Ennore Oil Spill-Chennai Coast

The Ecological Footprint - An Assessment

March-2017

Integrated Coastal and Marine Area Management (ICMAM)
Project Directorate
Ministry of Earth Sciences, Government of India

Date of spill: Jan 28, 2017

Location: Off Ennore, Tamil Nadu, India

Lat: 13.228166° N Long: 80.363333° E

Synopsis

On 28th January at about 3:45 AM, two ships MT Dawn Kanchipuram and MT BW Maple collided, two nautical miles off the Kamarajar Port at Ennore, MT Dawn Kanchipuram suffered damages, spilling tonnes of fuel oil into the sea. The extent of damage became visible on the next day when large patches of oil started appearing on the rocky shores close to Bharathiyar Nagar which is approximately 13 km from the Kamarajar Port. Organized cleanup began on January 29th, 2017 and by this time the oil had already reached the Ennore groin field. As computed by INCOIS, the oil slick drifted along the Chennai coast up to 32km south and beached at the Palavakkam beach on the East Coast Road. Later, about two weeks after the incident, reports emerged that traces of oil were observed even along Pondicherry coast, 180 km away from incident area.

An oil spill, no matter how big or small is considered a serious threat to marine environment. A study was undertaken immediately after the spill to assess the ecological footprint and its effects on water quality and biodiversity in the coastal areas of Chennai. The physio-chemical and biological datasets are compared with long term water quality data available with ICMAM-PD. As expected, total petroleum hydrocarbon (TPH) concentration was significantly high. However, other physico-chemical parameters were within normal range. Usually, in such events, the planktons and vertebrates get affected due to their proximity with toxic compounds floating on the sea surface, nonetheless, significant variations were not observed. No mass mortality of fish occurred however few incidences of Mullets and Anchovies deaths were reported by fishermen. Very few cases of dead Olive ridley turtle drenched with oil were reported, however, the reason of their deaths are uncertain. ICMAM team did not encounter any such incidents during their field campaign.

The impact of the spill has directly affected the local fishing community as there was a sharp fall in fish sale due to the existing notion amongst public that fishes are contaminated with oil and not fit to consume.

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1. The Ennore Oil Spill –An overview

In the early morning of January 28, 2017, a liquefied petroleum gas tanker, the BW Maple, while coming out of the Kamarajar port, Ennore, collided with another tanker, the MT Dawn Kanchipuram, laden with 32,813 tonnes of petroleum lubricant. As per the real-time data of Port's Vessel Traffic Management System (VTMS), the Maple crashed into the side of the Dawn Kanchipuram at about 3.45 AM, leaking dark waxy bunker oil of the latter into the sea at about 2 nautical miles from the coast (Figure1). According to the published reports, the hull of the ship Dawn Kanchipuram was ripped, damaging the ship's accommodation as well as the pipelines on the deck and the water ballast tank on the outer surface of the LPG tanker BW Maple.

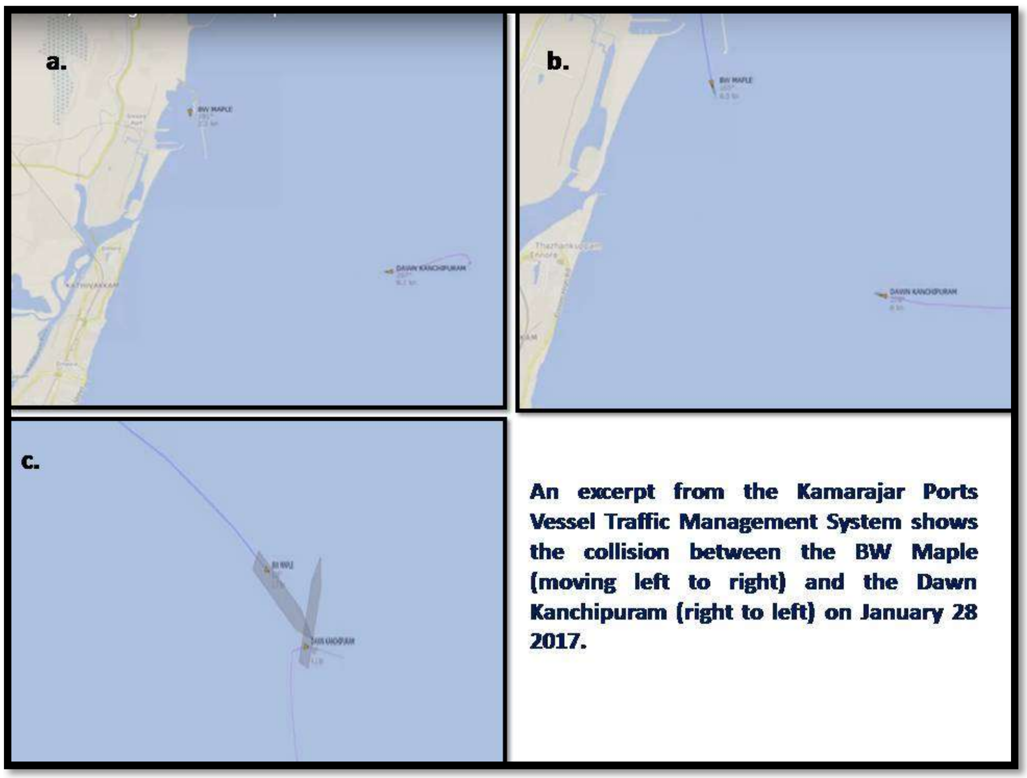


Figure 1. Collision as it happened – BW Maple leaving the port and Dawn Kanchipuram approaching on 28.2.2017, 3.30 AM

Initially, it was estimated that about one ton of Heavy Furnace Oil (HFO) Grade-IV was spilled; however, later it was confirmed by Indian Coast Guard that there is a probability of 20 metric tons of oil might have been spilled to the coastal waters. As soon as the oil spill event was made public, the Indian Coast Guard, Ministry of Defense, Govt. of India, deployed their contingent for cleaning, containment and recovery process in liaison with the district authorities, Tamil Nadu Pollution Control Board (TNPCB), Fisheries department and local volunteers. Simultaneously, INCOIS, Hyderabad (Ministry of Earth Sciences) came forward with the oil spill trajectory modelling and disseminated the information to user agencies. As reported by various media nearly 70 tonnes of oil sludge accumulated on the Ennore shore at Ramakrishna Nagar Kuppam beach and was removed by the Indian Coast Guard and the local volunteers. Finally, it has been estimated that 196 MT of bunker fuel oil (Grade 6) was spilled during this incident.

As computed by INCOIS, the oil slick moved along the Chennai coast and drifted up to 32km south and beached at the Palavakkam beach on the East Coast Road. Reports have emerged that traces of oil were found even along Pondicherry coast which is 180 km away, about two weeks after the spillage.

1.1 Impact of Oil Spill

ICMAM - Project Directorate, Ministry of Earth Sciences (MoES) carried out a preliminary assessment survey on 29th January 2017 and it was apparent that the Oil was drifting southwards and the coast north of the Ennore was severely affected (Fig.2).

Figure 2: Royapuram coast – Before and After the spill

By 29th January 2017, 6AM, the oil had reached Nettukuppam coast (Lat:13°13'42.25"N; Long:80°19'49.80"E) the northern most point where patches of oil were first noticed and on the southern side, oil beached on the rocky sea walls at Kasi Koil Kuppam (Lat:13°11'19.03"N; Long:80°19'2.31"E) extending up to the beaches north of Fishing harbour, Royapurm (Figure 3). A major portion of the spill was trapped in the Ennore groin field and oil patches were seen all along the north Chennai Coast.

A major portion of the spilled oil mixed with water / sludge was trapped near the groin at Bharathi Nagar (Lat: 13°11' 3.95"N; Long: 80°19' 1.28"E) and Radha Krishna Nagar Kuppam beach (Lat:13° 9' 21.04"N; Long: 80°18' 21.12"E) (Fig.4A & B). Further down south, at Washermenpet (Lat: 13° 8'12.71"N; Long: 80°17'53.51"E), north of Royapuram fishing harbour breakwater, floating oil patches in the nearshore water and tar balls on beaches were observed. Pictures of successive days i.e., on 29th & 30th January 2017 revealed that tar balls on the beach along the swash lines in the receding phase of tide on 29.01.2017 (Figure 5A) and near high water and low water line on 30. 01. 2017 (Figure 5B).

Figure 3: GPS Mapping of the of oil slick between Nettu kuppam and Kasi koil Kuppam on 29/02/2017, 10 -11AM

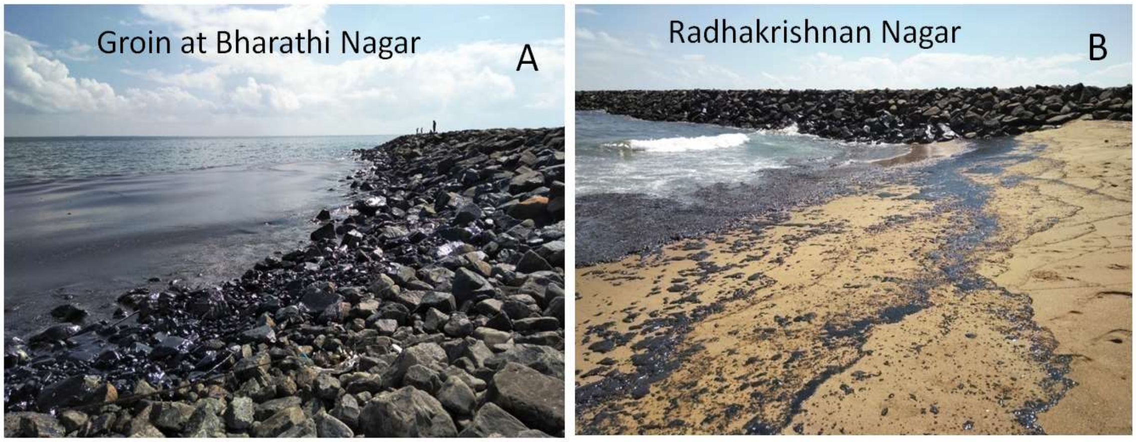


Figure 4: Extent of oil slick trapped between Groins at Bharati nagar and Radhakrishna Nagar, Royapuram coast on 29/02/2017, 10-11AM

Figure 5: Deposition of tar balls on the beach north of fishing harbour, Kasimedu

Tracing the extent and drift of the oil spill

2. Mapping the aerial extent of the oil spill using satellite data

Manually mapping of the aerial extent of the oil slick is a difficult and cumbersome exercise; remote sensing offers an ideal and efficient way to track the oil spill, its spread and movement through multi temporal datasets. Oil spills that may go unchecked for a period of time, to ascertain the extent of the spill, the rate and direction of movement, trajectory prediction and validation and for clean-up and control efforts, satellite images are suitably used.

Microwave sensors have an advantage over optical sensors as they can provide data even under poor weather conditions. For the present oil spill, Sentinel SAR (Synthetic Aperture Radar) datasets were used. The Sentinel (SAR) is a dual polarization instrument and operates in VH and VV nodes. Operating in the VH mode, bright targets like vessels are relatively easy to detect, while operating in VV mode oil spills become much more evident. SAR images measure the surface roughness depending on the backscatter. The main mechanism in detection of oil slicks is the dampening effect of oil on water. Dampening of sea waves results in reduced radar return from the affected area, so that oil slicks appear as relatively dark features on the SAR scenes. As an oil spill is physically a low backscatter area and appears as a dark area in SAR images, allows to some extent to estimate the size, location and dispersal of the oil spill.

Sentinel -1 images available for 6 AM of 29th January 2017, were used to map the extent of spill and the trajectory of its dispersion since the occurrence of spill on 28th January 2017 (Figure 6). The locations of the accident was at two nautical miles from the port and the shaded areas off the coast indicate the extent of oil slick, spreading in southeast direction up to 4 nautical miles from the coast. It is apparent that from the core area the slick has moved in a thin narrow band southwards travelling a distance of about 14km, and reached the coast by 29th January 2017. An area of about 8sq.km seems to be the core area of the spill and total aerial extent was about 13sq.km by 6AM of 29th January 2017.

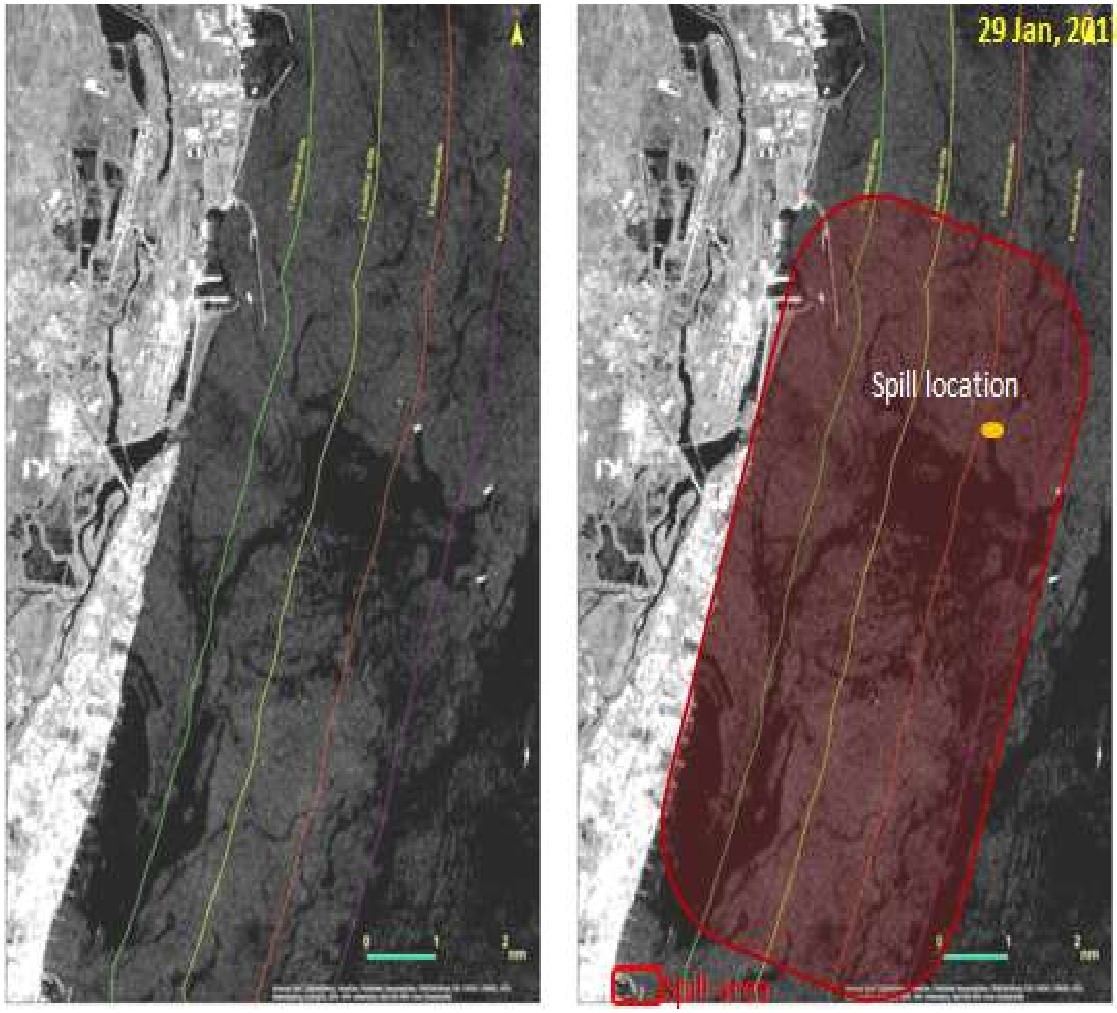


Figure 6: Oil slick as observed in Sentinel data (29-Jan-2017)

2.1 Oceanographic conditions during oil spill

The available wind and oceanographic parameters such as tide, wave and current data available for the region from 27th January to 2nd February, 2017 were analyzed for interpretation of the flow pattern at the spill source and the probable trajectory and flow direction.

Scatsat-1 scatterometer data on wind speed (29.01.2017) showed strong wind in the Ennore area. At the time of incident, north-easterly wind with an average speed of 4 m/sec (AWS data, Ennore) was prevailing, subsequently the wind was weak ~ 1m/sec and by 5AM of 29th January 2017, the wind speed regained to about 4.6 m/sec, and the predominant direction was north-easterly. The wind rose diagram revealed that 50% of wind velocity fell within 4-8 m/sec group and about 10 % of the wind was above 8 m/sec approaching from north-northeast quadrant (Figure 7).

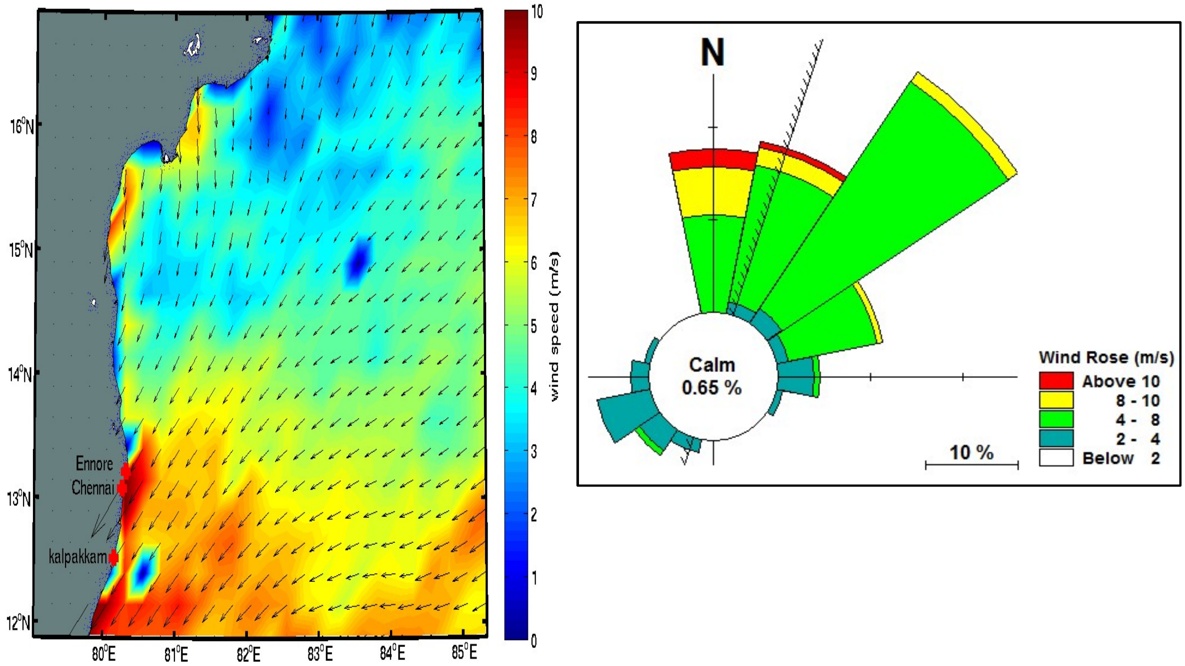


Figure 7: (a) Wind distribution (Scatsat-1 scatterometer) and (b) wind rose diagram

The tidal characteristics for the area was computed from the predicted global data and compared with the predicted Indian Tide Table data for Chennai (Madras) port (Figure 8). On 28th January 2017, the low tide was at 2:40 AM and high tide was at 8:26 AM. The tidal range was about 0.73 cm and the accident occurred when the tide was in flood (Low to high) phase (Figure 8).

