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Species-wise Mercury Accumulation in Fish from Ulhas River Estuary and Thane Creek in the vicinity of Mumbai, India and its Relation to the Feeding Habits of Fish

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Abstract

Thane Creek (73º14’ E, 19º14’N to 72º54’ E, 19º17’ N) and Ulhas River estuary (72º55’E, 19º N to 73ºE, 19º15’N), in the vicinity of Mumbai, India receive industrial effluents and sewage from industries and residential complexes respectively, located along their banks. Survey of the fishing villages along these water bodies revealed estuarine/creek fish as the dietary mainstay of the inhabitants here and species of fish consumed depends upon their availability in that particular site. Species-specific study of mercury levels in fish from three different sites on Ulhas River estuary and Thane Creek revealed that herbivorous species like juvenile prawns, *Tilapia mossambica* and *Mugil cephalus* accumulated lesser mercury (non-detectable to 0.357 $\mu g \cdot g^{-1}$) in comparison to the permissible limit of 0.5 $\mu g \cdot g^{-1}$recommended by World Health Organisation (WHO) while those of higher trophic levels like *Mystus gulio, Arius maculatus* and *Scylla serrata* had elevated levels of mercury (0.428 to 2.48 $\mu g \cdot g^{-1}$). The results also revealed that mercury in fish proportionally increased with the percentage of animal matter in the stomach. This study therefore recommends the fish-eating populations along Thane Creek and Ulhas River estuary to consume preferably the herbivorous fish; omnivorous fish should be consumed in moderation and avoid the consumption of carnivorous fish.

Introduction

Mercury is one of the most hazardous environmental pollutants due to its toxicity and its accumulation in aquatic organisms. The presence of mercury in the waters of Ulhas River estuary and Thane Creek in the vicinity of Mumbai, India, has been reported by several scientists (Zingde, 2001; Ram et al.2003). It is quite likely that fish from Ulhas river estuary and Thane creek may also be contaminated with mercury. Consumption of mercury contaminated fish can lead to deleterious effects on humans (Hightower and Moore, 2003).The survey of the fishing villages along Ulhas River estuary and Thane Creek revealed fish as the dietary mainstay of the inhabitants here and the species of fish consumed depends upon its availability in that particular site. Mullets, catfish, tilapia, mudskippers, crabs and prawns are commonly consumed in the study areas.

Several studies all over the world have established that the level of mercury accumulation in certain fish species was drastic enough to be a serious threat to public health (SACN, 2004). Morrissette et al. (2004) have confirmed that methyl-mercury, a well-established neuro-toxicant, even at low levels of exposure, bioaccumulates to differing degrees in various

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fish species and can have adverse effects on the development and functioning of the human central nervous system especially during pre-natal exposure. Thus, species of fish is a very important variable that influences mercury accumulation (Kojadinovic et al.2006).Because fish consumption dominates the pathway for exposure to methyl-mercury for most human populations, many governments provide dietary advice to limit consumption of fish where mercury levels are elevated. A declaration by FDA, USA on 'Advice on fish consumption' (SACN, 2004) recommends $0.5\mu g \cdot g^{-1}$ as the permissible limit of mercury in fish. In the study on indigenous fishing community of Amazon too, $0.5\mu g \cdot g^{-1}$Hg levels in fish have been taken as the maximum permissible level (Castilhos and Bidone, 2000). But the above mentioned reports were from different places in the world and thereby the species are also different from the selected study areas. No recent studies on the species related bioaccumulation of mercury from the selected areas have been reported. Mercury exposure of fish-eating populations depends not only on the quantity of fish consumed but also on the species of choice. No recommendations or advisories of any kind have been put forth so far in the concerned study areas or in India on the risk of fish consumption. Considering the present pollution status and the potential risks involved in mercury exposure, it was obligatory to study species-related mercury bioaccumulation so that fish safe for human consumption could be identified.

There is a predictive association between fish feeding strategy and fish-mercury concentration (Dorea et al.2006). As mercury bioaccumulates and biomagnifies through the food-chain, the top level predators accumulate the highest levels of mercury (Frery et al. 2001). With an increase in trophic levels, the amount of animal matter in the stomach contents tends to increase (Castilhos and Bidone, 2000). Hence, in the present investigation, an attempt has also been made to correlate percentage of animal matter (AM) in the stomach contents with fish mercury levels. Thus the objectives of the present study were to determine mercury levels in different species of fish, to identify the species with mercury levels above the permissible limits, to correlate the percentage of animal matter in their stomach contents with the mercury levels in fish species and to alert the local consumers about limiting/avoiding the consumption of certain fish species.

