Available online at: www.mbai.org.in
doi: 10.6024/jmbai.2017.59.2.1989-08

Impact of January 2017 oil spill on the biota off Chennai, southeast coast of India with emphasis on histological impact on crab, *Grapsus albolineatus*

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Received: 29 July 2017, Accepted: 15 Dec 2017, Published: 30 Dec 2017

Original Article

Abstract

This study documents the cascade of events that occurred in the coast and biota of the Chennai region exposed to an accidental oil spill near the Ennore port after the collision of two cargo ships. The impact of the collision was so severe that the oil compartment was damaged, spilling approximately 22 tonnes of oil at initial hours. Due to waves, tidal action and southern current, the spillage travelled a long distance up to a stretch of around 52 km along the coastline in Bay of Bengal. Damage to the biota was monitored at different zones based on the intensity of the oil spill to evaluate the environmental impact caused by it. The shorelines of most of these areas had shown signs of oil sludge deposited in the sediments and boulders from the very next day of the collision. An intensive survey indicated that the sea turtles, crabs, fishes and seaweeds were washed ashore that posed a threat to the coastal habitat. Further, in-depth, histological studies on gills, hepatopancreas and eggs of the crab *Grapsus albolineatus,* showed structural deformities with irregular gill tips and lower haemocytes counts in the gill samples. Whereas hepatopancreas and eggs did not show any structural deformities, although they appeared black due to adhesion of oil, but no sign of oil in the internal region. This pilot study provides baseline information about the post oil spill scenario of the coastal region as alarming and a threat to ecologically sensitive marine organisms.

Keywords: *Oil spill, flora, fauna, Grapsus albolineatus, Chennai, Bay of Bengal.*

Introduction

Oil spill is a major threat to the aquatic biota which also harms the livelihood of human beings in many ways. Oil spills are ranked among the major threat to the stability of the coastal and marine environment and can have severe impacts on near shore biodiversity and functioning (Peterson *et al.*, 2003). Accidental spill coats the shoreline with oil leading to immediate impacts (Paine *et al.*, 1996; Peterson, 2001). Whereas, responses are more subtle and less known in intertidal habitats, though, the effects may last up to two decades after the spill (Gundlach *et al.*, 1983; Dauvin, 1998). Crude oils composed mostly of diverse aliphatic and aromatic hydrocarbons (Chen *et al.*, 2017). The direct effect of environmental variability is known to affect the community structure. As the sensitivities of animals vary among species, the response of communities to oil spills is likely to change with environmental settings (Kotta *et al*., 2008). Spilled oil poses serious threats to fresh water and marine environment, affecting surface resources and a wide range of subsurface organisms that are linked in a complex food chain that includes human food resources. However, spilled oil does not readily penetrate into wet and water-saturated sand in the lower intertidal zone. As the tide rises and wave break on the beach, oil is lifted off the sand and concentrated in and above the high-tide line, an area of ecological importance because of the accumulation of wrack (Bejarano and Michel, 2016).

On 28 January 2017, at around 3:40 a.m. IST, an accidental oil spill had occurred, after the MT Dawn Kanchipuram and BW Maple collided off Ennore north of Chennai in the southeast coast of India. In this incident, the pollutant being heavy furnace oil (HFO) or bunker oil with high viscosity, posed a huge threat to the coastal and marine habitat. The oil spill, which was initially termed as a minor incident turned into a major environmental hazard. However, studies on the interactive effects of physical forcing and oil spills to coastal ecosystems are limited. Therefore, the present study was made to monitor the impact of oil spill on the biota of entire coastal region of Chennai, exposed to oil spill.