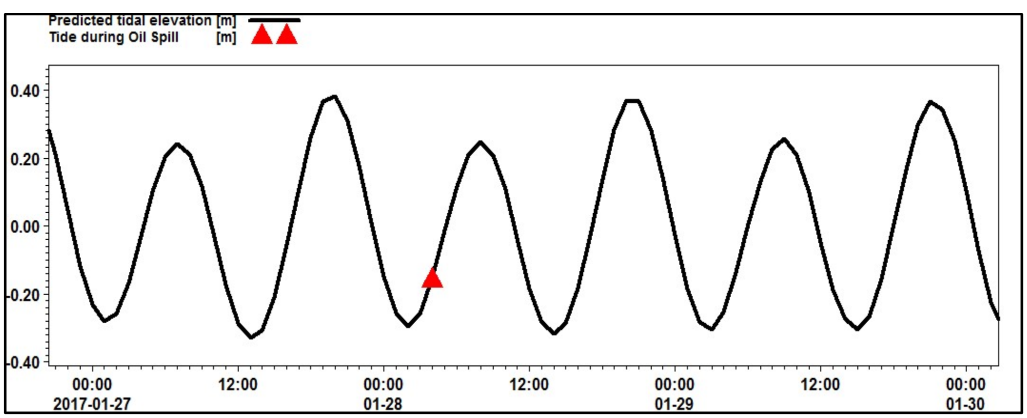


Figure 8: Tidal variation for Chennai coast

The significant wave heights was within a range of 0.70 to 0.80m with predominant direction of south-easterly (Figure 9).

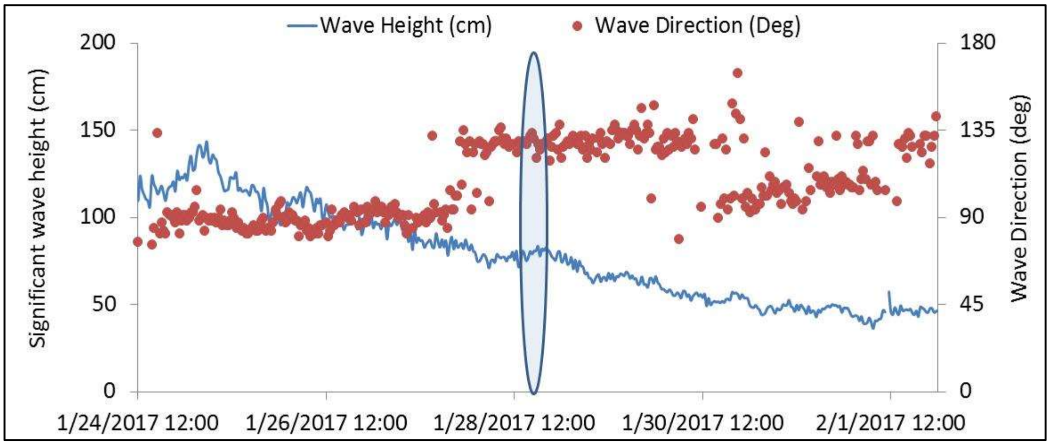


Figure 9: Wave characteristics off Chennai during 24 Jan - 02 Feb 2017.

Hydrodynamic simulations carried out and calibrated for the Chennai coast showed that the currents were predominantly towards south with a range of 6-10 cm/s along the coastal stretch of Chennai. It clearly indicates a strong flow near the source location moving southward parallel to the coast as shown in Figure 10. The current vectors near the lee side of the Ennore port breakwater converges and triggers a strong current of 7 to 8 cm/sec.

From the physical parameters, it is understood that the strong north-easterly wind parallel to the shore and the southerly current under flood tide and the prevailing southwest wave regime, a major portion of the oil slick was pushed southward, ultimately reaching the coast. However, the satellite imagery of 29th January 2017 showed the aerial extent of oil spill patch and a portion of it moved in SE direction. It might be due to the low height waves, weak current and tidal fluctuation within the preceding 24 hours. The oil spill trajectory simulated by INCOIS, MoES confirms our observations that the oil slicks reached the coast before 29.01.2017 at 13:00hrs. (Figure 11).

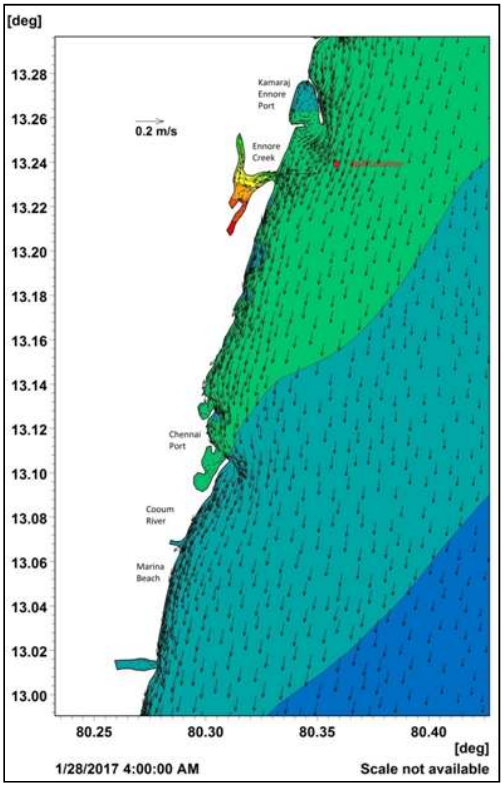


Figure 10 Simulated current vectors for Chennai coast

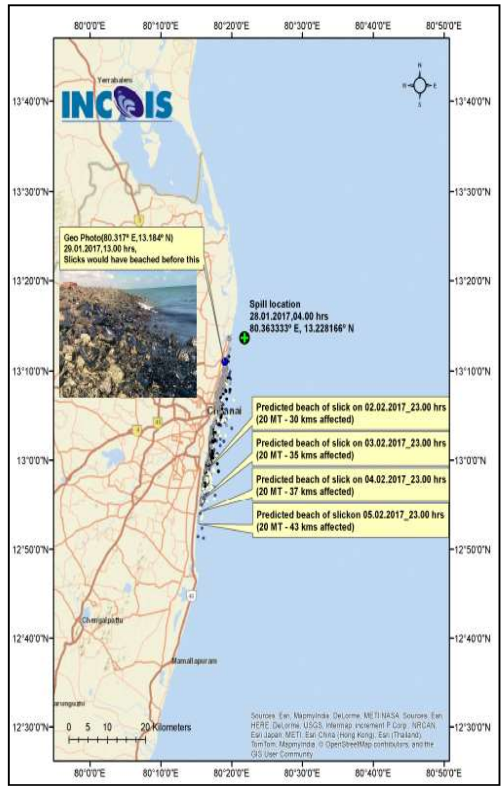


Figure 11 Simulated trajectory of oil spill (INCOIS, MoES)

Field data indicate that the oil spilled on 28.1.2017 had reached the groins in Ennore by the next day and was also seen in the satellite images (Figure 12). It was obvious from the satellite images, field survey and the orientation of the coast, that the strong southerly currents had drifted the oil in two patches. A major portion of the spilled oil was trapped in the Ernavur groin fields and subsequently drifted southwards spreading alongshore and oil patches were seen in near shore waters all along the Chennai coast. Another patch drifted along southerly current in the offshore at 3~4 nautical miles from the coast and subsequently landed in the south Chennai coast. This was confirmed by the fishermen during our survey and their probable dates and locations of appearances and arrival are mapped (Table 1 and Figure 13).

Figure 12. Arial extent of spill as on 29.1.2017

Table 1: Time lag between oil patches observed in offshore and nearshore (along the coast) as per field survey.

Location	Latitude	Longitude	Oil Spill Reached	
			Offshore	Nearshore
Srinivasapuram	13˚00'58.291"N	80˚16'40.605"E	29/01/2017	29/01/2017
Duminkuppam	13˚01'39.317"N	80˚16'44.941"E	x	29/01/2017
Fishing Habour	13˚07'48.054"N	80˚18'12.192"E	x	x
Thiruchanakuppam	13˚08'58.118"N	80˚18'12.511"E	28/01/2017	29/01/2017
Tiruvottiyur	13˚10'10.984"N	80˚18'41.844"E	28/01/2017	29/01/2017
Nettukuppam	13˚13'54.772"N	80˚19'48.313"E	28/01/2017	x
Sadaraskuppam	12˚31'29.871"N	80˚09'57.815"E	8/2/2017	5/2/2017
Venpurusham Kuppam	12˚35'48.588"N	80˚11'26.283"E	1/2/2017	6/2/2017
Mahabaliapuram	12˚37'32.983"N	80˚11'57.801"E	6/2/2017	11/2/2017
Puthiyakalpakkam	12˚43'46.753"N	80˚14'12.767"E	8/2/2017	11/2/2017
Kovalam	12˚47'23.946"N	80˚15'11.703"E	31/1/2017	31/1/2017
Nainarkuppam	12˚52'30.181"N	80˚15'04.258"E	1/2/2017	4/2/2017
Kotivakkam	12˚58'36.685"N	80˚16'02.654"E	29/1/2017	29/1/2017
Urur Kuppam	13˚00'10.638"N	80˚16'25.853"E	30/1/2017	30/1/2017

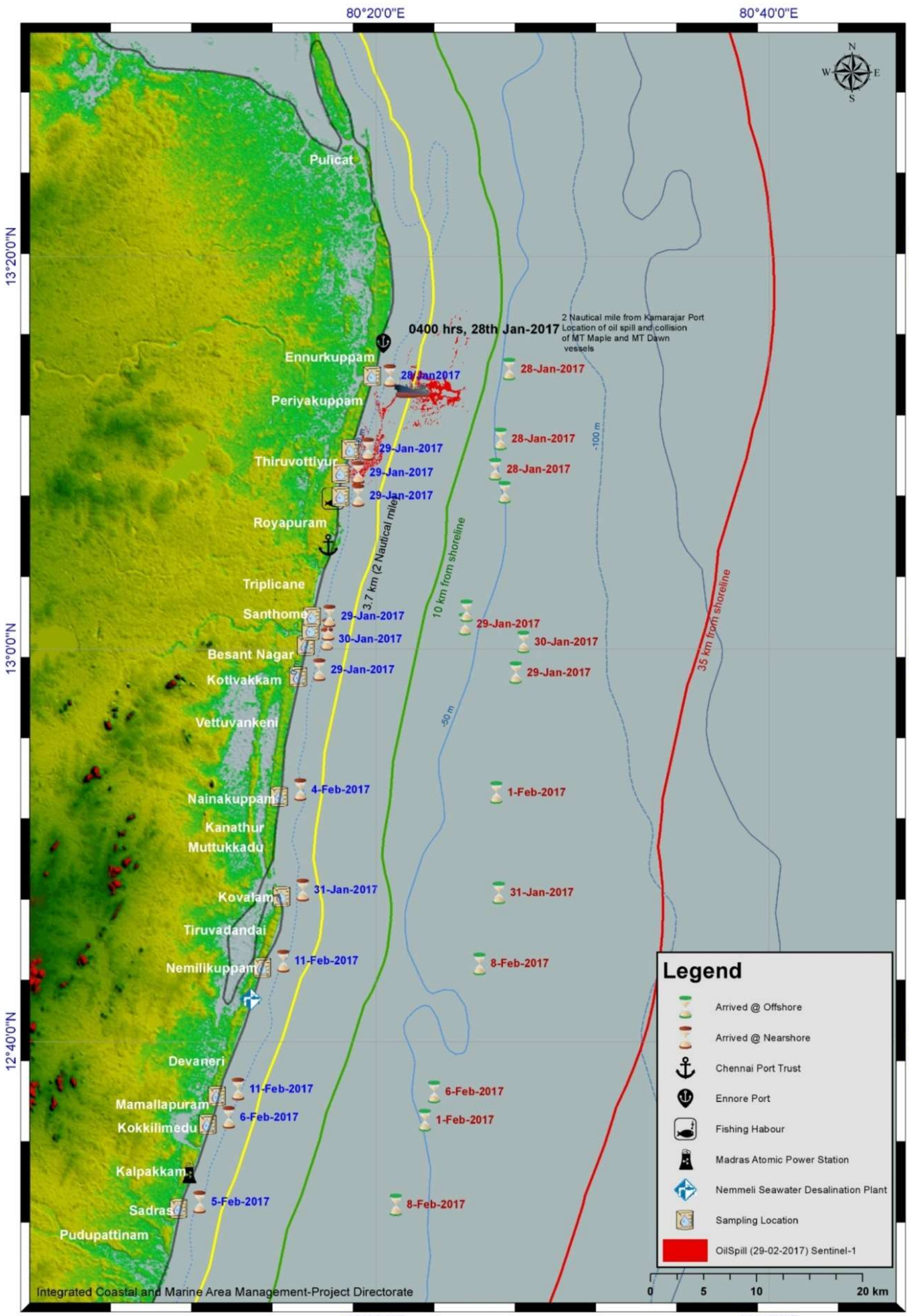


Figure 13: Movement of oil spill along the coast

By 8th February 2017, most of the beaches were clean except for the small oil patches and tar balls which were being washed ashore (Figure 14).

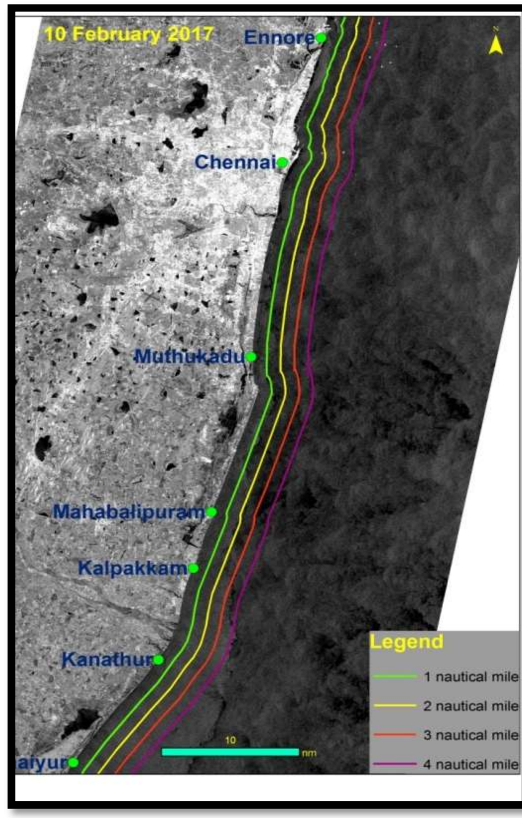


Figure 14: Tar balls washed ashore (8.2.2017)

Figure 15: Microwave data (10.2.2017) shows no major traces of oil

Microwave image of 10th February, 2017 showed no major patches of oil in the coastal waters and as per field reports most of the coast and beaches were clean (Figure 15).


Impact of Oil spill
on water quality

3. Impact of Oil spill on coastal water quality

ICMAM Project Directorate carried out a field campaign on 30 January, 2017 to assess the immediate impact of the spill on the coastal water quality. In this first phase, water and sediment samples were collected from 14 locations spatially distributed between Ennore and Adyar river mouth, covering about 20 km south from the spill location. The samples were collected and analysed for physio-chemical and biological parameters following standard protocols.

As the oil spread southwards beyond Adyar river mouth, a detailed sampling was planned and carried out in the second phase. Surface samples were collected at different offshore (up to Adyar, 30.1.17, 17.2.17 & 20.2.17) and shore (coastal) locations (up to Kalpakkam on 1. 2. 17, 8.2.17, 14.2.17, 17.2.17, 22.2.17 & 1.3.17) and analysed. Pre spill water quality data collected on 27.01.2017 were used as the benchmark for a comparison. 38 offshore samples and 34 coastal samples were collected as a part of the second phase of the water quality data collection (Table 2).

The parameters analyzed are atmospheric (AT) and sea surface temperature (SST), salinity, dissolved oxygen (DO), Total petroleum hydrocarbons (TPH), nutrients such as Phosphate (PO_4), silicate (SiO_3), Nitrate (NO_3), Nitrite (NO_2) and ammonia (NH_4). The details of the sampling locations are given in Table-2. The water quality parameters are analysed following standard parameters and discussed under respective sections. In the figures, the data are discrete observations, connected with lines to represent the trend.