Materials and Methods

Sampling stations

This study has been conducted in three different locations along Ulhas River estuary and Thane Creek. The three villages selected for the species-specific study are geographically apart from each other (refer Fig. 1). The sampling stations are described in brief.

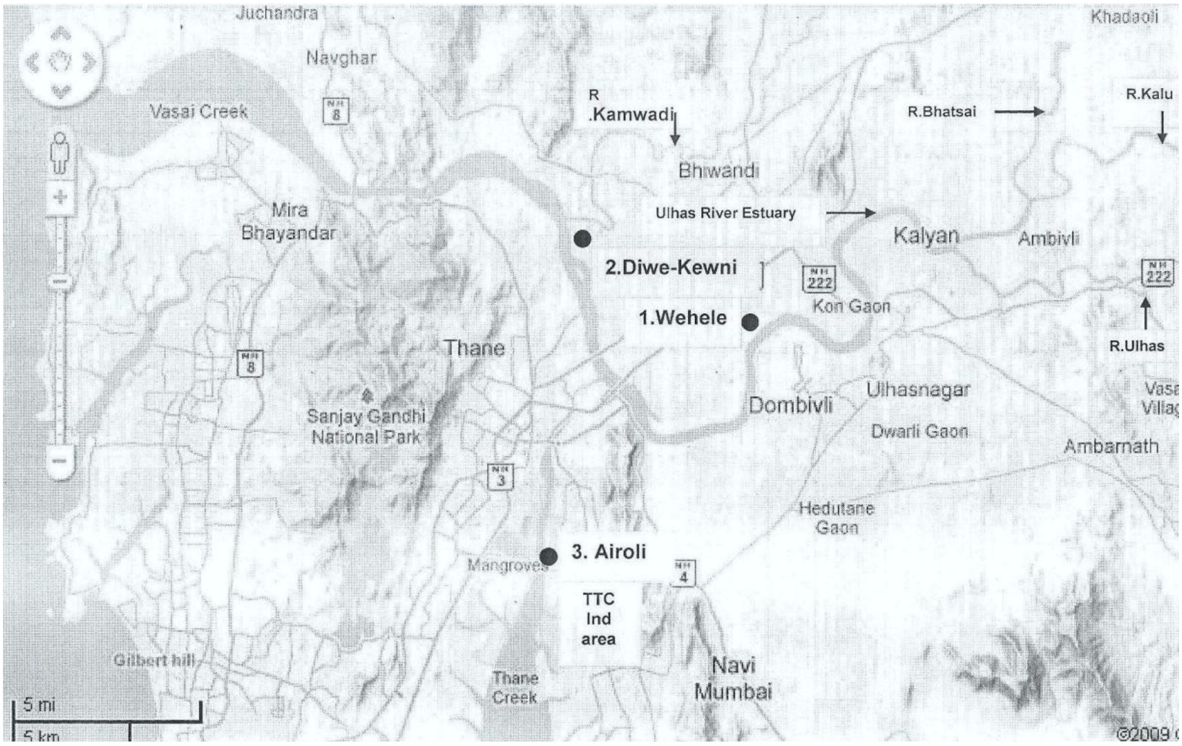

Fig.1. Map of Ulhas River Estuary, Thane Creek and Study Areas.

Station 1 – Wehele

This station (19º14’N and 73º03’ E) is located near Wehele village on the northern bank of Ulhas River estuary at a distance of 15 km downstream of Vadavli village where the estuarine zone of Ulhas River begins. On the opposite bank of this site lies the heavily polluted, industrialised and overcrowded city of Dombivli. Two outlets of MIDC (Maharashtra Industrial Development Corporation) Phase I and II of Dombivli discharge their effluents near this site. In addition, this site receives polluted water from the upstream industrial zones of Ulhasnagar, Badlapur, Ambarnath, Bhiwandi and Shahad-Ambivli through Kalu River and Waldhuni effluent outlet. The effluent outlets include discharges from various industries involving mercury such as chlor-alkali industries, dyeing industries, waste incinerators and paint industries.

Station 2 – Diwe-Kewni

This station is located near the twin villages of Diwe-Kewni (19º16’N and 73º E), on the northern bank of Ulhas River estuary. This is the site where the Kamwadi River meets Ulhas River estuary. It is 10 km upstream of the Vasai Creek where the Ulhas River joins the Arabian Sea. It is a comparatively less polluted site, except for the occasional sewage brought by the Kamwadi River from the township of Bhiwandi.

