

## **Total petroleum hydrocarbon in the tissue of some commercially important fishes of Bay of Bengal**

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### **Abstract**

The present study reports the level of total petroleum hydrocarbon (TPH) in 27 commercially important fish, crustaceans and cephalopods from Orissa coast, Bay of Bengal to provide the baseline data for oil contamination in marine biota. The results showed significant differences in the TPH concentration in different species. Of all fish, *Carangoides malabaricus* showed the maximum TPH level (av. 13.70  $\mu\text{g g}^{-1}$ ). In cephalopods, *Loligo* recorded the maximum TPH (av. 14.87  $\mu\text{g g}^{-1}$ ) while *Metapenaeus dobsoni* recorded the maximum TPH (av. 13.18  $\mu\text{g g}^{-1}$ ) among crustaceans. The concentration of TPH recorded in the present study were higher than the reported values from other studies in Bay of Bengal but were comparable with those of other Indian coast and Gulf water. The species recording maximum concentration and giving significant correlation coefficient may be of interest in oil pollution monitoring and can be used as indicator of hydrocarbon pollution in the region.

**Keywords:** TPH; fish; muscle tissue; seasonal variation; Orissa coast; Bay of Bengal

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## Introduction

Petroleum is the most critical source of energy and a major determinant of development at the international level. Total estimated input of petroleum to oceans is  $2.37 \times 10^6 \text{ ty}^{-1}$  (Kennish, 1997). Hydrocarbons are the most important constituents of petroleum which have inherent toxic effect on a variety of biological processes. The coastal ecosystem and its fishery resources are particularly at high risk of exposure to petroleum hydrocarbon during large oil spill (Burt et al., 1992; Halpern et al., 2008). Long term but low addition of oil into the marine environment from shipping, de-ballasting and other anthropogenic activities is absorbed by marine organisms because of its low degradability and persistence (Vandermeulen et al., 1985). The manifestation of petroleum hydrocarbon in sea food is a serious human health hazard and needs to be studied in detail for a better understanding and management.

The Bay of Bengal occupies an area of  $4.087 \times 10^6 \text{ km}^2$  between latitude  $0$  and  $22^{\circ}\text{N}$  and longitude  $80$  and  $100^{\circ}\text{E}$ . It is a semi-enclosed large tropical basin that is influenced by monsoonal wind and fresh water influx. It is distinguished by a strongly stratified reversing circulation and seasonal variability in the physico-chemical properties of the upper layer (Shetye et al., 1996). The four major rivers flowing into the Bay discharge annually approximately  $1.5 \times 10^{12} \text{ m}^3$  of freshwater into the bay (UNESCO, 1988). In addition the region receives annual rainfall in the excess of 2m. All these brings varying sediment load in the water column. According to Ramaswamy et al. (1997) a strong seasonality in the nature and quantity of biogenic and lithogenic fluxes occurs in the Bay due to varying input of freshwater and sediment from river. In the period of pre-southwest monsoon the Bay of Bengal could be characterized as a region of low productivity (Gomes et al., 2000). In this period the nutrient inputs are severely constrained by a strong halocline and a shallow mixed layer. This assumes considerable importance for biological productivity in the region.

Oil pollution is a major kind of marine pollution. In late nineties the global marine transport of oil was on an average, 49.6% of the total production. The major source of oil pollution in the Bay of Bengal is the transport of oil in large tankers from the oil terminals at the port in the middle east countries along the well known tanker route that passes through southern Bay of Bengal. A number of tanker accidents occurred on these routes, resulting in increased concentration of particulate and dissolved petroleum hydrocarbon (Sen Gupta, 1991). The increased urbanization, industrialization of the

coastal areas bordering Bay of Bengal and discharges from refineries are also contributing to the oil pollution.

Total petroleum hydrocarbon (TPH) is a term used to describe a broad family of several hundred chemical compounds that originally come from crude oil. The presence of petroleum hydrocarbon in the marine environment affects the marine food chain in several ways. It has been reported that petroleum concentration, as low as 0.1 ppm can be toxic to larvae of some species in the sea (USEPA, 1986). Oil spills can harm marine life, both in the long and short term. In the long term, the sub-lethal dose of oil and oil products have produced physiological and histo-pathological changes (Anderson et al., 1974; Mazhar et al., 1987; that can affect marine life by interfering with the ability to breed, reproduce, grow, or perform other vital functions. In extreme cases death and development of genetic mutation in fish, shellfish, marine mammals, reptiles and birds may occur.