Table 2: Details of sampling locations*

Sampling Date	Name of Location/ Code	Source	Latitude (N)	Longitude (E)	Depth (m)	Distance from shore (km)
30.01.17	Ennore (EN- 12)	EN-O	13^0 14.709'	$80^0$21.283'	12	2
17.02.17	Ennore (EN- 12)	EN-O	$13^0$14.991'	$80^0$20.847'	12	0.9
17.02.17	Ennore (EN- 22)	EN-O	$13^0$14.964'	$80^0$21.164'	22	1.5
30.01.17	KasiKoilKuppam (KKK-5)	KKK-O	$13^0$10.538'	$80^0$19.144'	5	0.5
17.02.17	Kassikoilkuppam(KKK-5)	KKK-O	$13^0$10.945'	$80^0$19.250'	5	0.5
17.02.17	Kassikoilkuppam(KKK- 8)	KKK-O	$13^0$10.887'	$80^0$19.341'	8	0.7
17.02.17	Kassikoilkuppam(KKK-21)	KKK-O	$13^0$10.841'	$80^0$20.108'	21	2

17.02.17	Kassikoilkuppam(KKK-22)	KKK-O	$13^{0}10.780'$	$80^{0}20.380'$	22	2.2
30.01.17	Tiruchanakuppam (TRK-5)	TRK-O	$13^{0}08.819'$	$80^{0}18.439'$	5	0.5
17.02.17	Tiruchinakuppam(TRK-8)	TRK-O	$13^{0}08.775'$	$80^{0}18.595'$	8	0.8
30.01.17	Tiruvottiyur (TVO-5)	TVO-O	13^{0} 08.437'	$80^{0}18.230'$	5	0.5
17.02.17	Tiruvotiyur (TVO- 5)	TVO-O	$13^{0}08.538'$	$80^{0}18.290'$	5	0.5
17.02.17	Tiruvotiyur (TVO- 8)	TVO-O	$13^{0}08.610'$	$80^{0}18.790'$	8	1
17.02.17	Tiruvotiyur (TVO- 12)	TVO-O	$13^{0}08.500'$	$80^{0}18.888'$	12	1.5
30.01.17	Fishing harbour (FH-8)	FH-O	$13^{0}07.970'$	$80^{0}18.352'$	8	0.85
17.02.17	Fishing harbour(FH- 8)	FH-O	$13^{0}07.970'$	$80^{0}18.352'$	8	0.85
17.02.17	Fishing harbour(FH-22)	FH-O	$13^{0}07.448'$	$80^{0}19.258'$	22	1.9
30.01.17	Chennai-Port (PORT-16)	PORT-O	$13^{0}06.500'$	$80^{0}18.757'$	16	1.4
20.02.17	Chennai port (CHP- 15)	PORT-O	$13^{0}06.321'$	$80^{0}19.262'$	15	2.2
20.02.17	Chennai port (CHP- 8)	PORT-O	$13^{0}05.932'$	$80^{0}18.493'$	8	0.3
30.01.17	Cooum-mouth (CUM-8)	CUM-O	$13^{0}04.096'$	$80^{0}17.839'$	8	0.5
20.02.17	Cooum(CUM- 4)	CUM-O	$13^{0}04.059'$	$80^{0}17.576'$	4	0.3
20.02.17	Cooum(CUM- 10)	CUM-O	$13^{0}04.130'$	$80^{0}17.914'$	10	0.9
20.02.17	Cooum(CUM- 15)	CUM-O	$13^{0}04.073'$	$80^{0}18.123'$	15	1.2
30.01.17	Marina Lighthouse(MA-6)	MA-O	$13^{0}02.507'$	$80^{0}17.120'$	6	0.5
20.02.17	Marina (MA - 15)	MA-O	$13^{0}02.363'$	$80^{0}17.954'$	15	1.9
20.02.17	Marina (MA - 8)	MA-O	$13^{0}02.349'$	$80^{0}17.254'$	8	0.7
20.02.17	Marina (MA - 4)	MA-O	$13^{0}02.336'$	$80^{0}16.993'$	4	0.3
30.01.17	Adyar Mouth (AD-6)	AD-O	$13^{0}00.810'$	$80^{0}16.929'$	6	0.5
20.02.17	Adyar Mouth (AD- 4)	AD-O	$13^{0}00.728'$	$80^{0}16.952'$	4	0.5
20.02.17	Adyar Mouth (AD- 8)	AD-O	$13^{0}00.705'$	$80^{0}17.225'$	8	1.1
20.02.17	Adyar Mouth (AD- 15)	AD-O	$13^{0}00.608'$	$80^{0}17.984'$	15	2
20.02.17	Elliot (EL- 4)	EL-O	$12^{0}59.467'$	$80^{0}16.436'$	4	0.3
20.02.17	Elliot (EL- 8)	EL-O	$12^{0}59.391'$	$80^{0}16.700'$	8	0.8
20.02.17	Elliot (EL- 15)	EL-O	$12^{0}59.519'$	$80^{0}17.725'$	15	2.5
20.02.17	Thiruvanmiyur(TH- 4)	TH-O	$12^{0}58.465'$	$80^{0}16.204'$	4	0.3
20.02.17	Thiruvanmiyur(TH- 8)	TH-O	$12^{0}58.531'$	$80^{0}16.491'$	8	0.8
20.02.17	Thiruvanmiyur(TH- 15)	TH-O	$12^{0}58.413'$	$80^{0}17.241'$	15	2.2
01.02.17	Ennore -S	EN-S	$13^{0}13.391'$	$80^{0}19.705'$	Beach	0
08.02.17	Ennore -S	EN-S	$13^{0}13.391'$	$80^{0}19.705'$	Beach	0
17.02.17	Ennore-S	EN-S	$13^{0}13.391'$	$80^{0}19.705'$	Beach	0
01.02.17	KasiKoilKuppam -S	KKK-S	$13^{0}10.420'$	$80^{0}18.775'$	Beach	0
08.02.17	KasiKoilKuppam -S	KKK-S	$13^{0}10.420'$	$80^{0}18.775'$	Beach	0
17.02.17	KasiKoilKuppam -S	KKK-S	$13^{0}10.420'$	$80^{0}18.775'$	Beach	0
01.02.17	Fishing Harbour -S	FH-S	$13^{0}08.083'$	$80^{0}17.892'$	Beach	0
08.02.17	Fishing Harbour -S	FH-S	$13^{0}08.083'$	$80^{0}17.892'$	Beach	0
17.02.17	Fishing Harbour -S	FH-S	$13^{0}08.083'$	$80^{0}17.892'$	Beach	0
01.02.17	Cooum-S	CUM-S	$13^{0}03.944'$	$80^{0}17.373'$	Beach	0
08.02.17	Cooum-S	CUM-S	$13^{0}03.944'$	$80^{0}17.373'$	Beach	0
17.02.17	Cooum-S	CUM-S	$13^{0}03.944'$	$80^{0}17.373'$	Beach	0
01.02.17	Marina Light house-S	MA-S	$13^{0}02.338'$	$80^{0}16.883'$	Beach	0
08.02.17	Marina Light house-S	MA-S	$13^{0}02.338'$	$80^{0}16.883'$	Beach	0
17.02.17	Marina Light house-S	MA-S	$13^{0}02.338'$	$80^{0}16.883'$	Beach	0
01.02.17	Adyar-S	AD-S	$13^{0}00.675'$	$80^{0}16.633'$	Beach	0
08.02.17	Adyar-S	AD-S	$13^{0}00.675'$	$80^{0}16.633'$	Beach	0

14.02.17	Adyar-S	AD-S	13^{0}00.675'	80^{0}16.633'	Beach	0
17.02.17	Adyar-S	AD-S	13^{0}00.675'	80^{0}16.633'	Beach	0
01.02.17	Elliot-S	EL-S	13^{0}00.129'	80^{0}16.417'	Beach	0
08.02.17	Elliot-S	EL-S	13^{0}00.129'	80^{0}16.417'	Beach	0
14.02.17	Elliot-S	EL-S	13^{0}00.129'	80^{0}16.417'	Beach	0
17.02.17	Elliot-S	EL-S	13^{0}00.129'	80^{0}16.417'	Beach	0
01.02.17	Thiruvanmiyur-S	TH-S	12^{0}58.609'	80^{0}16.050'	Beach	0
08.02.17	Thiruvanmiyur-S	TH-S	12^{0}58.609'	80^{0}16.050'	Beach	0
14.02.17	Thiruvanmiyur-S	TH-S	12^{0}58.609'	80^{0}16.050'	Beach	0
17.02.17	Thiruvanmiyur-S	TH-S	12^{0}58.609'	80^{0}16.050'	Beach	0
14.02.17	Uthandi-S	UT-S	12^{0}52.493'	80^{0}15.090'	Beach	0
17.02.17	Uthandi-S	UT-S	12^{0}52.493'	80^{0}15.090'	Beach	0
17.02.17	Muthukadu-S	MUK-S	12^{0}48.131'	80^{0}14.948'	Beach	0
14.02.17	Kovalam-S	KOV-S	12^{0}47.415'	80^{0}15.206'	Beach	0
17.02.17	Kovalam-S	KOV-S	12^{0}47.415'	80^{0}15.206'	Beach	0
14.02.17	Vedanamali-S	VN-S	12^{0}43.777'	80^{0}14.225'	Beach	0
14.02.17	Mahabalipuram-S	MH-S	12^{0}37.550'	80^{0}11.986'	Beach	0
14.02.17	Kokilamedu-S	KOM-S	12^{0}35.488'	80^{0}11.283'	Beach	0
14.02.17	Kalpakkam-S	KPK-S	12^{0}31.298'	80^{0}09.815'	Beach	0

*Code is assigned with a number indicating the depth at that point; Source: O indicates offshore, S denotes nearshore/ Coastal/ beach locations. Water quality data refers to surface water only.

3.1. Total Petroleum hydrocarbons (TPH)

Petroleum hydrocarbons are the organic input and most of them are toxic, mutagenic, and carcinogenic and causes serious environmental problems due to its persistence in the environment and bioaccumulation. Total petroleum hydrocarbons (TPH) is a mixture of hydrocarbons available in crude oil, can contaminate the environment.

As it is difficult to measure each of the compounds separately such as hexane, benzene, toluene, xylenes, naphthalene and fluorene, other constituents of gasoline, TPH is considered as an index that can be used to assess the immediate impact on the environment.

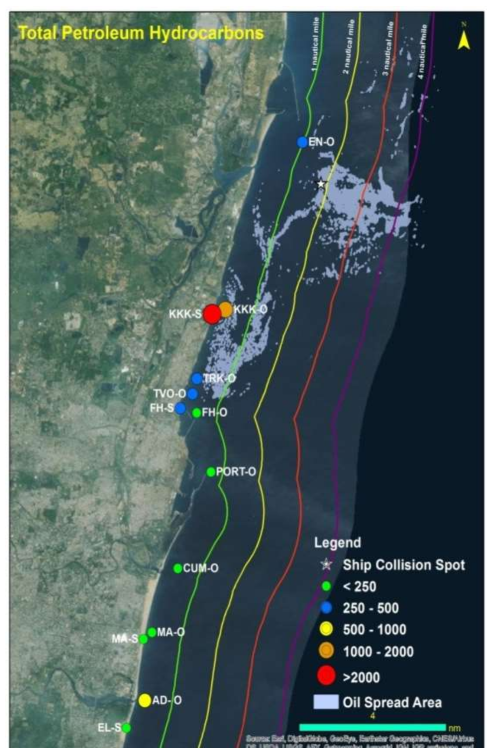
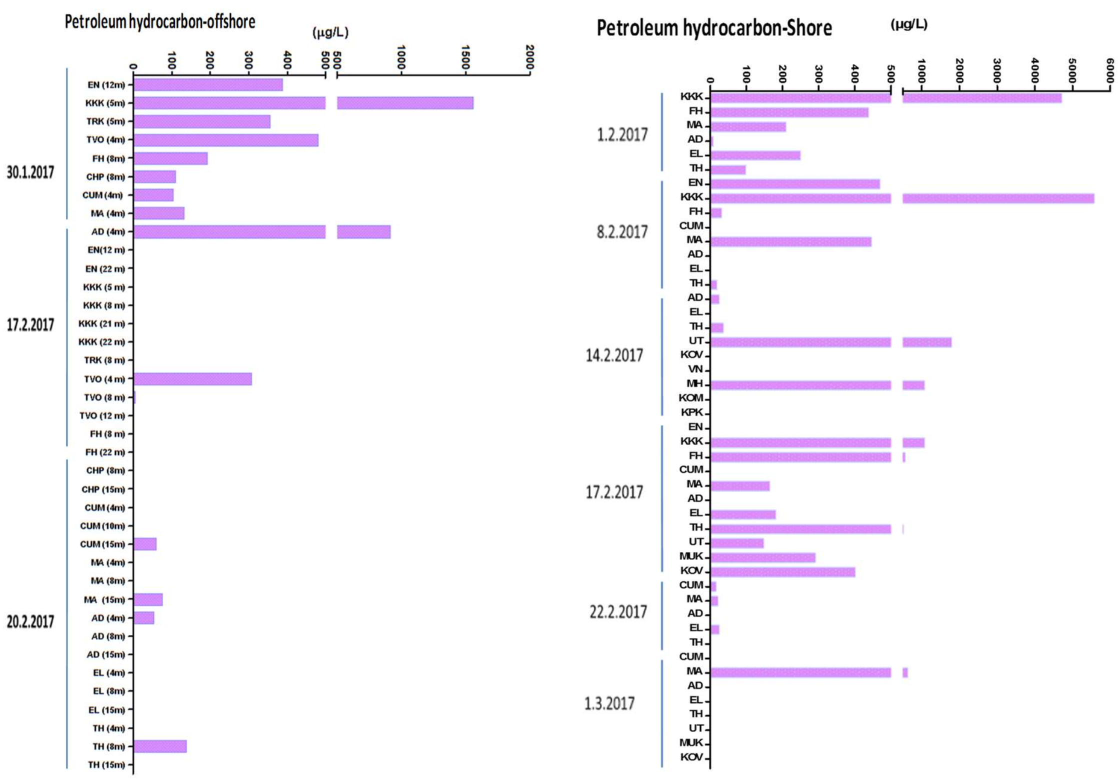


Figure: 16 TPH distribution on 30 Jan' 17

During our observation, along the shore (coastal) stations, highest value (5573 µg/l) of TPH were noticed at Kasikoilkuppam on 8.2.2017 (Figure 16); relatively, higher values at other beach locations are also observed till 17.2.2017 (Figure 17B). In the offshore waters, maximum value (1560 µg/l) was observed on 30.1.2017 at Kasikoilkuppam followed by Adyar (962 µg/l) on 17.2.2017 (Figure 17A). Thereafter, TPH was substantially declined in offshore region and by 20.02.2017, TPH was almost nil except at river mouths. The background value for Chennai coast in the pre oil spill scenario was 10-20 µg/l. No prominent signature of TPH in the offshore water and high values in the beach stations indicate that, most of the oil had reached to the south Chennai coast (Mahabalipuram) during 14th to 17th February 2017.



A B

Figure 17: Distribution of TPH in the Chennai coastal waters (A) offshore ; (B) shore (coast)

3.2. Distribution of volatile organic compounds (VOC's)

Volatile organic compounds (VOC's) are the compounds with minimum vapour pressure of 0.13 kPa at standard temperature and pressure (293 K, 101 kPa) excluding CO, CO_2, organometallic compounds and organic acids. VOCs are lipophilic and less reactive and the main sources are from dry-cleaning industries and physical spill of crude oil during transportation etc. The VOC concentrations measured for different locations from surface and bottom waters on 17th and 20th February 2017, varied from non-detectable range to 211µM (Figure 18). The mean VOC concentrations at the surface waters (66 µM) was lower than the bottom waters (83 µM) and particularly near-shore regions (<10m depth) were high. Mostly the mean VOC concentrations were found to be high at off Elliot, followed by off Kassikoilkuppam, off Chennai port, and off Thiruvanmiyur regions. VOC concentrations were not detected off Adyar and Cooum, Thiruvanmiyur, Kassikoilkuppam.

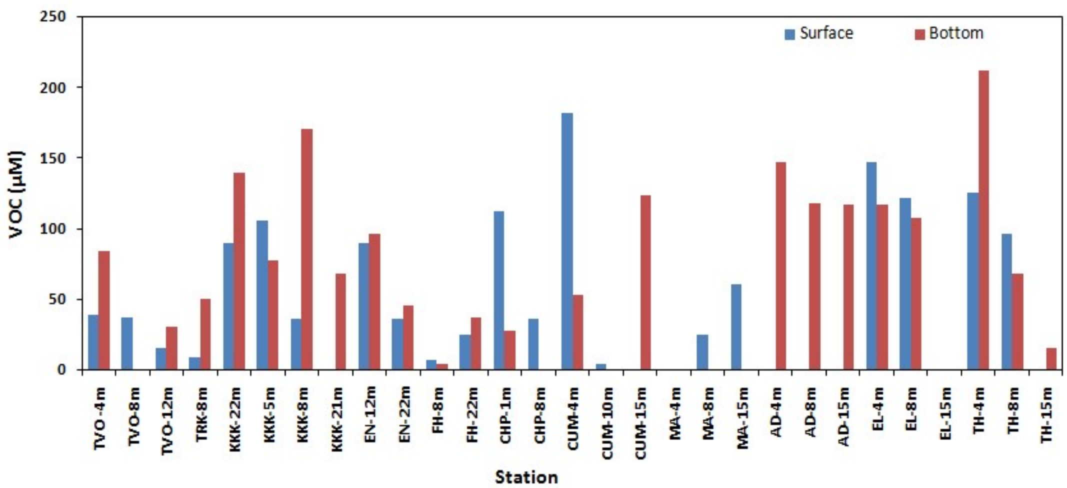


Figure 18: Spatial and vertical distribution of VOC's along the coastal waters of Chennai

3.3 Air temperature (AT) and Sea surface temperature (SST)

On 30.01.2017, the mean SST was 25.6°C and salinity was 30.3 for Ennore offshore waters and the specific gravity computed was 1021kg/m^3.

The air and sea surface temperature were mostly recorded during 9AM to 5 PM of the day, using a mercury thermometer and their spatio-temporal variations are shown in figure 19. AT during the sampling period varied from 24 to 32 °C. Maximum air temperature was recorded at TRK on 30.01.17. At Shore stations AT ranged from 24 to 30°C (mean 27.3°C). On an average, AT and SST followed the same trend; AT exceeded SST for locations measured before noon, mostly on the north of the Chennai harbour, whereas, for stations south of harbour measured after 1PM. Comparatively, wider variation in AT was recorded in the offshore waters in and around the oil slick region on 30.01.17.

SST ranged from 24.5 to 28.0 °C with an average of 25.8 °C at offshore stations and from 24 to 28.6°C for coastal stations with an average of 26.5°C (Figure 19 b &d). At offshore stations higher values were recorded at TRK (5m) on 30.01.17 and at EN (12m) and TRK (8m) on 17.02.17 (Figure 19 a & c). The variation between AT and SST was almost about 5˚ C found at Tiruchanakuppam (TRK-O) in the area where most of the oil slick had accumulated. Higher SST at these locations is probably due to the presence of oil film on the surface water.