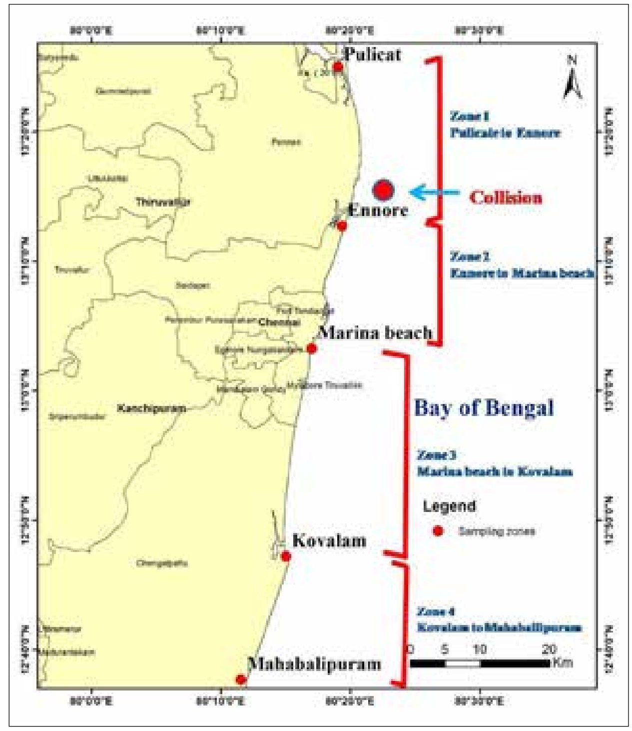

Fig. 1. Map showing accidental oil spill impact zones along the southeast coast of Tamil Nadu

Zone 1: Pulicat to Ennore; Zone 2: Ennore to Marina beach; Zone 3 Marina beach to Kovalam; Zone 4: Kovalam to Mahaballipuram

Material and methods

Description of study area

The Bay of Bengal is one of the busiest traffic lines in India, where, most of the cargo ship transportation is being handled. Ennore port is situated on the south-east coast of India, about 26 km north of Chennai. The geographical position of the recent collision of the cargo ships MT Dawn Kanchipuram and BW Maple carrying crude oil was 13°13'56.46"N and 80°21'22.78"E. The collision point was about 1.8 nautical miles (3.3 kms) from the Ennore port. The impacts of oil spill were monitored from Pulicat to Mahabalipuram (*Viz*: Zone 1: Pulicat to Ennore; Zone 2: Ennore to Marina beach; Zone 3: Marina beach to Kovalam; Zone 4: Kovalam to Mahabalipuram). With reference to the physical nature of the coastal zones, zone 1-3 represents sandy shore and zone 4 represents partial rocky shoreline at some regions (Fig.1).

Collection of biota

The preliminary observation was carried out on 29th January 2017 at 8.30 a.m. On the same day, at 9-10 a.m., the oil sludge had reached the zone 2, where the oil patches were first noticed. On the southern side, oil reached on the boulders, groin and sea walls at zone 2. On 30th January 2017, tar balls were observed on the beach along the swash lines in the receding phase of tide and near high water and low waterline. On the same day, the biota were found dead and washed away at different zones. The survey made was successive independent samples studies and it was conducted among the local residents and the fisherman community to make the proper documentation. We conducted a continuous monitoring at different zones for a week after the oil spill event, to document the proper effects. The survey was done within a transact distance of 1 km in all the four zones and the data on oil spill was given by the report provided by Tamil Nadu pollution control board (TNPCB). During our survey, the oil spill damage was more pronounced with the crab *Grapsus albolineatus,* a dominant form seen in entire stretch of the coastal region. Samples of crab were collected (n= 20) from each impact zone using hand net. Live crab samples were collected from oil spill affected and unaffected zones. The samples were brought to the laboratory on the same day through isolated plastic container with proper aeration and then dissected. Crabs were identified with the lab manual, according to the marine species identification portal (http://speciesidentification.org/species.php). Similarly, the seaweeds *Grateloupia lithophila* and *Chaetomorpha antenina* attached to the boulders were collected using scraper and transferred carefully into a plastic wrapper.

Histology

Samples of gills, hepatopancreas and eggs of *G. albolineatus* were dissected and fixed in 4% neutral buffered formaldehyde solution for histological studies. The samples were dehydrated through a graded alcohol series and embedded in paraffin wax. Sections of 5-6 μm thickness were taken and stained with haematoxylin and eosin. The stained sections were mounted using DPX and photomicrographs were taken at various magnifications using Leica DM 2500 (Germany) microscope.