The present communication reports the concentration of total petroleum hydrocarbon in the muscle tissue of 27 species of fish, crustaceans and cephalopods which are commercially exploited for human consumption on seasonal basis.

## **Materials and methods**

A total of 27 species of fish, crustaceans and cephalopods were collected and used for the estimation of TPH in the muscle tissue. Sampling was carried out during December 2006 (post-monsoon), April 2007 (pre-monsoon) and September 2007 (monsoon) using mechanized fishing trawlers. After collection fishes were put in ice box and brought to the laboratory where they were kept at -20°C in deep freeze for further analysis of TPH. Fishes were identified and standard length (cm) and total weight (g) of each specimen were measured before dissection. The muscle tissues of each species were kept in aluminium foil and frozen. All dissection instruments were pre-cleaned and precaution was taken to minimize contamination while handling. Frozen samples were defrosted and analyzed for TPH. Analytical methods for hydrocarbons and other precautionary methodology given in UNESCO (1981) and FAO (1983) were followed. Approximately one gram of fish muscle tissue was mixed with hexane solvent and then homogenized using the ULTRA TURRAX homogenizer until uniform consistency.

The homogenates were dried by passing through a bed of anhydrous sodium sulphate and filtered. The filtrate were recovered and added with hexane to a final volume of 25 ml, and then analyzed using Shimadzu RF-5000 Spectrofluorometer. Fluorescence conditions were as follows:

excitation at 310 nm and emission at 360 nm. The standard used was Bombay High Crude Oil. Results are expressed as  $\mu\text{g g}^{-1}$  wet tissue. Duplicate samples of fish tissue were collected for estimation of TPH. The data was then analysed using STATISTICA software for ANOVA Test from which the correlation coefficient between total length, total weight and TPH of some selected fishes was obtained. The aim of the study was to provide a baseline data on the state of Petroleum hydrocarbon pollution in the muscle tissues of the common fish, crustacean and cephalopod species locally consumed along Orissa coast. In addition, surface water samples were also collected from three locations in replicate with the help of Niskin sampler and 1 litre water was stored in glass bottle for analysis of TPH.

## Results

The coastal waters receive petroleum hydrocarbon from different sources. The concentration of TPH in the surface water is given in Table 1. The values for the three seasons are  $3.81\mu\text{g l}^{-1}$  in post-monsoon,  $2.43\mu\text{g l}^{-1}$  in pre-monsoon and  $2.50\mu\text{g l}^{-1}$  in monsoon season.

It is imperative that baseline data of common pollutants causing marine pollution on the Indian coast is worked out to demonstrate whether the concentrations of these pollutants can pose problem of health hazards to common man in the coastal areas. Such information becomes handy in future planning and management of the coastal living resources. In order to generate the baseline data on TPH in marine fish, 27 commercially important fish, crustaceans and cephalopods, which represent an important food for the coastal people of Orissa were investigated. The results of the body measurements and concentration of TPH in the tissues are presented in Table 2-4. During December 2006 (post-monsoon) the average value of TPH in the samples collected from Orissa coast varied between 1.45 and  $17.56\mu\text{g g}^{-1}$  wet weight. The minimum value was recorded in lean ribbon fish (*Trichiurus lepturus*) and the maximum in cephalopod (*Loligo indica*). The TPH concentration was also found to be high in crustaceans in particular prawns in the same period. The average value was  $11.42\mu\text{g g}^{-1}$  in *P. indicus* and  $13.69\mu\text{g g}^{-1}$  in *M. dobsoni*. Among fishes, *Carangoides malabaricus* recorded TPH of  $14.22\mu\text{g g}^{-1}$  wet weight. The lean fishes showed low concentration of TPH in the tissue. The result of the samples of pre-monsoon (April 2007) showed wide variability in the average TPH concentration in tissues. The minimum values were  $1.95\mu\text{g g}^{-1}$  in *T. lepturus* and maximum of  $15.22\mu\text{g g}^{-1}$  in *Loligo indica*, respectively. The high concentrations were also recorded in *P. indicus* ( $10.24\mu\text{g g}^{-1}$ ), *M. dobsoni* ( $11.04\mu\text{g g}^{-1}$ ) and *C. malabaricus* ( $15.28\mu\text{g g}^{-1}$ ). The trend was similar to that of post monsoon season. However, the values in the premonsoon season were comparatively lower in most species. Similarly in

the monsoon season (September 2007) the minimum value of TPH observed was  $1.94 \mu\text{g g}^{-1}$  in the tissue of mackerel (*Rastrelliger kanagurta*) and the maximum value of  $16.45 \mu\text{g g}^{-1}$  in prawn *Metapenaeus dobsoni*. While the concentration of most of the species fluctuated narrowly in the three seasons, the average value recorded in the post monsoon season was on higher side.