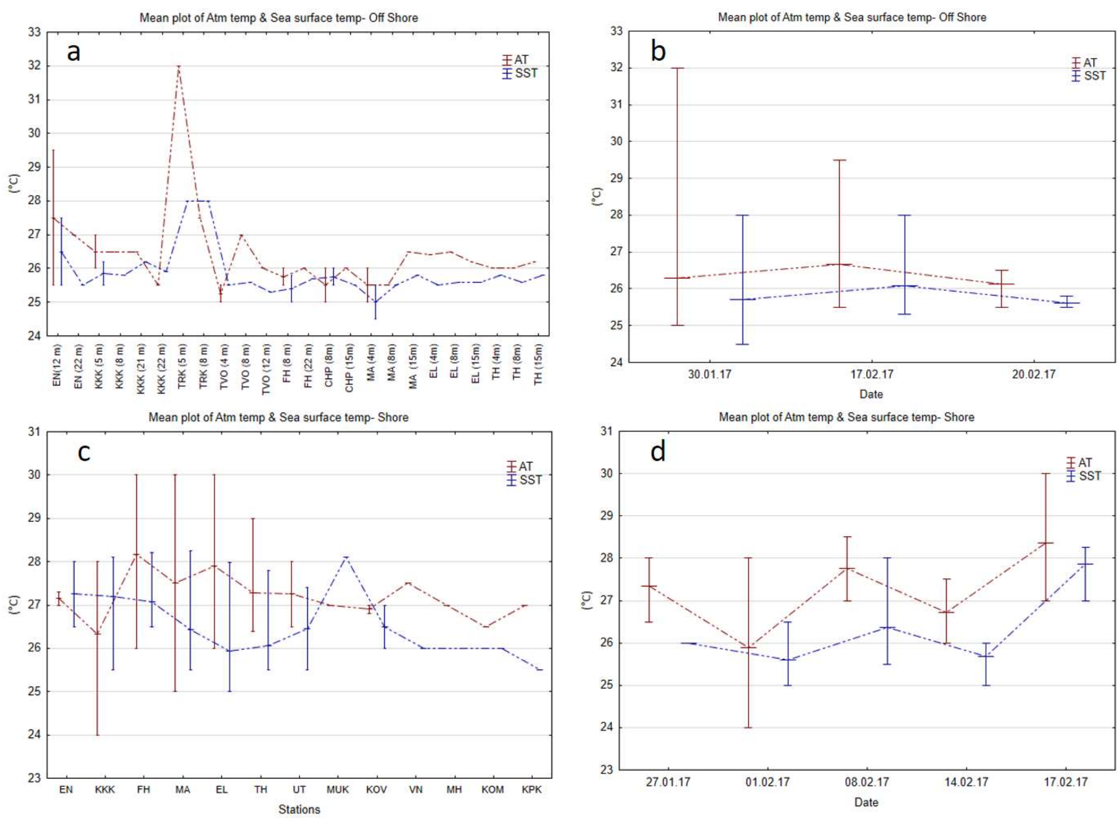


Figure 19: AT and SST variation at different stations as measured

3.4 Water quality parameters

3.4.a Salinity

Salinity is defined as the total dissolved salt content per unit volume of water. Coastal water salinity is generally regulated by freshwater inflow, ground water discharge, evaporation and precipitation. Salinity ranged from 27.1 to 30.9 with an average of 30.3 (Figure 20 a-d). Average salinity of 32.6 was recorded from the offshore stations with a variation of 27.1 to 33.9. In the coastal stations salinity ranged from 24.68 to 35.37 with an average of 31.96. As expected, low salinity was observed near river mouths at coastal and offshore waters.

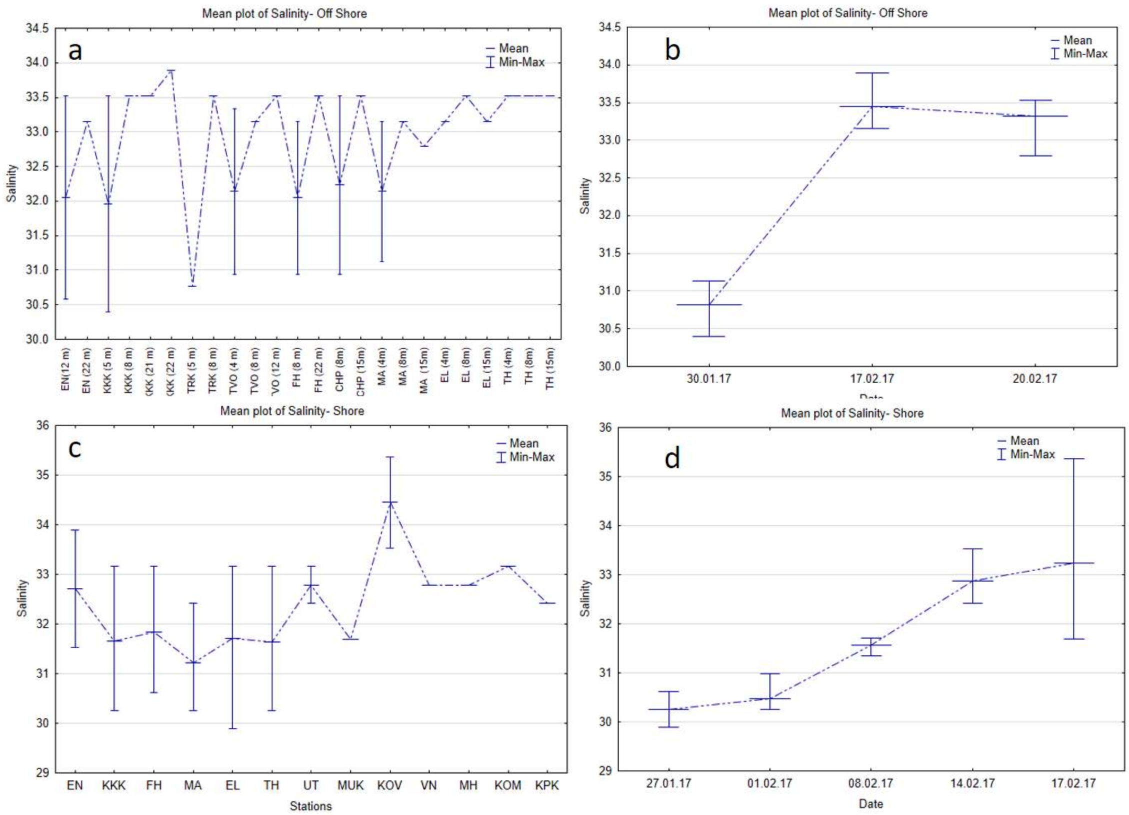


Figure 20: Spatio-temporal variation of Salinity off Chennai coastal waters

3.4.b. pH

pH is a measure of the hydrogen ion concentration that determines the acidity or alkalinity of water. Seawater with pH > 7 is alkaline or basic and pH < 7 is acidic and if seawater becomes acidic or alkaline, it is not suitable for marine life. pH in seawater is regulated by change in carbon dioxide, temperature, salinity along with alkalinity. Biological activities such as decomposition by microbes and high phytoplankton density may cause significant pH fluctuation.

The average pH recorded for all the offshore stations was 7.79 and ranged from 7.22 to 7.95 (Figure 21a & b). In the offshore locations, the average pH was 7.22 on 30.01.17, 7.91 on 17.02.17 and 7.78 on 20.02.17. At shore stations pH varied from 7.35 to 8.00 with an average of 7.77 and minimum was recorded from AD on 14.02.17 (Figure 21 c & d).

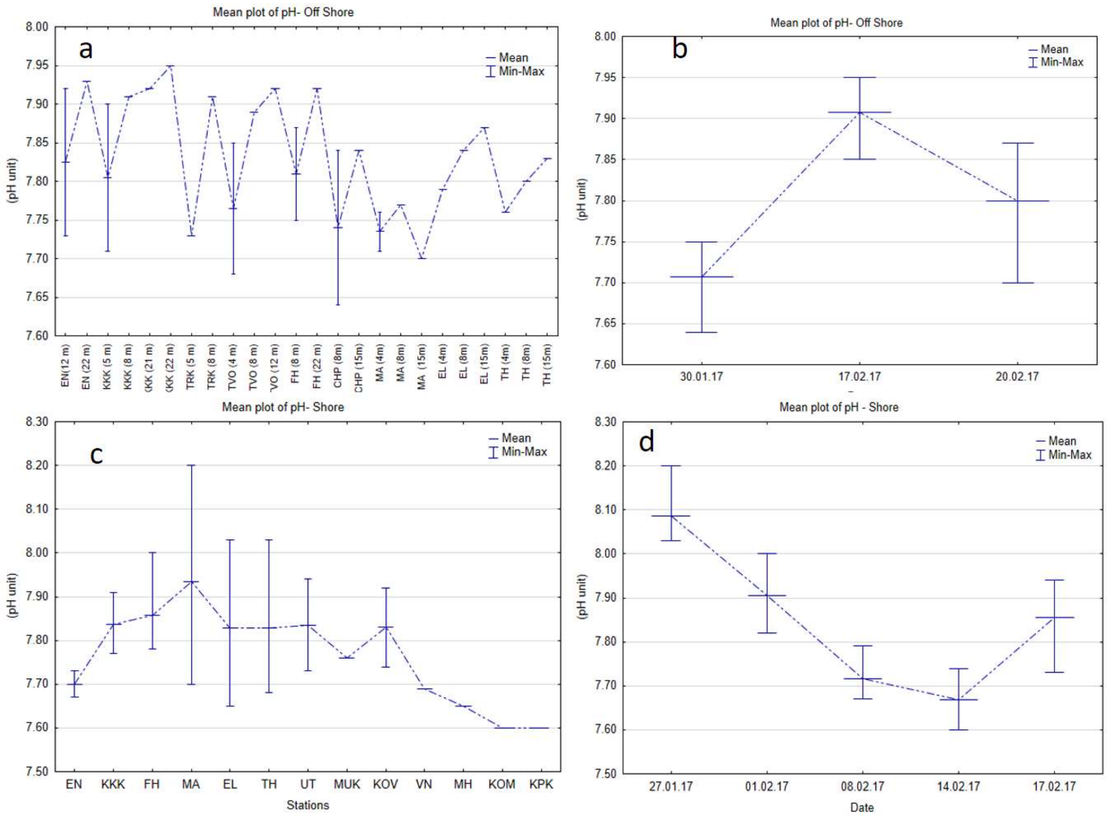


Figure 21: Spatio-temporal variation of pH in the coastal waters of Chennai.

3.4.c. Dissolved Oxygen (DO)

DO is an essential component and considered as one of the most important parameters for water quality assessment. As per Central Pollution Control Board (CPCB) guidelines, DO level should be in the range of 4 to 5 mg/L and not below 3.5 mg/L for aquatic life.

On an average, there is a slight decline of the order of 1mg/L in DO values in post oil spill event. On 30.01.17, the mean DO was 6.85 and ranged from 3.33 to 7.74 mg/L at offshore stations. Minimum (3.33 mg/L) was recorded at CUM (4m), might be attributed to the sewage discharge through Cooum river (Figure 22a & b). On 17.02.17, low DO (3.89 mg/L) was recorded at EN (12m) and 5.56 mg/L from EN (22m), in and around the oil slick region and the average DO in offshore waters was 6.84 mg/L and ranged from 3.89 to 7.71 mg/L. On 20.02.17, DO varied from 6.33 to 7.71 mg/L with an average of 7.10 mg/L and minimum DO of 6.33 mg/L was noticed from CUM (4m). At shore stations DO varied from 5.87 to 7.98 mg/L with an average of 7.09 mg/L. Lowest DO at shore was recorded from AD on 08.02.17 which may be due to organic load and decomposition processes in the Adyar water (Figure 22c &d).

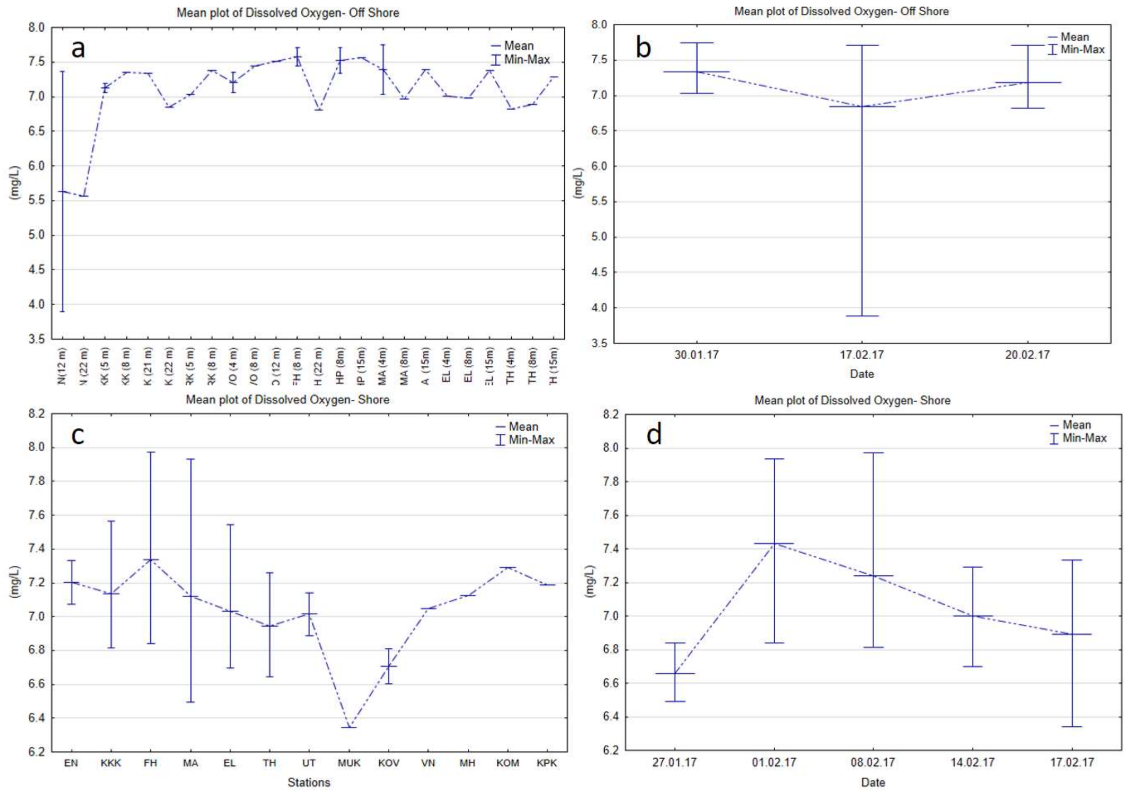


Figure 22: Variation of DO in the offshore and shore (coastal) stations

3.4.d. Nutrients

1. Nitrite (NO_2)

Nitrate (NO_3) and nitrite (NO_2) are essential nitrogen sources for phytoplankton growth and reproduction. In offshore waters (30.01.17), nitrite ranged from 0.33 to 0.55 µM (mean 0.43 µM) and the maximum value was recorded near fishing harbour (FH-8), indicating biological oxidation of ammonia by microbes through nitrification process in the water column (Figure 23a & b). On 17.02.17, nitrite ranged from 0.12 to 0.79 µM (mean 0.41 µM) and maximum value was recorded from TRK (8m) and FH (8m). On 20.02.17, nitrite concentration measured from fishing harbour to Thiruvanmiyur ranged from 0.19 to 2.67 µM (mean 0.94 µM) and maximum value recorded at 8 meters depth (TH8). In coastal waters, it ranged from 0.05 to 9.07 µM (mean 0.93 µM) and maximum value was observed at fishing harbour on 17.02.17 (Figure 23c & d).

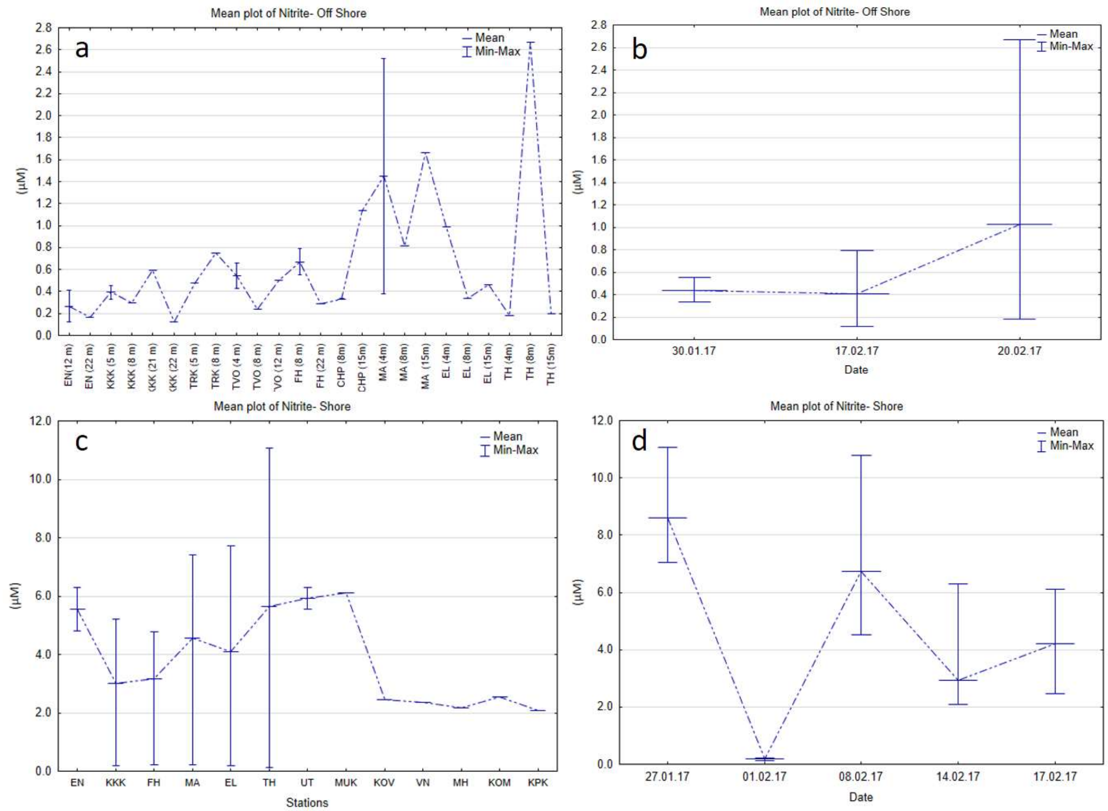


Figure 23: Nitrite variation recorded in the Offshore and coastal stations

2. Nitrate (NO_3)

Nitrate varied from 0.51 to 4.39 µM (mean 2.58 µM) with maximum value recorded from KKK (5m) on 30.01.17. It showed an increment on 17.02.17, with an average of 3.89 µM and ranged from 2.25 to 6.87 µM and maximum value was recorded from TVO (4m) (Figure 24a & b). Usually, high nitrate concentration infers active nitrification process by microbes and recycling of nitrogen. On 20.02.17, nitrate value ranged from 0.51 to 4.88 µM (mean 2.73 µM) and maximum value was at 4m depth of Cooum. Elevated values of nitrate at offshore water indicates the influx of nitrogen through sewage brought by Cooum river. In shore waters nitrate ranged from 0.12 to 10.79 µM with an average of 3.59 µM and maximum value was recorded from TH on 08.02.17. Comparing Pre-spill and post-spill nitrate concentrations at shore stations, the nitrate declined substantially on 1st February 2017 (Figure 24 c & d).