Results and discussion

The incident of oil spill occurred in Chennai region after the collision of two cargo ships. The impact of the collision was so severe that the oil compartment of the vessel MT Dawn Kanchipuram damaged, spilling an estimated 22 tonnes of oil at the initial hours. The ship was loaded with an estimated 32,813 tonnes of oil at the time of the accident. A total of 208 tonnes of sludge was removed as 99,000 litres of oil were mixed with water. This was the threatening factor for marine life and ecological balance, this impact was seen several stretches of the Bay of Bengal, which turned brown or black as tidal waves filled with a thick layer of black oil hit at high tide line (HTL). Oil spills are a global environmental problem with dramatic effects on local and regional scale (Santos and Andrade, 2009). Oil spills can have adverse impacts on both the environment and society, especially when the spilled oil reaches the shoreline (Kankara *et al.*, 2016). The impact of oil spill on the zones was recorded in the order of Zone 2>3>4>1. Due to the southern current and wave action, the oil sludge was easily spread to all the zones. Several oil spills, such as the M/T Athos oil spill (Delaware River) of 2004, the DBL-152 tug (50 km off Louisiana's coasts) and the catastrophic Deepwater Horizon oil spill (66 km off Lousiana's coast) were characterized by non-floating oil spill phenomena (Michel, 2008; Valentine *et al.*, 2014). Different studies on the Deepwater Horizon oil spill indicated that out of the 4.1 - 4.6 million barrels of fossil petroleum leaked, about 0.5% - 14.1% have firstly suspended and then settled over 3200 km^2 of seafloor around the Macondo well (Chanton *et al.*, 2015; Valentine *et al.*, 2014).

When a large spill drifts ashore, some of the oil may be trapped and remain for years and the concentration of oil reduce rapidly in the open sea, where the currents and diffusion occurs constantly. The polycyclic aromatic hydrocarbons (PAHs) are a minor constituent of crude oil; however, they are more toxic to the plants and animals (Atlas and Hazen, 2011). The acute and chronic consequences of oil spills deplete environmental resources which may result in death of living organisms in the environment, either immediately or with time (Cole, 1997; Hofer, 1998; MacFarland, 1998). Oil spill causes harm to wildlife through physical contact, ingestion, inhalation and absorption. The impact of oil spills on the living components of the environment may be lethal, sometimes affect reproductive ability, physiologic processes and behavior of the organisms (Cole, 1997). In addition, oil spill can raise the biomass levels of less sensitive species due to organic enrichment and decrease the biomass of sensitive species because of toxicity (Olsgard and Gray, 1995; Peterson *et al.*, 1996). The pollutants in the current oil spill event are heavy furnace oil (HFO) or bunker oil, which is toxic to plants and animals. During our survey, many of the living organisms like fishes, turtles, crabs and other crustaceans were found dead in different zones (Table 1). The dead olive ridley turtles were washed ashore and the turtle eggs had become black due to the adhesion of oil in the 'High Impact Zone' (zone 2) (Fig. 2A and B) while only a few turtles were seen on the shoreline of the other zones. Notably, seaweeds were seen predominantly affected in the coastal region of zone 2. The seaweeds *G. lithophila* and *C. antenina* attached on the boulders were washed away by the sludge making them brown and black in colour and the habitat was completely collapsed in zone 2 (Fig. 2D). According to many researchers, oil spills can affect benthic communities and macrophytes in multiple ways: (1) modification of habitat characteristics (OILECO, 2007), (2) suffocation and poisoning of flora and fauna (Herkül and Kotta, 2012) or (3) reduce the total coverage of macrophyte beds, which can result into biodiversity loss (Leiger *et al.*, 2012). In the present study, olive ridley turtles were seen more susceptible and it was evident victim of oil spill through inhalation when

Table 1. Mortality among marine fauna in the coast line

Impact zones	Fish mortality	Crabs and other shell fishes	Turtle Mortality
Zone 1: Pulicat to Ennore	×	×	< 10
Zone 2: Ennore to Marina beach	√ (Anchovies, Puffer fish and Mugil sp)	√	> 55
Zone 3: Marina beach to Kovalam	√ (Puffer fish)	×	> 37
Zone 4: Kovalam to Mahaballipuram	×	×	< 18