Seasonal variation in the average value of hydrocarbon concentration in tissue is presented in Fig. 1. Although, no strong seasonality was observed in the tissue concentration of TPH in the marine organisms, the values recorded in post-monsoon were on the higher side while those of pre-monsoon were on the lower side. The average concentrations were in the order of fish < crustaceans < cephalopods. Prawn and loligo showed high values in all season. Among fishes, only *Carangoides malabaricus* recorded high concentration in all three seasons. While most species showed similar trend in three seasons, the concentration in *Rastrelliger kanagurta* showed different pattern. There was significant change in the concentration in different season, varying from a minimum of  $1.94 \mu\text{g g}^{-1}$  in monsoon to a maximum of  $7.8 \mu\text{g g}^{-1}$  in pre-monsoon. These species could be considered as indicator species.

## Discussion

The major sources of oil pollution in the Indian Ocean is the transport of oil in large tankers from Middle East along the two well known tanker routes. Based on long term measurements, the concentration of dissolved Petroleum Hydrocarbon (PHC) along the tanker routes of Arabian Sea and Bay of Bengal is reported to vary between 0-50.2 and 0-74.4  $\mu\text{g l}^{-1}$ , respectively (Sen Gupta, 1991). The level of concentration of TPH in the fish tissue of the present study are below the recommended limits for food products of developed countries (NRA, 1999) except those in crustacean and cephalopods. Petroleum hydrocarbons tend to get concentrated in fish tissue when exposed to oil but retention is not indefinite (GESAMP, 1982). Some of the marine organisms release the accumulated hydrocarbon more rapidly and the rate of accumulation and release is species dependent (Neff et al., 1976). The early life stages in fish are more sensitive to petroleum than the adult fish. Therefore the assessment of the risk of any oil spill is important.

The range of values observed in the present study are higher than the reported concentration range of 0.52 to  $2.05 \mu\text{g g}^{-1}$  from Tamilnadu coast (Veerasingam et al., 2011) and those of 0.47 –  $3.77 \mu\text{g g}^{-1}$  (Av.  $3.67 \mu\text{g g}^{-1}$ ) reported in the fish tissue of north and central Arabian sea (Sen Gupta et al., 1993). In a more recent study Chouksey et al. (2004) reported PHC residue between 1.8 and 10.8 ppm (wet wt) in five fish species off Mumbai coast. These values are comparable to the values of the

present study. Ashraf and Mian (2010) reported TPH in the range of 2.1 to 7.4 $\mu\text{g g}^{-1}$  in fish tissue from Arabian Gulf. In contrast Shriadah (2001) reported significantly low values (0.28-1.38 $\mu\text{g g}^{-1}$ ) from Arabian Gulf fish. Heavy traffic and oil tanker route may be responsible for high concentrations of oil in water as stated earlier. It has been shown by Pruell et al. (1986) that hydrocarbons are accumulated by simple equilibrium between sea water and body lipids.

The availability and concentration of TPH in water will affect the marine life (Kennish, 1997). Higher TPH concentration in the muscle of some fish and crustaceans may be due to differences in habitat they live and their feeding habits. The high concentration observed in some fishes also suggest their ability to accumulate hydrocarbon in their tissue. The manifestation of petroleum hydrocarbon in adult fish may bring a variety of biochemical, blood and cellular changes. Therefore, the bioavailability of TPH to marine organisms and their physiological factors are important for any effect on the organisms (Veerasingan et al., 2011). The fishes of Red Sea and Gulf of Aden are reported to have TPH in the range of 0.2 to 1.7 $\mu\text{g g}^{-1}$  with significant variation between fish species (Al-Shwafi, 2008). The concentration of TPH in our study showed contrasting variation between some of the species. It is reported that PHC in sediment or water is rapidly taken by fish either by transport across cell membranes of skin and gills or diet by contaminated food (Moe et al., 1994). These compounds are transported through blood to different body organs where they can be accumulated at several thousand fold the concentration in the surrounding water.