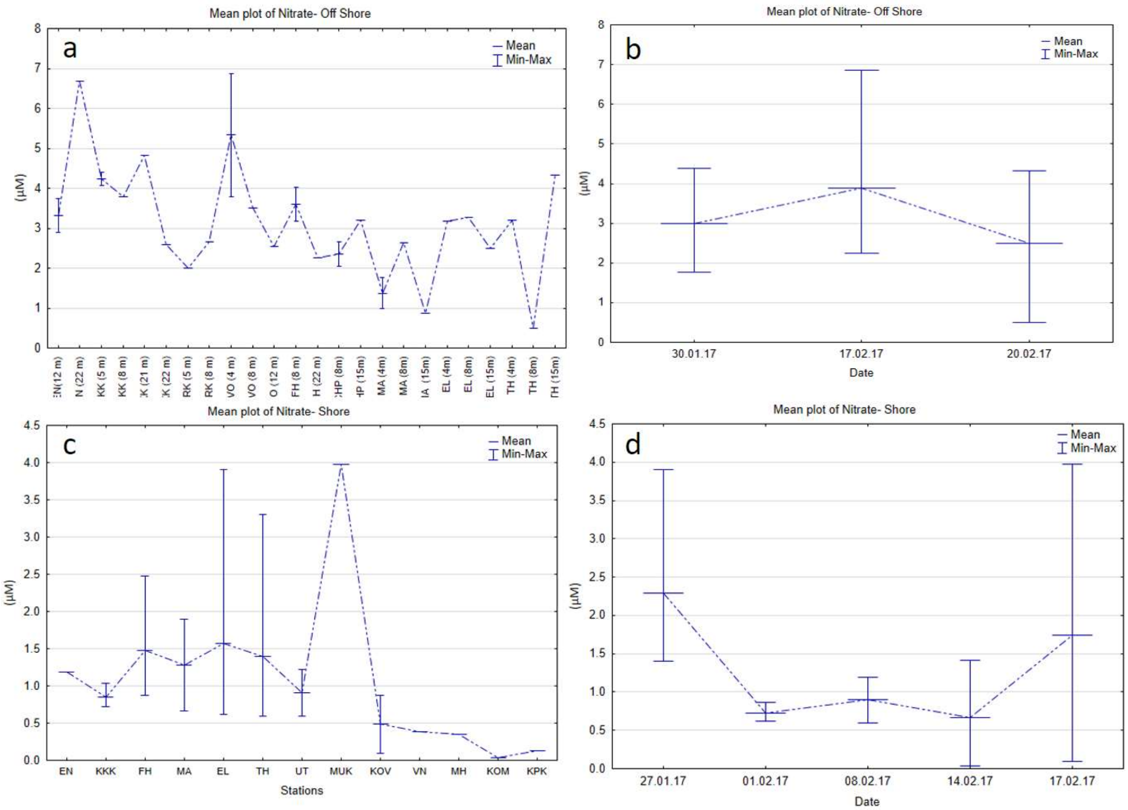


Figure 24: Nitrate variation recorded in the offshore and shore stations

3. Ammonia (NH_4)

Ammonia (NH_4) is a pollution indicator of water quality and is associated with sewage pollution. Average ammonia concentration at offshore water on 30.01.17 was 20.86 µM with a min-max range of 0.53 ~ 152.06 µM (Figure 25a & b) and maximum value was recorded at CUM (4m). It varied from 0.18 to 8.61 µM (mean 2.52 µM) on 17.02.17 with maximum value recorded at TVO (12m). Observed values of 20.02.17, varied from 1.64 to 63.05 (mean 9.54 µM) and maximum value was recorded at CUM (4m). In shore waters, the ammonia ranged from 0.07 to 187.9 with an average of 15.14 µM with highest value recorded at Adyar river mouth on 14.02.17. High ammonia level at shore and offshore water indicates the influence of sewage influx by Cooum and Adyar.

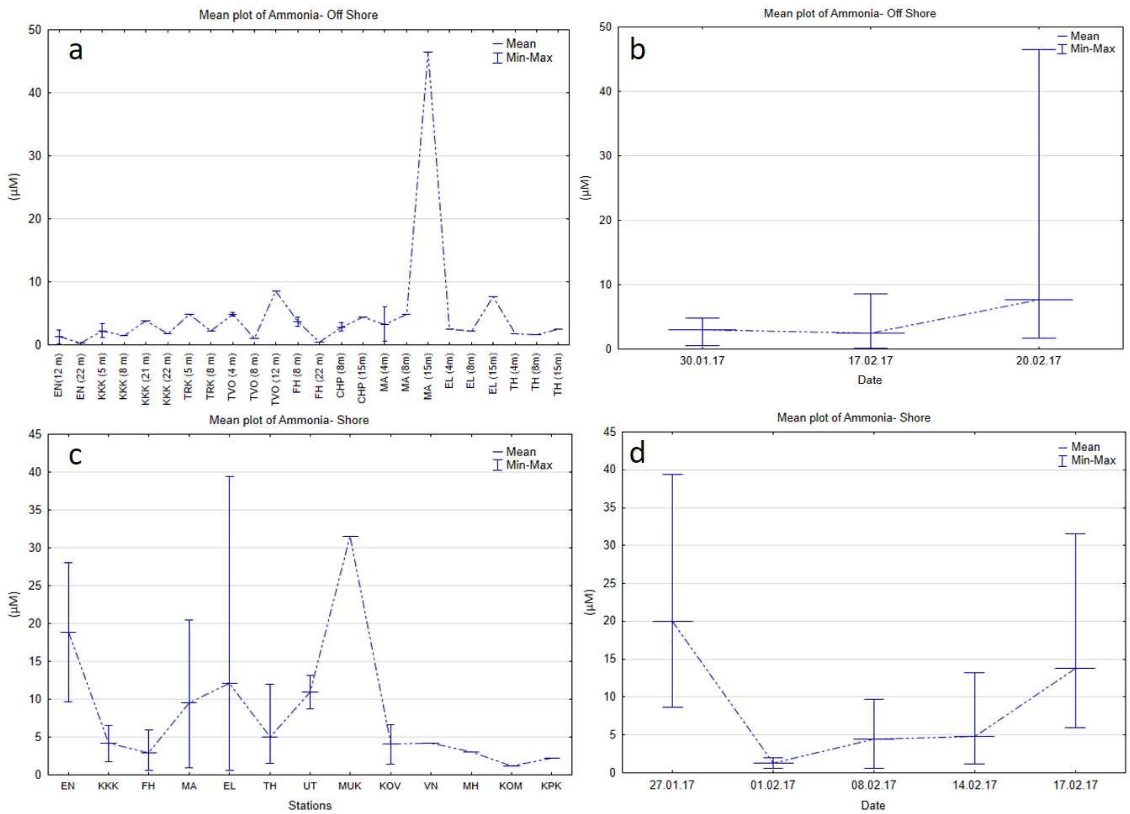


Figure 25: Ammonia variation recorded in the offshore and shore stations

4.Phosphate (PO_4)

Phosphate (PO_4) is an important nutrient for phytoplankton growth and mostly come to the coastal water through sewage. Phosphate in the offshore water on 30.02.17 ranged from 0.28 to 19.62 µM with an average of 2.91 µM (Figure 26a & b) and highest concentration of phosphate was detected from CUM (4m) indicating the influence of sewage laden Cooum water extending towards off shore. Later on 17.02.17 it ranged from 0.22 to 1.65 µM with an average of 0.64 µM and maximum value was detected from TVO (4m) which may attributed to recycling of this nutrient as a result of decomposition and mineralization in the water column by microbes. Further, on 20.02.17, the average phosphate was 0.74 and ranged from 0.07 to 3.28 µM, maximum value was recorded from CUM (4m). At shore stations phosphate ranged from 0.04 to 25.14 µM (mean 1.96 µM) and maximum was recorded from AD on 14.02.17 (Figure 26 c & d).

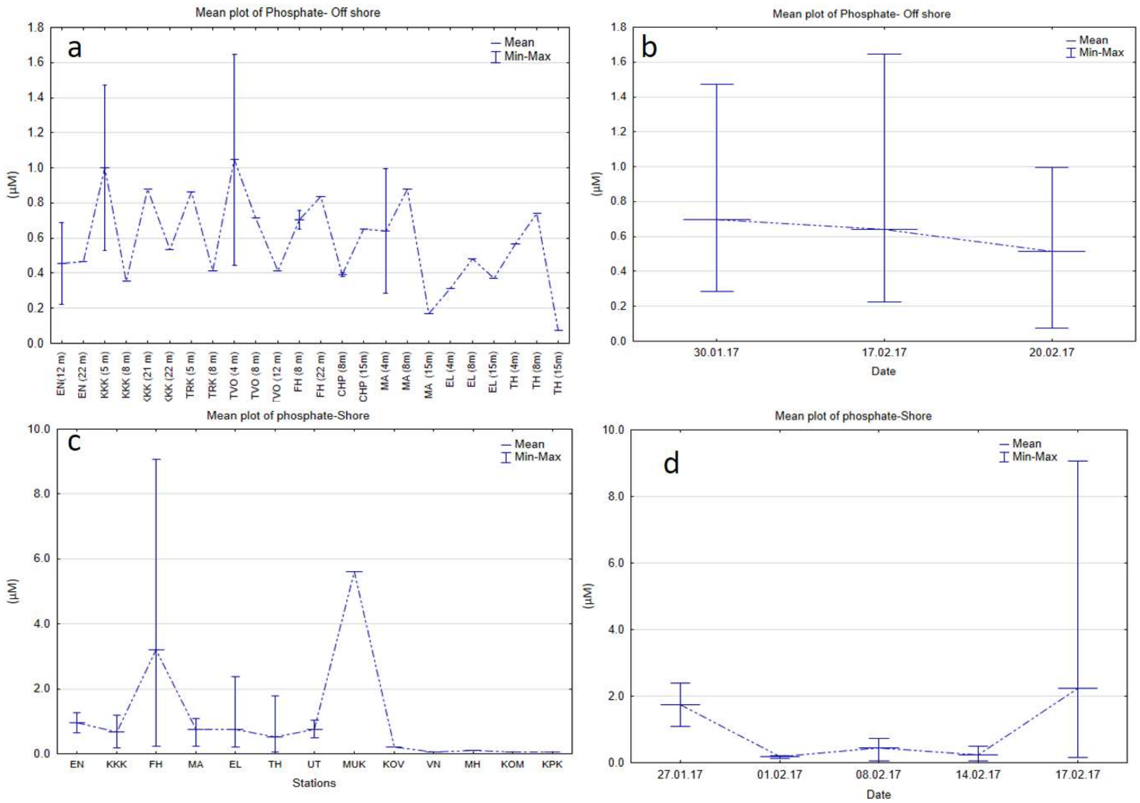


Figure 26: Phosphate variation recorded in the offshore and shore

5. Silicate (SiO_4)

Silicate (SiO_4) is particularly essential for diatoms, a major primary producer in the coastal water. Silicate measured on 30.01.17 for the offshore water ranged from 6.16 to 90.47 µM (mean 24.98. µM) with maximum value recorded at CUM-4m (Figure 27a & b). There was a sharp decline in silicate value measured on 17.02.17, varying from 5.23 to 9.31 µM with a mean of 7.08 µM (Figure 27c & d). Later on 20.01.17, it ranged from 6.13 to 24.79 (mean 9.36 µM) with maximum concentration was at CUM (4m). On shore stations silicate ranged from 4.59 to 173.63 µM (avg 17.38 µM) and maximum value was recorded at AD on 14.02.17. High values of silicate in shore and offshore near rivers.

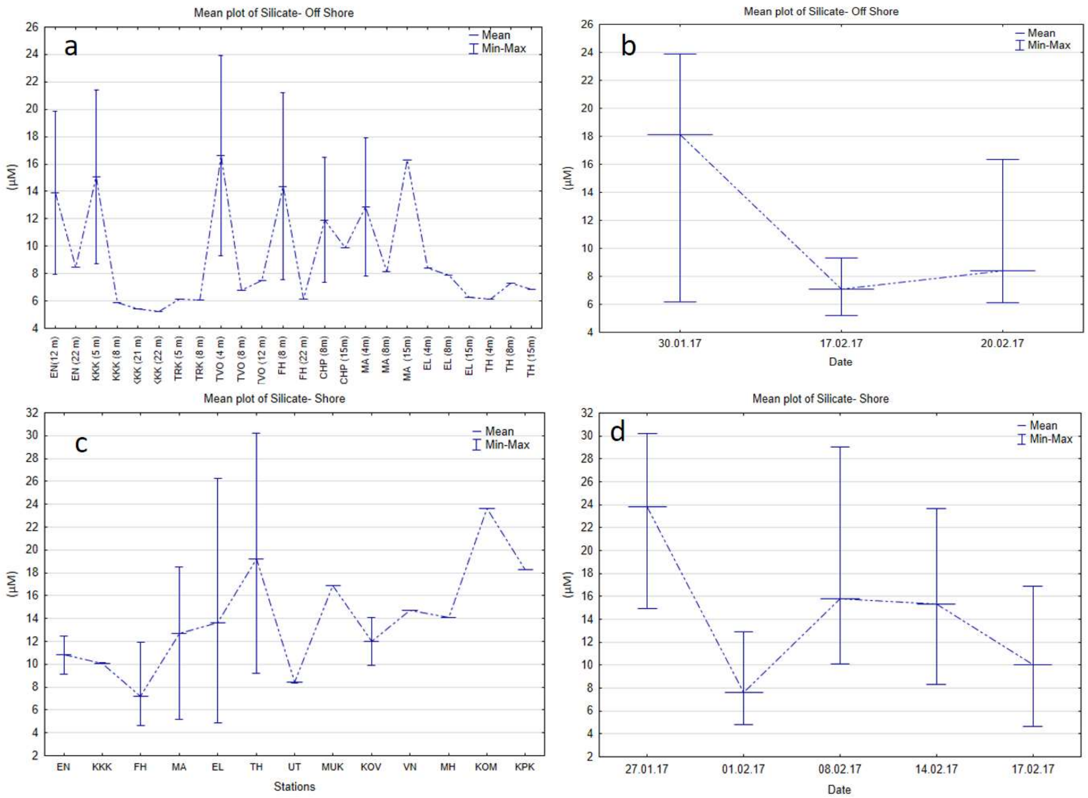
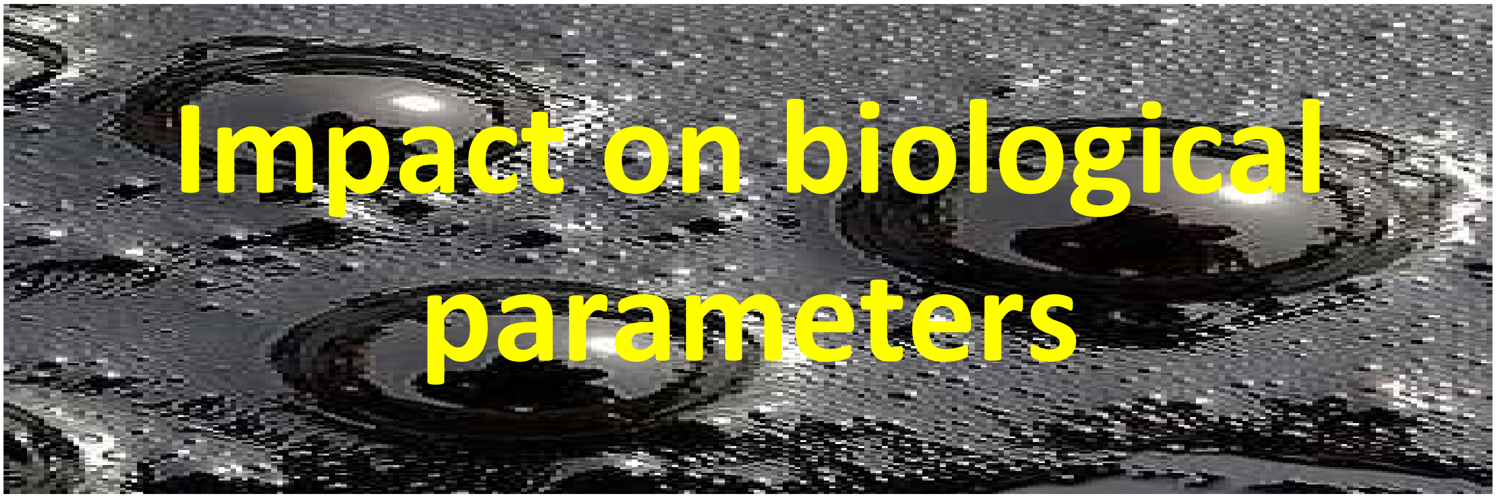


Figure 27: Silicate variation recorded in the offshore and shore stations



Impact on biological parameters

4. Impact of Oil spill on Biological parameters

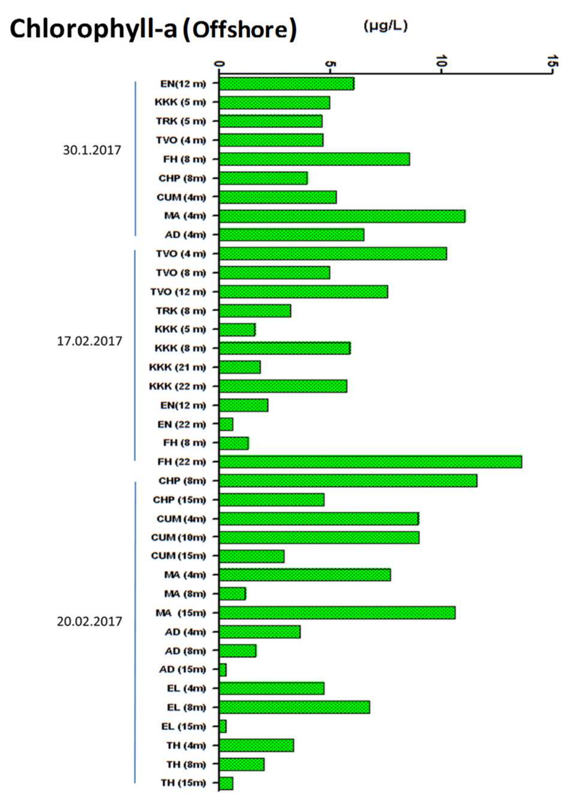
Phytoplankton are the principal primary producers of the aquatic ecosystem. They play a major role in food web dynamics and in the ecology of the marine ecosystems and also in carbon sequestration; therefore changes in their density and distribution pattern can have a significant impact on the entire ecosystem. In an event oil spill, the plankton may be at greater risk instantly than any the other biotic components of the marine ecosystem, due to the proximity to hydrocarbon compounds floating on the sea surface and their general sensitivity to the toxic components in the hydrocarbons.