Station 3- Airoli

It is located on the east bank of Thane Creek near Airoli village (19º8’N and 72º59’E), 4 km downstream of Vittawa. This station receives effluents from the residential and industrial areas of Airoli region including thermal power plant, chlor-alkali industry, waste incinerator and dyeing industries. There are many untreated sewage discharge in this region (Quadros et al. 2001).

Sample collection and storage

Different species of fish were collected from the three sampling stations from the local fishermen during pre-monsoon season (summer) in May 2005. The fish were caught using cast net, gill net, bag net and dragnet. While comparing the species-related mercury levels, fish belonging to same size-group, season and location were considered. Mercury levels of eight species of fish were analysed for the study from Station 1- Wehele, with a size ranging between11 and 15 cm. Similarly, seven species of fish with a size-class of 8 to 10 cm were analysed from Station 2- Diwe-Kewni and seven species ranging between 9 and 11.6 cm in size were analysed from Station 3- Airoli for the species wise study.

After collection, the fish were placed in ice-boxes and transported to the laboratory. The fork lengths (length of the body from the tip of the snout to the bifurcation of the caudal fin) of the fish were measured in cm. Identification of the fish was carried out with the help of Day (1878). The muscle tissues were dissected out, placed in polypropylene bottles, labeled with all details and then kept at a temperature of-4ºC till further processing.

In crabs (*Scylla serrata*), the carapace was separated, alimentary canal was removed and the remaining parts were digested. In prawns too, the entire mass was included, after de-shelling and removal of the gut. These practices were followed in accordance with the pattern of consumption by majority of local people from the study areas.

Sample analysis

At the time of digestion, the muscle tissues were thawed, homogenized and digested by APHA, AWWA and WPCF(1981) method, which was followed by reduction with $SnCl_2$.Mercury concentration was then estimated on Mercury Analyzer (AAS) Model no. MA 5804 at BARC (Bhabha Atomic Research Centre), Mumbai and expressed in $\mu g \cdot g^{-1}$ on a wet weight basis. Accuracy and precision of the analyses were assured using NRC Canada certified standard reference material, DORM-3. Reagent blanks were analysed periodically. In addition, sample duplicates and spiked samples were also included in every sample batch.

Determination of percentage of animal matter in the stomach contents

The stomach contents of the fish were collected in a pre-cleaned petridish, preserved in 5% formalin and later on observed under a compound microscope. Point method was used to determine the percentage of various animal matter.

Statistical analysis

The results of the species-wise mercury accumulation were subjected to statistical evaluation at 5% level of significance using ANOVA-single factor method and then further groupings were made by Tukey's test. Correlation between percentage of animal matter in the stomach content and mercury levels in different species was illustrated by regression analysis.

Results

The concentrations of mercury in different species of fish collected from each of the study areas are shown in Table1. In Station 1- Wehele, significant differences between species were observed by using ANOVA–single factor method. Further, groupings of the species were done by Tukey's test. Accordingly, the prawns, *Metapennaeus monoceros* and *Macrobrachium rosenbergii* and *Tilapia mossambica* with low mercury concentration came under one category. *Gobius bleekeri* and *Mugil cephalus* with moderate mercury concentrations were categorized as the second group. *Boleophthalmus dussumieri* (Mudskipper) and *S. serrata* which had slightly higher levels of mercury came under the third category whereas *Mystus gulio* (catfish) had high concentration of mercury and was grouped as fourth category.

In station 2- Diwe-Kewni too, statistical analysis by ANOVA–single factor revealed a significant difference between the species. An application of Tukey's test for grouping the species categorized *M. monoceros* and *M. rosenbergii* under one category followed by *T. mossambica* and *M. cephalus* in the second category. *Scylla serrata* and *B. dussumieri* were grouped under category three whereas *M. gulio* with the highest concentration was grouped under category four. In station 3 - Airoli too, application of ANOVA-single factor method revealed significant difference between species. Further statistical analysis by Tukey's test placed *M. monoceros, T. mossambica* and *M. cephalus* in one group, followed by *B. dussumieri* and *Lates calcarifer* in the second group. *Scylla serrata* was categorized in group three and *M. gulio*, like in the other two sites was categorized in group four.