The possible relationship between total petroleum hydrocarbon and standard length or total weight of some species was attempted and the results are given in Table 5. There was an absence of strong significant relationship in most cases except in case of *Upeneus vittatus*, *S. sihama*, *P. indicus*, *M. dobsoni* and *L. indica* where the relationship was significant ( $p < 0.01$ ). The significant results possibly suggest that these species are able to accumulate hydrocarbon in their body and hence can serve as indicator of oil pollution. Those species with no significant relation can be recommended as safe for consumption. In other studies of this nature no significant relation have been observed in marine fish from Arabian Sea and Gulf of Aden (Durrani and Siddiqui, 1990; Al- Shwafi, 2008).

## **Conclusion**

The present study gives the baseline distribution of total petroleum hydrocarbon in fish tissue of Orissa coast, Bay of Bengal. Accumulation of petroleum hydrocarbon may reduce the quality of fish tissue and cause tenting. TPH concentration in most of the fish was lower than critical level. The high

concentration of TPH in the tissue suggest that these muscle organs can act as indicator of exposure and the possible consequences of such high bioaccumulation on coastal people eating more fish cannot be ignored. There is an increased exploration of PHC in the Bay of Bengal which may enhance the concentration level in the natural environment and biota. Therefore periodical monitoring and assessment of TPH contamination and its bioaccumulation in marine organisms is recommended from public health view point.

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Table1: Concentration of total petroleum hydrocarbon in the surface water

Season/month	TPH ( $\mu\text{g l}^{-1}$ )
December 2006	3.81 $\pm$ 1.32
April 2007	2.43 $\pm$ 1.09
September 2007	2.50 $\pm$ 0.66

Table2: Range and mean values ( $\pm$ sd) of TPH ( $\mu\text{g g}^{-1}$  wet weight) in different fish species during December 2006

Fish species	Feeding Habit	n	Length (cm)	Weight (g)	TPH range	TPH mean
<i>Anchoviella commersoni</i>	Carnivores	6	9-11	10.8-12.6	3.58-5.57	4.97 $\pm$ 1.3
<i>Chirocentrus dorab</i>	Carnivores	4	32-34	95-112	2.38-3.25	2.69 $\pm$ 0.7
<i>Dasyatis zugei</i>	Carnivores	3	9.5-19.0	19.7-650.0	6.28-6.76	6.21 $\pm$ 1.9
<i>Mugil cephalus</i>	Detritivores	4	10.3-30.2	12.6-410.5	2.46-4.23	3.64 $\pm$ 0.4
<i>Mugil parsia</i>	Detritivores	6	11.2-13.5	15.2-46.8	2.18-5.57	3.88 $\pm$ 0.3
<i>Cynoglossus sp.</i>	Carnivores, Detritivores	9	22-33.4	34.5-65.9	1.93-2.82	2.22 $\pm$ 0.3
<i>Lutjanus ehrenbergi</i>	Carnivorous	3	16.9-19.5	102-108.2	2.25-4.66	3.42 $\pm$ 1.2
<i>Carangoides malabaricus</i>	Carnivores	4	14.5-18.8	30.9-95.2	9.24-17.13	14.22 $\pm$ 4.9
<i>Arius dussumieri</i>	Carnivores, Detritivores	3	15.6-29.3	48.5-216.2	4.26-6.13	5.37 $\pm$ 1.8
<i>Otolithes ruber</i>	Carnivores	3	24.2-29.0	145.6-225.5	3.36-7.89	6.36 $\pm$ 2.2
<i>Sillago sihama</i>	Carnivores, Detritivores	8	12.5-15.5	20.5-34.5	3.15-3.76	3.25 $\pm$ 0.6
<i>Rastreliger kanagurta</i>	Planktivores	12	18.8-21.9	34.5-47.8	2.12-2.64	2.15 $\pm$ 0.3
<i>Lacterius lacterius</i>	Carnivores	5	11.4-15.6	19.8-35.2	2.39-3.27	2.98 $\pm$ 0.2
<i>Nemipterus japonicus</i>	Carnivores	10	12.3-16.5	37.8-62.5	2.59-3.53	3.04 $\pm$ 0.3
<i>Alepes sp.</i>	Carnivores	3	17.2-25.0	58.6-120.4	5.34-6.62	5.45 $\pm$ 1.6
<i>Johnius dussumieri</i>	Carnivores	3	11.2-18.5	18.9-65.7	3.12-5.59	4.14 $\pm$ 1.2
<i>Upeneus vittatus</i>	Carnivores	8	10.3-16.5	34.4-69.5	2.83-4.15	3.24 $\pm$ 0.9
<i>Pampus argentius</i>	Carnivores	3	14.2-22.6	44.2-180.6	1.55-2.99	2.24 $\pm$ 0.4
<i>Formis niger</i>	Omnivores	4	17.8-25.5	105-304.2	3.20-4.46	3.84 $\pm$ 0.5
<i>Scomberomorus guttatus.</i>	Carnivores	3	23.7-334.6	108.8-236.5	2.07-3.59	2.82 $\pm$ 0.3
<i>Trichiurus lepturus</i>	Carnivores	9	48.2-54.8	109.8-114.6	1.38-1.85	1.45 $\pm$ 0.2
<i>Terapon jarbua</i>	Carnivores	14	15.2-23.5	61.3-181.4	1.05-2.16	1.68 $\pm$ 0.2
<i>Penaeus indicus</i>	Carnivores	10	9.5-11.5	5.7-6.8	7.69-12.95	11.42 $\pm$ 3.3
<i>Metapenaeus dobsoni</i>	Omnivores	8	8.6-12.5	4.6-10.8	11.34-14.91	13.69 $\pm$ 4.7
<i>Portunus pelagicus</i>	Opportunistic Omnivores	4	12.2-16.5	135.4-146.8	4.97-7.39	5.98 $\pm$ 2.4
<i>Loligo indica</i>	Carnivores	5	12.5-15.8	17.8-26.1	16.42-18.66	17.56 $\pm$ 5.3
<i>Sepia sp.</i>	Carnivores	4	17.5-20.4	110-120.5	4.86-8.22	6.80 $\pm$ 2.6

