus having a significant effect on the marine ecosystem, on particular fisheries. Therefore, control of aquatic pollution has been identified as an immediate need for sustainable management and conservation of the existing fisheries and aquatic resources.

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Salmonella Typhimurium invasion induces apoptosis in chicken embryo fibroblast

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***Salmonella* Typhimurium induces apoptosis in macrophages and intestinal epithelial cells. In the present study we report that it induces apoptosis in chicken embryo fibroblast (CEF), by a scatter experiment using flow cytometry. This finding makes CEF the best model for molecular analysis of apoptosis induced by *Salmonella*, since culture and handling of CEF is more convenient than any other specialized cells.**

Keywords: Apoptosis, chicken embryo fibroblast, *Salmonella* Typhimurium.

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APOPTOSIS is a genetically determined form of cell death that plays a central role during development and homeostasis of multicellular organisms[1,2]. Necrotic cell death is usually the consequence of physical injury and does not involve active participation of the cell. Apoptosis can be distinguished from necrosis on the basis of several morphological as well as biochemical parameters, such as nuclear condensation, loss of cell volume, cell shrinkage, DNA fragmentation[2], and phosphatidylserine exposure to the outer face of the plasma membrane[3]. This kind of cell death avoids spillage of intracellular contents in contrast to necrotic cell death, typified by cell and organelle swelling and membrane disruption, resulting in an inflammatory response[3]. The central executioners of apoptosis are a set of cysteine proteases that are part of a large protein family known as caspases[4]. Apoptosis is critically important to development, tissue homeostasis, and in the pathogenesis of various viral and bacterial diseases[5].

The ability of *Salmonella* to promote apoptosis may be important for the initiation of infection, bacterial survival and escape of the host immune response[5].

Flow cytometry is a simple and reproducible method useful for assessing apoptosis of specific cell populations. There are several methods that can be used to quantitate apoptosis by flow cytometry. The simplest method based on biochemical changes includes use of propidium iodide (PI) to stain the DNA and look for the sub-diploid, or Ao population of cells from a cell cycle profile. Staining of isolated nuclei with DNA-binding fluorescent dye PI showed that intensity of fluorescence is correlated with the extent of DNA degradation[6]. Flow cytometric analysis of the apoptotic cell population can be carried out using either single dye or a mixture of dyes.

Salmonella induces apoptosis in macrophages and dendrocytes through the caspase-1 pathway. In the present study we have made an attempt to find whether *Salmonella* induces apoptosis in chicken embryo fibroblast (CEF). The isolates selected for the study were ML-4, ML-7 and ML-5.

Primary CEF culture was prepared. After 45 min of bacterial infection to the fibroblast, the infected cells were washed three times with PBS (7.4) and incubated in fresh tissue culture medium containing 100 μg of gentamicin/ml for 30 min. Then the cells were washed with PBS twice, followed by trypsinization.

For trypsinization, trypsin (0.1 ml/cm^2 of 0.25% trypsin in PBS) was added to the side of the flask opposite the cells. Then the flask was turned over and left stationary for 15–30 s and all but a few drops of the trypsin was withdrawn, making sure that the monolayer was not detached. The cells were further incubated for 5–15 min with flask lying flat, until the cells rounded up when the bottle was tilted and the monolayer was able to slide down the surface. At this stage of trypsinization, culture medium (0.1–0.2 ml/cm^2) was added and the cells were dispensed by repeated pipetting over the surface bearing