4.1 Chlorophyll-a

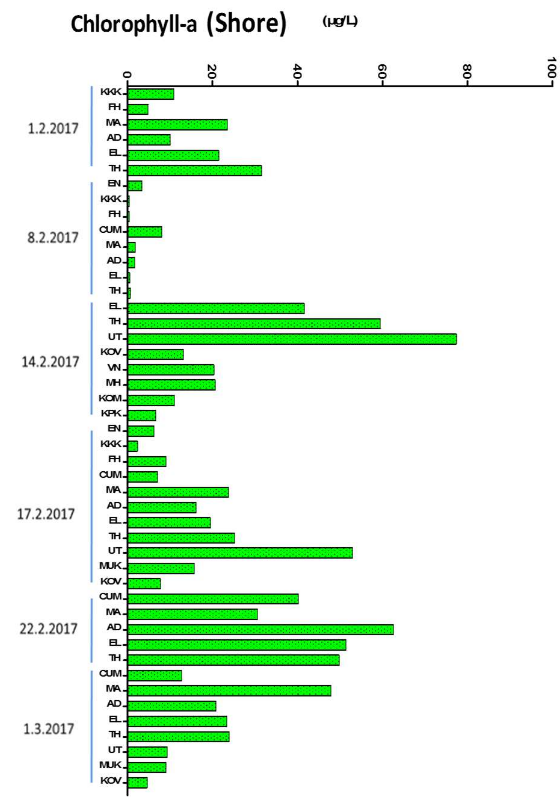
Chlorophyll-a (Chl-a) is the measure of phytoplankton biomass. Chl-a ranged from 1.7 µg/L to 66.38 µg/L and from 4 µg/L to 31.5 µg/L during pre oil spill and post oil spill (30.1.17) respectively. Higher Chl-a concentration was observed during pre oil spill compared to that of post oil spill. From the data it was observed that in all the coastal stations of 08.02.17, Chl-a value has substantially reduced, however revived from 14.02.17 onwards, clearly infers that the oil spill has affected the biomass to some extent (Fig.28).

4.2. Phytoplankton distribution

Abundance and species composition of phytoplankton were analyzed for the offshore 9 representative locations collected on 30th Jan and 17th Feb, 2017 from Ennore to Adyar. The abundance of surface phytoplankton varied from 0.12×10^5 to 16.87×10^5 cells per liter (Figure 29). In temporal scale, phytoplankton abundance did not indicate much variations, however, spatial variations were observed might be more related to natural variability of the ecosystem than oil spill event. Similar pattern was also observed in the Chl-a concentration in offshore water. Abundance and distribution of phytoplankton was found to be dependent on water quality. Among stations, high phytoplankton abundance was noticed at CUM which is nearer to Cooum river mouth due to the high availability of nutrients.



a



b

Figure 28: Distribution of chlorophyll-a in the (a) offshore ; (b) shore water.

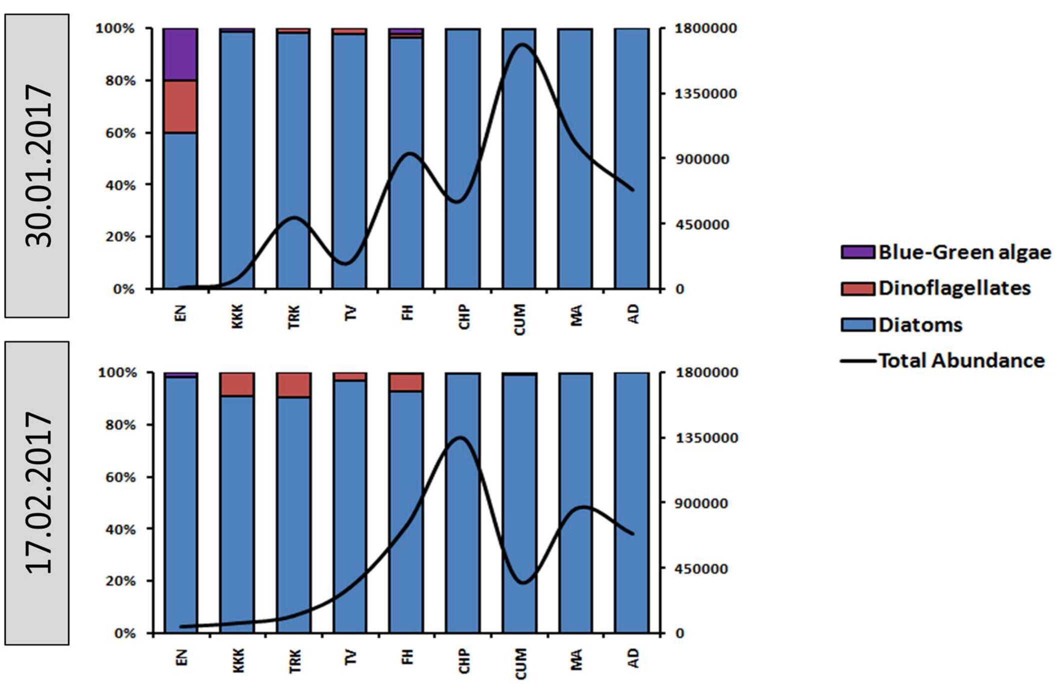


Figure 29: Abundance of phytoplankton in the coastal waters of Chennai.

A total of 45 species belonging to 3 taxonomic classes were enumerated and most of these species (82%) consisted of diatoms (37 species), followed by dinoflagellates (6 species) and blue green algae (2 species) (Figure 30). Diatom *Chaetoceros socialis* was the most dominant species during first phase of sampling on 30th January, 2017; *Skeletonema costatum*, *Chaetoceros currivisetes and Chaetoceros decipiens* were dominant along with dinoflagellates and blue-green algae exhibited lower population on 17th February 2017 (Figure 30).

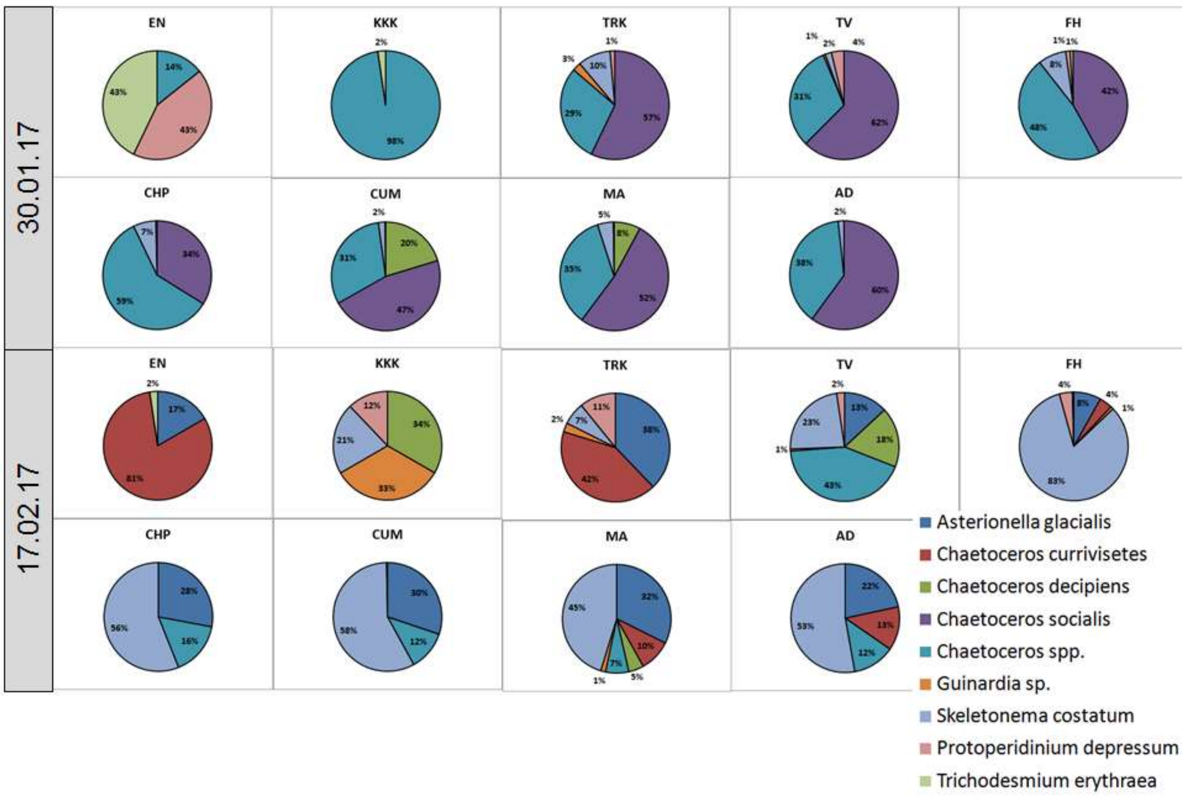


Figure 30: Percentage composition of phytoplankton species

4.2.a Phytoplankton community structure

Phytoplankton diversity varied between 0.5 and 1.2, whereas dominance varied between 0.07 and 0.4 (Figure 31). High dominance was noticed in FH on 17.02.17 due to the high contribution of *Skeletonema costatum.* High diversity has been observed in KKK on 17.02.17.

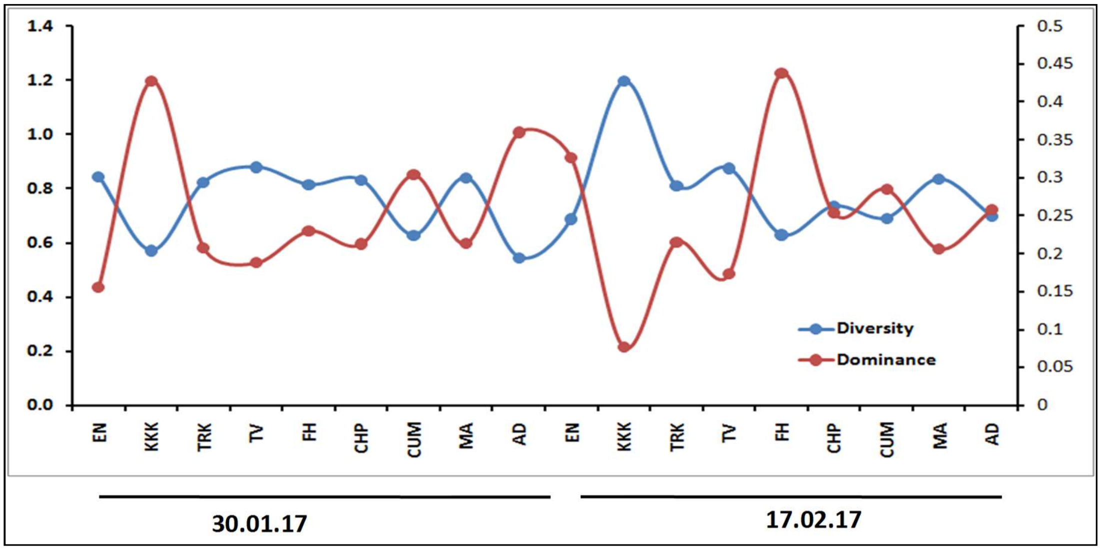


Figure 31: Phytoplankton community and diversity index

No significant pattern in phytoplankton abundance, species composition and community structure (diversity and dominance) was observed. In the present investigation, it is difficult to conclude whether the spill event has created any adverse impact on the distribution and abundance of phytoplankton, especially in a short term.

4.3. Meso-zooplankton

Meso zooplankton samples collected from offshore waters on 17th and 20th February 2017 were analyzed. The biomass ranged from 0.03 to 0.24 ml/m^3 with an average of 0.1 ml/m^3. Biomass was low in shallow waters (4-10m) and higher in deeper waters (12 – 22m; Station Ennore, Kasikoilkuppam and Fishing Harbor). Low biomass in shallow waters could be due to the high wave action and turbidity. The density values varied between 203 ind./m^3 to 3825 ind./m^3 with an average of 1406 ind./m^3 (Figure 32). Density distribution also followed similar pattern of biomass distribution.

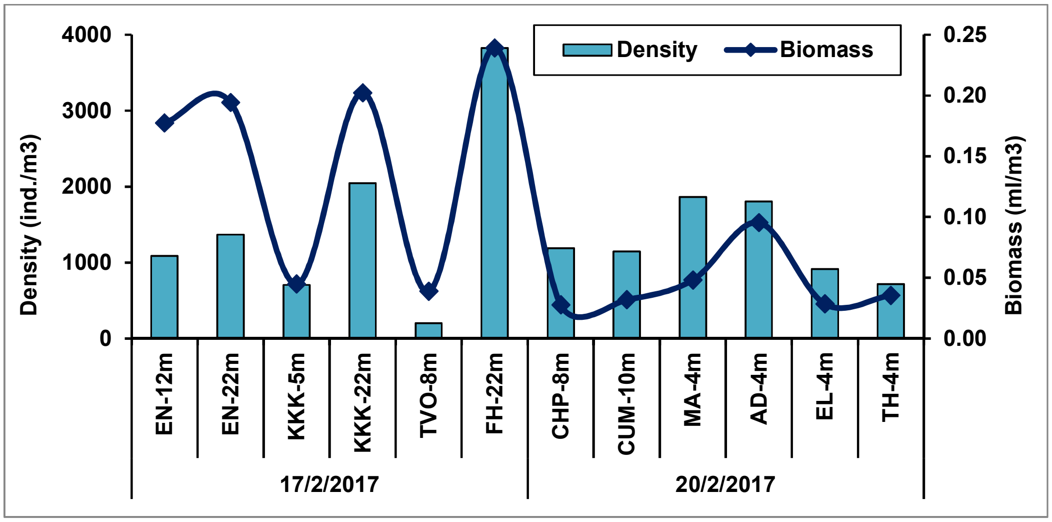


Figure 32: Distribution of zooplankton biomass and density

4.3.a. Faunal composition

Faunal composition of meso-zooplankton was represented by 57 taxa comprising of 15 taxonomic groups, whereas *Acartia danae, Acrocalanus gibber, Nanocalanus minor, Paracalanus parvus, Corycaeus catus, Oithona brevicornis,* copepodite, crustacean nauplii and Lucifer were encountered as common taxa. Copepoda was the most dominant group representing 28 species of calanoids, 5 species of cyclopoids and 2 species of harpacticoids. Copepod density (67.6%) ranged from 120 to 2989 ind./m^3 with an average of 951 ind./m^3. The dominant species were *Nanocalanus minor* (15.1%), *Corycaeus catus* (11.6%), *Acrocalanus gibber* (10.9%), *Euterpina acutifrons* (4.0%), *Acartia danae* (3.5%), *acartia erythraea* (2.0%), *Oithona brevicornis* (2.0%) and *Corycaeus danae* (2.1%). The second dominant group was crustacean larvae (18.7%) which was mainly dominated by crustacean nauplii (14.5%) copepodite (2.0%), barnacle larvae (1.4%) and zoea (0.8%) followed by group lucifer (2.5%), fish eggs and larvae (2.1%), ostracoda (2.0%), mollusca (1.7%), cladocera (1.5%), polychaete (1.1%) and other groups (amphipod, chaetognatha, hydromedusae, siphonophora, larvacea, echinoderm and bryozoan larvae) (< 1%).

4.3.b. Diversity indices

Diversity indices showed spatial variation of mesozooplankton community structure. Shannon's diversity index (H') is widely used for assessing biological diversity in the aquatic environments, which varied from 2.25 to 2.88. The highest diversity was recorded at 22m depth of Kasikoilkuppam and minimum was recorded at 22m depth of Fishing Harbor, whereas, decrease of diversity was noticed mostly in shallow water stations. Pielous evenness index (J') shows how evenly the individuals are distributed among the different taxa which was minimum (0.65) in deeper stations and maximum (0.87) in shallow stations (**Table 3**).

Table 3: Meso-zooplankton biomass, density and diversity indices in the coastal waters of Chennai during February 2017.

Stations	Taxa (Nos.)	Biomass (ml/m^3)	Density (ind./m^3)	Shannon Index (H')	Pielou's Index (J')
EN-12m	31	0.18	1081	2.79	0.81
EN-22m	36	0.19	1370	2.68	0.75
KKK-22m	34	0.04	2071	2.88	0.82
KKK-5m	28	0.20	707	2.79	0.84
TVO-8m	29	0.04	201	2.71	0.81
FH-22m	31	0.24	3830	2.25	0.65
CHP- 8m	24	0.03	1185	2.53	0.80
CUM-10m	25	0.03	1144	2.81	0.87
MA-4m	25	0.05	1860	2.31	0.72
AD-4m	32	0.10	1806	2.74	0.79
EL-4m	25	0.03	918	2.26	0.70
TH-4m	23	0.04	719	2.68	0.85

The meso-zooplankton abundance and the taxonomic groups observed in the present study were compared with earlier reported literature, suggests that the zooplankton communities were not affected by the oil spill incident.

4.4.Intertidal macrofaunal community

Field sampling was carried out on 17th February 2017 from Ennore to Kovalam in the intertidal zone. Sediment for macrobenthos was collected at mid-tide level using a quadrant (25x25 cm). Sediment was collected up to a depth of 5cm and preserved in neutralized 5% formaldehyde-Rose Bengal solution. Sediment samples were collected using a hand held acrylic core (∅ 4.5 cm). Some of the samples were collected near the groin field. The examination of the groin showed epibiota, hence fauna was also collected from the structures by quadrant method (25x25cm).

4.4.a. Beach Macrofaunal community

A total of 16 taxa were enumerated. The macrofaunal abundance ranged from 16 - 4816 ind m^{-2} (Table 4). The highest abundance was recorded at Marina and lowest at Cooum. Oligocheata was the most dominant taxa, except at Marina were the polychaete, *Pisione* sp. dominated (4256 ind m^{-2}). Highest abundance of Oligocheata was recorded at Ennore (3856 ind m^{-2}). The macrofaunal community were represented by juveniles and matured individuals (with eggs). In terms of species number, Polychaeta was the most diverse group with 11 taxa. Marina and Fishing harbour showed the highest species richness with 7 and 6 taxa, respectively. Macrofaunal biomass was highest at Fishing harbour (7.76 g m^{-2}) and lowest at Ennore (1.2 g m^{-2}).

Table 4: Macrofaunal abundance (ind. m^{-2}) and biomass (g m^{-2}) in the study area

	EN	KKK	CUM	FH	AD	MA
Polychaeta						
Pisione sp.	48	0	0	0	0	4256
Pisionidens indica	0	0	0	16	0	48
Glycera sp.	0	0	0	48	0	0
Saccocirrus sp.	0	0	0	0	0	16
Phyllodoce sp.	0	0	0	0	0	48
Scolelepis sp.	0	0	0	0	32	0
Unidentified Maldanidae	0	0	0	16	0	0
Unidentified Nereididae	0	0	0	16	0	0
Unidentified Capitellidae	16	0	0	0	0	0
Unidentified Polygordiidae	0	0	0	0	16	112
Unidentified Spionidae	0	0	0	16	0	0
Oliogochaeta	3856	0	16	0	672	0
Nemertenia	144	0	0	0	96	64
Nematoda	336	0	0	16	112	272
Bivalvia						
Donax sp.	0	0	0	64	0	0
Total	4400	0	16	192	928	4816
Biomass (g m^{-2})	1.2	0	-	7.76	-	0.992

4.4.b. Epibiota associated with the groin

Some of the sampling were made from the groin structures which had algae and few epibiota. In Ennore, the groin had algal growth (green and red algae). Two species of Gastropoda- the periwinkle *Littorina* sp. and the limpet *Cellana* sp. were recorded with density 1241 ind m^{-2} and 1241 ind m^{-2}, respectively. Barnacles spat was also observed at Ennore. At KKK, where the oil was deposited, no epibiota was observed. However, on the other side of the area *Littorina* sp. coated with oil was observed (Figure 33). The density of *Littorina* sp. was 1381 ind m^{-2}. *Nerita* sp. and oyster were the other epibiota observed in this location. The impact of oil spill on the groin community was observed upto the Fishing Harbour. At the Fishing harbor, oysters were the only fauna observed on the groins; however the shells were completely coated with oil (Figure 34).