Table 3: Range and mean values ( $\pm$ sd) of TPH ( $\mu\text{g g}^{-1}$  wet weight) in different fish species during April 2007

Fish species	n	Length (cm)	Weight (g)	TPH range	TPH mean
<i>Anchoviella commersoni</i>	6	10-14	11.2-14.2	3.16-5.27	3.29 $\pm$ 1.3
<i>Chirocentrus dorab</i>	3	28-31	80.2-115.5	2.14-2.85	2.26 $\pm$ 0.6
<i>Dasyatis zugei</i>	3	12.5-16.4	25.2-365.5	3.64-5.15	3.72 $\pm$ 2.5
<i>Mugil cephalus</i>	3	12.2-18.6	25.8-217	1.96-2.63	2.05 $\pm$ 1.6
<i>Mugil parsia</i>	4	12.5-15.6	17.7-105.2	1.66-4.72	2.82 $\pm$ 0.7
<i>Cynoglossus sp.</i>	5	20.5-36.2	27.2-78.4	2.05-2.55	2.08 $\pm$ 0.5
<i>Lutjanus ehrenbergi</i>	3	18.2-23.9	105.5-116.5	2.57-3.96	2.84 $\pm$ 0.7
<i>Carangoides malabaricus</i>	3	18.2-22.4	95.8-115.2	13.24-16.13	12.28 $\pm$ 4.6
<i>Arius dussumieri</i>	4	18-22.4	80.6-90.7	5.20-9.38	5.87 $\pm$ 1.8
<i>Otolithes ruber</i>	11	25-27.6	156.4-216.8	4.13-8.70	5.36 $\pm$ 1.6
<i>Sillago sihama</i>	9	12.4-15.8	21.6-35.5	3.68-6.45	3.85 $\pm$ 1.3
<i>Rastrelliger kanagurta</i>	5	19.5-20.5	45.8-48.8	1.12-2.14	1.80 $\pm$ 0.3
<i>Lacterius lacterius</i>	7	13.5-16.2	21.2-40.6	3.15-4.76	3.55 $\pm$ 0.7
<i>Nemipterus japonicus</i>	15	15.3-17.4	40.5-42.6	2.19-3.38	2.34 $\pm$ 0.3
<i>Alepes sp.</i>	4	15.5-23.6	50.4-92.6	3.84-6.12	4.15 $\pm$ 0.6
<i>Jonhies dussumieri</i>	21	12.6-16.4	18.8-25.2	3.52-5.14	3.87 $\pm$ 0.8
<i>Upeneus vittatus</i>	6	10.4-12.8	28.2-49.4	2.35-3.26	2.82 $\pm$ 0.4
<i>Pampus argentius</i>	3	14.2-16.6	40.5-67.8	4.29-7.82	4.65 $\pm$ 1.6
<i>Formis niger</i>	3	15.8-23.6	94.2-274.3	3.18-5.72	3.65 $\pm$ 1.3
<i>Scomberomorus guttatus</i>	21	26.4-32.6	115.5-218.8	1.25-3.18	1.59 $\pm$ 0.5
<i>Trichiurus lepturus</i>	5	50.2-56.5	110.2-120.4	1.75-2.08	1.95 $\pm$ 0.6
<i>Terapon jarbua</i>	6	13.2-16.4	25.5-85.8	4.92-6.76	5.06 $\pm$ 1.4
<i>Penaeus indicus</i>	15	9.5-10.5	8.2-7.4	9.15-12.76	10.24 $\pm$ 3.3
<i>Metapenaeus dobsoni</i>	14	10.6-12.2	10.5-14.4	11.78-13.66	11.04 $\pm$ 4.2
<i>Portunus pelagicus</i>	3	11.5-14.8	108-138.2	5.12-7.92	6.15 $\pm$ 1.9
<i>Loligo indica</i>	9	9.9-14.5	14.2-25.6	13.35-16.18	15.22 $\pm$ 3.7
<i>Sepia sp.</i>	7	15-18.6	98.6-115.5	5.46-9.52	7.74 $\pm$ 2.8