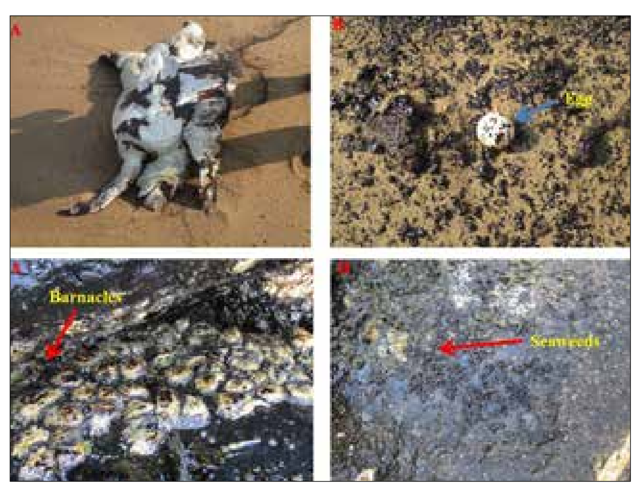

Fig. 2. Impact of oil spill (A) Dead olive ridley turtle in zone 2 (B) Contamination of the sediment and egg of olive ridley (C) Oil deposition on huge mass of barnacles (D) Seaweeds attached to the boulders

they come to the surface to breathe or through ingestion of soiled plant materials especially in the high impact zone 2. In addition, oil spill in the water surface resulted in oxygen depletion and lead to suffocation which caused the death of turtles. Generally, during January to April, the turtles show nesting and spawning activities along the Chennai coast. The accidental oil spill incident had completely degraded coastal habitat and therefore their nesting and spawning activities were affected. The present investigation also observed a large number of invertebrate fauna such as mussels, crabs and barnacles affected, mostly in zone 2, which is sandy in nature (Fig. 2C). Notably, only a few fishes were recorded to be affected in zone 2 (Table 1). Still, there are some boulders and sediment with crude oil still left on it, but the biota in the region seem to recover quite well in all other coastal zones.

Furthermore, crabs were seen predominantly abundant in zone 2 and maximum number of crabs were found dead and washed ashore. Most of the crabs had oil deposited in their organs like gill and egg (Figs. 4 A and B). The crabs had oil deposited on their eggs at the ventral side of their body and in the apron region (Fig. 3 A-D). The histological studies of the gills from zone 1, crabs showed gill rachis, the filament and the tips as intact; and the gill filaments were with intact pillar cells. The gill rachis was fully packed with haemocytes and epithelial lifting was seen in some of the gill filaments with more interlamellar spaces (Fig. 5 A and B). Whereas the gills of crabs collected from zone 2 showed the irregular architecture of the gill tips with connective tissues in the stem damaged, destructed and congestion of haemocytes in the gill lamellae. Besides the damage to the pillar cells, a thin connective fluid band was evident between the two gill lamellae (Fig. 5 C and D). However, there was no significant variation in the architecture of eggs and hepatopancreas of

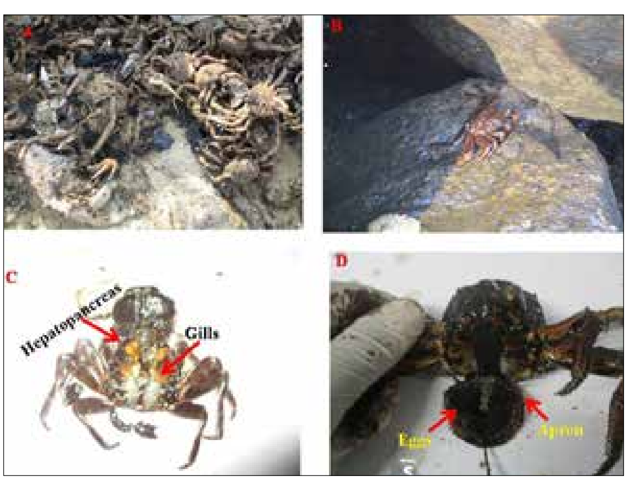

Fig. 3. (A) Large numbers of dead crabs washed on the shoreline, affected by oil spill (B) Live crab heavily oiled (C) Dissected crab showing internal organs affected by oil (D) oil deposited on apron with eggs

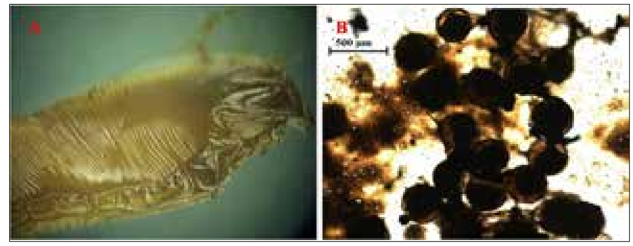

Fig. 4. Photomicrographs showing oil deposition in the gills (A) and eggs (B) of the crab collected from oil spilled zone