Figure 33. *Littorina* sp. (a) Ennore (a) and (b) KKK site with oil coating

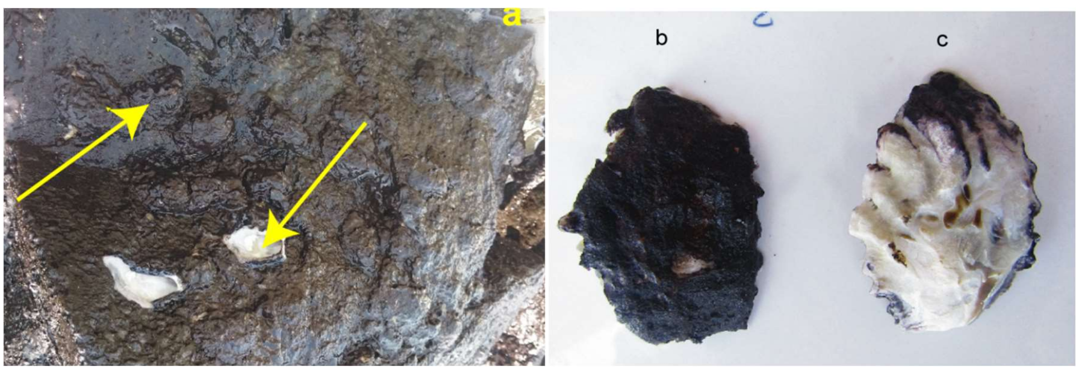


Figure 34: Field photo of a) oyster coated with oil from Fishing harbor, b) oyster coasted with oil and c) oyster without oil

4.5. Macrofauna composition and abundance

A total of 76 macro-invertebrate species from the present study was comprised, the macrofaunal abundance, ranged between 90 and 1080 no/m^2 (539 ±255); and the biomass (wet wt.) 0.25 and 18.9 g/m^2 (4.1 ±4; Figure 35). Polychaeta was dominant macrofaunal group at all the stations and was contributed by (66%), followed by crustaceans (14%), molluscs (4%), minor phyla (10%) and the rest of the group termed as “others” (6%). Although the macrofaunal group composition did not show any major changes. The maximum population density (1080; no/m^2) was observed at Tiruvotiyur (TVO- 4m) and maximum biomass (18.9 g/m^2) at station AD (4m). The higher biomass was largely due to the occurrence of the gastropoda. Among the polychaetes members of the family spionidae contributes to the maximum (13.4%), followed by Cirratulidae (12.6%), Orbiniidae (6.4) and Glyceridae (3.3%) to the total density. The species composition showed that, the macrobenthic community was represented by nine fewer species which contributed by nine dominant species; *Chaetozone setosa*, *Chatozone* sp.1, *Ophelia* sp., *Scoloplos* sp., *Pisione* sp., *Echiurida* sp, *Nemertina*, *Prionospio* sp.1, *Ampelica* sp. and *Urothoe* sp. (representing ~55% of the macrofaunal community; Figure 36). Species belonging to the above families are largely opportunistic and proliferate in the sediments. Most of the benthic polychaetes observed during present study were less in size. The probable reason for the presence of small-sized polychaetes is that area is frequently disturbed by natural and anthropogenic activities. It was noticed attached oil droplets to the external body parts of benthic fauna (gills, parapoda, celia etc. Figure 36).

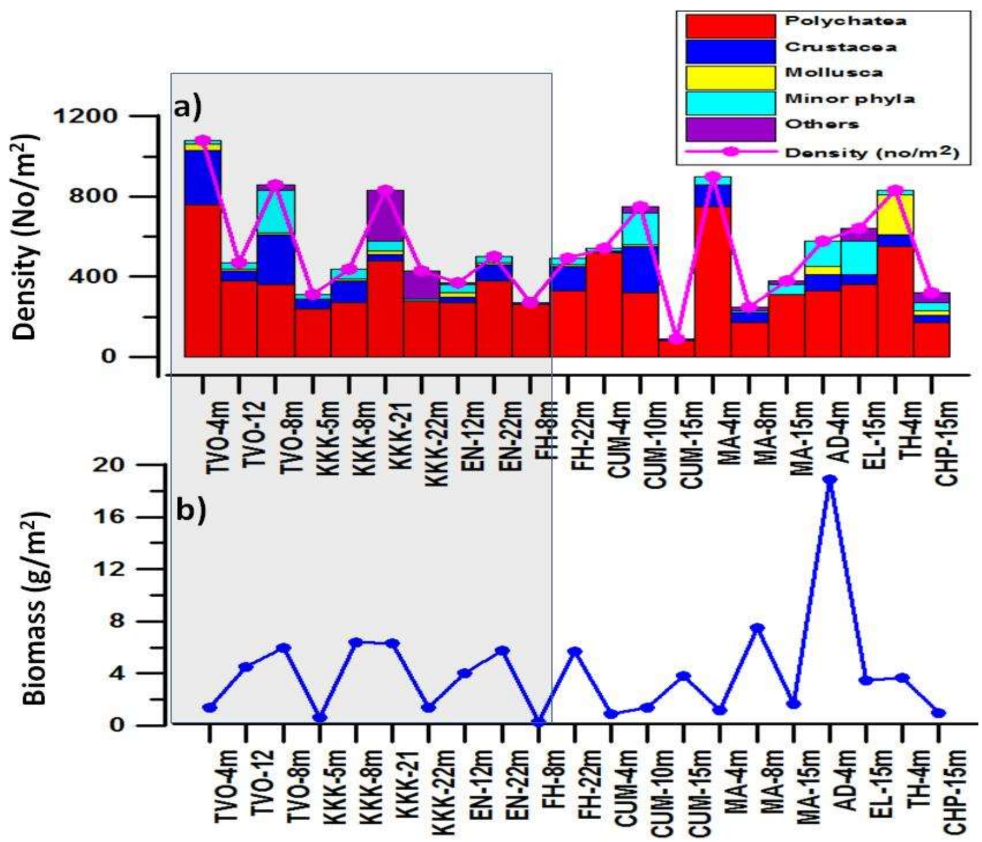


Figure 35: Macrofauna density and biomass distribution

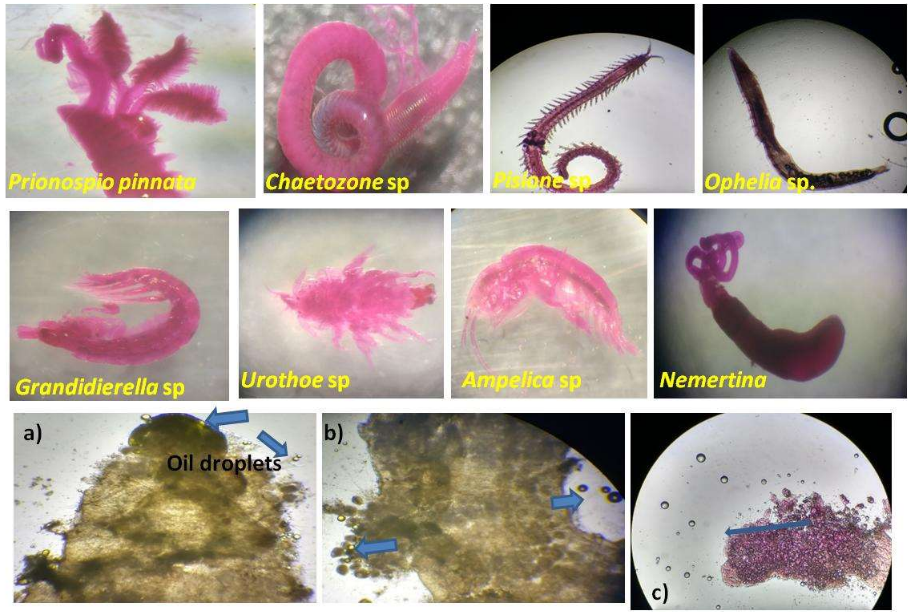


Figure 36: Macro and micro benthic fauna species observed

4.5.a.Diversity indices

The species diversity of polychaete was estimated based on Margalef species richness (d) and Shannon index (H'). Along the oil spilled stations species richness ranged 1.07–4.99 (TVO-4m to FH-8m), and along the other stations it was 1.33–3.87 at FH-22m and CHP-15m, respectively. Shannon index (H') values ranged from 1.10 to 3.33 along the stations from (TVO-4m to FH-8m) and 1.83 to 2.99 at FH-22m and CHP-15m, respectively, along the study (Figure 37).

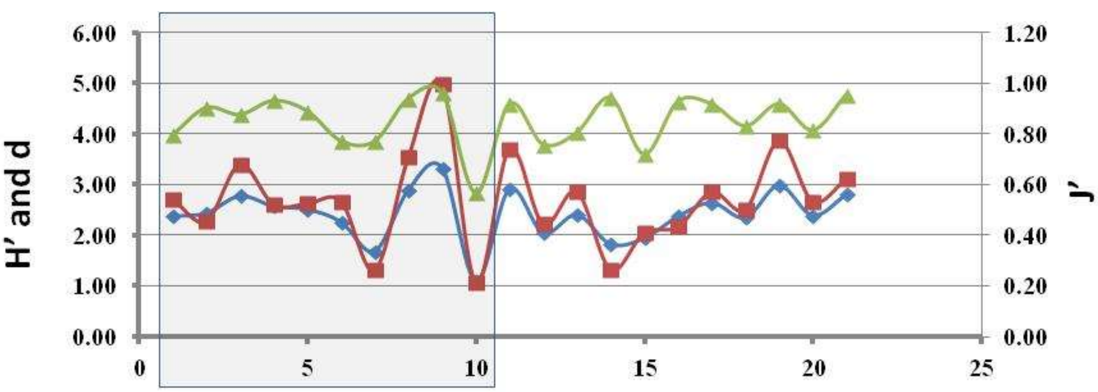


Figure 37: Diversity indices for benthic fauna

4.7 Impact on vertebrates (Fishes and sea turtles)

Field survey was conducted among the fishing hamlets and it was recorded from the local fishermen that, the mortality of fishes predominantly from mullets and Anchovies species (Table 5).

Between December and April every year, Olive Ridley turtles, one of the endangered species of sea turtles, come to nest on the Chennai coast. The beaches of Chennai viz., Elliot, Marina, Neelankarai and Muthukadu are nesting grounds for the endangered species of Oliver Ridley sea turtles and several organizations are involved in turtle conservation work. A number of dead turtles covered with oil were found along the coast (Figure 38), but the cause of the turtle mortality need to be ascertained since deaths due to trawling are normally reported during this season. The locations were the dead turtles and fish mortality were observed are shown in Figure 39.

Table 5: Mortality among marine life as observed by fishermen

Location	Fish mortality	Turtle Mortality (nos as reported by the fishermen)
Srinivasapuram	x	>10
Duminkuppam	5 km not available	x
Fishing Habour	x	x
Thiruchanakuppam	x	>2
Tiruvottiyur	x [Kelithi, Parai, Tirukai]	>5
Nettukuppam	x [Kadamaba, Kanakeluthi, Sala]	>30
Sadaraskuppam	x	<10
Venpurusham Kuppam	x	>10
Mahabaliapuram	√ (Anchovies)	<8
Puthiyakalpakkam	x	>20
Kovalam	√	>10
Nainarkuppam	x	>15
Kotivakkam	√ (Mugil Cephalus)	<6
Urur Kuppam	x	>10

Figure 38: Dead turtle washed ashore

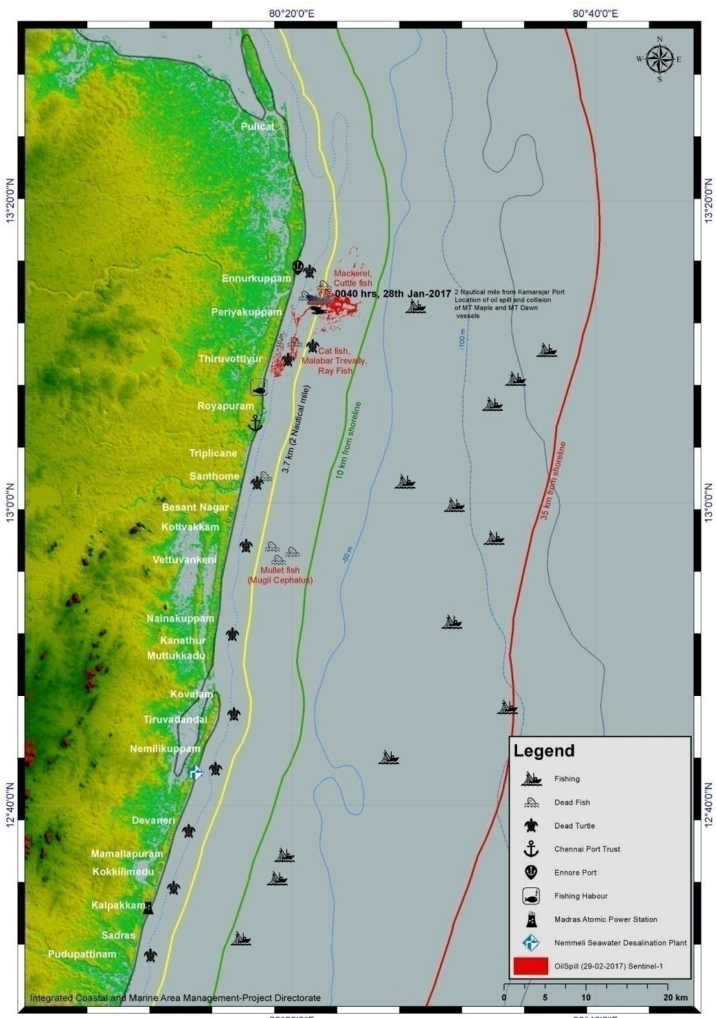
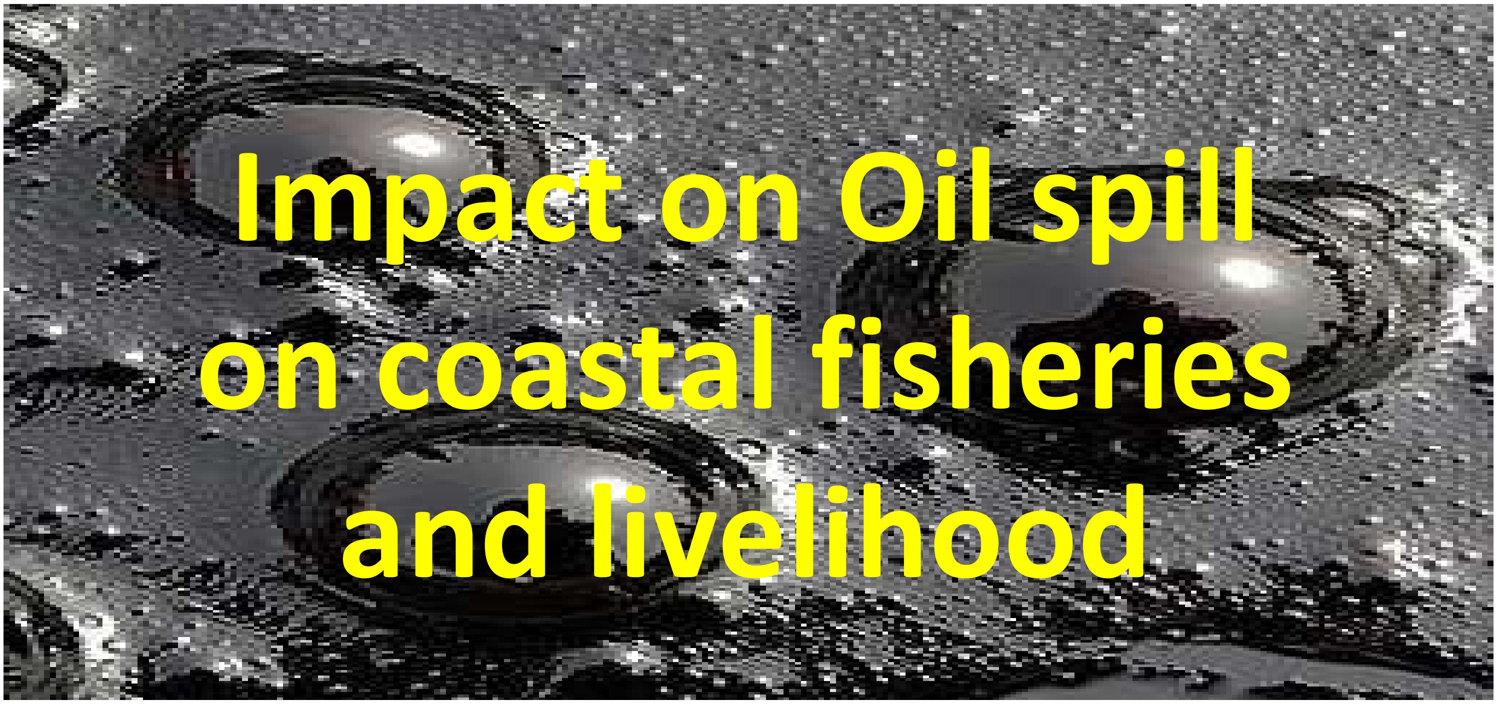


Figure 39: Locations of dead turtles and fish mortality as observed by the fishermen



Impact on Oil spill on coastal fisheries and livelihood

5. Impact of Oil spill on coastal fisheries and livelihood

5.1. Effect of Oil spill on edible fishes

A detailed investigation on fisheries along Chennai coast was carried out on 18 & 21 February 2017 to assess the impact of Ennore oil spill.

Experimental bottom trawling has been executed using mechanized fishing trawlers along Chennai coast covering 50 kilometer stretch between Ennore and Kovalam, in two phases. The trawl samples (both fin and shell fish) were collected and analyzed to quantify the bioaccumulation of TPH. The experimental trawls were carried out along the coast; based on the depth contours at three different depths (10m, 15m and 20m) near to spill location and at other places near to shore (Figure 40). Each and every trawl was performed for nearly 30 to 45 minutes at 3 to 4 knots. The details of the coordinates and the timings of trawl operations are given in the Table 6.