The Hg level in Standard Reference Material-DORM-3, Canada was 0.409 $\mu g \cdot g^{-1}$. In comparison, the average value of Hg in the Standard Reference Material obtained was 0.388 $\mu g \cdot g^{-1}$ showing a percentage recovery of 94.98%. The spiked material also showed an average percentage recovery of 97.87% and the sample duplicates exhibited a standard deviation of 0.005. Reagent blanks were detected with values below the detection limit.

The animal matter in the stomach contents of fish included copepods, polychaetes, nematodes, fish parts, appendages of prawn and crab. Fig. 2 shows the percentage of animal matter (AM) in the stomach contents and the mean mercury levels in the different species of commonly consumed fish from Ulhas River estuary and Thane Creek. Statistical analysis by regression method proved a significant correlation between the percentage of animal matter (X) and mercury concentration in the fish (Y) and the best fit equation (non-linear) obtained through regression analysis was of the type $Y = a X^b$ i.e. $Y = (0.035427) (X)^{0.7611}$ with multiple correlation co-efficient $R = 0.963$.

Table 1. Mercury concentration statistics in different species from three stations in µg·g^{-1}.

Species	Station-1 (SR- 11 to 15 cm)					Station-2 (SR- 8 to 10 cm)					Station -3 (SR- 9 to 11.6 cm)				
	N	Min	Max	Avg	SD	N	Min	Max	Avg	SD	N	Min	Max	Avg	SD
Metapennaeus monoceros	30	0.03	0.04	0.035	0.01	6	0	0	0	0	30	0.05	0.055	0.052	0.003
Macrobrachium rosembergii	25	0.045	0.045	0.045	0	12	0	0	0	0	NA	NA	NA	NA	NA
Tilapia mossambica	35	0.04	0.12	0.087	0.063	13	0.043	0.15	0.097	0.08	25	0.112	0.22	0.166	0.08
Gobius bleekeri	16	0.2	0.5	0.308	0.12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mugil cephalus	10	0.2	0.6	0.357	0.17	9	0.095	0.1	0.098	0.003	10	0.275	0.34	0.308	0.05
Boleophthalmus dussumieri	2	0.625	0.675	0.65	0.04	31	0.625	0.75	0.668	0.07	15	0.435	0.47	0.452	0.02
Scylla serrata	8	0.95	0.985	0.967	0.02	5	0.35	0.6	0.428	0.15	21	0.85	0.955	0.893	0.05
Mystus gulio	26	0.56	1.6	1.204	0.39	4	1	2.05	1.683	0.59	11	2.25	2.7	2.483	0.18
Lates calcarifer	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3	0.45	0.505	0.478	0.04