Table4: Range and mean values ( $\pm$  sd) of TPH ( $\mu\text{g g}^{-1}$ ) in different fish species during September 2007

Fish species	n	Length (cm)	Weight (g)	TPH range	TPH mean
<i>Anchoviella commersoni</i>	-	-	-	-	-
<i>Chirocentrus dorab</i>	3	34.-39.5	95.8-120.2	3.46-6.29	3.89 $\pm$ 1.25
<i>Dasyatis zugei</i>	-	-	-	-	-
<i>Mugil cephalus</i>	5	12-16.8	19.4-28.2	3.16-7.18	3.66 $\pm$ 0.47
<i>Mugil parsia</i>	3	10-14.5	16.8-22.5	3.08-5.94	2.54 $\pm$ 0.72
<i>Cynoglossus sp.</i>	12	22.5-25	57-76	2.83-4.64	2.57 $\pm$ 0.45
<i>Lutjanus ehrenbergi</i>	3	20.5-24.6	115-170	2.14-3.89	2.77 $\pm$ 0.22
<i>Carangoides malabaricus</i>	2	14.5-15	28.9-32.5	11.95-14.24	10.60 $\pm$ 3.28
<i>Arius dussumieri</i>	3	21-29	84-216	4.04-7.34	4.66 $\pm$ 1.85
<i>Otolithes ruber</i>	2	15.5-16.5	78-85.1	2.16-4.25	2.26 $\pm$ 0.43
<i>Sillago sihama</i>	10	15-17	24.2-40.8	2.08-3.46	2.15 $\pm$ 0.28
<i>Rastrelliger kanagartha</i>	6	14.5-16.2	25.3-30.7	1.64-2.18	1.94 $\pm$ 0.16
<i>Lacterius lacterius</i>	7	8-12.5	20.2-25.8	2.17-2.29	2.29 $\pm$ 0.13
<i>Nemipterus japonicus</i>	6	15-15.5	46-62	3.22-6.88	4.55 $\pm$ 1.22
<i>Alepes sp.</i>	4	22-23	125-131	4.51-6.35	4.82 $\pm$ 1.65
<i>Jonius dussumieri</i>	4	16-18	56.2-68.4	3.35-5.14	4.62 $\pm$ 0.88
<i>Upeneus vittatus</i>	10	10-16.5	40-69.5	4.30-6.74	5.06 $\pm$ 1.52
<i>Pampus argenteus</i>	5	14-17	50.5-108	3.02-4.52	3.39 $\pm$ 0.36
<i>Formis niger</i>	4	16-18.5	105-140	2.14-3.52	2.42 $\pm$ 0.16
<i>Scomberomorus guttatus .</i>	3	24-34	82-235	2.69-3.14	2.90 $\pm$ 0.15
<i>Trichiurus lepturus</i>	7	50-54.6	106-112.8	2.65-4.03	2.76 $\pm$ 0.38
<i>Terapon jarbua</i>	6	15.5-17	61-82	3.48-5.18	4.77 $\pm$ 0.42
<i>Penaeus indicus</i>	8	10-11.6	6.75-10.8	9.69-12.94	9.04 $\pm$ 3.36
<i>Metapenaeus dobsoni</i>	8	9.5-12.2	6.09-9.8	12.16-15.66	10.45 $\pm$ 4.12
<i>Portunus pelagicus</i>	4	12-14.5	135-212	4.13-6.99	5.16 $\pm$ 1.15
<i>Loligo indica</i>	3	12-15	17.8-26.2	9.55-12.77	10.83 $\pm$ 3.55
<i>Sepia sp.</i>	4	17.5-20.8	110-120.6	5.84-8.20	6.80 $\pm$ 2.74