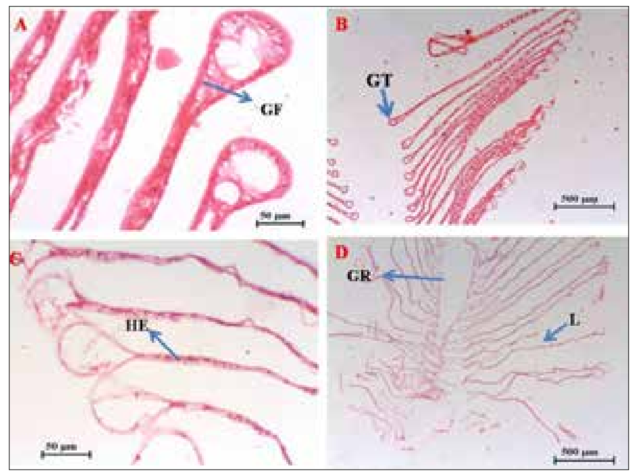

Fig. 5. Photomicrographs of section through gills of Grapsus albolineatus. (A & B) Unaffected crabs: normal architecture with gill tips (GT); gill rachis (GR); haemocytes (HE); gill filaments (GF); Lamella (L). (C & D) affected crabs with gill tips showing irregular architecture and low haemocytes count

the crabs collected from both oil spill affected and unaffected zones (Figs. 6 A-D). During the oil spill event, the inter-tidal organisms that live in the sand were more likely to be affected by the spill. Many species of bivalves which were considered as moderately sensitive, showed increased mortality due to oil contamination (Stekoll *et al.*, 1980). Particularly, in our study oil deposition was seen in various organs like gill, eggs and hepatopancreas of light foot crabs. The crabs that spawn on the coast were at the risk of being affected. Further, histological studies confirmed with structural deformities of gills. However, no significant variation was seen in the architecture of eggs and hepatopancreas of light foot crabs. Similar results were reported by Vasanthi *et al.* (2014) as the crab *Scylla serrata* collected from a pollution free site showed normal and intact gills whereas, the crabs collected from oil and metal polluted site showed disrupted structures which is evident that both acute and chronic exposure to metals contaminants produce irreversible histological changes in the architecture of gills and hepatopancreas of *S. serrata*. Like heavy metals (Thurberg *et al.*, 1973), the oil contaminants affect the osmoregulatory ability of crabs by inducing damage to their gills, as mentioned in our study.

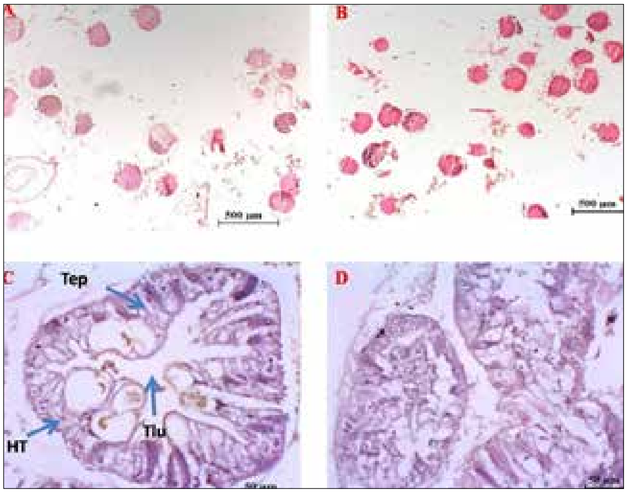

Fig. 6. Photomicrographs of (*Grapsus albolineatus*) section through (A) egg showing no significant variation in the egg architecture of crab collected from oil spilled zone and (B) other zones (C) Normal hepatopancreatic tubules (HT) are separated by connective tissues rich in reserve inclusion (RI) cells: Tubules containing normal epithelial cells (Tep) and lumens (Tlu) are surrounded (D) No variation in the architecture hepatopancreas of crabs collected from oil spilled zones and other zones

The impacts of oil spill to biological communities are difficult to predict because, the physical conditions interact with the community response. In addition, biological systems are complex and impacts often result from indirect effects rather than direct toxicological impacts (Peterson *et al*., 2003). Initially, the oil spill has the greatest impact on species that utilize the water surface, such as waterfowl and species that inhabit the near shore environment. The drastic spills indicate that oil combat management has failed to achieve environmental sustainability, partly because of insufficient generic understanding of how spills impact coastal biota on another side.

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