NA=Not Available
SD=Standard Deviation
SR=Size Range

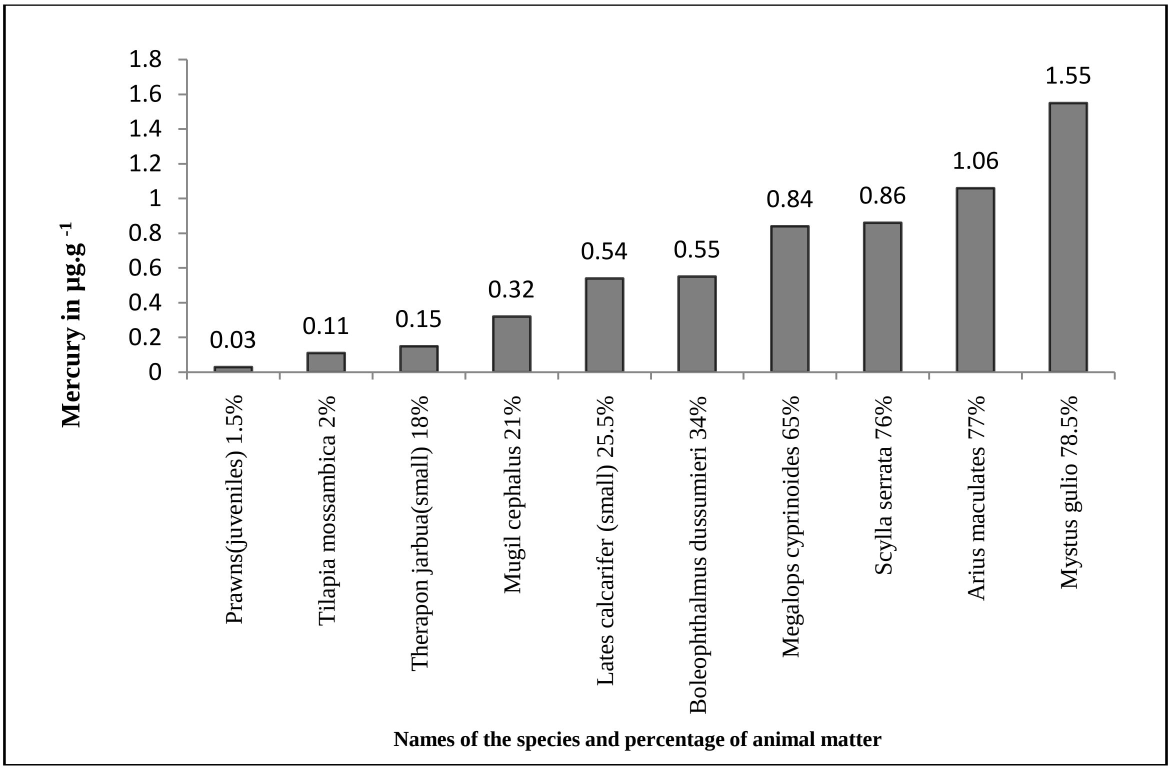

Fig. 2. Mercury accumulation in fish of Ulhas River estuary and Thane Creek in relation to the percentage of animal matter in their stomach contents.

Discussion

The study revealed that different species accumulated mercury in different proportions. In all the three stations selected for the study, namely Wehele, Diwe-Kewni and Airoli, species-wise mercury levels showed a uniform trend of accumulation. The safety limit of mercury in fish declared by WHO (1990) is 0.5$\mu g \cdot g^{-1}$. Relatively, lower mercury concentrations were observed in prawns and *T. mossambica* collected during the present study in all the three sites. *Mugil cephalus*, on the other hand showed a slightly higher mercury level than prawns and *T. mossambica.* Mudskippers demonstrated approximately the same range of mercury concentration as the permissible limit, whereas *S. serrata* and *M. gulio* showed higher levels of mercury.

Several studies on species-specific mercury accumulation have come out with similar observations. To mention a few, low levels of mercury in prawns have been accounted by Tejam and Haldar (1975) in their studies on fish from Mumbai Harbour. Many workers like FDA (2001) and Hightower and Moore (2003) have reported a low concentration of mercury in shrimps. Hightower and Moore (2003) even recommended consumption of small shellfish by patients having high blood mercury levels. Moreover, the concentration factor for heavy metals was found to be least in prawns according to a study by Mahajan et al. (1987).The above studies supported the present observation of low mercury levels in prawns.

Likewise, low mercury levels were determined in *Tilapia* spp. too. For instance, workers like Hightower and Moore (2003) and also FDA (2001) illustrated that *Tilapia* spp. had very low mercury concentrations and was therefore, highly safe for consumption. *Mugil cephalus,* too, according to FDA (2001) accumulated less amount of mercury. *Mugil* spp. were found to have mercury concentrations below the permissible levels according to the reports by Dogan-Saglamtimur and Kumbur (2002). Mudskippers were also recorded with moderate levels of mercury in their body (Mahajan et al. 1987). Tejam and Haldar (1975) in their studies on mercury in several fish from Bombay and Thane markets reported low mercury levels in *Tilapia* spp. and *Mugil* spp. However, there were variations in mercury levels in *Tilapia* spp. collected from the markets in and around Mumbai in their study probably due to the differences in sizes, seasons, site and time of collection; and ecological habitat as mentioned earlier. To overcome these shortcomings and obtain a more accurate result, different species of same size, same location and same season were considered in the present study.

There are several reports stating high mercury levels in crabs of the same study area. Mahajan et al. (1987) and Mishra et al. (2007) showed high levels of mercury in crabs in comparison to other organisms in their studies from the seaward stretch of Thane Creek. Crabs showed a high concentration factor for heavy metals in comparison to other organisms, according to the studies by Mahajan et al. (1987).

One of the main factors contributing to the accumulation of mercury in aquatic organisms was their position within the food webs (Frery et al. 2001). Therefore, variation in the mercury levels in different species may be attributed to their feeding habits. Results of the present study revealed that groupings of the species made by Tukey's test are related to their feeding habits. The first group included herbivores, second included herbi-omnivores, third included carni-omnivores and the fourth had voracious carnivores.