Table5: Correlation coefficient between total length, total weight and TPH of some selected fishes.

Species	n	Total length & TPH	Total weight & TPH
<i>Rastrelliger kanagurta</i>	23	0.33	0.26
<i>Upeneus vittatus</i>	24	0.44**	0.48**
<i>Cynoglossus sp</i>	26	0.29	0.32
<i>Trichiurus lepturus</i>	21	0.15	0.18
<i>Sillago sihama</i>	27	0.66*	0.72*
<i>Nemipterus japonicus</i>	31	0.18	0.26
<i>Lacterius lacterius</i>	19	0.32	0.28
<i>Penaeus indicus</i>	33	0.82*	0.75*
<i>Metapenaeus dobsoni</i>	30	0.62*	0.74*
<i>Loligo indica</i>	17	0.90*	0.87*

Significant at \*\*( $p < 0.05$ )

\*( $p < 0.001$ )

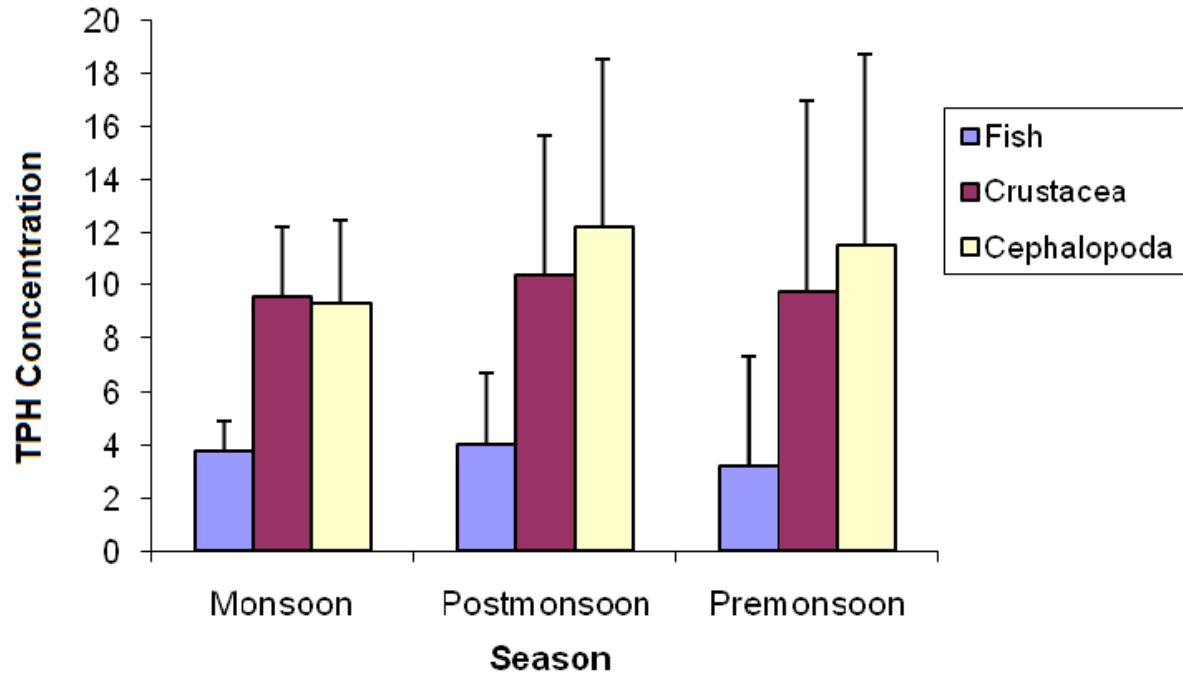


Figure 1 Seasonal distribution of average value of TPH in tissue of different marine organisms