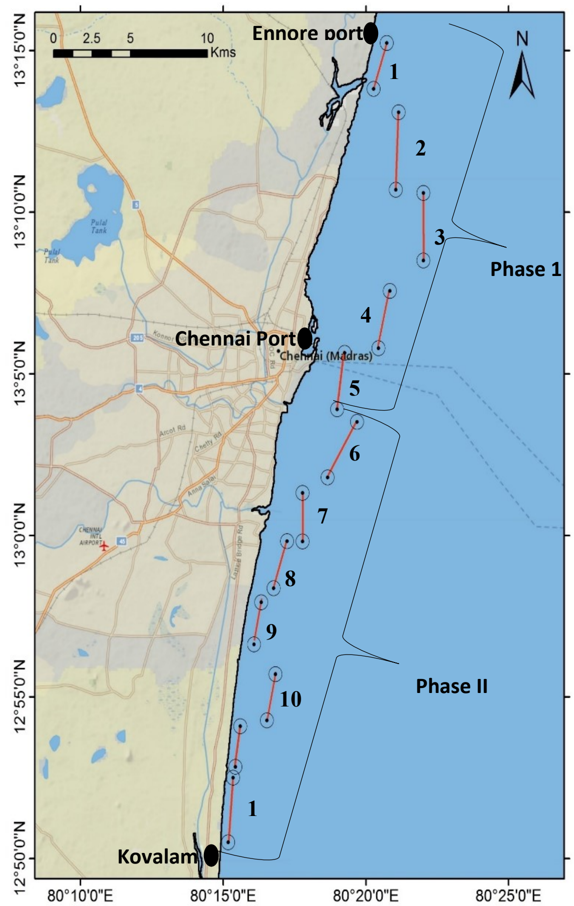


Figure 40: Map showing the phases of experimental trawls

Phase I:

Phase I of the experimental trawling was conducted on 18.02.17. The region between Ennore and Cooum (Approx. 25 km.) was sampled on 5 segmented trawls. Good catch was observed in all these trawl operations, the catch near Marina and Cooum brought high amount of litter (appro:

Phase II:

Phase II of experimental trawling was conducted on 21.02.17 between the regions Cooum and Kovalam (Approx. 25 km.) with a total of 6 trawl operations. The trawls (6, 7 & 8) were found to have very less fish catch and enriched with the litter (more than 75%). In particular, catch 7 was comprised of very few number of organisms and litter occupied almost (approx. 80 - 90 %) of the total volume. The trawls performed down south (9, 10 & 11) brought huge amount of fish catch and the litter composition is found to be lesser than ~ 20%.

Table 6: Details of experimental trawls

Date & Phase	Trawl No.	Initial Coordinates & Time	Final Coordinates & Time	Depth (m)
18.02.17 Phase I	Trawl 1	13º 15.243'N, 80º 20.735'E 11.15 AM	13º 13.824'N, 80º 20.277'E 11.45 AM	10
	Trawl 2	13º 13.100'N, 80º 21.150'E 12.10 PM	13º 10.700'N, 80º 21.050'E 01.00 PM	15
	Trawl 3	13º 10.600'N, 80º 22.020'E 01.25 PM	13º 08.514'N, 80º 22.022'E 02.05 PM	24
	Trawl 4	13º 03.114'N, 80º 17.403'E 03.30 PM	13º 05.799'N, 80º 20.448'E 04.05 PM	15
	Trawl 5	13º 03.900'N, 80º 19.000'E 04.35 PM	13º 05.655'N, 80º 19.264'E 05.05 PM	11
21.02.17 Phase II	Trawl 6	13º 01.317'N, 80º 17.977'E 07.40 AM	12º 59.814'N, 80º 17.792'E 08.15 AM	15
	Trawl 7	12º 59.825'N, 80º 17.242'E 08.55 AM	12º 58.363'N, 80º 16.771'E 09.25 AM	10
	Trawl 8	12º 57.934'N, 80º 16.339'E 09.45 AM	12º 56.634'N, 80º 16.091'E 10.15 AM	8
	Trawl 9	12º 55.712'N, 80º 16.838'E 11.00 AM	12º 54.278'N, 80º 16.535'E 11.30 AM	14
	Trawl 10	12º 54.100'N, 80º 15.610'E 11.50 AM	12º 52.842'N, 80º 15.432'E 12.20 PM	7
	Trawl 11	12º 52.505'N, 80º 15.354'E 12.45 PM	12º 50.503'N, 80º 15.180'E 01.30 PM	6

Details of specimens collected:

A total of ~90 species of fish, crustaceans and cephalopods were collected and preserved in ice box and brought to the laboratory. Specimens were identified, standard length (cm) and total wet weight (g) of each specimen were measured. Specimens were kept at -20º C in deep freezer for further analysis of TPH.

Plate: 1. Explaining the need and design of trawling to the Fishermen

Plate: 2. Launching of bottom trawl net

Plate: 3. Initiation of bottom trawling

Plate: 4. Bottom trawling underway

Plate: 5. Retrieval of the net to deck

Plate: 6. Release of the catch on deck

Plate: 7. Mass catch at one of the experimental hauls (No.11)

Plate: 8. Collection of specimens from the catch

Plate: 9. Collection of specimen from the catch

Plate: 10. Star fish

Plate: 11. Cuttlefish

Plate: 12. Specimen yet to be identified

Plate: 13. Puffer Fish

Plate: 14. Marine litter (catch 6)

Plate: 15. Marine litter (Catch 5)

Plate: 16. Marine litter (Catch 8)

Plate: 17. Marine litter (Catch 4)

Plate: 18. Marine litters (Catch 7)

Bioaccumulation of TPH in some edible fishes:

Out of total 90 samples collected, around 40 were found to be edible and economically important fishes for the coastal community. Those 40 fishes were used for the estimation of TPH in the muscle tissue. The early life stages of fish are more sensitive to petroleum than the adult, therefore, the smaller fishes were considered. The muscle tissue of each species was kept in aluminum foil and frozen. The frozen samples were thawed and analyzed for TPH as per the standard method. Out of 40 species selected, 9 samples were identified up to species level and 12 till genus level. The average values of TPH were found varying between 0.71±0.12 and 4.51±2.3 (µg g^{-1} wet weight). The maximum value was observed in *Anodontostoma chachunda* and the minimum in *Stolephorus indicus.*

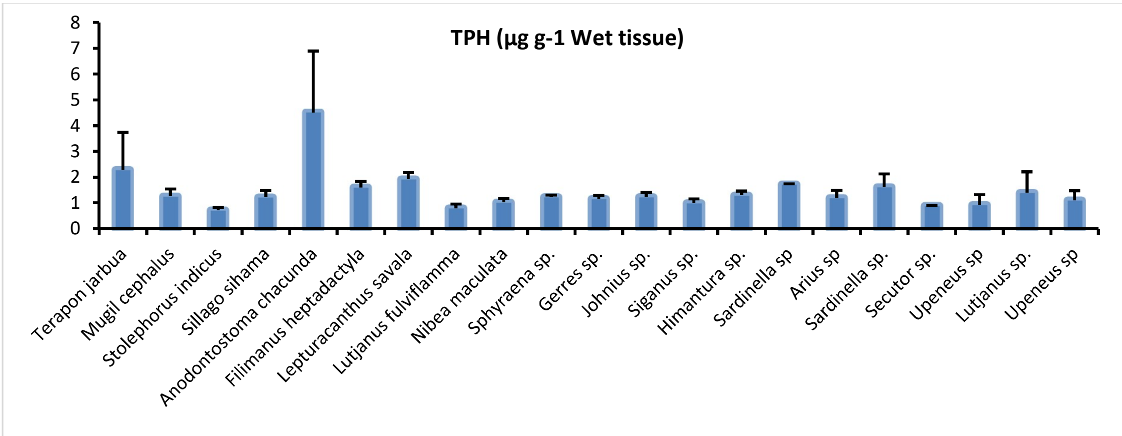


Figure 41 Mean TPH (±sd) (µg g^{-1} wet weight) in different fish species

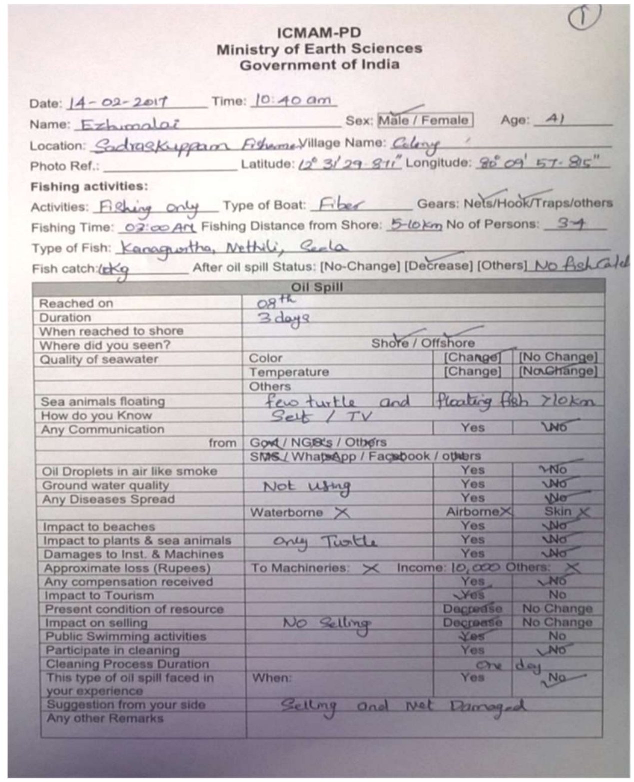
Table 7: Range and mean values (±sd) of TPH (µg g^{-1} wet weight) in different fish species

Specimen	**N**	**Length (in cm)**	**Weight (in gram)**	**Mean TPH (µg g^{-1} wet weight)**
Terapon jarbua	4	11.5 – 20.8	35.05 – 64.06	2.28±1.4
Mugil cephalus	4	8.6 – 15.6	25.23 – 49.28	1.25±0.2
Stolephorus indicus	5	6.5 – 9.4	7.5 – 9.15	0.71±0.1
Sillago sihama	4	12.7 – 18.0	30.15 – 39.65	1.21±0.2
Anodontostoma chacunda	4	10.2 – 15.7	55.22 – 83.78	4.51±2.3
Filimanus heptadactyla	4	8.3 – 10.2	15.68 – 19.89	1.60±0.2
Lepturacanthus savala	4	46.2 – 50.2	70.71 – 82.34	1.92±0.2
Lutjanus fulviflamma	3	12.2 – 18.3	50.42 – 68.76	0.79±0.2
Nibea maculata	4	16.7 – 21.3	100.21 – 112.45	1.02±0.1
Sphyraena sp.	4	20.8 – 25.6	64.06 – 78.54	1.23±0.07
Gerres sp.	4	12.3 – 20.4	56.12 – 80.34	1.16±0.1
Johnius sp.	4	14.4 – 19.6	47.91 – 62.23	1.23±0.2
Siganus sp.	5	15.2 – 18.3	59.44 – 64.54	0.99±0.2
Himantura sp.	2	18.5 – 22.5	195.30 - 210.15	1.29±0.2
Sardinella sp	3	9.7 – 12.4	12.90 – 18.93	1.71±0.02
Arius sp	2	21.4 – 25.6	143.53 – 166.56	1.19±0.3
Sardinella sp.	4	14.2 – 15.5	32.98 – 40.12	1.61±0.5
Secutor sp.	4	7.2 – 9.6	10.63 – 14.56	0.89±0.01
Upeneus sp	4	12.7 – 16.5	42.05 – 52.35	0.92±0.3
Lutjanus sp.	5	11.8 – 15.7	30.74 – 40.23	1.39±0.8
Upeneus sp	4	13.0 – 18.5	52.60 – 64.45	1.09±0.4

5.2. Impact of oil spill on the fisher folk community

A survey was carried out to assess the impact of the oil spill on the coastal fishing community and a survey was undertaken covering all fishing hamlets along the coast extending from Ennore to Mahabalipuram. (Figure 42)

Figure 42. Survey conducted among the local fishermen



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Ministry of Earth Sciences
Government of India

Date: 14-02-2017 Time: 10:40 am
Name: Ezhumalai Sex: Male / Female Age: 41
Location: Sadras Kuppam Fisherman Village Name: Colony
Photo Ref.: Latitude: 12° 31' 29.871" Longitude: 80° 09' 57.85"
Fishing activities:
Activities: Fishing only Type of Boat: Fiber Gears: Nets/Hook/Traps/others
Fishing Time: 03:00 AM Fishing Distance from Shore: 5-10 km No of Persons: 3-4
Type of Fish: Kanagurtha, Nethili, Seela
Fish catch: 10kg After oil spill Status: [No-Change] [Decrease] [Others] No fish catch

Oil Spill			
Reached on	08th		
Duration	3 days		
When reached to shore			
Where did you seen?	Shore / Offshore		
Quality of seawater	Color	[Change]	[No Change]
	Temperature	[Change]	[No Change]
	Others		
Sea animals floating	few turtle and	floating fish >10 km	
How do you Know	Seit / TV		
Any Communication		Yes	No
from	Govt / NGO's / Others		
	SMS / WhatsApp / Facebook / others		
Oil Droplets in air like smoke		Yes	No
Ground water quality	Not using	Yes	No
Any Diseases Spread		Yes	No
	Waterborne X	Airborne X	Skin X
Impact to beaches		Yes	No
Impact to plants & sea animals	Only Turtle	Yes	No
Damages to Inst. & Machines		Yes	No
Approximate loss (Rupees)	To Machineries: X	Income: 10,000	Others: X
Any compensation received		Yes	No
Impact to Tourism		Yes	No
Present condition of resource		Decrease	No Change
Impact on selling	No Selling	Decrease	No Change
Public Swimming activities		Yes	No
Participate in cleaning		Yes	No
Cleaning Process Duration		One day	
This type of oil spill faced in your experience	When:	Yes	No
Suggestion from your side	Selling and Net Damaged		
Any other Remarks			

The salient features of the survey (Table 8) are :

- There was no decline in fish catch but there was a fall in fish sales, so fishermen did not go for fishing.
- Most fishermen reported that though they fish only beyond 20km from the shore, however there is a sharp decline in sales due to a general notion that the fishes are contaminated with oil.
- Mortality of Mullets and Anchovies were reported at few places.
- Few dead turtles drenched with oil were found along the coast. However, the cause of their death is uncertain since deaths due to trawling are common during this season.
- There is a sharp decline in the number of people visiting to the beaches.

Table 8: Impact of the oil spill on the coastal community

Location	Fish sales	Tourist Inflow	Swimming	Diseases spread
Srinivasapuram	↓	↓	√	x
Duminkuppam	↓	↓	x	x
Fishing Habour	↓	↓	x	x
Thiruchanakuppam	↓	↓	x	x
Tiruvottiyur	↓	↓	x	x
Nettukuppam	↓	↓	x	x
Sadaraskuppam	↓	↓	√	x
Venpurusham Kuppam	↓	↓	x	x
Mahabaliapuram	↓	↓	x	x
Puthiyakalpakkam	↓	↓	x	x
Kovalam	↓	↓	x	x
Nainarkuppam	↓	↓	x	x
Kotivakkam	↓	↓	x	x
Urur Kuppam	↓	↓	√	x

Figure 43: Sharp fall in fish sales due to public perception of fish being toxic due to the oil spill

6. Conclusion

Initial measurements infer that the oil has drifted from the source at the rate of 8 to 10cm per second since it spilled on 28.01.2017, and reached the coast within 24 hours of the incident travelling a distance of 9 km. Satellite imagery of 06:00 hrs of 29.01.2017 confirms the spreading pattern of oil slick. It is apparent from the satellite image that the oil had moved southerly in two patches along 2 & 4 nautical miles from the coast due to strong southerly currents. A major portion of the spilled oil was trapped in the Ernavur groin fields and subsequently drifted southwards spreading alongshore and most of the oil slick were confined to north of Royapuram Fishing harbour. Another patch drifted onshore and reached the coast beyond south Chennai, as evident from the field survey.

Surface water samples were collected and compared with past datasets to study the impact on the oil spill on the physico-chemical and biological parameters in the coastal waters of Chennai. As expected high values of TPH were observed in the range of 1000-5573 µg/l in contrast to background value 10-20 µg/l for Chennai coast. The high concentrations observed offshore (0.5km) confirms the possibility of the oil to have moved along 4m contour before reaching the Chennai coast. However, by 1st March 2017, petroleum hydrocarbons concentrations were almost negligible at all stations except near Marina where it was about 1000 ug/l.

A slight decline (~1mg/L) in DO values was observed during post oil spill scenario but other physio-chemical parameters such as salinity, nutrients and pH were within acceptable limits probably due to dispersion of the floating oil, huge volume of water exchange and turbulence in the coastal waters.

Immediately after the spill there was a significant decline in Chl-a, subsequently it restored to its original state might be the effect of the high TPH immediately which later diminished with the oil movement. A total of 45 species of phytoplankton belonging to 3 taxonomic classes were enumerated and most of these species (82%) consisted of diatoms (37 species), followed by dinoflagellates (6 species) and blue green algae (2 species) . It was also observed that after the spill *Chaetoceros socialis* was the dominant species and by the end of March it was replaced by *Skeletonema costatum* and dinoflagellates and blue-green algae also exhibited lower abundance. However, no significant pattern in phytoplankton abundance, species composition and community structure (diversity and dominance) was observed.

The meso-zooplankton abundance and the taxonomic groups observed in the present study were compared with previous reports and the biomass and density values are in accordance with earlier values suggesting zooplankton communities were not affected by this oil spill incident.

In the beach macrofaunal community enumerated 16 taxa and the highest abundance was recorded at Marina and lowest at Cooum. Oligocheata was the most dominant taxa, except at Marina were the polychaete, *Pisione* sp. dominated. No epibiota was observed in areas such as Kasikoilkuppam which was severely impacted due to the oil spill. *Littorina* sp. coated with oil was observed and the impact of oil spill on the groin community was observed up to the Fishing harbour. At the Fishing harbor, oysters were the only fauna observed on the groins and their shells were completely coated with oil. It was also observed that the macrobenthic community were dominated by juveniles and matured adults (with egg) indicating that January-February is the recruitment period for the benthic organism in this region, there could be a huge impact on the benthic community. A total of 76 macro-invertebrate species were also observed and oil was found in the external body parts of benthic fauna (gills, parapoda, celia etc). As per the survey conducted among the fishing community and it was revealed that, there was mortality of fishes predominantly of Mullets and Anchovies species. A number of dead turtles covered with oil were also found along the coast but the cause of the turtle mortality was uncertain. There was no decline in fish catch but there was a sharp decline in sales due to the public perception of the fish being contaminated with oil.