The prawns from the present study areas fed primarily on organisms of the first trophic level; this probably led to a low concentration of mercury in them. The percentage of animal matter in its gut contents was 1.5%, thus confirming its herbivorous status. Many scientists support the herbivorous feeding habit of prawns (Datta and Datta, 1995; Roy and Singh, 1997). Moreover, both the varieties of prawns, i.e. *M. monoceros* and *M. rosenbergii* collected from the sites were juveniles. This has been supported by number of workers. Firstly, the fully mature commonly found estuarine prawns *M. monoceros* measure 17 cm (CSIR, 1957) while *M. rosenbergii* attains a length of 32 cm (Jhingran, 1982).The prawns of the same variety collected during the study from Ulhas River estuary and Thane Creek were both in the size-range of 5.5-13 cm, much lower than the adult sizes proving them to be juveniles. Karnik and Deshmukh (2002) in their studies on prawns of Thane Creek has also stated that juveniles of *M. monoceros* enter the inshore water for food, grow into sub-adults and then commence their seaward migration, as they reach 7 to 10 cm. The prawns collected in the present study too were of the same size range. It has also been stated in CSIR (1957) that the bulk of backwater production consists of immature juveniles and according to Adams and McMichael Jr.(1999), juveniles showed a herbivorous feeding habit. During the survey too, fishermen from Vittawa station commented that adult prawns were no more to be found in the creek. The same has been reported by Quadros et al. (2001). All these studies support the fact that the prawns collected during the present study were juveniles and of herbivorous nature.

The low levels of mercury in *T. mossambica* probably are due to its herbivorous habit. This is analogous to the present observation of a decreased percentage of animal matter (2%) in its stomach contents. Reduced mercury concentrations in the range of 0.1 to 0.2 ppm were observed in the low trophic level species in the areas of Amazonian region by Boischio and Henshel (2000), the values of which substantiated with the present study on *T. mossambica*. It is hereby proved that herbivorous fish accumulate very low mercury in their bodies and therefore these are safe for consumption. The percentage of animal matter in the stomach contents of *M. cephalus* was observed to be 21%, thus proving its herbi-omnivorous habit. Moderate mercury levels in *M. cephalus*, can thus be attributed to their herbi-omnivorous nature.

Boleophthalmus dussumieri was found to be benthic in their habitat. The percentage of animal matter in the stomach contents was 34%, thus proving its omnivorous habit. This was the probable reason for the moderate accumulation of mercury observed in these fish. On the other hand, *S. serrata* showed high levels of mercury concentration probably due to their benthic and carnivorous habit. A high percentage of animal matter in the stomach contents (76%) was estimated in *S. serrata* revealing its carnivorous nature. The carnivorous nature of *S. serrata* has been reported by Stevens et al. (1982).

Mystus gulio showed the highest level of mercury concentration among the species from all the three sites probably due to its avid carnivorous habit with the percentage of animal matter in the stomach contents being 78.5%. The predatory nature of *Mystus* spp. has also been reported by Quadros et al. (2001). Predatory fish accumulating higher levels of mercury has been reported by many (Goldstein et al. 1996; Boischio and Henshel, 2000)**.** This explains the elevated levels of mercury in *M. gulio*.

Thus the study on the relationship between the percentage of animal matter and mercury accumulation in fish revealed a significant increase in fish mercury levels with an increase in animal matter. According to this study, mercury accumulation was significantly less in herbivorous fish, prawns and *T. mossambica*, while slightly higher in fish like small-sized *Therapon jarbua* and *M. cephalus*, moderate in small-sized *L. calcarifer* and *B. dussumieri* and slightly higher in *Megalops cyprinoides* and very high in the carnivorous species like *S. serrata*, *Arius maculatus* and *M. gulio*.

Several other studies also confirmed the fact that predatory fish accumulated larger concentration of mercury than herbivorous, detritivorous or omnivorous ones (WHO, 1990; Adams and McMichael Jr., 1999; Frery et al. 2001;Dorea et al.2006).

Conclusion

Juvenile prawns, *T. mossambica* and *M. cephalus* from Ulhas River estuary and Thane Creek with lower levels of mercury can be safely consumed without any risk of mercury exposure.The mercury levels were slightly above the permissible limit (0.5 $ug^{.}g^{-1}$) in *B. dussumieri* and small-sized *L. calcarifer*, so it is advisable to consume these species in moderation. Mercury concentrations in *M. cyprinoides*, *S. serrata*, *A. maculatus* and *M. gulio* exceed greatly the permissible limit and therefore the consumption of these four species should be avoided.

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